UCL
Université
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de Louvain

Evaluation and improvement of climate simulations of sea ice

François Massonnet

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Doctoral Dissertation presented in
fulfillment of the requirements for
the degree of Doctor in Sciences

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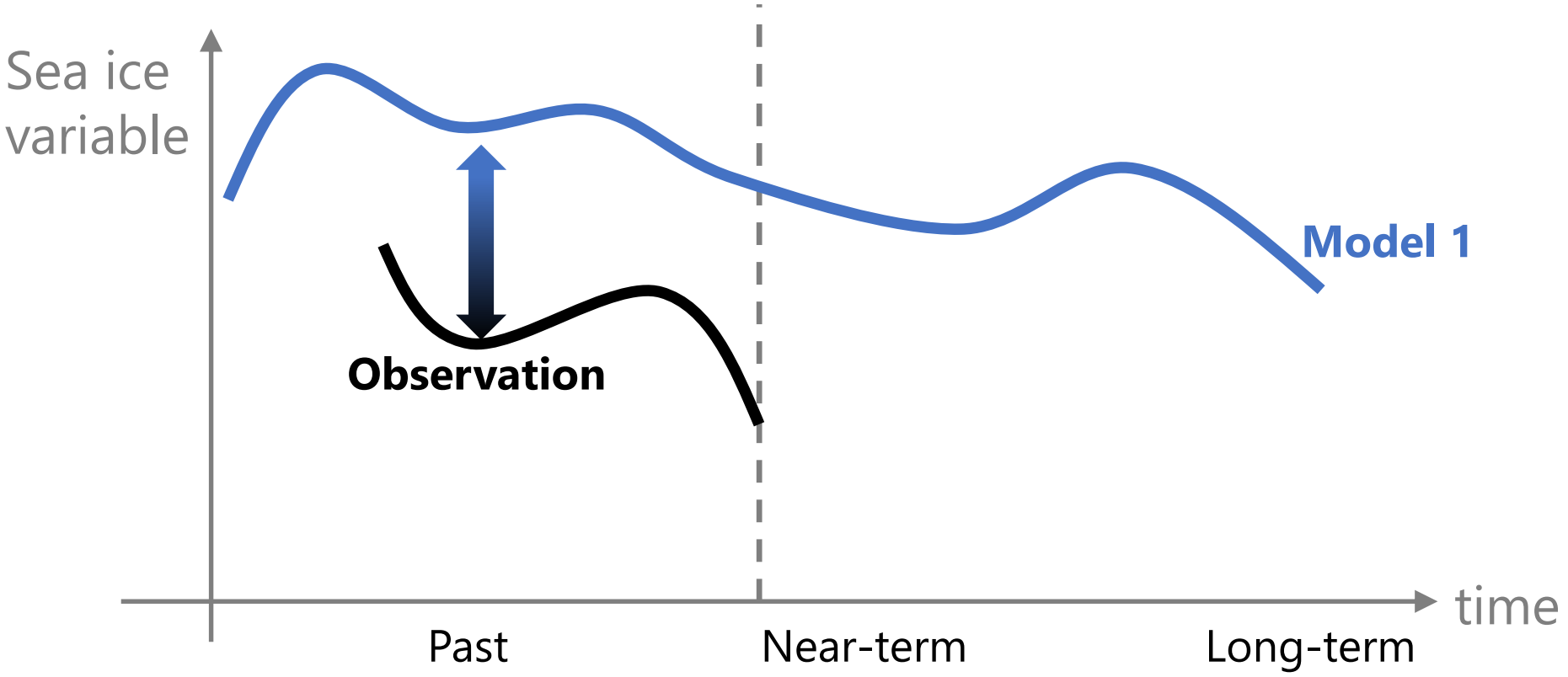
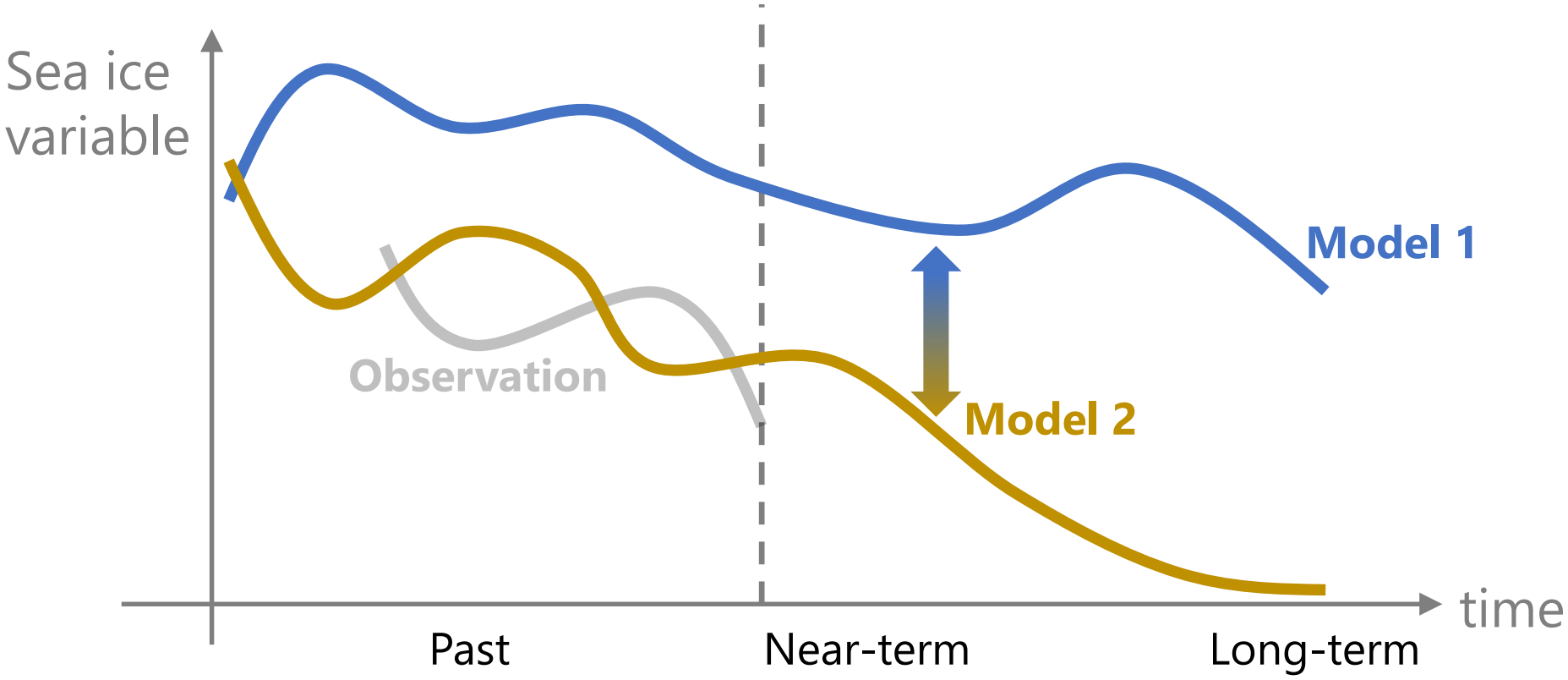
1. Assessing sea ice model performance

