IC3 • Barcelona
11th December 2013

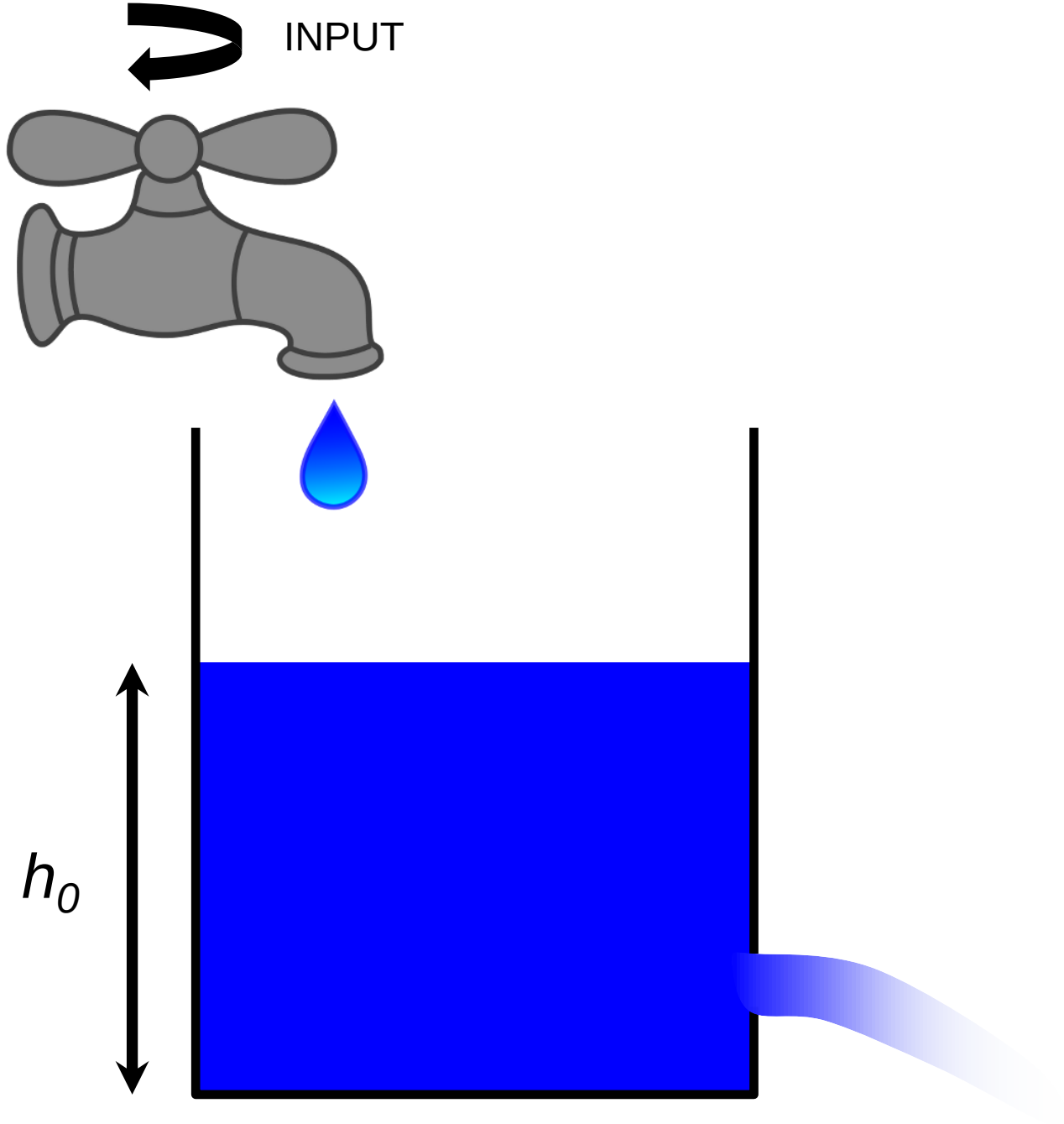
Calibration of sea ice dynamic parameters

François Massonnet

H. Goosse, T. Fichefet, F. Counillon

UCL Université catholique de Louvain

NERSC


INPUT
h_0

```
clc; clear all; close all

g=9.81;                                 % accélération de la
                                        gravité
h0=0.34;                                % hauteur initiale du
                                        niveau d'eau
dt=0.1;                                 % pas de temps
tf=30;                                  % durée de la
                                        simulation
h=zeros(length(0:dt:tf),1)              % h(t), à trouver

                                ...

alpha=1.34                              % Coefficient de
                                        % bidouillage


                                ...
