

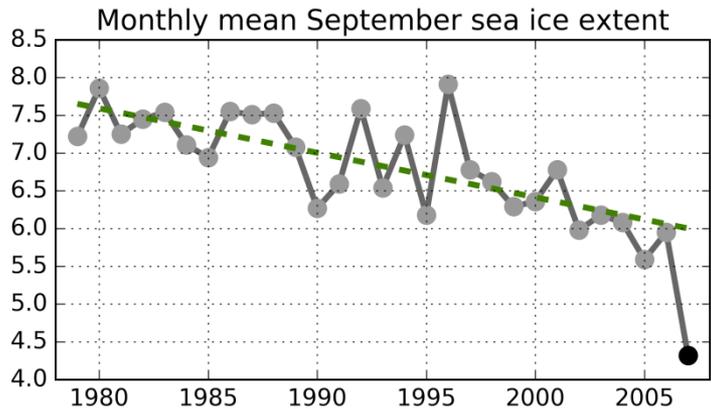
Arctic sea ice prediction from days to centuries

Are we there yet?

François Massonnet

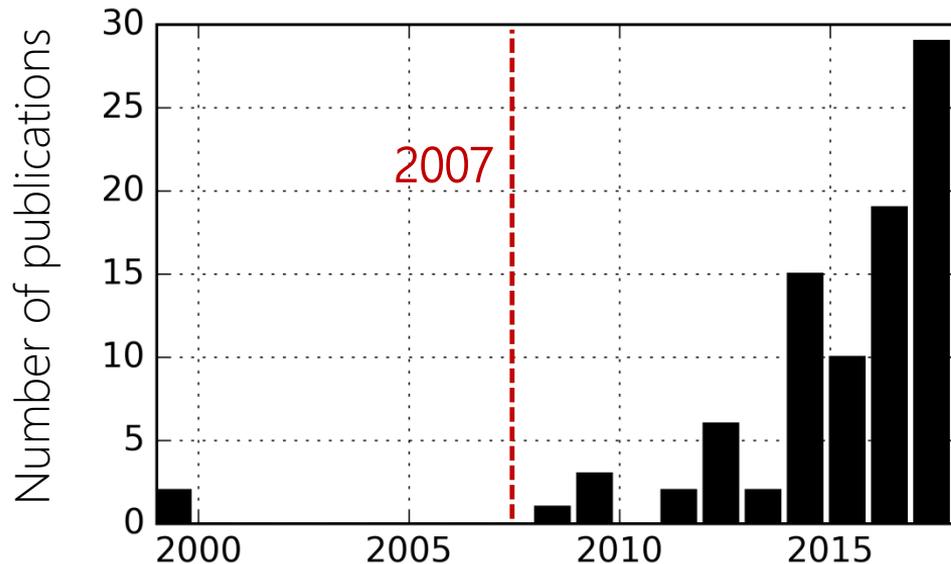


September 2007: the Arctic black swan



Arctic sea ice prediction: an emerging area of research

Number of results from Google Scholar query
« Arctic sea ice prediction » per year of publication



Three excellent articles on Arctic sea ice predictability and prediction



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. Tietsche¹, J. J. Day¹, V. Guemas^{2,3}, W. J. Hurlin⁴, S. P. E. Keeley⁵, D. Matei⁶, R. Msadek⁴, M. Collins⁷, and E. Hawkins¹

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

^aNCAS-Climate, Department of Meteorology, University of Reading, UK.

^bDepartment of Meteorology, University of Reading, UK.

^cEuropean Centre for Medium-range Weather Forecasts, Reading, UK.



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 Méliab and Steffen Tietsche^e

Arctic sea ice prediction

1. From days to centuries
2. What are the ways forward?

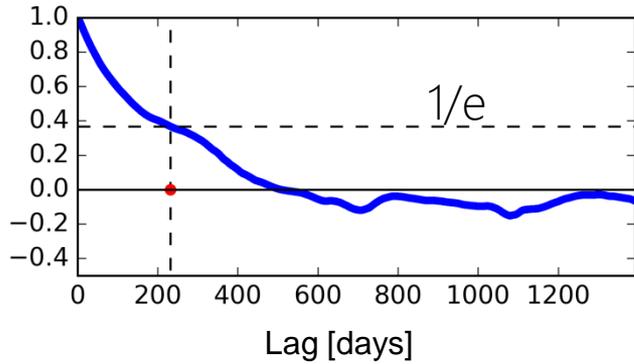
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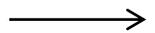
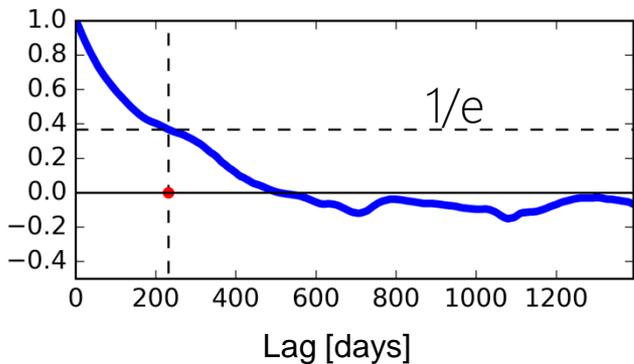
Persistence

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

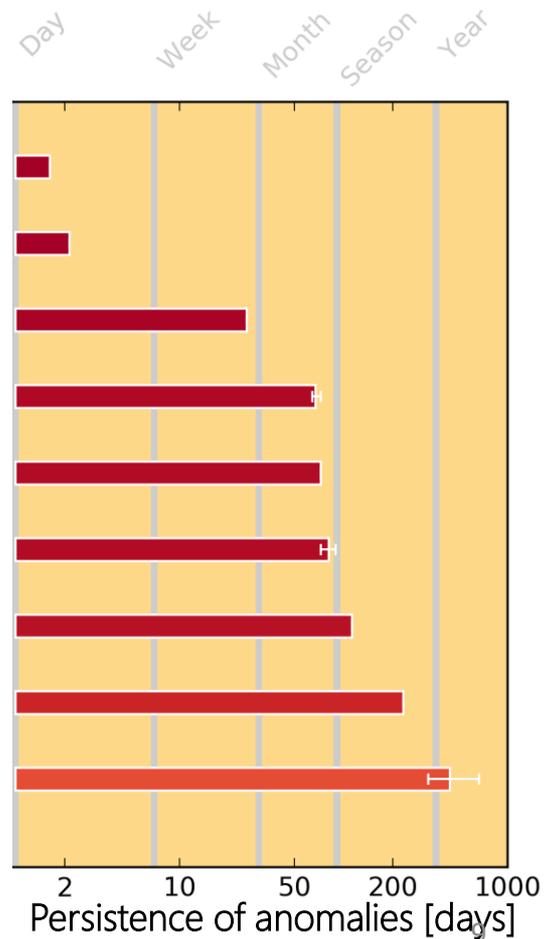


Persistence: a primary source of sea ice predictability on a spectrum of time scales

