



*Why is Arctic sea ice  
disappearing so rapidly?*

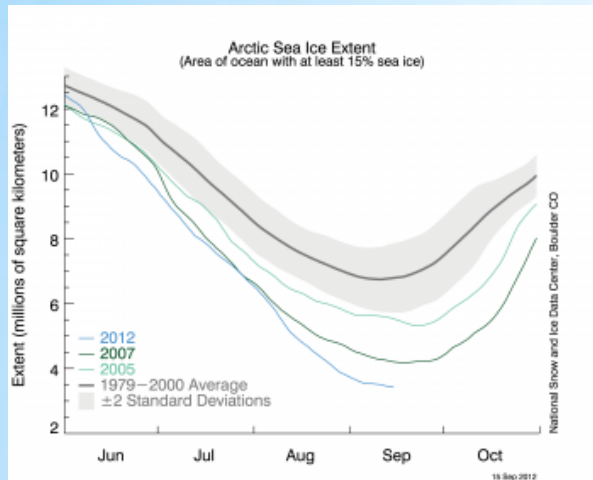
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[www.ecra-climate.eu](http://www.ecra-climate.eu)

- Sea Ice changes: observations and model results
- Possible culprits behind sea ice retreat
- Summary
  
- **Understanding Arctic Change, (especially sea ice) is truly multi-sectorial and multi-disciplinary**
  - EU ACCESS: <http://www.access-eu.org>
  - EU ICE-ARC: <http://www.ice-arc.eu>

# Summer sea ice extent



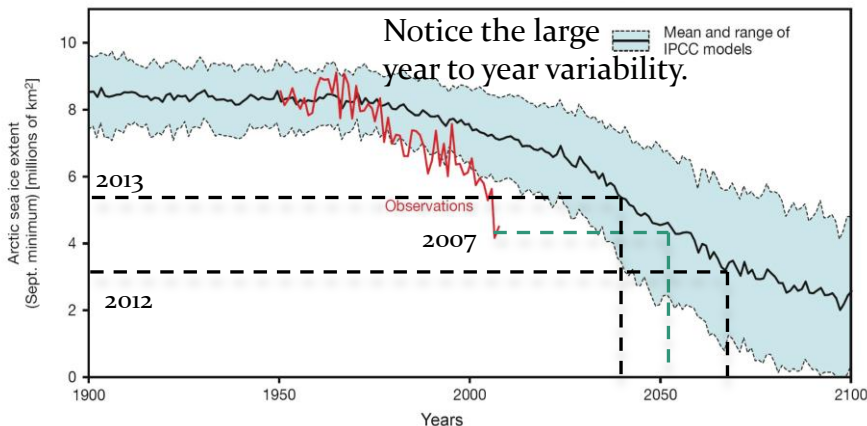
**Reduction of over 50% in summer sea ice extent since the 1970s million km<sup>2</sup> in the 1970s**

- 4.2 million km<sup>2</sup> in 2007
- 3.4 million km<sup>2</sup> in 2012
- 5.35 million km<sup>2</sup> in 2013\*\*

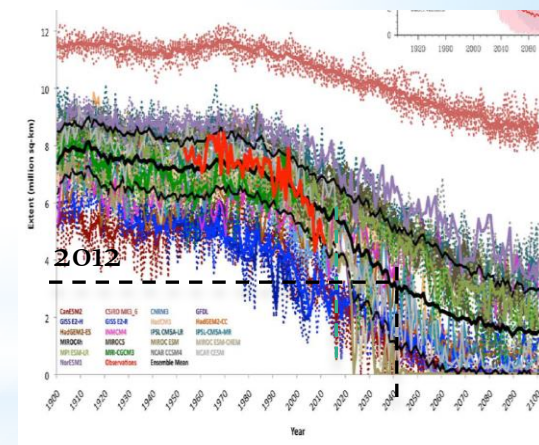
\*\* 1.17 million km<sup>2</sup> below the 1981 to 2010 average extent. Sixth lowest in the satellite record



<http://imbr.crrel.usace.army.mil/change.htm>



From: **The Copenhagen Diagnosis**, 2009: Updating the world on Latest Climate Science. I. Allison, N.L. Bindoff, R.A. Bindaschadler, P.M. Cox, N. de Noblet, M.H. England, J.E. Francis, N. Gruber, A.M. Haywood, D.J. Karoly, G. Kaser, C. Le Quéré, T.M. Lenton, M.E. Mann, B.I. McNeil, A.J. Pitman, S. Rahmstorf, E. Rignot, H.J. Schellnhuber, S.H. Schneider, S.C. Sherwood, R.C.J. Somerville, K. Steffen, E.J. Steig, M. Visbeck, A.J. Weaver. University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, 60pp.