for t=1:dt:tf
      [a,b,c]=compute_gain(h(t-1))
      ...
```

```
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```
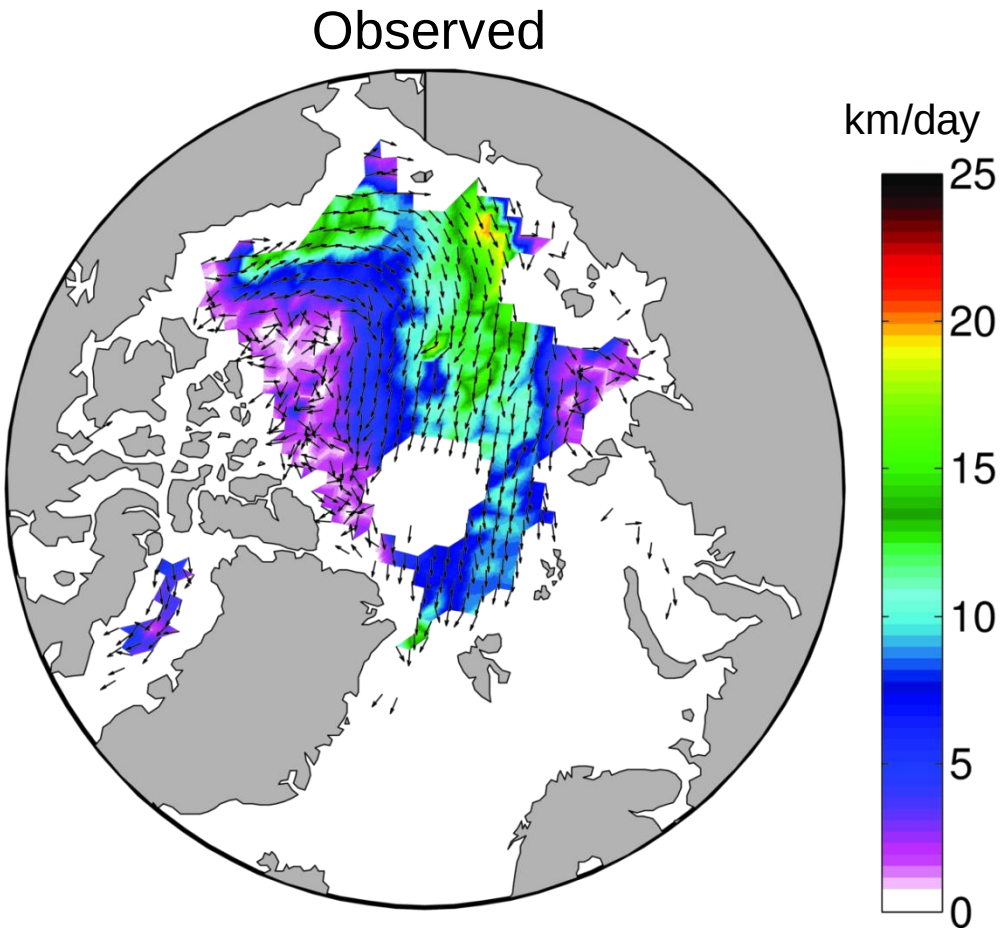


Winter 2010
www.nasa.gov

Arctic sea ice drifts (slowly)

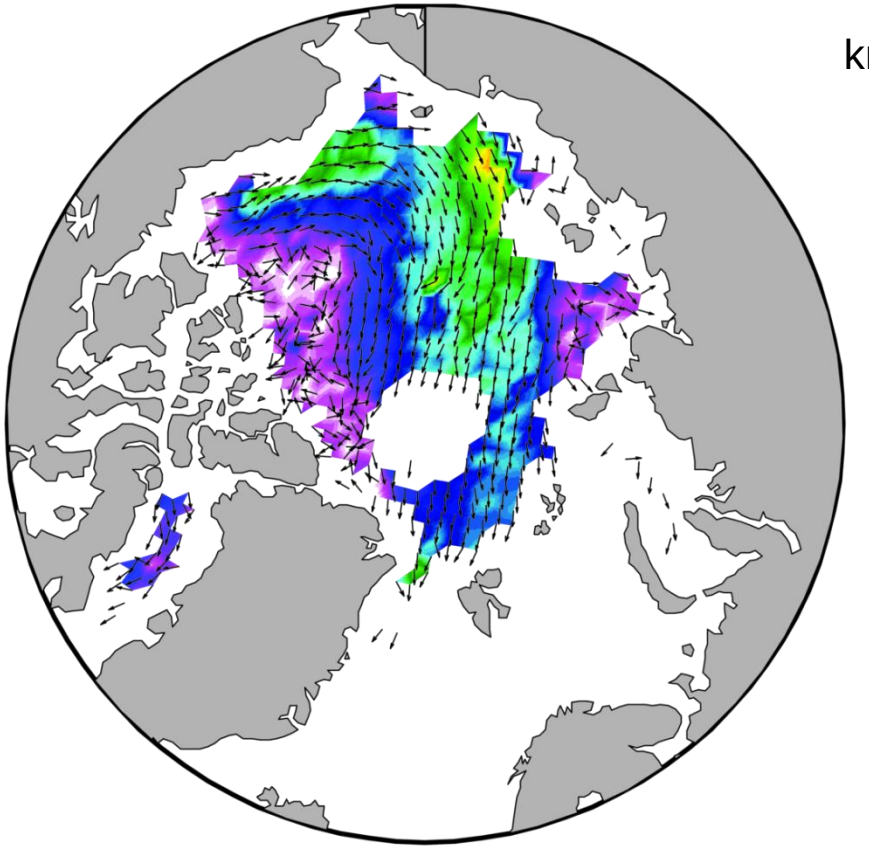
12→14 April 2012 sea ice drift

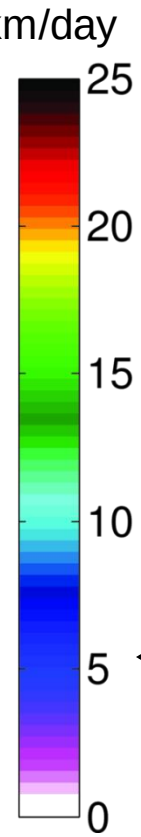


Arctic sea ice drifts (slowly)

12→14 April 2012 sea ice drift

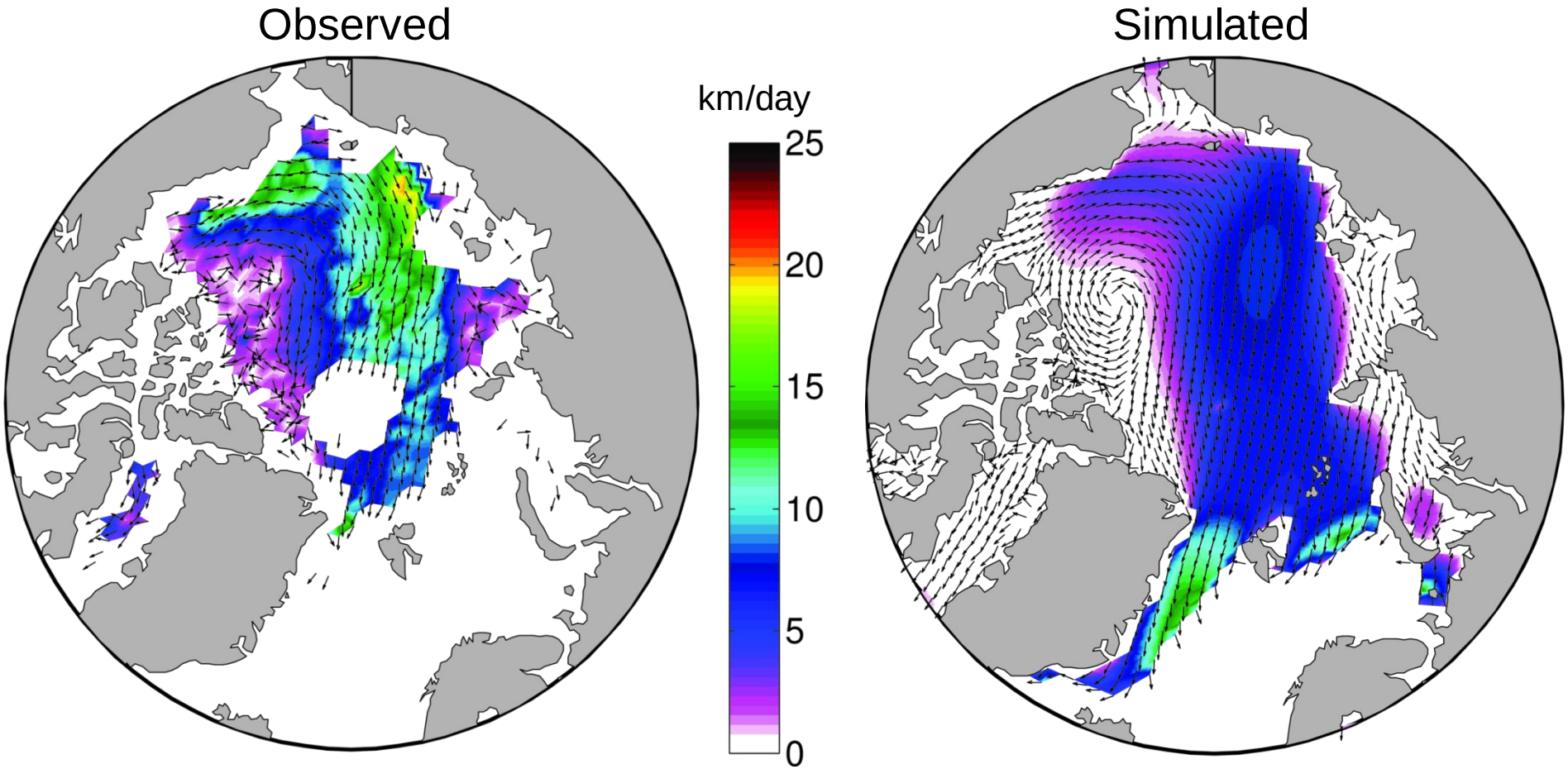
Observed





Our ocean-sea ice model underestimates sea ice speed

12→14 April 2012 sea ice drift



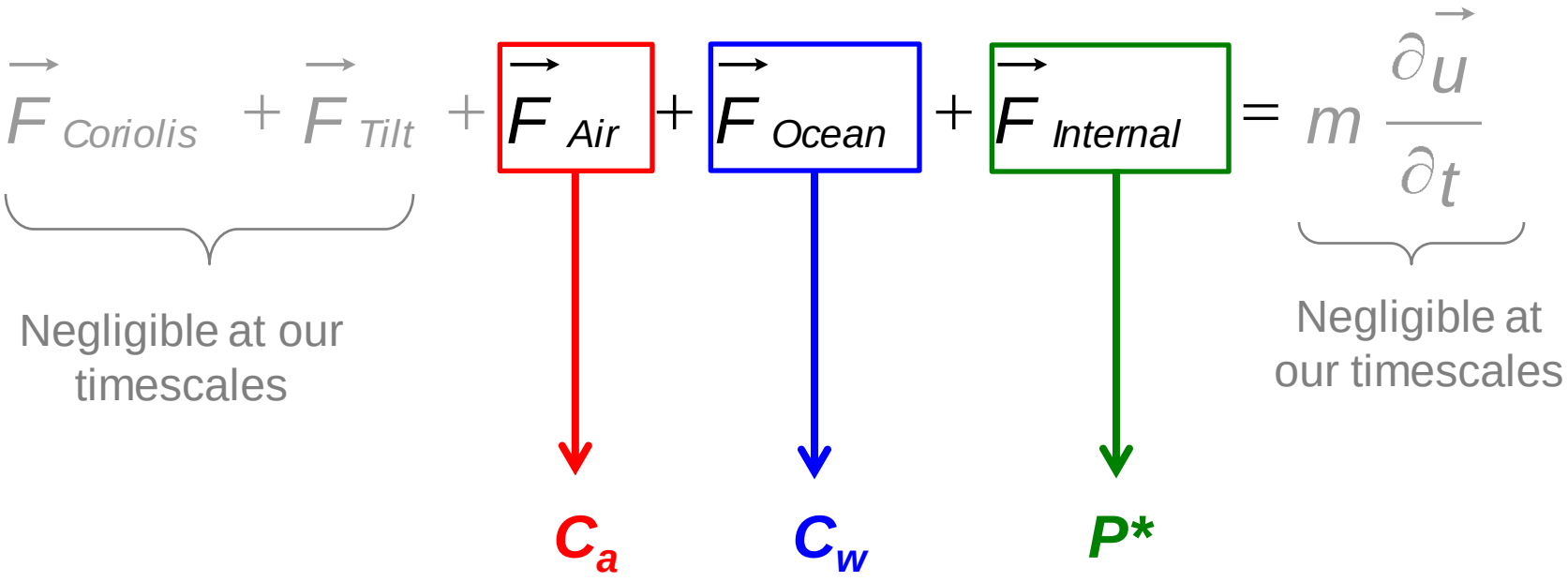
Sea ice drift is deduced by solving Newton's law

$$\vec{F}_{Coriolis} + \vec{F}_{Tilt} + \vec{F}_{Air} + \vec{F}_{Ocean} + \vec{F}_{Internal} = m \frac{\partial \vec{u}}{\partial t}$$

At daily timescales, 3 forces dominate the sea ice momentum balance