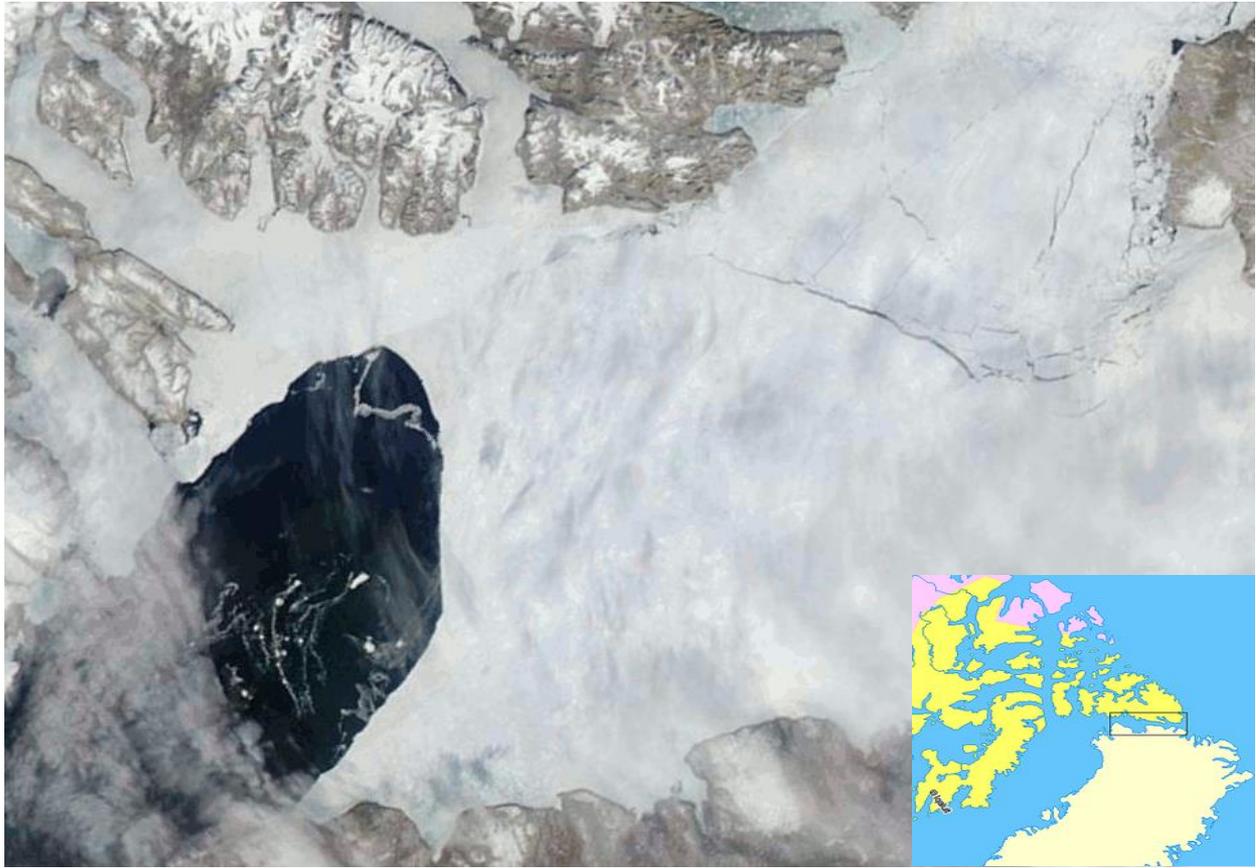
Autocorrelation of 1979-2015 sea ice thickness (model output, one grid point)



- Sea ice speed (one point)
- Total sea ice kinetic energy
- Sea ice concentration (one point)
- Total sea ice extent
- Total snow on sea ice volume
- Total sea ice area
- Snow on sea ice depth (one point)
- Sea ice thickness (one point)
- Total sea ice volume



