PARAMOUR Seminar Series
14 February 2019 - UCLouvain

Arctic sea ice predictions and how to evaluate them

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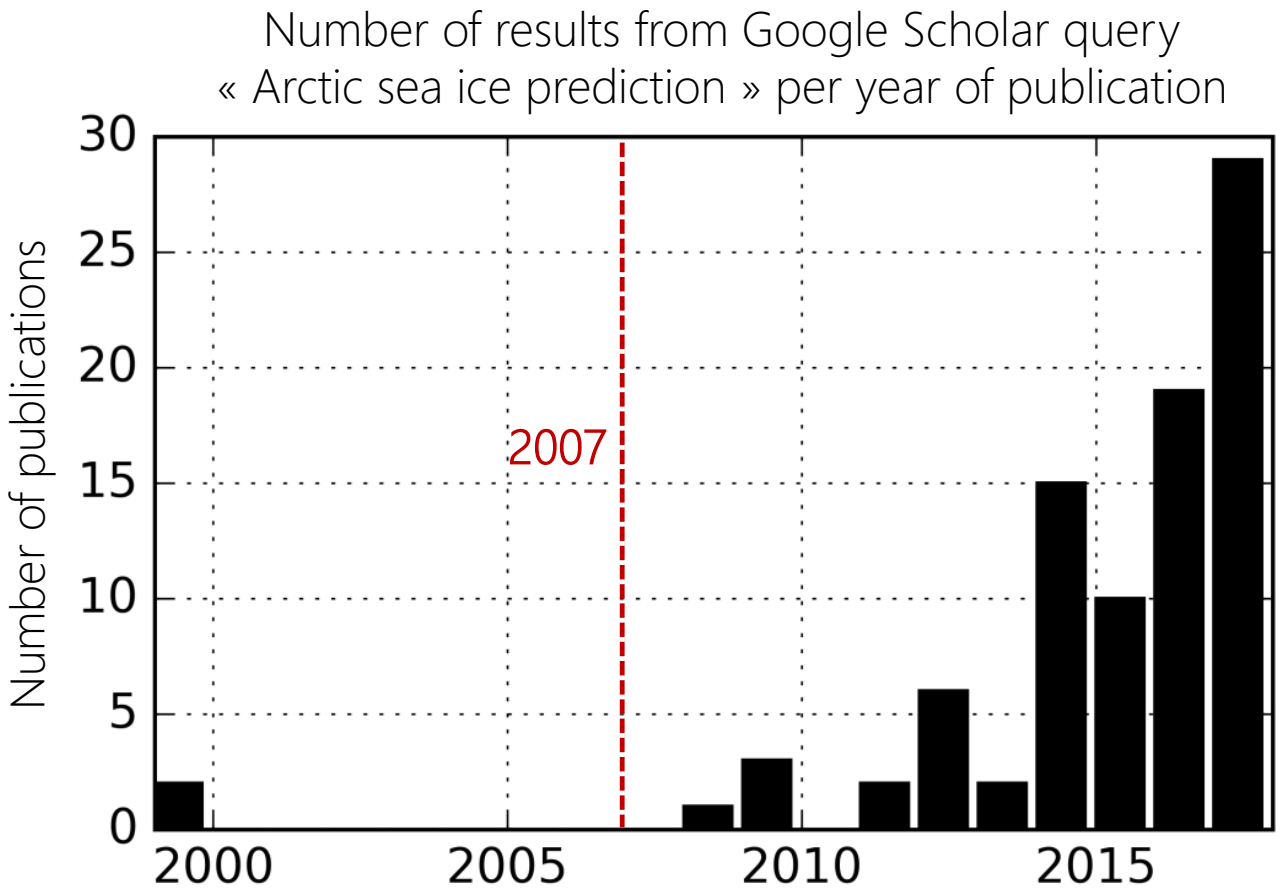
VALENTINE'S DAY 2019: PARAMOUR, THE DANCE AT THE CITY HALL AGAINST AIDS

For Valentine's Day 2019, let's all dance at the City Hall to support the fight against AIDS. Kylie Minogue's star choreographer Hakim Ghorab will host this crazy party to make over 1000 people dance on February 14, 2019.

It's the must-see event for **Valentine's Day in Paris**: **The Paramour Dance** by Hakim Ghorab on Thursday February 14, 2019.

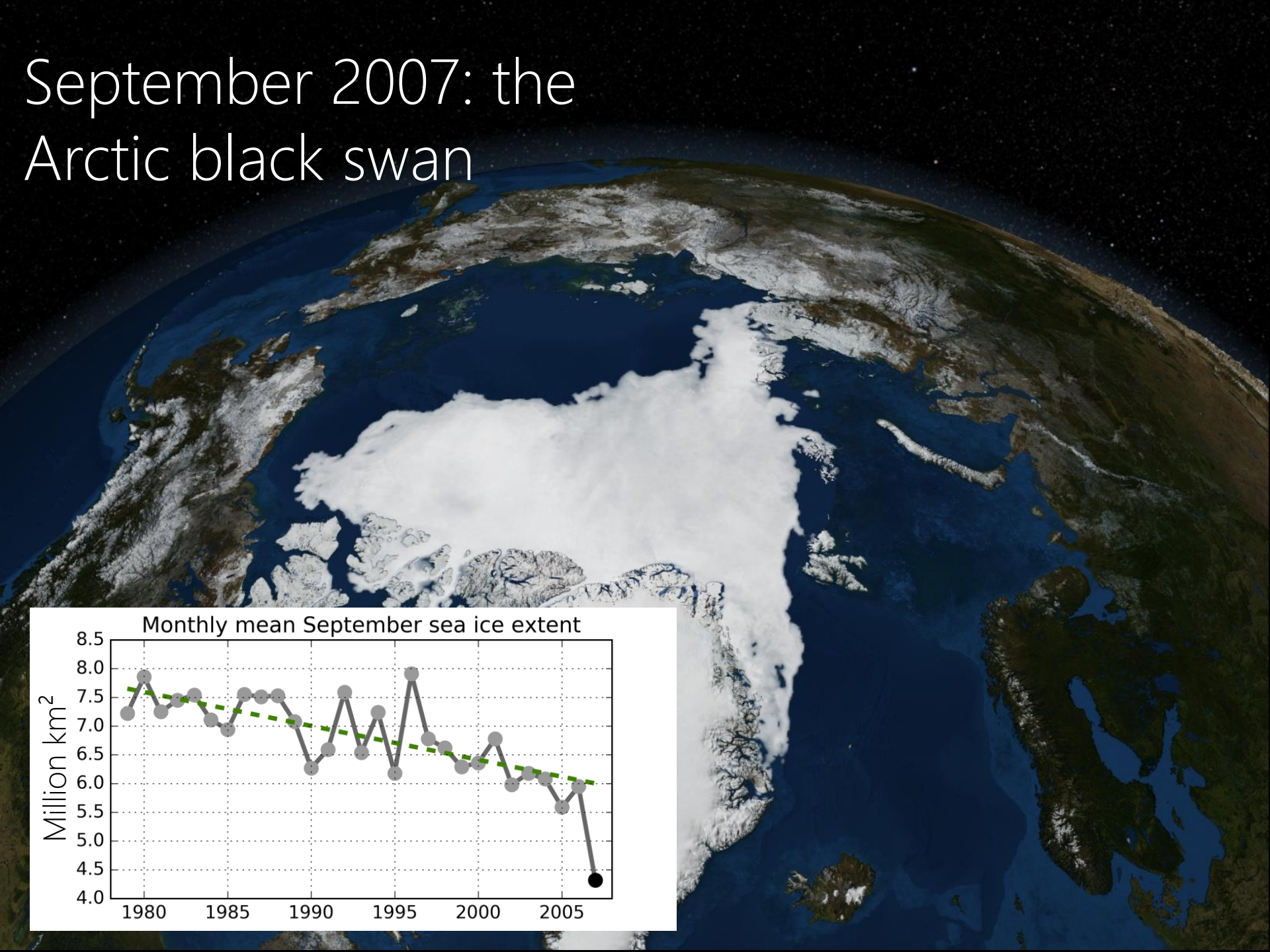
To celebrate love and fight against HIV, Paris City Hall opens the doors to over 1000 people who can

Arctic sea ice prediction: an emerging area of research



Black Swan

September 2007: the Arctic black swan



Four suggested references on Arctic sea ice predictability and prediction

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2013GL058755

Key Points:
- Arctic sea ice is potentially predictable for up to 3 years in current GCMs
- Potential prediction errors are amplified at the coasts of the Arctic ocean
- Advective processes are very important for spatial error patterns

Seasonal to interannual Arctic sea ice predictability in current global climate models

S. Tietsche[1], J. J. Day[1], V. Guemas[2,3], W. J. Hurlin[4], S. P. E. Keeley[5], D. Matei[6], R. Msadek[4], M. Collins[7], and E. Hawkins[1]

[1]NCAS-Climate, Department of Meteorology, University of Reading, Reading, UK, [2]Institut Català de Ciències del Clima, Barcelona, Spain, [3]CNRM/GAME, Toulouse, France, [4]Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey, USA, [5]European Centre for Medium-Range Weather Forecasts, Reading, UK, [6]Max Planck Institute for Meteorology, Hamburg, Germany, [7]College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter, UK

Aspects of designing and evaluating seasonal-to-interannual Arctic sea-ice prediction systems

Ed Hawkins[a]*, Steffen Tietsche[a], Jonathan J. Day[a], Nathanael Melia[a], Keith Haines[b], Sarah Keeley[c]

[a]*NCAS-Climate, Department of Meteorology, University of Reading, UK.*

ing, UK.

[c]*Eu*

, Reading, UK.

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ing, Reading. RG6 6BB. UK.

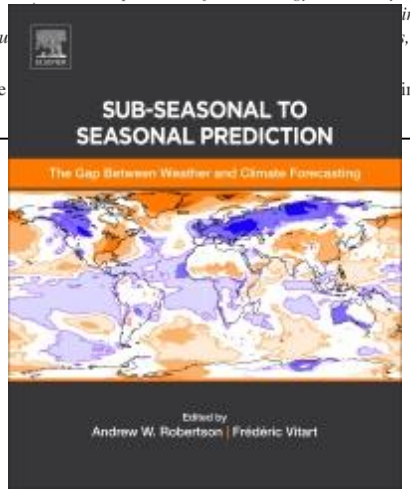
Quarterly Journal of the Royal Meteorological Society

Q. J. R. Meteorol. Soc. (2014) DOI:10.1002/qj.2401

RMetS
Royal Meteorological Society

A review on Arctic sea-ice predictability and prediction on seasonal to decadal time-scales

Virginie Guemas,[a,b]* Edward Blanchard-Wrigglesworth,[c] Matthieu Chevallier,[b,d] Jonathan J. Day,[e] Michel Déqué,[b] Francisco J. Doblas-Reyes,[a,f] Neven S. Fučkar,[a] Agathe Germe,[b,g] Ed Hawkins,[e] Sarah Keeley,[h] Torben Koenigk,[i] David Salas y Mélia[b] and Steffen Tietsche[e]



Chapter. 10; sea ice (Chevallier, Massonnet, Guemas, Goessling and Jung)

1. Predictability and prediction of Arctic sea ice from days to centuries

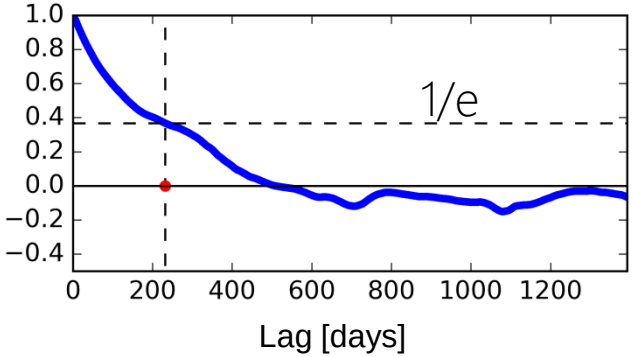
2. Important considerations regarding the evaluation of upcoming PARAMOUR predictions

