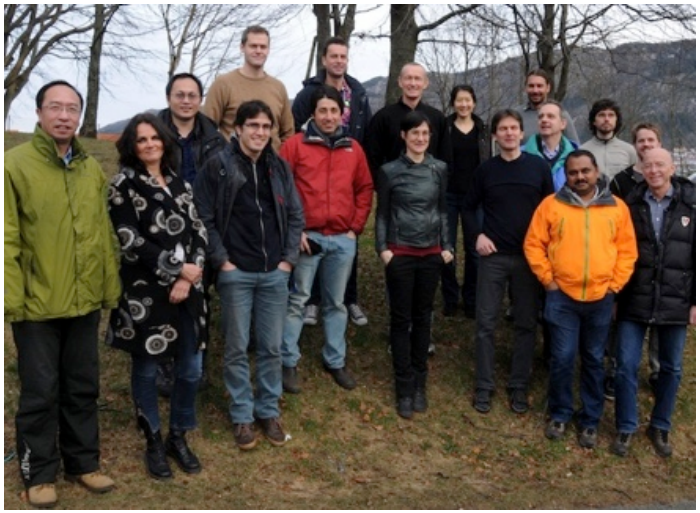
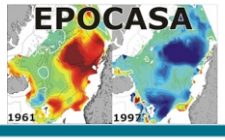
Bjerknes Centre for Climate Research

Norwegian Climate Prediction Model (NorCPM) getting ready for CMIP6 DCPP



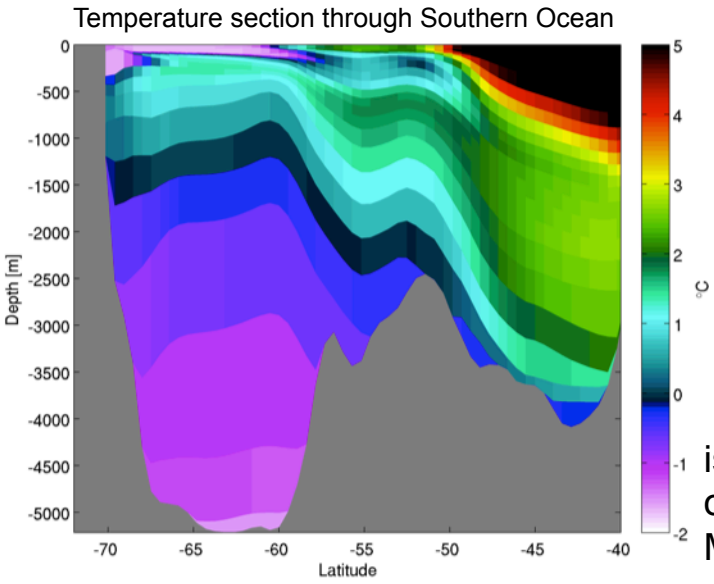
Francois Counillon, Noel Keenlyside, Mats Bentsen, **Ingo Bethke**, Laurent Bertino, Teferi Demissie, Tor Eldevik, Shunya Koseki, Camille Li, Retish Senan, Mao-Lin Shen, Thomas Toniazzo, Yiguo Wang and others...



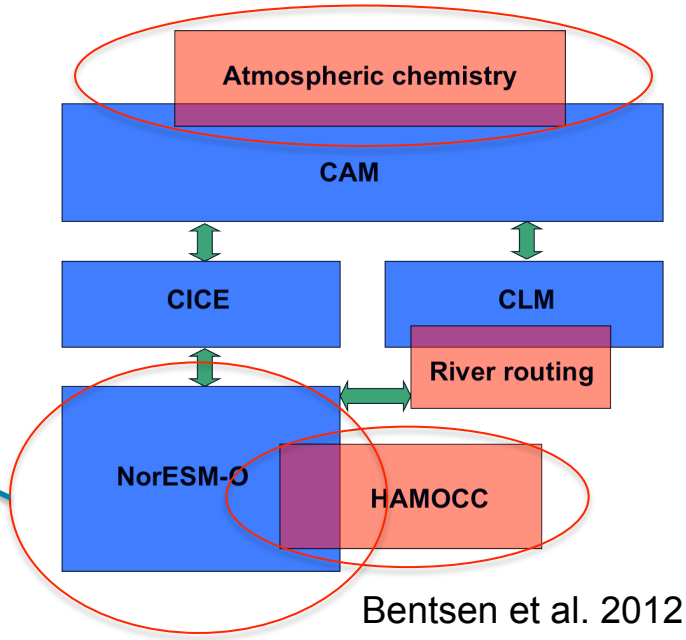
PRACTICE

Norwegian Earth System Model (NorESM)

