SEA LEVEL RISE, RADICAL UNCERTAINTIES AND DECISION-MAKER'S LIABILITY: THE EUROPEAN COASTAL AIRPORTS CASE

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Sea Level Rise, Radical Uncertainties and Decision-Maker's Liability: The European Coastal Airports Case

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Summary

Until now, most of the growing climate legal litigations mainly concern environmental associations or victims against energy of energy-users firms or States. However, in a near future, because of exacerbating sudden floods linked to climate change, future litigations could (will) concern infrastructure governance versus private companies. Indeed, sues would (will) concern the financial losses these last ones would (will) endure because the infrastructure managers did not made convenient protection choices in due time. This paper particularly investigates the case of coastal airports at the European level. It insists on the importance of climate scientists divergent opinions about the sea level rise and its consequences for decision-takers concerning their potential legal liability for negligence.

Keywords: Climate Change, Sea level rise, flood, airports, transportation infrastructures, legal liability, uncertainty.

JEL codes: K32, Q54, R53.

Thomas Stocker, Intergovernmental Panel on Climate Change's co-chair:
"*The power of the 2°C target is that it is pragmatic, simple and straightforward to understand and communicate all important elements when science is brought to policymakers*."

Introduction

Today, climate sciences' recent evolution indisputably associates global warming (GW) and anthropic origin of Greenhouse Gases (GHG) emissions. However, since the 1997 Kyoto protocol, progresses in the fight against climate change are scarcely spectacular. Indeed, according the fifth report of the International Panel on Climate Change (IPCC AR5)[1], GHG's emissions quickly grew further between 2000 and 2010 than in each of the three previous decades. Without additional mitigation, baseline scenarios indicate that global mean surface temperature could increase in the 2100 year from 3.7 to 4.8°C (median values) compared to pre-industrial levels. This detrimental situation need internationally synchronized fast mitigation and prevention measures. The sea level rise (SLR) is one of the hottest climatic stakes. The fastest the oceans increase, the more vulnerable coasts become to erosion, salinization but also to storms and hurricanes (Wahl and alii (2015)). Furthermore, IPCC AR5 shows that progresses in climate change knowledge raise new scientific uncertainties about the SLR's evolution. However, efficiently combatting against global warming involves that the governments dispose of reliable scientific knowledge.

The discrepancy between the populations' need for safety and the Authorities' inertia remains a serious problem to deal with. This, all the more, that, now, environmental associations, victims and citizens do no longer hesitate prosecuting governments and corporations for their alleged liability in GHG's emissions. Indeed, most of the time, spoiled populations sturdily criticize Public Authorities' inaction[2]. Resorting to local Courts is a way to both force States engaging climatic policies and affording victims due compensation. Mainly born in the United State, the climate lawsuit is steadily growing all over the World. However, the States face a dilemma. They must keep supplying enough wealth to growing populations and simultaneously care about the climate change consequences.

The decision-makers' responsibility about climate change is a multifaceted issue. A first level concerns the relationships between climatic scientists and governments or private or

[1] See IPCC (2014) last report.
[2] See the Climate litigation Chart made by the Sabin Center for Climate Change Law of the Columbia University that makes an exhaustive recension of the climate case law.
http://www.arnoldporter.com/resources/documents/ClimateChangeLitigationChart.pdf

public decision-takers that must impulse prevention and mitigations policies. Occasionally, because of insufficient evidence, scientists could supply inadequate data or forecast about a given environmental phenomenon as, for example, the 2007 IPCC's report[3] that underestimated SLR size. A second one regards the local authorities' low implication concerning global warming by diluting in time or under sizing prevention. In all cases, identifying decision-makers' responsibilities is fundamental to obtain compensation and repairs. The recent jurisprudence shows that judges will be less and less indulgent about climate negligence.

This article highlights the difficulties of coastal infrastructure managers' to achieve accurate choices under scientific uncertainty. Indeed, rapid and intense oceans rises may threaten publicly or privately managed facilities. Their board can specifically contradict choices made by local or national authorities. If until now, lawsuits oppose victims or citizen associations against governments or energy firms, further climate change acceleration could damage private firms. Then, these last one could sue infrastructures' governance for insufficient environmental care. More precisely, the paper analyzes the cases of coastal European airports. This choice justifies because airports are both strategic infrastructure and "structuring entities". Indeed, they generate road networks, railway tracks, housing, etc. In addition, their governance, decision-making system and the definition of responsibilities are complex because they mix private and public interests.

To investigate this issue, from an exhaustive panel of the European Union airports and the article assesses the SLR's structural impact for seashore airports and it defines the number of potentially affected airports and the potential damage in terms of activity (rather than in costs). As an important working hypothesis, it considers that the level of temperature will increase, or has to stay up to 2°C above the pre-industrial era. This mainly because the Intergovernmental Panel on Climate Change (IPCC) frames its Fifth Assessment to address this purpose. This methodology gives a unified view about similar situations in a given area (here Europe) and supply prospect to local governance to justify its prudential choice. This way can partially help solving the question of ambiguous choices when decisions-makers face radical scientific uncertainty by lessening their potential responsibility. In all cases, this paper helps understanding that judges should have to consider how European airports managers made relevant or irrelevant choices.

[3] See for instance Rahmstrofs (2007)'s conclusion.

1. Climate Change, SLR: the Impact on Infrastructures

The 2007 IPCC's report underestimated the SLR range. This topic raised heated debates among climate scientists and all related specialists. The controversies mainly concern the evolution of ocean warming, the melting of polar ice caps and glaciers, specifically Greenland and Antarctic. The question is of particularly importance because world's population constantly grows near seashores (Brown and alii (2013)). However, the SLR involves accelerating wetlands and lowlands, coastal erosion, exacerbating coastal flooding, threatening infrastructures, raising water tables, and increasing the salinity of rivers, bays, and aquifers (Barth and Titus, (1984), Neumann and alii (2015)).

1.1 SLR and infrastructures: The airports case

Economic analyses appraise the incurred losses involved by climatic SLR. However, these studies stay either at too high global macroeconomic level or at too much lower one (monographs) that prevents significant comparisons. Consequently, this paper changes the usual way of thinking by building a sector analysis that allows internationally comparing coastal infrastructures. This scope could appear limited; however, it better highlights the nature of the choices to be made by the decision-makers by associating the SLR specific problem to the airports' governance choices.

Coastal damages due to SLR present visible and invisible impacts. Generally, about it, economists give values to exchangeable market assets, public goods and environmental out of market inheritances (Bruun(1962), Gosselink, Odum and Pope (1974), Gunter(1974)). In the eighties, economist particularly studied it (Barth and Titus, eds. 1984), Everts (1985) Smith, and Tirpak, (1989). Titus and alii (1991) showed that a sea level increase of 1 to 2 meters during 2000-2100 century will involve a 36.000 kilometers square loss in the United States. The study proposed to particularly defend about 1500 square kilometers of densely developed coastal lowlands. However, the authors recognize the subjectivity of allocating monetary costs to such situations. Economic studies also consider how coastal storms affect countries and cities. Dasgupta and alii(2009) indicate that a 1 meter sea rise involves amplified harm. Hinkel and alii (2014) assess the global costs of defense against it according several scenarios. They find that without mitigation, under the assumption of 25 to 123 cm of global mean sea-level rise, annual flooding could affect 0.2 to 4.6% of the global population in 2100. This corresponds to expected annual losses of 0.3 to 9.3% of global gross domestic product. These studies favor building dykes as systematic defense device. Annually, until 2100, these investments cost around US$ (2005) billion 12 to 70. However, on 20 years, without discounting, the range of errors is about US$ (2005) billion 1,160[4].

Uncertainty concerning mitigating costs remains important because of unknown factors as demography or relationships between GHG emissions and SLR. Furthermore, economists only consider low and proportionate sea water increase. However, under more extreme values, population should abandon flooded areas and build new infrastructures. Besides, these evaluations do not provide any clue about the decision process. Indeed, the considered geographic areas legally depend on different stakeholders: National and regional governments, private owners, etc.

