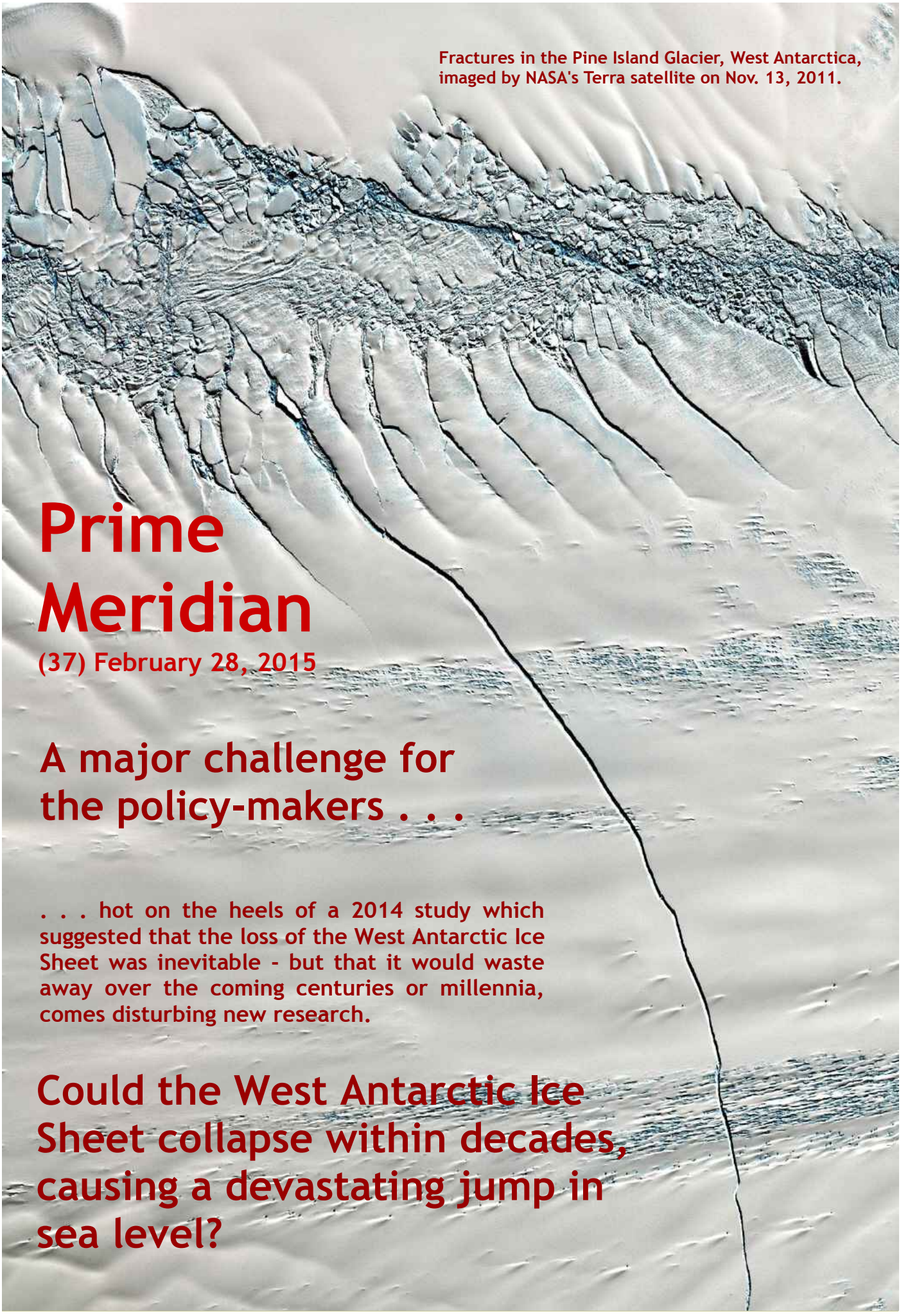


Fractures in the Pine Island Glacier, West Antarctica, imaged by NASA's Terra satellite on Nov. 13, 2011.

Prime Meridian

(37) February 28, 2015

A major challenge for the policy-makers . . .

