Modelling of suspended riverine sediment fluxes at global, regional and locals scales: major controls, anthropogenic perturbations and associated pollutant fluxes from land to sea

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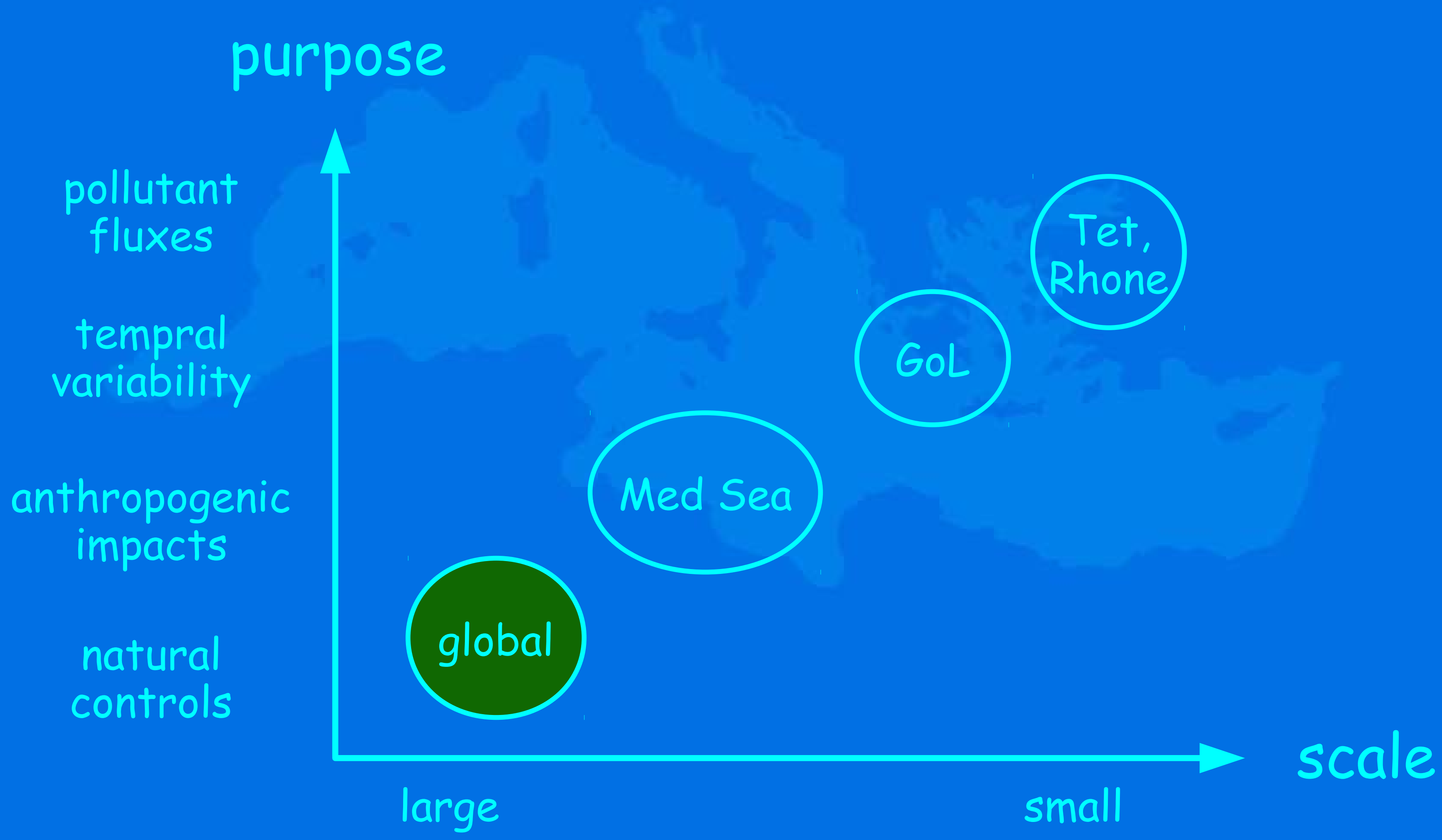
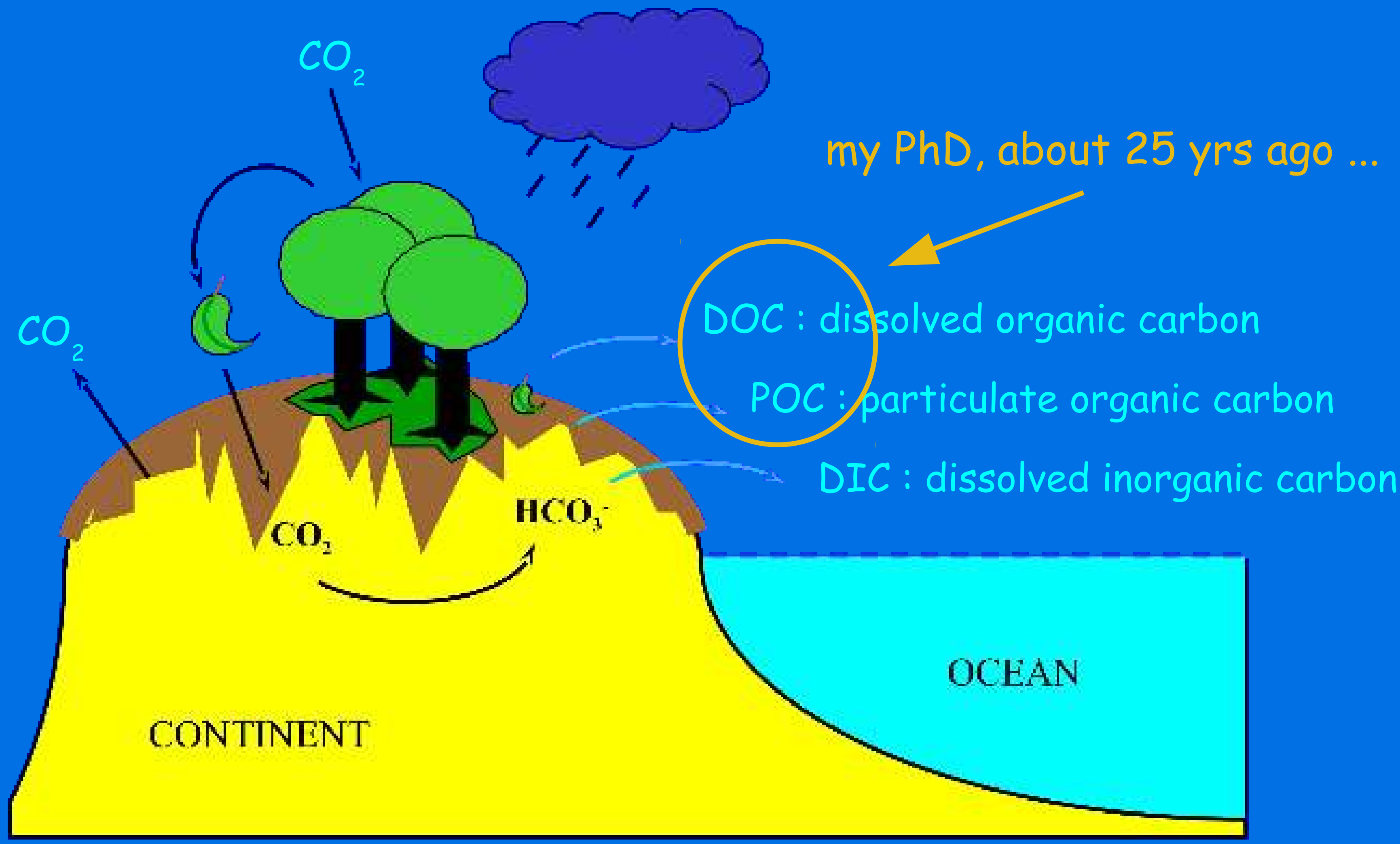
Modelling of riverine sediment fluxes



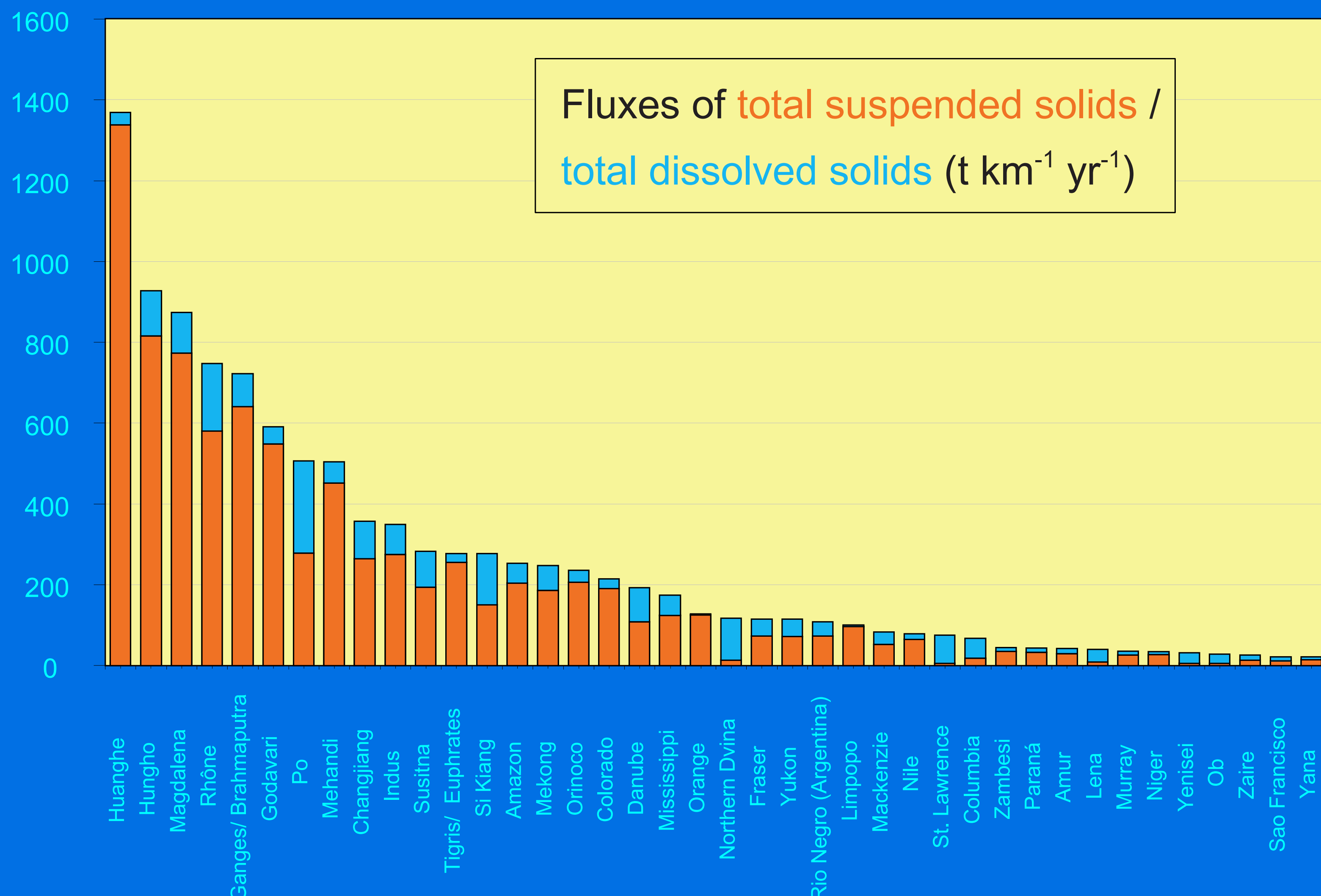
Modelling the atmospheric CO_2 consumption by continental erosion



In order to predict particulate matter fluxes, one has to predict the vector of these fluxes :

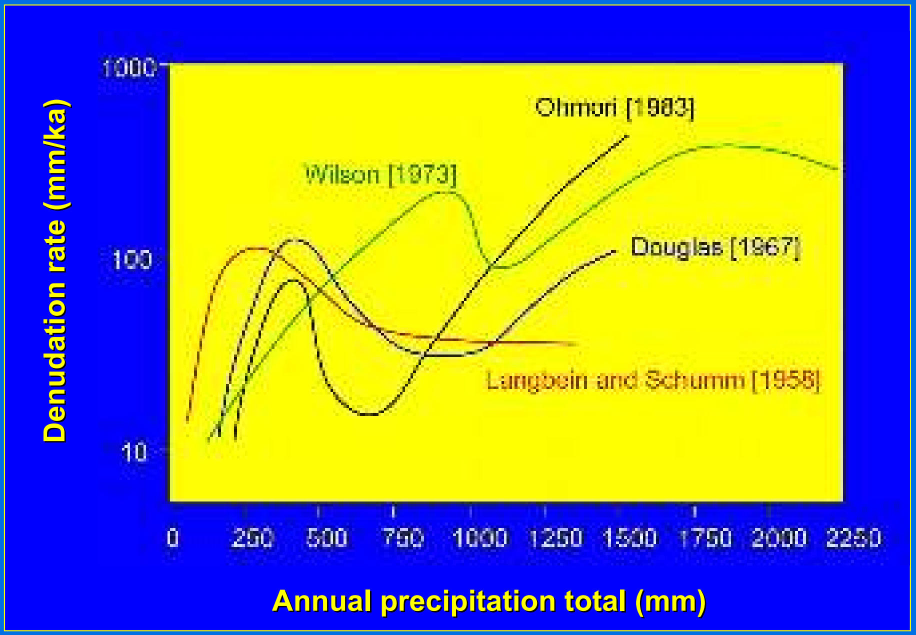
Total suspended solids (TSS)

… bad news: TSS fluxes (FTSS) are highly variable



What globally controls river sediment fluxes ?