Higher air temperatures raise the seas level and induces changes in geographic moisture regime which intensifies wind and storms' frequency. This involves airports activities interruptions for short or longer periods and costs for mitigation and compliance. It also encompass increasing business costs as change in the insurance premiums, legal liability and all kind of services disruptions, changes in consumers' habits, etc. The International Civil Aviation Organization (ICAO) recognizes the detrimental consequences of climate change but under-sizes the SLR's consequences. For Burbidge (2013 p.189)) "*precipitation and storm patterns are expected in the near-term, and certainly by 2030. The impacts of sea level rise will be more gradual and are not expected to be a factor until later in the century. However, more frequent and intense storm surges will have earlier impacts, reducing capacity and increasing delays in the shorter term*". Implicitly, this opinion depends both on the perceived past SLR and new scientific knowledge that could question the well-accepted idea of gradual SLR. Now, the institutional concerns about the SLR on airports and its consequences do not go beyond institutional or scientific reports (Port Authority of New York and New Jersey (2011), DesRoches (2011), Philadelphia International Airport (2010), Los Angeles World Airports (2010)). Except for Alaska (Baglin (2012)), Larsen, and alii (2008)), little is done for protecting airports from SLR. However, as both scientific knowledge and uncertainty progress about the possible range and speed of the climatic SLR, the question becomes increasingly important.

Expecting regular and low SLR tend to induce progressive protection. However, rapid SLR, accompanied with violent storms could lead airports' governance to change their initial plans. For Pümpel (2013 p.186): "*Scarcity of large areas of level ground near population centers is a main concern for the development of new airports. In many cases, this pressure*

[4] US$ (2005) billion ((70-12).20)= 1,160.

has led to the location of new hub airports close to the seashore on artificially created islands, or in semi-protected floodplains. With climate change, such installations are likely to become vulnerable to sea level rise, storm surges, and tropical cyclones". One should consider also more drastic solutions as, for instance, moving to new airports and new infrastructures. Furthermore, this tough change makes quite dicey the SLR effective costs.

1.2 A sector analysis: The case of the European Airports

Modern airports are generally located near giant cities and constitute nodes for terrestrial, industrial and urban relationships. Furthermore, as they are built on quasi-standard structure (landing strips, transit hubs, transportation ways, etc.) this makes easier comparing them. Besides, focusing on airports does not prevent to combine this analysis with other infrastructures (terrestrial transport, local utilities, coastal activities, etc.).

1.2.1 The data and research method

Taking 2013 as reference year (Sorokin and Mondello (2015)), the study delimits a stationary state of the climate system in response to changes in specific meteorological parameters and it assesses the possible damages to EU airports infrastructure. It analyzes their vulnerability (changes in the volume of passenger and air cargo within the EU due to SLR). This involves identifying the conditions under which it is possible adapting simply the infrastructure to climate change and where building safe to flooding new airports will be necessary. The database comprises the 865 EU's airports. 146 of them are of large size, 458 medium, 163 small, 15 heliports and 72 closed (see appendix 1). The airports network is very unevenly distributed. The majority of them are closely located to coasts and few in altitude. Figure 1 and table 3 show that up to 1 meter altitude, seven airports are below the sea level; 6m correspond to 80 airports (13.9%) and 15m to 172 airports (19.9%)[5]. Almost half of flights conducted by European airports and 40.8% of airport terminals lie in potential flood zones (65m above sea level).

[Insert FIGURE 1]

Table1 lists data concerning the air traffic types (domestic and international) and transportation centers. Most of air transport in the European Union consists in passengers' transport. Table1 shows that 67.29% of passengers use major international airports while the proportion of domestic transport accounts for 20.56%, which gives a leading role to major

[5] with for 2 meters -> 11 airports 1.3%, for 4 meters -> 49 airports, 8% for 6 meters -> 80 airports, 13.9% for 15 meters -> 172 airports, 19.9%, for 65 meters -> 353 airports, 40.8%).

transport nodes. The mean-sized airports carry 11.725% of passengers and the proportion of small airports and other air transport structures is insignificant.

[insert TABLE 1]

The data on the transport of freight and mail in the European Union are presented in table 2. The greatest part of the traffic goes through the major airports 95.67% (see table 2) and medium-sized airports represent only 4.05% of the total traffic[6].

[Insert TABLE 2]

For 2013, several small airports were closed (Table 1 and 2), but their contribution to the overall flow is extremely low. However, in the database "airports" are undefined objects corresponding to 0.374% of passengers and 0.266% cargo and mail transportation. Thus, the paper focuses on large and medium-sized airports (other types are less than 1% of the traffic).

1.2.2 SLR, economic consequences and future litigations

Table 3 shows the SLR's impacts on the reduction in flow of passengers transport, cargo and mail in the European Union concerning the 865 European airports. The first ones to be flooded will be the two major airports located at the level -4 meters under the sea level – this corresponds to the zero Sea level. In the column "The number of airports in a range of heights (1 m)" we calculate the number of airports affected to the future Sea level rise on 1m corresponding to increase of the Global Warming temperature (see part 3.1.3). Until an altitude up to 25 m it presents the data in increments of 1 meter. Then, in the range of 25-65 m, the sample values are presented every 5 meters. Using the data base, the paper considers the consequences of a mechanical rise of the sea level on the vulnerable airports and it assesses the activity losses in terms of passengers, freight and airmail-post. Rather than expressing them in monetary terms, the article evaluates the losses in terms of activity percentages. This choice avoids the approximation of monetary data and gives more expressive figures.

Numerous large and medium-sized airports lie near major coastal cities. Then, considering a given increase of the oceans, we define directly and indirectly threaten airports. At the level -4m under the sea level, two major airports will be flooded. Accordingly, at a height of 2m, eleven airports are located under the sea level, this involves regarding airports just above one meter that is four airports. Indeed, as water increases, the extreme hazards that provoke floods grow and threaten the whole infrastructure of the next 17 airports in the range

[6] We take away the data on the transport of passengers and cargo by helicopters, airships and marine aircraft because they are insignificant.

from 2 up to 3m SLR. Consequently, at 2m altitude, SLR threatens not only 11 already flooded European airports but around 28 of them. Obviously, each airport depends on particular geographical conditions and global warming may negatively or positively widen its effects.

Today, the climate litigations mainly concern environmental associations or victims against energy of energy-users firms or States. Although trials against companies still do not succeed, corporations are growingly involved by parties for their contribution to global warming. In the near future, because of exacerbated climate change, litigations could concern airports governance versus private airways companies or insurance companies. Indeed, until now victims are inhabitants, private persons as under the Katrina event, or still association. However, table 3 shows that airways corporations could endure financial losses due to the different kind of airports activity reductions. Lawyers could show that the early airports governance and/or local or national authorities did not undertake necessary prevention investment in time. Consequently, to avoid legal liability, the airports governances need concordant scientific information about the range of the future SLR. The question to rise is to know whether how this one is sufficiently relevant. This information bears upon an enormous range of data about the specific geographic location of the infrastructure, the local impact of climate change, the expected speed of the sea rise, the frequency of storms, etc. Consequently, concerning the SLR the field is far from being unified.

[Insert TABLE 3]

2. SLR litigations: the decision-makers' liability

Now, victims, environmental associations and corporations, Countries and regions, resort to courts to repair or prevent climatic damages decision-takers and growingly involve the authority's representative that made choices long time ago after a catastrophe occurrence. Climate lawsuit is a citizen answer to the governments' inertia facing GHG emissions.

2.1 The growth of the climate lawsuits

The climatic dispute mainly grows in the United States, Australia, and New-Zealand but very few in Europe. Among hundreds of appeals it generates, the courts do not reject all of them. By the end of 2013, judges solved more than 420 cases in the USA against 173 in the whole world (M.G.Gerrard (2015)). When they bring to courts climatic questions, associations and citizens use tort law, administrative litigation, or still human rights international jurisdictions. Indeed, as victims, the claimants no longer hesitate attributing its causes to human behavior and more specifically to States or large companies. Hence, Courts sue them for negligence or because they developed polluting activities.

