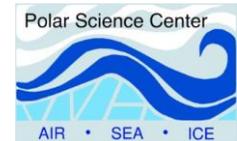


IGS Meeting, Hobart  
10th March 2014

# Constraining projections of summer Arctic sea ice

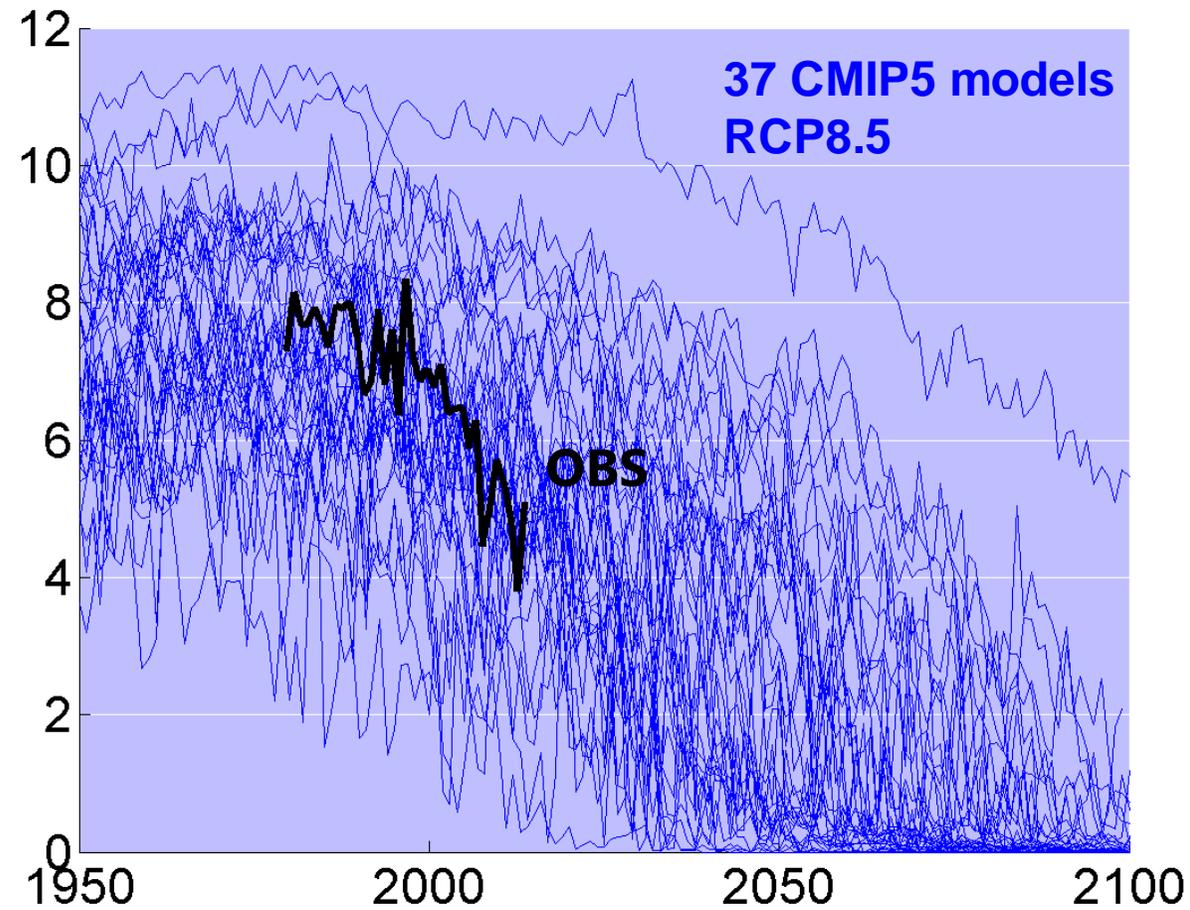
François Massonnet

T. Fichefet, H. Goosse,  
P. Hezel, C. Bitz, M. Holland,  
G. Philippon, P.-Y. Barriat



# The spread in summer Arctic sea ice projections is large

September sea ice extent [ $10^6 \text{ km}^2$ ]



# Constraining projections of summer Arctic sea ice

1. Extrapolation

2. Multi-model mean

3. Model selection

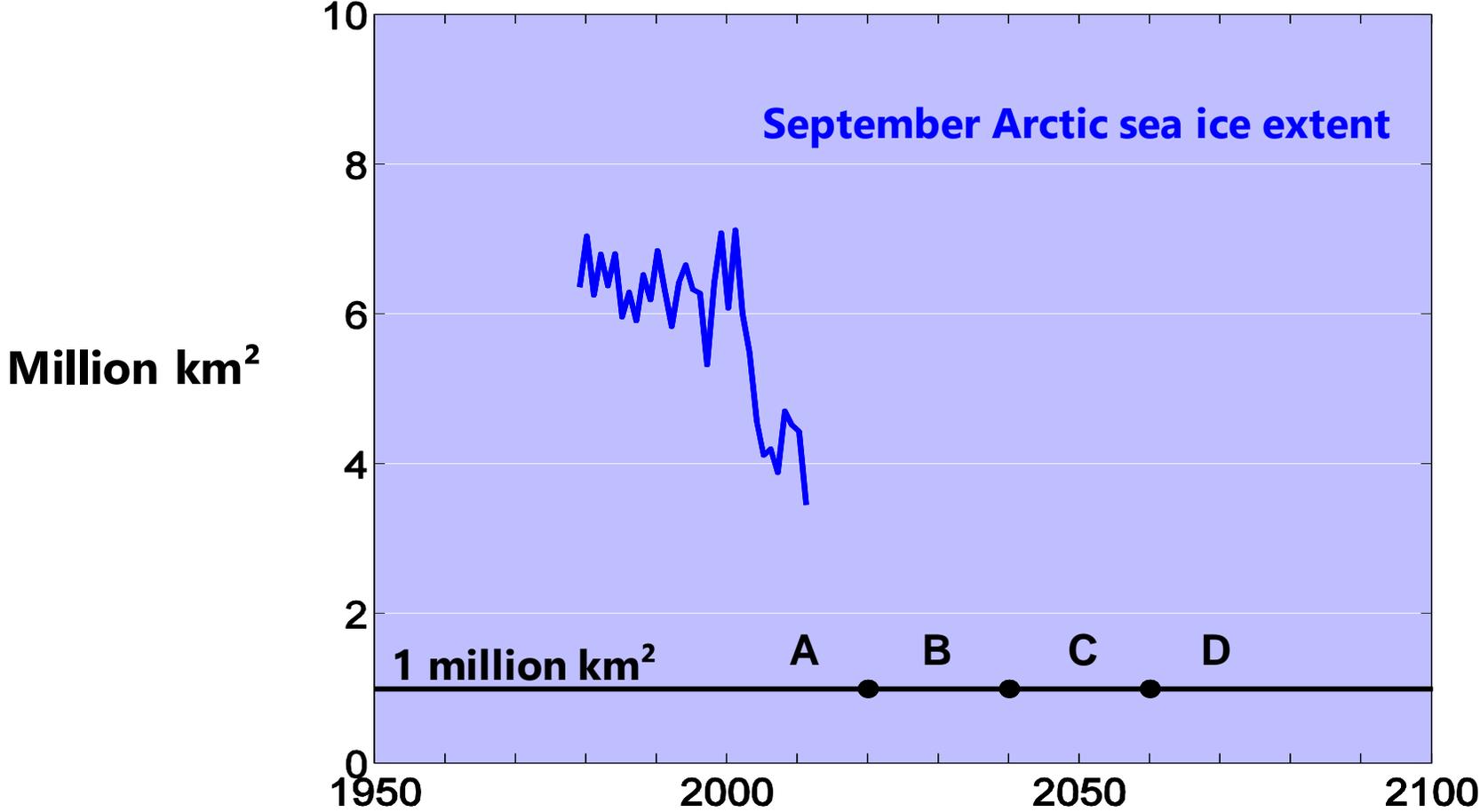
# Constraining projections of summer Arctic sea ice

