Ice Sheets and Flying Buttresses

Why it is so hard to predict ice;

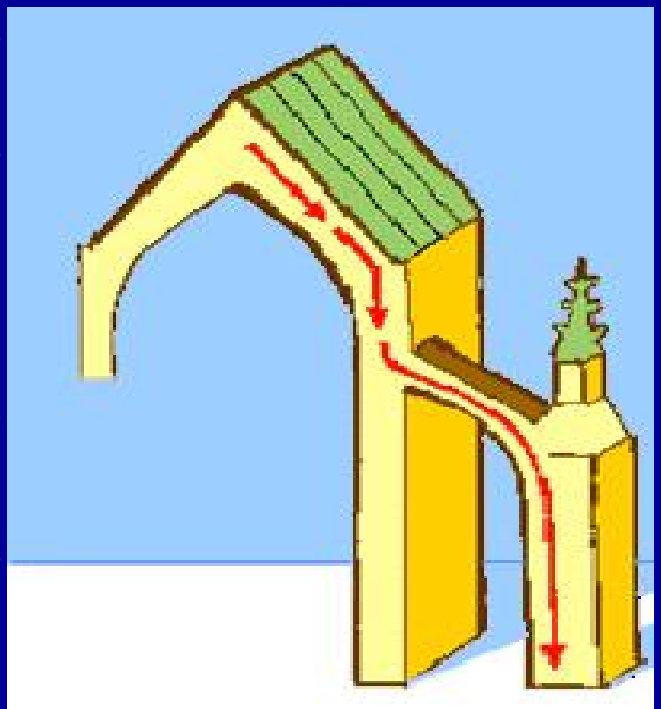
and, what might be done.

Please note: I work for Pennsylvania State University
And help UN IPCC, NRC, etc.,
But I am not representing them,
Just me.

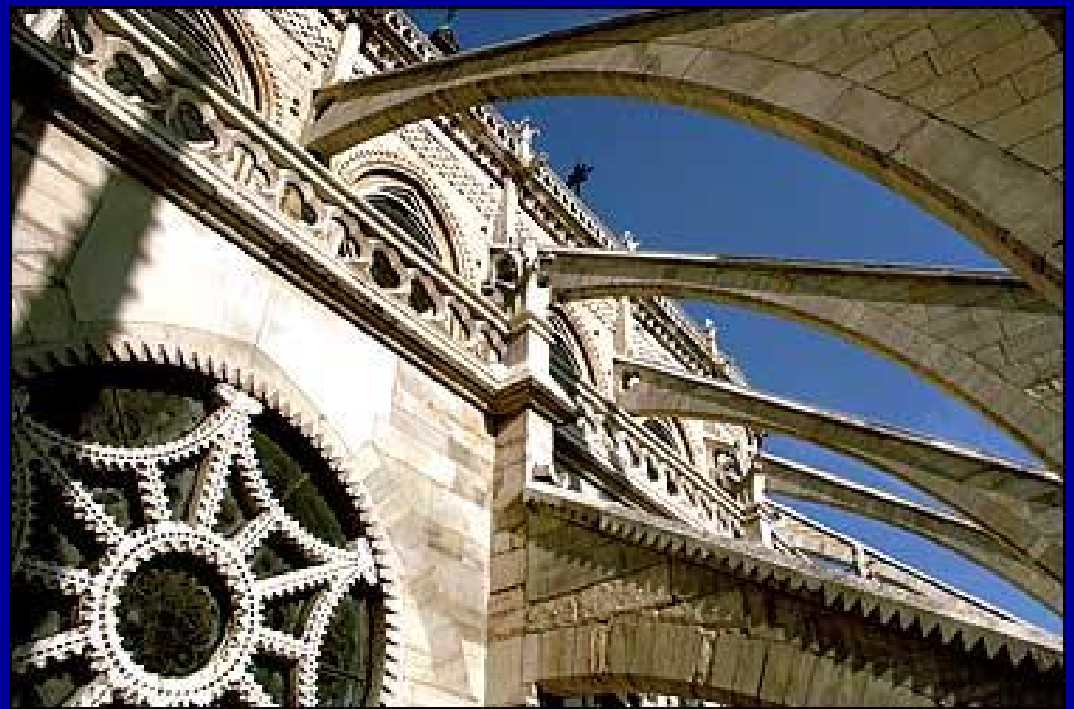
NSF
PENNSTATE
NASA
CRESIS
G. Comer Foundation

