Facing the dangers of climate change: A sea level rise scenario and case study in France

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Introduction

As a risk issue, climate change confronts us with many challenges. These challenges lie in *scientific uncertainty* (regarding the climatic variations over time, anthropogenic impact, likelihood, magnitude and consequences of climate change) *public policy* (in case human and natural systems are threatened), and include *societal factors* (adaptation and/or reduction of activities associated with greenhouse gas production, change in behavior and lifestyle). Potential crises are associated with these interdependent dimensions of climate change.

This complex situation is somewhat captured in the 1992 UN Framework convention on climate change (UNFCCC), whose objective as presented in article 2 is to achieve: "…stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner".

The occurrence of the heat wave during the summer of 2003 and the related health impact (an excess mortality of some 15 000 persons in less than two weeks in France was observed) shows us that the dangers of climate change are "here and now" and as well how little we are prepared (Poumadère et al., submitted).

In a way, to avoid a disaster requires us to be convinced that it may happen (Dupuy, 2004). To go beyond this paradox, specific methodologies have to be developed.

The EC-sponsored study Atlantis takes place in that general context of management of climate threats, and addresses three main questions:

- Is it possible to develop a decision-making methodology adapted to dealing with such major uncertainties?
- Can it be applied to build several case studies in Europe?
- What new information and learning are produced through the process?

The Atlantis study considers an extreme climate scenario through stakeholder participatory methods applied in three case studies (The Netherlands, the Thames estuary in the UK, the Rhone delta in France). We built scenarios of what would happen under given climatic conditions in a specific geographical context, in terms of physical and socio-economic impacts, and above all, in terms of management adaptation. These local scenarios and possible futures are developed with the contributions of concerned experts and stakeholders, using individual interviews but

also a group work setting, the policy workshop. These methodological developments and the results obtained in France are presented here[1].

The collapse of the West Antarctic Ice Sheet

The extreme climate scenario used in the Atlantis project involves the possible collapse of the West Antarctic Ice Sheet (WAIS). The consequences studied are those of rapid sea level rise in the three geographical areas cited above. Other extreme climate scenarios resulting over time in an increase of sea level may be conceived as well. Gregory et al. (2004), for instance, have considered loss of the Greenland ice sheet followed by melting of the ice. However, the best-known scenario involving low probability - high impact events is probably the collapse of thermohaline circulation (THC), which could produce fast cooling of Northern and Western Europe (Schiller et al., 1997; Link and Tol, 2004). A recent Hollywood movie brought this perspective to the public's attention.

More than 25 years ago, Mercer (1978) presented the possibility of a collapse of the WAIS due to global warming accelerated by human production of CO2. If the WAIS collapses and slides into the ocean, it has been recently assessed that its volume would lead to a 5 to 6m sea level rise (Vaughan & Spouse, 2002; Oppenheimer & Alley, 2004). The hypothetical impact over France is shown in Figure 1. The WAIS is only a small part of the Antarctic continent whose total volume of ice is some 30 million km3, representing 90% of the world's ice. Total melting of this ice would result in a sea level rise (SLR) of some 70m (Lorius, 1991).

--- figure 1 here----

For the purpose of the Atlantis study, a supplementary sea level rise[2] of 5m is reached in a period of 100 years, in a linear fashion, and starting after the collapse of the WAIS shortly after 2030. Although this specific configuration of rate and duration is considered by some to be highly unlikely (Oppenheimer, 2004), research shows that comparable events have happened in the past and that present climate change can alter the WAIS (cf. Bohn et al., 2004). The scenario has the distinct advantage of presenting the issue in a way relatively easy to grasp by a wide array of interlocutors, whom we were to meet during the policy workshop and its preparation.

The potential impact of such a steep sea level rise would be significant, as the density of the population living in coastal zones is three times the global mean density (Small and Nicholls, 2003). The populations of large deltas, most in Asia, would be

[1] Along with the authors of this paper, the following researchers participated in this interdisciplinary study sponsored by the Commission of the European Communities DG Research (EVK2-CT-2002-00138): Richard S.J. Tol (University of Hamburg, coordinator), Maria Bohn, Thomas E. Downing, Marie-Laure Guillerminet, Eva Hisznyik, Roger Kasperson, Kate Lonsdale, Robert J. Nicholls, Alexander A. Olsthoorn, Ferenc L. Toth, Nassos Vafeidis, Peter E. van der Werff and I. Hakan Yetkiner. The final report of the French case study will be terminated in January 2005 and can be obtained from the first author. As well, the Atlantis team will report the entire study in a special issue of the journal *Climatic Change* (expected in late 2005 or early 2006). A summary paper has been prepared (Tol et al., submitted) and can be obtained from M. Poumadère.

