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Construction of a database for the biogeochemical classification of estuaries

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Construction of a database for the biogeochemical classification of estuaries

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Summary

Increased anthropogenic activities in coastal areas have modified the nutrient inputs and transport across the land-ocean interface. Water quality and ecological concerns have mostly been addressed in site-specific studies, in which estuarine biogeochemical functioning is usually considered independently from the physical and hydrodynamic characteristics. This project aims to interconnect the physical (geometrical and hydrodynamic) parameters of estuaries to their biogeochemical functioning, with a particular focus on nutrient and carbon dynamics. The main objectives are to 1) construct a global-scale database that defines the geometrical/hydrodynamic/biogeochemical characteristics of representative estuaries and 2) analyze the data collected in order to identity relationships between physical and chemical parameters as well as global trends. This database will serve as the basis for defining estuarine scenarios that will be later used to quantify the present and future contribution of estuarine systems to the CO_2 pumping efficiency of the global coastal ocean.

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Construction of a dataset for the biogeochemical classification of estuaries

1 Introduction

Estuaries are land-ocean transition zones where rivers meet the sea. An estuary can be either the discharge of freshwater from the river into the coastal zone or the fill of salty water from the sea in the estuary (Savenije, 2005). The high importance of estuaries is that they provide a unique aquatic environment that hosts a broad biodiversity from two different water bodies. Having specific hydraulic, morphologic and biologic characteristics, estuaries serve as an ecotone between two adjacent communities, containing species characteristic of both, as well as other species specific to this zone. Therefore, they play an important role not only for the life cycle of flora and fauna species but also for the goods and services that they can provide to humankind (Savenije, 2005).

Due to the potential features of estuaries, most of the population growth has been taking place in coastal areas close to estuaries. As a consequence, estuaries have been under constant pressure caused by, for example, the increase of nutrient inputs leading to the deterioration of ecological health. Apart from the role of estuaries in the delivery of land-derived nutrients to the coastal zone, their importance in the CO_2 air-water exchange fluxes and hence in the global carbon cycle has recently been advocated (Borges, 2005)

The functioning of estuaries is controlled by the complex combination of hydrodynamic, geological, geochemical and biological processes that are interlinked and that act at different time and spatial scales.

1.1 Estuarine physical features

1.1.1 Geometry

The banks of an ideal estuary follow an exponential function that converges in the upstream direction (Pillsbury, 1939 & Langbein, 1963; Figure 1.1). The principal components that determine the shape are defined by: depth (h), width convergence length (b), cross-sectional convergence length (a), mouth width (Bo) and cross-sectional area (Ao).

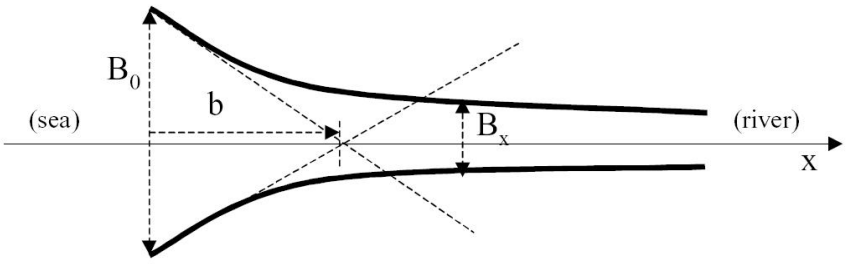


Figure 1.1 Geometrical and hydrodynamic elements of an ideal estuary
Source: Savenije, 1992

$$B = B_o \exp\left(-\frac{x}{b}\right)$$ [Eq 1]

The width convergence length (b), defined as the distance measured from the mouth to the point where the tangents intersect the x axis, is an indicator of estuarine shape and it is directly related to the dominant hydrodynamic regime. Estuarine geometries vary between funnel-shaped, characterized with low values of b and converging upstream banks, and prismatic, having a relatively high b, parallel banks and a constant cross-section (Figure 1.2). According to Savenije (1992), the shape of the estuary is influenced by a combination of factors, including tidal movement, river floods, wave and storm action.

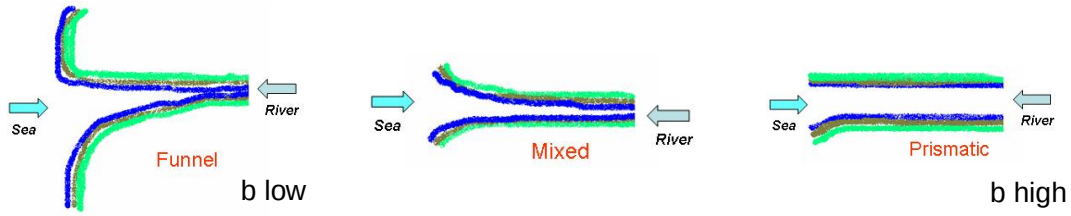


Figure 1.2 Estuarine shape classification based on the width convergence length

1.1.2 Hydrodynamics

The hydrodynamic ratio, also known as the Canter-Cremers number (C), gives information on the hydrodynamic characteristics of an estuary and is calculated as shown in Equation 2. The non-dimensional estuarine shape number (S) is determined by Equation 3. Based on an analysis of 18 estuaries (Savenije, 2006), a relationship was established between C and S, as indicated in Equation 4.

$$C = \frac{Q_b T}{P}$$ [Eq 2]

$$S = \frac{a}{H}$$ [Eq 3]

Where:

C: Canter-Cremers number
Q_b: bankfull discharge
T: tidal period
P: tidal prism
S: estuarine shape number
a: cross-sectional convergence length
H: mean water depth

$$S = 12500(C)^{0.26}$$ [Eq 4]

Due to the interdependence between the geometrical, hydrodynamical and biogeochemical functioning of estuaries (Figure 1.3), the combination of C and S gives insight in the biogeochemical behavior as shown in Arndt (2008).

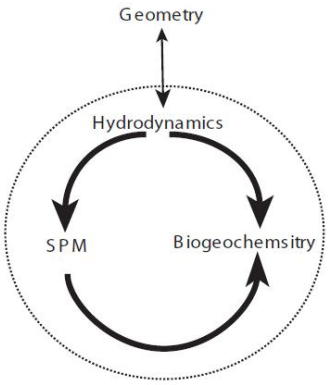


Figure 1.3 Physical forcing components and the interaction with estuarine biogeochemistry
Source: Arndt, 2008

1.2 Estuarine biogeochemical features

As a result of the population increase, anthropogenic activities on land such as food production, land use conversion, sewage discharges, and the construction of dams for hydropower, have among others, modified the hydrological regimes and the export of dissolved and particulate nutrients from land to rivers and finally to the coastal seas (Meybeck & Vorosmarty, 2005; Seitzinger et al., 2010). The increase in nutrient levels has brought positive and negative consequences. On one hand, it has allowed food production coping with the population growth demands but on the other hand, it has modified the ecosystems due to the increase in nutrient export to the coast leading to possible eutrophication risks and other environmental impacts.

1.2.1 Biogeochemical substances

Silica

Dissolved silica is one of the most important elements in the marine and continental systems, while particulate silica plays an important role in the nutrient cycle of surface estuaries. Both dissolved and particulate silica are derived from the weathering processes of sedimentary rocks. Dissolved silica concentrations are also being modified due to the increase in nitrogen and phosphorus related to human activities and the long residence times in reservoirs behind dams. According to Eyre and Balls (1999), estuaries located in the tropical estuaries have much higher silicate concentrations in comparison to temperate estuaries. The largest contributors of SiO_2 are South America (25%) and Asia (23%) (Bouwman et al., 2010).

Nitrogen

Nitrogen is transported is various forms such as nitrate (NO_3^-), nitrite (NO_2^-), and ammonium (NH_4^+), collectively known as dissolved inorganic nitrogen (DIN), dissolved organic nitrogen (DON), and particulate nitrogen (PN). Most of the nitrogen concentration associated with anthropogenic activities, such as excess fertilization and animal waste in agricultural lands, is transported to rivers through runoff. Sewage and atmospheric deposition of NH_4^+ from industries also contribute to the DIN pool (Bouwman et al., 2010). The changes in agriculture and land use have increased the levels of DIN in rivers by approximately 30%. Consequently, an increase in the export fluxes to coastal waters has also been observed, in particular in South Asia where more than half of the global increase has occurred (Seitzinger et al., 2010). A small percentage of nitrogen comes from non-anthropogenic sources, including organic matter degradation and internal recycling in sediments.

Phosphorus

In aquatic systems, phosphorus occurs as dissolved inorganic phosphorus (DIP), dissolved organic phosphorus (DOP), particulate inorganic phosphorus (PIP) and particulate organic phosphorus (POP). As for nitrogen, phosphorus is associated to anthropogenic activities and is transported to the coastal systems through estuarine pathways, although a significant fraction of DIP is generally retained in estuaries due to sorption. According to Seitzinger et al. (2010), the main sources that contribute to the rising levels of DIP are sewage effluent and detergent use rather than agriculture.

Carbon

Every year 0.9 Gt of carbon is transported by rivers in the world, of which 40% is organic and 60% inorganic (Meybeck, 1993). Carbon fluxes are likely to increase due to anthropogenic activities (Abril et al., 2002). Dissolved organic carbon (DOC) goes through strong changes in nature and composition in estuaries (Abril et al., 2002). Particulate organic carbon (POC) is generated by the dynamics of suspended sediments and is therefore extremely heterogeneous. It is subject to sedimentation and erosion during neap and spring tides, part of which deposits in estuaries while the rest is exported to the coastal zones (Abril et al., 1999). Polluted rivers and estuaries tend to have higher concentrations of POC.

Total Suspended Solids

Total suspended solids (TSS) are key elements for the uptake and release of chemical components in the water column. Dissolved and suspended particulate in water are related to conductance and turbidity (light availability in estuaries) therefore have important implications on the ecological processes, such as primary production.

TSS are related to the weathering rates, erosion and discharges rates. TSS also absorb heat and increase surface water temperature playing an important role in surface estuaries (Mitchell and Stapp, 1992).

1.2.2 Nutrient Fluxes

Nutrient loadings are subject to riverine discharge rates that determine the capacity to dilute excessive nutrient inputs. For this reason, nutrient fluxes, computed as the product of nutrient concentrations and riverine discharge, are usually calculated. One can distinguish between “import fluxes” (nutrient fluxes transported from the river to the upper estuary) and “export fluxes” (nutrient fluxes from the lower estuary to the coastal zone). The difference between these two fluxes can be attributed to the so-called “estuarine filter” (Kennedy, 1984). The latter refers to the role of estuaries in the physical, chemical and biological removal of nutrient inputs such that the water leaving the estuary has a different chemical composition than that which enters the estuary. In relation to the “estuarine filter”, the terms “retention” are “filtering capacity” of an estuary are defined as the fraction of the nutrient input that is removed within an estuary. The extent of transformation, which is partly determined by the physical controls and external forcings, has chemical and ecological implications on the adjacent coastal waters and on the global nutrient cycling.

A modeling framework that links the human activities and natural processes in river basins called Global NEWS (Global nutrient export from watersheds) has been developed by the UNESCO’s Intergovernmental Oceanographic Commission. A summary of the global nutrient exports computed using Global NEWS for past and future nutrient scenarios is presented in Table 1.1. More details on the nutrient river export for different continents and worldwide can be found in Seitzinger et al, (2010), Meybeck & Vorosmarty (2005), Gattuso et al. (1998) and Borges (2005).

Table 1.1 Nutrient export from land to marine coastal systems [Tg/yr]

Year	Scenario	DIN	DON	PN	TN	DIP	DOP	PP	TP	DOC	POC	TSS/100	DSi
1970	NEWS	14	10	12	37	1	0.6	6	8	161	127	123	141
1970	Meybeck 1982	12	10	21				20					
2000	NEWS	19	11	14	43	1	0.6	7	9	164	140	145	144
2000	Global Orchest.				78								
2030	NEWS		12	13				6			125		
2030	Global Orchest	22	11	12	46	2	0.6	6	9	161	124	127	137
2050	Global Orchest	24	12	12	48	2	0.6	6	9	160	120	120	136

Source: Seitzinger et al., 2010; Bouwman et al., 2010

The transition of the nutrient exports from 1970 to 2000 and the future trends based on different scenarios are shown in the Figure 1.4.

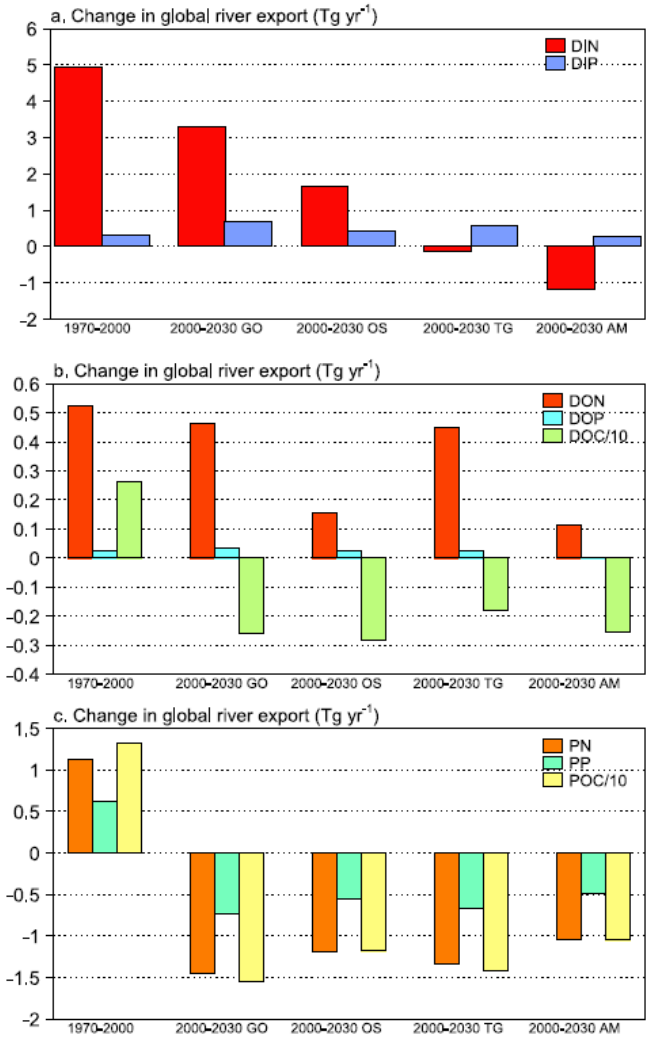


Figure 1.4 Transition of nutrient export between 1970 and 2000 and future scenarios between 2000 and 2030 (NEWS Results)
Source: Seitzinger et al., 2010

In the context of climate change, more attention has been recently given to link between nutrient and CO_2 fluxes in the coastal ocean since they act as sinks for organic matter and therefore potential sources of CO_2 to the atmosphere (Gattuso et al., 1998; Borges, 2005). An impact on the land-ocean interaction due to the global change is also envisaged, as shown by Holmes et al. (2000) in an analysis of nutrient fluxes from Russian rivers to the Arctic Ocean. For this reason, the understanding of current nutrient behavior and fluxes will help constrain the models used for predicting future changes in nutrient fluxes and their ecological implications.

1.3 Existing estuarine classifications and databases

In order to understand the global functioning of estuaries it is crucial to identify and group estuaries with similar characteristics. This is the basis of traditional estuarine classifications that are generally based on physical parameters, such as geometrical/geomorphic features (Pritchard 1955, 1967), hydrodynamic behaviour and mixing patterns (Cameron and Pritchard, 1963). Classical geomorphological classifications consider four subdivisions (Dalrymple et al., 1992): 1) drowned river valleys, 2) fjord type estuaries, 3) bar-built estuaries and 4) estuaries produced by tectonic processes (Pritchard, 1967). The classifications proposed by Hume and Herdendorf (1988) are based on the origin and behavioral features of estuaries. Other classification criteria are based on the presence of a single or multiple mouth, constructed or unconstructed mouth, branched or unbranched main drainage lines, giving rise to 32 possible combinations of physical types (Pierson et al., 2002).

Pethick (1984) proposed a classification of estuaries based on three groups according to their tidal range: micro-tidal estuaries (range < 2m), meso-tidal estuaries (range between 2 to 4m) and macro-tidal (range > 4m). However, such a classification has limited relevance to studies of estuarine morphology (Savenije, 1992). For instance, although Banyuasin and Lalang estuaries both have the same tidal range, their shape and morphology varies significantly. With a convergence length of 20 km, Banyuasin is funnel-shaped whereas Lalang has a convergence length of 200km and is therefore prismatic-shaped (Savenije, 1992). This implies that depending on the attributes used for defining the categories, different estuarine classifications may lead to equivocal groups. Also, it is important to note that real estuaries do not always fall within the idealized classification categories.

Even though the classifications based on geometry and hydrodynamics features may appear to be unrelated, they are in fact directly correlated. This was illustrated by Savenije (2005) in his classification based on shape, tidal influence, river influence, geology and salinity. In the latter, the width convergence length (b), defined as the distance from the mouth to the point where the tangents intersect the x axis (Savenije, 2002), was used as the main classification indicator.

More recent classification schemes (e.g. Hume et al., 2007; Swaney et al. 2008; Arndt, 2008) generally aim at increasing the understanding and ability to predict the response of coastal ecosystems to enhanced nutrient delivery. For example, Swaney et al. (2008) proposed a simple estuarine classification scheme focusing on the biological response of the river-dominated estuarine systems and the role of water residence time using nutrient-phytoplankton-zooplankton models. The ‘estuary environment classification’ presented in Hume et al. (2007) considers a four-level hierarchical system of the abiotic components, such as climatic, oceanic, riverine and catchment factors, that determine the physical and ecological characteristics of estuaries. Arndt (2008) proposes an estuarine classification based on the mutual interdependence between: 1) geometry and hydrodynamics, and 2) hydrodynamics and biogeochemistry (Figure 1.3). Here a reactive transport modelling approach is proposed that accounts explicitly for the coupling of hydrodynamics and biogeochemistry along the tidal river-coastal sea continuum, including the mechanistic process-based description of the estuarine filter.

Studies of estuarine functioning at the global-scale rely on databases in which site-specific geometric, hydrodynamic or biogeochemical data of estuaries are collected. Extensive literature review has revealed that various estuarine databases are already available.

However, in all cases, these databases focus either on one particular country or on one set of attributes, mainly hydrodynamic or ecological features. Toffolon and Savenije (2008) have put together an inventory of databases of estuaries worldwide, called DBest, focusing on morphology and hydrodynamic features. A list of country-based estuarine databases considered by Toffolon and Savenije (2008) is given below:

Australia and New Zealand:
- Australian Estuarine Database - AED
- Australian Estuaries Database - CAMRIS
- OZCoast and OzEstuaries - Australia's online coastal information portal
- Simple Estuarine Response Model (SERM I and SERM II, Australia): datasets
- Australia - Coastal Habitat Resources Information System (CHRIS)
- New Zealand - Estuaries database

UK:
- British Oceanographic Data Centre - Estuaries Database 2003
- The Estuary Guide - Estuaries database

USA:
- National Estuarine Eutrophication Assessment - NEEA Estuaries Database
- USGS-South Florida Information Access (SOFIA) - Ecosystem History of South Florida Estuaries Data
- NOAA's Estuary Restoration Act (ERA) - National Estuaries Restoration Inventory
- Henry Lee's estuarine database seems more concerned with ecological problems.

In another study carried out by WL| Delft Hydraulics, a geomorphological database for European estuaries was constructed and used as the basis for the development of a “Generic Estuary Model for Contaminants” (GEMCO, 2003).

2 Aim

Within the large scale project on “The quantitative significance of estuaries for the CO_2 pumping efficiency of the global coastal ocean“, three main objectives are identified (Figure 2.1):

1. To compile a global database for estuaries through extensive literature search that includes geometric, hydrodynamic and biogeochemical features
2. To set up estuarine hydrodynamic-biogeochemical modeling scenarios based on the data collected in the database
3. To assess the contribution of estuaries to CO_2 air/water fluxes at the local scale and extrapolate to global scale

This report focuses on the first objective, i.e. the construction of the global estuarine geometrical, hydrodynamical and biogeochemical database. Since it is not possible to study all estuaries world-wide, the aim of this database is to identify and group estuaries with similar characteristics and use this information to define estuarine model scenarios, to be used in the step 2 of the project (outside scope of this study).

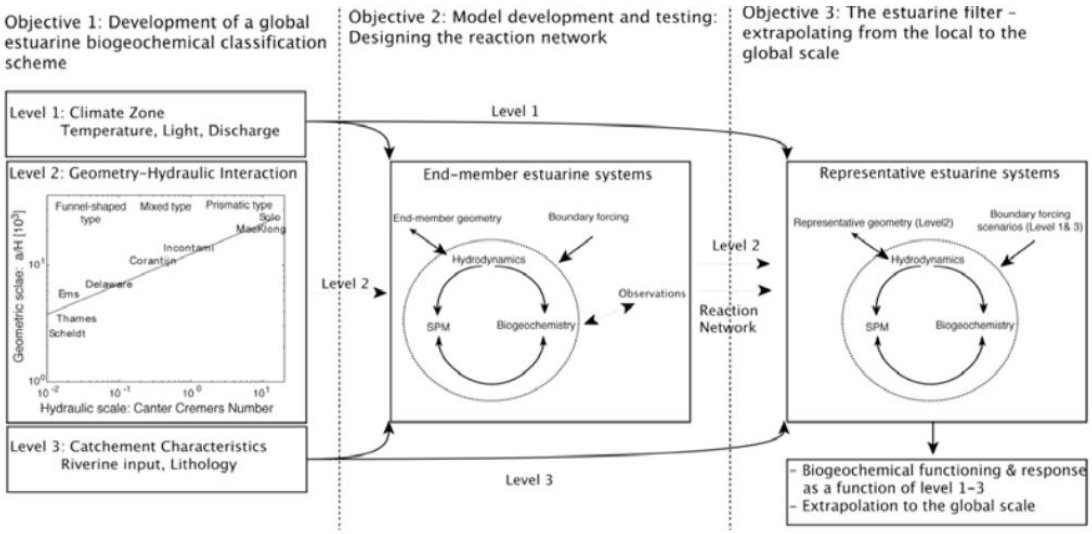


Figure 2.1 Scheme for the main objectives of the project
Source: Modified from Savenije (2005)

3 Methodology

3.1 Construction of database

Table 3.1 summarizes the main estuarine attributes compiled in the database. Data was organized in two main excel sheets; one with physical attributes, one with biogeochemical parameters.

Table 3.1 Main attributes included in the estuarine database

Physical	Biogeochemical
Climate: Latitude Longitude Temperature (T^oC) Incident solar radiation	Nutrient concentrations [mg/l]: Silica: Si Nitrogen: NO_3^-, NO_2, NH_4^+, DIN, DON (TN), PN Phosphorus: DIP, DOP, PP
Hydrodynamic: Discharge (Q) [m^3/s] Basin area (A) [km^2] Runoff [mm/yr]	Carbon concentrations [mg/l]: DIC DOC, POC (TOC) HCO_3^- Total Alkalinity pH pCO_2 CH_4

Physical	Biogeochemical
Geometric: Water depth at the mouth (h_o) Mouth area (A_o) Width at the mouth (B_o) Tidal range at the mouth (H_o) Cross-sectional convergence length (a) Width convergence length (b)	Others: Total suspended solids (TSS) Salinity intrusion length (Ls)

Note:

DIN	Dissolved Inorganic Nitrogen
DON	Dissolved Organic Nitrogen
TN	Total Nitrogen
PN	Particulate Nitrogen
DIP	Dissolved Inorganic Phosphorus
DOP	Dissolved Organic Phosphorus
PP	Particulate Phosphorus
DIC	Dissolved Inorganic Carbon
DOC	Dissolved Organic Carbon
POC	Particulate Organic Carbon
TOC	Total Organic Carbon

All the data entries were collected from primary sources, including scientific papers, publicly-available databases and other information (refer to Annex A for a list of links to estuarine studies and data) with the exception of the width convergence length (b). This parameter is not readily available in literature and therefore was calculated as explained below. For hydrodynamic parameters, such as discharge rates, annual average values were considered whereas for the chemical parameters, average concentrations at salinity zero or close to zero were considered whenever available.

3.2 Calculation of the width convergence length (b) of estuaries

Based on the work Savenije (1992), the following methodology for the calculation of the width convergence length (b) was established. Although the methodology is similar to that used in previous studies, for example (Bals, 2002), satellite images were used here for measuring geometrical features instead of site maps.

In accordance to the relation between B and x (Eq 1), the following steps were taken:

1) Width at the mouth [Bo]

   Google Earth (imagery date between 2005 and 2010) was used to measure the width at the mouth of a specific estuary.

2) Width [B(x)] at different distances [x]

   The width and distances were measured upstream in each change of direction of the river. Multiple measurements were taken to obtain high resolution of the estuarine profile (Figure 3.1).

Figure 3.1 Measurement of the estuarine width at the mouth and at different x (Barito Estuary)
Source: Google Earth, imagery July 2005

In cases where islands were found in the middle of the channel, only the width of the active channel was considered [Figure 3.2].

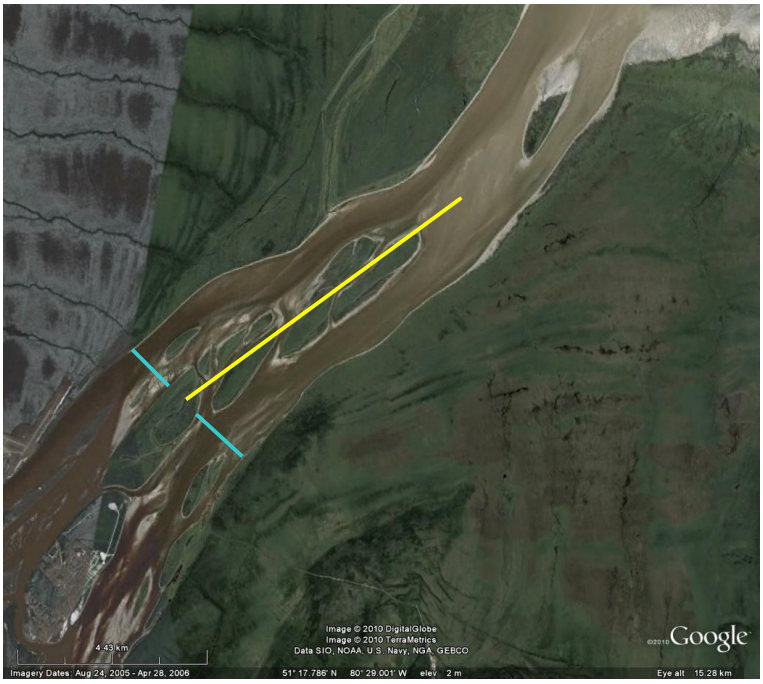


Figure 3.2 Measurement of the width in case of isles within the channel
Source: Google Earth, imagery July 2005

3) The measurements taken (x and B(x)) were plotted. From the graph, the inflection point was determined [Figure 3.3].

