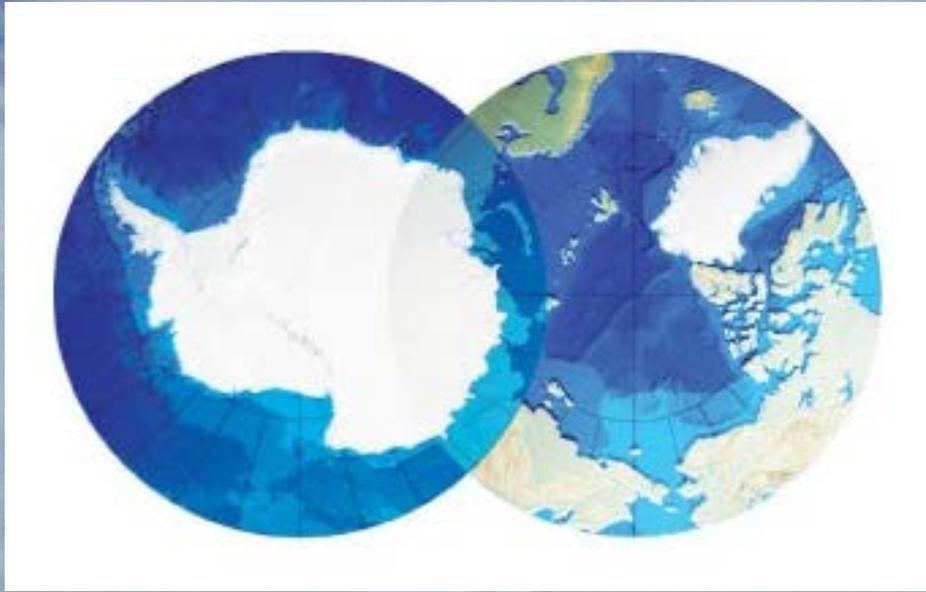
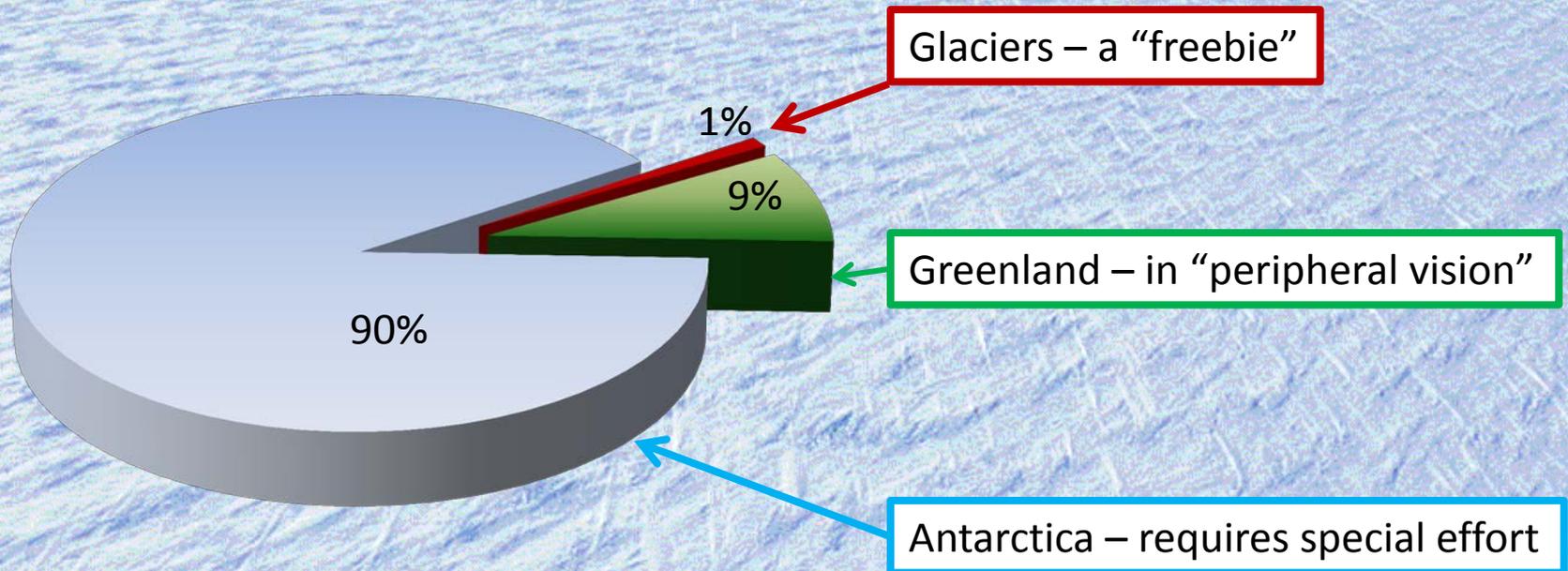


Keeping a sharp lookout: Landsat monitoring of Earth's Ice: Reflections, Accomplishments and the Future

Robert Bindschadler
NASA Emeritus Scientist



Land Ice (by Volume)



Glaciers – a “freebie”

Greenland – in “peripheral vision”