$$\underbrace{\vec{F}_{Coriolis} + \vec{F}_{Tilt}}_{\text{Negligible at our timescales}} + \vec{F}_{Air} + \vec{F}_{Ocean} + \vec{F}_{Internal} = \underbrace{m \frac{\partial \vec{u}}{\partial t}}_{\text{Negligible at our timescales}}$$

At daily timescales, 3 forces dominate the sea ice momentum balance



1. Parameter estimation with the ensemble Kalman filter

2. Improved sea ice dynamics with calibrated parameters

3. Side effects and impacts on the global sea ice cover

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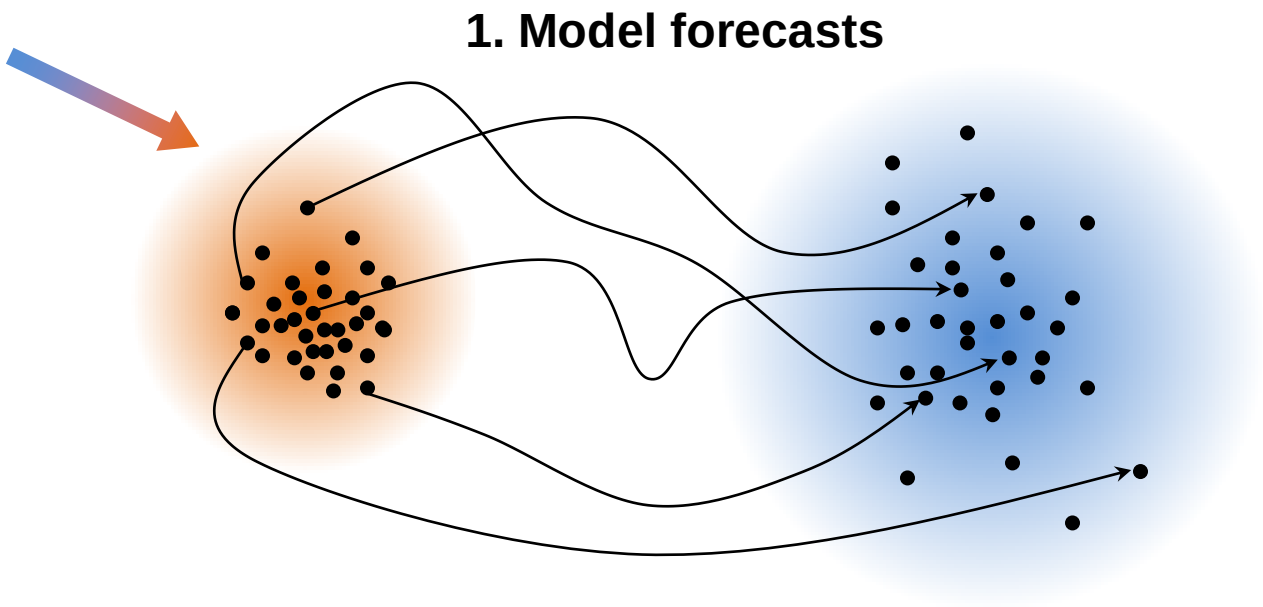
The ensemble Kalman filter is designed to sample model uncertainty



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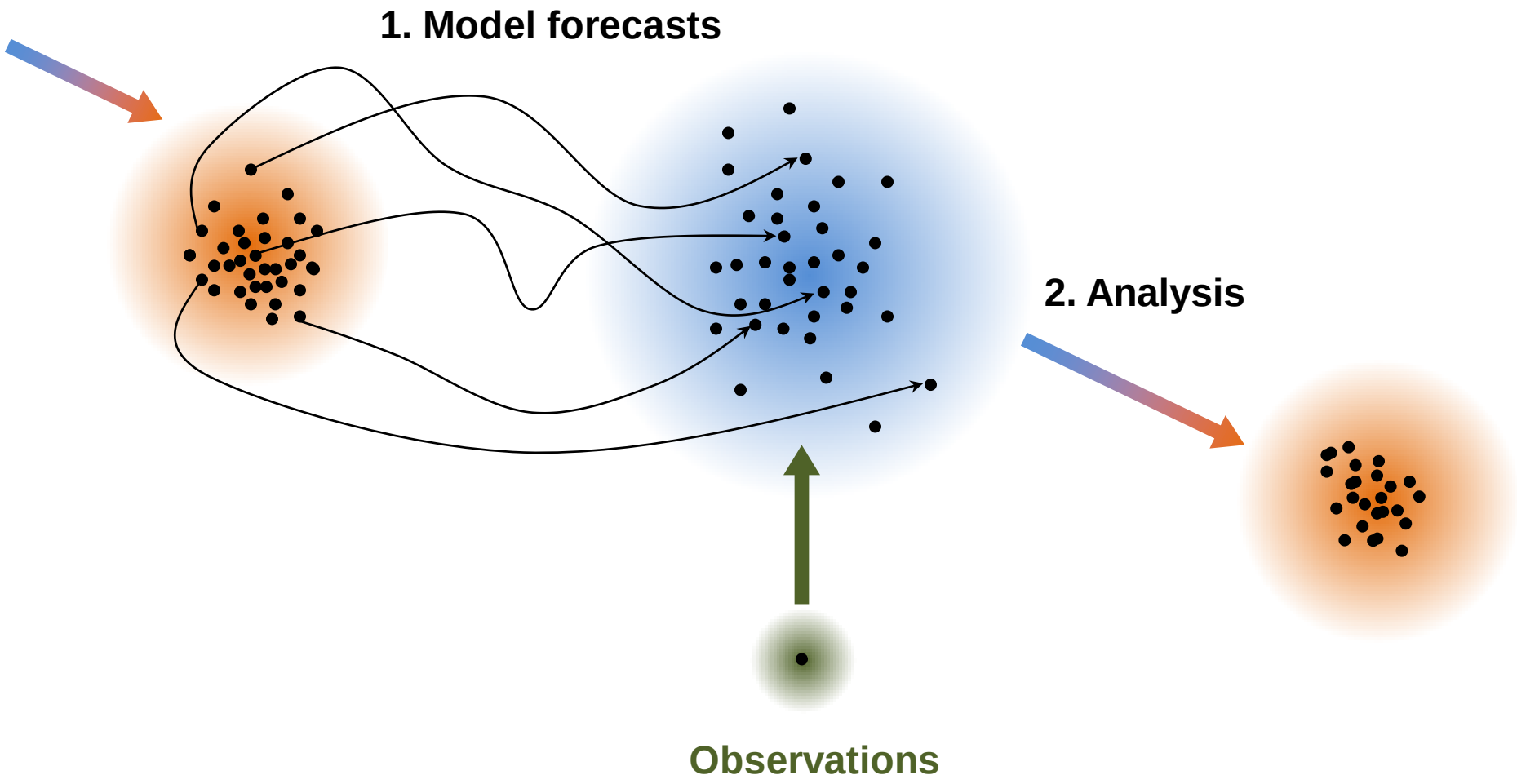

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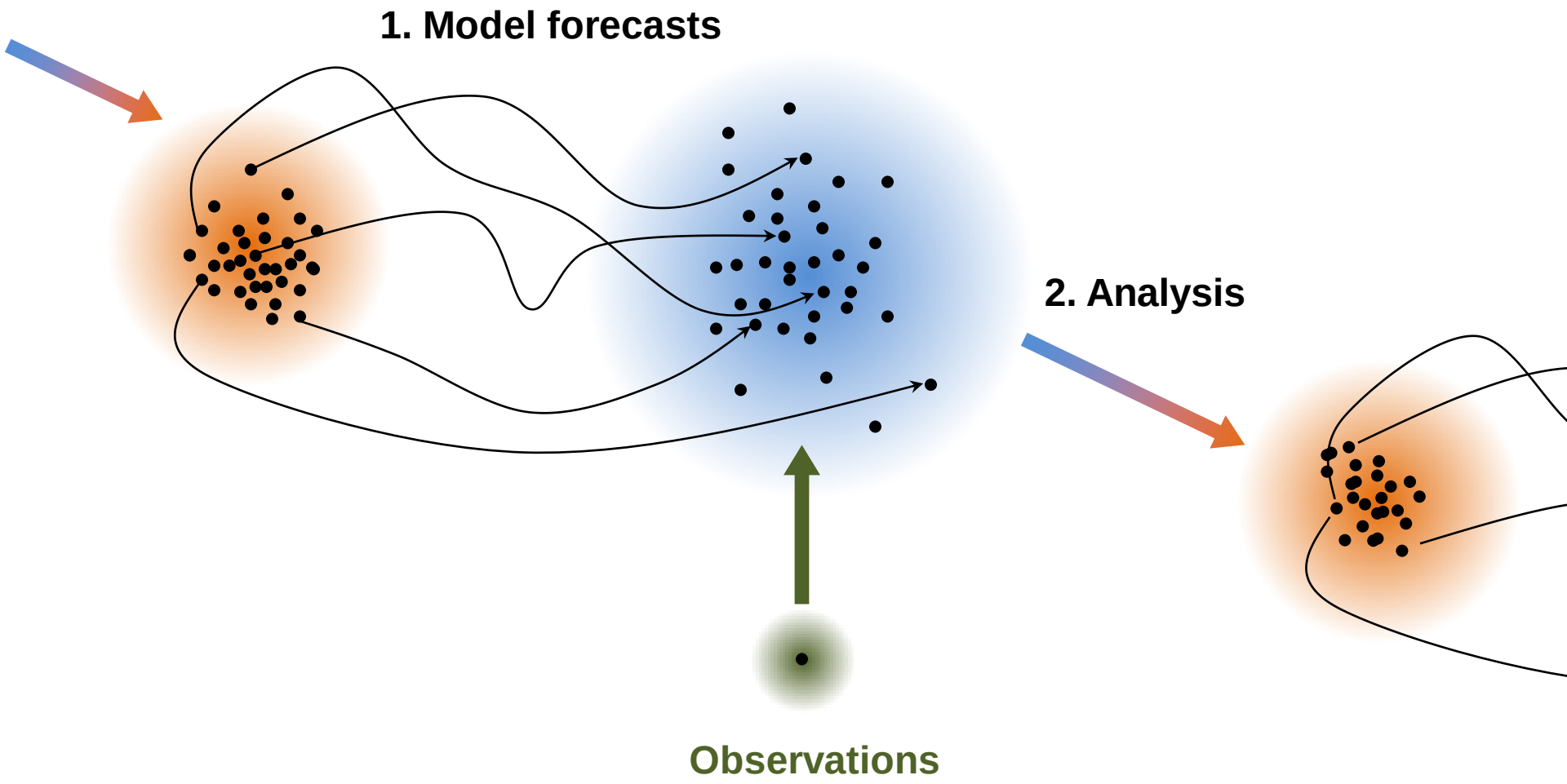
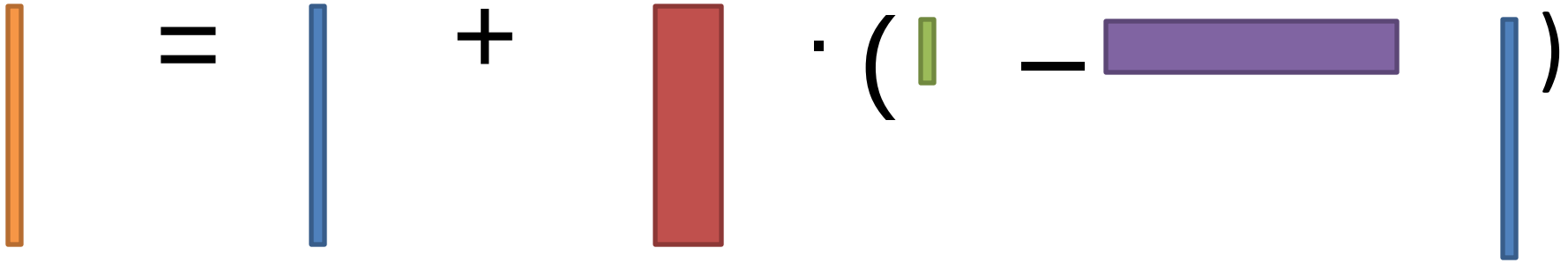


State estimation with Ensemble Kalman Filter