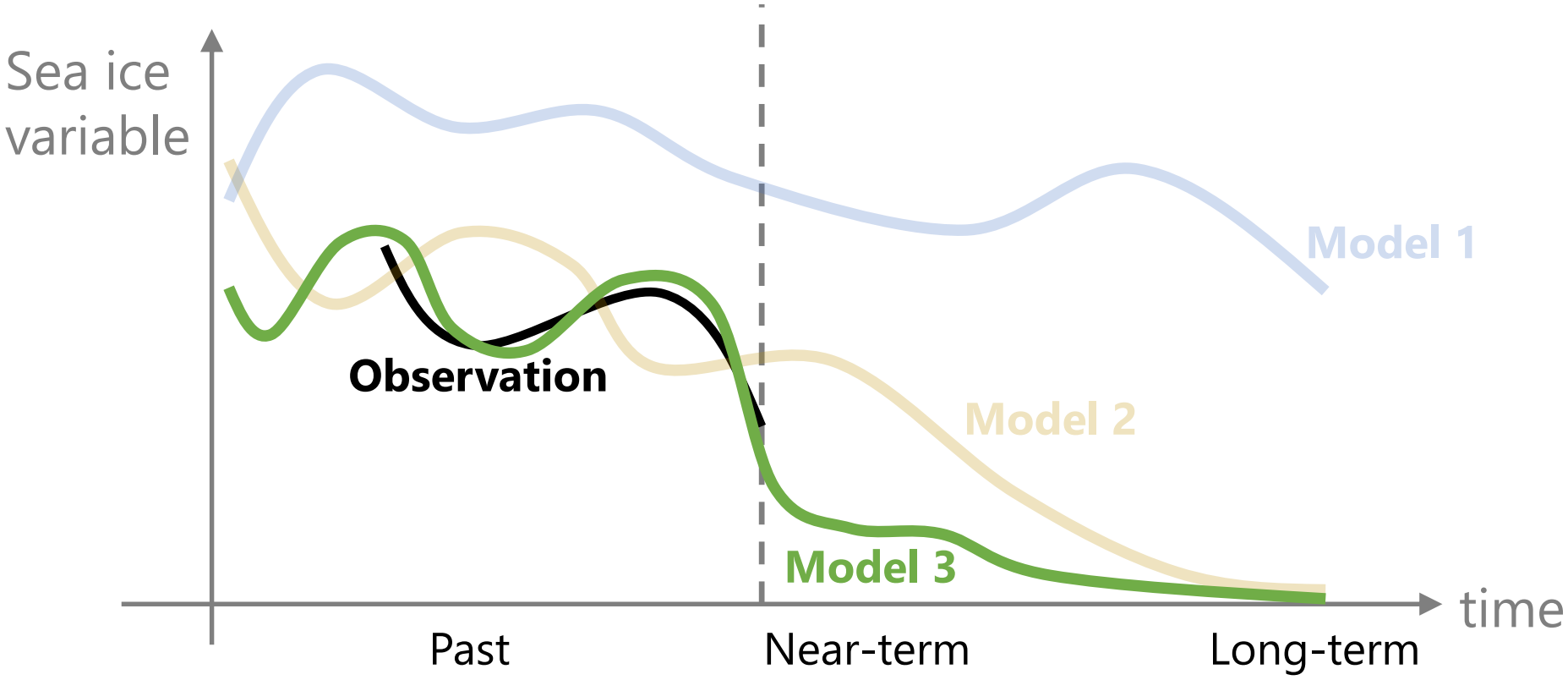


1. Assessing sea ice model performance

2. Identifying the sources of spread



1. Assessing sea ice model performance
2. Identifying the sources of spread
3. Improving the simulation of sea ice



1. **Assessing sea ice model performance**
