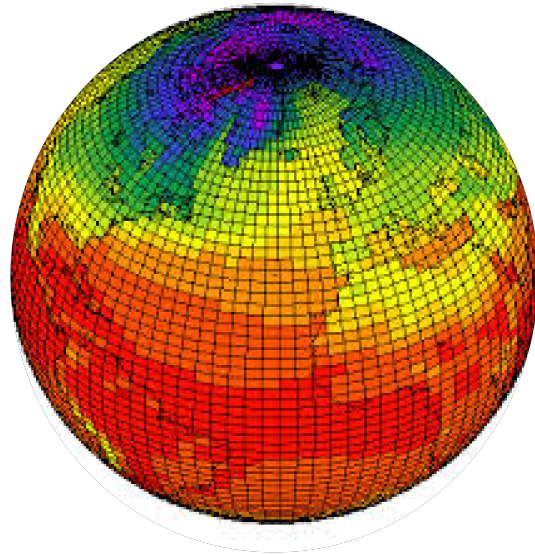


# Joint uncertainty assessment of models and observations in verification of climate predictions

Omar Bellprat

Francois Massonnet, Stefan Siegert, Martin Ménégoz,  
Chloé Prodhomme, Virginie Guemas, Francisco Doblás-  
Reyes, David Stephenson

## Model



Observations



## Reality



# A shift in the paradigm



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## Reality

**Model A**

**Observation A**



**Observation B**

Is model system B superior to model system A?

A

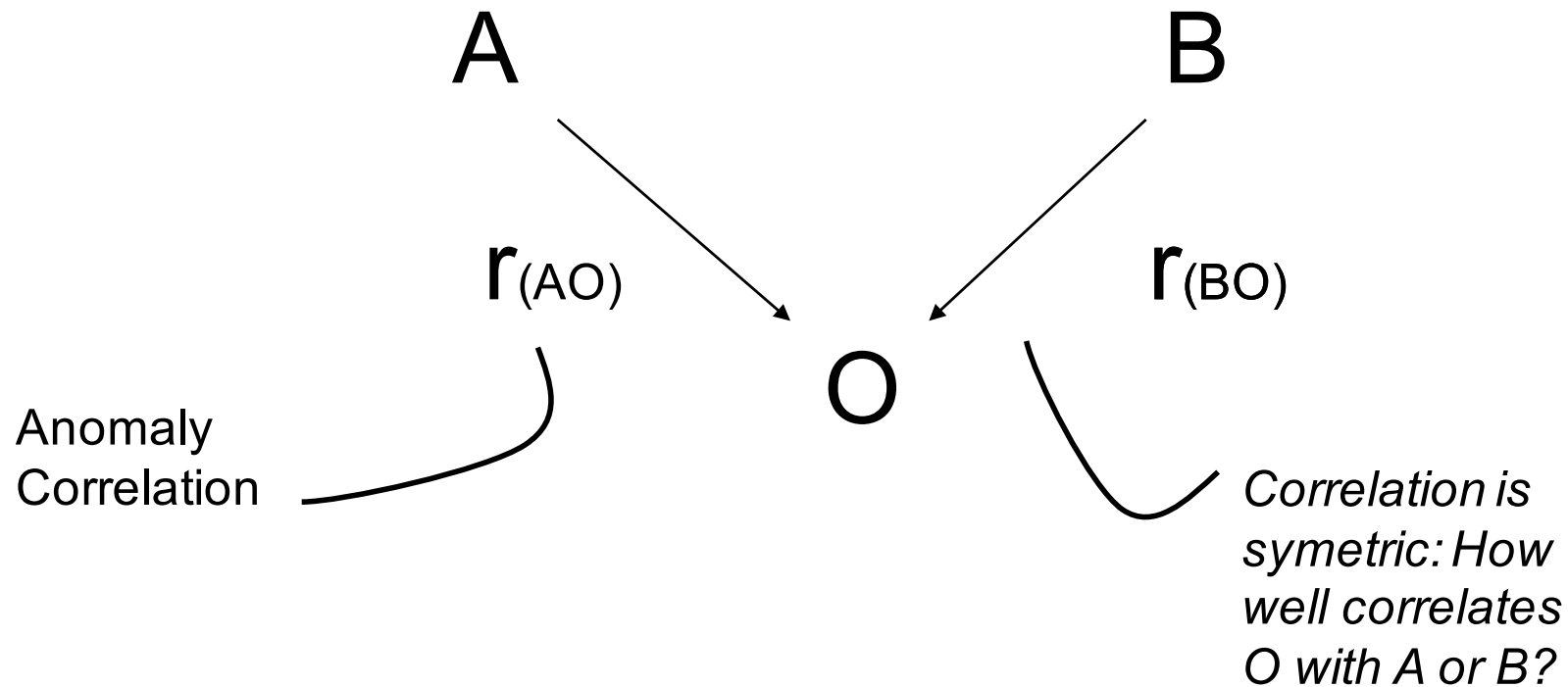
Low horizontal resolution

B

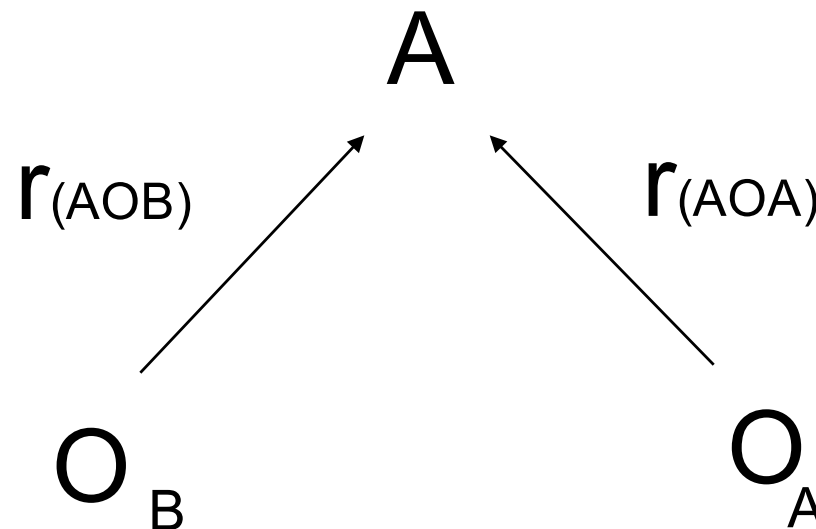
High horizontal resolution



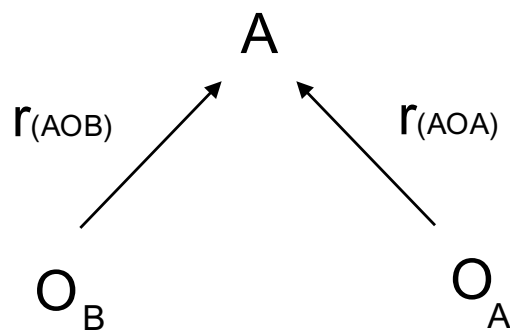
## Compare hindcast skill with an observation



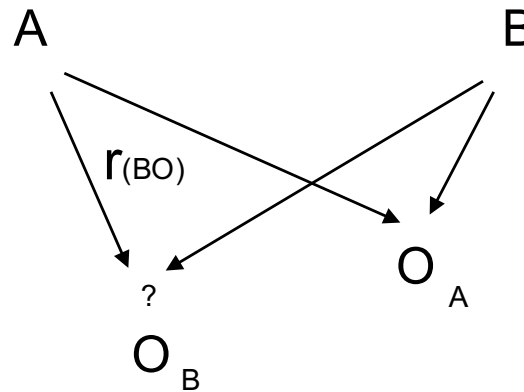
Which observation is better? A useful question?