Analysis **Forecast** (NEMO-LIM3) **Kalman gain** **Observations** 48h Arctic sea ice drift

$$\mathbf{x}^a = \mathbf{x}^f + \mathbf{K} \cdot (\mathbf{d} - \mathbf{H}\,\mathbf{x}^f)$$



[Evensen, 2003]

Parameter estimation: state is augmented

Analysis **Forecast** (NEMO-LIM3) **Kalman gain** **Observations** 48h Arctic sea ice drift

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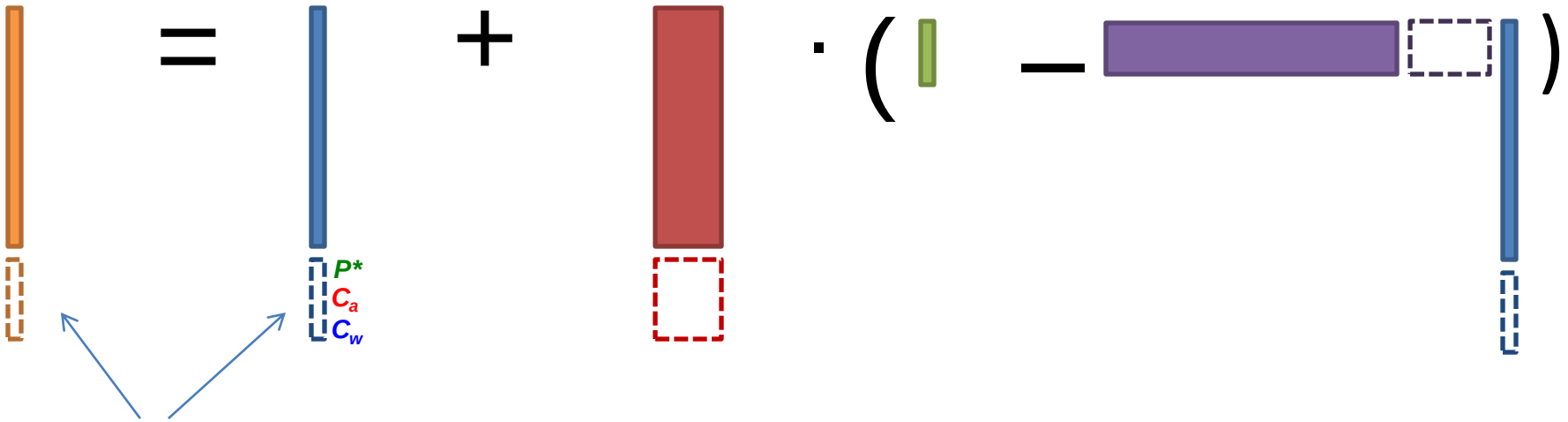
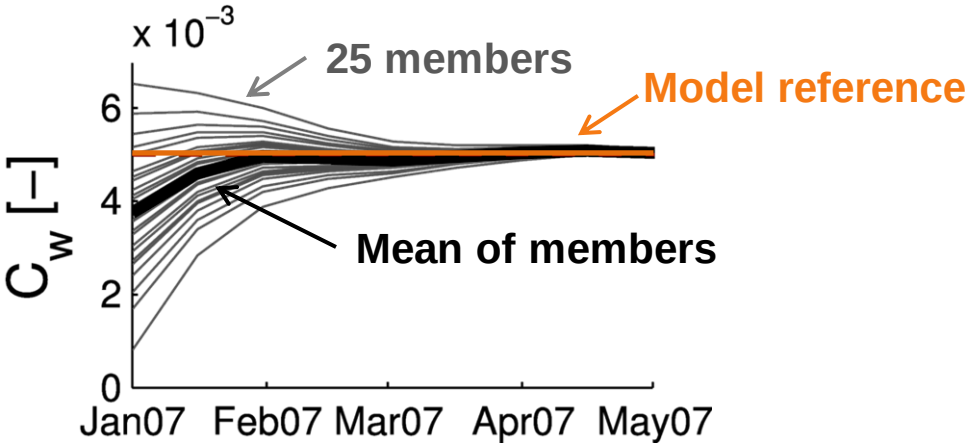
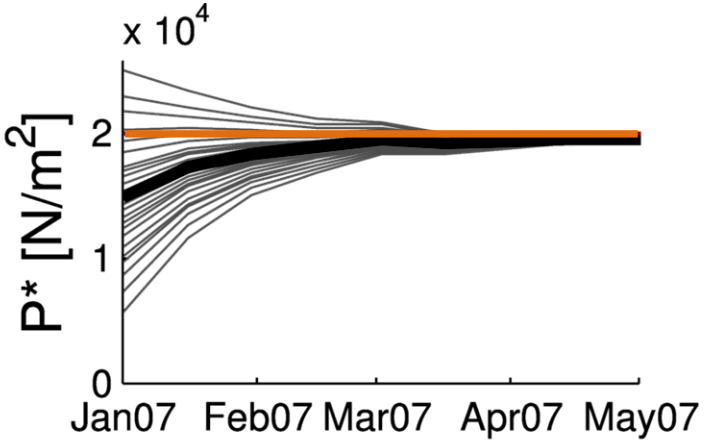


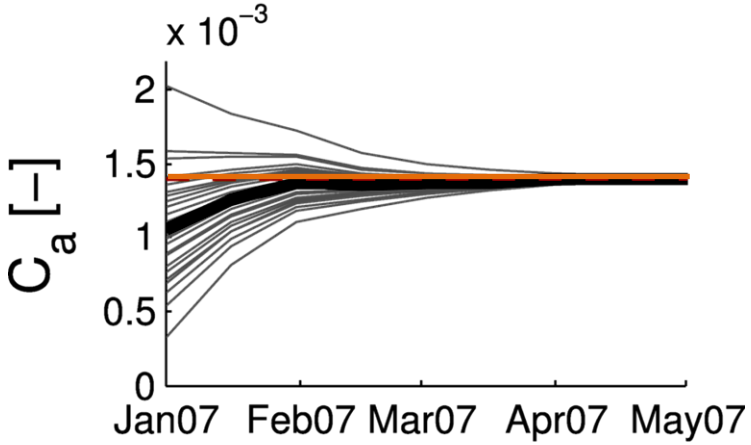
Parameters

[Evensen, 2003]

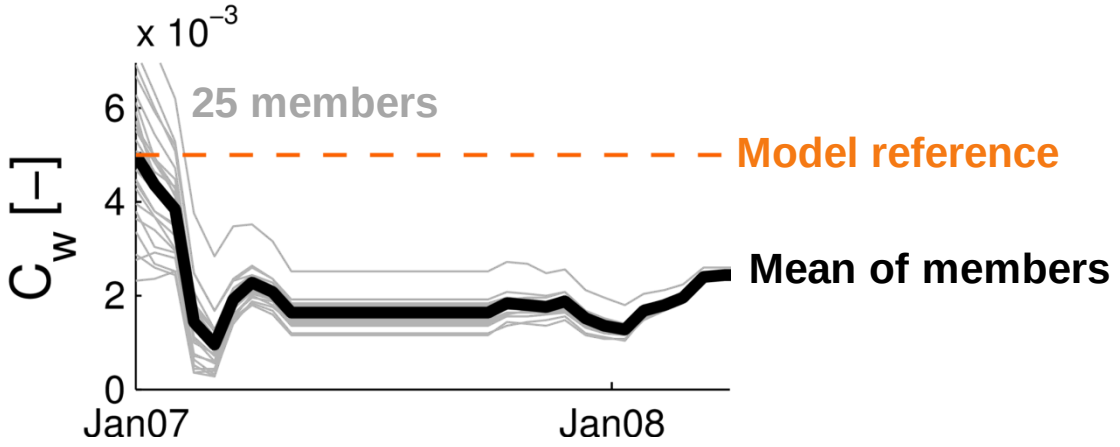
Under perfect model assumptions, the original set of parameters is retrieved

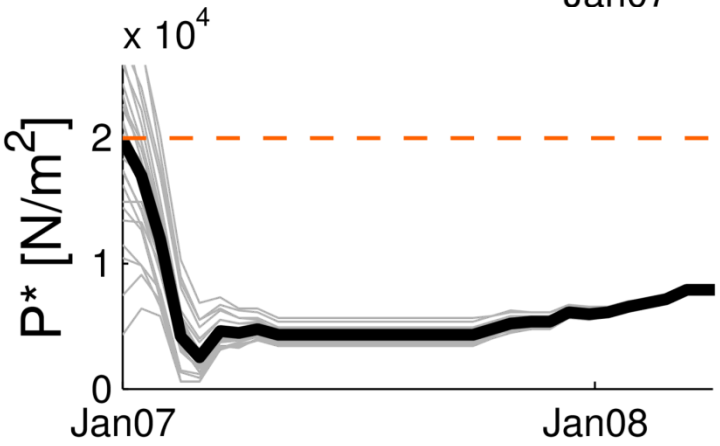


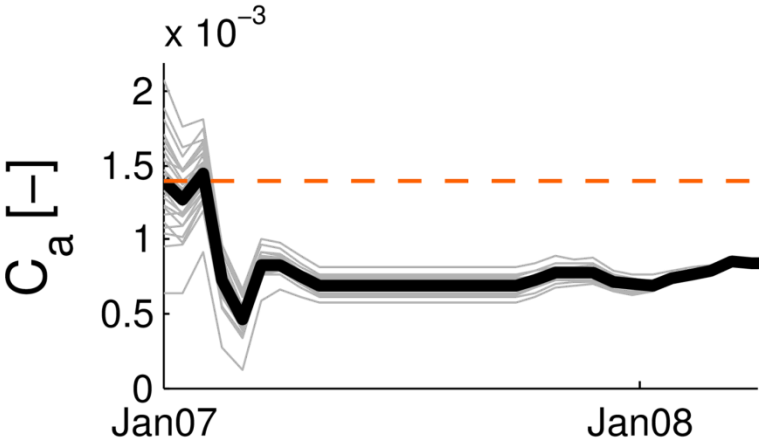




Convergence in the real case,
new parameter values need to be tested







1. Parameter estimation by state augmentation