All piles tend to spread under their own weight:

- Strong things resist spreading (a block of wood), but weak things spread easily (pancake batter);
- Lubrication speeds spreading (pancake batter spreads faster on a greased griddle than on a waffle iron);
- Supports oppose spreading (a flying buttress keeps a cathedral from spreading and falling apart).



www.designcommunity.com/ scrapbook/images/1032.gif



www.pbs.org/wgbh/buildingbig/skyscraper/gothic.html

An ice sheet is a two-mile-thick, continent-wide pile

- Spreads under its own weight;
- Snowfall on center adds to pile;
- Melting at edges, or break-off of icebergs, subtract from pile;
- An increase in snowfall grows pile, but faster melting or faster flow shrink pile;
- Water in ice-sheet pile came from ocean, so sea level falls when ice sheet grows, and sea level rises when ice sheet shrinks.

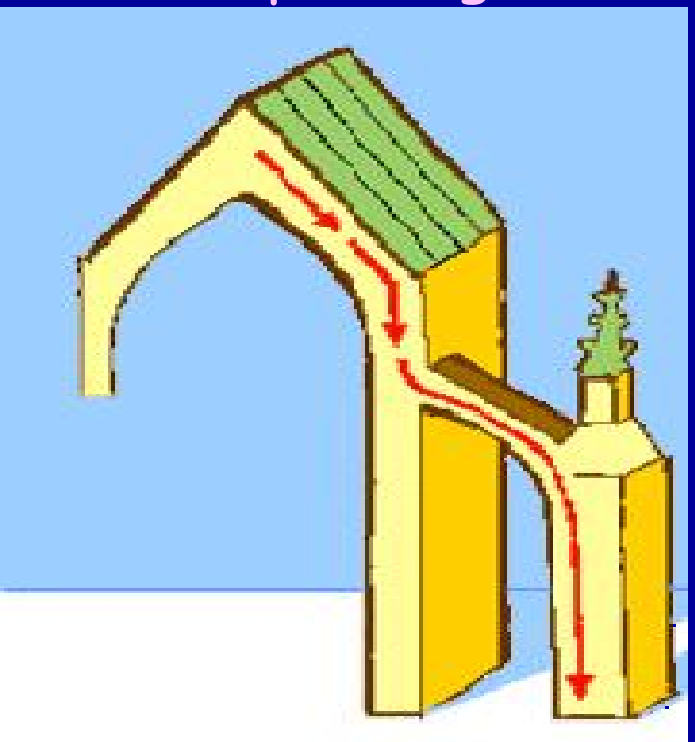
Size, thickness of ice make measurement difficult

