Antarctic Climate Change and the Environment

Key Findings

The Antarctic is a critically important part of the Earth system. The climate, physical and biological properties of the continent and the surrounding ocean are closely coupled to other parts of the global environment through both ocean and atmosphere circulation and CO_2 exchange. Antarctica contains 90% of the world's ice and 70% of the world's fresh water, which is enough to raise sea level by 63 m. It also holds high resolution records of past climate change and sensitive biological indicators of contemporary change. The Antarctic 'ozone hole' was one of the most significant scientific discoveries of the last century and it has had a profound impact on the Antarctic environment.

1. FOR THE LAST 30 YEARS THE OZONE HOLE HAS SHIELDED THE BULK OF THE ANTARCTIC FROM THE EFFECTS OF 'GLOBAL WARMING'
    a. The loss of stratospheric ozone has intensified the polar vortex, a ring of winds around the South Pole, altered weather patterns around the continent, and increased westerly winds by about 15% over the Southern Ocean in summer and autumn.
    b. This has resulted in the Antarctic becoming more isolated and there being little change in surface temperature across the bulk of the continent over the last 30 years.
    c. There has been no significant change in snowfall across the Antarctic as a whole over the last 50 years, although snowfall has increased across the Antarctic Peninsula.
    d. The Peninsula is affected by the stronger westerlies and these have given rise to a large summer warming on its eastern side.
    e. The loss of stratospheric ozone has increased biologically harmful UV-B radiation at the Earth's surface.

2. THE SOUTHERN OCEAN IS WARMING – THE ECOSYSTEM WILL CHANGE
    a. The waters of the Antarctic Circumpolar Current (the largest ocean current on Earth) have warmed more rapidly than the global ocean as a whole.
    b. The Southern Ocean is one of the major sinks of atmospheric CO_2, but in recent decades it has become less effective in absorbing CO_2, because the increasing westerly winds have caused more upwelling of CO_2 rich water.
    c. Ecological key species (such as planktonic snails) are expected to be negatively affected by progressive ocean acidification, with cascading consequences through the ecosystem.
    d. If seawater temperatures continue to rise, species may be able to adapt, but they may become extinct if their physiological and ecological limits are exceeded.
    e. Increased seawater temperature may open the door to the immigration of a variety of "alien" species that are superior to local species in

competition and replace the original Antarctic inhabitants; the arrival of crabs would severely impact the current benthic ecosystem

f. The climate-induced shift in the food regime will lead to a decrease in the rich Antarctic seabed biodiversity.

3. THERE HAS BEEN RAPID EXPANSION OF PLANT COMMUNITIES ACROSS THE ANTARCTIC PENINSULA
    a. Along with higher temperatures, the Antarctic Peninsula has experience a marked switch from snowfall to rain during the summer.
    b. These linked changes have led to rapid expansion of plant communities and the colonisation of newly available land by plants and animals.
    c. In regions on land where there is greater availability of liquid water and higher temperatures, plant, animal and microbial communities will expand.
    d. Humans have inadvertently introduced alien organisms, including grasses, flies and bacteria.

4. PARTS OF THE ANTARCTIC ARE LOSING ICE AT A RAPID RATE
    a. There has been significant thinning of the West Antarctic Ice Sheet, especially around the Amundsen Sea Embayment, as well as a few smaller coastal areas in East Antarctica.
    b. The loss of ice shelves along the Antarctic Peninsula, such as the Larsen B Ice Shelf, is primarily a result of regional warming caused by intensification of the westerlies as result of the ozone hole.
    c. Ninety percent of glaciers across the Antarctic Peninsula have retreated over recent decades
    d. Beyond these areas the bulk of the Antarctic ice sheet has shown little change over recent decades.
    e. Ice shelf disintegration will cause the extinction of some benthic species, but others will colonise the newly exposed seabed in these areas.

5. SEA ICE HAS INCREASED IN EXTENT AROUND THE ANTARCTIC OVER THE LAST 30 YEARS AS A RESULT OF THE OZONE HOLE
    a. While sea ice extent across the Arctic Ocean has decreased markedly over recent decades, around the Antarctic it has *increased* by 10% since 1980, particularly in the Ross Sea region.
    b. This increase is a result of the stronger winds around the continent, changes in atmospheric circulation and the isolating effect of the ozone hole.
    c. In contrast, there has been a large regional decrease of sea ice to the west of the Antarctic Peninsula, because of changes in the local atmospheric circulation.

