melting ice, rising seas

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the cryosphere
glaciers
northern hemisphere

Hansbreen, Svalbard
Engabreen, Norway
Storglaciären, Sweden
Vatnajökull, Iceland
Nigardsbreen, Norway
U.Grindelw., Switzerland
Glac.d'Argentière, France
Hintereisferner, Austria
Rhonegletscher, Switzerland
Elena Glacier, Uganda
Franz-Josef Gl., New Zealand

southern hemisphere

Blue Glacier, USA
U.Grindelw., Switzerland
Glaciar Lengua, Chile
Sofiskyi Glacier, Altai
Gangotri Glacier, India
Elena Glacier, Uganda
Meren Gl., Irian Jaya
Glaciar Artesonraju, Peru
Glaciar Lengua, Chile
Franz-Josef Gl., New Zealand

Length (unit = 1 km)

1500 1600 1700 1800 1900 2000

Year

tropics
glacier retreat

1800 - 2005

8.4 ± 2.1 cm

1950 - 2005

3.2 ± 0.8 cm
antarctica
24,700,000 km$^3$
56 m

greenland
2,900,000 km$^3$
7.3 m

all glaciers
120,000 km$^3$
0.31-0.53 m

land ice
Greenland
Melting on the lower parts of the surface, icebergs calve off from ice sheet edges into ice fjords and the sea

Antarctica
Ice shelves, with subglacial melting. Icebergs calve off from ice shelves
ICEsat (laser) or CryoSat (radar)
Eric Rignot, JPL Pasadena

This is the first map of ice velocity over the entire continent of Antarctica. It is derived from ALOS PALSAR, Envisat ASAR, Radarsat-2, ERS-1 and ERS-2 satellite radar interferometry overlaid on a MODIS mosaic of Antarctica. These new findings are critical to measuring the global impact to sea-level rise resulting from ice flowing into the ocean. - Image credit: E. Rignot et al
I. GRACE

II. IceSAT

III. Input-Output
basal melt by warmer oceans

Pritchard et al., Science, 2012
Sermeq Kujalleq - Ilulissat Glacier - Jakobshavn Isbrae
5 June 2007
14:10 - 14:28 UTC

Photos by Jason Amundson
University of Alaska Fairbanks
mass loss (Gt y\(^{-1}\))
1992-2001  -34 ± 40
2002-2011  -215 ± 59

Shepherd et al., Science, 2012

363 Gigaton = 1 mm sea level
Global mean sea level rise (m) 2081-2100 relative to 1986-2005

- Sum
- Thermal expansion
- Glaciers
- Greenland ice sheet (including dynamics)
- Antarctic ice sheet (including dynamics)
- Land water storage
- Greenland ice-sheet rapid dynamics
- Antarctic ice-sheet rapid dynamics

Global mean sea level rise (m)

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<th>Scenario</th>
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<th>RCP4.5</th>
<th>RCP6.0</th>
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<td>SLR 2100</td>
<td>43 (28 – 60)</td>
<td>52 (35 – 70)</td>
<td>54 (37 – 72)</td>
<td>73 (53 – 97)</td>
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IPCC AR4 (2007): 18 - 59 cm
The graph shows the relationship between temperature change (K) and SLC (m) for two different models, AR5 and AR4. The slopes indicate the change in SLC per unit change in temperature:

- For AR5, $d\text{SLC}/dT = 0.08$
- For AR4, $d\text{SLC}/dT = 0.06$
a) Northern Hemisphere, Annual

Ice Extent ($10^6$ km$^2$)

- Red: Walsh and Chapman (Updated)
- Blue: Hadley (HADISST1 ICE)
- Black: SBA (SMMR,SSMI)
- Green: NT1 (SMMR,SSMI)
- Purple: ABA (AMSR-E)
- Orange: NT2 (AMSR-E)

b) Seasonal

Ice Extent ($10^6$ km$^2$)

- Blue: JFM
- Green: AMJ
- Red: JAS
- Orange: OND
- Black: SBA