21st century changes in the Arctic sea ice cover

Constraining CMIP5 sea ice projections

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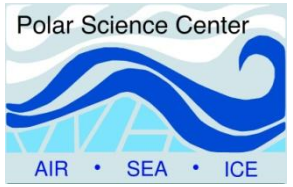
M. Holland, P. –Y. Barriat

Hamburg, MPI
20 September 2012



Mothers all want their sons
to grow up to be president

John F. Kennedy

Mothers all want their sons to grow up to be president

but they don't want them to become politicians in the process.

John F. Kennedy

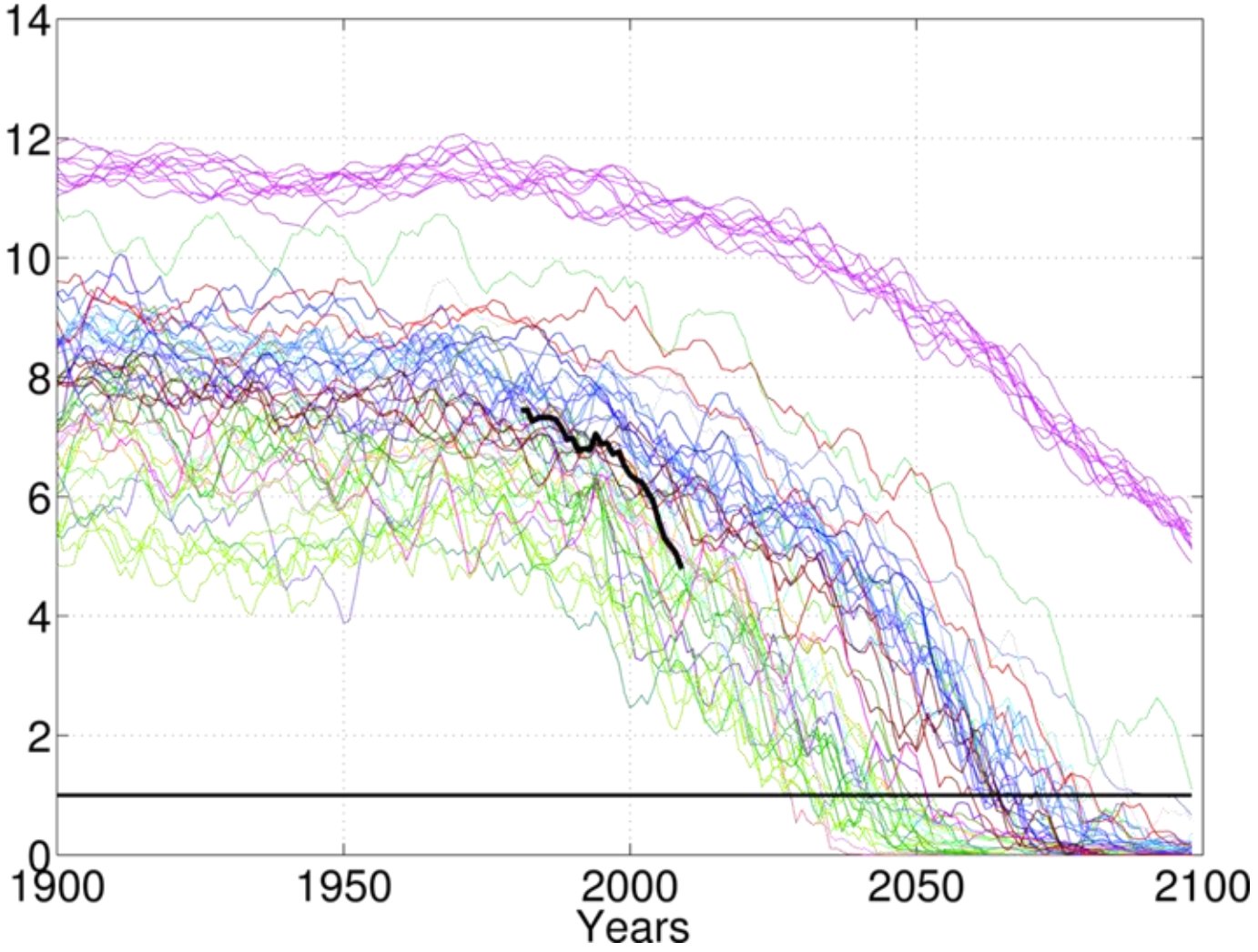
CMIP5 contributors all want their model to grow up to be the best at projections

but they don't want them to be evaluated in the process.

A model user

The spread in CMIP5 summer Arctic sea ice projections is still large

September sea ice extent [10^6 km^2]



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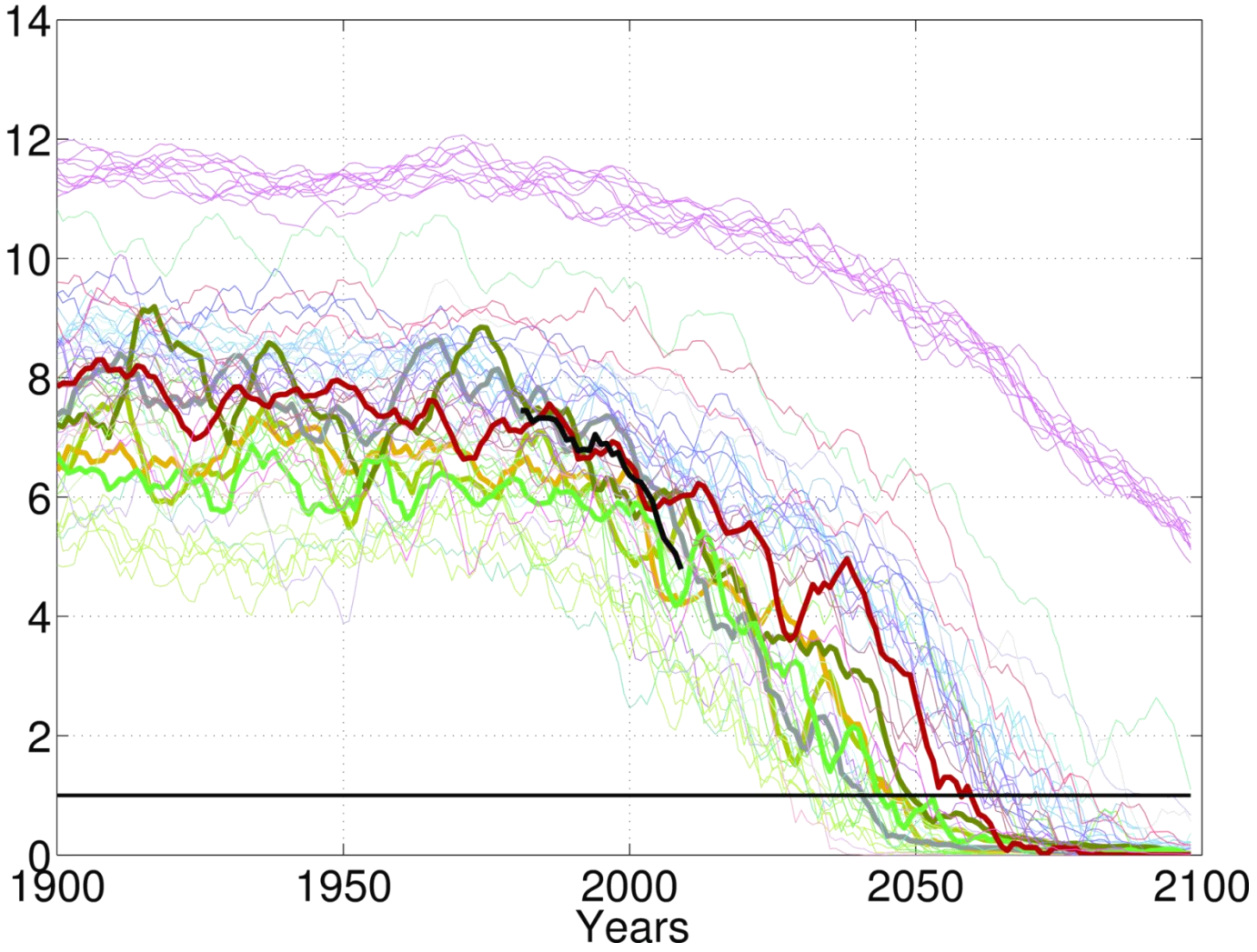

Constraints and correlations

Yes, we can!

Effective model selection

Constraints and correlations

Yes, we can!

Effective model selection

A constrain is a set of rules that the model output must satisfy

Based on empirical relationships

between present-day and future properties

If possible, with a physical basis

[Bitz, 2008; Boé et al., 2009; Holland et al., 2008]

Arctic sea ice projections

thought to be « constrainable » [Collins et al., 2012]

Be careful when using correlations: know what you correlate

$X^{(29x1)} \sim$ Normal (8.10^6 km² , 1.10^6 km²)