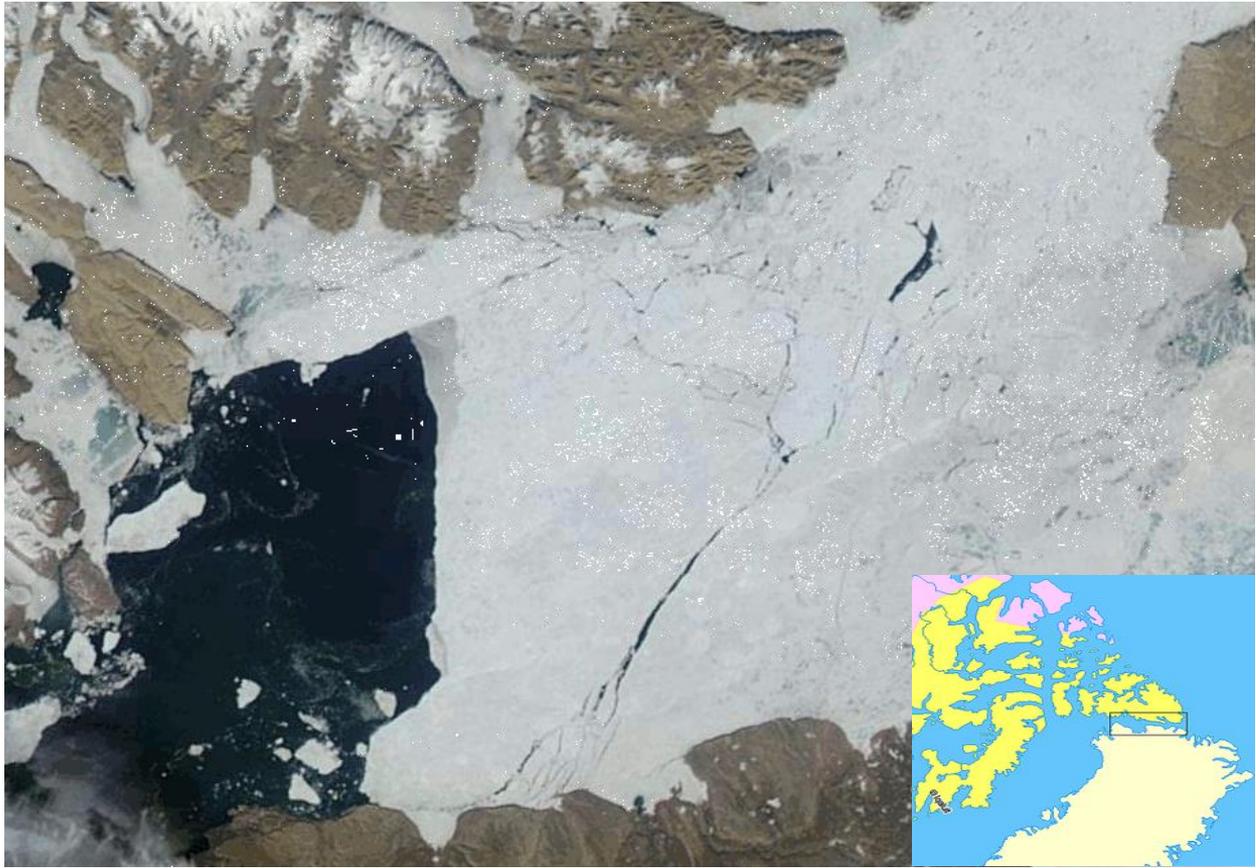




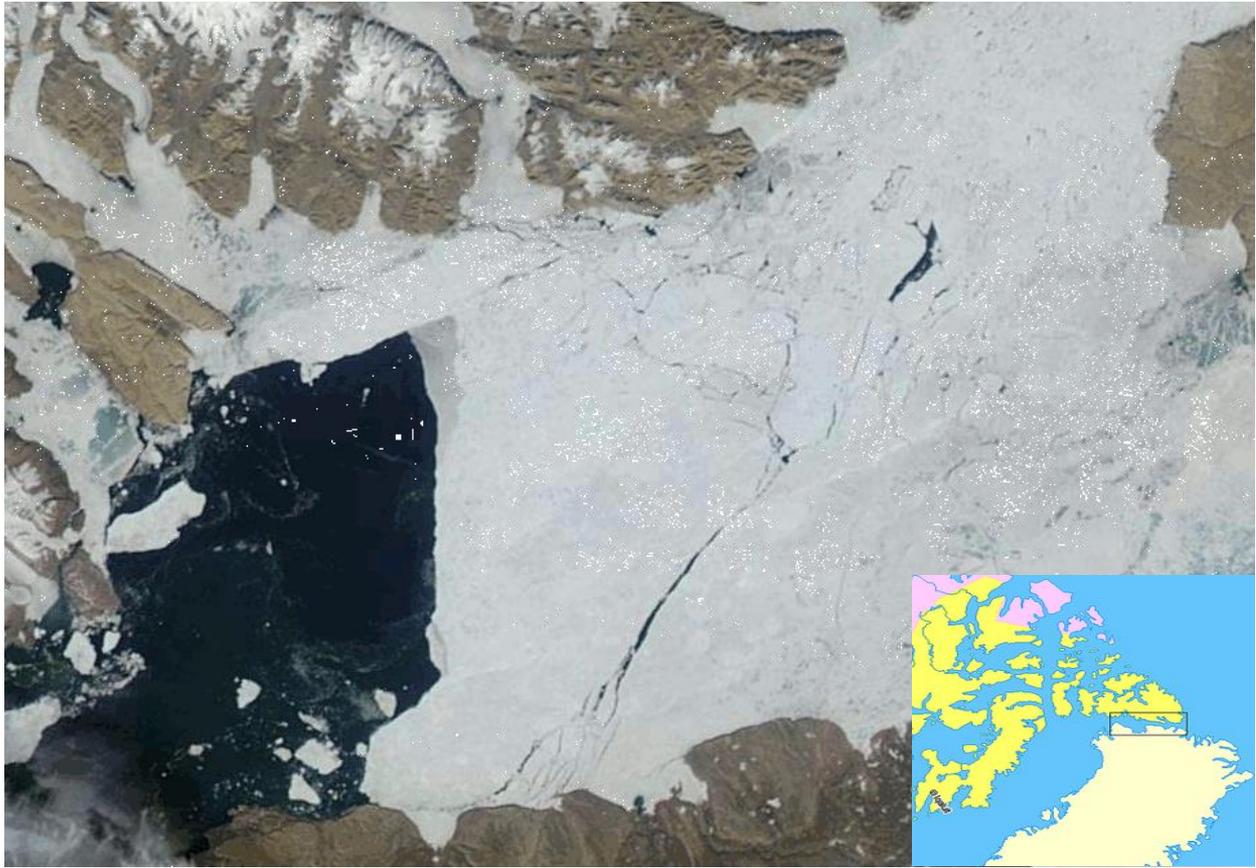
June 20th – July 12th 2015, LANCE-MODIS, 2 images per day
<https://forum.arctic-sea-ice.net/index.php?action=dlattach;topic=176.0;attach=18238;image>