Flavor of NCARs Community Earth System Model version 1 (CESM1)



isopycnic coordinate ocean model based on MICOM (Bleck 2002)



Bentsen et al. 2012

NorCPM pilot configuration

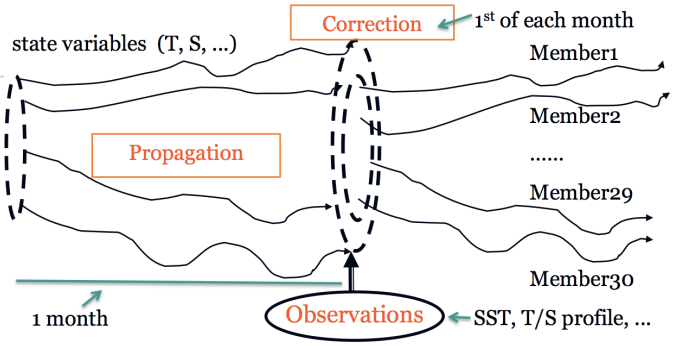
- NorESM1-L (Zhang et al 2012, GMD)
- atmosphere: standard CAM4 on T31 (~4º), 26 levels
- ocean: MICOM on 3.6º, 36 levels

NorCPM current configuration

- NorESM1-ME (Tjiputra et al 2013, GMD)
- atmosphere: CAM4-OSLO on 1.9ºx2.5º, 26 levels
- ocean: MICOM on 1º, 53 levels
- CMIP6 DCPP: possible upgrade to NorESM2 (CAM5-OSLO, 30 levels)

Ensemble Kalman Filter (EnKF)

Sequential Monte-Carlo method with propagation and correction step (Evensen & van Leeuwen 1996)



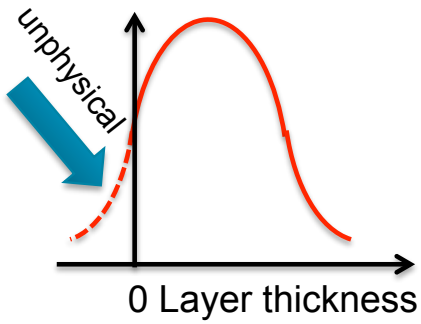
Covariance information from model ensemble is used to relate observations (e.g., SST or SSH) to model state variables (e.g., salinity)

- does not require any knowledge/modification of model code
- flow-dependent (i.e., function of time and space)
- complete ocean state update (i.e., 3-dimensional, all variables)

EnKF applied in isopycnic coordinated framework

- split of update: ***density stratification*** vs ***density compensated T/S anomalies***
- gaussian update of layer thickness problematic as truncation leads to non-conservation of T/S

➔ solved with help of super-layers (Y. Wang et al., to be submitted)



NorCPM in a nutshell

What is NorCPM?

- Norwegian Earth System Model + assimilation capability

What makes it special?

- isopycnic coordinate ocean component
- Ensemble Kalman Filter data assimilation adapted to ocean layer model
- comprehensive aerosol-cloud chemistry (moderate global warming trend)

What do we want to use it for?

- reasses historical decadal variability with constrained ESM runs
- assess climate predictability with focus on the subpolar and tropical Atlantic
- take part in multi-model prediction efforts (DCPP and similar)

