Federal Service for Hydrometeorology
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Arctic
Sea ice change in the 21st century: are we getting more certain?

Vladimir Kattsov

WARNING: PRELIMINARY RESULTS!

WCRP Open Science Conference
Denver, USA, October 24-28, 2011

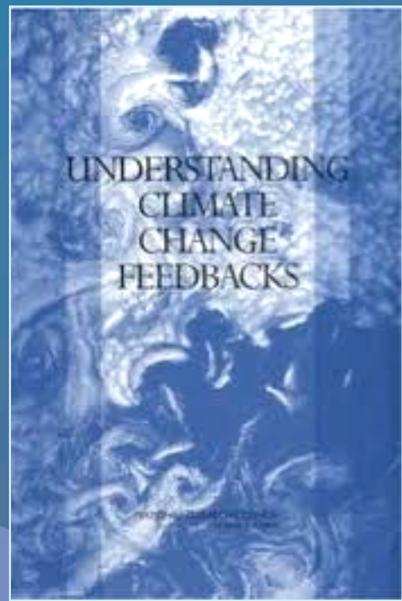
Part 1: The context

Relative stability of polar climate?

“Our best estimate at present is that all of the individual cloud, snow, and sea-ice feedbacks in the polar regions are positive, with the exception of the aerosol-dehydration feedback.

“It remains a major task in climate modeling **to explain the relative stability of the polar climate** in the presence of these positive feedbacks.

“Possibilities include unexpected negative cloud feedbacks, or negative feedbacks between the sea ice and ocean.”



National Research Council of the National Academies, 2003. Understanding Climate Change Feedbacks, Washington D. C., National Academies Press, 152 p.

Annual surface air temperature area-averaged over the 60°-90°N latitudinal zone (Arctic)

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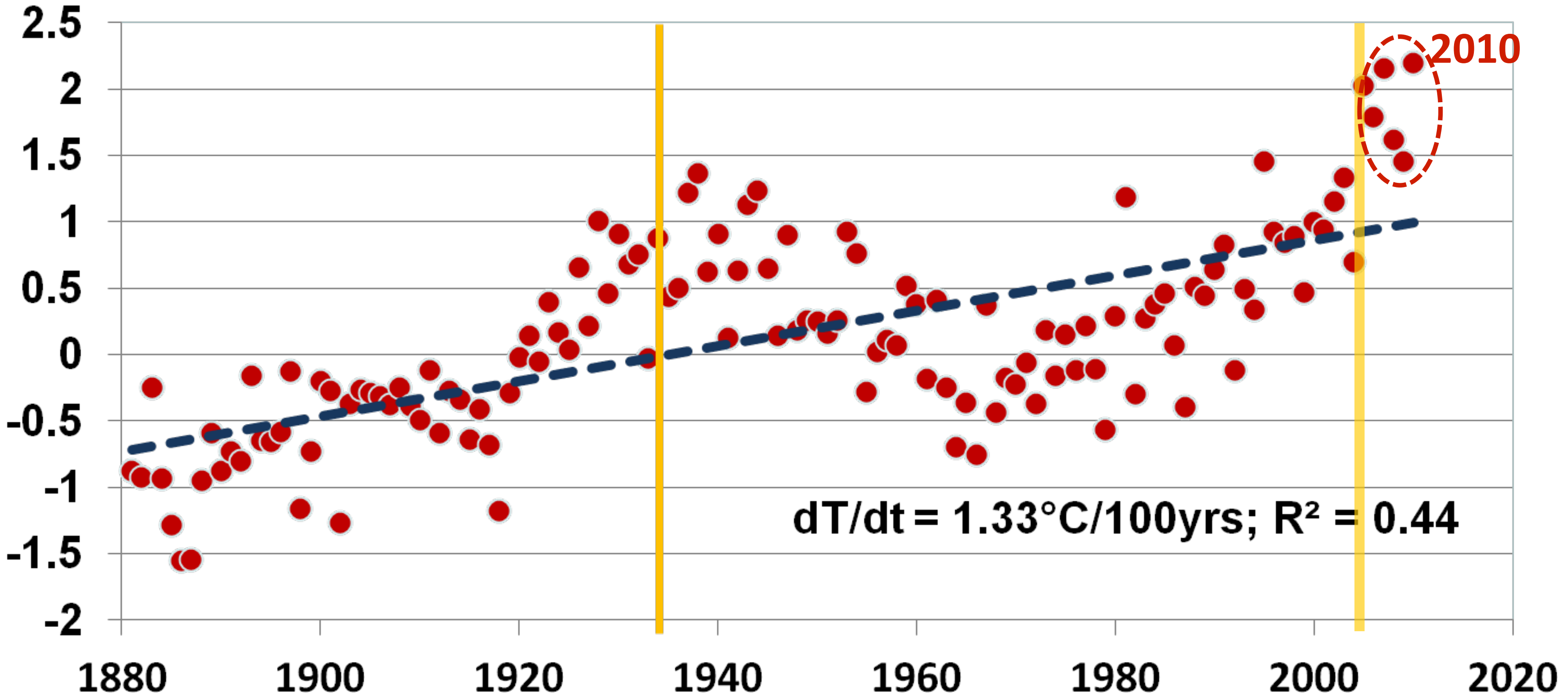

Linear trend for the entire period of instrumental observations is **1.73°C/130 yr** but there were periods (e.g., 1936-2004) when there was no statistically significant linear trend (*Groisman et al. 2006, updated*).

Zonal temperature projection: a robust pattern

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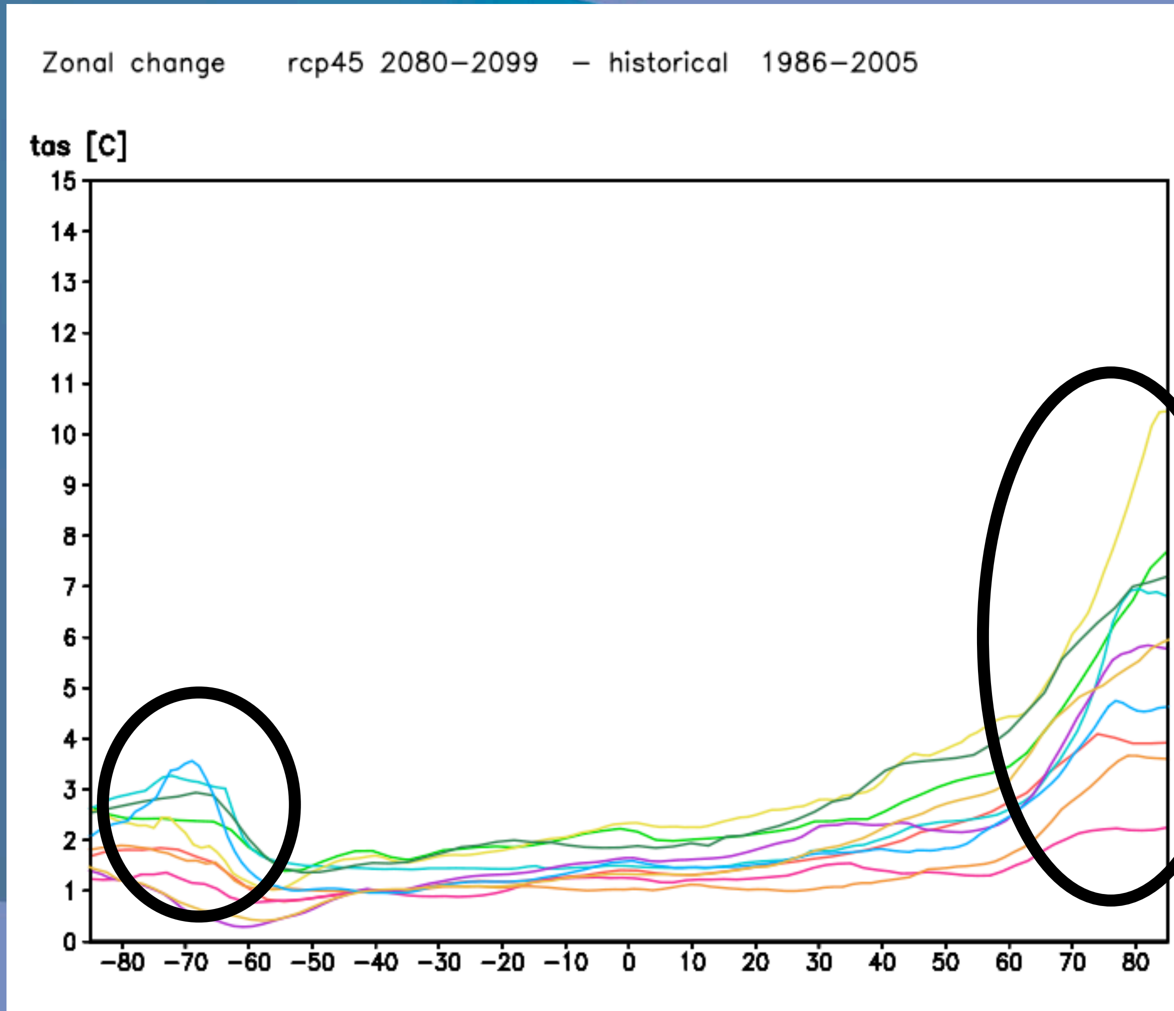
CMIP5: Annual mean SAT change by 2080-99 (RCP 4.5)



Insufficient knowledge (understanding) of important physical processes and feedbacks results in differences in model responses to the same forcing.