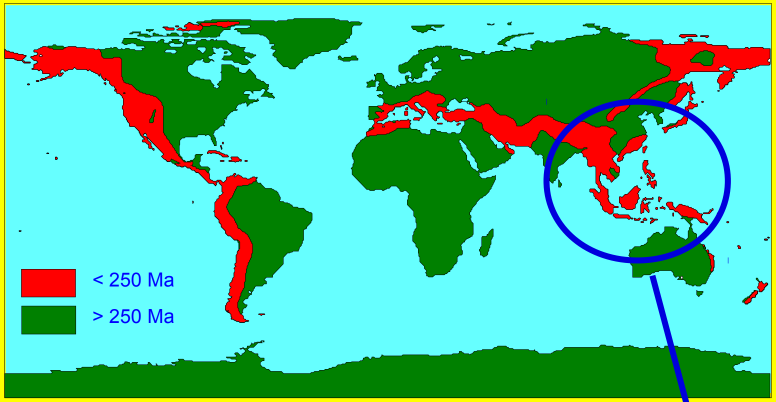
Climate ?



Model of Pinet and Souriau (1988)

$Ds = 419 \times 10^{-6}\ Elev - 0.245$	*young orogenes*
$Ds = 61 \times 10^{-6}\ Elev$	*old orogenes*

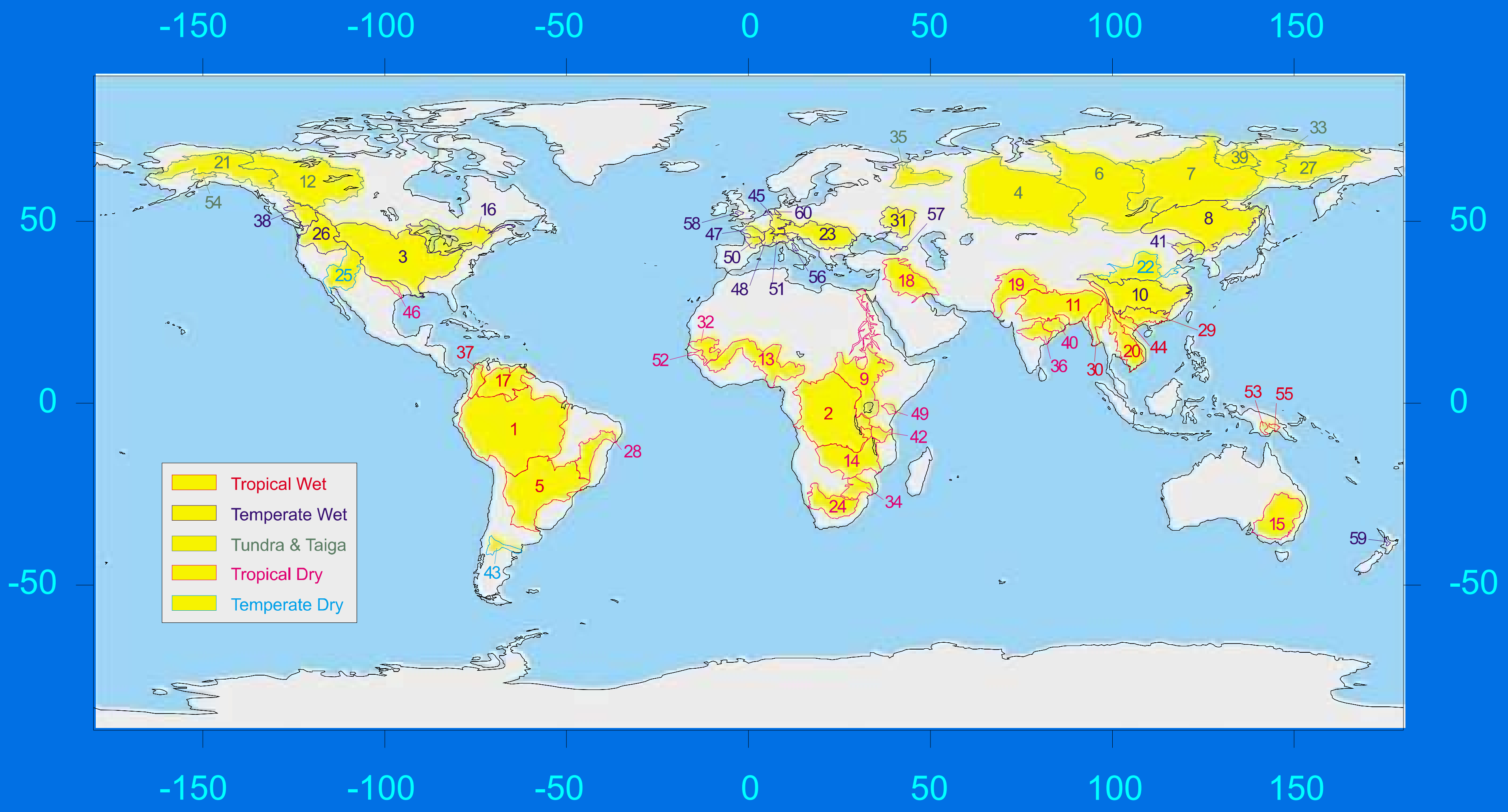
Ds = denudation rates (m/ka); Elev = mean elevation (m)



… or morphology/ tectonics ?

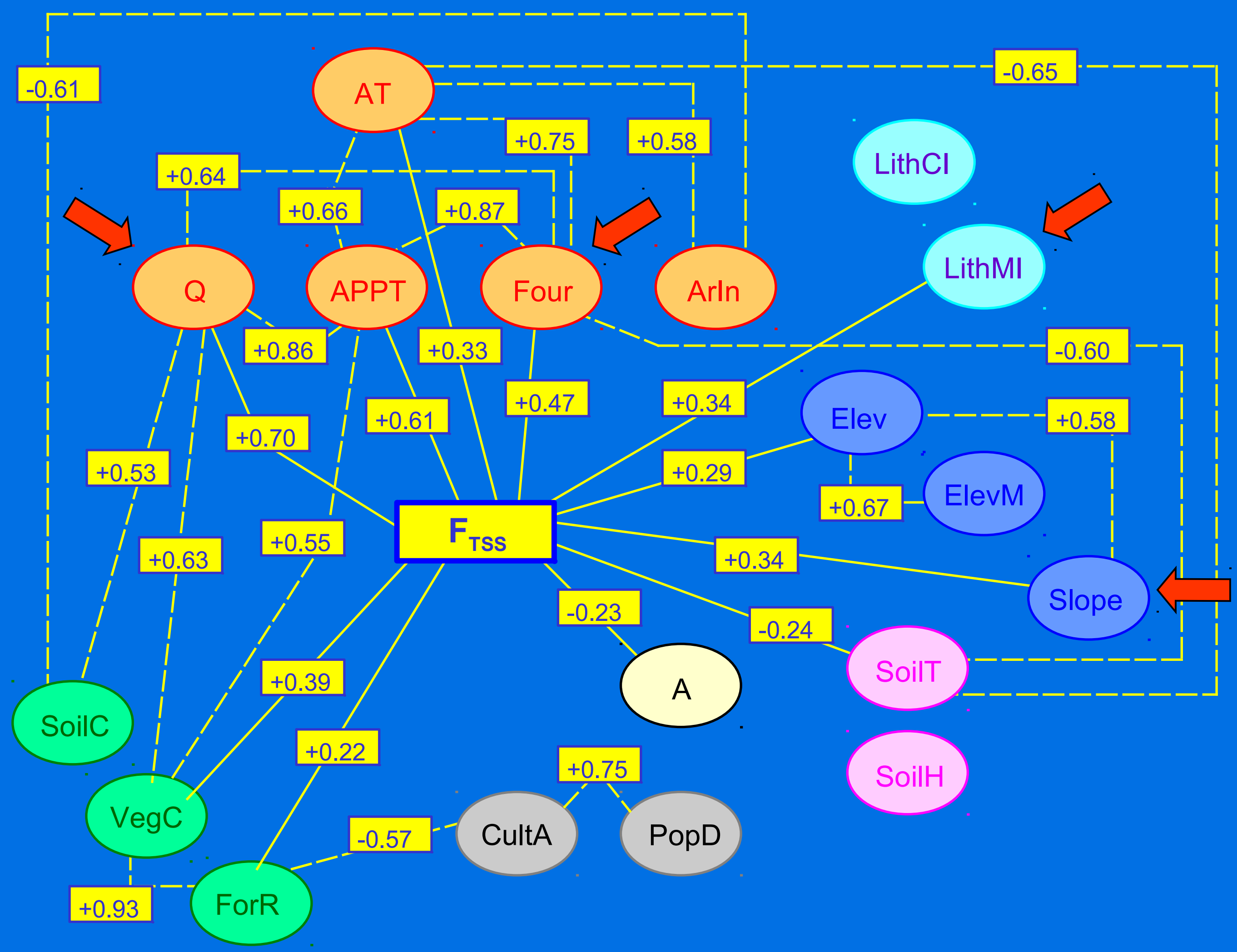
according to Milliman and Meade (1983),
up to 70 % of global fluxes (Himalayan faulting!)

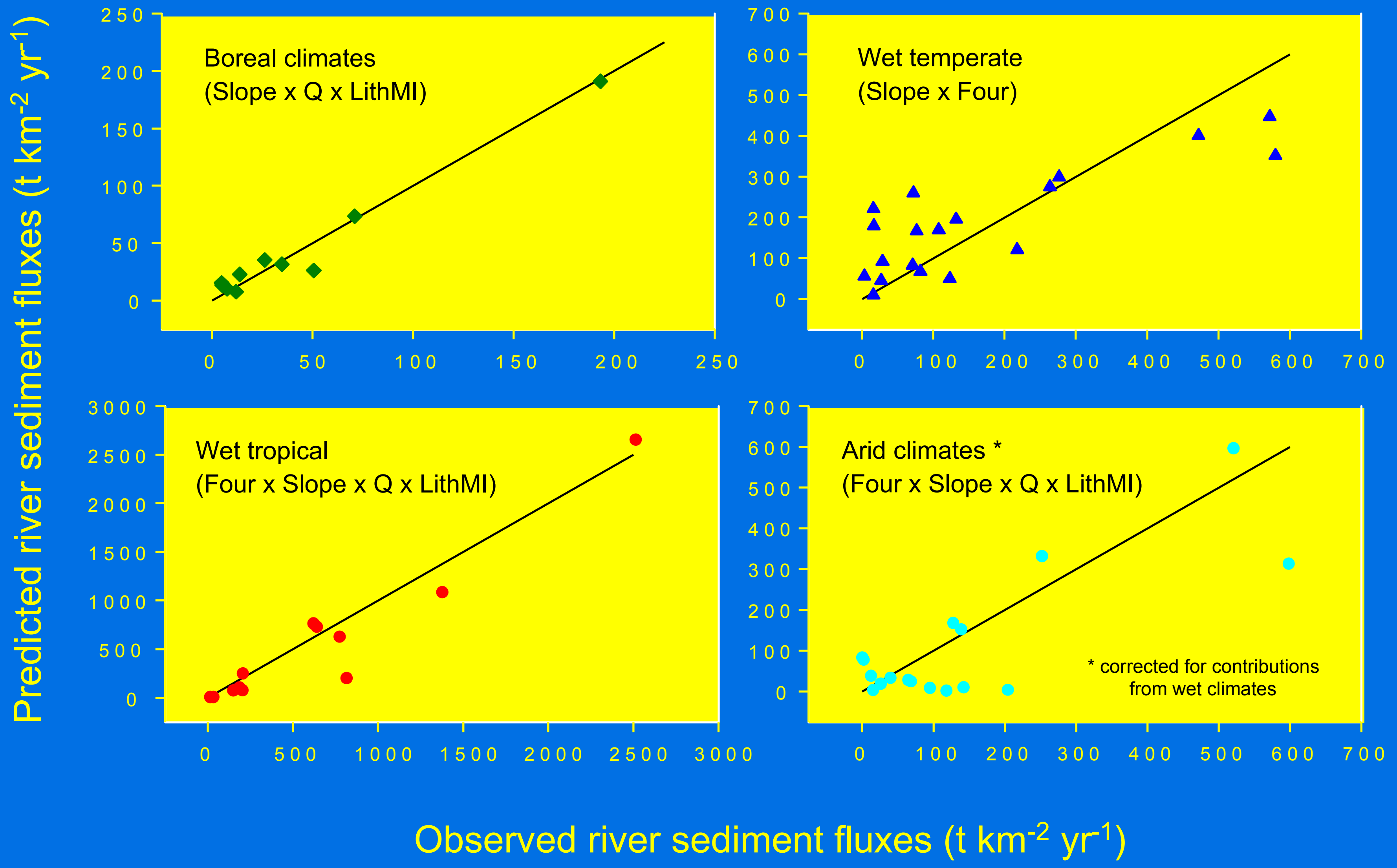
Major World rivers



1 - Amazon; 2 - Zaire ; 3 - Mississippi; 4 - Ob; 5 - Paraná; 6 - Yenisei; 7 - Lena; 8 - Amur; 9 - Nile; 10 - Changjiang; 11 - Ganges/Brahmaputra; 12 - Mackenzie; 13 - Niger; 14 - Zambesi; 15 - Murray; 16 - St. Lawrence; 17 - Orinoco; 18 - Tigris/Euphrates; 19 - Indus; 20 - Mekong; 21 - Yukon; 22 - Huanghe; 23 - Danube; 24 - Orange; 25 - Colorado; 26 - Columbia; 27 - Kolyma; 28 - Sao Francisco; 29 - Si Kiang; 30 - Irrawaddy; 31 - Don; 32 - Senegal; 33 - Indagirka; 34 - Limpopo; 35 - North Dvina; 36 - Godavari; 37 - Magdalena; 38 - Fraser; 39 - Yana; 40 - Mahandi; 41 - Liao He; 42 - Rufiji; 43 - Rio Negro (Argentine); 44 - Hungho; 45 - Rhine; 46 - Brazos; 47 - Loire; 48 - Rhône; 49 - Tana; 50 - Garonne; 51 - Po; 52 - Gambia; 53 - Fly; 54 - Susitna; 55 - Purari; 56 - Tiber; 57 - Rioni; 58 - Severn; 59 - Waikato; 60 - Ems;

