IC3 • Barcelona
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Calibration of sea ice dynamic parameters

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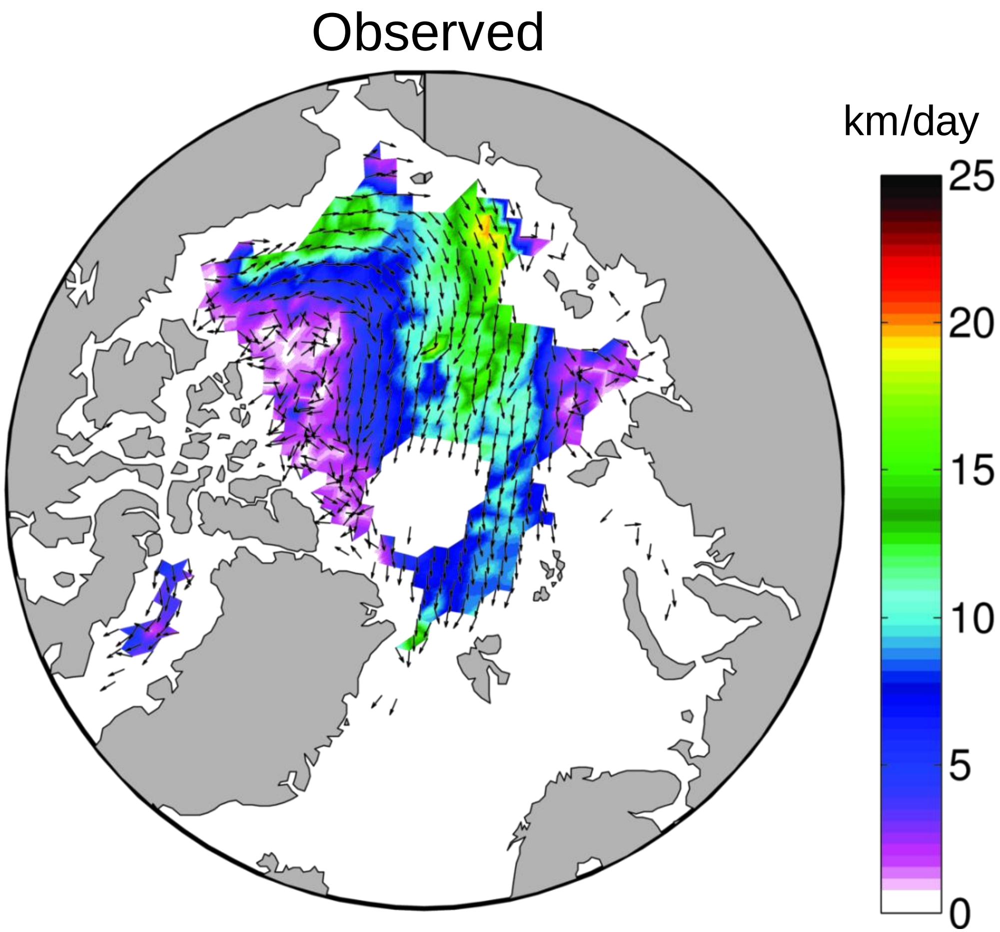
Making informed
choices is all but easy


Winter 2010
www.nasa.gov

Arctic sea ice drifts slowly

12→14 April 2012 sea ice drift



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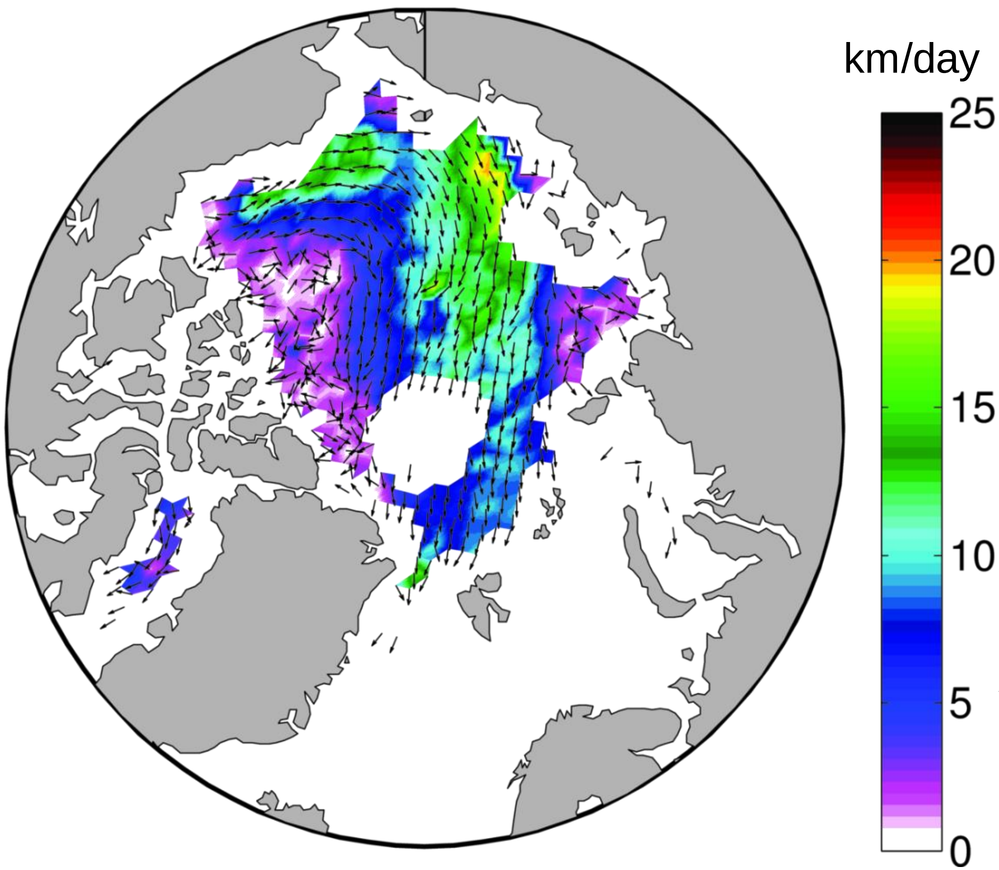
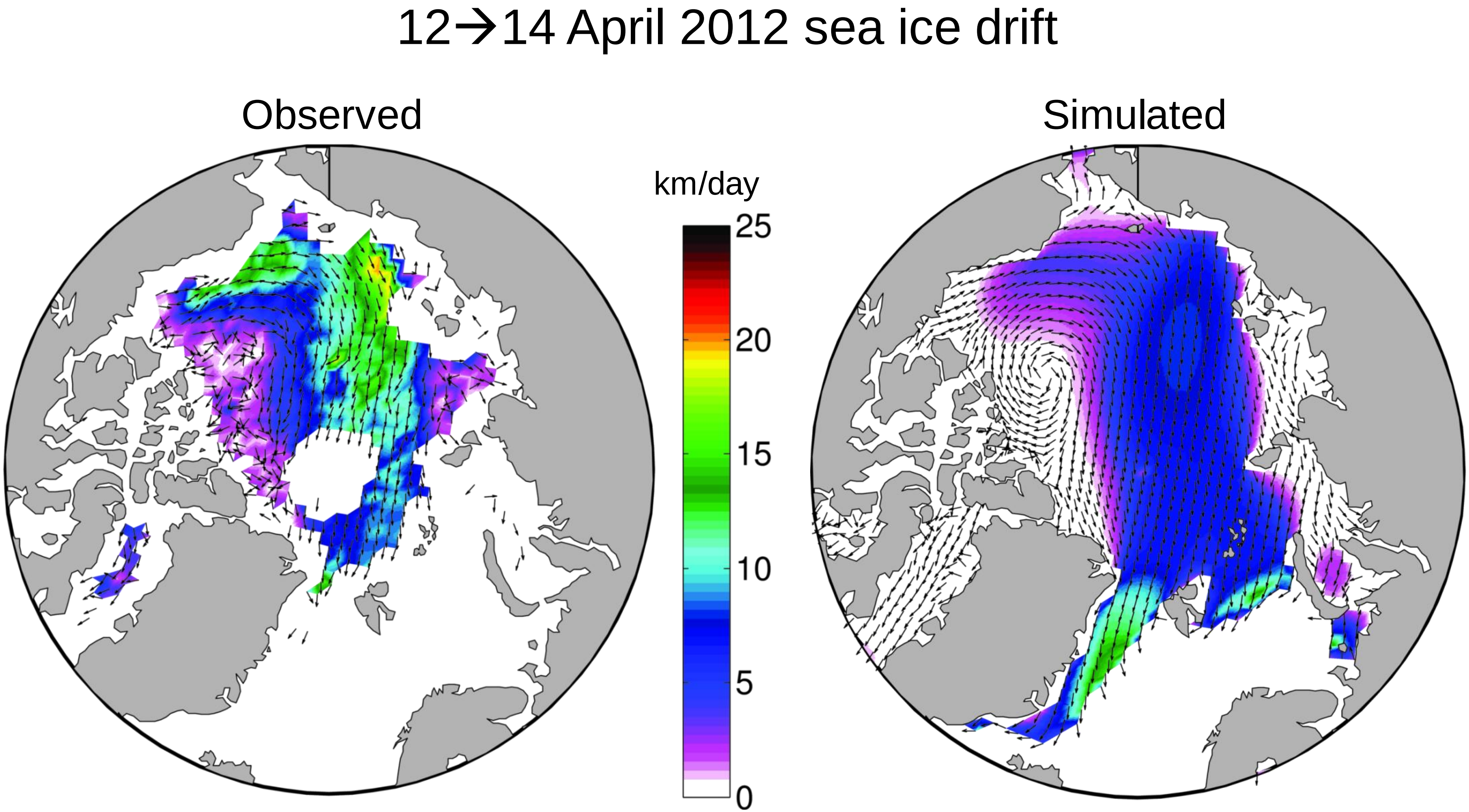
12→14 April 2012 sea ice drift