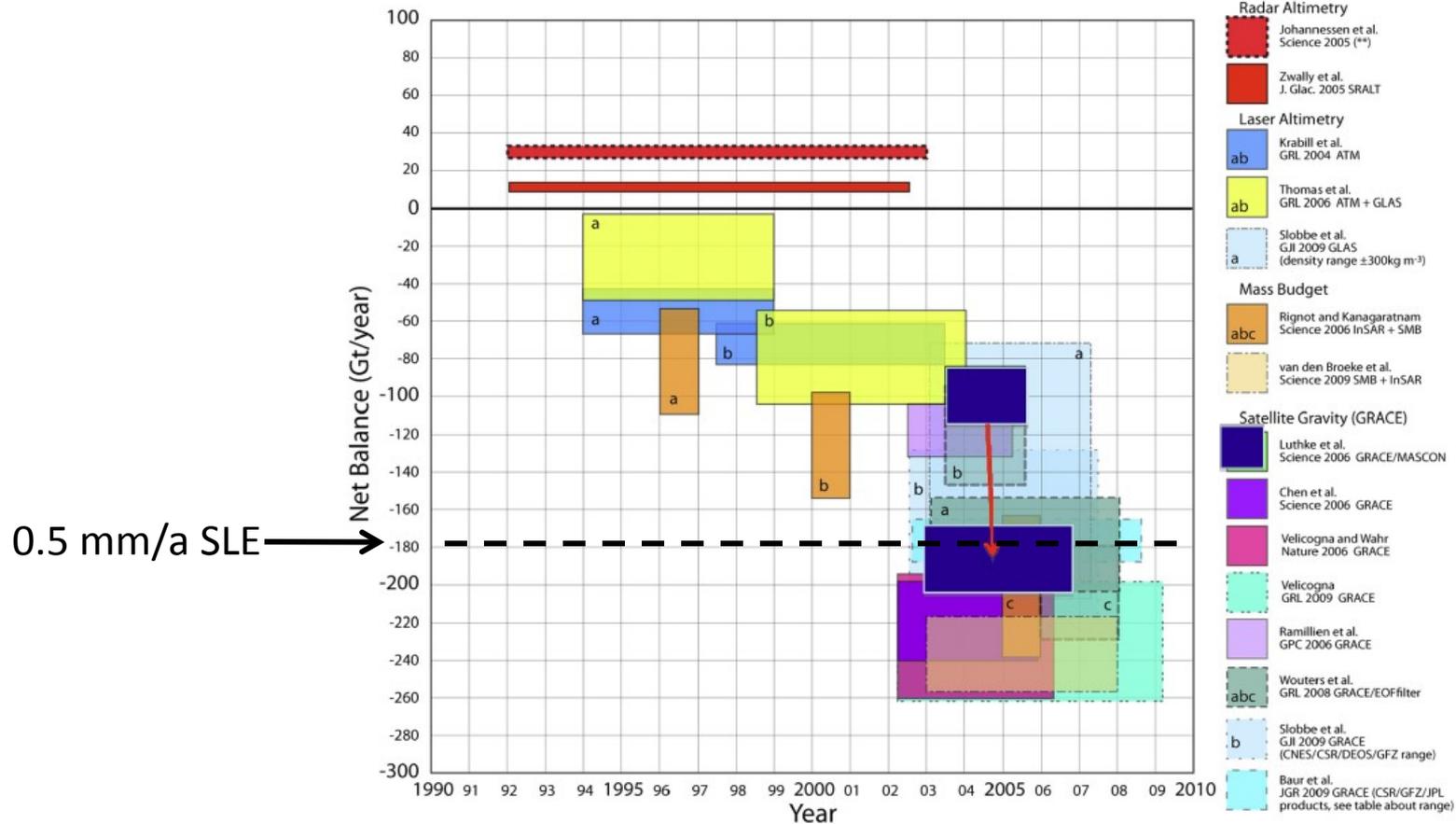
Antarctica – requires special effort

65 meters of “SLE”

10% of Earth’s land area

Ice Sheets are Changing

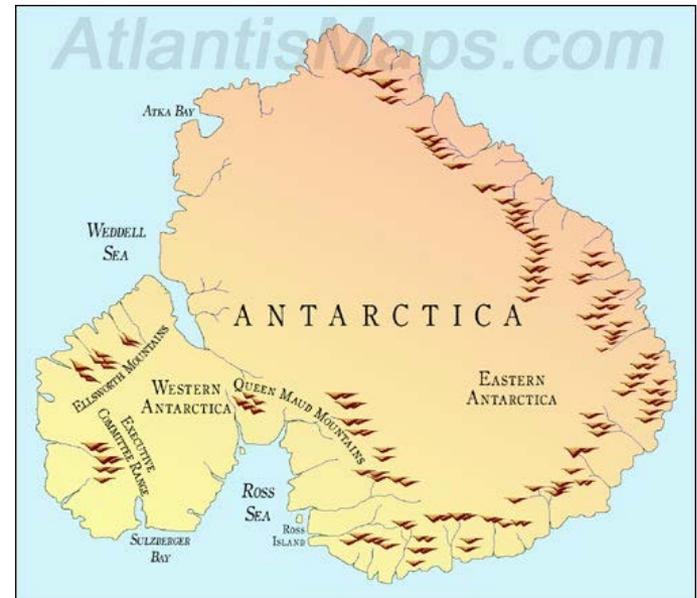
Greenland Rate of Mass Change



ERTS-1

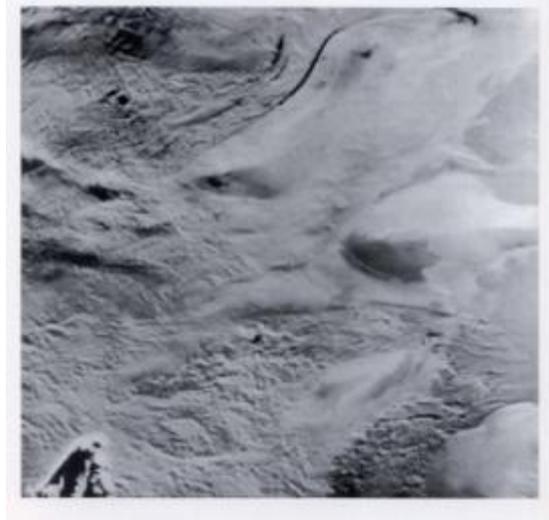
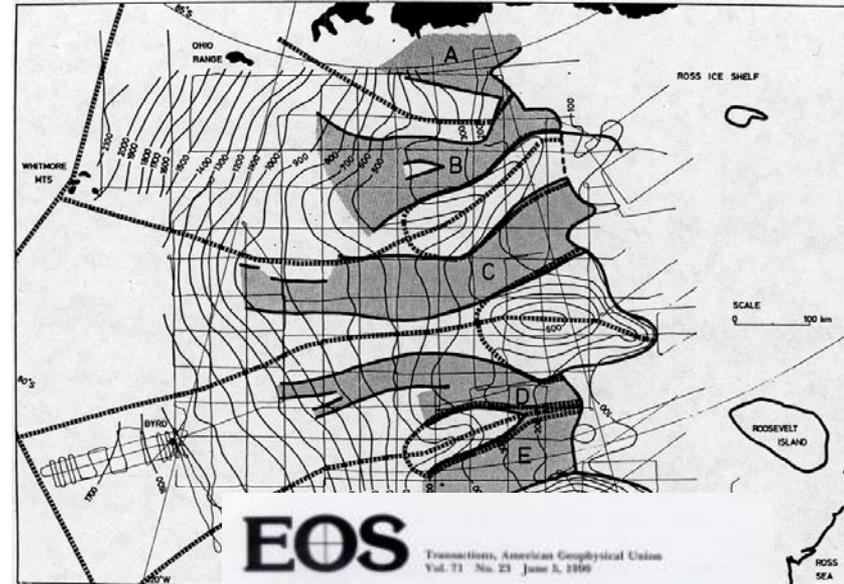
- First Landsat collections of Antarctica accomplished in 1972
 - Thanks to W.R. MacDonald
- Used to improve poor coastal maps