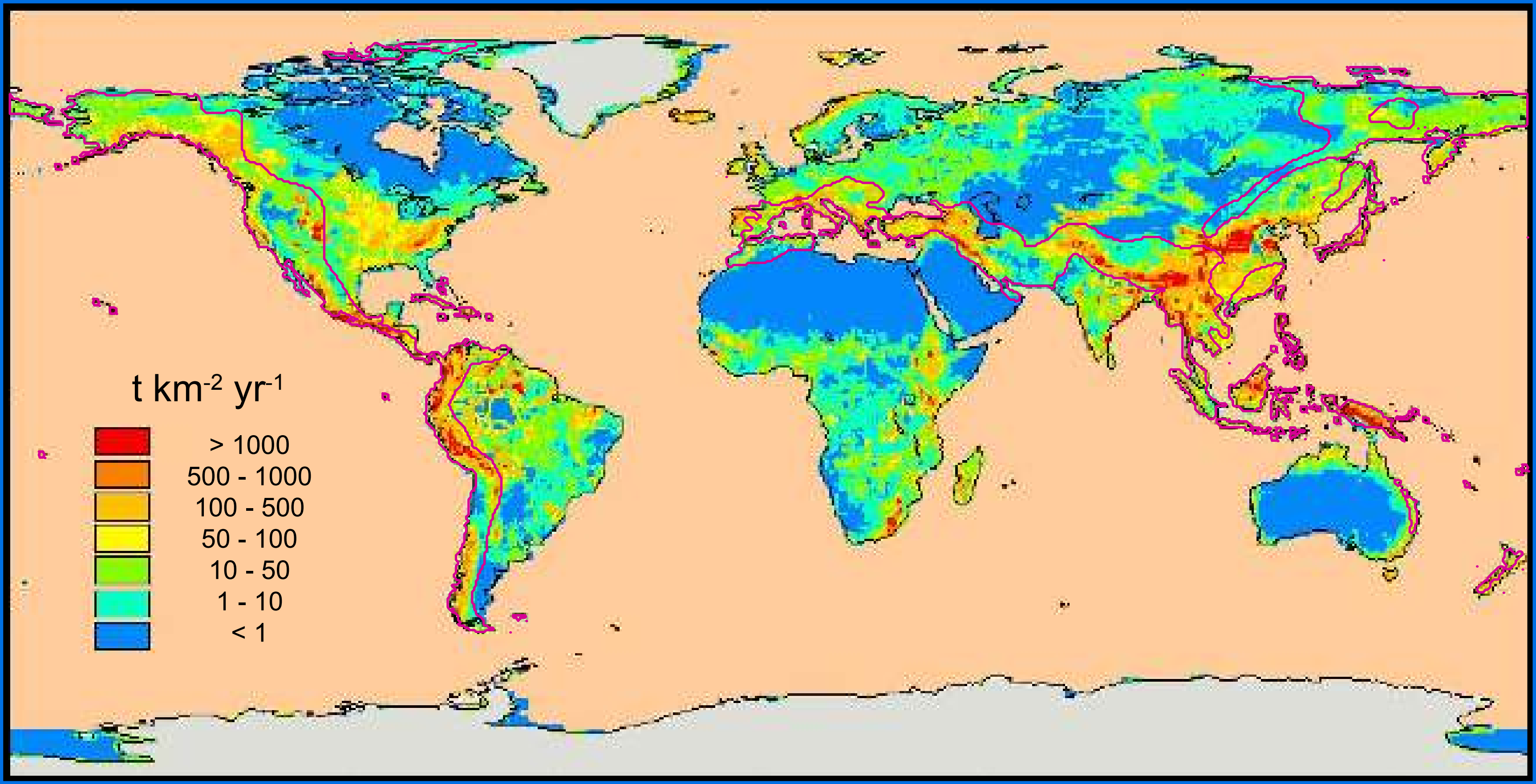
Correlation matrix for TSS fluxes and environmental characteristics





Predicted river sediment fluxes (t km-2 yr-1)
Boreal climates
(Slope x Q x LithMI)
Wet temperate
(Slope x Four)
Wet tropical
(Four x Slope x Q x LithMI)
Arid climates *
(Four x Slope x Q x LithMI)
* corrected for contributions
from wet climates
Observed river sediment fluxes (t km-2 yr-1)

Spatial variability of riverine sediment yields



27% of the continental area, but 70% of the total sediment flux  < 250 Ma

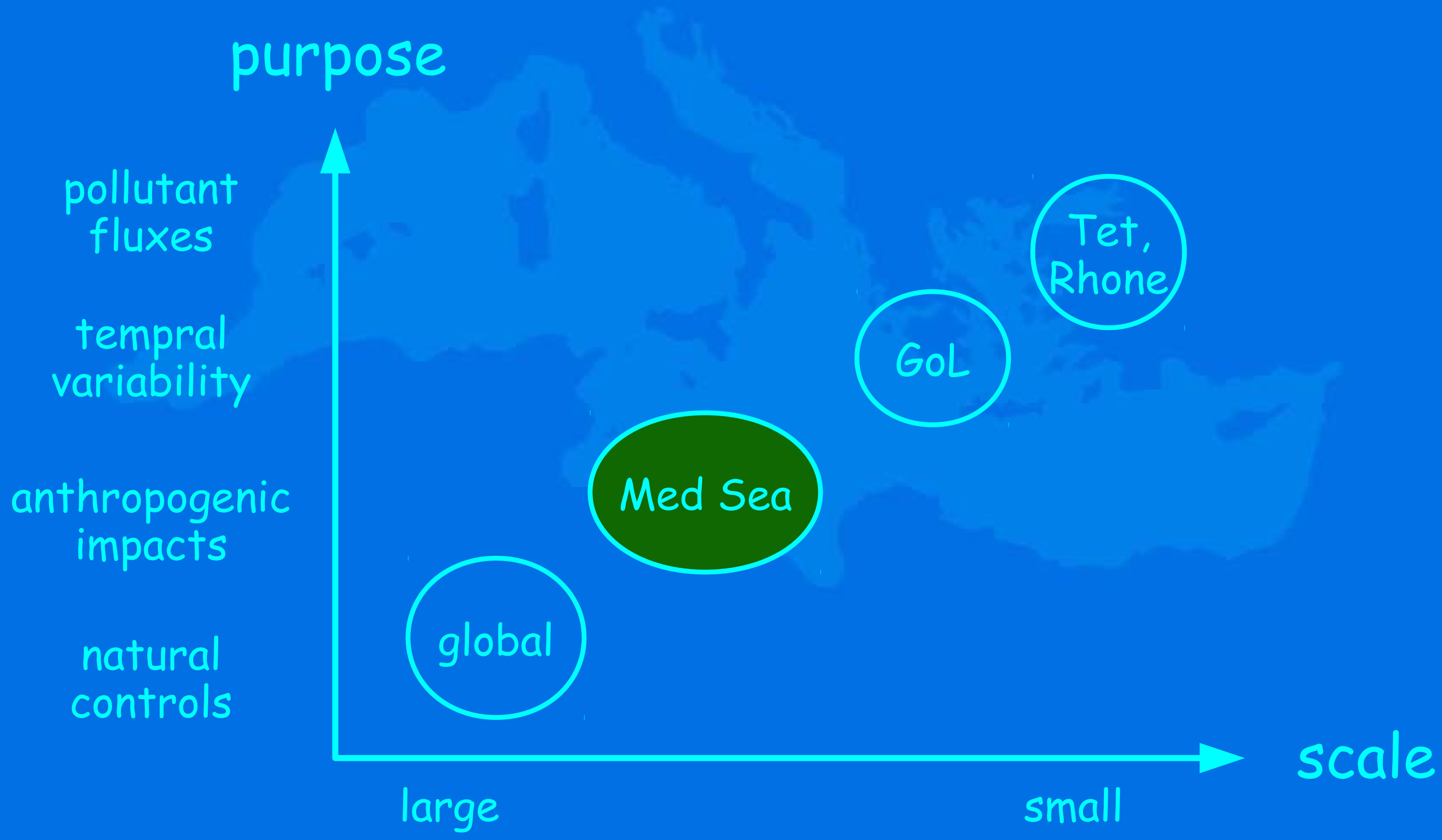
Ludwig and Probst, 1998

« take home » messages ...

- River sediment yields (specific fluxes) result from a combination of hydroclimatic, morphological and lithological factors

- In young orogenes they often combine to high flux conditions, but orogeny itself is not a major control

Modelling of riverine sediment fluxes



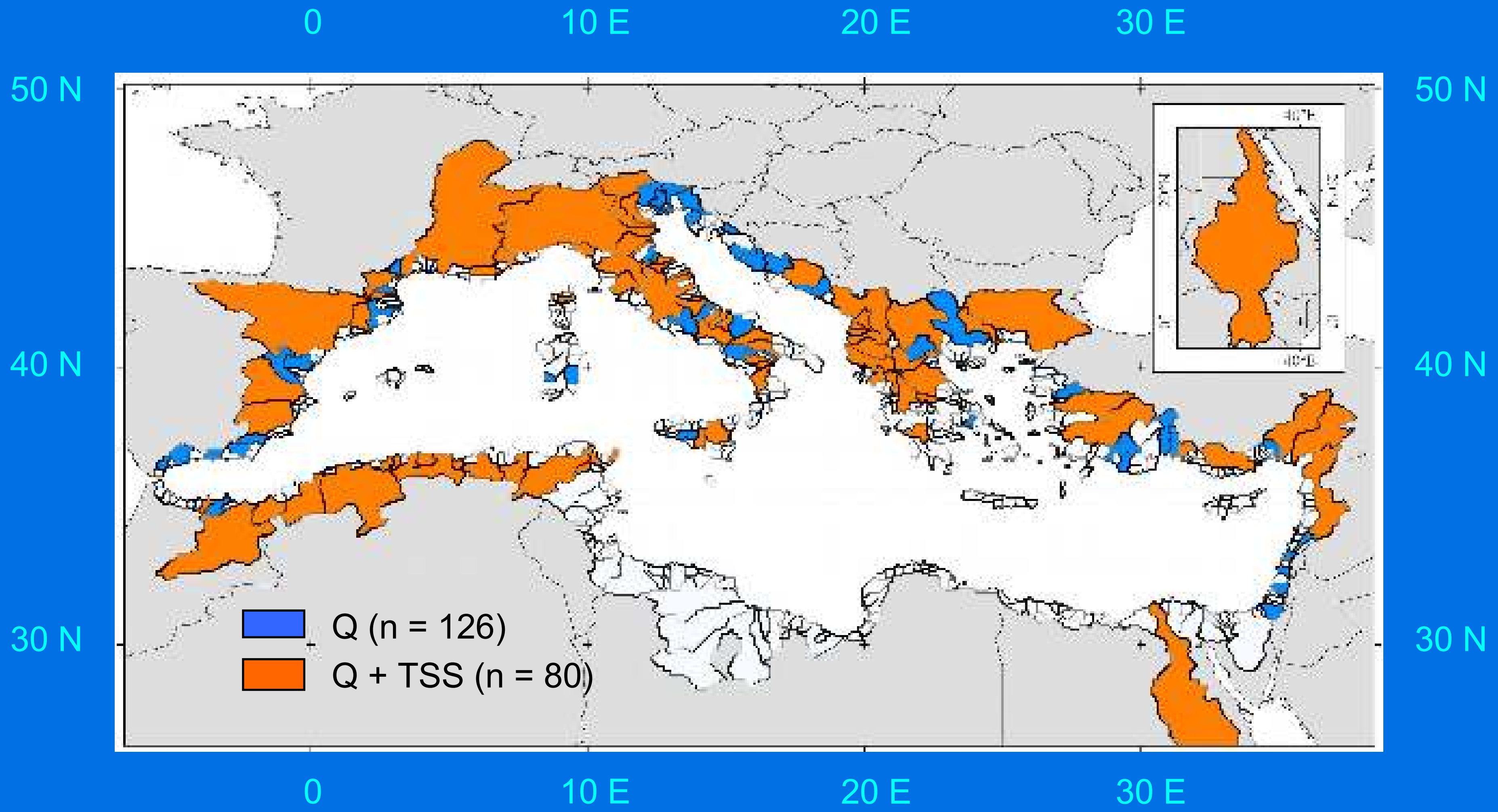
Why to focus on the Mediterranean ?