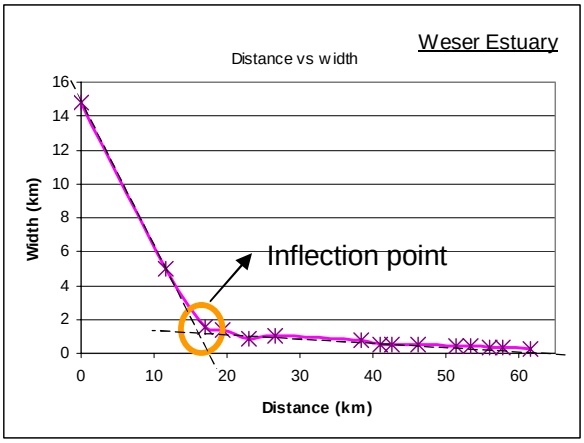


Figure 3.3 Determination of inflection point

4) x and log B(x) were plotted in order to derive the equation of the trend line for the points before the inflection point [Figure 3.4].

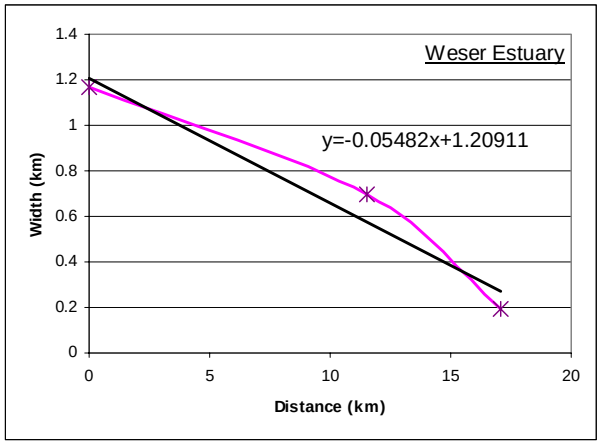


Figure 3.4 Distance vs log B(x)

5) From the relation determined by Savenije (2002),

$$B(x) = B_o \exp^{\left(-x/b\right)} \qquad \text{[Eq 1]}$$

the following equation was obtained by applying log on both sides:

$$\log_{10}(B) = \log_{10}(B_o e^{-x/b})$$
$$\log_{10}(B) = \log_{10}(B_o) - \frac{x \log_{10}(e)}{b} \qquad \text{[Eq 5]}$$

Taking the basic linear equation

$$Y = mx + c \qquad \text{[Eq 6]}$$

Replacing equation 5 in 6

$$Y = \log_{10}(B)$$
$$m = -\frac{\log_{10}(e)}{b} \qquad \text{[Eq 7]}$$
$$c = \log_{10}(B_o)$$

From equation 7, the convergence length was obtained

$$b = -\frac{\log_{10}(e)}{m} \qquad \text{[Eq 8]}$$

For example:

$$Y = -0.05482x + 1.20911$$
$$b1 = -\frac{\log_{10}(e)}{0.05482}$$
$$b1 = 7.92$$

Inflection point at x=17 km (x1)

6) A scatter plot (log scale) was drawn with the values x and B(x) (original values) and in the same graphic the line obtained with 2 equations was added [Figure 3.5]:

For the points before the inflection point:

$$B_1' = B_o \exp^{-x/b1} \qquad \text{[Eq 9]}$$

For the points after the inflection point:

$$B_2' = B_1 \exp^{-(x-x1)/b2} \qquad \text{[Eq 10]}$$

where:

$$B_1 = B_o \exp^{(-x1/b1)}$$

x1= distance at the inflection point

b2= estimated value that is calibrated to fit the second line

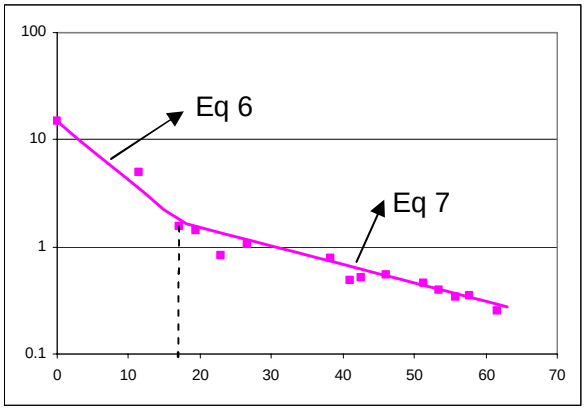


Figure 3.5 Scatter plot x vs B(x) and best fit lines for the determination of convergence length

In this example:

$$B_o = 14.8km$$
$$x1 = 17km$$
$$B_1 = 2km$$
$$b1 = 7.9km$$
$$b2 = 25km$$

3.3 Statistical Analyses

Statistical analyses were carried out to evaluate possible relationships between hydrodynamical and biogeochemical attributes of estuaries with respect to the same controlling factors, such as geographical distribution and shape. The objective was to assess whether the observed characteristics and trends in the datasets can be supported mathematically.

Statistical analyses were performed using the statistical software R version 2.8.1. In all analysis, the level of significance was set at 0.05. The Spearman's correlation was used to test the significance between latitude, width convergence length and nutrients (fluxes and concentrations). One-way ANOVA was performed to test for differences among the climatic zones and the estuarine shapes. The former indicates whether changes in nutrient concentrations/fluxes are related to the selected controlling factors. The latter gives an indication of whether the differences among groups of samples with similar characteristics are mathematically significant.

Other assessments performed included data analysis using boxplots (Figure 3.6). A boxplot is a convenient and practical way to visualize a dataset, through which the most important features of the data distribution, such as dispersion, skewness and possible outliers can be clearly depicted. The principal components are: whisker diagrams (minimum and maximum), quartiles (lower and upper) and outliers.

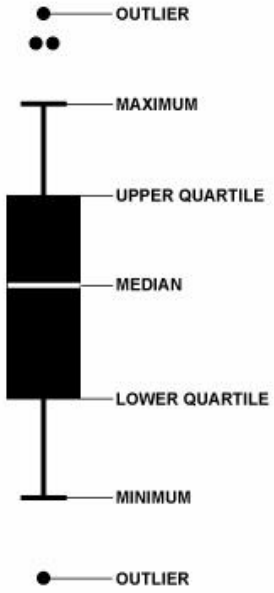


Figure 3.6 Main components of a boxplot and whisker diagram

4 Results and Discussion

4.1 Distribution of estuaries in the database

As a first target, we focus on the collection of hydro-morphological and biogeochemical data of 181 estuaries around the world. Figure 4.1 shows the distribution of the estuaries among

the different continents. Based on data available in literature, most of the estuaries considered are in the northern hemisphere, in Europe and North America, whereas the data collected for estuaries in Africa and South America is disproportionably lower. The physical and biogeochemical database entries for the above estuaries are found in Annex E.

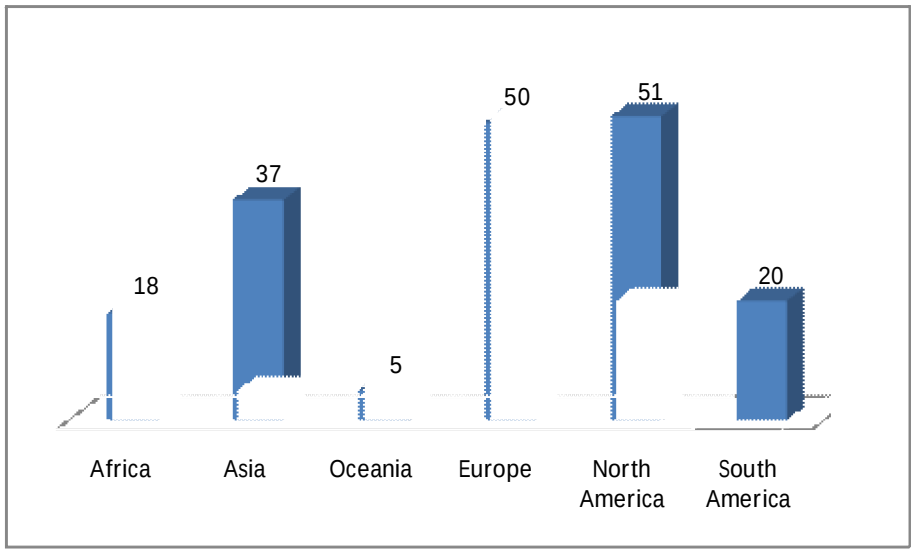


Figure 4.1 Distribution of selected estuaries per continent

In this study, we do not differentiate between the five coastal typology basin types (small delta, tidal estuary, lagoon, fjord and large river) proposed in Laurelle (2009). According to this classification, the number of entries for each type is: 24 'small delta', 54 'tidal estuary', 25 'lagoon', 16 'fjord' and 26 'large rivers'. In this case, 'alluvial estuaries' fall under the basin type 'tidal estuaries'.

As explained above, the objective of the classification is to cluster estuaries with the same features subject to the same controlling factor. In this way, possible correlations and trends can be easily identified. Firstly, we define an estuarine classification based on similar climate conditions, where the main drivers are light availability and temperature. Three climatic zones are considered: polar (60^o – 90^o), temperate (30^o – 60^o) and tropics (0^o – 30^o) associated by similar influences of continental landmasses, ocean currents and regional meteorology. Most of the biogeochemical processes including metabolic rates and nutrient uptake dynamics are also temperature-sensitive. Note that the uneven geographical distribution in the estuarine entries (Figure 4.1) is not accounted for when assessing the significance of trends and relationships as a function of climate zones. Secondly, estuaries are classified according to the shape based on the convergence length (b) subdivided in three groups: funnel (b<28 km), mixed (b<42 km) and prismatic (b>42 km), based on Arndt (2008). In this study we assume that b is an indicator of estuarine shape.

The estuaries are clustered as follows:

Geographical distribution (climate zones):

1) Polar
2) Temperate
3) Tropics
    a. North
    b. South

Estuarine shape (convergence length):

1) Funnel
2) Mixed
3) Prismatic

Figure 4.2 shows the distribution of the number of estuaries in the database based on both geographical distribution and estuarine shape. It is not possible to identify a direct link between the estuarine type and geographical location (Figure 4.1 and Figure 4.2), primarily due to the non-representative geographical distribution of the considered estuaries (Figure 4.1). In all three climatic zones (polar, temperate and tropics), the “mixed” type predominate (Figure 4.2). No clear relationship between estuarine shape and climate zones can be established based on Figure 4.2, except for the prismatic type that show an increasing trend from polar zones (5 estuaries) to the tropical zones (18 estuaries).

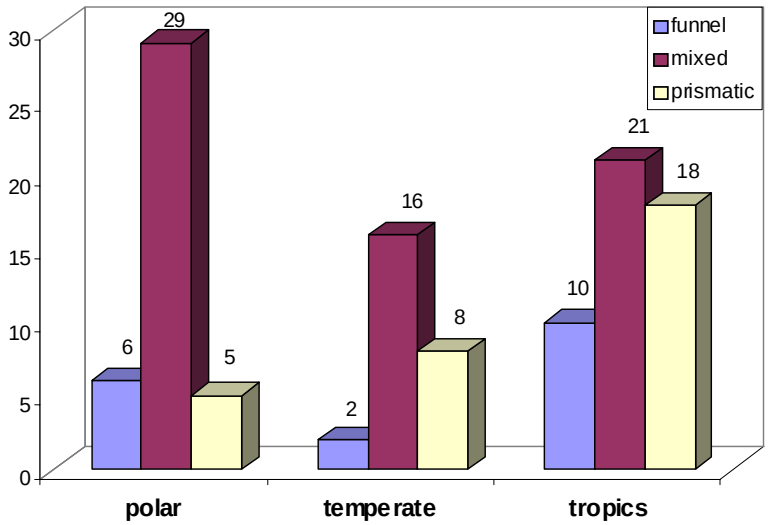


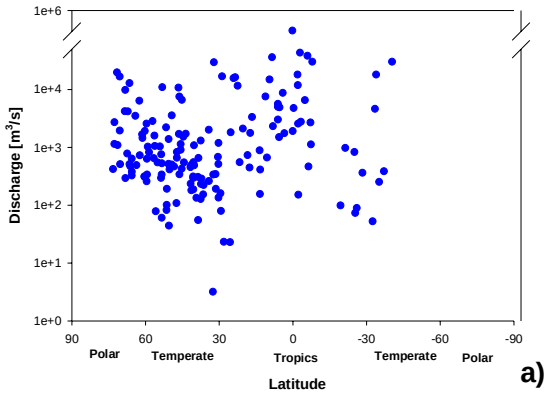
Figure 4.2 Distribution of the estuaries based on geographical distribution and estuarine shape

4.2 Hydrodynamic parameters

4.2.1 Variation with latitude

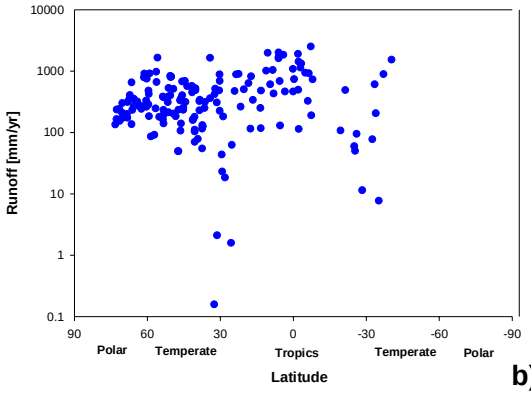
Figure 4.3 shows the distribution of the discharge and runoff data with latitude for most estuaries in the database. Values for runoff are calculated from discharge and basin area as follows:

$$\text{Runoff} = \frac{discharge}{area} \qquad \text{[Eq 11]}$$



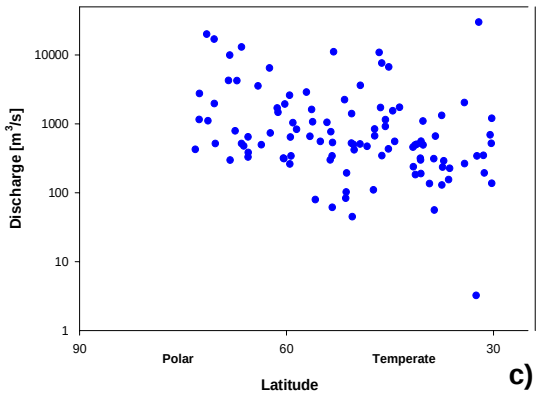
a)

r = -0.0939
n = 163
p > 0.05 (n.s.)



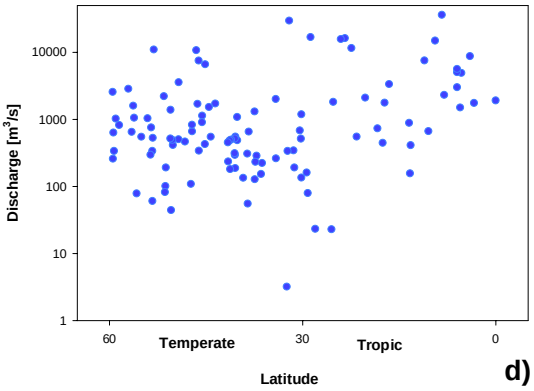
b)

r = -0.1586
n = 163
p = 0.0431 (*)



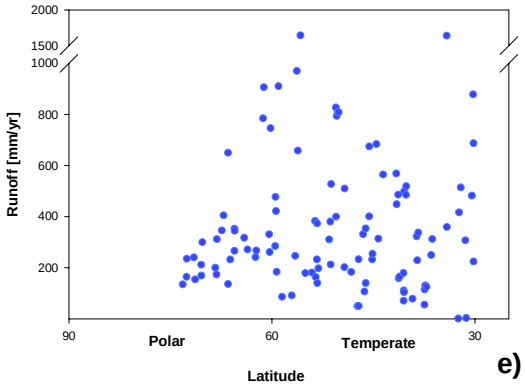
c)

r = 0.353
n = 106
p = 0.0002 (**)



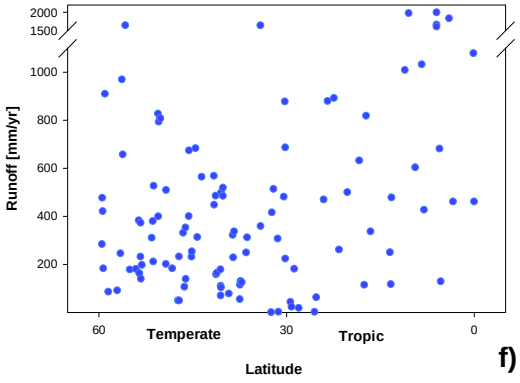
d)

r = -0.244
n = 110
p = 0.01 (*)



e)

r = -0.0130
n = 106
p = 0.8900 (n.s.)



f)

r = -0.1698
n = 110
p = 0.0761 (n.s.)

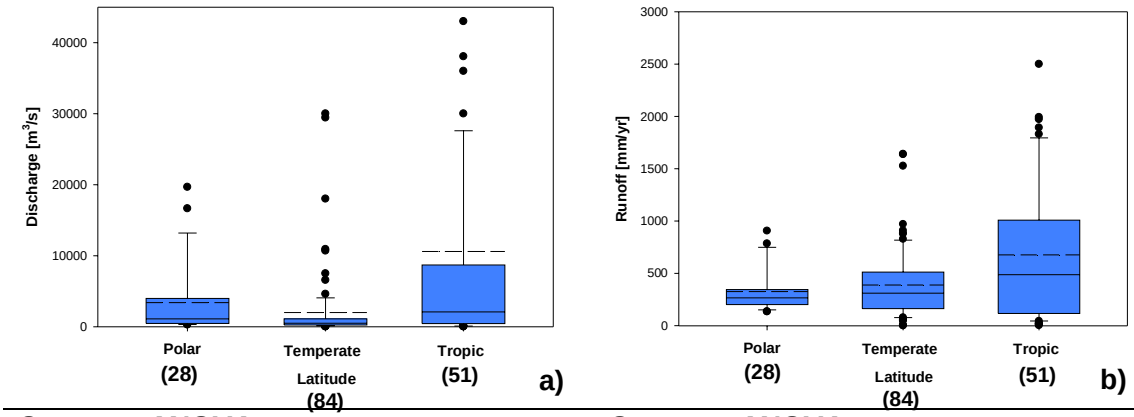
<u>Figure 4.3</u> Distribution of discharge along: a) & b) Latitude, c) – f) separate latitude bands in the North hemisphere

Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).

According to Figure 4.3a, no significant correlation is found between discharge and latitude when all climate zones are considered together. The correlation obtained for

runoff is significant but low (Fig. 4.3b). A general positive correlation with latitude is observed, with some outliers at 30°. When a more detailed analysis is carried out for distinct climate zones/latitude bands, a significant negative correlation for discharge is obtained going from polar to temperate zones (Fig. 4.3c) and an increasing trend from the temperate to the tropics (Fig. 4.3d). This implies that the lowest discharges are found in the temperate zone. Parallel analysis for runoff (Fig. 4.3e & f) does not yield statistically significant correlations.

The boxplot analysis for discharge rates based on climate zones (Fig. 4.4a) shows a similar trend that observed in Fig 4.3a & c, which highest discharges in the tropic zone and lowest in the temperate. The geographical variation in runoff (Fig. 4.4b) showing a gradual increase from the polar to the tropic regions. Since we do not include all estuaries in the world, the conclusions drawn on selected data may be biased. However, a statistically significant increasing trend is still obtained (Fig. 4.4b) although the number of estuaries in the tropics is less than the one in the temperate.

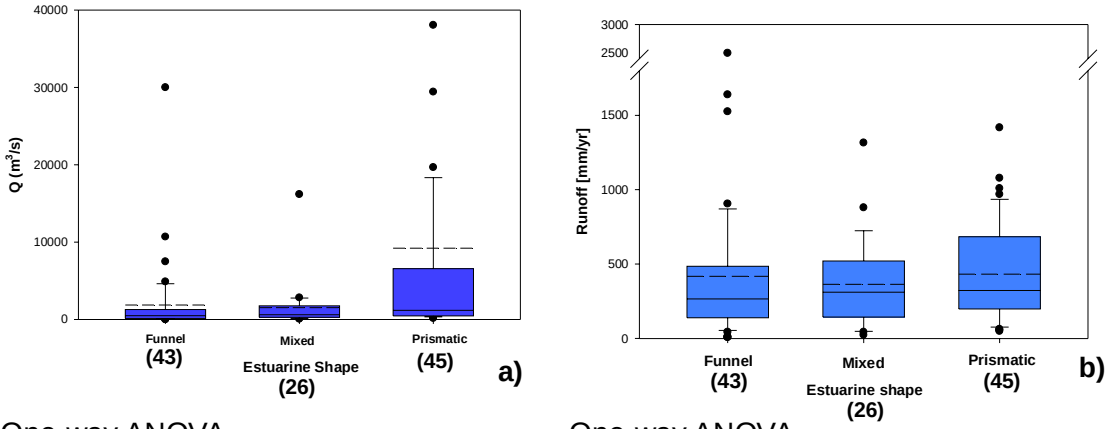


One-way ANOVA
F = 2.6375
n = 163
p = 0.079 (n.s.)

One-way ANOVA
F = 6.6299
n = 163
p = 0.0021 (**)

Figure 4.4 Boxplots for a) discharge and b) runoff based on climate zones
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis are the number of sample units per group

4.2.2 Variation with estuarine shape/width convergence length



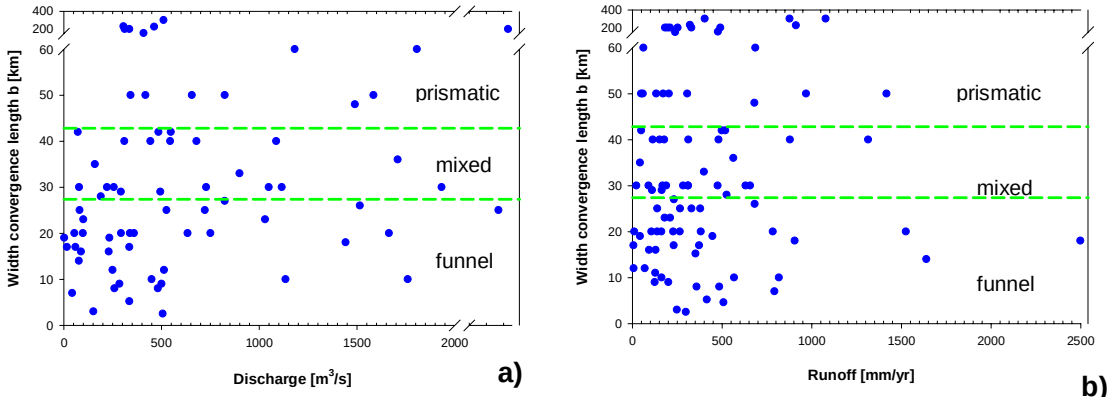
One-way ANOVA
F = 1.4453, n = 114
p = 0.2424 (n.s.)

One-way ANOVA
F = 0.4092, n = 114
p = 0.6658 (n.s.)

Figure 4.5 Boxplots for a) discharge and b) runoff in estuaries based on shape
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis are the number of sample units per group

The statistical correlations obtained between discharge/runoff and estuarine shape are both mathematically insignificant (Figure 4.5a & b). However, a qualitative positive trend is observed between discharge and estuarine shape (Figure 4.5a) in which the prismatic-type estuaries are characterized by distinctly higher discharge rates (up to 5 times higher than funnel- and mixed-shaped). This observation can be directly linked to the combined outcome of Figure 4.2 and 4.3d, where the highest number of prismatic-shaped estuaries and the highest discharge rates are found in the tropics. Note that although these observations are based on the data available in the database, which does not include all estuaries world-wide, the observed trends are still significant. The number of prismatic- and funnel-shaped estuaries considered in Figure 4.5a is comparable, yet the mean discharge for prismatic-type is higher.

The median runoff of the three categories is ~ 400-500 mm/yr (Figure 4.5b), implying that the differences in discharge based on estuarine shape are normalized when the basin area is taken into account. This implicitly means that basin area varies between the three different estuarine shape categories.



r = 0.3755
n = 115
p = 3.85e^{-5} (***)

r = 0.1104
n = 115
p = 0.2422 (n.s.)

Figure 4.6 Scatter plots and Spearman's correlation for discharge/runoff agianst width convergence length

Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).

Figure 4.6a shows a positive significant correlation between discharge and the width convergence length of 115 estuaries. It is possible to identify that the funnel-shaped estuaries are mainly characterized by low discharges up to 500 m^3/s, while the mixed and the prismatic shape estuaries exhibit a larger range of discharge rates. As in Figure 4.5b, there is no significant correlation among different estuarine shapes when runoff values are considered (Figure 4.6b).

An alternative way to investigate the relation between the geometrical (estuarine shape or width convergence length) and hydrodynamic (discharge) features is through the relationship between the dimensionless estuarine shape number (S; Eq 3) and Canter-Cremers number (C; Eq 2). Based on the data available in our database, a clear trend is obtained between S and C (Figure 4.7), in which the funnel-shaped estuaries are characterized by low C and S values, whereas prismatic-shaped lie on the other end of the continuum. This is in line with the trend presented in Savenije (2006). Two outliers can be identified for the prismatic-shaped estuaries (*a* and *b*) exhibiting rather low S and C values. With a width convergence length value of 50 km, Anabar estuary (*a)* lies on the threshold between prismatic and mixed type estuaries. Kolyma Estuary (*b)* has a depth of 41.7 km, which is typically characteristic of funnel-shaped estuaries.