Observed Arctic ice anomalies and linear trends (relative to 1979-2000)

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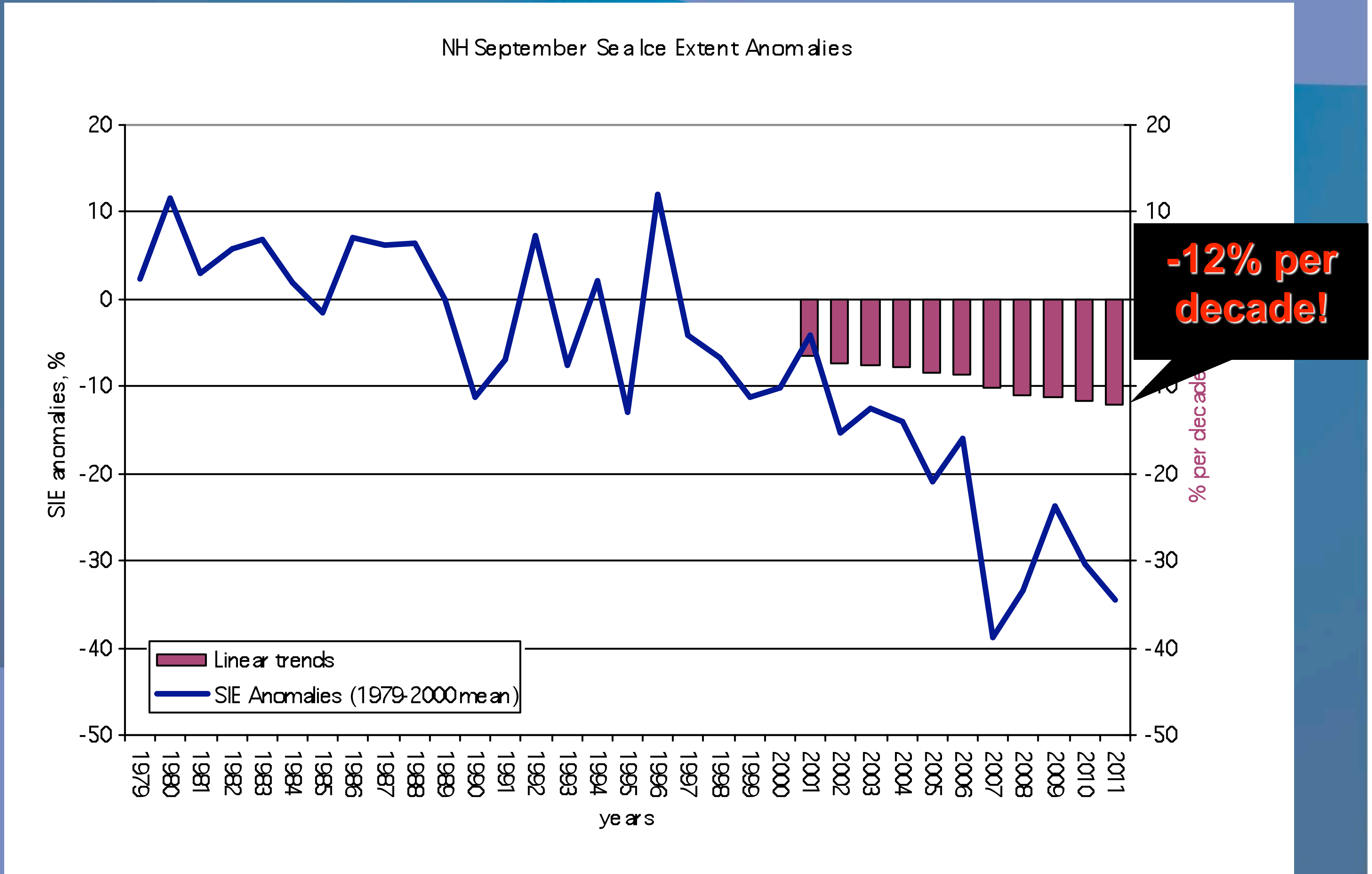

Based on NSIDC data

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Part 2: Models too conservative?

Models too conservative?

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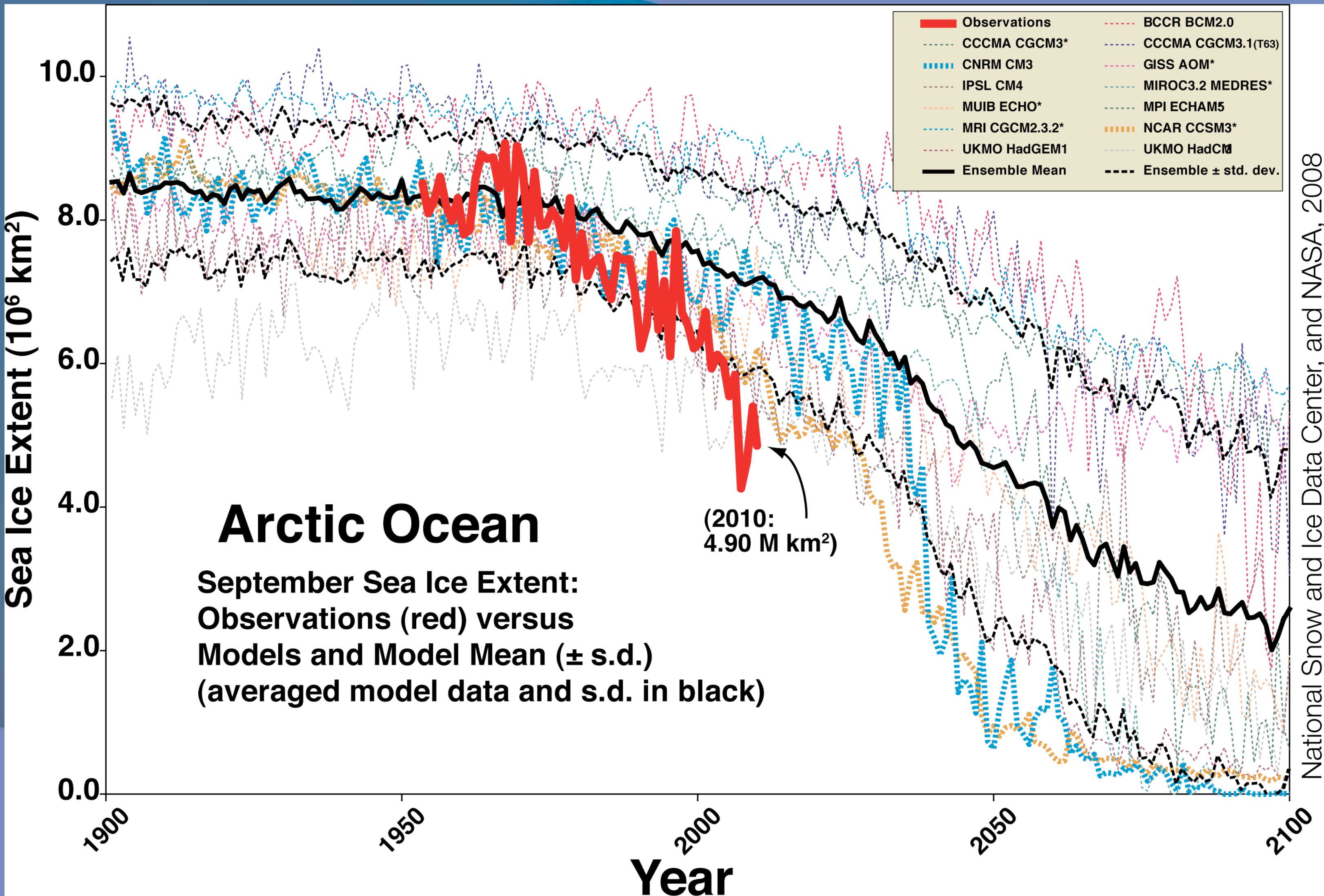

J.Stroeve, 2007 (updated)

Models too conservative?

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Journal of Glaciology, Vol. 56, No. 200, 2010 1115

Arctic sea-ice change: a grand challenge of climate science

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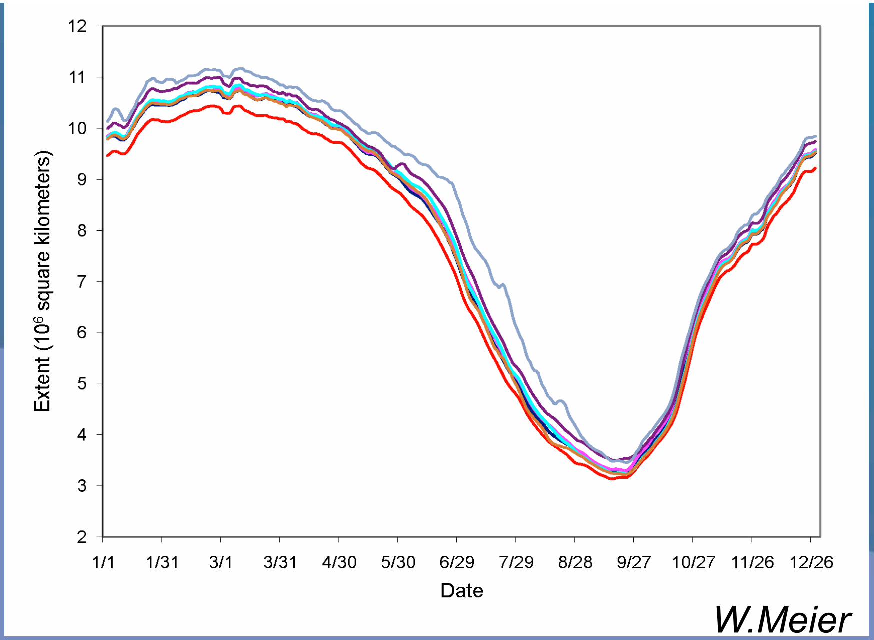
ABSTRACT. Over the period of modern satellite observations, Arctic sea-ice extent at the end of the melt season (September) has declined at a rate of >11% per decade, and there is evidence that the rate of decline has accelerated during the last decade. While climate models project further decreases in sea-ice mass and extent through the 21st century, the model ensemble mean trend over the period of instrumental records is smaller than observed. Possible reasons for the apparent discrepancy between observations and model simulations include observational uncertainties, vigorous unforced climate variability in the high latitudes, and limitations and shortcomings of the models stemming in particular from gaps in understanding physical process. The economic significance of a seasonally sea-ice-free future Arctic, the increased connectivity of a warmer Arctic with changes in global climate, and large uncertainties in magnitude and timing of these impacts make the problem of rapid sea-ice loss in the Arctic a grand challenge of climate science. Meaningful prediction/projection of the Arctic sea-ice conditions for the coming decades and beyond requires determining priorities for observations and model development, evaluation of the ability of climate models to reproduce the observed sea-ice behavior as a part of the broader climate system, improved attribution of the causes of Arctic sea-ice change, and improved understanding of the predictability of sea-ice conditions on seasonal through centennial timescales in the wider context of the polar climate predictability.