1. Predictability and prediction of Arctic sea ice from days to centuries

2. Important considerations regarding the evaluation of upcoming PARAMOUR predictions

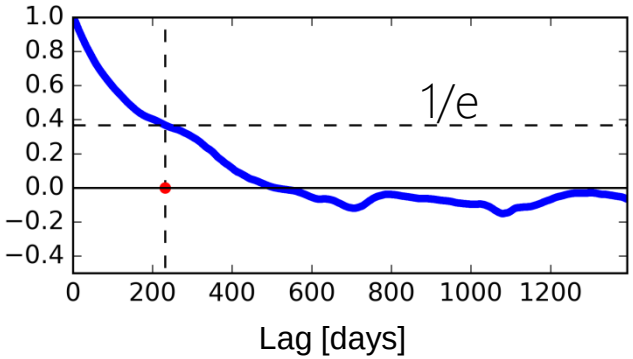
Persistence

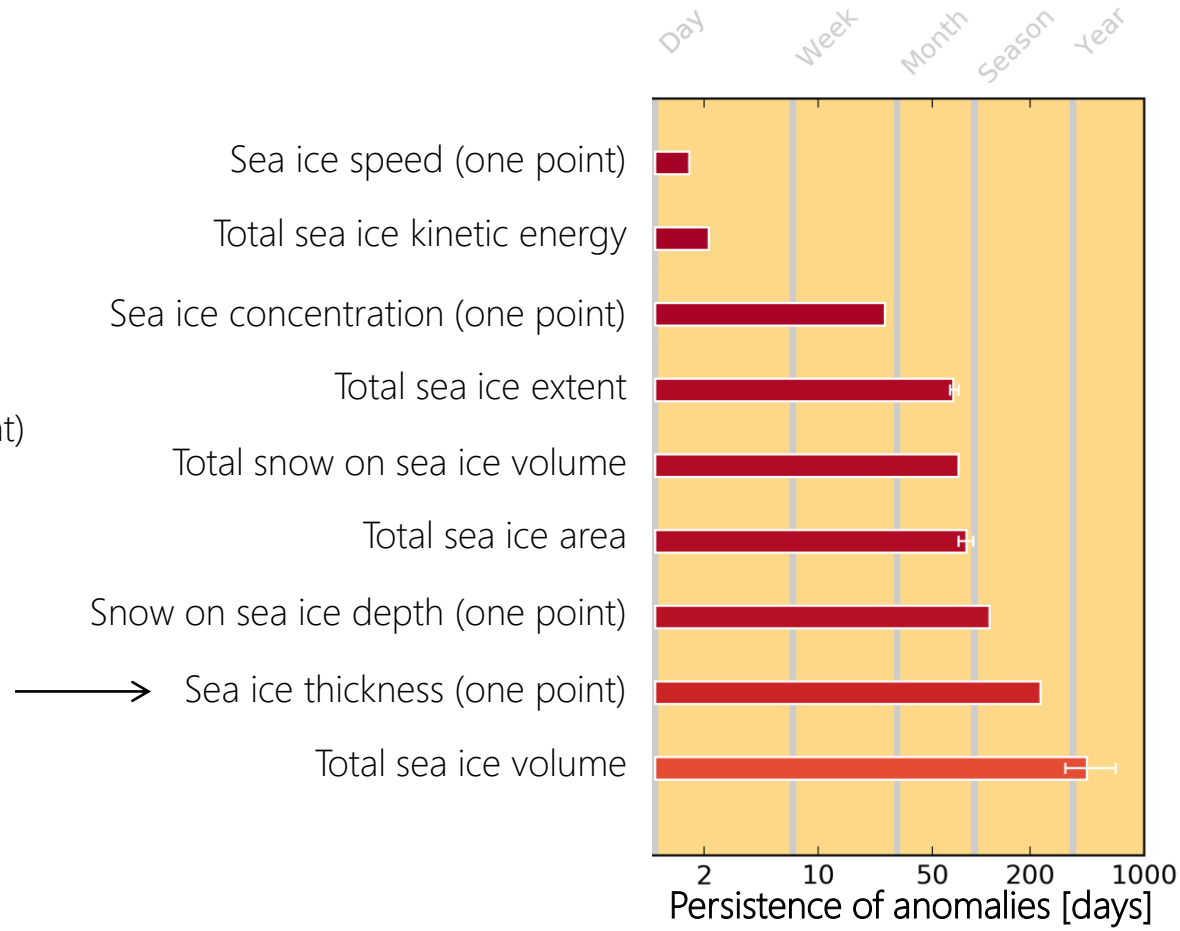
Autocorrelation of 1979-2015 sea ice thickness (model output, one grid point)



Persistence: a primary source of sea ice predictability on a spectrum of time scales

Autocorrelation of 1979-2015 sea ice thickness (model output, one grid point)





S2S book - Chapter. 10: sea ice (Chevallier, Massonnet, Guemas, Goessling and Jung)
Data: satellite (NSIDC) + reanalysis (PIOMAS) + ocean-sea ice global simulations


days
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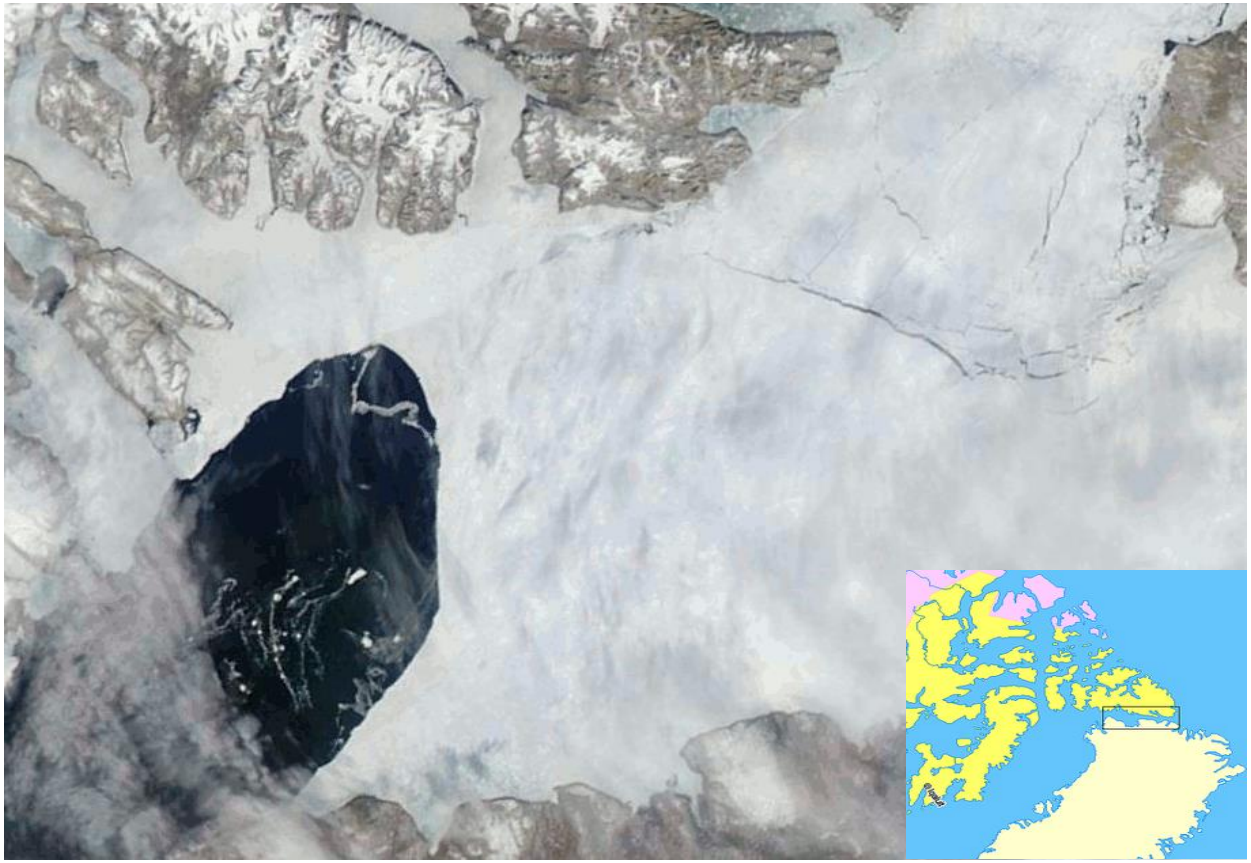
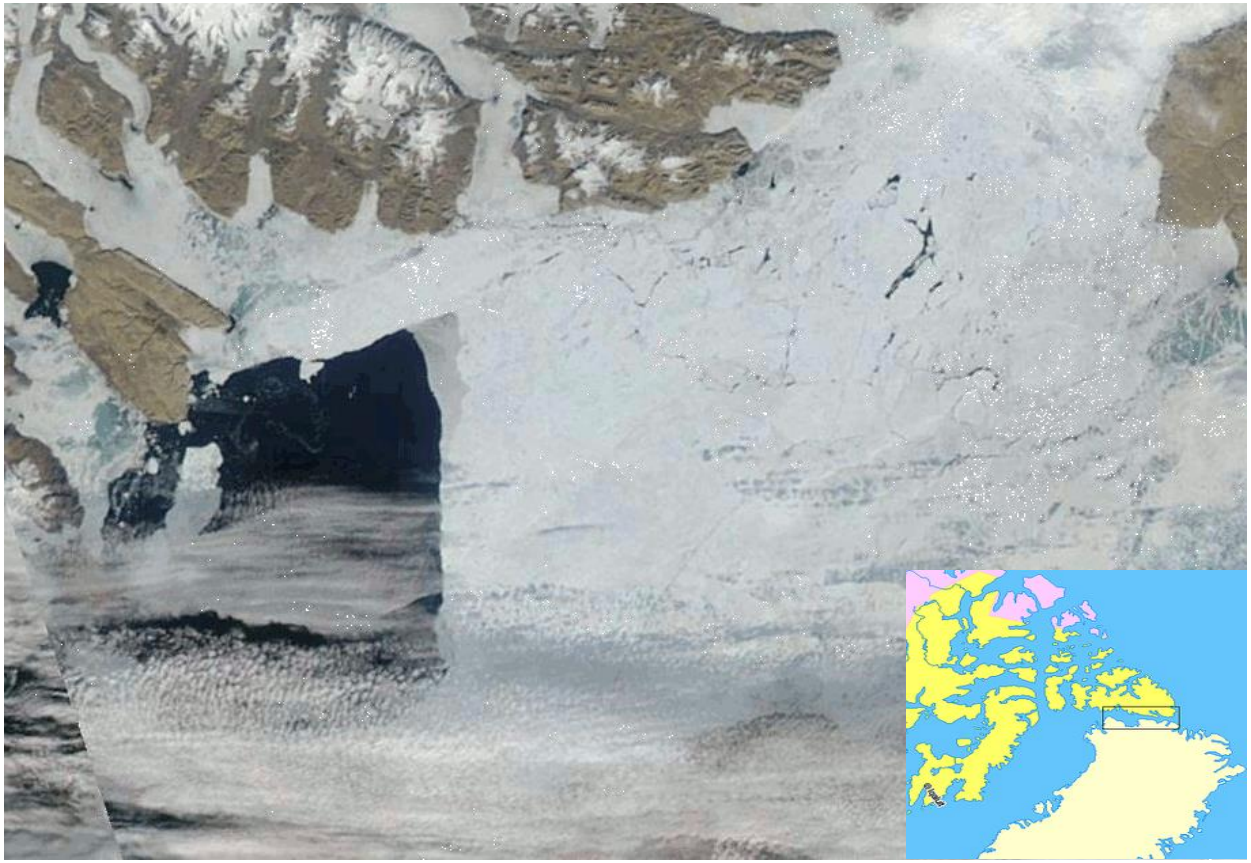
centuries

days weeks months seasons years decades centuries



June 20th – July 12th 2015, LANCE-MODIS, 2 images per day
https://forum.arctic-sea-ice.net/index.php?action=dlattach;topic=176.0;attach=18238;image

days weeks months seasons years decades centuries



June 20th – July 12th 2015, LANCE-MODIS, 2 images per day
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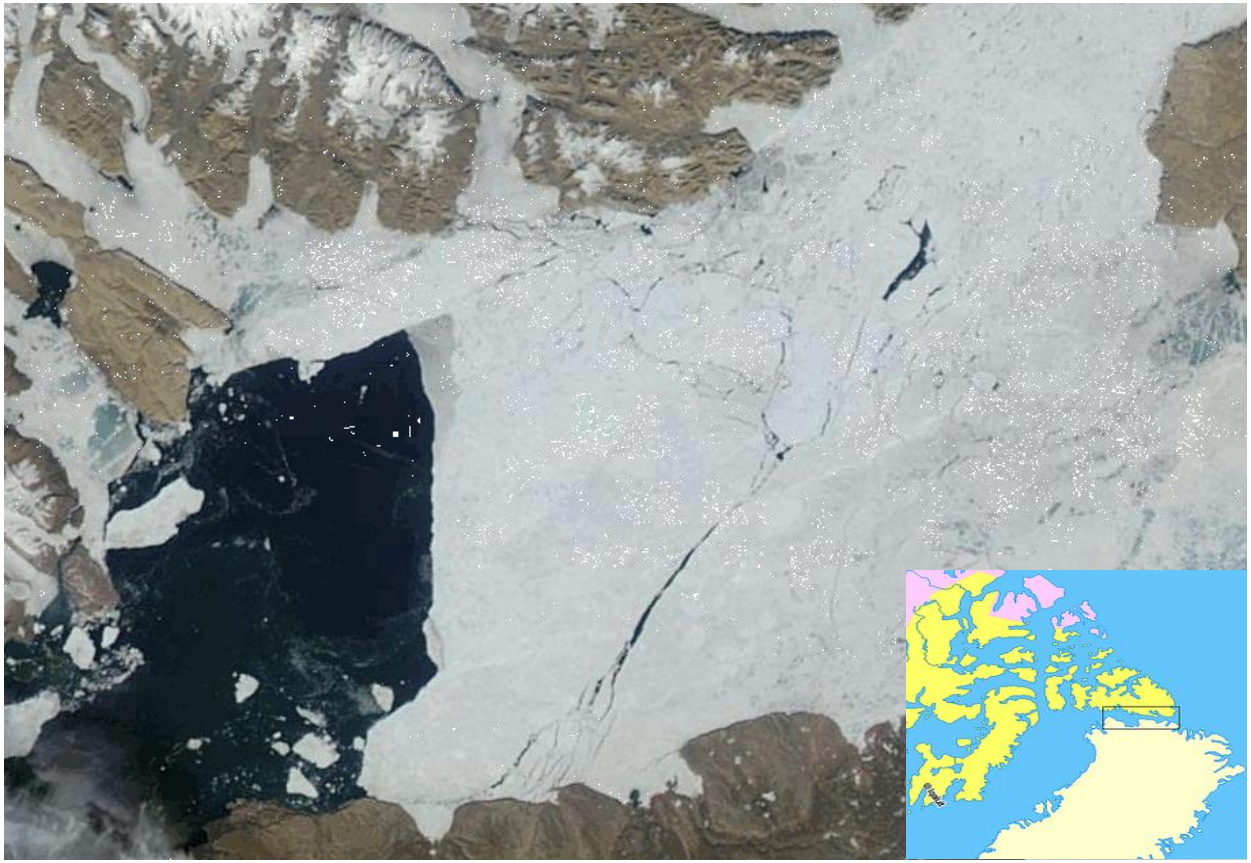