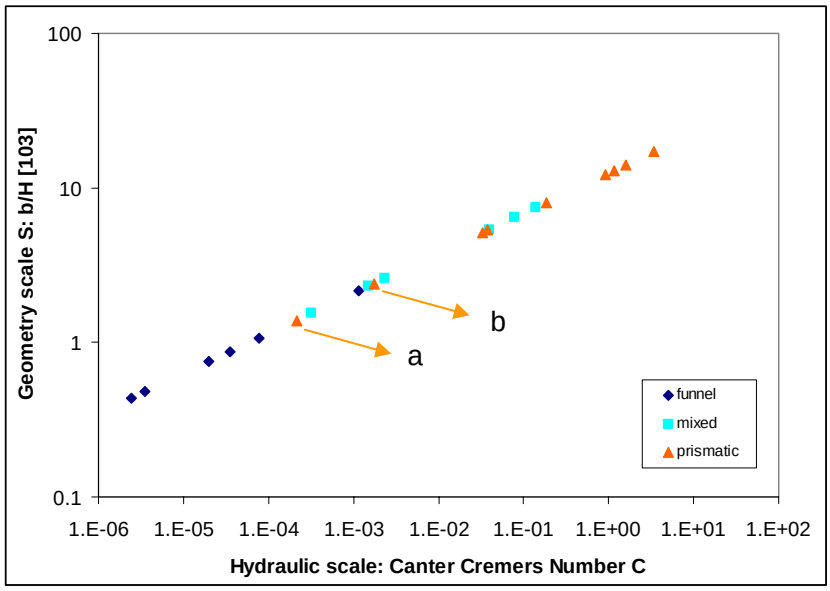


Figure 4.7 Relationship between geometry (S) and hydrodynamics (C)

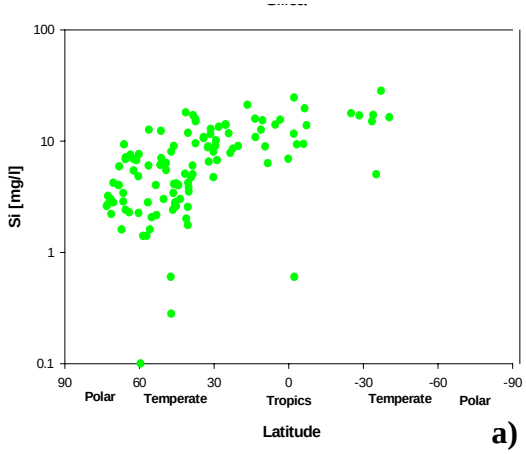
4.3 Biogeochemical behavior

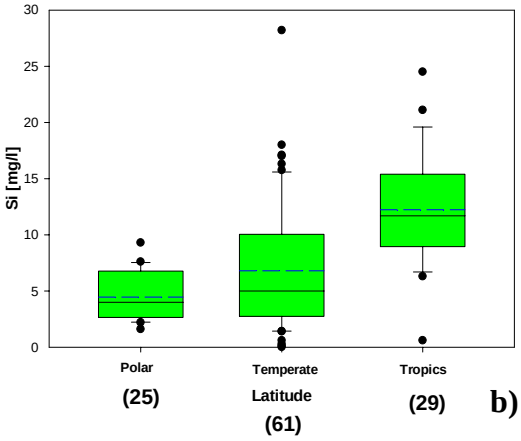
The analysis of biogeochemical behavior based on the biogeochemical data collected in the database (Table 3.1) is performed by considering both substance concentrations (mg/l) and fluxes (Ton/yr, computed as the product of discharge and concentration). In what follows, the trends of the main chemical parameters (namely Si, DIN, DON, TN, DIP, DOC, POC and TSS) with geographical distribution (latitude/climate zones) and estuarine shape/convergence length are investigated. For the other biogeochemical parameters, such as DIC, PN, PP, the number of data entries is not sufficient for carrying out statistical analysis. Since the substance concentrations considered refer to the upper estuary where salinity is zero or close to zero, the trends based on estuarine shape cannot be directly related to biogeochemical behavior within estuaries.

A summary of the statistical tests performed on the biogeochemical data is found in the Annex C. A list of additional statistical analyses of the other physico-chemical parameters can be found in Annex D.

4.3.1 Nutrient concentrations

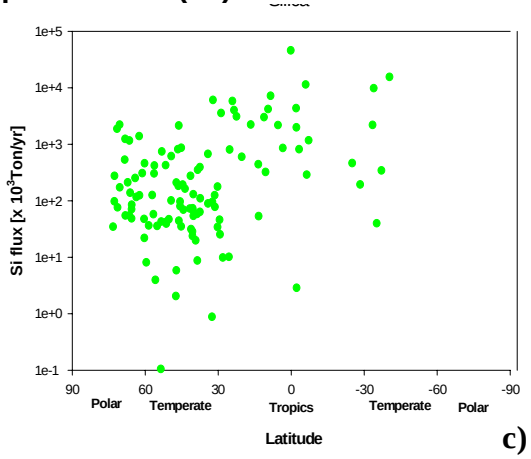
A. Silica

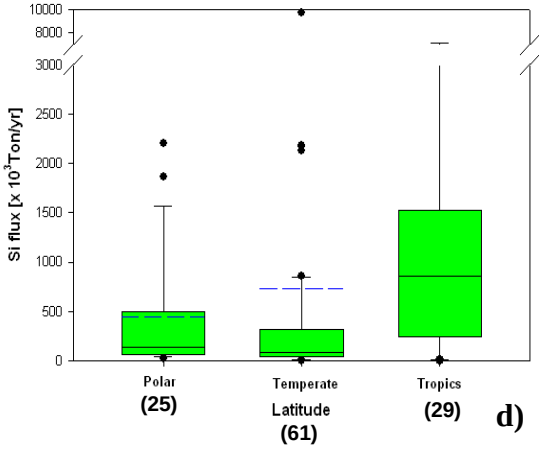




Spearman's correlation
r = -0.6448, n = 115
p = 7.37e-15 (***)

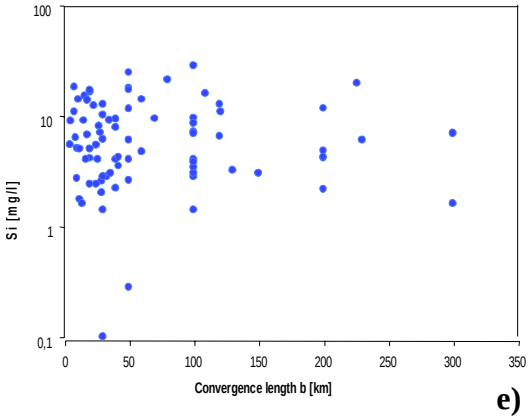
One-way ANOVA
F = 29.1049, n = 115
p = 1.07e-9 (***)



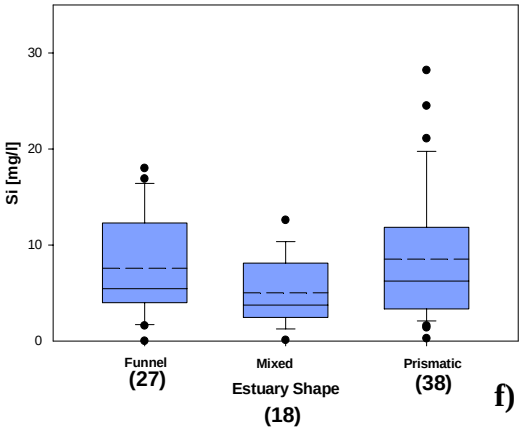


Spearman's correlation
r = -0.2915, n = 115
p = 0.0015 (**)

One-way ANOVA
F = 2.3069, n = 115
p = 0.1091 (n.s.)



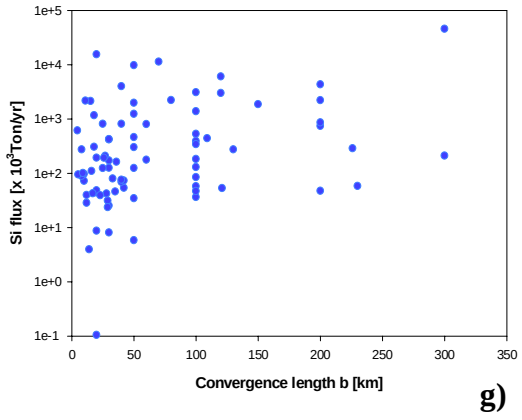
e)



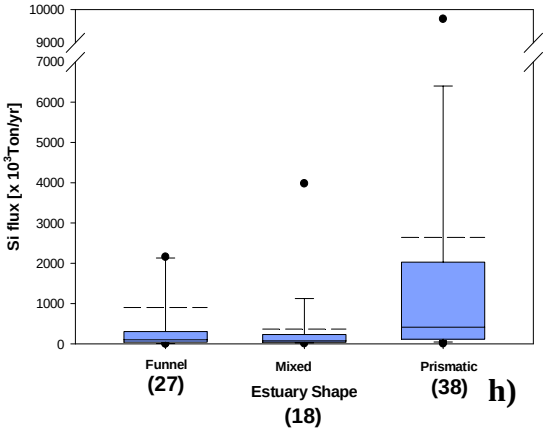
f)

Spearman's correlation
r = 0.0062, n = 83
p = 0.9556 (n.s.)

One-way ANOVA
F = 3.7396, n = 83
p = 0.0304 (*)



g)



h)

Spearman's correlation
r = 0.3240, n = 83
p = 0.0028 (**)

One-way ANOVA
F=1.9303, n = 83
p = 0.1564 (n.s.)

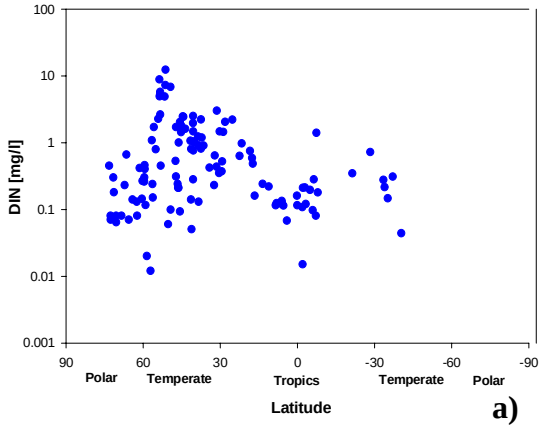
Figure 4.8 Latitude/climate zones: a) & b) silica concentration [mg/l], c) & d) silica fluxes [x10^{3}Ton/yr];
Convergence length/estuarine shape: e) & f) silica concentration [mg/l], g) & h) silica fluxes [x10^{3}Ton/yr];
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis refer to number sample units per group

In line with the study by Eyre and Balls (1999), Figure 4.8a and b show a distinct and statistically significant increase in Si concentrations from polar to the tropical region. A similar increasing trend is observed in Figure 4.8c, and to a lesser extent in Figure 4.8d, with Si fluxes increasing from the polar to tropical regions. In addition to higher discharge rates (Figure 4.3a), tropical zones are characterized by higher temperatures and therefore exhibit higher weathering rates. This leads to high Si fluxes (Figure 4.8c) and concentrations (Figure 4.8a), respectively. In the same way, Figure 4.8b and Figure 4.8d show a clear and gradual increase in silica fluxes and concentrations among the estuaries grouped per climate zone. This implies that Si concentrations vary proportionally to discharge rates, with highest Si concentrations in rivers with highest discharge rates, as is generally observed for

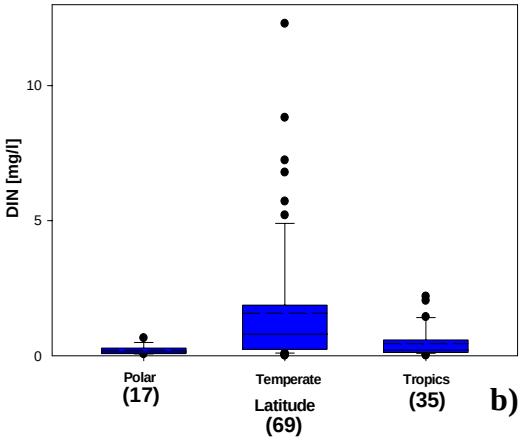
substances resulting from weathering processes (Jolankai, 1992). Such a pronounced trend is observed despite the fact that the number of tropical estuaries in the analysis is only half of that from temperate zone and comparable to the number of estuaries in the polar region (Figure 4.8b & d).

The trend in Si concentrations and fluxes with estuarine shape as determined by b, is less pronounced (Figure 4.8e-h). In terms of Si concentrations, the difference among the three climate groups is rather small even though a significant statistical correlation is obtained (Figure 4.8f). This result does not follow the observation drawn for Figure 4.8b, in which estuaries with high discharge rates (typically found in tropics or prismatic-shaped) also exhibit higher Si concentrations. The mean Si flux in the prismatic category is the highest, possibly attributed to the high discharge rates characteristic of prismatic estuaries (Figure 4.5a).

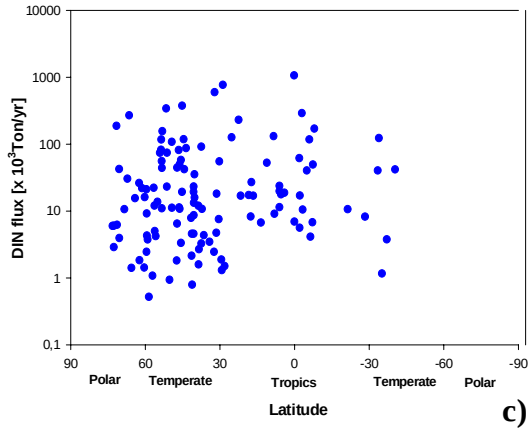
B. Dissolved Inorganic Nitrogen (DIN)



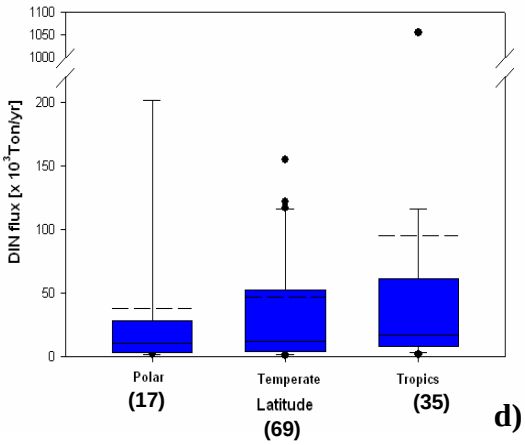
Spearman's correlation
r = -0.0651, n = 121
p = 0.4780 (n.s.)



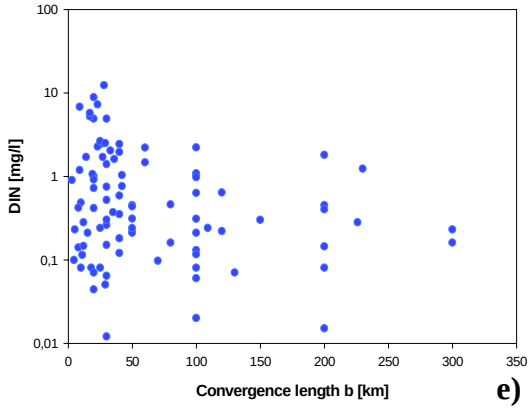
One-way ANOVA
F = 14.5821, n = 121
p = 4.77e^{-6} (***)



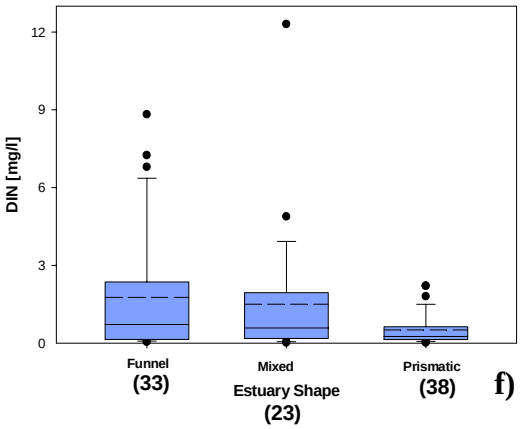
Spearman's correlation
r = -0.122, n = 121
p = 0.1825 (n.s.)



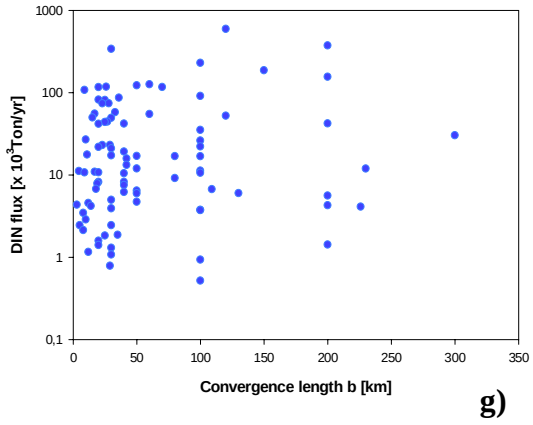
One-way ANOVA
F = 0.9907, n = 121
p = 0.379 (n.s.)



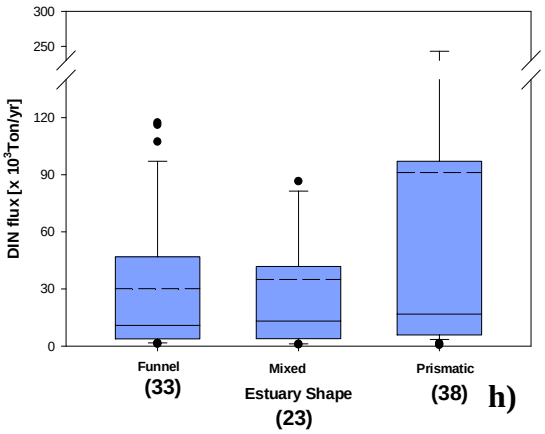
Spearman's correlation
r = -0.1758, n = 94
p = 0.090 (n.s.)



One-way ANOVA
F = 5.5667, n = 94
p = 0.0070 (**)



Spearman's correlation
r = 0.168, n = 94
p = 0.1054 (n.s.)



One-way ANOVA
F = 1.7122, n = 94
p = 0.192 (n.s.)

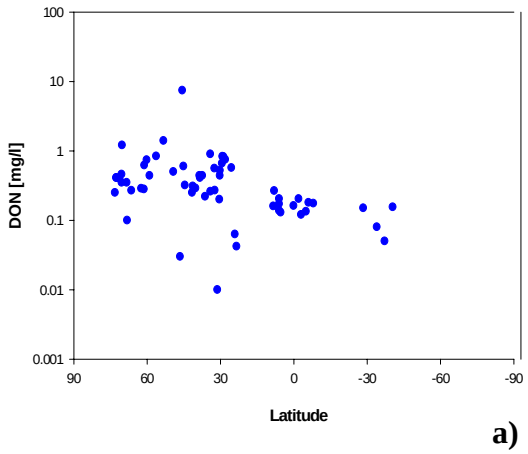
Figure 4.9 Latitude/climate zones: a) & b) DIN concentration [mg/l], c) & d) DIN fluxes [x10^{3}Ton/yr];
Convergence length/estuarine shape: e) & f) DIN concentration [mg/l], g) & h) DIN fluxes [x10^{3}Ton/yr];
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis refer to number sample units per group

Figure 4.9a and b show a significant difference in DIN concentration among the estuaries based on climate zones, with the highest DIN values found in the temperate area. Estuaries in North America and Europe located in the temperate zone are directly influenced by increased nutrient levels in rivers due to high anthropogenic activities, leading to DIN concentrations ~ two orders of magnitude higher than in the other climate zones. Such an inversed relation between concentration and discharge rates (high DIN concentrations in temperate zones with generally low discharge rates - Figure 4.3c & d; Fig 4.4a) is typically observed for substances released from point sources (Jolankai, 1992).

When considering fluxes (Figure 4.9c & d), the high DIN concentrations in the temperate regions are compensated by the high discharge rates characteristic of tropical rivers (Figure 4.9d). This gives rise to a significantly higher median DIN flux in tropical area.

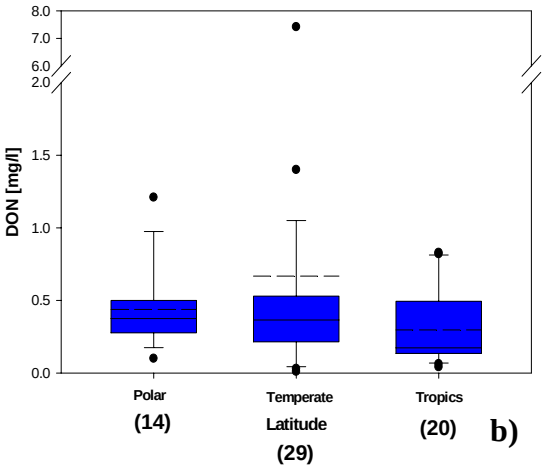
The correlations between DIN concentration/fluxes and estuarine shape (Figure 4.9e-h) are generally not significant expect for Figure 4.9f which shows a general decrease in the mean DIN concentration from the funnel- to the prismatic-shaped estuaries. The factors contributing to the observed decrease cannot be readily identified based on the trend obtained in Figure 4.9f and the distribution of estuarine shapes among the different climate zones (Figure 4.2).

C. Dissolved Organic Nitrogen (DON)



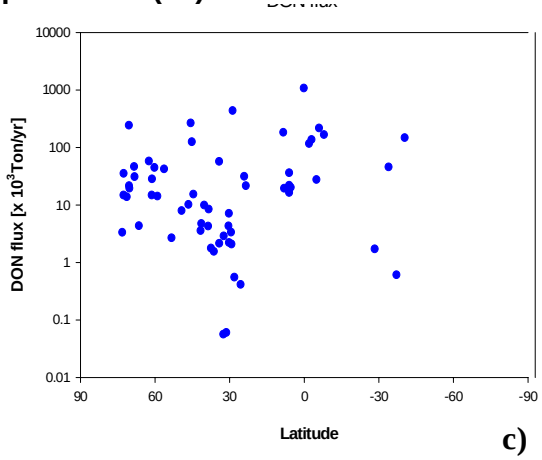
a)

Spearman's correlation
r = 0.4846, n = 60
p = 8.71e^{-5} (***)



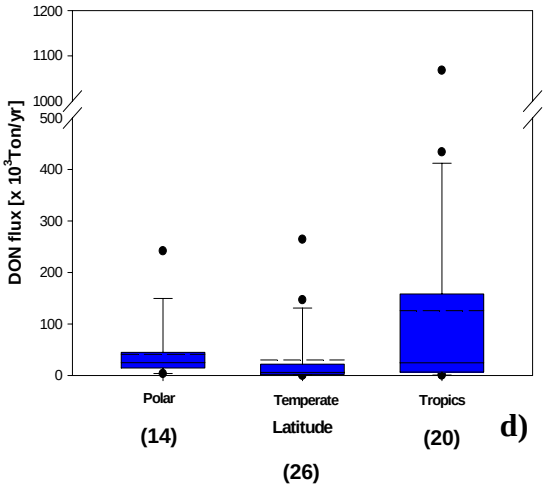
b)

One-way ANOVA
F = 1.7426, n = 60
p = 0.1898 (n.s.)



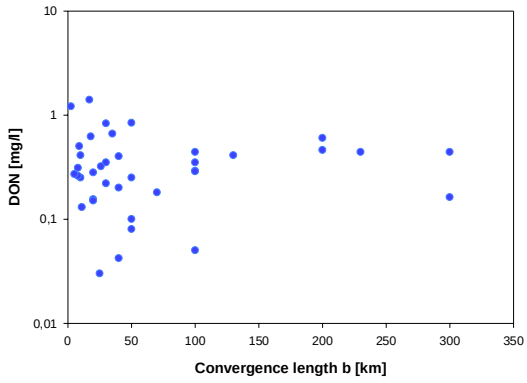
c)

Spearman's correlation
r = 0.0597, n = 60
p = 0.6499 (n.s.)



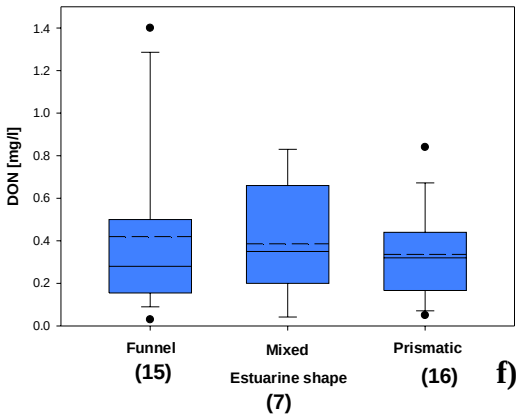
d)

One-way ANOVA
F = 1.4691, n = 60
p = 0.2461 (n.s.)



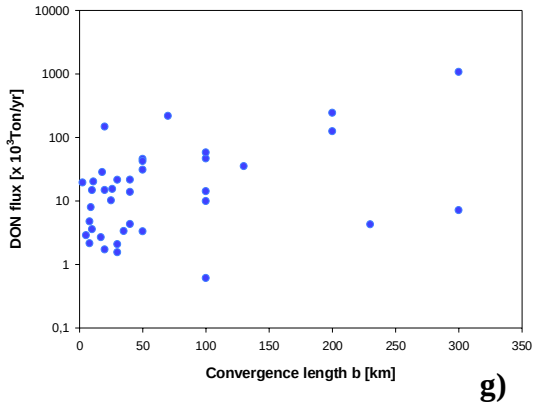
e)

Spearman's correlation
r = -0.0039, n = 38
p = 0.9815 (n.s.)



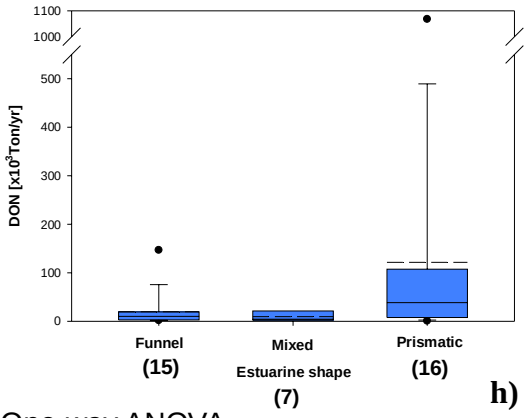
f)

One-way ANOVA
F = 0.2951, n = 38
p = 0.7463 (n.s.)



g)

Spearman's correlation
r = 0.3768, n = 38
p = 0.0197 (*)



h)

One-way ANOVA
F = 1.8659, n = 38
p = 0.1790 (n.s.)

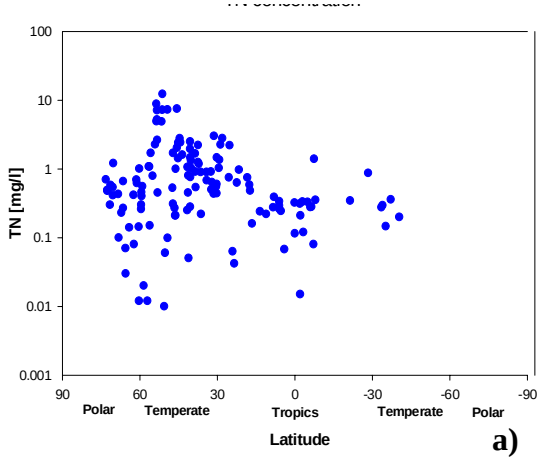
Figure 4.10 Latitude/climate zones: a) & b) DON concentration [mg/l], c) & d) DON fluxes [x10^{3}Ton/yr];
Convergence length/estuarine shape: e) & f) DON concentration [mg/l], g) & h) DON fluxes [x10^{3}Ton/yr];
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis refer to number sample units per group

The Spearman's correlation test carried out to evaluate the relationship between DON concentration with latitude yields a statistically significant correlation (Figure 4.10a), although the corresponding One-way ANOVA is statistically insignificant (Figure 4.10b). An overall decrease in DON concentration can be observed from the polar-temperate zone to the tropic regions (Figure 4.10a). In terms of fluxes (Figure 4.10c & d), the general trend is reversed owing to the higher discharge rates in the tropics.

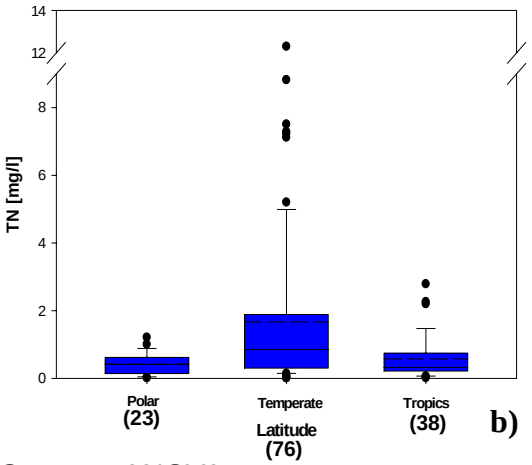
The analysis of DON concentration with estuarine shape does not yield neither qualitative nor statistically significant correlations (Figure 4.10e & f). A significant correlation is obtained between DON flux and convergence length (Figure 4.10g) using the Spearman's correlation test, showing higher fluxes in estuaries with higher convergence lengths, namely the prismatic estuaries (Figure 4.10h). The higher DON fluxes in tropical and prismatic-

shaped groups can be attributed to higher discharge rates as well as higher predominance of prismatic-shaped estuaries in tropic regions (Figure 4.2). This is because the pronounced increase in tropic/prismatic-shaped groups (Figure 4.10d & h) is not observed for DON concentrations (Figure 4.10b & f).