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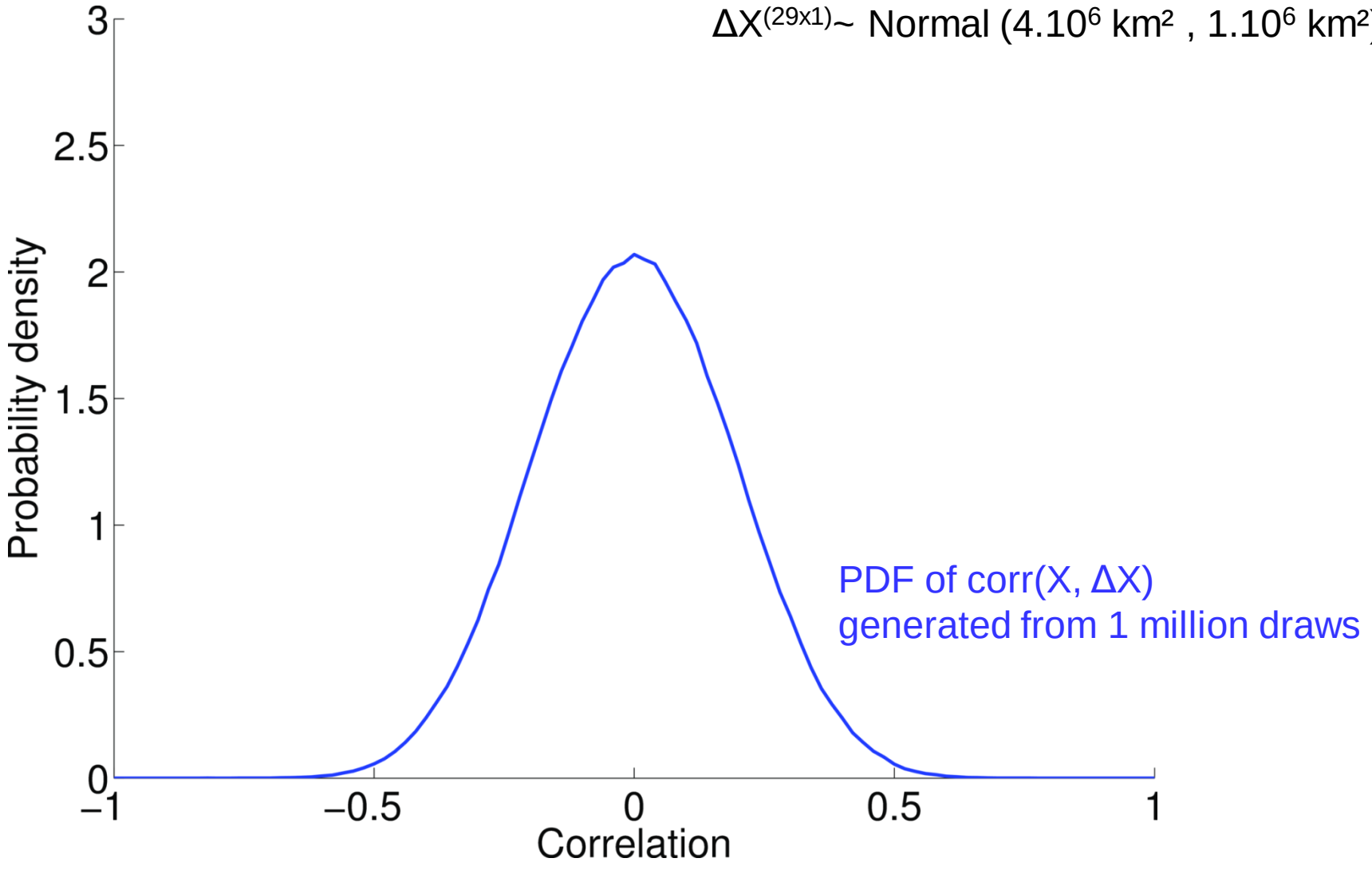

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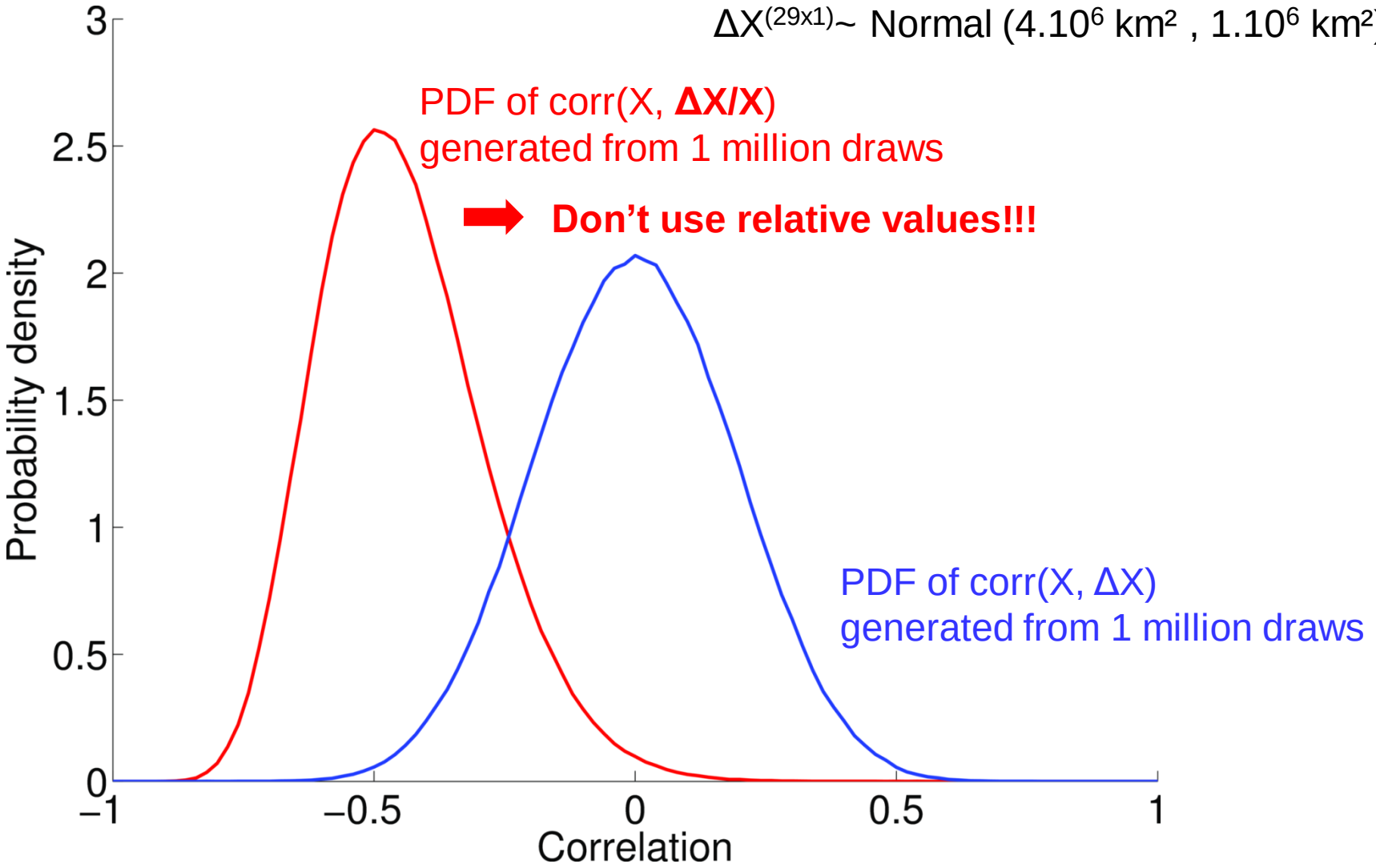
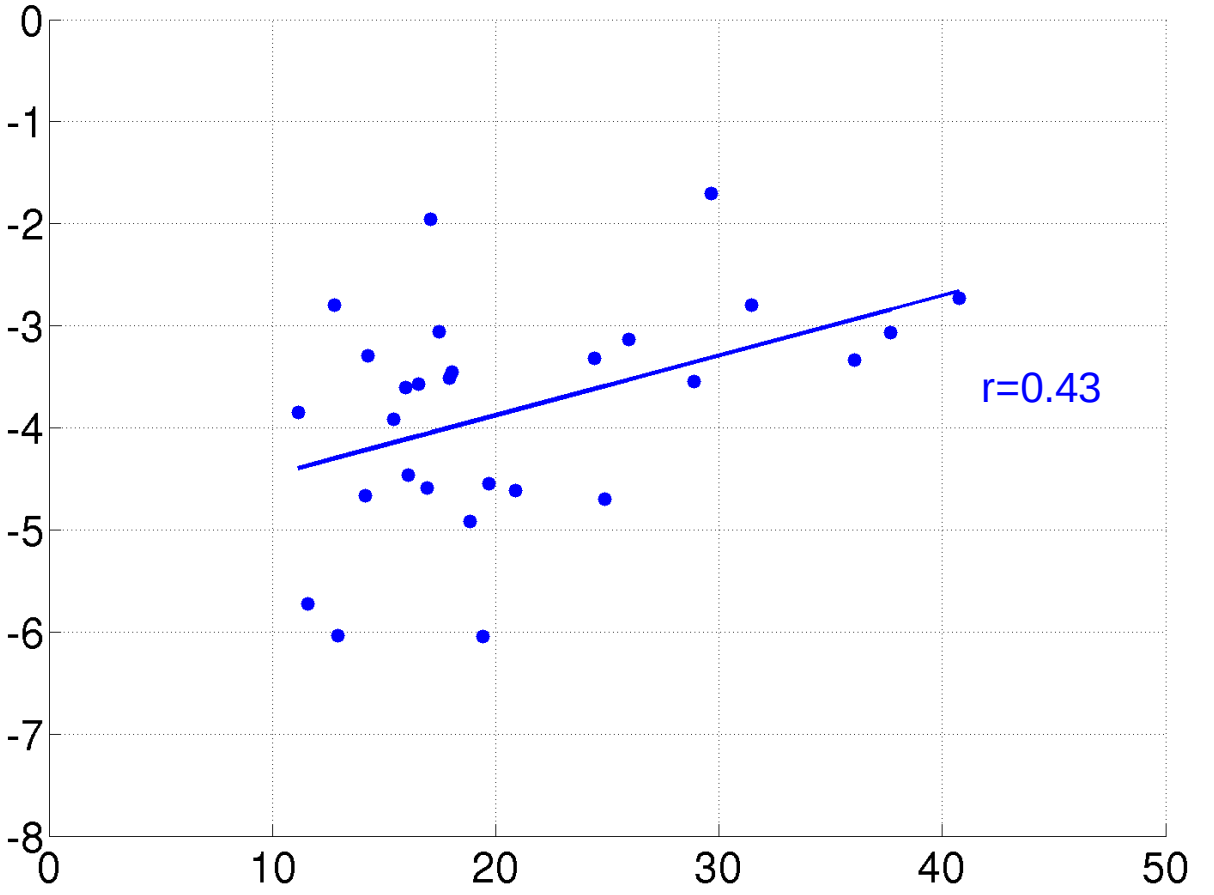