- The Mediterranean region is a hot-spot area for global change with increasing anthropogenic pressure on water resources => river damming !

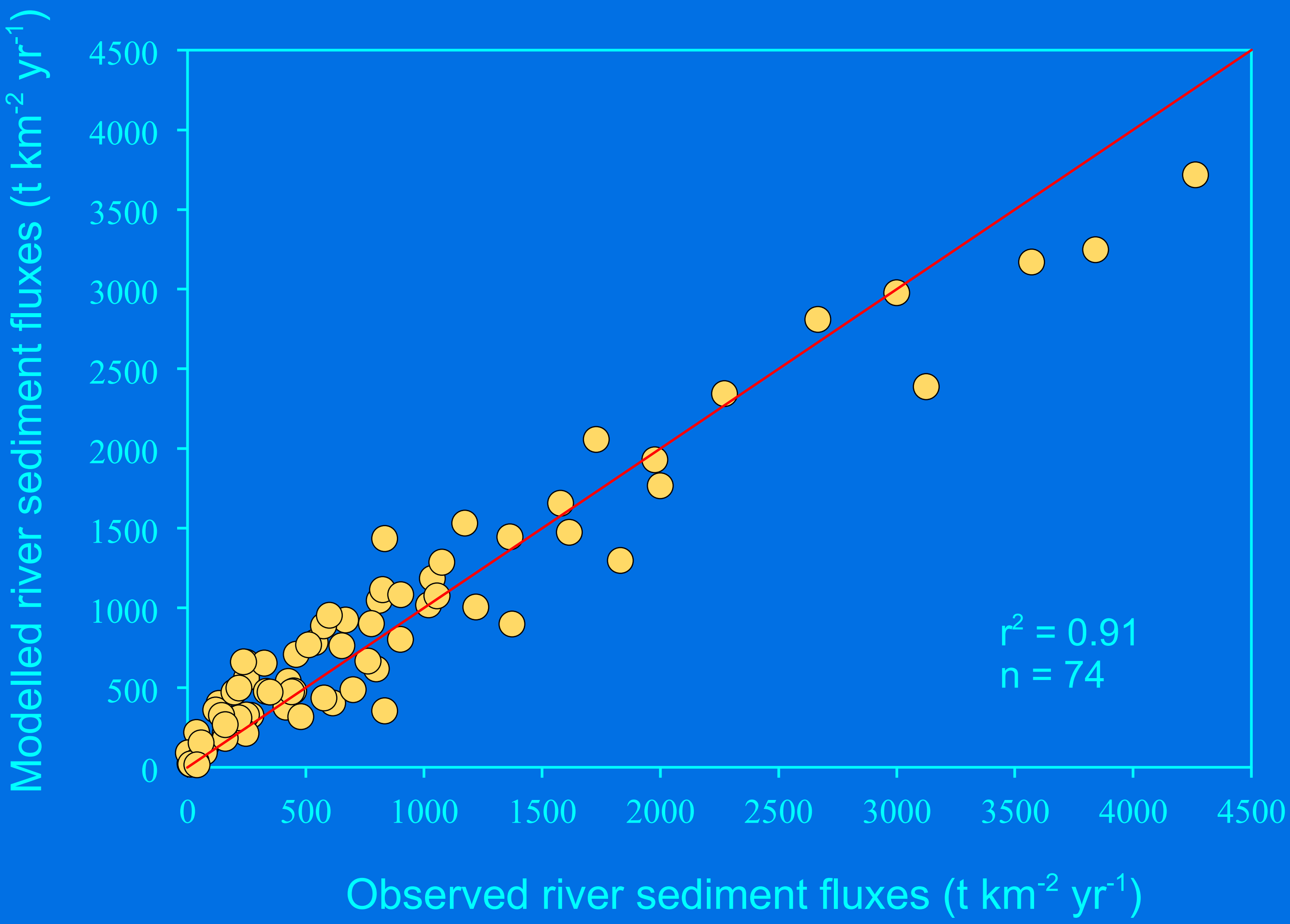
- Small mountain rivers are numerous in this area, which could be hot-spots for TSS fluxes

according to Milliman and Syvitski (1992),
these rivers might considerably increase the global budgets

Mediterranean drainage basins
for which mean long-term estimates exist in the literature



Sadaoui et al., 2017

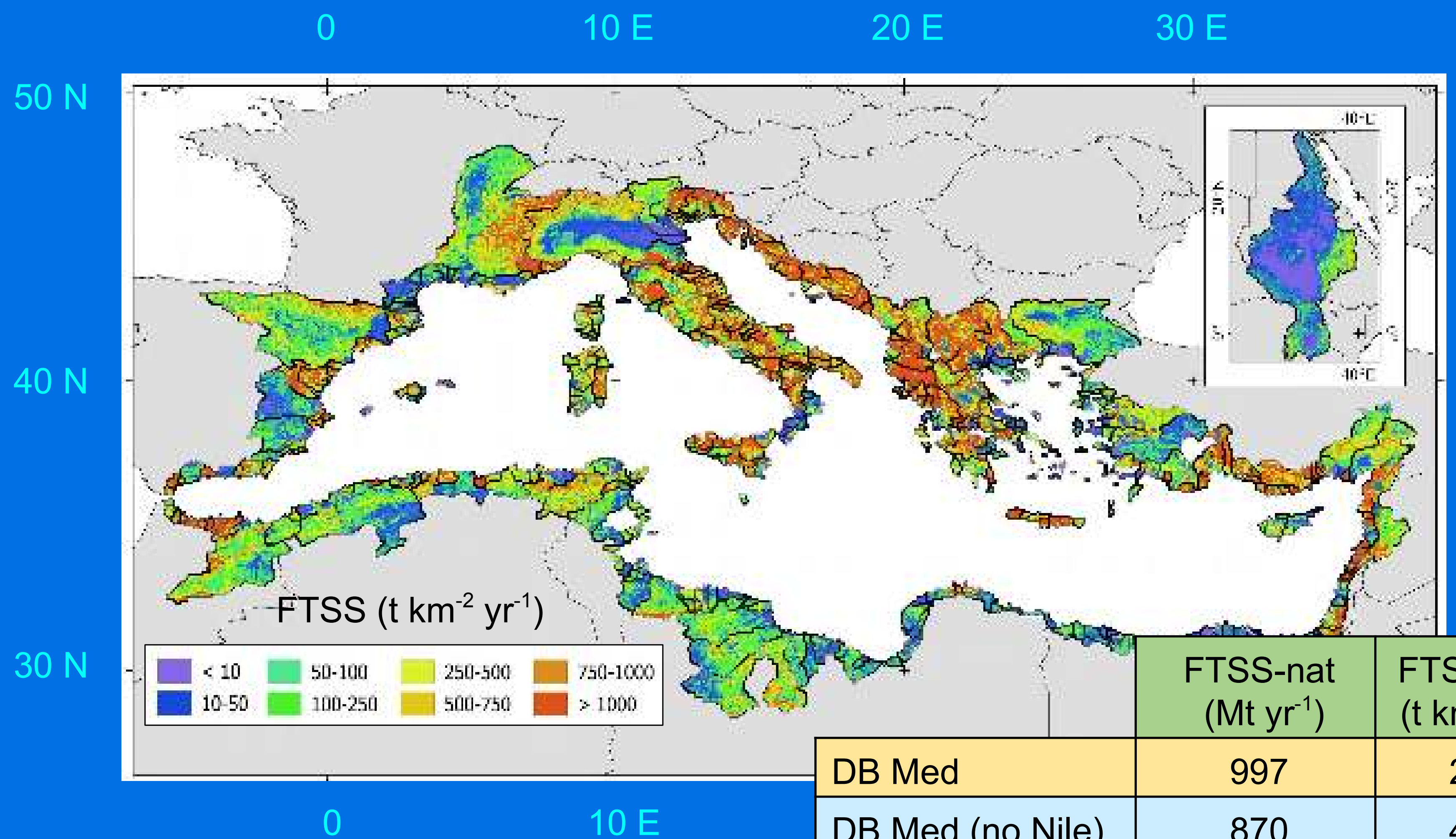


% of shrub land, grasslands and agriculture land use types

$$FTSS = -3668.51 + 0.12\,Q + 270.79\,Slope + 33.67\,SRe + 19.14\,Er$$

% of sedimentary rocks > 600m altitude

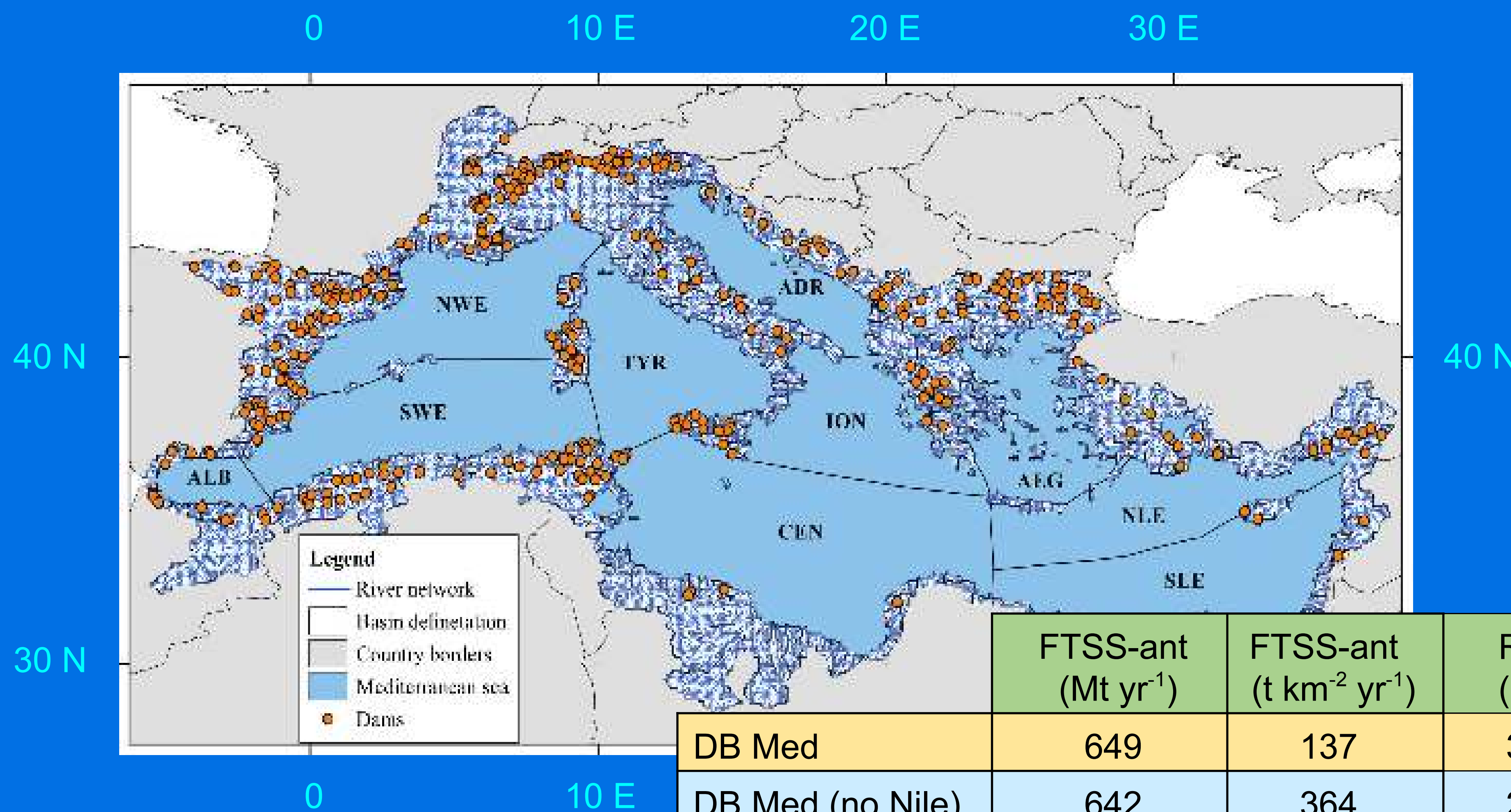
Spatial variability of natural riverine sediment yields



	FTSS-nat (Mt yr^{-1})	FTSS-nat (t km^{-2} yr^{-1})
DB Med	997	211
DB Med (no Nile)	870	493

Sadaoui et al., 2017

(Large) reservoirs in the Mediterranean drainage basin (source : DB GranD, reference year : 2003)