Observed



Our ocean-sea ice model underestimates sea ice speed



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

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

C_a C_w P^*

3 key sea ice parameters

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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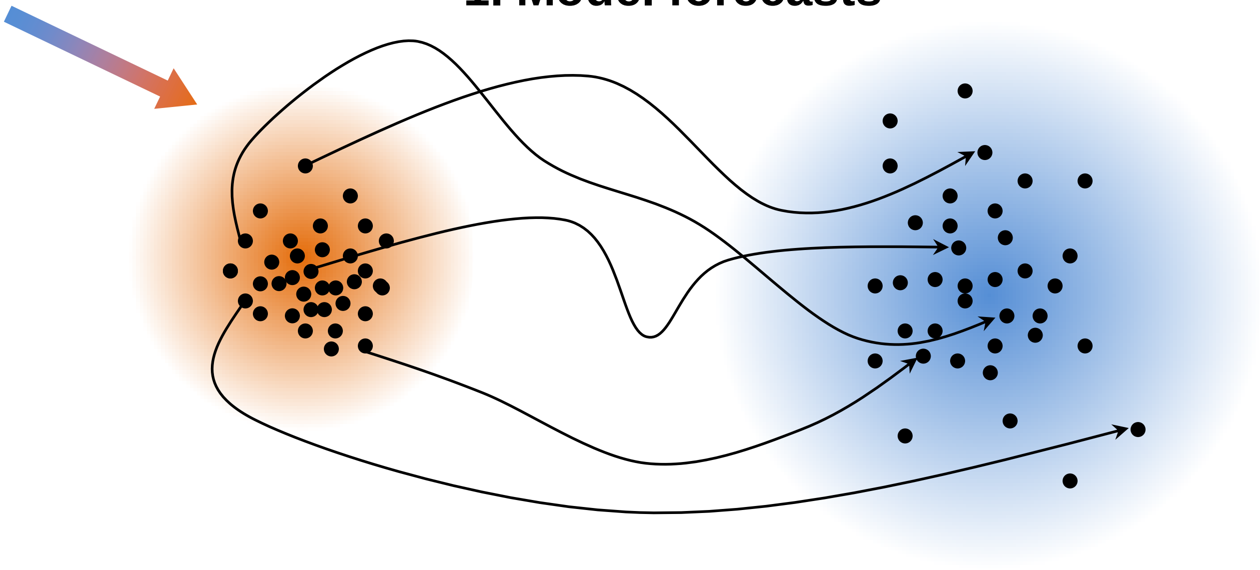
The ensemble Kalman filter is designed to sample model uncertainty

1. Model forecasts



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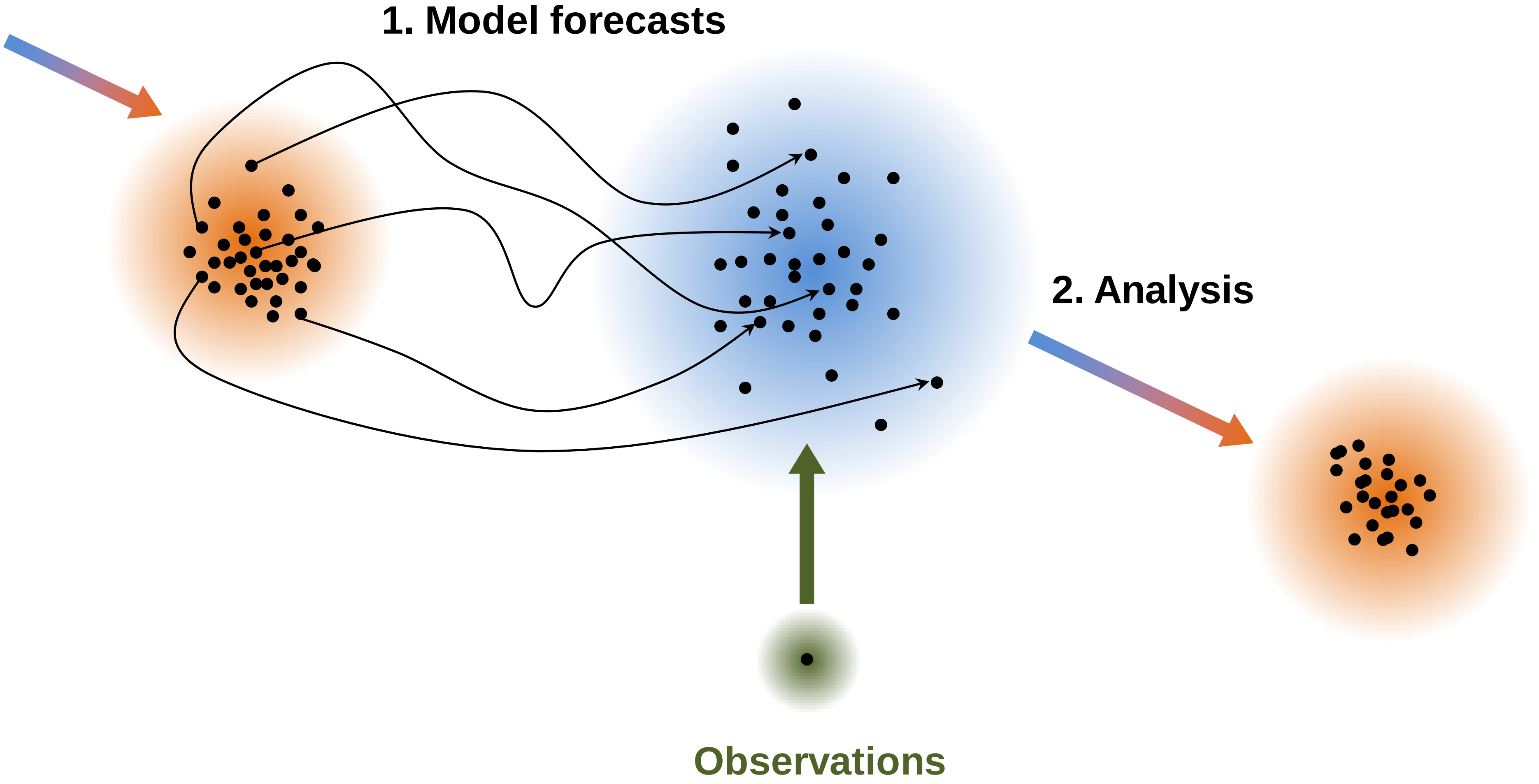