Be careful when using correlations: compare apples with apples

September sea ice extent loss [10^6 km^2] w.r.t. 1979-2010 in **2030-2061**



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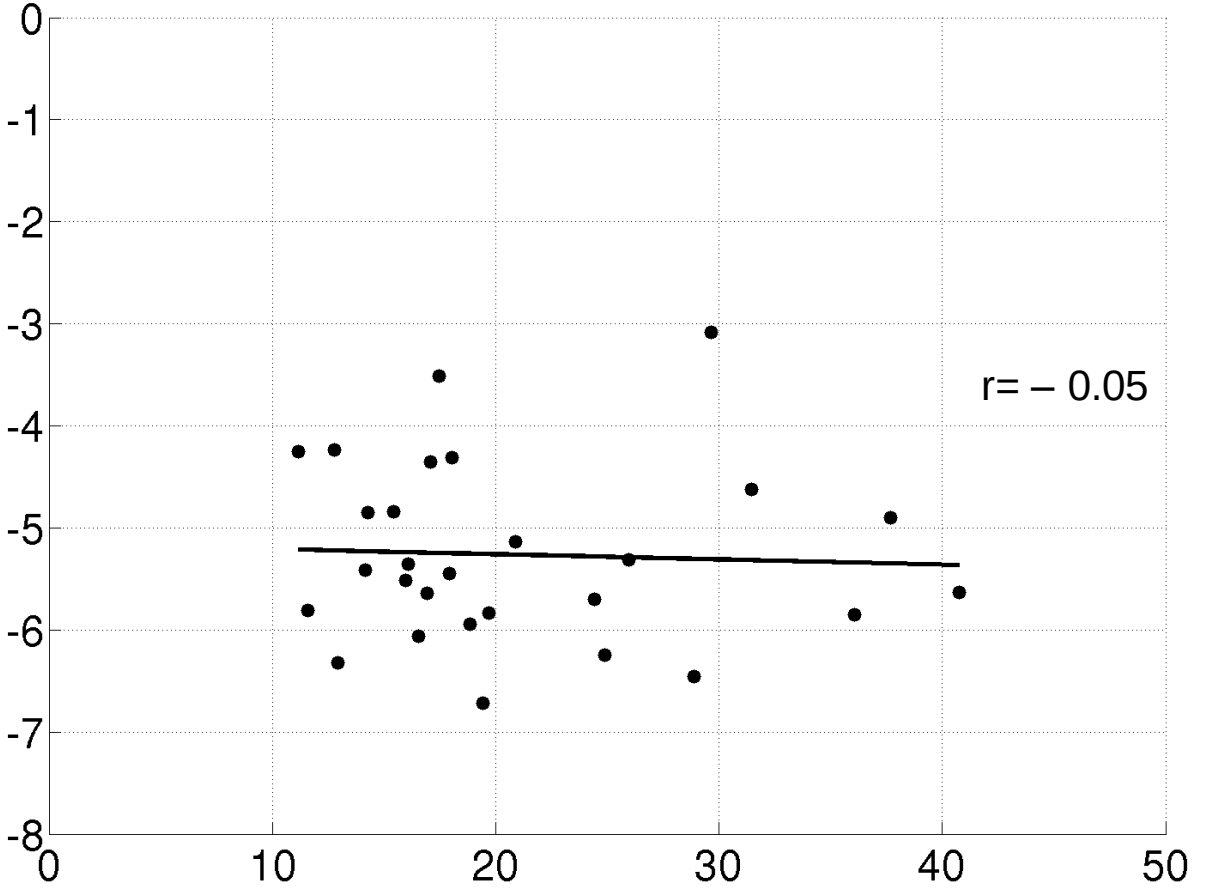
September sea ice extent loss [10^6 km^2] w.r.t. 1979-2010 in **2050-2081**



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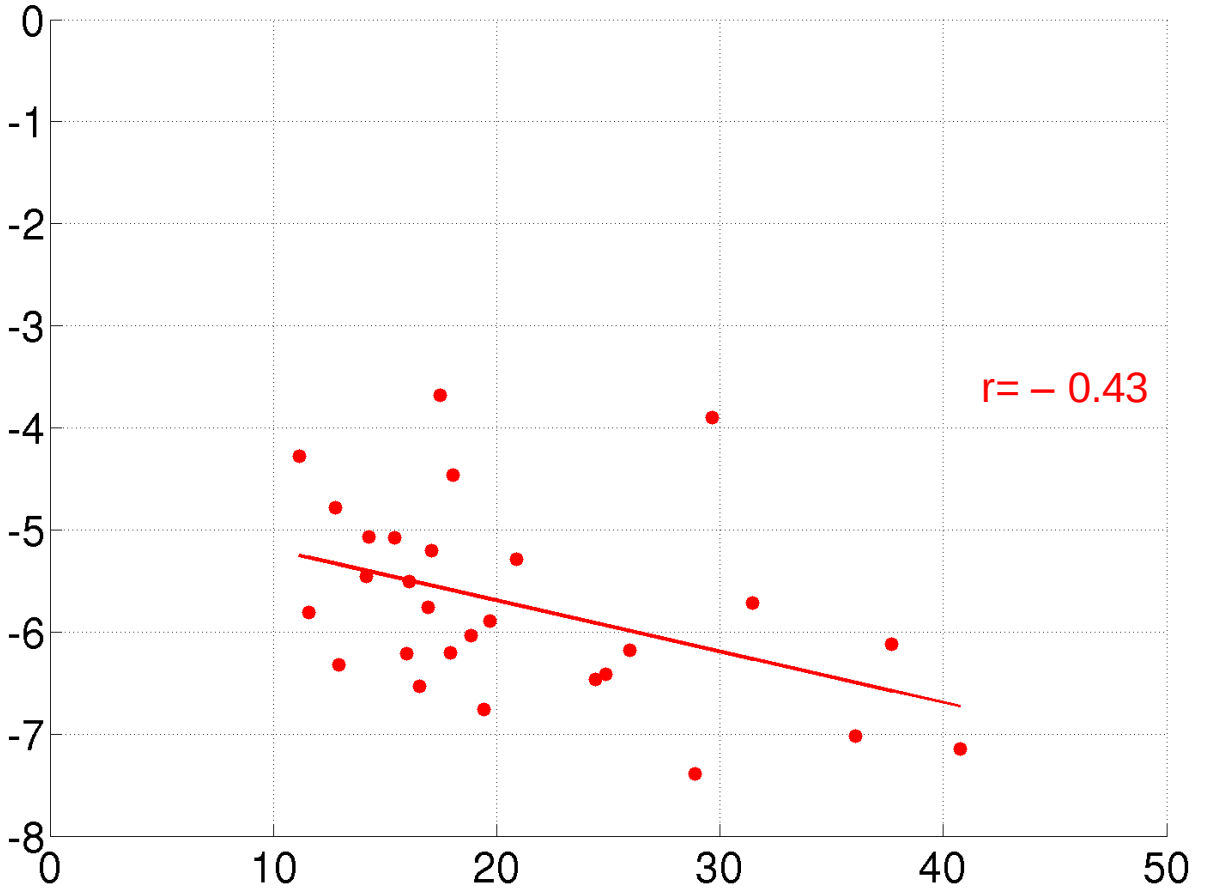
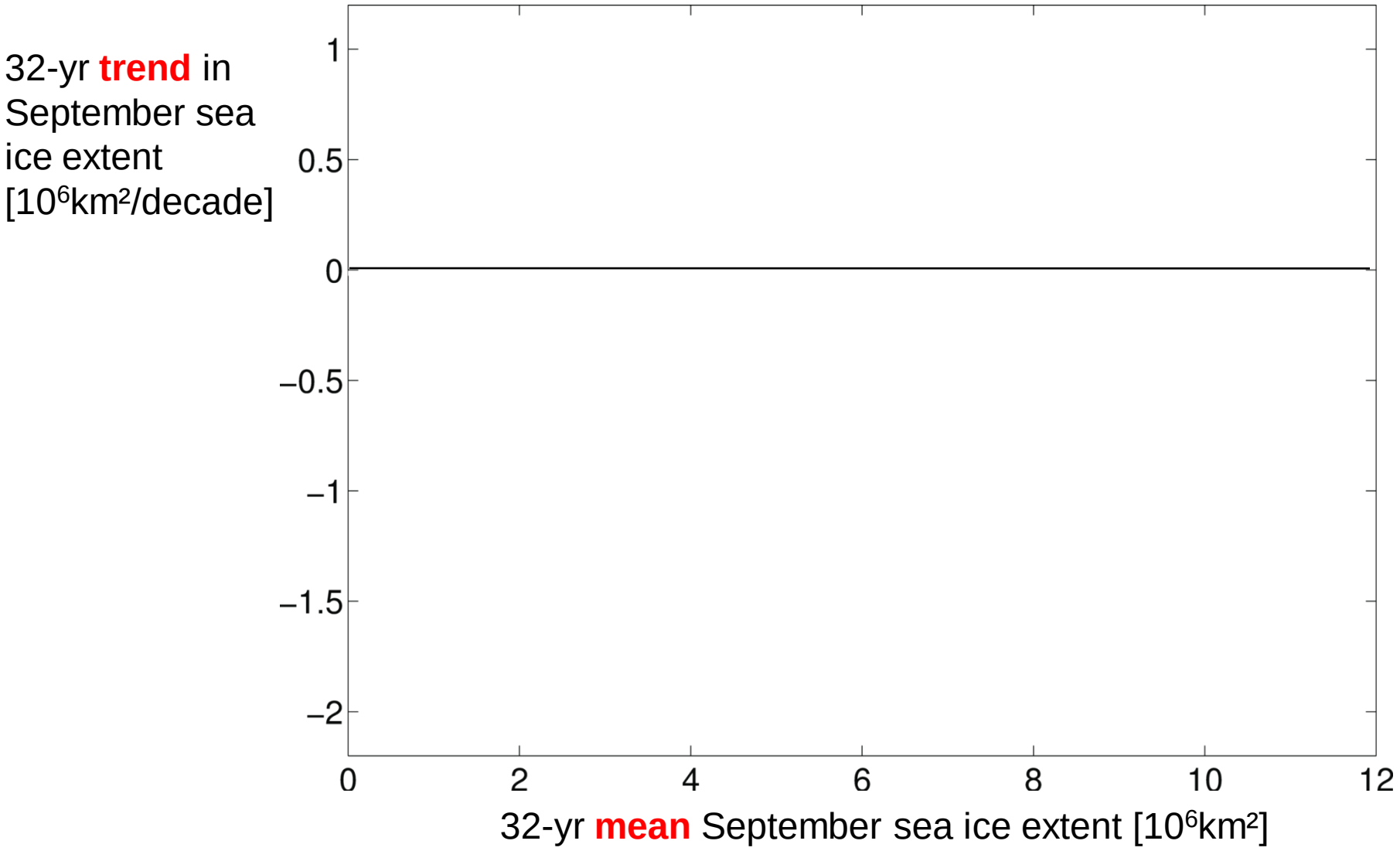
September sea ice extent loss [10^6 km^2] w.r.t. 1979-2010 in **2060-2091**