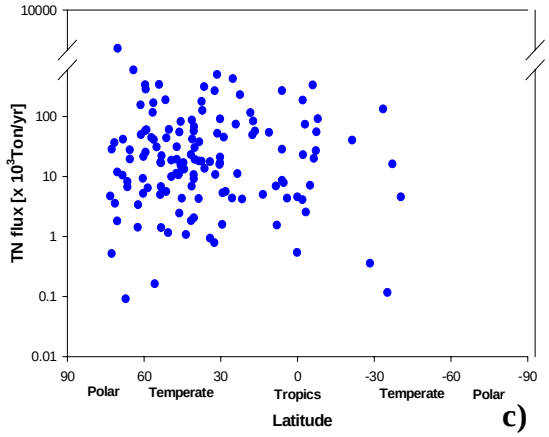
D. Total Nitrogen (TN)



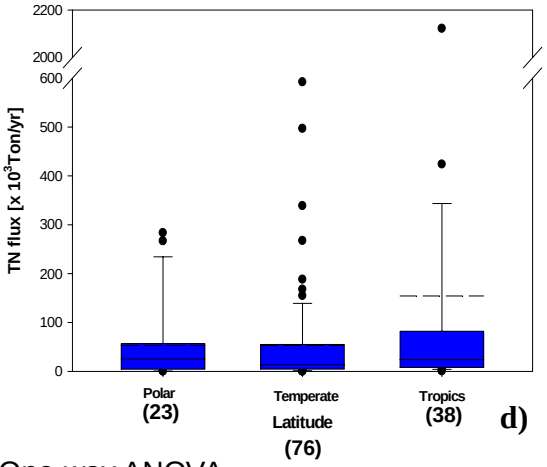
Spearman's correlation
r = 0.1092, n = 137
p = 0.2041 (n.s.)



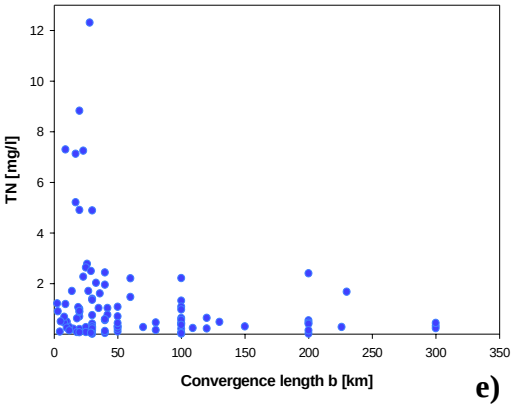
One-way ANOVA
F = 10.5543, n = 137
p = 7.98e^{-5} (***)

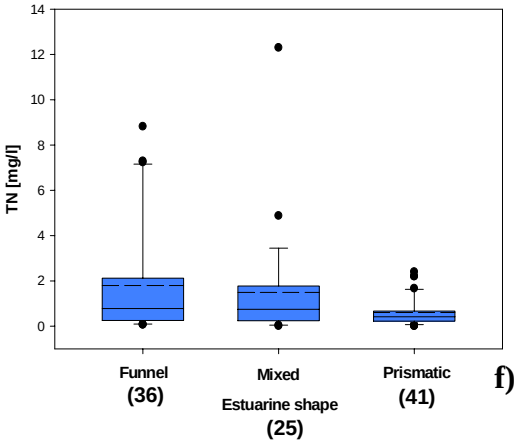


Spearman's correlation
r = -0.0580, n = 137
p = 0.4961 (n.s.)



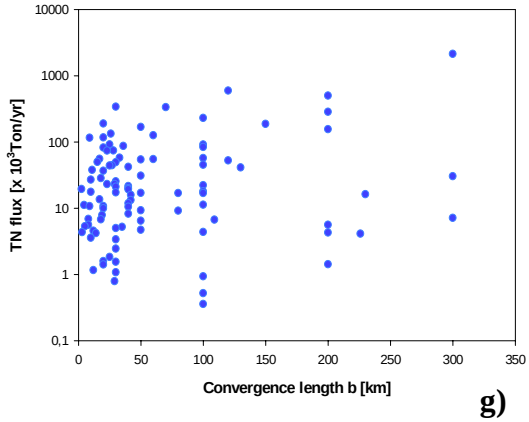
One-way ANOVA
F = 1.2320, n = 137
p = 0.4961 (n.s.)

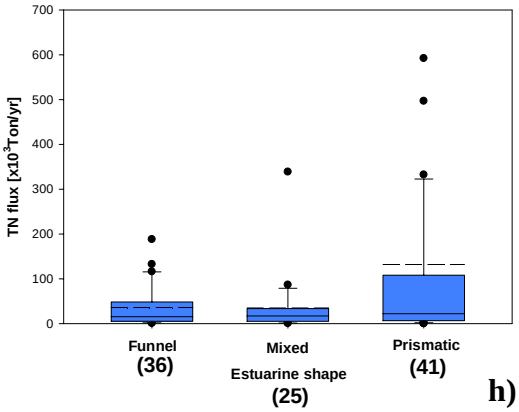




Spearman's correlation
r = -0.1961, n = 102
p = 0.0482 (*)

One-way ANOVA
F = 5.3604, n = 102
p = 0.0085 (**)





Spearman's correlation
r = 0.1557, n = 102
p = 0.1182 (n.s.)

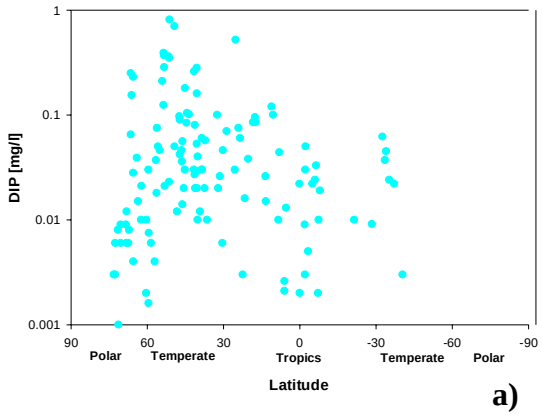
One-way ANOVA
F = 1.5550, n = 102
p = 0.2207 (n.s.)

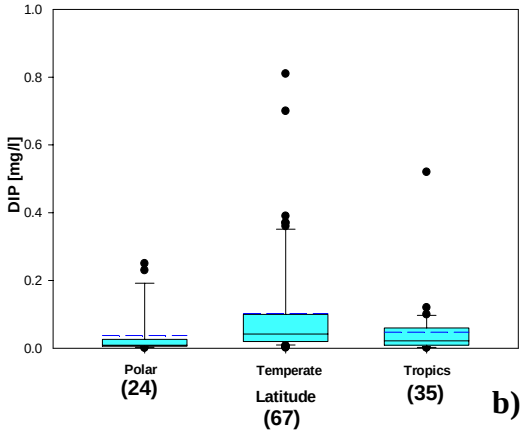
Figure 4.11 Latitude/climate zones: a) & b) TN concentration [mg/l], c) & d) TN fluxes [x10^{3}Ton/yr];
Convergence length/estuarine shape: e) & f) TN concentration [mg/l], g) & h) TN fluxes [x10^{3}Ton/yr];
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis refer to number sample units per group

The most statistically significant correlation is obtained in the analysis of TN concentrations based on climate zones (Figure 4.11b) using the One-way ANOVA test. Higher concentrations are found in estuaries located in the temperate in comparison to the polar and tropical zones due to higher anthropogenic activities in this climate zone. This is in line with the observations for DIN concentrations (Figure 4.9 b). The same feature is observed in the temperate zone in Figure 4.11a, although the Spearman's correlation test does not yield a significant statistical correlation. The analysis of TN fluxes shows that the effect of higher discharge rates in the tropics dominates over the high temperate TN concentrations, resulting in a markedly higher median TN flux in the tropical zone (Figure 4.11d).

Figure 4.11e and f yield statistically significant negative correlations between TN concentrations and width convergence length/estuarine shape. A direct link between estuarine shape and concentration cannot be readily derived based on the Figure 4.11b and the distribution of estuarine shapes among the three climate zones (Figure 4.2). TN fluxes follow the opposite trend, with TN fluxes increasing going from funnel- to prismatic estuaries (Figure 4.11h). Estuaries with prismatic shapes show higher TN fluxes in comparison to the other estuarine shapes due to the contribution of high discharge rates in the tropics, where most of the prismatic estuaries are found (Figure 4.2). The overall trends observed in the analysis of TN concentrations and fluxes are similar to those for DIN. Also, the comparable DIN and TN concentrations and flux values imply that DIN is the most significant fraction of TN.

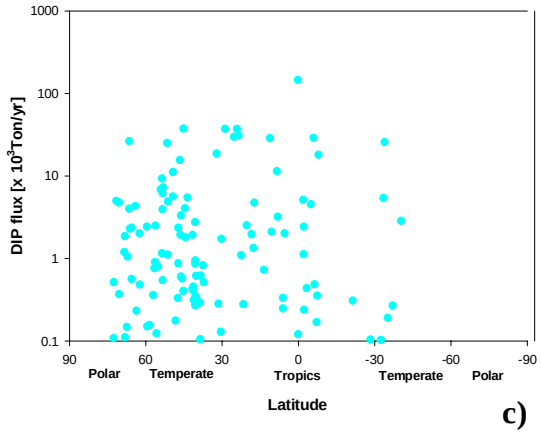
E. Dissolved Inorganic Phosphorus (DIP)

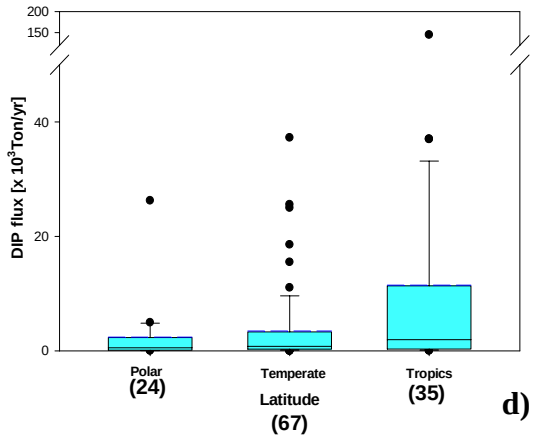




Spearman's correlation
r = -0.0163, n = 126
p = 0.8550 (n.s.)

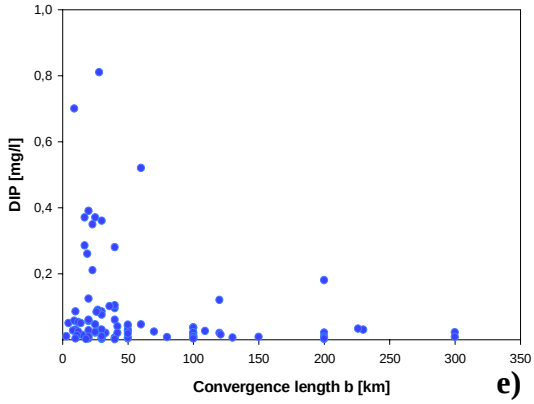
One-way ANOVA
F = 3.9704, n = 126
p = 0.0230 (*)

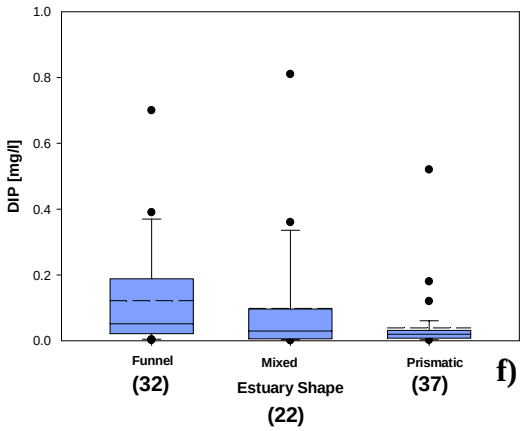




Spearman's correlation
r = -0.0809, n = 126
p = 0.3676 (n.s.)

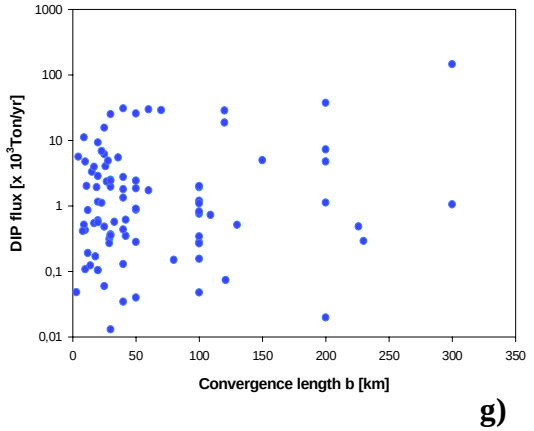
One-way ANOVA
F = 2.0514, n = 126
p = 0.1382 (n.s.)

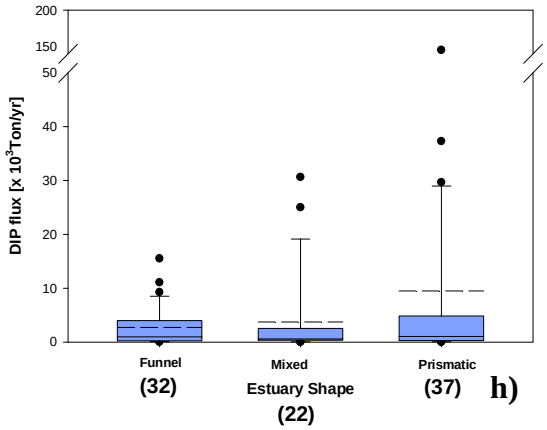




Spearman's correlation
r = -0.3134, n = 91
p = 0.0020 (**)

One-way ANOVA
F = 3.7936, n = 91
p = 0.0304 (*)





Spearman's correlation
r = 0.0651, n = 91
p = 0.5396 (n.s.)

One-way ANOVA
F = 1.4062, n = 91
p = 0.2564 (n.s.)

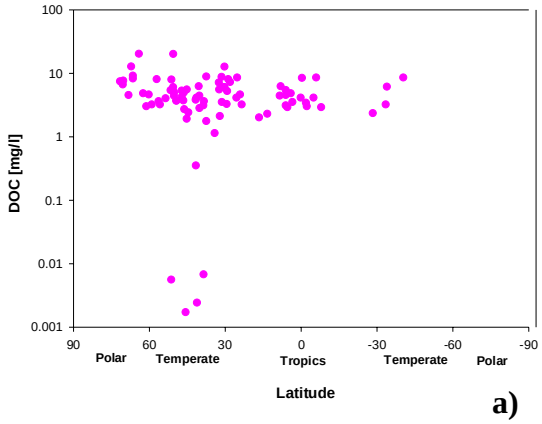
Figure 4.12 Latitude/climate zones: a) & b) DIP concentration [mg/l], c) & d) DIP fluxes [x10^{3}Ton/yr];
Convergence length/estuarine shape: e) & f) DIP concentration [mg/l], g) & h) DIP fluxes [x10^{3}Ton/yr];
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis refer to number sample units per group

Figure 4.12a and b show that the highest DIP concentrations are found in temperate estuaries. As for nitrogen, this relates to the anthropogenic inputs in North American and European estuaries. The analysis of DIP fluxes with latitude/climate zones indicates higher DIP fluxes in tropical zones, followed by temperate and polar (Figure 4.12c & d), although the statistical correlations are not significant.

Figure 4.12e and f show statistically significant negative correlations between DIP concentrations and estuarine shape, with higher DIP concentrations in funnel-shaped estuaries, decreasing towards the prismatic estuaries. The opposite trend is obtained in Figure 4.12g and h although the statistical tests do not show a significant correlation. In general, trends identified for DIP correspond to those observed for DIN (Figure 4.9) and TN (Figure 4.11).

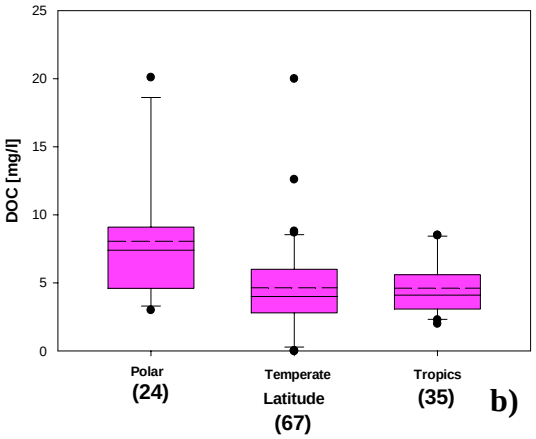
4.3.2 Carbon concentrations

A. Dissolved Organic Carbon (DOC)



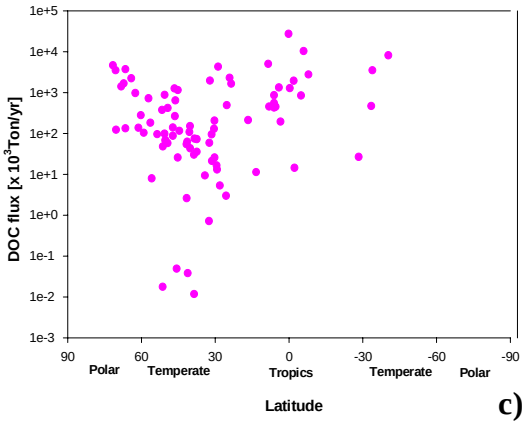
a)

Spearman's correlation
r = 0.1425, n = 84
p = 0.1950 (n.s.)



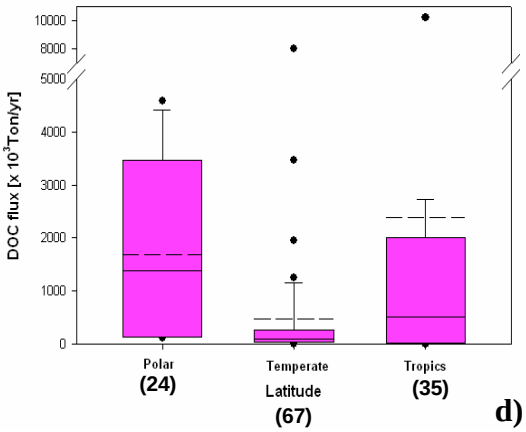
b)

One-way ANOVA
F = 2.6119, n = 84
p = 0.0930 (n.s.)



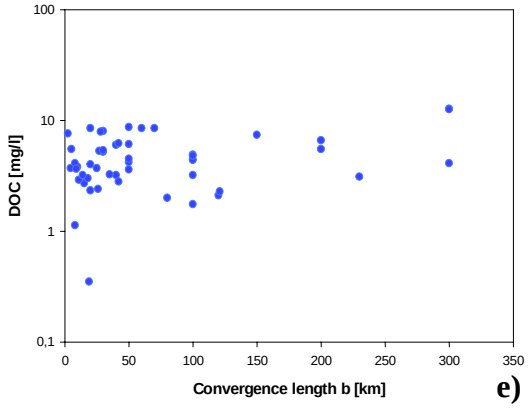
c)

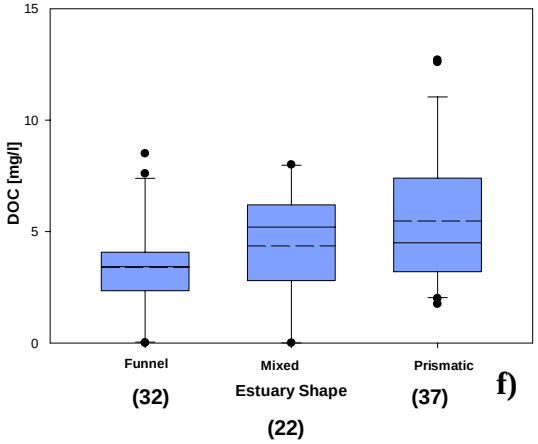
Spearman's correlation
r = -0.1065, n = 84
p = 0.3346 (n.s.)



d)

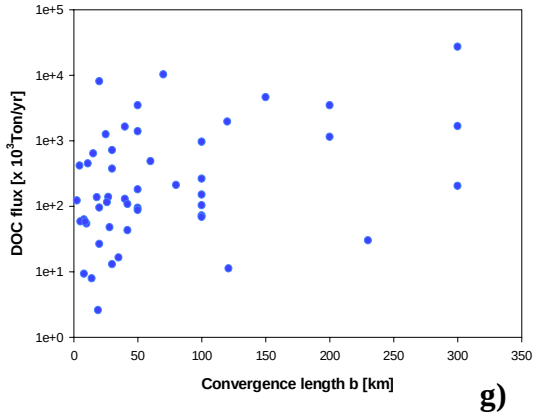
One-way ANOVA
F = 4.0015, n = 84
p = 0.0321 (*)

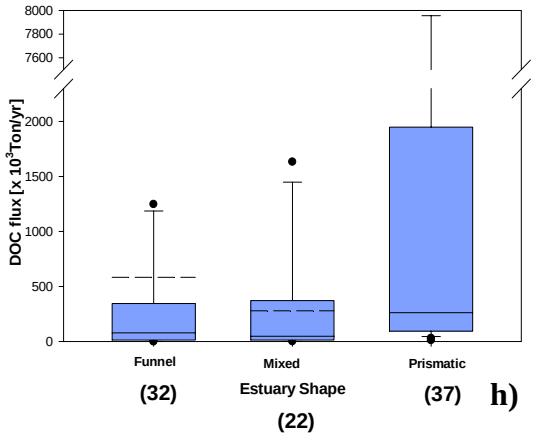




Spearman's correlation
r = 0.2589, n = 54
p = 0.0580 (n.s.)

One-way ANOVA
F = 3.1528, n = 54
p = 0.0510 (n.s.)





Spearman's correlation
r = 0.3938, n = 54
p = 0.0030 (**)

One-way ANOVA
F = 1.8300, n = 54
p = 0.1774 (n.s.)

Figure 4.13 Latitude/climate zones: a) & b) DOC concentration [mg/l], c) & d) DOC fluxes [x10^{3}Ton/yr];
Convergence length/estuarine shape: e) & f) DOC concentration [mg/l], g) & h) DOC fluxes [x10^{3}Ton/yr];
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis refer to number sample units per group

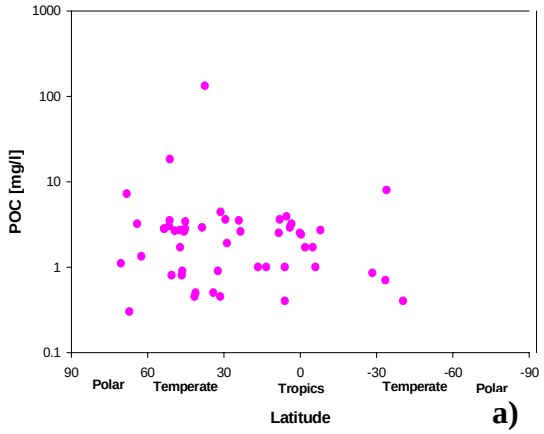
Although both the Spearman's correlation and One-way ANOVA tests do not yield statistically significant correlations, an overall decreasing trend in DOC concentrations from the polar to the tropic is observed (Figure 4.13a & b). As shown in other studies, for example Pocklington & Dartmouth (1987), Arctic rivers transport high quantities of terrestrially-derived DOC.

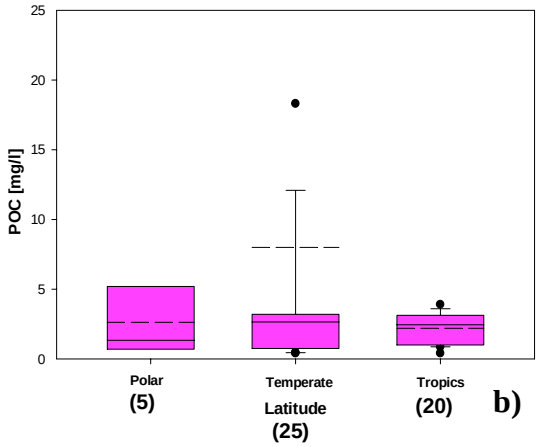
Figure 4.13b shows a significant statistical correlation among the estuaries grouped by climate zones, despite the difference in the number of estuaries in each climate category. The median DOC concentration in the temperate and tropic zones is 4.2 and 4.1mg/l (Figure 4.13b), respectively, which is reasonably close to the median value of 5 mg/l found in most of the rivers around the world (Meybeck, 1982).

DOC fluxes show a generally increasing trend with latitude (Figure 4.13c). Although a higher median is observed for the tropics (Figure 4.13d), estuaries in the polar region show a higher DOC flux range. In the tropics, the high fluxes can be explained by the high discharge rates, whereas in polar regions, the observed high fluxes can be attributed to high DOC concentrations (Figure 4.13a & b). This is in line with generally high erosion rates for TOC (Pocklington & Dartmouth, 1987), of which DOC is the major fraction, characteristic of the Euroasian and the Soviet rivers of Siberia, included here in the polar category.

A generally increasing relation between DOC concentrations/fluxes and estuarine shape is observed (Figure 4.13e-h). A steady increase in DOC concentration is seen going from funnel- to prismatic-shaped estuaries although the correlation is not statistically significant (Figure 4.13f). The opposite trends obtained in the Figure 4.13b and Figure 4.13f cannot be explained based on available information. A statistically significant positive correlation between DOC fluxes and width convergence length is seen in Figure 4.13g, showing the highest DOC fluxes in prismatic-shaped estuaries (Figure 4.13h). This is related to the predominance of prismatic-shaped estuaries in tropical regions (Figure 4.2) which are generally characterized by high discharge rates (Figure 4.4).

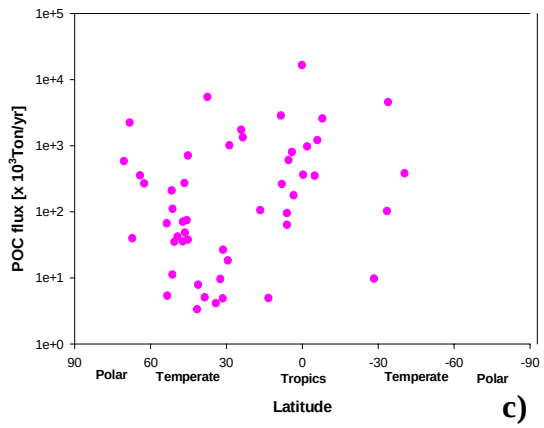
B. Particulate Organic Carbon (POC)

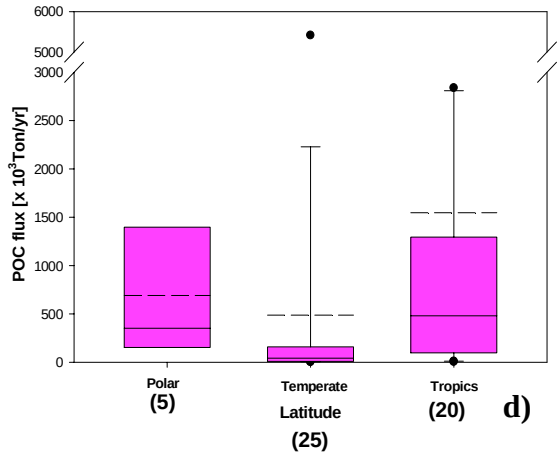




Spearman's correlation
r = 0.1189, n = 50
p = 0.4105 (n.s.)

