The Antarctic Peninsula: A canary in a coal mine?

- A region of rapid environmental change
  - Biological
  - Environmental
  - Glaciological
  - Ice shelf collapse
  - Speed up of outlet glaciers
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This region has warmed by 2.5°C in the last 50 years (much more than the global average), with a striking consequential change in winter sea-ice cover.

Winter sea ice breaking up on the Northern Antarctic Peninsula. Note the Weddell Seal lying on the sea ice, and the ponds and pressure ridges on the surface.

Measured and predicted global average temperatures based on IPPC estimates.
• Over the Southern Ocean the pressure pattern and prevailing winds are undisturbed by land

• The result is the vast clockwise circulation of the Antarctic Circumpolar Current

• Because there is a net surface transport to the left (in the southern hemisphere) of the winds, the low pressure regions around Antarctica are zones of upwelling
Recently Global Environmental Change

Ice and climate: a view from space

Krill numbers may have dropped by as much as 80% since the 1970's - so today's stocks are a mere 1/5th of what they were only 30 years ago. The decline in krill may in turn account for the decline in the numbers of some penguin species.

The Antarctic Peninsula, a key breeding ground for the krill, is one of the places in the world where there has been the greatest rise in temperatures due to global warming. Although not fully understood there is clearly a relationship between warming and reduction in krill stocks. This is critical as krill forms the basis of the food chain in Antarctica and The southern ocean.

Biological Implications

The Antarctic Peninsula has many ice free areas, and seasonally becomes one of the most biologically diverse parts of Antarctica. However, in recent years changes have suggested that this system is under stress from environmental factors.

Some suggest this is due to climate change, whilst other suggest it potentially may result from fishing activities in the southern ocean. However, what ever the cause there is no doubt that something is affecting the one key species in the Antarctic food web: Krill.

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Although not unique to Antarctica as they occur in the Arctic too, much of Antarctica is fringed by ice shelves, and calving from these is the principal mechanism of ablation of the Antarctic Ice Sheets where there is little or no direct melting. The Peninsula has many such
Ice shelves are critical to the Antarctic Ice sheet system. They exist where influx from the ice sheets is sufficient to flow off shore and into the surrounding ocean. Initially this ice is grounded to the sea floor, however once in deeper water the ice begins to float due to the unique physical properties of water. The thickness of an ice shelf will vary due to several factors. Can you think what these are?

Ice shelves can also accrete (and get thicker) due to basal freezing and addition of new ice in the form of snow.
Flying over George VI Ice Shelf, formed between The Antarctic Peninsula and Alexander Island. The surface is covered in large melt pools.
In 2002 the large Larsen B Ice Shelf broke up. This event was spectacularly recorded by NASA's MODIS satellite, revealing the 3,250 square kilometre ice shelf breaking up over a 35-day period from January 31st to March 5th.

Although not the first major ice shelf to break up this was seen as evidence of the effects of global warming as predicted by scientists as early as the 1970's.
“One of the warning signs that a dangerous warming trend is under way in Antarctica will be the breakup of ice shelves on both coasts of the Antarctic Peninsula, starting with the northernmost and extending gradually southward.”

Concluding statement in Mercer (1978)

We are now seeing instability in ice shelves steadily migrating south down the length of the Antarctic Peninsula, echoing Mercer’s predictions.
Monitoring Ice Shelf thinning and collapse

- Traditionally very difficult due to scale and remote locations
- Past records from repeat aerial photography / ship or ground survey
- Satellite Remote Sensing provides a unique viewpoint on this question
- Able to record:
  - Geographic extent (visible / NIR Infrared)
  - Thickness (from laser / RADAR altimetry)
  - Motion (InSAR)

These techniques have demonstrated remarkable thinning of ice shelves surrounding the peninsula over the past decade. These observations have also demonstrated that following loss of the ice shelves the glaciers that fed them have accelerated and thinned.

Cross section of the grounding line between an ice sheet and an ice shelf at the point where the water depth is sufficient to cause the ice to float. Rapid calving of these floating 'ice tongues' leads to rapid draw down of the ice sheet and thus velocity increases.
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- Ice shelf disintegration appears to be correlated with air temperatures.
- When the surface becomes warm enough to melt in summer the ice shelf becomes unstable.
- South of the line of stability thinning has been observed. This may have an oceanic origin.
Larsen ice shelf surface has lowered by 30 cm yr$^{-1}$

Satellite altimetry has shown that even south of the -9°C isotherm that rapid thinning is occurring. It is suggested this is down to basal melting of the ice shelf due to potential ocean warming.
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Although the collapse of ice shelves do not lead directly to sea level rise, as this ice is already floating, it does lead to important regional changes in the ice feeding the shelf system. Destruction of an ice shelf by surface or basal melting leads to rapid velocity increases in the glacial system feeding the ice shelf as the buttressing effect of the ice shelf is lost.

This leads to reduced friction at the base and flow increase and a non-linear response. Sudden changes in friction can also be caused when the glacier passes pinning points, topographic obstacles which allow the glacier to stabilise until new buoyancy thresholds are pasted. This process has been recorded in detail from satellite based observations around the periphery of the former Larsen B embayment. Rignot et al., GRL, 2004