Mean sea ice conditions and variability are nonlinearly related to each other



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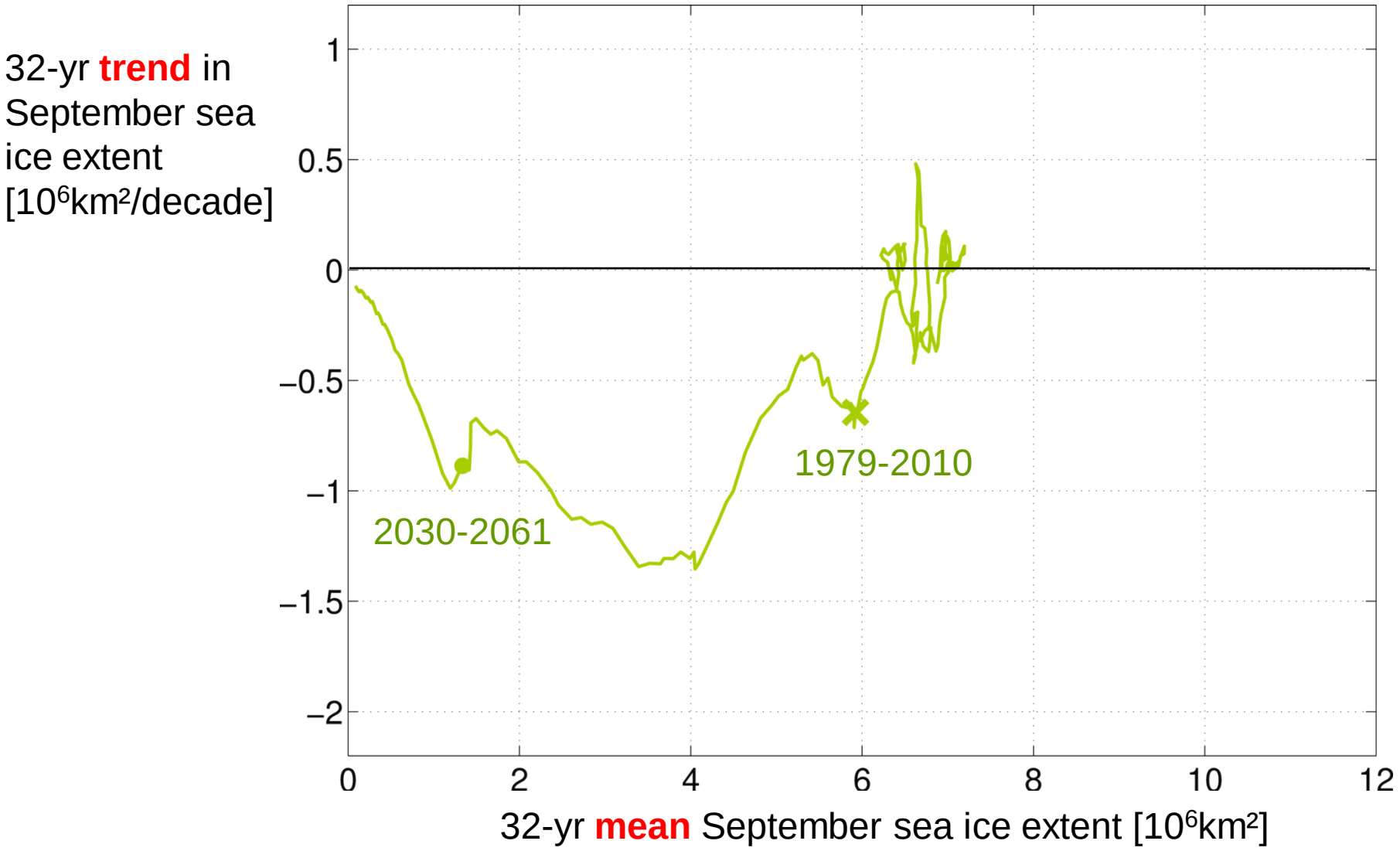
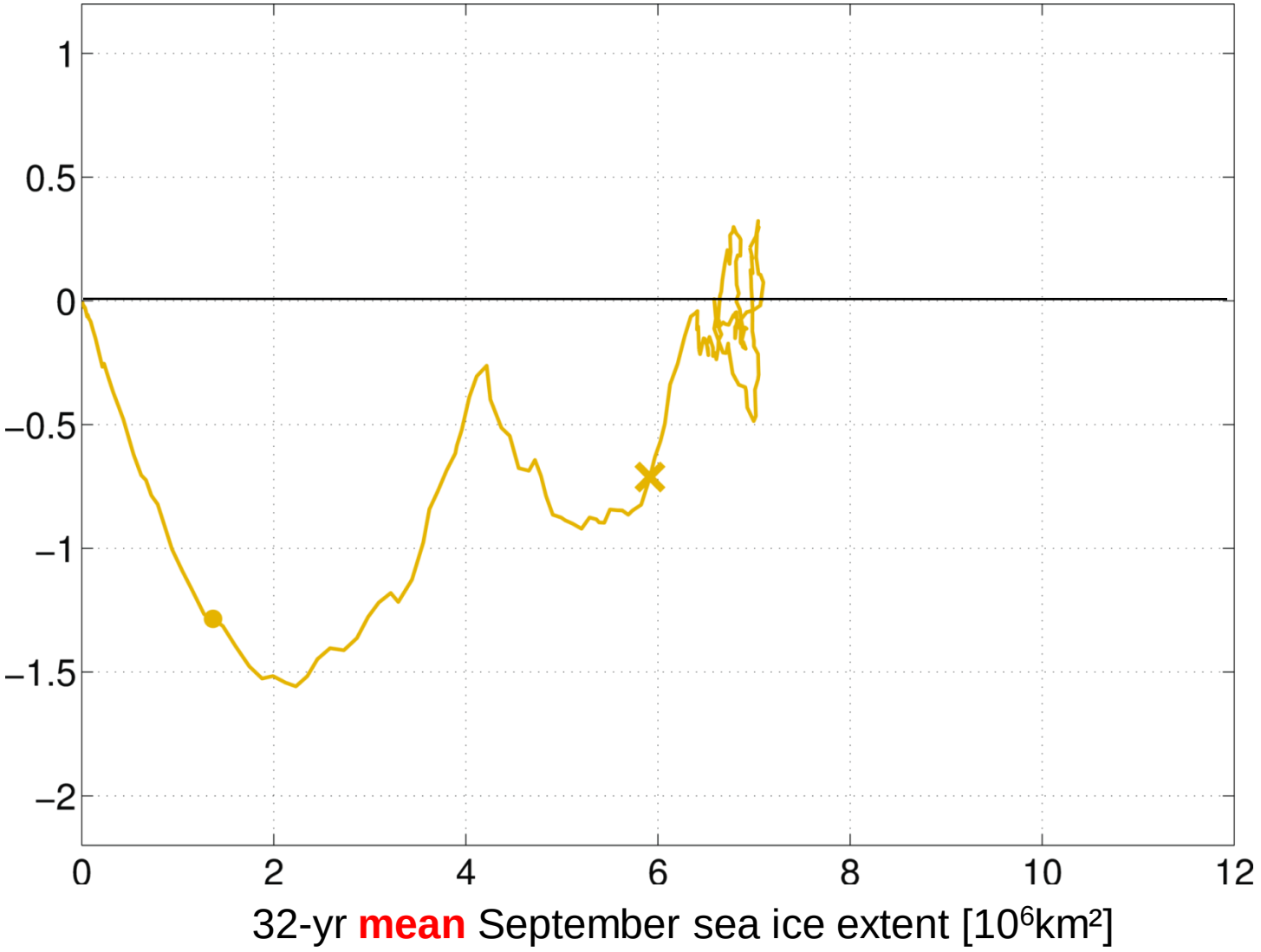


Mean sea ice conditions and variability are nonlinearly related to each other

32-yr **trend** in September sea ice extent [$10^6 km^2$/decade]



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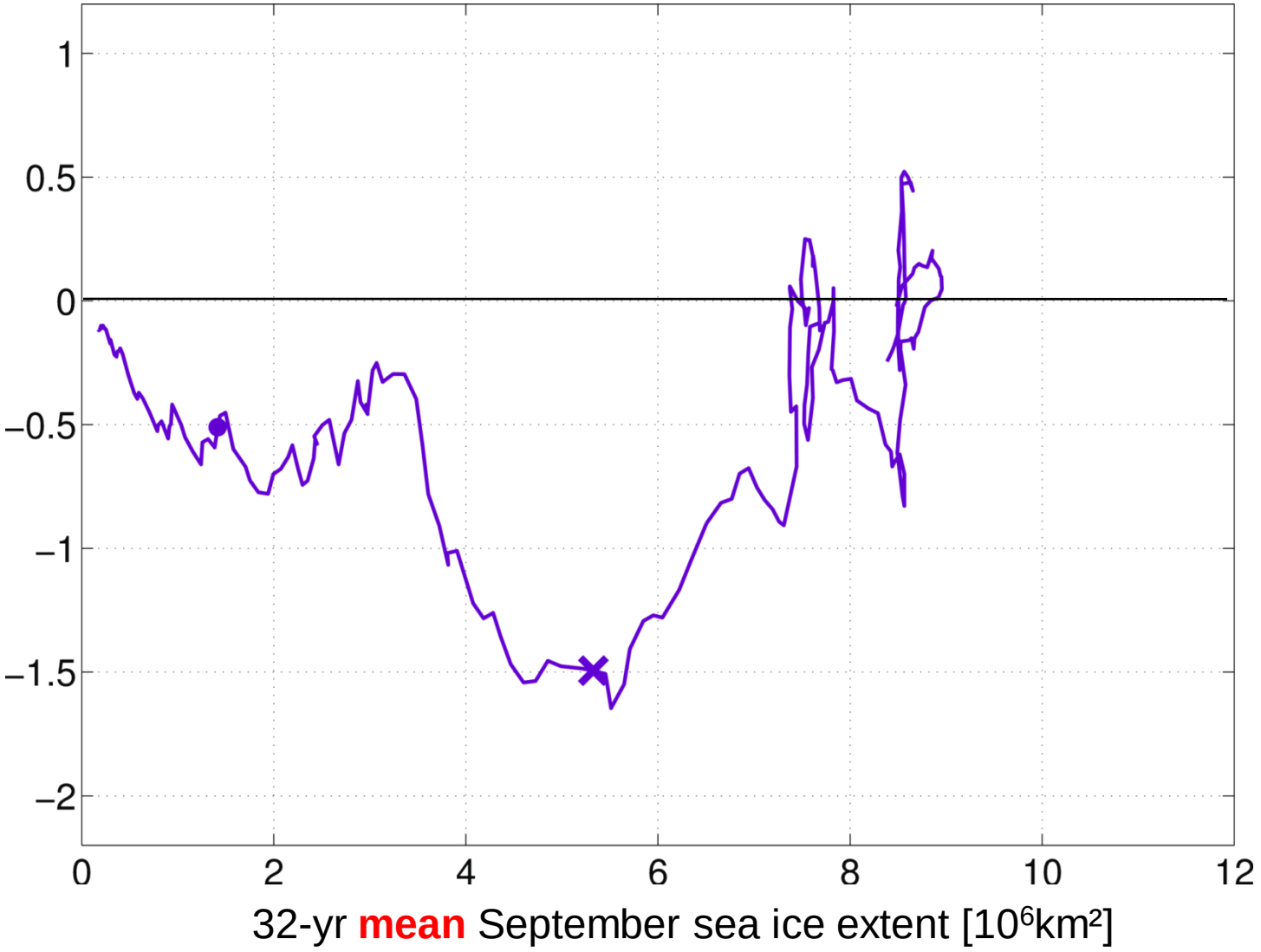