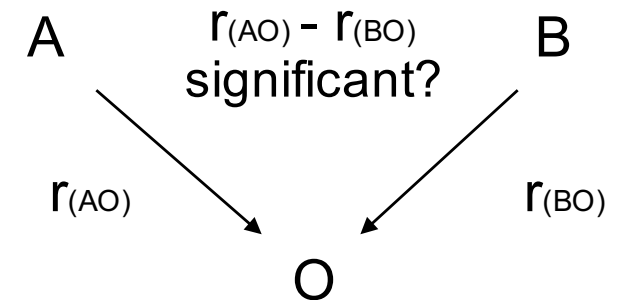
# Overview this presentation



**(a) Which observations has the smallest error**

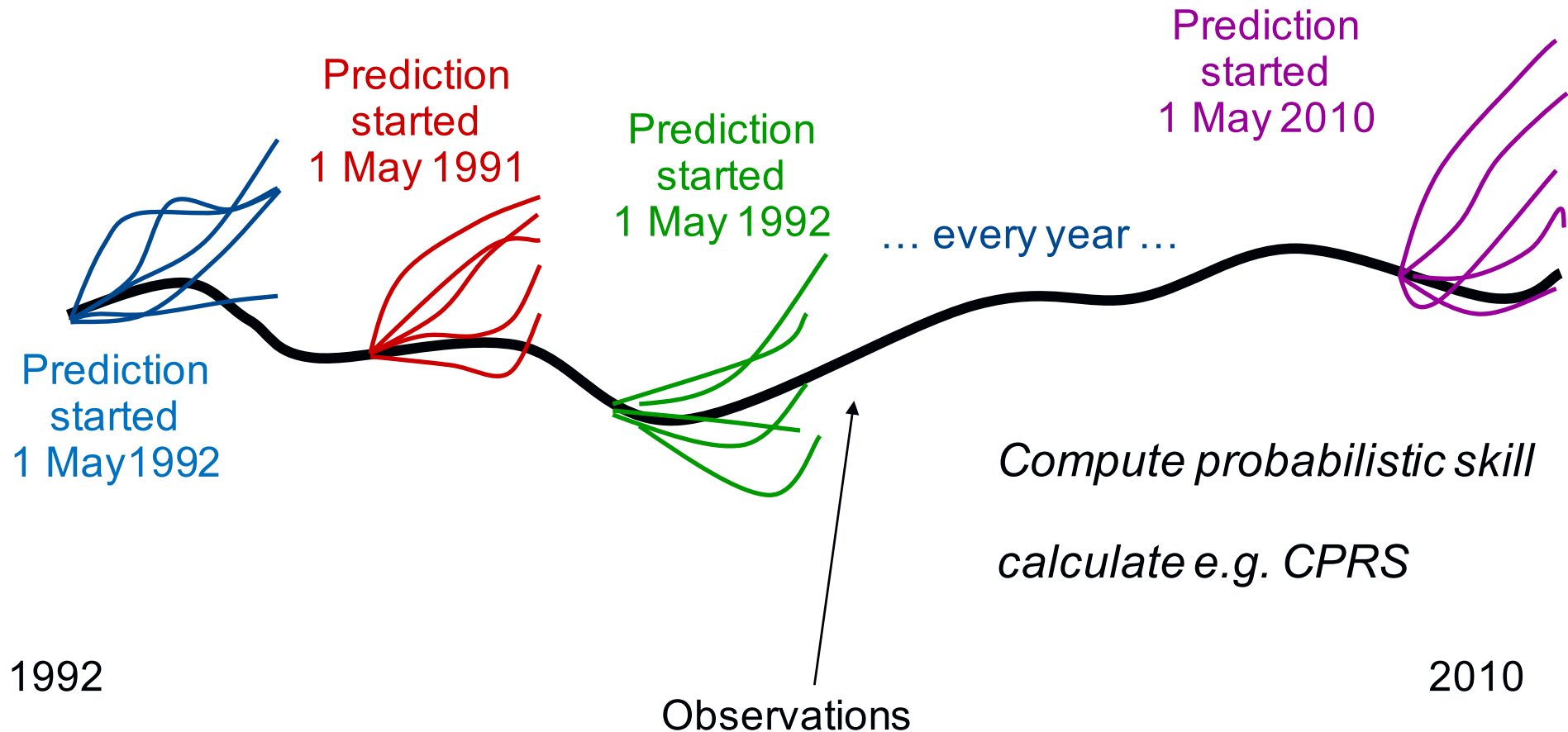


**(b) How important is observational uncertainty**

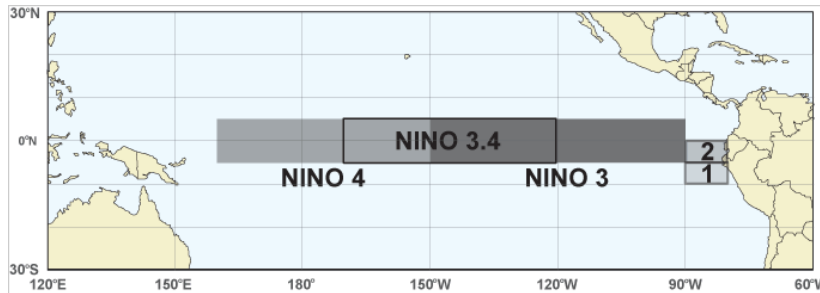


**(c) How to detect improvements in models or observations**

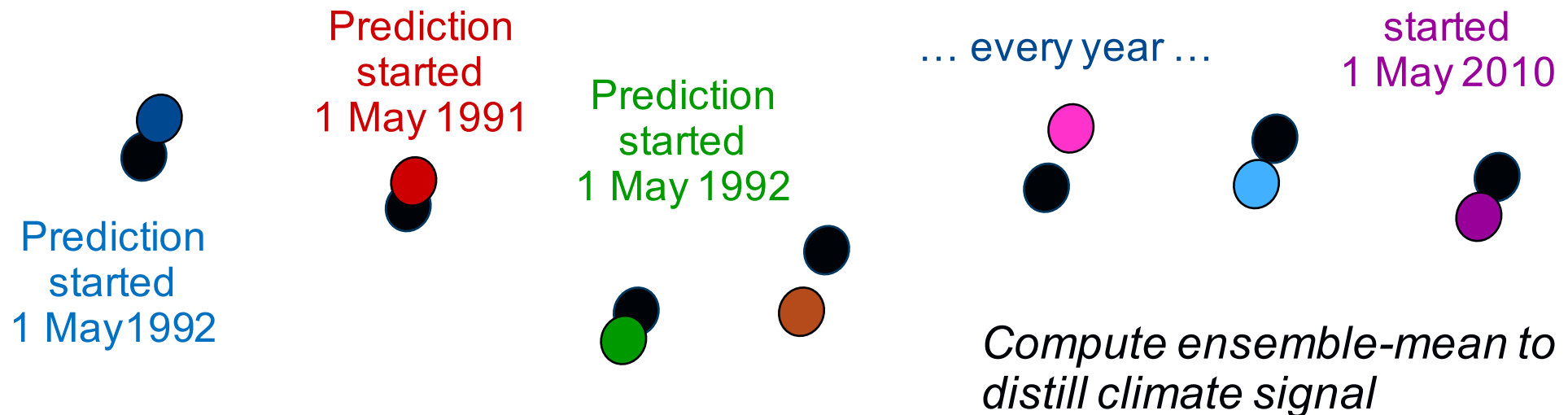
# Seasonal forecast skill



## Target: Global and Niño3.4 SST



**Observations:** 4 Sea-surface Temperature (SST) observations: ESA-CCI, HadISST, ERSST4, ERA-Interim



Prediction started 1 May 1992

Prediction started 1 May 1991

Prediction started 1 May 1992

... every year ...

Prediction started 1 May 2010

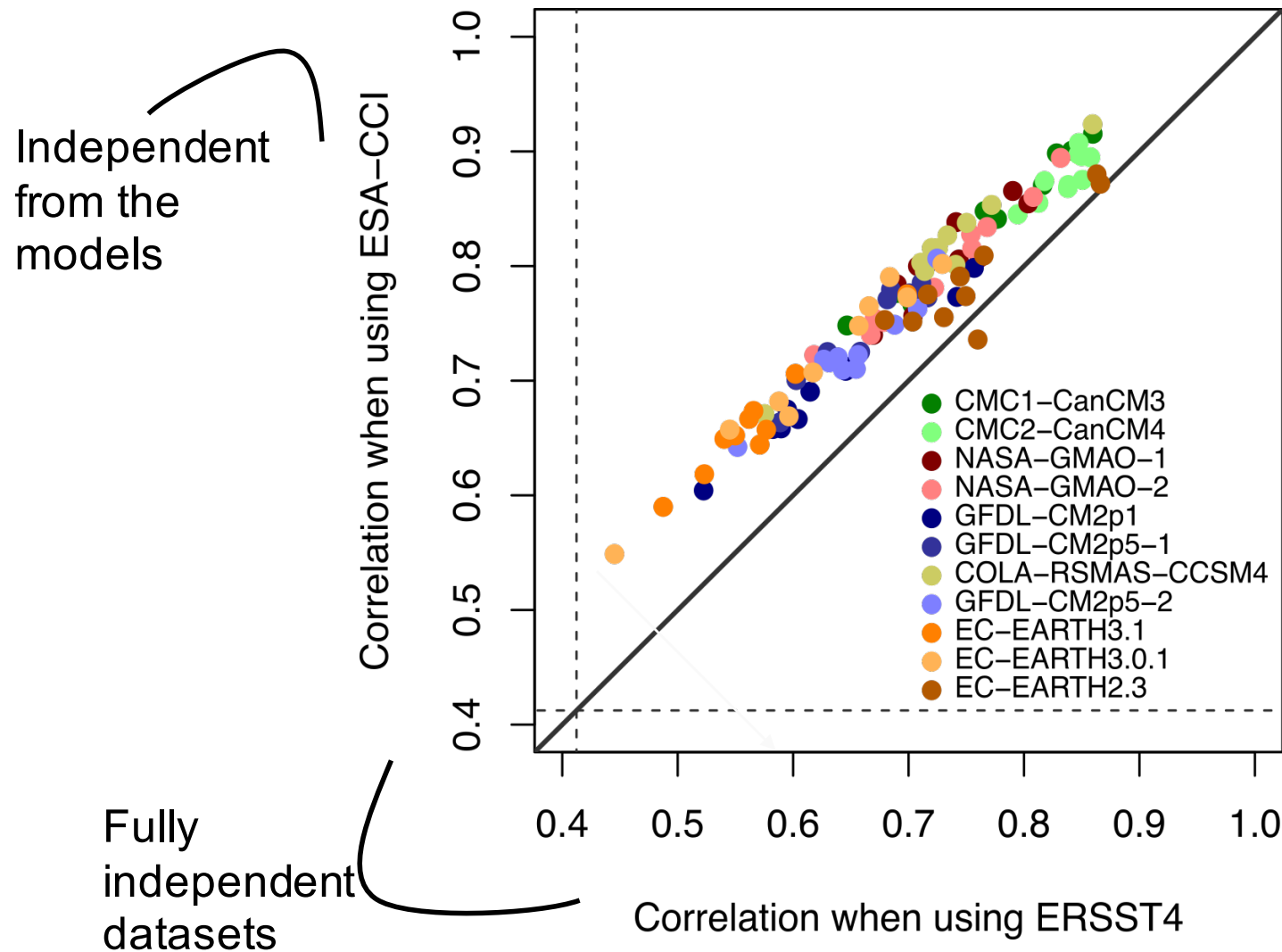
*Compute ensemble-mean to distill climate signal*

**Models:** EC-Earth (3 versions), ECMWF S4, North American Multi-Model Ensemble (NMME, 7 models) 10 – member forecast each