## **1. Extrapolation**

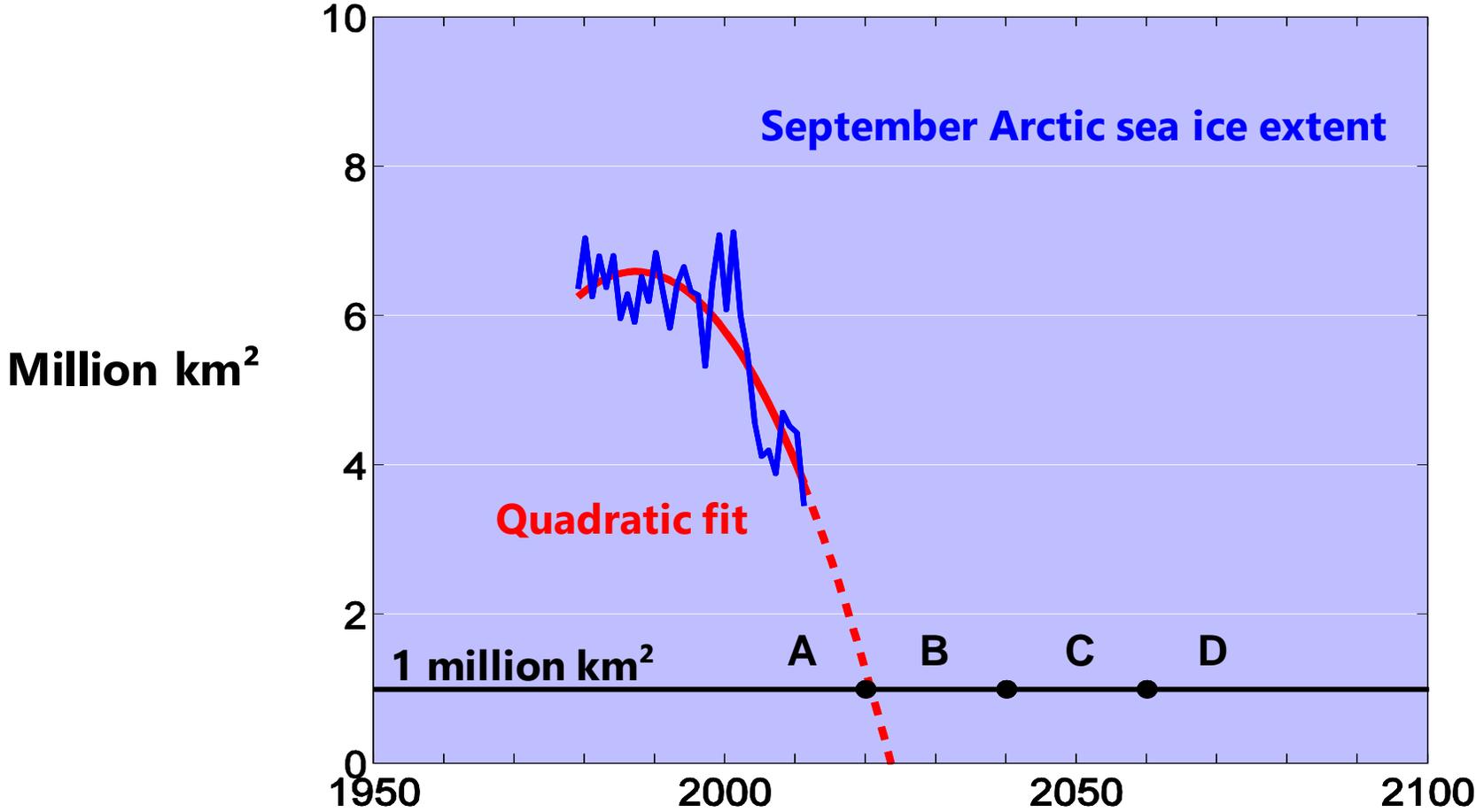
2. Multi-model mean

3. Model selection

# Poll: When will Arctic be sea ice-free?

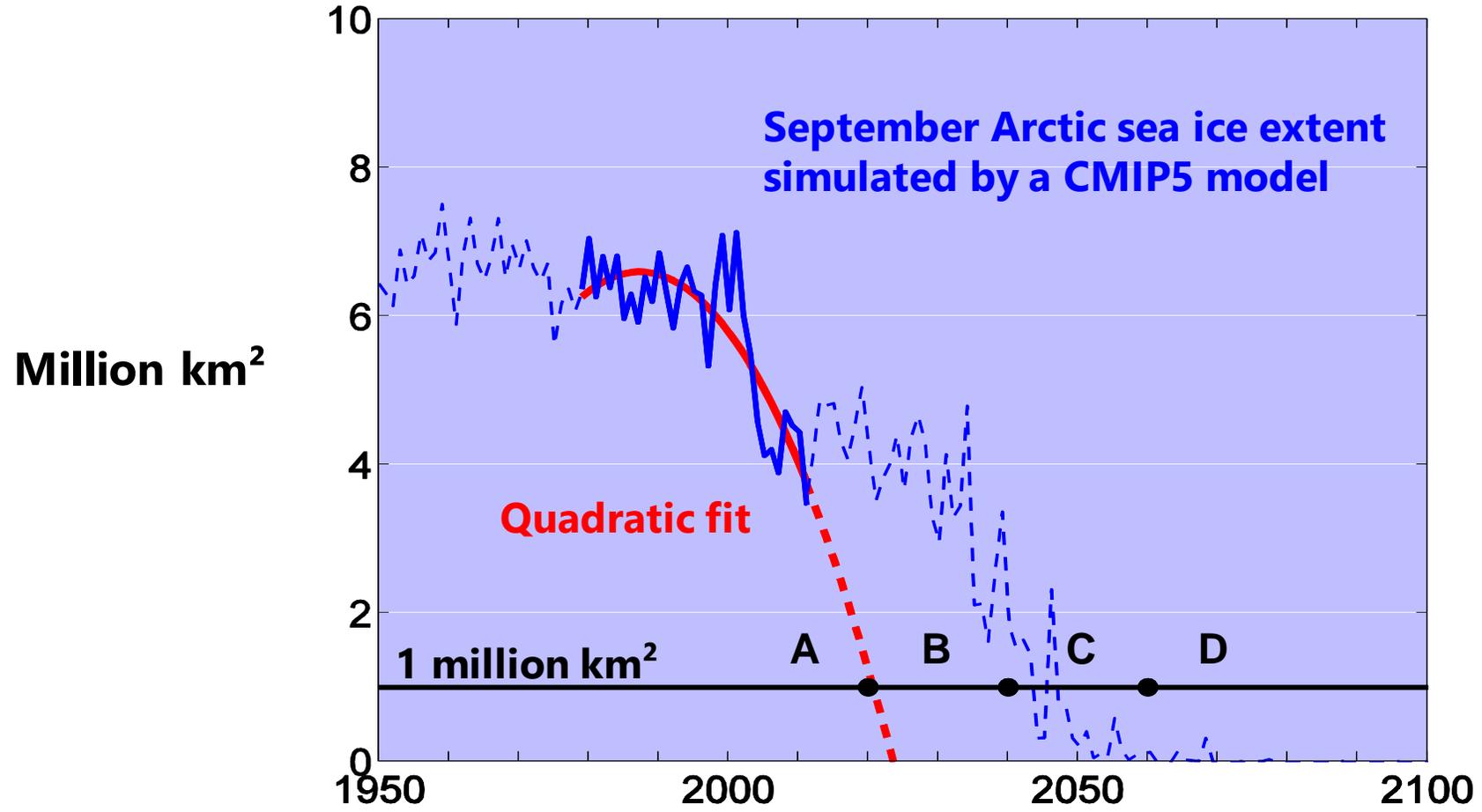


# Poll: When will Arctic be sea ice-free?



In climate change science,  
never rely on your intuitions

Poll: When will Arctic be sea ice-free?



# Constraining projections of summer Arctic sea ice

## 1. Extrapolation

Not appropriate for highly nonlinear systems