“Polar” problems of current GCMs (verification)

- ✓ Sparse and inconsistent *in situ* observations
- ✓ Specific observations (sea ice thickness and other characteristics, solid precipitation, cloudiness, etc.)
- ✓ Scatter between existing observationally based products

Arctic sea ice extent for 2007 from seven algorithm products.



“Polar” problems of current GCMs (physics)

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- ✓ Stable stratification in the lower troposphere
- ✓ Low water vapour content in the atmosphere
- ✓ Multi-layer clouds, specific types of clouds
- ✓ Specific features of the ocean TH structure (+ river discharge in NH)
- ✓ Sea ice (dynamics & thermodynamics + biogeochemistry + biology?)
- ✓ Vigorous unforced variability
- ✓ …
- ✓ …

Myriad feedbacks

"…the quantitative influence of the myriad feedbacks associated with sea ice is unclear."

Bony et al., 2006

Outstanding issues

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- ✓ multi-year and decadal climate variability, incl. heat storage in the upper layer of the ocean during the summer and ocean heat transport from the Atlantic and Pacific to the Arctic Ocean;
- ✓ small scale processes, e.g. convection in brine pockets or in melt ponds;
- ✓ black carbon;
- ✓ a statistically rare event associated with unforced variability?
- ✓ predictability of unforced variations?

Kattsov et al., 2011

Some CMIP3 models do simulate rapid changes

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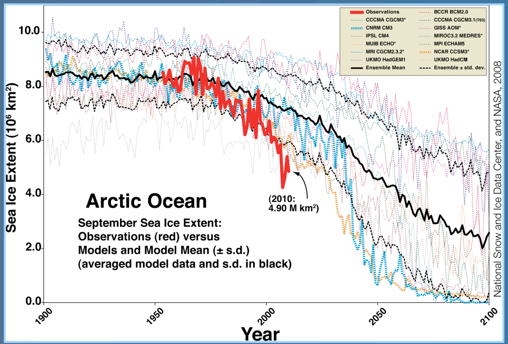

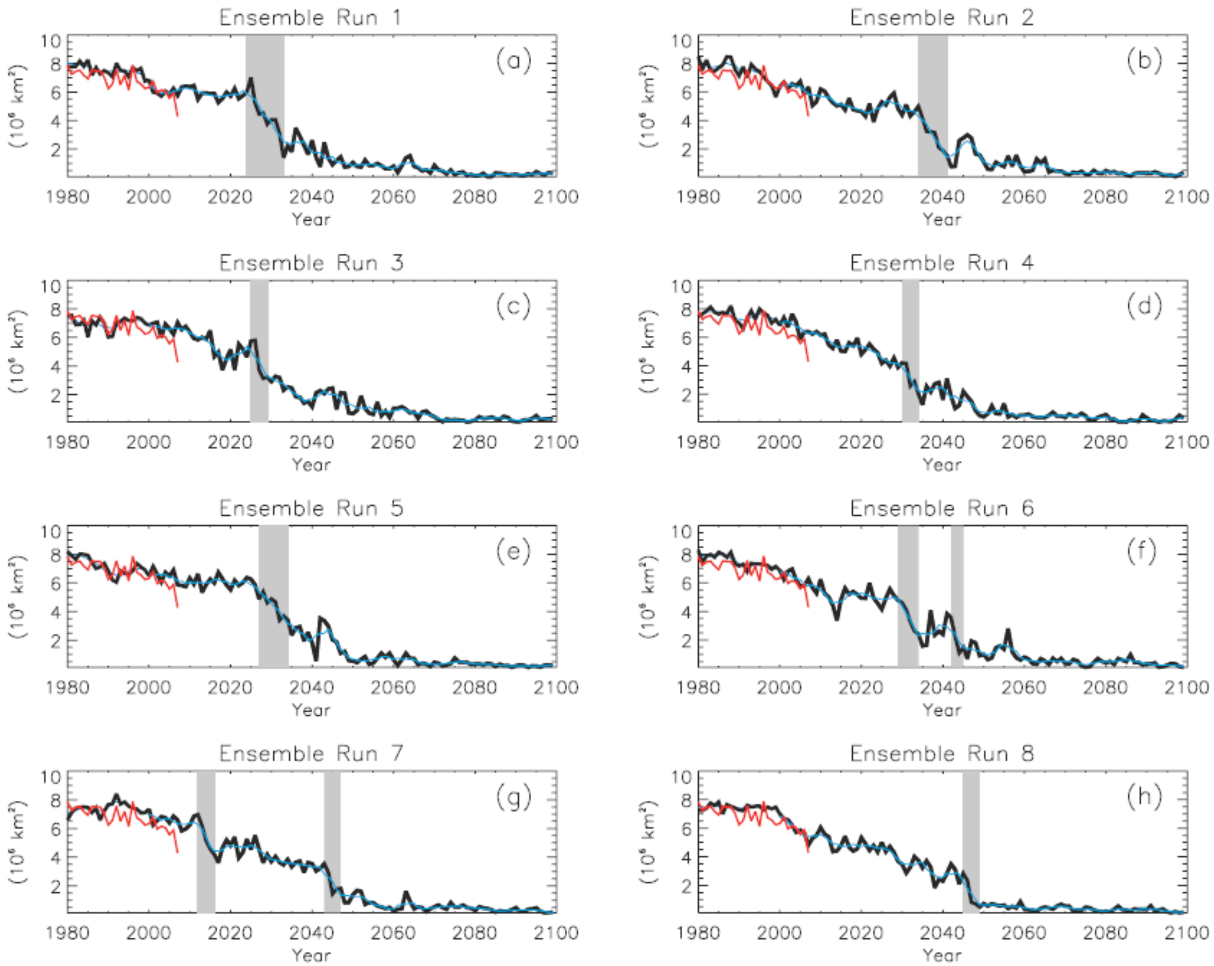

Plate 2. Time series of September ice extent from the (a–h) eight IPCC-AR4 CCSM3 ensemble members. The blue line shows the 5-year running mean time series. The observed time series from 1979 to 2007 is shown in red. Grey shading indicates abrupt events as defined in the text.

Holland et al., 2008

So, are the models too conservative?

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Not enough evidence for this

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Part 3: Getting more certain?

Model improvement:
What do we mean by that?

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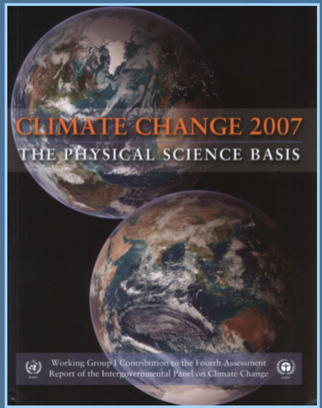
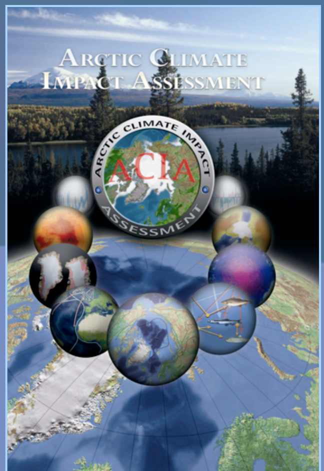
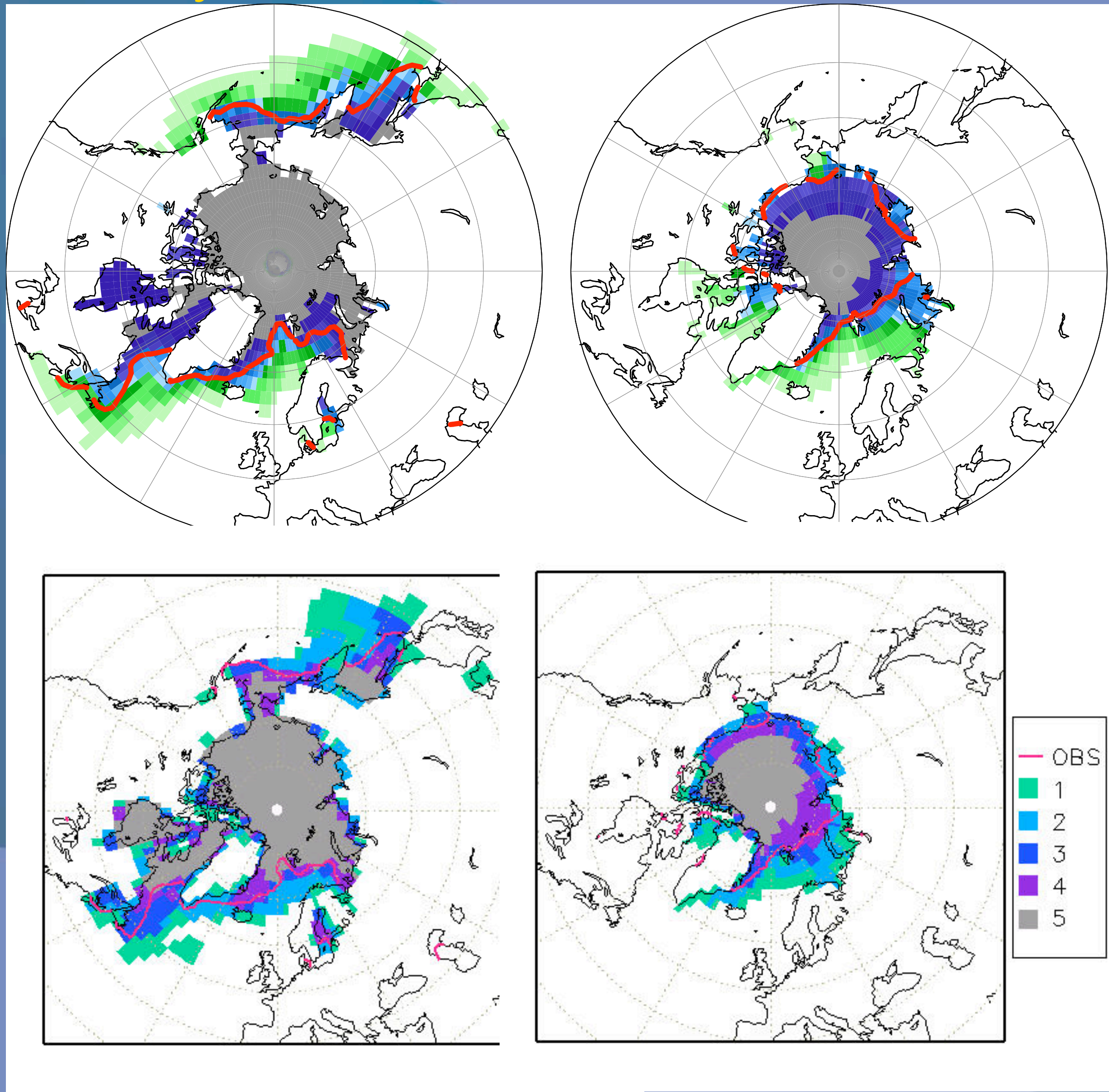


CMIP3



CMIP2



March September

Model improvement:
What do we mean by that?