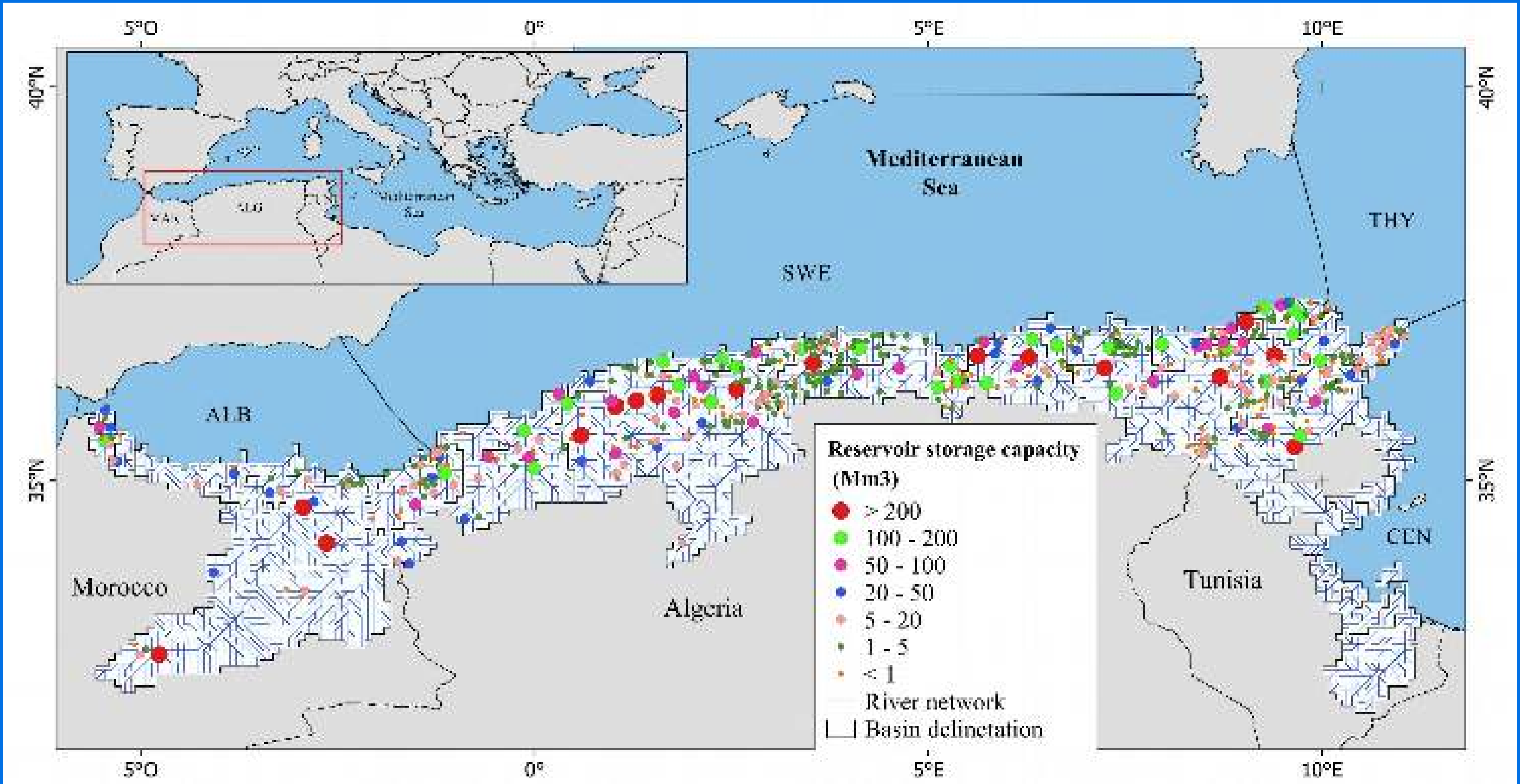


	FTSS-ant ($Mt\ yr^{-1}$)	FTSS-ant ($t\ km^{-2}\ yr^{-1}$)	Ret (%)
DB Med	649	137	35
DB Med (no Nile)	642	364	26

(for sediment retention behind dams, see Vörösmarty et al., 1997)

Sadaoui et al., 2017

Data mining for additional dams in the Maghreb region

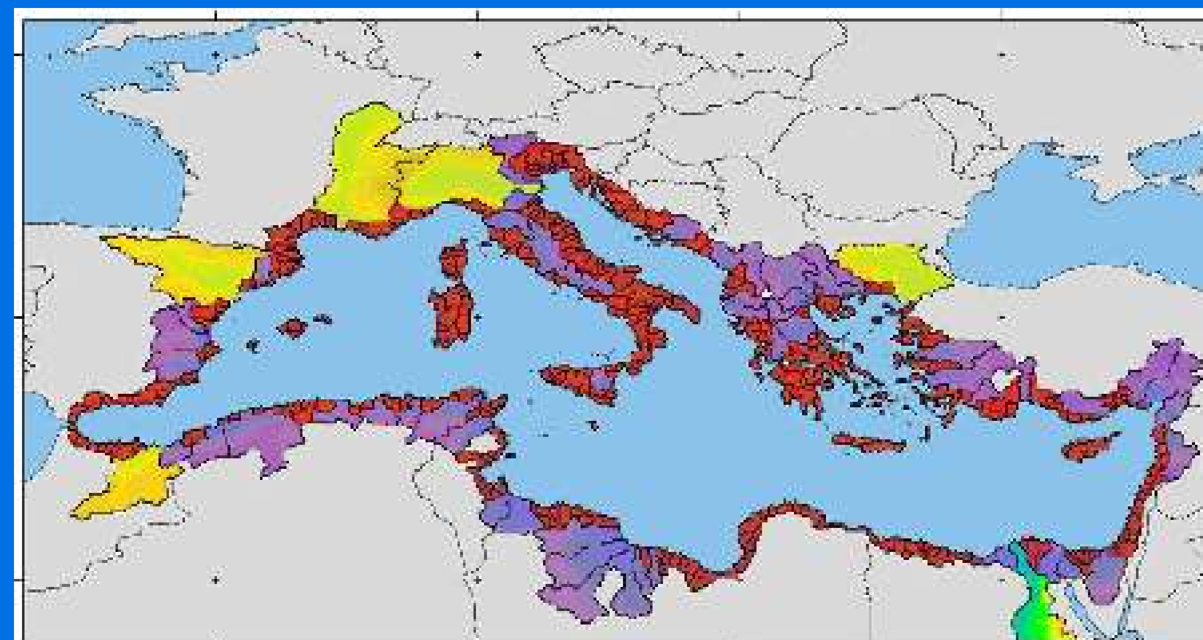


n = 450, FTSS retention = 63 %

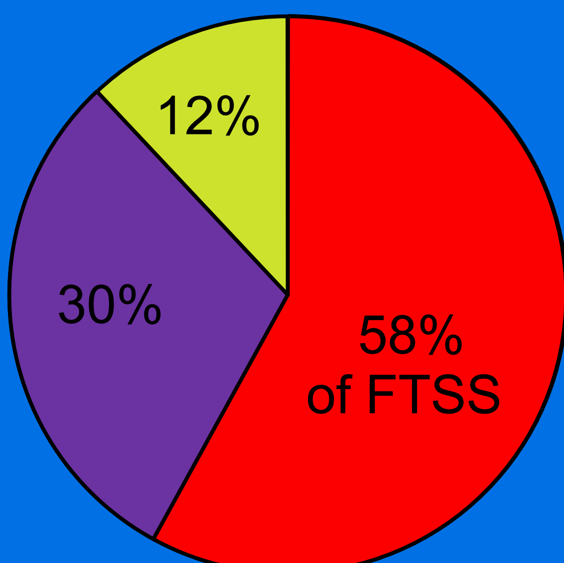
(DB GranD : n = 53, FTSS retention = 36 %)

Sadaoui et al., ready for submission

The role of « coastal rivers » in the natural FTSS budgets



large rivers : > 50 * 10^3 km ^{2}
24 % of total area*



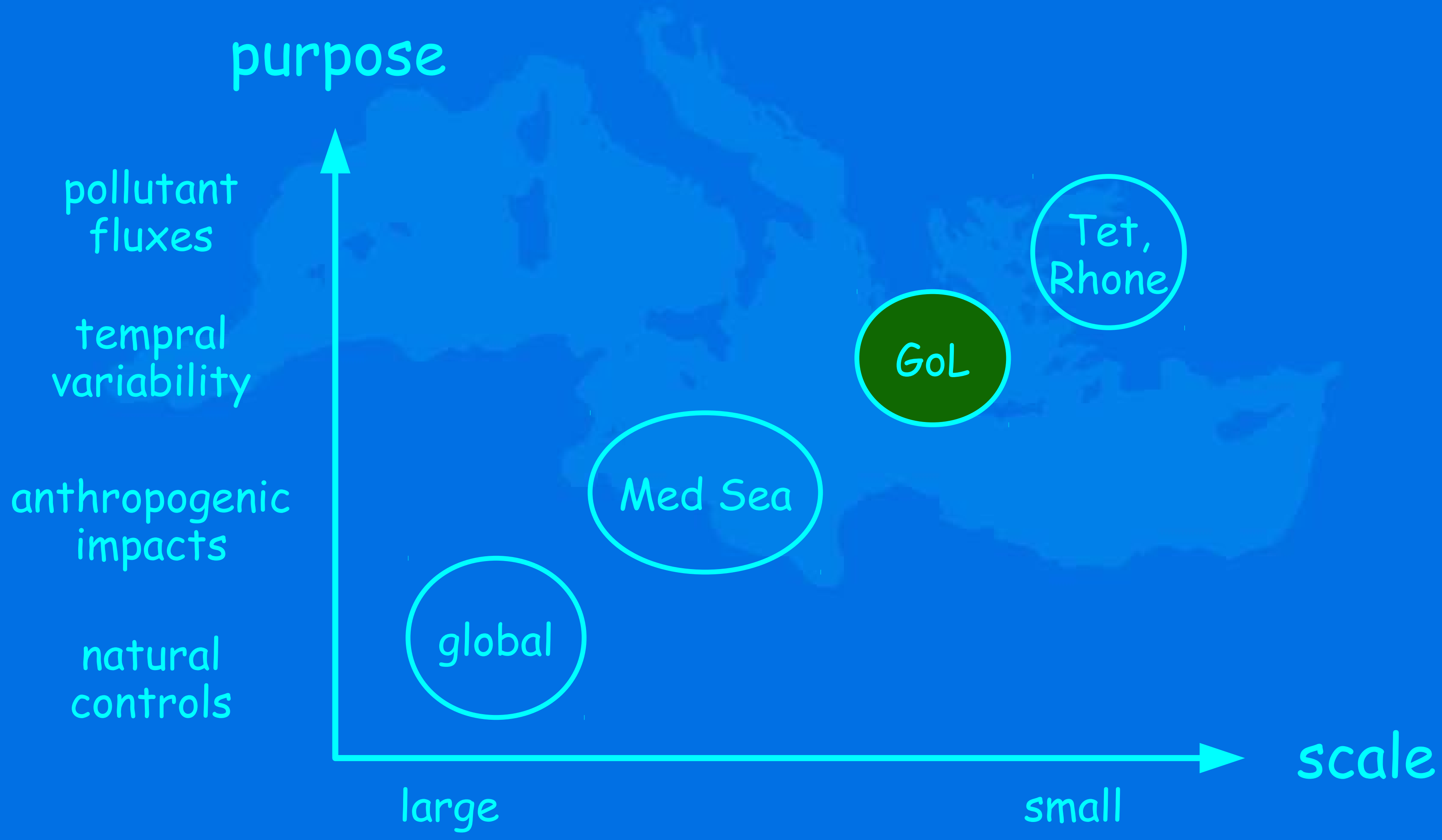
coastal rivers : < 5 * 10^3 km ^{2}
38 % of total area*
(*without Nile)

intermediate rivers
38 % of total area*

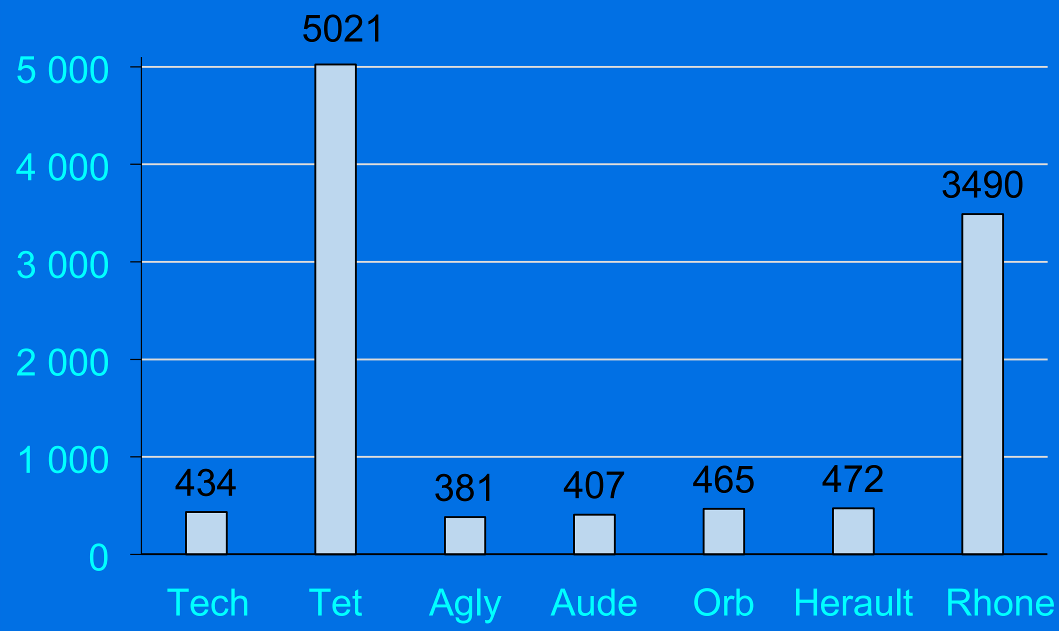
« take home » messages ...