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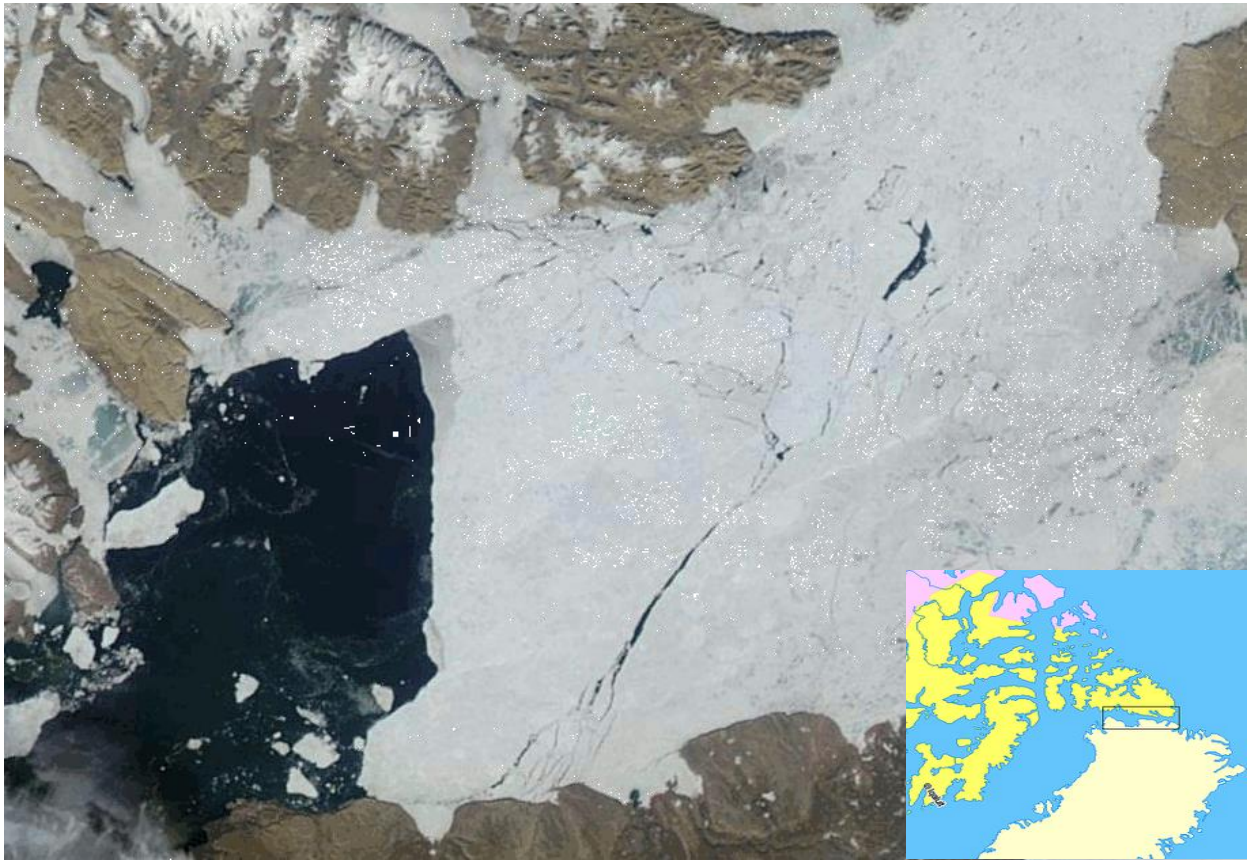

June 20th – July 12th 2015, LANCE-MODIS, 2 images per day
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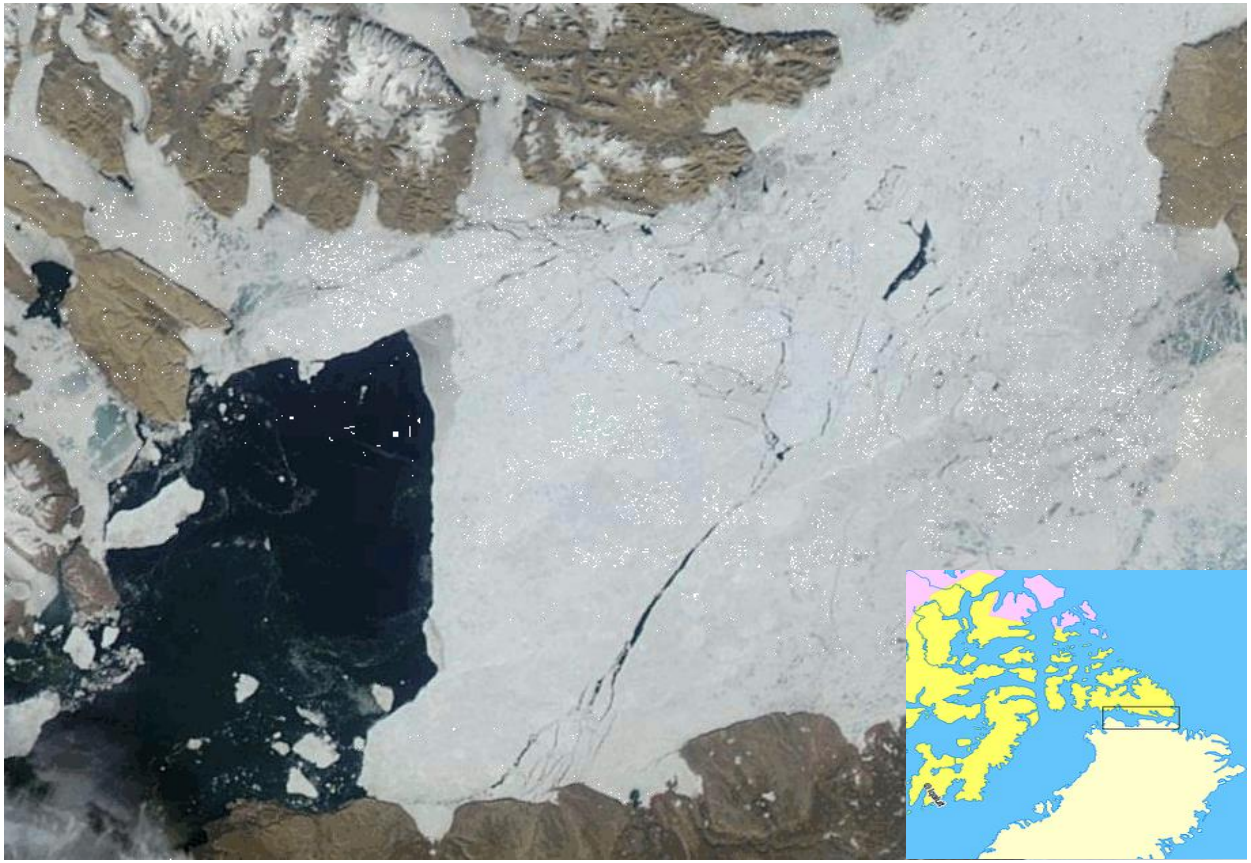
Sources of predictability -Persistence

days weeks months seasons years decades centuries



June 20th – July 12th 2010, LANCE-MODIS, 2 images per day
https://forum.arctic-sea-ice.net/index.php?action=dlattach;topic=176.0;attach=18238;image

Sources of predictability
-Persistence
-Mechanical forcing by wind
-Current ice state (deformation, age, thickness , compactness)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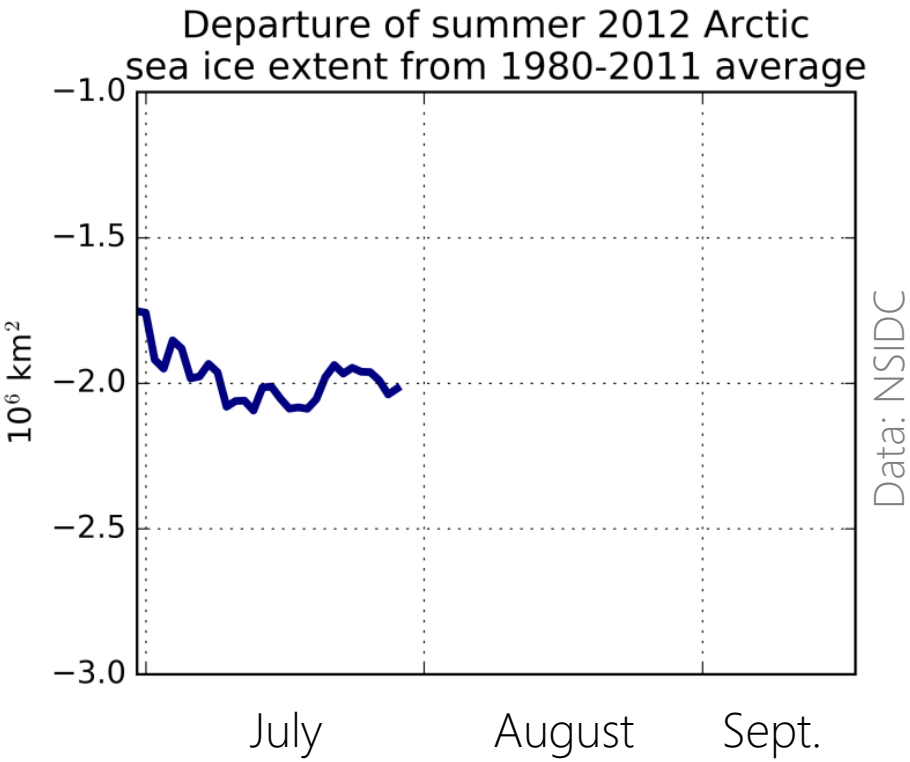
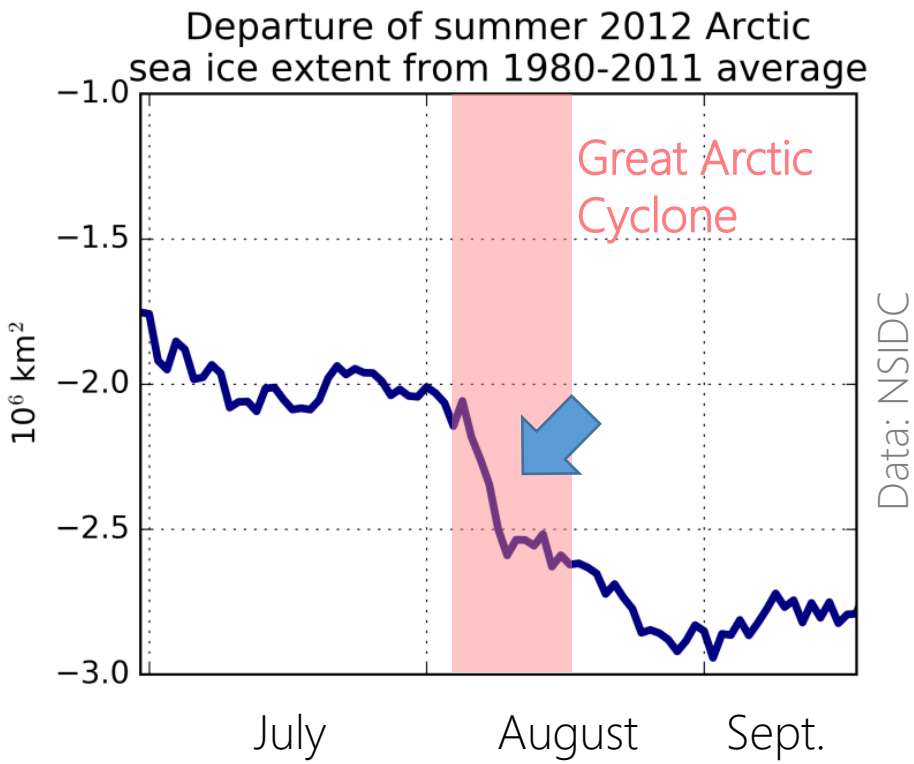
Weekly sea ice extent predictability stems from persistence

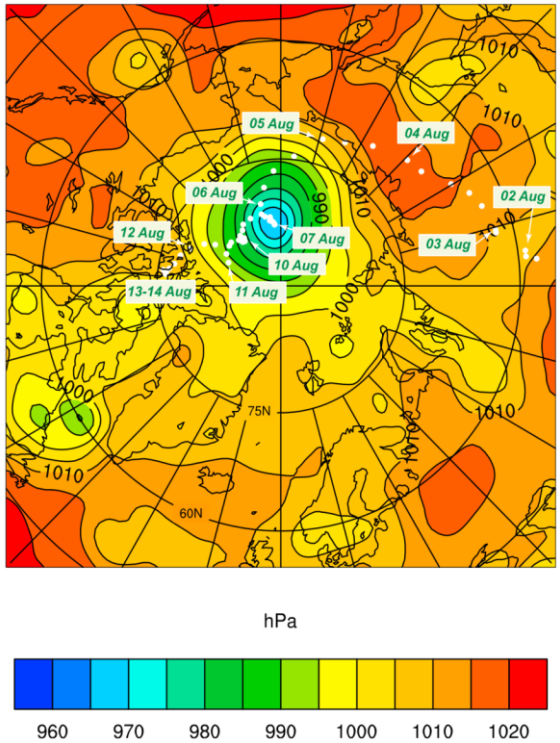


days weeks months seasons years decades centuries

Weekly sea ice extent predictability stems from persistence but can be affected by synoptic events



Sea Level Pressure 6th Aug
2012 1800 UTC (NCEP-CFSR)