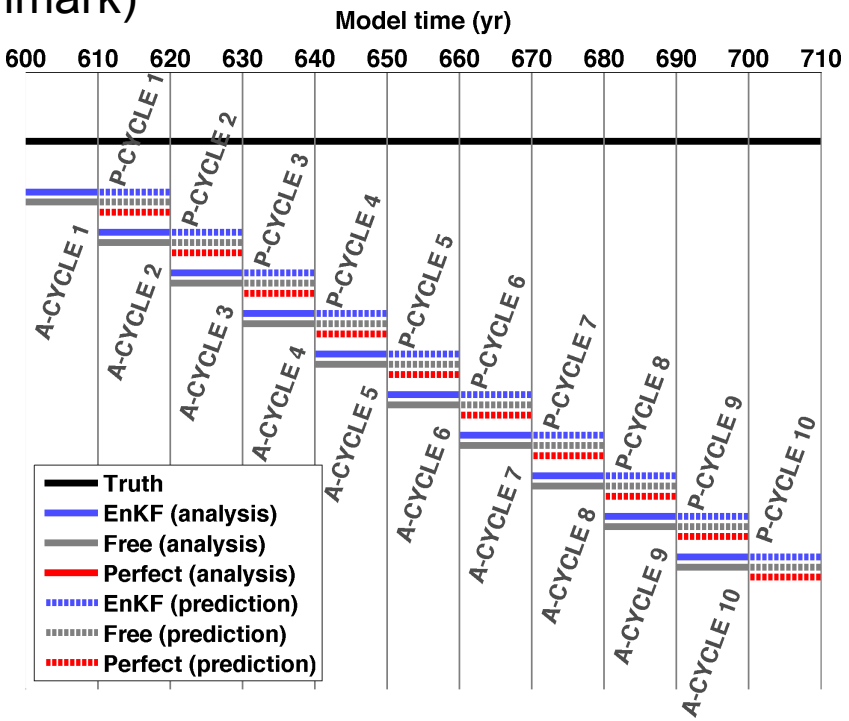
Perfect model prediction (Counillon et al 2014, Tellus)

Truth (synthetic observations)
- 110 years of data from pre-industrial simulation with NorESM

EnKF (assimilation/initialized)
- 10 assimilation/prediction cycles (10 yr assimilation followed by 10 yr prediction)
- 30 member ensemble with independent initial conditions
- SST only assimilated data

Free (uninitialized = base-line, lower benchmark)
- as ENKF but without assimilation

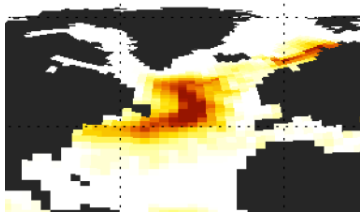
Perfect (potential predictability runs = upper benchmark)
- initial conditions for all components taken from TRUTH + small perturbation added to mixed layer temperature



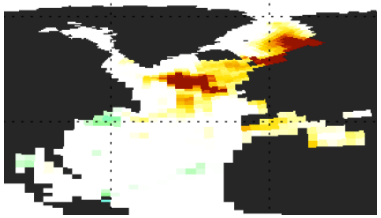
Perfect model prediction

Error reduction in sub-surface temperature of North Atlantic:

