Modelling recent and future sea ice changes

An assessment of CMIP5/COMBINE results

T. Fichefet, **F. Massonnet**

with contributions from

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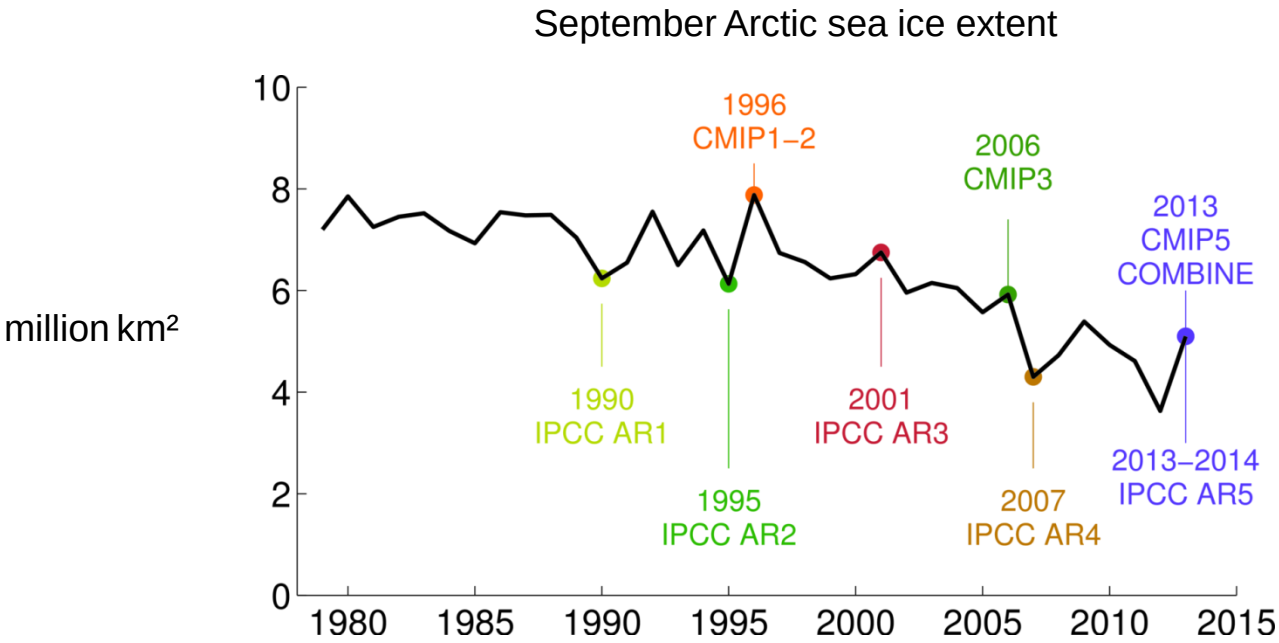
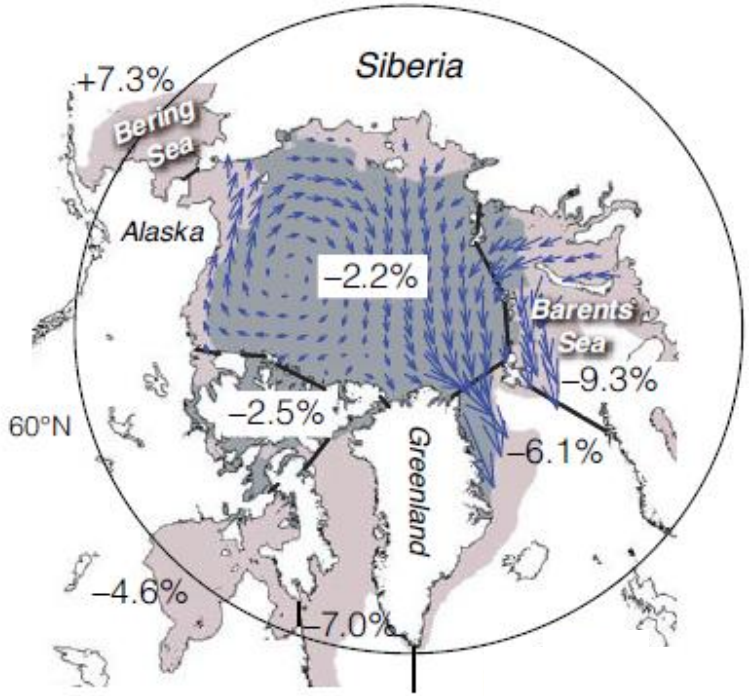
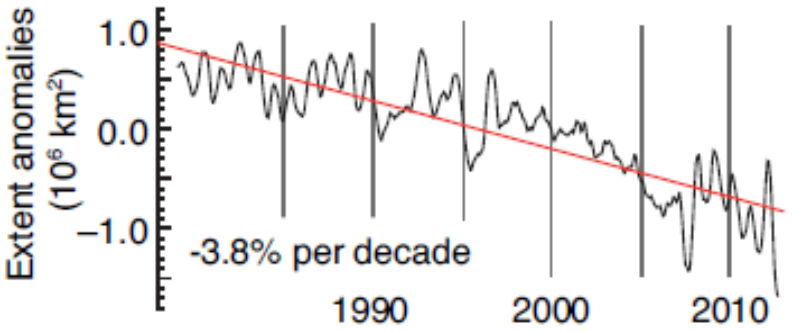
D. Salas y Mélia, G. Vergé-Dépré and K. Wyser



The Arctic sea ice clock is ticking

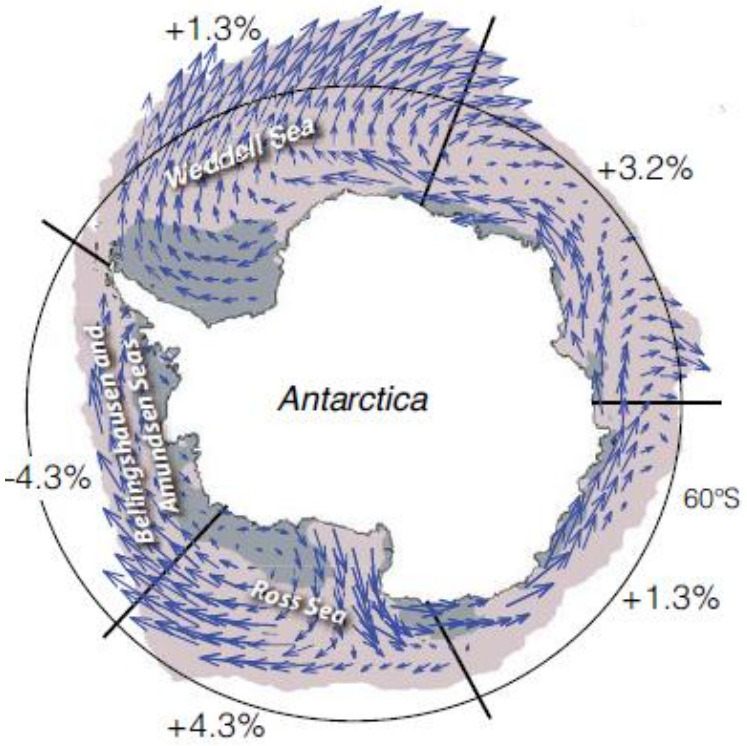


Annual Arctic sea ice extent anomalies



(IPCC WG1 AR5, 2013)

Antarctic sea ice variability is more puzzling than ever



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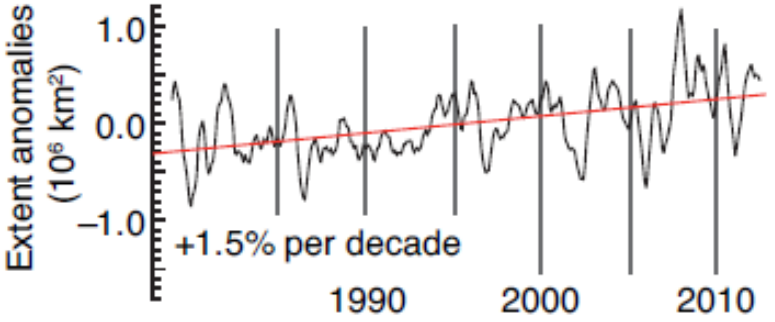

(IPCC WG1 AR5, 2013)

1. Modelling sea ice : from CMIP3 to CMIP5

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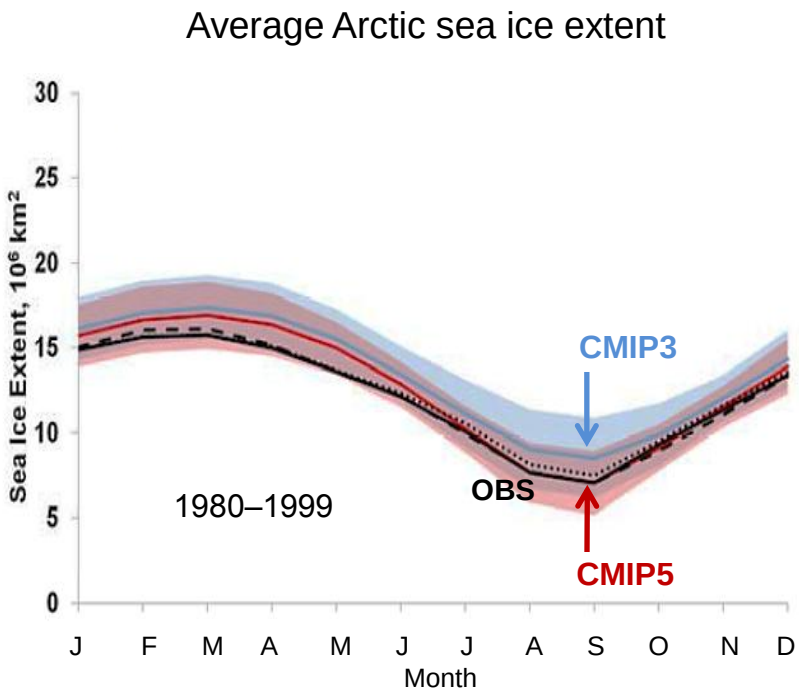
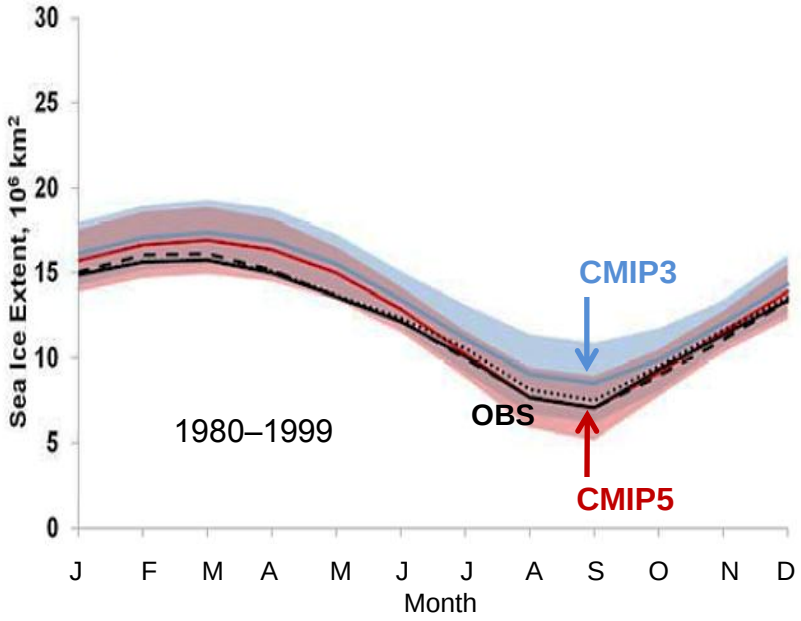
The seasonality of Arctic sea ice extent is better simulated in CMIP5 than CMIP3



(IPCC WG1 AR5, 2013)

The CMIP5 model spread around the mean is still large

Average Arctic sea ice extent



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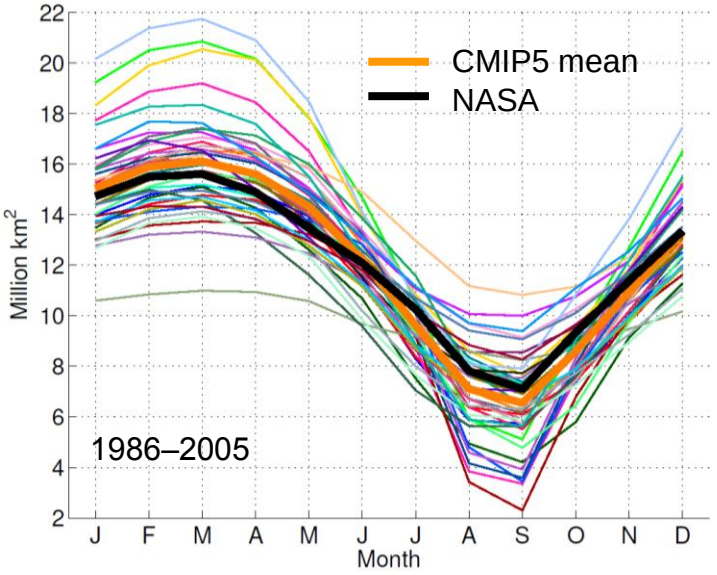