[Simmonds and Rudeva, *Geophys. Res. Lett*, 2012, Zhang et al., *Geophys. Res. Lett.*, 2013; Parkinson and Comiso, *Geophys. Res. Lett.*, 2013]


days
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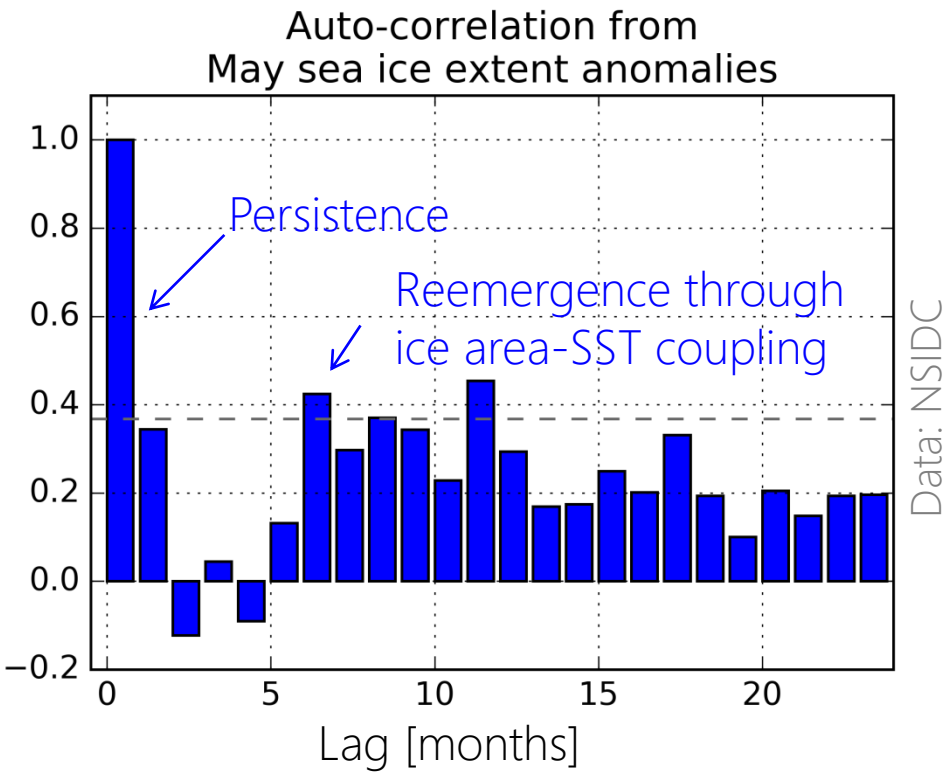
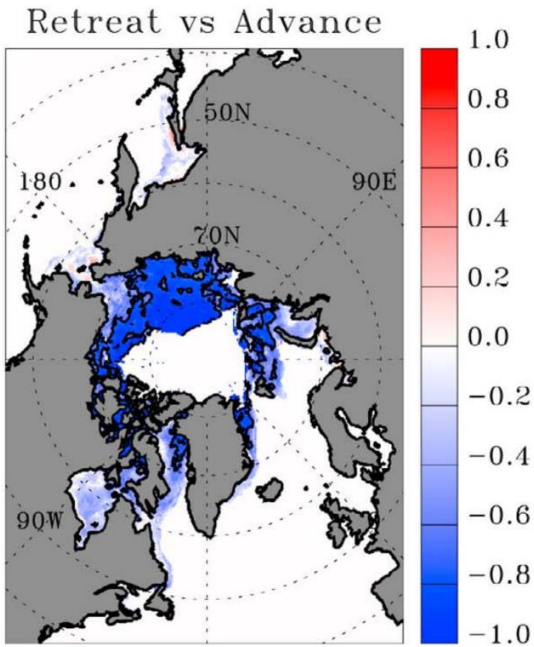
Example of reemergence: melt to freeze up



Correlation date of ice retreat *vs* date of ice advance (1979-2010)



Blanchard-Wrigglesworth et al., *J. Clim.*, 2011; Chevallier et al., *J. Clim.*, 2012; Day et al., *J. Clim.*, 2014, Stammerjohn et al., *Geophys. Res. Lett.*, 2012

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2017GL073155

Skillful regional prediction of Arctic sea ice on seasonal timescales

Key Points:
- Coupled dynamical prediction system skillfully predicts regional sea ice extent on seasonal timescales
- Ocean subsurface temperature initialization yields North Atlantic regional winter skill at lead times of 5-11 months
- Sea ice thickness initialization

Mitchell Bushuk[1], Rym Msadek[2], Michael W
Anthony Rosati[3], and Xiaosong Yang[3]

[1]Atmospheric and Oceanic Sciences Program, Princeton U
UMR 5318, Toulouse, France, [3]National Oceanic and Atmo
Princeton University, Princeton, New Jersey, USA, [4]Depart
Jersey, USA

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2016GL069314

Using timing of ice retreat to predict timing of fall freeze-up in the Arctic

Special Section:

Julienne C. Stroeve[1,2], Alex D. Crawford[1], and Sharon Stammerjohn[3]

Seasonal Forecasts of the Pan-Arctic Sea Ice Extent Using a GCM-Based Seasonal Prediction System

MATTHIEU CHEVALLIER, DAVID SALAS Y MÉLIA, AURORE VOLDOIRE, AND MICHEL DÉQUÉ

Centre National de Recherches Météorologiques/Groupe d'Etude de l'Atmosphère Météorologique, Météo-France, CNRS, Toulouse, France

GILLES GARRIC

Mercator-Océan, Ramonville Saint-Agne, France

Clim Dyn (2015) 44:147–162
DOI 10.1007/s00382-014-2190-9

Assessing the forecast skill of Arctic sea ice extent in the GloSea4 seasonal prediction system

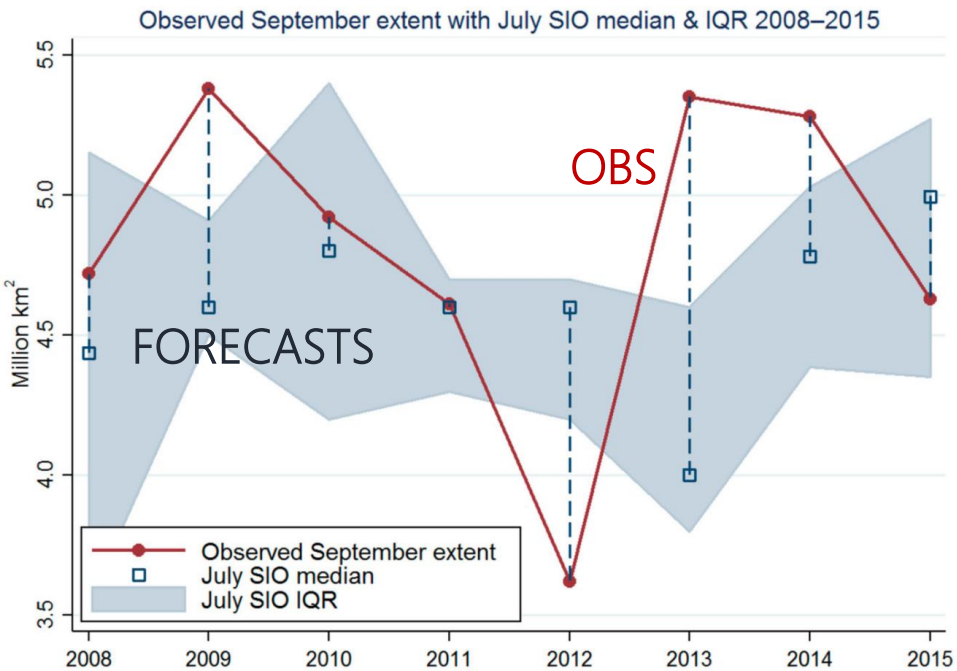
K. Andrew Peterson · A. Arribas · H. T. Hewitt ·
A. B. Keen · D. J. Lea · A. J. McLaren

ill of Arctic sea ice area in a dynamical forecast system

G. M. Flato,[2] V. V. Kharin,[2] and W. J. Merryfield[2]

7 December 2012; accepted 27 December 2012; published 7 February 2013.

Chevallier et al., *J. Clim.*, 2013; Msadek et al., *Geophys. Res. Lett.*, 2014; Sigmond et al., *Geophys. Res. Lett.*, 2013; Peterson et al., *Clim. Dyn.*, 2015; Massonnet et al., *Ocean Model.*, 2015; Merryfield et al., *Geophys. Res. Lett.*, 2013; Bushuk et al., *Geophys. Res. Lett.* 2017



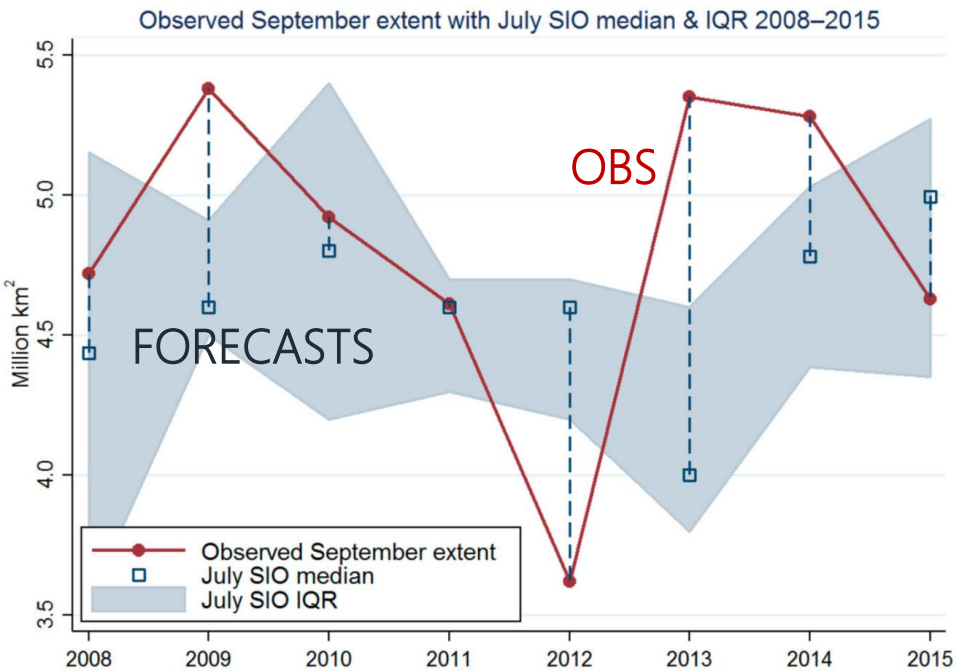
Hamilton and Stroeve, *Polar Geography*, 2016

Predictions are unfortunately not skillful in « operational » mode.

Possible reasons:

- Technical issues (e.g., fields not available at time of forecast) imply that groups cannot perform as well as on retrospective predictions

- Predicting sea ice is tougher today than it used to be

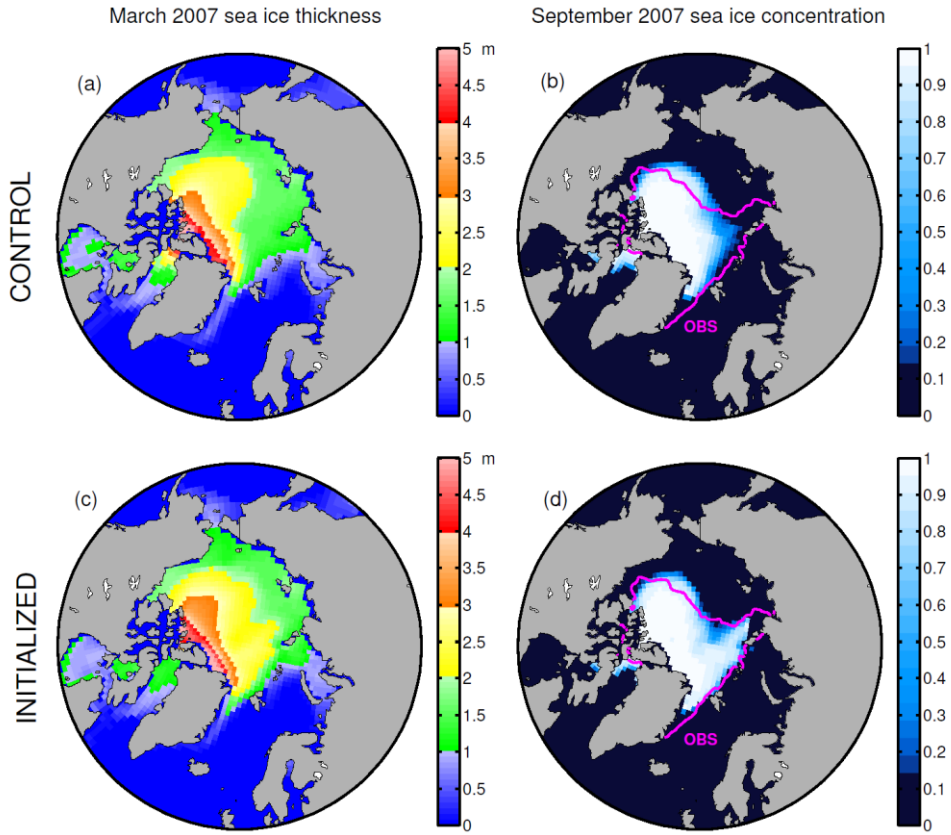


Hamilton and Stroeve, *Polar Geography*, 2016

days weeks months seasons years decades centuries

Sea ice data assimilation yields encouraging results for seasonal predictions

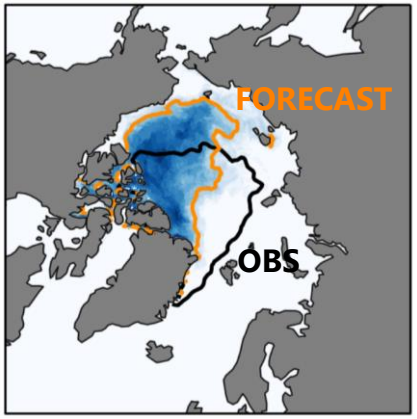
Forecasting September 2007 (ocean-sea ice model)



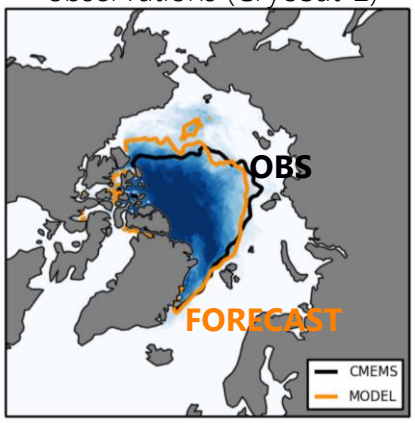
Massonnet et al., *Ocean Model.*, 2015

Forecasting September 2012 (coupled model)

