The Arctic as a warning system

for the entire planet

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Willem Barentsz discovered Bjørnøya and Svalbard in 1596
Arctic tundra climate on Svalbard with maritim influence

Midnight sun: 20. April to 23. August
Dark season: 26. October to 15. February
Pollution from mid latitudes is transported into the Arctic.
The weather station at Svalbard airport has been measuring temperatures since 1912.

Last 50 years: increase 3.2 degrees, trend = 0.65 degrees per decade.
The temperature increase at Svalbard is highest during the winter season. The variability is large due to the strong influence of the sea-ice.
During the last decades, the Arctic has warmed twice as much as the global mean, mainly due to feedbacks in the system.

You can make this plot on your own here: [http://data.giss.nasa.gov/gistemp/maps/](http://data.giss.nasa.gov/gistemp/maps/)
Long-term change in summer Arctic air temperatures, as estimated from lake sediments, ice cores and tree rings ('proxy' records)

Temperature change relative to the 1961–1990 mean, °C

Variability in proxy records

Summer temperatures estimated from proxy records

Summer temperatures from Arctic weather station data

Long-term trend in proxy records

Figure: SWIPA (http://www.amap.no)
The sea ice reaches its minimum thickness and extent in September – is roughly half the size of the winter maximum.
Monthly September ice extent for 1979 to 2016 shows a decline of 13.3% per decade.

Credit: National Snow and Ice Data Center
Sea-ice extent 1979-2016

by Climate.gov, adapted from NSIDC’s Charctic (http://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph/)
Sea-ice extend

Yellow line: average 1979-2000
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http://earthobservatory.nasa.gov/Features/WorldOfChange/sea_ice.php?all=y
Northwest Passage clear of ice again in 2016
Not only the sea-ice extend, but also the thickness is decreasing
ESA's CryoSat-2 satellite measuring sea ice freeboard

(Image courtesy ESA)
Measuring the sea-ice thickness
Arctic sea-ice is getting younger and therefore more fragile

In 1987:
- 57% > 5 years old
- 25% > 9 years old

When they returned to the Arctic again in 2007:
- 7% > 5 years old
- the ice that was at least 9 years old had vanished

Albedo (% of radiation reflected)

- Dry snow
- Wet snow
- Bare ice
- New melt pond
- Mature melt pond
- Open water

Figure: Hugo Ahlenius, UNEP/GRID-Arendal
now you see it  now you don’t

Muir Glacier, Alaska: August 13, 1941 and August 31, 2004

photo: William O. Field

photo: Bruce F. Molnia
Alaska Range, Bear Glacier
Photographed by Ulysses Sherman Grant on July 20, 1909 (top) and by Bruce F. Molnia on Aug. 5, 2005 (bottom).

www.cicero.uio.no
Department of Geosciences and Environmental Research - Oslo
African Rift Zone, Kilimanjaro Glacier

Top view and side view, photographed by NASA's Landsat satellite on Feb. 17, 1993, (top) and again on Feb. 21, 2000 (bottom).
Greenland ice loss that has accelerated in the past few years
NASA's Operation IceBridge monitors the Greenland ice melt
How much ice are Greenland loosing?

- **Greenland ice loss 2002**
  - 137 gigatonnes per year

- **Greenland ice loss 2009**
  - 286 gigatonnes per year
The world we avoided

... by saving the ozone layer

And why the Montreal agreement was such a success!
The year is 2065.

Nearly two-thirds of Earth’s ozone is gone—not just over the poles, but everywhere...
The discovery of the ‘ozone hole’ in Antarctica – is now slowly start to recover to its pre-1980s levels.
The ozone layer would have collapsed globally by 2050

Control simulation with phase-out of ozone-depleting substances

‘The world avoided’ simulation without the Montreal Protocol

Garcia et al. 2012, JGR