$$\mathbf{RMSE_{Free} - RMSE_{EnKF}}$$

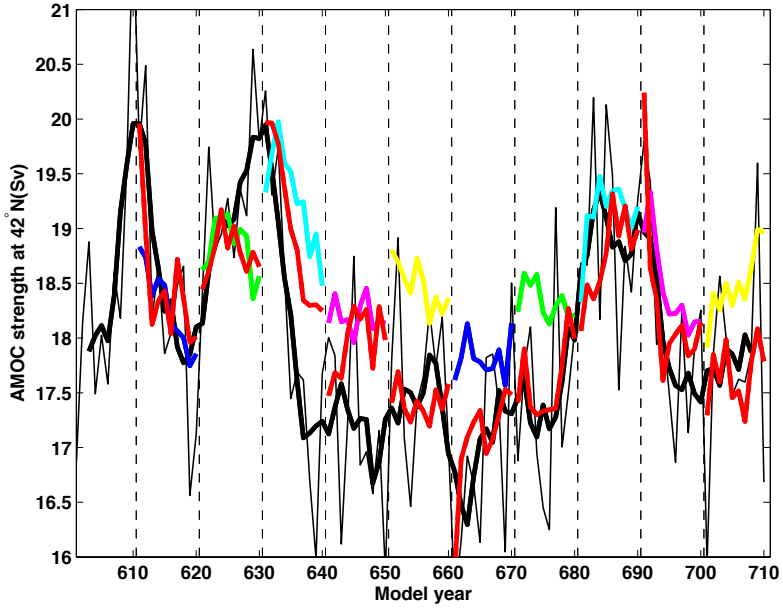


0-225m



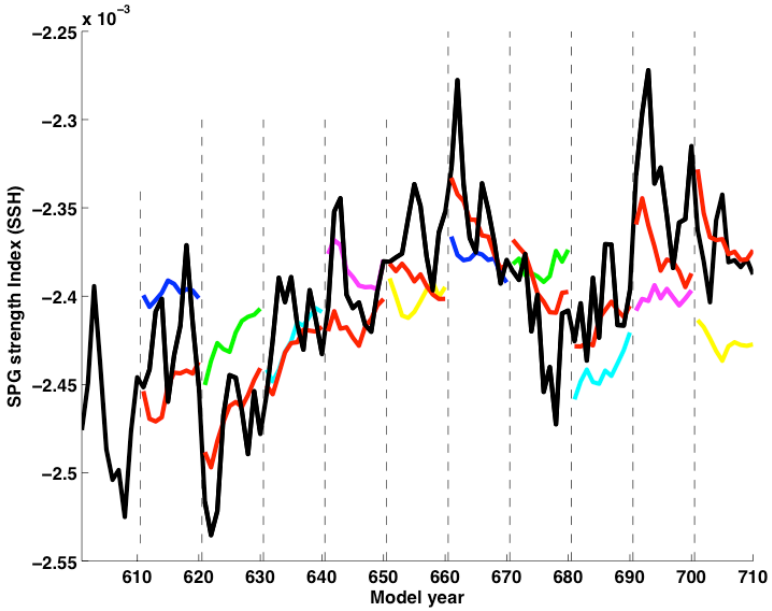
225-500m

AMOC index



	EnKF	Perfect
Correlation skill	0.54	0.66

SPG index



	EnKF	Perfect
Correlation skill	0.31	0.78

black: truth
red: perfect
color: EnKF

Perfect model prediction

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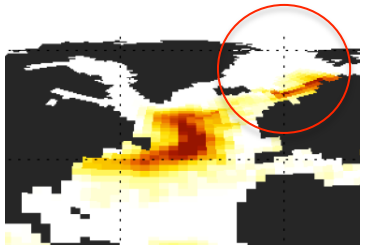

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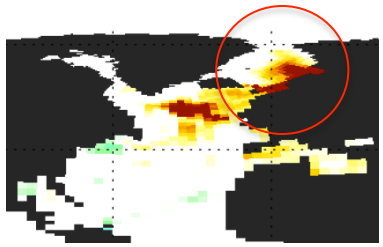
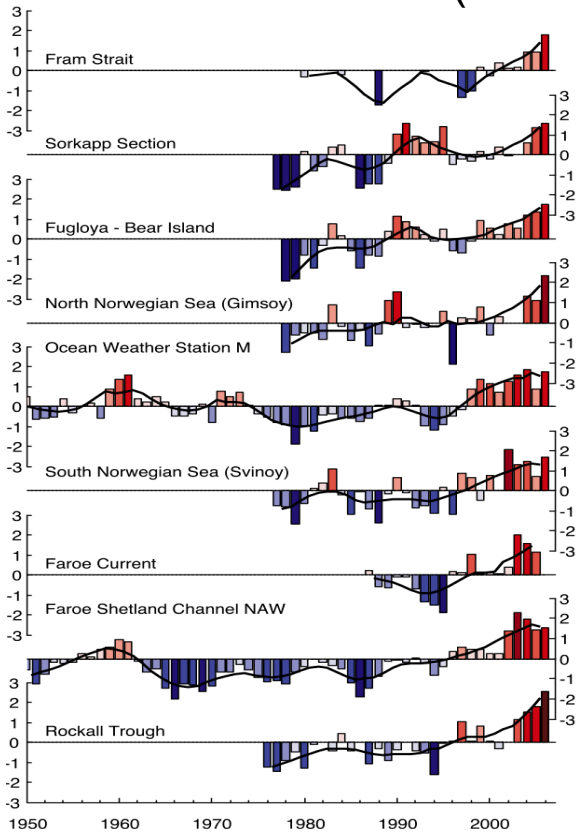
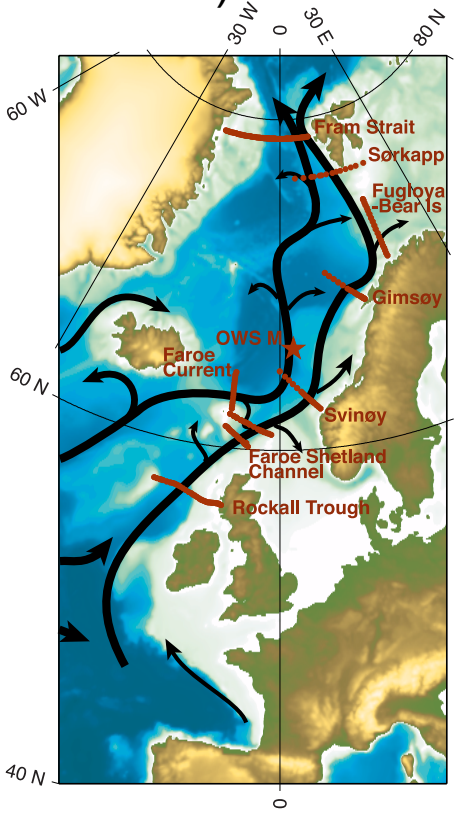