Sea ice thickness not initialized



Sea ice thickness initialized from observations (CryoSat-2)



Blockley and Peterson., *Cryosphere*, 2018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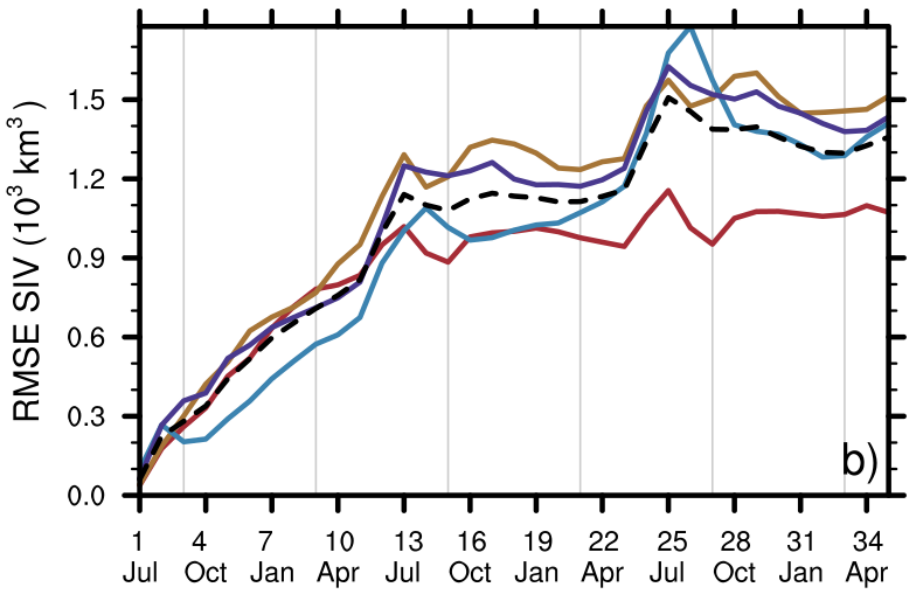
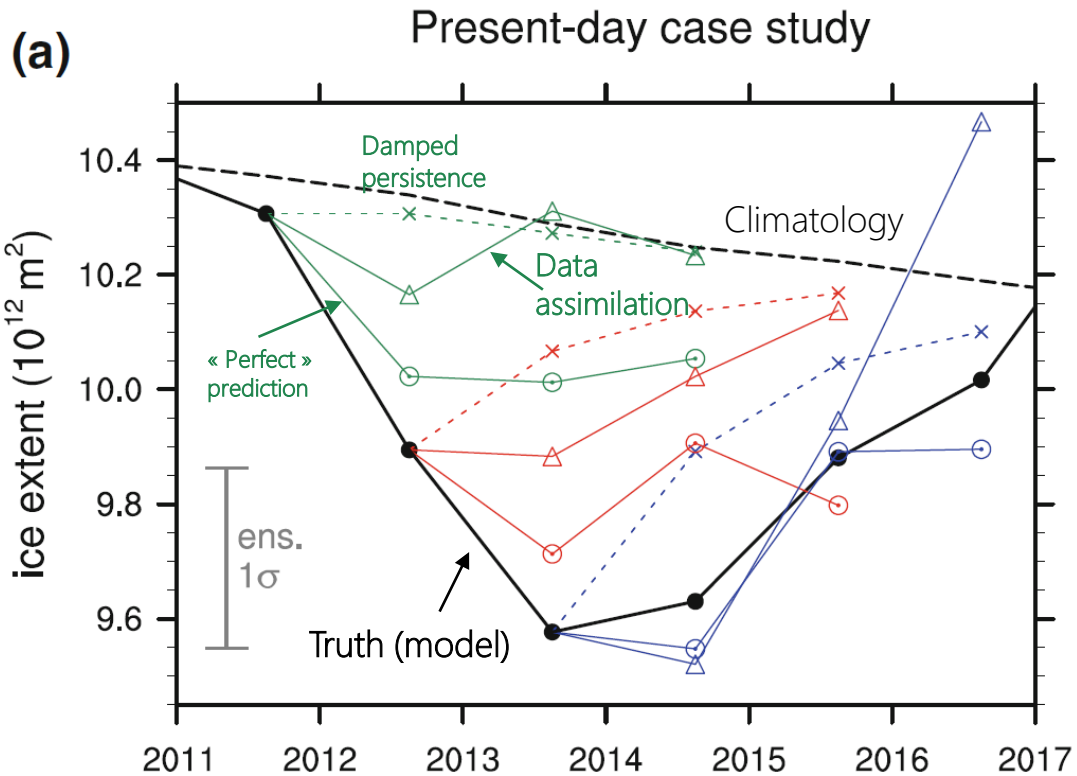
Interannual time scales: « grey zone » of sea ice predictability

Ensemble spread of total sea ice volume from 4 GCMs



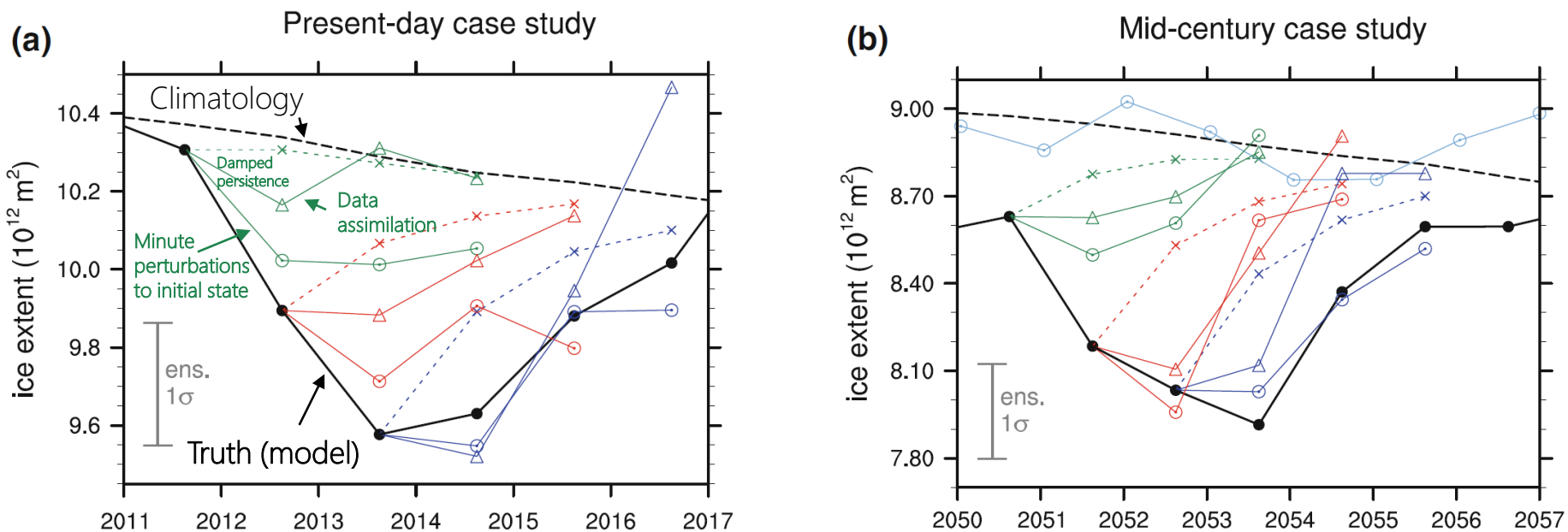
Tietsche et al., *Geophys. Res. Lett.*, 2014

Interannual time scales: « grey zone » of sea ice predictability



Tietsche et al., Clim. Dyn., 2013

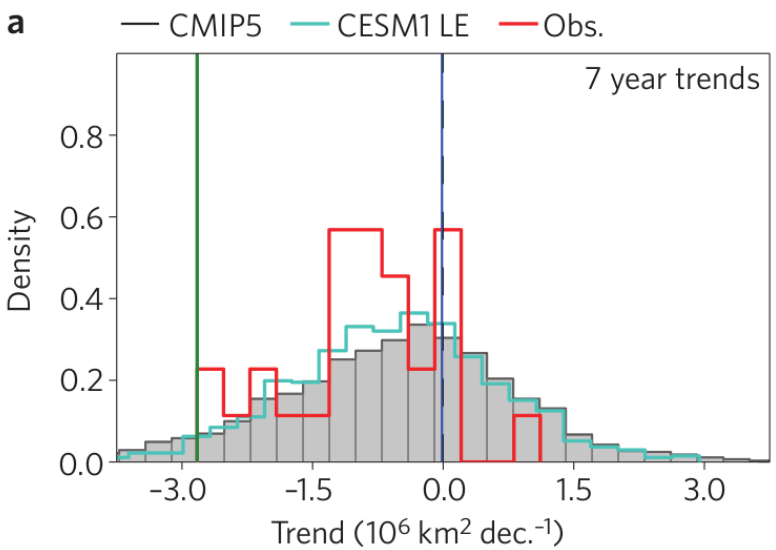
Interannual time scales: « grey zone » of sea ice predictability



Tietsche et al., Clim. Dyn., 2013

Interannual time scales: « grey zone » of sea ice predictability

Distribution of all possible 7-yr trends (1979-2013) in September sea ice extent



Swart et al., *Nature Clim. Change*, 2014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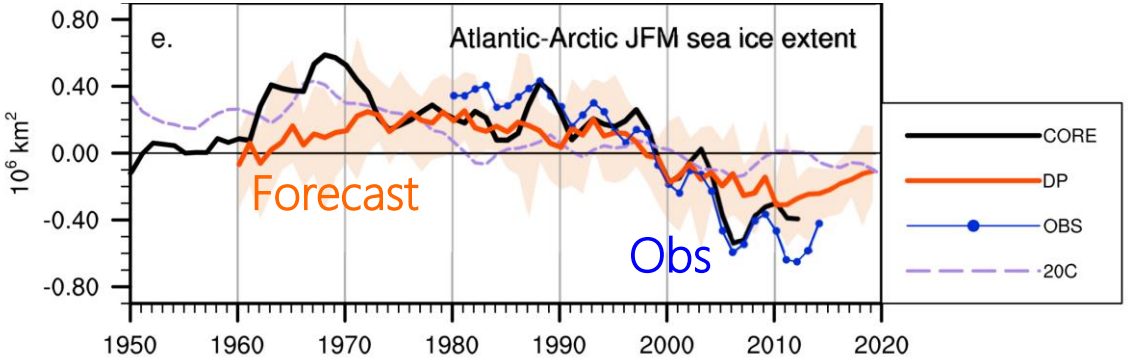

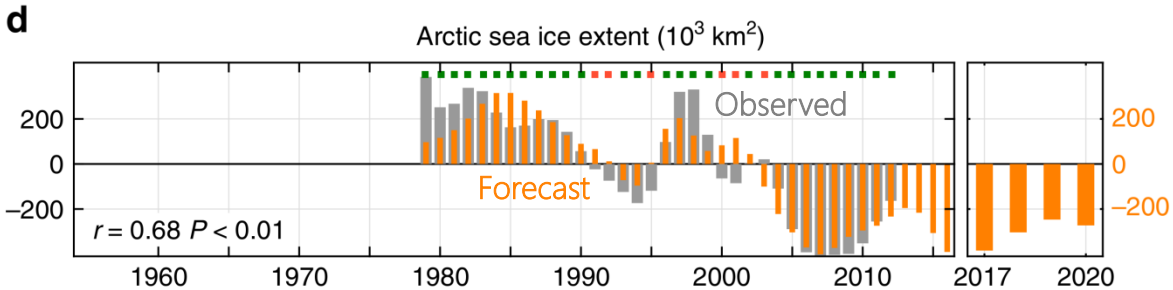

Decadal predictions are mostly skillful
-In winter
-In the Atlantic Sector

Skill stems from poleward oceanic heat transport and from radiative forcing (trend)

Yeager et al., *Geophys. Res. Lett.*, 2015; Årthun et al., *Nat. Comm.*, 2017


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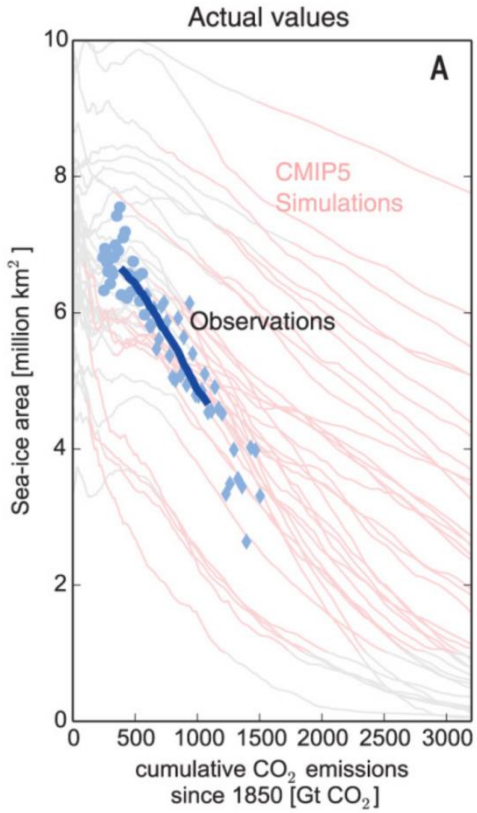
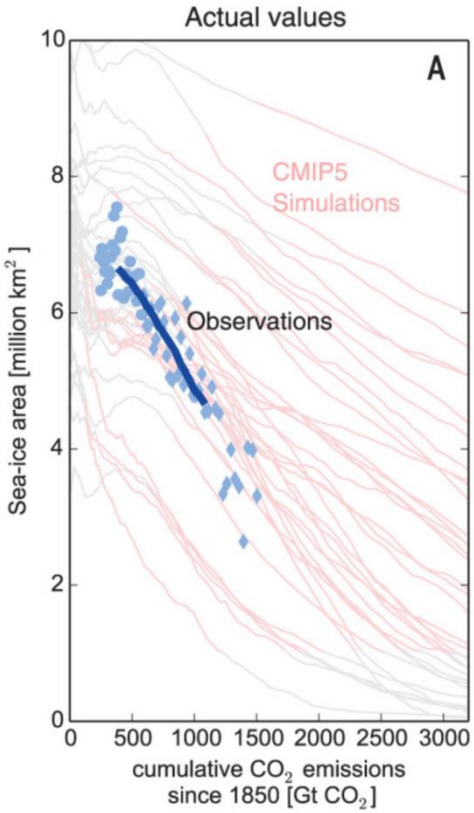


Arctic sea ice area is slaved to the forcing

...