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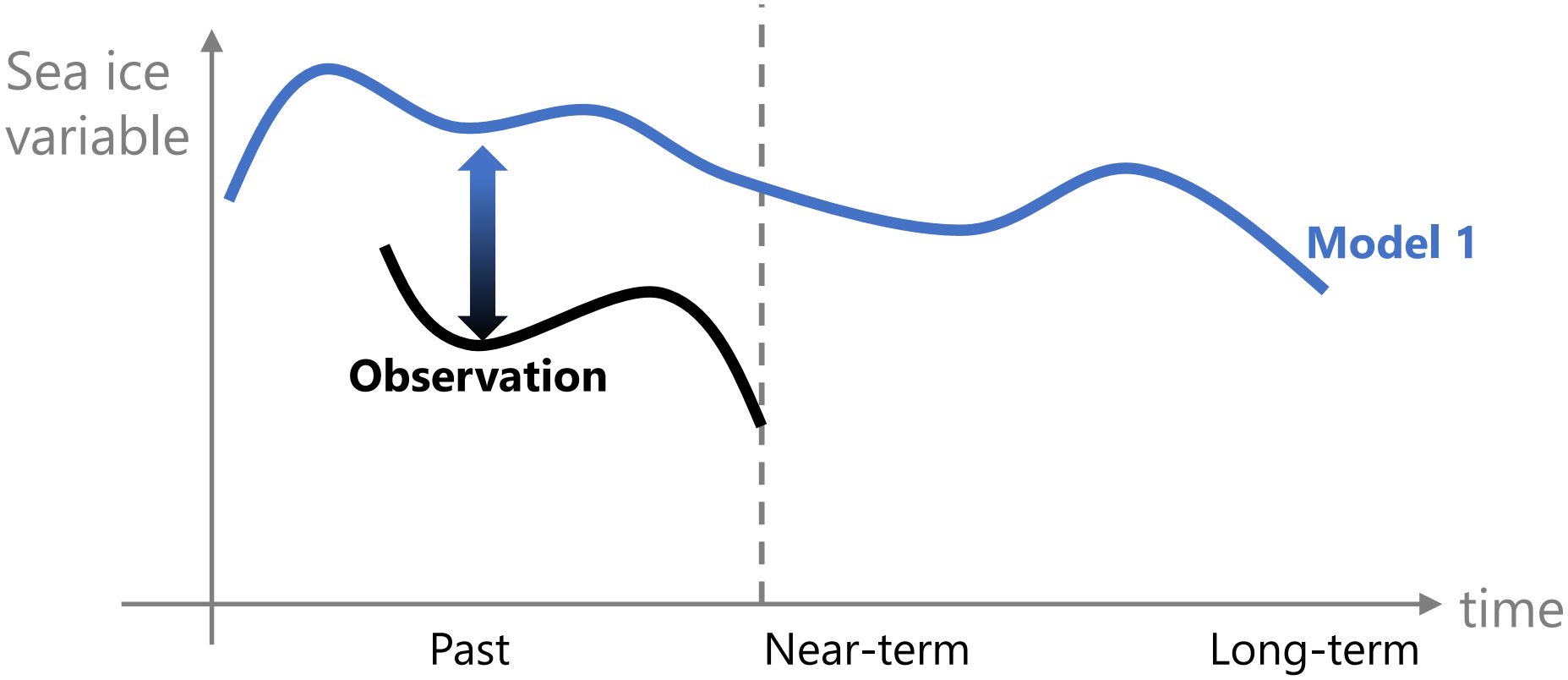
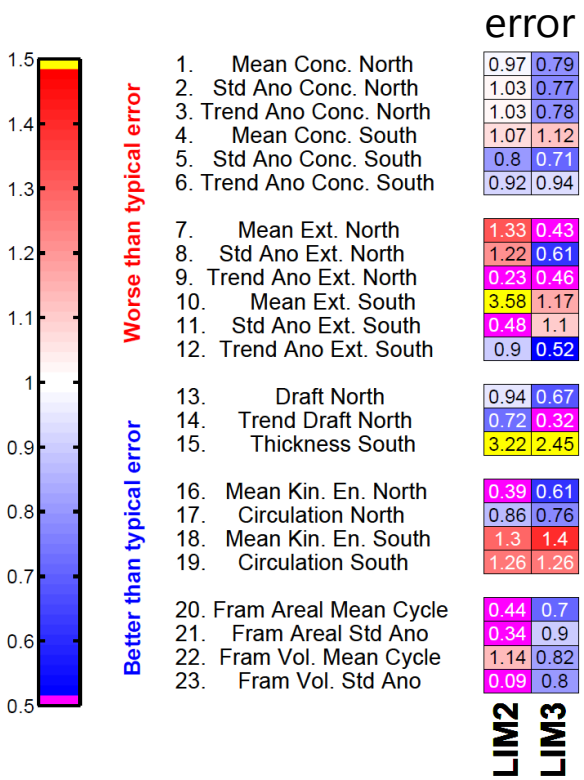
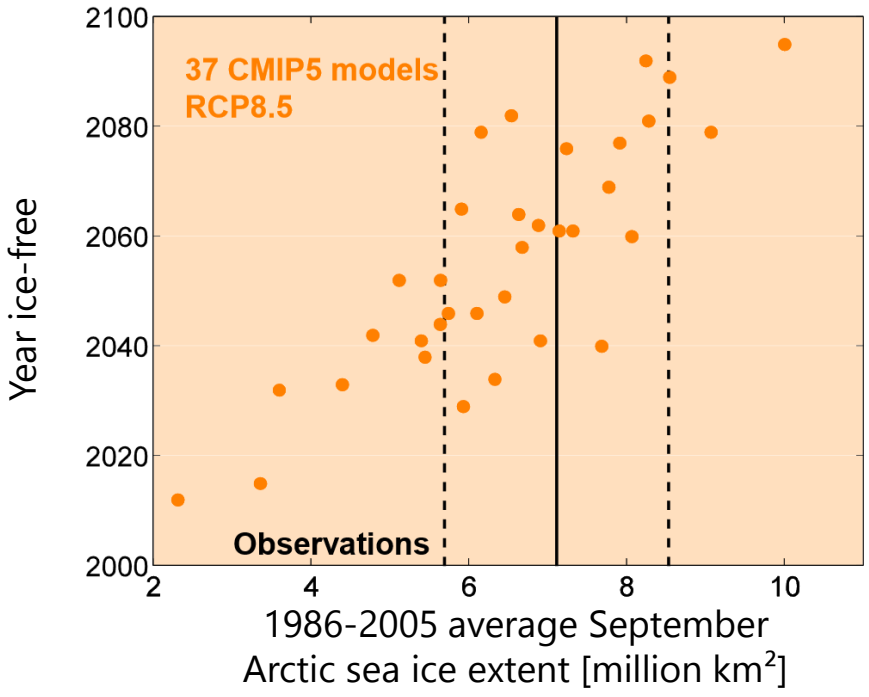


Metrics for model evaluation depend on the user's intention

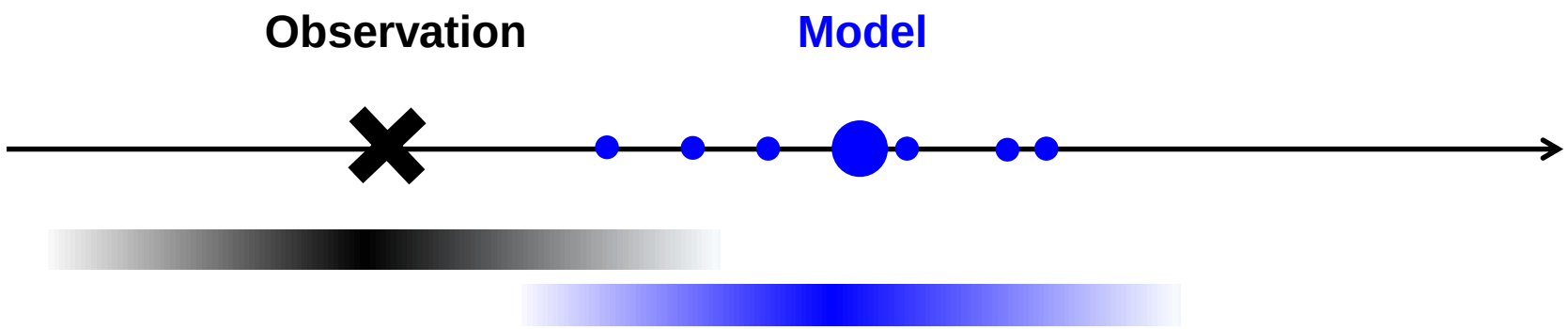
Testing the sensitivity of a model to sea ice physics