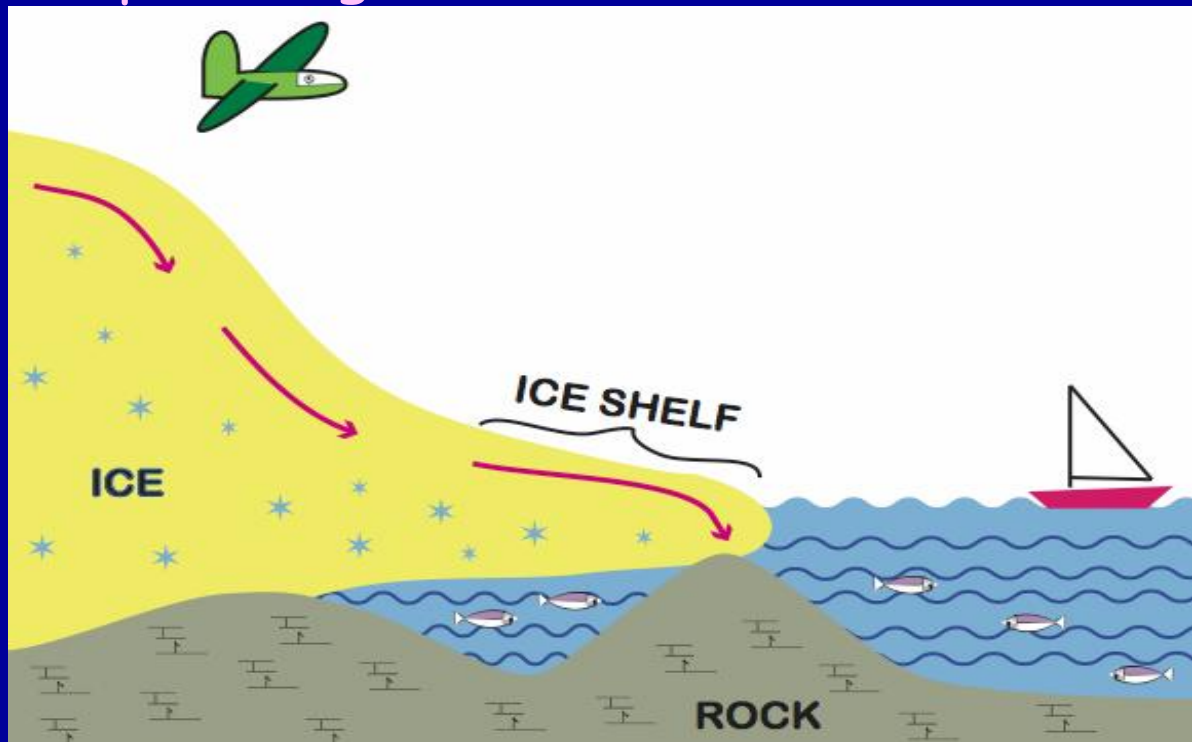
- In places, ice rests on a water-and-mud-lubricated "pancake griddle", in other places on a bumpy bedrock "waffle iron"; these can be mapped through two miles of ice, but job is far from done;
