DON'T EAT ME
(NOW)

University of Washington
July 6th, 2017

From Pole to Pole Sea ice research in Belgium and Europe

François Massonnet (I'm at AT506)

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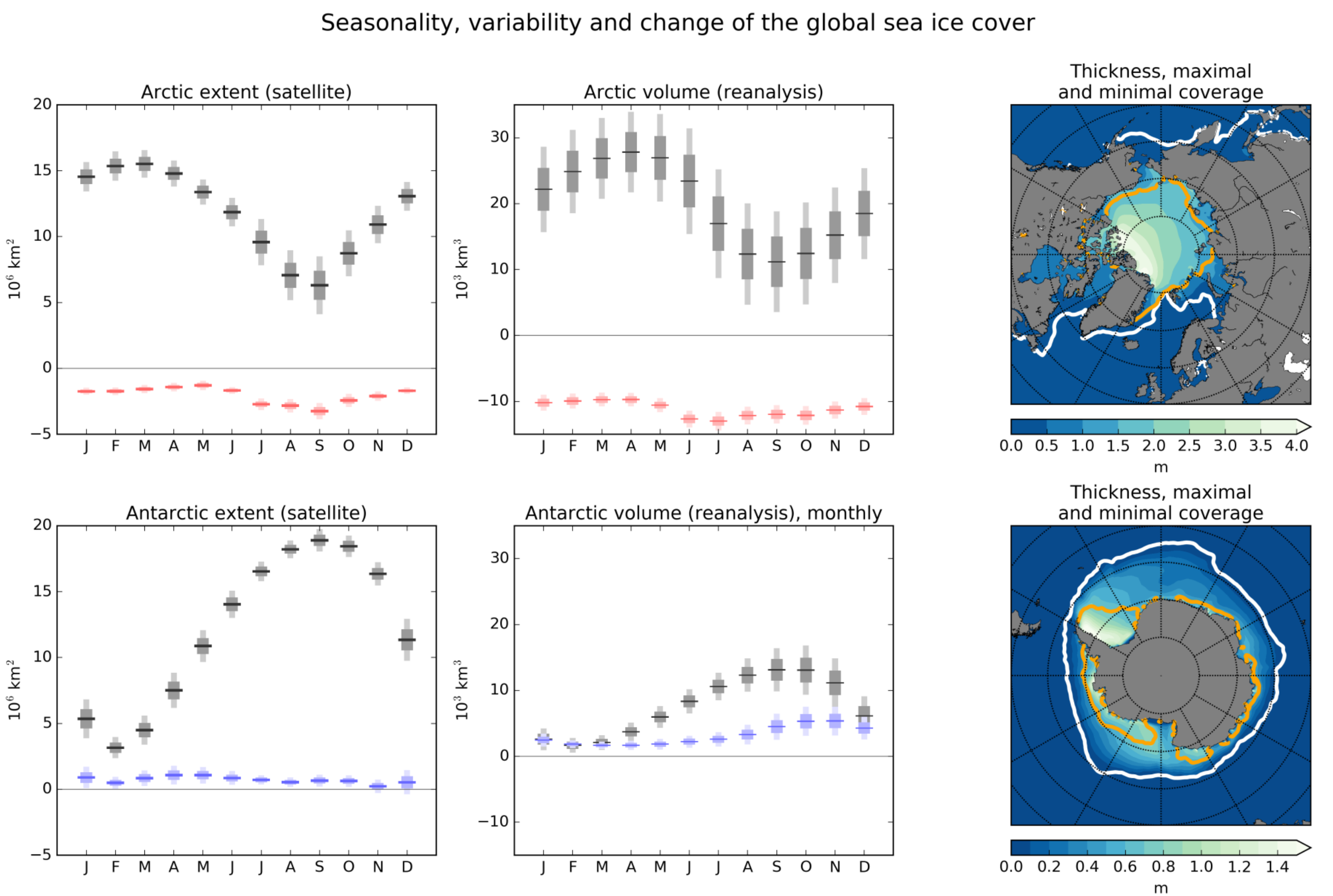
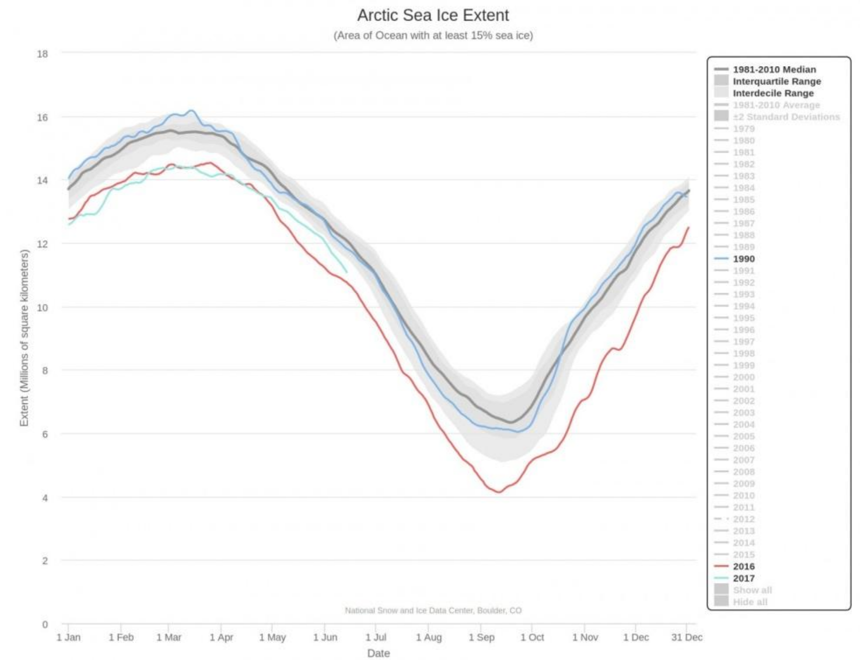
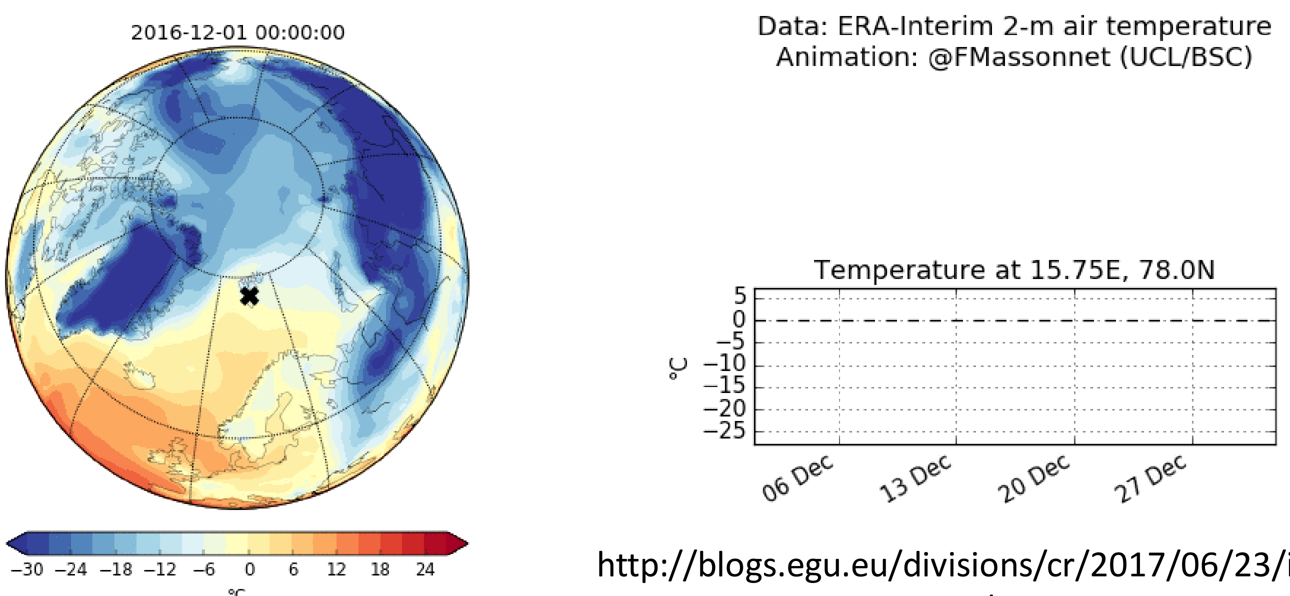
Sea Ice 101



Data: NSIDC (extent); PIOMAS (volume/thickness NH); ORAP5 (volume/thickness SH)

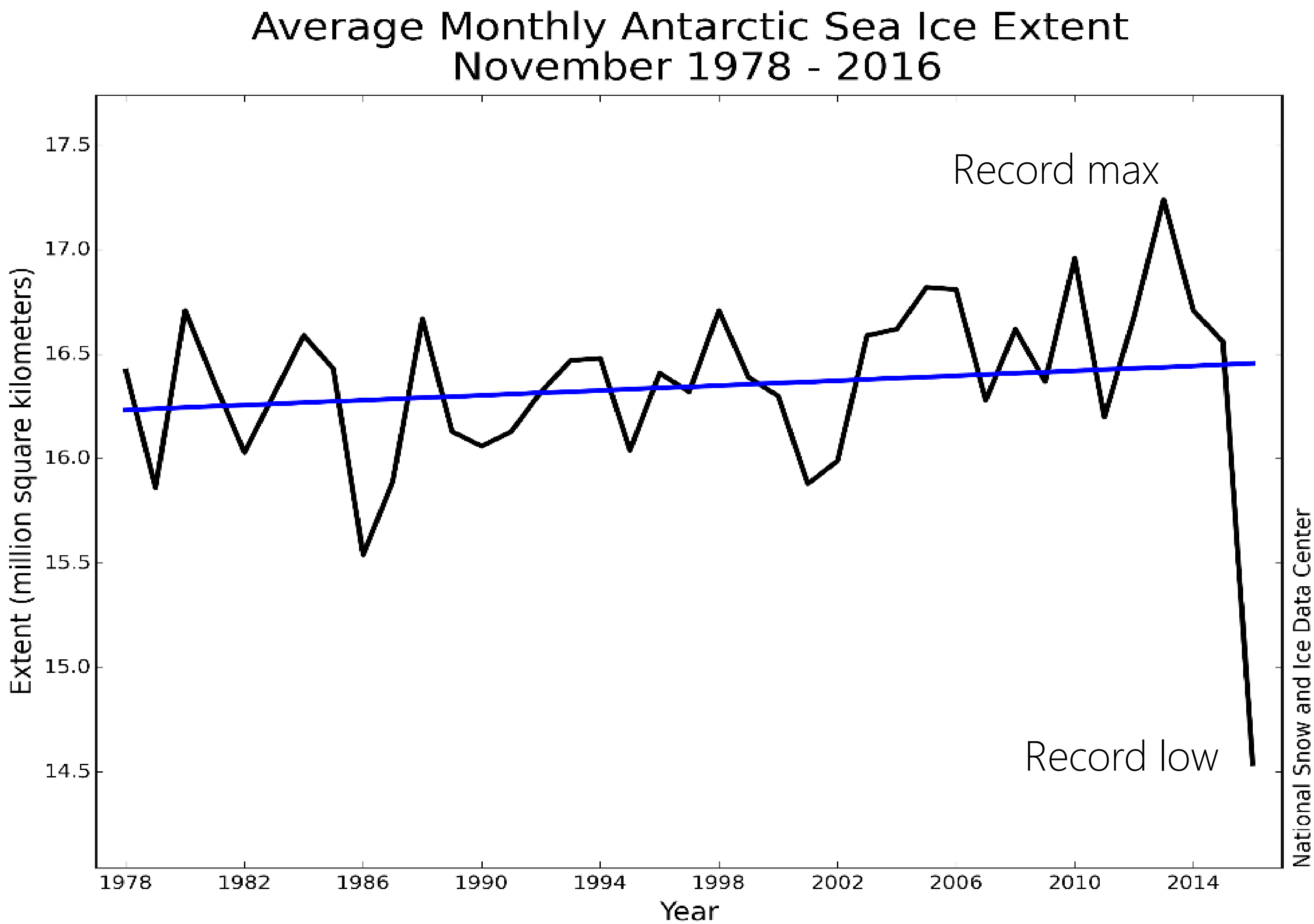
From Pole…





http://blogs.egu.eu/divisions/cr/2017/06/23/image-of-the-week-heat-waves-during-polar-night/

… to Pole


Average Monthly Antarctic Sea Ice Extent
November 1978 - 2016
Extent (million square kilometers)
17.5
17.0
16.5
16.0
15.5
15.0
14.5
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year
Record max
Record low
National Snow and Ice Data Center