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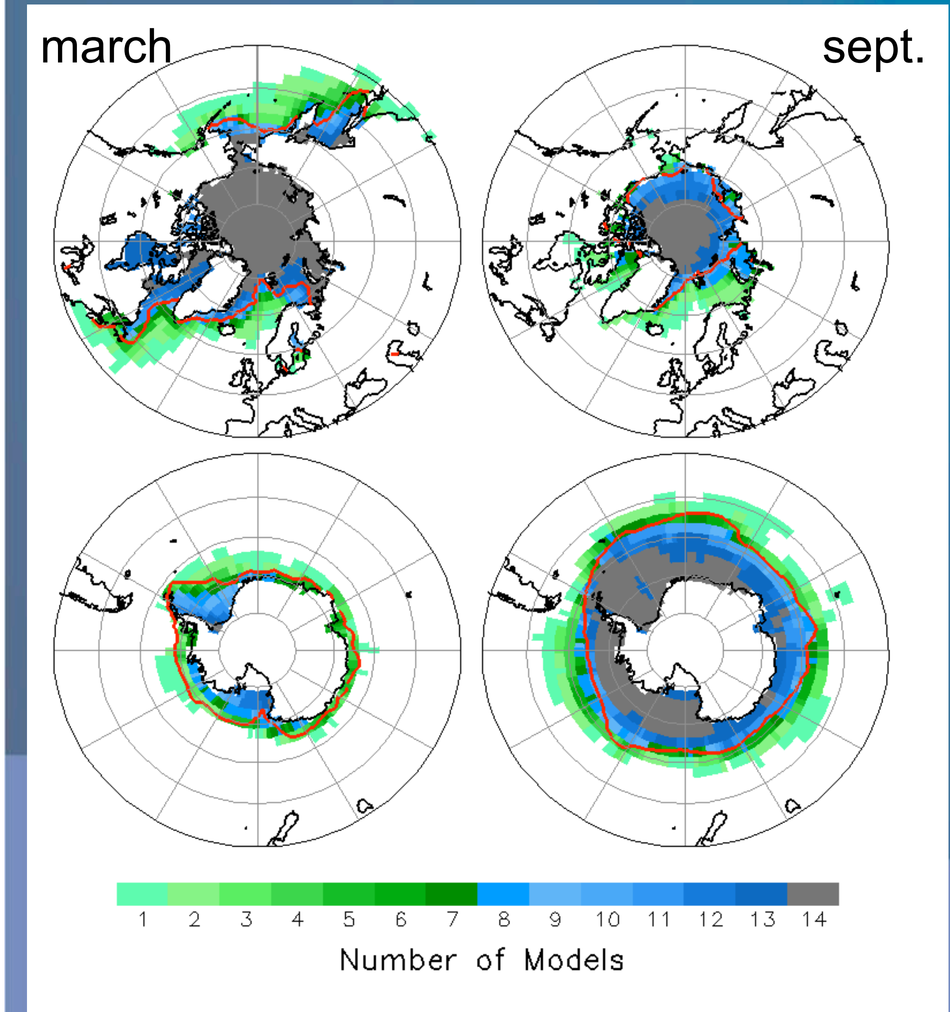
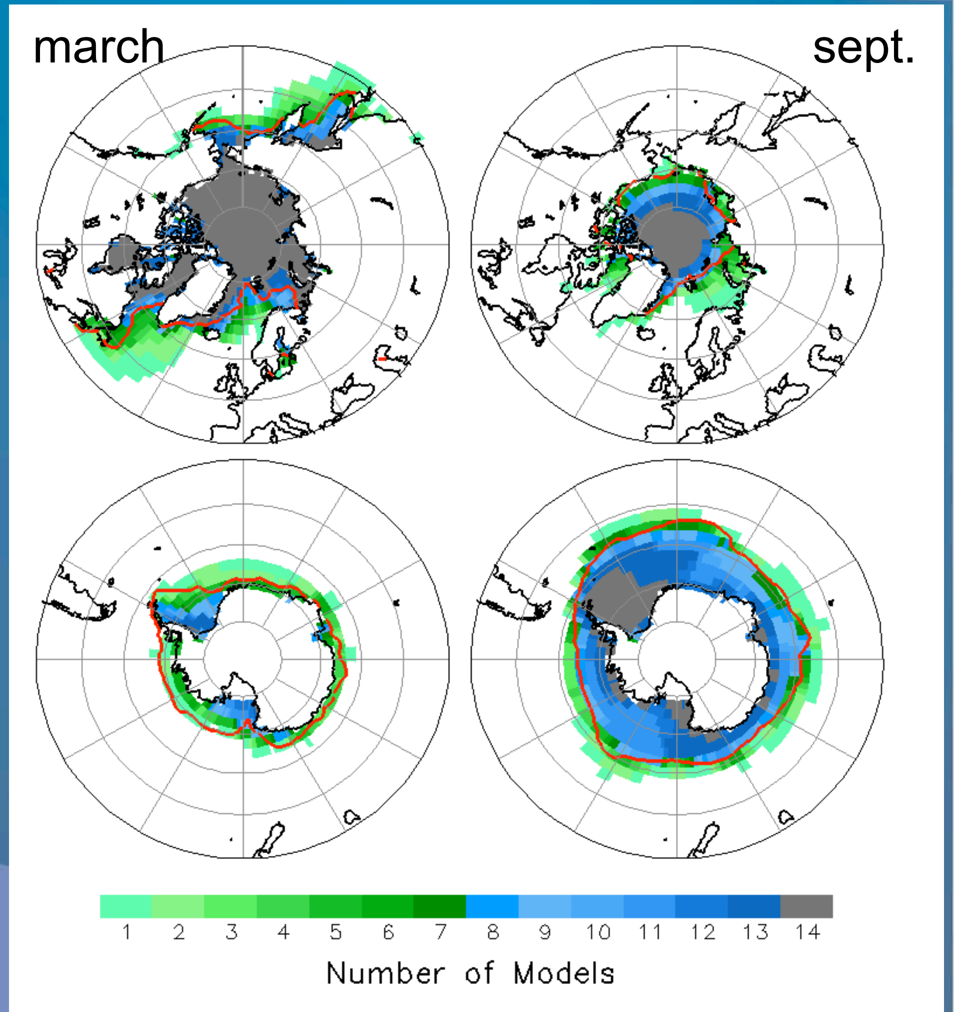
CMIP3



CMIP5



IPCC, 2007; Pavlova et al., 2011

Model improvement:
What do we mean by that?

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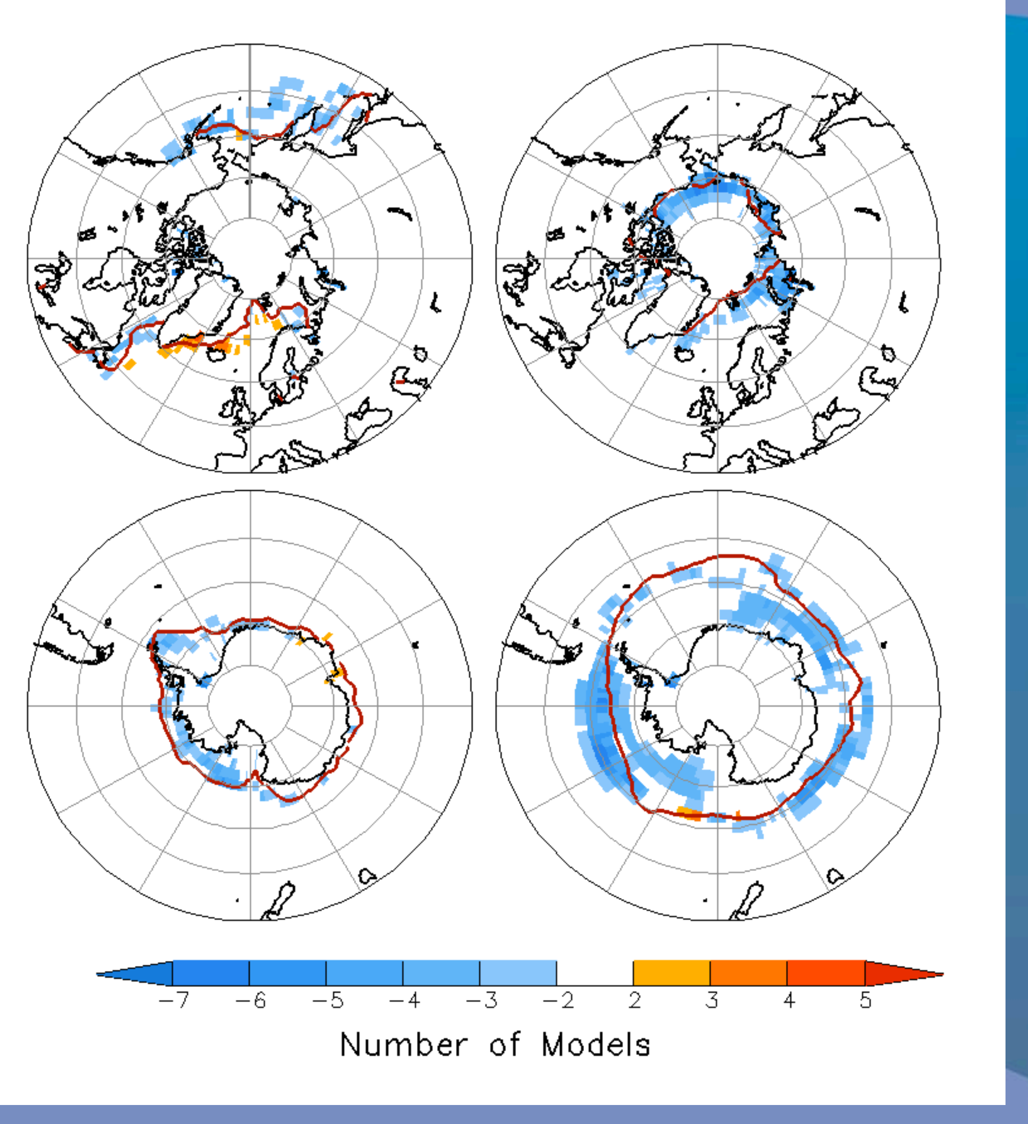
CMIP5 minus CMIP3



Pavlova et al., 2011

Model improvement:
What do we mean by that?