2. Improved sea ice dynamics with new parameters

3. Side effects: impacts on the global sea ice cover

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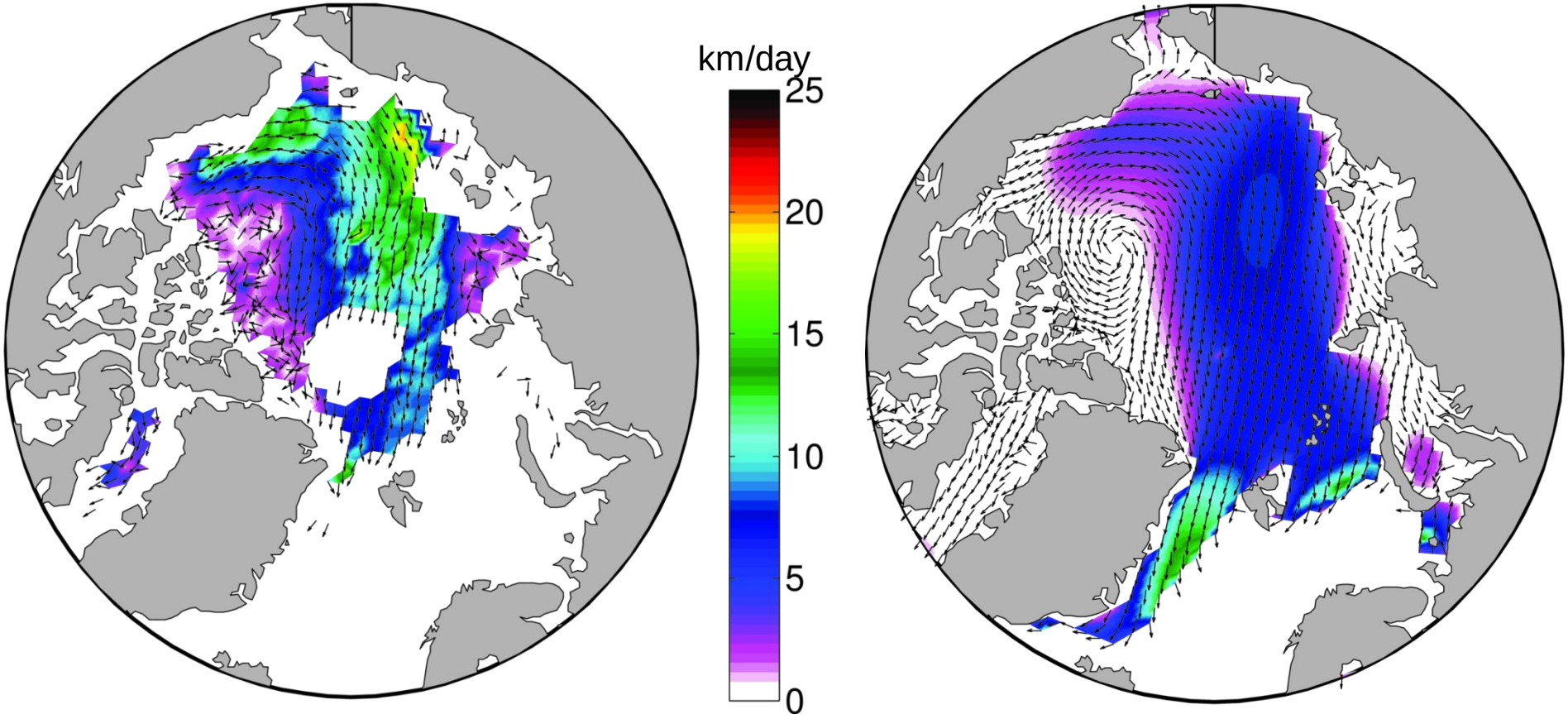
Our ocean-sea ice model underestimates sea ice drift

12→14 April 2012 sea ice drift

Observed

Simulated, no calibration

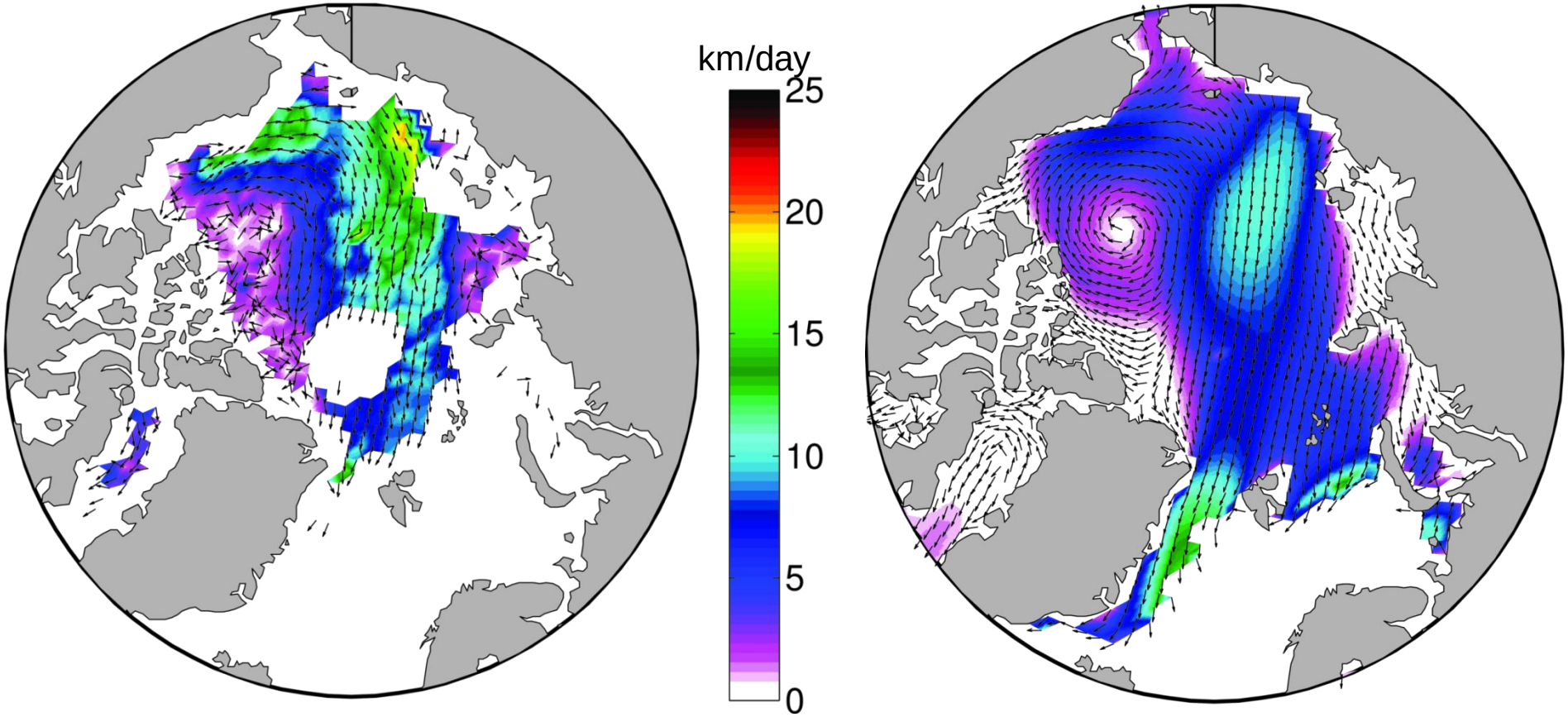


Calibration of one parameter: in the right direction

12→14 April 2012 sea ice drift

Observed

Simulated, *P** calibrated

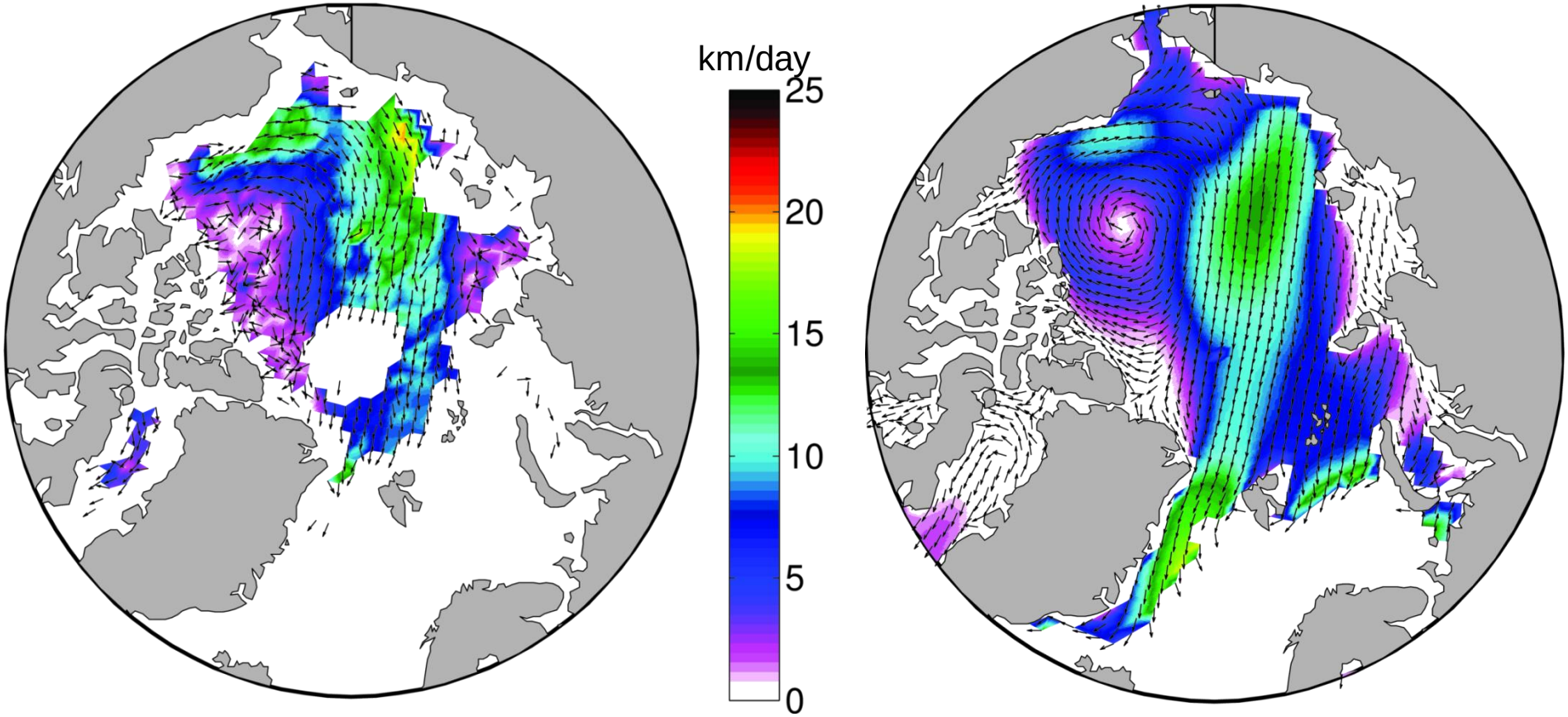


Calibration of two parameters: further improvements

12→14 April 2012 sea ice drift

Observed

Simulated, (P^*,C_w) calibrated

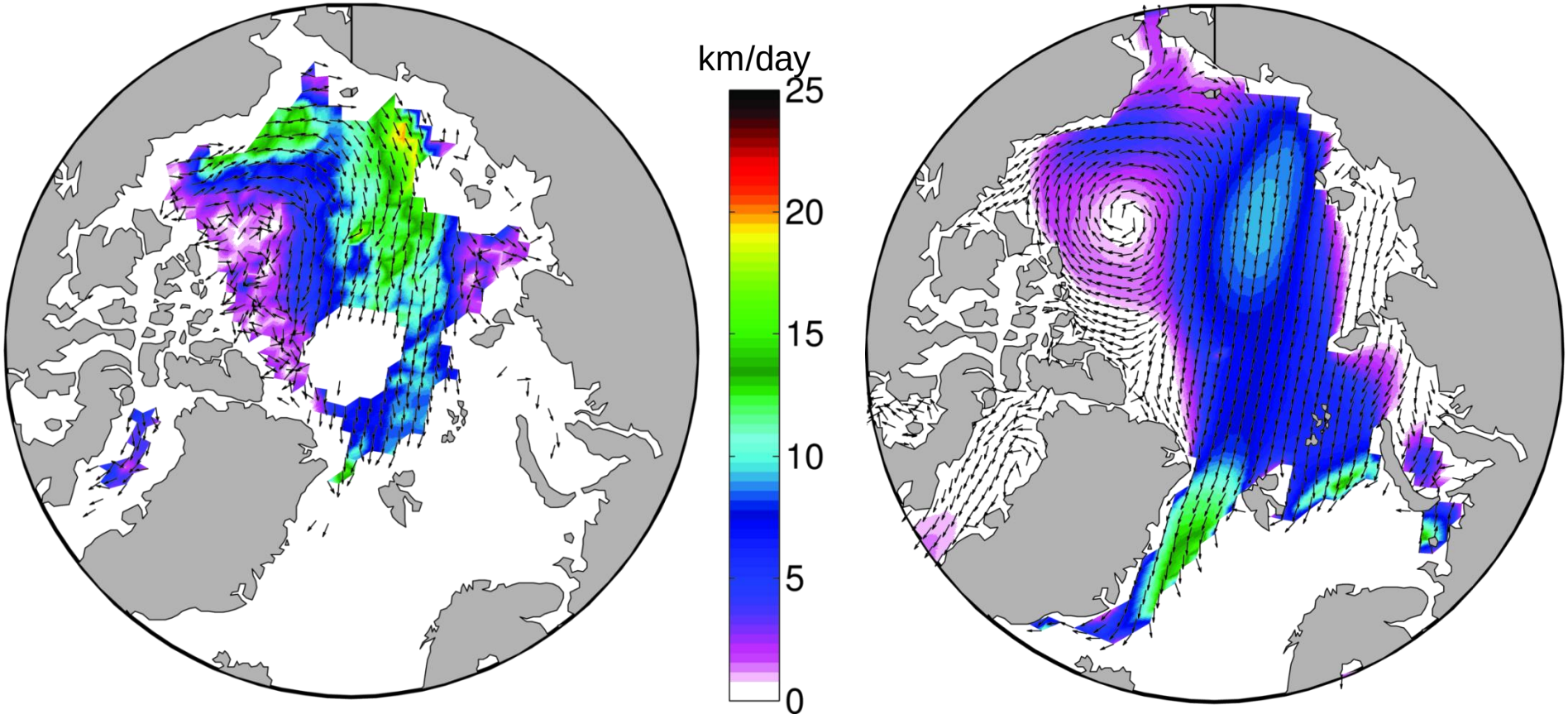


Calibration of three parameters: not as expected

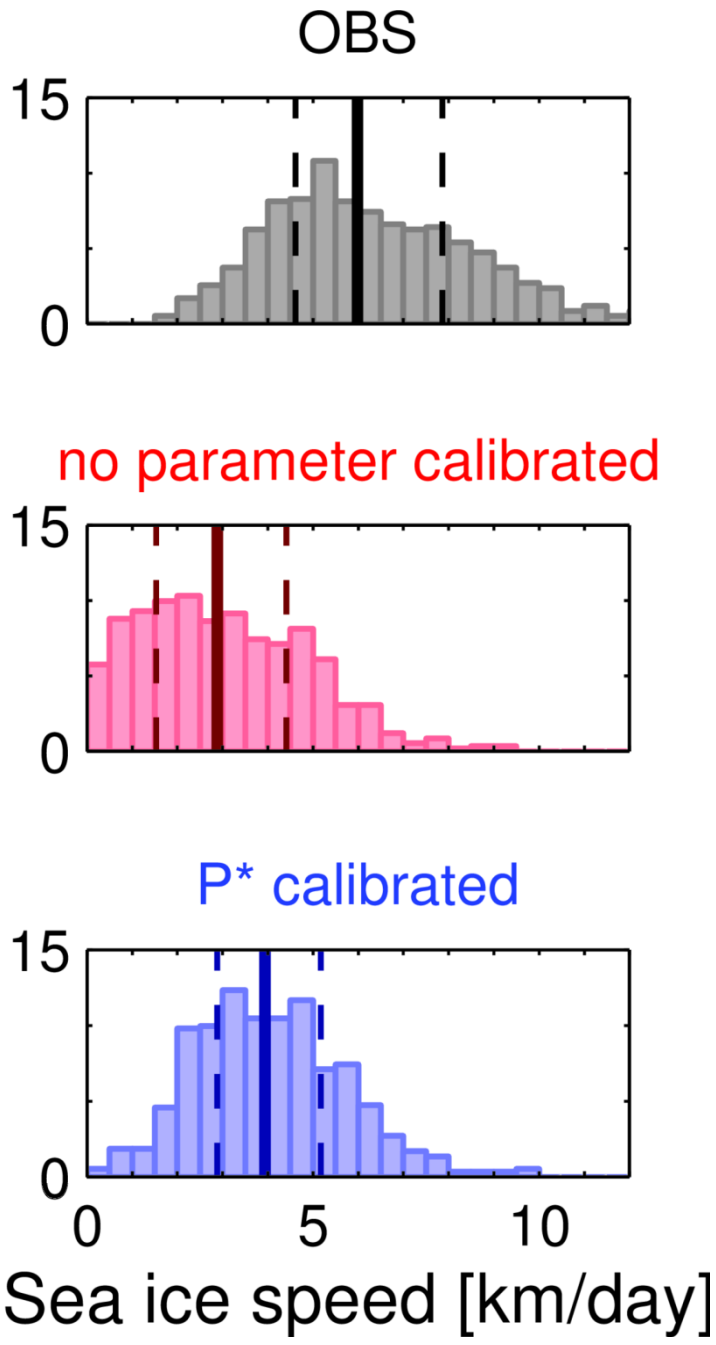
12→14 April 2012 sea ice drift

Observed

Simulated, (P^*,C_w,C_a) calibrated