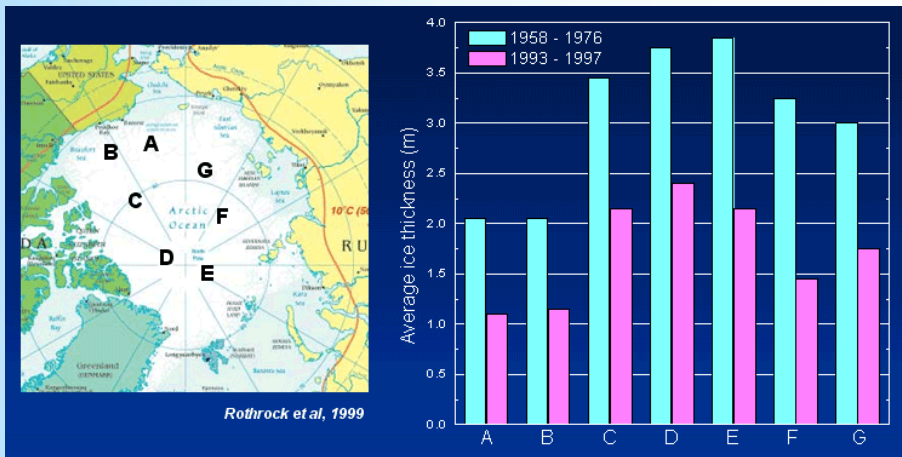


Stroeve et al., 2012

**Satellite Observations**, **Best 17 models**

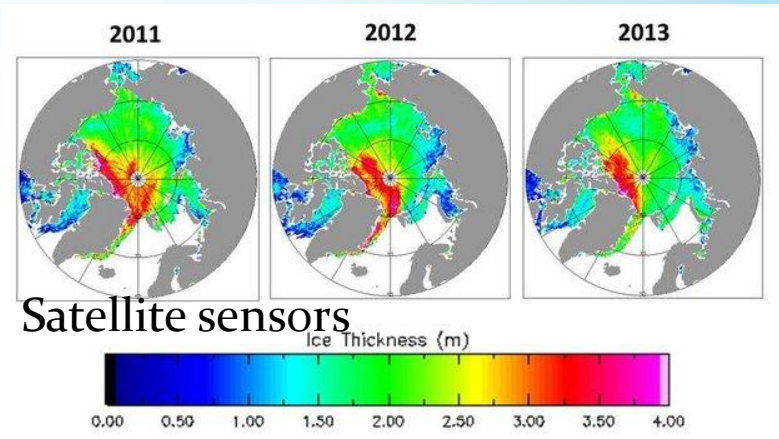
# Sea ice thickness

UK and US Submarine missions provide ice thickness data for time series analysis.



Results show that there was thinning across the entire Arctic Ocean. The thinning averaged 40%, representing a decrease from about 3 m to less than 2 m.

## Electromagnetics



Changes in ice thickness for March/April 2011, 2012 and 2013 as measured by CryoSat. Source: ESA