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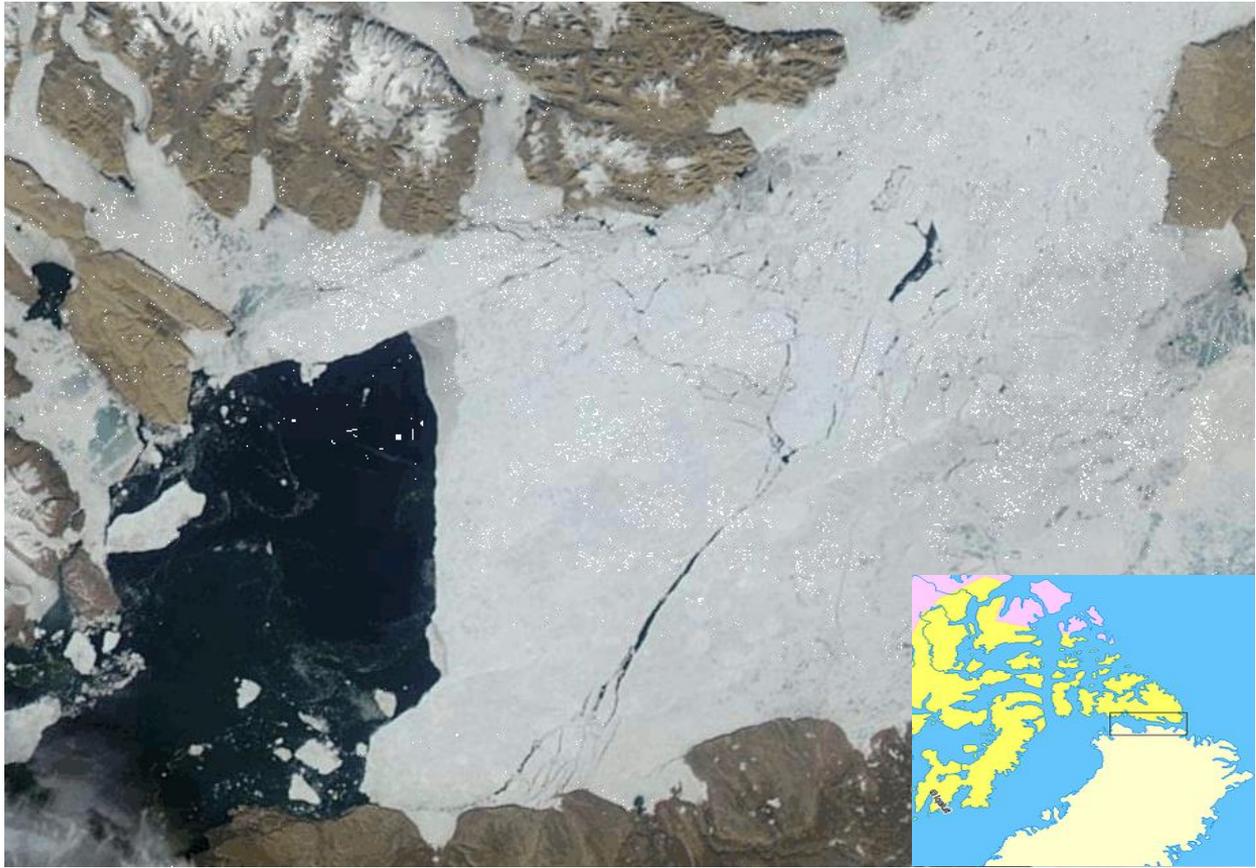


June 20th – July 12th 2015, LANCE-MODIS, 2 images per day
<https://forum.arctic-sea-ice.net/index.php?action=dlattach;topic=176.0;attach=18238;image>



Sources of predictability -Persistence

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>



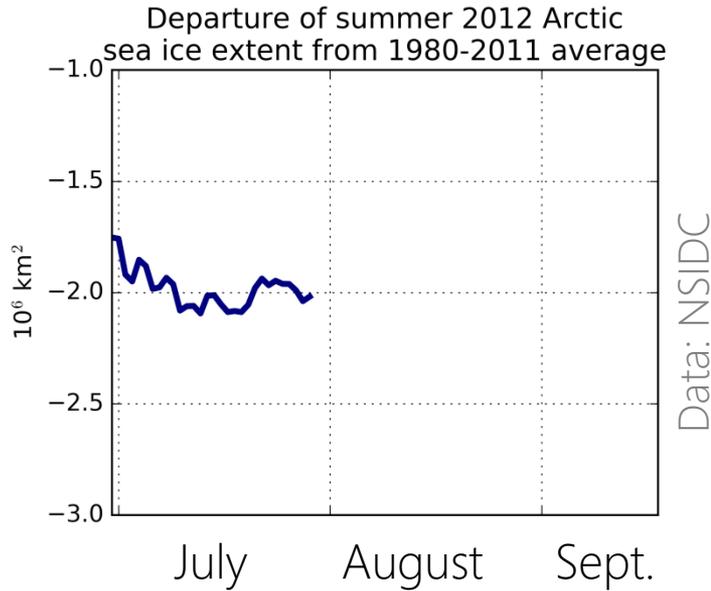
- ### Sources of predictability
- Persistence
 - Mechanical forcing by wind
 - Current ice state (deformation, age, thickness, compactness)

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>



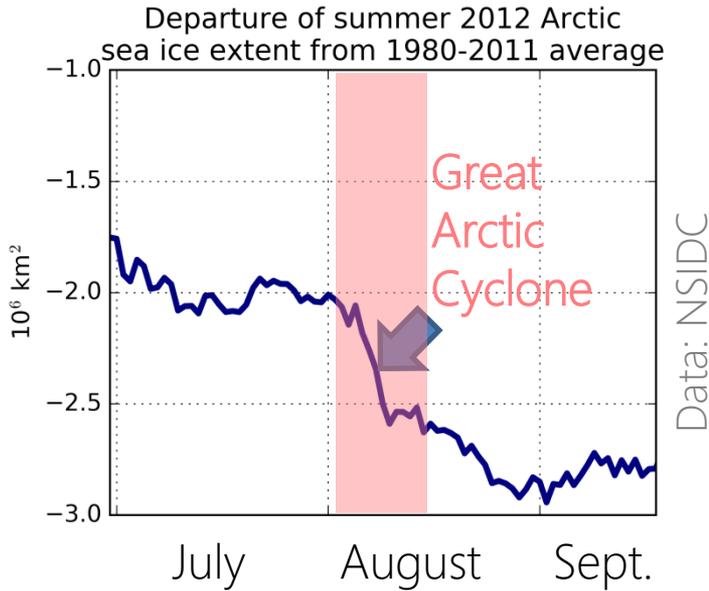


Weekly sea ice extent predictability stems from persistence

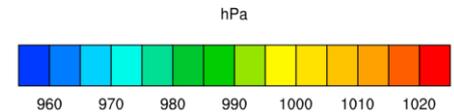
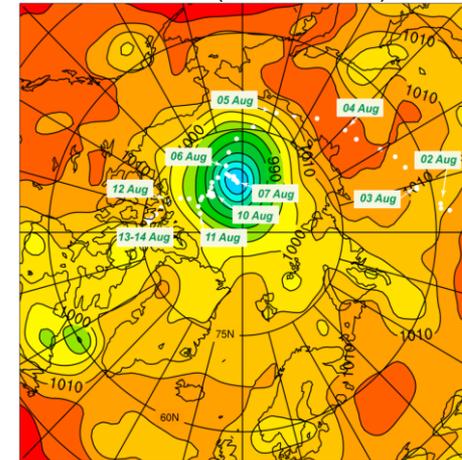




Weekly sea ice extent predictability stems from persistence but can be affected by synoptic events