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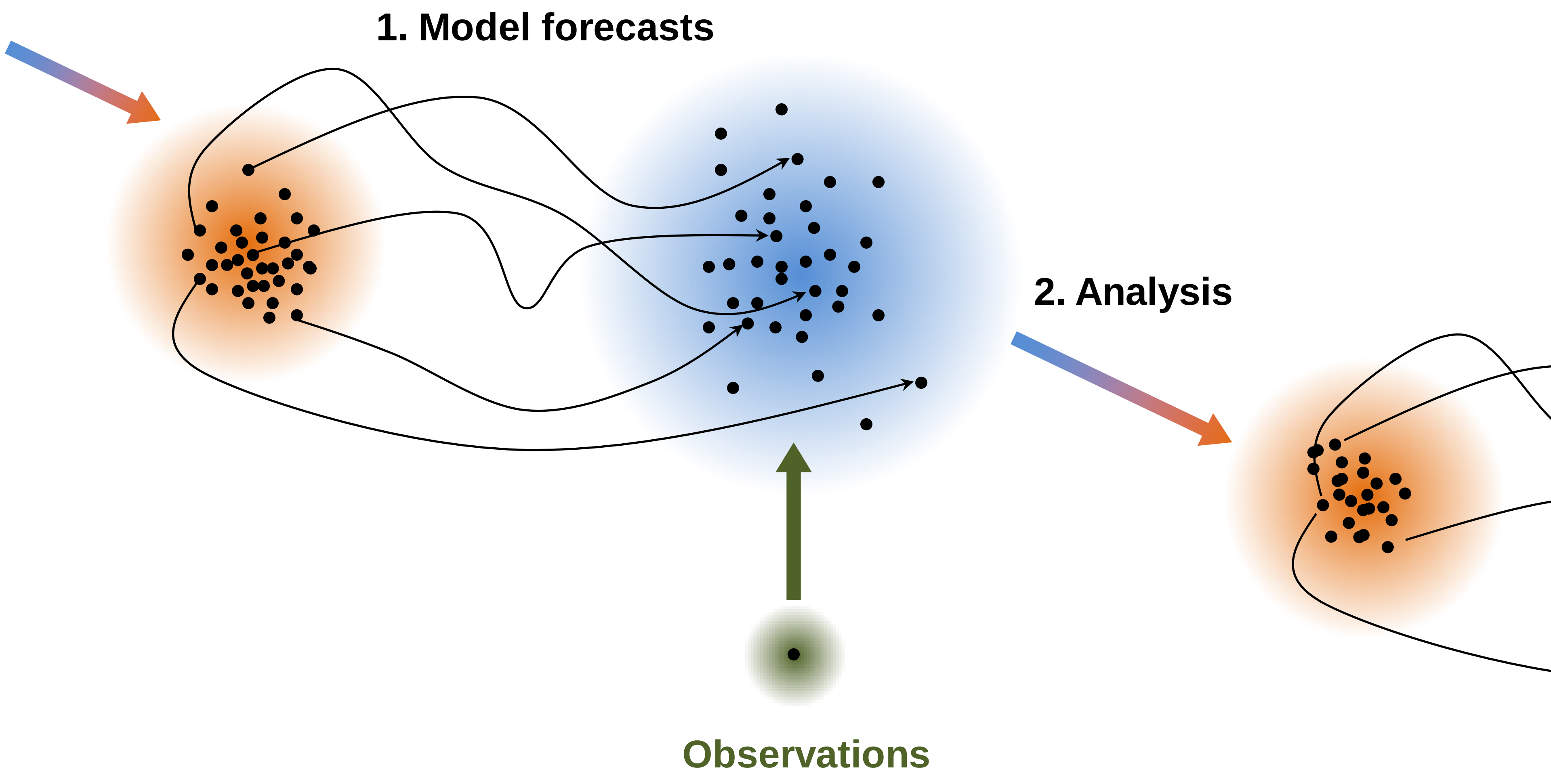
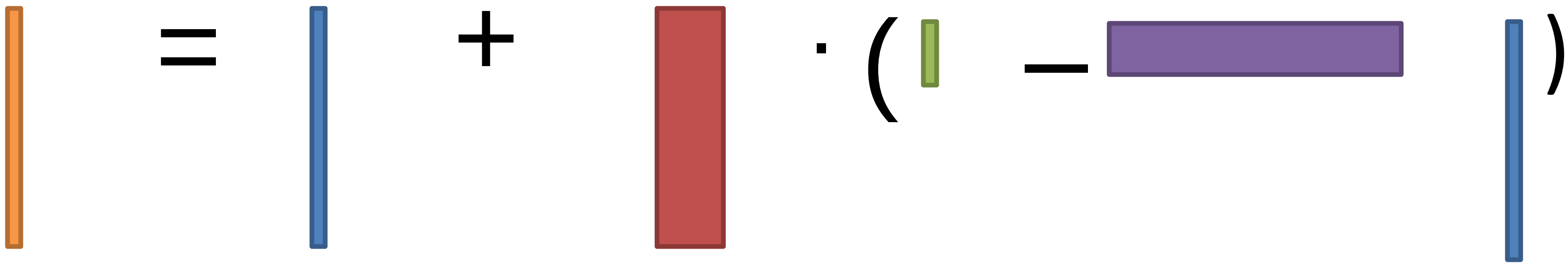


State estimation with Ensemble Kalman Filter

Analysis **Forecast** (NEMO-LIM3) **Kalman gain** **Observations** 2-day 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 2-day Arctic sea ice drift			

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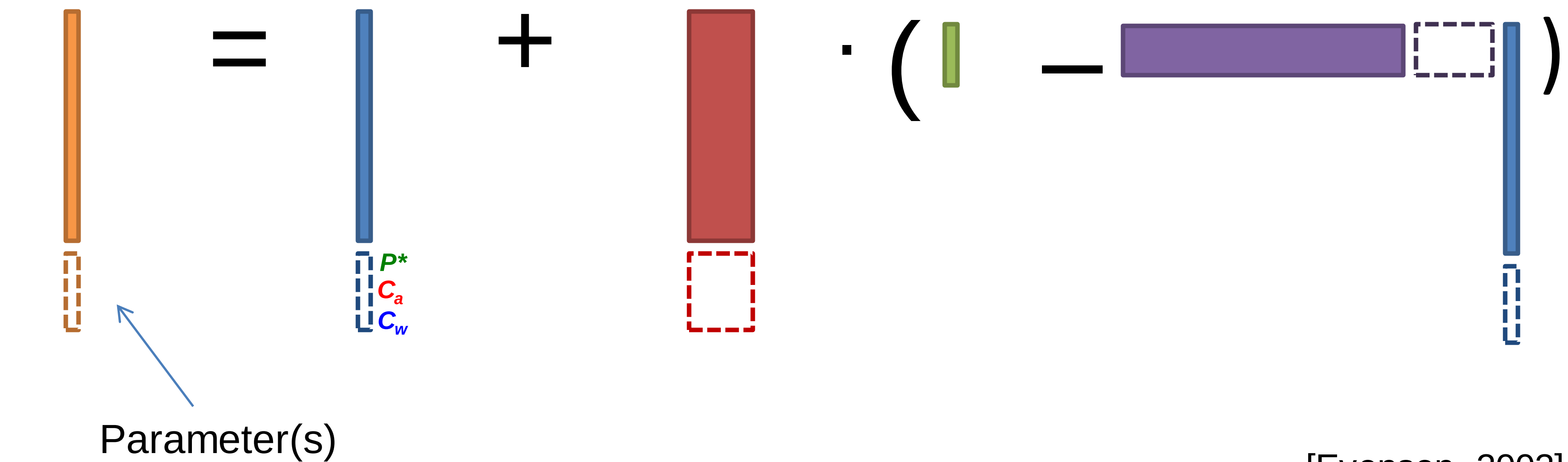
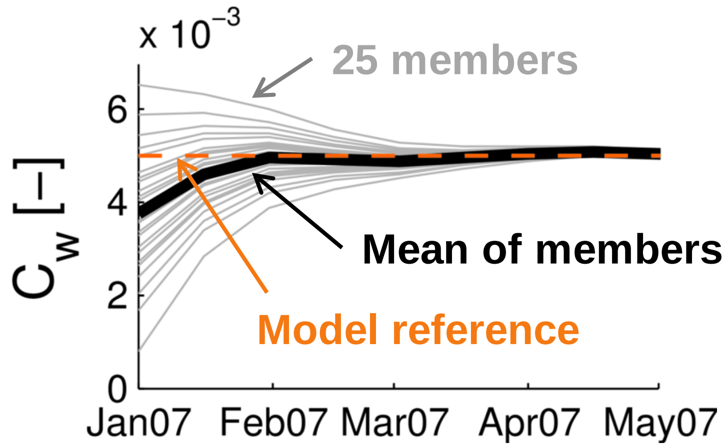
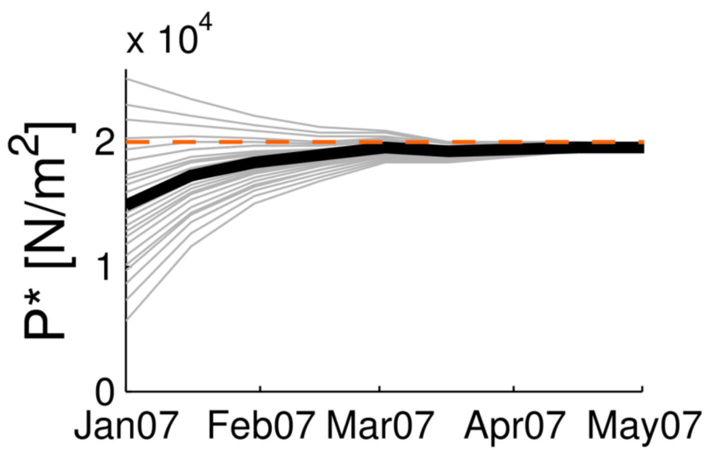
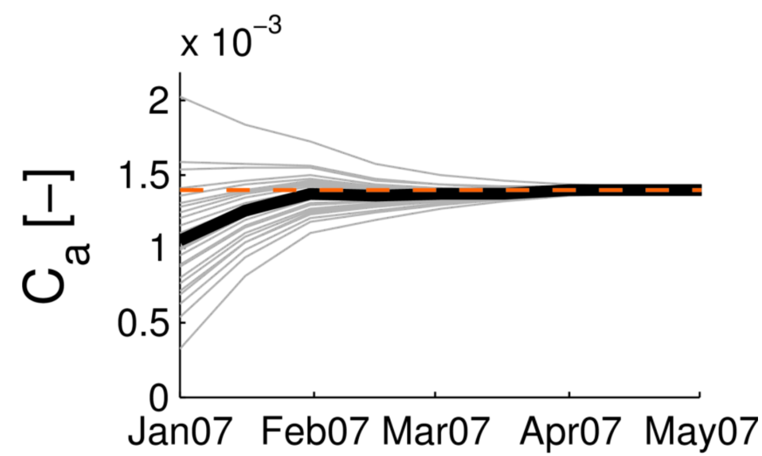