Improved 2007-2012 distribution of Arctic sea ice speeds



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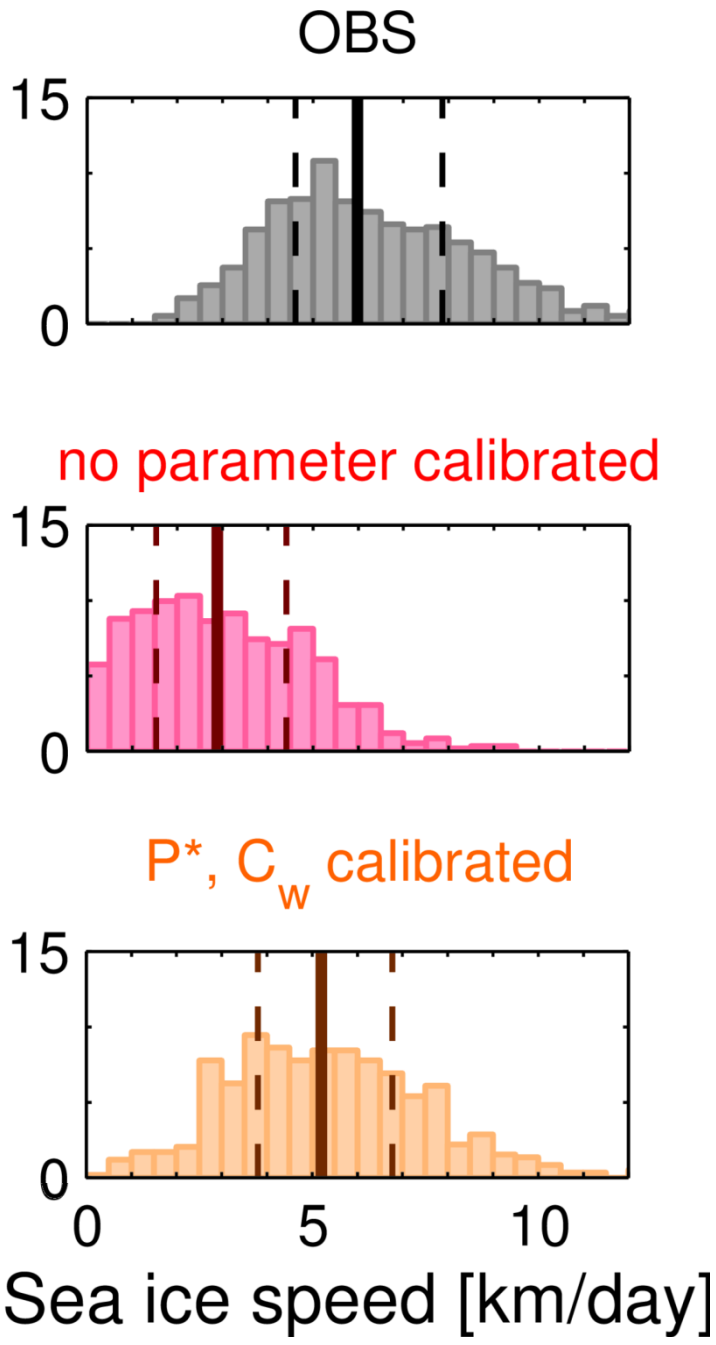

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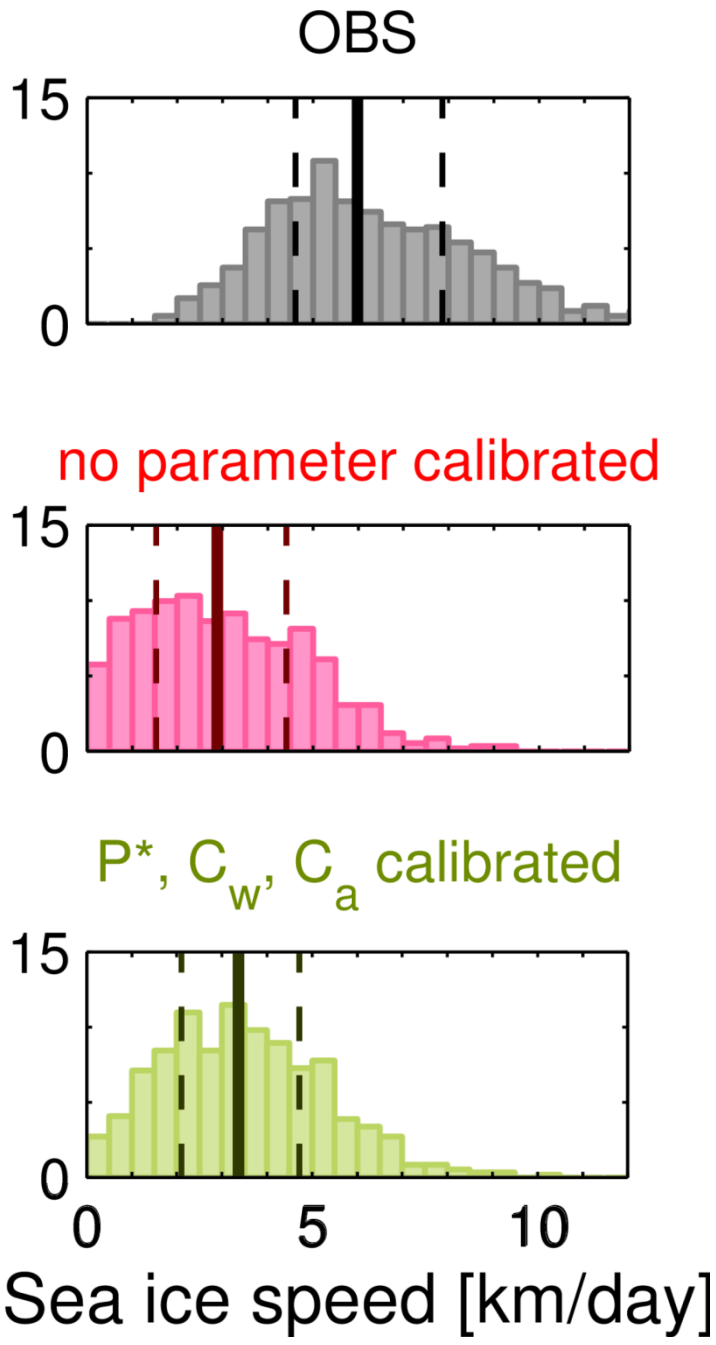


Winter 2010
www.nasa.gov

$$\vec{F}_{Air} + \vec{F}_{Internal} + \vec{F}_{Ocean} = 0$$

C_a P^* C_w

Two dominant regimes for winter Arctic sea ice drift at daily time scales

$$\vec{F}_{Air} + \vec{F}_{Internal} + \vec{F}_{Ocean} = 0$$

C_a P^* C_w

1.	$\vec{F}_{Air} + \vec{F}_{Internal} = 0$		Dominant
2.	$\vec{F}_{Air} + \vec{F}_{Ocean} = 0$		Dominant
3.	$\vec{F}_{Air} + \vec{F}_{Internal} + \vec{F}_{Ocean} = 0$		Less common

[Steele et al., 1997]

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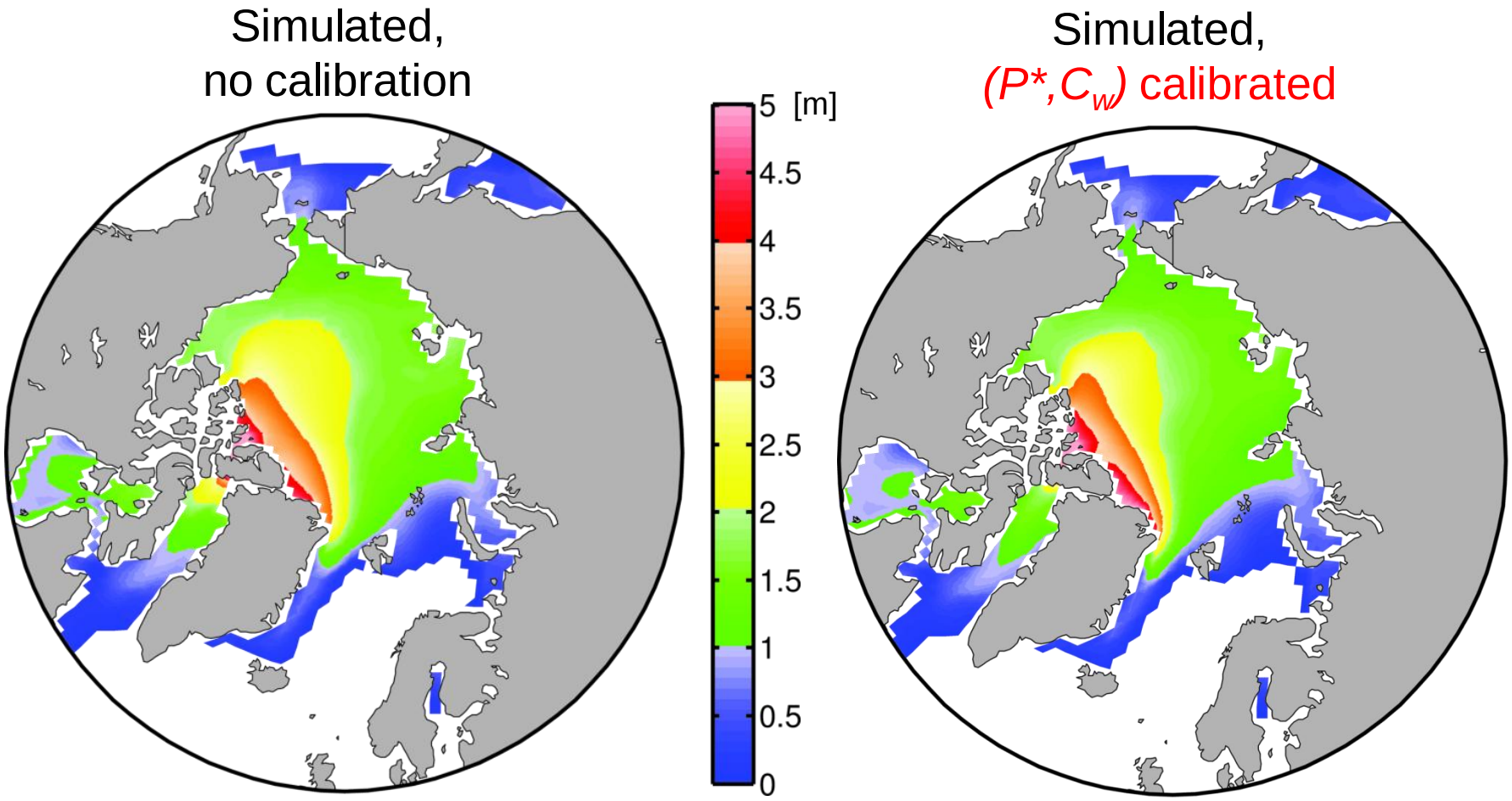
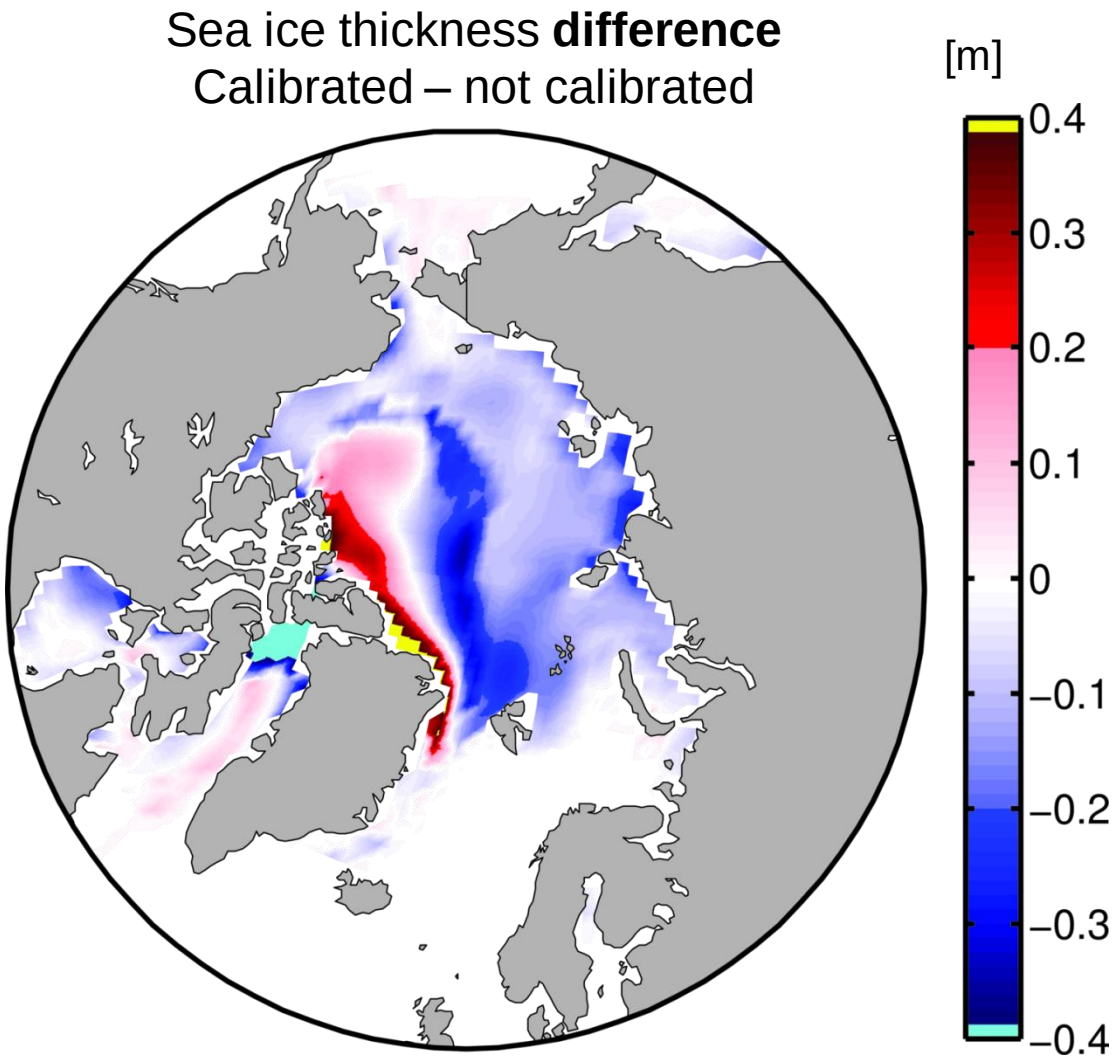
Minor changes in sea ice thickness