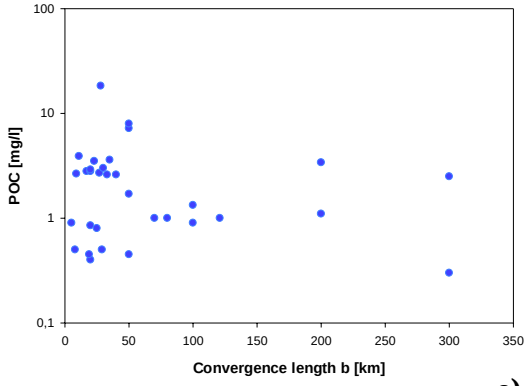
One-way ANOVA
F = 0.6276, n = 50
p = 0.5541 (n.s.)



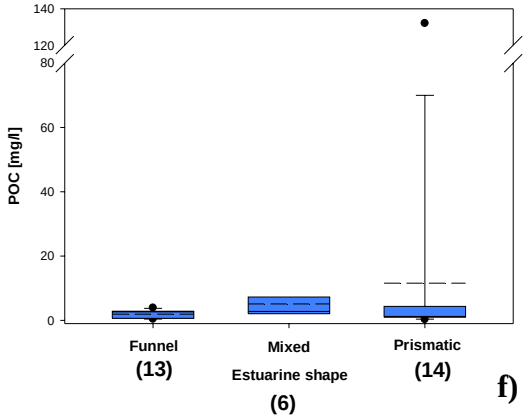


Spearman's correlation
r = -0.3066, n = 50
p = 0.0303 (*)

One-way ANOVA
F = 0.76, n = 50
p = 0.4844 (n.s.)



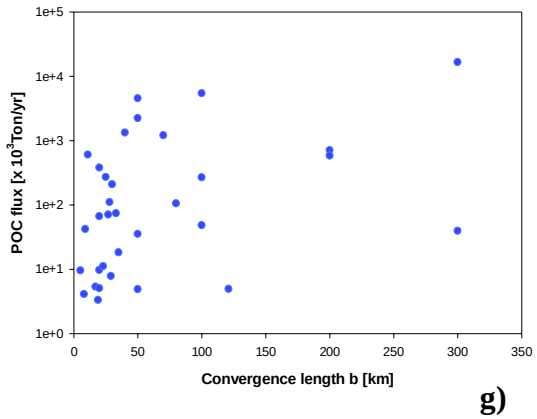
e)



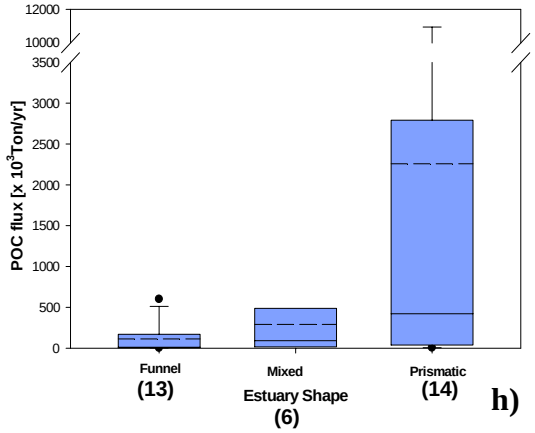
f)

Spearman's correlation
r = 0.0174, n = 33
p = 0.9233 (n.s.)

One-way ANOVA
F = 1.1413, n = 33
p = 0.3581 (n.s.)



g)



h)

Spearman's correlation
r = 0.4488, n = 33
p = 0.0087 (**)

One-way ANOVA
F = 1.8301, n = 33
p = 0.2081 (n.s.)

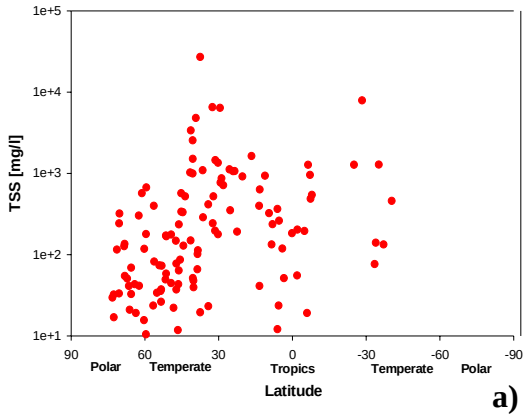
Figure 4.14 Latitude/climate zones: a) & b) POC concentration [mg/l], c) & d) POC fluxes [x10^{3}Ton/yr];
Convergence length/estuarine shape: e) & f) POC concentration [mg/l], g) & h) POC fluxes [x10^{3}Ton/yr];
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis refer to number sample units per group

As shown in Figure 4.14a and b, there is no significant relation between POC concentrations and latitude, although temperate estuaries show higher median concentrations in comparison to the polar and tropics. This could be possibly related to the anthropogenic activities in temperate estuaries, since polluted rivers and estuaries tend to have higher concentrations of POC. A positive statistical correlation is observed between POC flux and latitude (Figure 4.14c), which however is less visible in the analysis of climate groups (Figure 4.14d).

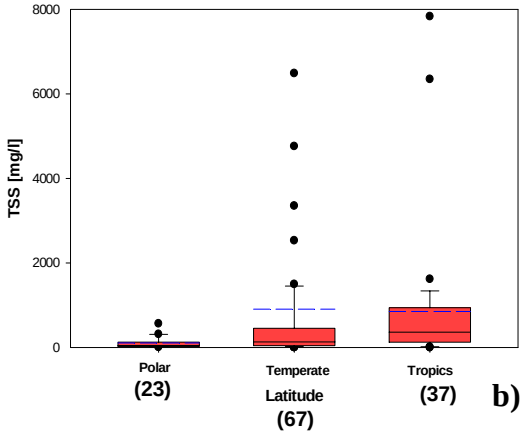
POC fluxes exhibit a statistically significant trend with estuarine shape (Figure 4.14g), with values increasing going from the funnel- towards the prismatic-shaped estuaries. A steady increase in the median and range is also observed in Figure 4.14h, although the statistical correlation obtained by the One-way ANOVA test is not significant. The observed trends generally correspond to those identified for DOC concentrations and fluxes (Figure 4.13).

The comparison of Figure 4.13 and Figure 4.14 shows that DOC concentrations are ~one order of magnitude higher than POC, as also stated in Olsson and Anderson (1997). DOC is also roughly comparable to TOC (not shown), implying that DOC is the major TOC fraction. This is generally true for all the estuaries in the database for which DOC and POC is available, except for Huang He estuary in which the POC concentration (132 mg/l) is 7.2 times higher than the DOC concentration.

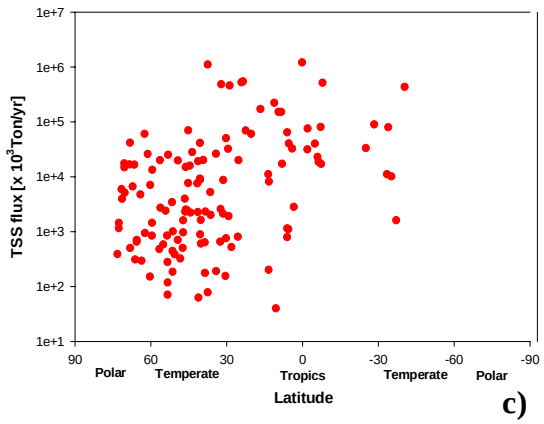
4.3.3 Total Suspended Solids (TSS)



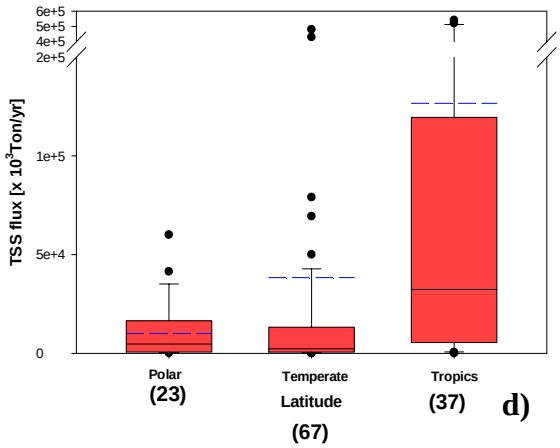
Spearman's correlation
r = -0.4011, n = 127
p = 2.97e^{-6} (***)



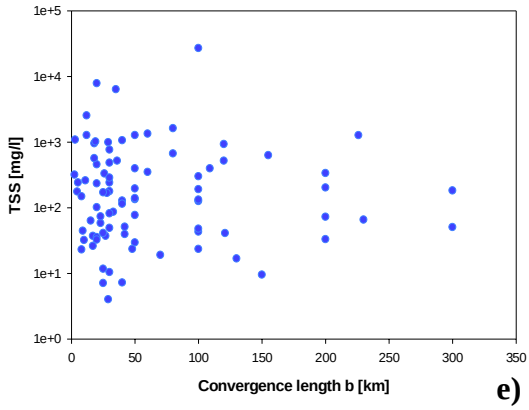
One-way ANOVA
F = 5.8102, n = 127
p = 0.0048 (**)



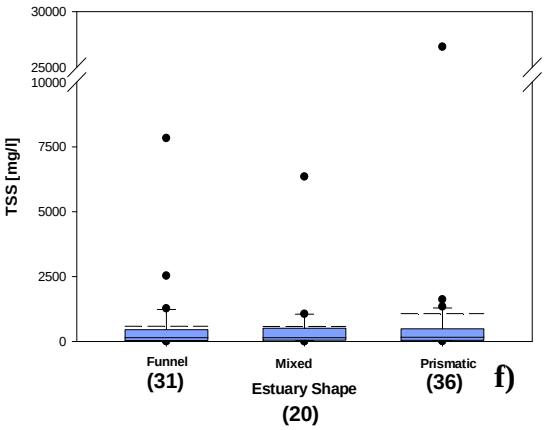
Spearman's correlation
r = -0.4022, n = 127
p = 2.767e^{-6} (***)



One-way ANOVA
F = 5.4022, n = 127
p = 0.006 (**)



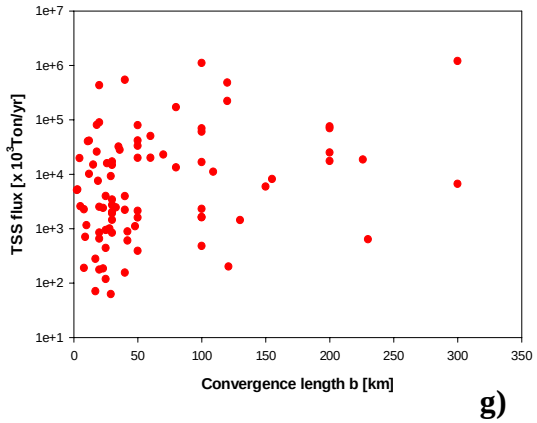
e)



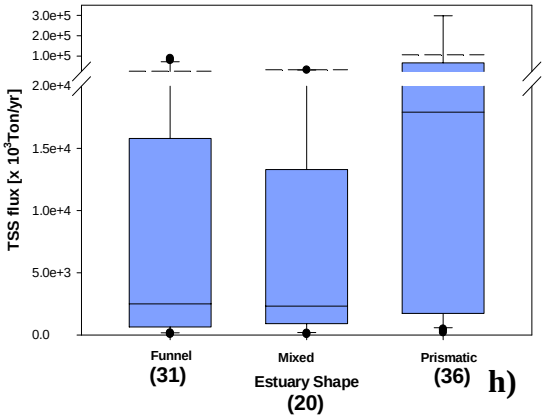
f)

Spearman's correlation
r = -0.0052, n = 87
p = 0.9615 (n.s.)

One-way ANOVA
F = 0.2025, n = 87
p = 0.8173 (n.s.)



g)



h)

Spearman's correlation
r = 0.2694, n = 87
p = 0.0110 (*)

One-way ANOVA
F = 1.4344, n = 87
p = 0.2492 (n.s.)

Figure 4.15 Latitude/climate zones: a) & b) TSS concentration [mg/l], c) & d) TSS fluxes [x10^{3}Ton/yr];
Convergence length/estuarine shape: e) & f) TSS concentration [mg/l], g) & h) TSS fluxes [x10^{3}Ton/yr];
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).
Numbers in parenthesis refer to number sample units per group

The analysis of TSS concentrations and fluxes with latitude yields statistically significant correlations (Figure 4.14a-d). A positive trend is obtained with increasing concentrations and fluxes going from the polar to tropical regions. The markedly high class range obtained for the tropical group (Figure 4.14d) indicates that the high fluxes are not only attributed to the high discharge rates (Figure 4.2) but also to high TSS concentrations (Figure 4.14b) characteristic for this climate zone. In line with previous results (e.g. silica; Figure 4.8), a combination of factors, namely high temperatures, high erosion and weathering rates, are the main contributing factors.

The variations of TSS with estuarine shape are not statistically significant, with the exception of the Spearman's correlation test for fluxes. The higher fluxes in estuaries with

higher convergence length (Figure 4.14g) are attributed to the high discharge rates that generally characterize these estuaries (Figures 4.5a & 4.6a). However, the difference between the prismatic group and the other estuarine shapes is less pronounced in the box-plot analysis (Figure 4.14h).

5 Shortcomings

5.1 Physical and geometrical parameters

In order to test the accuracy of our calculation, the methodology used here for the determination of the width convergence length (Section 3.2) was also applied to other estuaries for which the convergence length has been already measured and reported in other studies. A comparison of the calculated and previously available values of b (Table 5.1) shows that in most cases, b is on the same order of magnitude although not necessarily the same value. The difference in values can be related to the different applied methodologies. For instance, in GEMCO (2002) topographical maps available by that year were used as compared to this study, where satellite imagery maps available in Google Earth were used. This latter method provides an easier and more accurate way of measuring the widths and distances of estuaries. Other differences can be attributed to the dynamic nature of estuarine geomorphologies, for example in the measurement of the width at the mouth, especially in cases where the main river splits in several branches before discharging in the sea. Some examples of different estuaries that proved to be difficult to measure due to the presence of multiple mouths, branched main drainage lines and where main drainage lines form a bay are given in Annex B.

Table 5.1 Width convergence length calculated for some estuaries

Estuary	convergence length b [km] From literature	Reference	convergence length b [km] This study	x [km] measured
Guadiana	9	GEMCO (2003)	15	20.14
Ebro	29	GEMCO (2003)	120	32.66
Mae Klong	155	Savenije (1992)	150	30.56
Chao Phya	109	Savenije (2001)	80	43.54
	56	Toffolon et al., (2006)		
Tha Chin	87	Savenije (2001)	20	24.4
	50	Toffolon et al., (2006)		
Loire	27	GEMCO (2003)	20	51.5
Eems	17	GEMCO (2003)	8	40.44

In this study we assume that the width convergence length (b) is equal to the cross-sectional convergence length (a). This major assumption is only valid for estuaries with a constant estuarine depth (h). Due to lack of bathymetric data for most estuaries in our database, this assumption was not further investigated. However, the distribution of the modeled a and b for a number of UK estuaries shows that a and b are not necessarily the same and hence the assumption of constant depth is not always valid.

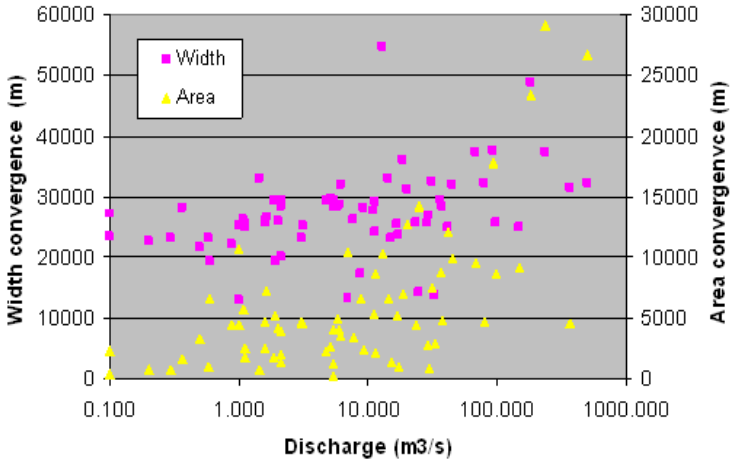


Figure 5.1 Distribution of width and area convergence length [m] along the discharge [m3/s] of estuaries
Source: Provided by Ian Townend, HR Wallingford Ltd

In a separate study on Australian estuaries, the difference in the measured convergence lengths can be attributed to the change of the geometry at the mouth. This change of the estuary mouth could be due to natural reasons in response to fresh water inflows and littoral drift, and anthropogenic structures. All these factors have an important implication for the water quality and ecology as well (Pierson et al., 2002).

5.2 Biogeochemical parameters

These analyses rely on annual average concentrations and quantities and therefore do not give insight in the spatial and temporal variations.

6 Summary and outlook

A summary table with an overview of the significant statistical correlations between the tested chemical parameters and other factors included in the estuarine database (namely geographical distributions, climate zones, convergence length and estuary shape) is given in Table 6.1. Further details on the actual correlation indices are given in the Annex C.

Table 6.1 Overview of the significant statistical correlations obtained for the variation in chemical parameters with respect to latitude/climate zone and width convergence length/estuarine shape

Parameter	Latitude (Spearman)	Climate Zones (ANOVA)	Convergence Length (Spearman)	Estuary Shape (ANOVA)
Si	○ ●	●	○	●
DIN		●		●
DON	●		○	
TN		●	●	●
DIP		●	●	●
DOC		○	○	
POC	○		○	
TSS	○ ●	○ ●	○	

○ flux

● concentration

According to the statistical results, it is possible to conclude that the geographical distribution and estuarine shape have some implications for the biogeochemical functioning of estuaries, in particular for Si, TN, DIP and TSS. In the analyses with latitude/climate zones, it became clear that climate plays an important role on the biogeochemical behavior of estuaries since most of the processes are temperature-dependant. Variation in discharge rates between the different climatic groups generally determines the trends in chemical fluxes. In the case of nutrients, anthropogenic activities characteristic to distinct climate zones greatly influence the concentration ranges.

In general the following trends with latitude/climate zones have been identified:

- Si, TSS concentrations/fluxes: increasing trend from polar to tropic
- DIN, DON, TN, DIP, POC concentrations: increasing from polar to temperate, decreasing from temperate to tropic
- DIN, DON, TN, DIP fluxes: generally increasing from polar to tropic
- DOC concentrations: decreasing trend from polar to tropic

Si and TSS showed the most statistically significant correlations with positive trends for both concentrations and fluxes, increasing from the polar towards the tropics. Temperature-dependent erosion and weathering rates, as well as high discharge rates are the main characteristics of rivers located in the tropical region.

In general, the highest nitrogen and phosphorus concentrations were observed in estuaries located in the temperate region, as a result of high anthropogenic activities in Europe and North America.

Organic carbon in the form of DOC showed a negative trend decreasing from the polar to tropical zones. This is attributed to huge quantities of terrestrially-derived DOC transported by Arctic rivers to the Arctic Ocean. Concentrations of POC follow a similar trend as those

established for nitrogen and phosphorus, in which the highest concentrations are found in the temperate regions as a result of anthropogenic activities.

An important outcome is that substances resulting from erosion processes, such as Si and TSS vary directly with discharge, i.e. higher concentrations in rivers with higher discharges typically found in tropical regions. Substances possibly resulting from point sources, such as nutrients, vary inversely with discharges rates, i.e higher concentrations are found in rivers with generally lower discharges, such as in temperate regions.

The identified trends with width convergence length/estuarine shape are less clear. This is because the values for chemical parameters in the database refer to the upper estuary characterized by salinities close to zero, whereas the estuarine shape is a characteristic of the lower estuary. Although it is not easy to establish a direct link with biogeochemical behavior, the concentration ranges and trends with estuarine shape will be used to define the upper estuarine boundary conditions in model scenarios that assume different estuarine shapes.

The following trends with width convergence length/estuarine shape have been identified:

- Si, TSS concentration/fluxes: generally increasing from funnel- to prismatic-shaped
- DIN, TN, DIP concentrations: decreasing from funnel- to prismatic-shaped
- DIN, TN, DIP fluxes: increasing from funnel- to prismatic-shaped
- DOC, POC concentration/fluxes: generally increasing from funnel to prismatic

The classification and analysis of estuarine data presented above gives insight in the geometric-hydrodynamic-biogeochemical trends in estuaries world-wide. The trends and typical concentrations ranges established through data analysis will provide useful information for defining the hydrodynamic – biogeochemical estuarine modeling scenarios. The overall aim of the subsequent modeling study is to assess the contribution to CO_2 air/water fluxes of estuaries, which be later upscaled from the regional scale to the global scale.

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ANNEX A

Information About Estuaries
US Environmental Protection Agency (EPA)
EPA Office of Water Resource Center (OWRC)
Operated by The Track Group

NOTE: This information resource includes links to non-EPA web sites mention of these web sites, organizations, or services should not be considered an endorsement by EPA.

"Estuaries are places where rivers meet the sea. Estuaries are critical to the health of coastal environments and to our enjoyment of them. EPA's National Estuary Program was established by Congress in 1987 to improve the quality of estuaries of national importance."

[Source: http://www.epa.gov/owow/estuaries/]

National Estuary Program (NEP)

++ Home ++
http://www.epa.gov/owow/estuaries/

Basic Information About Estuaries
http://www.epa.gov/owow/estuaries/about.html

Challenges
http://www.epa.gov/owow/estuaries/challenges.html

Climate Ready Estuaries (CREs)
http://epa.gov/cre/

Basic Information
http://www.epa.gov/cre/basic.html
Coastal Toolkit
http://www.epa.gov/cre/toolkit.html
Explore
http://www.epa.gov/cre/explore.html
News and Events
http://www.epa.gov/cre/news.html
Where You Live
http://www.epa.gov/cre/live.html

Contact Us
http://www.epa.gov/owow/estuaries/contact.html

EPA's 2004-2006 National Estuary Program (NEP) Implementation Report
http://www.epa.gov/owow/estuaries/pdf/2004-2006_irreportfinal_6-19-08.pdf

Estuaries and Clean Water Act of 2000
http://www.epa.gov/owow/estuaries/pdf/s835_estuaries2000.pdf

Estuaries in the National Estuary Program
http://www.epa.gov/owow/estuaries/estuaries.html

- Contact Information
  http://www.epa.gov/owow/estuaries/contactinfo.html
- Comprehensive Conservation and Management Plans (CCMPs)
  http://www.epa.gov/owow/estuaries/ccmp/index.html
- Home Pages
  http://www.epa.gov/owow/estuaries/nep_home.html
- Profiles
  http://www.epa.gov/owow/estuaries/profiles.html
- Study Areas
  http://www.epa.gov/owow/estuaries/studyareas.html
- Watersheds
  http://www.epa.gov/owow/estuaries/watersheds.html

Exploring Estuaries *[Content for children, students & teachers]*
http://www.epa.gov/owow/estuaries/kids/

Frequently Asked Questions (FAQs)
http://www.epa.gov/owow/estuaries/questions.html

Habitat Protection & Restoration Overview
http://www.epa.gov/owow/estuaries/pivot/overview/intro.htm

- Contributing Factors
  http://www.epa.gov/owow/estuaries/pivot/overview/factors.htm
- Habitat Goals and NEP Plans
  http://www.epa.gov/owow/estuaries/pivot/habitat/doing.htm
- Habitat Loss and Degradation
  http://www.epa.gov/owow/estuaries/pivot/habitat/problem.htm
- Local NEP Projects and Regional Summary
  http://www.epa.gov/owow/estuaries/pivot/habitat/hab_fr.htm
- National Program Results
  http://www.epa.gov/owow/estuaries/pivot/habitat/progress.htm

National Coastal Condition Report III (2008)
http://www.epa.gov/owow/oceans/nccr3/downloads.html

National Estuary Program Booklet
http://www.epa.gov/owow/estuaries/pdf/nep_brochure_timeless_new.pdf

National Estuary Program Evaluation Guidance
http://www.epa.gov/owow/estuaries/pdf/final_guidance_sept28.pdf

National Estuary Program in Action
http://www.epa.gov/owow/estuaries/action.html

National Program Results
http://www.epa.gov/owow/estuaries/pivot/habitat/progress.htm

Smart Growth: Estuary Programs and Improvement
http://www.epa.gov/owow/estuaries/smartgrowth.html

State of Our NEP Estuaries
http://www.epa.gov/owow/estuaries/bay.html

Videos from the National Estuary Programs
http://www.epa.gov/owow/estuaries/nepvideos.html

Chesapeake Bay Program Office *[The Chesapeake Bay is protected under its own federally mandated program, separate but related to the National Estuary Program]*

++ Home ++
http://www.epa.gov/Region3/chesapeake/

Bay Barometer: A Health and Restoration Assessment of the Chesapeake Bay and Watershed in 2008
http://www.chesapeakebay.net/content/publications/cbp_34915.pdf

Chesapeake Bay Program
http://www.chesapeakebay.net/

Civil Enforcement
http://www.epa.gov/compliance/civil/initiatives/chesapeakebay.html

Contacts
http://www.chesapeakebay.net/comments.aspx

Oceans, Coasts & Estuaries

++ Home ++
http://www.epa.gov/OWOW/oceans/index.html

A – Z Index
http://www.epa.gov/owow/oceans/a-z.html

General Information & Resources
http://www.epa.gov/owow/oceans/geninfo.html

Ocean Regulatory Programs
http://www.epa.gov/owow/oceans/regulatory/index.html

Related Information Resources

National Oceanic & Atmospheric Administration (NOAA)

++ Home ++
http://www.noaa.gov/index.html

Estuaries
http://oceanservice.noaa.gov/education/tutorial_estuaries/welcome.html

Estuaries.Gov
http://www.estuaries.gov/

Further Reading
http://oceanservice.noaa.gov/education/tutorial_estuaries/est12_references.html