Constraining 21st century summer Arctic sea ice projections



We should never reject a model for wrong reasons



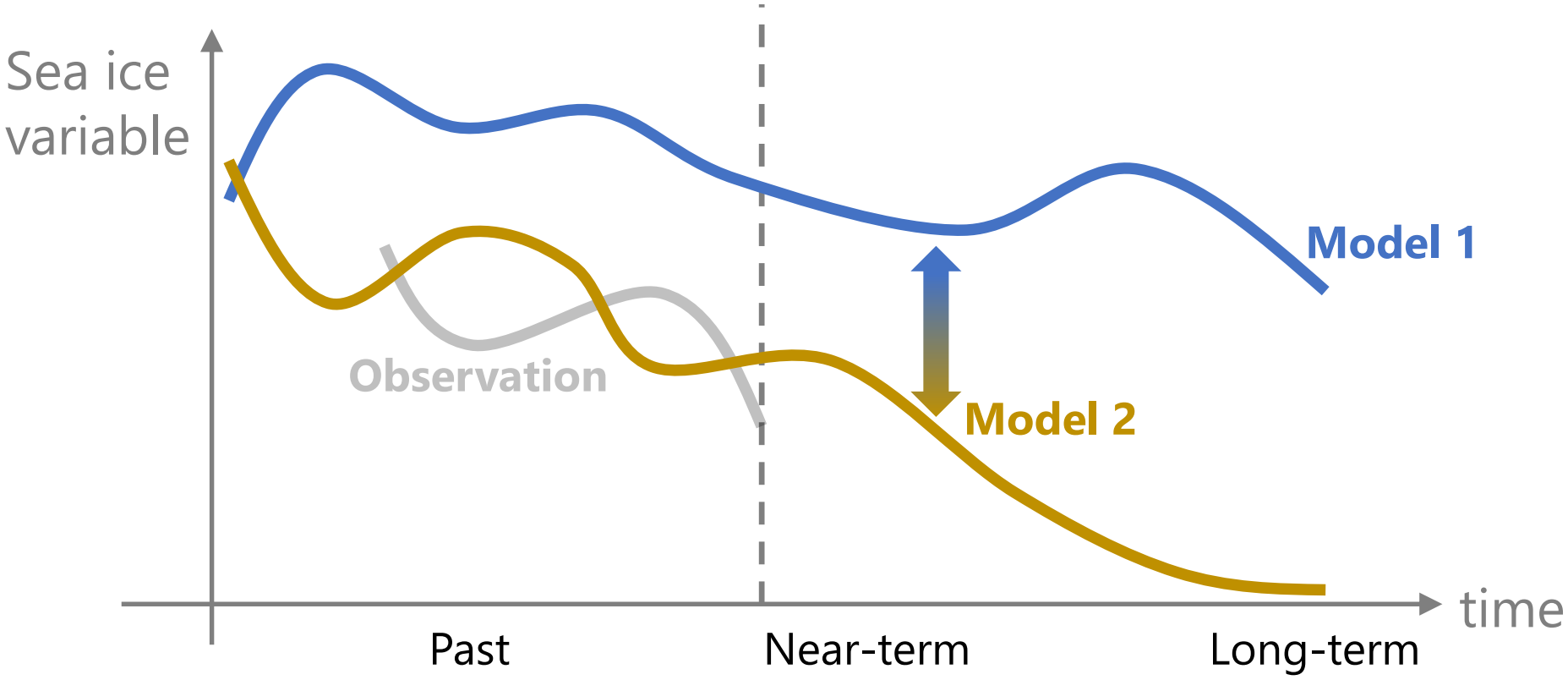
Consider all reasons why there might be a difference:

- Measurement error
- Methodological error
- Internal climate variability
- Actual model error

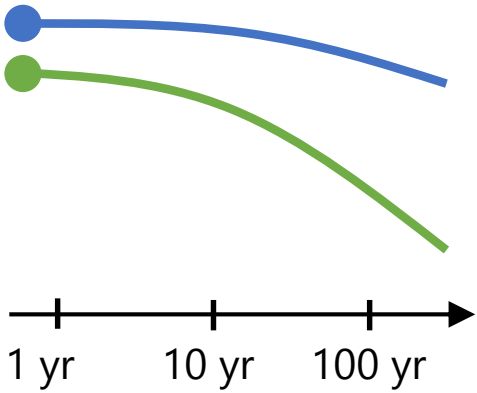
1. Assessing sea ice model performance

Lessons learned	Contributions from PhD thesis
- Any set of metrics is always application-oriented - Always give the models the maximal benefit of the doubt	- Comprehensive metrics to test new ocean-sea ice model configurations - Simple metrics to constrain summer sea ice projections (IPCC)

1. Assessing sea ice model performance
   Know your intentions and be careful
2. **Identifying the sources of spread**

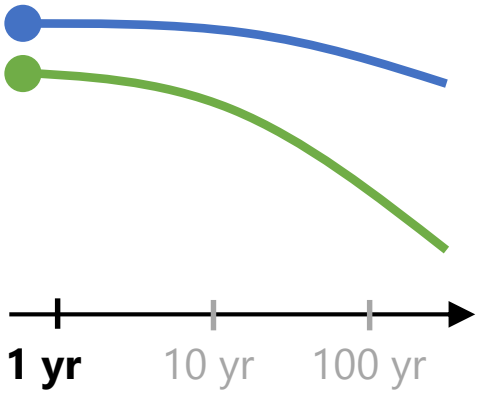


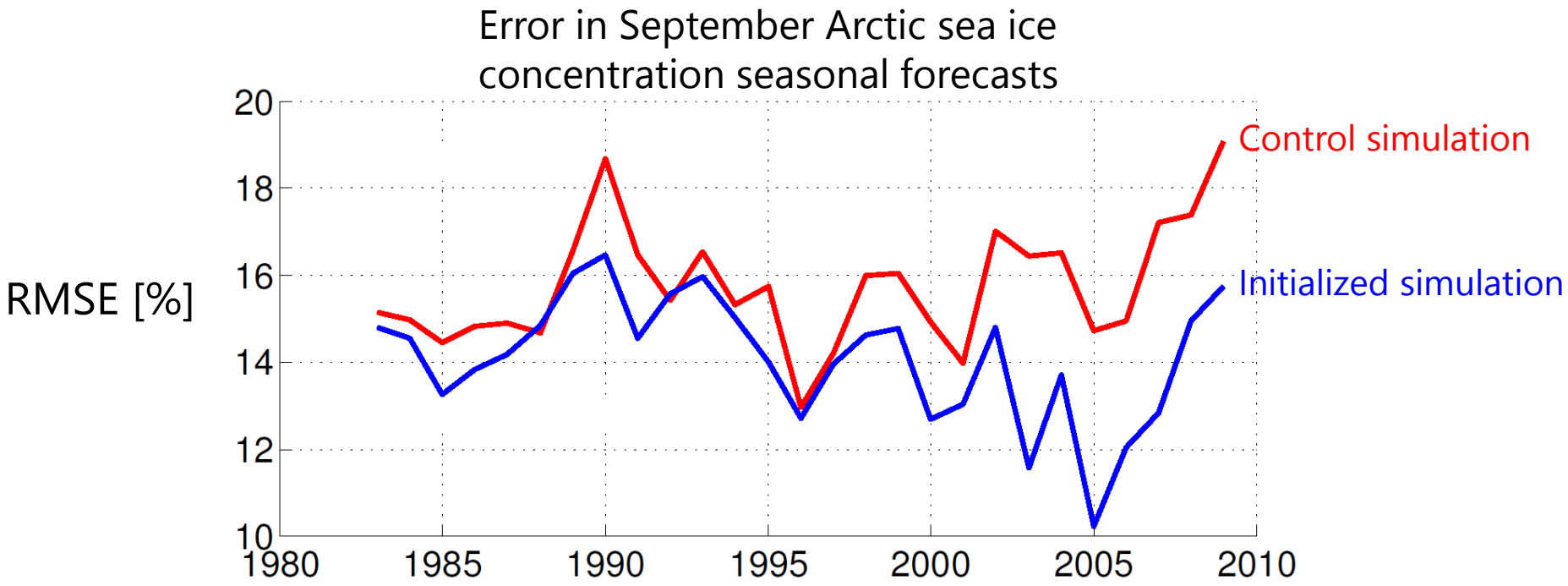
Two climate simulations may depart from each other due to