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

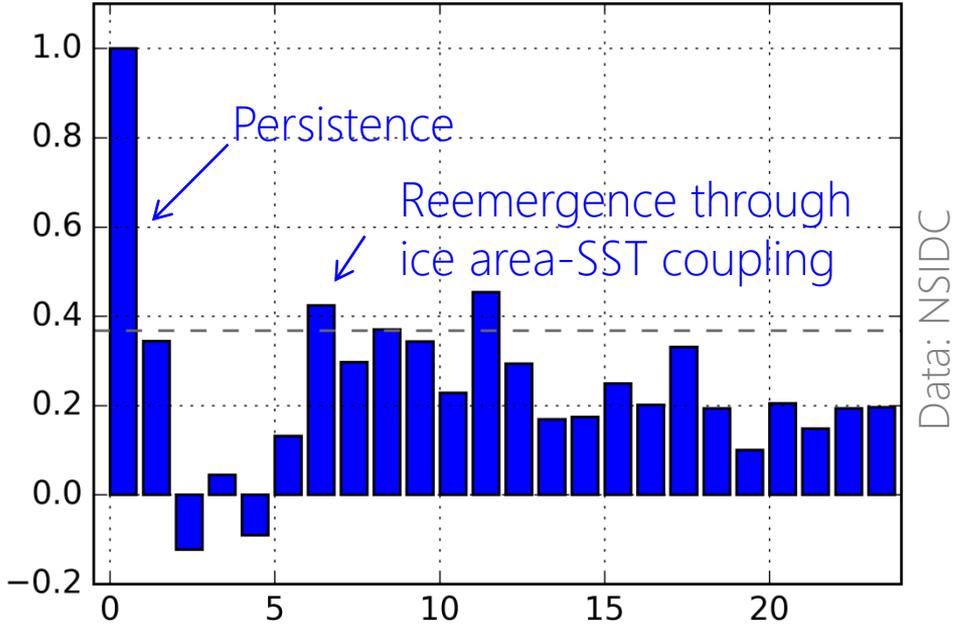




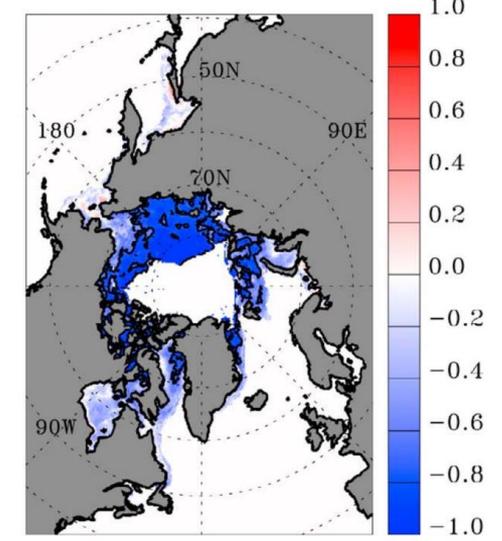


Example of reemergence: melt to freeze up

Auto-correlation from May sea ice extent anomalies



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





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 Bushuk¹, Rym Msadek², Michael W. Anthony Rosati³, and Xiaosong Yang³

¹Atmospheric and Oceanic Sciences Program, Princeton University, Princeton, New Jersey, USA, ²UMR 5318, Toulouse, France, ³National Oceanic and Atmospheric Administration, Princeton, New Jersey, USA, ⁴Department of Earth and Atmospheric Sciences, Princeton University, Princeton, New 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:
The Arctic An AGU Issue

Julienne C. Stroeve^{1,2}, Alex D. Crawford¹, and Sharon Stammerjohn³

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

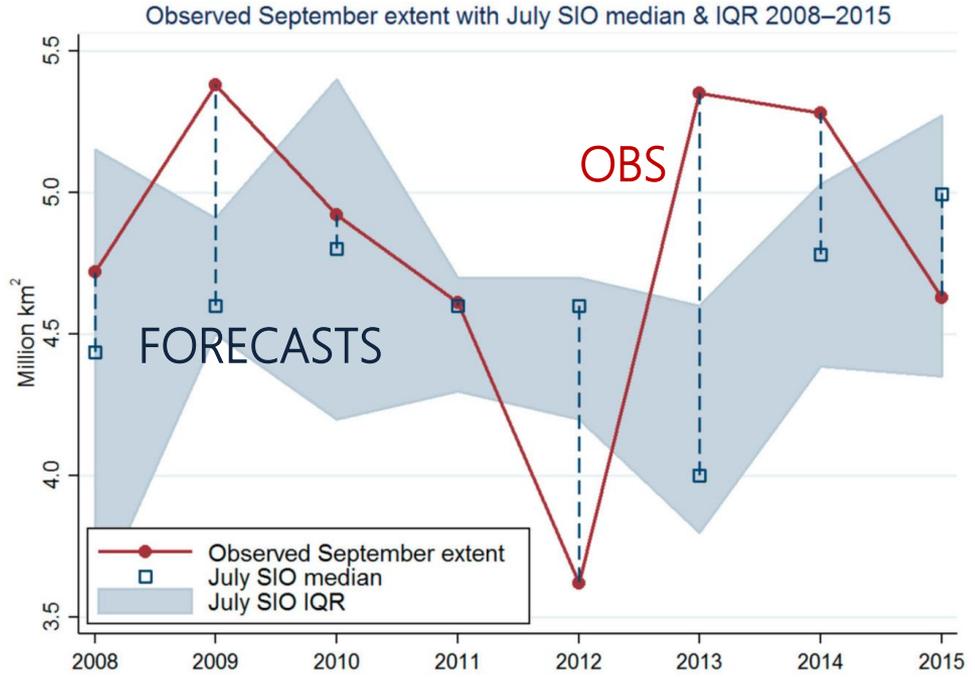
K. Andrew Peterson · A. Arribas · H. T. Hewitt · A. B. Keen · D. J. Lea · A. J. McLaren