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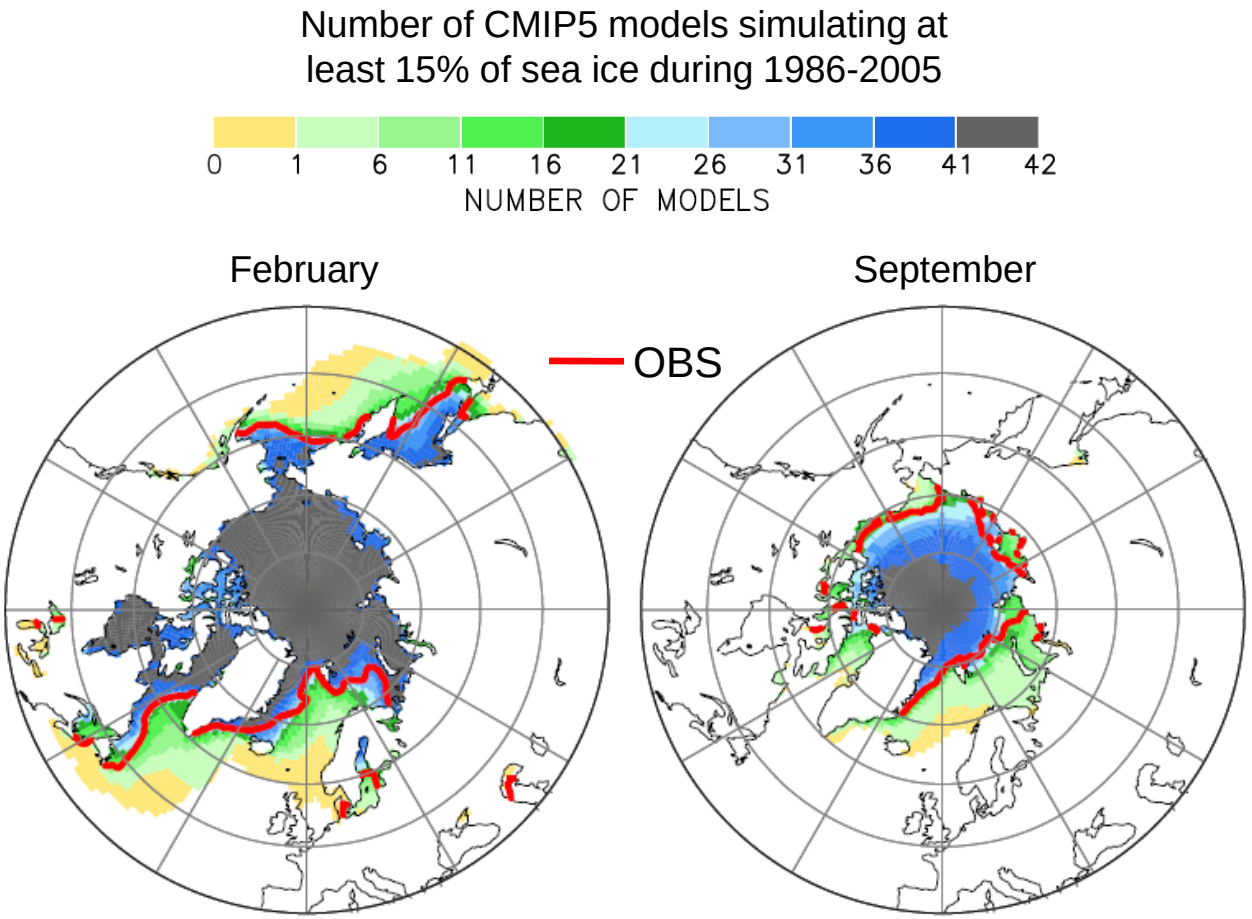

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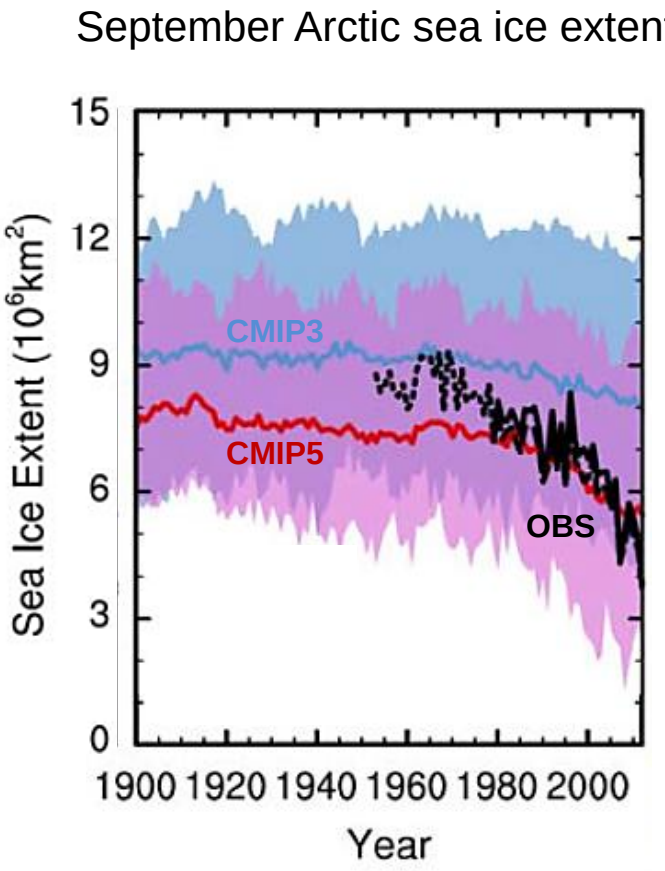
Trends in September Arctic sea ice extent are better simulated in CMIP5 than CMIP3



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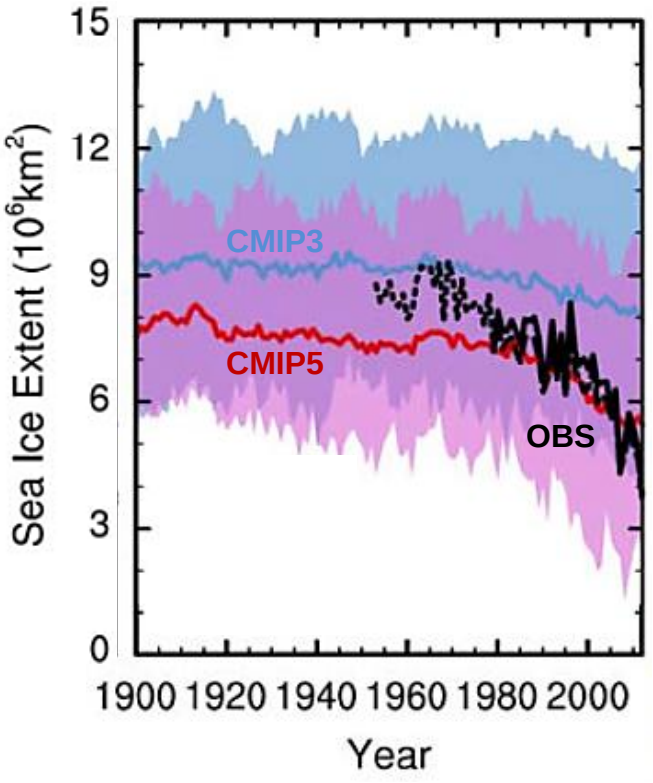
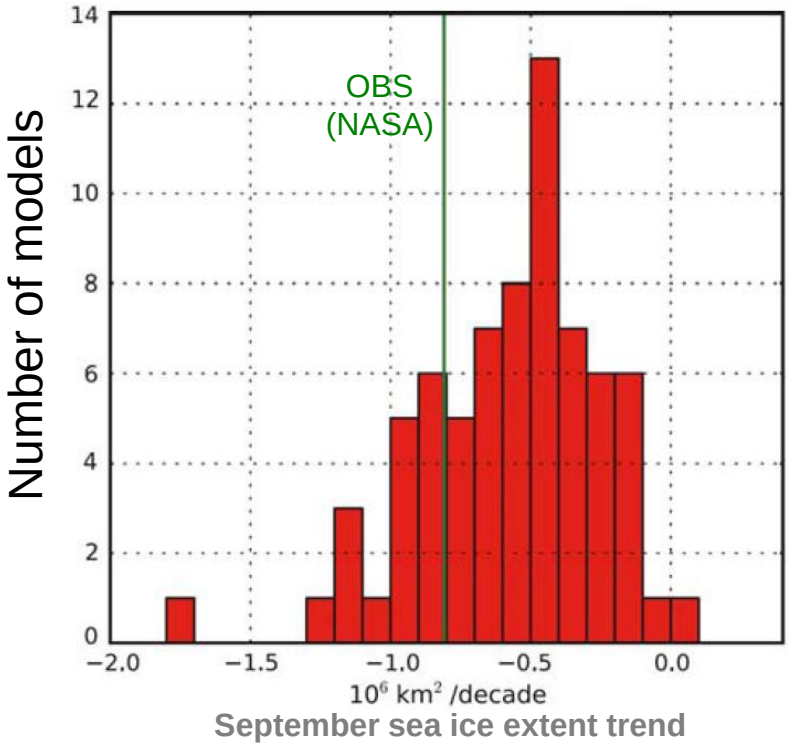
September Arctic sea ice extent

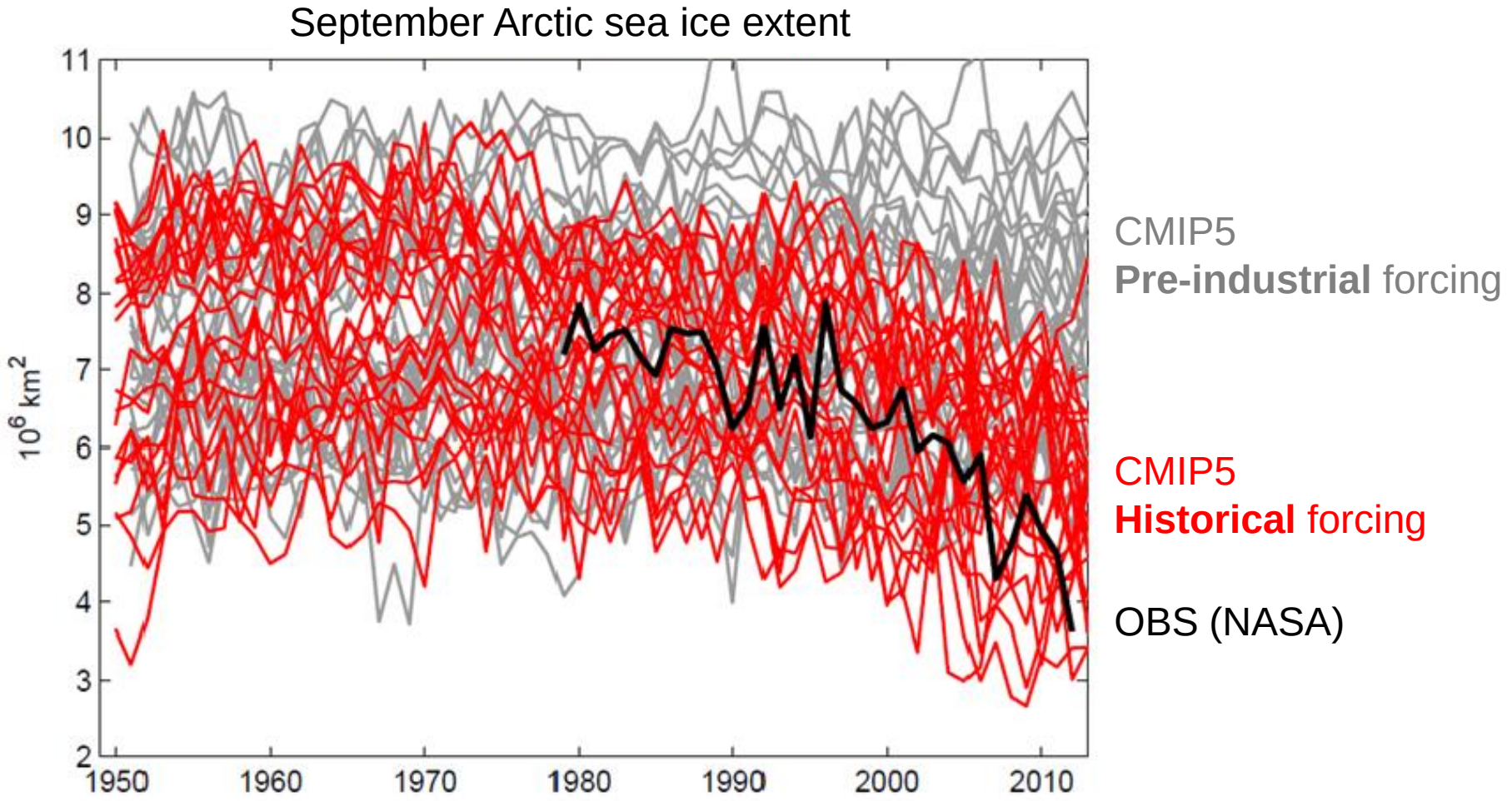


Distribution of CMIP5 September Arctic sea ice extent **trends** (1979-2010, 66 realisations)