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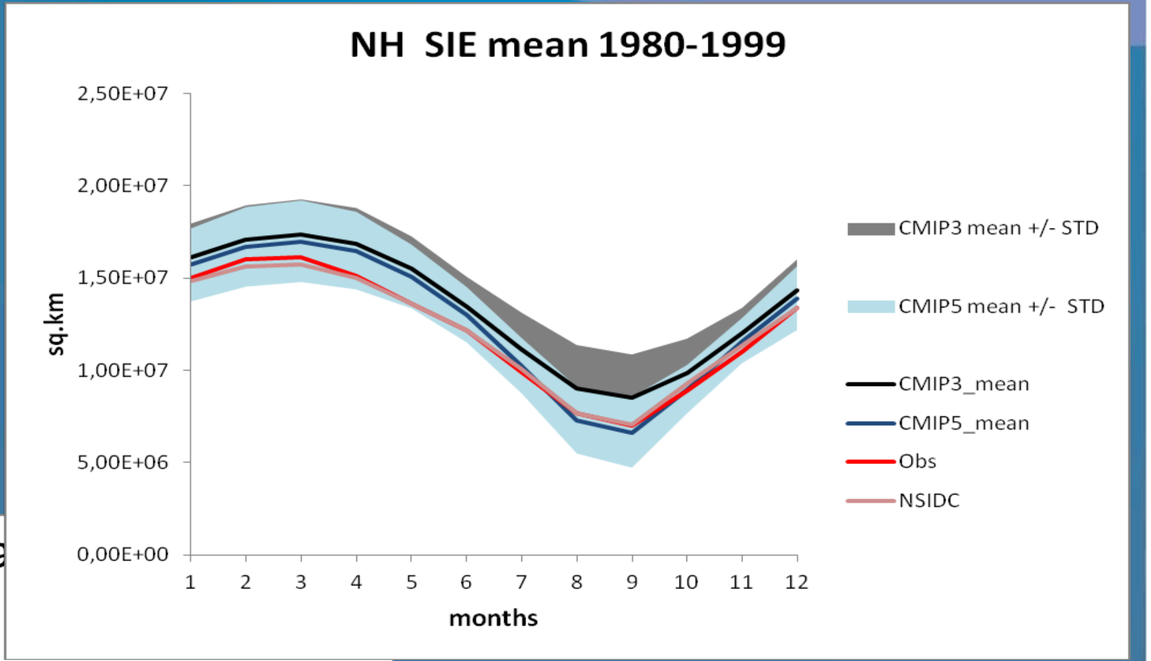
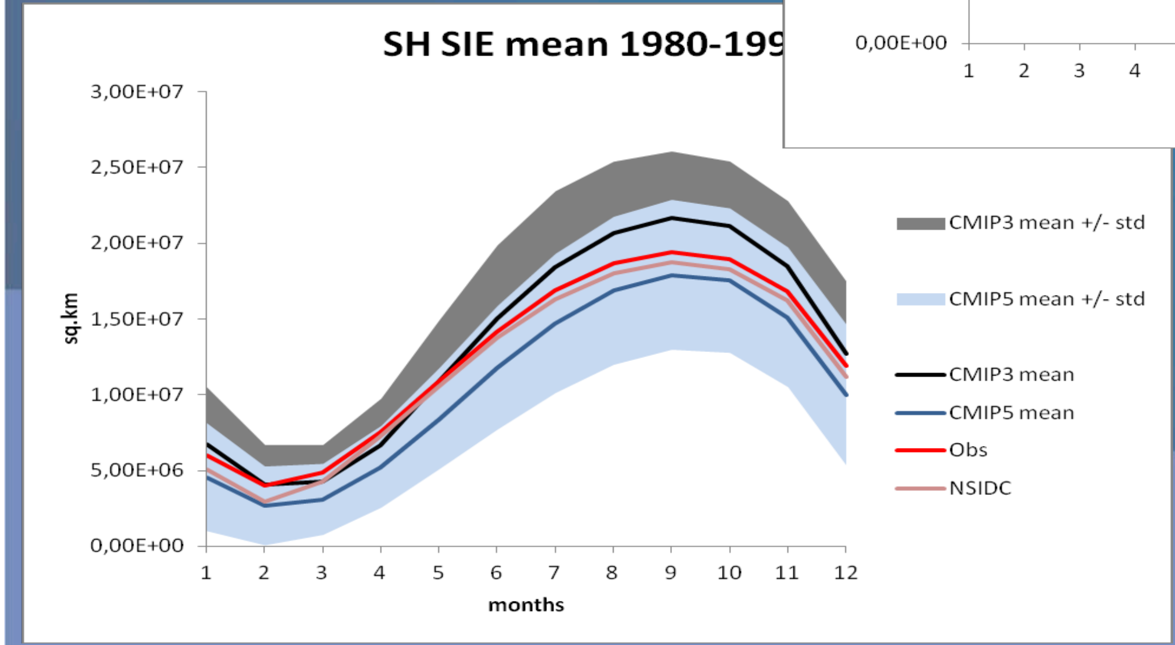
CMIP5 vs. CMIP3





Pavlova et al., 2011

Model improvement:
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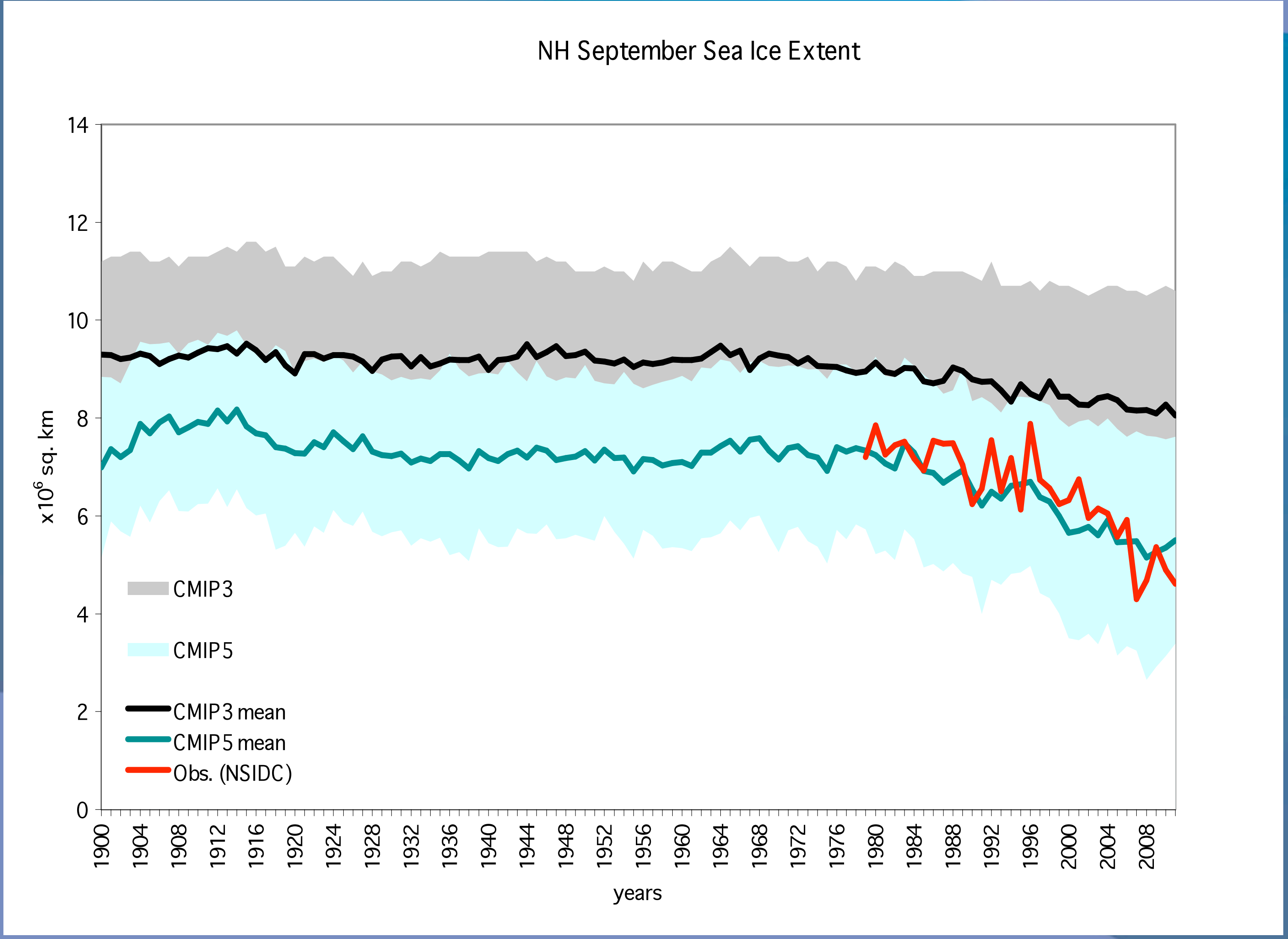
CMIP5 vs CMIP3



Pavlova et al., 2011

Model improvement:
What do we mean by that?