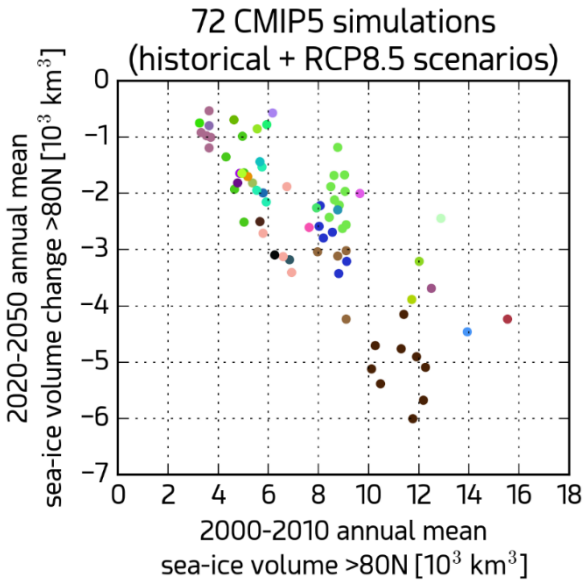
Notz and Stroeve, *Science*, 2016



Arctic sea ice area is slaved to the forcing

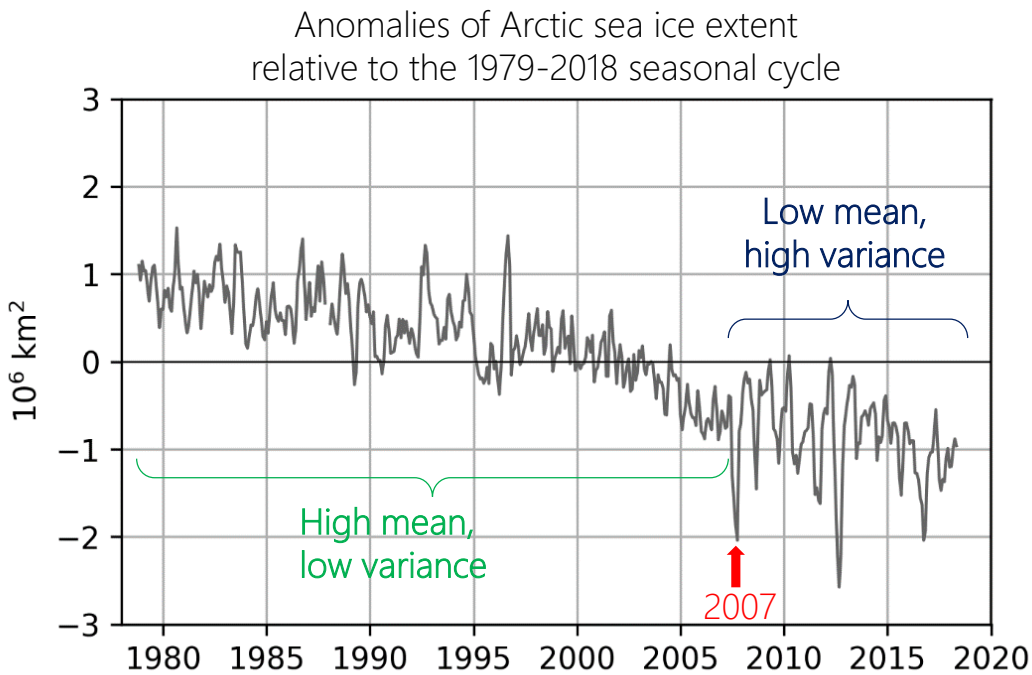
...

but thinning rate depends on initial thickness



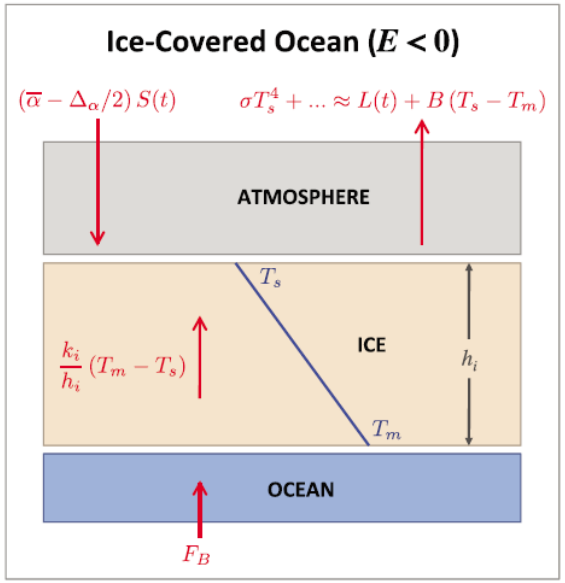
Notz and Stroeve, *Science*, 2016; Bitz and Roe, *J. Clim.*, 2004; Massonnet et al., *Nature Clim. Change*, 2018

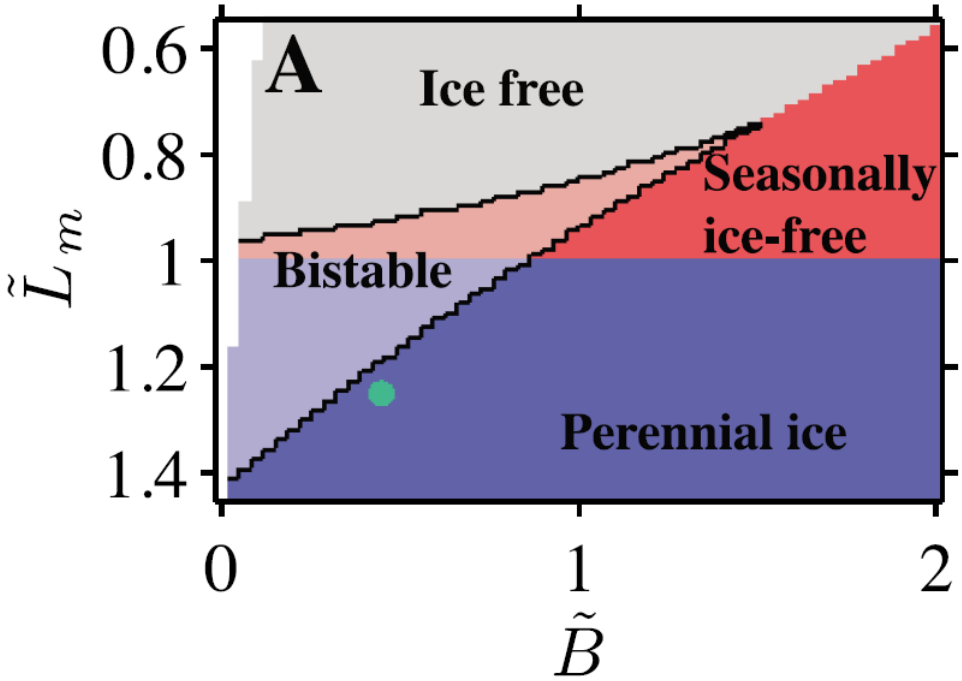
Has Arctic sea ice passed a tipping point?



Data: NSIDC sea ice index

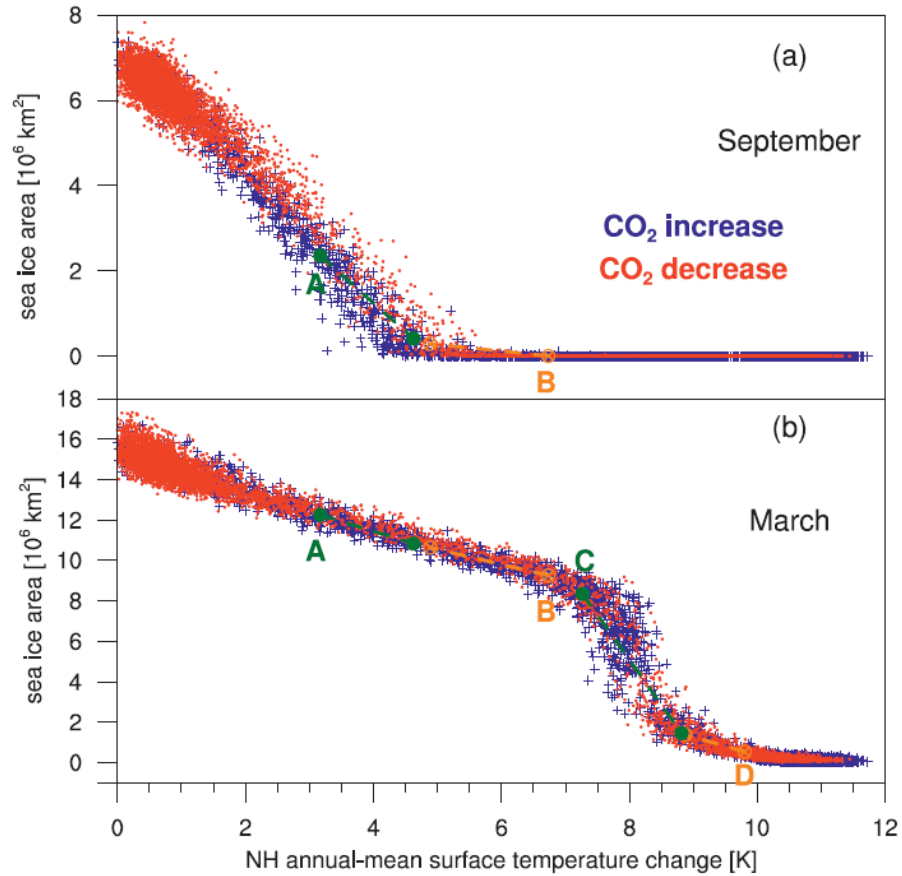
Simple, conceptual models *can* exhibit multiple equilibria, but this is a parameter-dependent feature





Eisenman, *J. Geophys. Res.*, 2012

No evidence for Arctic sea ice irreversibility from comprehensive models



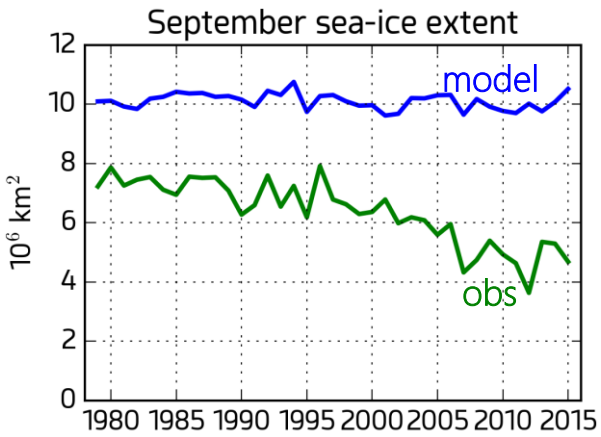
Li et al., *J. Climate*, 2013

Arctic sea ice predictions: conclusions

- There is in general predictability beyond persistence, but predictive capacity depends on
  - Time scale considered
  - Season considered
  - Region considered
  - Parameter considered
- Knowledge of baseline sea ice+ocean state is key to perform skillful predictions
- There is a « grey zone » of Arctic sea ice predictability at interannual-to-decadal time scales

2. Important considerations regarding the evaluation of upcoming PARAMOUR predictions

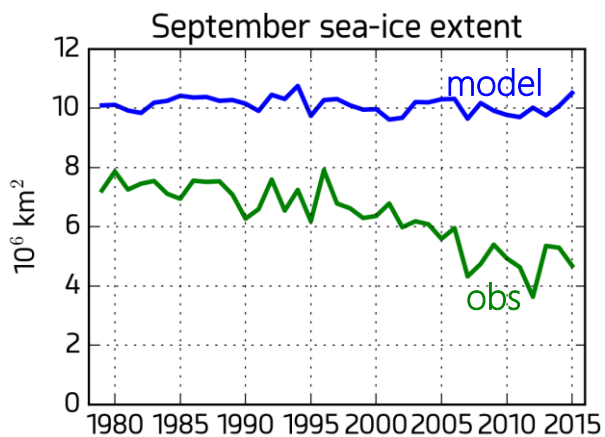
Why don’t models and observations match each other?



Why don't models and observations match each other?