Remember what the EROS Director said about monitoring



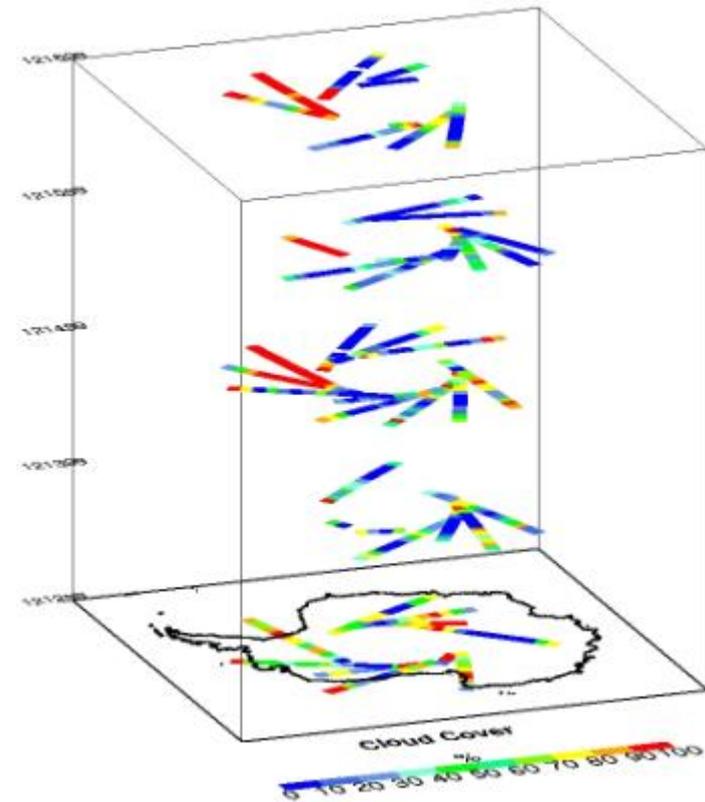
Mapping was the Early Focus

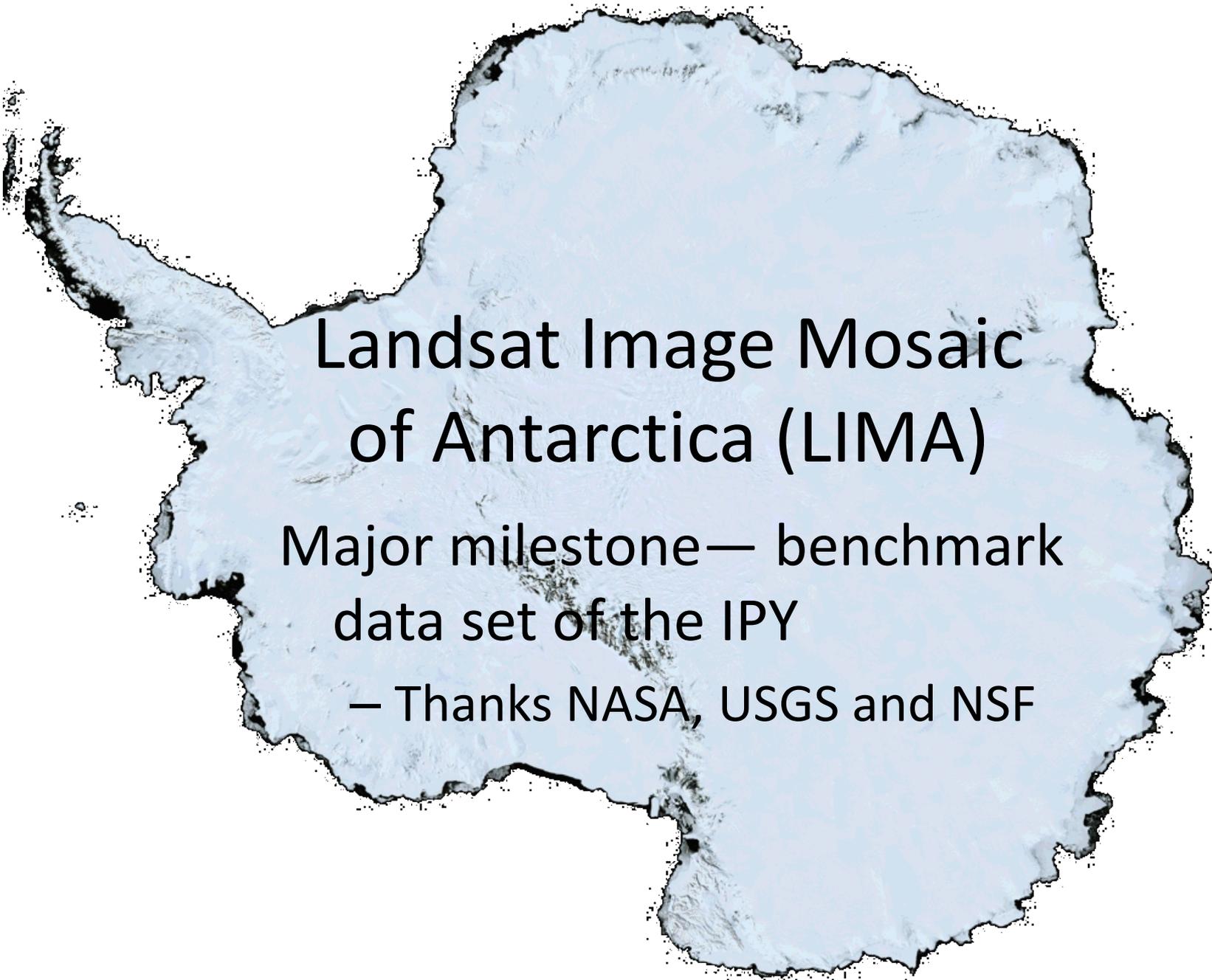
- Need for maps in inland areas
 - Aerial photography was expensive, slow and inadequate
 - Landsat composites began to replace 1:250,000 map sheets
 - Thanks to F. Brownworth and J. Kelmelis (USGS)
- EOSAT era was a low point
 - Limited imagery use due to high image cost, poor coverage, often cloudy for single shots