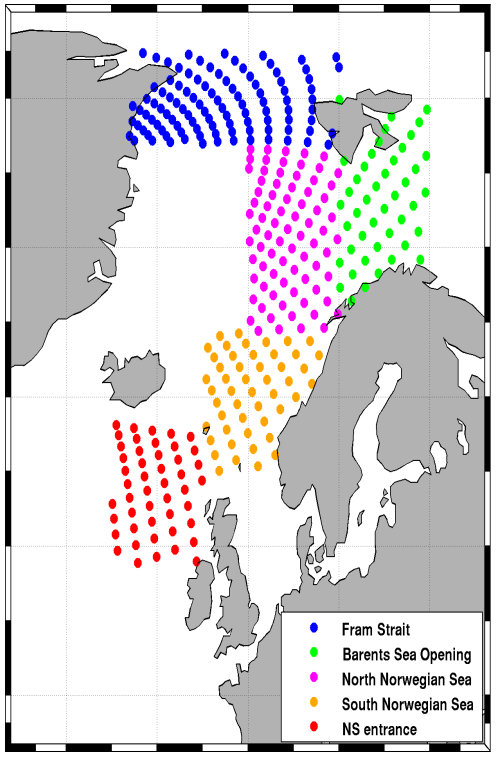
225-500m

Observations (Holliday et al. 2008)