(IPCC WG1 AR5, 2013)

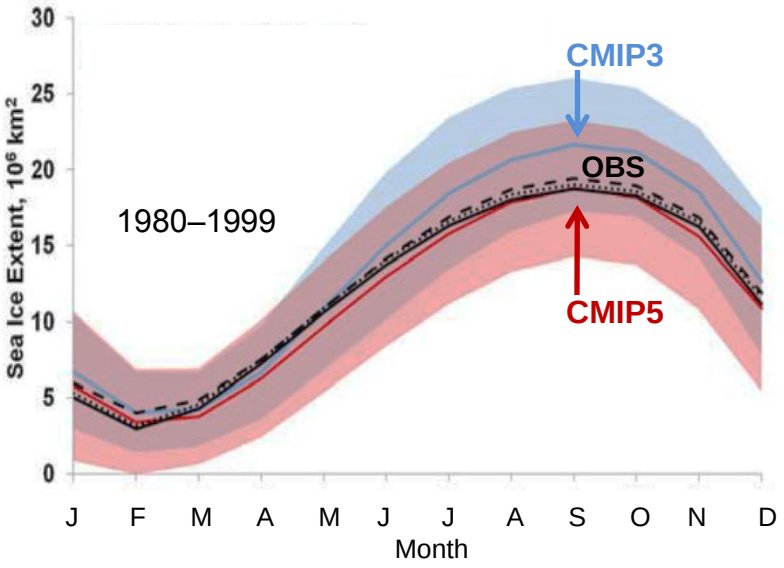
Anthropogenic influences have *very likely* contributed to Arctic sea ice loss since 1979



(IPCC WG1 AR5, 2013)

Mean Antarctic sea ice extent: noticeable improvements, but still very large spread

Average Antarctic sea ice extent



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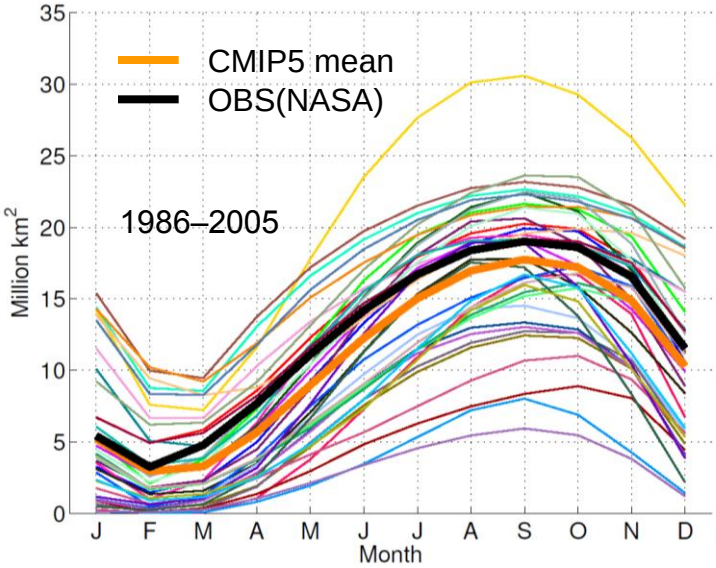
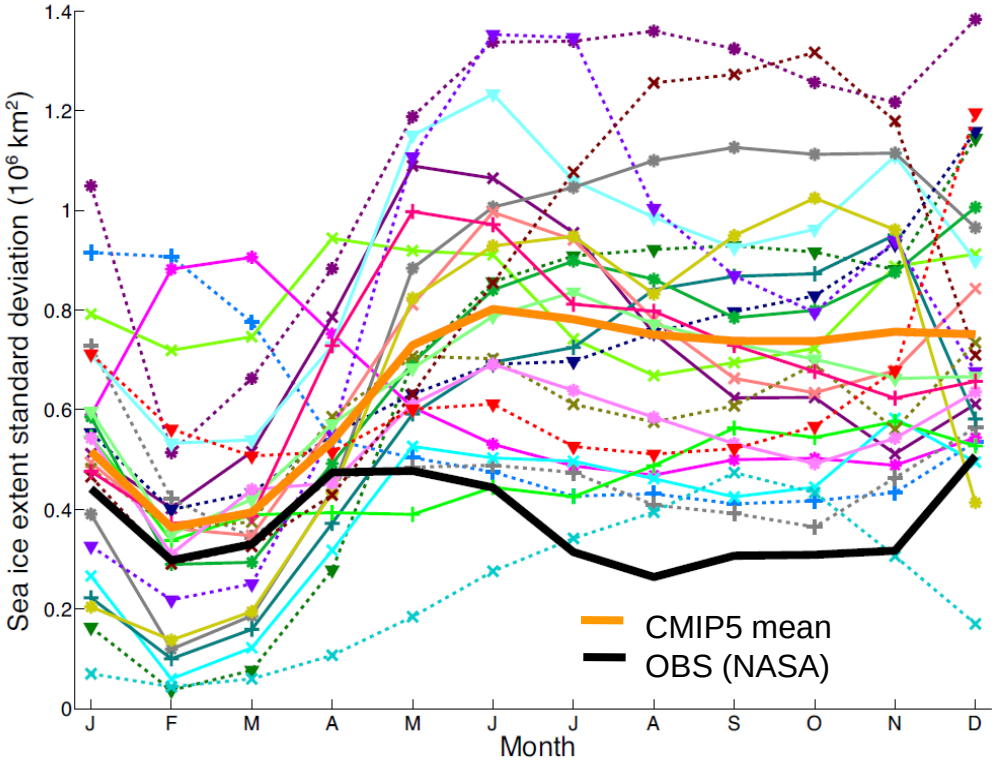


(IPCC WG1 AR5, 2013)

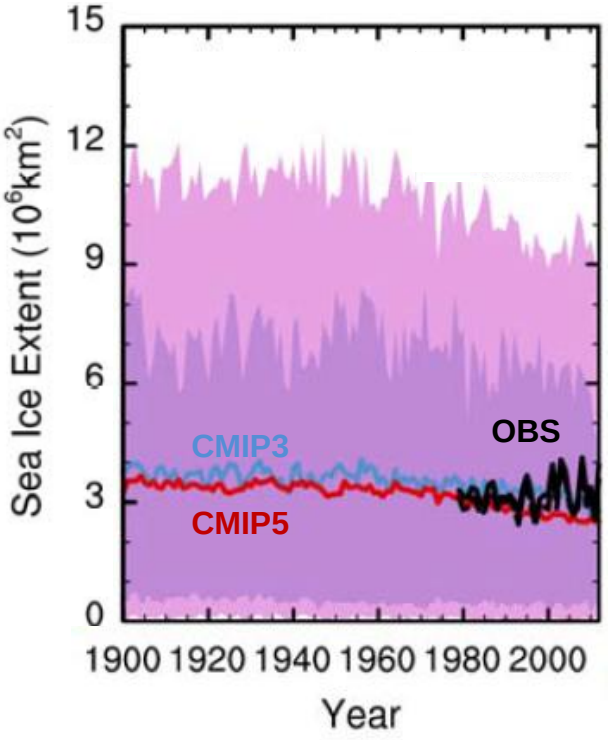
Mismatch between observed and simulated Antarctic sea ice variability

1979-2005 **standard deviation** of the detrended Antarctic sea ice extent



(Zunz et al., The Cryosphere, 2013)

February Antarctic sea ice extent



(IPCC WG1 AR5, 2013)

Conclusion 1

CMIP3 → CMIP5: improvements with persistent uncertainties

	Arctic	Antarctic
Mean state	Improved (large spread)	Improved (large spread)
Trends/ variability	Improved	Status quo
Attribution/ Detection	Changes detectable and attributable	Uncertain

1. Modelling sea ice : from CMIP3 to CMIP5

   Improvements with persistent uncertainties

2. Sea ice projections

3. Developments in sea ice modelling

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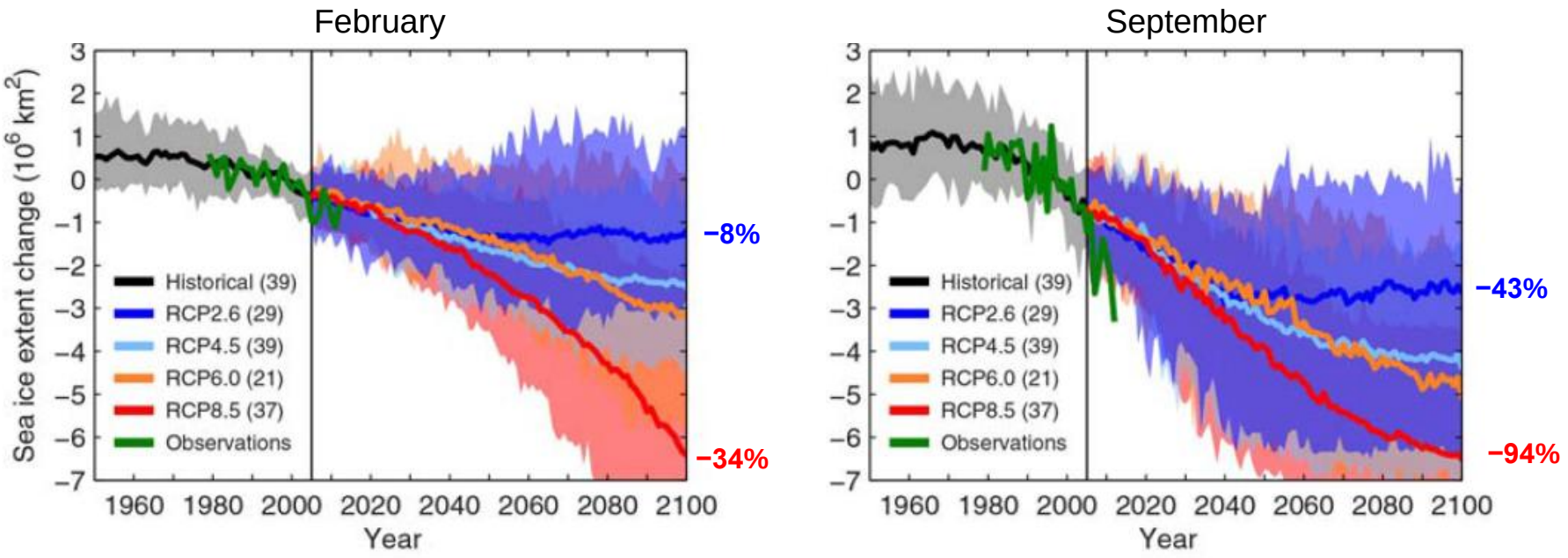
The Arctic sea ice cover will *very likely* continue to shrink as global temperature rises

Changes in CMIP5 Arctic sea ice extent (reference: 1986-2005)