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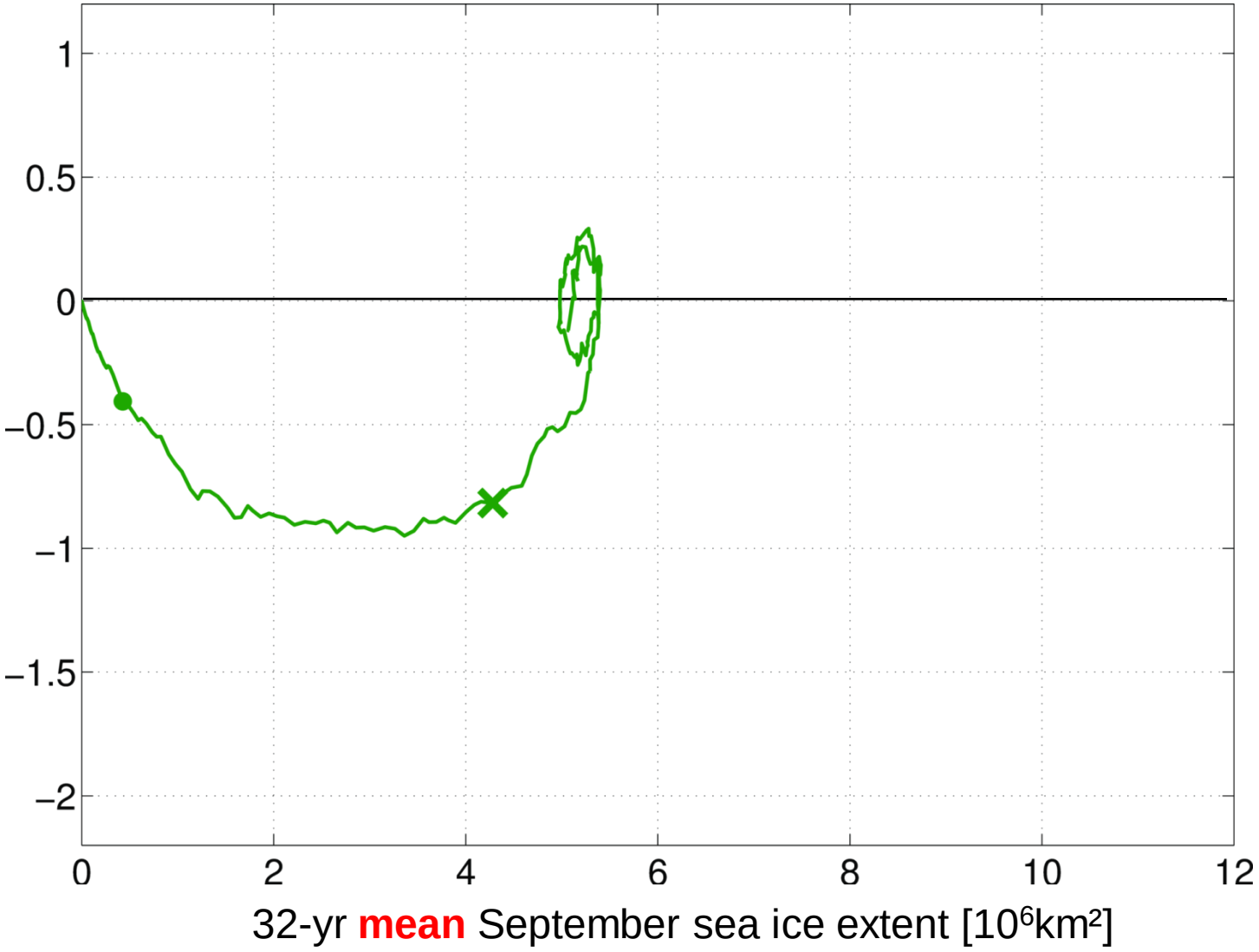
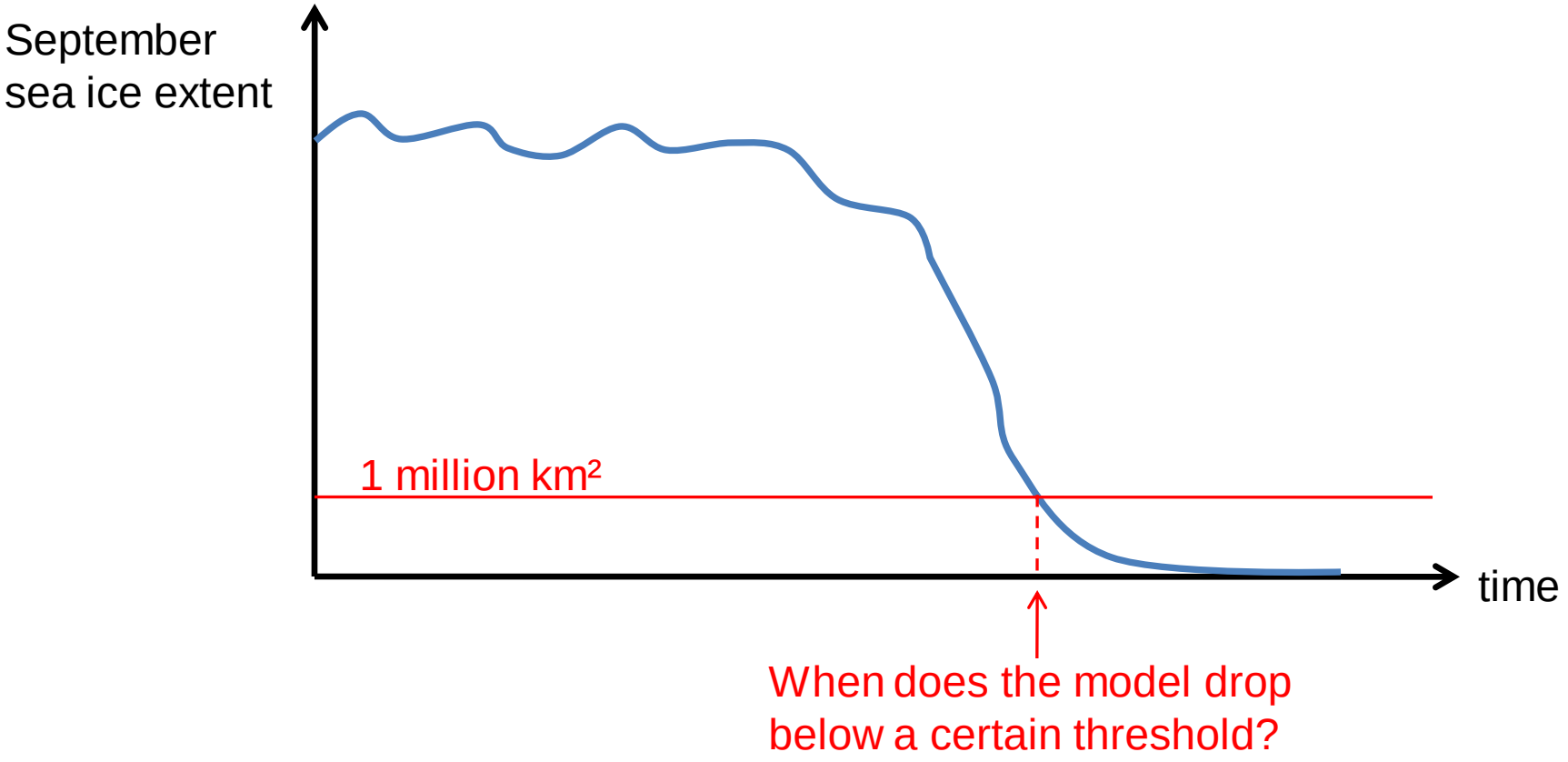


Constraints and correlations

Yes, we can!