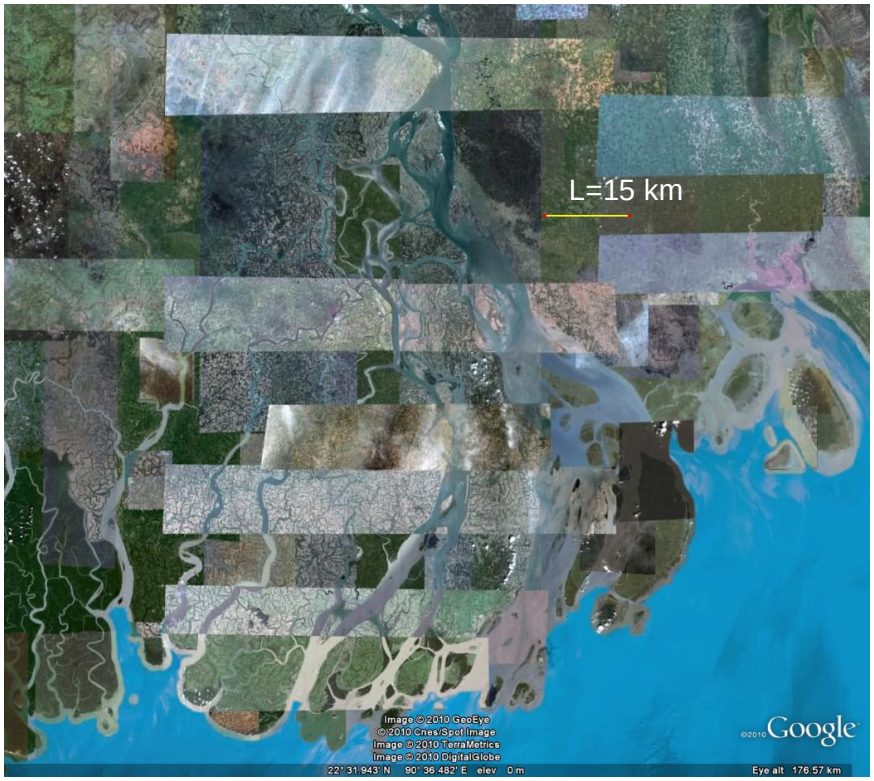
Resources
http://www.estuaries.gov/estuaries101/Resources/Home.aspx

What is an Estuary?
http://oceanservice.noaa.gov/education/tutorial_estuaries/est01_whatis.html

Where We Work
http://www.estuaries.gov/estuaries101/About/Default.aspx?ID=349

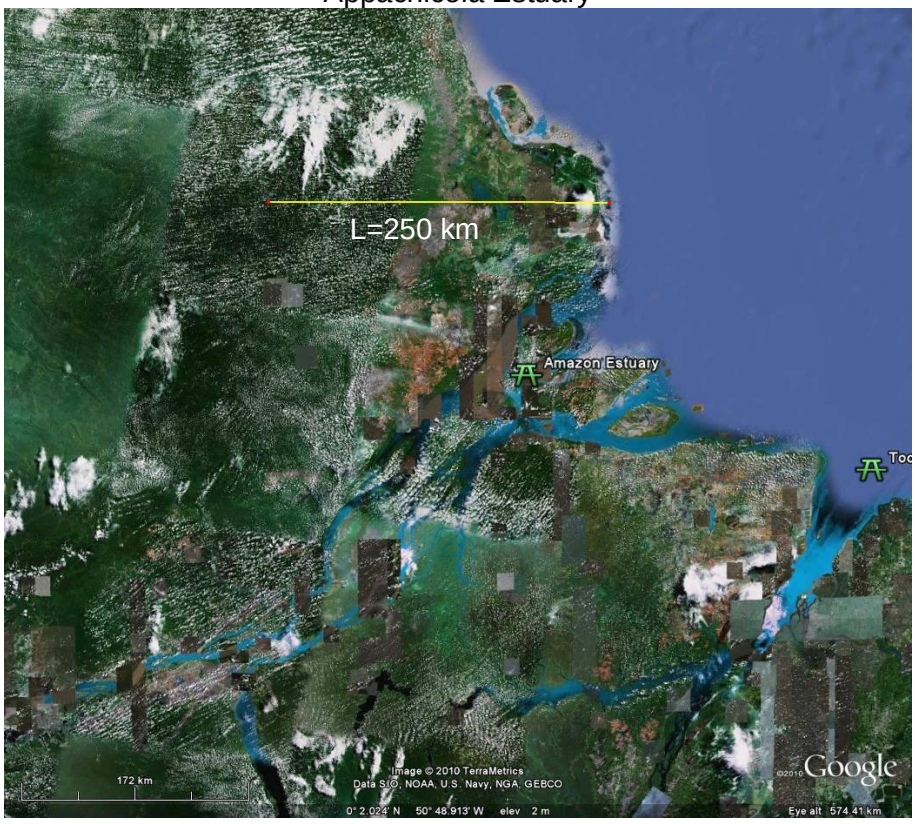
ANNEX B

Rhine and Schedlt Estuaries



Brahmaputra Estuary

Appachicola Estuary



Amazon Estuary

ANNEX C

Table C1: Summary statistics for biogeochemical features (fluxes) among the estuaries clustered by climate zone and shape

Parameter flux	sampling sites grouped by	test	F/t /r - value	n	p - value	Signific.
Si	Geographical distribution	One-way ANOVA	2.3069	115	0.1091	n.s.
		Spearman's corr.	**-0.2915**	**115**	**0.0015**	*** ***
	Estuarine shape	One-way ANOVA	1.9303	83	0.1564	n.s.
		Spearman's corr.	**0.3240**	**83**	**0.0028**	*** ***
	Tropics	t - test	0.5547	29	0.5837	n.s.
DIN	Geographical distribution	One-way ANOVA	0.9907	121	0.379	n.s.
		Spearman's corr.	-0.122	121	0.1825	n.s.
	Estuarine shape	One-way ANOVA	1.7122	94	0.192	n.s.
		Spearman's corr.	0.168	94	0.1054	n.s.
	Tropics	t - test	1.0246	35	0.3153	n.s.
DON	Geographical distribution	One-way ANOVA	1.4691	60	0.2461	n.s.
		Spearman's corr.	0.0597	60	0.6499	n.s.
	Tropics	t - test	0.1789	20	0.86	n.s.
	Estuarine shape	One-way ANOVA	1.8659	38	0.1790	n.s.
		Spearman's corr.	**0.3768**	**38**	**0.0197**	*****
TN	Geographical distribution	One-way ANOVA	1.232	137	0.299	n.s.
		Spearman's corr.	-0.058	137	0.4961	n.s.
	Tropics	t - test	0.7518	38	0.458	n.s.
	Estuarine shape	One-way ANOVA	1.5550	102	0.2207	n.s.
		Spearman's corr.	0.1557	102	0.1182	n.s.
DIP	Geographical distribution	One-way ANOVA	2.0514	126	0.1382	n.s.
		Spearman's corr.	-0.0809	126	0.3676	n.s.
	Estuarine shape	One-way ANOVA	1.4062	91	0.2564	n.s.
		Spearman's corr.	0.0651	91	0.5396	n.s.
	Tropics	t - test	1.5778	35	0.1277	n.s.
DOC	Geographical distribution	**One-way ANOVA**	**4.0015**	**84**	**0.0321**	*****
		Spearman's corr.	-0.1065	84	0.3346	n.s.
	Estuarine shape	One-way ANOVA	1.8300	54	0.1774	n.s.
		Spearman's corr.	**0.3938**	**54**	**0.0030**	*** ***
	Tropics	t - test	-0.0227	26	0.9821	n.s.
POC	Geographical distribution	One-way ANOVA	0.76	50	0.4844	n.s.
		Spearman's corr.	**-0.3066**	**50**	**0.0303**	*****
	Estuarine shape	One-way ANOVA	1.8301	33	0.2081	n.s.
		Spearman's corr.	**0.4488**	**33**	**0.0087**	*** ***
	Tropics	t - test	0.5088	20	0.6171	n.s.
TSS	Geographical distribution	**One-way ANOVA**	**5.4022**	**127**	**0.006**	*** ***
		Spearman's corr.	**-0.4022**	**127**	**$2.767e^{-6}$**	*** * ***
	Estuarine shape	One-way ANOVA	1.4344	87	0.2492	n.s.
		Spearman's corr.	**0.2694**	**87**	**0.0110**	*****

Tropics	t - test	0.6883	37	0.4968	n.s.

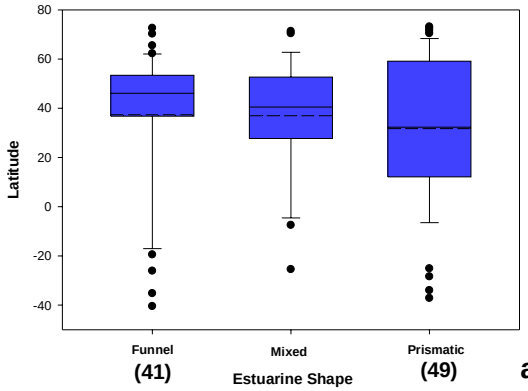
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).

Table C2: Summary statistics for biogeochemical features (concentrations) among the estuaries clustered by climate zone and shape

Parameter concentration	sampling sites grouped by	test	F /r - value	n	p - value	Signific.
Si	Geographical distribution	**One-way ANOVA**	**29.1049**	**115**	**1.07^{e}-9**	*** * ***
		Spearman's corr.	**-0.6448**	**115**	**7.37^{e}-15**	*** * ***
	Estuarine shape	**One-way ANOVA**	**3.7396**	**83**	**0.0304**	*****
		Spearman's corr.	0.0062	83	0.9556	n.s.
DIN	Geographical distribution	**One-way ANOVA**	**14.5821**	**121**	**4.77^{e}-6**	*** * ***
		Spearman's corr.	-0.0651	121	0.4780	n.s.
	Estuarine shape	**One-way ANOVA**	**5.5667**	**94**	**0.0070**	*** ***
		Spearman's corr.	-0.1758	94	0.0900	n.s.
DON	Geographical distribution	One-way ANOVA	1.7426	60	0.1898	n.s.
		Spearman's corr.	**0.4846**	**60**	**8.71e-5**	*** * ***
	Estuarine shape	One-way ANOVA	0.2951	38	0.7463	n.s.
		Spearman's corr.	-0.0039	38	0.9815	n.s.
TN	Geographical distribution	**One-way ANOVA**	**10.5543**	**137**	**7.98^{e}-5**	*** * ***
		Spearman's corr.	0.1092	137	0.2041	n.s.
	Estuarine shape	**One-way ANOVA**	**5.3604**	**102**	**0.0085**	*** ***
		Spearman's corr.	**-0.1961**	**102**	**0.0482**	*****
DIP	Geographical distribution	**One-way ANOVA**	**3.9704**	**126**	**0.0230**	*****
		Spearman's corr.	-0.0163	126	0.8550	n.s.
	Estuarine shape	**One-way ANOVA**	**3.7936**	**91**	**0.0304**	*****
		Spearman's corr.	**-0.3134**	**91**	**0.0020**	*** ***
DOC	Geographical distribution	One-way ANOVA	2.6119	84	0.0930	n.s.
		Spearman's corr.	0.1425	84	0.1950	n.s.
	Estuarine shape	One-way ANOVA	3.1528	54	0.0510	n.s.
		Spearman's corr.	0.2589	54	0.0580	n.s.
POC	Geographical distribution	One-way ANOVA	0.6276	50	0.5541	n.s.
		Spearman's corr.	0.1189	50	0.4105	n.s.
	Estuarine shape	One-way ANOVA	1.1413	33	0.3581	n.s.
		Spearman's corr.	0.0174	33	0.9233	n.s.
TSS	Geographical distribution	**One-way ANOVA**	**5.8102**	**127**	**0.0048**	*** ***
		Spearman's corr.	**-0.4011**	**127**	**2.97e^{-6}**	*** * ***
	Estuarine shape	One-way ANOVA	0.2025	87	0.8173	n.s.
		Spearman's corr.	-0.0052	87	0.9615	n.s.

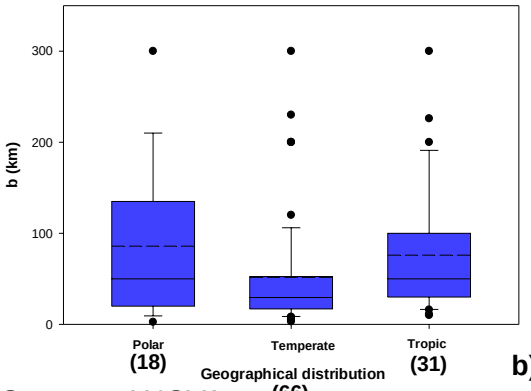
Level of significance (Significance codes: '***' 0.001 '**' 0.01 '*' 0.05).

ANNEX D



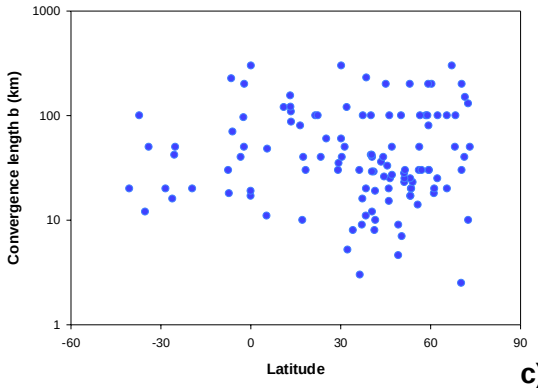
a)

One-way ANOVA
F = 0.5373, n = 116
p = 0.5858 (n.s.)



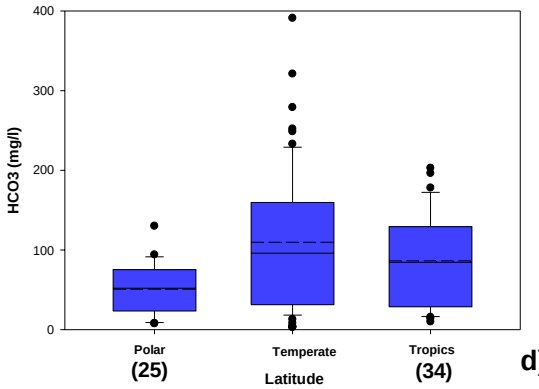
b)

One-way ANOVA
F = 2.6929, n = 115
p = 0.0721 (n.s.)



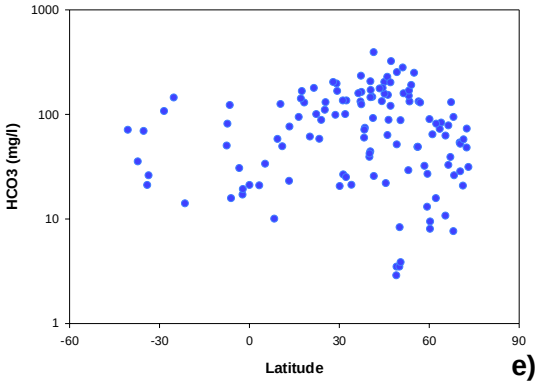
c)

Spearman's correlation
r = -0.006, n = 117
p = 0.9448 (n.s.)



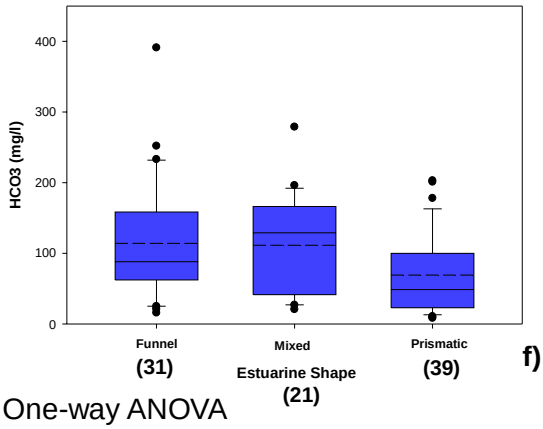
d)

One-way ANOVA
F = 12.8436, n = 125
p = 1.59e^{-5} (***)



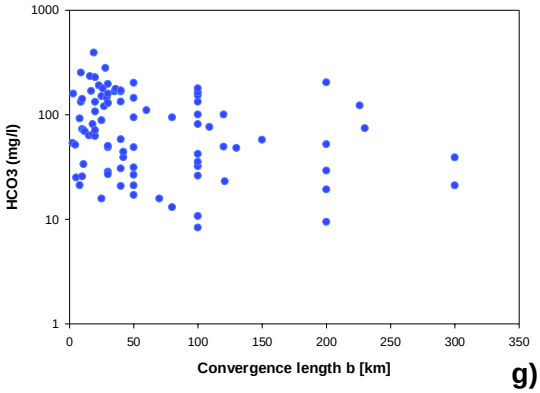
e)

Spearman's correlation
r = -0.0557, n = 125
p = 0.5374 (n.s.)



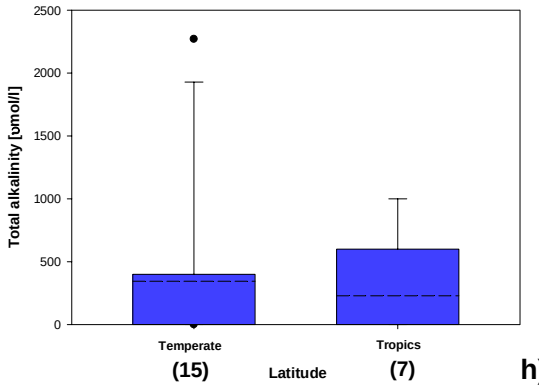
f)

One-way ANOVA
F = 4.38, n = 91
p = 0.0154 (*)



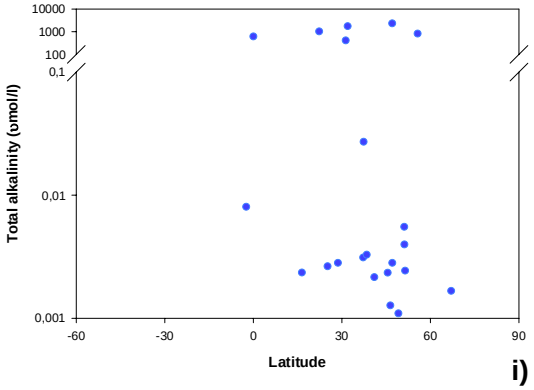
g)

Spearman's correlation
r = -0.2664, n = 91
p = 0.0107 (*)



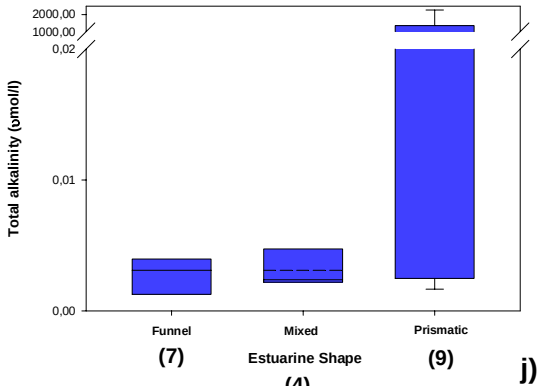
h)

t-test
t = 0.3996, n = 22
p = 0.6937 (n.s.)



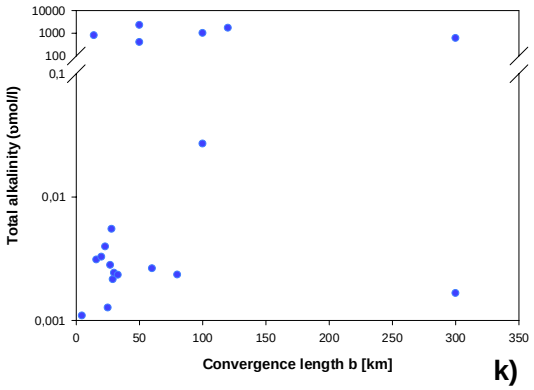
i)

Spearman's correlation
r = -0.1414, n = 23
p = 0.5200 (n.s.)



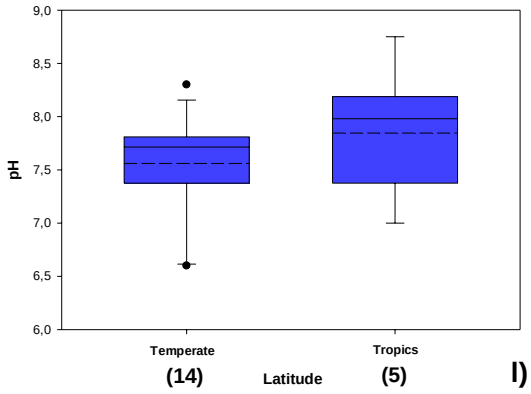
j)

One-way ANOVA
F = 3.1011, n = 20
p = 0.0937 (n.s.)



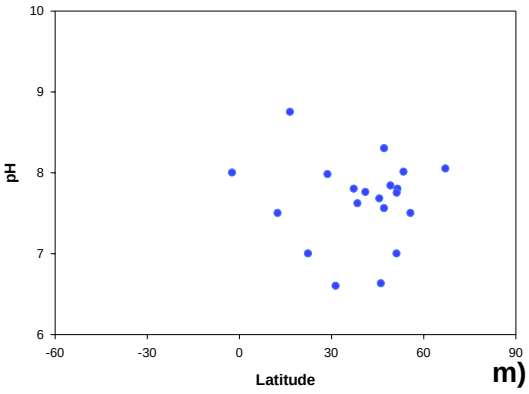
k)

Spearman's correlation
r = 0.2741, n = 20
p = 0.2422 (n.s.)



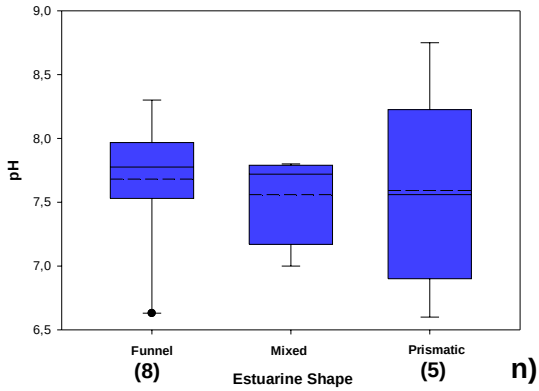
l)

t-test
t = -1.0462, n = 19
p = 0.3101 (n.s.)



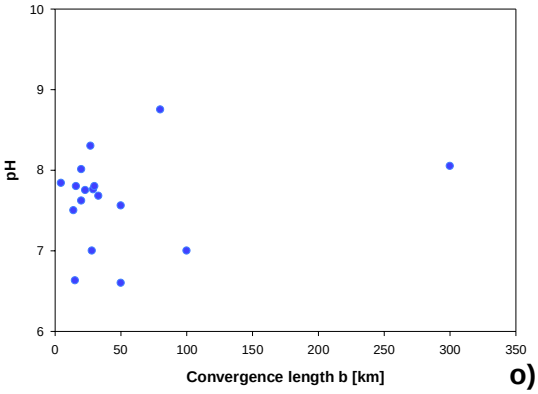
m)

Spearman's correlation
r = 0.0752, n = 20
p = - (n.s.)



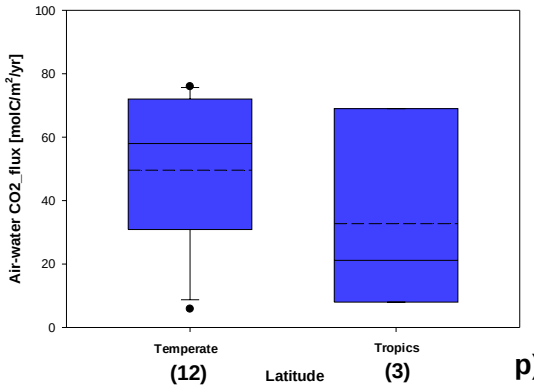
n)

One-way ANOVA
F = 0.0379, n = 17
p = 0.9629 (n.s.)



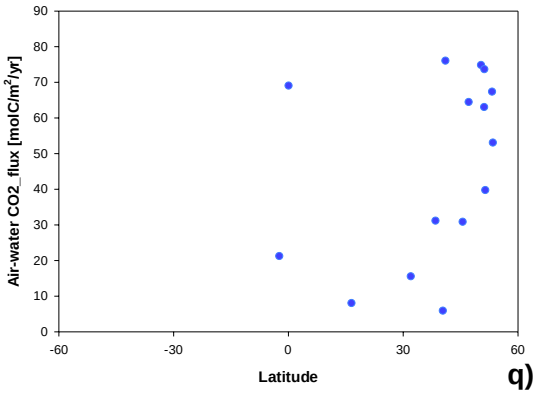
o)

Spearman's correlation
r = 0.1064, n = 17
p = - (n.s.)



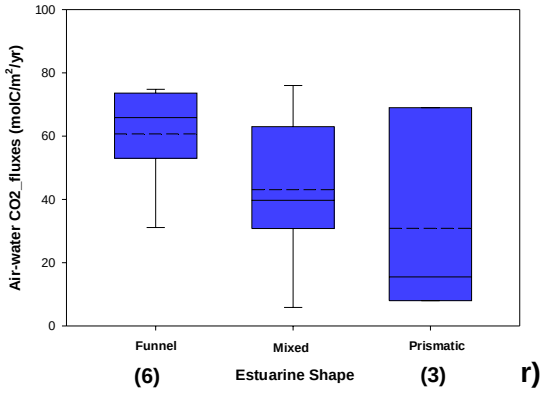
p)

t-test
t = 1.0180, n = 15
p = 0.3272 (n.s.)



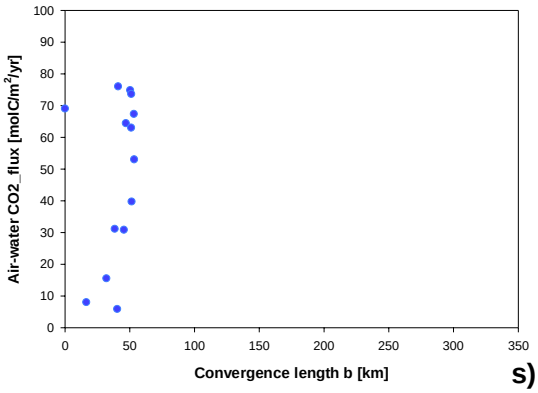
q)

Spearman's correlation
r = 0.4179, n = 15
p = 0.1227 (n.s.)



r)

One-way ANOVA
F = 1.6445, n = 14
p = 0.2372 (n.s.)



s)

Spearman's correlation
r = -0.4775, n = 14
p = 0.0842 (n.s.)