. . . hot on the heels of a 2014 study which suggested that the loss of the West Antarctic Ice Sheet was inevitable - but that it would waste away over the coming centuries or millennia, comes disturbing new research.

Could the West Antarctic Ice Sheet collapse within decades, causing a devastating jump in sea level?

Above: A rocky outcrop in the vicinity of the Fleming Glacier, West Antarctica, photographed during NASA's Operation Ice Bridge on Nov. 16, 2014. NASA/Michael Studinger.

A paper from three scientists in the USA, David Pollard (Pennsylvania State University) Robert M DeConto (University of Massachusetts) and Richard B. Alley (Pennsylvania State University) in *Earth and Planetary Science Letters* (published online Jan. 6, 2015), has raised the alarming possibility that the loss of Antarctic ice due to global warming and resulting sea level rise could be very much faster than has been supposed.

They pointed out that sea level has risen and fallen on time-scales from a thousand to a million years over the last 25 million years and, at times, it has stood over 20 m higher than its present level.

Such rapid changes in sea level can only be explained in terms of the build up and melting of our planet's great ice sheets - and that has direct implications for how vulnerable they are to warmer climates.

Potential sources of sea level rise. Left (from top): Greenland - re-frozen melt-water ponds in E. Greenland photographed from a NASA research aircraft in 2013 (NASA/Michael Studinger). West Antarctica - Thwaites Glacier, which enters the Amundsen Sea at Pine Island Bay, 2014 (NASA). Ice Dome C, 1,100 km from the sea in East Antarctica, 2004 (Stephen Hudson, CC BY 2.5).

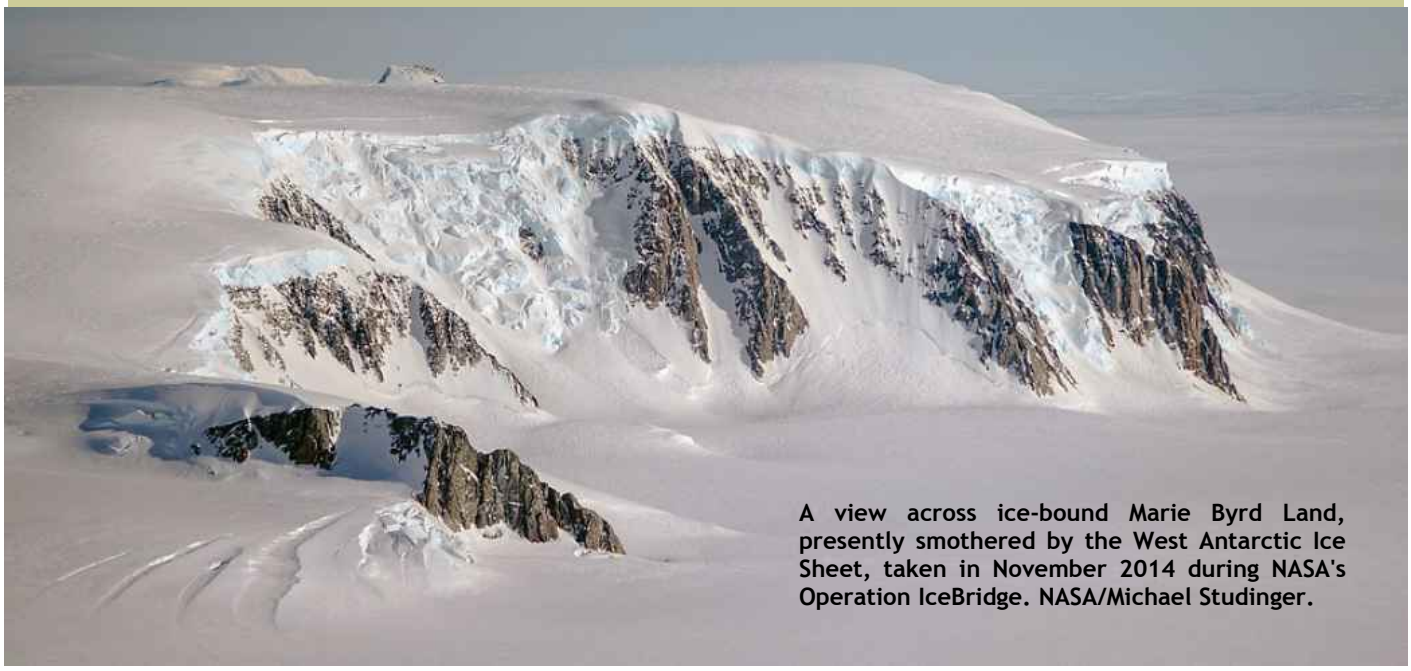
Are Antarctica's great ice sheets much more vulnerable than widely supposed?