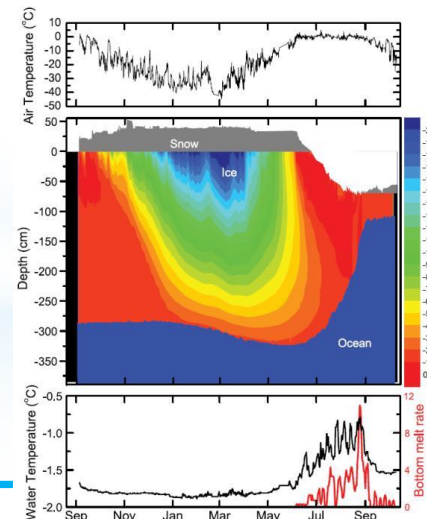


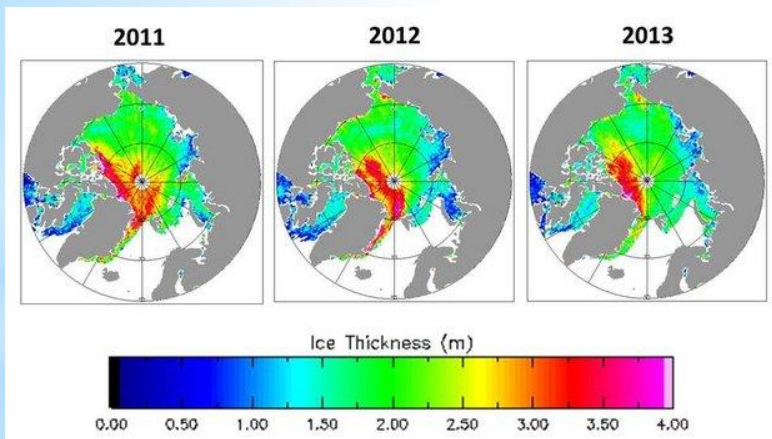
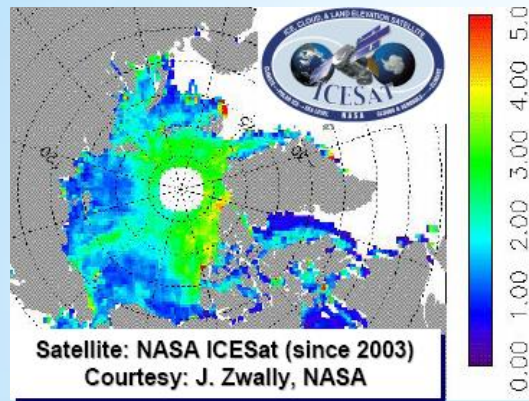
Figure 5. Time-series results for an ice mass balance buoy deployed in the Beaufort Sea from August 2006 to November 2007. Plot includes air temperature (top panel); internal ice temperature, snow depth, and ice thickness (middle panel); and ocean temperature beneath the ice (black) and bottom melt rate (red) (bottom panel). In the middle panel, the gray shaded area represents snow, the black areas are missing data, and the dark blue represents the ocean. From Perovich et al. (2008)