[2] We state "supplementary" sea level rise because, even in the absence of the extreme Antarctic events hypothesized here, the sea if continuing its current trend is expected to rise about one meter in the next century.

particularly threatened. Policy issues of protection against higher tides or adaptation are thus posed (Paskoff, 2001).

Background: Policy workshops

Along with uncertainties regarding the physical nature of the potential WAIS collapse and its implications, several levels of uncertainty are to be dealt with in regard to social and economic impact. Such important variables as social perception of risks and stakeholder decision-making regarding a low probability event with future high consequences are obviously difficult to model.

Several participatory techniques can be used to study such decision making, e.g.: Focus groups, Simulation techniques and Policy exercise method. Based on in-depth knowledge of the Policy exercise method (Toth, 1988a, b) the Atlantis research team proposed two elaborated designs to structure expert and stakeholder participation, the Classic design and the Backcasting design.

In the Classic design situation, workshop participants get the original scenario outlining the information about socioeconomic development and the regional specifics for the year 2030 together with projections about the magnitude and timing of SLR. In a series of steps, participants develop strategies and put in place the necessary actions for the subsequent decades. The research team evaluates these strategies and provides new information about improved scientific knowledge and other features of the original sea-level-rise scenario. At the end of the time horizon, the research team produces the full scenario including the final state of the world. The Backcasting design in contrast starts with a scenario presenting the impacts of SLR in 2130 if no adaptation was made. Participants then consider what should have been done in 2030 when the first reports about the plausibility of SLR became available and agree on basic policy strategy: total/partial retreat or full protection. The implications of this strategy are projected to the year 2130, “correcting” the state of the world at the end of the process. The backcasting process regresses from this endpoint in 20- or 30-year time steps and involves in-depth clarification of actions and preconditions required to ensure the successful implementation and completion of the strategy.

The Atlantis policy workshops held in the three different geographical contexts adapted procedural elements of these two workshop designs and brought innovations. The French team chose to mount a flexible Policy Exercise based on the Classic (forward moving) design assisted by carefully prepared information packages that were used according to the evolution and branching points in the scenario progression. This arrangement provided an effective and inspiring analytical-discursive procedure in which stakeholders participated with ease.

Scenario development for the French case study

Each Atlantic workshop in the three case study contexts used the same SLR scenario (a sea level rise of 5m is reached in a period of 100 years, in a linear fashion, starting after the collapse of the WAIS soon after the year 2030). However, the three case studies dealt with highly contrasted local situations. For The Netherlands, the whole country and its development would be concerned by a +5m sea level rise. With the Thames estuary, a densely populated area expanding from London seaward is

threatened. The Rhone delta is primarily a wetland in which some control of sea and river water movements have been set up to support human activities that gently co-exist with nature reserves.

The Rhone delta or Camargue in SE France resembles a 750 km island embraced by the two branches of the Rhone and the Mediterranean Sea. It is sparsely populated (60 000 inhabitants) and the main city, Arles, situated at the top of the triangle, contains 83% of the population. The Camargue is well known for its regional natural park protecting the biological diversity of the area. Protected since 1859 by a sea dike and much later embankments, the present shape of the delta, its rice farming and exceptionally rich wildlife reserves depend upon irrigation and draining. The Camargue is a popular nature-oriented tourist destination and important pilgrimage site; 8 000 gypsies fete their patron saint each May in the seas-side village of Saintes-Maries-de-la-Mer, which receives in all several hundred thousand visitors each year.

The French policy workshop therefore was prepared by applying the SLR scenario to the Camargue topography, producing maps of land mass to be lost at different points in the progression inland of the tide line (Nicholls et al., 2003). Figure 2 shows the final submersion of Camargue in one hundred years' time.

---Figure 2 here---

The sea level rise scenario is adapted to the Camargue and aims at helping stakeholders to grasp this unusual situation. It is divided in five parts, each corresponding to a time period chosen by the research team during the project preparation. The first part, SLR 2004, summarizes the present situation concerning, on one hand, the possibility of WAIS collapse and its ensuing potential consequences and, on the other hand, observations relating to the SLR in the Camargue and in Marseille (the largest city on the French Mediterranean coast). The following parts of the SLR scenario correspond to extreme projections of present data, but are plausible. In 2030 (SLR scenario 2030), the extreme scenario of SLR (5 m in 100 years, linear rate) is judged at this point of time to have a probability of 20%. In 2050, the collapse has already occurred and the process it has set into motion is considered engaged and irreversible. A supplementary rise of 1 m is observed and the probability that it continue in a linear manner is revised upward to 80% in the SLR scenario of 2050. A snapshot in 2080 shows that the SLR has indeed continued in linear fashion. The final SLR scenario (2130) describes the impact of a + 5 m SLR over the Camargue, recognizing this is just one small region affected in a global context.