It's the modelers fault

-Physical equations are wrong
-Equations are discretized
-Forcing is not correct
-Initial conditions are not correct
-Processes are parameterized
-There are computational errors



[Orrell et al., *Nonlin. Proc. Geophys.*, 2001]

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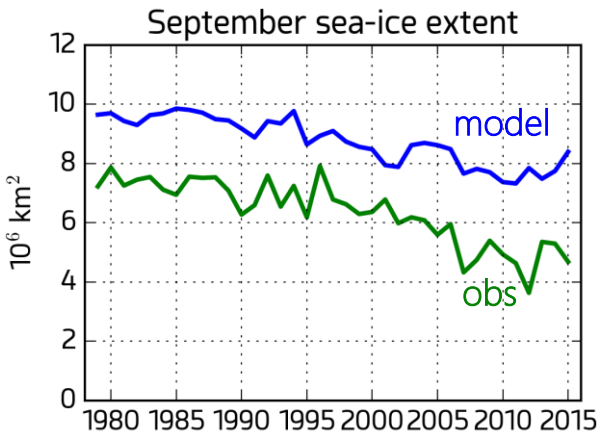


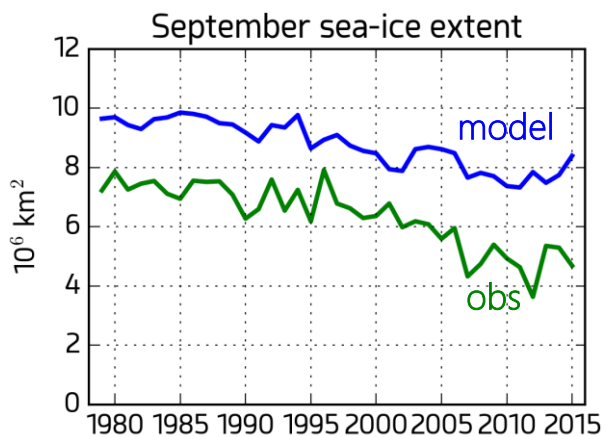
[Orrell et al., *Nonlin. Proc. Geophys.*, 2001]

Why don't models and observations match each other?

It's the modellers fault

It's the observers fault

Instrumental errors
Algorithm errors
Assumptions (e.g. hydrostatic)
Sampling errors



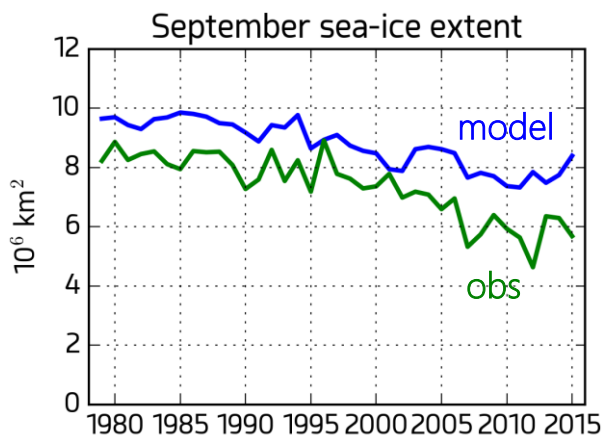
[Ivanova et al., *Cryosphere*, 2014; Zygmuntowska et al., *Cryosphere*, 2014; Worby et al., *J. Geophys. Res.*, 2008]

Why don't models and observations match each other?

It's the modellers fault

It's the observers fault

Instrumental errors
Algorithm errors
Assumptions (e.g. hydrostatic)
Sampling errors



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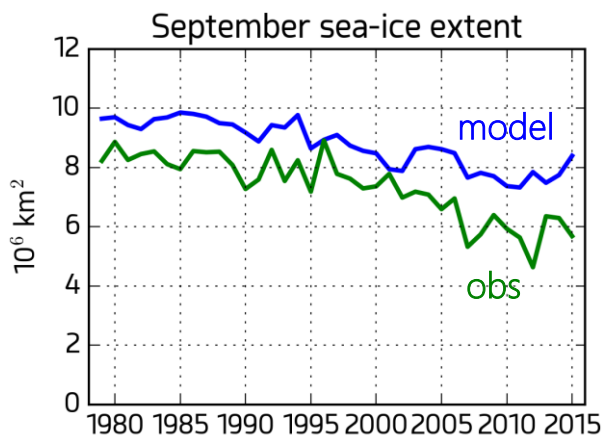

It's my fault

No scale-awareness

No definition-awareness

[Kay et al., *J. Geophys. Res.*, 2016]

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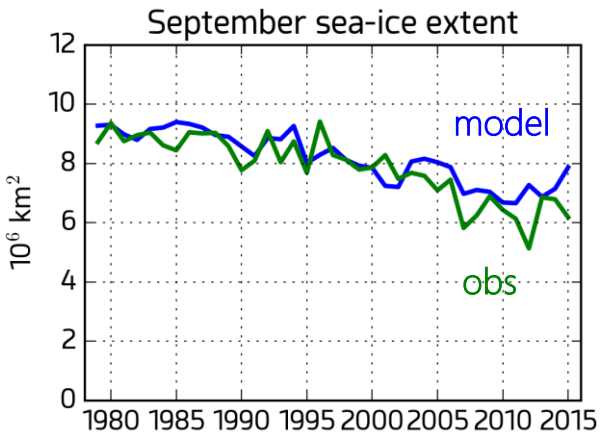

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[Kay et al., *J. Geophys. Res.*, 2016]

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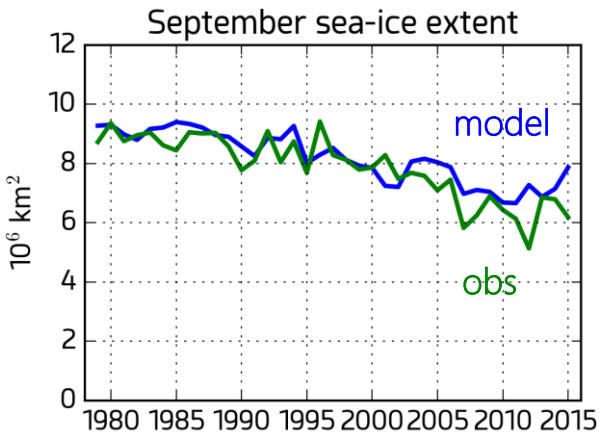


It's my fault

No scale-awareness

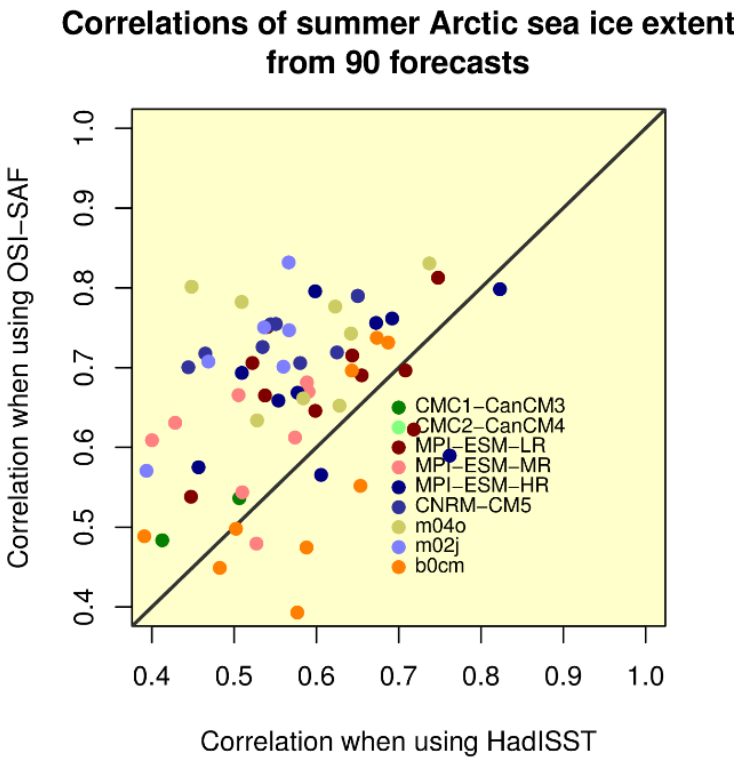
No definition-awareness

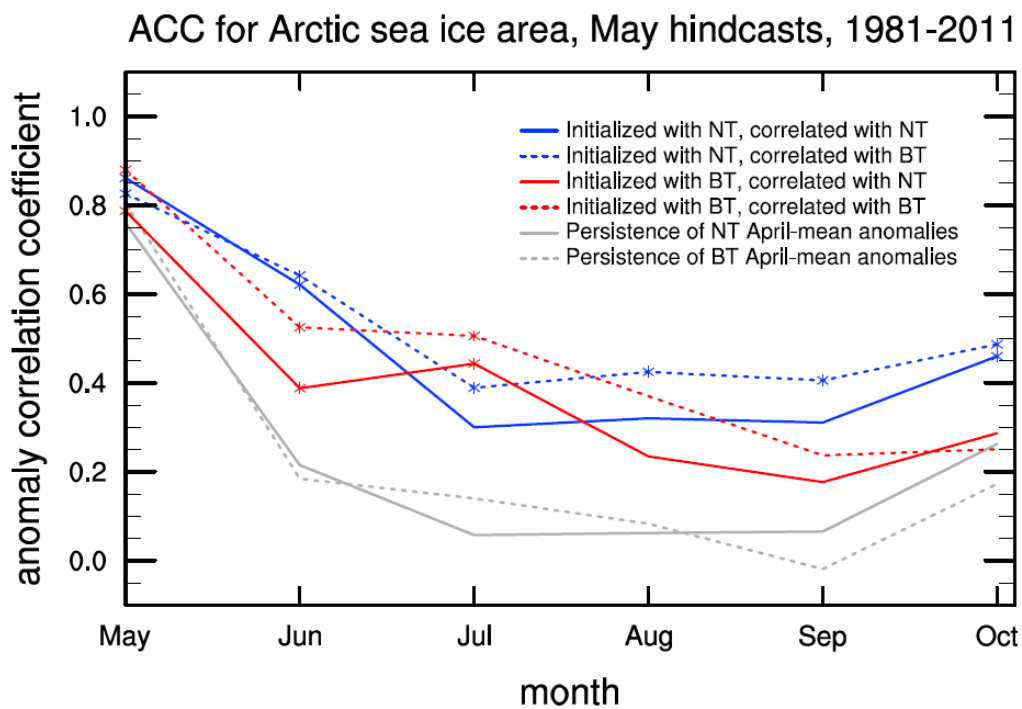
It's no one's fault

Internal variability

[Notz, *Phil. Trans. Roy. Soc.*, 2015]

Seasonal sea ice prediction skill is significantly affected by the choice of the verification product





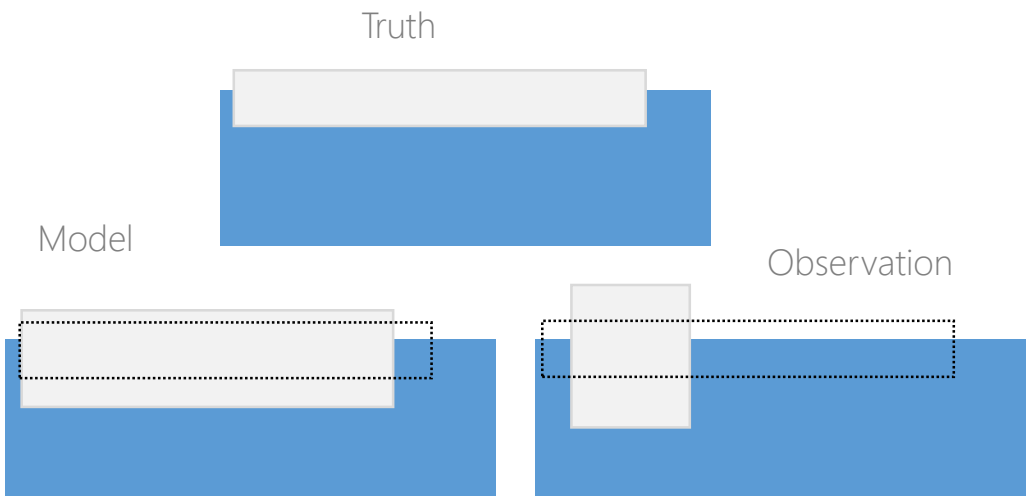
Massonnet et al., *Science*, 2016

Bunzel et al., *Geophys. Res. Lett.*, 2016

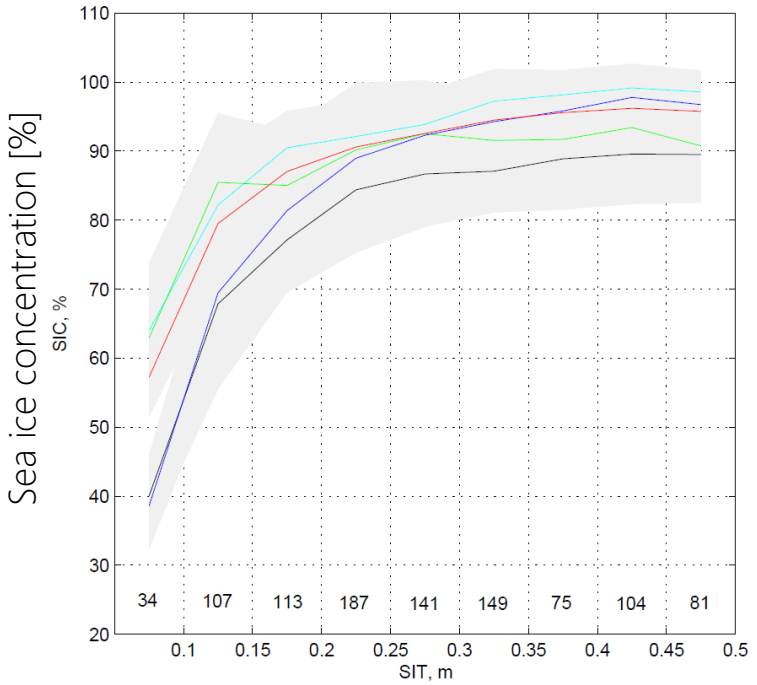
Why do models score better for the two most advanced and recent products?

Models simulate directly sea ice concentration and output it as a physical variable; observations don't.
Models can be really good references in that case!