Ice mass balance buoys



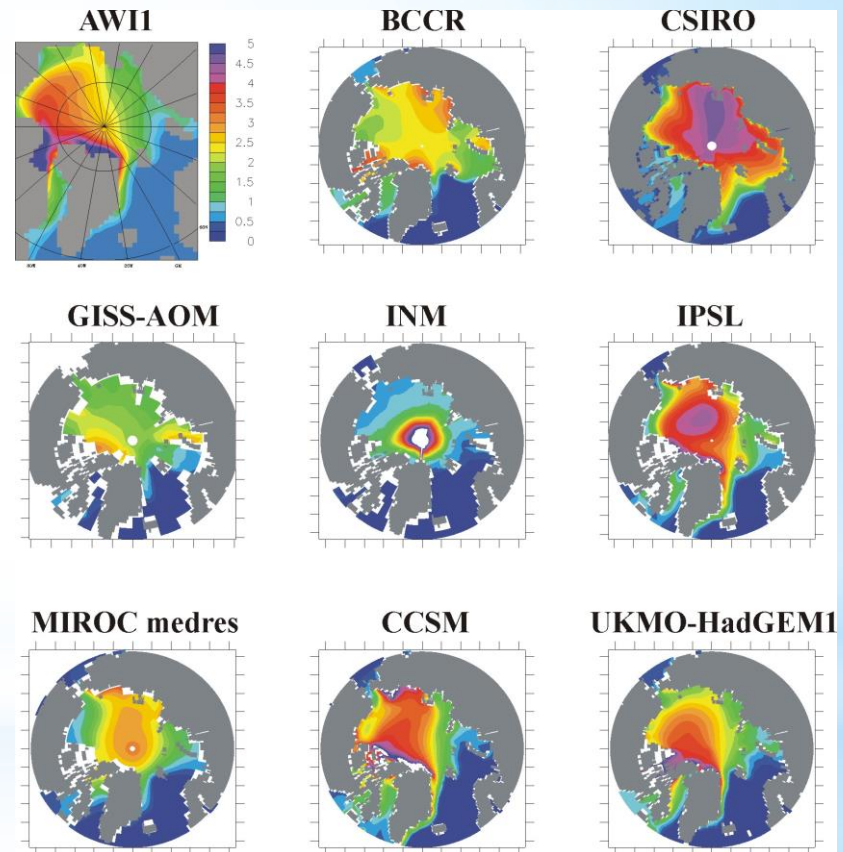
# Ice thickness: Observations / Models

## Satellite derived data



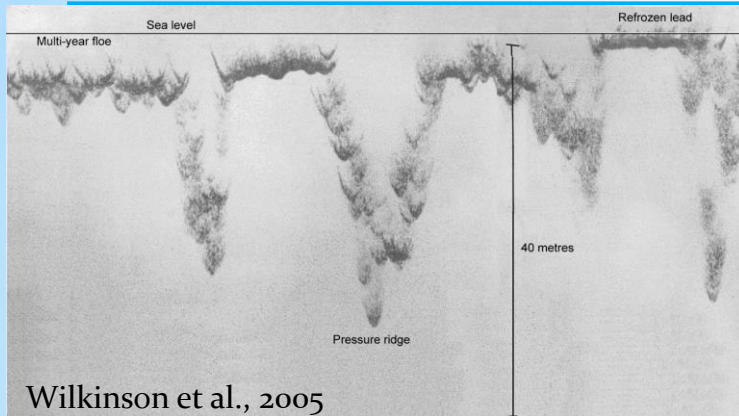
Changes in ice thickness for March/April 2011, 2012 and 2013 as measured by CryoSat. Source: ESA

## 20th century ice thickness results from IPCC (coupled climate) models

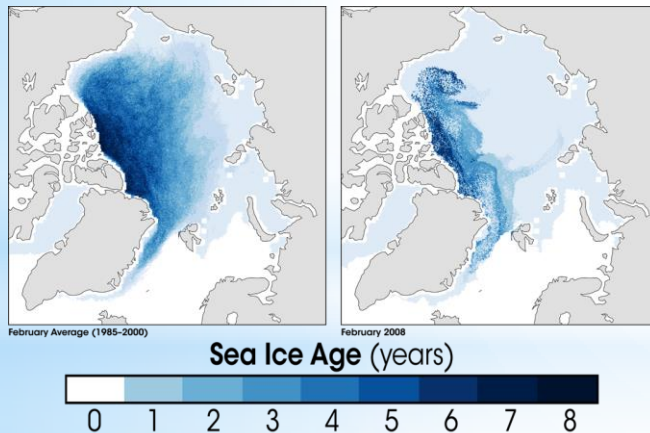


# Ice dynamics and age

Submarines, buoys and remote sensing imagery



Reduction of some 73% in the frequency of deep pressure ridges (Wadhams and Davis, 2001), indicating a radical change in ice dynamics.



Arctic Sea ice age in February 2008 compared to the average for 1985-2000 (NASA).