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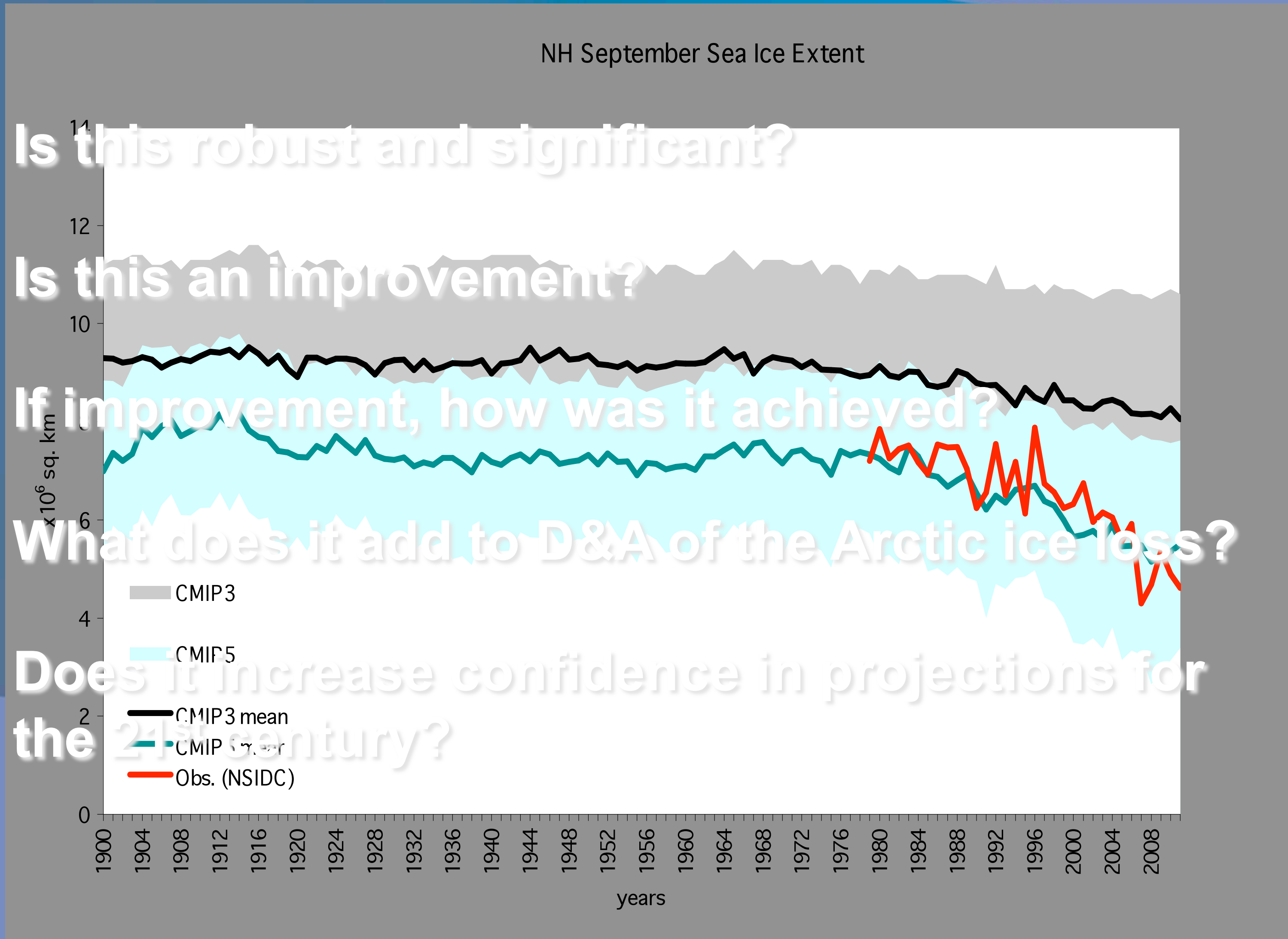
CMIP5 vs CMIP3



Is this robust and significant?

Is this an improvement?

If improvement, how was it achieved?

What does it add to D&A of the Arctic ice loss?

Does it increase confidence in projections for the 21st century?

Pavlova et al., 2011

Model improvement:
What do we mean by that?

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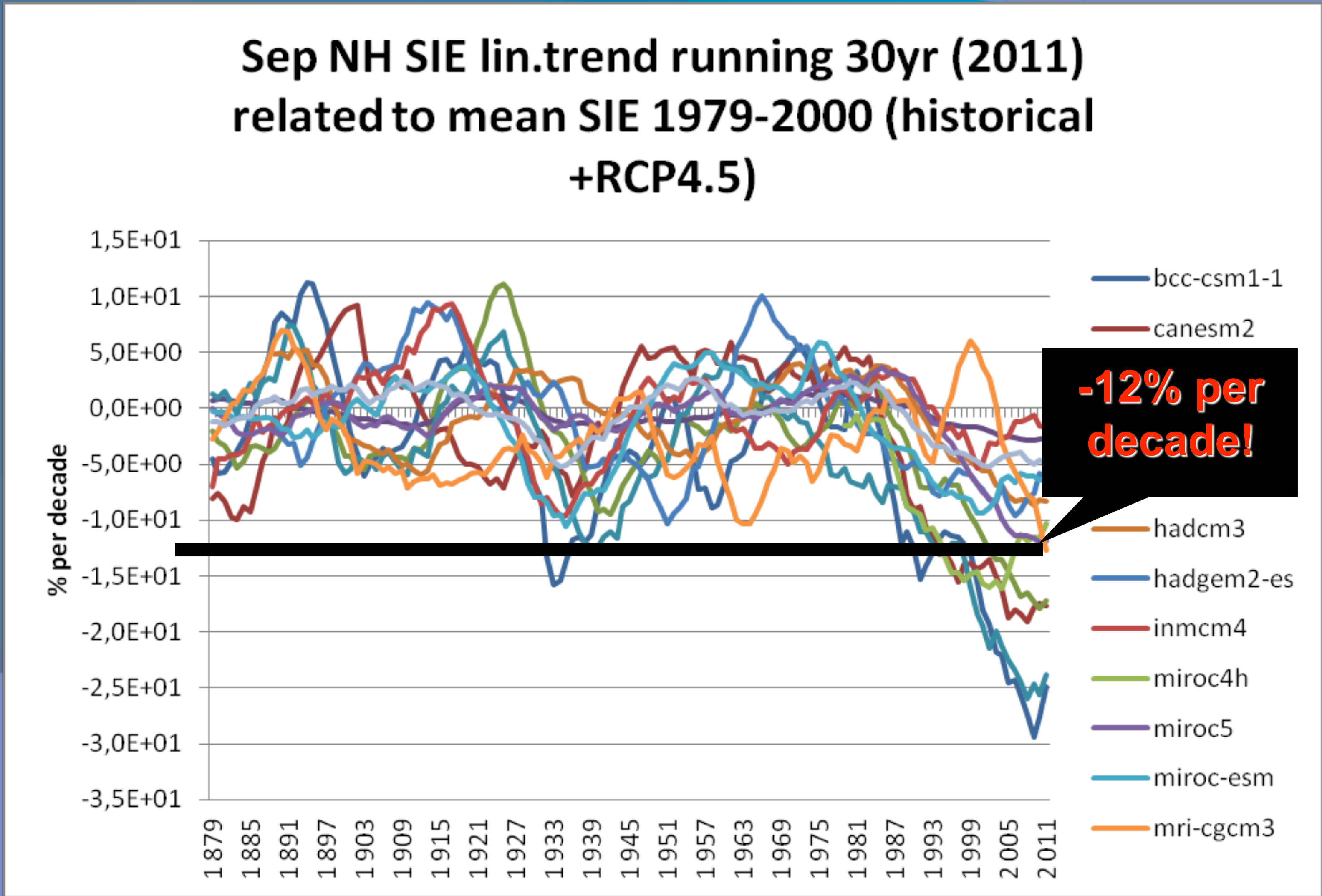
CMIP5



