The cryospheric contribution to recent SLR: AR5 Chapter 4

Jonathan Bamber, Bristol Glaciology Centre, RE Chapter 4
Context and Concepts:

- “Modern era” began in 1992: launch of ERS-1
- Quantum advance with launch of ICESat and GRACE circa 2002
- Two processes control ice sheet mass balance
  - Surface mass balance (SMB)
  - Ice Dynamics (D)
Where were we: AR4
IPCC AR4 (2007) on ice sheets
Where are we now: AR5
Fig. 6. Global estimates of glacier mass change. All estimates have been multiplied by the ratio of the total glacier area used in this study, 729,400 km², to that used in each source. 95% CIs are shown for all estimates except the arithmetic averages of CO9 (2), which have formal errors in the range from 410 to 1520 Gt year⁻¹. The two CO9 estimates are determined from an updated set of glaciological records using the methods of Cogley (2).

Greenland trends:

- Blue line = ice dynamics
- Red line = precip
- Yellow = runoff
- Green = sum of above
- Black = GRACE

Elevation change 2003-2007

Pritchard et al., 2009 – Nature, 23 September 2009
B. Observed Changes in the Climate System

B.3 Cryosphere

- The average rate of ice loss from the Greenland ice sheet has *very likely* increased from 34 [−6 to 74] Gt yr⁻¹ over the period 1992–2001 to 215 [157 to 274] Gt yr⁻¹ over the period 2002–2011.

- The average rate of ice loss from the Antarctic ice sheet has *likely* increased from 30 [−37 to 97] Gt yr⁻¹ over the period 1992–2001 to 147 [72 to 221] Gt yr⁻¹ over the period 2002–2011.

There is *very high confidence* that these losses are mainly from the northern Antarctic Peninsula and the Amundsen Sea sector of West Antarctica.
Ice-loss from glaciers and ice sheets

- 2005–2010 (6-year) 1.04 ±0.37
- 1993–2010 (18-year) 0.60 ±0.18
Antarctic ice sheet change

- Substantial improvement on AR4
- Assessment of geographical and temporal pattern of ice-loss
- Agreement between techniques
- Assessment of contribution to GMSL uses published values for two periods:

  2005–2010 (6-year) 0.41 ±0.20 mm GMSL
  1993–2010 (18-year) 0.27 ±0.11 mm GMSL
Greenland ice sheet change

- Substantial improvement on AR4
- Assessment of geographical and temporal pattern of ice-loss
- Agreement between techniques
- Assessment of contribution to GMSL uses published values for two periods:

  2005–2010 (6-year)
  0.63 ±0.17 mm

  1993–2010 (18-year)
  0.33 ±0.08 mm

IPCC WGI Fig 4.13
AR5 Final Draft September 2013
Grace – satellite gravity

Updated to include mass budget back to 1992 in
Rignot, E., I. Velicogna, M. van den Broeke, A. Monaghan, and J. Lenaerts (2011),
Acceleration of the contribution of the Greenland and Antarctic Ice Sheets to sea

182 citations to date.....
But:
Interannual variability:

Is the acceleration statistically significant?

Is the acceleration statistically significant?

AR4 predictions of future response:

Gregory & Huybrechts, 2006, Phil Trans Roy Soc
Why might the models be “wrong”

21st-Century Evolution of Greenland Outlet Glacier Velocities

T. Moon, I. Joughin, B. Smith, I. Howat

Earlier observations on several of Greenland’s outlet glaciers, starting near the turn of the 21st century, indicated rapid (annual-scale) and large (>100%) increases in glacier velocity. Combining data from several satellites, we produce a decade-long (2000 to 2010) record documenting the ongoing velocity evolution of nearly all (200+) of Greenland’s major outlet glaciers, revealing complex spatial and temporal patterns. Changes on fast-flow marine-terminating glaciers contrast with steady velocities on ice-shelf-terminating glaciers and slow speeds on land-terminating glaciers. Regionally, glaciers in the northwest accelerated steadily, with more variability in the southeast and relatively steady flow elsewhere. Intraregional variability shows a complex response to regional and local forcing. Observed acceleration indicates that sea level rise from Greenland may fall well below proposed upper bounds.
And prior to 1992?

Intentionally left blank!
Summary, Conclusions & Challenges

• Big advances since AR4 especially in errors
• Extrapolation of trends “unsafe”
• Is it weather or is it climate? =>
• Are deterministic models suitable tools?
• How do we extend the time series backward?