Landsat-7 and the LTAP

- Annual collection campaigns
- Low gain prevented saturation
- Ascending node campaign (2000-01)
- Manual cloud cover assessments required
- Laid the groundwork for LIMA



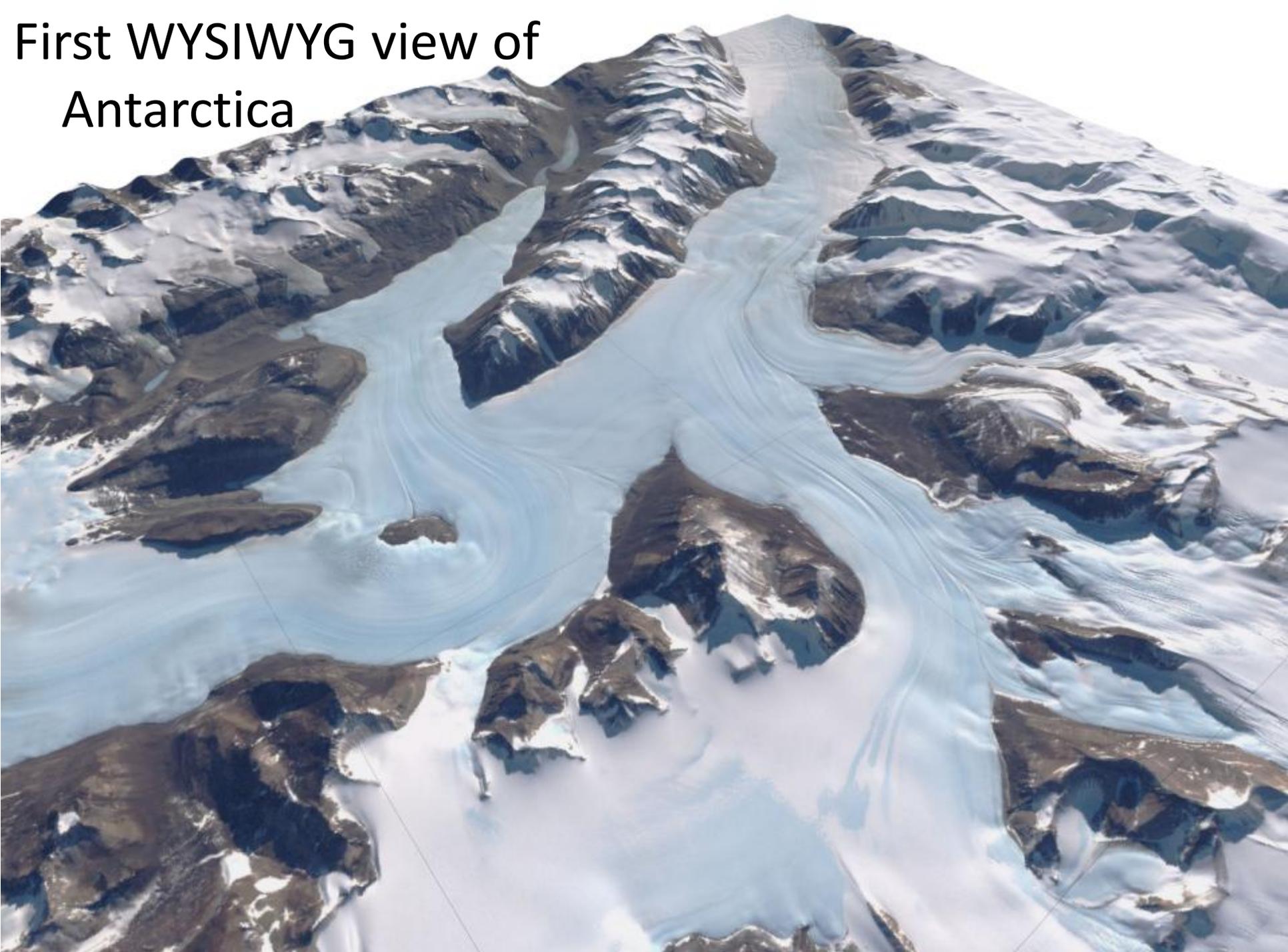


Landsat Image Mosaic of Antarctica (LIMA)