Sea Ice

Sea Ice

Research at the European level

Predictability and prediction

State and parameter estimation

Non-radiative feedbacks

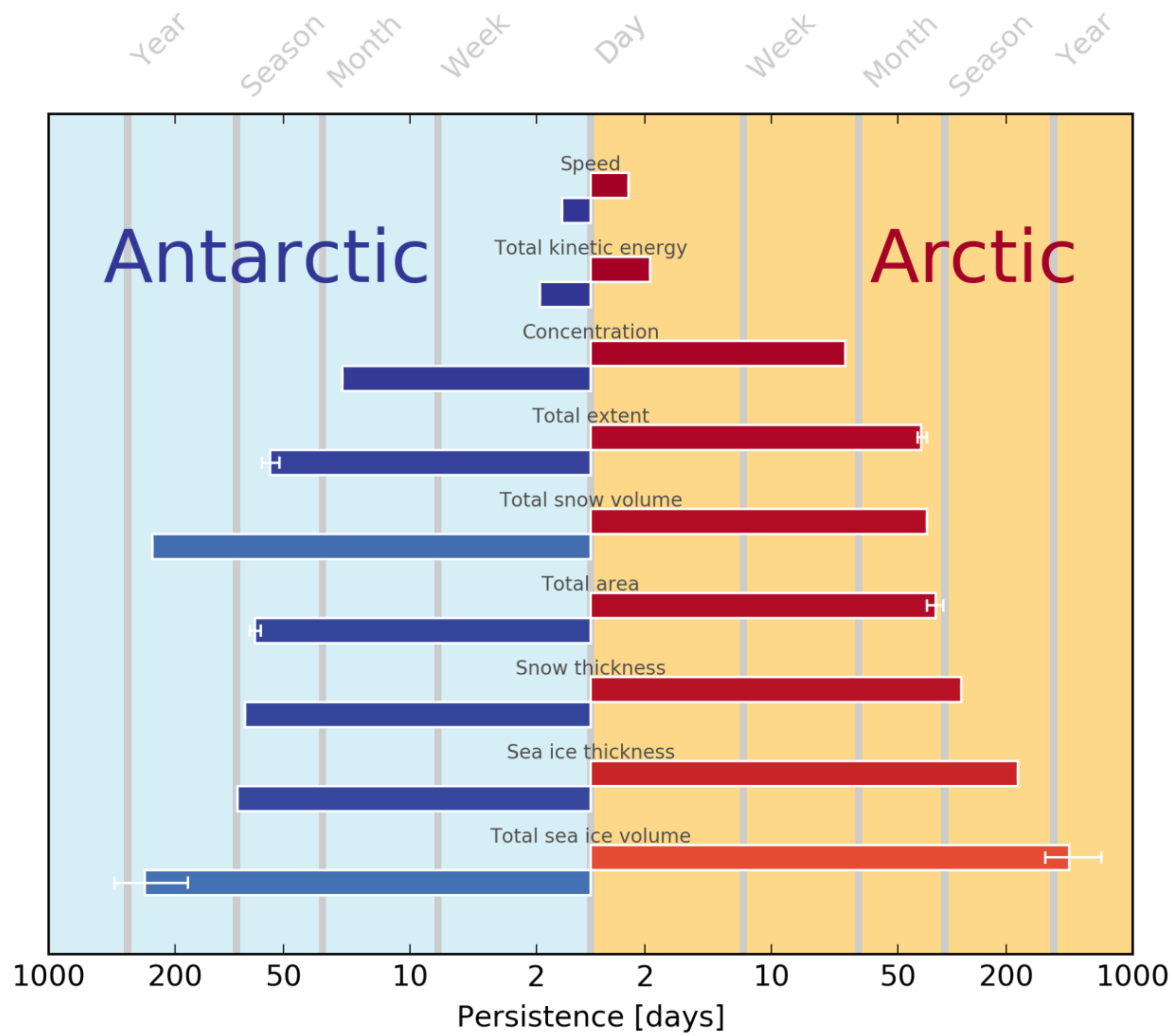
Model evaluation & sensitivity

Model development

Predictability and prediction

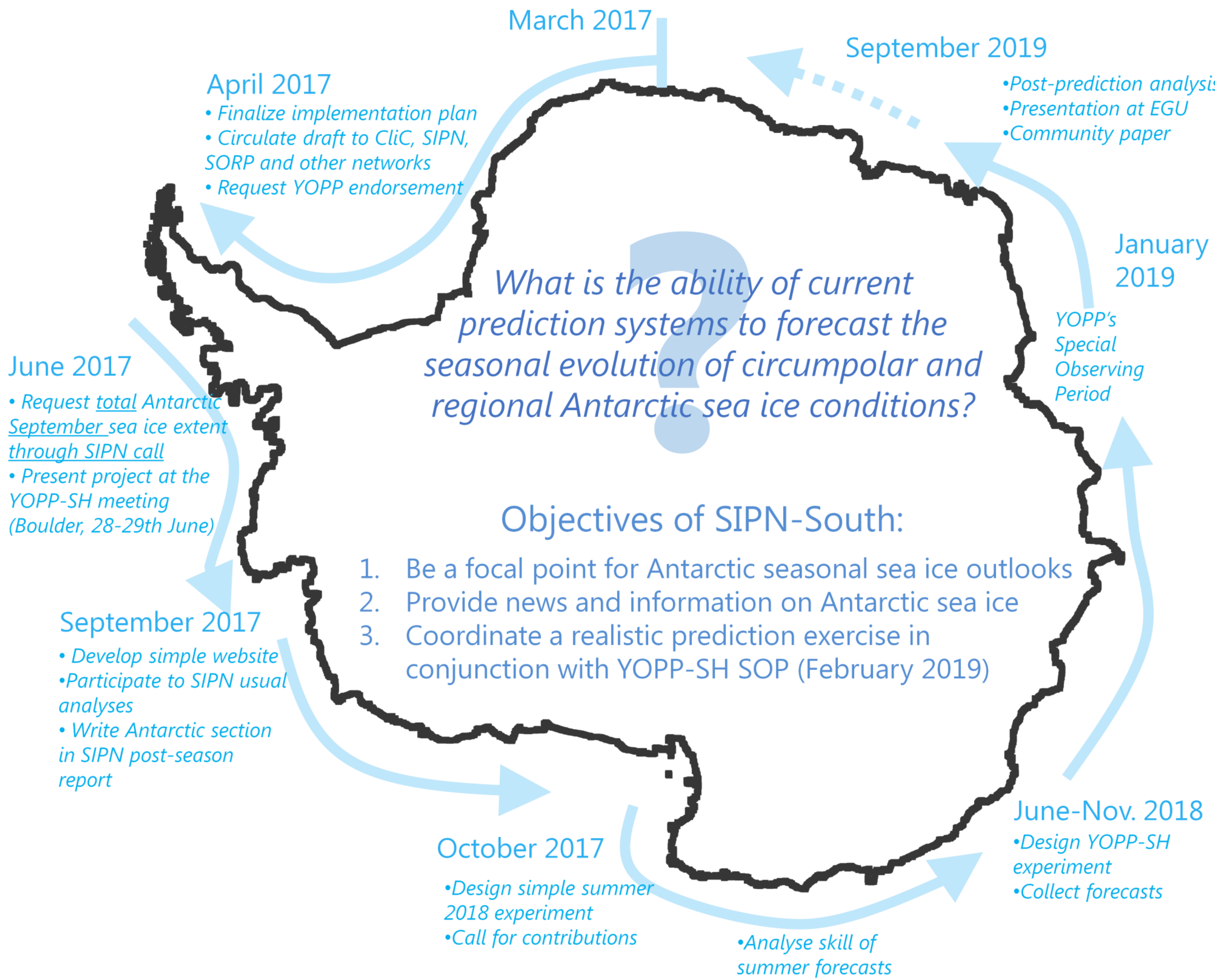
Sea Ice

Sub-seasonal to seasonal predictability of sea ice

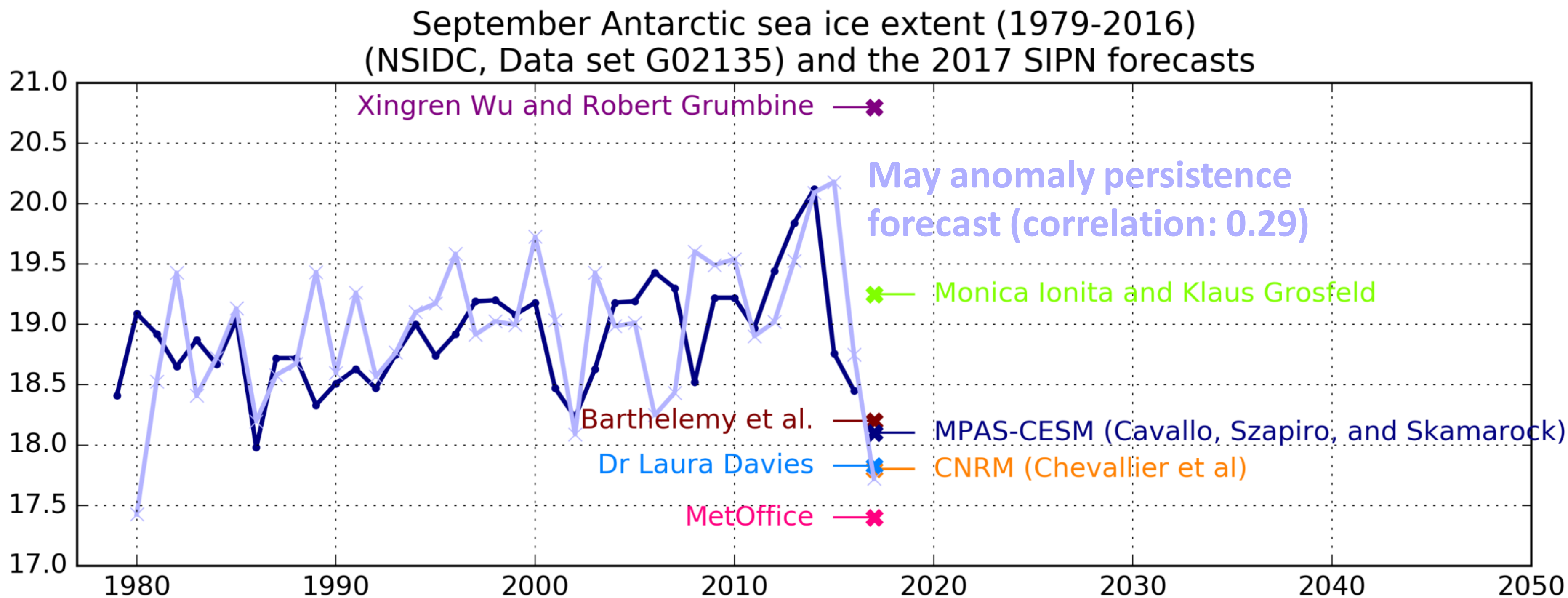


Chevallier, Massonnet, Goessling, Jung, Guemas, in prep.