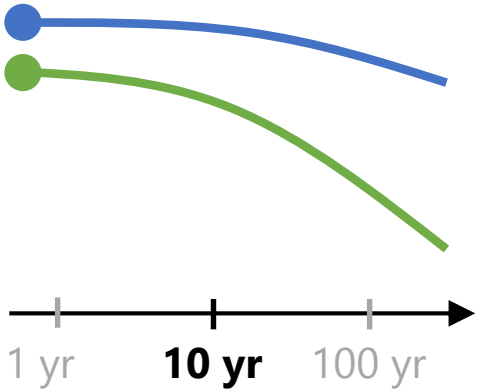
- different initial conditions
- different model physics
- (different forcings)

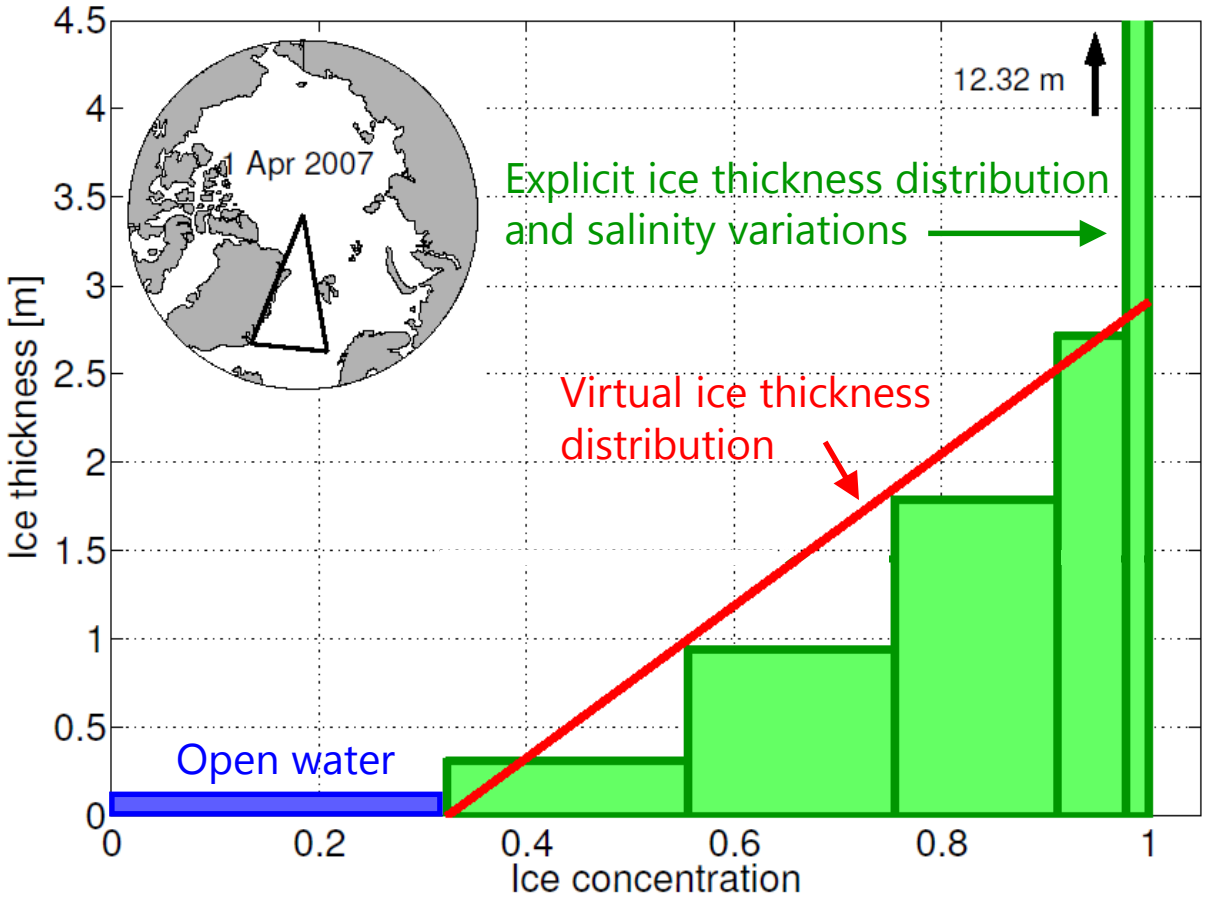
Arctic sea ice initial conditions matter for seasonal prediction



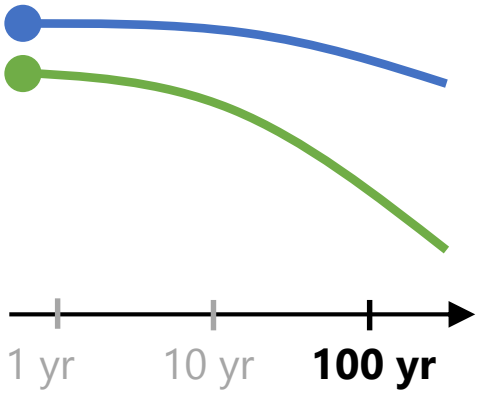


Model sea ice physics matter for the simulation of Arctic sea ice

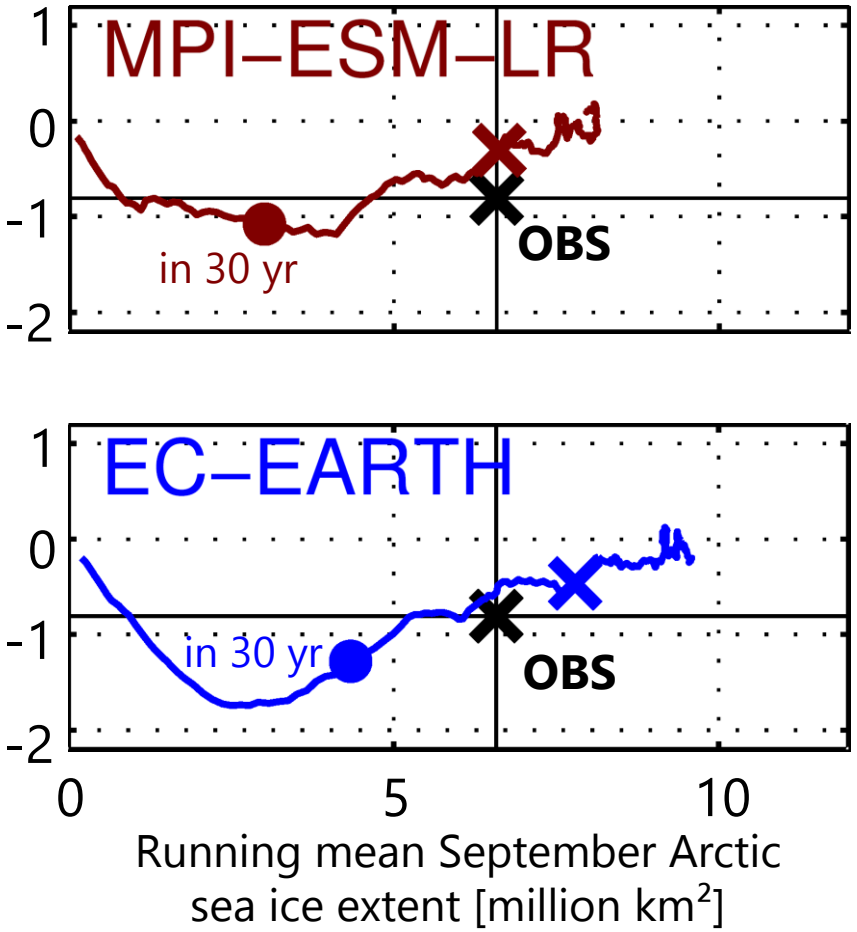




Baseline Arctic sea ice climatology matters for 21st century projections



Running trend September sea ice extent [million km^2/10yr]



