Oceanographic regime of the West Antarctic Ice Shelves

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1. Forcing on continental shelf water temperatures

a) Atmospheric forcing in Southern Oceans (without continental obstacles)

Mechanism:
Surface pressure => Surface winds => Westerlies and Easterlies => Ekman transport => Divergence => Upwelling (in particular Circumpolar Deep Water - CDW - upwelling) => modification of shelf waters.

b) What happens in the Weddell and Ross seas?

- Steep topographic gradients drive katabatic wind direction (funnel) forcing continuously northward transport of ice sea.
- The inflowing waters from the east are cooled by mixing at the shelf edge.
- Water is cooled to the surface freezing point and sea ice growing raises the salinity.
- Melting occurs beneath the ice shelves because pressure lowers the freezing point => Ice Shelf Water (ISW, T< -1.9°C).
- Dense waters flowing off the shelf form Antarctic Bottom Water.

c) What happens in the Amudsen and Bellinghausen seas?

- Weaker topographic gradients => weaker atmospheric forcing.
- Inflow into the ice-shelf.
- Only the surface layers are close to the freezing point.
- Almost unmodified CDW survives because either warmer CDW comes on shelf and/or less sea ice forms.
- Ice shelf melt rates are much higher and no ISW or AABW forms.

2. Ice-ocean interaction in the Ross and Weddell seas

- Melting drives the mixed layer along the ice shelf base.
- The strongest depth-mean flows follow routes of constant f/H => warm (-1.9°C) inflow to the deepest parts of the cavity.
- Tides determine the turbulent transport of heat to the ice shelf base.
- Most meltwater exits the cavity at depth in the form of ISW.
- Some ISW contribute to AABW formation.
- Analogous processes take place in the Ross Sea but with a slighter production of ISW.

3. Ice-ocean interac in the Amundsen Sea

Two major differences with the previous type of ice shelf:
1. The continental shelf is flooded of Circumpolar Deep Water (system of troughs seems to be guiding CDW under the ice shelves)
2. Melting rates are much higher (20m/yr for Pine Island Glacier)

But we also observe a seasonal, inter-annual and decadale scale variability of the ocean forcing due to wind forcing.

Westerly winds drive the inflows of CDW and the position of the westerlies does vary. So the inflow of CDW under the ice shelves vary in strength depending on the position of the winds.

The decadal variability is due to atmospheric circulation:

- Southern annular mode
- El Niño Southern Oscillations

<u>4. Autosub 3 under Pine Island Glacier</u>

Autonomous Underwater Vehicle designed to go under ice shelves
It is equipped with an echosounder to map the seabed and a CTD to measure changes in salinity and temperature

The british Antarctic Survey used it to map the seabed and PIG in order to try to better understand its behavior.
PIG (in west Antarctica) has been thinning and accelerating steadily since at least the 70s and the mechanism which lead to this thinning is still not well understood.

Contrary to what they expected, the sea bed was far from flat and the ice shelf base full of deep crevasses (and this is how they almost lost it: the submarine could not find its way back).

Very interesting finding: they found a 300m high ridge under the ice shelf, which seems to be a significant barrier to CDW (Circumpolar Deep Water).

On the crest of the ridge, they found lineations parallel to the ice front which indicates that the ice shelf was in contact with the ridge in the past.

This ridge could have been an old morraine and then a pinnig point or ice rise that stabilized PIG. We can see that in 1973, the ice shelf seemed to be pushed upward by the bed topography.

PIG current acceleration could be part of a longer term change that was already underway in the 1970s.
By thinning, the shelf detached from the bed, which started its unstable phase:
1) less basal resistance
2) A widening of the gap between the ice shelf and the ridge.

This widening allowed the warm water to penetrate under the ice shelf and increased the melting of the ice shelf base.