- In places, ice is "self-lubricating"--surface meltwater plunges to bottom to make it more slippery, so warming may bring faster flow, but depends on griddle vs. waffle iron character.

Zwally et al., 2002, Science

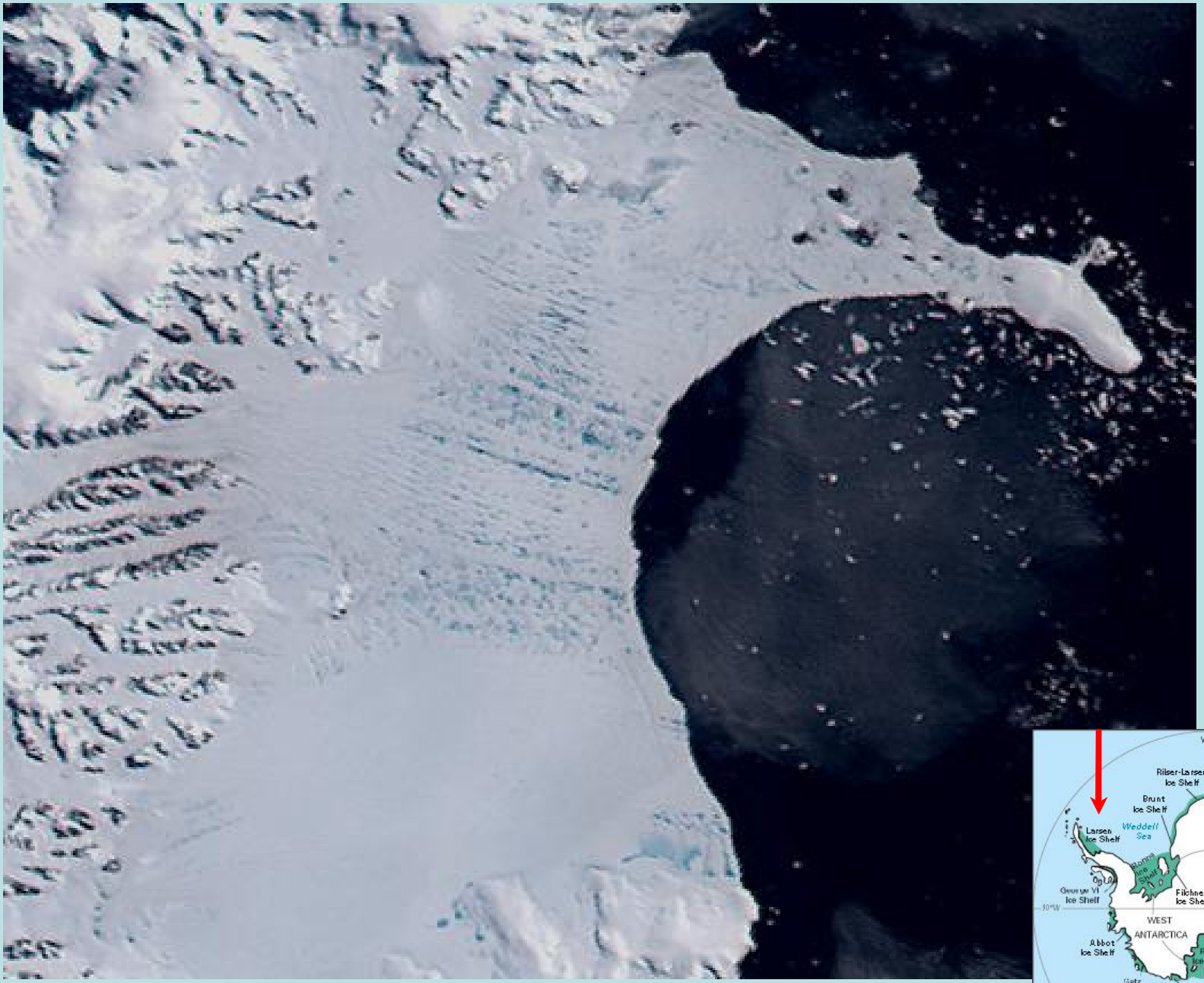
Ice sheets have "flying buttresses", too