## 2. Multi-model mean

## 3. Model selection

# Constraining projections of summer Arctic sea ice

## 1. Extrapolation

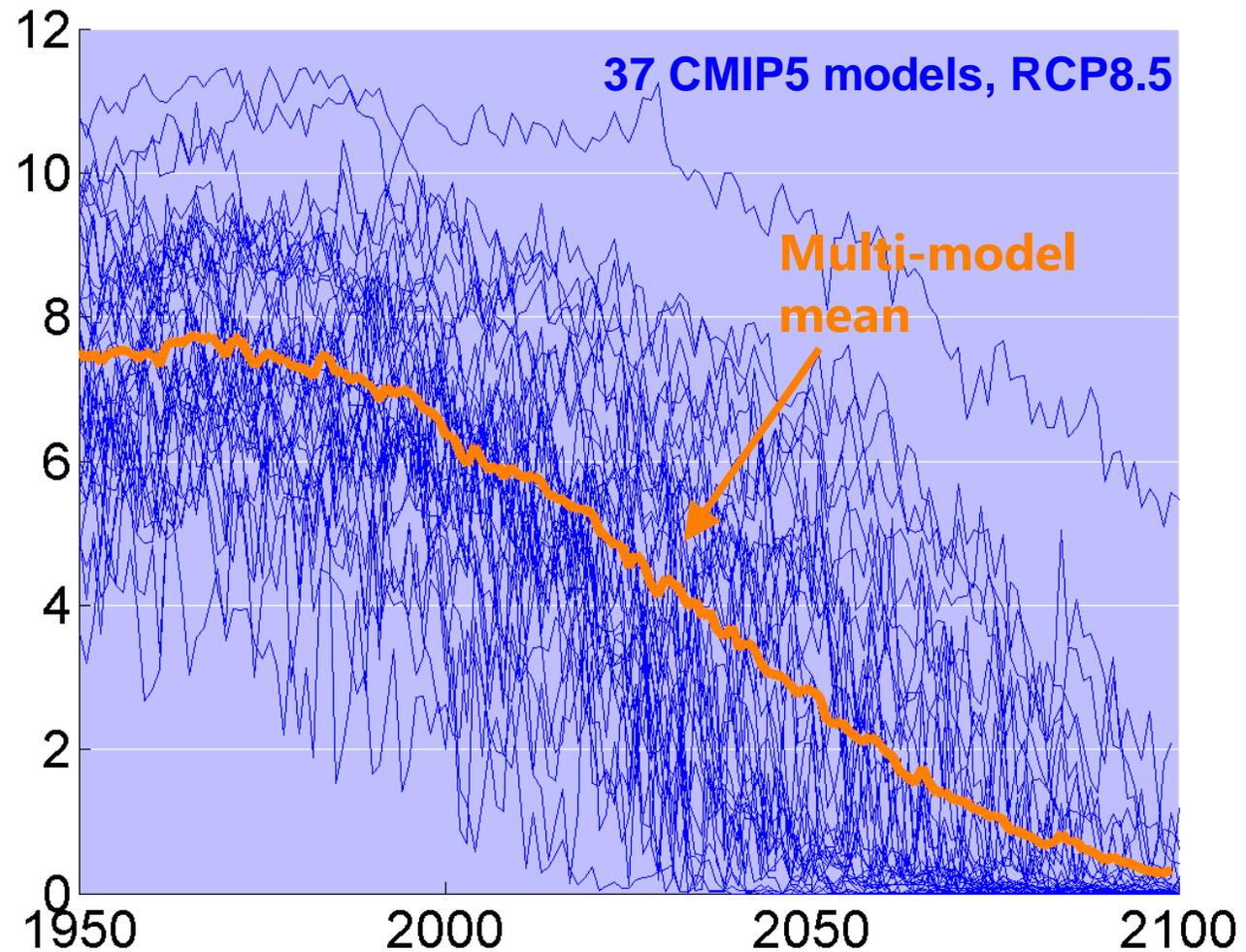
Not appropriate for highly nonlinear systems

## **2. Multi-model mean**

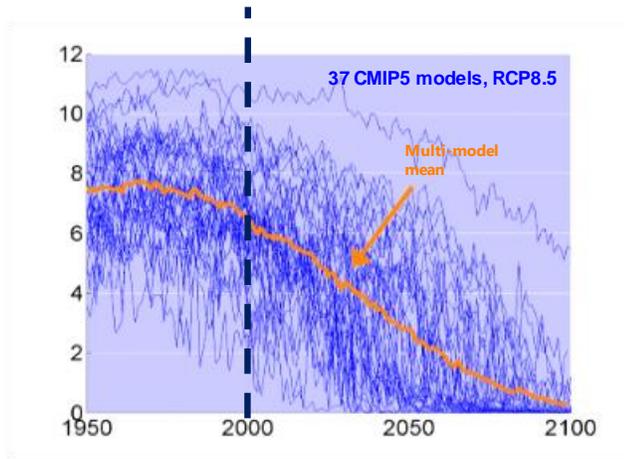
## 3. Model selection

# Uses and misuses of the multi-model mean

September sea ice extent [ $10^6 \text{ km}^2$ ]