SIPN South: roadmap (2017-2019)

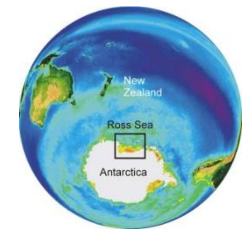


The first Antarctic sea ice outlook

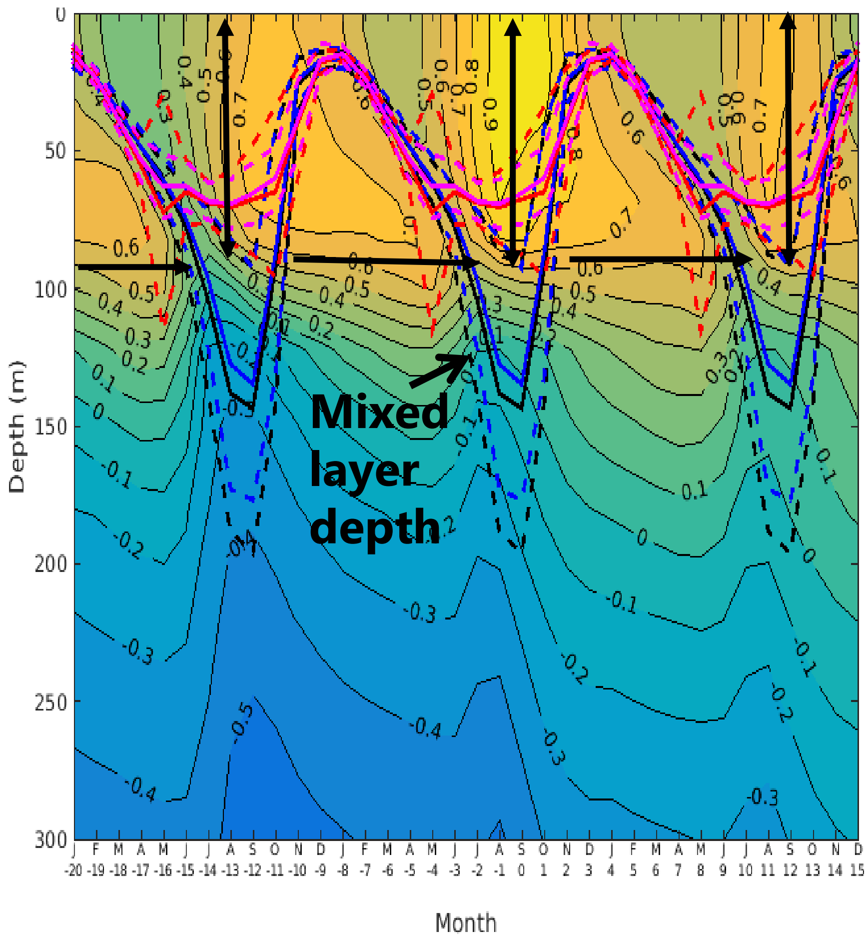


- The circumpolar sea ice extent as such has limited meaning
- Spread in forecasts is larger than historical range

A mechanism for sea surface predictability in the Southern Ocean

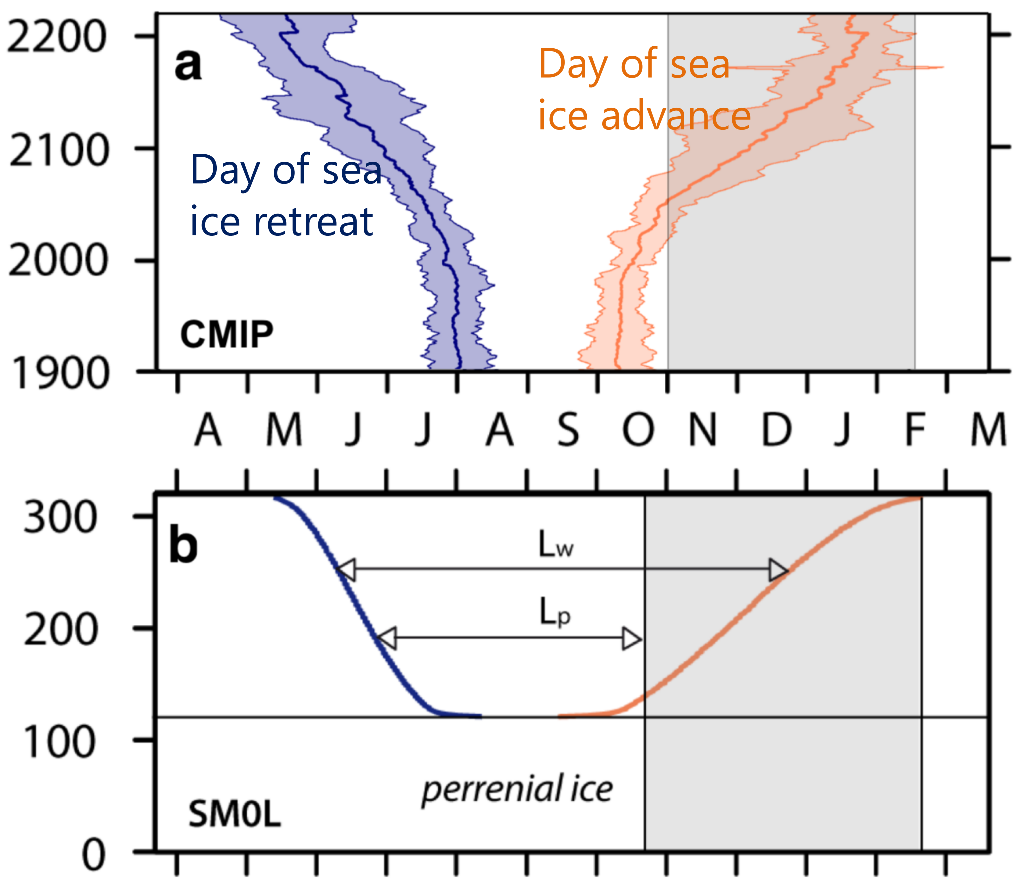


Correlation SST/Potential Temperature
(ctrl run, MPI-ESM model)

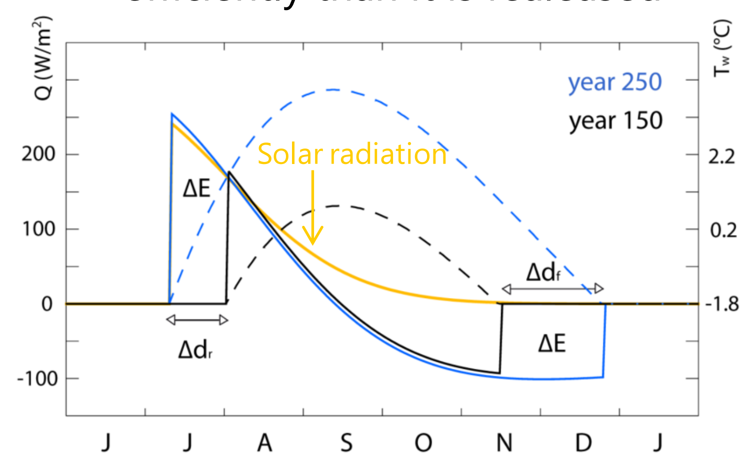


Sylvain Marchi (sylvain.marchi@uclouvain.be)

Amplification of the seasonality of Arctic sea ice



Heat is absorbed much more efficiently than it is realeased



Note: this mechanism is not (yet?) seen in observations

Marion Lebrun (marion.lebrun@locean-ipsl.upmc.fr)

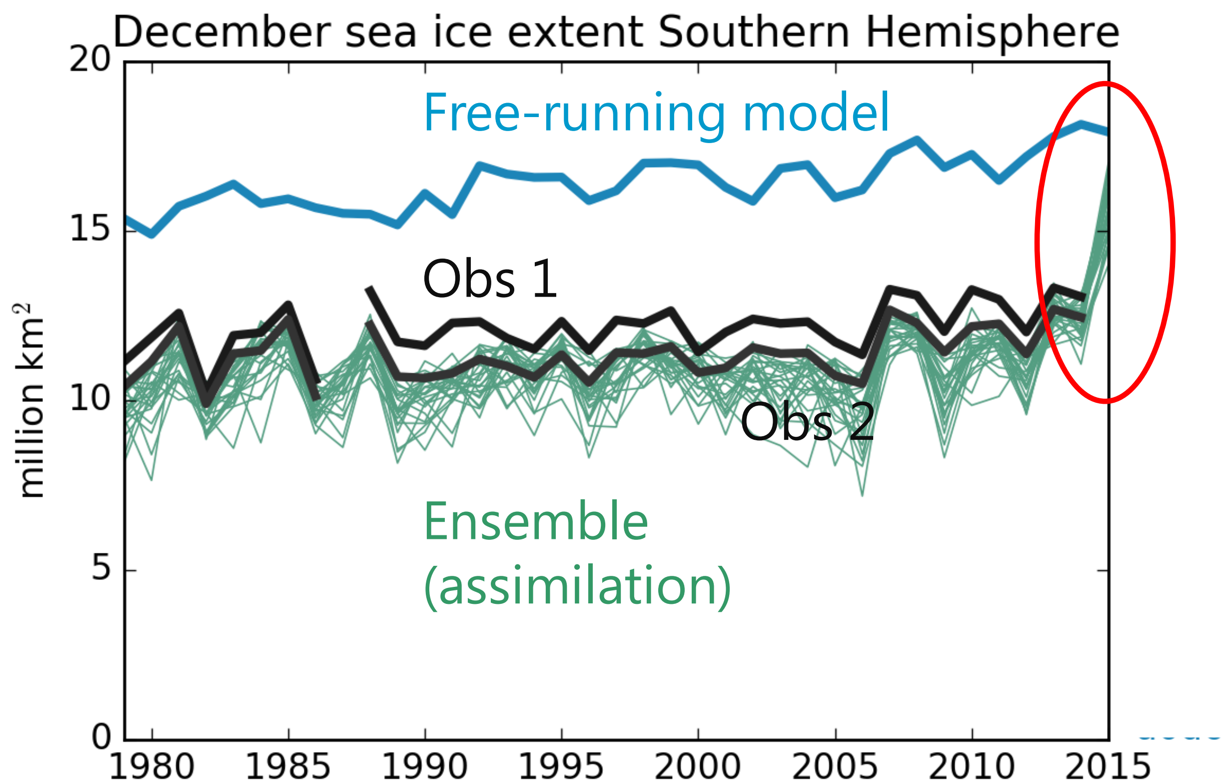
State and parameter estimation

Ensemble Kalman Filter for sea ice data assimilation: pro's and con's

	Nudging	Variational (3D/4D Var)	Sequential methods (EnKF)	Particle filtering
Ease of implementation	Fair	Hard (coding adjoint)	Medium-Hard	Medium
CPU consumption	Low	Low-Medium	High (~20-50 members)	Very high (~100 members to avoid degenerate solution)
Needs changes in model code?	Yes (restoring term added to tendencies)	Yes (adjoint)	No	No
Physical consistency	Little (univariate)	Up to linear approximation	Up to linear approximation	Full consistency
Estimation of prior uncertainty	None	Static	Dynamic	Dynamic
Assumptions to reach optimality	Not defined as an optimization problem	Gaussian centered errors	Gaussian centered errors	None
Produces ensembles?	No	No	Yes (hence available as IC)	Yes (hence available as IC)

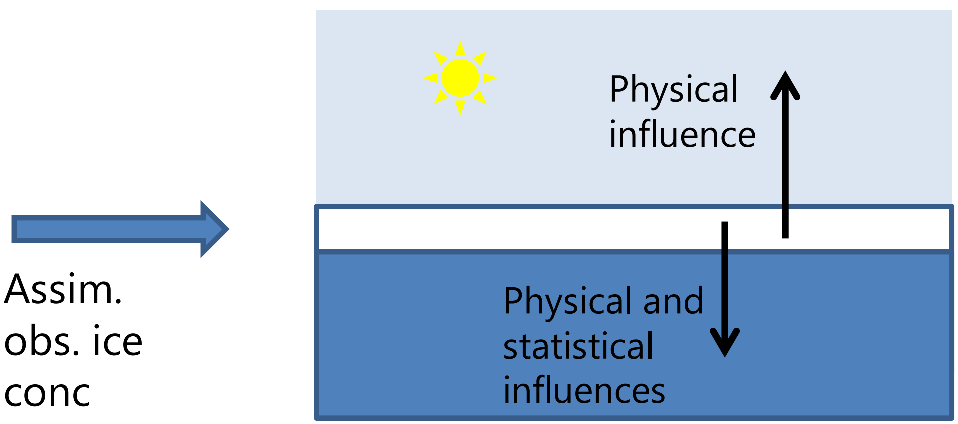
The EnKF is, all in all, a honest tradeoff to estimate a system state with satisfactory physical consistency given limited resources available

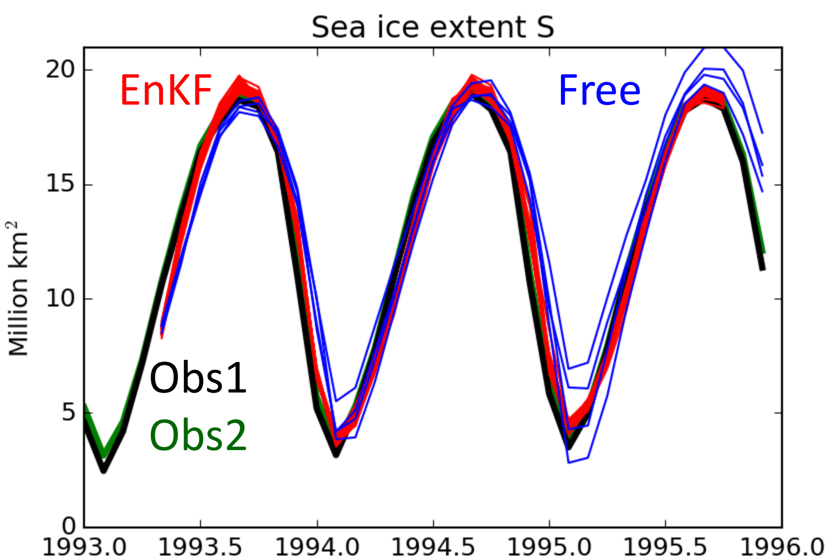
State estimation corrects temporarily the model