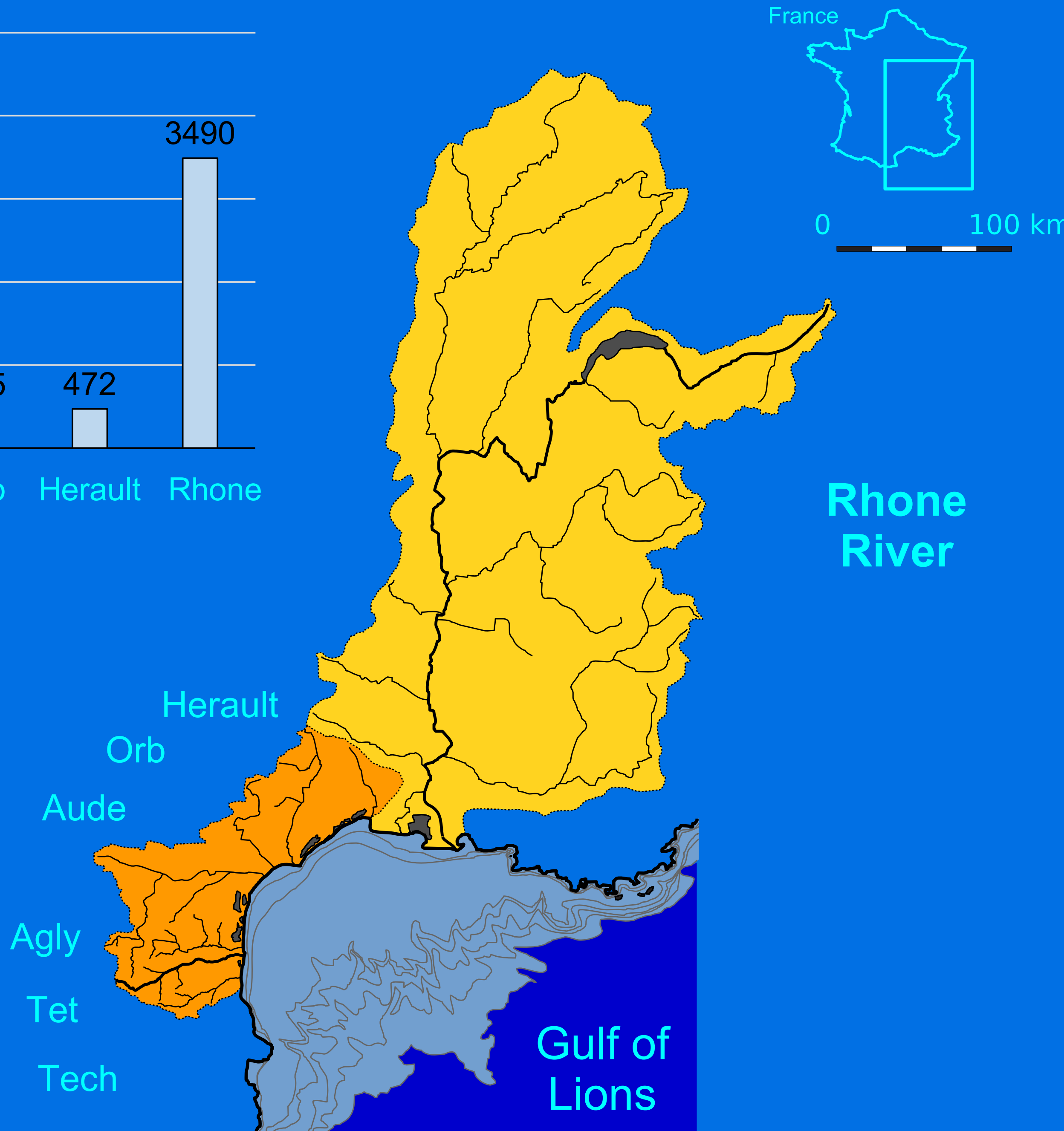
- Mediterranean rivers have in general high natural sediment yields
- But actual river damming considerably reduced the particulate matter fluxes to the Med Sea (probably by $\geq$ 50% ?)
- Small coastal rivers are indeed important in the global budgets

