



REPORTS OF MEETINGS

Sea-Level Rise Research in Europe: *State of the art and future research needs*

INTEGRATED CONCLUSIONS OF THE WORKSHOP

In what follows, a summary of the main identified scientific advances and still open research questions regarding sea-level rise research in Europe is presented. It corresponds to the workshop on this topic (describing the state of the art and future research needs) that was held in Mataró (Barcelona) on 9–12 April 1997. It is structured in a number of headings built with contributions from the invited speakers and rapporteurs who attended the workshop. In the present format the conclusions are, naturally, biased by the authors' knowledge and background.

CONTRIBUTORS

Although most of the ideas contained in this summary have been presented and discussed at the workshop—and thus reflect the workshop opinion and mood—only the list of researchers who have explicitly contributed in written format to these conclusions is here included. The list is as follows (in alphabetical order):

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CONCLUSIONS

Observations

- Need to have an “adequate” (transdisciplinary and with enough time/space coverage) data set to characterise the “reference state”. This is a “must” to assess impacts (*e.g.* a minimum of 4 years—in the sense of a running average—of shore-line positions is required to have present “yearly” rates of shore-line advance/retreat not “polluted” by seasonal variations in the Spanish Mediterranean coast). In any case, a better understanding of the nature and rate of coastal physical change requires empirical evidence/studies on a time scale greater than a few years since trends in the natural systems take longer to become apparent.
- Need to have data geographically representative of the “environment” studied (*e.g.* present glacier observations correspond mostly to small—less than 100 km² in area—easily accessible glaciers, tide gauge measurements are concentrated mainly along the mezo/macro-tidal coasts of developed countries, *etc.*). This raises the question of the “representativeness” of available measurements.
- Need to have an observational characterisation of high-en-

ergy episodic events (*e.g.* storms, floods, tsunamis..), which are so influential in coastal dynamics (*e.g.* one of the main “drivers” for deltaic evolution and survival in terms of coastal shape and sedimentary budget). These events are hard to observe and have normally been “reduced” in magnitude by human interference with potentially large, but uncertain implications for the coastal zone.

- Need to cope with inconsistencies in observational records (differences in local observations, in analysed products, *etc.*). These inconsistencies may distort the resulting analyses of extremes, which because of the scarcity of data is “heavily” dependent on all available “bits” of information.
- Need to obtain more accurate observational evidence (*e.g.* when estimating sedimentary budgets in the face of a rise in sea level). This applies particularly to the combination of recent, instrumental records—which have a high level of accuracy—with geological records (paleo-information of extraordinary importance to reconstruct the past behaviour of *e.g.* a coastal system), but also to the inclusion of error bounds when *e.g.* assessing sediment budgets (the error bounds may be twice or more the calculated budget).
- Need to obtain observational evidence in a cost-effective manner (*e.g.* optimising GPS and gravity observation strategies to determine “height” changes or using airborne laser altimetry to “bridge” the gap between open sea observations—covered by satellite altimetry—and coast-line tide gauges). This will allow the establishment of long-term observational networks (of *e.g.* tide gauges with regular benchmarking and cm. accuracy).

Underlying Process

- There is a need to improve our present understanding of processes in complex coastal “natural” zones (coastal drivings and responses, the human impact which may obscure records of “natural” processes, *etc.*), particularly with reference to the multiplicity of scales present (in time and space) and the integration of processes (hydromorphodynamic plus ecology plus socio-economy).
- There is a need to consider the coast as a “punctuated” equilibrium system which is most of the time in a dynamic equilibrium but which experiences sudden changes from time to time. This changes (*e.g.* switch of river mouths, wetland erosion/formation) when not properly considered may distort the interpretation of data series.
- The impulsive-type (step-like variations) coastal dynamics occur associated with the exceedance of certain thresholds

(*e.g.* in mean sea level, in wave direction or energy, in sediment availability) which are poorly known but essential for the understanding of long-term coastal evolution.

- The significance of paleo-forcings and responses in determining the present status of the coastal system remains largely unknown (both for drivings—paleotsunamis, paleo storms, paleo surges, *etc.*—and responses—sediment transport, budget, *etc.*—) and requires improved knowledge to provide a better set of initial and boundary conditions for present-day predictions.
- The use of present analogues to interpret the geological record (rather than using black-box type models or curve-fitting approaches) and the analyses of different types of coastal environments to derive generic knowledge of the underlying processes appear to be the most promising approaches (to quantify the links between drivings and responses, at different scales, for different coastal types, *etc.*). This can be illustrated by the study of presently subsiding barrier/spit beaches whose behaviour may improve our knowledge on profile response to SLR with respect to the commonly applied Bruun rule.
- The coupling between different coastal cells or domains may provide knowledge to advance the present state-of-art (the coupling between shelf and nearshore—*i.e.* the inner shelf and, in particular the shoreface—is of importance as a source or sink of sediment by cross-shore transport and for long-term nearshore and shelf dynamics).
- The contributions to sea-level rise from land ice and sea ice masses, and thermal expansion are still poorly known (thermal expansion and ice masses cannot easily explain the observed rise in sea-level during the last century, and the rise/fall contribution of Greenland/Antarctica—associated to an increase in temperature—are still not well quantified, *etc.*).
- The role and contribution of the hydrological cycle to sea-level rise are still poorly known (*e.g.* the contribution and implications of river discharges, dam construction, groundwater mining the role of permafrost, *etc.*).
- The assessment of vertical crustal movements and “true” sea-level variations at local/regional scales still needs a better understanding, based upon improved observational evidence.
- The coastal system appears to be more vulnerable to speed in climatic change/sea level-rise than on “change” by itself (the morphological and ecological systems, left alone, would naturally adapt to SLR).