Markell and Ruhl (2010) empirically show that quarrels compel States or environmental agencies to limit GHG's emissions. They accounted for nearly 40% of the whole litigations. Civil Society (individuals or associations), States, corporations and non-governmental organizations initiated them to require from the Federal government. Lawsuits under the US Federal Common law decrease while regulatory claims increase. Courts appear as the only way to hear the voices of global warming's victims. Indeed, only the formal setting of a court can fairly evaluate the decision-makers' responsibility in the wake of damage. Certainly, the recognition of the existence and the degree of a legal liability can only trigger the repair process. However, it is in the USA that climate litigation spreads over the fastest. Consequently, legal litigations become public policy instruments for combatting climate warming (Sigman (2007)); they play a "gap-filling role" following Hari Osofsky's words (Osofsky (2010)). Or still, following Eric Posner: "*Litigation seems attractive to many people mainly because the more conventional means for addressing global warming—the development of treaties and other international conventions, such as the Kyoto Accord—have been resisted by governments*". E. Posner, (2007, p.1925).

2.2 The importance of the SLR cases law in climate litigation

The detrimental consequences of rising sea levels greatly nourish the climatic lawsuit. In 2002, Tuvalu State threatened to take USA and Australia to the International Court of Justice because of their failure to stabilize GHG concentrations. Tuvalu claimed that the RSL endangered its territory. However, Tuvalu's government resigned and the application stopped. Currently, there is no regime imposing liability for causing climate change – nobody can sue a State for directly causing climate change but for not taking relevant measures. Furthermore, the United Nations Framework Convention on Climate Change (UNFCCC) does have legal provision for such liability regime[7].

The US climate change precedents are mainly of three kinds. First, lawsuits nourish particularly administrative litigation (Statutory claims). Second, plaintiffs more rarely resort to Common Law. Third, appeals to international courts (Public International Law Claims) concern very few cases. Consequently, civil and statutory claims remain the main Courts that deal with climate change litigation. Civil actions aim at either stopping harm or demanding compensation. In administrative courts, plaintiffs challenge the government's decisions for

[7] For a more complete treatment see D. A. Weisbach (2012).

inducing it to enforce effective measures against GHG's emissions. In fact, five well known cases law (most of them related to SLR) structure the courts' decisions. In order to save space, the paper rather concentrates on the cases associated to the SLR because victims perceive its importance through the damages they suffer (floods due to storms, hurricanes, and the worsening of coastal natural hazards). The five cases are: Native Vill. of Kivalina v. ExxonMobil[8], California v. Gen. Motors Corp.[9], Comer v. Murphy Oil USA,[10] Connecticut v. Am. Elec. Power Co[11]. and Massachusetts v. EPA (or Environmental Protection Agency)[12].

Currently, sensitive to global warming, judges accept both the interest in bringing the parties and, the climate change phenomenon. Further, judges recognize both that climate changes cause harmful damage to individuals (Kivali, Comer, op.cit.), regions and States (Massachusetts, op.cit.), and, also, its anthropogenic origin. In addition, courts consider that they contribute to GHG's emissions, although parties insufficiently demonstrate the causal nexus to engage the major polluters' responsibility. This fact dismisses allocating compensation.

The dispute Massachusetts v. EPA case issued on a success. This last one, led by more than twenty parties, started because EPA refused regulating vehicles CO_2 emissions[13]. EPA advanced that it had no authority to control them and did not get cantilever with President Bush's environmental policy. Among the arguments, plaintiffs stated that: "*According to petitioners' uncontested affidavits, global sea levels rose between 10 and 20 centimeters over the 20th century as a result of global warming and have already begun to swallow Massachusetts' coastal land. Remediation costs alone, moreover, could reach hundreds of millions of dollars.* (Supreme Court of the USA, 2006, P.23)"[14]. This quotation is one among several about RSL. In fact, the Supreme Court argued that beyond CO_2 emissions the real issue focused on the pollutants emission and the EPA's position appeared

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[8] Native Vill. of Kivalina v. ExxonMobil Corp., 663 F. Supp. 2d 863 (N.D. Cal. 2009)
(granting defendants' motion to dismiss); 2) California v. Gen. Motors Corp., No. C06-05755 MJJ, 2007 WL 2726871 (N.D. Cal. Sept. 17, 2007) (granting defendants' motion to dismiss);

[9] California v. Gen. Motors Corp., No. C06-05755 MJJ, 2007 WL 2726871 (N.D. Cal. Sept. 17, 2007) (granting defendants' motion to dismiss);

[10]Comer v. Murphy Oil USA, No. 1:05-CV-436-LG-RHW, 2007 WL 6942285 (S.D. Miss. Aug. 30, 2007) (granting defendants' motion to dismiss), rev'd, 585 F.3d 855 (5th Cir. 2009), panel opinion vacated en banc, 607 F.3d 1049 (5th Cir. 2010);

[11] Connecticut v. Am. Elec. Power Co., 406 F. Supp. 2d 265 (S.D.N.Y. 2005) (granting defendants' motion to dismiss), vacated, 582 F.3d 309 (2d Cir. 2009), cert. granted, 79 U.S.L.W. 3342 (U.S. Dec. 6, 2010) (No. 10-174).

[12] Massachusetts v. EPA, 549 U.S. 497, 516 (2007) (quoting Flast v. Cohen, 392 U.S. 83, 95 (1968)).

[13] Twelve States, four territorial and local governments, and numerous trade associations.

[14] Supreme Court of the USA, 2006, syllabus, Massachusetts Et Al. V. Environmental Pro
-Tection Agency Et Al. Certiorari To The United States Court Of Appeals For The District Of Columbia Circuit, 2006.
http://www.arnoldporter.com/resources/documents/Mass_v_EPA.pdf

as "*arbitrary, capricious . . . or otherwise not in accordance with (statutory) law.*[15]" Then, it followed a legislative reform constraining EPA to define a GHG emission regulatory framework. However, this statutory claim success did not spill over into Common Law lawsuits. Indeed, Common Law requires establishing a direct causal link between damages and the involved polluting entities activities and, concerning climatic phenomena, practically, causation is impossible to prove. In all cases, whatever the jurisdiction, the existence of large scale damages constitutes the minimum condition for inducing litigation, as Butti (2011, p.33) summarizes it: "*The most difficult standing-related hardship that applicants must face when filing emissions-related court claims is proving an emitter's direct responsibility. It is often argued that there are not a definitive number of entities liable for climate change, or that, on the contrary, this number is too great. Scholars have tried to overcome such hurdles by applying innovative theories on climate change liability, some of which aim to establish a link between local causation and local consequences. These doctrines may prove successful in those cases where the damages at stake are clearly identifiable (and, therefore, the obstacle of locus standi has already been surmounted) and where such damages occur in areas where major emitters directly operate".*

Civil courts follow the same rules for global warming harm than for "usual" prejudices. Therefore, accepting the complainants' request needs fulfilling three criteria. The first one is standing for adjudication (interest in acting) which associates the injury. The second one must highlight a causal link between harm and the polluters' activities (causation). Finally, the third one consists in the tribunal jurisdiction's ability to define remedies and relief. These three elements apply to civil courts (common law) as well as for administrative queries (statutory claims). In the United States, the standing question is linked to the nature of the damage. Accordingly, the Kivali village, in Alaska, argued that climate change highlighted the storms strength, the melting of the icebergs raised the water level and the shore erosion resulted in a deterioration of its inhabitant's life quality. Plaintiffs questioned all the actors that they thought responsible for global warming as, primarily, EXXON Corporation and the major energy companies[16.] In fact, this case falls within litigation which dismisses the plaintiffs' claims. Indeed, these last ones have relied on Common Law which requires the accurate identification of those responsible in the reconstitution of the causal chain that was impossible here.