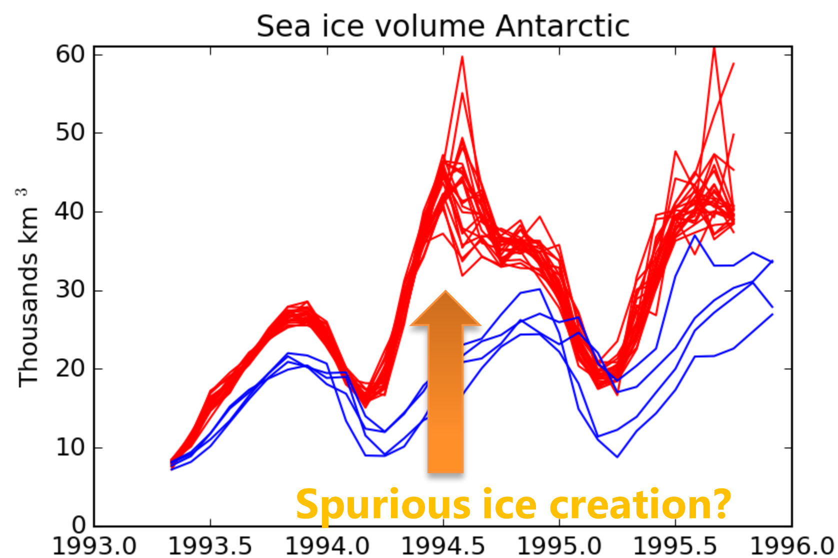


Model: ocean-sea ice + atmospheric forcing

Strongly coupled sea-ice / ocean data assimilation in a coupled model

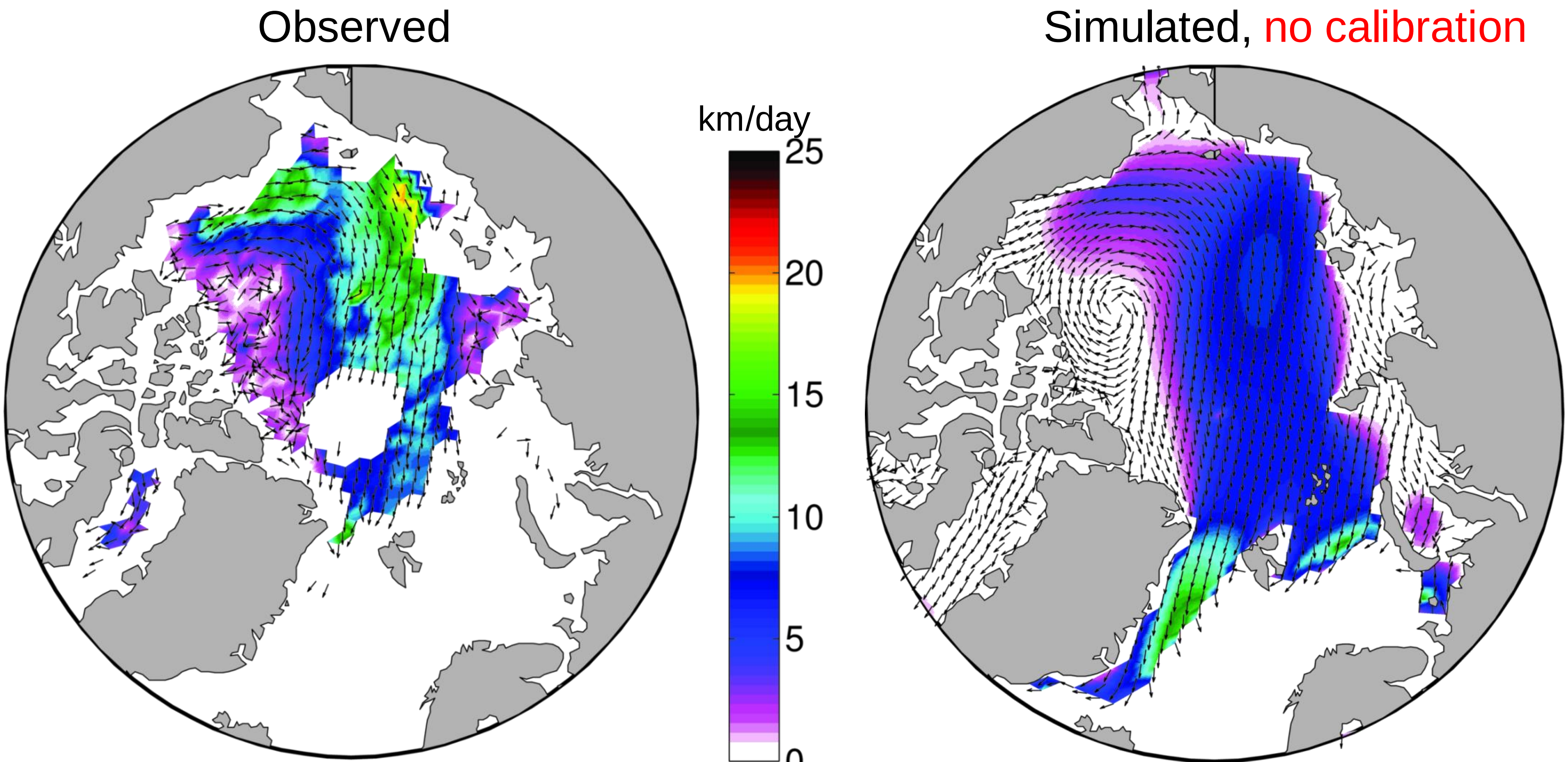






Parameter estimation

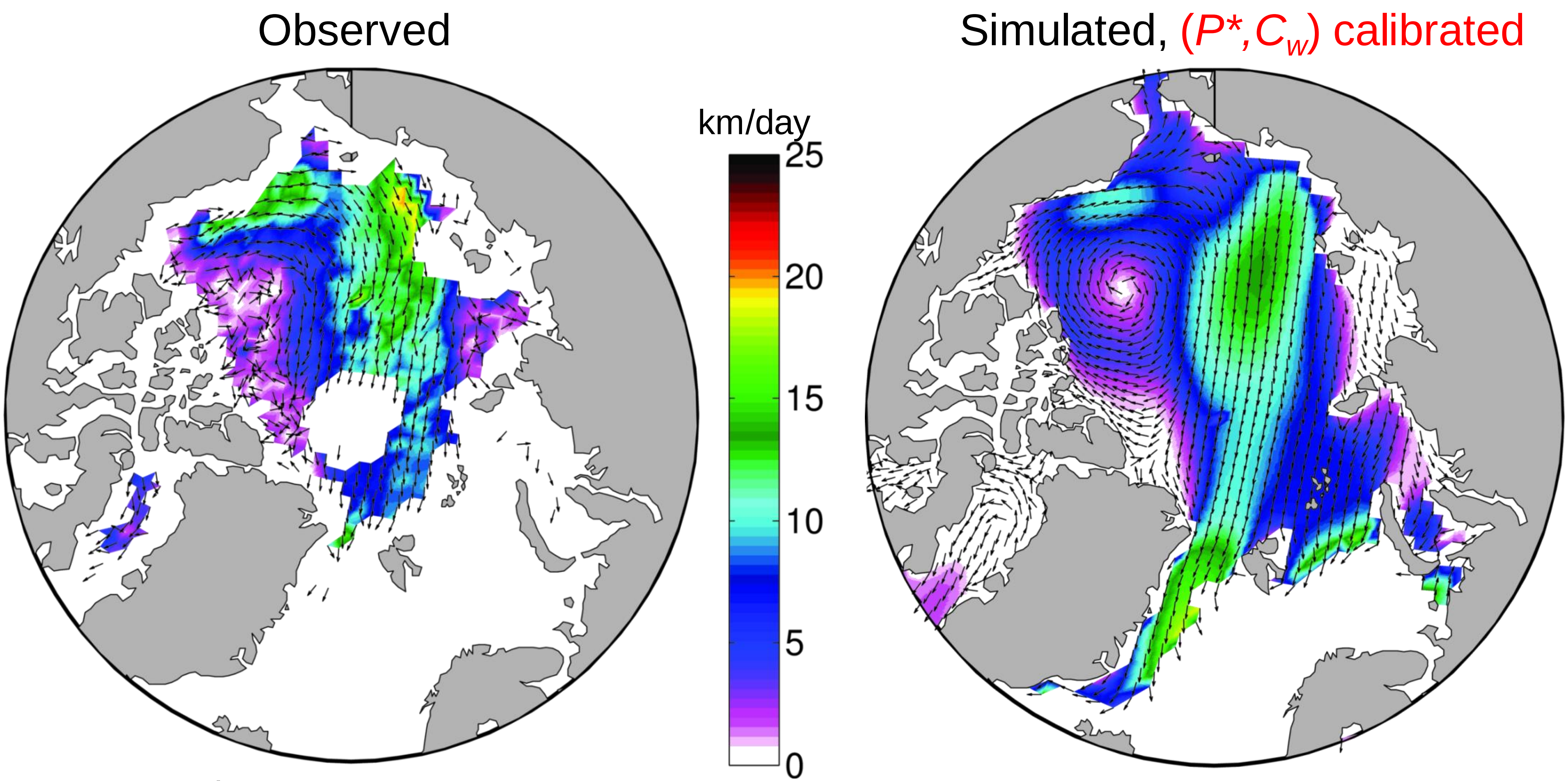
12→14 April 2012 sea ice drift



Massonnet al., JGR, 2014

Parameter estimation

12→14 April 2012 sea ice drift



Massonnet al., JGR, 2014


Non-radiative
feedbacks

Linear radiative feedback theory

$$\Delta R = F + \lambda \Delta T_s$$

Top-of-atmosphere radiative imbalance

Radiative forcing

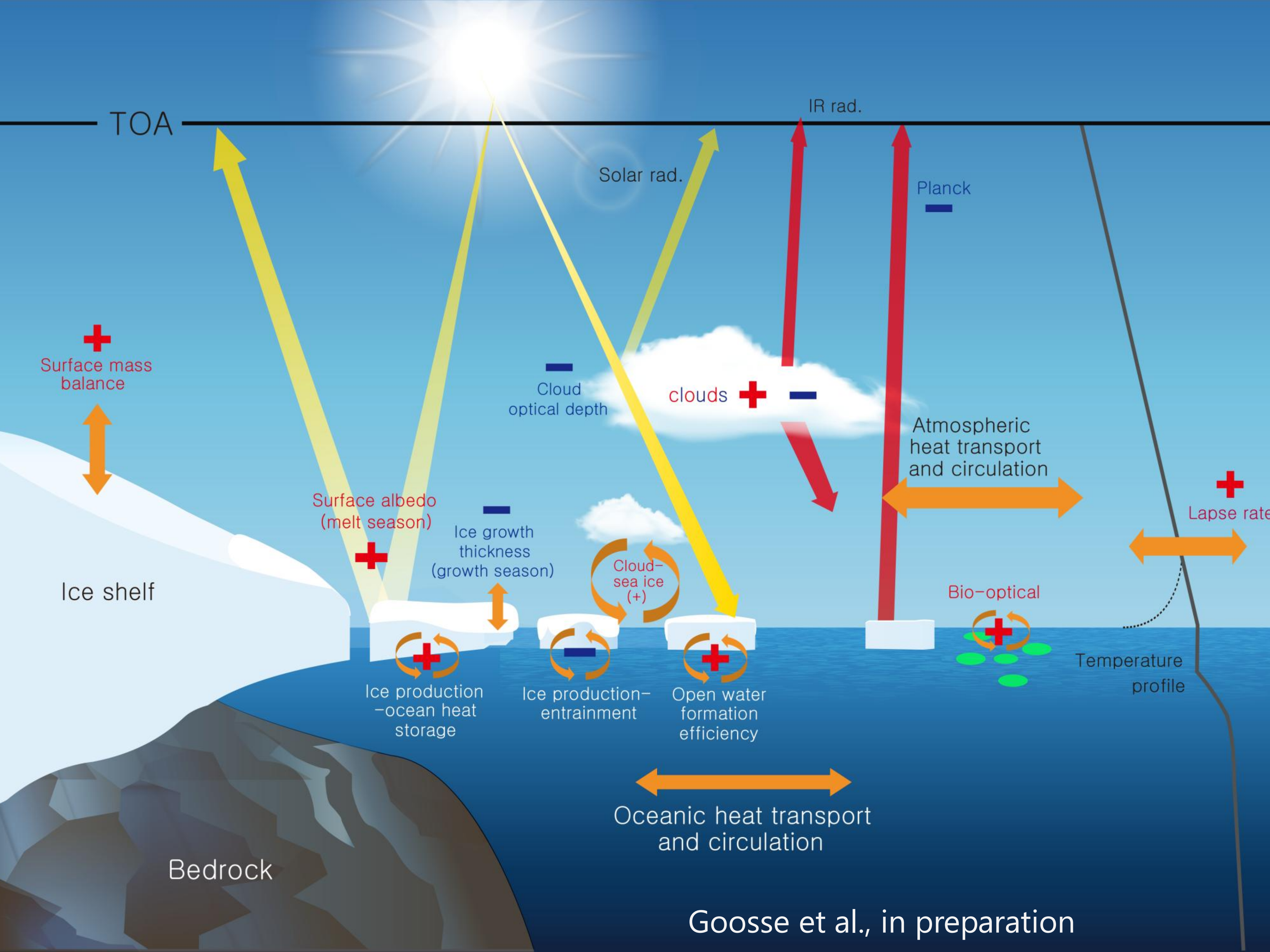
(Net) climate feedback parameter

Surface temperature change

$$\lambda = \lambda_{Planck} + \underbrace{(\lambda_1 + \lambda_2 + \ldots)}_{\text{Parameters associated to specific agents (albedo, clouds, ...)}}$$

Parameter associated to a reference response (black-body)

Parameters associated to specific agents (albedo, clouds, ...)