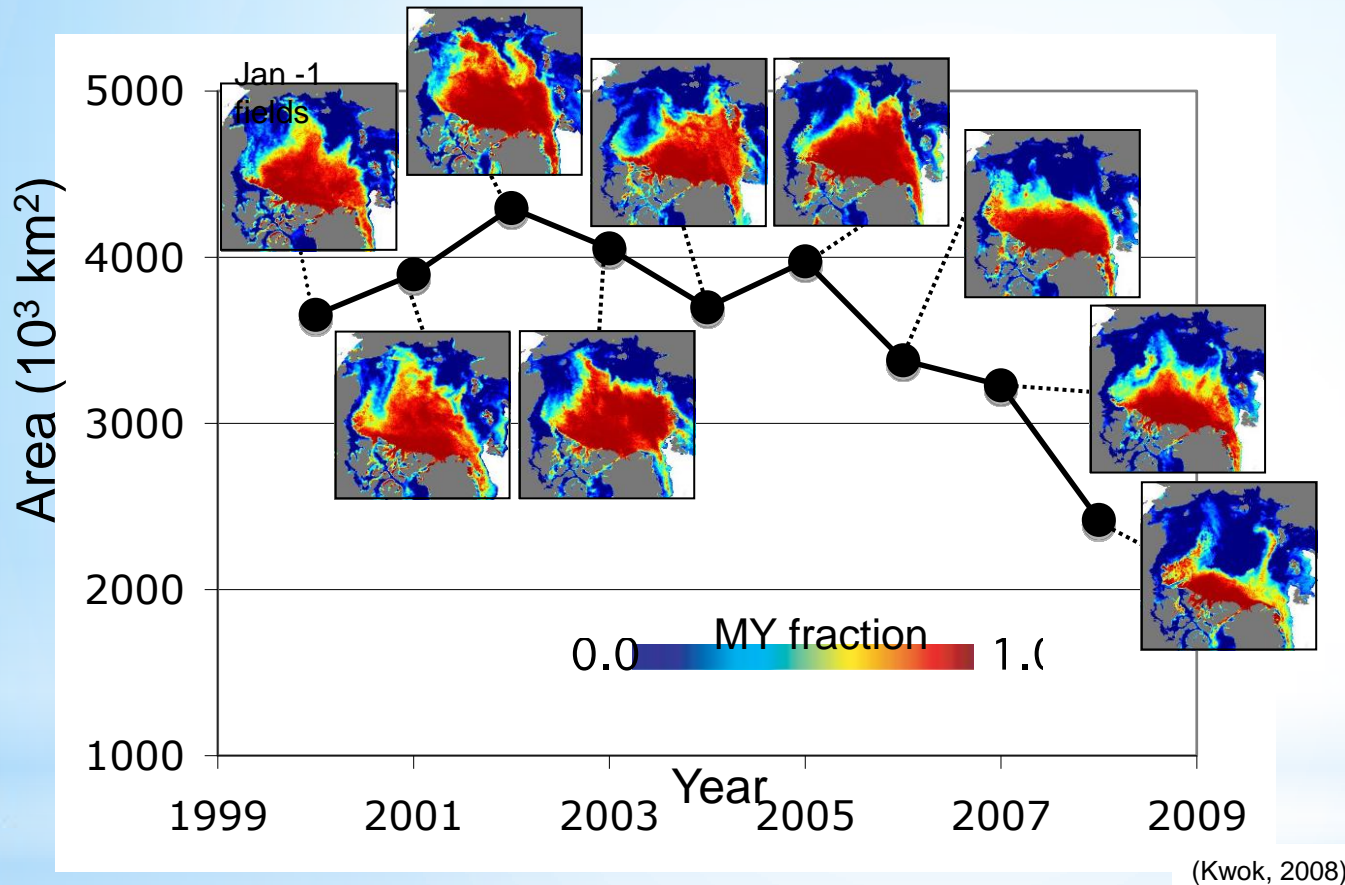


Buoys directly measure the drift of sea ice. BAS deployed 44 buoys in the Arctic this spring (2014). All data transmitted to BAS in near-real time. Possibly the largest number of active buoys in the Arctic of any institute.

**1980' s:**

- Less open water
- Less younger, thinner ice
- More older, thicker ice

# First-year / multi-year fraction



- Significant reduction in the amount of Multiyear ice in the Arctic.

- Change from a multiyear dominant ice cover to a first year dominant ice cover.

- This major shift influences all aspects of sea ice, from its strength through to its dynamics.

Decline in Arctic Ocean Multiyear Sea Ice Coverage



# Why is the ice disappearing?

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- Indisputable evidence that the summer sea ice is reducing, both in extent and thickness, but also the nature of the ice is changing.
- Sea ice changes are driven by changes in the atmosphere and ocean
- Cannot look at sea ice in isolation.
- Complex feedbacks