These SLR scenarios were prepared to support the stakeholder policy workshop, which simulated deliberations situated at the corresponding points in time. At the opening of the workshop (present-day 2004), the risk of a WAIS collapse is announced but not quantified. Stakeholders are then asked to imagine they are in 2030. In 2030, the WAIS collapse risk (with its potential consequence of linear SLR totaling 5-6m over one century) is assessed at 20%. They must reflect on management strategy in the face of this uncertain event. In 2050, participants learn the actual collapse did indeed occur and the Rhone Delta has already experienced a 1-meter SLR, with continuation assessed at 80%. After their deliberations and new strategic recommendations, they see the snapshot of the situation in 2080 as the sea has continued to mount. In a final phase of the workshop, they learn the shape of the Camargue and its socioeconomic situation after the sea has indeed risen to +6 meters total in 2130.

Another aspect of our preparation for the workshop therefore was to produce socioeconomic scenarios (SES) following the same time scale (Pfeifle, Mays & Poumadère, 2004). First an inventory of the Camargue (SES 2004) took into account current data related to population, economic background, and perspectives for development. Simple extrapolations were then made to project future situations in 2030, 2050 and 2130. The population growth rate, for instance, was obtained through the synthesis of several indicators (WHO, OECD, French Statistics Institute). The future economic development integrated both the present growth trends and existing planning projects. Through desk research and interviews, detailed socio-economic accounts were developed reflecting the different major management options that could be chosen when adapting to the potential impacts of the SLR, ranging between "abandon" the area to "fully protect from the rise of the sea", with various hybrid options in between. Obviously, different stakeholder choices would open different development pathways, thereby influencing different future options. For instance, the protection option, i.e., the choice to erect dikes to protect existing land and activities, would allow the use of land under sea level but would create additional risks (vulnerability of existing or new installations placed behind dikes if these should be overwhelmed). Alternatively, to allow the mounting sea to ingress unhindered upon the land would imply abandoning areas that currently support residential and economic activities: thus subsequent management decisions would principally concern population retreat inland. Each of these options presents advantages and costs to weigh in taking a decision.

Considering that it is impossible to predict precisely which of these choices and decisions would be taken by real-life stakeholders and experts participating in the workshop, we chose to develop socioeconomic scenarios (SES) to accommodate two extreme possibilities: the protection option and the retreat option. Thus, while the SES 2030 is a reasonable linear projection of the situation actually observed in 2004, the SES 2050 was generated in two different versions: one to be presented to workshop participants if they chose (in 2030) to favor the protection option, and another for use in case of choice of the retreat option. Three SES 2130 versions were generated: full protection (reflecting a choice to protect in both 2030 and again in 2050), partial protection (modest retreat in 2030 and protection in 2050 after experiencing a SLR of +1 m compared to normal expected ingress from today's coastline), full retreat (as of 2030, or only after 2050: the 2080 socioeconomic consequences for the abandoned area are the same in both cases).

These socioeconomic and local impact scenarios were informed by individual interviews with experts (geology, hydrology, geography, sociology), professionals (land use planning, risk analysis, public health, insurance), and local stakeholders (industry, elected bodies and management support, farmers, hunters, clergy). After consenting to set a date for an interview, each person received a summary of the research project, an introduction to the climate change, WAIS collapse and potential SLR issues, and a pre-questionnaire indicating the points to be covered in the interview. During the actual interviews, those points were covered in a semi-directive way that allowed participants to freely express their point of view and bring in new or unanticipated points or information. The interviews in sum allowed the following broad areas to be explored in regard to the idea of rapid SLR: similarity with existing or known situations[3], response options, involved and concerned stakeholders, local

[3] Interviews took place just weeks after the occurrence in Dec. 2003 of major flooding from an overspill of the Rhone river, seriously affecting Arles and other parts of the Camargue. Local

identity and specificities in historical, cultural, economic, technical and political terms. Overall, the interviews made valuable contributions to the development of the SES including insight into the different management options that might be favored and contextual costs and advantages of each one.