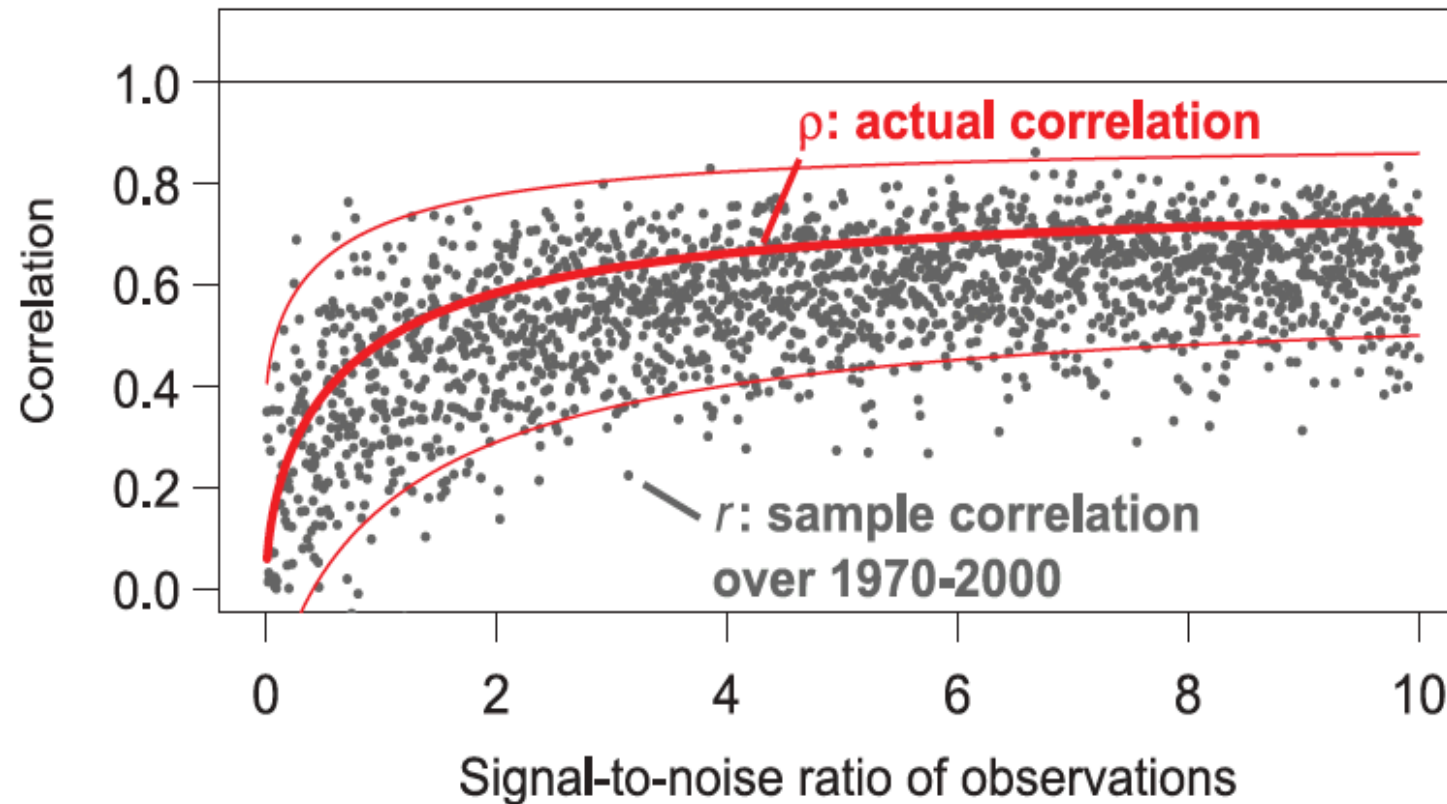
*calculate e.g. anomaly correlation*



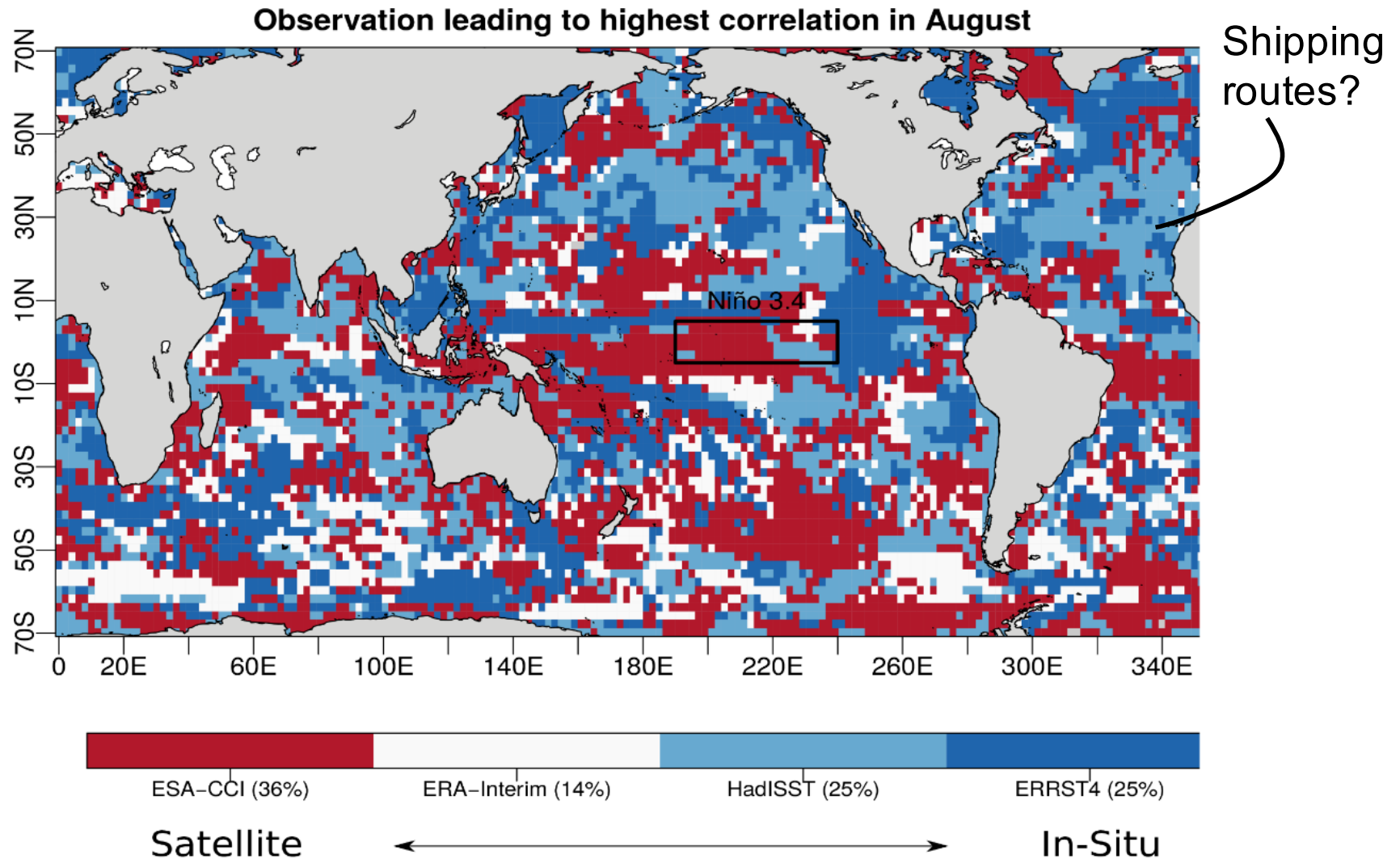
## CCI SST yields systematic higher correlation skill across many models



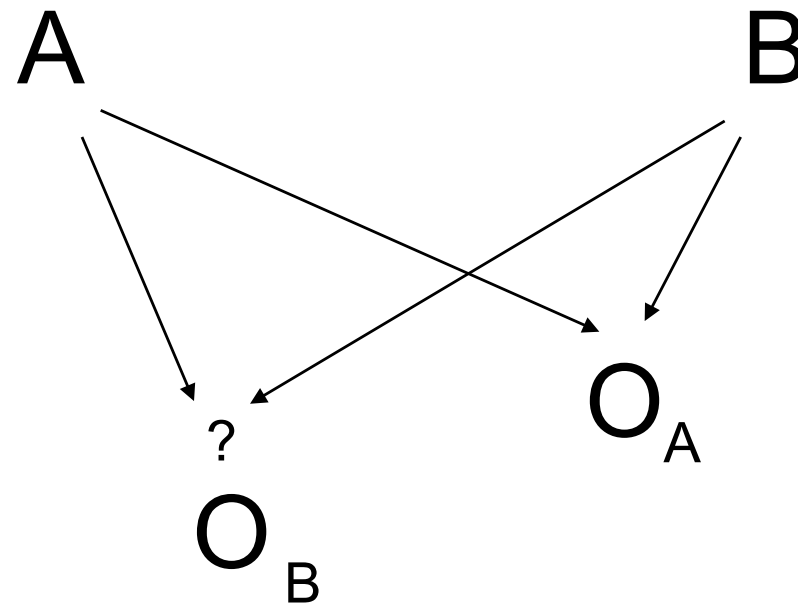
## Correlation reduces with noise either co-variates: observational uncertainty reduces forecast skill



## Choice of observation may differ on the location, overall CCI best



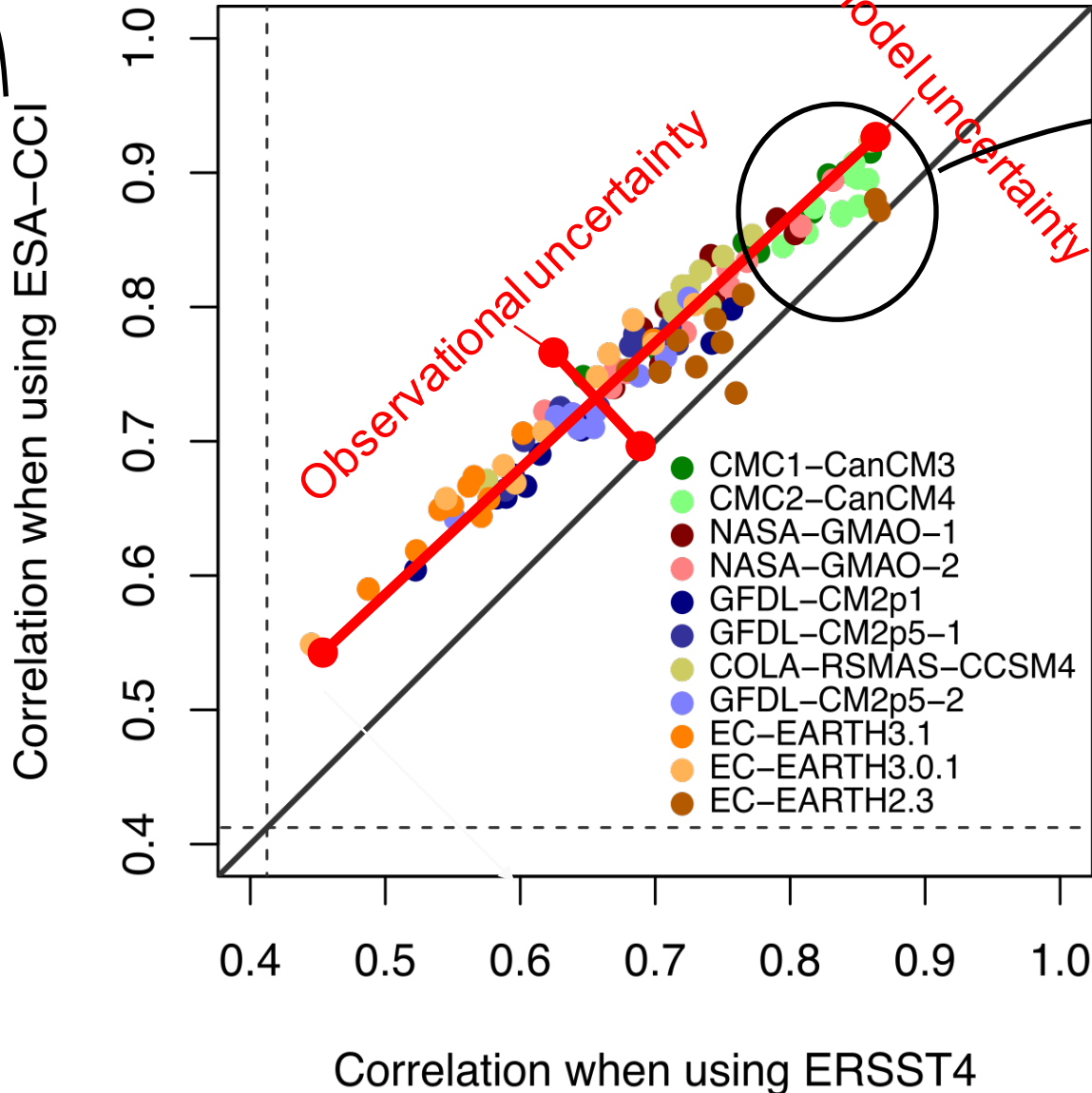
How important is the observational uncertainty?