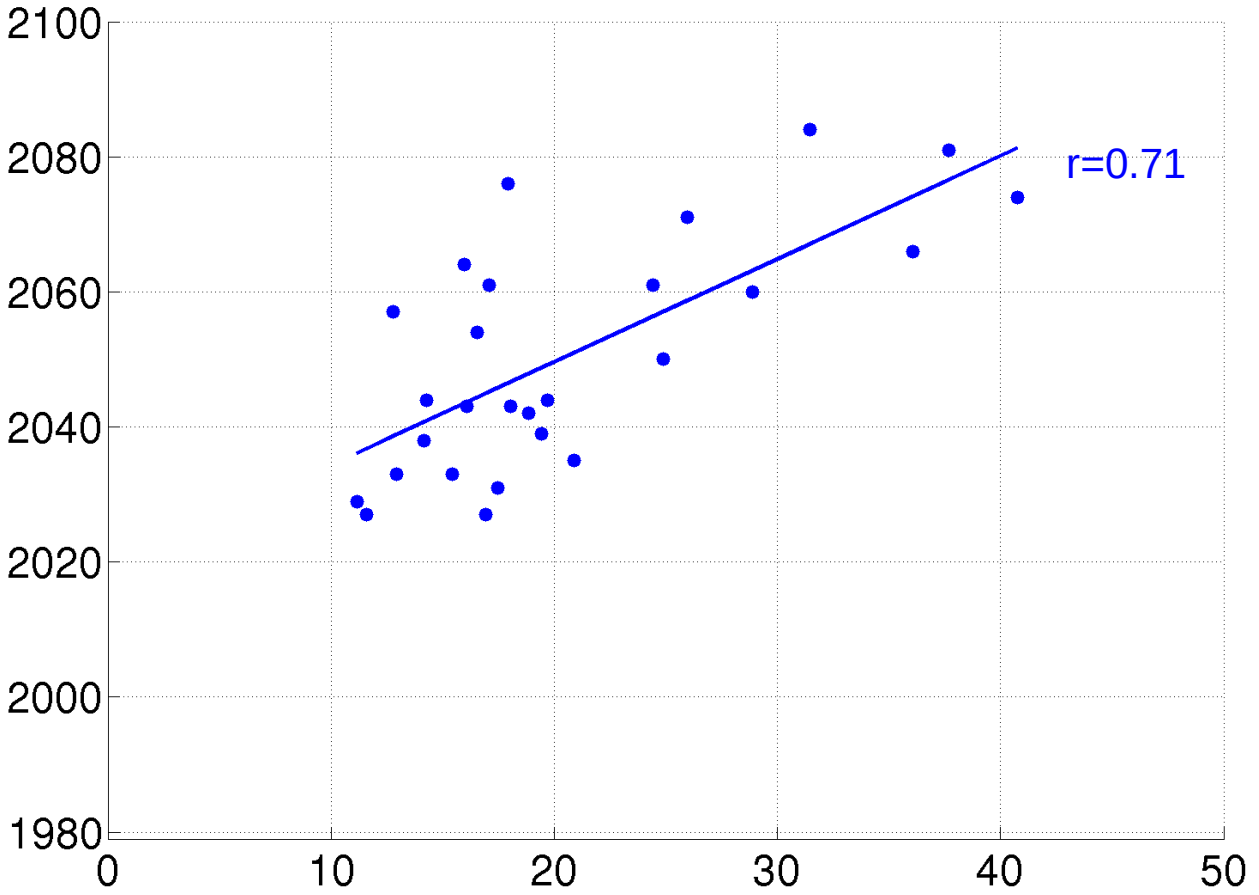
Effective model selection

Dual problem: time as the dependent variable



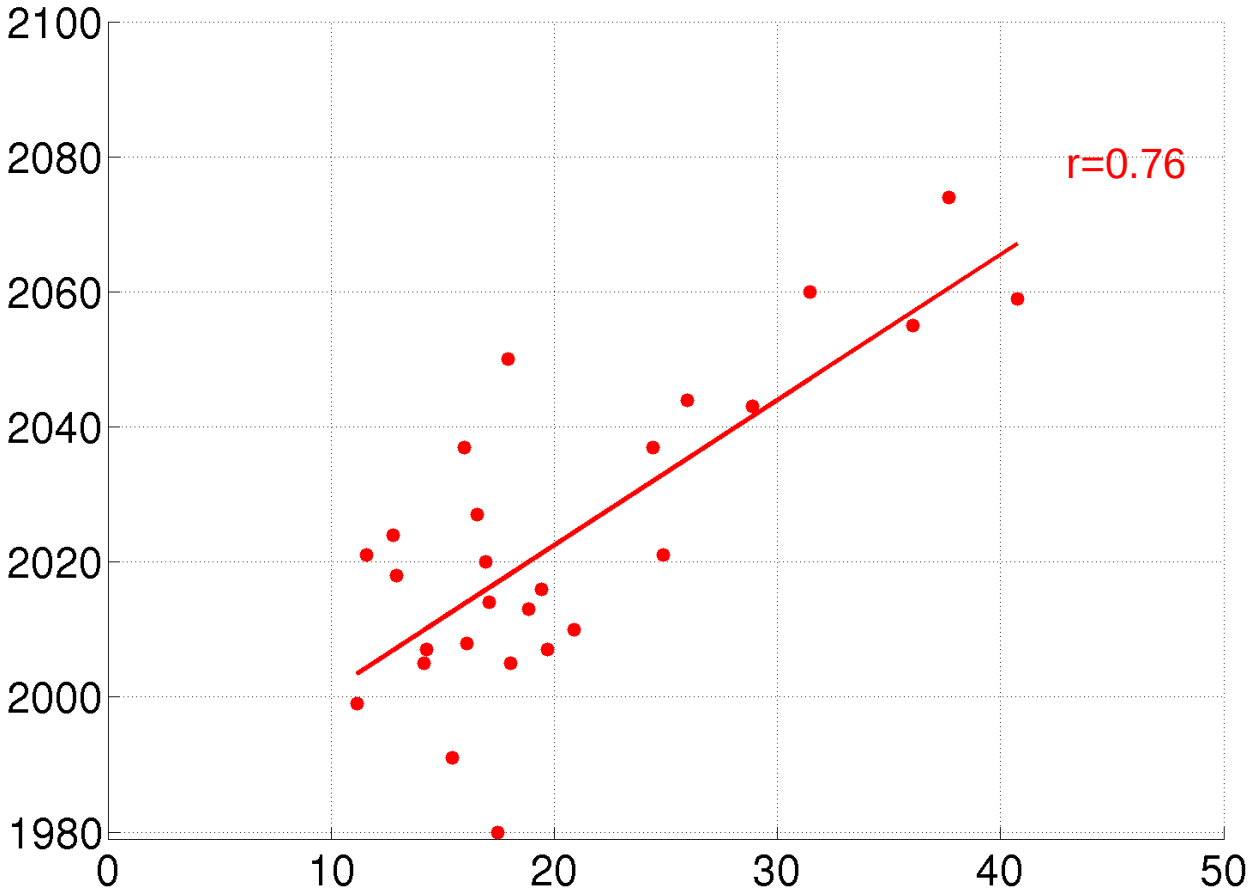
Year of disappearance relates linearly to present-day sea ice

First year with September sea ice extent < **1 million km²**



Year of disappearance relates linearly to present-day sea ice

First year with September sea ice extent < **4 million km²**



Constraints and correlations

Yes, we can!

Effective model selection

From qualitative patterns to quantitative evaluation

Qualitative criteria for selection

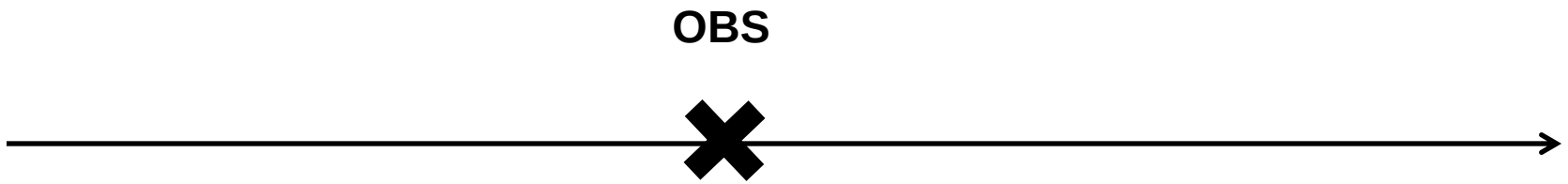
from empirical and physically-based relationships:

- 1979-2010 mean September sea ice extent [NSIDC]
- 1979-2010 amplitude seasonal cycle of sea ice extent [NSIDC]
- 1979-2010 trend in September sea ice extent [NSIDC]
- 1979-2010 annual mean sea ice volume [Schweiger et al., 2011]

Quantitative selection

based on arbitrary numerical thresholds (e.g., 20% within the observations)

Beware the perverse effects of internal variability



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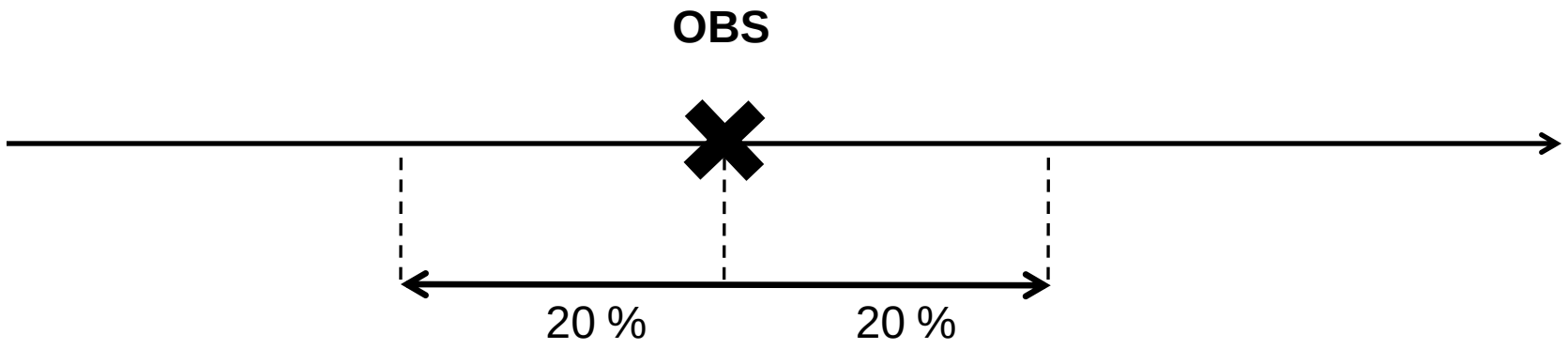

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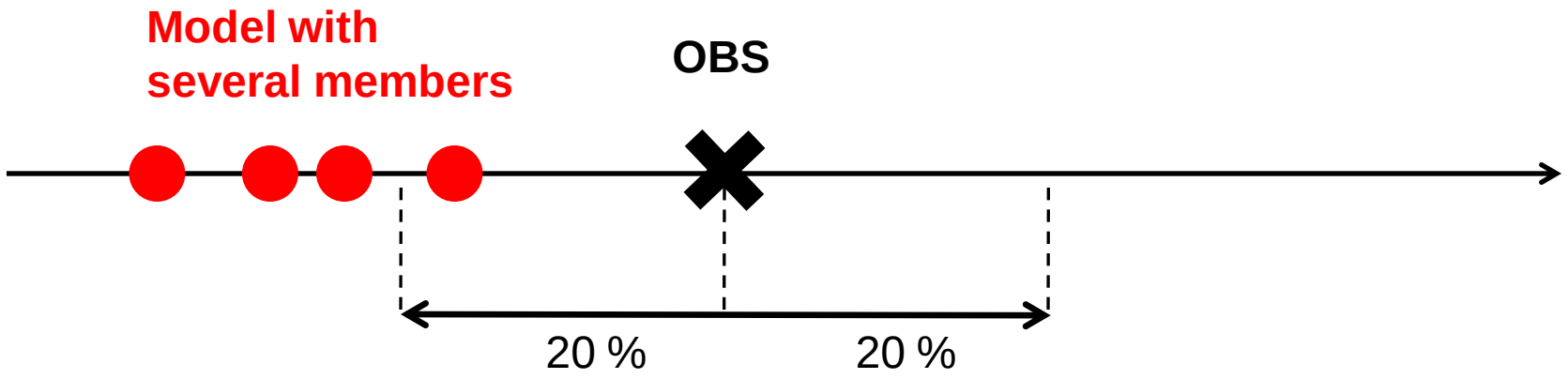