During previous warm spells between ice ages, shrinkage of the Greenland ice sheet has probably caused a sea level rise of 2.0 m, but even if it melted completely it would probably contribute a maximum of 7.3 m. Total melting of the West Antarctic Ice Sheet would contribute around 3.3 m to global sea level rise. The only way to produce a sea level around 20 m higher than today's is through major changes, up to 20 to 30%, in the volume of the East Antarctic Ice Sheet, but this has been hard to explain using climate simulations. Instead, doubling present CO_2 warms the atmosphere and this causes more snowfall, which means that the ice sheet over East Antarctica actually grows (Vizcaino *et al.*, 2010; Ligtenberg *et al.*, 2013). Pollard's team looked at processes which might speed up ice loss. They highlighted masses of ice shearing from the tops of ice cliffs, which would be encouraged by hydraulic fracturing caused by melt-water and rainfall entering crevasses in the ice. Once these mechanisms come into the picture, it appears that the West Antarctic Ice Sheet could be seriously depleted during this present Century.

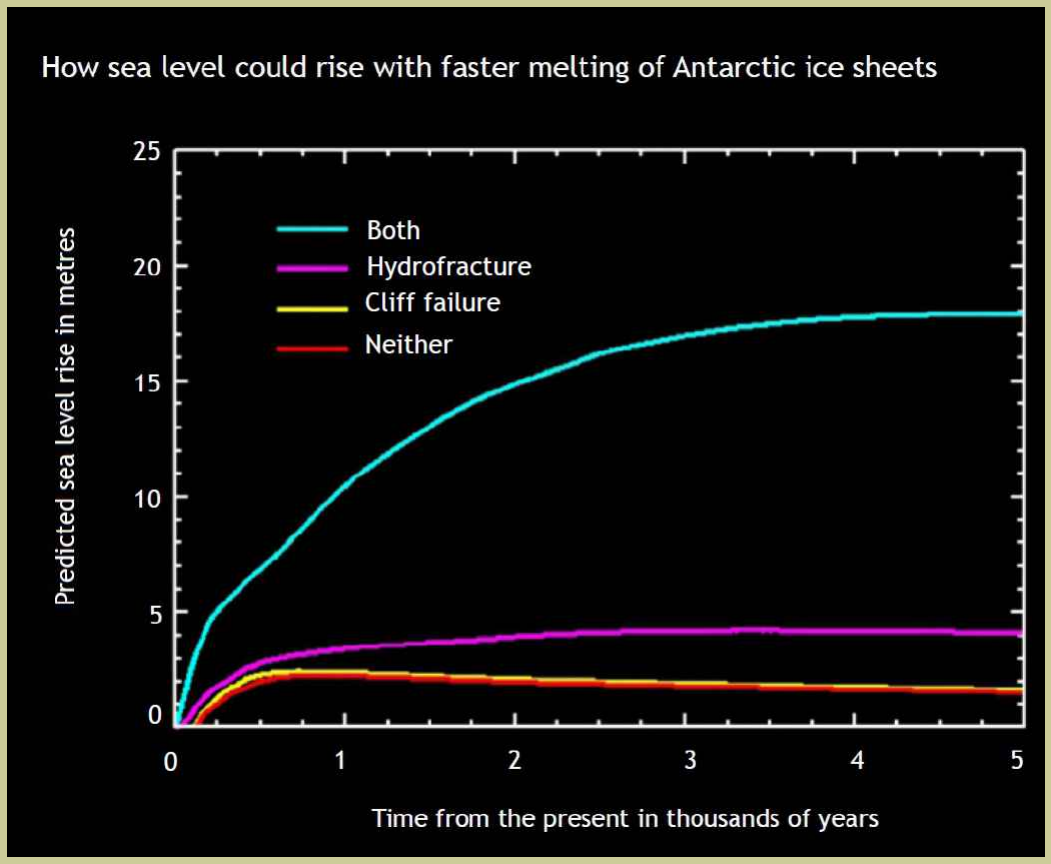
Pollard *et al.* (2015, p. 116) explained that in their model: "*melt-driven hydrofracturing and cliff failure cause a very rapid collapse of West Antarctic ice, on the order of decades. This is followed by retreat of East Antarctic basins within several hundred to a few thousand years. The total Antarctic ice loss corresponds to ~+17 m sea-level rise, in good agreement with high stands in geologic sea-level records*"

