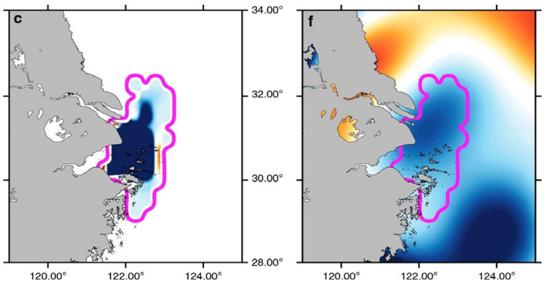
CSQ-35 Summary

Question	Knowledge Advancement Objectives	Geophysical Observables	Measurement Requirements	Tools & Models	Policies / Benefits
Can we quantify erosional processes of drainage basins and the resulting sediments discharge to the oceans	A) Quantify the long-term present-day sediment discharge to the oceans, and locate modern sedimentation zones, at the mouth of major rivers. An objective could be to resolve accumulations of ~0.5 cm year $^{-1}$ of sediment at 200-km spatial resolution, close to the highest river discharges (Amazon, Ganges-Brahmaputra, Yangtze, ...).	● Gravity to constrain mass changes ● River discharge and surface water levels (as from SWOT), to correct for hydrological leakage effects in coastal areas.	● Accumulation of 0.5 cm/year of sediment replacing water over a 200-km radius region: ~1 Gt/year net mass increase. Highest river sediment discharges: ~1 Gt/year, as in the case of the Amazon and the Yellow River delta (see Table in the Narrative). For comparison, threshold MAGIC: 1 cm EWH/year @ 200km, long-term. ● Coverage of the land-sea transition ● Multi-satellite missions with orbit inclination choice can help to improve the gravity recovery	A proper correction of hydrological leakage effects in coastal areas is needed. Knowledge on the location of the sedimentation zones. Use Lagrangian circulation models (such as Parcels https://doi.org/10.5194/gmd-10-4175-2017) to evaluate the deposition areas Decipher the elastic and visco-elastic response of the crust and mantle to the accumulated sediment load from the sediment Newtonian effect alone.	Global quantification of erosion Identify areas suffering from severe erosion rates Promote sustainable land management by quantifying erosion processes Relates to UN SDG 15 https://sdgs.un.org/goals/goal15
	B) Resolve large variations in sediment discharge following	. Gravity to constrain mass changes		Compile available information on the	

	typhoons and El Nino events. So far only accumulated sediment over long time periods could be considered, in order to build up enough mass to be detected by GRACE. With a higher sensitivity, the detection of temporal variations in sediment discharge might be considered.	• River discharge and surface water levels (as from SWOT), to correct for hydrological leakage effects in coastal areas.		time variability of the sediment discharge to better evaluate its signature in the gravity time series. Model the dynamics of sediment transport in rivers, to relate water discharge to sediment discharge.	
	C) Quantify sediments loss in mountaneous areas	• Gravity to constrain mass changes • Data on ice thickness variations		Requires accurate hydrological corrections. Need for data on ice thickness variations (to account for ice mass variations and induced solid Earth deformations, on gravity data) Ability to improve the spatial resolution of the results in post-processing (for instance using mascons modelling of the gravity field)	

CSQ-35 Narrative

Contemporary erosion of drainage basins is controlled by natural processes (frost and precipitations related to climate versus topography changes related to tectonics) and also by human activities (agriculture, deforestation, sand extraction). Monitoring and modelling the on-going erosional processes is needed in order to constrain landscapes dynamics including coastal subsidence, how it responds to natural and human forcings, and to quantify the sediments discharge from sources to sinks (oceans). The latter is still not accurate enough, because in-situ measurements of sediment transport at rivers mouths are difficult and expensive. Redistribution of mass at the Earth's surface associated with erosional and depositional processes could provide a new proxy to quantify erosional fluxes : eroded mass loss in mountainous areas, accumulation in deltas after the transport by river networks, and discharge into the oceans, bringing organic matter and nutrients. For the first time, observations of gravity and mass changes associated with sedimentation offshore the Amazon, the Changyiang, the Indus and the Magdalena rivers have been obtained from the GRACE mission (Mouyen et al., 2018), complementing in-situ data over a broader range of spatial and temporal scales. These results suggest that future satellite missions could provide new insights on the processes of sediment transport.



Left : modelled annual sedimentation at the mouth of the Yangtse river ; right : equivalent sedimentation observed by GRACE (Mouyen et al., 2018). Dark blue : 3mm/yr.