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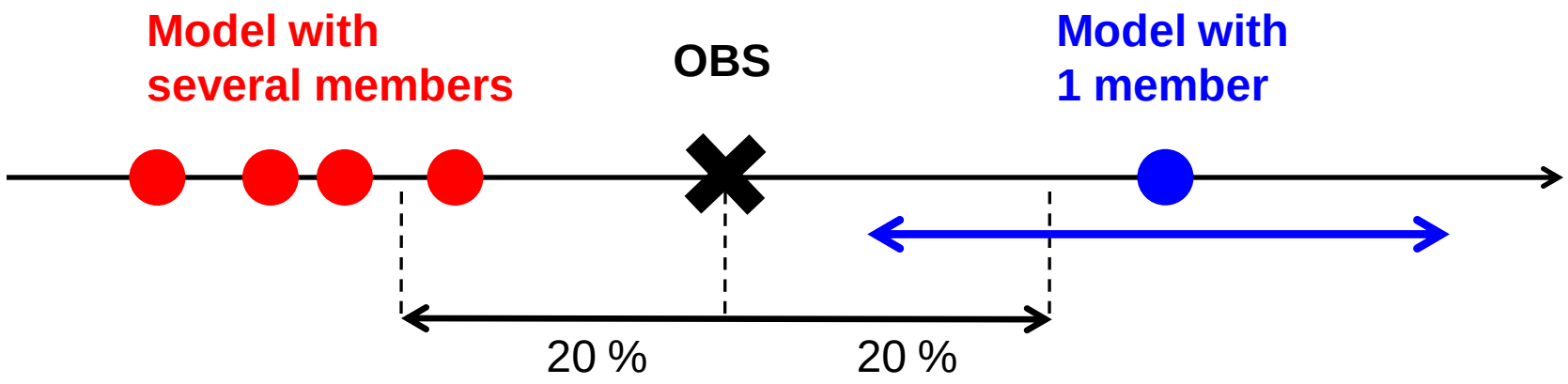
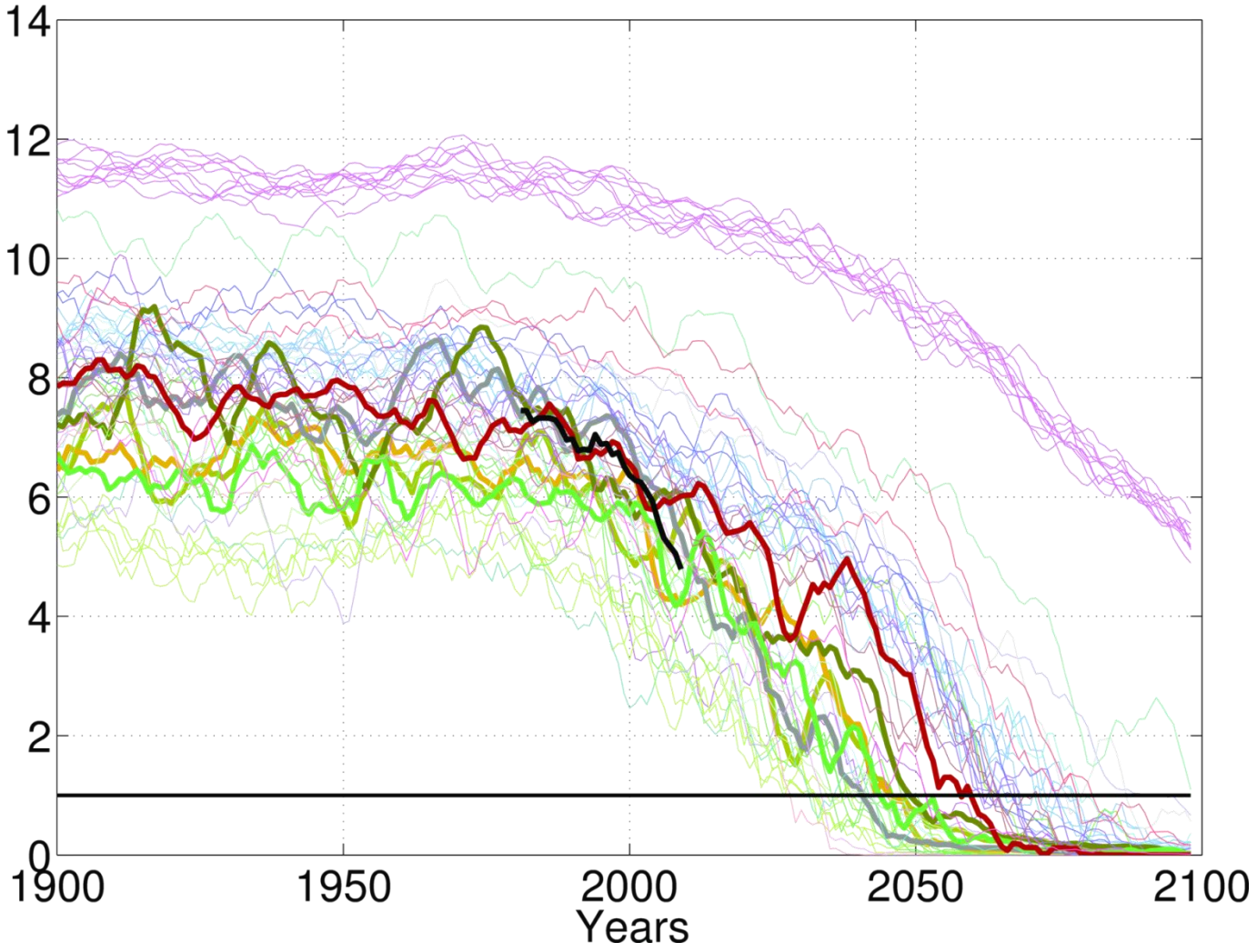


Arctic sea ice-free in summer « When I'm 64 »

September sea ice extent [10^6 km^2]



Do’s and dont’s with the multi-model mean

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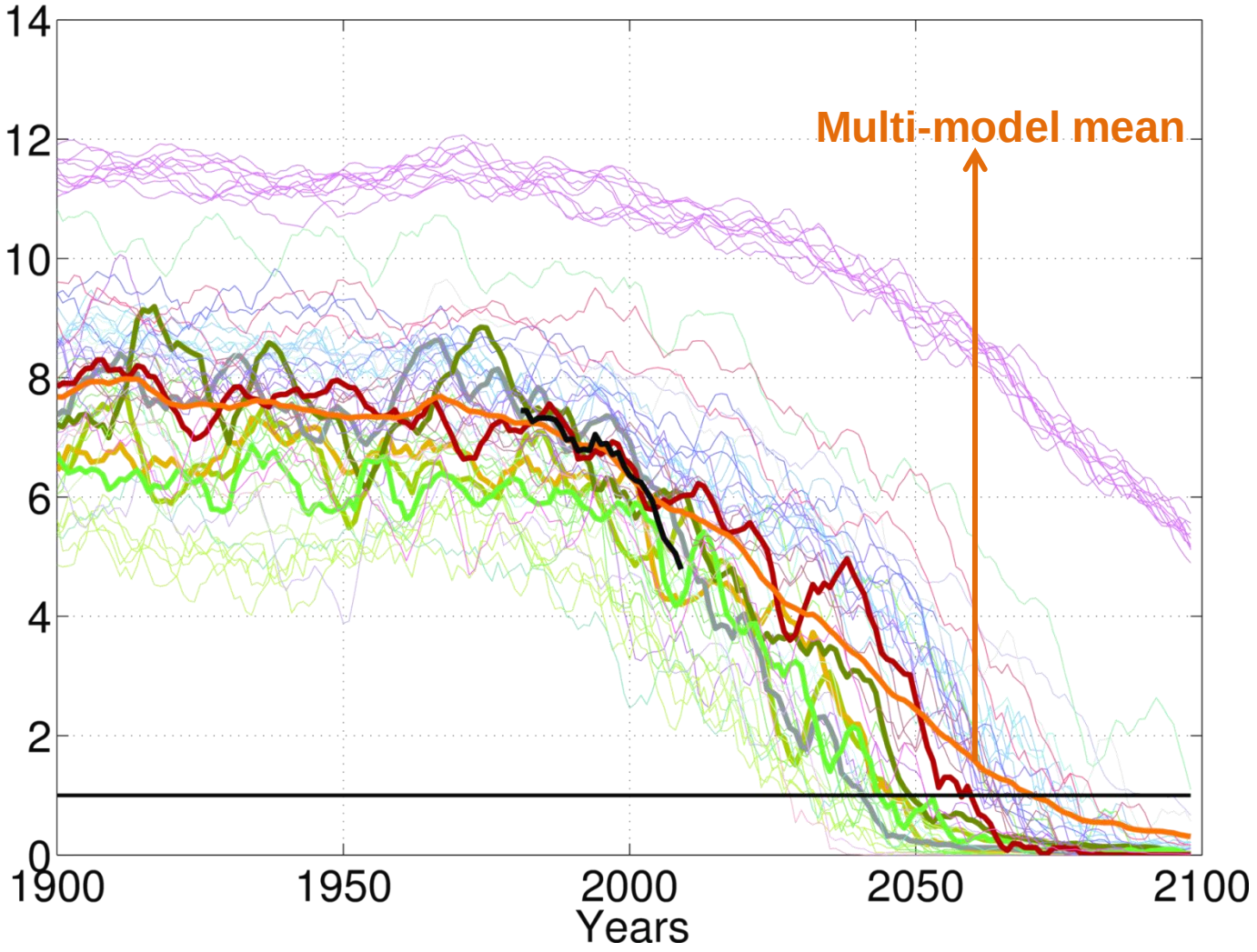

Constraints and correlations

Correlation does not mean physical relationship
No correlation does not mean no relationship

Yes, we can!