Major milestone— benchmark
data set of the IPY

– Thanks NASA, USGS and NSF

First WYSIWYG view of Antarctica



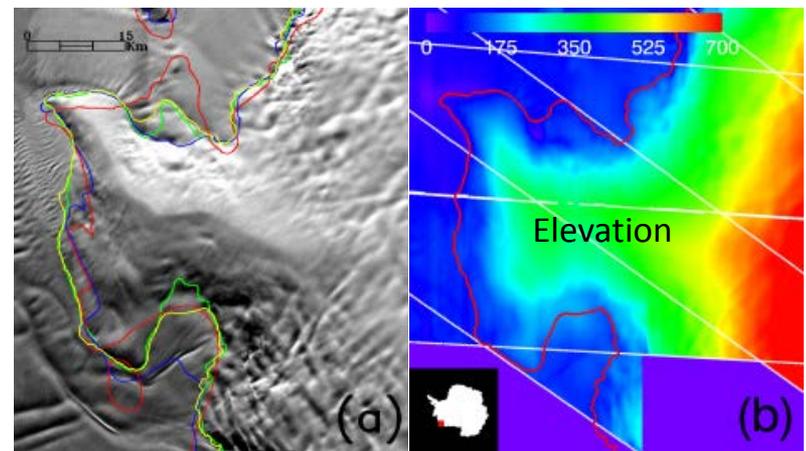
LIMA set a New Standard



- Accurate surface reflectance at the pixel level
 - Traceable back to DN for each pixel
- Very accessible
 - High interest brought down USGS servers

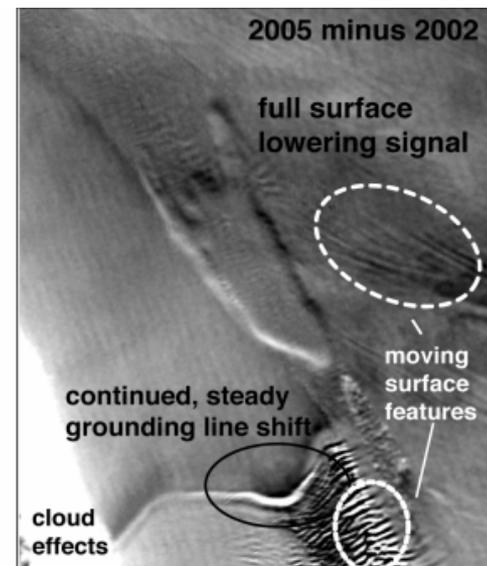
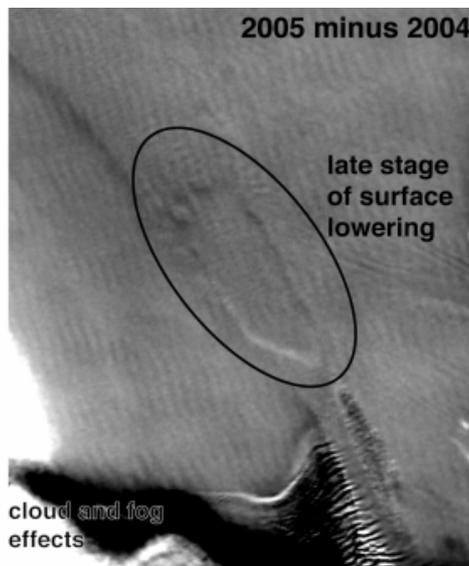
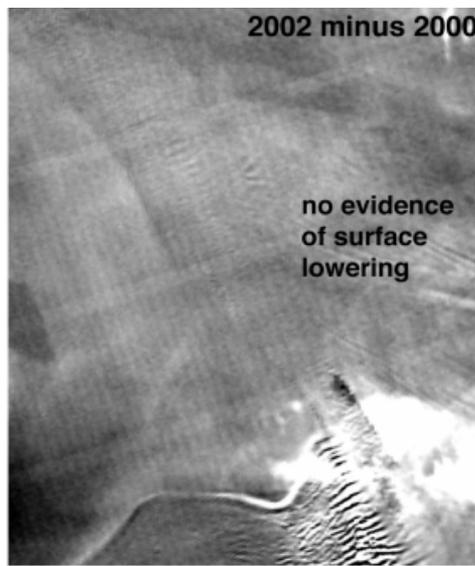
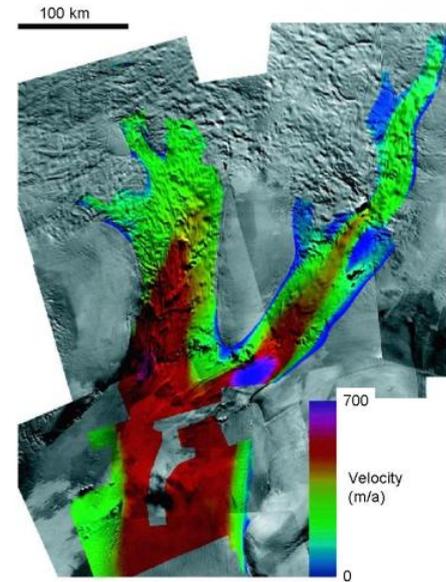
LIMA Uses

- Exploration
 - By scientists and general public
 - Linked to GNIS
- New mapping
 - New basal stress boundary
 - New floating boundary
 - Fused with other satellite data
 - Surface elevation via photoclinoetry