Skill of Arctic sea ice area in a dynamical forecast system

G. M. Flato,² V. V. Kharin,² and W. J. Merryfield²

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

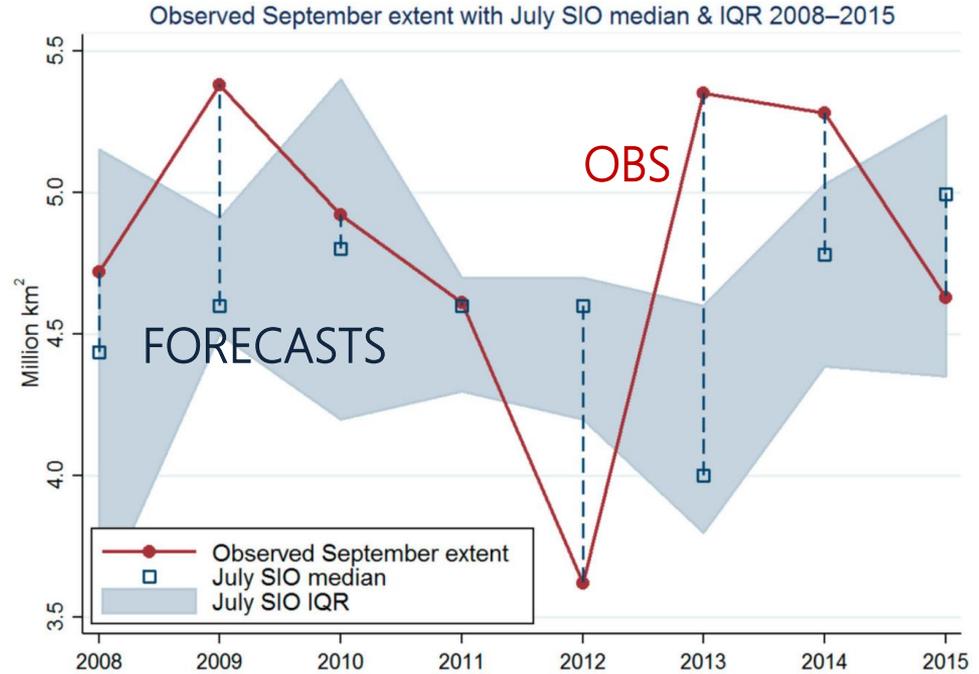




Predictions are unfortunately not skillful in « operational » mode.