Relationships exist between
present-day and future Arctic sea ice

Effective model selection

High forcing scenario, possible summer
ice-free conditions in the Arctic by 2040

I’m an idealist without illusions

John F. Kennedy

I’m an idealist without illusions

but we can work it out

A model user

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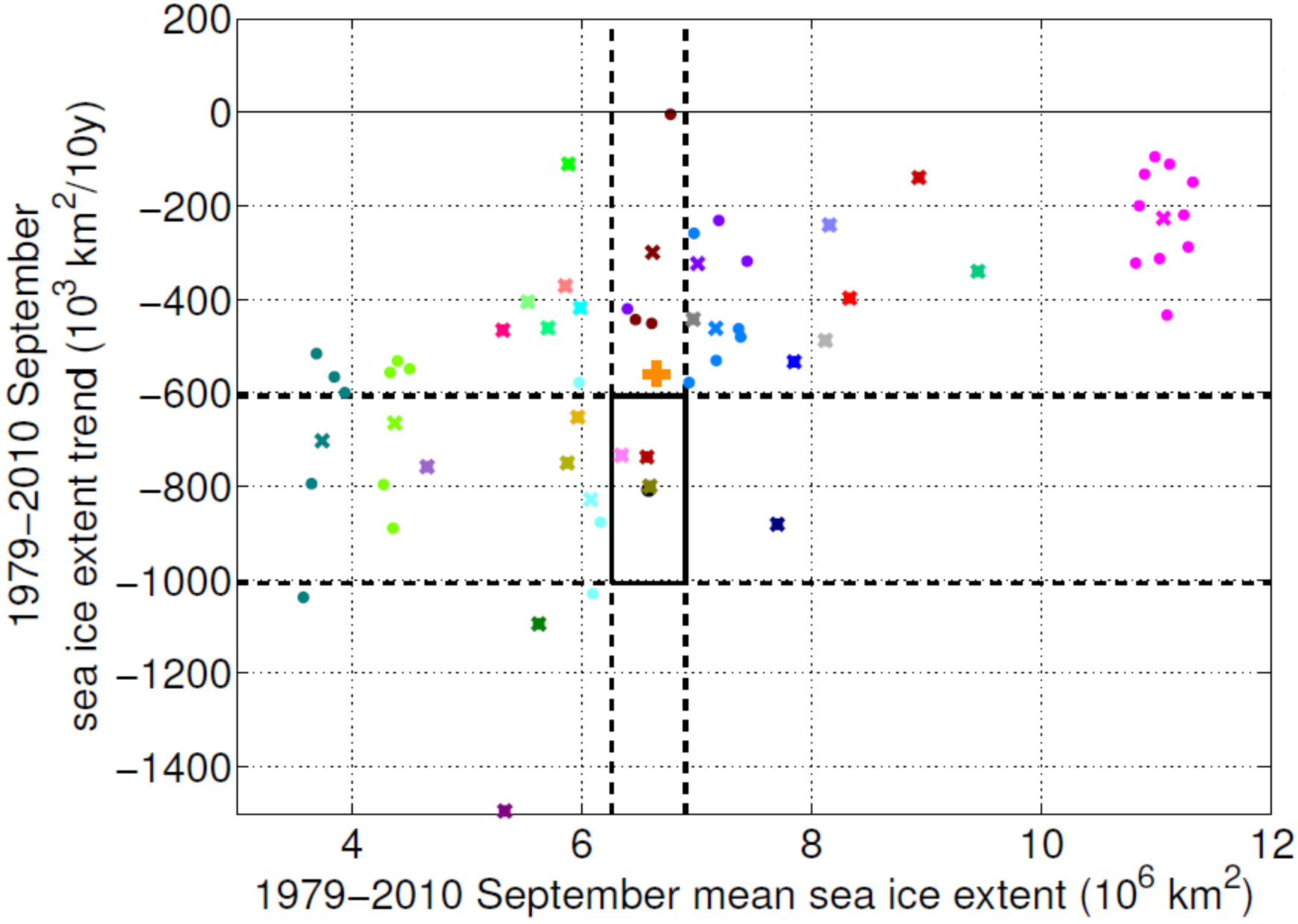
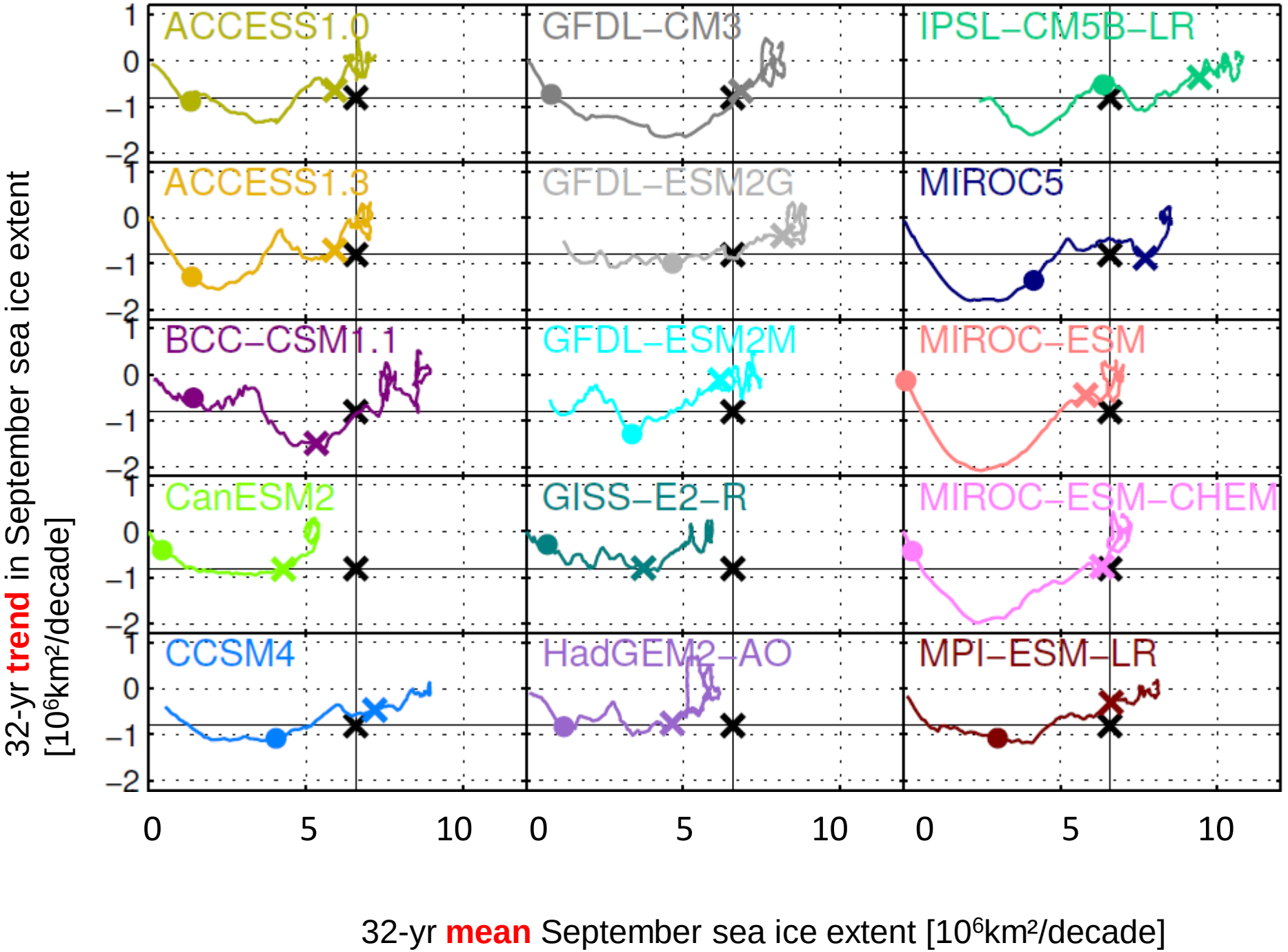
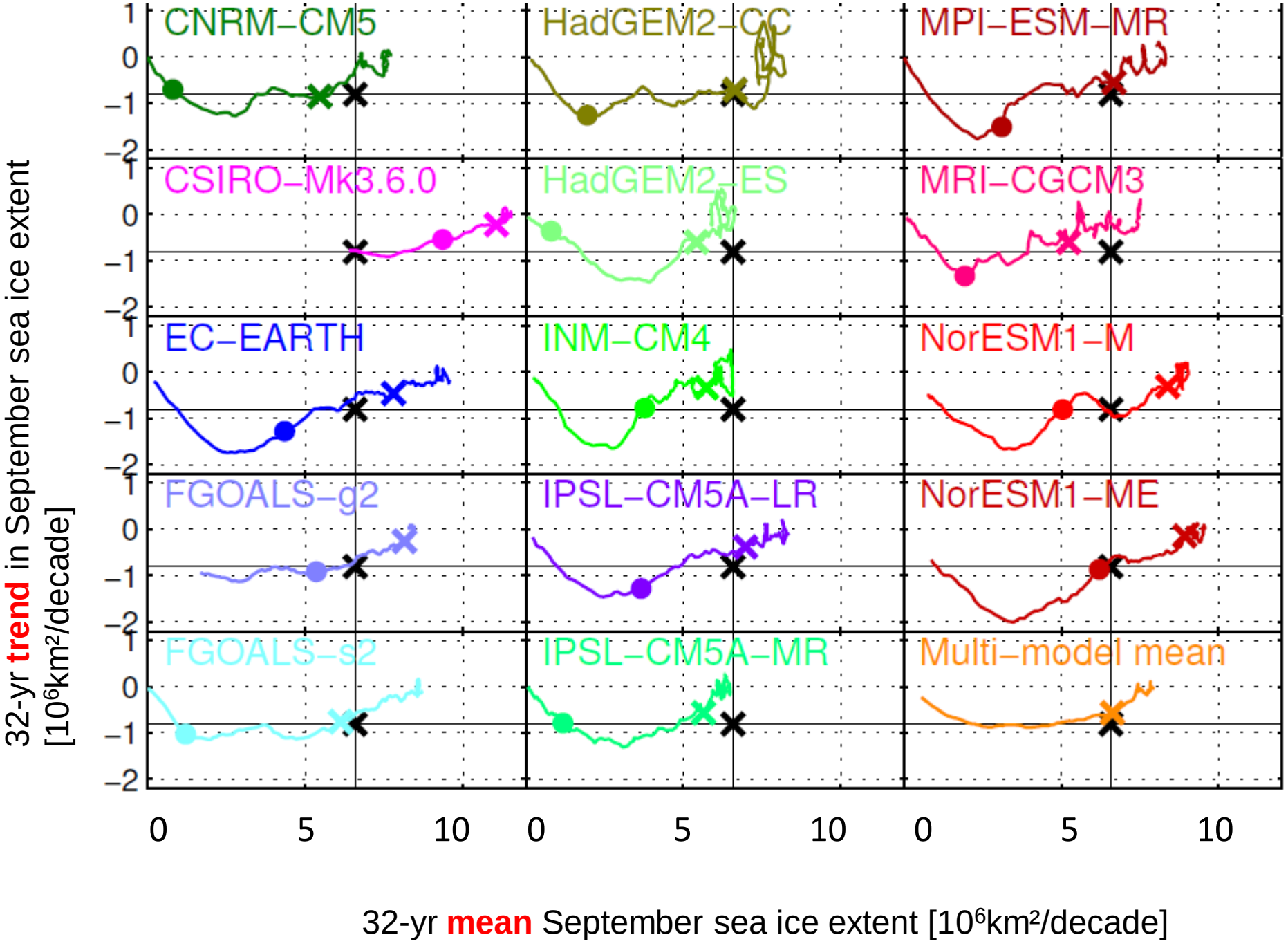
francois.massonnet@uclouvain.be


200
0
−200
−400
−600
−800
−1000
−1200
−1400
4
6
8
10
12
1979–2010 September
sea ice extent trend (10^3 km^2/10y)
1979–2010 September mean sea ice extent (10^6 km^2)


ACCESS1.0
GFDL–CM3
IPSL–CM5B–LR
ACCESS1.3
GFDL–ESM2G
MIROC5
BCC–CSM1.1
GFDL–ESM2M
MIROC–ESM
CanESM2
GISS–E2–R
MIROC–ESM–CHEM
CCSM4
HadGEM2–AO
MPI–ESM–LR
1
0
−1
−2
0
5
10
32-yr trend in September sea ice extent [10⁶km²/decade]
32-yr mean September sea ice extent [10⁶km²/decade]


CNRM–CM5
HadGEM2–CC
MPI–ESM–MR
CSIRO–Mk3.6.0
HadGEM2–ES
MRI–CGCM3
EC–EARTH
INM–CM4
NorESM1–M
FGOALS–g2
IPSL–CM5A–LR
NorESM1–ME
FGOALS–s2
IPSL–CM5A–MR
Multi–model mean
1
0
−1
−2
0
5
10
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