[15] Massachusetts, 549 U.S. at 528 (quoting 42 U.S.C. § 7607(d)(9) (2006)) (internal quotation marks omitted).
[16] Native Vill. of Kivalina v. ExxonMobil Corp., 663 F. Supp. 2d 863, 877 (N.D. Cal. 2009) (citing *Lujan*, 504 U.S. at 559–60 (1992)) (discussing the need to fulfill standing requirements).

Concerning Katrina disaster in the Mississippi Gulf Coast in 2005, victims also resorted to anthropic climate change. The hurricane's victims tried to obtain reparations pursuing thirty four major oil and energy companies actively involved in global warming[17]. However, on May 14, 2013, the U.S. Court of Appeals for the Fifth Circuit affirmed the dismissal of Comer v. Murphy Oil USA, Inc., 718 F.3d 460 (5th Cir. 2013) (Comer II) concerning the plaintiffs' second attempt to recover damages. The Fifth Circuit concluded that the petitioners' claims were barred by res judicata. However, among plaintiffs almost succeed in the Saint Bernard Parish Government, et al., v. the United States[18]. Indeed, landowner's victims for the Hurricane Katrina considered that they suffered a taking of property without just compensation by the United States government. The court found negligent the Army Corps of Engineers' (the Corps) and underlined a failure to maintain the Mississippi River Gulf Outlet (MR-GO), that this Corps constructed in the 1950s. However, court of appeals for the Fifth Circuit dismissed the judgment.

In the California State v. General Motor case[19], California sued six car companies plaintiff arguing about the disorders induced by the Climate Change and among them the consequences of the SLR. Consequently, "*Plaintiff requests monetary damages, attorneys' fees, and declaratory judgment for future monetary expenses and damages incurred by the State of California in connection with the nuisance of global warming*". However, the Court dismissed the case considering that six formulations indicate the existence of non-justiciability. This fact corresponds to political questions, i.e. those questions that are better responded by the legislative or the executive divisions and mainly concern foreign and public policy, and political issues. They are deemed inappropriate for courts by the US Constitution.

An important law case remains Connecticut v. Am. Elec. Power Co[20] that after the 2011's Supreme Court decision prevents for a long time to access to federal common law. Indeed, in 2004, eight states, the City of New York, and three land trusts, alleged that the five largest emitters of GHGs in the United States (Am. Elec. Power, Cinergy Co., Southern Co. Inc. of Georgia, and Xcel Energy Inc. of Minnesota, (collectively emitting 650 million tons of

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[17] Comer v. Murphy Oil USA, Inc. (S.D. Miss. dismissed Aug. 2007) (5th Circ. partially reversed dismissal Oct. 2009) (en banc petition for rehearing granted Feb. 2010) (appeal dismissed May 2010) (petition for writ of mandamus filed by plaintiffs Aug. 2010) (writ denied Jan. 2011) (complaint refiled May 2011) (dismissed March 2012) (notice of appeal filed April 2012) (5th Cir. affirmed dismissal May 2013).

[18] St. Bernard Parish Government v. United States, No. 1:05-cv-01119 (Fed. Cl., filed 2005), see also Government Found Liable for Hurricane Katrina Flooding Posted on May 11th, 2015 by Jennifer Klein - See more at: http://blogs.law.columbia.edu/climatechange/2015/05/11/government-found-liable-for-hurricane-katrina-flooding/#sthash.nO5AHN1o.dpuf

[19] California v. Gen. Motors Corp., op.cit.

[20] Connecticut v. Am. Elec. Power Co., 406 F. op.cit.

carbon dioxide annually in twenty states) are a public nuisance because their carbon-dioxide emissions contribute to global warming which, consecutively, led to serious environmental consequences. After several divergent views between the District Courts that dismissed the claim before trial, considering that global warming are "political questions" that should be resolved by the legislature, not by the courts. The Second Circuit Court of Appeals considered that courts can hear such cases, and, plaintiffs bear the burden of proof. Then, the last word remained to the United States Supreme Court that said that because the Clean Air Act (CAA) allocates the controlling of carbon dioxide and other GHG emissions to EPA, the defendants (the electric companies) cannot be indicted for GHG under federal common law[21.]

In conclusion, local courts substitute themselves to the lack of international regulatory bodies concerning the GHG's excessive emissions. Consequently, as autonomous authorities they may engage the liability of any actor who, directly or indirectly, contribute in increasing global warming (Kassman, (2013)), this in so far that statutory claims are required and not federal common law. In other words, although originally, the local courts "raison d'être" is to solve local conflicts, in some cases, , economic agents can involve them to solve a global phenomenon if they gather sufficient evidence. Accordingly, it follows that judges can hold as responsible any decision-maker in charge of polluting activities.

3. Scientific uncertainty and the decision-makers' liability

Concerning airports, the decision-makers choice will be either to adapt progressively their facility to climate changes (for instance building or reinforcing dykes) or to move the installation's location. This choice does not suffer compromise: either they adapt existing infrastructures, or, they remove them to a safer place. Table 3 showed that progressive adaptations of airports to global warming are possible up to 1 meter level, which corresponds to an acceptable economic cost of maintenance. Beyond one meter, extreme events (flooding associated to storms or all detrimental coastal hazards associated to global change) could structurally affect the airports and all associated amenities. This fact could deter insurance companies to continuously insure fragile to climate infrastructures. Therefore, bad choices could have deep consequences. After a harm occurrence, the decision-makers' legal liability highly depends on the relevancy of their choices long time before the catastrophic event. However, these choices depend on available scientific knowledge which, at the present, is quite contradictory.

[21] See Schwartz, Goldberg , and Appel, 2012.

3.1 Do SLR's scientists offer enough certainties to decision-takers?

Let us consider an airport's governance particularly aware about SLR. It intends planning future mitigating investments for the long term. For instance, airport may be located on the Mediterranean coast for near seashore airports (Barcelona (1m) or Nice (2-3m) or, still, Roma (Leonardo da Vinci, 3m). Let us assume that the planner prospects for the future forty years (2055). What are the factors he should take into considerations? Can he reasonably rule out the assumption of finding another location for a new airport? An appropriate answer to this question needs having a clear understanding of the SLR consequences. Indeed, the decision-maker faces several unknown data. Mainly, the analysis defines three scenarios. The first one corresponds to IPCC's view that considers that the SLR does not exceed one meter during the 21st century. The second one comes from scientists that raise doubts about it. This need considering then the three following points: i) The relevancy of the 2°C assumption, ii) Sea-level rise and past warm periods and, iii) The relevancy of semi-empirical models that deal with SLR.

3.1.1 Discussing about the 2°C benchmark

IPCC considers as an effective GW benchmark an air temperature of 2°C above the preindustrial era. Above this level, IPCC thinks that the climate change detrimental consequences could (will?) dangerously increase. Consequently, States have to devote financial and economic resources to limit global GHG emissions not beyond 2°C. However, such and accepted level raises questions about the effects of the climate change and especially the associated SLR. Concerning the projections for 2100, the IPCC 5th report (13, Sea Level Change) or IPCC AR5-13) admits that its fourth report (2007) underestimated the relationship between global warming and SLR ("*Confidence in projections of global mean sea level rise has increased since the Fourth Assessment Report (AR4) because of the improved physical understanding of the components of sea level, the improved agreement of process-based models with observations, and the inclusion of ice-sheet dynamical changes*". (IPCC AR5-13, p.1139).

The main 2007's failure was the lack of relevant data about ice flow from the poles. Taking it into count involves that, basically, IPCC estimates the sea level rise of 28 (low assumption) to 98 centimeters (high assumption) by 2100 (more than 50 percent higher than the 2007 projections). However, IPCC recognizes relevant uncertainties about the oceans dynamics: the steric sea level, the dynamical response of the ocean to meltwater input or the GIA/rotational/gravitational processes associated with this ice mass loss, the necessity of better parametrization of physical models, etc. Table 3 shows that a sea level increase about 98 cm involves that 5 airports will be flooded (in a range of heights 1 m) and total 7 are below the sea level. Furthermore, 7 of them need mitigating or moving off solutions and the next 4 are under the threat of the SLR from 1m up to 2m. Consequently, at the European level, taking into account the IPCC's assessment entails that 11 airports need serious amenities.