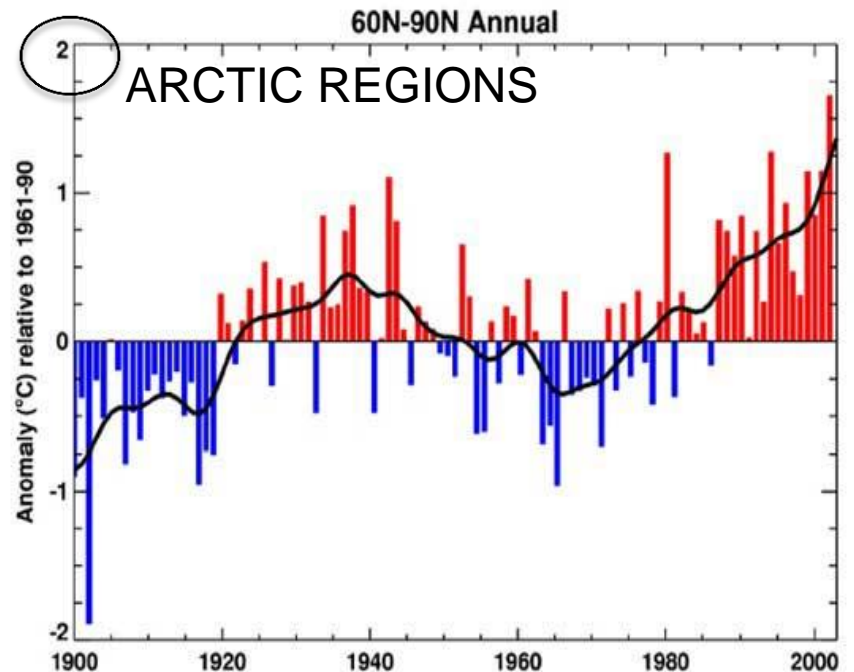
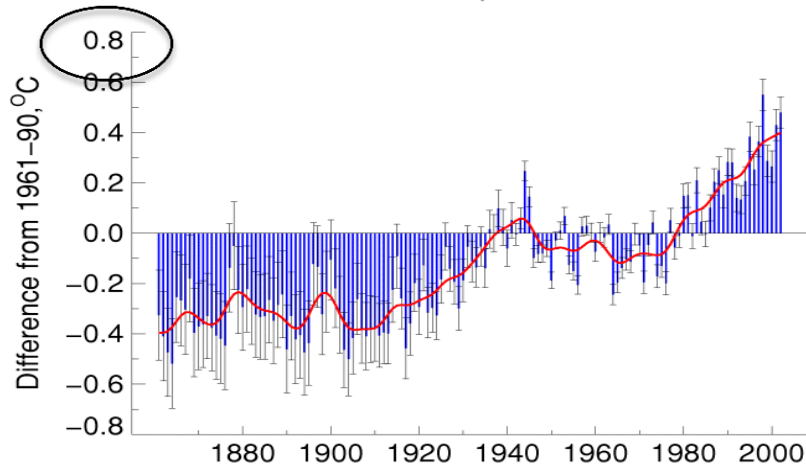


# Why is the ice disappearing?

- Atmosphere is warming...twice as fast as the the rest of the world

## GLOBAL TEMPERATURES

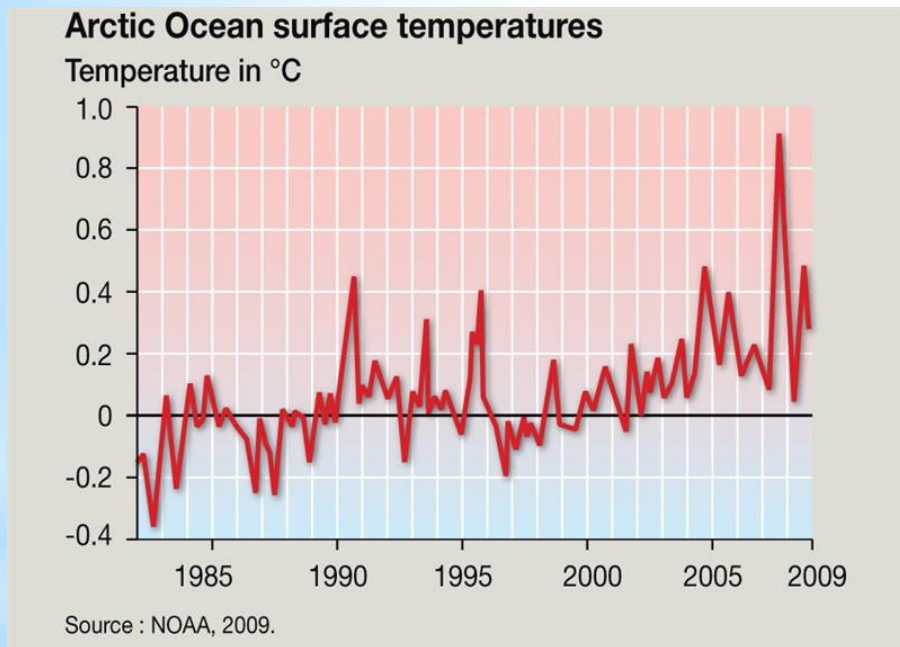
Global Annual land air and sea surface temperature anomalies, 1861 – 2002