The workshop process

A representative subset of 12 interviewees then went on to participate in the policy workshop. The stakeholder participants were asked to call upon their expertise and personal knowledge to elaborate a response strategy in the face of a (hypothetical) uncertain future situation.

On the day of the workshop, held locally, this group was treated as a Camargue Consultative Committee mandated in 2030 and in 2050 by the European Commission to examine SLR risk and provide recommendations in any field of action they felt appropriate. The alternative SES scenarios were held in reserve, to be brought out as appropriate as the participants made strategic and practical decisions to adapt to the different states of WAIS risk knowledge at each time juncture in the workshop. Along with the various scenarios, maps too provided a basis for group discussion and decision. For instance, participants examined with interest maps showing what the Camargue would look like after 30 or one hundred years if the sea rose without protection. To add to the realism of the Committee setting, we also generated newspaper articles dated between 2004 and 2030, and between 2031 and 2050, describing local developments, climate change findings and SLR impacts.

As suggested above in the discussion of the SLR scenarios and SES (socioeconomic scenarios), the day-long workshop unfolded in several stages. Upon arrival, the participants' knowledge was refreshed with a short powerpoint review of the current 2004 inventory of the Camargue and the non quantified scenario of WAIS potential collapse. In the second stage, participants were asked to jump to the year 2030, when they learned through a powerpoint presentation and written documents that rapid SLR after a WAIS collapse was assessed at 20% probability, and reviewed the 2030 SES. They discussed and analyzed these materials and together developed a strategy for the next 20 years, choosing a "wait and see" partial protection option.

Stage 3 followed the same pattern: discussions were supported by the SLR 2050 (WAIS collapsed, +1m SLR, further rapid linear rise seen to be 80% likely) and SES 2050 (in the appropriate version as dictated by the option chosen in 2030). Participants analyzed the effects of the 2030 decisions and "corrected course", setting strategy for the next 30 years. At that time, they favored retreat. In the final part of the day, participants saw a presentation of the 2080 socioeconomic outcomes of their strategic choices. The hypothetical state of the world in 2130 served as a final debriefing and closed the workshop.

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sensitivity to flood risk and management experience certainly exist in Camargue, although the proposed SLR scenario introduces specific differences : the threat comes from the sea rather than from the river, and once engaged the SLR is irreversible.

Social values

Individual and group values are strongly solicited during this type of role-playing and strategic workshop. Values are apparent in both the positions adopted in response to the climate risk decisions, and, in the real-time interactions between persons whose expertise and social roles are different. In order to capture information about the values influencing these levels, an individual social values questionnaire (cf., Bales, 2001) was constructed for the workshop context. It is structured around 3 bipolar dimensions of opposed or polarized values, each relating to a specific issue. The "power and influence" dimension is bounded by the opposed of values on dominance vs. submission. The "interpersonal and social trust" dimension is bounded by the opposed values on sociability vs. individualism. The third dimension "legitimacy of authority and its projects" is bounded by values on accepting established authority vs. innovation and creativity. Combinations of these values can be found and are represented in the questionnaire. The social values questionnaire was administered before and after the workshop so as to test several hypotheses regarding group interaction in such decision-making situations. The questionnaire asked each participant which values should be called upon to work together in facing a hypothetical and uncertain situation, and furthermore which values would be needed for decision makers to face the extreme events evoked by the Atlantis scenario. After the workshop, the same questionnaire form was used to ask which values had actually been shown throughout the day.

Workshop results

The results of the workshop may be presented as a list of the action strategies and recommendations developed by the participants as they responded to the differing SLR risk scenarios and socioeconomic scenarios across the workshop phases. We report them in the terms agreed and written up on a paperboard by the participants (one of the roles of the Atlantis researchers was to ensure that the group choices were respected and represented, rather than substituting just interpretations and choices by the volunteer group reporter or by the researchers themselves). The recommendations are listed in the order in which they emerged from discussion, rather than by their importance according to the group. It is interesting to see which strategies and choices emerged early, and which choices, refinements and elaborations these early choices then led to.

The chosen options reflect the desire of the workshop participants to protect the existing Camargue. This does not reflect a backward culturally conservative attitude but rather is a response to the probability of WAIS collapse and rapid SLR, which at 20% in 2030 is judged relatively low by the workshop group. They judge that the best adaptation is to make some prudent zoning decisions, reasonably reinforce defences where recent flood experience proves they will be needed in any case, and integrate scientific knowledge and management structures to prepare better future decisions. In a consensual manner, the participants consider that a strong "protection" response would be justified only by high economic stakes. As there is no such stake in the area, and because existing economic activities in case of rapid SLR would require disproportionate protective measures, they opt for a sensitive "wait and see" policy that includes prudent preparations for an organized strategic retreat should that become necessary.