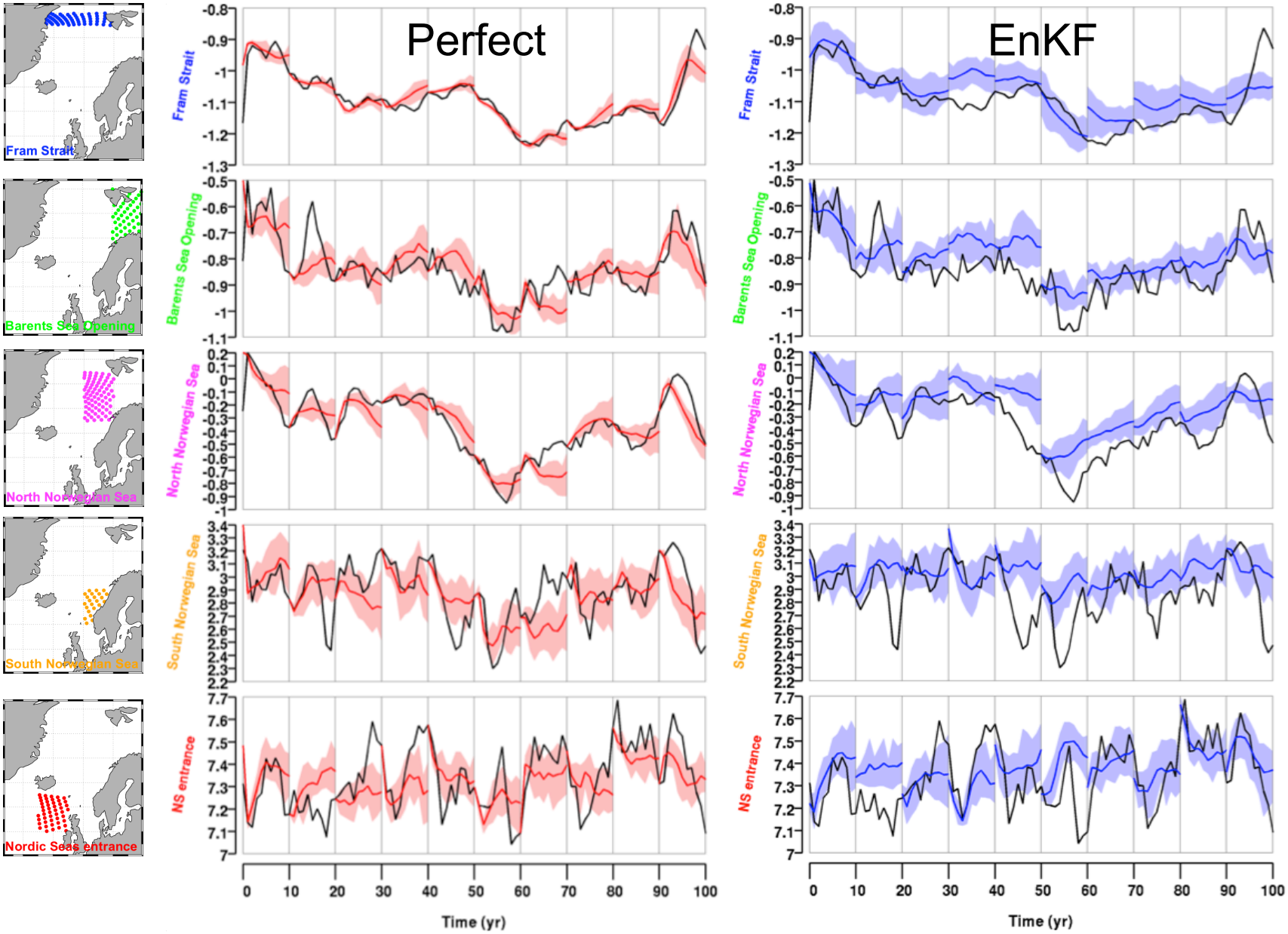


Model ?