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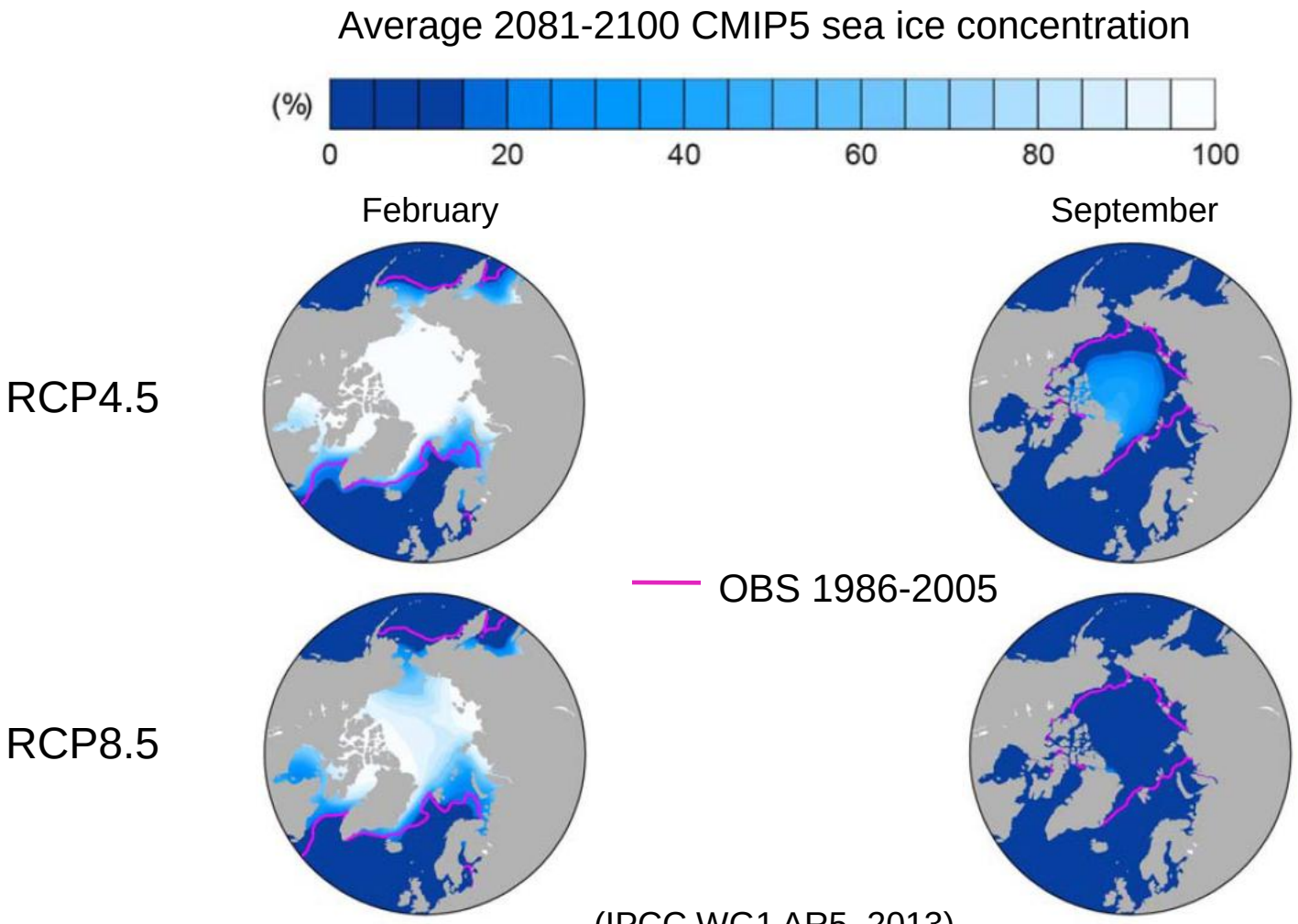
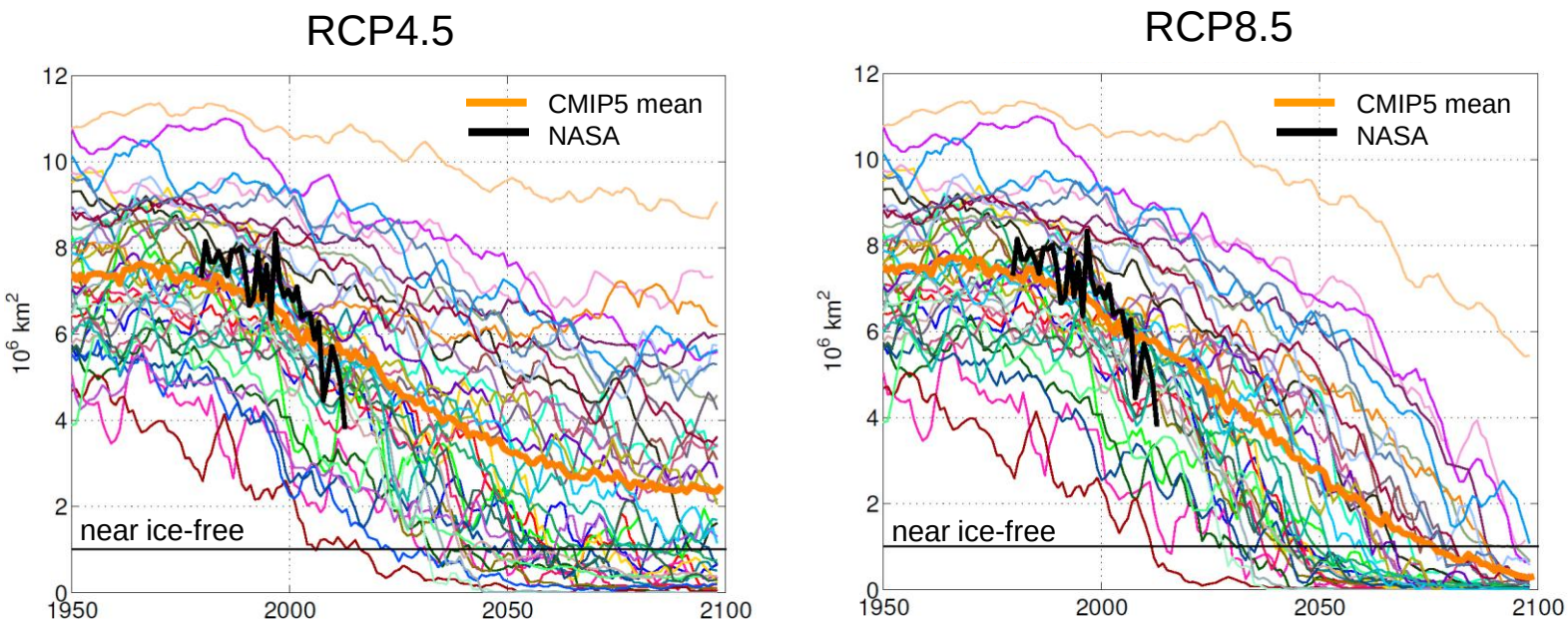


(IPCC WG1 AR5, 2013)

The spread in summer Arctic sea ice projections remains wide

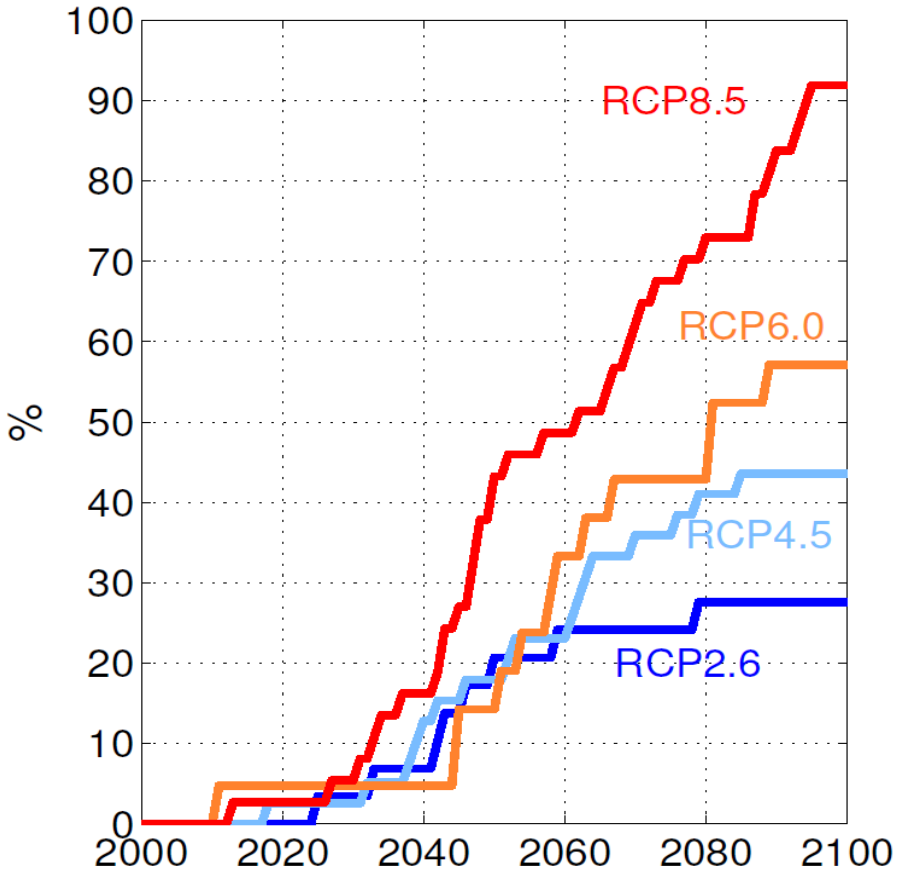
September Arctic sea ice extent simulated by CMIP5 models



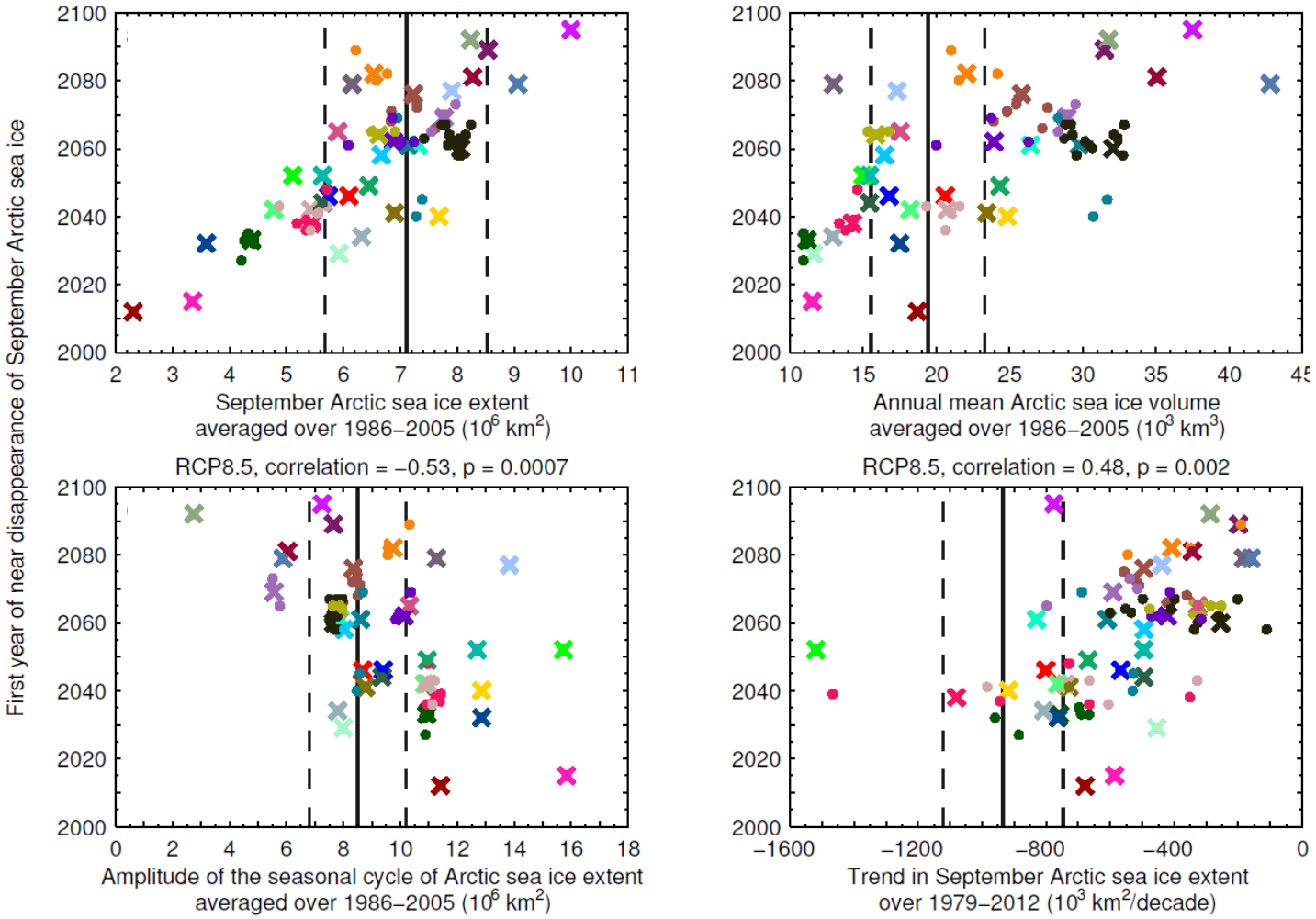
(Massonnet et al., The Cryosphere, 2012)

The spread in summer Arctic sea ice projections remains wide

Proportion of CMIP5 models with September Arctic sea ice extent < 1 million km² for at least 5 years

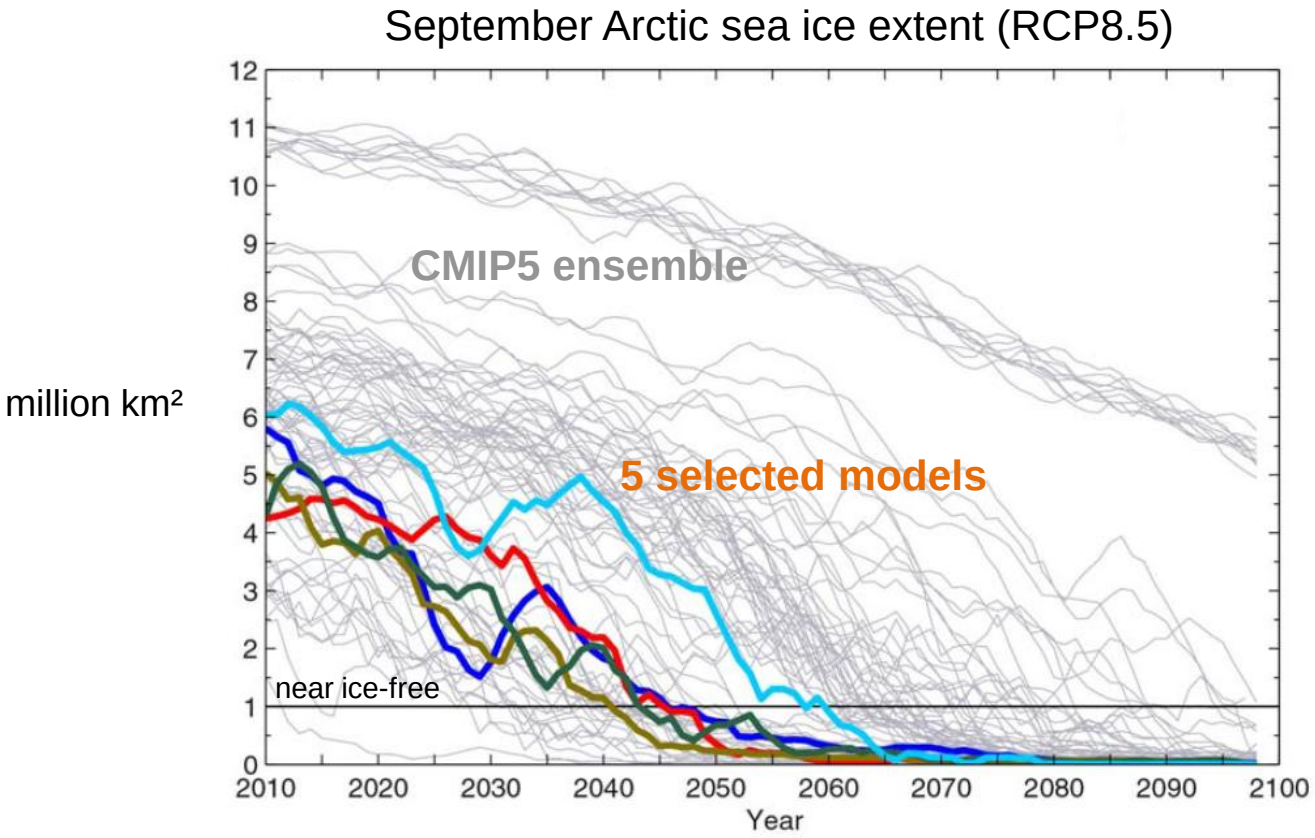


Year of disappearance of summer Arctic sea ice is linked to baseline sea ice state