[Evensen, 2003]

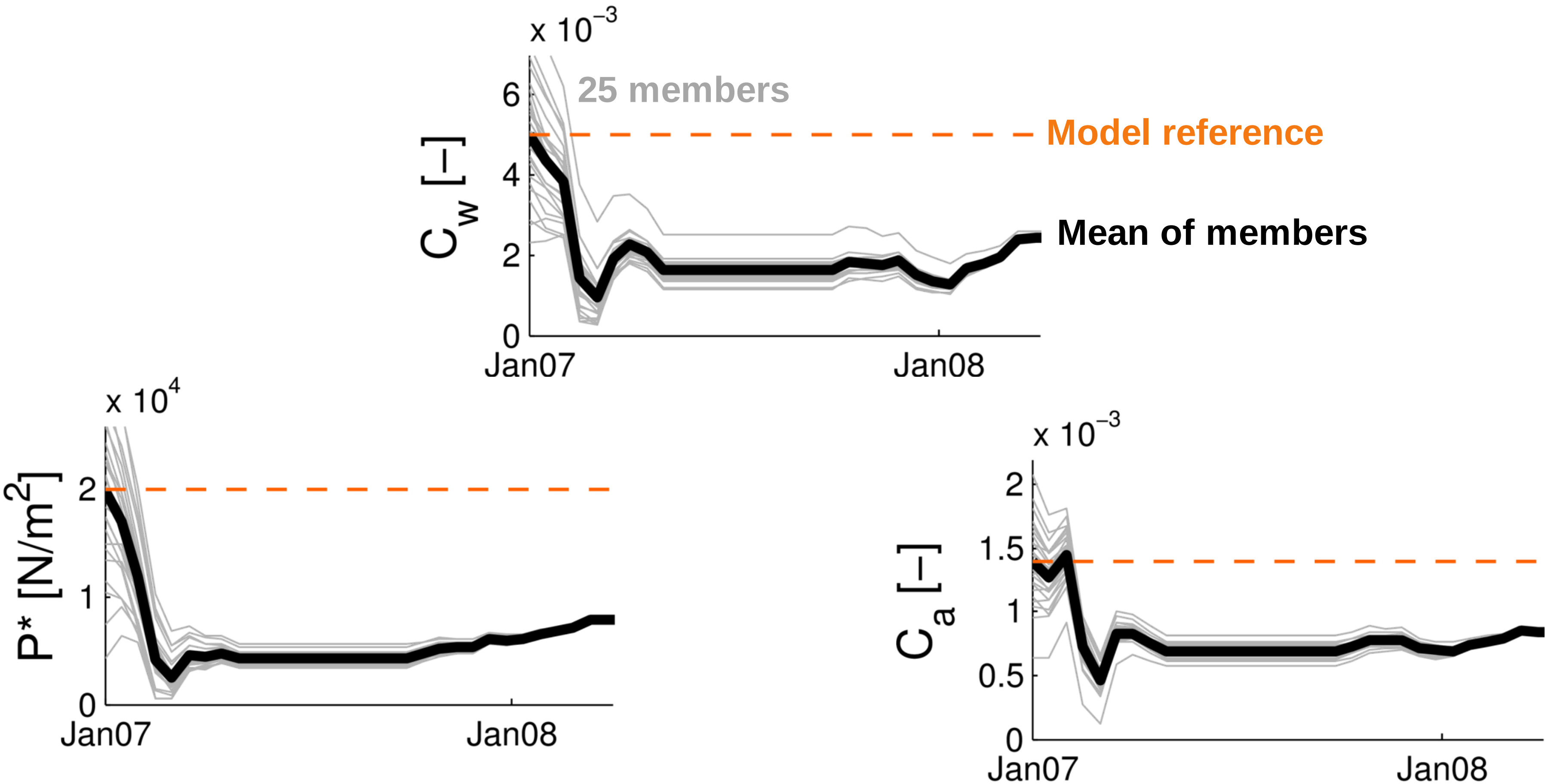
Under perfect model assumption, the original set of parameters is retrieved







With real observations, parameters also converge



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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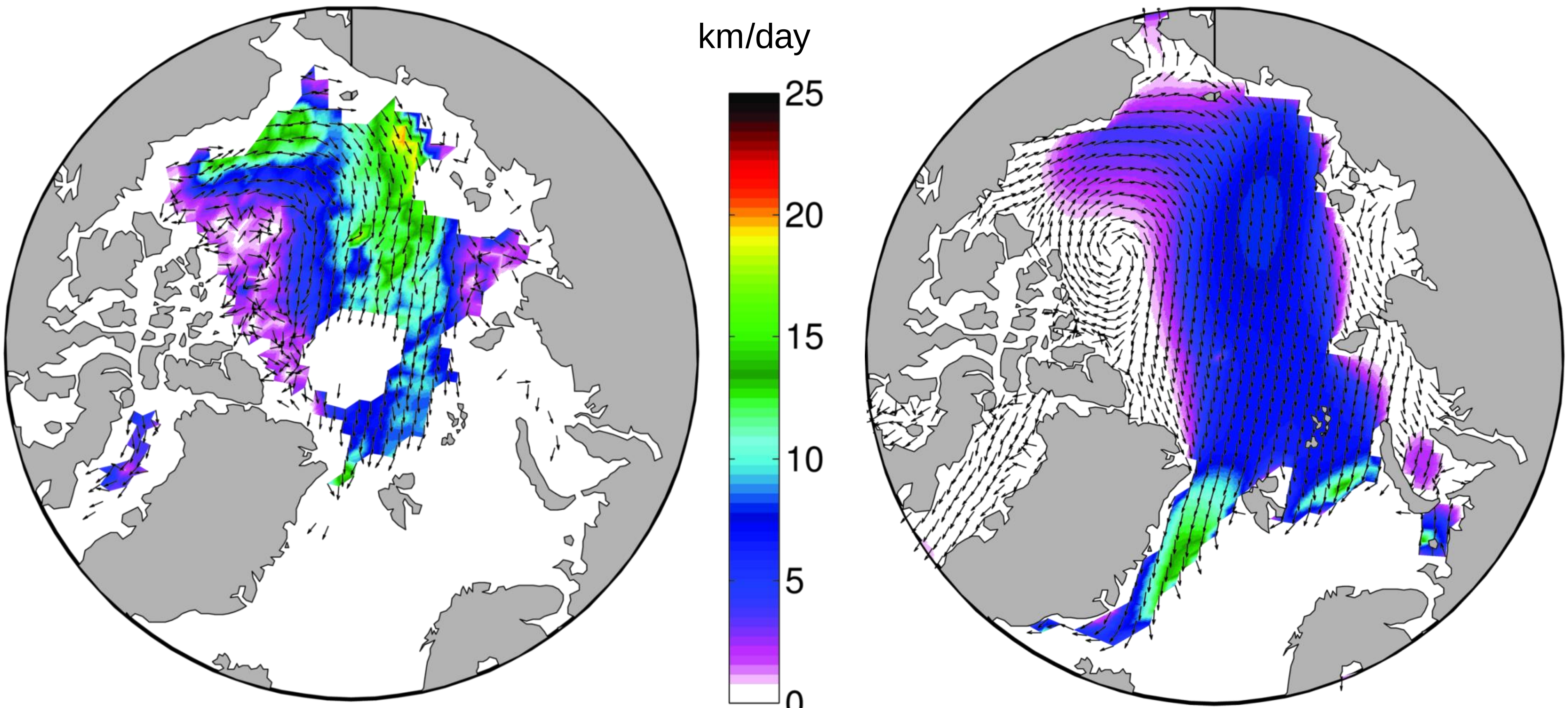
Our ocean-sea ice model underestimates sea ice drift