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

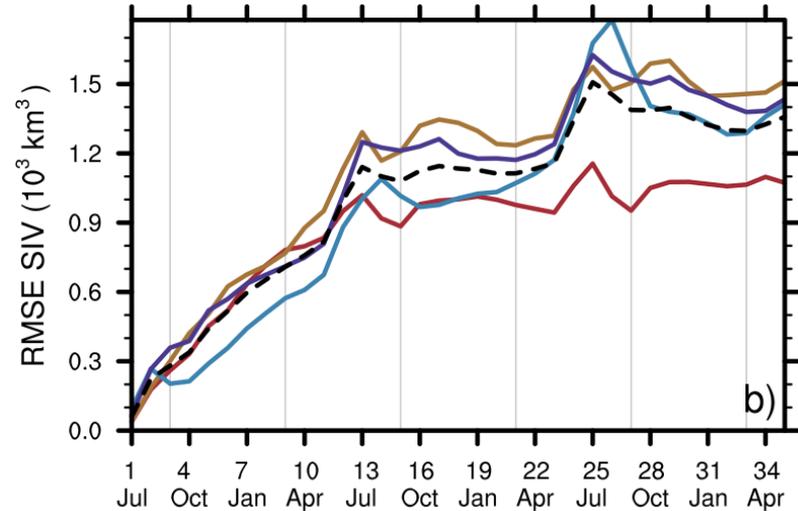






Interannual time scales: « grey zone » of sea ice predictability

Ensemble spread of total sea ice volume from 4 GCMs

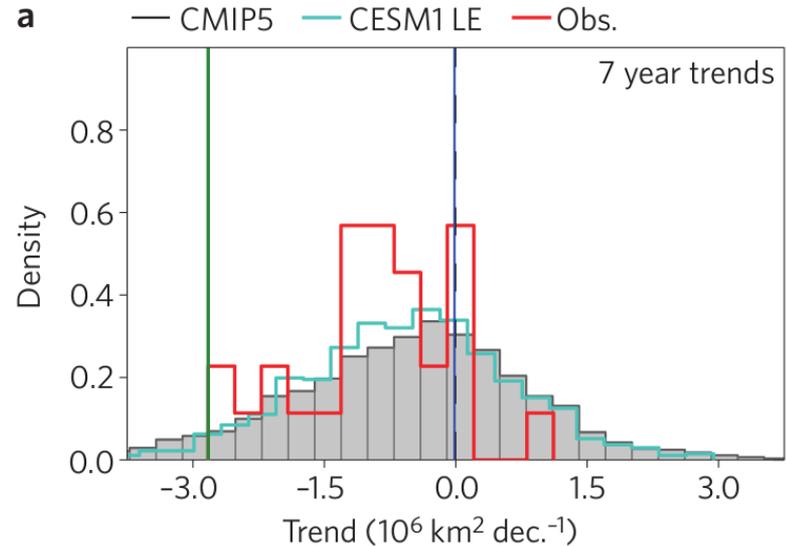


Tietsche et al., *Geophys. Res. Lett.*, 2014

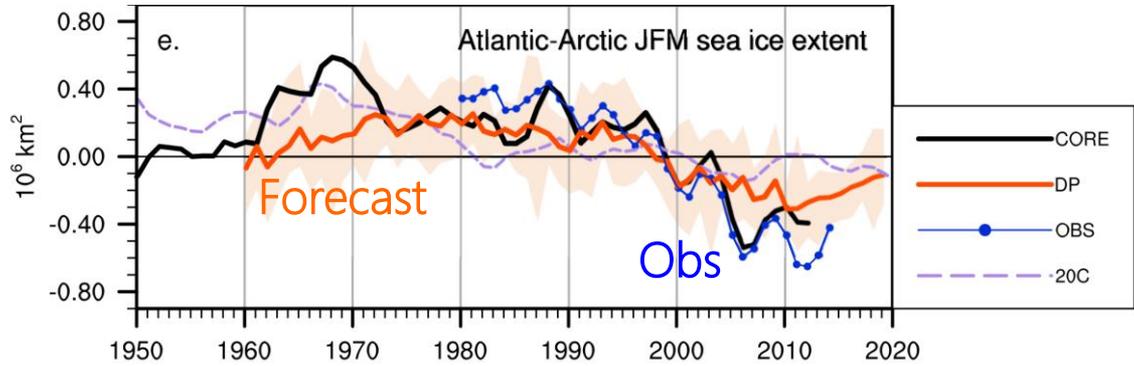


Interannual time scales: « grey zone » of sea ice predictability

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

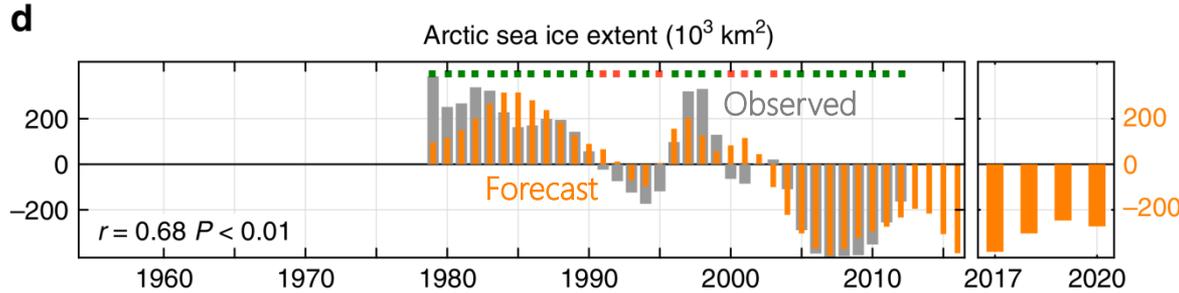






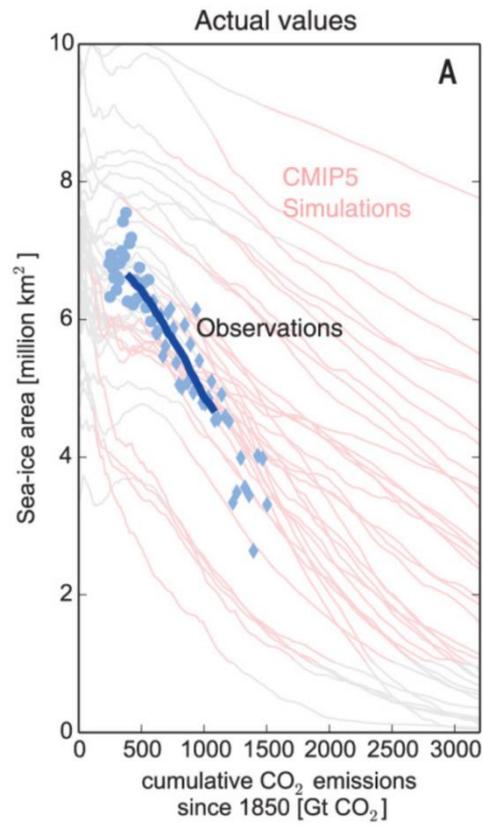
Decadal predictions are mostly skillful

- In winter
- In the Atlantic Sector



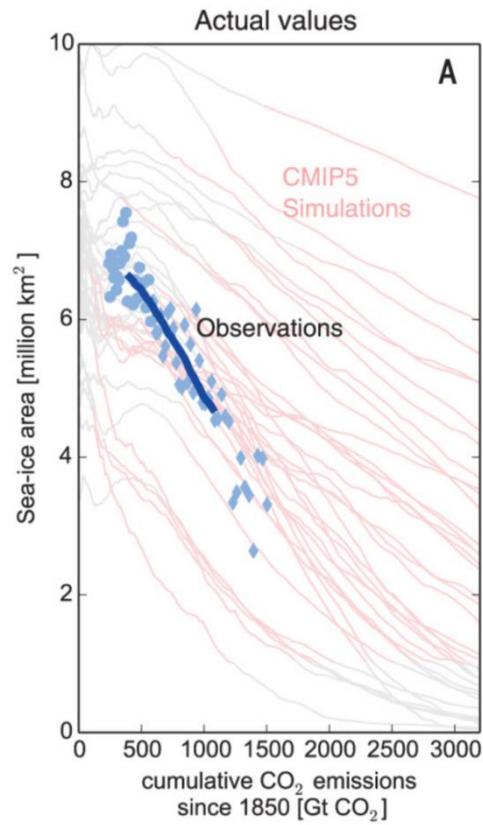
Skill stems from poleward oceanic heat transport and from radiative forcing (trend)





Arctic sea ice area is slaved to the forcing

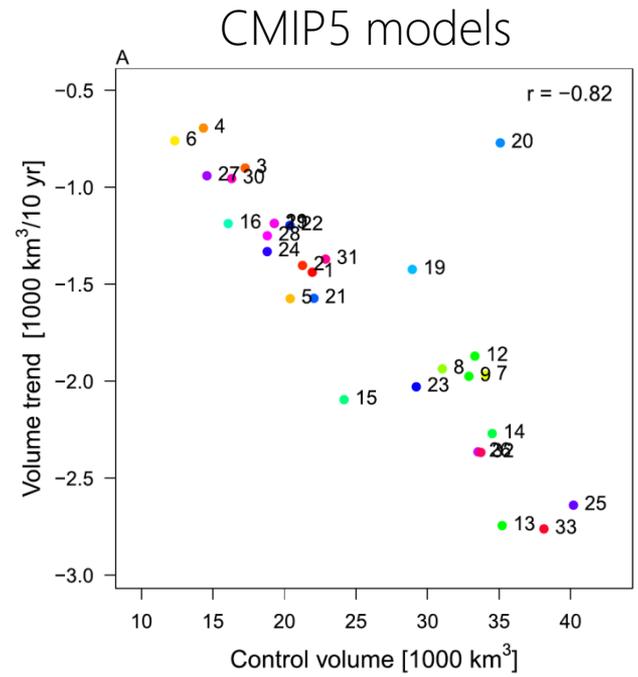
...



Arctic sea ice area is slaved to the forcing

...

but thinning rate depends on initial thickness



Arctic sea ice prediction

1. From days to centuries

- 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

2. What are the ways forward?

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What Is a Good Forecast?

An Essay on the Nature of Goodness in Weather Forecasting

ALLAN H. MURPHY

College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, Oregon

(Manuscript received 11 August 1992, in final form 20 January 1993)

ABSTRACT

Differences of opinion exist among forecasters—and between forecasters and users—regarding the meaning of the phrase “good (bad) weather forecasts.” These differences of opinion are fueled by a lack of clarity and/or understanding concerning the nature of goodness in weather forecasting. This lack of clarity and understanding complicates the processes of formulating and evaluating weather forecasts and undermines their ultimate usefulness.

Three distinct types of goodness are identified in this paper: 1) the correspondence between forecasters’ judgments and their forecasts (type 1 goodness, or *consistency*), 2) the correspondence between the forecasts and the matching observations (type 2 goodness, or *quality*), and 3) the incremental economic and/or other benefits realized by decision makers through the use of the forecasts (type 3 goodness, or *value*). Each type of goodness is defined and described in some detail. In addition, issues related to the measurement of consistency, quality, and value are discussed.