Modelling of riverine sediment fluxes

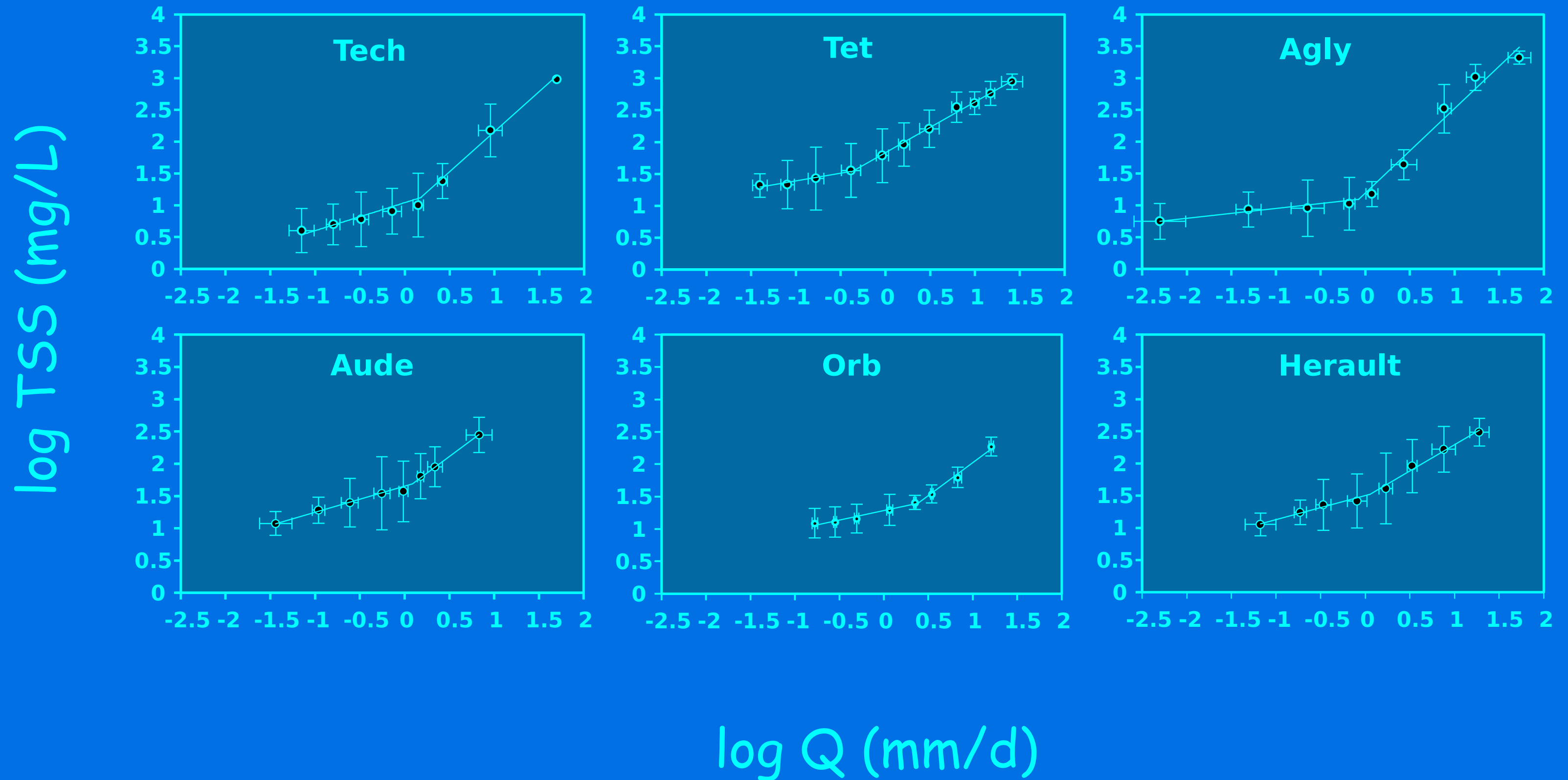


Number of Q - TSS data pairs

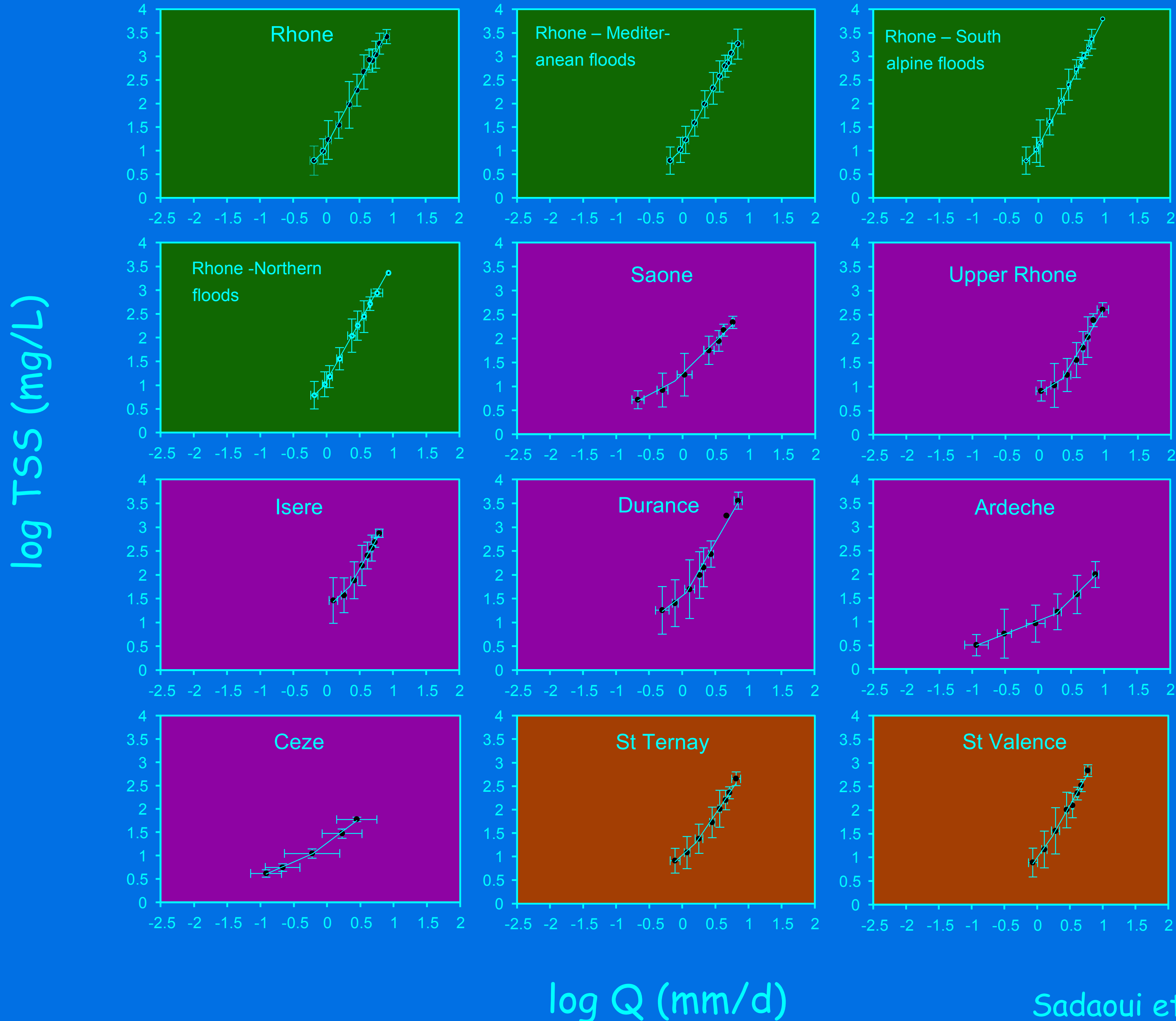




TSS - Q rating curves for FTSS calculations

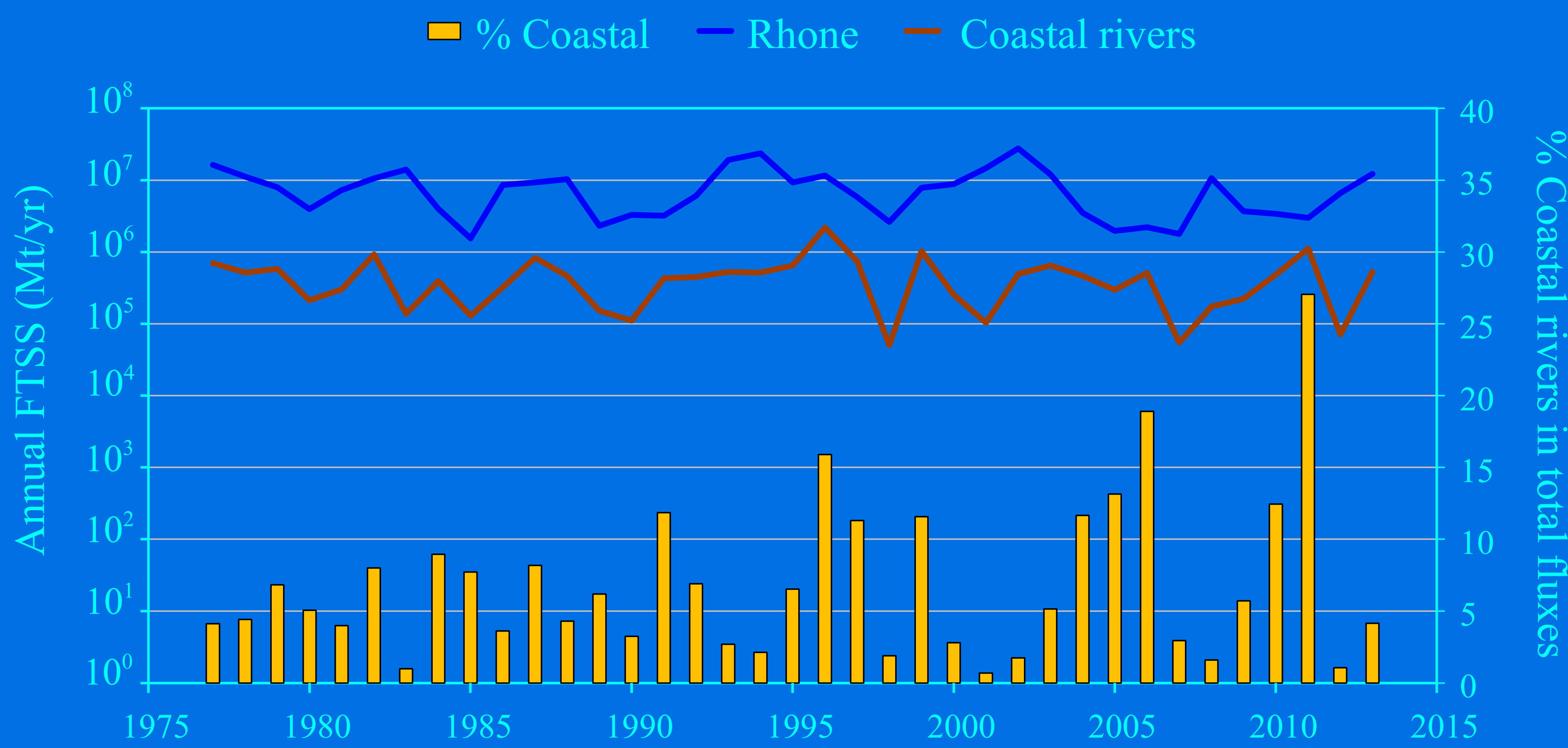


Sadaoui et al., 2016



Sadaoui et al., 2016

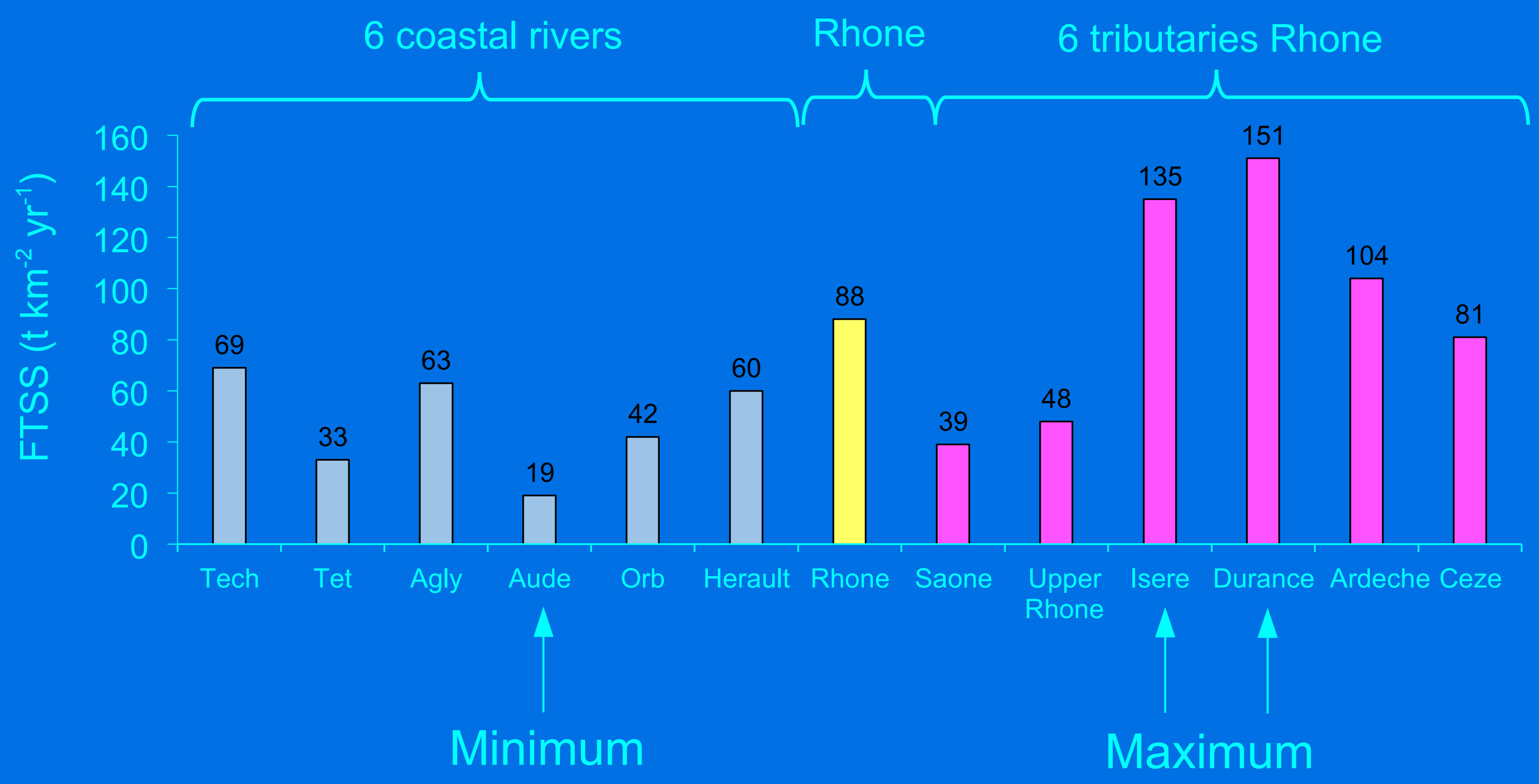
Temporal variability of river sediment fluxes to the Gulf of Lions

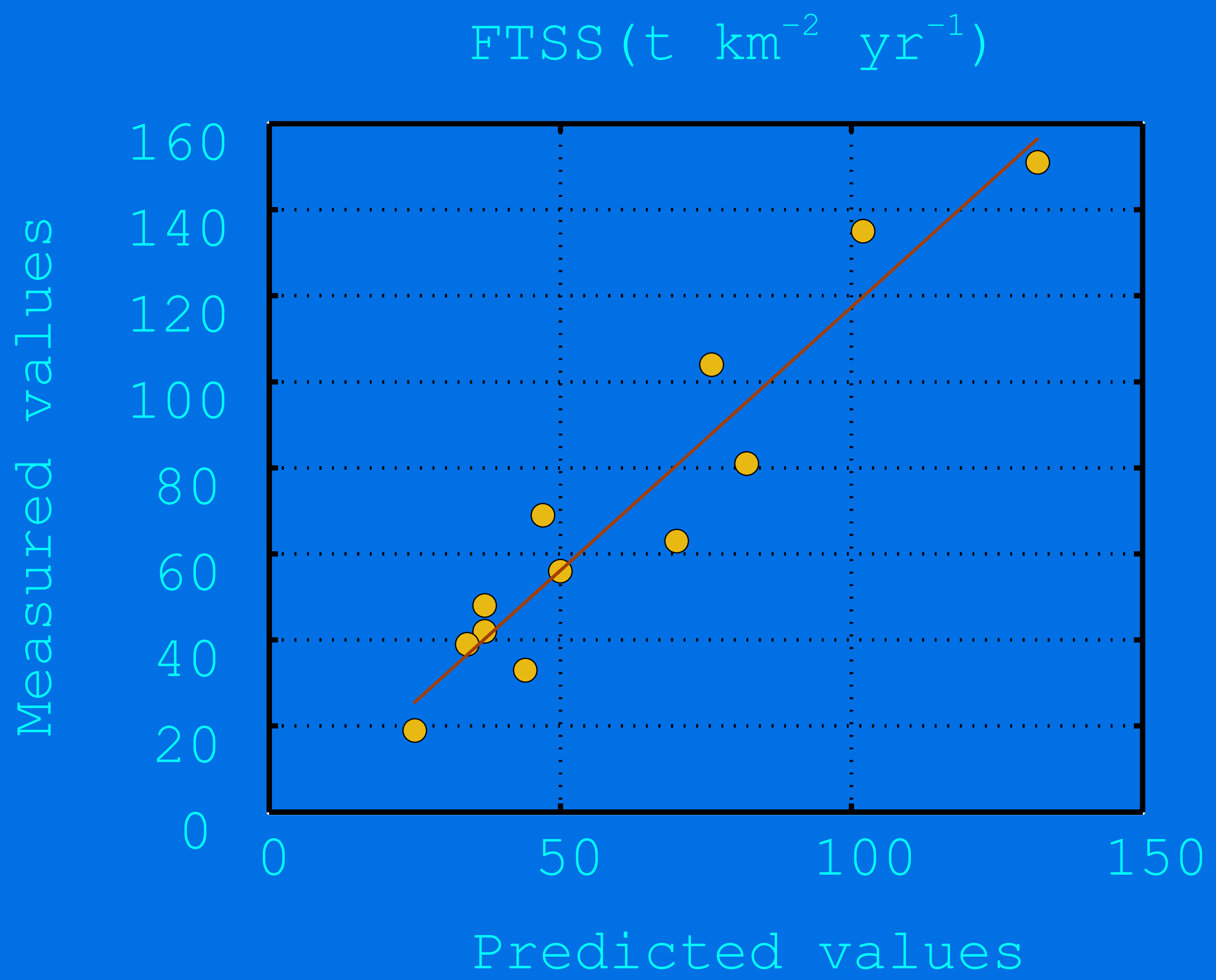


On average, the coastal rivers only contribute with **about 5 %** to the total fluxes. For individual years, however, their contribution can strongly fluctuate (1 % in 1983 and 27 % in 2011).

Sadaoui et al., 2016

Spatial variability of river sediment yields in the Gulf of Lions drainage basin





$r^2 = 0.90$
n = 12
(coastal rivers, Rhone tributaries)

ratio of sedimentary rocks / cristalline rocks > 750m

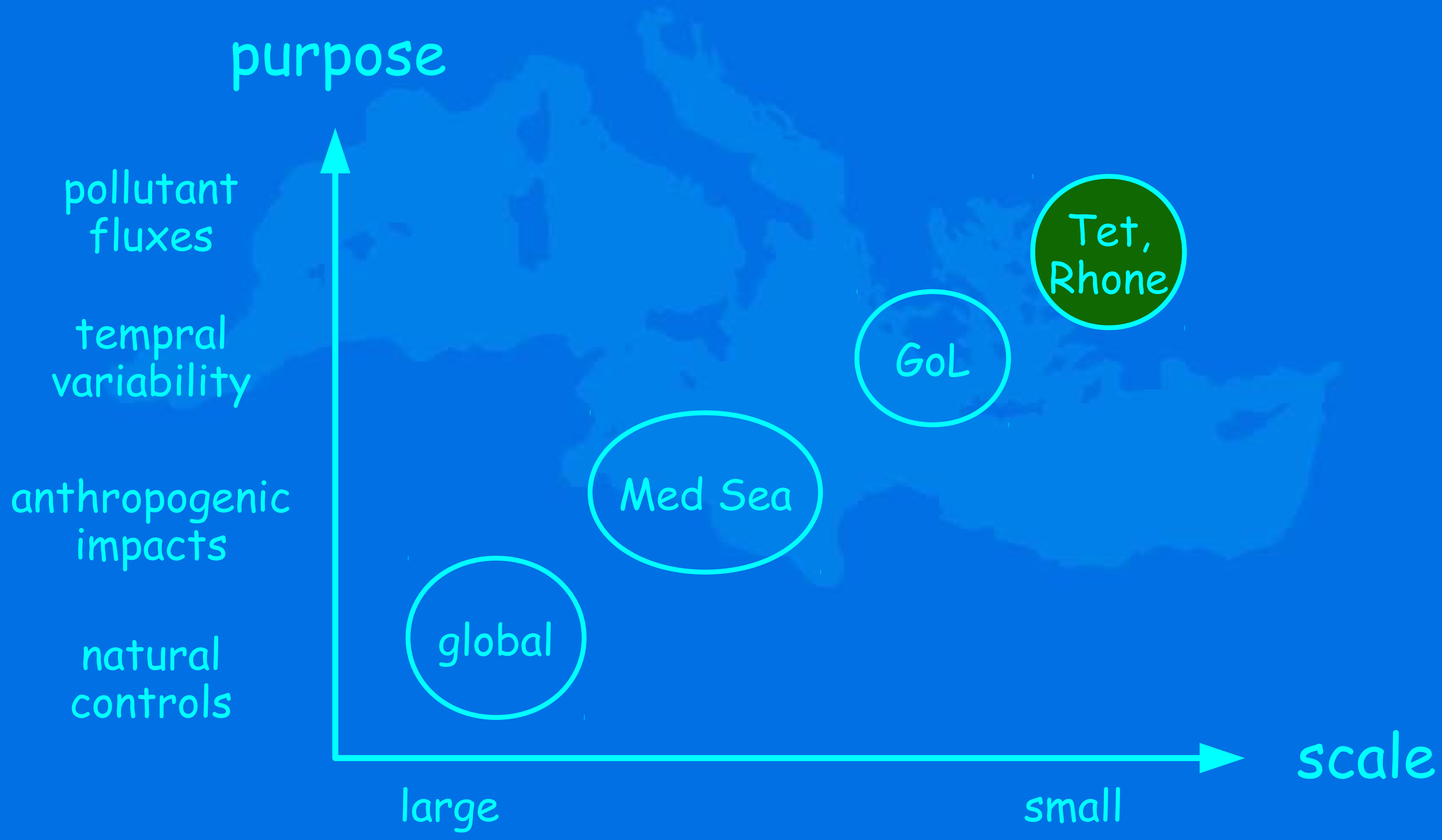
FTSS = 3.97 Tr + 0.04 Elev + 5.13 Rsa - 41.19