- Floating extensions called "ice shelves"--ice flows over water for a while before breaking off to make bergs;
- Ice shelves may run aground on islands or scrape past rocky sides of bays;
- Friction from this slows ice-sheet spreading;
- Warming air or water can attack ice shelves quickly, speeding ice-sheet spreading and sea-level rise.

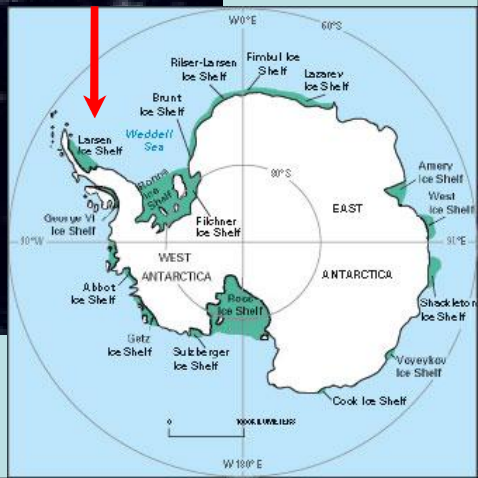




http://svs.gsfc.nasa.gov/vis/a000000/a002400/a002421/index.html

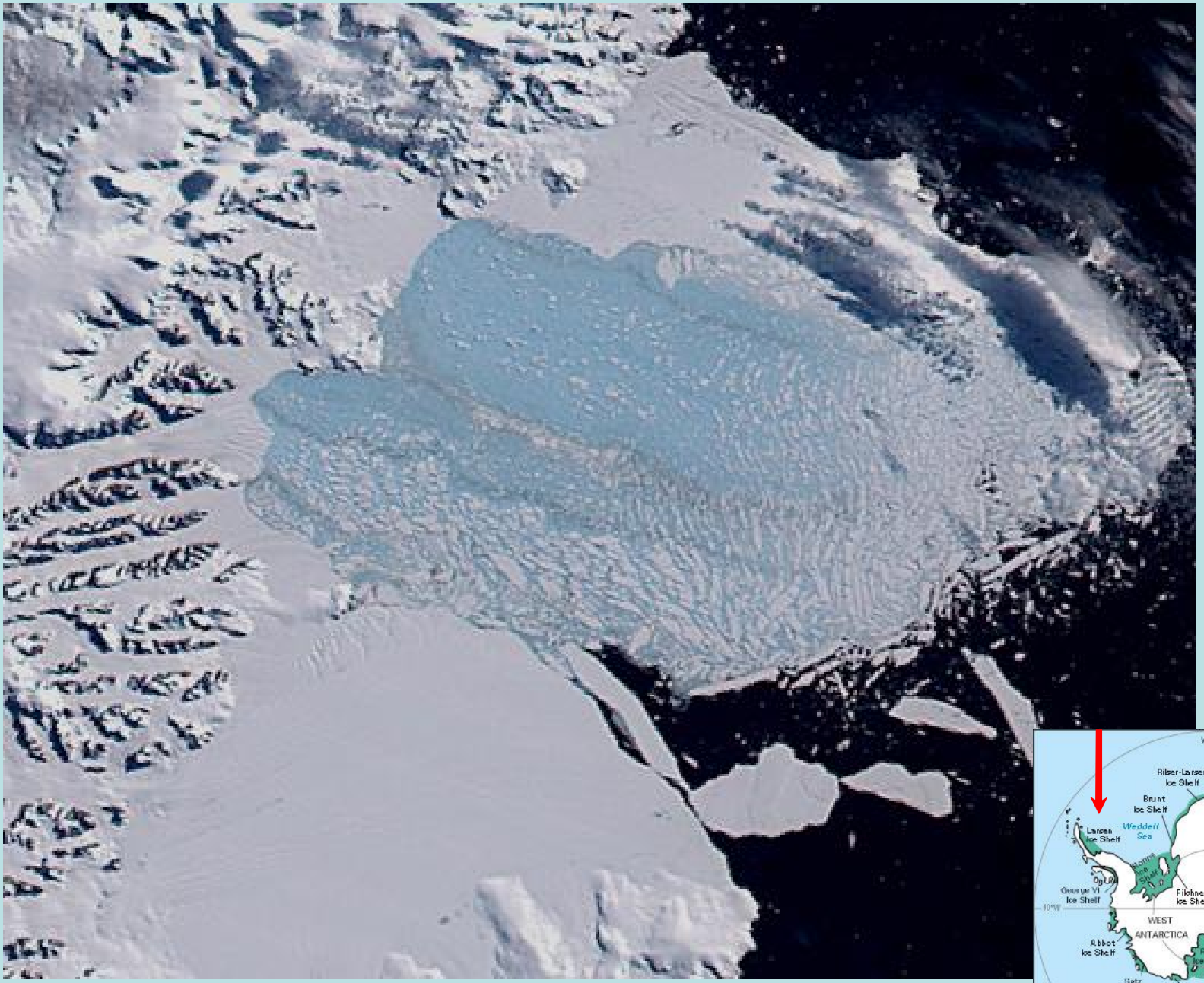


12 mi
20 km

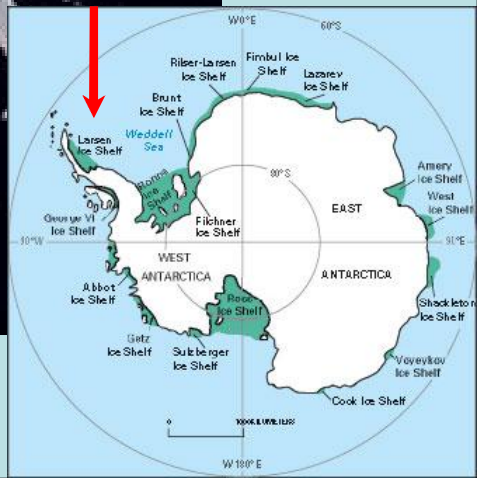


January 31, 2002

http://svs.gsfc.nasa.gov/vis/a000000/a002400/a002421/index.html



12 mi
20 km

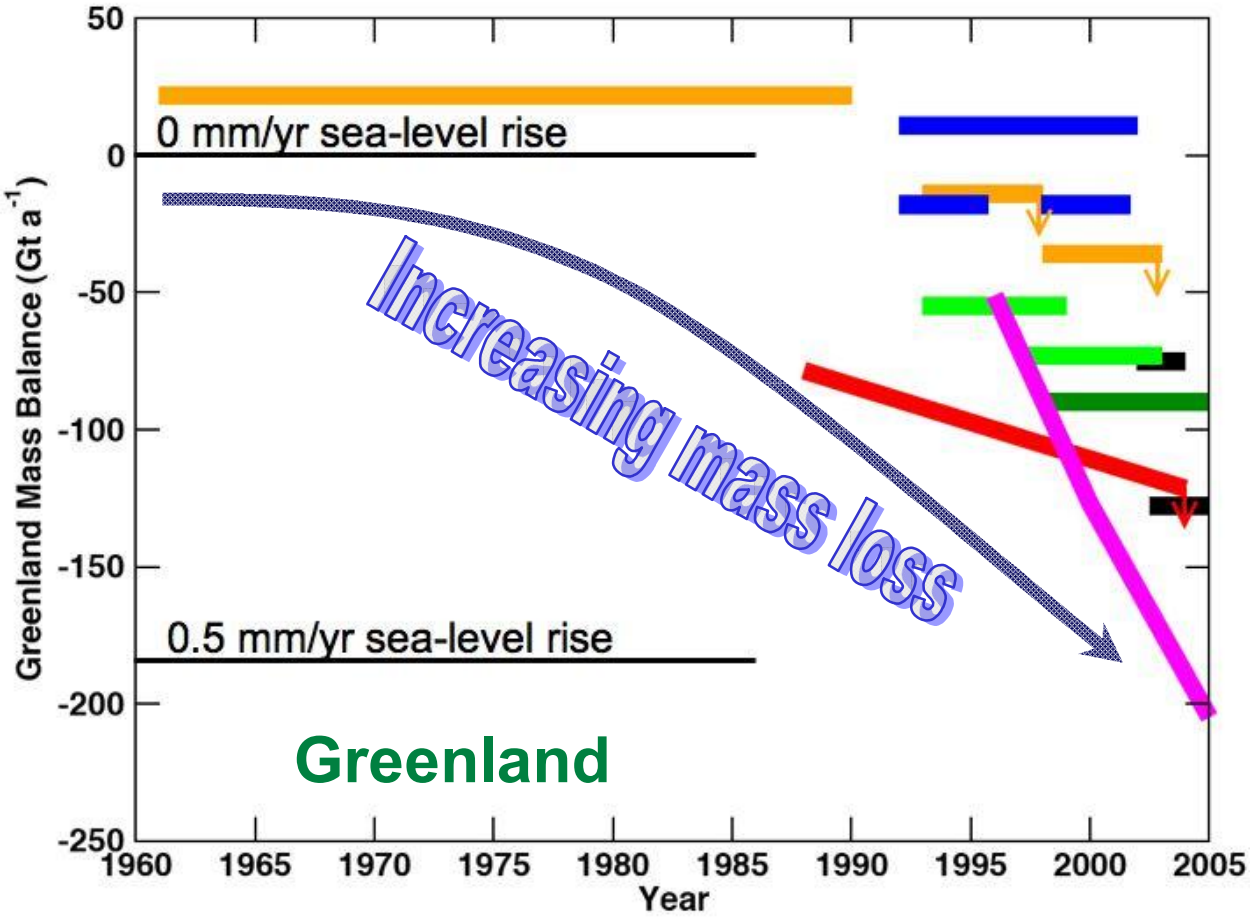


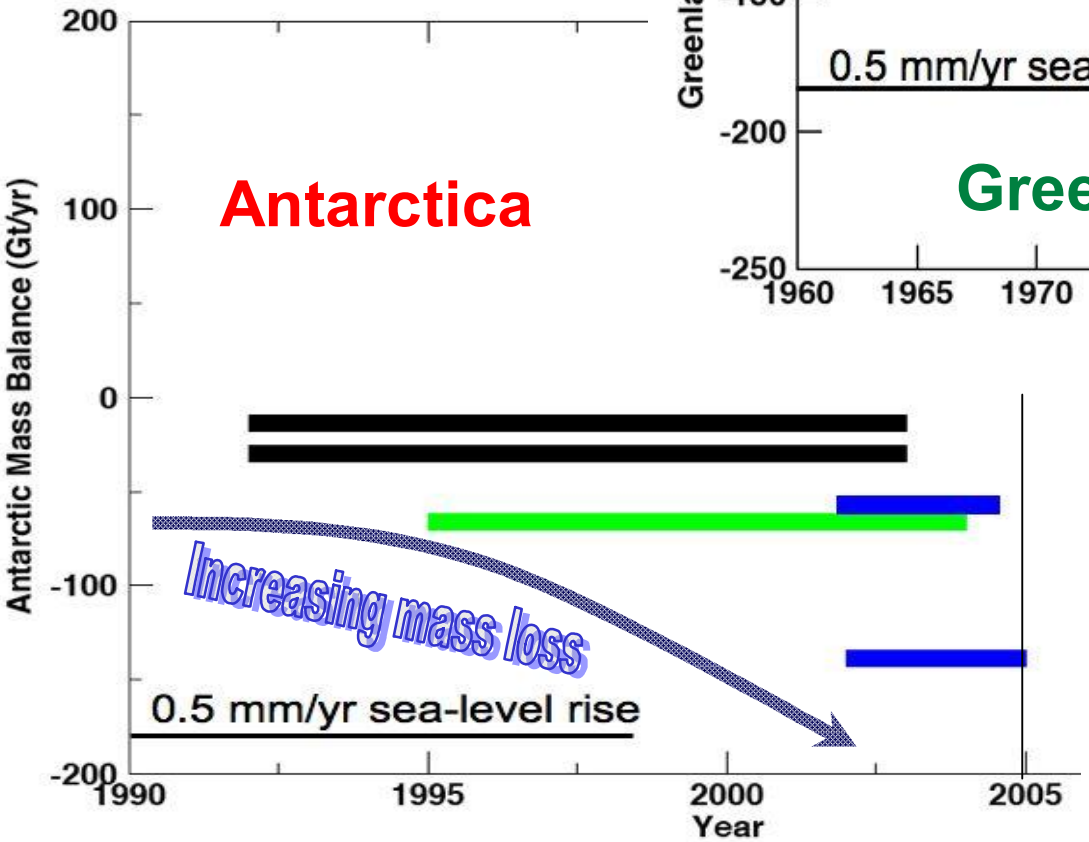
March 7, 2002

IPCC (2001) on ice sheets:

- Assessed state of scientific knowledge;
- Noted large uncertainties;
- Best estimate that warming over next century would cause:
  - →Snowfall to increase more than melting;
  - →Little change in ice flow;
  - →Net ice-sheet growth partially offsetting sea-level rise from other sources;
- Five years later, new studies show ice sheets likely contributing to sea-level rise, likely from warming;
- Increased ice-sheet spreading from ice-shelf breakup and meltwater lubrication likely involved, and not included in models available to IPCC (2001).