Modelling

- There is a need to significantly improve the modelling related to climatic and sea level change, with special emphasis on: process development and variations with climatic conditions, model validation and coupling between scales and processes (this can be illustrated by the significant differences between decadal scale models for *e.g.* sea level, coastal evolution, *etc.*).
- The validity of present models—derived from knowledge corresponding to a period in which mean sea level was nearly steady—to carry out projections into a future char-

acterised by an accelerating sea-level rise must be carefully considered. Some of our present models are probably valid for the next century, since the expected acceleration of sea-level rise is not outside their range. However, the projections for more than one century or the extrapolations of models very sensitive to sea-level is more doubtful.

- The coastal “driving terms” are known qualitatively but their interactions and frequency/magnitude relations remain largely unknown in quantitative terms (this can be illustrated by *e.g.* the changes in frequency/magnitude of coastal storms due to a climatic change and the effect this would have on coastal dynamics).
- There is a need to develop coastal response models which work at time scales from 10–100 years and space scales from a few kms to 100 kms. These models should deal with “the coast” in an integrated sense, *i.e.* combining in an interactive manner physics, morphodynamics, ecology and social and economic aspects.
- There is a need to improve and get more knowledge on the up-scaling and down-scaling of processes and results (illustrated *e.g.* by the low accuracy of regional-scale data derived from GCMs). Specific modelling blocks also need further research and improvement, particularly when linking more than one time-scale (*e.g.* the inner-shelf sedimentary transport in along- and across-shelf directions, or the modelling of sea water density—and the associated variations in mixing and transport processes—as a non-linear function of temperature and salinity).

Vulnerability/Resilience

- There is a need to define better the related concepts of susceptibility and resilience and their “integration” (denoted as vulnerability) together with their practical implementation for coastal zone management/impact assessment in the context of climatic change.
- There is a need to establish thresholds which define the status of the coastal system. The impacts of a possible climatic change on the coast are believed to depend more on thresholds and “critical paths” than on a change in climate (*e.g.* the coast is more sensitive to the rate of sea-level rise than on sea-level rise by itself).
- There is a need to assess vulnerability/resilience considering long-term trends (such as a “slow” although accelerated rise in sea-level) together with episodic events (*e.g.* changes in extreme storms or surges, which may be more “crucial” for the coastal system than SLR itself).
- There is a need to relate vulnerability/resilience to the main “causative” factors (*e.g.* for deltaic systems the main factor defining resilience—“survival” in front of an accelerated SLR—is sedimentary and biomass input) and combining coastal responses which may vary depending on the time-scale (*e.g.* salt marshes which show a short-term erosional behaviour imbedded within a long-term accretionary record).

Management

- Although many times stated, it is worth while repeating that integrated coastal zone management (ICZM) requires

the combined efforts of physical, biological and social scientists plus the corresponding "decision takers" and policy "makers". This group of "experts", when considering climatic change and the associated variations in sea level, should be enlarged with the appropriate representations from climatology, meteorology and observational techniques.

- ICZM in the face of climatic change requires an "adequate" data base of field observations (adequate accuracy, spatial coverage, time span of decadal order and integrating the various coastal subsystems). This, which is also applicable for ICZM without climate change, could be achieved by selecting a number of coastal zones (COASTAL OBSERVATORIES) from which local and generic knowledge on the coastal system and its processes/responses could be derived.
- The selected Coastal Observatories should possess an adequate wealth of field observations (to start "de-novo" would be extremely time and money consuming) and belong to a coastal zone vulnerable to sea-level change and in which competing demands and "cohesive" decision making appear "possible". These observatories would contribute to the development of an "enhanced" knowledge for a number of "coastal typologies", of immediate use for the CZ in Europe and elsewhere.
- The management practices appear at present to condition coastal system behaviour and evolution more than climatic change by itself. In any case, there is a need to better understand the full range of possible responses to sea-level and climate changes.
- One of the most effective ways to cope with the effects of climatic/sea-level-rise changes would be the enhancement

of "natural" resilience mechanisms present in the coastal system (*e.g.* to allow more flooding and riverine sand discharges would greatly enhance the natural survival of Mediterranean deltaic systems).

- Coastal system management in the coming years will have to cope with a continual and increasing reduction in sediment availability and an increased difficulty in the evacuation of continental waters. These two factors associated with the predicted change in climate and sea level, may pose serious threats for the survival and health of coastal communities.
- Even though SLR, and climatic change in general, is perceived as a threat to the coastal zone, it is seldom considered in CZM. One reason is the fact that few national entities are applying ICZM (due to cultural, financial, legislature and scientific reasons). Another reason may be the limitations of present scientific knowledge—still large uncertainties, lack of spatial and temporal resolution and lack of integration. The general use of inland-based management approaches for CZM does not help either.

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