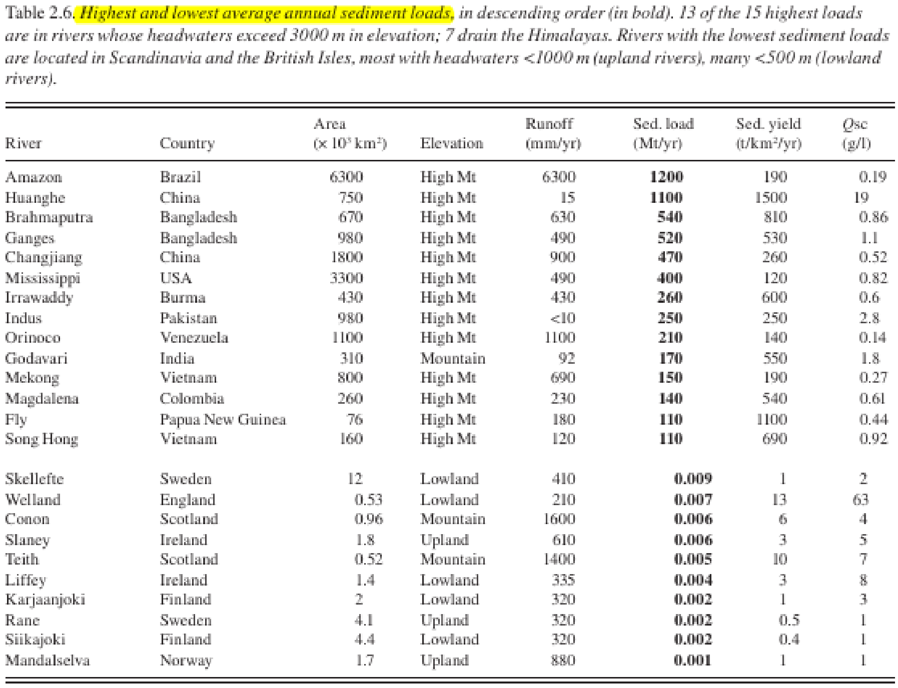


Table 2.6. *Highest and lowest average annual sediment loads, in descending order (in bold). 13 of the 15 highest loads are in rivers whose headwaters exceed 3000 m in elevation; 7 drain the Himalayas. Rivers with the lowest sediment loads are located in Scandinavia and the British Isles, most with headwaters <1000 m (upland rivers), many <500 m (lowland rivers).*

River	Country	Area (× 10³ km²)	Elevation	Runoff (mm/yr)	Sed. load (Mt/yr)	Sed. yield (t/km²/yr)	*Qsc* (g/l)
Amazon	Brazil	6300	High Mt	6300	**1200**	190	0.19
Huanghe	China	750	High Mt	15	**1100**	1500	19
Brahmaputra	Bangladesh	670	High Mt	630	**540**	810	0.86
Ganges	Bangladesh	980	High Mt	490	**520**	530	1.1
Changjiang	China	1800	High Mt	900	**470**	260	0.52
Mississippi	USA	3300	High Mt	490	**400**	120	0.82
Irrawaddy	Burma	430	High Mt	430	**260**	600	0.6
Indus	Pakistan	980	High Mt	<10	**250**	250	2.8
Orinoco	Venezuela	1100	High Mt	1100	**210**	140	0.14
Godavari	India	310	Mountain	92	**170**	550	1.8
Mekong	Vietnam	800	High Mt	690	**150**	190	0.27
Magdalena	Colombia	260	High Mt	230	**140**	540	0.61
Fly	Papua New Guinea	76	High Mt	180	**110**	1100	0.44
Song Hong	Vietnam	160	High Mt	120	**110**	690	0.92
Skellefte	Sweden	12	Lowland	410	**0.009**	1	2
Welland	England	0.53	Lowland	210	**0.007**	13	63
Conon	Scotland	0.96	Mountain	1600	**0.006**	6	4
Slaney	Ireland	1.8	Upland	610	**0.006**	3	5
Teith	Scotland	0.52	Mountain	1400	**0.005**	10	7
Liffey	Ireland	1.4	Lowland	335	**0.004**	3	8
Karjaanjoki	Finland	2	Lowland	320	**0.002**	1	3
Rane	Sweden	4.1	Upland	320	**0.002**	0.5	1
Siikajoki	Finland	4.4	Lowland	320	**0.002**	0.4	1
Mandalselva	Norway	1.7	Upland	880	**0.001**	1	1

Table from: River discharge to the coastal ocean, a global synthesis, by J.D. Milliman and K. L. Farnsworth, Cambridge University Press, ISBN 9780511781247, 2011.

References

Mouyen, M., Longuevergne, L., Steer, P., Crave, A., Lemoine, J-M., Save, H., Robin, C. (2018). Assessing modern river sediment discharge to the ocean using satellite gravimetry, *Nature Communications*, 9, 3384.