Recently published or reported estimates of ice-sheet behavior (solid bars) for different time intervals, indicating increase in mass loss.





Ice sheets can shrink rapidly:

- History: ice has grown slowly, shrunk rapidly over ice-age cycles;
- Balance: any DC parking lot can melt more snow in a summer than falls in the world's snowiest place;
- Additional processes: most ice is spreading very slowly, but a little ice goes much faster--there is more opportunity for speed-up than for slow-down, and our understanding of physical processes points toward a greater likelihood of speedup;
- Observations: in a few places, rapid shrinkage is occurring now--loss of buttressing ice shelves caused up to 8-fold increase in speed of no-longer-buttressed ice.

Issues for improved modeling:

- Data: we don't even know the ice thickness everywhere, or the depth of water under ice shelves, or the bumpiness of the bed, or others--these can be measured, but take work;
- Processes: some key physical processes are not as well-understood as they should be;
- Models: physical processes known to occur were omitted from models because of computational difficulties, but now must be included;
- Model coupling: major ocean-atmosphere modeling efforts have not targeted the ice-sheet interfaces, such as oceanic heat transport beneath ice shelves;
- Modeling effort: ice scientists are great but lack the resources of the major operational modeling groups, which have not focused on large ice sheets.

An ice-flow-modeling center (Penn State Ice and Climate Exploration Center--PSICE--Great Place!!!)

A climate modeling center that doesn't do much with ice sheets (NCAR--also a great place)

I believe science shows that:

- Projections of ice-sheet changes are not yet possible with high confidence;
- Sufficient warming is possible to melt Greenland's ice sheet, and perhaps parts of the Antarctic ice;
- The time-scale for any such melting is likely to be centuries or longer, not decades or shorter; but
- We may cross threshold for survival of Greenland, maybe West Antarctica, this century;
- Many people would consider such melting to be highly consequential--the deepest water in New Orleans after Katrina was about 20 feet; Greenland alone could raise sea level more than that globally.

In summary, with fairly high confidence, recent results show:

- The large ice sheets are shrinking;
- The shrinkage is faster than previously expected by comprehensive assessments;
- Warming is contributing to shrinkage;
- Sea-level rise from loss of most or all ice in Greenland and parts of Antarctica is of concern;
- Understanding of causes, and ability to model changes, are improving; but,
- Modeling is not sufficiently advanced to provide quantitatively useful projections to policy-makers.