Goosse et al., in preparation

Linear radiative feedback theory

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Top-of-atmosphere radiative imbalance

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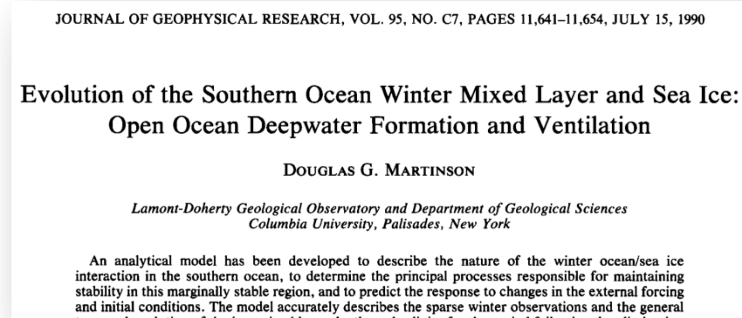
Surface temperature change

$$\lambda = \lambda_{Planck} + \underbrace{(\lambda_1 + \lambda_2 + \ldots)}_{\text{Parameters associated to specific agents (albedo, clouds, ...)}}$$

Parameter associated to a <u>reference</u> response (black-body)

$$\gamma_i = -\lambda_i / \lambda_{Planck} = \frac{\text{Total response} - \text{Reference response}}{\text{Total response}}$$

The negative ice production-ocean entrainment feedback

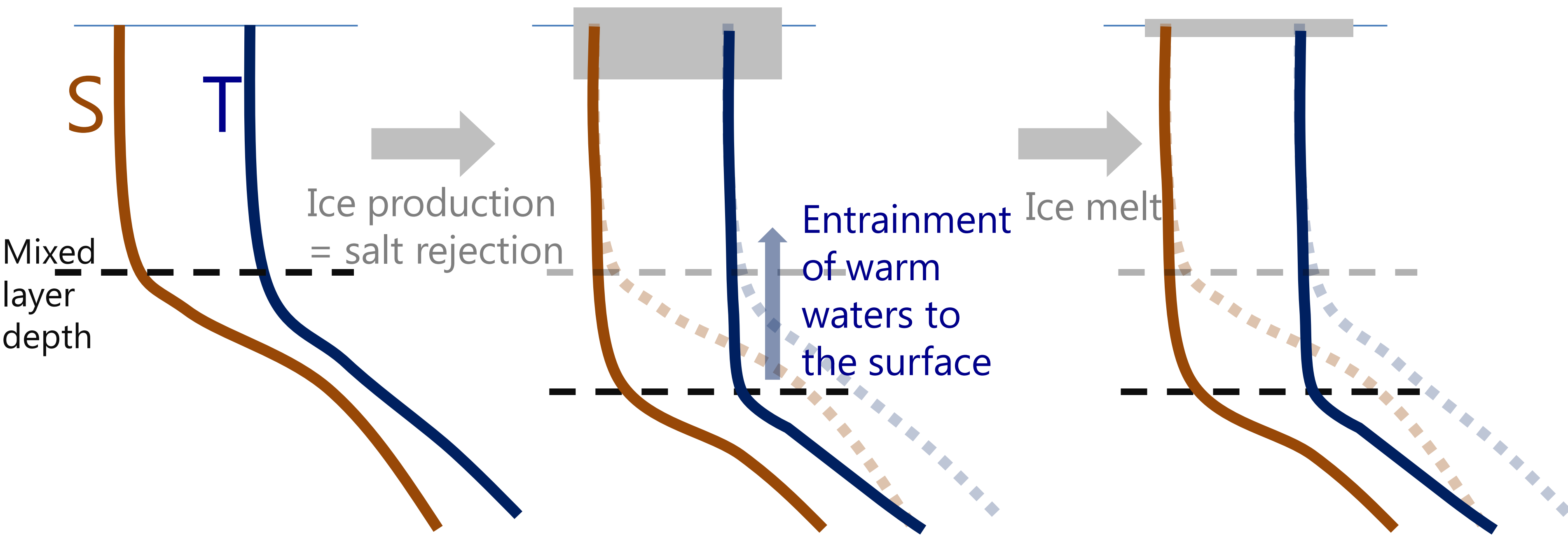

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 95, NO. C7, PAGES 11,641–11,654, JULY 15, 1990

Evolution of the Southern Ocean Winter Mixed Layer and Sea Ice: Open Ocean Deepwater Formation and Ventilation

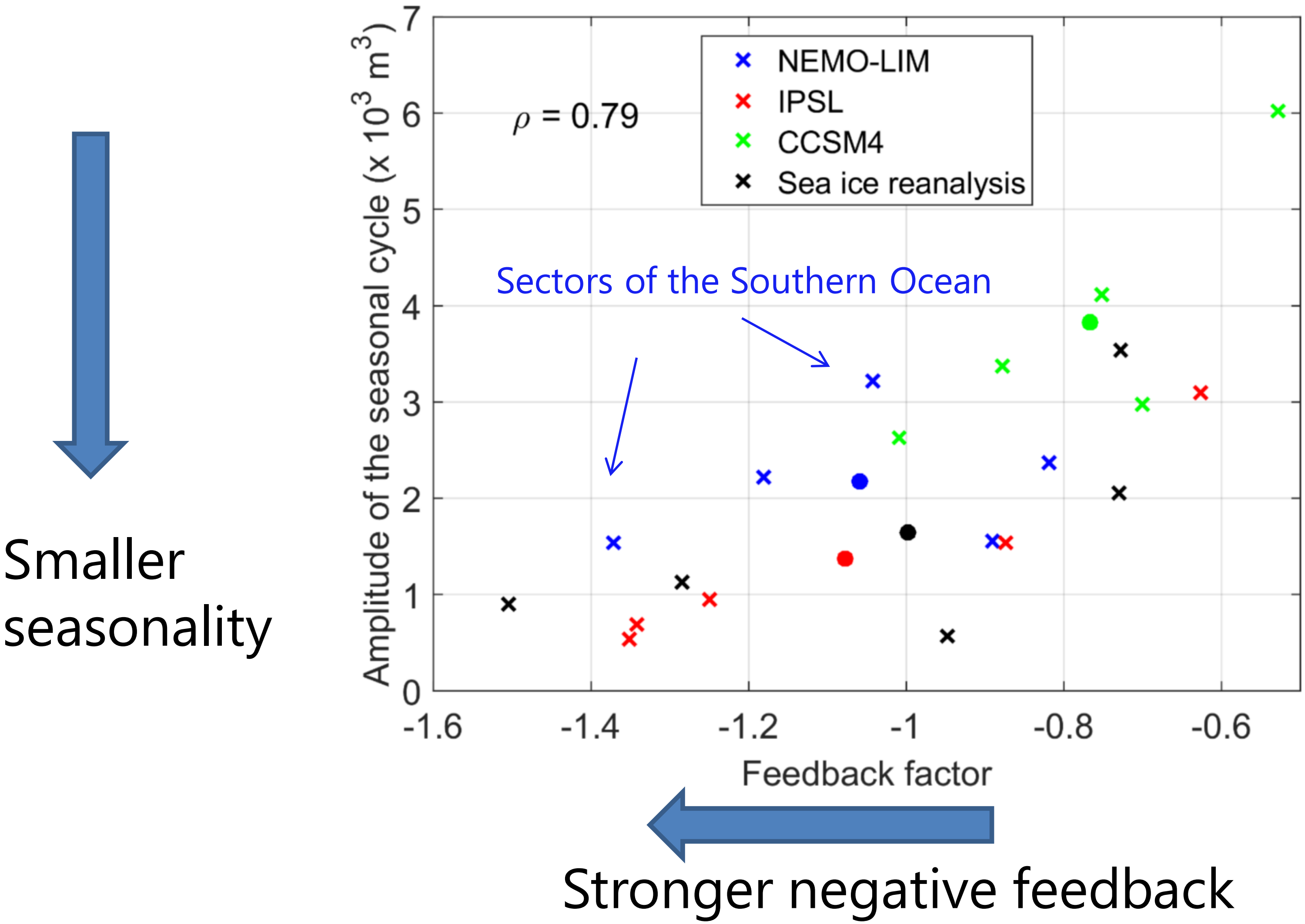
DOUGLAS G. MARTINSON

Lamont-Doherty Geological Observatory and Department of Geological Sciences Columbia University, Palisades, New York

An analytical model has been developed to describe the nature of the winter ocean/sea ice interaction in the southern ocean, to determine the principal processes responsible for maintaining stability in this marginally stable region, and to predict the response to changes in the external forcing and initial conditions. The model accurately describes the sparse winter observations and the general



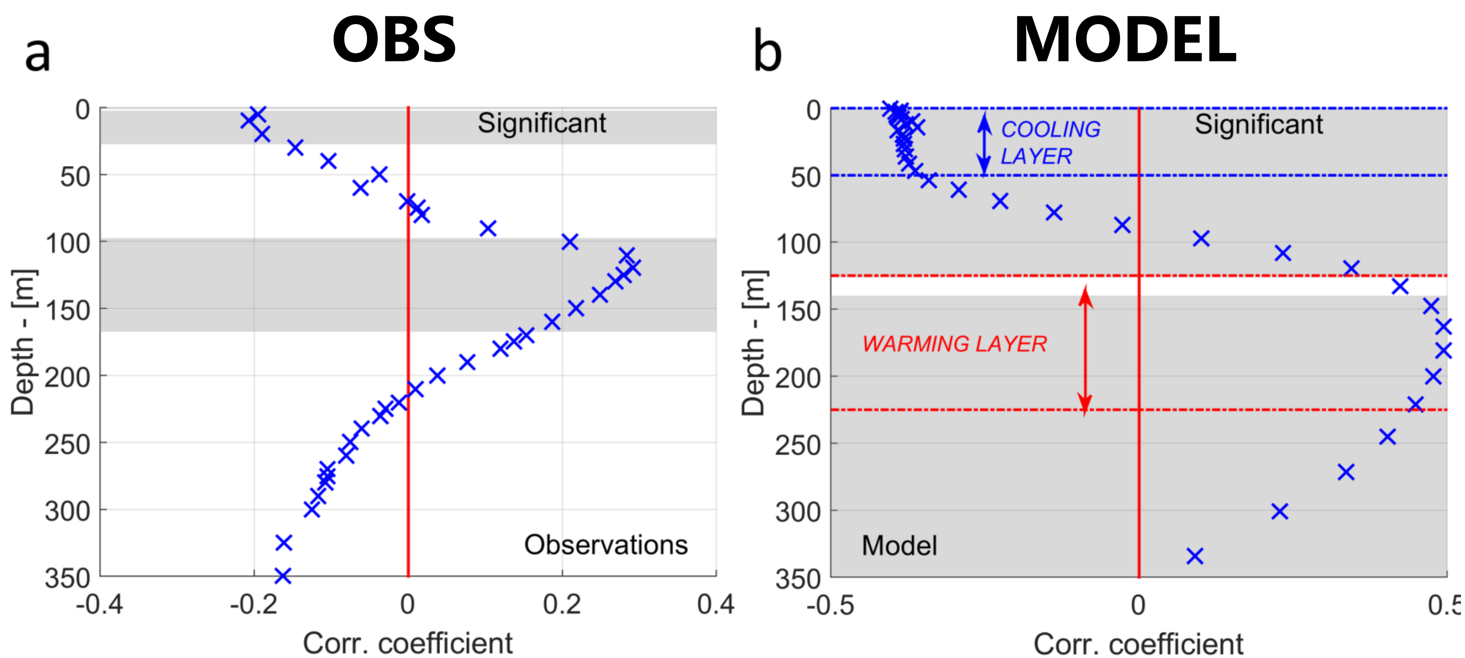
Spread in feedback explains spread in mean state