Average air temperatures at 60-90°N have risen by 2°C since 1980 compared with 0.7°C for the planet as a whole.

# Why is the ice disappearing?

- **Arctic ocean is warming...**increased temperatures in the subsurface water layer in the Arctic leading to greater ocean heat fluxes



## Potential culprits..

- Pacific water
- Atlantic water
- Increased solar radiation
- Increased mixing
- ...

# Why is the ice disappearing?

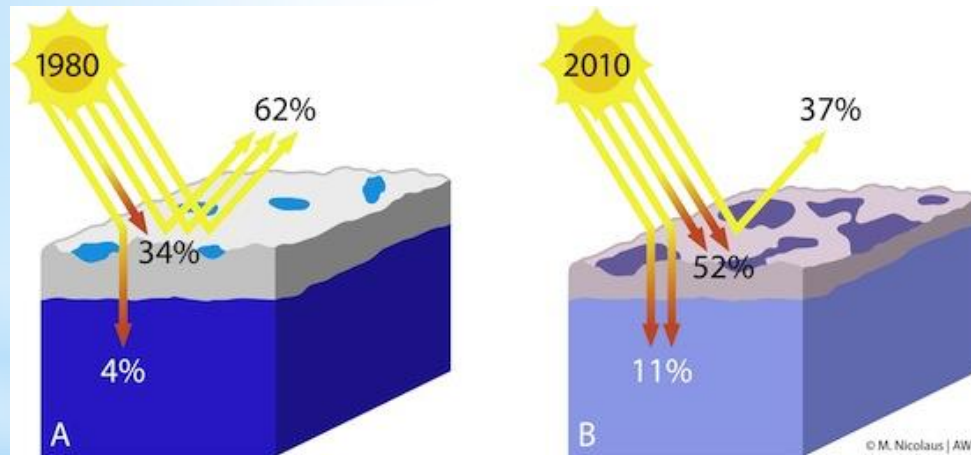
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## Other contributing factors

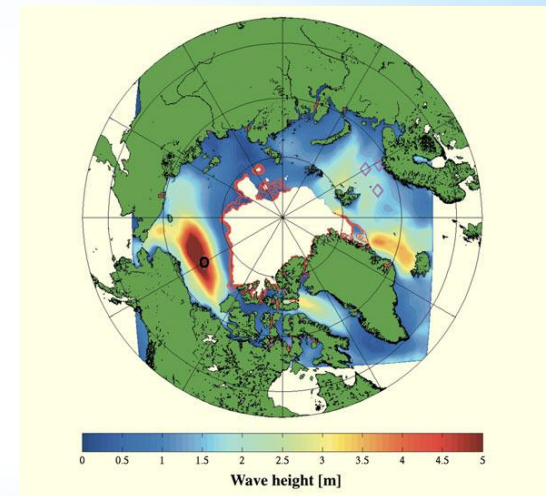
- Snow cover on land, melting earlier and as a result the land mass is warming.
- Clouds are a key factor in the energy budget of the Arctic ocean-ice system. Feedbacks between clouds (aerosols) and the ice/ocean surface is thus of prime importance for improved predictions.
- Change in albedo of snow/ice due to black carbon
- And more...

# Why is the ice disappearing?

- Complex feedback mechanisms
- Ice-albedo feedback
- Wave-ice interaction



*The growing coverage of the ice by darker meltponds increases the share of sunlight that passes the sea ice.*  
Source: AWI



September 2012 storm in Arctic Ocean. The color scale indicates significant wave height from 0 to 5 m.  
Source: Jim Thomson APL.