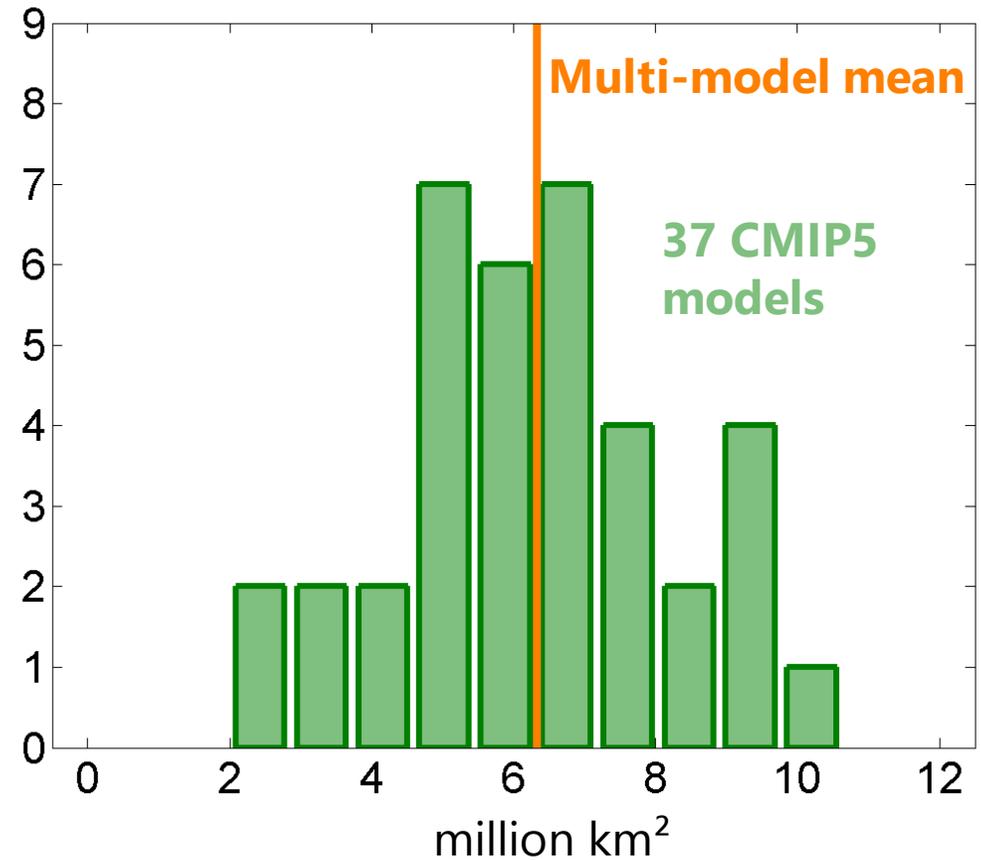


# Uses and misuses of the multi-model mean

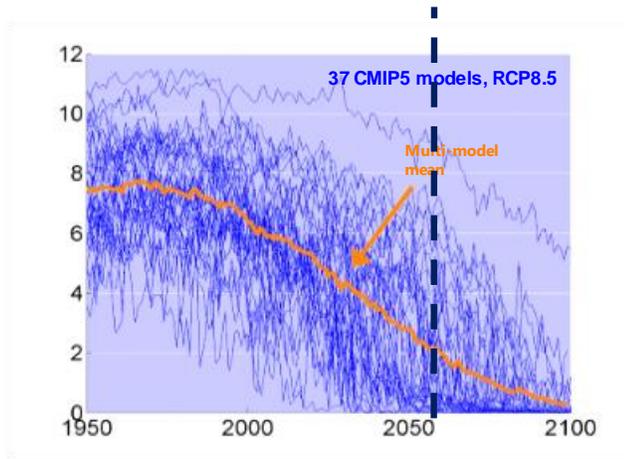


Number of models

## Distribution of CMIP5 September sea ice extent **in 2000**

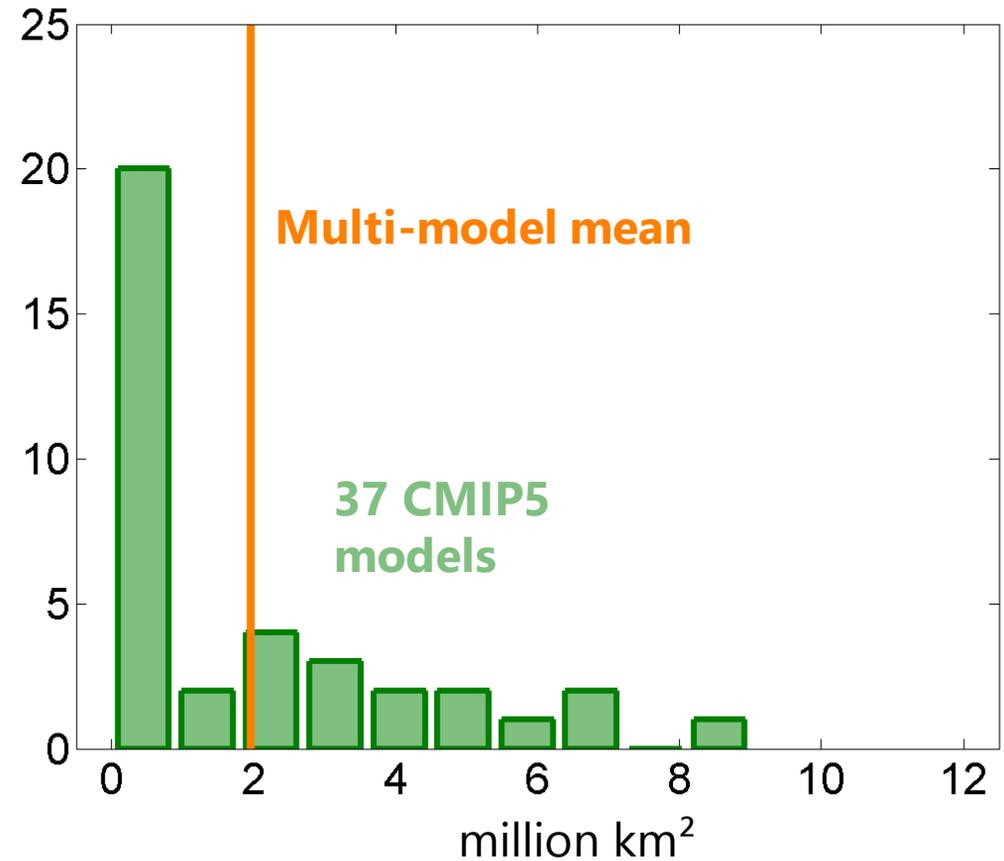


# Uses and misuses of the multi-model mean



Number of models

Distribution of CMIP5 September sea ice extent **in 2060**



# Constraining projections of summer Arctic sea ice

## 1. Extrapolation

Not appropriate for highly nonlinear systems

## 2. Multi-model mean

Not appropriate for skewed distributions

## 3. Model selection

# Constraining projections of summer Arctic sea ice

## 1. Extrapolation

Not appropriate for highly nonlinear systems

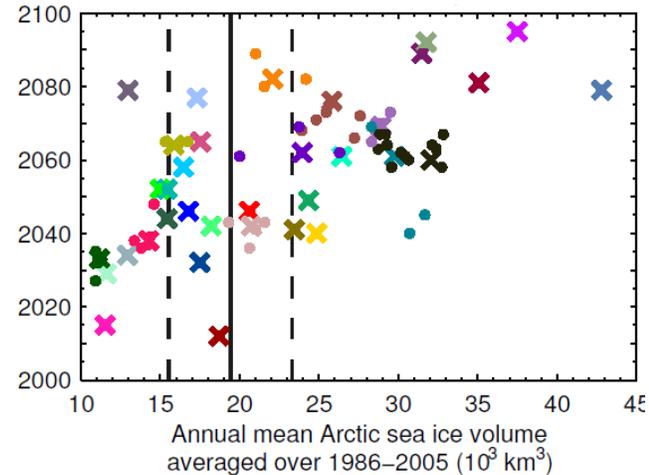
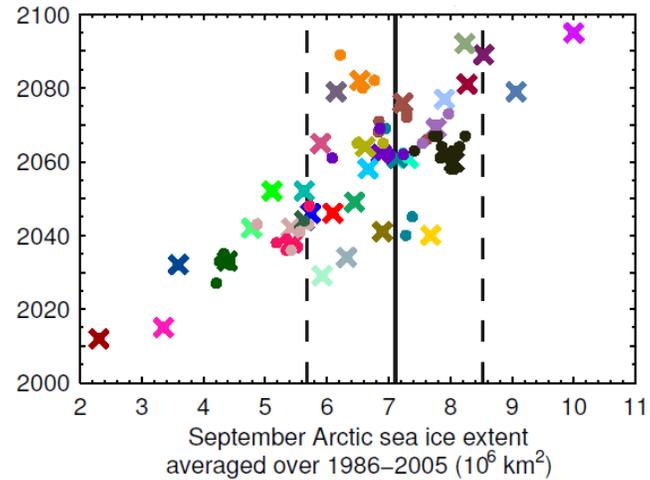
## 2. Multi-model mean

Not appropriate for skewed distributions

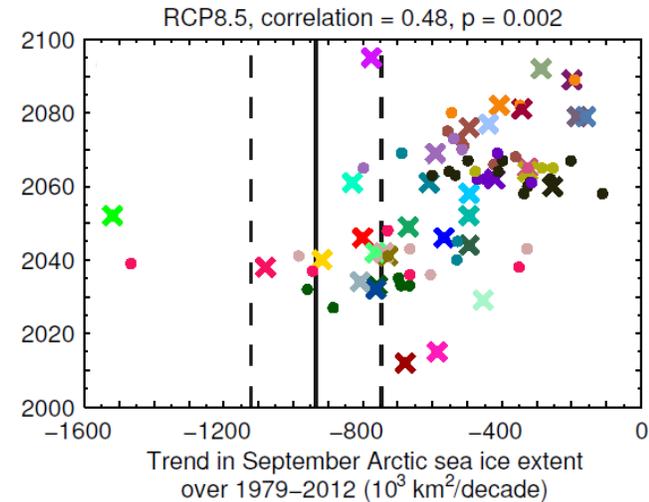
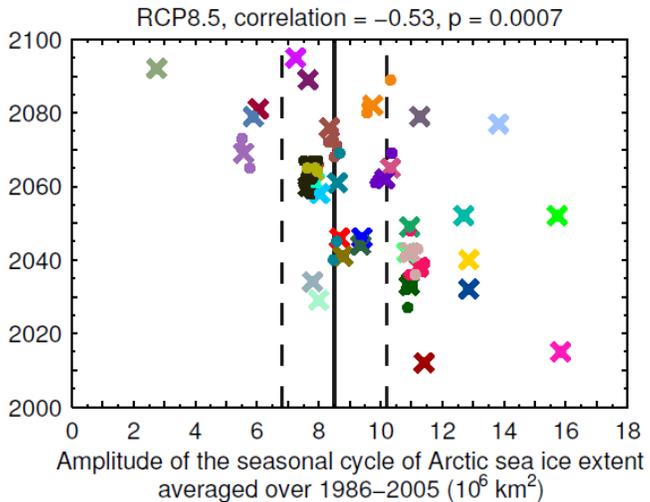
## **3. Model selection**