Goosse et al., in preparation (hugues.goosse@uclouvain.be)

A positive feedback to explain increases in Ross Sea

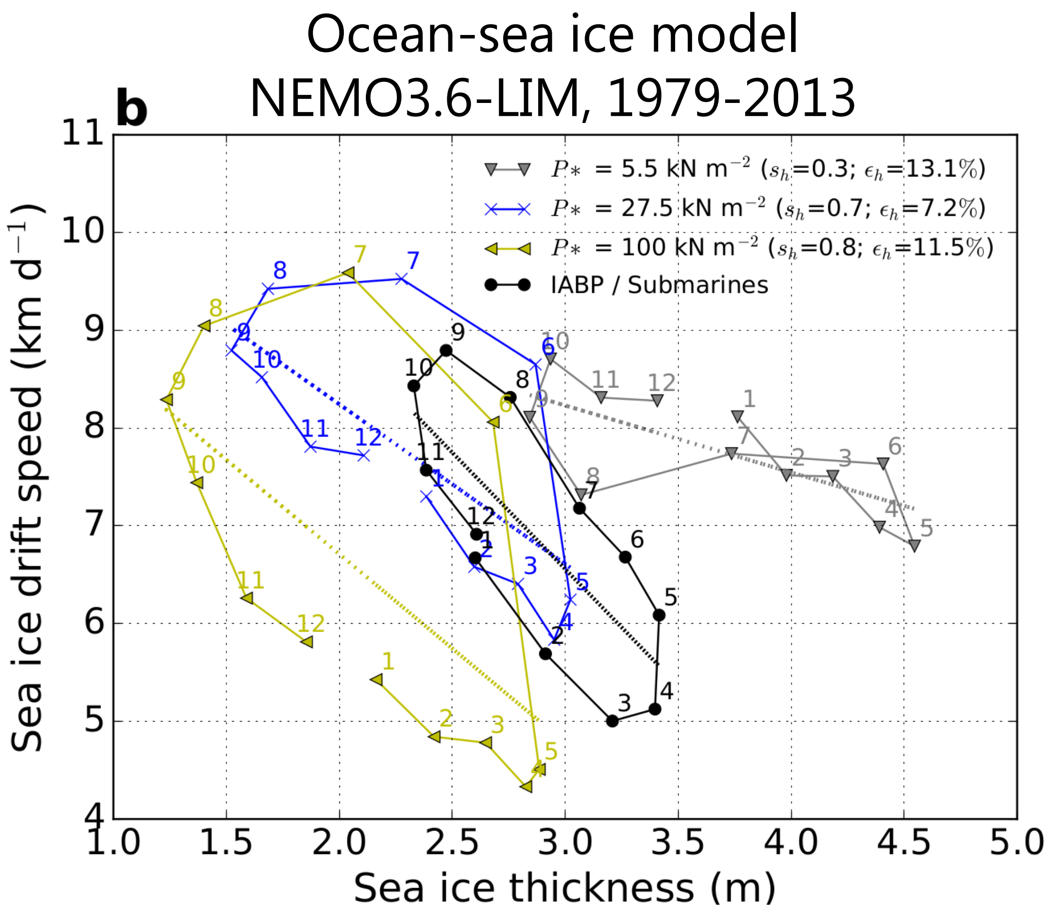
Correlation sea ice concentration x ocean temperature trends



Lecomte et al., Nature Comm. (accepted)
(olivier.lecomte@uclouvain.be)

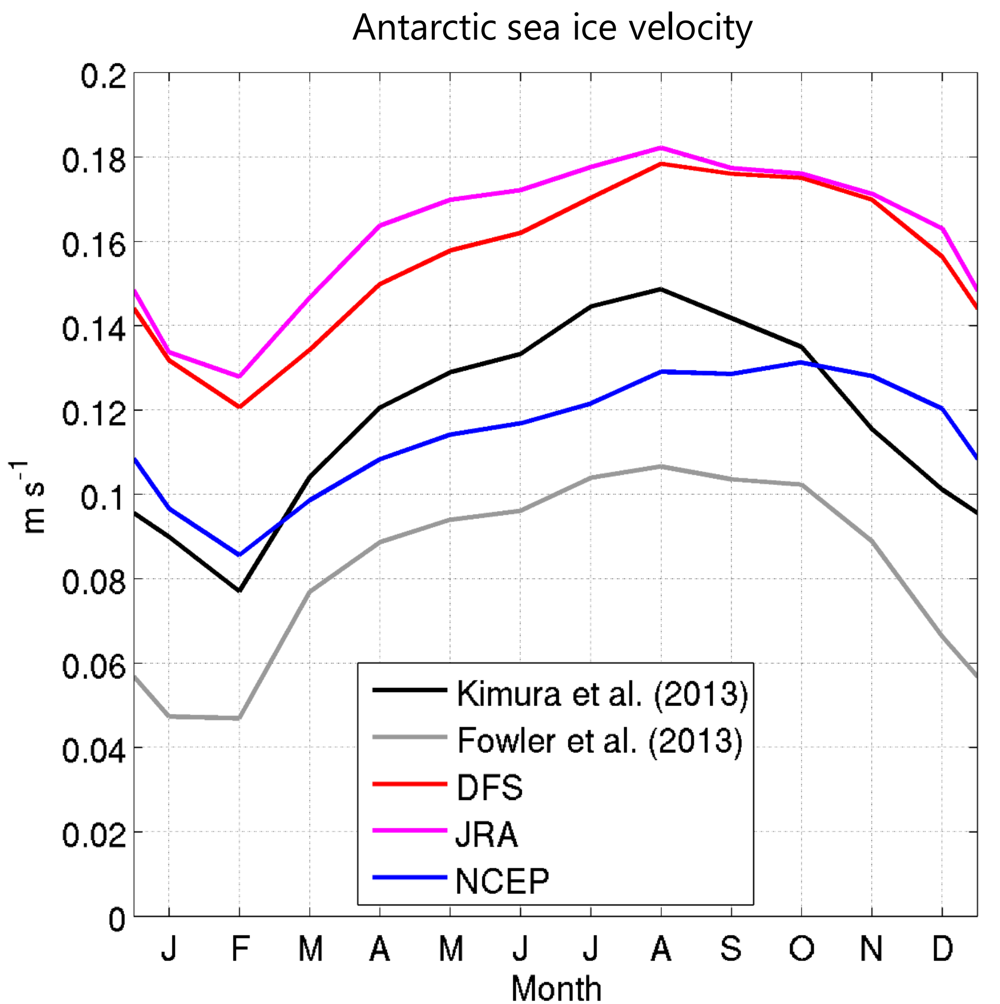
Model evaluation & sensitivity

Process-oriented metrics allow to better understand the role played by uncertain parameters



David Docquier (david.docquier@uclouvain.be)

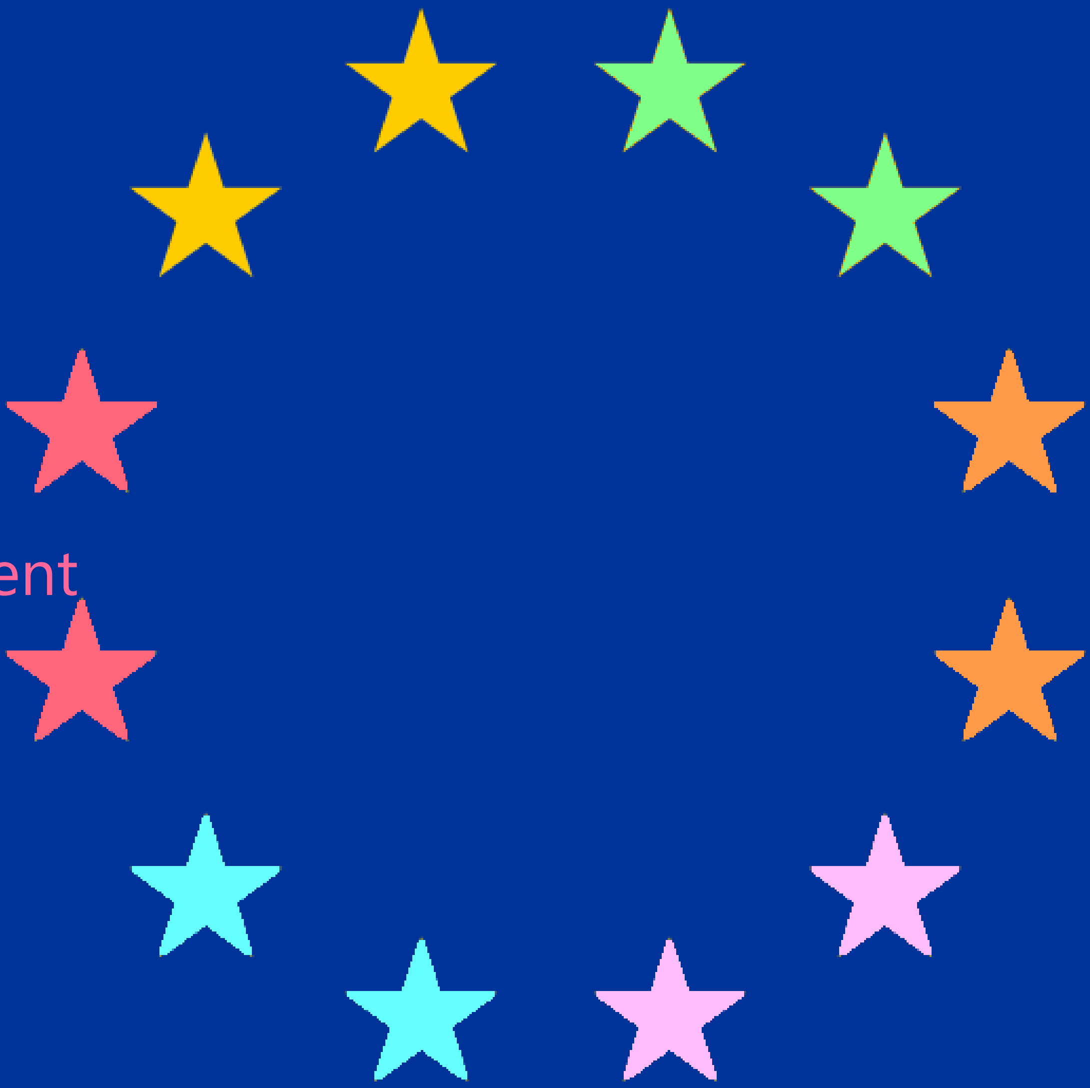
Exploring the uncertainty of sea ice response to atmospheric forcing