Observations have deficiencies that models don't have e.g. concentration of thin ice



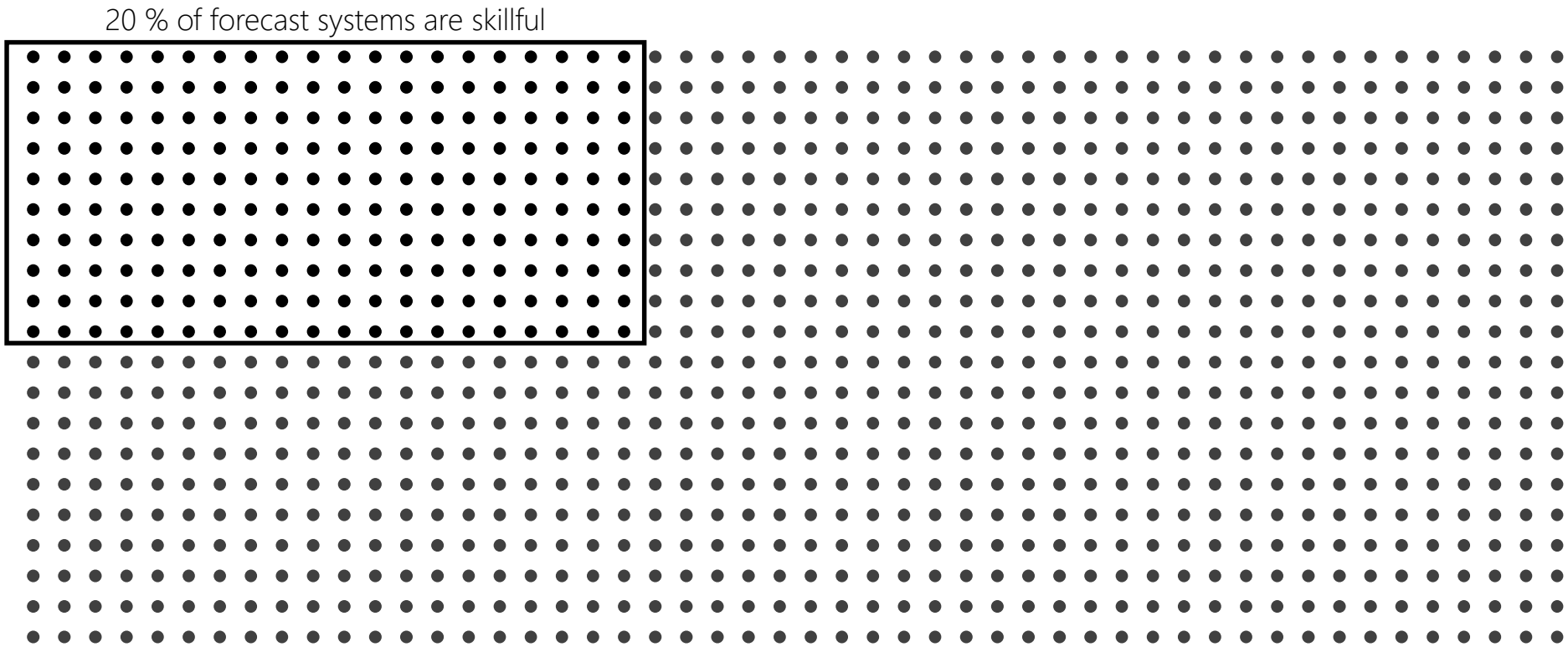
Satellite estimation of sea ice concentration where it's known to be 100%



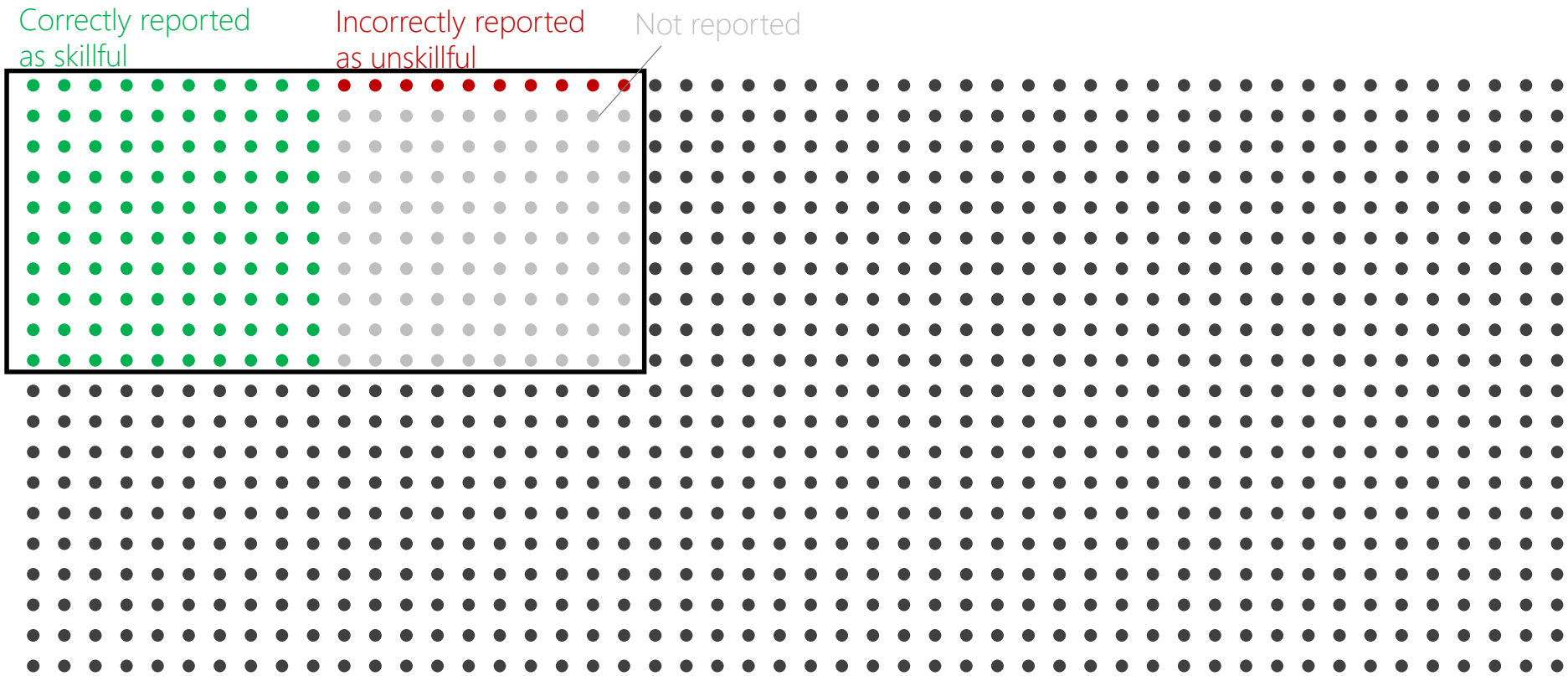
Sea ice thickness [m]

Challenges related to ensemble size, statistical power and statistical testing

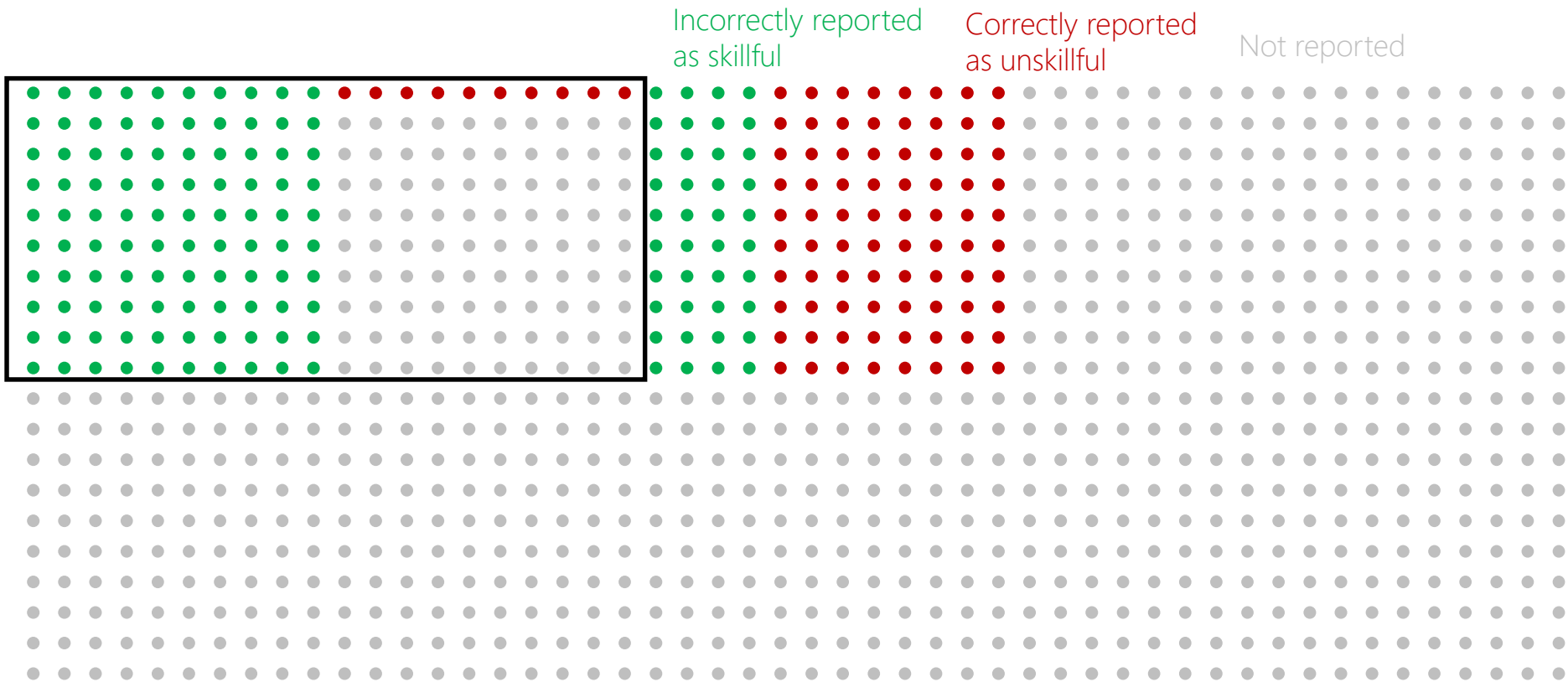
Imagine 1000 forecast systems trying to predict the Arctic sea ice. Assume that 20% (200) are good enough to be skillful (actual correlation with obs is positive)



Due to limited statistical power (say, 50%), not all of the skillful systems will be recognized as skillful (100).
All positive results will be published (100), while only few of the negative results (10%) will be published (10).

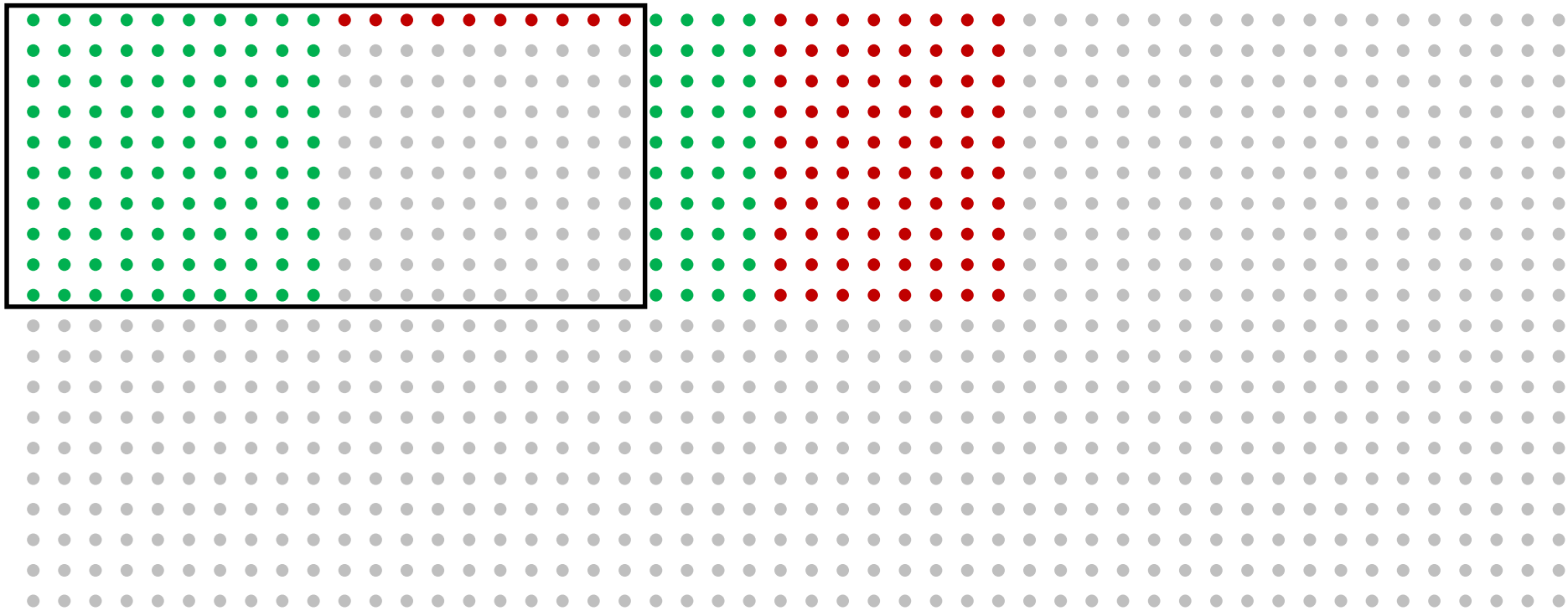


In addition, 5% of the nonskillful forecast systems (40) will produce skillful results just by chance, and all will be published. Again, only a limited number (10%) of negative results will be published (80)



Conclusion: From 230 published studies, 140 (61%) will report skillful results even though only 20% are actually skillful.

Due to low statistical power and unreported negative results, climate predictions are probably less often skillful than suggested by the literature.



Final remarks: data

- At UCLouvain we are hosting much sea ice and related data:
  - Observational references
  - Reanalyses
  - Model output (CMIP5, now CMIP6)
- We are keen to provide support or expertise when PARAMOUR people outside UCLouvain would like to use them