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

First year of summer ice-free Arctic



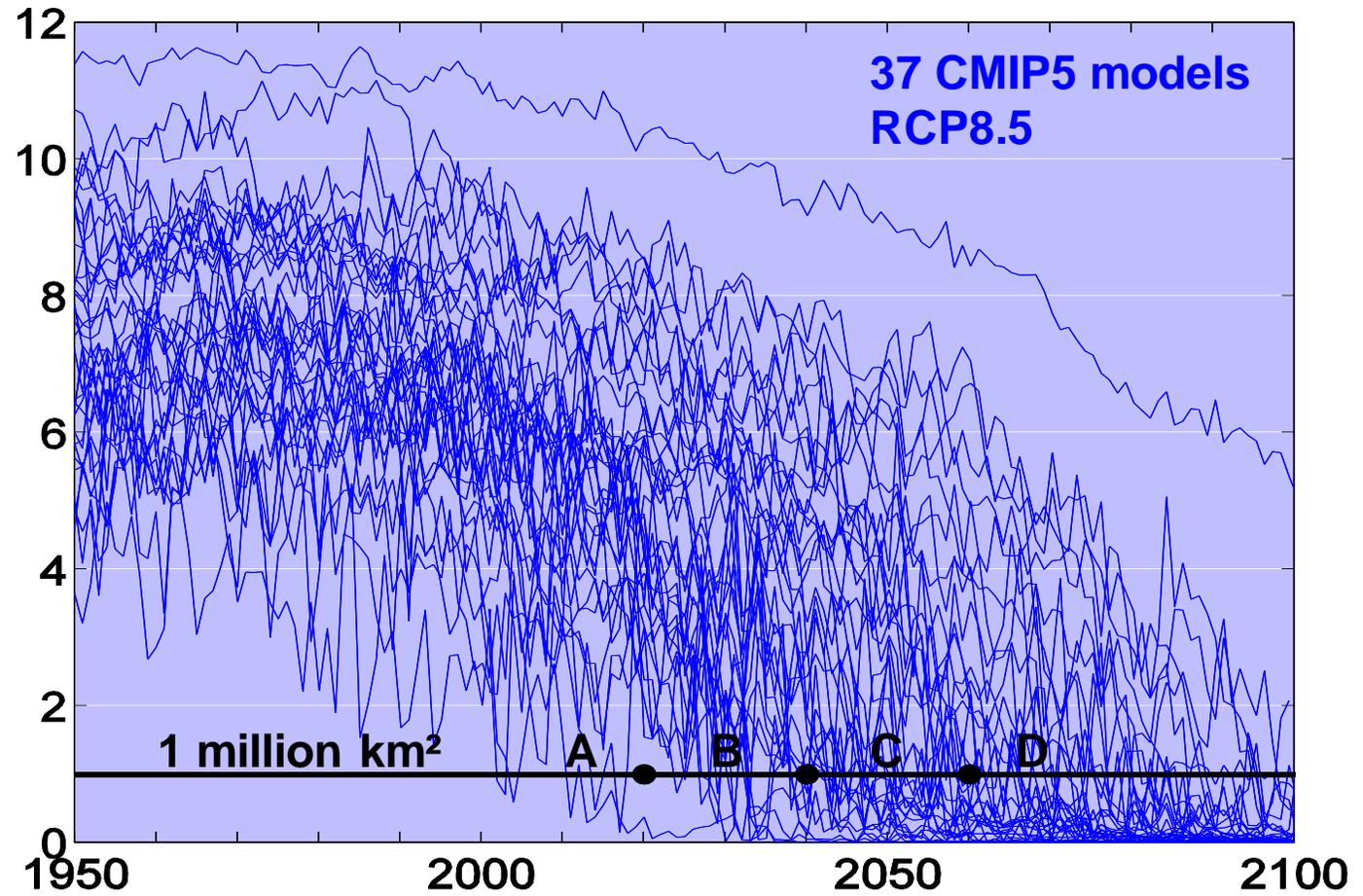
First year of summer ice-free Arctic



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

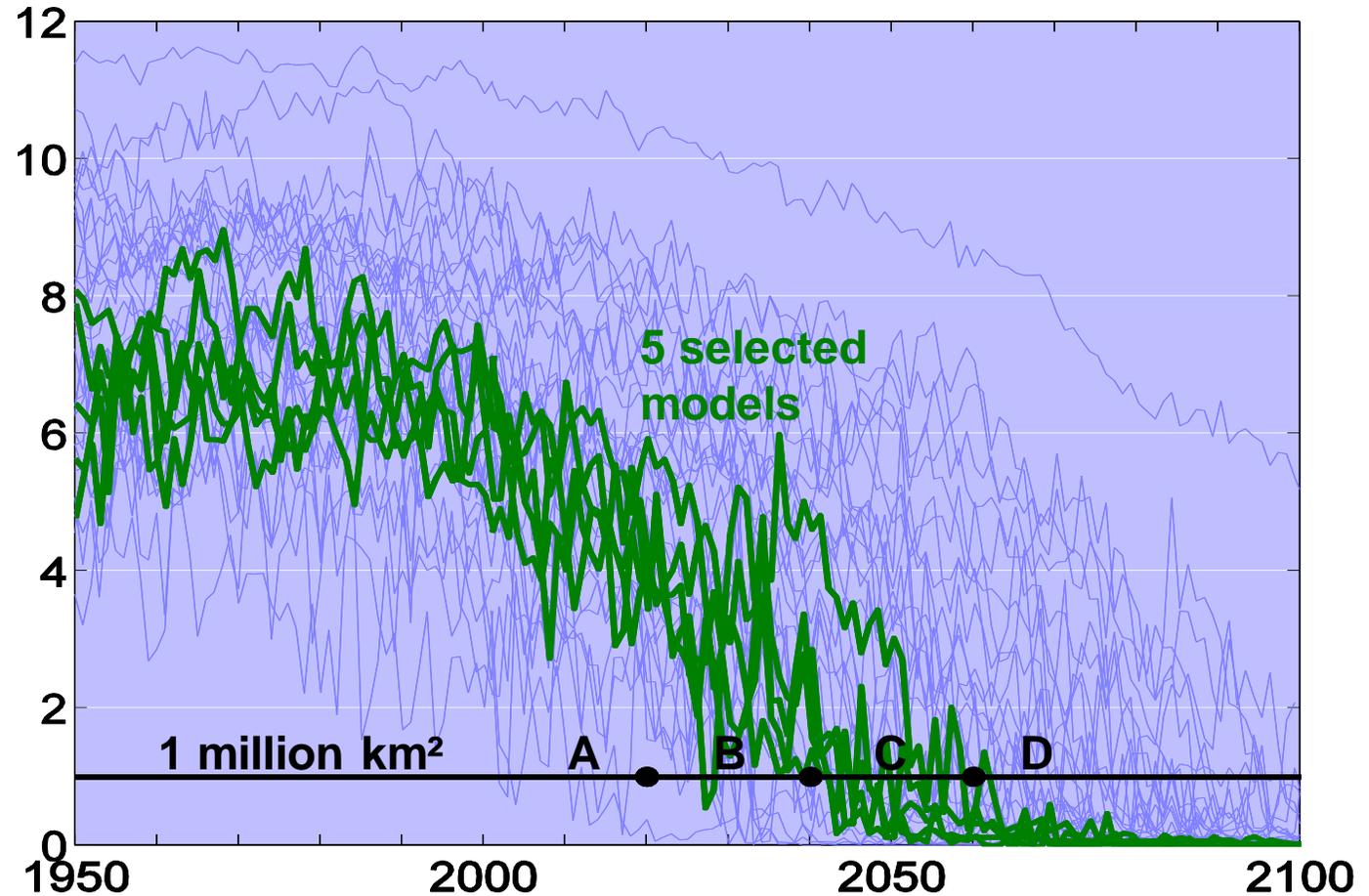