This will impact on the airports' transportation activities for flights (3.1%), passengers (3.5%), freight and mail (9.9%). However, the detrimental consequences do not stop here, because airports located in a today 2 meters altitude are also concerned because of the change in the intensity in storms and floods that largely remain unknown. Thus, the 2°C assumption does not remove uncertainties about the effective consequence of the SLR. Hope and Pearce (2014) recall how Nordhaus in 1975 defined this value, and how it became the actual indisputable benchmark for policy makers. Reaching this point, we must distinguish two things. The first one is the relationship between the 2°C benchmark and the well accepted idea of a rise of sea level limited to one meter in the worst IPCC's scenario. The second one concerns threatened Countries by the ocean rise that reject this temperature as detrimental for them and Petra Tschakert (2015) shows that it is highly controversial: "*Among parties to the United Nations Framework Convention on Climate Change (UNFCCC), many Caribbean states proclaimed already at COP15 that a 2°C temperature rise was unacceptable as a safe threshold for the protection of small island states and that even a 1.5°C increase would undermine the survival of their communities*". Tschakert (2015, p.2).

More embarrassing is Rogelj and alii (2012)'s analysis. They show that this target involves the formulation of numerous hazardous assumptions regarding the technologies' capacity to help reaching this level. Indeed, stabilizing global temperatures requires limiting the emission of accumulating greenhouse gases and requires technological changes and strong carbon saving innovations (electro-nuclear parks, bio-gases, etc.). This viewpoint adds to Peters and ali (2013)'s recent comments for whom reaching a global warming of +2°C or less is possible by cutting CO_2 global emissions by 3% per year for a start fixed in 2020. Beyond, the goal of limiting global warms to 2°C "may become unfeasible".

In conclusion, even if the decision-maker thinks true the relationship between the temperature increase of 2°C with a one meter SLR, he may duly raise doubts about the capacity of nations to reduce GHG emissions to an acceptable level. Evidence of the contrary is the continuous use of CO_2 energy emitters. This fact constitutes the first uncertainty cause that should lead coastal airport managers to consider alternative locations rather than long term mitigation measures.

3.1.2 Sea-level rise and past warm periods in the range of 2°C

Another scientific contention source that may influence the air decision-taker concerns some scientists' conception about the effective SLR in a near future regarding the past warming period. There, the temperatures were over or near 2°C as by now. Two 2015's contributions insist on the consequences of such changes if, in the present times, the same conditions gather. Dutto and alii (2015) underline that present climate warms to a similar pace to significant polar ice-sheet loss in the past. They outline advances and challenges involved in constraining ice-sheet sensitivity to climate change with the use of paleo–sea level records. Hansen and alii (2015), in a still under revision paper, show that glaciers in Greenland and Antarctic could melt 10 times faster than projections put forward by IPCC. For them the nowadays average global temperatures are only less than a degree cooler than they were during the last major interglacial or 'Eemian' period 120,000 years ago. In these times, global temperatures stood just 2°C above the pre-industrial climate and sea levels raised at five to nine meters upper than they are today.

Relying on these different authors' views, it appears that a progressive increase of oceans about an intermediary level of six meters (Sorokin and Mondello (2015)) will concern about 80 airports situated under the sea level, while 16 of them are in the direct neighboring from 5m to 6 m (table 3). Globally, this corresponds to 9.2.6% of total EU airports and about 13.6% of total traffic including passengers', freight and mail. As ever mentioned above, this do not involves that the next 12 airports are under the threat of flooding (the one concerned by an SLR of 7 meters). Obviously, these last figures have to be cautiously taken because these are data of 2013 for future times. For higher levels of sea rise, the number of concerned airports is much higher. It seems useless to go further in the economic consequences as it is sufficient to look at table 3.

3.1.3 Can airports' managers rule out the semi-empirical models?

Until now, no accepted models describing effectively the relation between the global sea level variations with changes in Earth's climate exist. Climate models contain large numbers of parameters and use supercomputers for grid technologies. Secure forecasts involve assessing heat and mass transfers, including phase transitions (melting ice, and freezing and evaporation of water). However, evaluating the correspondent changes in the global sea level is too time-consuming.

In a previous work, following Hansen (2007) and Rahmstorf (2007) works', in a semi-empirical model, Sorokin and Mondello (2013) highlighted the links between changes on the planet average surface temperature and rising sea levels compared to pre-industrial era (see appendix 2). By hypothesis, this model considers as stationary the present sea level. The study assesses the significance of the rise in sea levels associated with the increase in average temperatures on the planet (Sorokin and Mondello (2013)). This kind of model considers a close relationship between global warming and the future SLR (Sorokin and Mondello (2013a)). There are various estimates for identifying some possible levels of climate warming; these vary from 1°C to 5.8°C and higher (IPCC (2012)). However, none establishes a unique relationship between the change in temperature and the rise of the sea level. Currently, considering global warming, for a short term (until 2100), the European Union considers that the increase in sea level will be around 1 meter for a temperature increase of 2°C, (European Union Commission, (2013)). However, assuming that currently the average temperatures rose by 0.8°C compared to the pre-industrial values, then the seas levels increase proportionally. For the contemporary period, this is an expected value of 0.21 meters compared to the era of industrial development. Table 3 shows that the rising water at 1m will lead to the flooding of 7 airports (0.8%) and the reduction of about 3.4% in passengers and about 9.9% in freight and mail transport. Consequently such changes in air traffic will not lead to catastrophic consequences. However, now, an adapting strategy to the sea level elevation of 1m does not exist.

In Table 3, we calculate the excess of the average air temperature at the Earth surface ΔT_S for the future stationary values of the Sea level SL_{st} that corresponds to the stationary solution (Sorokin and Mondello (2013), following the formula:

$\Delta T_S = \frac{SL_{st}}{7,5}$, where $SL_{st} \geq 0$.

Consequently, further increase in the overall level of the sea of 6 m (equivalent to the level currently exceeded by an increase in the average temperature of 0.8 °C relative to the pre-industrial era of development) would inundate 80 airports (9.2%) and lead to a reduction of air traffic by 13.6% (see Table 3). Similar economic losses are unacceptable and could lead to many airlines bankruptcies and the collapse of the whole airline industry. Returning back to the EU's adaptation strategy to climate change of 2°C, in the long run, this temperature will lead to rising sea levels up to 15 meters (see Appendix 2). Consequently, this involves the flooding of 172 airports (19.9%), a reduction of 20.4% in passenger traffic and cargo by 14.7%. The EU strategy on adaptation to climate change does not consider the possibility of a SLR in the upper level 1 m. In the near future, this restriction could lead to catastrophic economic losses. The worst-case scenario of a 8.67°C global warming concern the melting of icecaps and the SLR will be 65 meters (National Geographic (2013)). This can lead to a loss of 40.8 per cent of all airports in the EU by reducing by half the flights and passenger flows and reduces the amount of cargo and mail by 32.6% (Table 3).

As mentioned in the introduction the analysis sticks to the internationally well-accepted level of 2°C increase in temperature above the pre-industrial era. Obviously, nobody knows if by this century end, the Earth's temperature increase will reach this level or not. Consequently, at 2°C GW, the SLR in the nearest future could reach 15 meters. That means that this score is 15 times greater than the maximum rising oceans of 1 m allowed by the climate change scenario A1B. However, the EU's adaptation strategy to climate change does not accept such a development of events that could lead to a sharp increase in economic losses from rising sea levels.

3.2 Sharing liability as a consequence of scientific uncertainty

In what follows, the paper assesses how decision-makers are legally liable when they have to take strategic decisions about fragile infrastructures in a controversial scientific environment.