# Acknowledging joint uncertainty

### Correlation skill ENSO

Independent from the models

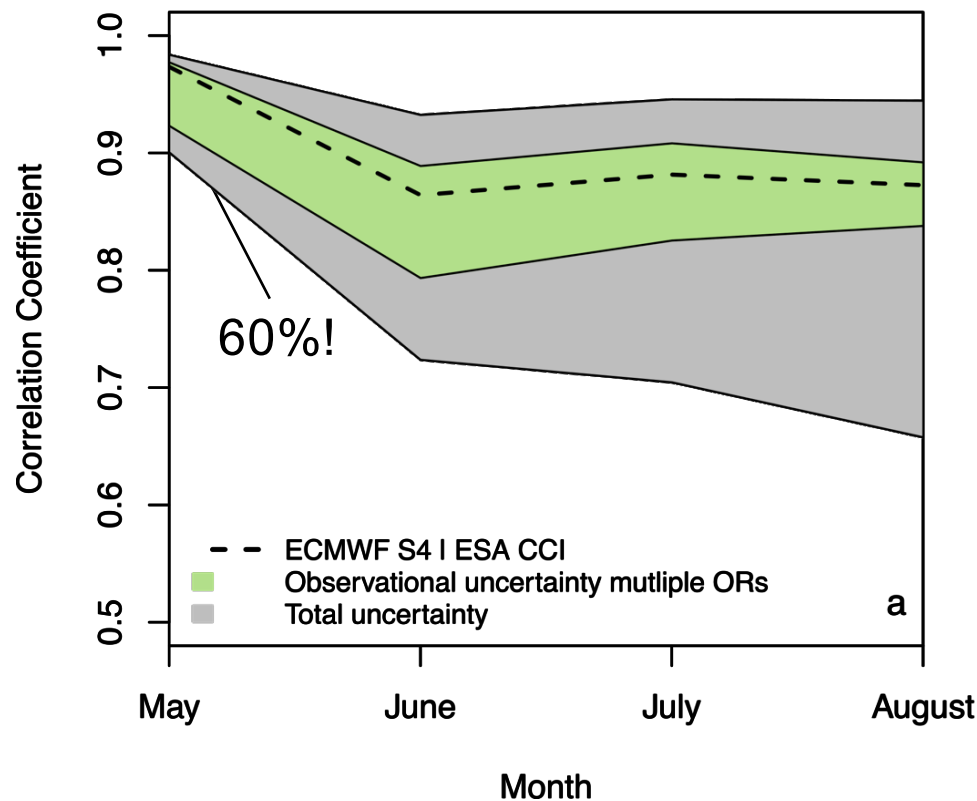


How important for individual system?

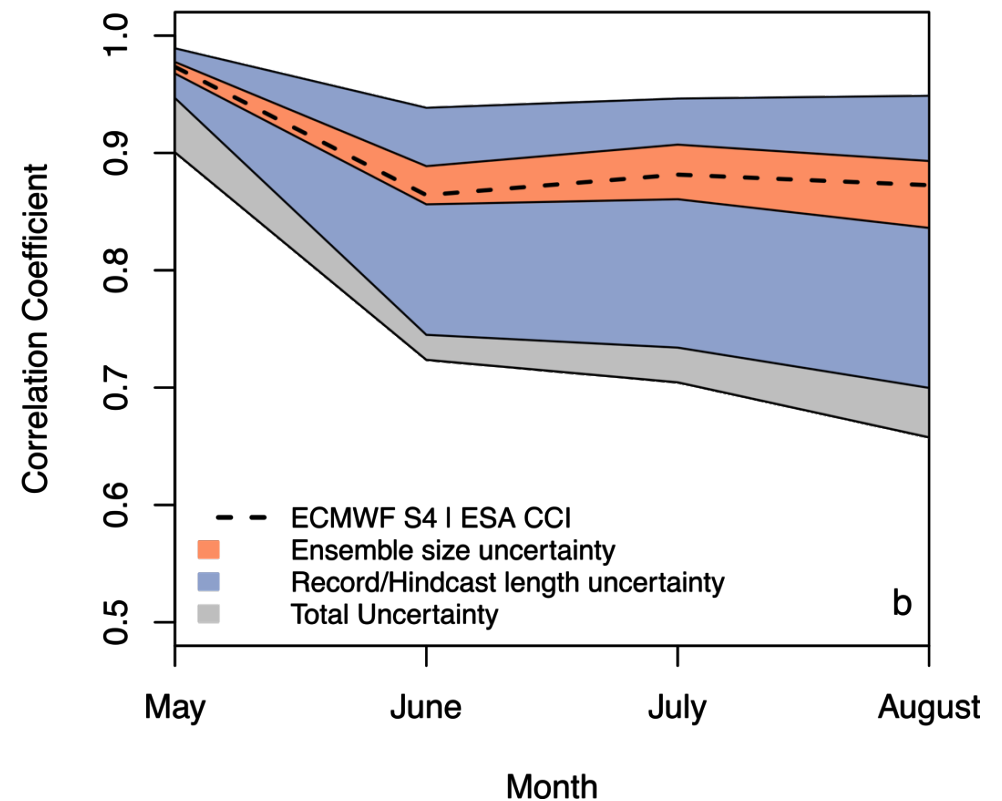


## Comparison to sample uncertainties: observational uncertainty is an important source of verification uncertainty for ENSO

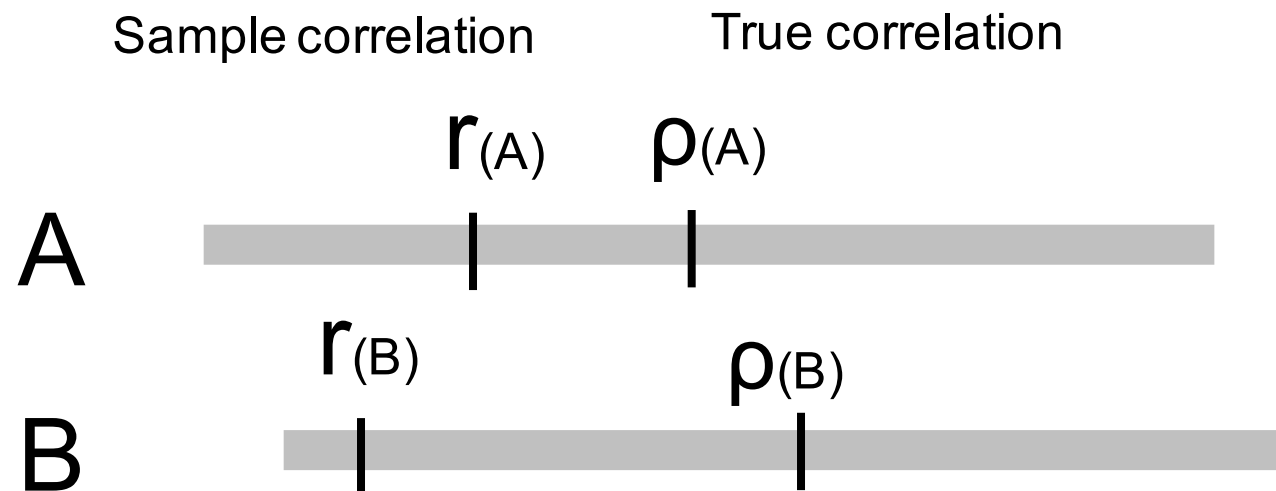
### ENSO Prediction (Observational uncertainty)



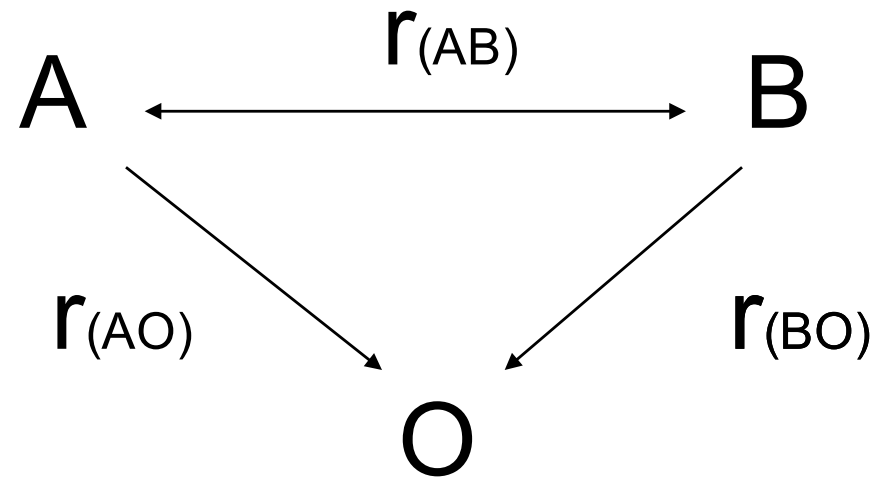
### ENSO Prediction (Sampling Uncertainty)



Are the differences in performance of models or observations significant  $r_{(CCI)} > r_{(ERSST)}$  ?



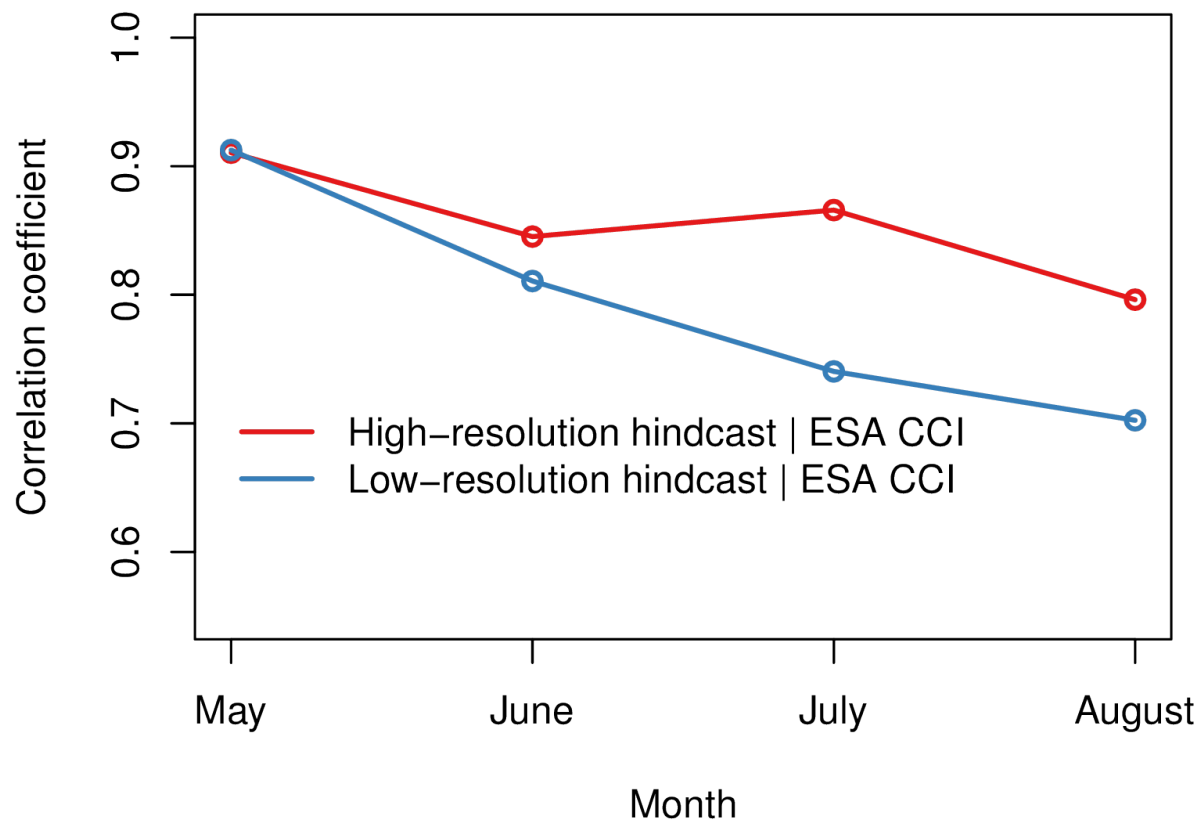
Models and observations are statistically dependent!