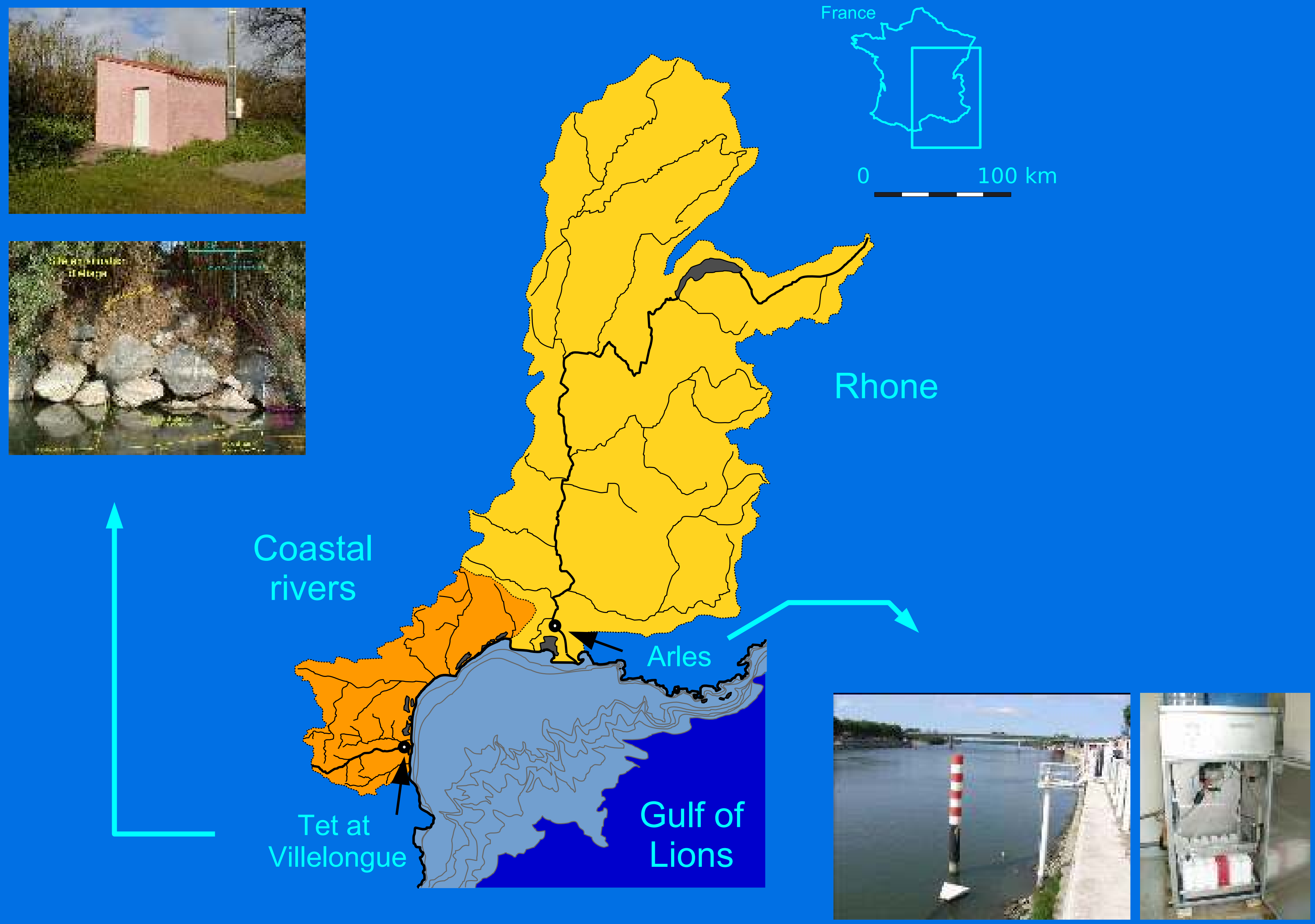
ratio of flood discharge / mean annual discharge

« take home » messages ...

- The Rhone River has (still) high sediment yields, mainly because of badland outcrops in the Durance and Isere tributaries
- Sediment yields in the coastal rivers are moderate. Basin size is not a control for sediment yields

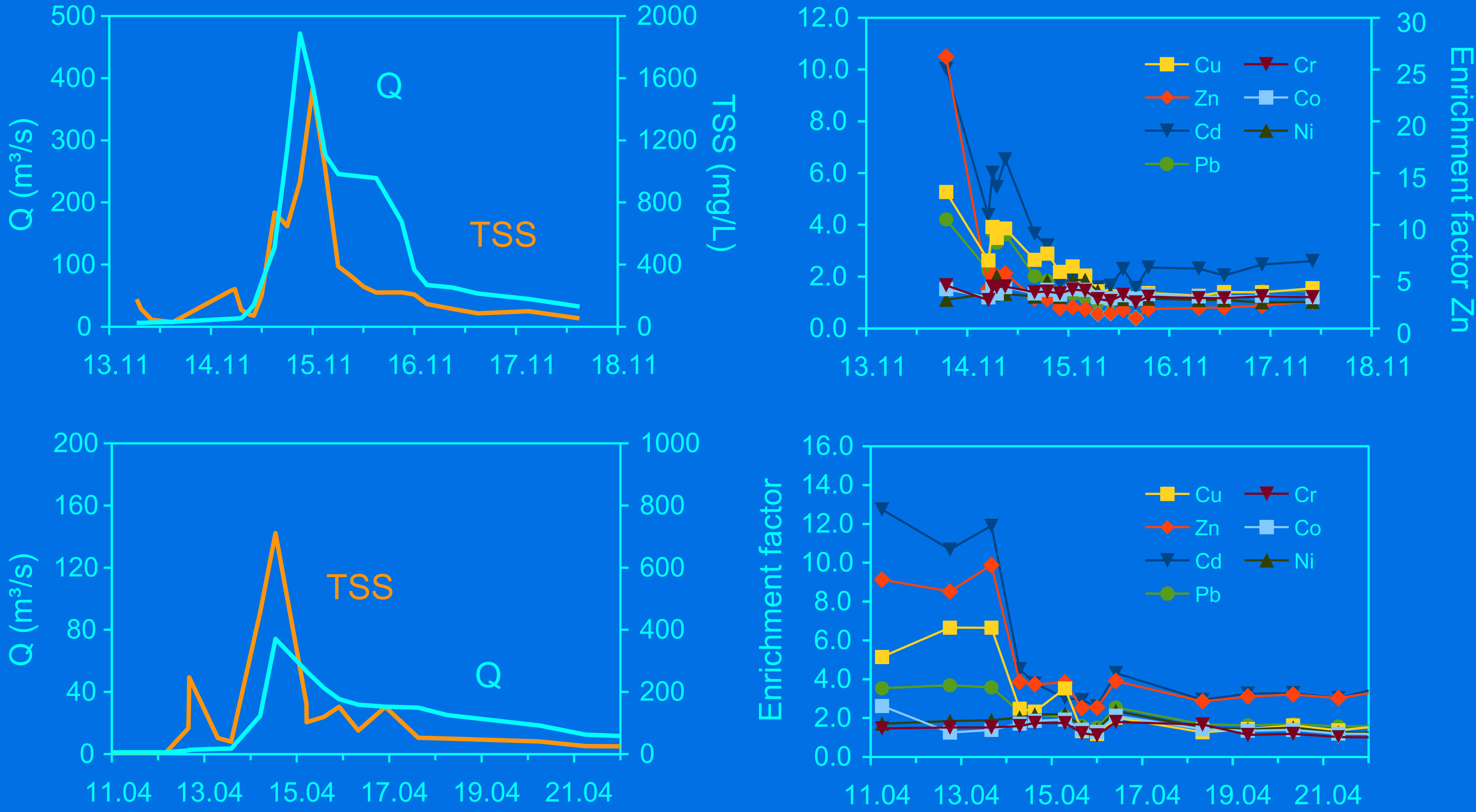
Modelling of riverine sediment fluxes



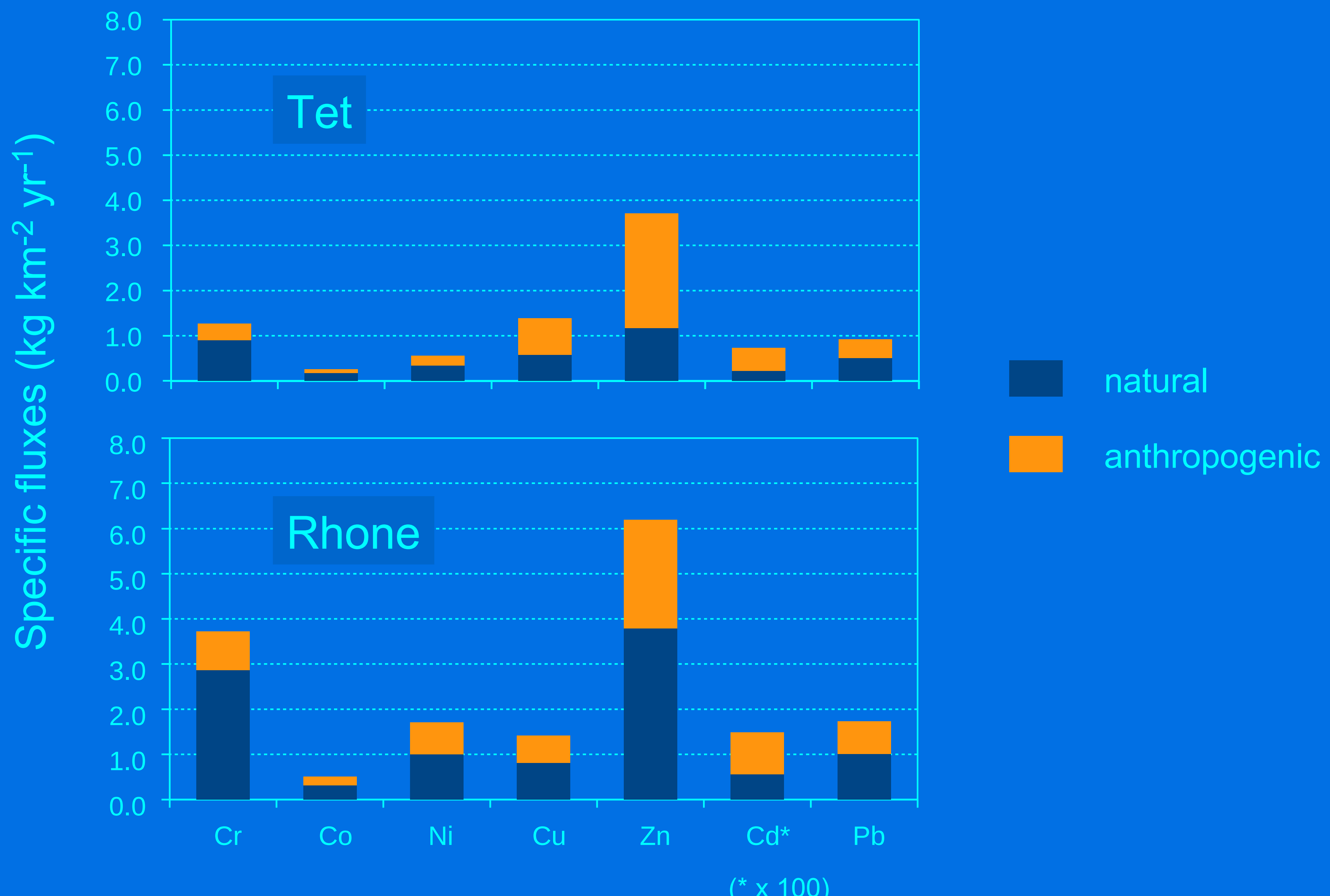

France
0
100 km
Rhone
Coastal
rivers
Arles
Tet at
Villelongue
Gulf of
Lions

Sampling for particulate trace metals (PTM)

PTM - enrichment factors during flooding in the Tet River



Dumas et al., 2015



Dumas et al., 2015

« take home » messages, all scales ...

- Empirical models are only as good as the input data they use and do not always catch reality
- They are nevertheless useful in the testing of large scale hypothesis
- Crossing of different scale models confirm the dominant control of hydroclimatic, morphological and lithological factors
- Consideration of sediment rocks in elevated areas and the formation of badlands are probably a key for model improvements

Cited references

Ludwig, W., and Probst, J.-L. (1998). River sediment discharge to the oceans: Present-day controls and global budgets. American J. Science, 296, p. 265-295.

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