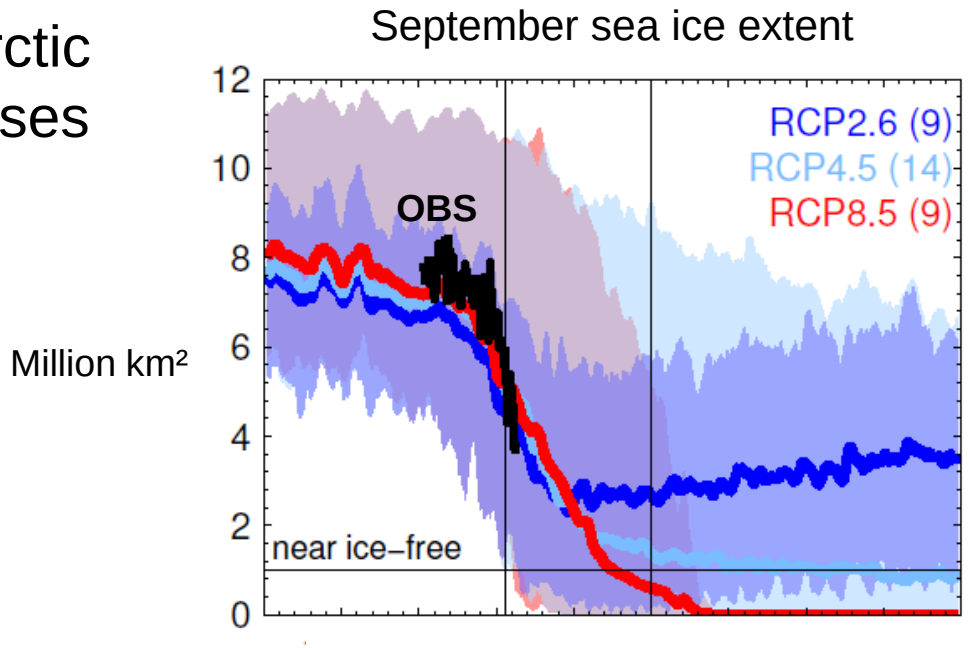
(IPCC WG1 AR5, 2013 ; Massonnet et al., The Cryosphere, 2012)

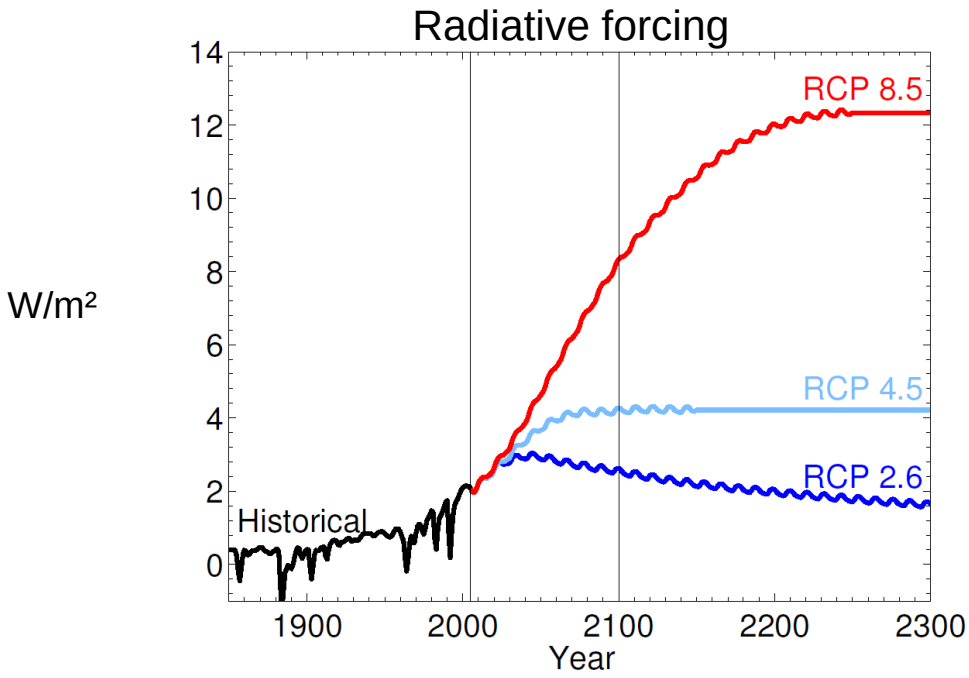
A nearly ice-free Arctic Ocean in September is *likely* by mid-century (high-emission scenario)



(IPCC WG1 AR5, 2013 ; Massonnet et al., The Cryosphere, 2012)

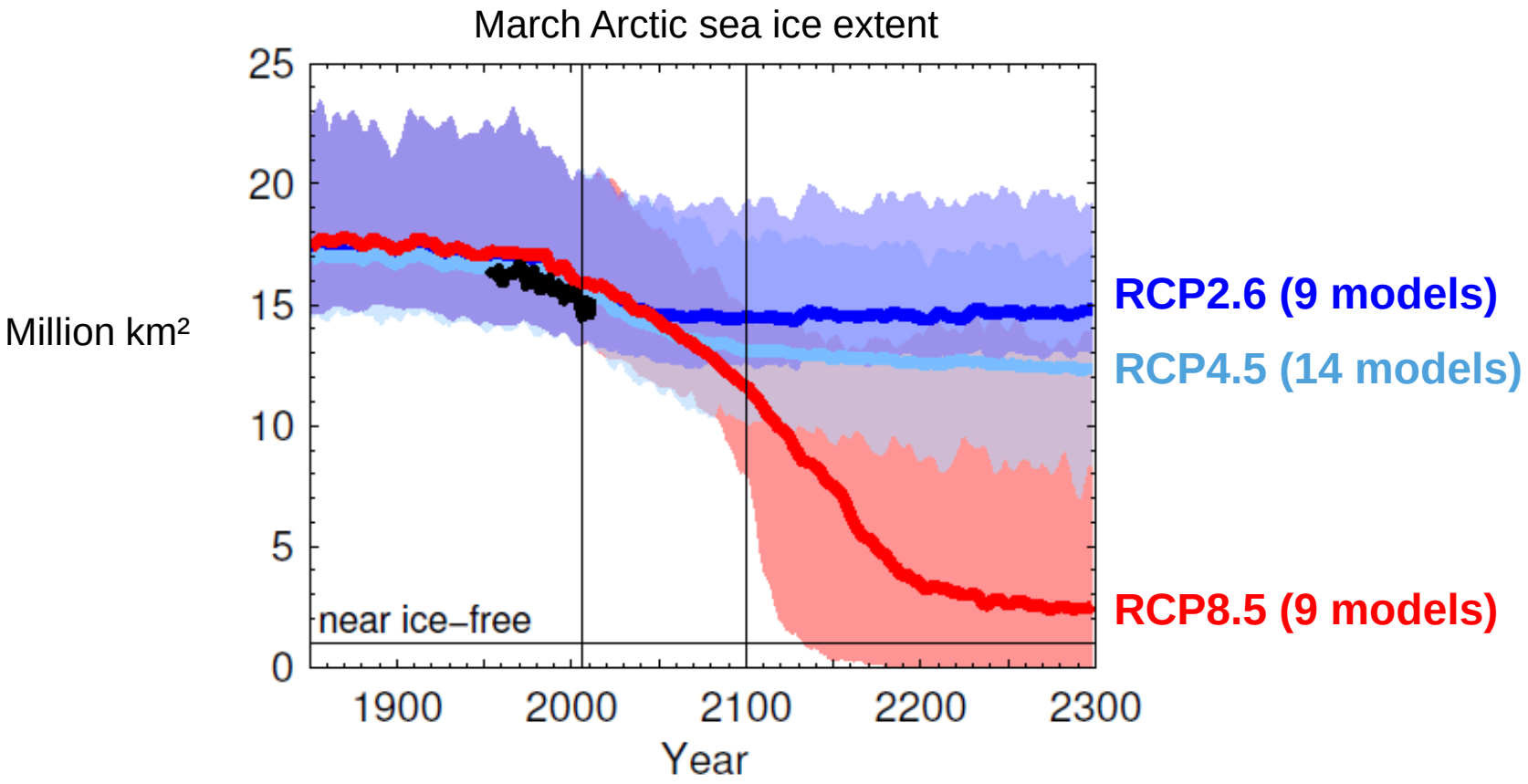
Possible recovery of summer Arctic sea ice if radiative forcing decreases





(Hezel et al., in prep.)

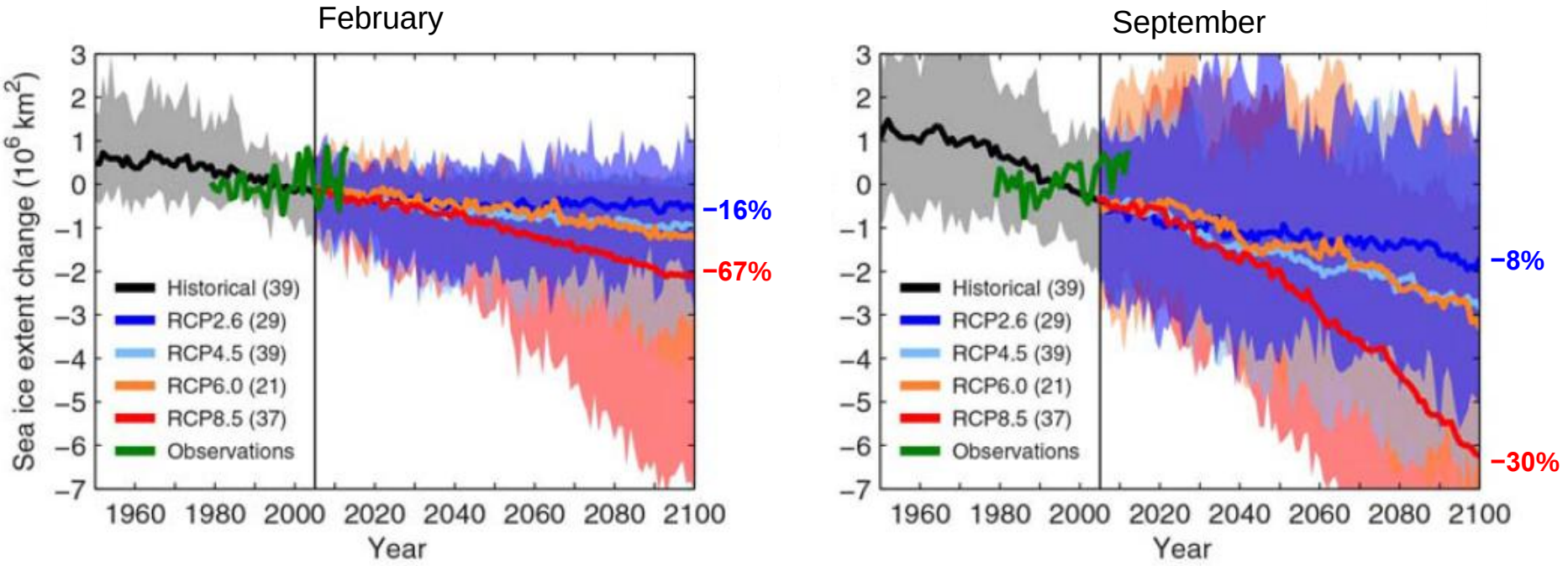
7 out of 9 CMIP5 models reach ice-free conditions in winter by 2300 under a high-emission scenario



(Hezel et al., in prep.)