During the 2050 phase of the workshop discussion, when indeed SLR has commenced, this retreat option is maintained and reinforced. The 80% probability that the sea continue to rise in a linear fashion, resulting in +5-6 m by 2130, is judged serious or equated to a quasi-certainty, and is used as an *ex post* justification of the strategic choices made in 2030.

2030 (before WAIS collapse) ***The group chooses a "wait and see"/"prepare strategic retreat" option.*** ***Recommendations:***
Land use planning policy to reflect a "hold off, wait and see" attitude; moratorium on development
Create a margin of liberty for the sea: certain zones to be declared uninhabitable ; review and alter building zones
Elected officials and scientific experts to support and become engaged in public information and participatory mechanisms
Cost-benefit analysis to be performed on the "protection" option; study and model possible futures
Build protection against Rhone river flooding, in the Camargue and upstream (integrate the top of the river basis; free up river expansion zone
Create a coordinating decision structure
Perform an interdisciplinary synthesis of studies and review relevant knowledge
Accompany the population in economic, social and psychological terms: create the conditions favorable to possible retreat.

2050 (after WAIS collapse and effective SLR of +1m) ***The group chooses a "retreat" option*** ***Recommendations:***
1. Organise retreat:
◊ Determine retreat zones
◊ Strong laws and decrees of application
◊ Set up accompanying measures (economic)
◊ Create solidarity fund
◊ Organise longterm medical response
◊ Create psychological therapeutic units
2. Restore the hydraulic function of the Rhone Delta:
◊ Protective spill areas for city of Arles
◊ Same for Baux Valley, Bourg Plain
3. Rhone flood reduction programme : continue the action begun in 2030.
4. Set up a unitary management organisation
5. Develop a culture of "territorial evolution" (acceptance of change by the population...).
6. Prepare for crises (public health, political confidence…)
7. Redistribute local economy into appropriate (less vulnerable) sectors.

The option thus retained in 2050 for the coming years is that of an organized strategic retreat (rather than ignoring evolutions that would one day result in the need for an urgent full-scale evacuation). The population is to be relocated in areas to the north

not threatened by the consequences of SLR, while respecting the possibility that certain elderly residents, for example, might prefer to wait it out on their ancestral land.

It is interesting to note that participants did not regard this projected abandonment of areas today invested by residences and economic activities, both traditional and modern, as a threat to Camargue identity. The delta is recognized as a wetland that already is reclaimed from or shared with the natural elements; its land and water dynamics seem at the same time to be more powerful than human actions and constitutive of the Camargue social identity.

The social values questionnaire provides results in line with the consensual group process observed. Results from the questionnaire filled out by participants, without conferring, just before the start of the workshop show quasi-unanimity on the need for values identified as particularly needed for a group analytic-deliberative process: values on active efforts towards common goals, equality and democratic participation in decisions, responsible collaboration, low search for personal power.

Responses to the second leg of the questionnaire (at the close of the workshop) confirm that the anticipated needed values were indeed observed by participants during the day. Interestingly, each participant judged that the group showed the desirable values to a greater extent than the individual respondent felt he or she had exercised them personally! These perceptions may signify recognition that the group's effective achievements go beyond what each individual member could contribute alone. This result is in line with the strong acculturation that occurred during the workshop, during which the researchers observed that each stakeholder learned from the others and from the materials provided by the team to facilitate reflection and deliberation.

Conclusion

The methodological unfolding of the study revealed several interesting points. Interviews brought out persons' variable capacity to project oneself into the uncertain future and consider decision making under hypothetical conditions. The extreme scenario of 5-6m SLR in one hundred years was very often rejected as far-fetched. More salient for interviewees often was the recent severe flooding experienced in 2003, in which the Rhone river, and not the sea, constituted the menace. In contrast, the workshop group when assembled plunged very seriously into the simulation, assimilating the materials provided and rarely stepping out of role to question the credibility of the scenarios or the decision-making context. The workshop setting and the materials stimulated cross-fertilisation among the transdisciplinary group. The group appeared united in the goal of developing the best possible responses to the risk situation, and group recommendations were both well-discussed and consensual.