Pollard and his colleagues noted uncertainties in their analysis. They assumed that the ancient sea level indicators had not been displaced upwards by geological processes, giving a false impression of higher past sea levels. Also (p.117): "*this preliminary study does not include several feedback processes that could reduce the drastic retreat rates found here, such as clogging of seaways by ice mélange, and ice-ocean gravitational interaction . . . But if the geologic sea-level data and our model simulations are even approximately realistic, the mechanisms described here offer an explanation for past high sea-level stands, and suggest that East Antarctic subglacial basins may be more vulnerable than in most previous models.*"

Last year, Eric Rignot of the University of California at Irvine was lead author on a paper which indicated that the loss of ice from West Antarctica was probably beyond the point of no return. Readers may remember his statement, reproduced in PM 29 (August 20, 2014) that: *"A conservative estimate is it could take several centuries for all of the ice to flow into the sea.*" Now, we have to think about more dramatic possibilities. If anyone took the recent words of travel writer Jonathan Thompson in the METRO (one of London's free newspapers) as alarmist, the new work should give them pause for thought. He wrote: "*If there's one destination you need to see before it changes irrevocably, it's Antarctica. . . . The ice is retreating, the food chain is fraying. Now a new race has begun: to see the Earth's last great wilderness in all its frozen glory before it melts away.*"



A view across ice-bound Marie Byrd Land, presently smothered by the West Antarctic Ice Sheet, taken in November 2014 during NASA's Operation IceBridge. NASA/Michael Studinger.



The diagram above is modified after Fig. 4 of Pollard *et al*. (2015). It shows the contribution of ongoing melting of the Antarctic ice sheets to future sea level rise (ignoring other sources of sea level rise). Note that by the year 2100, the estimated contribution of Antarctica to sea level will be over 2.5 m).

The East Antarctic Ice Sheet has previously seemed to be much more resilient to climate change than the West Antarctic Ice Sheet. It first spread to continental proportions million years ago, at the boundary between the Eocene and Oligocene (presently estimated at 33.9 million years ago; Cohen *et al*., 2013), and climate models indicated that extreme conditions would be needed in the future in order to see it melting back drastically.

Pollard and co-workers noted (p. 113): "*The atmospheric warming necessary to produce substantial retreat from continental size in previous ice-climate model simulations is considerable, ~ 15 to 20°C (Huybrechts, 1993) or atmospheric CO_2 levels of ~ 4 × to 9 × PAL (Preindustrial Atmospheric Level, 280 ppmv) (Pollard and DeConto, 2005).*"

These studies, however, did not take into account loss of ice shelves buttressing the continental ice sheets and deep hydraulic fracturing, which, as Pollard and his colleagues discussed, could make cliff collapse much more likely.

The new study, which assumed a uniform rise in ocean temperature of 2°C, predicted that the front of the ice would "*retreat deep into the major East Antarctic basins within a few thousand years*. " After the first 200 years, the amount of water from the melting ice sheets would be sufficient to raise sea level by 5 m. After 3,000 years, sea level could have risen by 17 m.

This work has shed new light upon our understanding of both the geological past and our possible future. It warns us that our predictions about climate change will have to continue to adjust as scientific knowledge advances. This means that policy-makers are going to have to develop responses that are both flexible and effective - no mean feat.

As the loss of the unique habitat of Antarctica unfolds, rising sea levels will prove hazardous in lower-lying regions around the world.