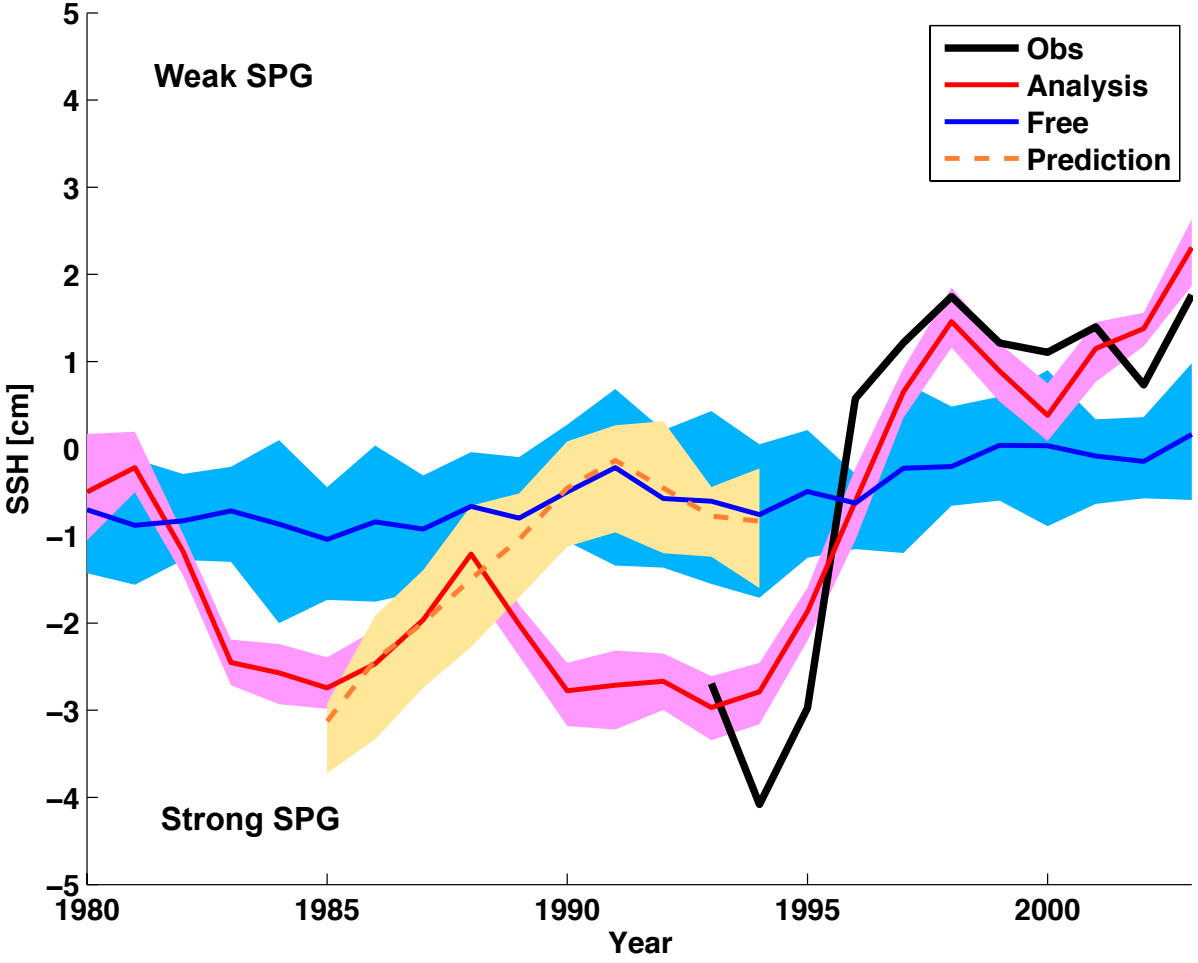
Perfect model prediction

Nordic Seas T (0-300m)



SST anomaly assimilation (1980-present)

SPG index = box-averaged SSH [60W-15W,48N-65N]



- NorESM1-ME
- historical forcings from CMIP5
- assimilation of SST from HadISST2

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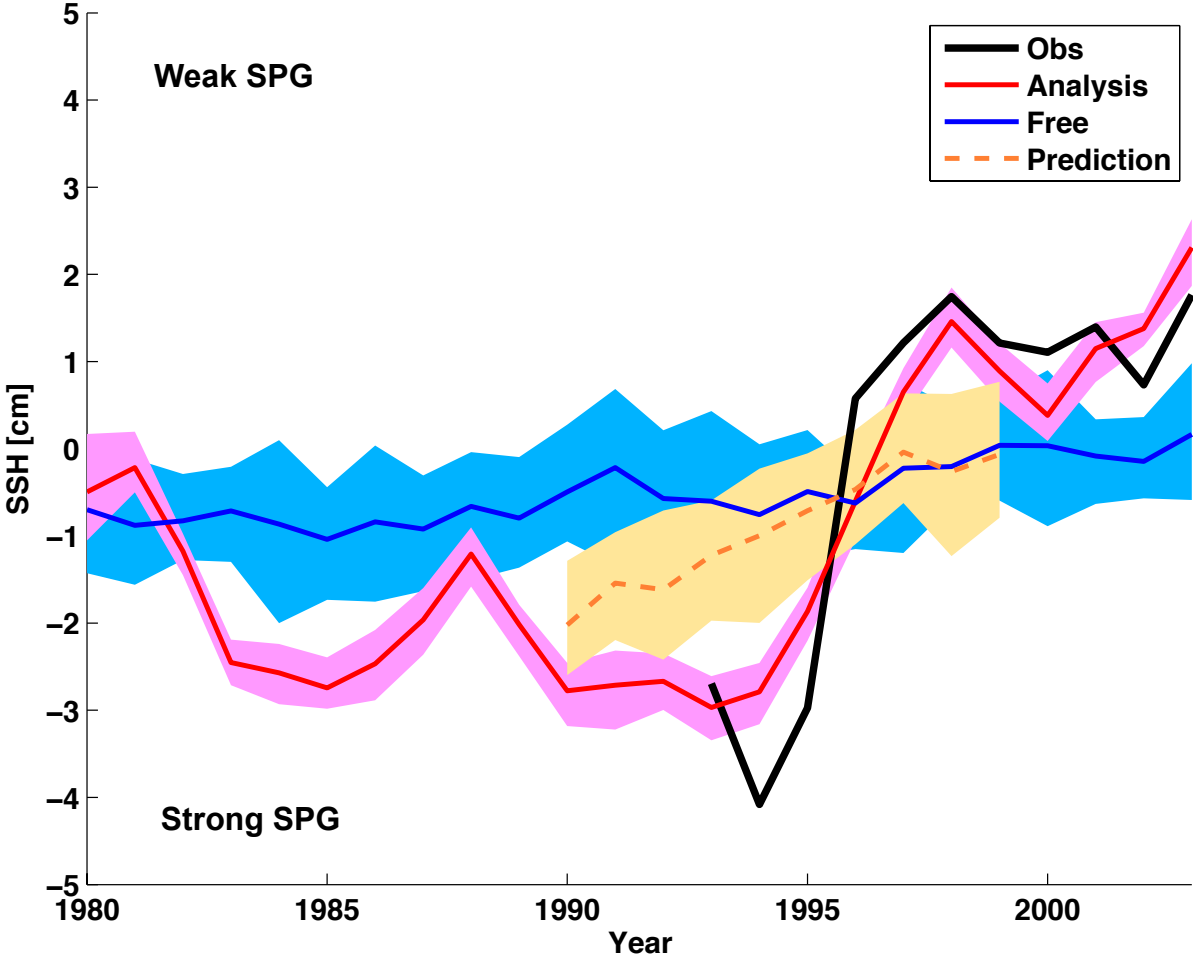