These elements favor such a methodology for long term issues of sustainability and crisis prevention. The combination of scientific construction of scenario material (including maps and descriptive states of the future), together with a participatory group approach appears productive. Future research should investigate how such methodology can be applied to develop case studies and decision-making in other contexts.

The need today to consider the "worst case" or "extreme scenarios" makes us face a grim and potentially dramatic future, full of "bad news" that many societal actors

might rather ignore or deny. This unpleasant process can generate various levels of resistance in individuals and society. However, such consideration might be a means to better adapt and to avoid some of the worse events of the future.

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Figure 1: Impact over France of a five meter sea level rise

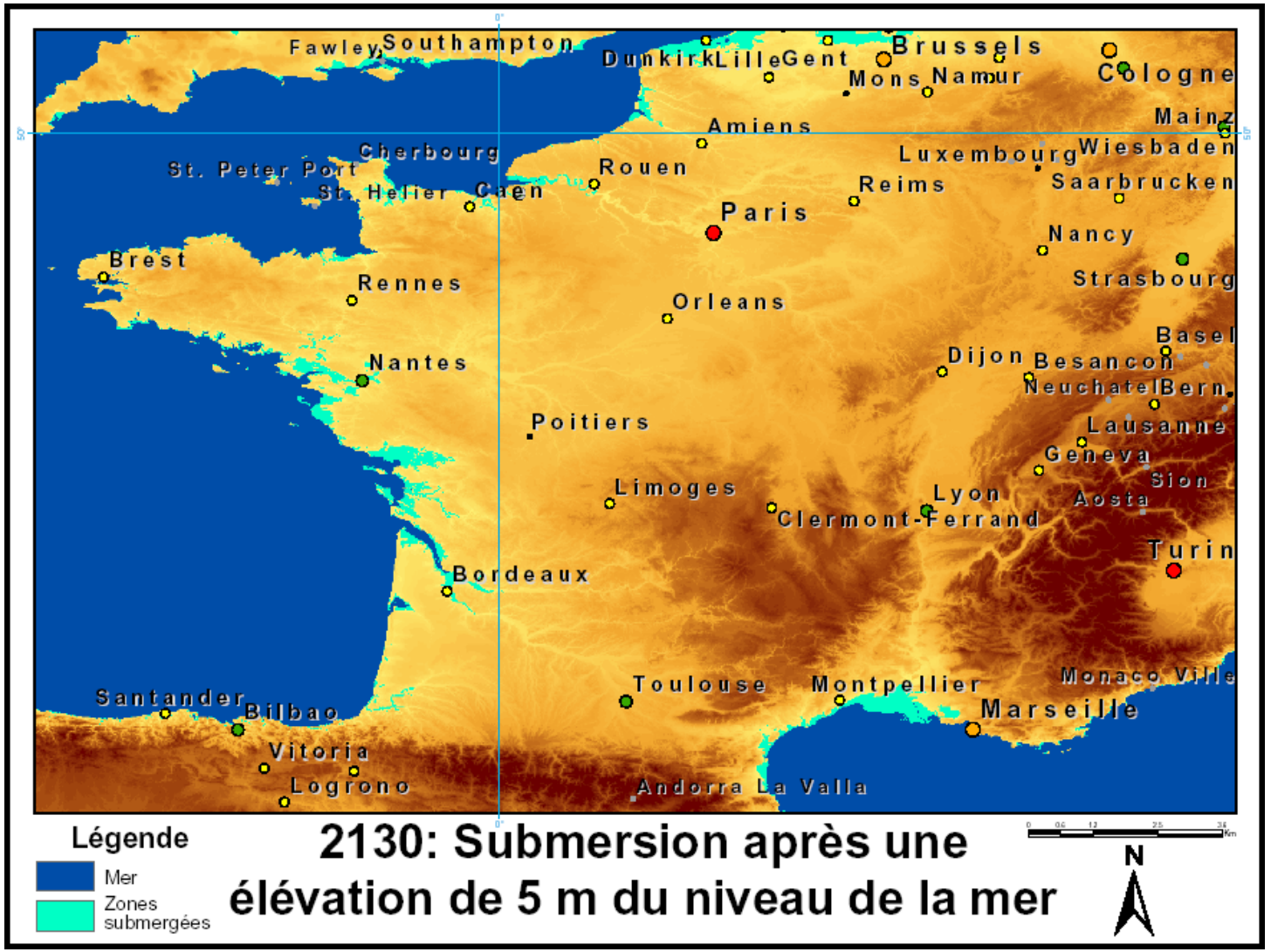

Figure 2: Camargue submersion after a five meter sea level rise