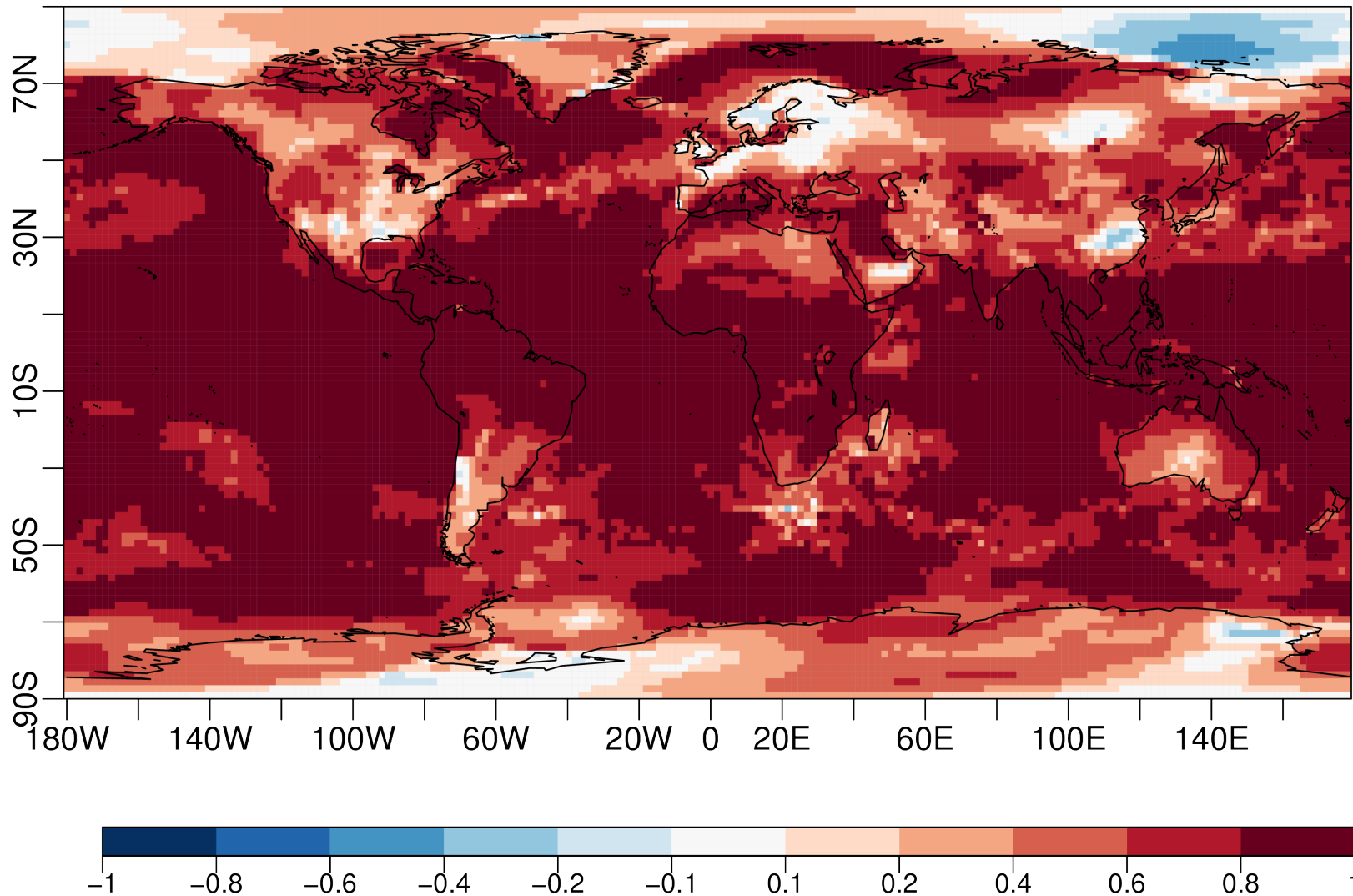
Fisher-test (common test in community) assumes independence while newer tests (Steiger, 1980, Zou, 2007) don't.

## High-resolution hindcasts improves El Niño Southern Oscillation (ENSO) predictions, but change not significant at 5% (Fisher-test)

Prediction skill ENSO: Increase in resolution

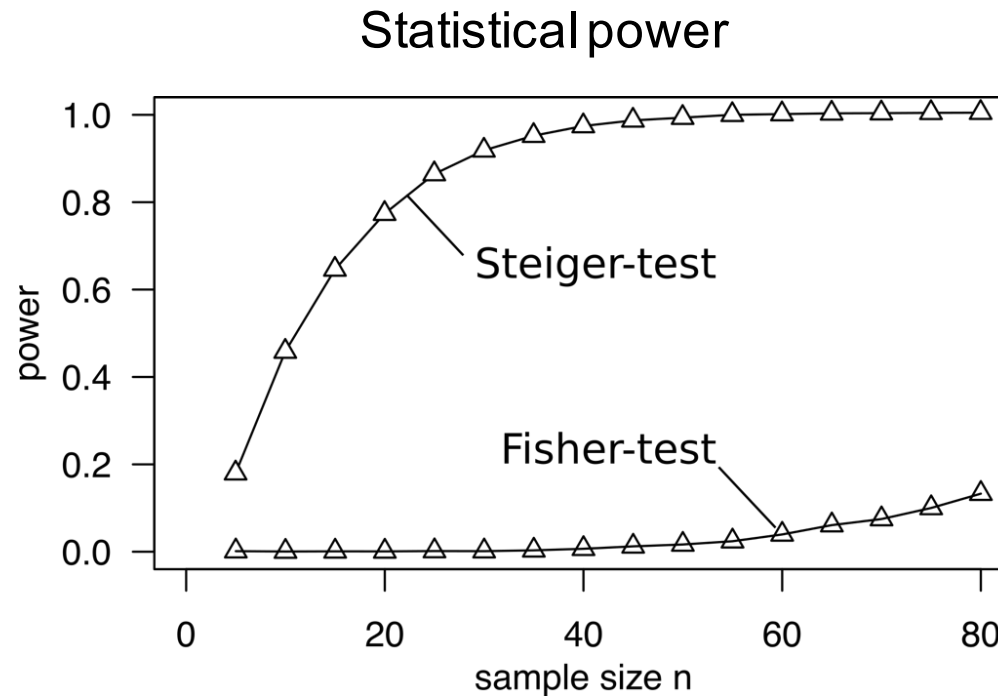


## Correlation of Low and High-resolution hindcast





**Power to detect a difference between increases dramatically.  
Improvement now statistical significant at 1% level.**

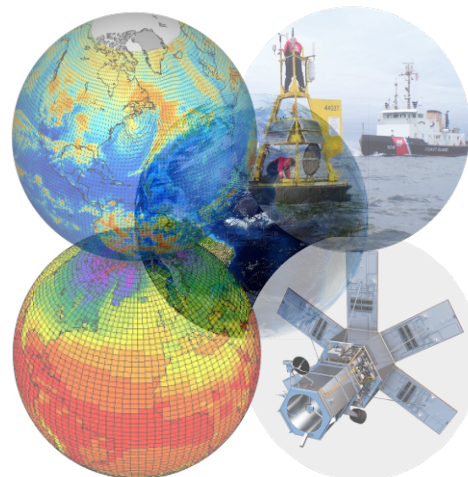


In medicinal science only studies with power > 80% are accepted, a guideline for forecasting?

**Models and observations are both approximations of the truth and uncertainty in both sources can be important.**

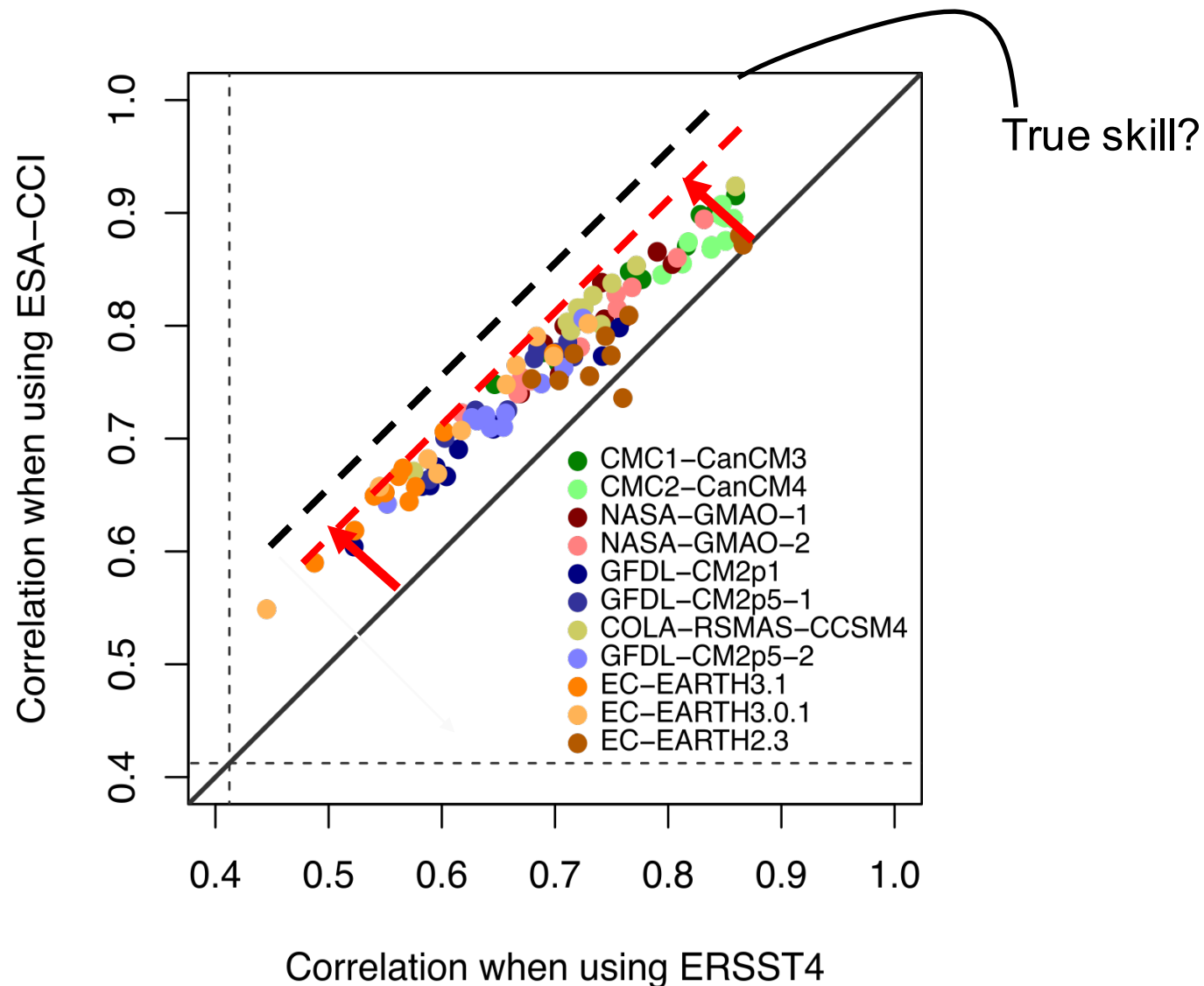
**Models can be valuable in assessing observational quality and thus guide a more objective dataset selection**