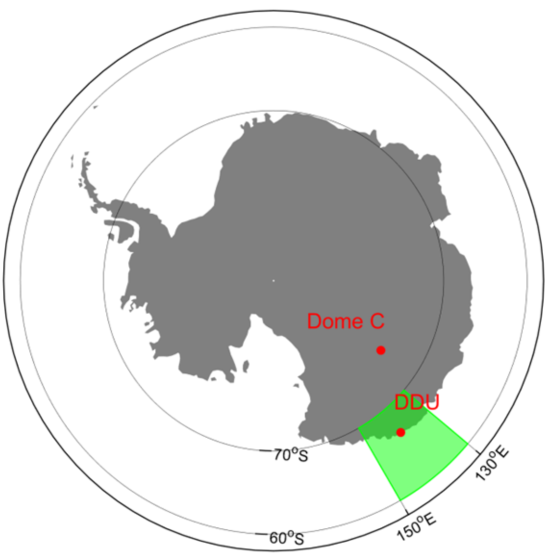
Same model, 3 atm. forcings

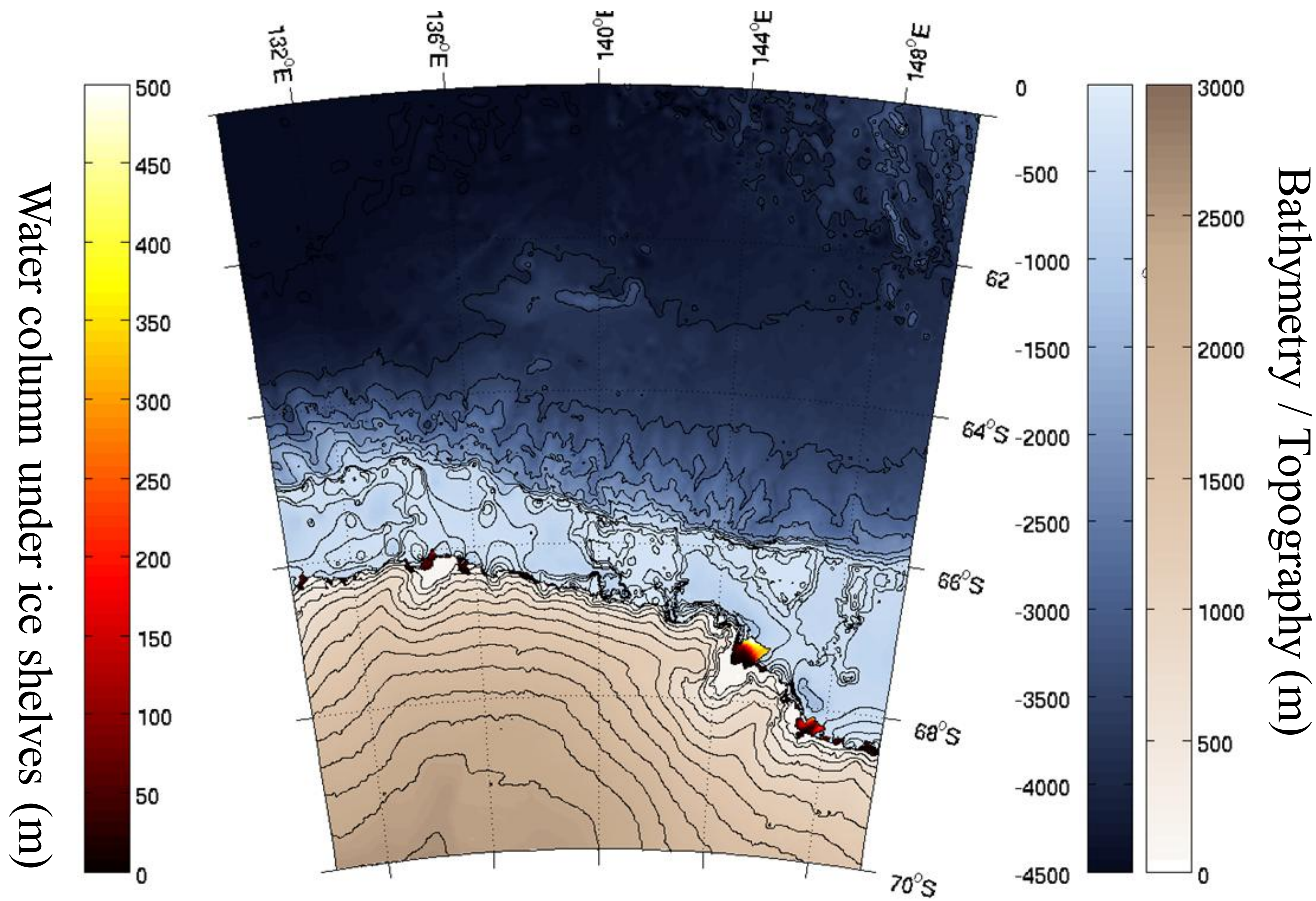
2 obs. products

Model
development



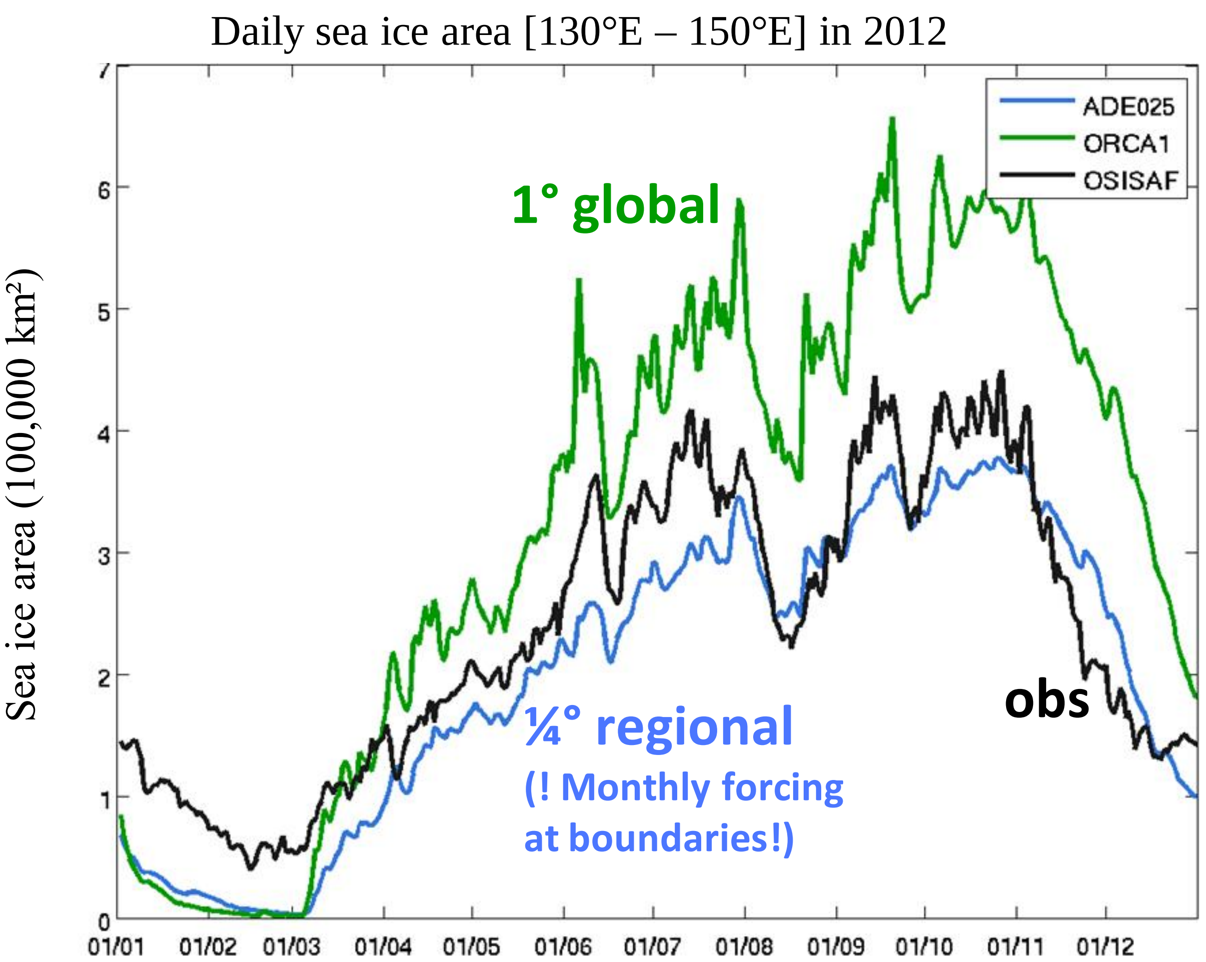
Development of a regional coupled ocean-sea ice-atmosphere model (~2km)



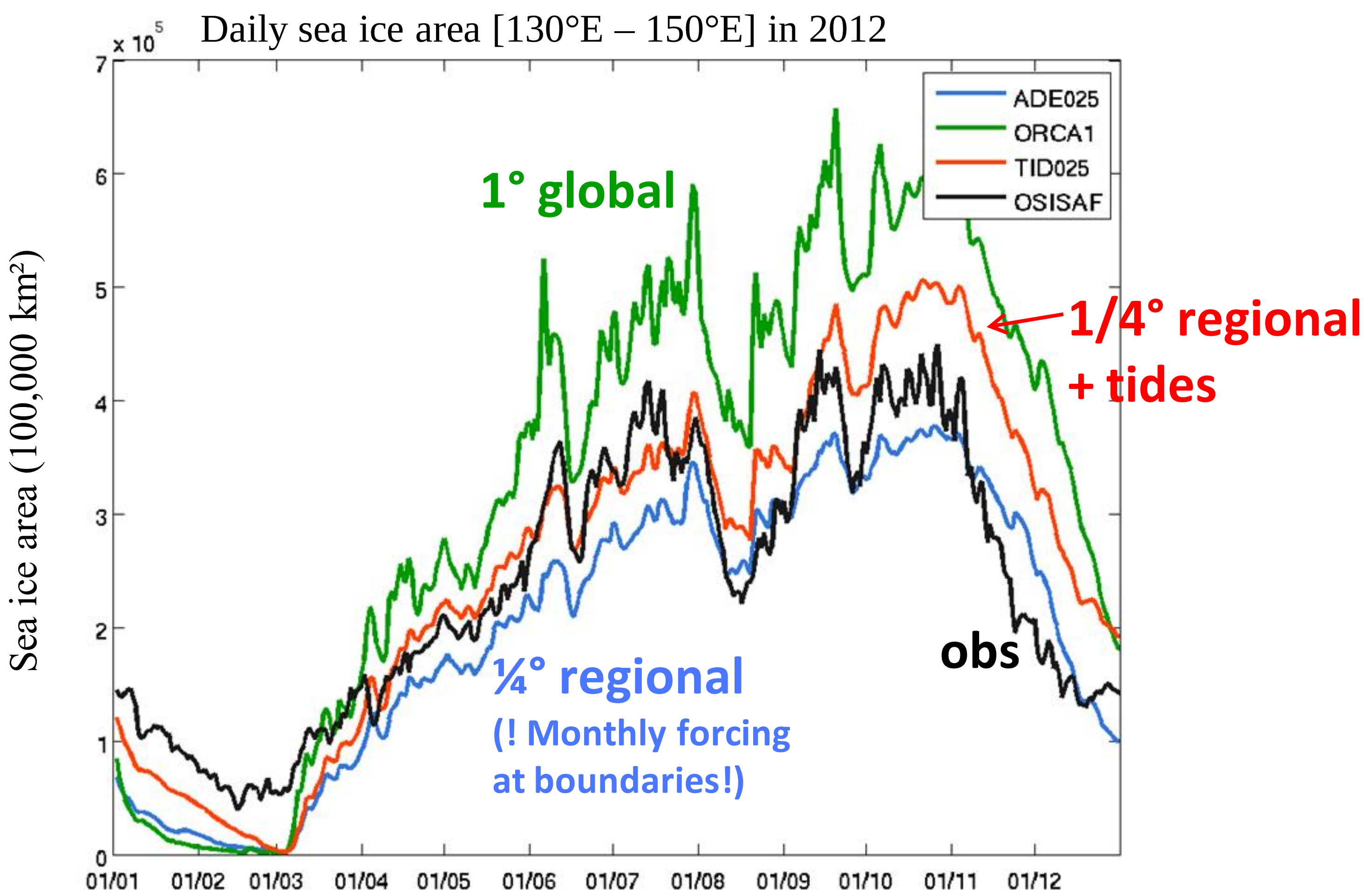


Pierre-Vincent Huot (pierre-vincent.huot@uclouvain.be)
Thierry Fichefet (thierry.fichefet@uclouvain.be)

Effect of switching from global 1° res to regional 1/4° res.



Effect of switching from global 1° res to regional 1/4° res.