Pavlova et al., 2011

Model improvement:
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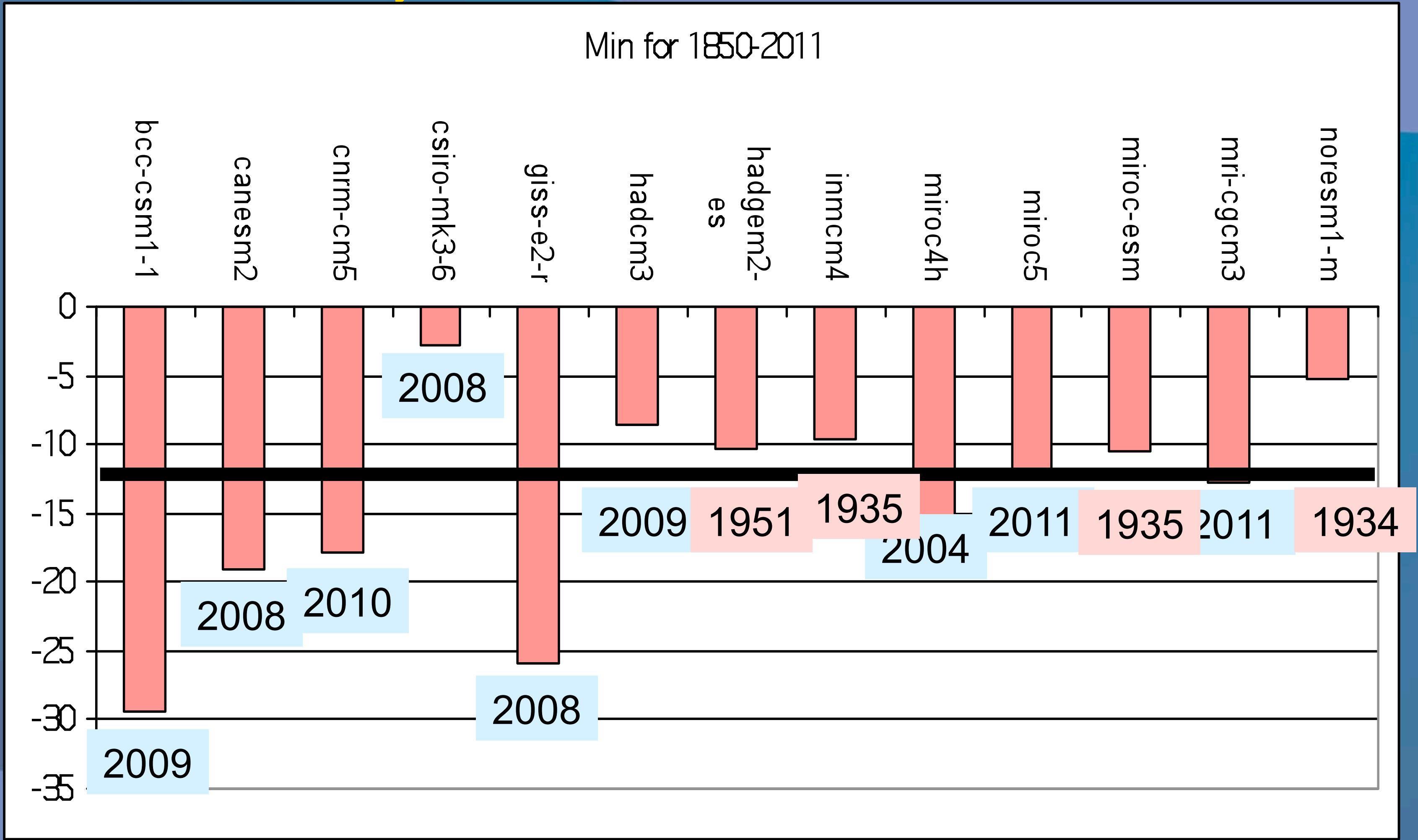

Pavlova et al., 2011

Model improvement:
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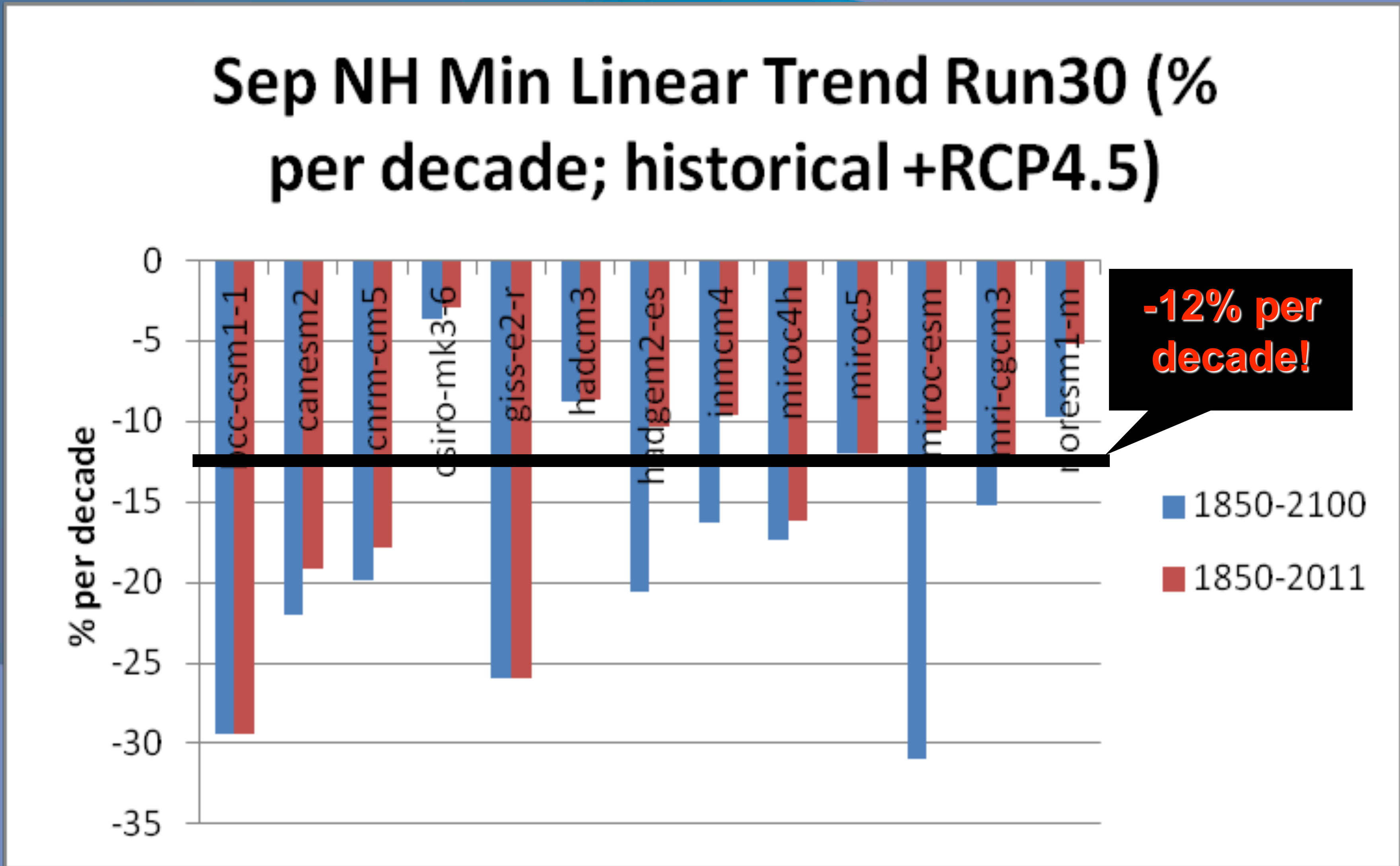

Pavlova et al., 2011

Arctic SIE change over 2.5 centuries

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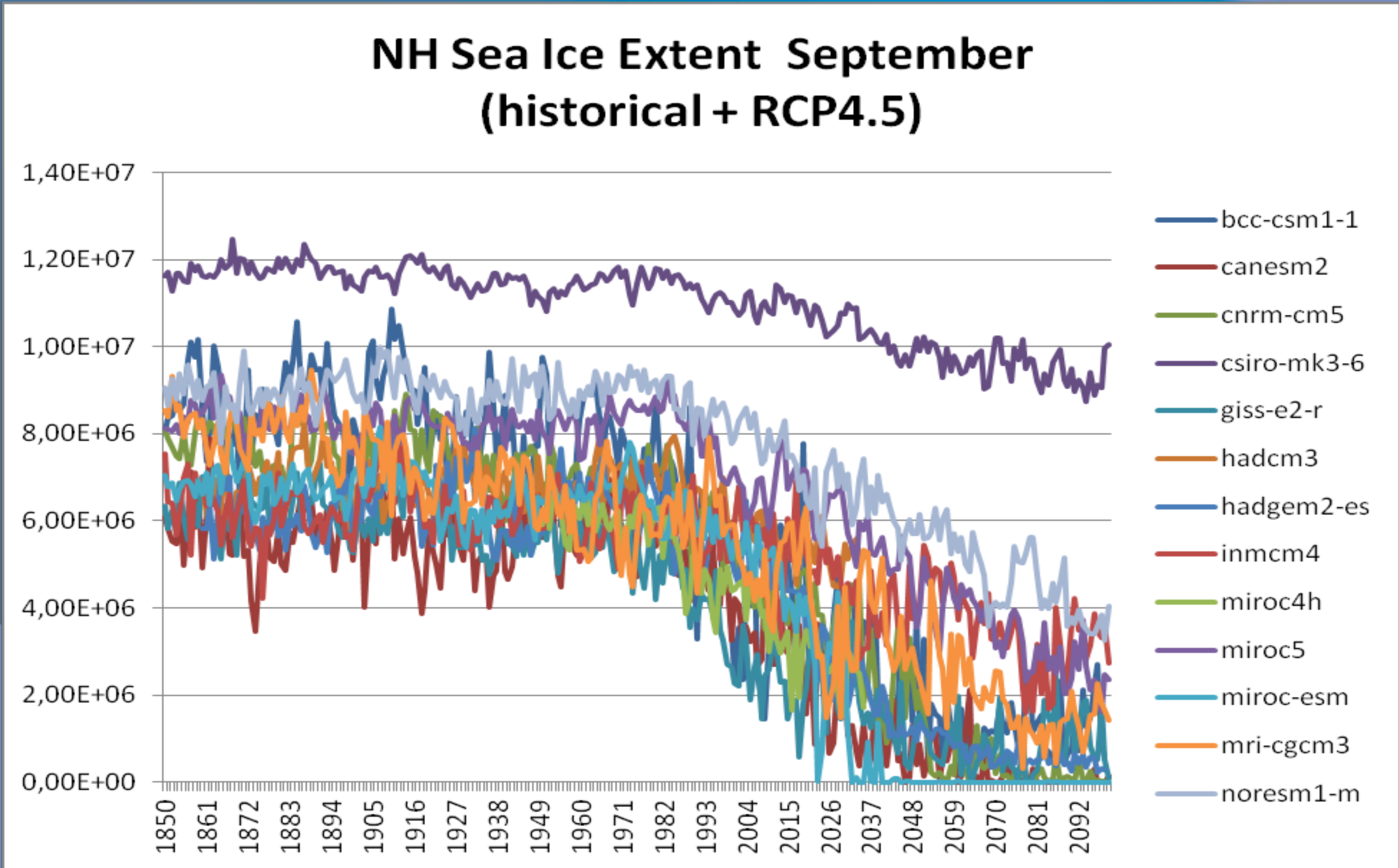
CMIP5