3.2.1 The scientists' liability question

Concerning technological or natural hazards, decision-takers increasingly require advice and councils near risk agencies or experts. For Marzeion and Levermann(2014), SLR involves dealing with quantifiable and unquantifiable uncertainty. However, high uncertainty does not prevent applying legal liabilities to decision-makers. They have to make irreversible choices and deceived populations can attempt indicting them. Prosecution can also include experts as in the Katrina case where judges considered as partially liable the Army Corps of Engineers (see supra sub.sect 2.2). Consequently, today, scientists cannot fully escape liability.

Indeed, in case of major harm, too low prevention could induce victims to sue both decision-makers and experts. Thus, to avoid liability, all of them must be sensitive to the nature of their economic decisions. Facing a kind of "bang-bang" choice (hugely investing or not in safety), the decision-takers face a kind of dilemma when the experts' advice give a fifty-fifty chance for each option. A cautious behavior will lead them to invest, but scarce resource or their high degree of optimism could involve the reverse. However, when clear decision rules are lacking, the judge should make weaker the regulator's liability. Indeed, the Courts consider missing information or expert's ambiguous opinion and they can partially exonerate the decision-makers.

Nevertheless, when the scientists' advice is fundamental this can lead them to prosecution as after the Aquila earthquake on April 6, 2009. A trial lasted from September 2011 until October 2012 that indicted six scientists and a former local government guilty of involuntary manslaughter. Judges considered them as "*falsely reassuring*" giving "*an assessment of the risks that was incomplete, inept, unsuitable, and criminally mistaken*", and they were sentenced for six-year jail on 22 October 2012 (Hall (2011)). Obviously, this trial is exception not the rule. Italian scientists' viewpoint was too clear about the Aquila earthquake risk and misled the Authorities. It was a kind a take-or-leave decision that induced the decision-makers to choose the bad decision: the weight associated to weak earthquake consequences was stronger than the opposite.

3.2.2 Threaten airports and governance's liability

Under radical uncertainty making airports' governance fully responsible for potential damages seems difficult. In fact, their liability depends heavily of how the local and national authorities considered (or consider) the rise of seas associated to climate change. This last one depends on the convergence or the divergence of scientists' views about the strength and the range of the rise of the seas.

Case 1: *Convergent views among scientists*.

The convergence may bear about some high or moderate increase of the sea level. The decision-takers will accept more easily moderate ones than high ones. Nevertheless, the most important is the consensus among scientists' because the infrastructures' governance must accept it. Indeed, in case of harm, the judge can verify whether managers took relevant protection measures when scientific opinions converge. This makes them fully liable. Indeed, the judge will consider that no compliance to some common knowledge is clearly negligence and consequently a fault (Klein (2015)). More interesting is the second case where scientists diverge.

Case 2: *Divergent views among scientists*

Here the considered divergence bears upon the SLR range: either high for some or low for others. What does this discrepancy means? In this case, allocating liability could be a hard job for judges. In fact, considering Table 3, divergent opinions among scientists involve ipso-facto uncertainty on the future of several airports. For instance, let us consider the actual discrepancy among IPCC's views and those scientists that consider past warming periods. Under an ocean moderate rise (around 1m as IPCC and European Union evaluate it) few airports will suffer. Accordingly, in this case, if infrastructure's governance did not take serious precaution, courts will involve them in liability (negligence). Indeed, evidence for some moderate sea rise was strong, and stakeholders had to undertake light mitigation.

However, the question is not how moderate will be the ocean rise under climate change, but how relevant and sufficiently convincing is the scientific knowledge to induce decision-makers to take due care in due time? Consequently, in the future, judges will have to understand how the community of airports managers took their strategic decisions facing scientific disputes and uncertainties. Indeed, bearing in mind actual uncertainty about the SLR, the interval of concerned airports on 85 years (2015-2100) regards almost one hundred airports. Consequently, at the EU level, the question does not bear only on airports, but on the whole related activities (airports, roads, railways, industrial activities). The question is quite simple but the answers extraordinarily complex: Is it preferable to defend in place the infrastructures or to moving away the whole infrastructure on a new area? Then, the answers depend on the beliefs and consensus among the stakeholders about the scientific debate.

4. Conclusion

The rise of oceans due to changing climate constitutes one among the main stake of global warming. This paper's main concern is about the understanding of how scientists influence the governance of coastal airports facing the SLR. The point on which we mainly focus on is about the airports managers' liability and how they should behave facing radical scientific uncertainty. Can they fully believe the European Union and IPCC conclusions about the rise of the sea level that associates a 2°C rise of temperature and a related increase of 1 meter of the sea level around 2100? This means that they consider these values as sufficiently relevant or, in the opposite, should they take also in consideration other scientific views considering that the above benchmarks are too low estimates?

Consequently, if new scientific knowledge and scientific opinions are sufficiently convincing for raising sufficiently doubts, then, the airports decision-takers should apply the precautionary principle that roughly says that "*When human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm.*" This means that they should adopt cautious decisions that consist for a great panel of airports to consider moving of toward less threaten areas. The paper did not advance specifically the precautionary principle as such. This is the object of a more explicit future paper.

5. Bibliography

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APPENDIX ONE

Details on the Data Base

The paper mainly uses the Eurostat statistics (Eurostat)[22] - Statistical Office of the European Union and the Database airports[23]. The Eurostat database for 2013 contains statistical data on 865 airports. The database contains detailed information on the situation and the length of airstrips, their geographical coordinates and altitude of the airstrips above the sea level, as well as information for international codes, names and types of airports. This broad information base includes:

- The number of flights;
- The volume of passengers, cargo and mail;
- The number of seats on board;
- Domestic and international air transport;
- Monthly and annual reports;
- Other details as well.

Usually, the sectoral analysis of the air transport in the European Union is carried out for the year 2010 because, there, the transport volumes reached their local maximum. This is related to the air traffic variations over time. The reduction of air cargo is linked to the economic crisis and the European support for US sanctions against the Russian Federation. However, the content of the Eurostat database on air transport is constantly improving and up 2013, the number of airports in the database increased. The statistics for 2014 are not yet fully integrated into the base, which is associated with a delay in processing the data. Thus, for our analysis, 2013 is the most representative year.

Table 3 corresponds to an abbreviated form. Until an altitude up to 25m it presents the data in increments of 1 meter. Then, in the range of 25-65 m, the sample values are presented every 5 meters.

[22] Eurostat., URL: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

[23] OurAirports., — URL: http://ourairports.com/data/

APPENDIX TWO

A semi-empirical model of the rise of sea level

The definition of the Global Mean Sea stationary state level (SL_{St}) that responds to a fixed change of the average air temperature (T_{S_t}) must conform to the mentioned below main characteristics. Then, to reach a stationary state solution, Earth's climate system needs a sufficiently large relaxation time (Sorokin L.V., 2015) and from a few hundred years up to the millennium. The present applied approach gives an estimate of the upper bound of the sea level rise due to changes in the fixed air temperature on the overall globe in the long run (Sorokin L.V., Mondello G., 2013). The boundaries definition for a stationary state of the climate system induced by the fixed change of meteorological parameters allows verifying this hypothesis.