[OBS: Comiso and Nishio, 2008  
Sea ice volume reanalysis:  
Schweiger et al., 2009]

**September sea ice  
extent [ $10^6 \text{ km}^2$ ]**



# A possible summer ice-free Arctic by mid-century (RCP8.5)

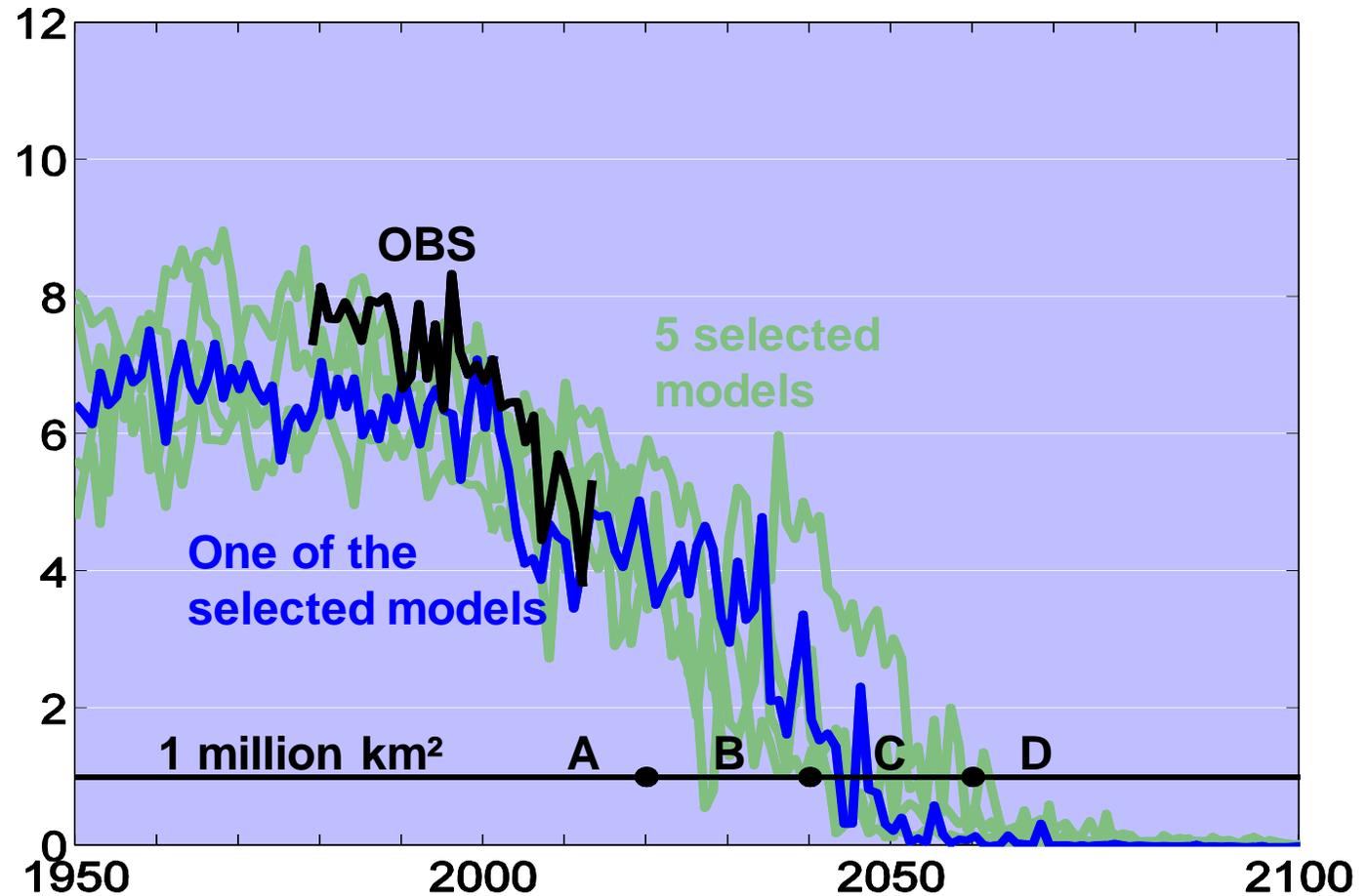
September sea ice extent [ $10^6 \text{ km}^2$ ]