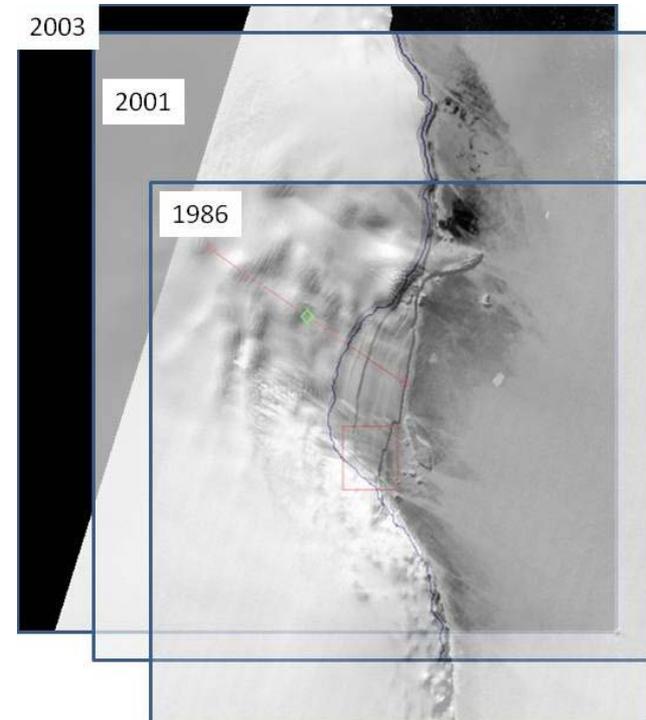
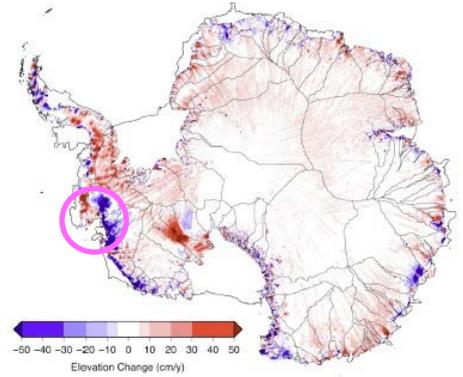
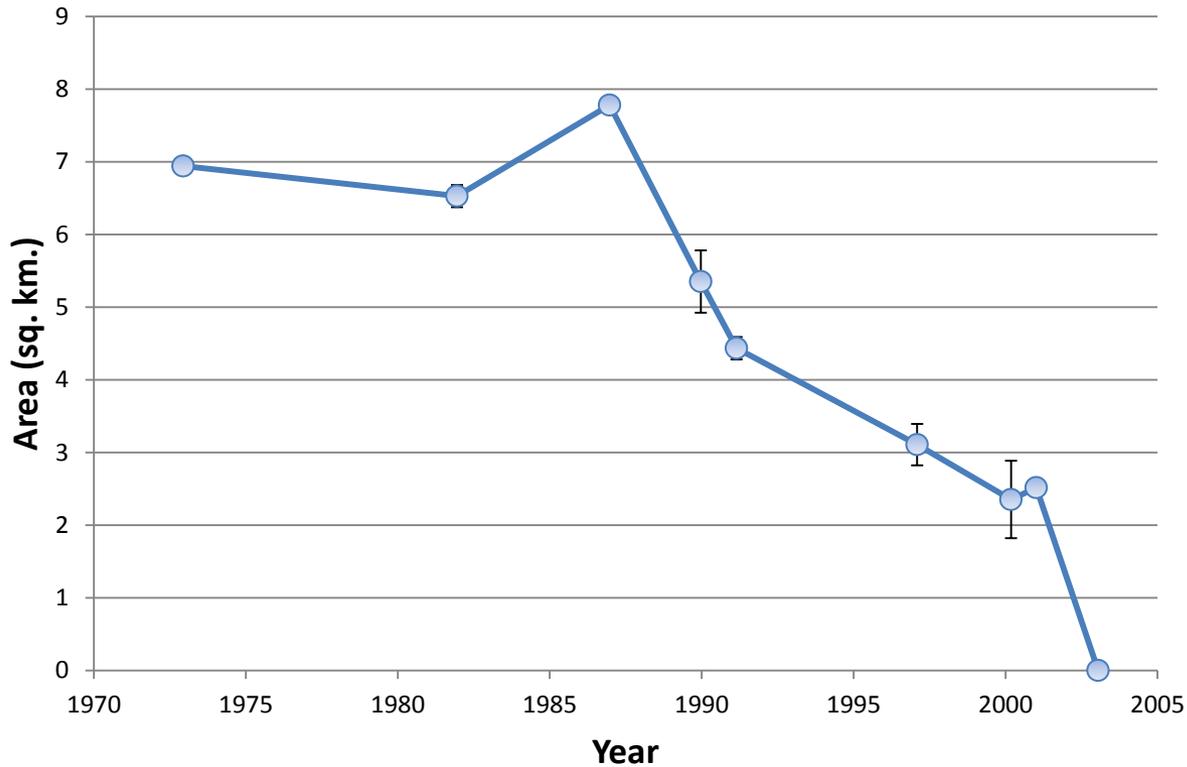
Not just mapping

- Change detection
 - Surface velocities
 - Elevation
 - Ungrounding of coastal ice
 - Slope changes
 - Subglacial lake activity
 - MODIS proved more capable



and Discovery!

Average area of "ECSU Ice Shelf"

