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# Decay of glaciers, ice caps and ice sheets



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#### **Glaciers and small ice caps**





- Number: > 160000.
- ~ 0.5 m sea-level equivalent.





Photo credit: www.glaciers-online.net

**Ice sheets** 







~ 61 m sea-level equivalent.  $\sim$  7.2 m sea-level equivalent.

#### **Contribution to sea level rise**

 Sea level rise in the 21<sup>st</sup> century is predicted to be mainly caused by thermal expansion of sea water and the melting of glaciers and small ice caps.

~ 0.5 m sea-level equivalent

 However, surprisingly rapid decay of the large ice sheets (Greenland, Antarctica) has been detected recently, in conjunction with a general speed-up of ice streams and outlet glaciers (ice dynamics!).

~ 7.2 m sea-level equivalent

~ 61 m sea-level equivalent

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#### **Recent changes of the Greenland ice sheet**



Source: Witze (2008)

- Interior ice sheet: on average in balance, some regions of local thickening or thinning.
- Marginal areas: thinning predominant.
- Overall mass balance negative: -50 to -90 km<sup>3</sup>/a, corresponding to a sea-level contribution of 0.15 to 0.25 mm/a.

(Ohmura, 2004)

 New results from satellite gravity measurements indicate -239 ± 23 km<sup>3</sup>/a for the period 2002 - 2005 (sea-level contribution 0.66 ± 0.06 mm/a).

(Chen et al., 2006)

#### **Recent changes of the Antarctic ice sheet**

• The Third Assessment Report (TAR) of the IPCC lists an overall mass balance of  $-376 \pm 384 \text{ km}^3/a$  (sea-level contribution 1.04  $\pm$  1.06 mm/a). (Church et al., 2001)



- New results from satellite gravity measurements indicate -152 ± 80 km<sup>3</sup>/a for the period 2002 - 2005 (sea-level contribution 0.42 ± 0.22 mm/a). (Velicogna and Wahr, 2006)
- Main contribution seems to be from West Antarctica.

## Simulation results for Greenland

- Model time: *t* = 1990 CE (present) ... 2350 CE.
- Climatic forcing: "WRE1000" scenario (future stabilization of atmospheric CO<sub>2</sub> at 1000 ppm).



 Ice flow: Set-up #1 → slow basal sliding (usual approach). Set-up #2 → basal sliding accelerated by surface meltwater (controversial process).

(Greve and Otsu, 2007)

## **Simulation results for Greenland**

**Surface velocity**  $\rightarrow$  differs greatly for the two set-ups!



#### 2100 CE, set-up #2:



# Simulation results for Greenland

#### **Contribution to sea-level rise**

	2100 CE	2200 CE	2300 CE
Set-up #1	0.12 m	0.55 m	1.21 m
Set-up #2	0.58 m	1.51 m	2.71 m

#### And there is also Antarctica...

- $\rightarrow$  Large uncertainties due to ice-sheet dynamics
  - → IPCC AR4 (Fourth Assessment Report) sea-level predictions for the 21<sup>st</sup> century may be significantly too small!