12→14 April 2012 sea ice drift

Observed | Simulated, no calibration

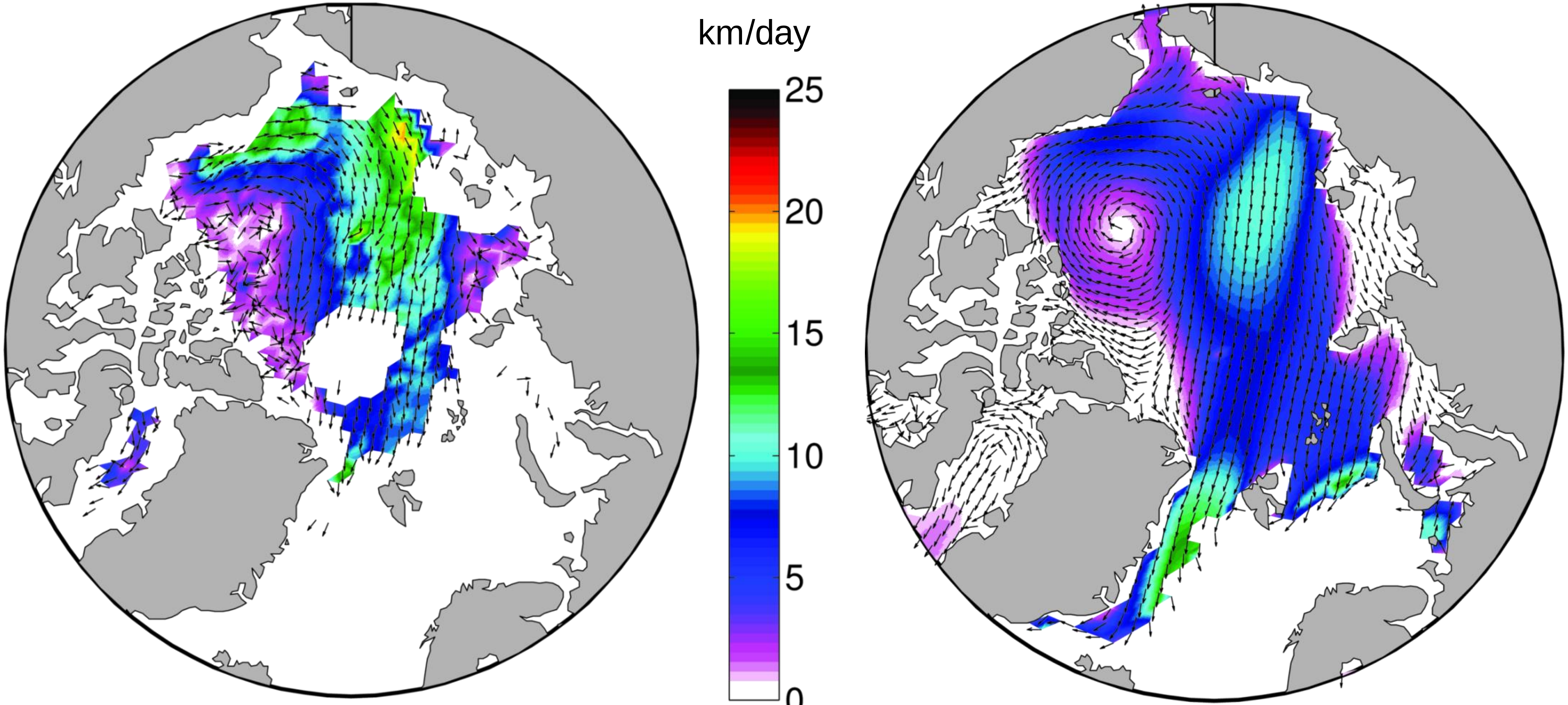


Our ocean-sea ice model underestimates sea ice drift

12→14 April 2012 sea ice drift

Observed

Simulated, *P** calibrated



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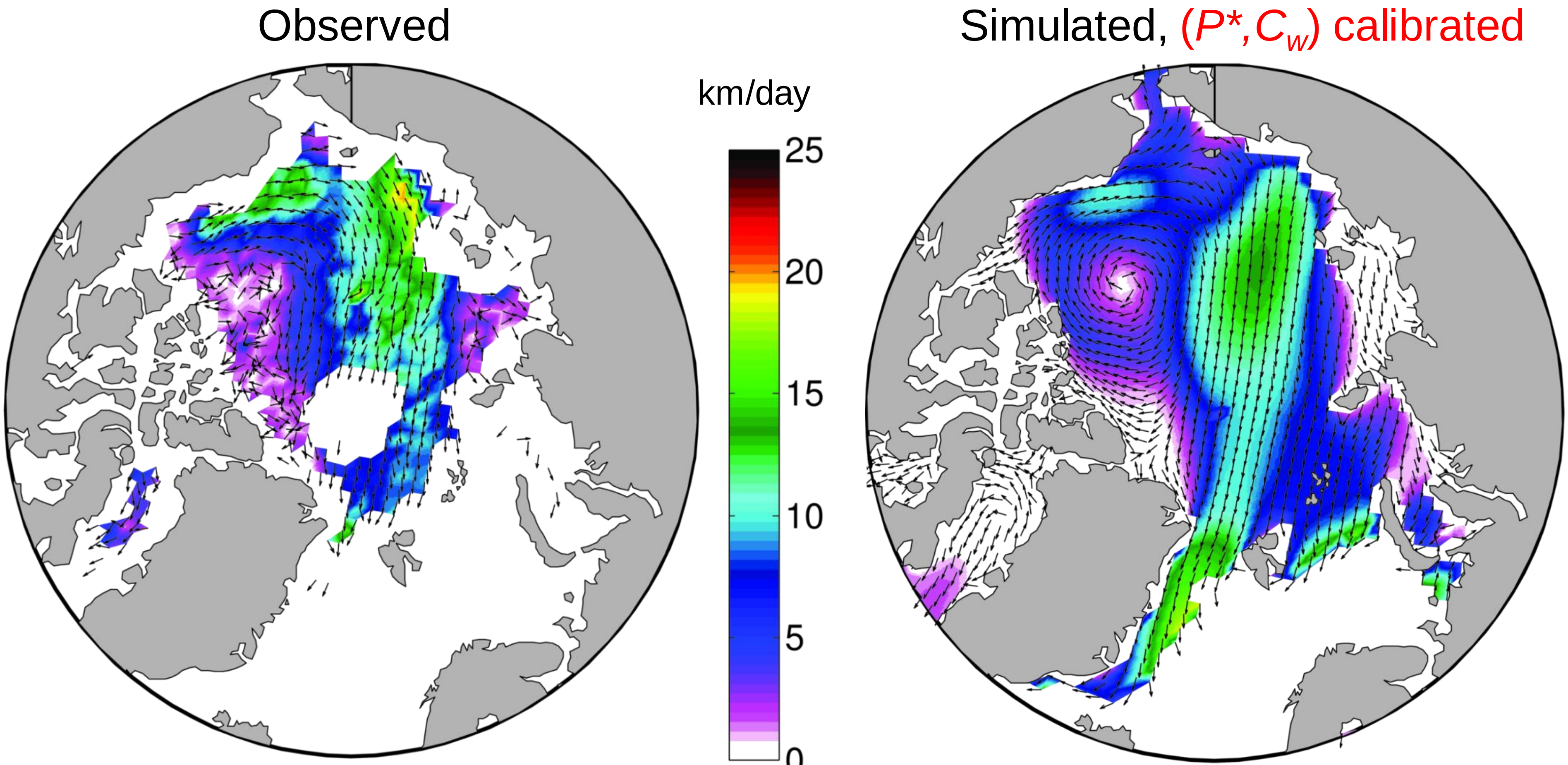