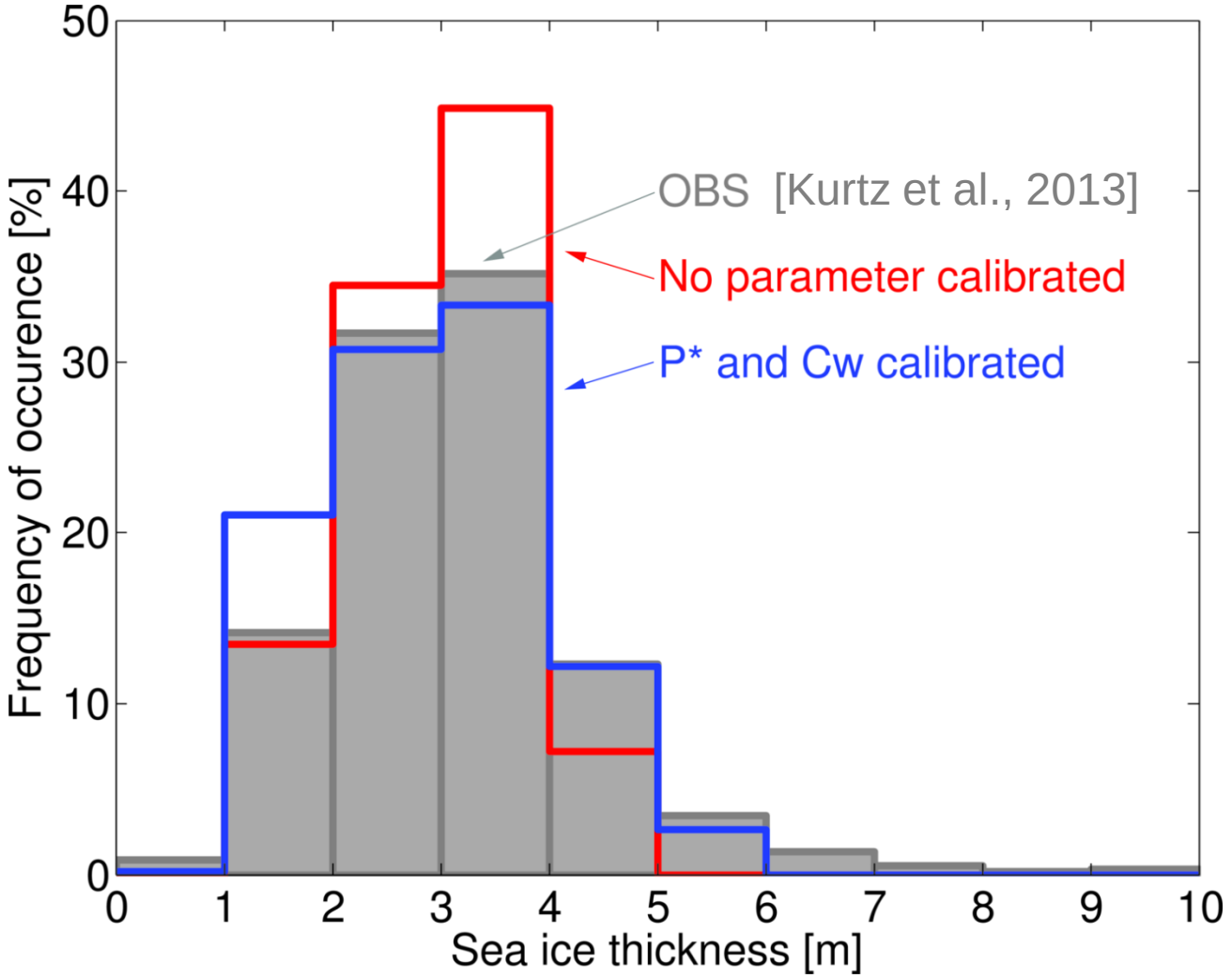
March 2007-2012 sea ice thickness

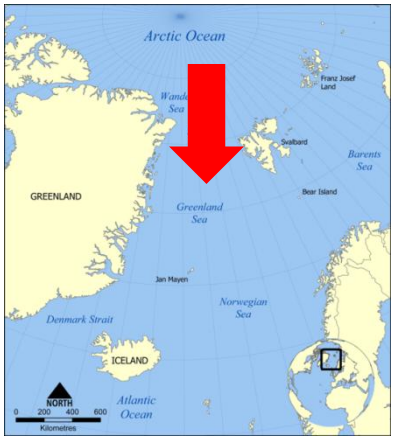


Thick ice gets thicker, thin ice gets thinner

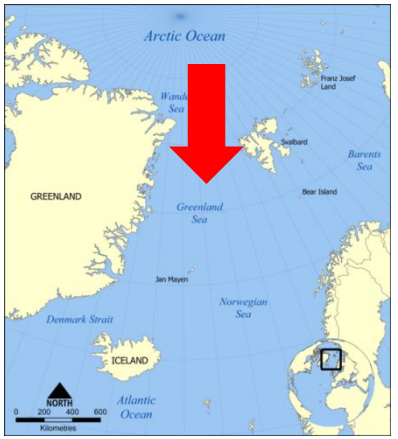


Slight improvement in 2009-2012 sea ice thickness distribution

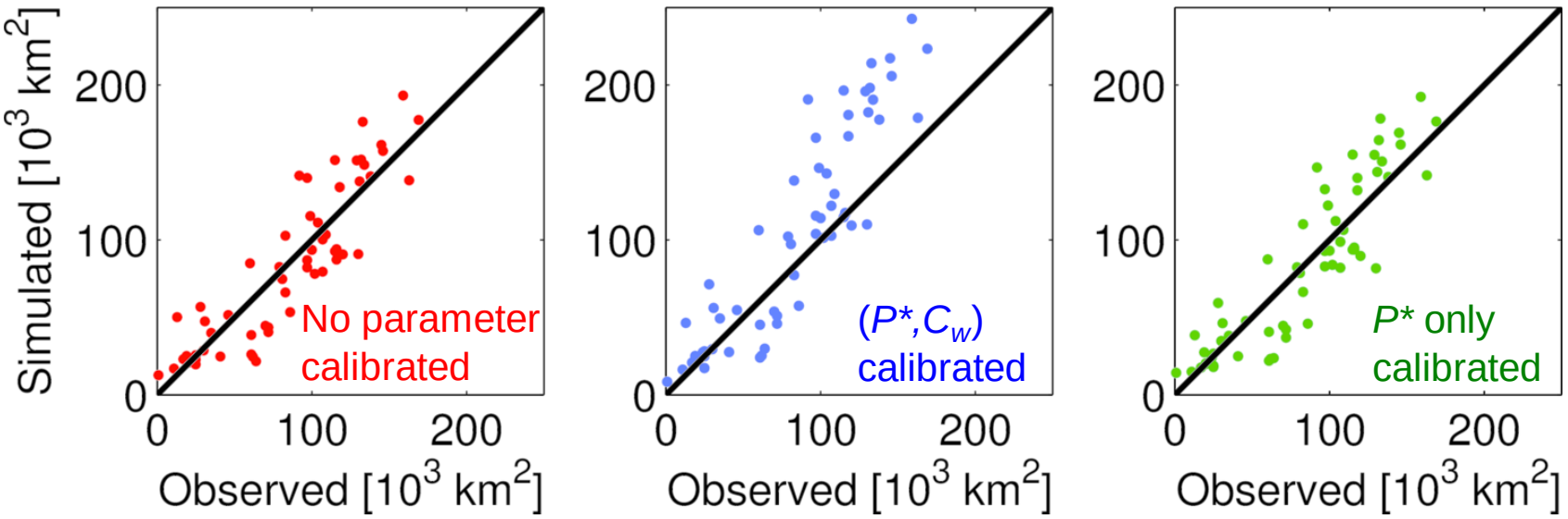



Arctic Ocean
Franz Josef Land
Svalbard
Barents Sea
Bear Island
GREENLAND
Greenland Sea
Jan Mayen
Norwegian Sea
Denmark Strait
ICELAND
NORTH
0 200 400 600
Kilometres
Atlantic Ocean

Limitations in a global analysis framework



Monthly areal export of sea ice through Fram Strait



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The calibration scheme is extensible

Parameter calibration for GCMs / ESMs

Spatial parameter calibration

Time-dependent calibration

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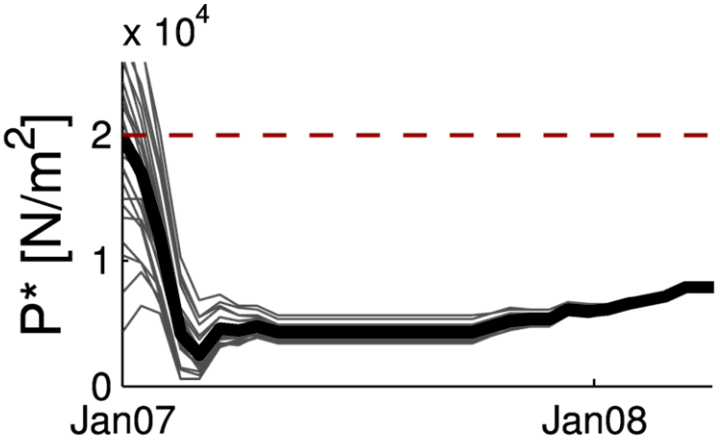