**Testing improvements in models and observations requires the consideration of dependence between all source of information**



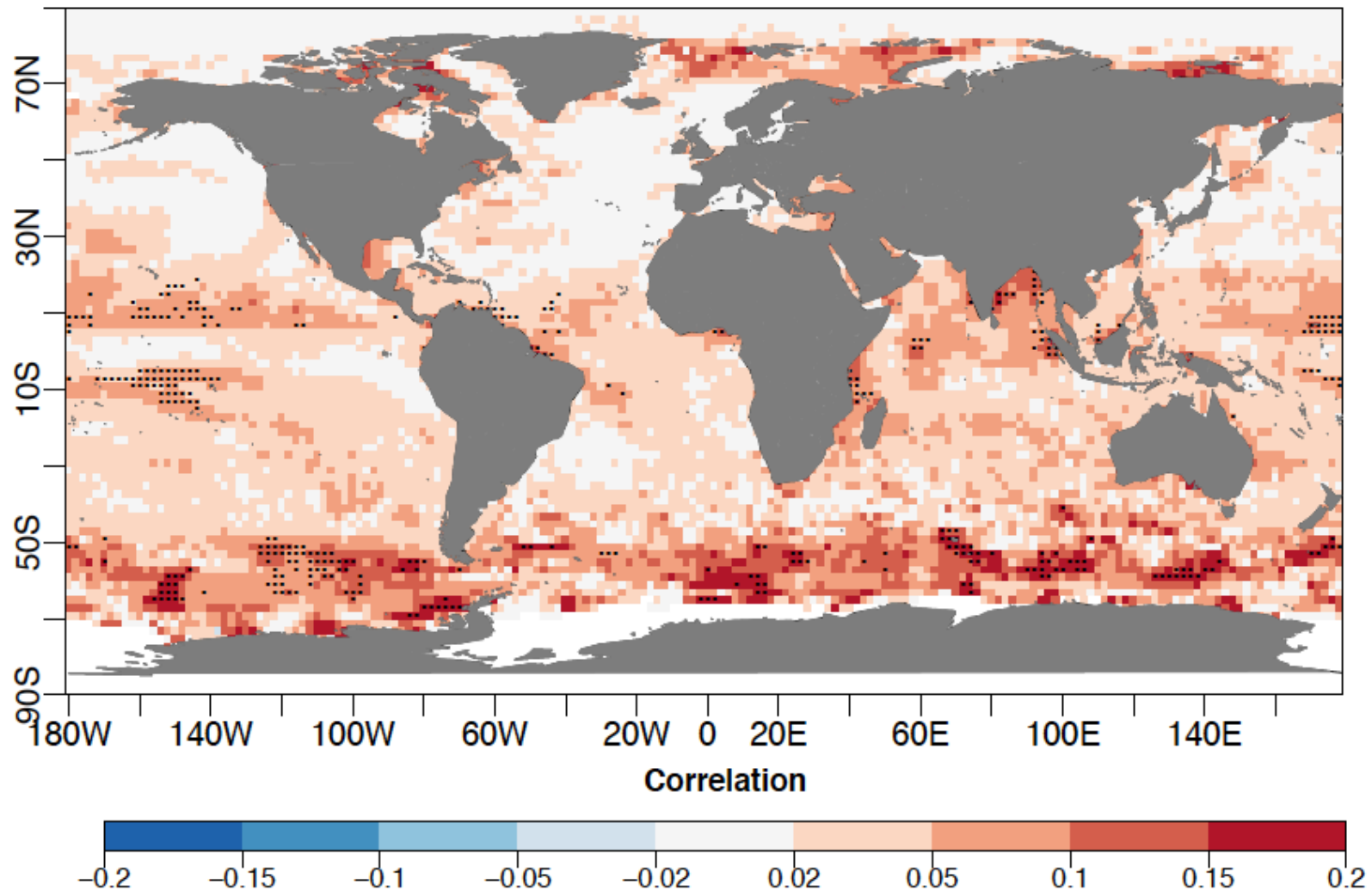
# Outlook: What is the “true” skill ?

**True climate predictions skill is systematically underestimated due to uncertainties in the observations**

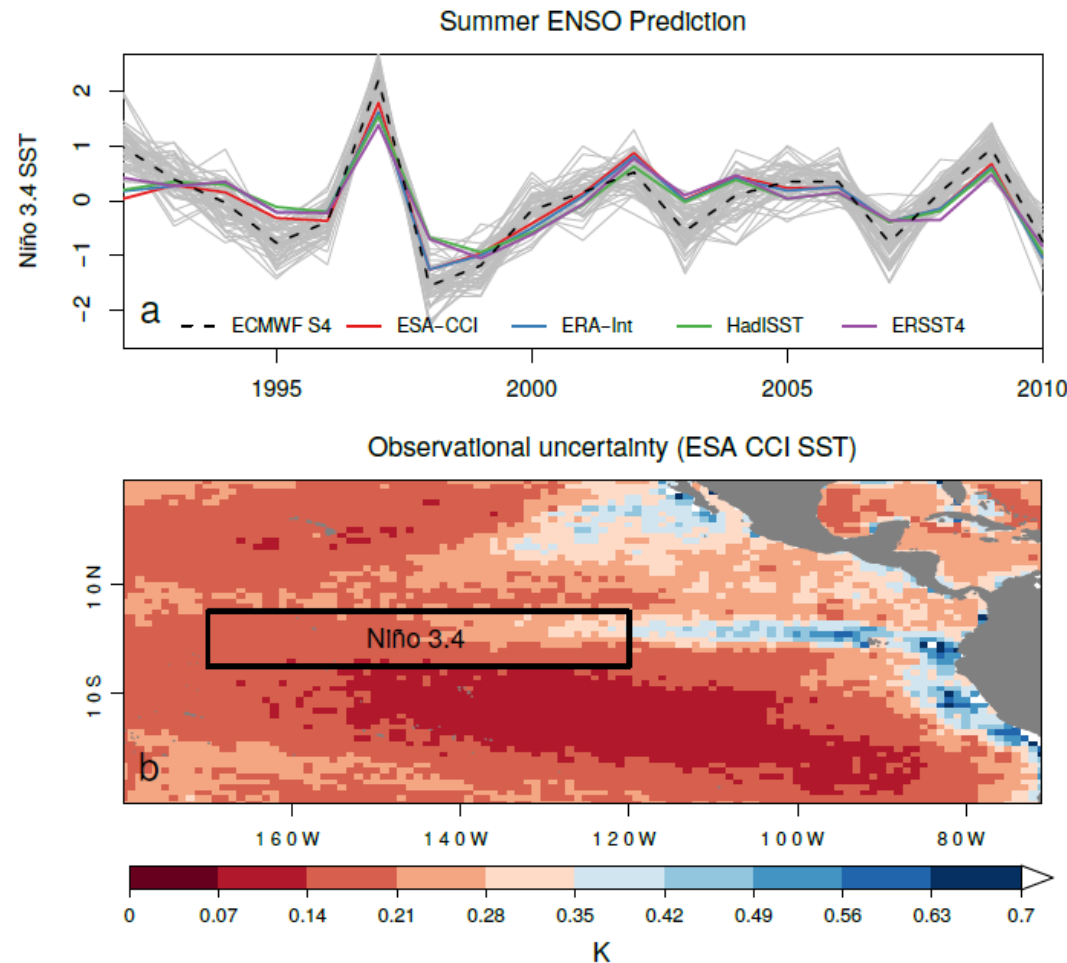


## Seasonal SST forecast skill is underestimated up to 0.2 correlation

Lost skill due to observational uncertainty



Model evaluation often requires spatial and temporal averaging,  
requires the consideration of error correlation scales



Monthly  
Niño3.4

Uncorrelated uncertainty  
reduces by  $1/\sqrt{N}$   
but errors are not  
uncorrelated!

Daily, 4 km



**Quantifying observational uncertainty is a challenge and propagation scales represented to by the models is a big gap – A stronger interaction is required with the observational data community**

**ESA *Climate Modelling User Group (CMUG)* is going to explore observational uncertainty in model – observation inter-comparison strongly in the future**

**Metrics and new statistical tests are required that can make use of the observational uncertainty data that future data sets are going to provide**

# Thank you!



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Massonnet, F., Bellprat, O., Guemas, V., Doblas-Reyes, F. J., (2016). Using climate models to estimate the quality of global observational data sets, *Science (AAAS)*

Bellprat, O., Massonnet, F., Siegert, S., Guemas, V., Doblas-Reyes, F. J. (2017). Exploring observational uncertainty in verification of climate model predictions, *Remote Sensing of the Environment (RSE)*, in review