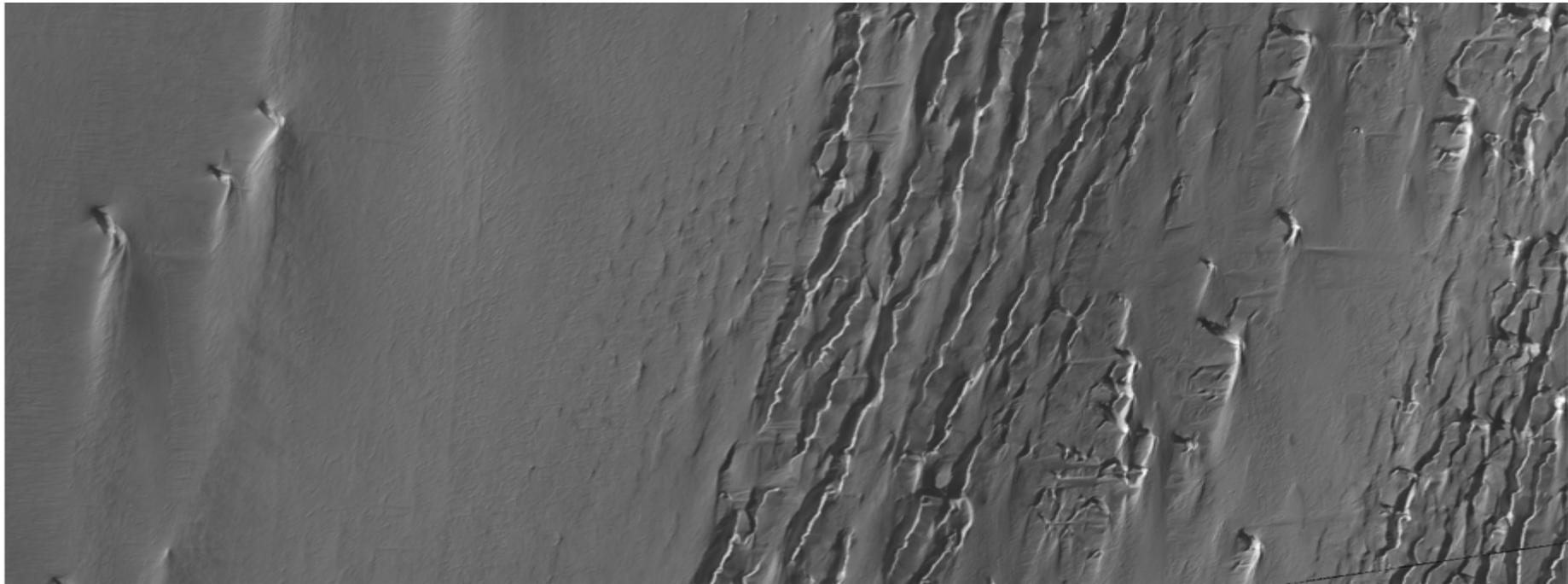


Lessons from MODIS

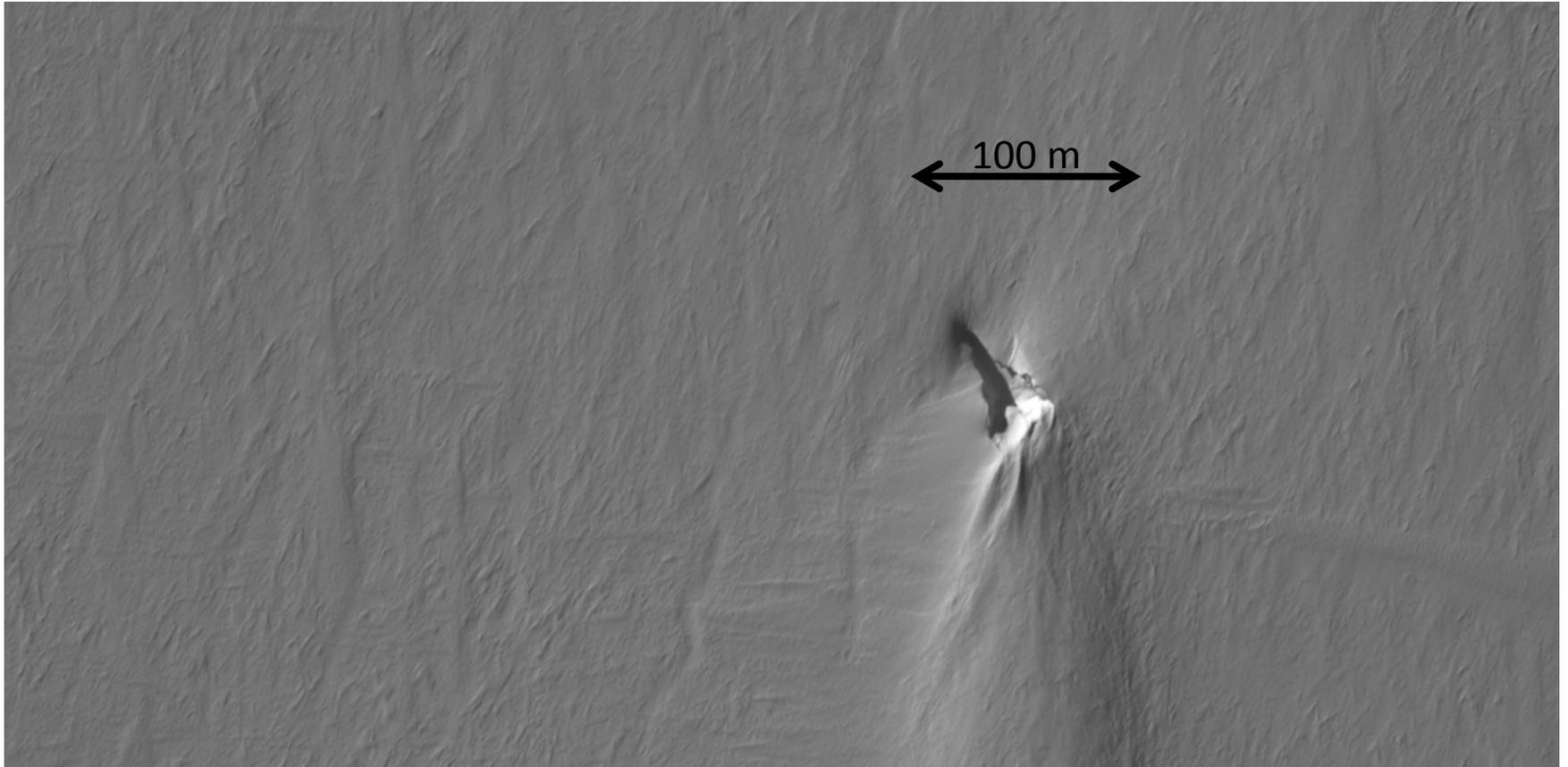
- Things that would help make future Landsats more useful for ice monitoring
 - Larger field of view
 - More frequent coverage (to minimize clouds)
 - 12-bit radiometry (we'll take 10-bit)
- Multi-spec still not a big deal
 - Not sure about thermal