In Sorokin and Mondello (2013a), the following equations ((1), (2)) associate both future sea level (SL) and average air-temperature (Ts) on Earth:

$$SL_{St} = 7.5\, T_{S_t} - 106.875 \quad (SL>0) \tag{1}$$

$$SL_{St} = 24.793\, T_{S_t} - 353.306 \quad (SL<0) \tag{2}$$

The assessment of the average temperature in pre-industrial era development ($T_{S_{SL=0}}$) for (SL = 0) follows from equations (1) and (2):

$$T_{S_{SL=0}} = 14.25°C \tag{3}$$

The Global Surface Air Temperature (GSAT), corresponds to the current sea level $SL_{t=0} = 0.21\ m$:

$$T_{S_{SL=0.21}} = 14.278°C \tag{4}$$

Then, the GSAT in the present time (t=0) expresses as:

$$T_{S_{t=0}} = T_{S_{SL=0}} + 0.8 = 15.05\ °C \tag{5}$$

Comparing with the era before the industrial development (SL=0) in terms of the present time (t=0) we get the following current climate conditions concerning the Global Mean Sea Level (GMSL) rise:

$$\mathrm{SL_{t=0}} = 0.21\ \mathrm{m} \tag{6}$$

due to the Global warming and the GSAT exceeds by

$$\Delta\mathrm{T} = \mathrm{T_{S_{t=0}}}\text{-}\mathrm{T_{S_{SL=0}}} = 0.8°\mathrm{C} \tag{7}$$

Consequently, from equations (1) and (5), an increase of GSAT of 0.8ºC corresponds to a 6m stationary Sea level. Furthermore, from equations (1) and (4) it is clear, that in the aim at preventing any Sea level rise and maintaining it on the current level (6) the GSAT compared with the era before the industrial development should be reduced by 28.5 times

$$\Delta T = T_{S_{SL=0.21}} - T_{S_{SL=0}} = 0.028°C \tag{8}$$

is equal to $LE_{(\Delta T=0.028)} = SL_{t=0} = const = 0.21\mathrm{m}$

For the transient modeling of the Sea-level (GMSL) growth in response to the temperature (GSAT) jump it is reasonable to apply the saturation model, which can be formalized using the logistic equation (Sorokin L.V., 2015):

$$LE_{(T,t)} = \frac{SL_{St} * SL_{t=0} * (1+\Delta T)^{(\frac{t*m_{(\Delta T)}}{k})}}{SL_{t=0} * (1+\Delta T)^{\left(\frac{t*m_{(\Delta T)}}{k}\right)} + SL_{St} - SL_{t=0}} \quad (9)$$

The logistic equation (9) should meet the following requirements:

- t – time scale (t=0 corresponding to the present time);
- equation (9) for the present time t=0 is equal to $LE_{t=0} = SL_{t=0} = 0.21m$;
- equation (9) at a value $\Delta T = T_{S_{SL=0.21}} - T_{S_{SL=0}} = 0.028°C$ is equal to $LE_{(\Delta T=0.028)} = SL_{t=0} = const = 0.21m$;
- equation (9) at a value $\Delta T = 0$, $a = (1 + \Delta T) = 1$, consequently $LE_{(T,t)} = SL_{t=0} = const$;
- The coefficient $\frac{m_{(\Delta T)}}{k}$ defines the relaxation time for the transient function;
- Considering the condition (6), the coefficients tuning $a = (1 + \Delta T)$, $\frac{m_{(\Delta T)}}{k}$ should initially provide an exponential growth model (9) up to the present time. This one considers that the global sea level doubles every 10 years (Hansen J.E., 2007);
- at a value $t \rightarrow -\infty$, equation (9) tends to zero, $LE_{((\Delta T>0, t\rightarrow -\infty)} = 0$;
- at a value $t \rightarrow +\infty$, equation (9) reaches the stationary level (1) , $LE_{((\Delta T>0, t\rightarrow +\infty)} = SL_{St}$.

For the current climate conditions we estimate the future sea level change, using the logistic equation (9) with parameters (1), (5), (6), (7) and coefficients $m_{(\Delta T)} = 9$, $k = 100$. Figure 2 illustrates the future Sea level model based on the logistic equation (9) and we consider two significant cases. The first one shows the current climate conditions. This one corresponds to a 0.8ºC global warming above the pre-industrial level (7). The second one starts from the equation (8) where the temperature is 0.028ºC which is 28.5 times less than the first one.

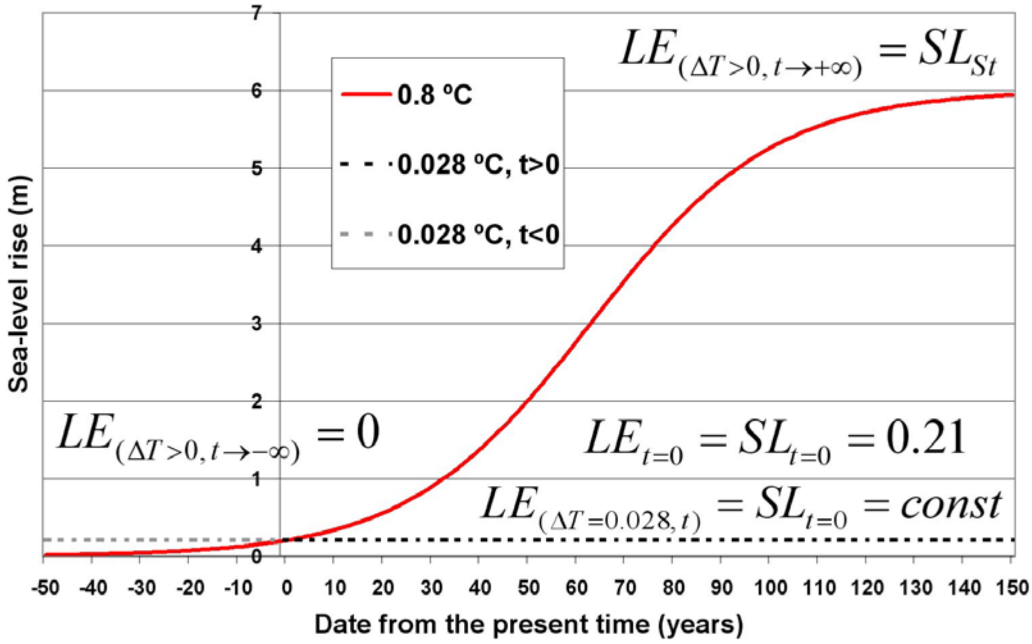

Figure 2. The future Sea level rise model based on logistic equation for the current climate conditions

Figure 2 shows that, maintaining global warming at the current value of 0.8ºC for 95 years will increase the sea level to +5 m level. This value fits well with Hansen's prognosis (Hansen J.E., 2007). Furthermore, during a 150 years relaxation time it will reach +6 meters.

If global warming could reduce of 28.5 times (equation (8)) to the value of 0.028ºC, the sea level would stabilize to 0.21 meter which is represented by the black dotted line for t>0, on Figure 2. The grey dotted line for t<0 (Figure 2) is only virtual because time does not reverse. The above optimistic scenario is not realistic because the EU Strategy on adaptation to climate change aims at stabilizing to global warming 2ºC.

We discuss now this widespread assumption. Then, if Earth's average temperature increases to 2 ºC above the prior industrial era, this will lead to an inevitable rise of the global sea level by +15 meters according our logistic model. In the current time, we have no data to estimate the relaxation time for reaching this sea-level.

However, we can conceive three possible scenarios:

- The relaxation time does not change;
- It will happen faster or,
- It will take more time.

How fast such catastrophic changes in the Earth's climate can occur? If Hansen (2007) is right and if the rise of sea levels continues to double every 10 years that it seems reasonable expecting that the sea level will rise to a +5 meters level in 2100 compared to the preindustrial era level.

For the current climate conditions (global warming on 0.8ºC), the logistic equation (9) provides a solution according which, within the next 95 years, the sea level will rise up to +5m and stabilize at + m level within a 150 years relaxation time. If global warming reaches the 2ºC, then we dispose of three possible scenarios for a +15 meters sea level rise: the relaxation time does not change; it will happen faster or it will take more time. To answer this question we need new data on global warming and sea level rise.

The highest level of Pleistocene period sea-level rise was 9.8 m above the level before the industrial era. It means that we can fall in the next glacial period faster than reaching the limit to below 2ºC above pre-industrial level and corresponding for it sea-level increase of +15 m. In the millennium time scale the Global Warming and the Sea-level rise will provoke the next glacial period that starts with fast temperature falling down and the 7.5 m sea-level declining per 1ºC (equation 1) up to "zero" sea-level and after that accelerating 3.3 times to 24.79 m per 1ºC (equation 2). The new infrastructure should be adopted both for 2ºC higher temperatures as for the extreme low temperatures of the future glacial period.