6. PALAEOCLIMATE STUDIES IN ANTARCTICA SHOW THE CURRENT SHOCK TO GLOBAL CLIMATE IS UNUSUAL
    a. Ice core studies show that atmospheric concentrations CO_2 and CH_4 are at high levels unprecedented in the last 800,000 years, and that

concentrations are increasing at rates that have probably not been seen in the geologically recent past

b. Geological records of deep time show that, previously, high atmospheric CO_2 levels have led to temperate climates, transient ice sheets, sea level changes in the order of tens of metres and out-gassing of methane hydrates
c. Antarctica was warmer than at present, in the last interglacial, about 130,000 years ago. Sea level was higher then, but the absolute contribution of West Antarctica to that rise is not yet known
d. Warm periods in the geological record of the last 11,000 years caused rapid loss of some ice masses, shifts in ocean circulation and enhanced biological production
e. Studies of sediments under newly lost ice shelves suggests that the recent ice shelf loss is unprecedented in the last several thousand years
f. Ice core studies show that atmospheric circulation patterns over Antarctica and the Southern Ocean, including the Amundsen Sea Low and the westerlies, have changed in intensity and position abruptly, on the order of years to decades, several times in the past 11,000 years.

7. MARINE ECOSYSTEM COMPONENTS, SUCH AS KRILL AND PENGUINS, LINKED TO THE SEA ICE SHOW A CLEAR RESPONSE TO CLIMATE CHANGE
    a. Due to the loss of sea ice west of the Peninsula, changes in algal growth are seen along with a shift from large to smaller species.
    b. As a consequence, stocks of krill (the shrimp-like key species in the Antarctic food web) have declined significantly.
    c. The distribution of Adélie penguins has changed with many populations on the northern Antarctic Peninsula declining due to a reduced period of sea-ice and prey species, whilst in the Ross Sea and East Antarctica populations are generally stable or increasing
    d. The consequences of historical harvesting reduce our ability to understand the impacts of climate change particularly on krill, seals and whales.
    e. It can be predicted that some whale species may not get the chance to continue to recover further from whaling if the krill population remains at a low level.

8. ASSUMING A DOUBLING OF GREENHOUSE GAS CONCENTRATIONS OVER THE NEXT CENTURY, ANTARCTICA IS EXPECTED TO WARM BY AROUND 3º C
    a. By the late Twenty First Century the ozone hole is predicted to heal, but at the same time greenhouse gases are expected to continue to increase.
    b. The net result is expected to be that winds will continue to increase across the Southern Ocean in most seasons.
    c. Sea ice extent around the continent is predicted to decrease by a third, which will lead to increased phytoplankton productivity.
    d. The predicted warming of around 3º C is not enough to cause melting across most of the ice sheet.

e. Snowfall will increase across the continent offsetting sea level rise by a few centimetres.

9. WEST ANTARCTICA COULD MAKE A MAJOR CONTRIBUTION TO SEA LEVEL RISE OVER THE NEXT CENTURY
    a. Loss of ice from the West Antarctic ice sheet is likely to contribute some tens of centimetres to global sea level by 2100.
    b. This is expected to contribute to a projected total sea level rise of up to 1.4 metres by 2100.

10. IMPROVED REPRESENTATION OF POLAR PROCESSES IS NEEDED IN MODELS TO PRODUCE BETTER PREDICTIONS
    a. Higher resolution global models, regional climate models, and ecosystem and ice sheet models are required.
    b. Climate models require better simulation of polar-specific processes, such as sea ice and the very stable atmospheric boundary layer.
    c. Climate variability in the polar regions is larger than in other parts of the world, and improved monitoring and more detailed understanding of past climate is needed in order to be able to discriminate natural variability from anthropogenic influences.
    d. There is an urgent need to establish marine and terrestrial biological baseline monitoring programmes set in the perspective of understanding past change, operating over decades, so as to establish firmly the links between physical and biological variability.
    e. There is a requirement for greater cross- and intra-disciplinary observational effort and modelling studies.