2. Identifying the sources of spread

Lessons learned	Contributions from PhD thesis
- Sea ice model physics, initial conditions and baseline climatology matter in the Arctic - Thinner ice, coarse model resolution and lower baseline skill do not allow to confirm this hypothesis in Antarctica	- Evidence that the community should move towards advanced sea ice models in GCMs - Evidence that the sea ice state should be correctly initialized in seasonal prediction systems.

1. Assessing sea ice model performance
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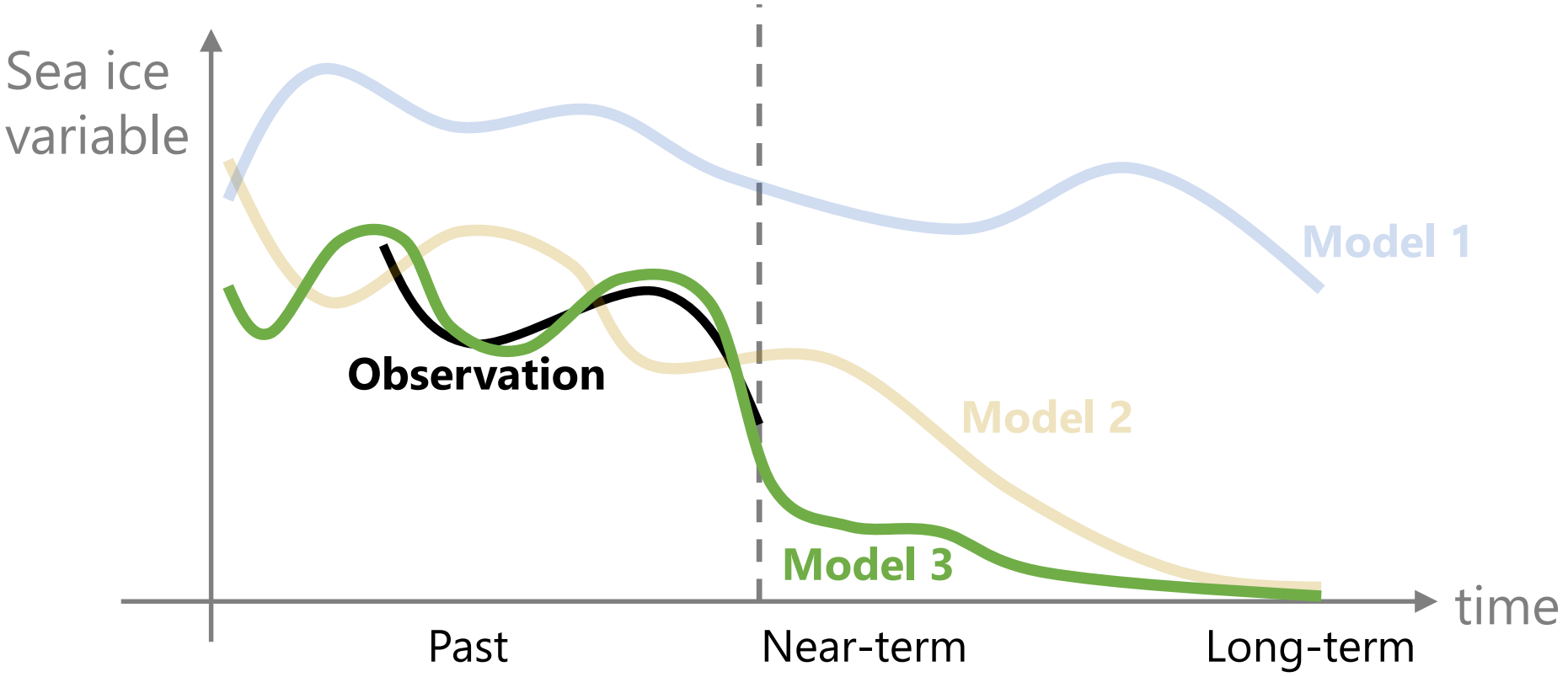
2. Identifying the sources of spread
   sources of spread in the Arctic than in the Antarctic

Clearer

3. Improving the simulation of sea ice



How to improve the simulations?

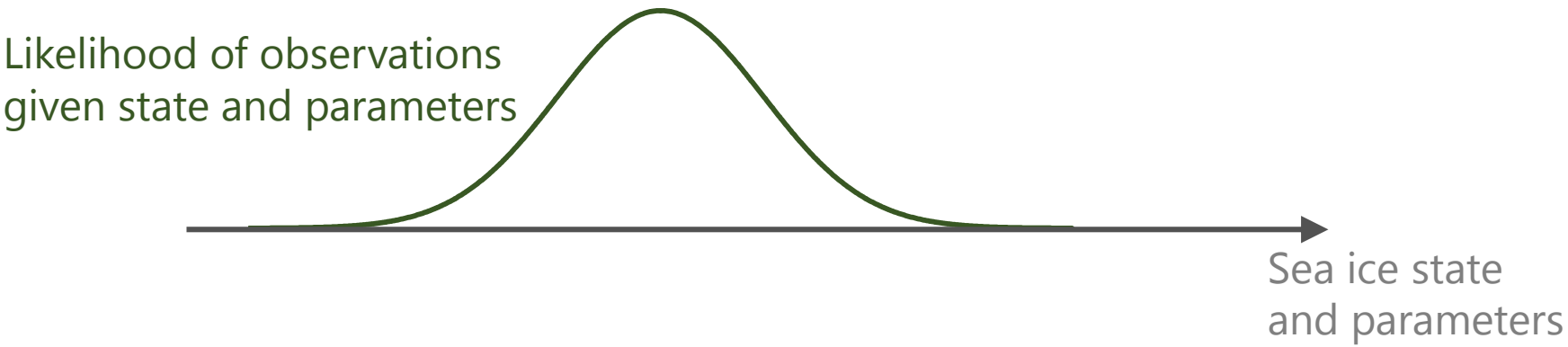
Arctic sea ice initial conditions matter