# Summary

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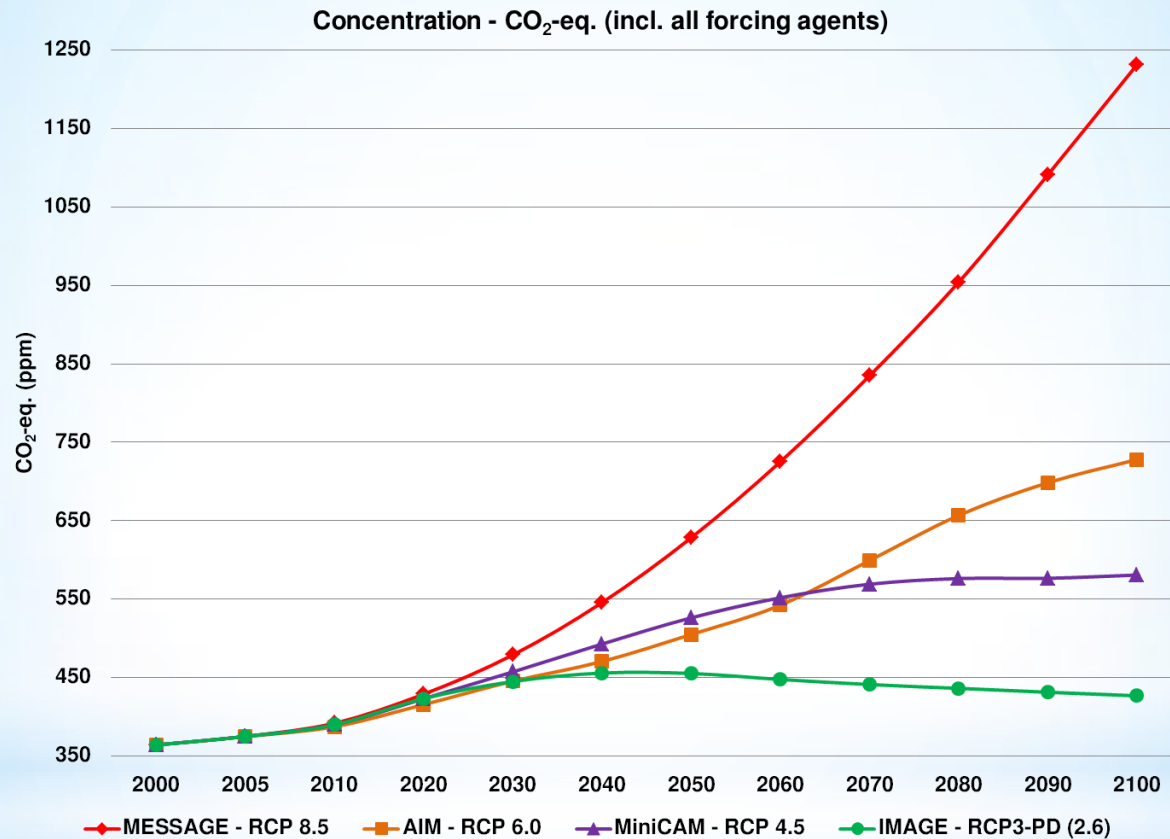
- **Indisputable evidence that the Arctic sea ice is changing**
- **Anthropogenic greenhouse gas forcing appears to be a necessary factor for major loss of sea ice to occur.**
- **We cannot look at sea ice alone, must be an integrated approach that involves the ocean and atmosphere (and ecosystem).**
- **Difficult to predict how the summer sea ice will retreat.** Will it be a continuation of rapid sea ice loss over the next decade, or step changes bought about by the occurrence of 'rare' warm years such as 2007 to continue the sea ice decline.
- **Observational evidence suggest the change is occurring faster than models suggest.**

# Arctic Change: Why is Arctic sea ice disappearing so rapidly?

Thank you for your attention



# Arctic Change



All forcing agents' atmospheric CO<sub>2</sub>-equivalent concentrations (in parts-per-million-by-volume (ppmv)) according to four RCPs.