Figures and Tables

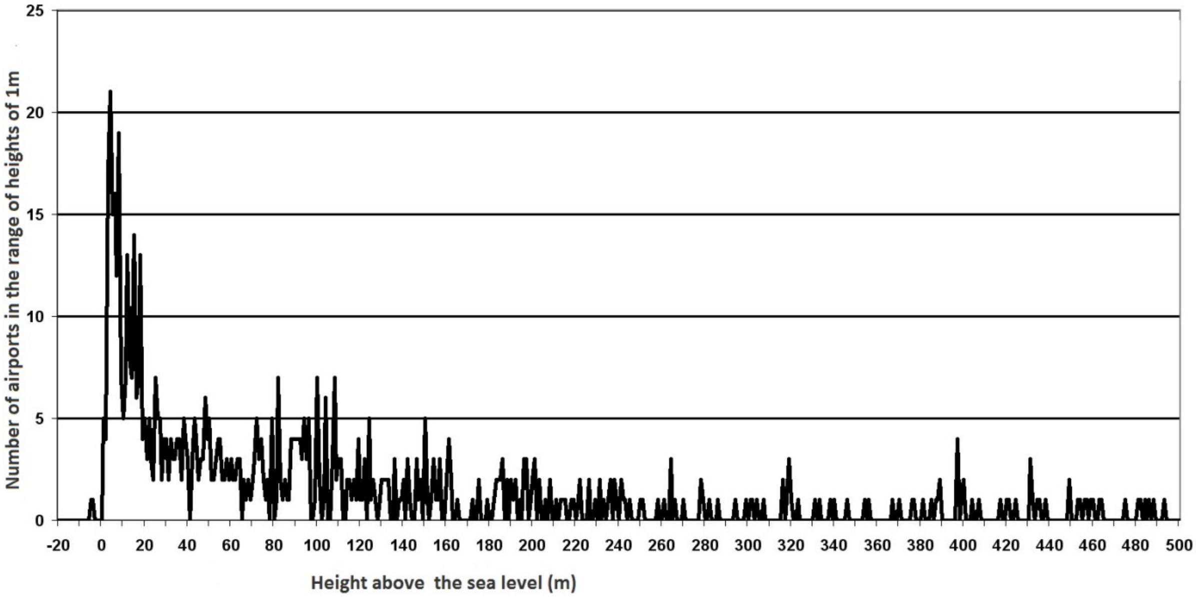

Figure1. Density (of the order of 1 m) of the distribution of the airports number from the level of the sea to beyond.

	Domestic air transportation	**International air transportation**	**All passengers on board**
Large airports	20,561%	67,292%	87,853%
Secondary airports	5,376%	6,349%	11,725%
Small airports	0,026%	0,017%	0,042%
Closed	0,005%	0,001%	0,006%
No data	0,031%	0,343%	0,374%
Total	25,998%	74,002%	100,000%

Table 1: Transportation of passengers in the European Union for the year 2013.
Sources: Compilation by the authors of data Eurostat.

	Domestic air transportation	**International air transportation**	**All freight and mail on board**
Large airports	5,713%	89,961%	95,674%
Secondary airports	1,104%	2,949%	4,052%
Small airports	0,007%	0,000%	0,008%
Closed	0,000%	0,000%	0,000%
No data	0,011%	0,255%	0,266%
Total	6,835%	93,165%	100,000%

Table 2 : Freight and mail in the European Union in 2013. Sources: data Eurostat.
Sources: Compilation by the authors of data Eurostat.

Climat		Airports			Flights	Passengers			Cargo and mail		
Global Warming Temperature (ºC)	Future Sea Level Rise (m)	The number of airports in a range of heights 1 m	The number of airports below sea level	Airports (%)	Flights (%)	All passengers on board (%)	Domestic airlines (%)	International airlines (%)	Freight and mail on board (%)	Domestic freight (%)	International freight (%)
0,00	0	0	2	0.2%	3.1%	3.5%	0.0%	3.4%	9.9%	0.0%	9.9%
0,13	1	5	7	0.8%	3.1%	3.5%	0.0%	3.4%	9.9%	0.0%	9.9%
0,27	2	4	11	1.3%	3.4%	3.9%	0.1%	3.8%	10.0%	0.0%	10.0%
0,40	3	17	28	3.2%	4.4%	4.8%	0.3%	4.5%	10.4%	0.0%	10.4%
0,53	4	21	49	5.7%	8.0%	8.3%	1.5%	6.8%	11.6%	0.2%	11.3%
0,67	5	15	64	7.4%	11.0%	11.2%	2.6%	8.6%	12.6%	0.4%	12.2%
0,80	6	16	80	9.2%	13.9%	13.6%	3.1%	10.5%	13.6%	0.5%	13.1%
0,93	7	12	92	10.6%	14.6%	14.4%	3.4%	11.0%	13.7%	0.5%	13.2%
1,07	8	19	111	12.8%	16.1%	15.9%	4.0%	11.9%	13.9%	0.7%	13.2%
1,20	9	7	118	13.6%	17.6%	17.7%	4.5%	13.2%	14.0%	0.7%	13.3%
1,33	10	5	123	14.2%	17.9%	17.8%	4.7%	13.2%	14.0%	0.8%	13.3%
1,47	11	7	130	15.0%	18.7%	18.3%	4.8%	13.5%	14.4%	0.8%	13.6%
1,60	12	13	143	16.5%	19.6%	19.1%	5.3%	13.8%	14.5%	0.9%	13.6%
1,73	13	8	151	17.5%	20.0%	19.4%	5.4%	13.9%	14.6%	0.9%	13.6%
1,87	14	7	158	18.3%	20.2%	19.5%	5.5%	14.0%	14.6%	0.9%	13.6%
2,00	15	14	172	19.9%	21.4%	20.4%	5.9%	14.5%	14.7%	1.1%	13.7%
2,13	16	6	178	20.6%	21.6%	20.4%	6.0%	14.5%	14.7%	1.1%	13.7%
2,27	17	7	185	21.4%	23.3%	22.2%	6.4%	15.8%	14.9%	1.1%	13.8%
2,40	18	13	198	22.9%	24.0%	22.8%	6.7%	16.1%	15.0%	1.1%	13.8%
2,53	19	4	202	23.4%	24.0%	22.8%	6.8%	16.1%	15.0%	1.1%	13.8%
2,67	20	5	207	23.9%	24.7%	23.5%	7.3%	16.2%	15.0%	1.1%	13.9%
2,80	21	3	210	24.3%	24.8%	23.7%	7.4%	16.3%	15.2%	1.3%	14.0%
2,93	22	5	215	24.9%	25.0%	23.8%	7.5%	16.3%	15.2%	1.3%	14.0%
3,07	23	3	218	25.2%	25.8%	24.6%	7.7%	16.9%	15.6%	1.5%	14.1%
3,20	24	2	220	25.4%	26.4%	25.2%	7.9%	17.3%	15.7%	1.6%	14.1%
3,33	25	7	227	26.2%	26.9%	25.6%	8.0%	17.6%	15.7%	1.6%	14.2%
4,00	30	4	247	28.6%	31.2%	31.1%	8.8%	22.3%	25.4%	1.6%	23.8%
4,67	35	4	263	30.4%	31.9%	31.8%	9.1%	22.6%	25.5%	1.7%	23.8%
5,33	40	3	281	32.5%	34.5%	34.1%	9.9%	24.2%	26.1%	1.8%	24.3%
6,00	45	2	295	34.1%	39.4%	38.7%	11.0%	27.6%	27.4%	2.1%	25.3%
6,67	50	5	316	36.5%	43.3%	42.9%	12.5%	30.4%	27.6%	2.2%	25.4%
7,33	55	4	331	38.3%	46.7%	46.7%	13.5%	33.2%	29.3%	2.3%	27.0%
8,00	60	3	343	39.7%	48.6%	48.4%	13.6%	34.8%	32.0%	2.4%	29.6%
8,67	65	0	353	40.8%	50.8%	51.2%	13.9%	37.3%	32.6%	2.4%	30.2%

Table 3: Data from the logistic model and impact of the increase of the sea level on the reduction of the flow of passengers, freight and mail in the EU.
Source: compiled by the authors according to Eurostat and database airports.

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