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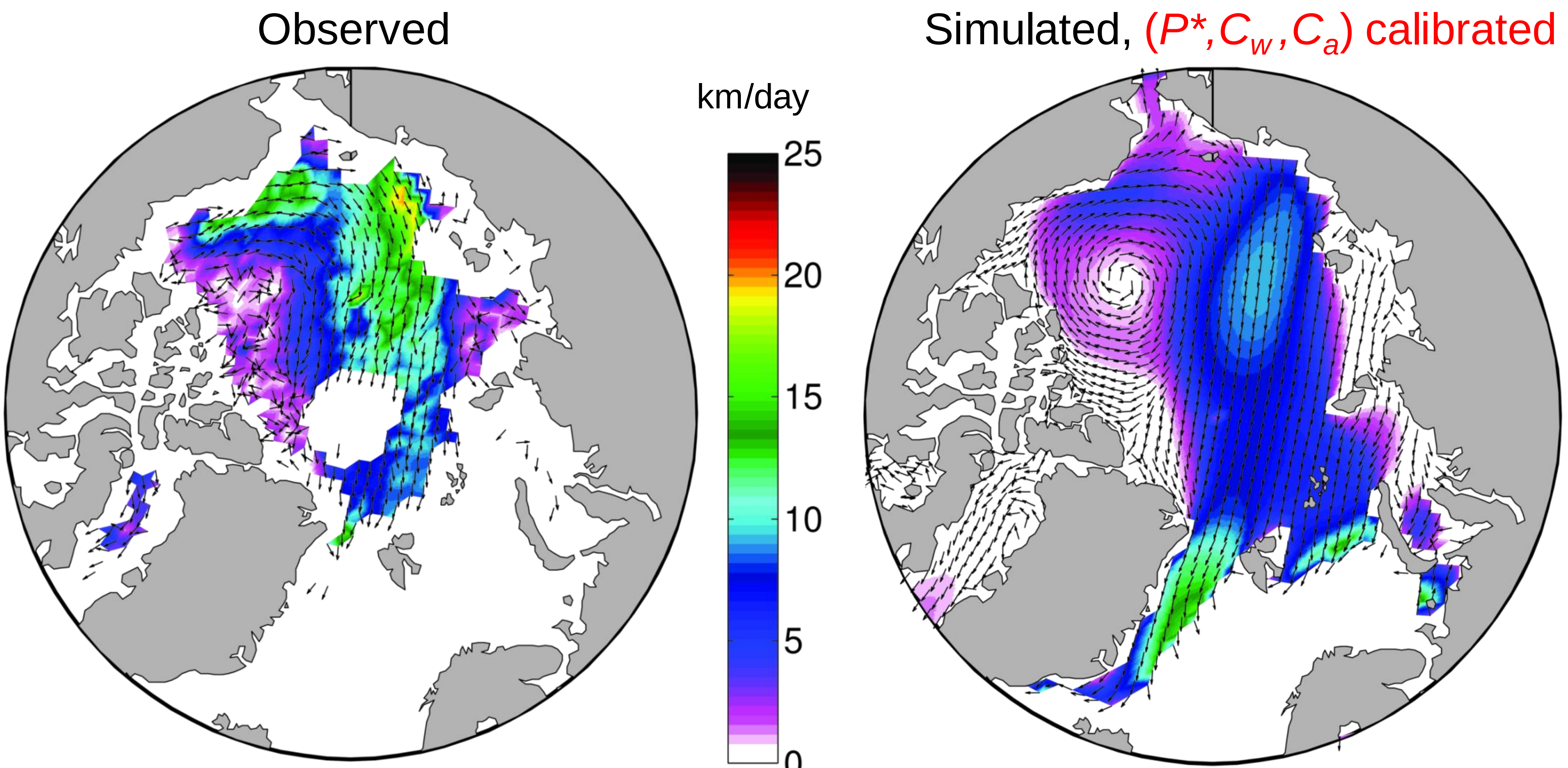
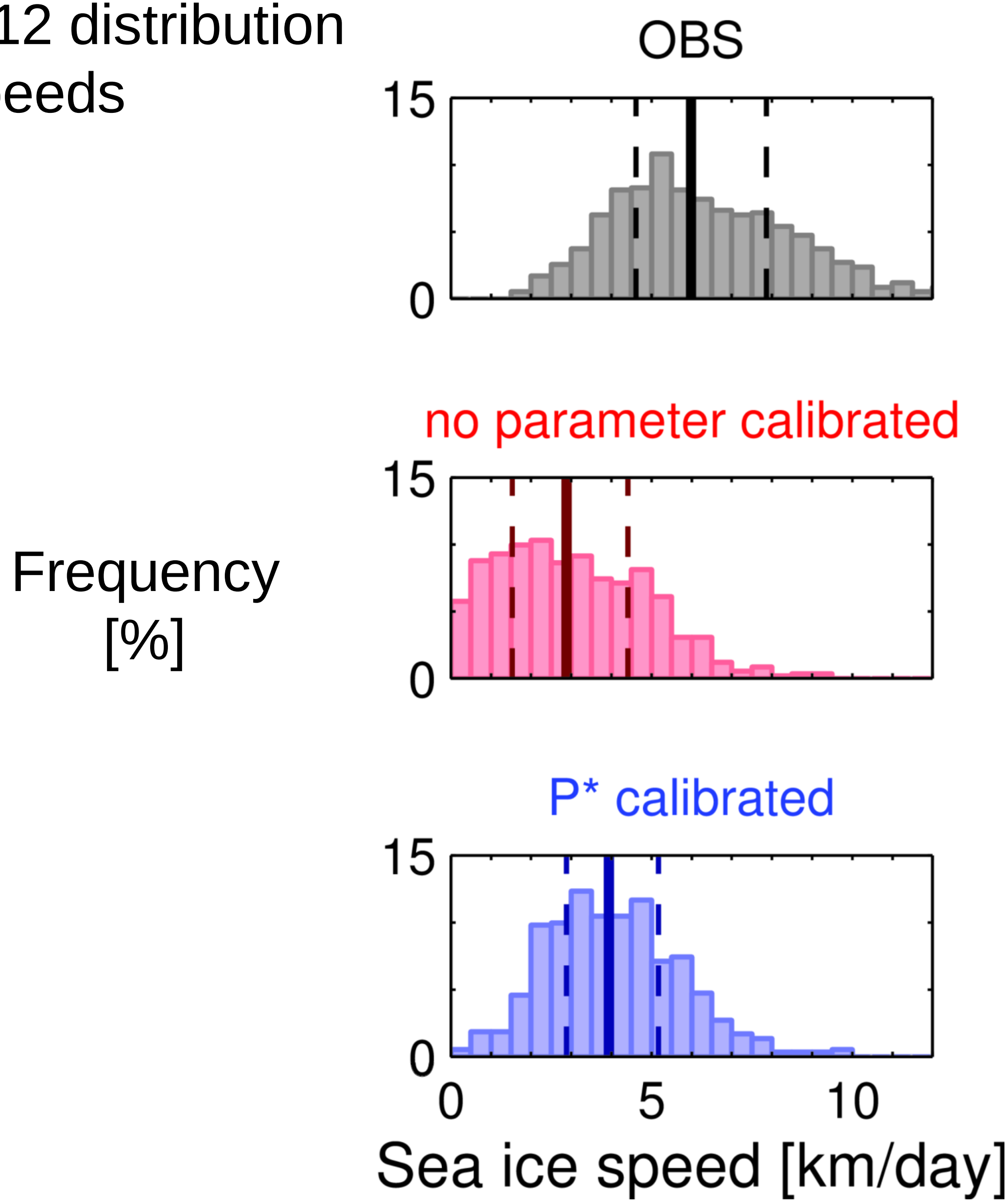


Improved 2007-2012 distribution of Arctic sea ice speeds



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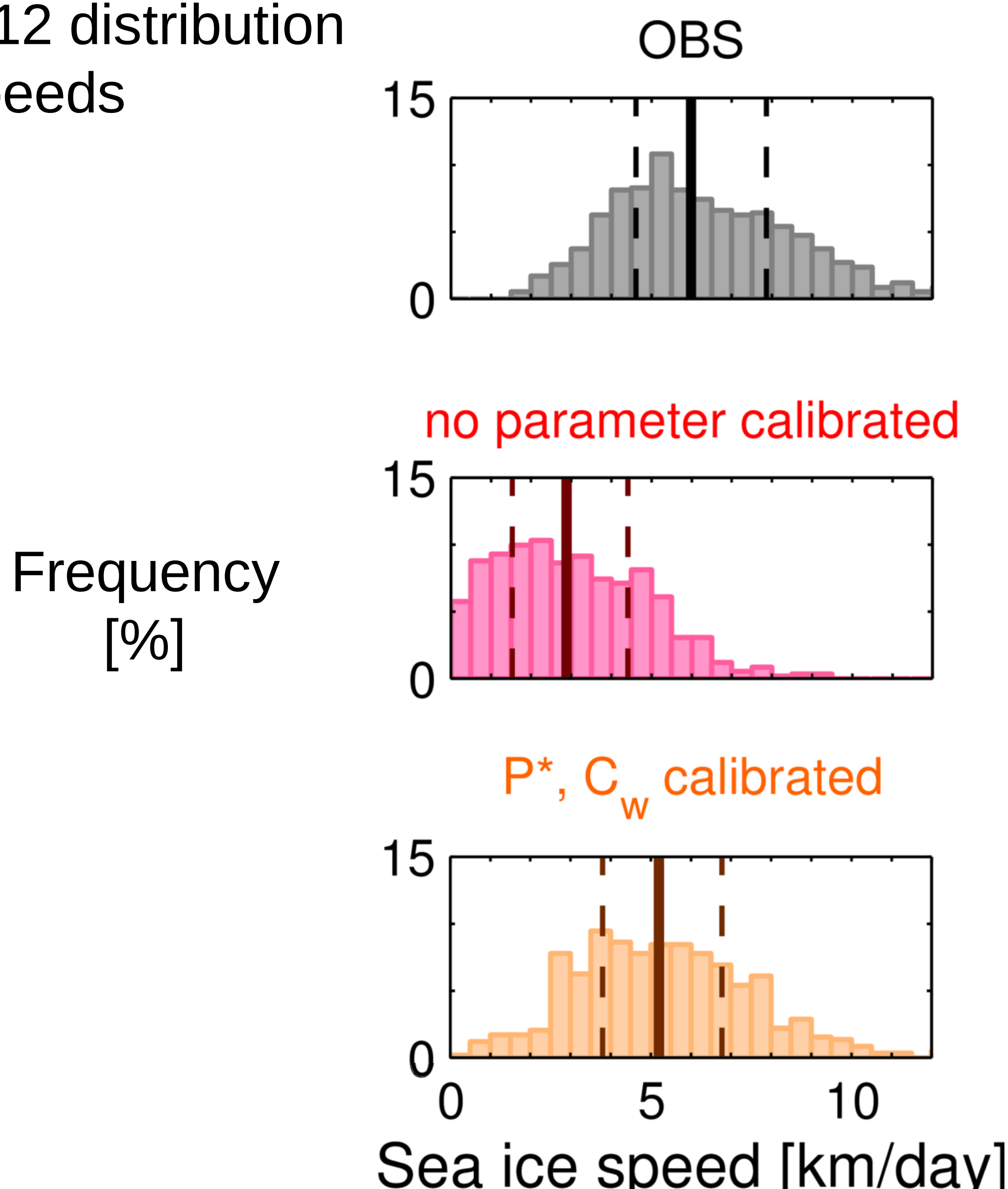