# Is nature experiencing a Rapid Ice Loss Event?

**(Must) see Paul Hezel's talk on RILEs Friday**

September sea ice extent [ $10^6 \text{ km}^2$ ]



# Constraining projections of summer Arctic sea ice

## 1. Extrapolation

Not appropriate for highly nonlinear systems

## 2. Multi-model mean

Not appropriate for skewed distributions

## 3. Model selection

Appropriate for intended purpose

# Model selection is an appropriate approach but it relies on hypotheses



- It is based on physical arguments
- It does not filter out natural variability

- The radiative forcing is assumed known



- Model performance should not depend on the mean climate state
- Model performance should be genuine, not resulting from compensation of errors

Thank you

[francois.massonnet@uclouvain.be](mailto:francois.massonnet@uclouvain.be)

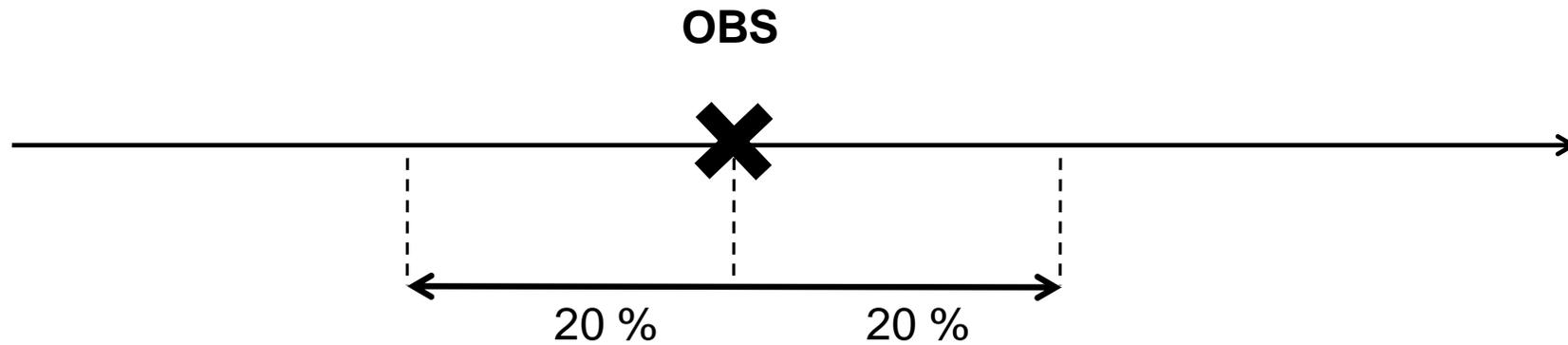
[www.climate.be/u/fmasson](http://www.climate.be/u/fmasson)