ANNEX E

Hydro-morphological characteristics

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
Alabama	N.America				56894									g=2;
Altamaha	N.America	31.39N	81.50W	23.8	35224	10.8	1.96	3500			50			a,b,h=1; g=2; c,j=33; k,n=calc
Amazon	S.America	0.10N	49.00W	27	6112000	6590		149000			300			a,b,c,h=1; g=2; k,n=calc
Amguema	Asia	68.1N	177.40W		29600	9.2								a,b,h=1; g=2
Amur	Asia	53.10N	140.44E	-1	1748000	344		15000			200			a,b,c,h=1; g=2; k,n=calc
Anabar	Asia	73.14N	113.35E		98550	13.2		28000			50			a,b,h=1; g=2; k,n=calc
Appalachicola	N.America	30.42N	84.52W	23.7	44548	21.43	1.81	800			40			a,b,h=1; g=2; c,j=33; k,n=calc
Apure	S.America	8N	70W		170000	72.5328								a,b=8; g=2;h=10
Aux Outar	N.America	49.09N	68.24W		191000									a,b=1; g=2;
Balsas	N.America	17.55N	102.10W		122600	14		600			40			a,b,h=1; g=2;k,n=calc
Barito	Asia	3.32S	114.29E		66000	86.8		12700			40			a,b,h=1; g=2; k,n=calc
Brahmaputra	Asia	23.42N	90.22E	15.3	580000	510		24400			40			a,b,c,h=1; g=2; k,n=calc
Brazos	N.America	29.35N	95.45W	23.9	116568	5.04	4.62	700			35			a,b,h=1; g=2; c,j=33; k,n=calc
Bug	Europe	47.33N	30.47E		68980	3.4								a,b,h=1; g=2
Caroni	S.America	6N	63W		95000	157.68								a,b=8; i=10; g=2

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
Casamance	Africa	12.50N	16.60W					10000	28000					a,b= 35; k,l=7
Caura	S.America	6N	66W		47500	94.608								a,b=8; g=2; j=10
Cauweri	Asia	10.45N	79.50E		10600	20.9								a,b,h=1; g=2
Chang Jiang (Yangtze)	Asia	32.06N	121.04E	12	1808000	928	5	59000			120			a,b,h=1; g=2; j=36; k,n=calc
Chao Phrya	Asia	13.44N	100.30E		111435	27.8	8	600	4300	1.8	109/56	50	120	a,b,h=1; g=2; k-m=7;o,p=26; j=29; n=7,30
Churchill (Hudson Bay)	N.America	58.47N	94.12W		302400	25.83		700			100*			a,b,h=1; g=2; k,n=calc
Colorado (Ari)	N.America	32.44N	114.38W	16	638951	0.1								a,b,c,h=1; g=2
Colorado (Texas)	N.America	29.18N	96.06W		108787	2.49		500			30			a,b,h=1; g=2; k,n=calc
Columbia	N.America	46.12N	123.50W	10/11.7	669000	236	10/4.63			1	15.2			a,b,h=1; g=2; n=30;c=1,33; j=28,33
Colville	N.America	70.25N	150.30W		53535	16		500			2.5			a,b,h=1; g=2; k,n=calc
Connecticut	N.America	41.59N	72.36W	11.9	25019	14.2	2.22	3100			10			a,b,h=1; g=2; c,m=33; k,n=calc
Copper	N.America	61.28N	144.27W		66990	52.5		15400			20			a,b=1; g=2; h=1; k,n=calc
Corantijn	S.America	5.52N	57.00W		69000	47		30000	69000	2.2	48	50	120	a,b,h=1; g=2; k-n=7;o,p=26
Dalalven	Europe	60.38N	17.27E		29820	9.84		200			200*			a,b,h=1; g=2; k,n=calc
Danube	Europe	45.11N	28.48E	10	817000	207		5000			200*			a,b,c,h=1; g=2; k,n=calc
Daugava	Europe	56.53N	24.08E		83160	20.4		1000			100			a,b,h=1; g=2;

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
Delaware	N.America	40.13N	74.47W	12.1	29500	15.3	5.8/6.12	37655	255000	1.5	42/54	140	200	k,n=calc a,b,h=1; c=33; g=2; k-m=7; o,p=26; j=28,33; n=7,30
Dnepr	Europe	46.30N	32.18E		504000	53.4		5400			100*			a,b,h=1; g=2; k,n=calc
Dnestr	Europe	46.10N	30.19E		77000	10.7		7000			20			a,b,h=1; g=2; k,n=calc
Don	Europe	47.15N	39.45E		422000	20.7		200		3.7	50			a,b,h=1; g=2; m=37; k,n=calc
Douro	Europe	41.09N	8.37W	22.6	95000/115320	15.6	6	800	4800	2.8/ 1-3	29	30.3		a,b,h=1; c=38; g=1,5; j-o=3; m=3,5
Drammenselva	Europe	59.44N	10.15E		17000	8.1		2800			30			a,b,h=1; g=2; k,n=calc
Ebro	Europe	40.49N	0.31E		84000	9.24	6.8	1500	10200	0.6	29	46.6		a,b=1; g=2; h=4; j-o=3
Eems	Europe	53.30N	9.00E		5100/9000	1.9	3.9	12000	46800	3.6/ 2-3	17	61		a,b,h=1; g=1,5; j-o=3, m=3,5; k,n=7
Elbe	Europe	53.50N	7.00E	8.78	146000/145800	23.7	13.5	17250	232875	3.3/ 2-3	20/56	93.6		a,b,h=1; g=2,5; j-o=3; m=3,5; c=39; n=3,30
Evros	Europe	40.53N	26.10E		55000	9.81		500			40			a,b,h=1; g=2; k,n=calc
Fraser	N.America	49.23N	121.27W	4	220000	111.9528	9				4.6			a,b,c,h=1; g=2; ;j=28; n=30
Fuchun Jiang	Asia	30.18N	120.07E		54349	37.3		27300			60			a,b,h=1; g=2; ; k,n=calc

River	Continent	Lat a	Long b	Temp °C c	Basin Area (km^2) g	Discharge (km^3 yr^{-1}) h	ho (m) j	Bo (m) k	Ao (m^2) l	Ho (m) m	b (km) n	Ls (km) o	Ts (km) p	References
Gambia	Africa	13.31N	14.50W		42000	4.9	8.7	9687	84400	1.2	121/56/40	300	500	a,b,h=1; g=2; k-m,p=7,o=26; j=29; n=7,29,30
Ganges	Asia	24.05N	89.02E	18	1050000	493								a,b,c,h=1; g=2
Garonne	Europe	44.25N	0.14E		55000	17.2		23400			40			a,b,h=1; g=2; k,n=calc
Gironde	Europe	45.6N	-1.1E	23.44	71000	28.3824	10	14000	140000	4.5/ 2-5	33/87	100		a,b=6; g=5; j-l,o,p=3; m=3,5; c=40; n=3,30
Glama	Europe	59.36N	11.07E		47310	19.9		800			80			a,b,h=1; g=2; k,n=calc
Godavari	Asia	16.55N	81.47E	29	312000	105		3300			80*			a,b,c,h=1; g=2; k,n=calc
Grijalva	N.America (MX)	18.36N	92.39W		36400	23		1600			30			a,b,h=1; g=2; k,n=calc
Guadiana	Europe	37.13N	7.24W		72000	9	1.5	1450	2175	3.2	9	15.5		a,b,h=1; g=2; j-o=3
Gualdalquivir	Europe	37.31N	5.59W		56000	7.29	2	6750	13500	3.2	16	37.9		a,b,h=1; g=1; j-o=3
Guaviare	S.America	4N	69W		150000	274.3632								a,b=8; g=2; j=10
Huang He	Asia	37.44N	118.36E	13	752000	41	2	1800			100*			a,b,c,h=1; g=2; j=36; k,n=calc
Hudson	N.America	40.42N	74.02W	12.4	34700	17.3	9.2/6.13				42			a,b,h=1; c=33; g=2; j=28,33; n=30
Humber	Europe	53.60N	0.10E		24240	9.271584	19	12000	228000	8	20	109		a,b=41; j-o=3; g=42
Hunter	Australia	32.55S	151.46E		21411	1.65	2			3.1				a,b,h=1; g=2; j,m=32

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
Incomati	Africa	25.46S	32.43E		46200	2.3	3	4500	8100	2.7	42/5.5	50	100	a,b,h=1; g=1; k-m=7; o,p=26; j=29; n=7,30
Indigirka	Asia	70.39N	147.50E	-12	362000	61		6900			30			a,b,c,h=1; g=2; k,n=calc
Indus	Asia	25.23N	68.24E	18.8	916000	57		4200			60			a,b,h=1; g=2; k,n=calc
Japura	S.America	2S	68W		300000	567.648								a,b=8; g=2
Jurua	S.America	5S	68W		220000	204.984								a,b=8; g=2
Kamchatka	Asia	56.14N	162.28E		50370	33.1		2400			30			a,b,h=1; g=2; k,n=calc
Khatanga	Asia	72.55N	106.00E		364000	85.3		23300			130			a,b,h=1; g=2; k,n=calc
Klamath	N.America	41.31N	123.58W	12.2	31339	15.2	2.81	2700			8			a,b,h=1; g=2; c,j=33; k,n=calc
Kobuk	N.America	66.45N	161.00W		24657	16								a,b,h=1; g=2
Kolyma	Asia	68.34N	160.58E	-9	663200	132		14200			100			a,b,h=1; g=2; k,n=calc
Kuban	Europe	45.16N	162.27W		57900	13.4								a,b,h=1; g=2
Kuskowin	N.America	60.17N	162.27W		80549	60								a,b,h=1; g=2
Kymjoki	Europe	60.30N	26.52E		37200	9.68								a,b,h=1; g=2
Lalang	Asia	2.38S	104.66E				10.6	350	2550	2.7	96/217/60	65	200	a,b=7; k-n=6; o,p=26; j=29; n=29,30
Lena	Asia	70.42N	127.39E	-9	2490000	525		21000			200*			a,b,c,h=1; g=2; k,n=calc
Liao	Asia	40.50N	121.48E	7	232000	16.2		10800			12			a,b,c,h=1; g=2; k,n=calc
Limpopo	Africa	25.15S	33.30E	21	440000	26	7	371	2600	1.1	50/215	60	150	a,b,c,h=1; g=1; k-m=7; o,p=26;

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
														j=29; n=7,30
Loire	Europe	47.16N	2.11W	19.5	112000/115000	26	13	12750	165750	5.1/ 3-6	27	102		a,b,h=1; g=2,5; j-o=3; m=3,5; c=43
Luan	Asia	39.20N	119.10E		54000	4.2								a,b,h=1; g=2
Maas (Meuse)	Europe	65.50N	44.20E		29000	10.2								a,b,g,h=1
MacKenzie	N.America	68.16N	133.40W	-4	1787000	308		10700			50			a,b,c,h=1; g=2; k,n=calc
Madeira	S.America	8 S	62W		1300000	946.08								a,b=8; g=2
Mae Klong	Asia	13.21N	100.00E		27000	12.9		250	1400	2	155	20-30	120	a,b,g,h=1; k-o=7; p=26
Magdalena	S.America	11.06N	74.51W	24	235000	237		1400			120*			a,b,c,h=1; g=2; k,n=calc
Mahanadi	Asia	20.26N	85.56E	24	132100	66								a,b,c,h=1; g=2
Manicoagan	N.America	49.14N	68.20W		45800									a,b=1; g=2
Maputo	Africa	26.11S	32.42E		29800	2.8	3.6	9000	40000	2.7	16/109	40	100	a,b,g,h=1; k-m=7; o,p=26; j=29; n=7,30
Mekong	Asia	9.42N	106.18E	21	774000	467								a,b,c,h=1; g=2
Meta	S.America	6N	69W		110000	176.6016								a,b=8; g=2
Mezen	Europe	65.50N	44.20E		75430	20		12200			20			a,b,h=1; g=2; k,n=calc
Mississippi	N.America	28.75N	89.24W	13/23.9	2926507	529	7.01							a,b,h=1; c=1,33; g=2; j=33
Moise (Moisie)	N.America	50.21N	66.11W		19200	15.5		2400			100			a,b,h=1; g=2; k,n=calc
Moose	N.America	50.49N	81.18W		109000	43.5								a,b,h=1; g=2
Murray	Australia	35.22S	139.22E	18	1028000	7.9		1100			12			a,b,c,h=1; g=2; k,n=calc

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
Musi	Asia	2.20S	104.56E		56700	80.4		3800			50			a,b,h=1; g=2; k,n=calc
Nadym	Asia	66.12N	72.00E		64000	14.8								a,b,h=1; g=2
Narva	Europe	59.27N	28.02E		58010	10.6		800			200*			a,b,h=1; g=2; k,n=calc
Natashquan	N.America	50.12N	61.36W		16100	13								a,b=1; g=2; h=6
Negro	S.America	40.48S	62.59W	16	620000	946.08		6300			20			a,b,c=1; g=2; k,n=calc
Nelson	N.America	57.04N	92.30W		982900	89.26		20000			30			a,b,h=1; g=2; k,n=calc
Nemanus	Europe	55.02N	21.50E		96630	17.2								a,b,h=1; g=2
Neva	Europe	59.48N	30.43E		283500	80.4		1200			30			a,b,h=1; g=2; k,n=calc
Niger	Africa	5.33N	6.33E	29	1200000	154.12		2800			11			a,b,c,h=1; g=2; k,n=calc
Nile	Africa	31.26N	31.48E	27	2870000	6								a,b,c=1; g=2; h=4
North Dvina	Europe	64.06N	42.10E	2	348000	110								a,b,c,h=1; g=2
Nueces	N.America	28.02N	97.52W		39956	0.73								a,b,h=1; g=2
Nushagak	N.America	59.00N	158.30W		35300	32.1		9700			100			a,b,h=1; g=2; k,n=calc
Ob	Asia	66.45N	69.30E	-1	2990000	404								a,b,c,h=1; g=2
Odra	Europe	53.25N	14.32 E		119400	16.6	6	1500	9000	0.1	25	37.6		a,b,h=1; g=2; j-o=3
Ogooe (Ogooue)	Africa	00.41S	10.14E		205000	150.1								a,b,h=1; g=2
Olenek	Asia	72.59N	119.57E		219000	35.8		1800			10			a,b,h=1; g=2; k,n=calc
Onega	Europe	63.58N	37.55E		56900	15.4								a,b,h=1; g=2

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
Orange	Africa	28.41S	16.28E	16	1000000	11.36		700			20*			a,b,c,h=1; g=2; k,n=calc
Orinoco	S.America	8.37N	62.15W	24	1100000	1135								a,b,c,h=1; g=2
Panuco	N.America (MX)	21.59N	98.34W		66300	17.3		300			100*			a,b,h=1; g=2; k,n=calc
Paraguay River	S.America	19S	57W		363500									a,b=8; g=2
Paraibado Sul	S.America	21.45S	41.20W		62760	30.6								a,b,h=1; g=2
Parana	S.America	34.00S	58.17W	21	2783000	568		11300			50*			a,b,c,h=1; g=2; k,n=calc
Pechora	Europe	67.12N	52.03E		324000	131		8100			300*			a,b,h=1; g=2; k,n=calc
Pee Dee	N.America	34.12N	79.33W		22870	8.2		2200			8			a,b,h=1; g=2; k,n=calc
Peel	N.America	67.37N	134.40W		71000	24.5								a,b,h=1; g=2
Penzhina	Asia	62.28N	165.18E		85540	22.8		8200			25			a,b,h=1; g=2; k,n=calc
Petit (Mecatina)	N.America	50.52N	59.36W		19600	16.2								a,b,h=1; g=2
Po	Europe	44.53N	11.39E	13	70000	47.8	2	2100	4200	0.8	26	9.46		a,b,c=1; g=2; h=4; j-o=3
Potomac	N.America	38.58N	77.09W	12.5	30000	9.654	6/5.13				230			a,b,h=1; c=33; g=2; j=28,33; n=30
Pungue (Pungoe)	Africa	19.50S	34.48E		29000	3.1	4.3	6512	28000	6	20/34	70	120	a,b,h=1; g=2; k-m=7; o,p=26; j=29; n=7,30
Purari	Oceania	7.25S	145.05E		33670	84.13		28300			18			a,b,h=1; g=2; k,n=calc

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
Rhine	Europe	51.52N	6.02E	7.3	224000	69.4		15000		2-3	30			a,b,c=1; g=2,5; h=1,5; m=5; k,n=calc
Rhone	Europe	43.55N	4.4E	13	95600	53.9	7	1000	7000	0.3	36	26		a,b,c=1; g=2; h=4 ; j-o=3
Rio Coatzacoalcos	N.America				29497									a,b=1; g=2
Rio Grande (US)	N.America	25.50N	97.31W		456700	0.72								a,b,h=1; g=2
Roanoake	N.America	36.28N	77.38W		22458	7		22200			30			a,b,h=1; g=2; k,n=calc
Rufiji	Africa	7.48S	37.55E	21	186100	35.2		2300			30			a,b,c,h=1; g=2; k,n=calc
Sabine	N.America	30.18N	93.45W	23.4	18982	4.24	2.49							a,b,h=1; g=2; c,j=33
Sacramento	N.America	38.35N	121.30W		60870	20.5								a,b,h=1; g=2
Sado	Europe	38.5N	-8.9E	22.9	7600	1.73448	1	2600	2600	2.9/ 1-4/2.7	20	17.6		c=44; g=5; i=3,5 ; j-o=3; m=3,5,34
Saint John	N.America	45.58N	67.14W		52850	35.6								a,b,h=1; g=2
Sakarya	Asia	40.45N	30.23E		56830	5.87								a,b,h=1; g=2
Saloum	Africa							3000	20000					k,l=7
San Joaquin	N.America	37.41N	121.16W		35058	4								a,b,h=1; g=2
Sanaga	Africa	3.36N	10.04E		119300	55								a,b,h=1; g=2
Savannah	N.America	32.32N	81.16W	23.7	25511	10.6	3.08	3600			5.2*			a,b,h=1; g=2; c,j=33; k,n=calc
Scheldt	Europe	51.22N	4.15E	18.7	11400/21600	6	10	15000	150000	3.7/ 2-5	28	123	150	a,b=1; c=45; g=2,5; h=1,5; j-o=3; m=3,5; p=7
Sebou	Africa	34.15N	6.40W		38492	63								a,b,h=1; g=2

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
Seine	Europe	49.26N	00.26E		78600	15.8	6	13500	81000	7	9	44.2		a,b,h=1; g=2; j-o=3
Severn	Europe	51.35N	2.40W		6800	2.58	10	19500	195000	12.3	25/20	118		a,b,g,h=1; j-o=3; n=3,30
Seyhan	Europe	36.43N	34.53E		19300	4.8		200			3			a,b,h=1; g=2; k,n=calc
Skagit	N.America (in Harrison, Europe!)	48.25N	122.20W		80000	14.6								a,b,g,h=1
Solimoes at Ica	S.America	3S	70 W		1200000	1356.048								a,b=7; g=1
Solo	Asia	6.47S	112.33E		16000	14.6		222	2070	0.5	226			a,b=1; g=2; h=6; k-n=7
St .Johns	N.America	30.24N	81.24W	24.8	18373	16.12	2.21	3850			300*			a,b=1; g=2; c,j=33; k,n=calc
St.Lawrence	N.America	46.50N	71.15W	4	1020000	337	7/70				25			a,b,c,h=1; g=2; j=28,30; n=30
Stikine	N.America	56.28N	132.23W		51593	50		12100			50			a,b,h=1; g=2; k,n=calc
Susitna	N.America	61.16N	150.30W	-1	50246	45.5		12500			18			a,b,c,h=1; g=2; k,n=calc
Susquehanna	N.America	40.15N	76.52W		70189	34		2300			100			a,b,h=1; g=2; k,n=calc
Swan Canning	Australia	38.23S	144.70E		126021		6	4110						a,b=1; g=2; k=31; j=46
Tamar	Europe	50.4N	-4.2E		1750	1.387584	10/2.9	4800	48000	4.7	7/25.5	46.4		a,b=6, k-m,o=3;g=27; j,n=3,30

River	Continent	Lat a	Long b	Temp °C c	Basin Area (km^2) g	Discharge ($km^3\ yr^{-1}$) h	ho (m) j	Bo (m) k	Ao (m^2) l	Ho (m) m	b (km) n	Ls (km) o	Ts (km) p	References
Tana	Africa (not Tana in Norway)	2.32S	40.31E		42000	4.75								a,b,h=1; g=2
Tees	Europe				76200	0.53	18/7.5	700	12600	4.4	17/217	84.5		a,b,h=1; g=2; k-m,o=3; j,n=3,30
Tejo	Europe	38.44N	9.08W		73090		7	5800	40600	3.4	11	47		a,b,h=1; g=2; j-o=3
Tha Chin	Asia	13.5N	100.3E				5.3	3600	3000	2.6	87/50	70	120	a,b,k-n=7;o,p=26;j=29; n=30
Thames	Europe	51.28N	0.43E	16.98	15000/14000	3.17	8	7500	60000	6.5 / 3-6	23/42	86.8	110	a,b,h=1; c=47; g=1,5; j-l,o=3; m=3,5; p=26; n=3,30
Tiber (Tevere)	Europe	41.54N	12.29E		16500	7.38	4	400	1600	0.8	19	20.1		a,b,g=1; h=4; j-o=3
Tocantins	S.America	2.12S	49.30W		757000	372		66500			200			a,b=1; g=2; k,n=calc
Tornionjoki	Europe	65.48N	24.08E		34510	11.86		2300			100*			a,b,h=1; g=2; k,n=calc
Trinity	N.America	30.26N	94.51W		47380									a,b=1; g=2
Trombetas	S.America	0N	58W		130000	59.9184								a,b=8; g=2
Tugela	Africa				30112									a,b=1; g=2
Tweed	Europe	55.75N	2W		1500	2.459808	3	150	450	4.1	14	14.6		a,b=1; j-o=3
Tyne	Europe				2200	0.094608	12	1200	14400	4.3	19	103		j-o=3; g=6
Ubangi	Africa				356000	228								a,b,h=1; g=2
Uruguay	S.America	33.55S	58.22W		240000	145								a,b,h=1; g=2
Usumacinta	N.America (MX)	17.25N	91.30W		67890	55.52		700			10			a,b,h=1; g=2; k,n=calc
Volga	Europe				1350000									

River	Continent	Lat	Long	Temp °C	Basin Area (km^2)	Discharge ($km^3\ yr^{-1}$)	ho (m)	Bo (m)	Ao (m^2)	Ho (m)	b (km)	Ls (km)	Ts (km)	References
		a	b	c	g	h	j	k	l	m	n	o	p	
	(Russia)													
Waikato	Oceania	37.17S	175.04E		13700	12.1		3000			100*			a,b,h=1; g=2; k,n=calc
Weser	Europe	53.32N	8.34E		45800	10.6	10	12000	120000	3.6	17	78.8		a,b,h=1; g=2; j-o=1
Wisla	Europe	54.06N	18.47E		180000	32.5	4	2000	8000	0.1	23	25.3		a,b,h=1; g=2; j-o=3
Xijiang	Asia				409000	270								a,b,h=1; g=2
Yana	Asia	71.31N	136.32E	-15	224200	34.3		6200			40			a,b,c,h=1; g=2; k,n=calc
Yenisei	Asia	71.50N	82.40E	-7	2590000	620		126300			150			a,b,c,h=1; g=2; k,n=calc
Yesil	Asia (Turkey)	41.24N	36.35E		35960	5.67								a,b,h=1; g=2
Yukon	N.America	62.39N	164.48W	-4	831387	200		7000			100*			a,b,c,h=1; g=2; k,n=calc
Zaire (Congo River)	Africa	6.04S	12.24e	23.6	3698000	1200		22800			70			a,b,c,h=1; g=2; k,n=calc
Zhujiang (Pearl River)	Asia	22.40N	113.05E	21	407100	363	7	7100			100*			a,b,c,h=1; g=2; j=36; k,n=calc

Note: List of symbols and references at the end of the matrices.