If Pollard and colleagues are correct, then policy-makers, whose job is to protect human communities are facing a serious challenge. For the global community, particularly poor countries, to devote many billions of pounds to raise coastal defences to protect low lying areas would be a huge undertaking in its own right - but the challenge is compounded by the fact that we cannot know for certain exactly what is going to happen to sea levels, which may rise several metres higher than has been supposed during coming decades.

Left: Annotated NASA image of Bangladesh and adjacent countries.

Bangladesh is a well-known example of a country for which the rising waves already threaten national catastrophe.

The country (total population exceeding 156 million) lies at the confluence of the deltas of the Ganges, Brahmaputra and Meghna Rivers. Back in the last decade, climate specialist John Houghton warned (2009, p. 182): "A*bout half of the country's habitable land (with about 6 million population) would be lost with half a metre of sea level rise and about 20% (with about 15 million population) would be lost with a 1-m rise*."

Estimates of sea level rise by 2050 included 70 cm subsidence due to land movements and the extraction of groundwater and 30 cm from global warming. There would be nearly 2 m sea level rise by 21000. Of this 1.2 m would be due to subsidence with 0.7 m from global warming. Rising sea levels would mean increasing vulnerability to high seas associated with storm surges. It is not only flooding that is damaging, however, because as sea level rises, there is increased intrusion salt water into fresh groundwater reservoirs.

Houghton noted that the fishing industry could relocate, but (p. 184): "*It is less easy to see what the population of the affected agricultural areas can do to relocate or to adapt. No significant areas of agricultural land are available elsewhere in Bangladesh to replace that lost to the sea, nor is there anywhere else in Bangladesh where the population of the delta region can be easily located*."

Last year, a study by S. Jevrejeva of the National Oceanography Centre, Liverpool, UK and co-workers concluded (tentatively) that the chances of sea level rise exceeding 1.8 m by 2100 were 5%. The new work by Pollard and colleagues undermines certainty about sea level rise and confronts policy-makers with a need to act decisively, but also with flexibility. The contribution of melt water from the West Antarctic Ice Sheet needs to be taken into account, but how high and how fast sea level will rise, how many millions of people will be displaced and how and where they could find new homes are open questions. The melting of the West Antarctic Ice Sheet on a time-scale of decades would exacerbate a looming humanitarian crisis.

References: Cohen, K. M. *et al*. (2013, updated). The ICS International Chronostratigraphic Chart. *Episodes* 36: 199-204. **Houghton, J. (2009).** G*lobal Warming the complete briefing*. 4th Edition. Cambridge, UK: Cambridge University Press. **Huybrechts, P. (1993).** *Geogr. Ann.* 75A: 221–238. **Jevrejeva, S. *et al*. (2014).** ***Environ. Res. Lett.*** **9** (2014) 104008 (9pp). **Ligtenberg, S.R.M. *et al*. (2013).** *Clim. Dyn.* 41: 867–884. **Pollard, D. & DeConto, R.M. (2005).** *Glob. Planet. Change* 45: 9–21. **Pollard, D. *et al*. (2015).** *Earth and Planetary Science Letters* 412**: 112-121. Rignot, E. *et al*. (2014).** *Geophysics Research Letters* Article first published online: 27 MAY 2014. DOI: 10.1002/2014GL060140. **Thompson, J, (2015).** The end of a world as we know it. *METRO* Monday, February 23, 2015, p. 41. **Vizcaino, M. *et al*. (2010).** *Clim. Dyn.* 34,:301–324.

Rising sea levels are not an issue for the developing world alone. They will impinge upon many regions of economic and historic importance in the developed world.

The faster and the higher that sea levels rise, the more urgent will become the task of finding an answer.