A decrease in Antarctic sea ice extent is expected during the 21st century, but with *low confidence*

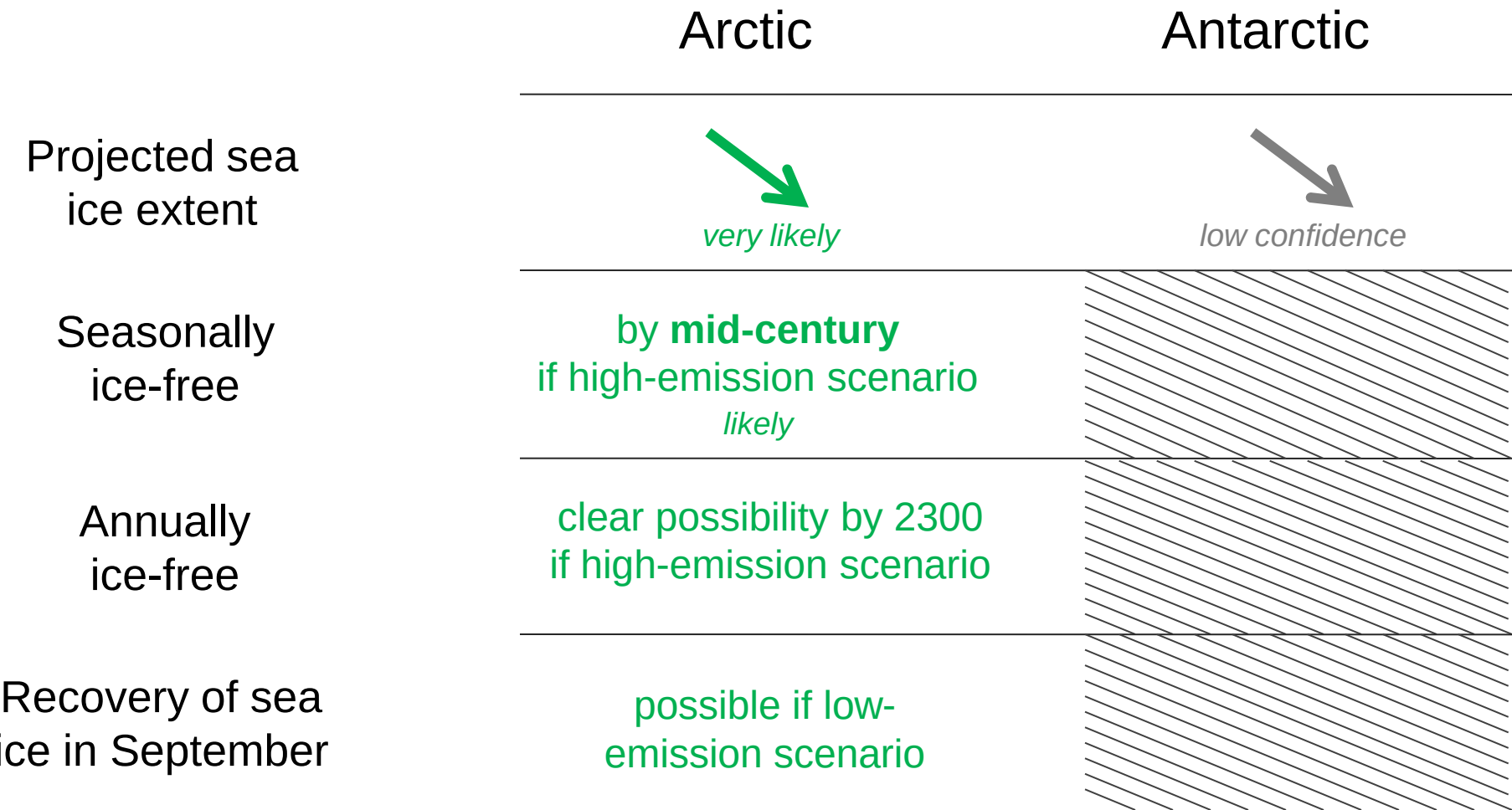
Changes in CMIP5 Antarctic sea ice extent (reference: 1986-2005)



(IPCC WG1 AR5, 2013)

Conclusion 2

CMIP5 offers the possibility to investigate Arctic sea ice projections, caution has to be taken for Antarctic



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Seasonality of simulated mean sea ice extent sensitive to freshwater and salt conservation

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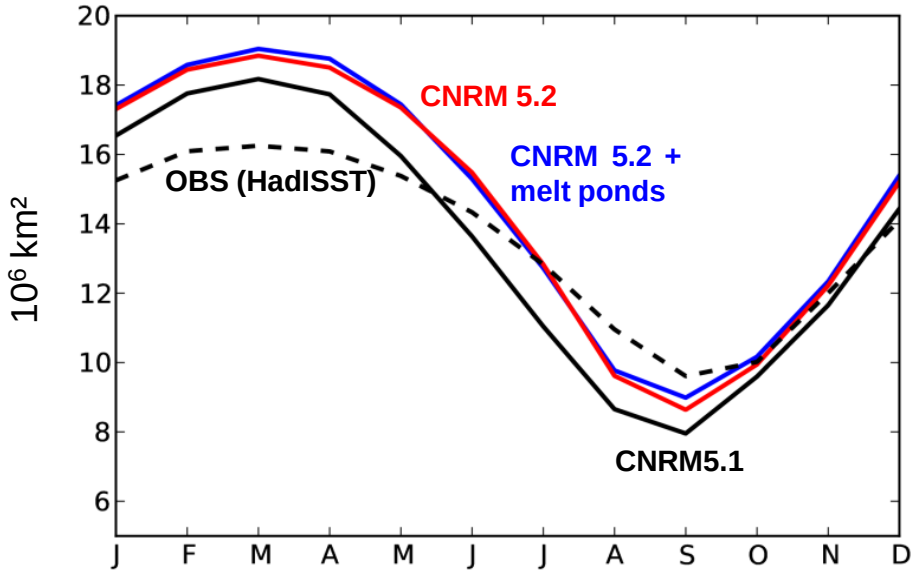
CNRM 5.1 → Improved conservation of salt and freshwater
Surface melt ponds parameterisation (Holland et al., J. Clim., 2012)
→ **CNRM 5.2**

1980-1989 Average Arctic sea ice extent



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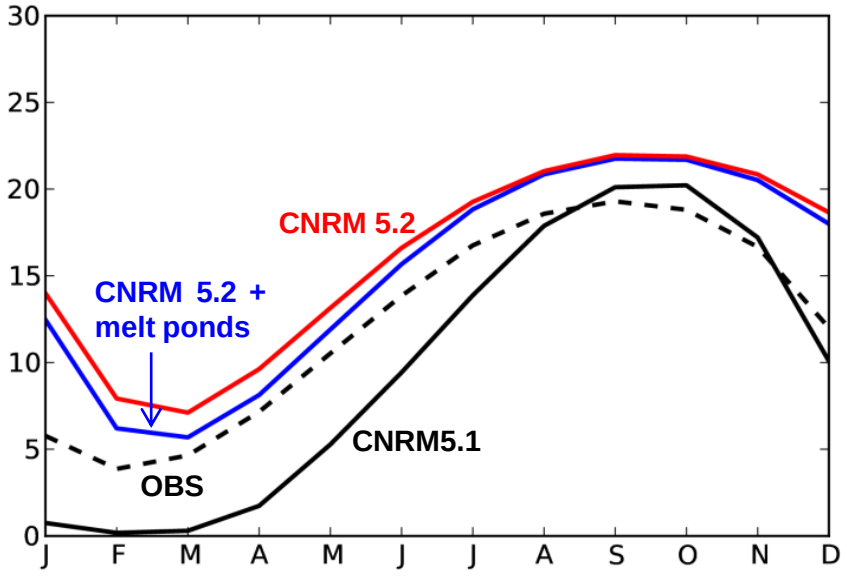
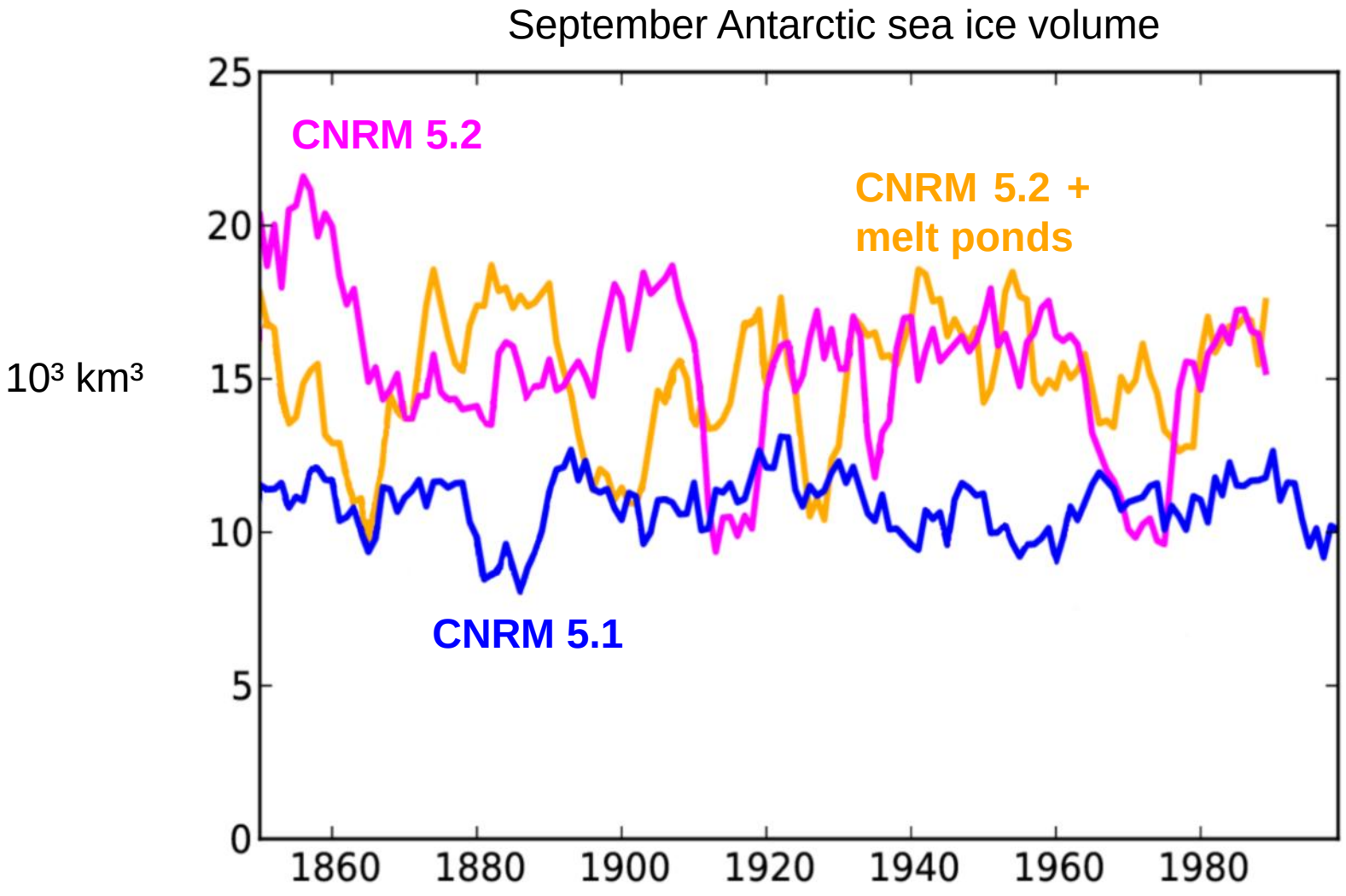
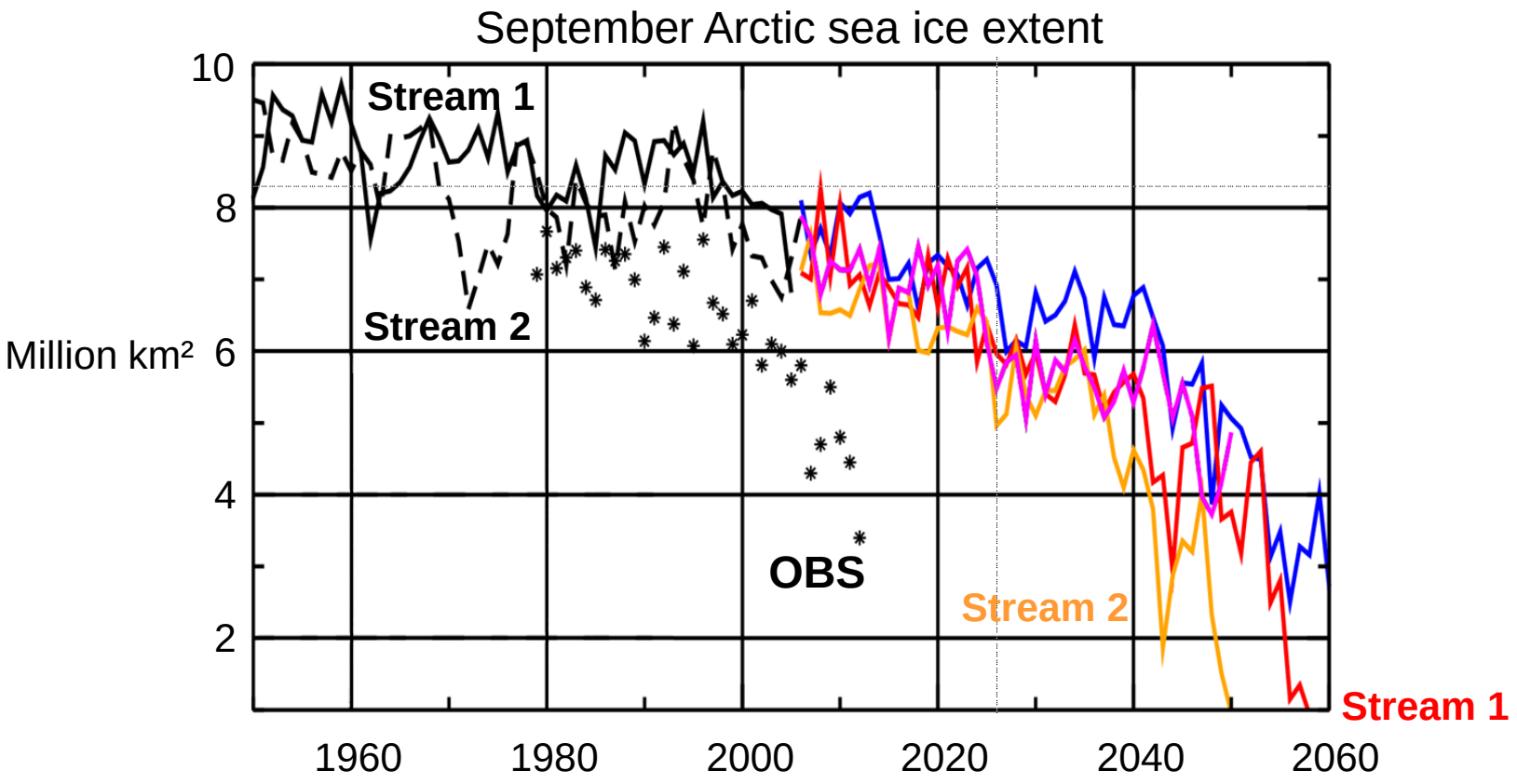