Beware the perverse effects  
of internal variability

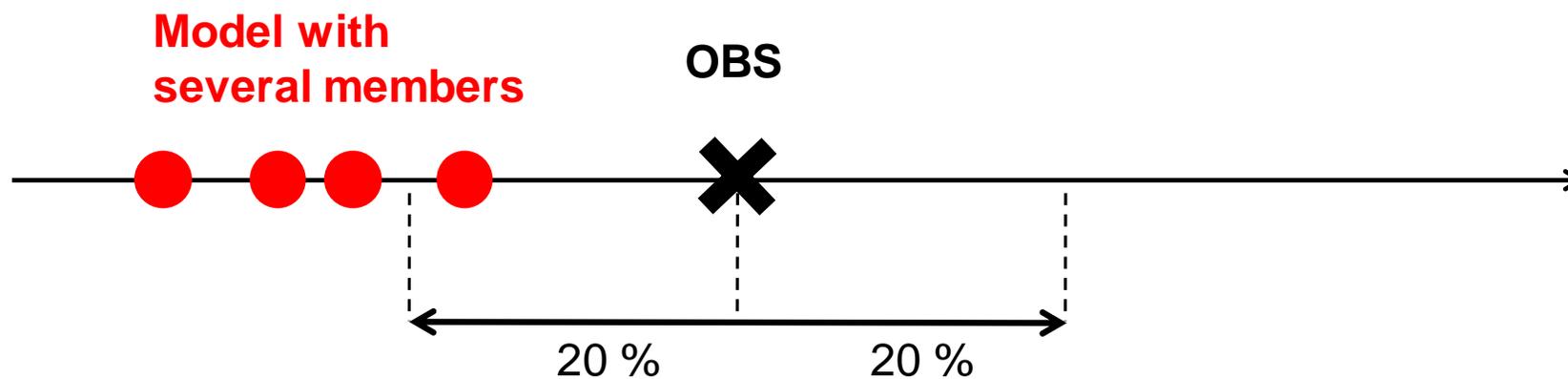
OBS



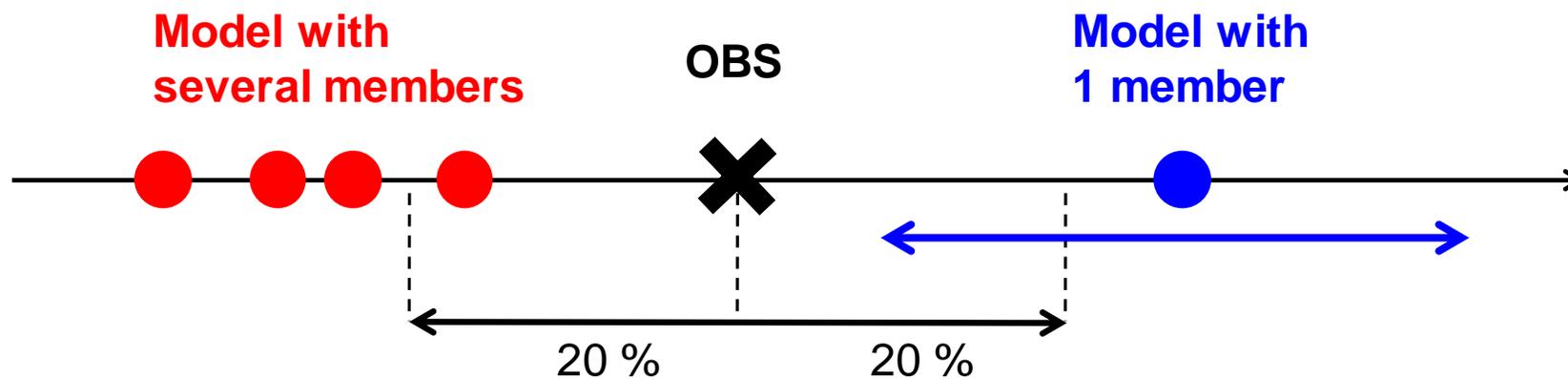
Beware the perverse effects  
of internal variability



Beware the perverse effects  
of internal variability



Beware the perverse effects  
of internal variability



# CMIP5 models are not inconsistent with available Arctic sea ice data

How many CMIP5 models successfully simulate ...

Average 1986-2005  
September Arctic sea ice extent **26** out of 37

Amplitude of the 1986-2005  
seasonal cycle of Arctic sea ice extent **19** out of 37

Trend in 1979-2012  
September Arctic sea ice extent **23** out of 37

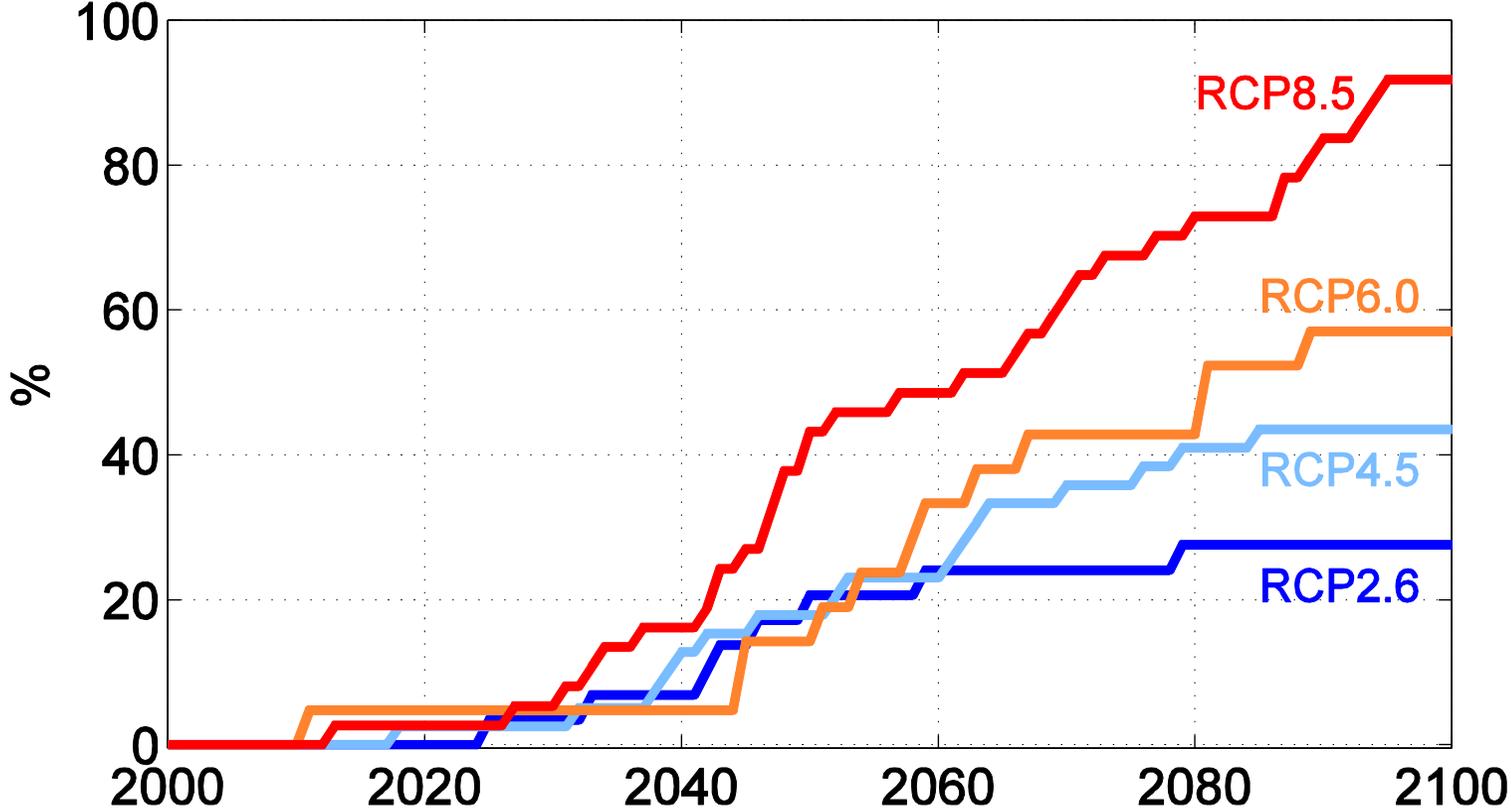
Annual mean 1986-2005 annual Arctic sea  
ice volume (reanalysis) **19** out of 37

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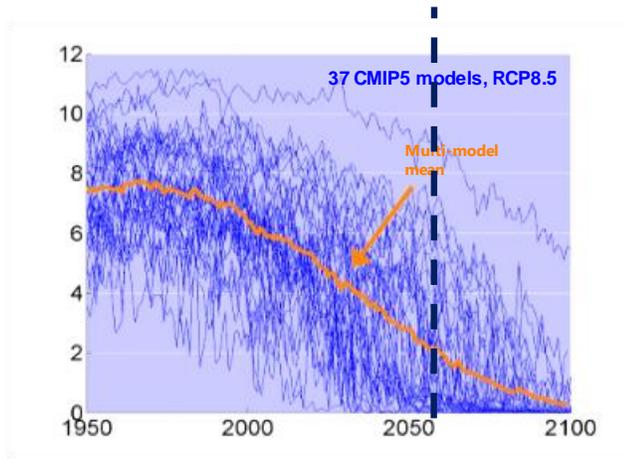
All four criteria **5** out of 37

# The spread in summer Arctic sea ice projections is large

Proportion of models with September Arctic sea ice extent < 1 million km<sup>2</sup>



# Uses and misuses of the multi-model mean



Number of models

Distribution of CMIP5 September sea ice extent **in 2060**