Winter 2010
www.nasa.gov

$$\underbrace{\vec{F}_{Coriolis} + \vec{F}_{Tilt}}_{\text{Negligible at our timescales}} + \underset{\underset{C_a}{\downarrow}}{\boxed{\vec{F}_{Air}}} + \underset{\underset{C_w}{\downarrow}}{\boxed{\vec{F}_{Ocean}}} + \underset{\underset{P^*}{\downarrow}}{\boxed{\vec{F}_{Internal}}} = \underbrace{m\frac{\partial \vec{u}}{\partial t}}_{\text{Negligible at our timescales}}$$

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

C_a C_w P^*

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

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

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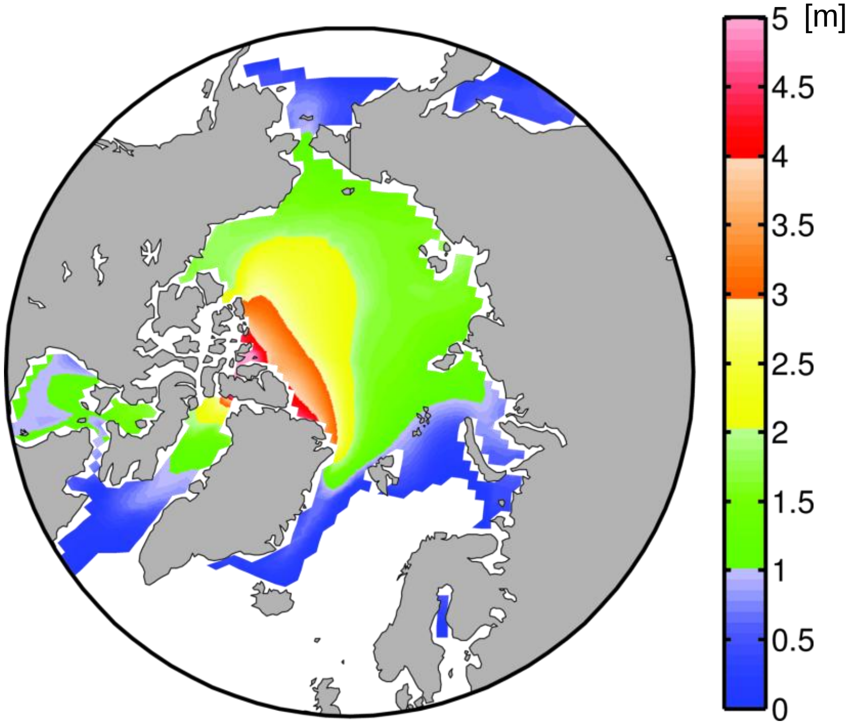
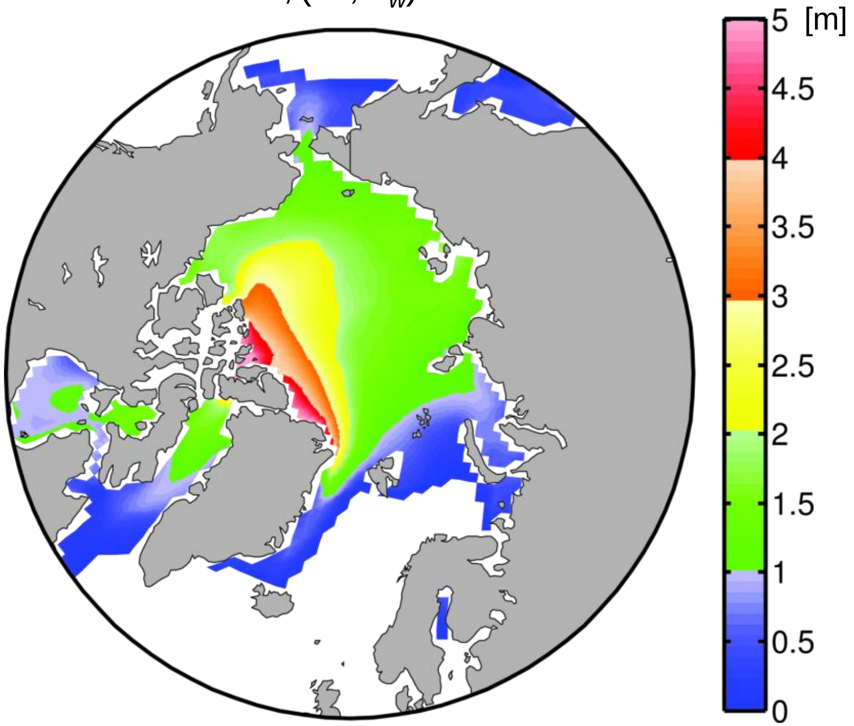
Thick ice gets thicker, thin ice gets thinner