Parameter calibration for GCMs / ESMs

Spatial parameter calibration

Time-dependent calibration



Take home messages

Nature ignores what is a parameter

Optimal parameter values are configuration-dependent

Know your system before calibrating parameters

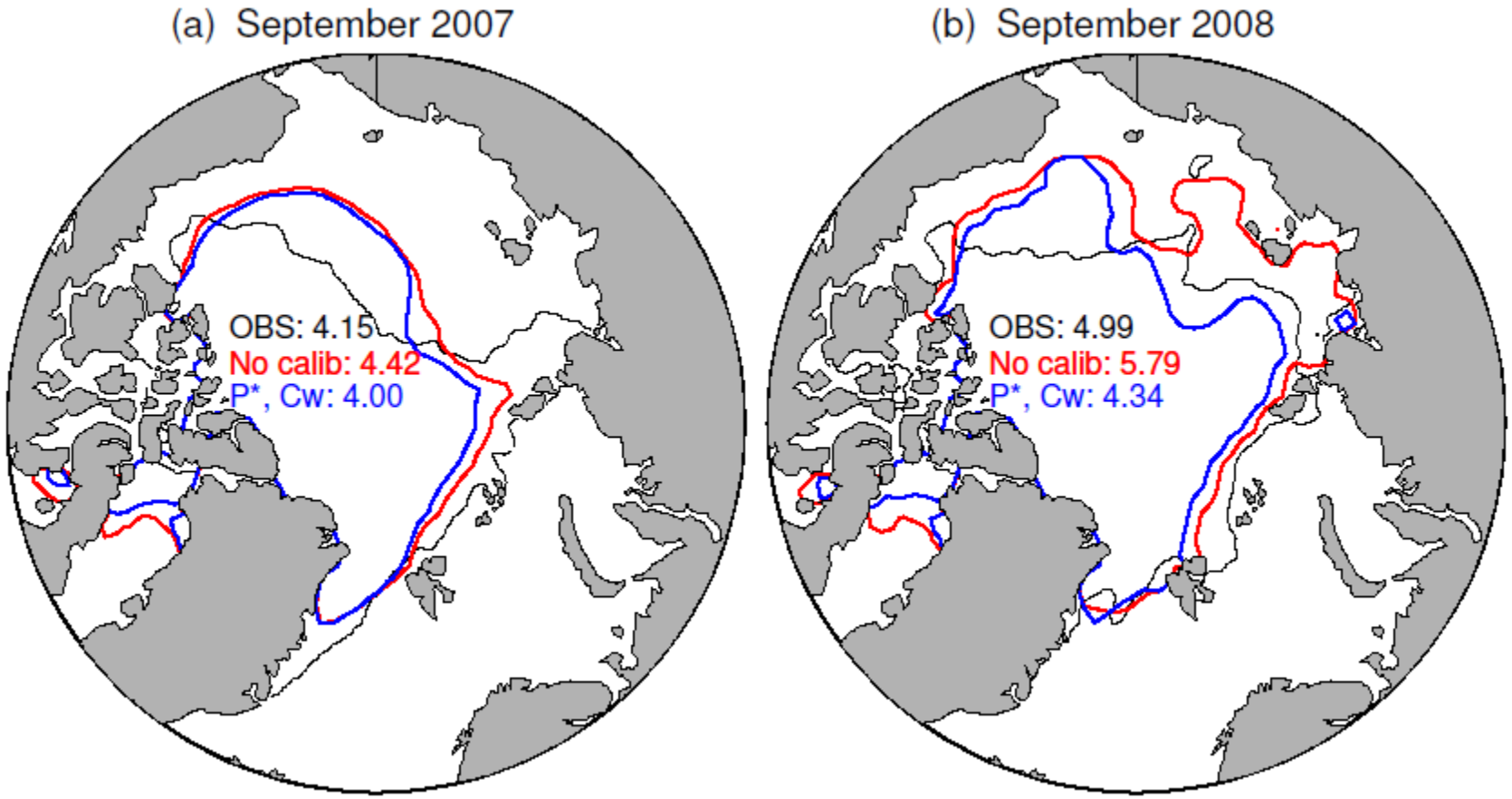
Calibrating too much/inappropriate parameters may lead to suboptimal solutions

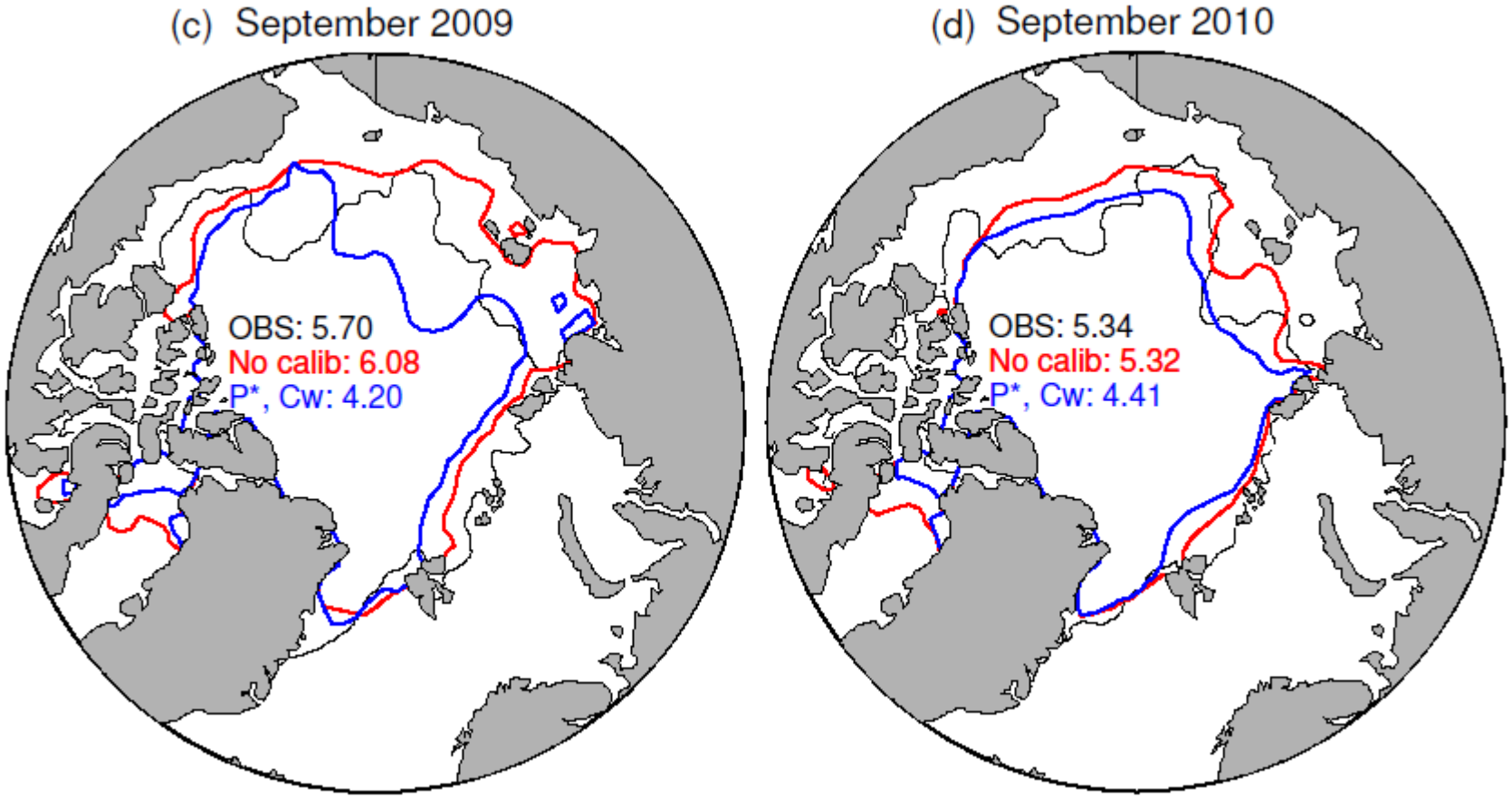
Thank you

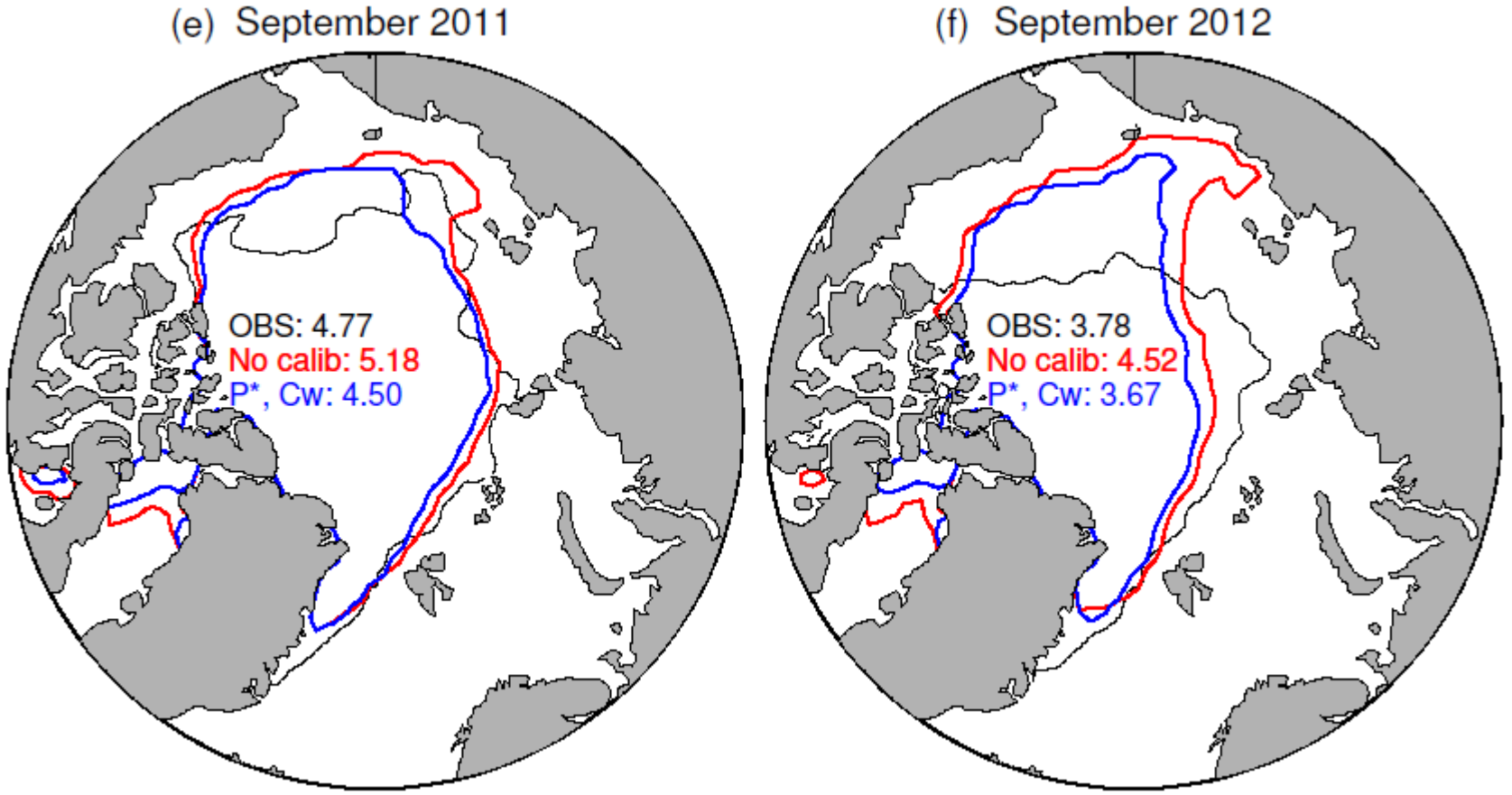
francois.massonnet@uclouvain.be

www.climate.be/u/fmasson

Winter 2010
www.nasa.gov


(a) September 2007
OBS: 4.15
No calib: 4.42
P*, Cw: 4.00
(b) September 2008
OBS: 4.99
No calib: 5.79
P*, Cw: 4.34


(c) September 2009
OBS: 5.70
No calib: 6.08
P*, Cw: 4.20
(d) September 2010
OBS: 5.34
No calib: 5.32
P*, Cw: 4.41


(e) September 2011
OBS: 4.77
No calib: 5.18
P*, Cw: 4.50
(f) September 2012
OBS: 3.78
No calib: 4.52
P*, Cw: 3.67