Antarctic Ice Sheet and Sea Level Rise

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Antarctica plays a critical role in the Earth's climate system on a wide variety of timescales and by many processes. These include driving of the ocean circulation, climate teleconnections and sea level changes. Antarctica's contribution towards sea level is determined by a delicate balance between snowfall, and loss mainly through ice sheets. Melting and iceberg calving account for about 90% of the loss, the remainder resulting from blowing snow from the continental land mass into the oceans (10%).

Ice sheet dynamics are governed mainly by the thickness of the ice, the slope and the friction at the base of the glacier. Flow rates over most of Antarctica are ~10 m per annum, but the streams draining the ~35 basins flow at more than 1 km/year. It is these ice streams that are responsible for most of the ice loss from Antarctica.

Antarctica has had a permanent ice sheet for the last 30M years since the opening of the Drake Passage and the establishment of a vigorous circumpolar current. Through the many glacial cycles the size of the Antarctic ice sheet has waxed and waned, with an increase in sea level since the last glacial maximum of ~120m.

Recent climate change shows a very rapid warming of the climate in the Antarctic Peninsula region (~2.5°) over the last 5 years. This is having a dramatic effect on the ice sheets in the region. Of the 400+ glaciers on the Peninsula over 75% have shown retreat. Major ice shelves have collapsed, these all lying to the north of the current 0°C summer isotherm. Whilst floating ice sheets do not contribute to sea level, new research has demonstrated that virtually all glaciers that feed these ice shelves have accelerated by a factor of two to six after collapse. Present estimates suggest that the Peninsula is contributing ~0.06mm/year to sea level rise.

Much of the West Antarctic Ice Sheet (WAIS) lies below sea level and as a result is much more likely to rapid disintegration and melting that elsewhere. In recent years, the area in the Pine Island Basin has shown the most rapid changes compared with anywhere else in Antarctica. This rapid thinning of the ice sheet is equivalent to 0.24 mm/y sea level increase.

The cause of the rapid changes of the WAIS is not understood. Competing theories suggest the changes are due to ocean circulation or may result from internal dynamics of the ice sheet. Whilst present computer models are becoming much more sophisticated and now contain the key processes, they cannot yet reproduce the full range of observations.

There is now a significant focus of research in the WAIS area using a wide range of approaches. There is continual monitoring of change by satellite. This will be further enhanced with the imminent launch of ESA's Cryosat mission. This austral summer, there has been a major field campaign jointly between the USA and the UK. They used ground-based observations and remote sensing from planes to determine the thickness, topography, velocity, and basal conditions of the region.

East Antarctic is by far the largest area covered by ice (~60m equivalent sea level), but it is showing little sign of change.

The Inter-Governmental Panel on Climate Change (2001) indicated that Antarctica would not contribute much to sea level change over the next century. It suggested that any increased melting would be offset by additional precipitation. However research in the last 5 years has indicated that the combination of the Peninsula warming and the rapid thinning of the Pine Island area of the West Antarctic Ice Sheet are contributing ~0.3 mm/year, which are not offset by increased accumulation. The nest steps are to improve these quantitative estimates, and to understand the processes causing the rapid changes in the WAIS. This will allow more accurate predictions of the future impact of Antarctica on sea level and then address if there are any "critical" thresholds, such as ice shelf viability, that would cause rapid collapse of the WAIS. The International Polar Year (IPY) will provide a further impetus to deepen understanding of ice sheet processes and their linkages to global sea level and to climate.