Relationships among the three types of goodness are also considered. It is shown by example that the level of consistency directly impacts the levels of both quality and value. Moreover, recent studies of quality/value relationships have revealed that these relationships are inherently nonlinear and may not be monotonic unless the multifaceted nature of quality is respected. Some implications of these considerations for various practices related to operational forecasting are discussed. Changes in these practices that could enhance the goodness of weather forecasts in one or more respects are identified.

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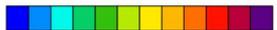
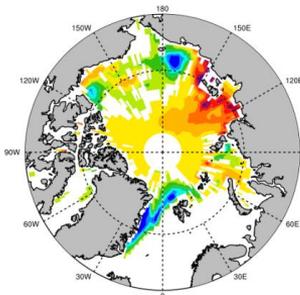
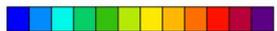
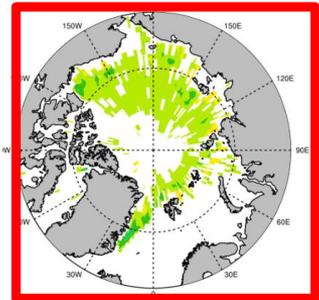
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Reanalyzed thickness: all over the place

September 1993-2007

mean sea ice

concentration bias



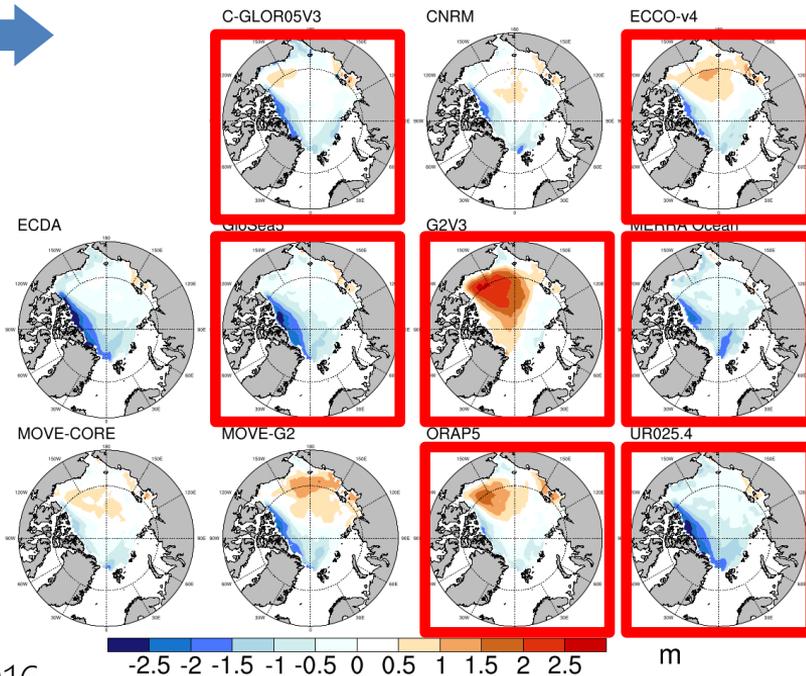
With DA

Without DA



March 1993-2007 mean sea ice

thickness bias (wrt IceSat)



Chevallier et al., *J. Clim.* 2016

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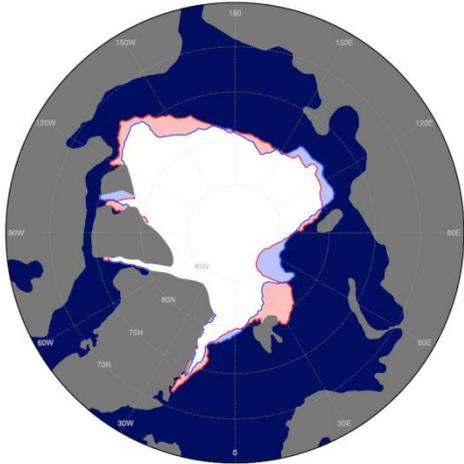
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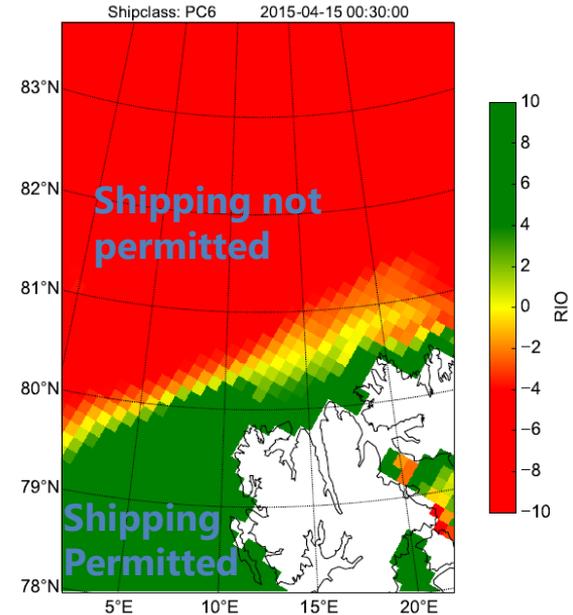
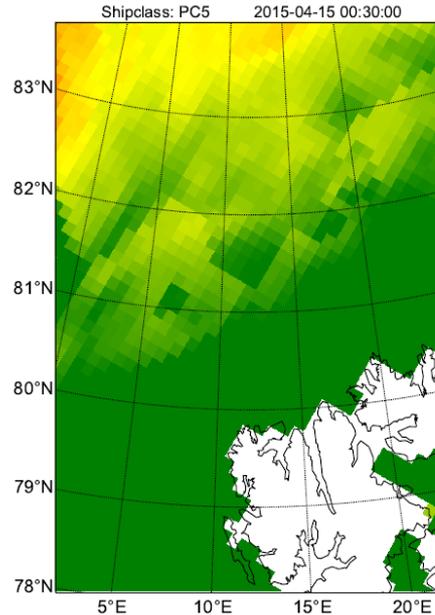
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Need for new metrics and diagnostics



Error = **OVERESTIMATION** + **UNDERESTIMATION**

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



Courtesy Andrea Gierisch

Arctic sea ice prediction

1. From days to centuries

2. What are the ways forward?

Concluding thoughts

Concluding thoughts

- Arctic sea ice prediction is « in the making »

Concluding thoughts

- Arctic sea ice prediction is « in the making »
- A seamless polar prediction community is building



Concluding thoughts

- Arctic sea ice prediction is « in the making »
- A seamless polar prediction community is building
- We are chasing a moving target



Thank you!

 @FMassonnet

@ francois.massonnet@uclouvain.be

www www.climate.be/u/fmasson