Other higher-res imagers have their place, too

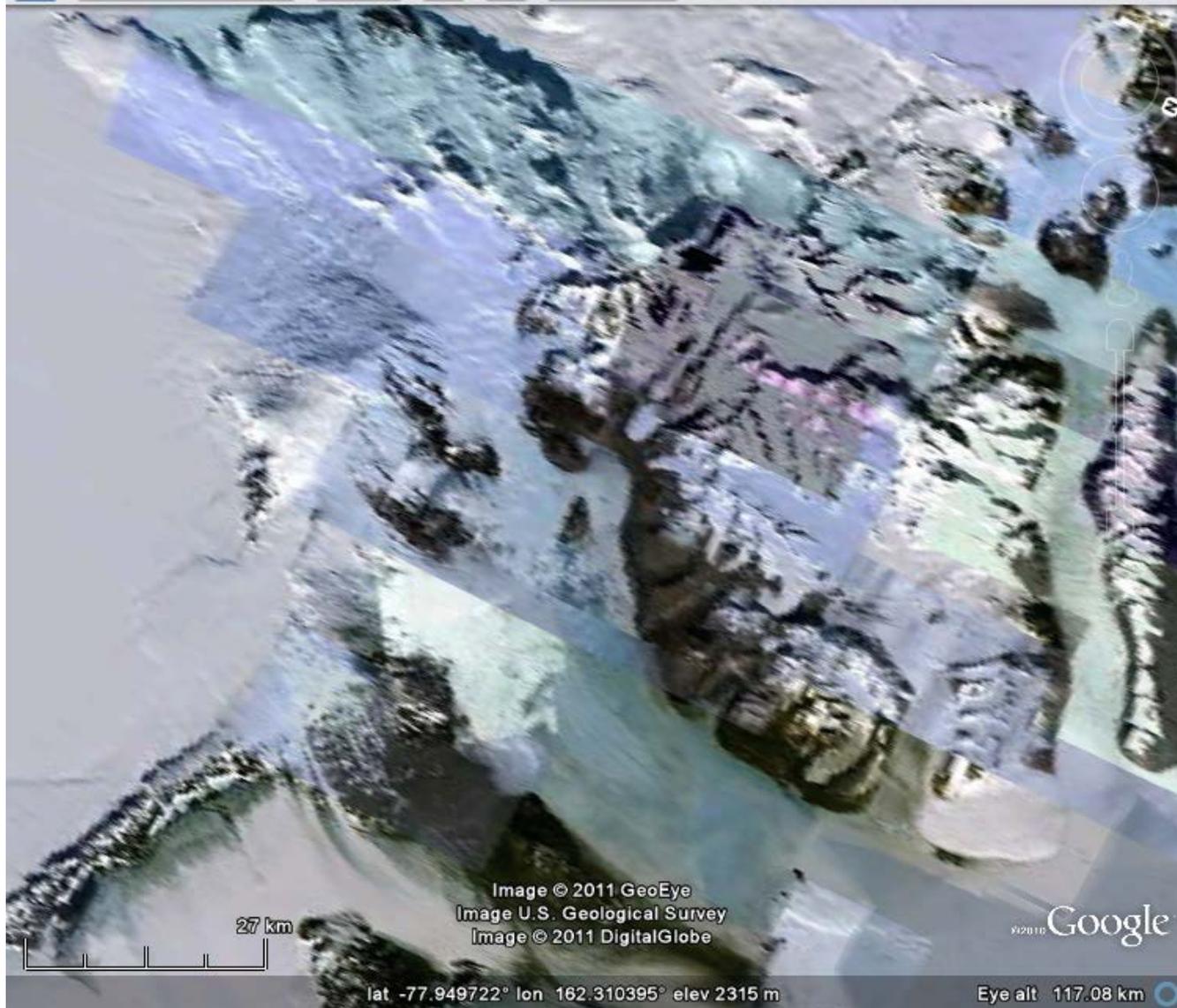
- Route finding
- Field support
- Small-scale process studies



“I can see more surface detail in the imagery than out the cockpit window”



Room for improvement



Glaciers are not forgotten



Satellite Image Atlas
of Glaciers of the World

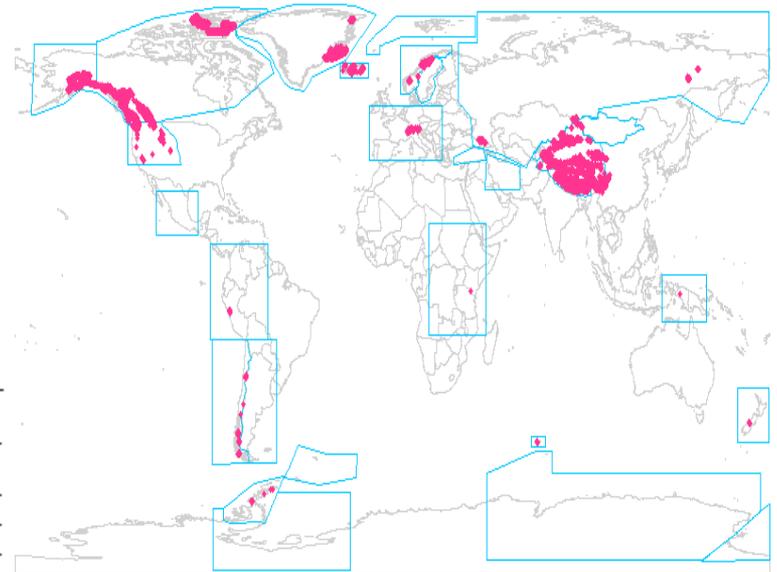
NORTH AMERICA



United States Geological Survey
Professional Paper 1386-J



GLIMS: Global Land Ice Measurements from Space
Monitoring the World's Changing Glaciers



| Chapter | | Date Published |
|---------|---|----------------|
| A | State of the Earth's Cryosphere w/map | in press |
| B | Antarctica w/map ¹ | 1988 |
| C | Greenland w/map ² | 1995 |
| D | Iceland w/map | in press |
| E | Continental Europe ² | 1993 |
| F | Asia | in press |
| G | Turkey, Iran, and Africa ¹ | 1991 |
| H | Irian Jaya (Indonesia) ¹ and New Zealand | 1989 |
| I | South America ² | 1998 |
| J | North America ² | 2002 |
| K | Alaska ¹ | 2008 |

and maybe, just maybe...

- Sea ice might matter
 - Indicator of ocean heat content
 - Resists land ice discharge
- AMSR-E sea ice concentrations at 25 km inadequate
- MODIS can't resolve leads

Summary

- Landsat-scale imagery has and will continue to be of great value for land-ice monitoring and research
 - Useful compromise between FOV and resolution
- Fusion with other data expands its utility
- Room for improvement
 - Radiometric resolution (for detail and saturation avoidance)
 - Agility (global vs. near-global)
 - More repeats (to avoid clouds)
 - Stereo

Thanks to...

- Science Team colleagues
 - especially Curtis W. and Tom L.
- Project Science Office
 - especially Jim I.
- Landsat Project
- All the cryo-users of Landsat data