Antarctic sea ice volume variability enhanced due to stronger ocean convection variability



Increased summer Arctic sea ice sensitivity with realistic surface albedo

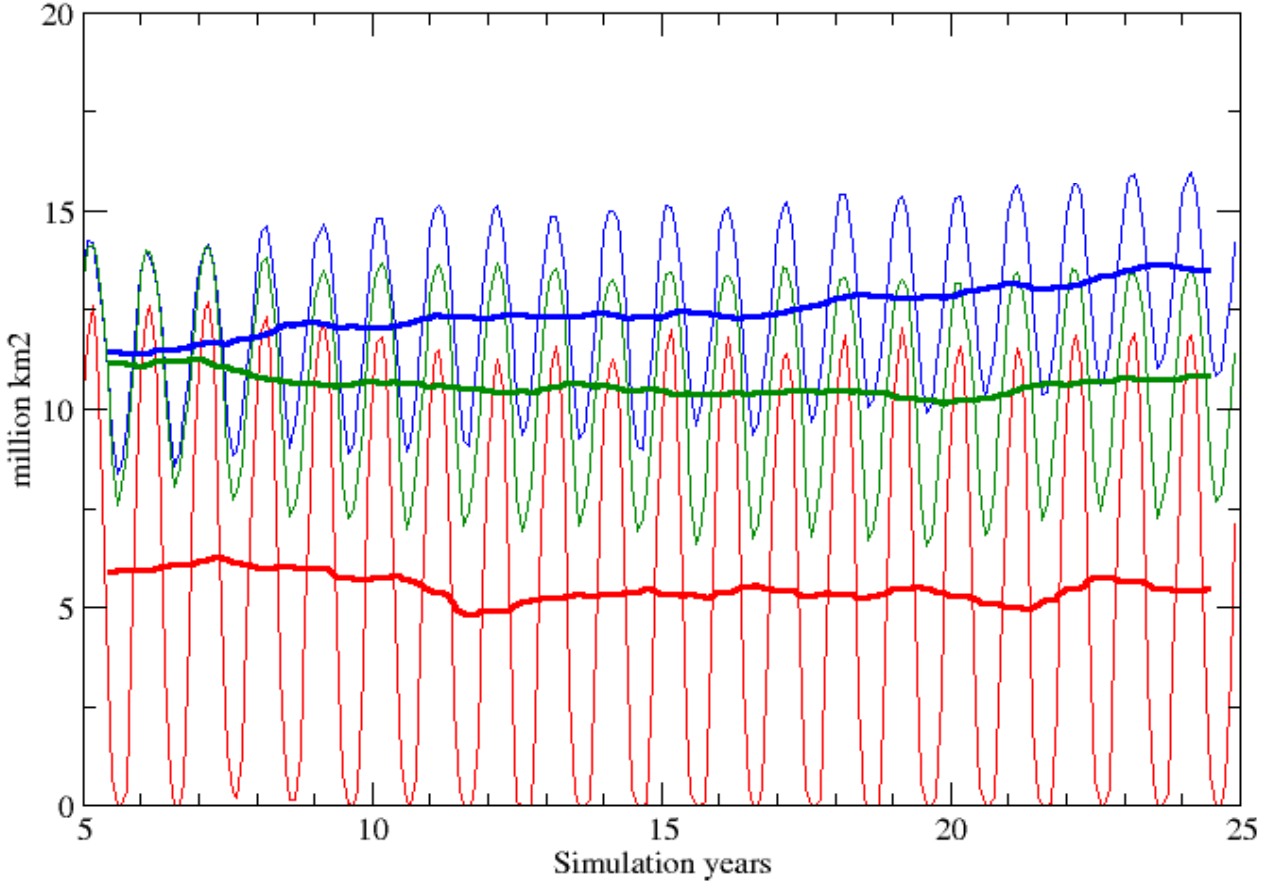
EC-Earth Stream 1 → Surface melt ponds parameterisation (Koltzow et al., JGR, 2007) → **EC-Earth Stream 2**



Simulated Arctic sea ice is highly sensitive to coupling formulation with atmosphere

SMHI

EC-Earth Arctic sea ice extent



with LIM2 (1 ice category)

with LIM3 (1 ice category)

with LIM3 (5 ice categories, equal fluxes)

Implementing atmospheric coupling and process-level developments in NEMO-LIM3

- Coupling of LIM3 (Vancoppenolle et al., Oc. Modell., 2009) to IPSL-CM5

- Wave-ice interactions in NEMO-LIM3 (Vancoppenolle et al., in prep.)

- Implementation in NEMO-LIM3 of a comprehensive snow scheme (Lecomte et al., JAMES, 2013)

- Detailed represesentation of surface melt ponds, refreezing meltwater and blowing snow (poster O. Lecomte)

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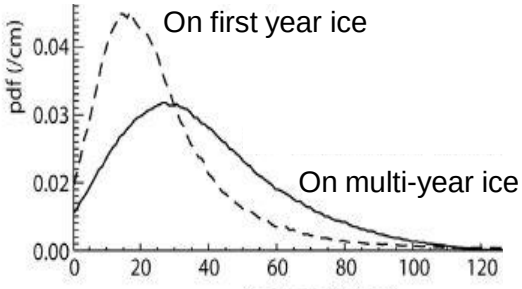
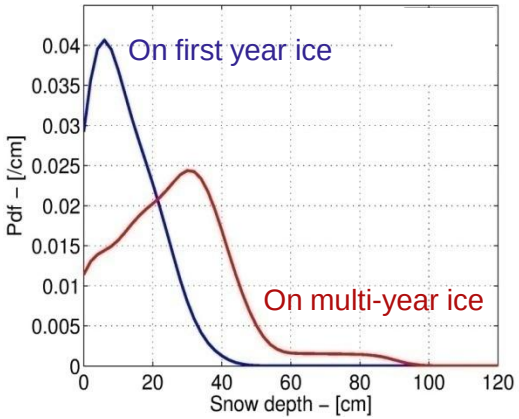
Distribution of snow depth on Arctic sea ice

Observed (Kwok et al., JGR, 2013)



Simulated (Lecomte et al., JAMES, 2013)



Conclusion 3

All in all, improving sea ice physics generally improves sea ice simulations

	COMBINE contributions	Impacts
Snow processes	Space+time varying snow properties & distribution	Realistic snow depth distribution
Surface processes	Melt ponds and albedo parameterisation	Decreased sea ice extent and increased sensitivity
Conservation issues	Strict conservation of salt & freshwater in sea ice	Increased sea ice extent
Coupling to atmosphere	Flux formulation by ice category	Strong sensitivity to type of formulation

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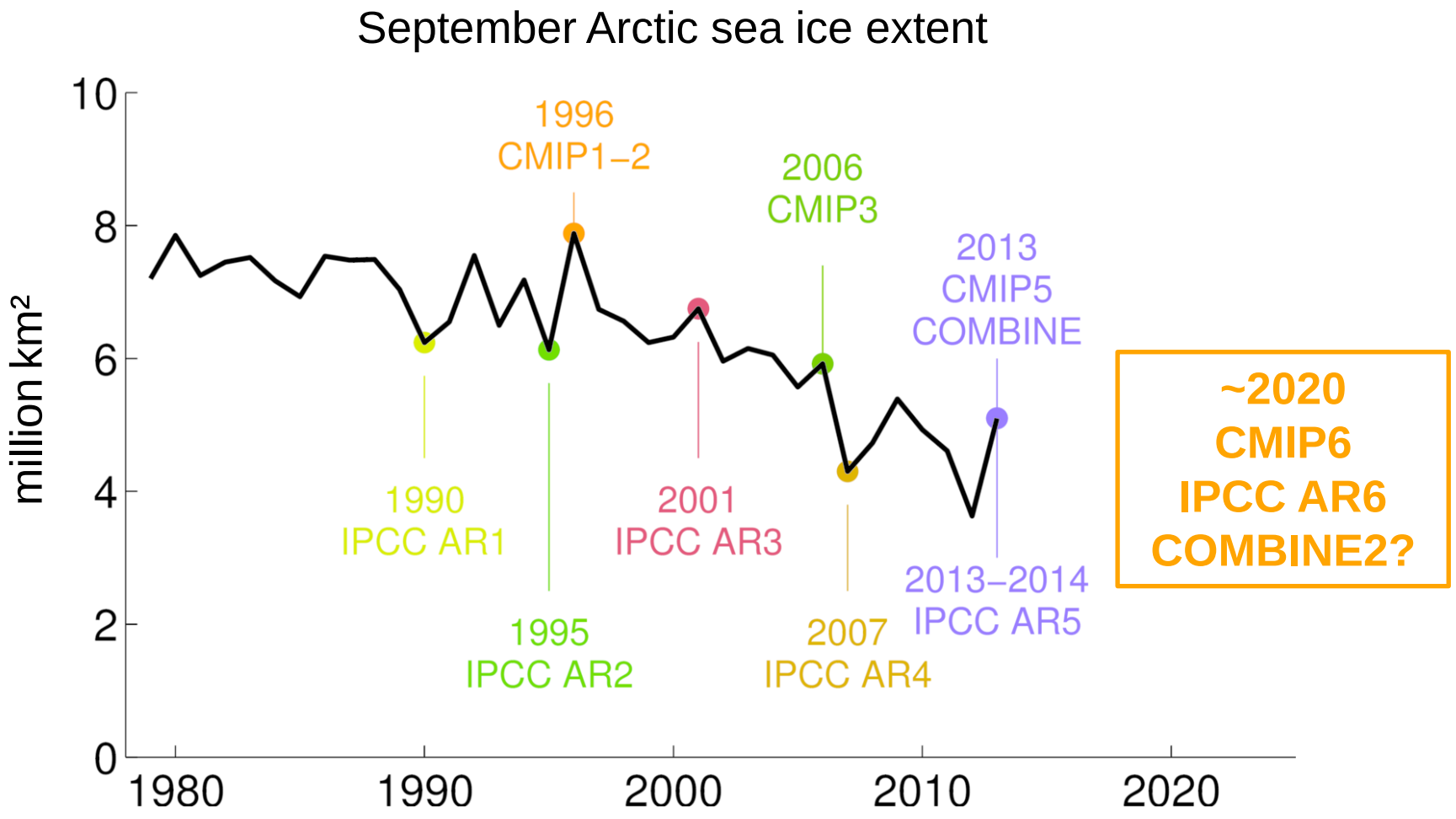
   All in all, improving sea ice physics generally improves sea ice simulations

Keep working and stay focused – there is a payoff!