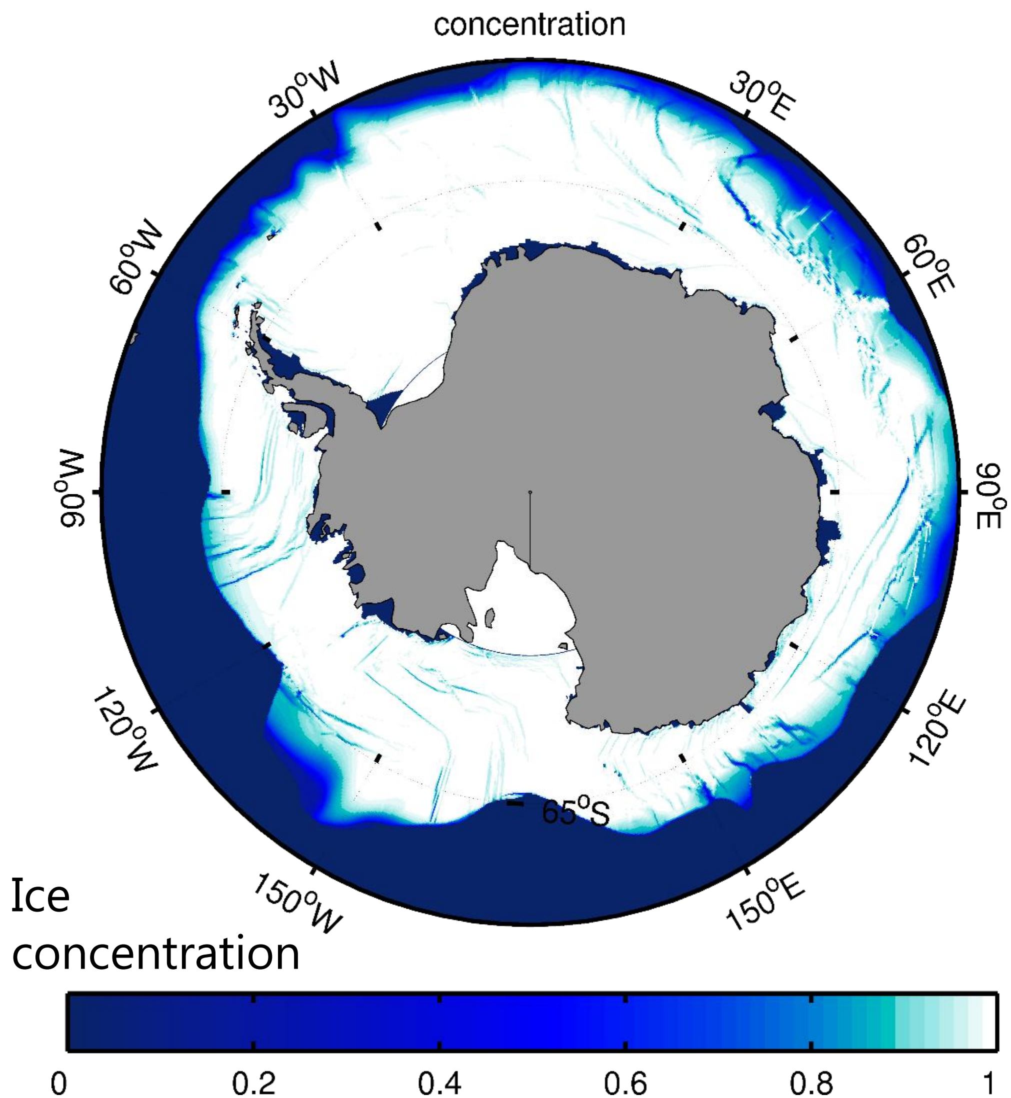
Introduction of the Maxwell-elastic-brittle rheology into NEMO-LIM3

Maxwell-elasto-brittle rheology:

- Maxwell model :
  → **elastic** media + apparent **viscosity.**
- Brittle behaviour :
  → **damaging** event;
  → **weakening** of sea ice.

Purposes :

- reproduce the **anisotropy** and **intermittency** of the deformation;
- simulate the right degree of **localization** of the deformation;
- reproduce the formation and evolution of **leads.**



Jonathan Raulier
(jonathan.raulier@uclouvain.be)

Research at the European level

APPLICATE:
-8 M€ project
-4 years
-16 partners from 9 countries (incl. Russia & UK)

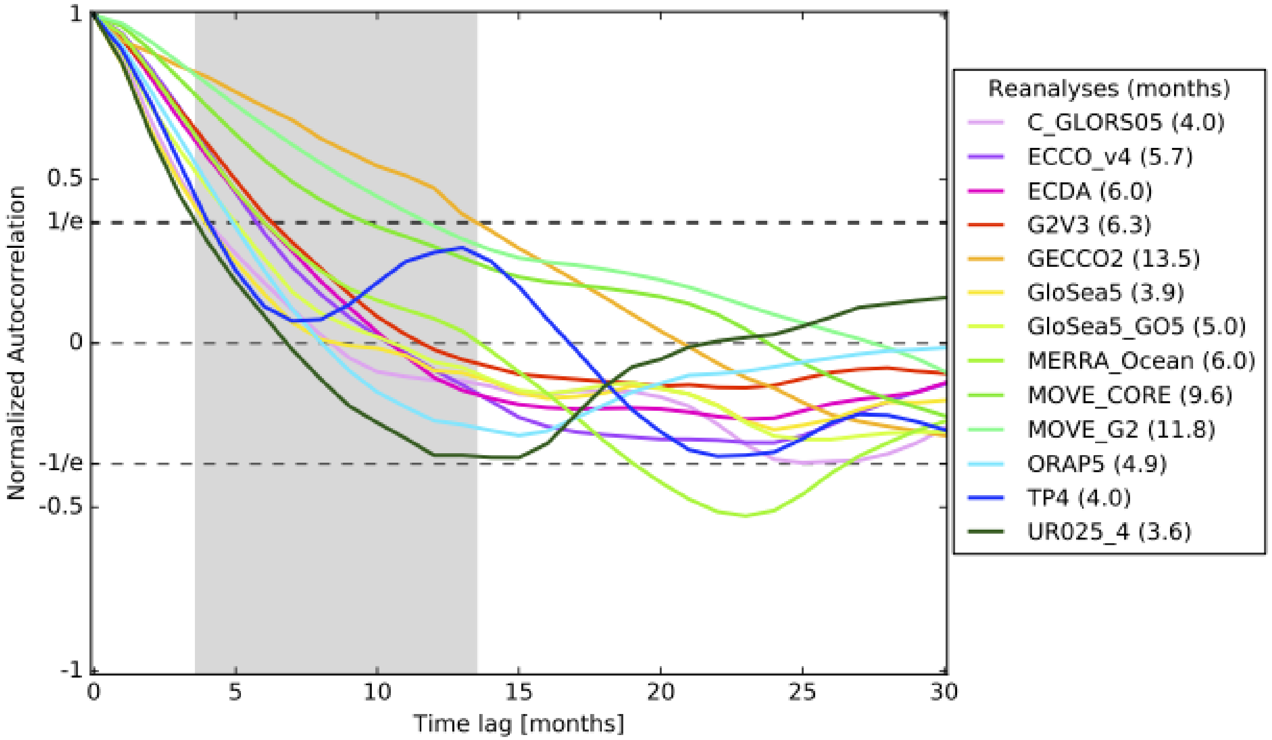
Goals
1. Improve weather and climate prediction in Arctic region
2. Study linkages to lower latitudes of a changing Arctic
3. Build a seamless polar research community

European Commission
Horizon 2020
European Union funding
for Research & Innovation

APPLICATE
www.applicate.eu
Advanced prediction in Polar regions and beyond

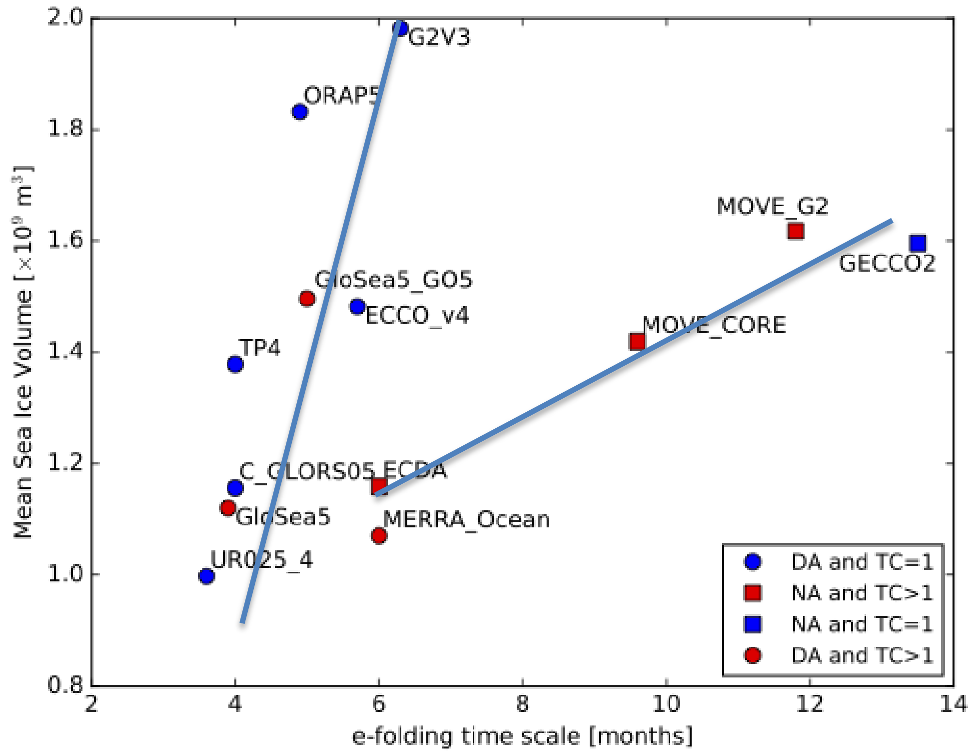
Persistence characteristics of state-of-the-art reanalyses

Auto-correlation of Arctic sea ice volume

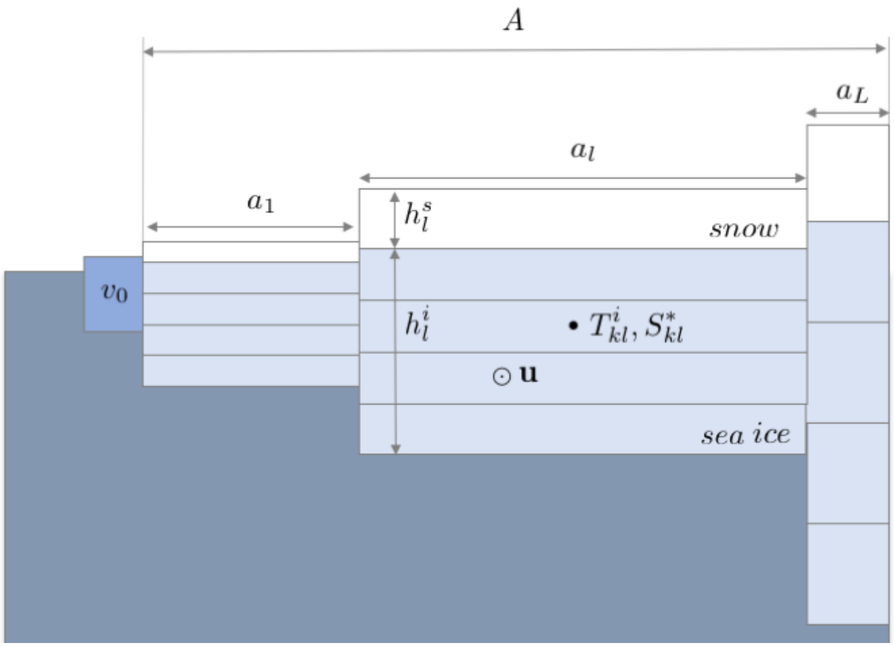


L. Ponsoni (leandro.ponsoni@uclouvain.be)

Sea ice data assimilation systematically shortens persistence



L. Ponsoni (leandro.ponsoni@uclouvain.be)



LIM 3.6
GELATO
CICE

C/C/B-grid AIDJEX model (Coon et al 74) with enthalpy and salt conservation and rheology

$$m \frac{\partial \boldsymbol{u}}{\partial t} = \boldsymbol{\nabla} \cdot \boldsymbol{\sigma} + A\left(\boldsymbol{\tau}_a + \boldsymbol{\tau}_w\right) - m f \boldsymbol{k} \times \boldsymbol{u} - m g \boldsymbol{\nabla} \eta,$$

Momentum

$$\boldsymbol{\sigma} = \boldsymbol{\sigma}(\dot{\epsilon}, \text{ice state}).$$

Rheology

EVP, EVP, EVP/EAP

$$\frac{\partial X}{\partial t} = -\underline{\nabla.(\mathbf{u}X) + \Theta^X + \Psi^X}$$

Tracer conservation

$$q_m(S,T) = \left[c_i(T + \mu S) - L\left(1 + \frac{\mu S}{T}\right) - c_w \mu S\right]$$

Enthalpy formulation

Sea ice in NEMO in 2017

- 4 sea ice models (LIM2, LIM3, GELATO, CICE)
  No major difference

- Many duplications

- Slow evolution:
  more time spent on technical details
  than on scientific progress

Choice:
a <u>unified</u>
sea ice model
for NEMO

Sea Ice

Research at the European level

Predictability and prediction

State and parameter estimation

Non-radiative feedbacks

Model evaluation & sensitivity

Model development

Thank you!

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