Pavlova et al., 2011

Arctic SIE change over 2.5 centuries

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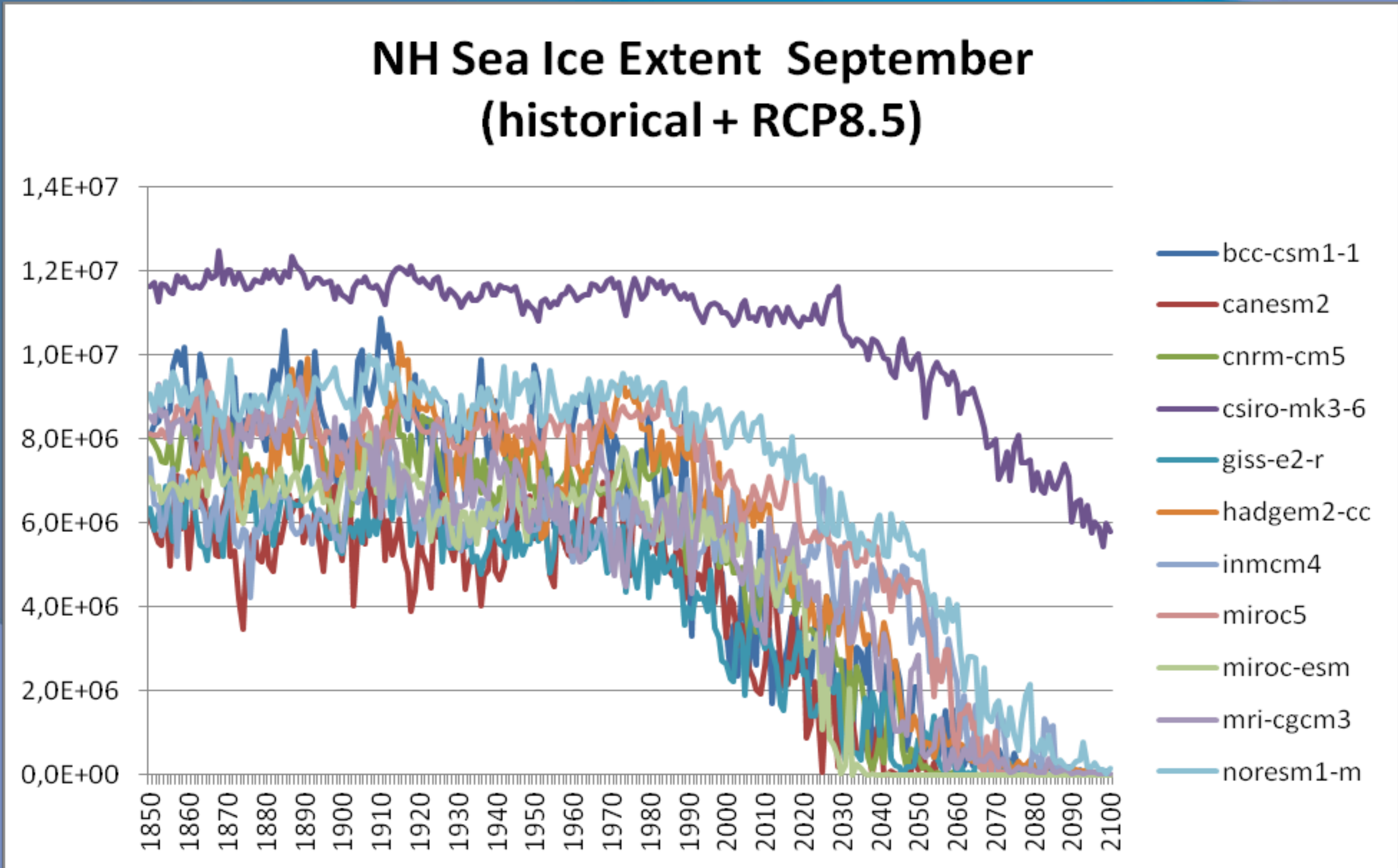
CMIP5



Pavlova et al., 2011

Arctic SIE change over 2.5 centuries

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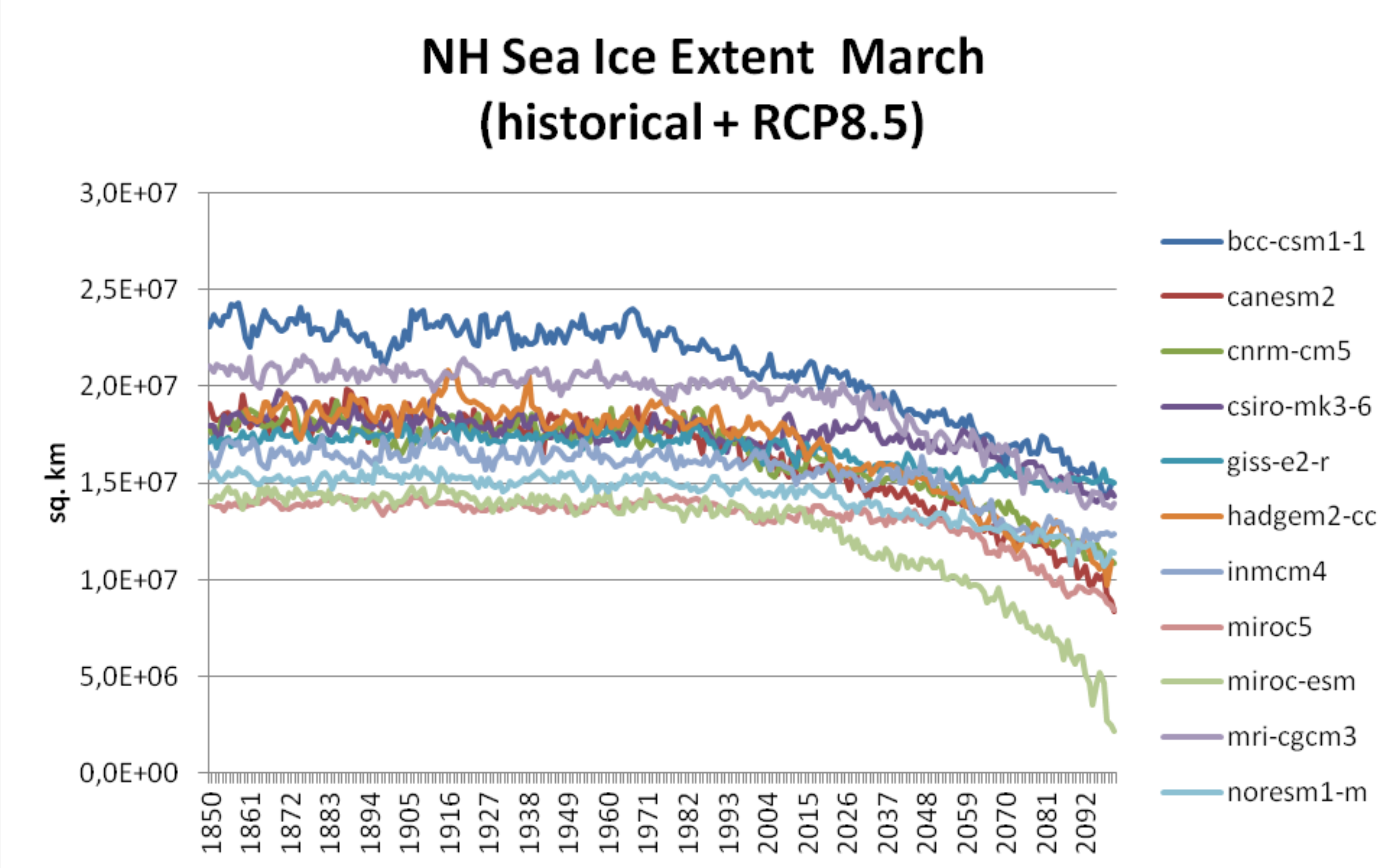
CMIP5



Pavlova et al., 2011

What is next?

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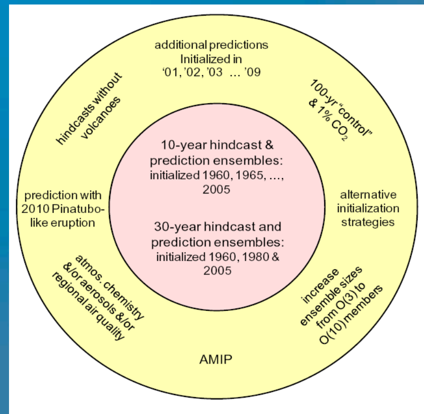
Further efforts in advancing sea-ice models, but …

Biases in simulated sea-ice extent due to:

- ✓ High-lat winds
- ✓ Ocean heat advection, vertical and horizontal mixing
- ✓ Surface energy fluxes (BL, cloudiness)
- ✓ …

CMIP5 – still a lot of sea-ice analysis to do!



SHEBA-like campaigns – to better understand processes

IPY => decade-long observations

Initialization (e.g. *Gerdes*'s suggestion) and data assimilation (*Massonet et al.*)

Rapid loss of sea ice:
We may be losing potential predictability faster than understanding it?

More certainty through model discrimination?

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Increasing number and complexity of the models leave poor chances for decreasing projection uncertainties.

This calls for discrimination of the models, i.e. quantification of our confidence in the projections.

Easy to announce the “end of model democracy”;
Hard, if possible at all, to “objectively” discriminate models.

Evaluation (discrimination) of climate models is absolutely dependent on observational data availability.

For a number of reasons, sea ice is a particular challenge in this context.

Knutti, 2010; Overland et al., 2011

So, are we getting more certain?

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In what sense?

Is the precise “date” of Arctic ice disappearance important?

Has our confidence in models increased since AR4?

Do we know what to do to increase our certainty?

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Part 4: Back to Grand Challenges

A Grand Challenge is…

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"… a fundamental problem in science or engineering, with broad applications, whose solution would be enabled by the application of high performance computing resources that could become available in the near future."

"… a problem that by virtue of its degree of difficulty and the importance of its solution, both from a technical and societal point of view, becomes a focus of interest to a specific scientific community.".

There are other definitions…

The problem of rapid loss of Arctic sea ice combines a serious scientific challenge with a keen public interest, it clearly addresses quite a number of major environmental, economic, etc. issues, and it gives a hope (no guarantee, of course) to be fixed within a reasonable period of time.

Obviously, cryosphere is very generous for Grand Challenges.

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Thank you!