March 2007-2012 sea ice thickness

Simulated, no calibration



Simulated, $(P^*;C_w)$ calibrated



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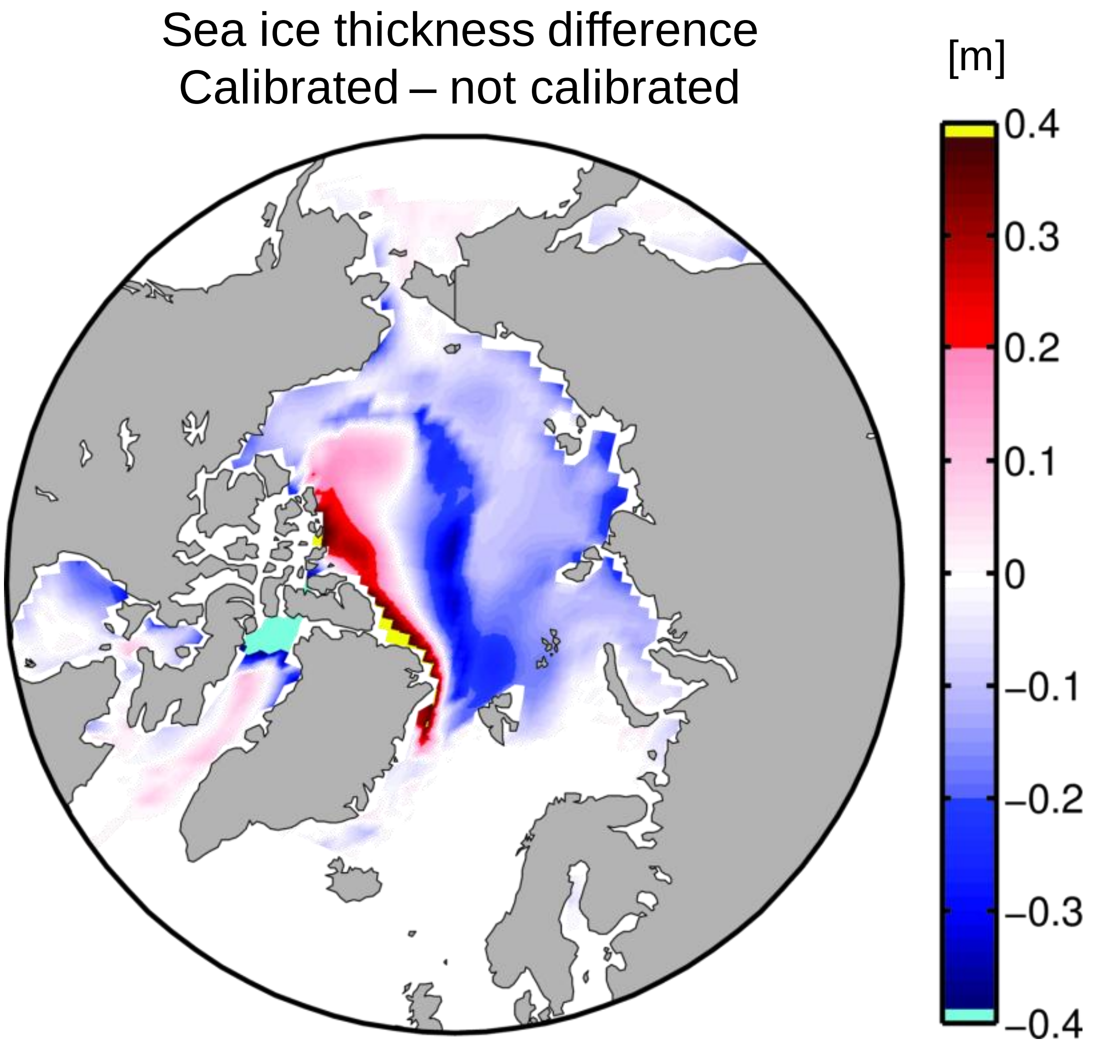
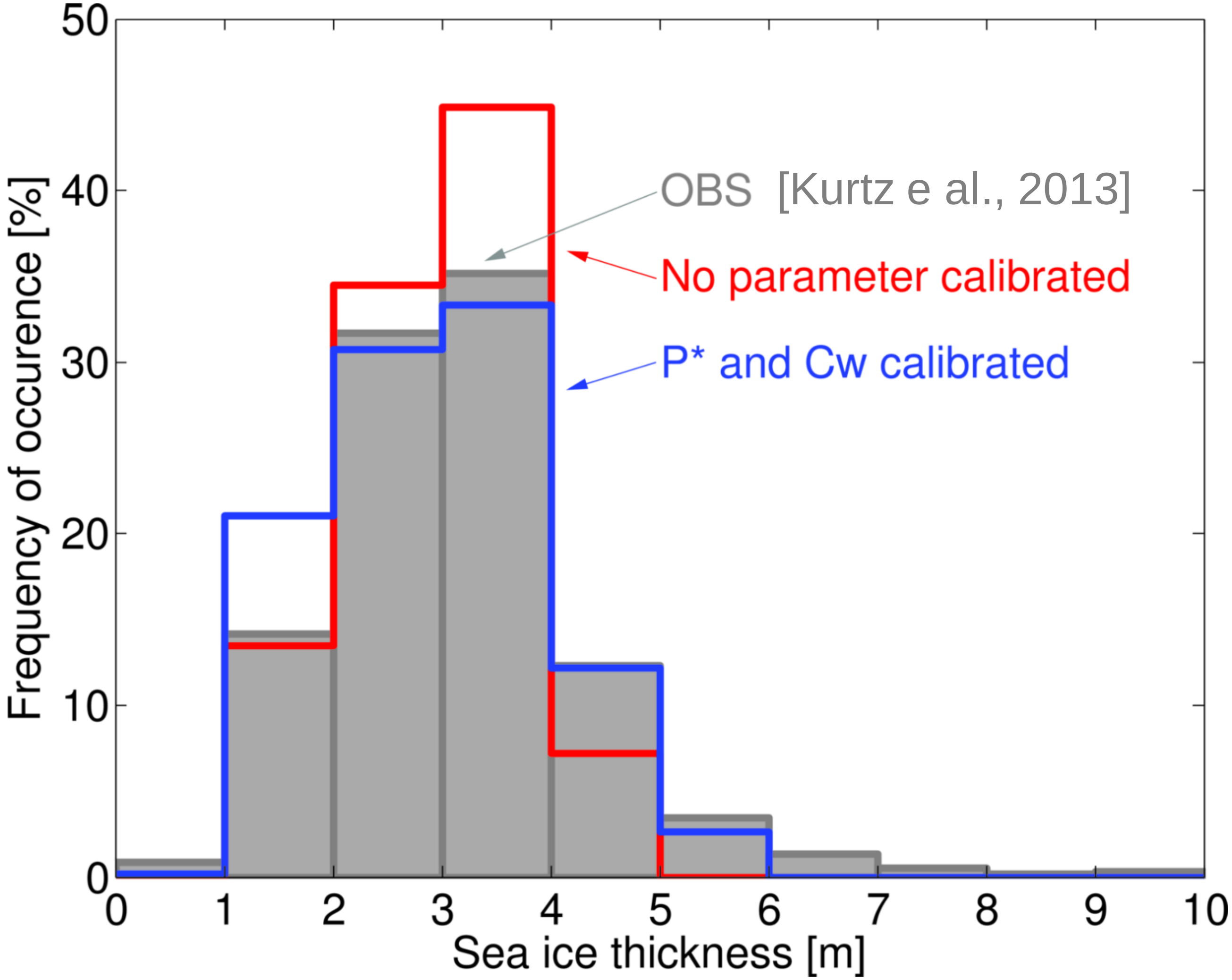
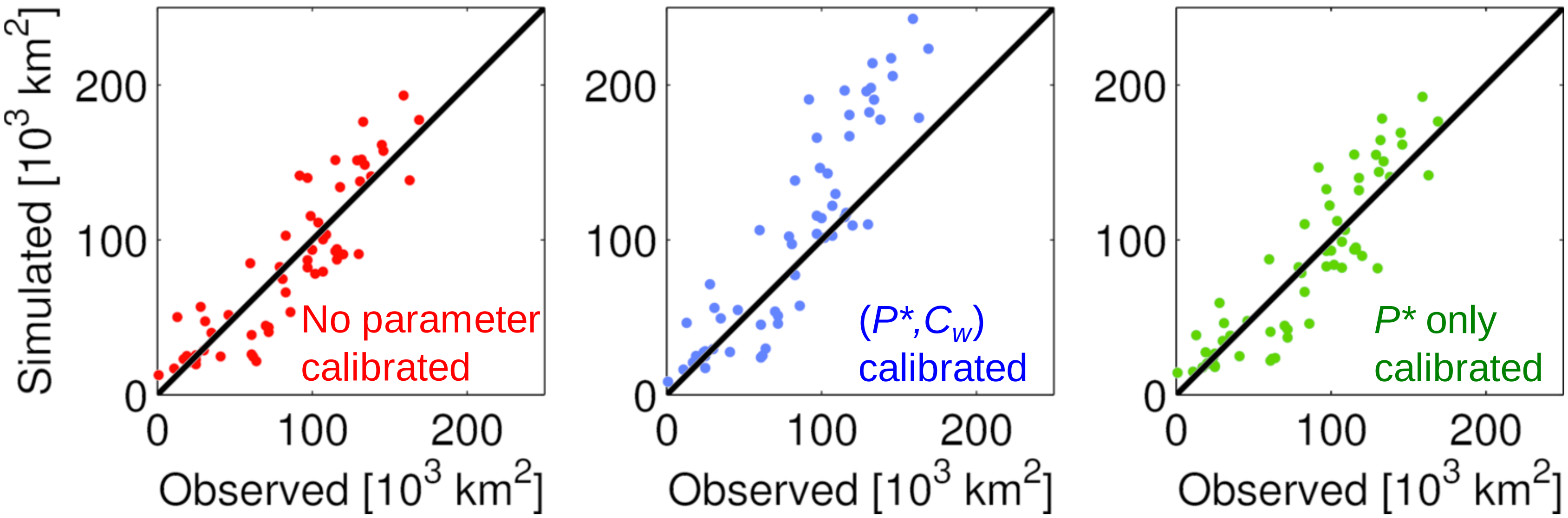


Slight improvement in sea ice thickness distribution



Limitations in a global analysis framework

Areal export of sea ice through Fram Strait



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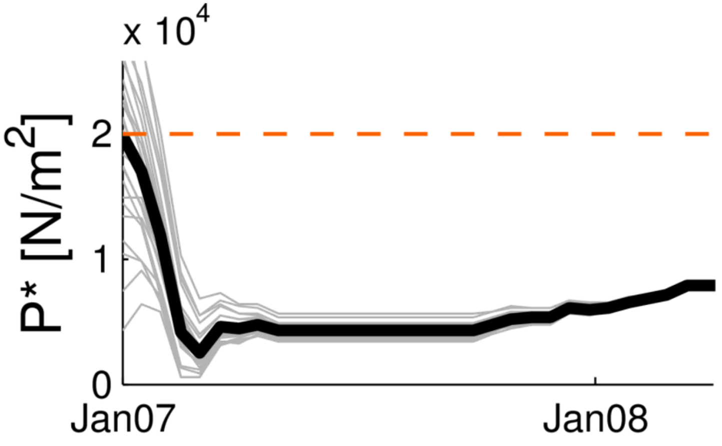
The calibration scheme is extensible

Parameter calibration for GCMs / ESMs

Spatial parameter calibration

Time-dependent calibration



Take home messages

Objective calibration methods become unavoidable

Optimal parameter values are configuration-dependent

Calibrating too much/inappropriate parameters may lead to suboptimal solutions

Thank you

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www.climate.be/u/fmasson