Estimate the state of the model

Arctic sea ice model physics matter

Develop the model physics

Calibrate the model parameters



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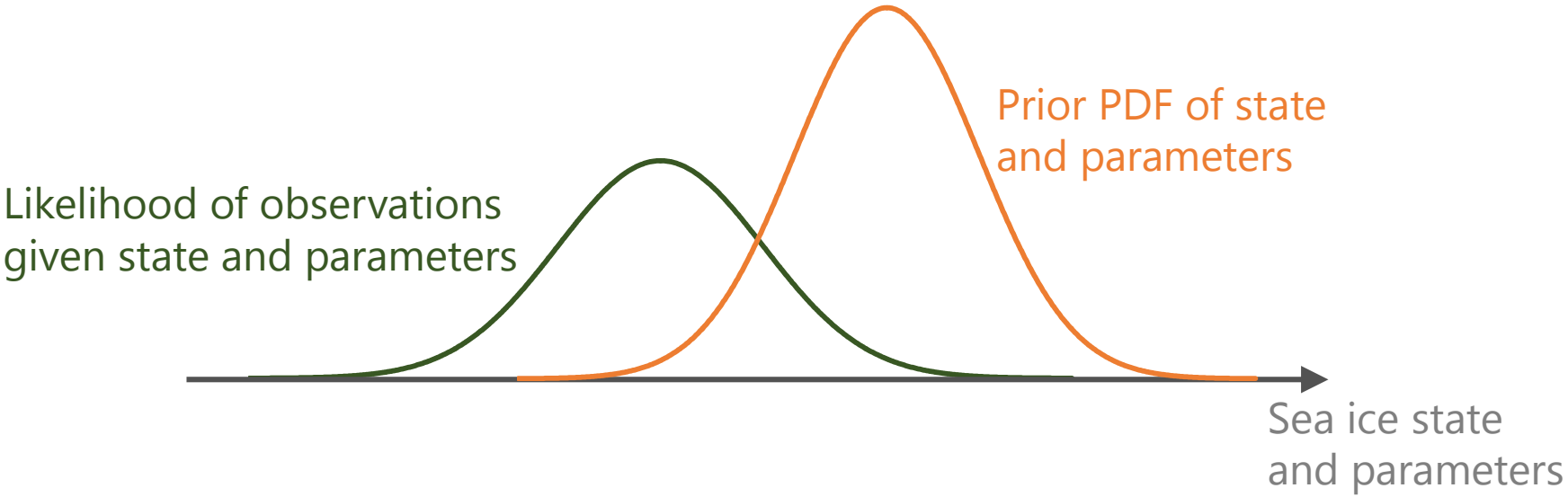