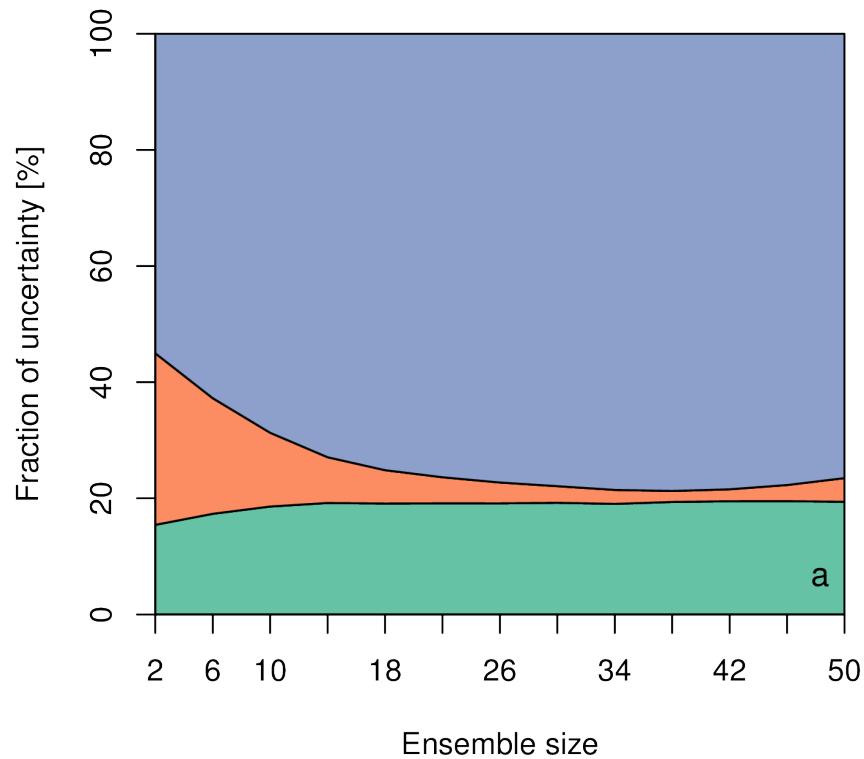
Siegert, S., Bellprat, O., Menegoz, M., Stephenson, D., Doblas-Reyes, F. (2016). Detecting improvements in forecast correlation skill: Statistical testing and power analysis. *Monthly Weather Review*

# Extra Slides

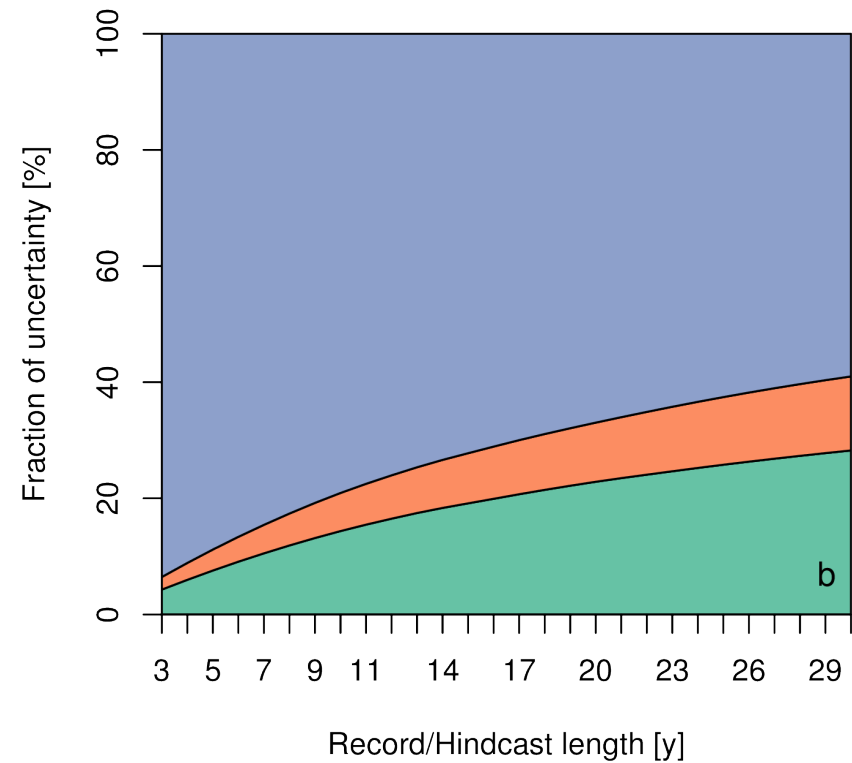
# Sensitivity to sample



### Correlation Uncertainty ENSO

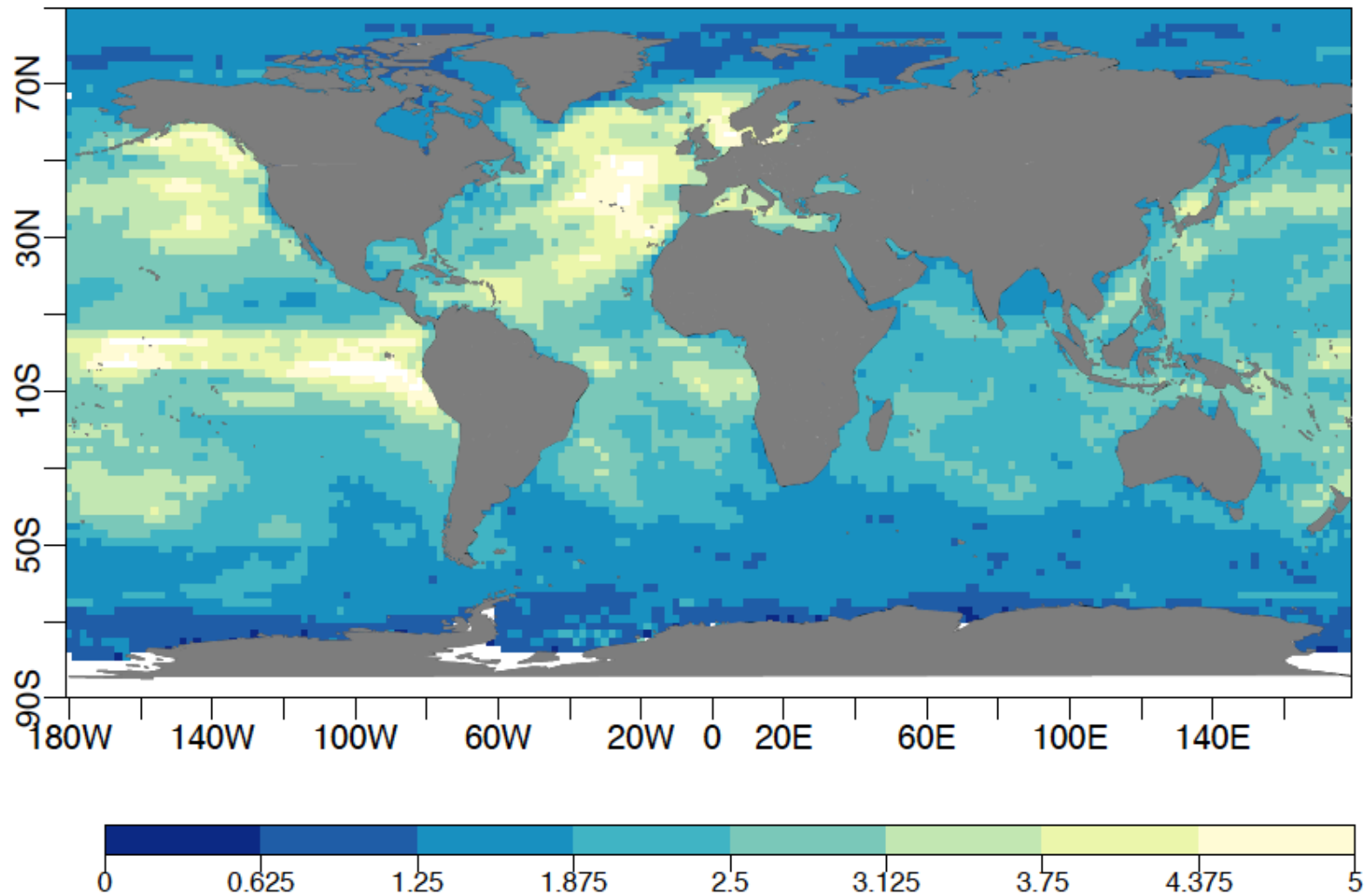


### Correlation Uncertainty ENSO



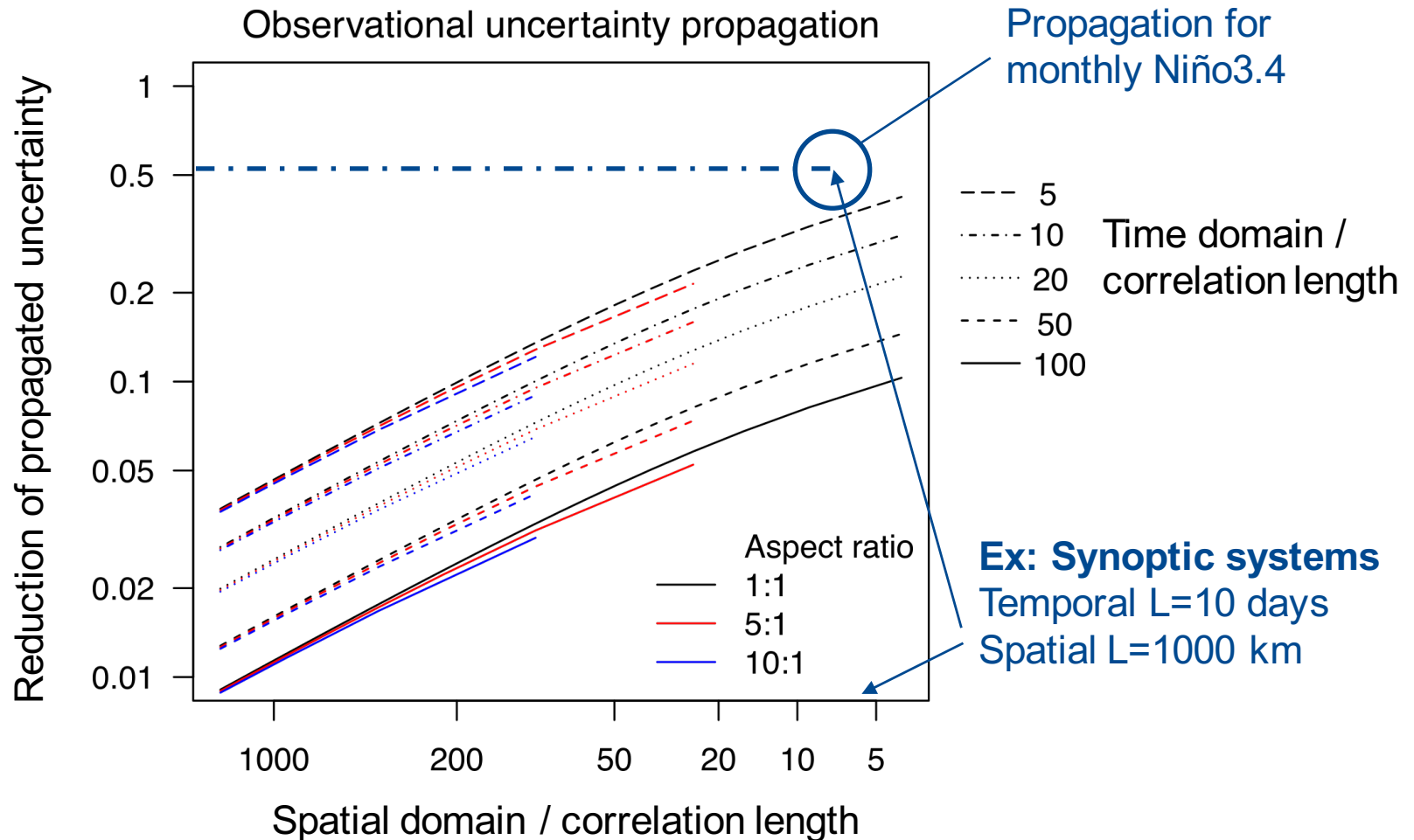
## Signal (inter-annual variability) versus observational uncertainty (noise)