Where: **ho=** water depth at the mouth

Bo= width at the mouth

Ao= cross sectional area at the mouth

Ho= tidal range

b= width convergence length

Ls= salt intrusion length

Ts= tidal intrusion length

Biogeochemical characteristics

For details on the values look at the file *Surface_Est_Classification.xls*

River	Si (mg/l) d	NO3 (mg/l) e	NH4 (mg/l) f	DIN (mg/l) g	DIP (mg/l) h	DOP (mg/l) i	DON (mg/l) j	DOC (mg/l) k	DIC (mg/l) l	POC (mg/l) m	TOC (mg/l) n	PN (ug/g) o	PP (ug/g) p	HCO3- (mg/l) q	TSS/SPM (mg/l) s	ph v	pCO2 (uatm) w	Air-water CO2 fluxes (molC m-2 yr-1) x	References
Alabama					0.01	0.02	0.41	6.00									3028		j,k=24; w=14; h=23
Altamaha	11.5	0.21		0.43	0.03	0.03		8.70	5.2 / 8.4	0.45	6.7			26.5	195.3	6.6-6.8	380-7800		d,e,k-n,q,s=1; l,v,w=48; g=20; h=23
Amazon	6.9 / 3.86-2.07	0.14	0.02	0.16	0.02	0.02	0.16	4.10	4.1	2.5	5.6	920	1660	21	182.1		4350 (> 10 000 in some tributaries)	*ref	d-s=1; d=91; w,x=49
Amguema	5.9	0.03			0.01				1.5		6.7			7.6	54.3				d,e,h,l,n,q,s=1
Amur	2.15	0.02	0.43	0.45	0.02									29.1	72.4				d-h,q,s=1
Anabar	2.6	0.02	0.43	0.45	0.00	0.00	0.25		6.1		5.1			31.2	29.4				d-j,l,n,q,s=1
Appalachicola		0.25		0.35	0.01	0.01	0.2/0.183	6.00			7.9				7.2		4132		n,s=1; e,j=50; g,j=51; w=14; h,i=23; k=24
Apure		0.14		0.12	0.04		0.27	6.20		3.6		512*	128*		235				e,h, j,k,m,o,p,s=10; g=20
Aux Outar(des)		0.05		0.05				4.80	0.6					2.87					e,k,l,q=1
Balsas		0.19	0.40	0.59	0.10				32.7					166					e-h,l,q= 1
Barito	9.3	0.11	0.01	0.12	0.01				4.1					30.5					d-h,l,q =1
Brahmaputra	7.8			0	0.06		0.04	3.20	11.4	2.6				58	1058.8				d,h,f,j,l,m,q,s =1; k=64
Brazos	9.06	0.37		0.37	0.01	0.02	0.66	3.25	32.8	3.6	7	6500		166.6	6349.2		3115		d-g,l-o,q,s =1; w=14; j,k=24; i=23; h=33
Bug	0.6	0.25	0.28	0.53	0.10				63.1					321	147.1				d-h,l,q,s =1

River	Si (mg/l) d	NO3 (mg/l) e	NH4 (mg/l) f	DIN (mg/l) g	DIP (mg/l) h	DOP (mg/l) i	DON (mg/l) j	DOC (mg/l) k	DIC (mg/l) l	POC (mg/l) m	TOC (mg/l) n	PN (ug/g) o	PP (ug/g) p	HCO3- (mg/l) q	TSS/SPM (mg/l) s	ph v	pCO2 (uatm) w	Air-water CO2 fluxes (molC m-2 yr-1) x	References
Caroni		0.09		0.12	0.00		0.14	5.40		0.4		44*	5.6*		5		2957		e,h, j,k,m,o,p,s=10; w=14; g=20
Casamance			0.42					2.4-2.6	26.4	8.4						7.5			f,k,l,m,v=35
Caura		0.07		0.12	0.00		0.17	4.5		1		127*	9.9*		12				e,h, j,k,m,o,p,s=10; g=20
Cauweri	15.3			0.00	0.10				34.8					125	1.9				d,h,l,q,s =1
Chang Jiang (Yangtze)	6.5	0.32	0.32	0.64	0.02			2.1	27.7				1200	100	517		650-1440	15.5-34.2	d-h,k,l,q,s=1; l=52; l,w,x=53; k=24
Chao Phrya	15.8	0.14	0.1	0.24	0.03				15					76	395.7				d-h,l,q,s =1
Churchill (Hudson Bay)	1.4	0.01	0.01	0.02	0.01				12.1		8.8			32					d-h,l,n,q =1
Colorado (Ari)	8.75	0.35		0.35	0.10	0.02	0.56	7.1	40.4		3.3		540	135	6487				d,e,h,l,n,p-s=1; j,k=24; i=23
Colorado (Texas)	10.1	0.52		0.52		0.03	0.83	5.2	38.6		4.6			196.2	763.1				d,e,l,n,q,s=1; j,k=24; i=23
Columbia	9 / 3.25-0.69	0.2	0.01	0.21	0.01	0.01		2.7		0.26	2.34			63	63.6	6.63-8.68	560-950		d-h,l,q,s=1; d=91; w=13; m,n=54; v=55; i=23; k=24
Colville				0			1.21	7.6	10.5					53.5	317.5				l,q,s=1; j,k=24
Connecticut	5.06 / 3.36-0.87	0.03			0.03	0.02	0.25	3.8	5		7.1			25.6					d,l,n,q=1; d=91; j,k=24; h,i=23; e=33
Copper				0.41		0.02	0.28				6.3				1236.7				n,s=1; g=20; i=23; j=24
Corantijn															23.4				s=1
Dalalven	4.8	0.13	0.01	0.14	0.00				1.6					9.41					d-h,l,q=1
Danube	4.14 /	1.8		1.80	0.18	0.035	0.6	5.5	39.9	3.4			790	203	335				d,e,h-m,p-s=1; d=91

River	Si (mg/l)	NO3 (mg/l)	NH4 (mg/l)	DIN (mg/l)	DIP (mg/l)	DOP (mg/l)	DON (mg/l)	DOC (mg/l)	DIC (mg/l)	POC (mg/l)	TOC (mg/l)	PN (ug/g)	PP (ug/g)	HCO3- (mg/l)	TSS/SPM (mg/l)	ph	pCO2 (uatm)	Air-water CO2 fluxes (molC m-2 yr-1)	References
	d	e	f	g	h	i	j	k	l	m	n	o	p	q	s	v	w	x	
Daugava	1.54-0.51 2.8	0.19/0.98	0.1	1.08	0.04				26		13.1			132.4	23.4				d,e,h,l,n,q,s=1;e,f,g=56
Delaware	3.5	1	0.03	1.03	0.04/0.08			2.8	8.8		3		3100	39	39.3		2172		d-h,k,l,n,q,s=1; h,p=57; w=14
Dnepr	3.4	0.21		0.21	0.04			4.9	30	0.9	5.8			152.6	42.9				d,e,h,k-n,q,s=1
Dnestr	4.1	1		1	0.06				44.7		4.8			227.2	233.6				d,e,h,l,n,q,s=1
Don	0.28/4.8	0.23	0.08	0.31/ 3.7	0.042/ 0.13			4.2	39.4	1.7	5.9			201	76.9	7.56	*ref		d-h,k-n,q,s=1; d,g,h=58; v,w=59
Douro	2 / 0.8-1.12	0.05-1.3	0.003-0.11	0.0503-1.41	0.02-0.04			2.41	28.7	0.5				146	4/3.22	7.76	1330–2200	76	d,l,q=1; m,s,w=5; x=21, e-g=9; d,h=60; k,s,v=38
Drammenselva		0.28	0.02	0.30	0.00						2.9				177.7				e-h,n,s=1
Ebro	2.55	2.32	0.17	2.49	0.03				25.9					145	989				d,h,l,q,s=1; e-g=4
Eems		5.39	0.33	5.72 / 8.4	0.285 / 0.1	0.03	1.4 / 0.7			2.8					37		560–3755	67.3	e-h=1; m,s,w=5, x=21; g-j=61
Elbe	4.40	3.60	1.30	4.90	0.39			4	26	2.8	20.42			132	35.4/ 43/15.03	8.01	580–1100	53	e-h,k,l,q,s=1; m,s,w=5; x=21; d,n,s=39; v=90
Evros		1.90	0.05	1.95	0.28				33.4					170					e-h=4; l,q=1
Fraser	5.46	0.10		0.10	0.05			3.7	10.1		6.3			51.3	175.4	7.84			d,e,h,k,l,n,q,s=1; v=62
Fuchun Jiang	4.72	1.43	0.03	1.46	0.05										1340				d-h,s=1
Gambia	10.8			0.00	0.02			2.28	4.5	1		2850	985	23	40.8 / 19.5		2072		d,h,k-m,o-s=1; w=14; s=16
Ganges	11.7			0.00	0.08		0.06	4.6	23.4	3.5		1150	500	88	1055				d,h,j-m,o-s=1
Garonne	4		0.23	2.43	0.10				26.2				1300	133	127.9		1675		d-h,l,p-s=1; w=14

River	Si (mg/l)	NO3 (mg/l)	NH4 (mg/l)	DIN (mg/l)	DIP (mg/l)	DOP (mg/l)	DON (mg/l)	DOC (mg/l)	DIC (mg/l)	POC (mg/l)	TOC (mg/l)	PN (ug/g)	PP (ug/g)	HCO3- (mg/l)	TSS/SPM (mg/l)	ph	pCO2 (uatm)	Air-water CO2 fluxes (molC m-2 yr-1)	References
	d	e	f	g	h	i	j	k	l	m	n	o	p	q	s	v	w	x	
Gironde	2.8-5	2-2.1	0.025-0.1	2.025-2.3	0.02-0.16			1.71	29.14	2.6					86/ 650/1131.47	7.68	465–2860	30.8	m,s,w=5, x=21; d-h,s=92; k,l,s,v=40
Glama		0.42	0.04	0.46	0.01				2.6		4.17			13	665.2				h,l,n,q,s=1
Godavari	21.1	0.16		0.16				2	20.7/27	1-1.3				94	1619	8.75	293-500	*ref	d,e,l,q,s=1; k,l,m,w=63; x=64
Grijalva		0.68	0.07	0.75	0.09				25.4					129					e-h,l,q=1
Guadiana		1.18	0.01	1.19	0.06				26					132					e-h,l,q=1
Gualdalquivir	15			0.00					36-59					233		7.8	1029-3605		d,q=1; l,v,w=65
Guaviare		0.05		0.07				4.8		2.9			31*		118				e,k,m,p,s=10; g=20
Huang He	9.5	2.20	0.01	2.21	0.02			1.75/2-4	40.3 / 28-29	132		1000	1100	163	26829		1137		d-h,k-s=1; k,l=52; w=14
Hudson	4.2	0.67	0.09	0.76	0.02	0.013		6.2	12.9		5			44	51		1125 / 1062	5.84-13	d-h,l,n,q,s=1; w,x=66; w=13; i=23; k=24
Humber		8.40	0.42	8.82	0.12														e,f,h=42
Hunter				0.00	0.06														h=23
Incomati				0.00															
Indigirka	2.8	0.02	0.04	0.06	0.01	0.009	0.35		5.6		7.7			28.4	240.7				d-j,l,n,q,s=1
Indus	14	2.00	0.20	2.20	0.52			8.5	17.6	2.2			900	110	349		1748		d-h,l,m,p,q=1; w=14; s=18; k=24
Japura		0.10		0.11	0.01		0.204	3.4		1.7		122*	47*		55				e,h, j,k,m,o,p,s=10; g=20
Jurua		0.20		0.20	0.02		0.134	4.1		1.7		160*	146*		194				e,h, j,k,m,o,p,s=10; g=20
Kamchatka	12.6	0.10	0.05	0.15	0.08				9.6					48.6	81.6				d-h,l,q,s=1
Khatanga	3.2	0.03	0.04	0.07	0.01	0.006	0.41		9.4		6.3			47.9	16.8				d-j,l,n,q,s=1

River	Si (mg/l)	NO3 (mg/l)	NH4 (mg/l)	DIN (mg/l)	DIP (mg/l)	DOP (mg/l)	DON (mg/l)	DOC (mg/l)	DIC (mg/l)	POC (mg/l)	TOC (mg/l)	PN (ug/g)	PP (ug/g)	HCO3- (mg/l)	TSS/SPM (mg/l)	ph	pCO2 (uatm)	Air-water CO2 fluxes (molC m-2 yr-1)	References
	d	e	f	g	h	i	j	k	l	m	n	o	p	q	s	v	w	x	
Klamath	18	0.14		0.14	0.03	0.014	0.31	4.1	18.1		2.4			91.8	148.1				d,e,k,l,n,q,s=1; j=24; h,i=23
Kobuk	3.4		0.02		0.25		0.269	8.2	6.4		5.4			32.7					d,f,h,l,n,q=1; j=16; k=24
Kolyma	4	0.03	0.05	0.08	0.01	0.015	0.35		6.8		8.1			26	125.8		716-1779		d-j,l,n,q,s=1;w=67
Kuban	2.6	1.07	0.36	1.43	0.03			1.9	39.7	2.8	4.7			156.6	566.2				d-h,k-n,q,s=1
Kuskowin	7.6			0.27		0.026	0.74	4.6	17.6		4.1			89.6	116.9				d,k,l,n,q,s=1; g=20; i=23; j=24
Kymjoki	2.25		0.01	0.01	0.01				1.6		9.5			8	15.5				d,f,h,l,n,q,s=1
Lalang				0.00															
Lena	4.2 / 2.01-0.22	0.04	0.04	0.08	0.01	0.022	0.46	6.6	10.4	1.1	7.7			52	33				d-n,q,s=1; d=91
Liao	1.75	0.11	0.18	0.28	0.05										2531				d-h,s=1
Limpopo	17.7			0.00					28.3					144	1269				d,l,q,s=1
Loire	8	1.70		1.70	0.09			5.3	23.6/26.4-32.4	2.7/ 2.9 / 2.7	8.1			120	37 / 35.5	8.3	630-2910	64.4	d,e,h,k,l,m,q=1; m,s=5; w,x=21; m,n,s=68; l,w=69; v=43
Luan	4.7	0.94			0.01										4762				d,e,h,s=1
Maas (Meuse)	6.85	2.78			0.23						6				68.6				d,e,h,n,s=1
MacKenzie	4	0.10			0.01		0.1	4.5	21.6	7.2 /3.2	12.5 / 22.6	2000		94	134.4		4663		d,e,h,j,k,l,m,n,o,q,s=1; w=14; m,n=18
Madeira		0.18		0.18	0.02		0.175	2.9		2.7		274*	304*		540				e,h, j,k,m,o,p,s=10; g=20

River	Si (mg/l) d	NO3 (mg/l) e	NH4 (mg/l) f	DIN (mg/l) g	DIP (mg/l) h	DOP (mg/l) i	DON (mg/l) j	DOC (mg/l) k	DIC (mg/l) l	POC (mg/l) m	TOC (mg/l) n	PN (ug/g) o	PP (ug/g) p	HCO3- (mg/l) q	TSS/SPM (mg/l) s	ph v	pCO2 (uatm) w	Air-water CO2 fluxes (molC m-2 yr-1) x	References
Mae Klong				0.00											627.9				s=1
Magdalena	12.6	0.22		0.22	0.12				9.7					49.3	928.3				d,e,h,l,q,s=1
Mahanadi	9			0.00	0.04				12					60.9	909.1				d,l,q,s=1; h=23
Manicoagan		0.03		0.03				5.2	0.7					3.48					e,k,l,q=1
Maputo				0.00															
Mekong	8.9 / 0.14-1.4			0.00					11.4				2000	57.9	321.2		280-4110		d,l,p,q,s=1; d,w=70
Meta		0.11		0.13			0.204	3.1			7		75*		362				e,j,k,n,p,s=10; g=20
Mezen	2.4	0.01	0.06	0.07	0.03				12.3					62.3	32.5				d-h,l,q,s=1
Mississippi	6.7 / 2.74-0.39	1.4 / 0.56	0.04 / 0.03	1.44	0.07 / 0.25	0.015	0.82	8/4.2	23.7	1.9	5.5	2800		98.5	862.1	7.98	2000, 4593/4752		d-h,k,l-o,q,s=1; e,f,h=71; d=91; v,w=72; w=14; k=15; j=24; i=23
Moise (Moisie)	3	0.06		0.06				4.4	1.6					8.29					d,e,k,l,q=1
Moose				0.00				20	17.2	0.8				87.5	8.8				k,l,m,q,s=1
Murray	5	0.11	0.04	0.15	0.02				19.5		9			69	1271.2				d-h,l,n,q,s=1
Musi	24.5	0.16	0.05	0.21	0.03				3					17					d-h,l,q=1
Nadym	9.3	0.14	0.83		0.15						5				20.8				d,e,n,s=1; h=23; f=73
Narva				0.40															g=20
Natashquan				0.00				5	0.7					3.48					k,l,q=1
Negro	16.3	0.04		0.04	0.00		0.155	8.5	13.9	0.4	8.36	1*	9*	70.8	454.2				d,l,q,s=1; e,h, j,k,m,o,p=10; n=11; g=20
Nelson	1.4	0.01		0.01	0.00			8	25.4		9			129					d,e,h,k,l,n,q=1

River	Si (mg/l)	NO3 (mg/l)	NH4 (mg/l)	DIN (mg/l)	DIP (mg/l)	DOP (mg/l)	DON (mg/l)	DOC (mg/l)	DIC (mg/l)	POC (mg/l)	TOC (mg/l)	PN (ug/g)	PP (ug/g)	HCO3- (mg/l)	TSS/SPM (mg/l)	ph	pCO2 (uatm)	Air-water CO2 fluxes (molC m-2 yr-1)	References
	d	e	f	g	h	i	j	k	l	m	n	o	p	q	s	v	w	x	
Nemanus	2.06	0.37	0.42	0.79	0.05				48.9		7.1			248.6	33.7				d-h,l,n,q,s=1
Neva	0.1	0.23	0.03	0.26	0.03				5.3		8.6			26.8	10.4				d-h,l,n,q,s=1
Niger	14 / 14.61	0.10	0.01	0.11	0.01		0.13	2.9 / 3.54	6.6	3.9	5.88	1600		33.5	259.5 /127		35617		d,j-l,o,q,s=1; e-h=11; w=14; d,k,m,n,s=16
Nile	12.8	3.00		3.00			0.01	3.5	34.2	4.4		900		135	1442 / 54				d,j-m,o,q,s=1; e=4; s=16
North Dvina	2.28	0.02	0.12	0.14	0.04			20.1	16.3	3.2	23.4			83	42.9				d-h,k-n,q,s=1
Nueces	13.4	2.04		2.04		0.04	0.75	7.2	39.9		21.2			202.8	710				d,e,l,n,q=1; s=6; j,k=24; i=23
Nushagak				0.12		0.011	0.44	3.2											g=20; i=23; j,k=24
Ob	2.85	0.06	0.60	0.66	0.07			9.1	29.5	0.9	10			78	40.8		30-140		d-h,k,l,m,n,q,s=1; k=24; w=67
Odra		2.42	0.21	2.63 / 2.7	0.370 / 0.09				29.5					150	7.1				e-h,l,q,s=1; g,h=74
Ogooe (Ogooue)				0.00				8.4		2.4									k,m=1
Olenek	2.7	0.03	0.05	0.08	0.00	0.006	0.41		14.3		7.2			72.6	32				d-j,l,n,q,s=1
Onega	7.5	0.15	*ref		0.02				15.8		20.7			72.3	19				d,e,h,l,n,q,s=1; f=73
Orange	16.9	0.72		0.72	0.01		0.15	2.33	21	0.85				107	7834.5 / 57				d,e,j-m,q,s=1; h=11; s=16
Orinoco	6.3	0.08	0.04	0.12	0.01	0.01	0.16	4.4	2	2.5	6	2200	550	9.99	132.2				d-s=1
Panuco		0.92	0.05	0.97	0.02				35					178					e-h,l,q=1
Paraguay River				0.00															g=20
Paraibado Sul		0.31	0.04	0.35	0.01				2.8					14					e-h,l,q=1
Parana	17.1	0.17	0.05	0.22	0.05		0.08	6.1	8.3	7.95	2.95	1400	598	21	139.1		3139		d-h,j-q,s=1; w=14
Pechora	1.6	0.01	0.22	0.23	0.01			12.7	7.7	0.3	13			38.9	50.4	8.05			d-h,k-n,q,s=1; v=75

River	Si (mg/l) d	NO3 (mg/l) e	NH4 (mg/l) f	DIN (mg/l) g	DIP (mg/l) h	DOP (mg/l) i	DON (mg/l) j	DOC (mg/l) k	DIC (mg/l) l	POC (mg/l) m	TOC (mg/l) n	PN (ug/g) o	PP (ug/g) p	HCO3- (mg/l) q	TSS/SPM (mg/l) s	ph v	pCO2 (uatm) w	Air-water CO2 fluxes (molC m-2 yr-1) x	References
Pee Dee	10.8	0.42		0.42		0.018	0.26	1.13	4.2	0.5	11			21.1	23				d,e,k,l,m,n,q,s=1; j=24; i=23
Peel				0.00	0.01				25.6					130					h,l,q=1
Penzhina	5.41	0.03	0.05	0.08	0.02				3.1					15.7	41				d-h,l,q,s=1
Petit (Mecatina)		0.01		0.01				6	0.8					3.84					e,k,l,q=1
Po	4	2.19	0.26	2.45	0.08	0.01	0.32	2.4	35		4.7	6500	1400	178	330.4				e-h=4; d,i-l,n-q,s=1
Potomac	6	1.20	0.03	1.23	0.03	0.03	0.44	3.1	14.6		5			74	65.5		646-878		d-h,k,l,n,q,s=1; w=13; j=24; i=23
Pungue (Pungoe)				0.00															
Purari	13.8	0.04	0.04	0.08	0.00				15.9					81	950.9				d-h,l,q,s=1
Rhine	6.08	3.94	0.94	4.88	0.36			5.36	31.1	3/ 0.8	7			158	49.1/ 15	7.8	545–1990	39.7	d-h,k-n,q,s=1; m,s,w=5, x=21; v=76
Rhone	3.0 / 1.37-0.66	1.48	0.12	1.60	0.10				34.6					176	517.5		2015		e-h=4; d,l,q,s=1; d=91; w=14
Rio Coatzacoalcos				0.00			0.87												j=24
Rio Grande (US)	14	0.15	0.03	0.18	0.03	0.016	0.57	4.1	31.4		7			130	1111.1		1205		d-h,l,n,q,s=1, w=14; j,k=24; i=23
Roanoake				0.00		0.018	0.22				7.1				285.7				n,s=1; j=24; i=23
Rufiji		1.30	0.10	1.40	0.01				9.8					50	483				e-h,l,q,s=1
Sabine	8	0.08		0.08	0.01	0.017	0.52	6	4.0 / 7.2		8.3			20.5	176.9				d,e,l,n,q,s=1; k,l =77; j=24; i=23; h=33
Sacramento	17	0.10	0.03	0.13	0.03	0.018	0.41	3.6	11.7		2			59.5	112.2		1955		d-h,k,l,n,q,s=1; w=14; j=24; i=23
Sado	5	0.84	0.07	0.91	0.06			6.72	28.21	2.9					101 / 80-250	7.62	575–5700	31.1	m,s,w=5,x=21; d-h,s=92; k,l,v=44

River	Si (mg/l) d	NO3 (mg/l) e	NH4 (mg/l) f	DIN (mg/l) g	DIP (mg/l) h	DOP (mg/l) i	DON (mg/l) j	DOC (mg/l) k	DIC (mg/l) l	POC (mg/l) m	TOC (mg/l) n	PN (ug/g) o	PP (ug/g) p	HCO3- (mg/l) q	TSS/SPM (mg/l) s	ph v	pCO2 (uatm) w	Air-water CO2 fluxes (molC m-2 yr-1) x	References
Saint John	2.7	0.08	0.01	0.09			7.42		4.3		11.3			21.9					d-g,l,n,q=1; j=20
Sakarya	11.8	1.11	0.35	1.46	0.16				39.3					206	1499.1				d-h,l,q,s=1
Saloum				0.00															
San Joaquin	15.75	0.81		0.81		0.027	0.44	8.8	24.4		5.2			124	19.4				d,e,l,n,q,s=1; j,k=24; i=23
Sanaga	15.5			0.00				3.5	4.1	3.2				20.85	50.9				d,k,l,m,q,s=1
Savannah	8.9	0.23		0.23	0.01	0.025	0.27	5.5	4.9	0.9	4.6			25	241.4				d,e,k,l,m,n,q,s=1; j=24; i=23; h=33
Scheldt	7 / 2.8-7.3	4.6 / 3.5 /4.5	7.7 / 1.4	12.30	0.81/0.5/0.25/ 0.16	0.031		7.9/10.8	54.9 / 66 / 39.6-85.2	18.3 / 10.8	7.05		5580	279	166.7/163	7-7.5	125–9425 /5000	63 /240	e-h,k,l,n,q,s=1, m,s,w=5; x=21; d,e,h,v=78; e,f,g,k,l=79; h,i,p=80; l,w,x=45; d=81; l=82
Sebou	10.6			0.00			0.9						960		412.7				d,p,s=1; j=24
Seine	6.33	4.38	2.41	6.79	0.70		0.5	3.65	49.6	2.65	6.3			252	44.3		826-5345		d-h,j-n,q,s=1; w=13
Severn				0.00	0.02										170.5				s=1; h=23
Seyhan		0.59	0.31	0.90	0.01				31.2					158.5	1083.3				e-h,l,q,s=1
Skagit				0.00	0.01						2.8				22				n,s=1; h=23
Solimoes at Ica				0.21			0.12												g,j=20
Solo	19.6	0.28		0.28	0.03				24					122	1266.7				d,e,h,l,q,s=1
St .Johns		0.0042			0.01	0.012	0.44	12.6			13.7								n=1; i=23; j,k=24; e,h=33
St.Lawrence	2.4	0.16	0.08	0.24	0.05	0.021	0.03	3.7	17.1	0.8	4.5		820	88.1	11.7		*ref		d-g,i-n,p-s=1; i,h=23; w=83
Stikine	6	0.09		0.24	0.02	0.017	0.84	3.6	12.8		2.4			48.7	396				d,k,l,n,q,s=1; e=11;

River	Si (mg/l)	NO3 (mg/l)	NH4 (mg/l)	DIN (mg/l)	DIP (mg/l)	DOP (mg/l)	DON (mg/l)	DOC (mg/l)	DIC (mg/l)	POC (mg/l)	TOC (mg/l)	PN (ug/g)	PP (ug/g)	HCO3- (mg/l)	TSS/SPM (mg/l)	ph	pCO2 (uatm)	Air-water CO2 fluxes (molC m-2 yr-1)	References
	d	e	f	g	h	i	j	k	l	m	n	o	p	q	s	v	w	x	
Susitna	6.7			0.00		0.034	0.62	3	12.6		2.8			64	565.6				g=20; h,i=23; j=24 d,l,n,q,s=1; j,k=24; i=23
Susquehanna	3.8 / 1.46-0.64	1.00	0.03	1.03	0.01	0.013	0.29	4.4	8.9		4			42	47.6				d-h,k,l,n,q,s=1; d=91; j=24; i=23
Swan Canning				0.00	0.06														h=23
Tamar				0.00													380-2200	74.8	w,x=21
Tana	0.6				0.05			3								8	4000-5500	*ref	d,h,k,v,w=84; x=64
Tees				0.00															
Tejo	5	0.66	0.12	0.78	0.148				18.7					71					d-h,l,q=1
Tha Chin				0.00															
Thames	12.3	7.03	0.21	7.24	0.35			5.55	49.50	3.5					58	7.75	465–4600	73.6	d-h=1, m,s,w=5, x=21; k,l,v=47
Tiber (Tevere)		0.024/0.04	1.038/0.06	1.062/ 0.1	0.26/0.0035			0.35	76.9	0.45	5.4 / 0.8			391	1016.3				e-h=4; l,n,q,s=1; e-h,k,m,n=17
Tocantins	11.6	0.02		0.02	0.00				3.8					19.2	201.6				d,e,h,l,q,s=1
Tornionjoki	7.1	0.02	0.01	0.03	0.00				2.1		7			10.7					d-h,l,n,q=1
Trinity				*ref		0.027	0.52	6			8.3								n=1; g=20; i=23; j,k=24
Trombetas		0.05		0.11	0.00														e,h=10; g=20
Tugela				0.00	0.05														h=23
Tweed	1.6	1.60	0.10	1.70	0.05			3.2								7.5-9.5	*ref		d-h=58; v=85; k,w=59
Tyne				0.00															
Ubangi				0.00															

River	Si (mg/l) d	NO3 (mg/l) e	NH4 (mg/l) f	DIN (mg/l) g	DIP (mg/l) h	DOP (mg/l) i	DON (mg/l) j	DOC (mg/l) k	DIC (mg/l) l	POC (mg/l) m	TOC (mg/l) n	PN (ug/g) o	PP (ug/g) p	HCO3- (mg/l) q	TSS/SPM (mg/l) s	ph v	pCO2 (uatm) w	Air-water CO2 fluxes (molC m-2 yr-1) x	References
Uruguay	15	0.23	0.05	0.28	0.04			3.2	7.1	0.7	4			26	75.9				d-h,k-n,q,s=1
Usumacinta		0.44	0.05	0.48	0.09				27.7					141					e-h,l,q=1
Volga				0.00	0.01														h=11
Waikato	28.2	0.30	0.01	0.31	0.02		0.05		8.3		6.1		2300	35.3	132.2				d-h,j,l,n,p-s=1
Weser	4	5.08	0.13	5.21	0.37				33					168	26.11		4395		d-h,l,q,s=1; w=14
Wisla		1.83	0.44	2.27	0.21				37.4					190	73.3				d-h,l,q,s=1
Xijiang				0.00													600-7200	69-130	w,x=86
Yana	2.2	0.01	0.17	0.18	0.00	0.01	0.4		4.1		6.7			20.7	114.4				d-j,l,n,q,s=1
Yenisei	3	0.02	0.28	0.30	0.01			7.4	11.3		7.4			57.3	9.5		30-140		d-h,k,l,n,q,s=1; w=67
Yesil		0.53	0.27	0.80	0.08										3351				e-h,s=1
Yukon	6.9 /7.7	0.1/0.117	0.03/0.061	0.13/0.178	0.01/0.011	0.018	0.287	4.8	21.4	1.33	7			81/ 109	300		5205/2767		d-h,k-n,q,s=1; w=14; d-h,j=16; i=23
Zaire (Congo River)	9.4 / 5.2-1.07	0.09	0.01	0.10	0.02		0.18	8.5	3.1	1	8.8		2060	15.7	19				d-h,j-m,p-s=1; d=91; n=11; s=16
Zhujiang (Pearl River)	8.5/ 3.5-4.0	0.62	0.01	0.63/1.05-1.54	0.003/0.0062-0.037				19.7					100	190.1	7.0-7.7	4000		d-h,l,q,s=1, l,v=87, d,g,h,l=88; w=89

* (columns: o & p) are in ug/l

*ref = check reference

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