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Thank you

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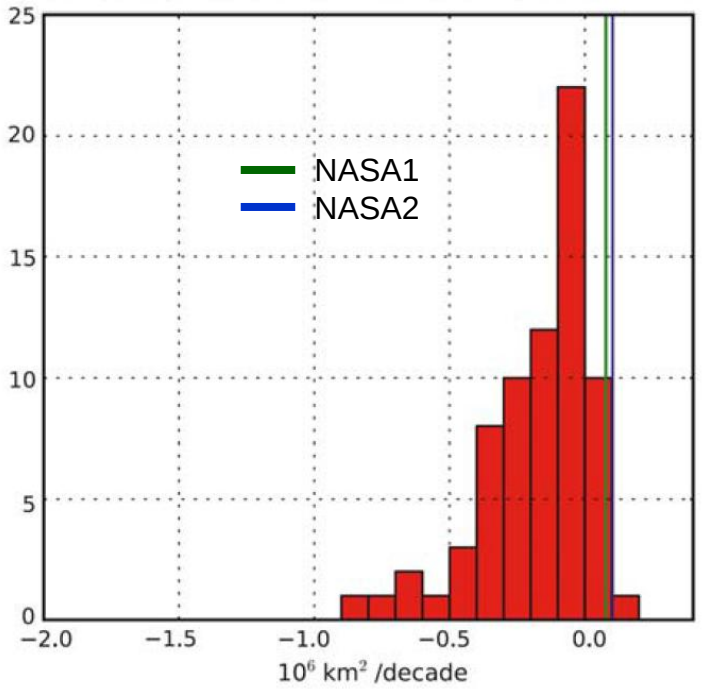
Table 1. Likelihood Scale	
Term*	**Likelihood of the Outcome**
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

* Additional terms that were used in limited circumstances in the AR4 (*extremely likely* – 95-100% probability, *more likely than not* – >50-100% probability, and *extremely unlikely* – 0-5% probability) may also be used in the AR5 when appropriate.

(IPCC WG1 AR5, 2013)

Distribution of CMIP5 February Antarctic sea ice extent **trends** (1979-2010, 66 realisations)



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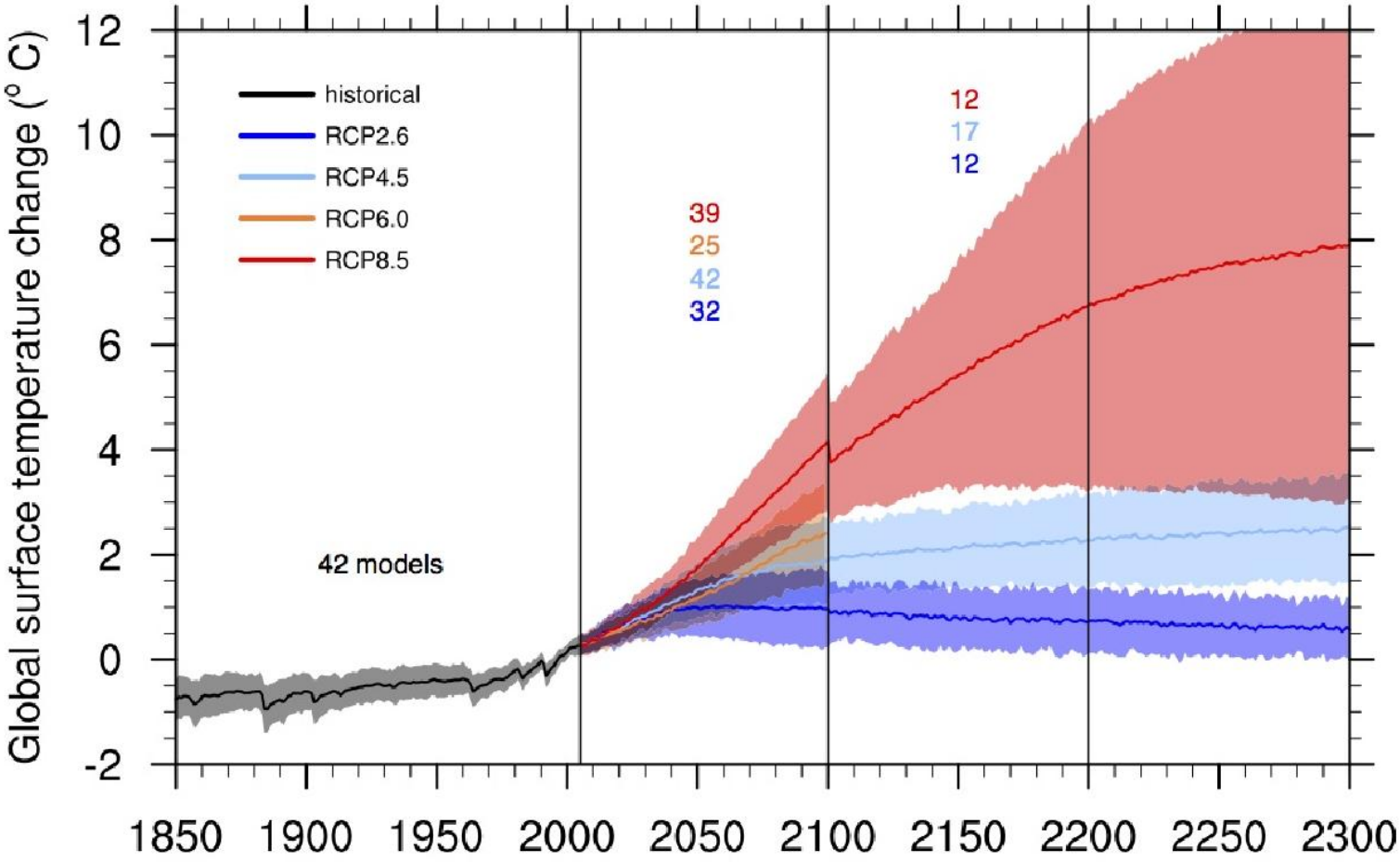

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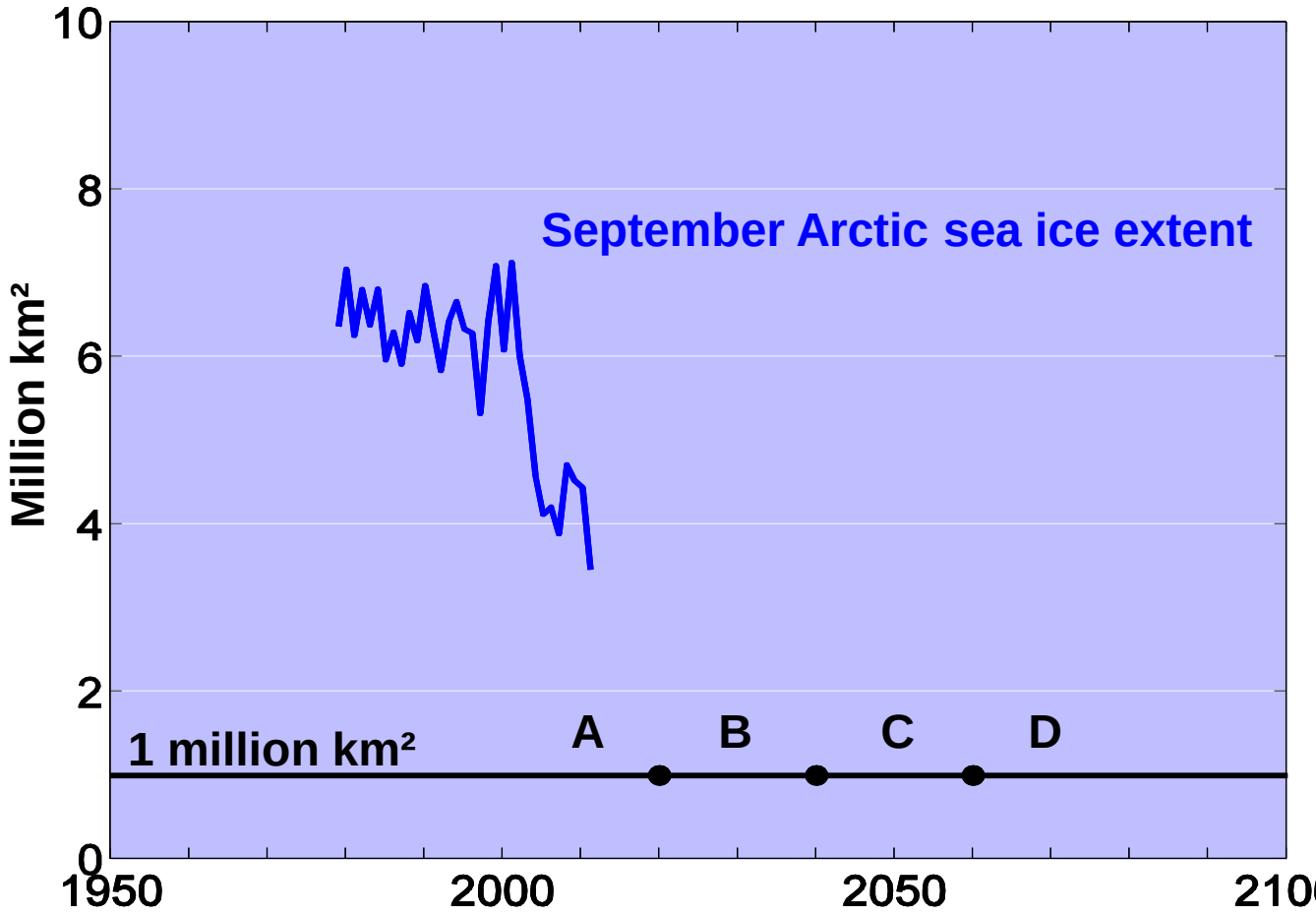
The one million dollar question



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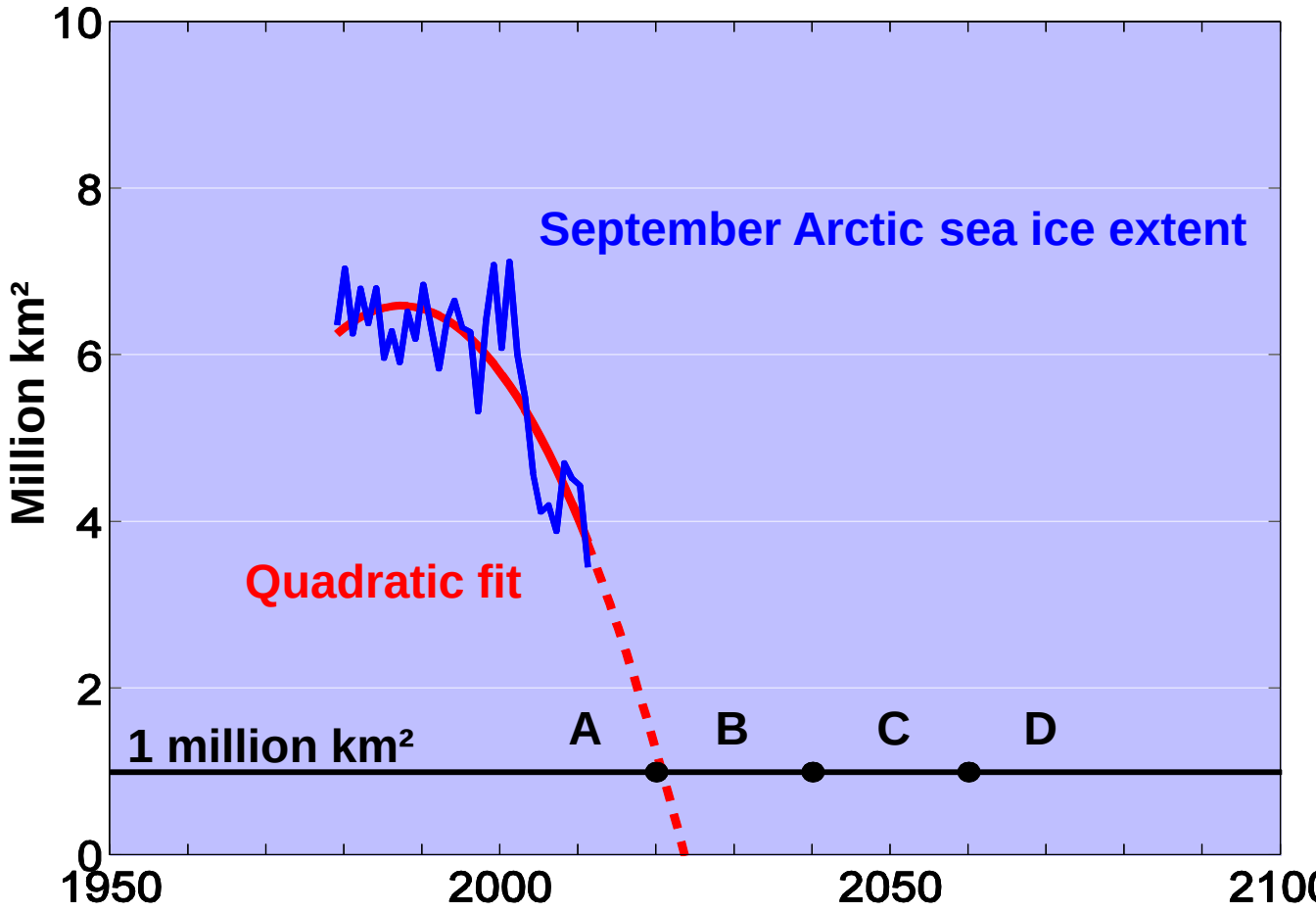

In climate change science, never rely on your intuitions