Signal-to-noise ratio



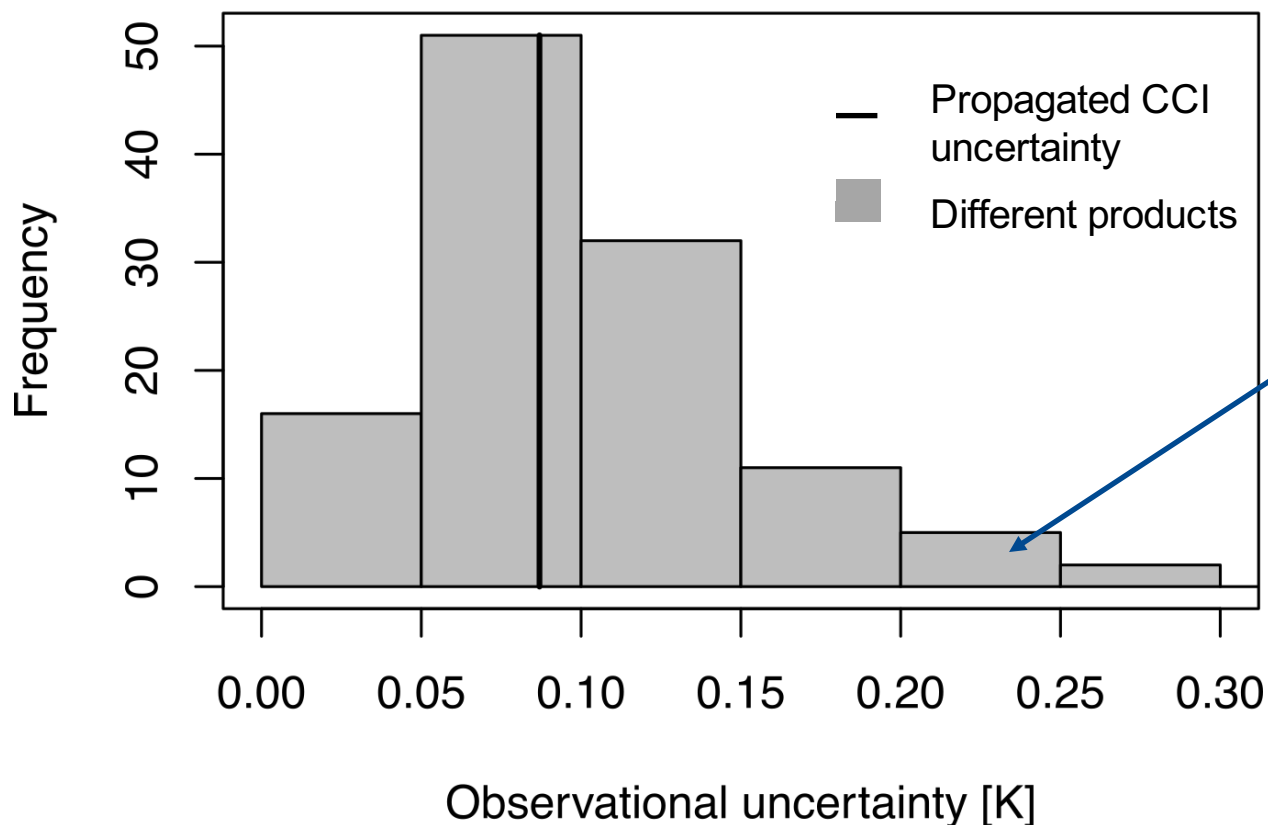
# A “look-up” propagation figure

## Use of error correlation scales: analytical solution that allows to look-up propagation factors



Propagation assuming synoptic scales (1000 km, 10 days) of weather systems agrees well with deviations between existing products

### Observational uncertainty Niño3.4 SST

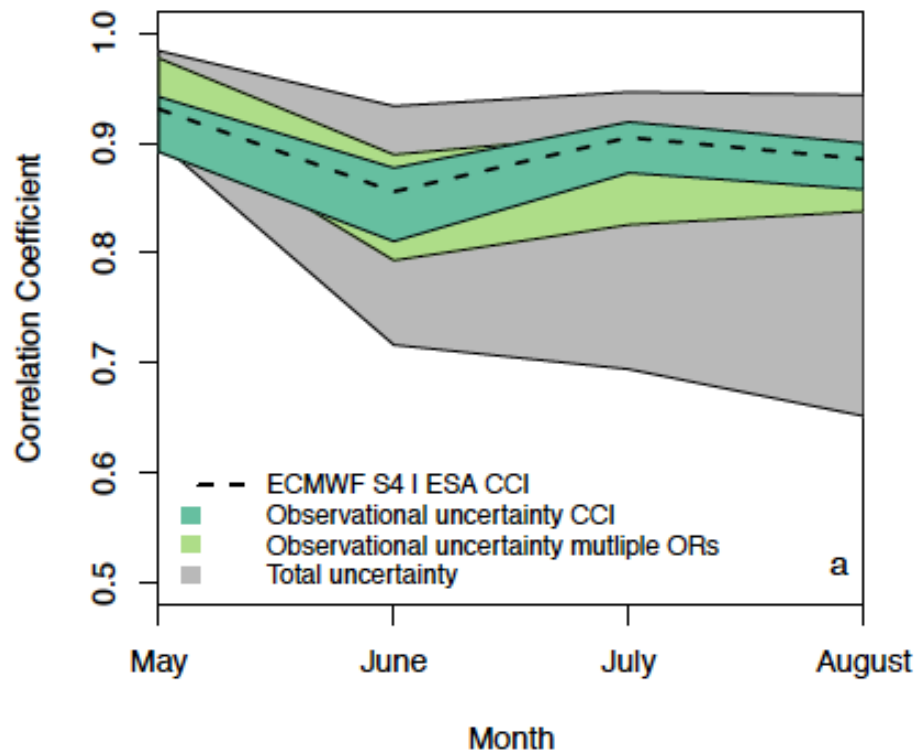


Assumes all observations are equally "likely"

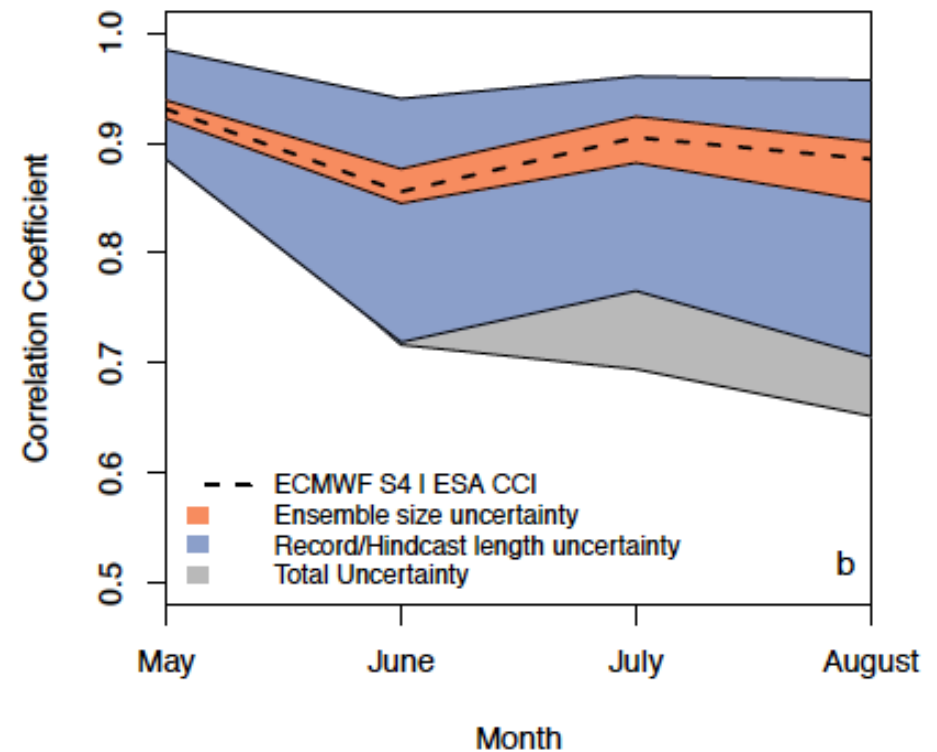
# ESA CCI Uncertainty estimate



### ENSO Prediction (Observational uncertainty)



### ENSO Prediction (Sampling Uncertainty)

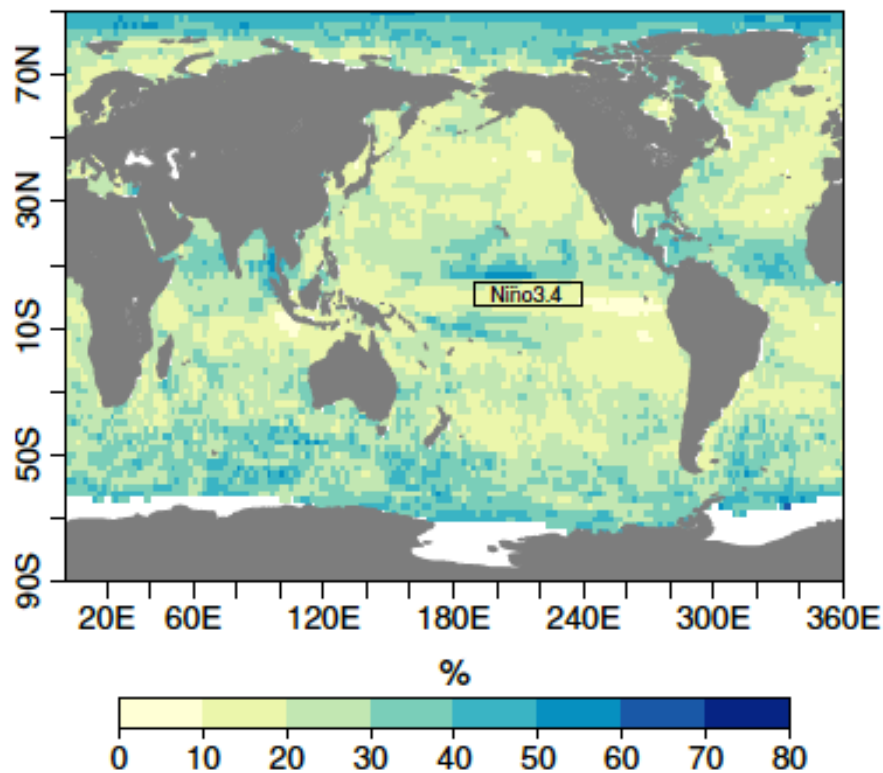




# Relative contributions



### Observational uncertainty



### Ensemble size uncertainty