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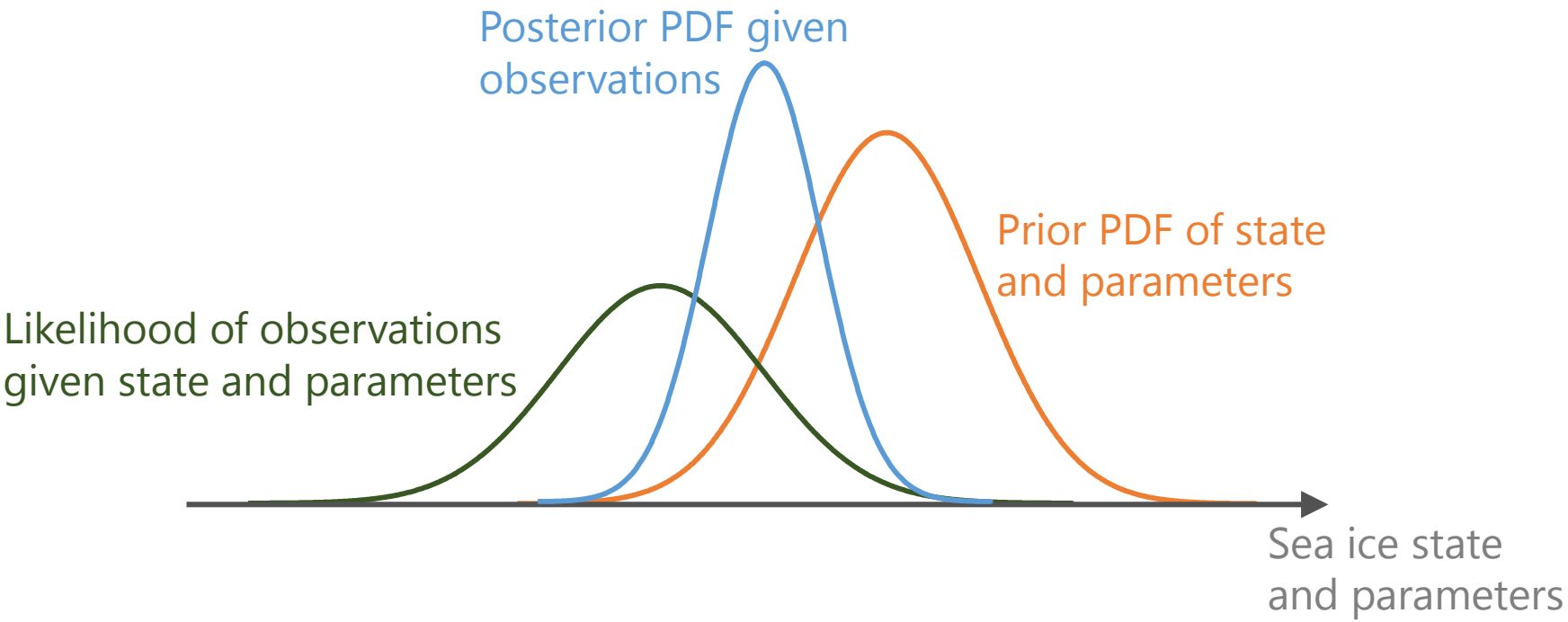
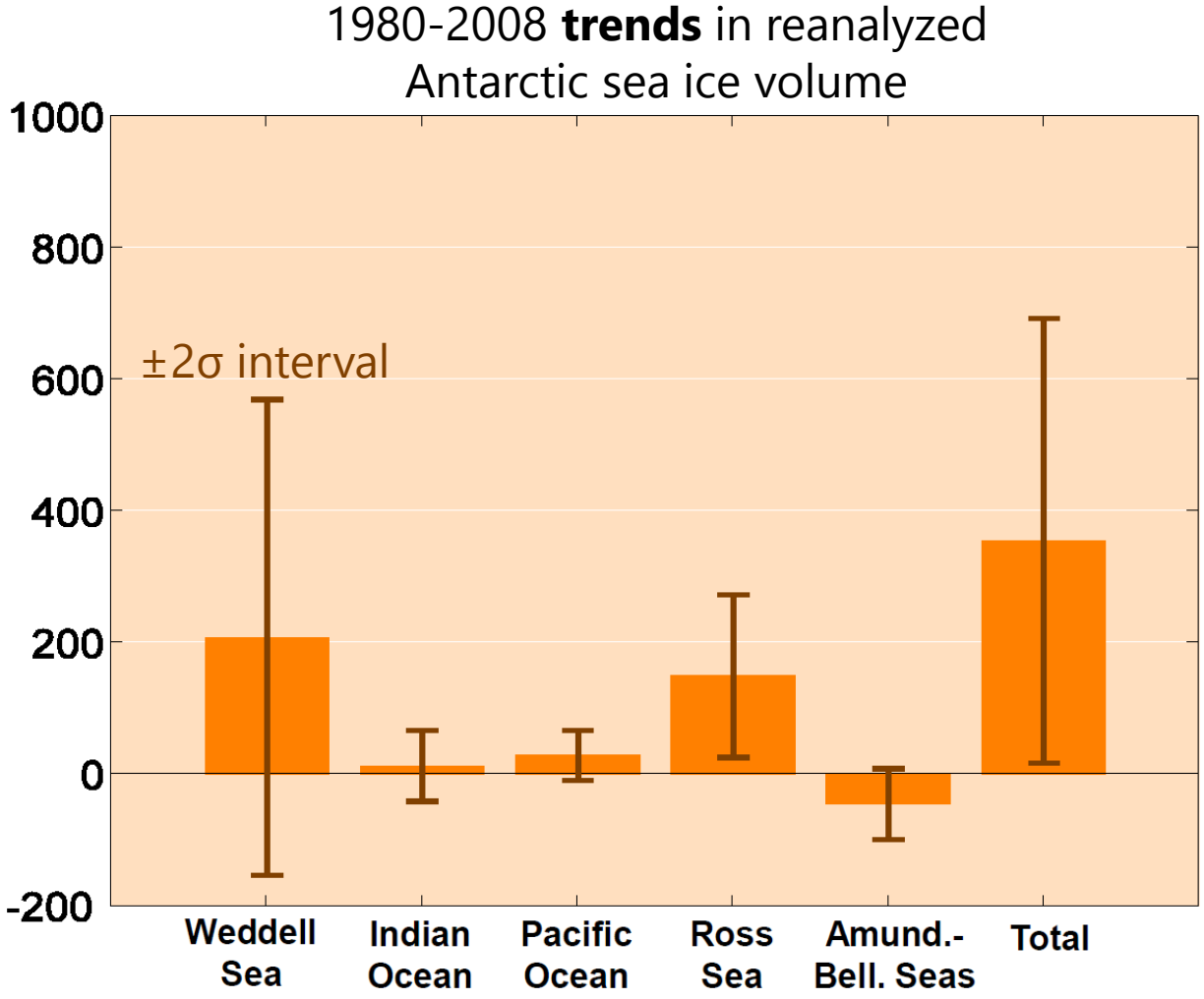
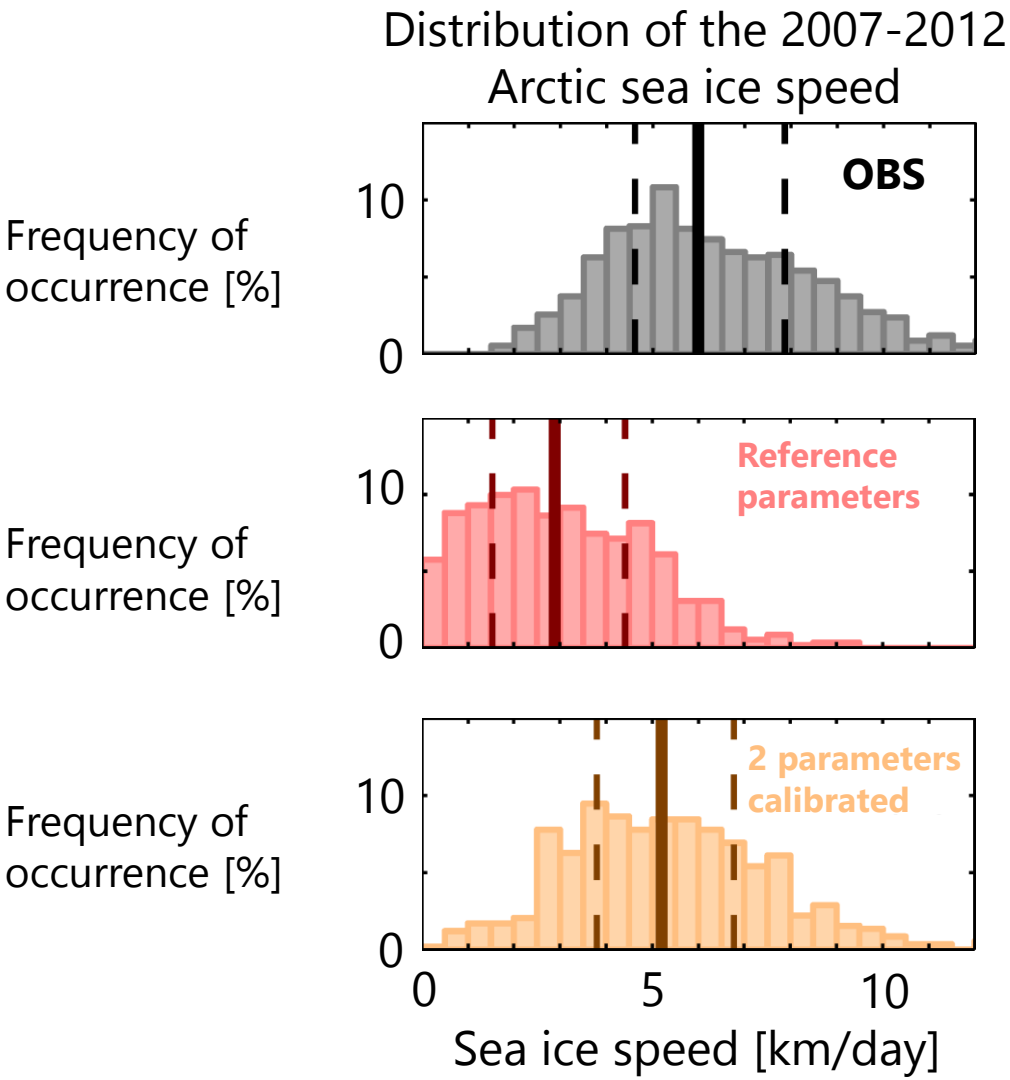


Data assimilation is an appropriate tool to reanalyze the sea ice cover



Data assimilation is an appropriate tool to calibrate sea ice model parameters



3. Improving the simulation of sea ice

Lessons learned	Contributions from PhD thesis
- Parameter estimation requires prior expert knowledge - Sea ice data assimilation requires more than nudging	- Three decades of reanalyzed sea ice volume - Collection of initial states for seasonal to decadal prediction - Affordable methods to calibrate slippery model parameters

Thesis

Advanced sea ice model physics, better initial conditions and optimized parameters are necessary to improve Arctic sea ice climate simulations, while the skill of Antarctic sea ice simulations is generally lower and less sensitive to these improvements