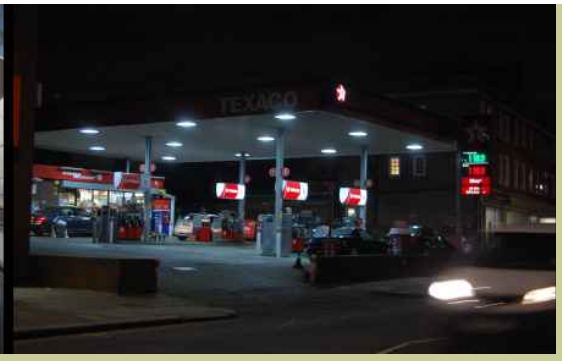
Will we, over coming decades, have to accept that we have no realistic option but to surrender these locations? Will we find ourselves in a world, familiar from futurist fiction, of ruining sky scrapers and world-famous historic buildings rising from the sea? In reality, we would lose areas as soon as irreparable flood damage to buildings' structural integrity or to underground services (water, electricity, communications cables, gas, sewers and transport) became unavoidable - long before the sea were lapping anywhere near a picturesque 20 m mark.

The gauntlet lies at the policy-makers' feet.

Top: The Thames Barrier, looking across from the north bank of the Thames to New Charlton on the southern bank.

At right we see London's Shard, with the financial district across the Thames; Venice Grand Canal and Rialto Bridge; Boston's financial district and flooding in Manhattan's Avenue C, caused by hurricane Sandy in October 2012.





Energy intensive London: the lights are on, public transport is serving a city of 8.6 million people (roughly 1/850 the total population of the planet) and the fuel is flowing from roadside petrol pumps.

A positive message from KCL climate change discussion.



A February 18 event staged on the Guys Campus of Kings College London by chaplain Rev Stephen Stavrou brought together three eminent Christian speakers to share their perspectives. They were the Rev Professor Bernard Silverman Chief Scientific Advisor to the Home Office (top right) Mike Hulme, Professor of Climate and Culture (centre right), and Brother Samuel, a Franciscan Friar (lower right).

Prof Silverman noted an opinion that we are presently passing from the Holocene (the 11,700 years since the end of the last ice age) into the Anthropocene (a time when human activity is a dominant force in the Earth environment). He remarked, "*We **have** conquered the planet, that's the trouble*." Because the full impacts of climate change will be felt by future generations, they can only appear as less than real to us. In that sense, we all share something of the outlook of climate change deniers.

Prof Hulme considered that there was no avoiding the "*intractable politics of climate change*" and highlighted the need to recognise the cultural differences of particular communities if we are to explain the issue effectively.

Brother Samuel stressed that *"Climate change is a moral, ethical indeed, a spiritual challenge*" and that it required solutions in those terms. His community in Dorset attempted to live as an integral part of the environment.

One central concern of the editorial team of this newsletter is the dilemma arising from the fact that the very processes that sustain our civilisation and allow us to reap its benefits also threaten to undermine it. Another is the failure of the policy makers to have plotted a realistic road map out of our present situation in which nations are apparently incapable of extricating themselves from hydrocarbon dependence.

Hulme responded to my comments that the narrative must not to be purely negative, nor focus exclusively on CO_2 emissions without reference to the positive achievements of civilisation; increasing the affluence, education and medical support for huge numbers of people. He was correct. Some environmentalism is destructively negative.

Readers of this newsletter will be aware that my colleagues and I are motivated by a concern that civilisation, which has taken thousands of years to develop, and which presently supports billions of human lives, is an enterprise worth fighting for. Hulme's comments reminded me that there is a need to place that message more clearly and explicitly at the forefront of what we are saying.

Developing a relevant narrative will be essential if we campaigners are to assert any useful influence over policy makers and the public and encourage the development of a road map for safeguarding human communities and their cultural heritage.

Martin Heath, Editor.

Left: Rev Stavrou introduces the panel.

This newsletter follows global environmental issues alongside the cycle of the seasons in South East England, and we shall be looking at the opening of 2015 in the next issue of PM. We have been passing through the months of chilly weather and sere hedgerows, but here and there, even in January, one could find, on a grassy bank, the flowers of an early primrose, or a lesser celandine, and by the end of February, the green shoots of bluebells were raising themselves through the leaf litter covering the woodland floor.

At top we see a hedgerow near West Kingsdown, Kent, on Jan.31. Apart from brambles and ivy, the green of new shoots was almost entirely absent. The red shoots are of dogwood. Above left, we see another stretch of hedgerow in the same area, on Feb. 28, with the bare branches of a beech tree against an overcast of low cloud, beneath which cold and wintry drizzle was spattering.

Editor M. J. Heath. Editorial assistance, Penelope Stanford.

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