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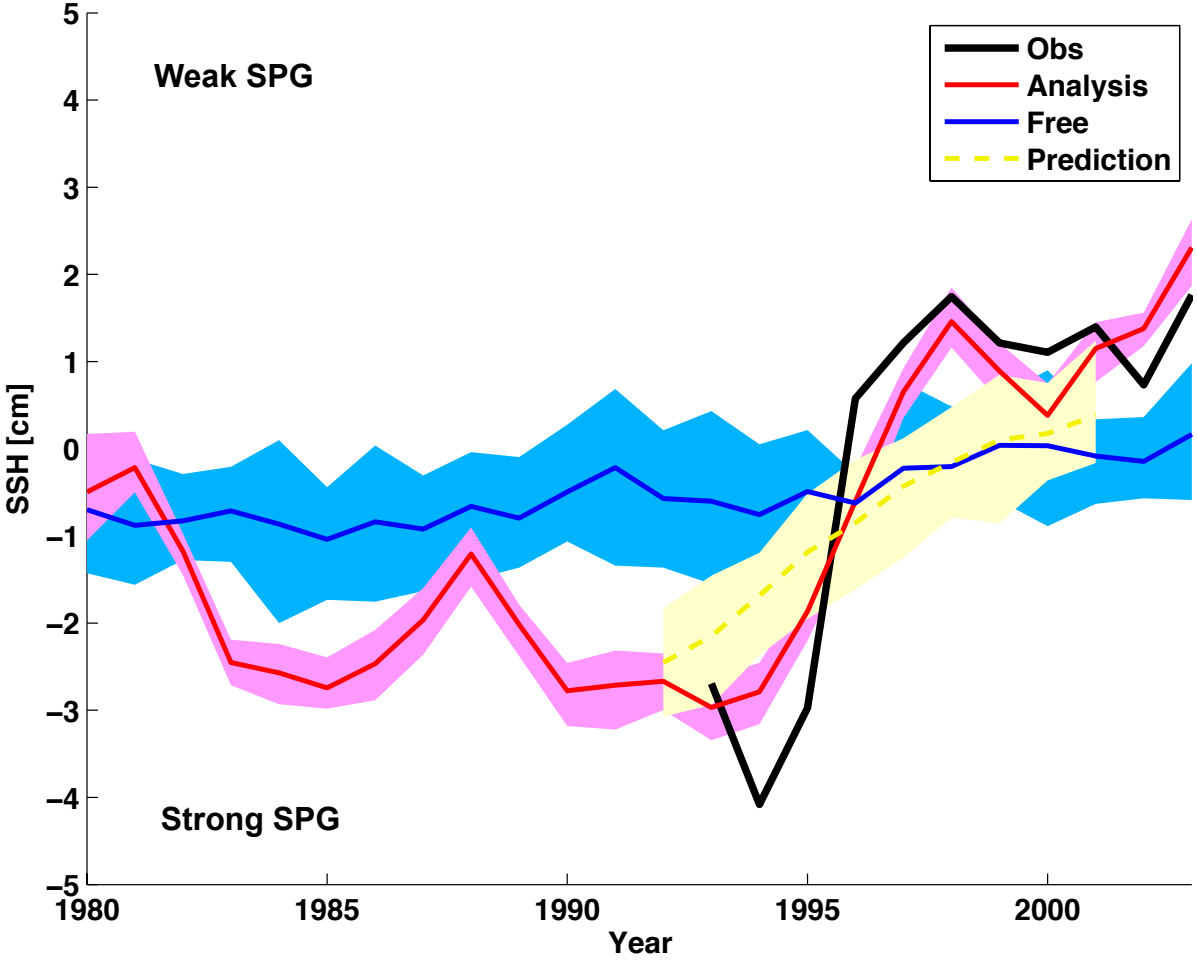

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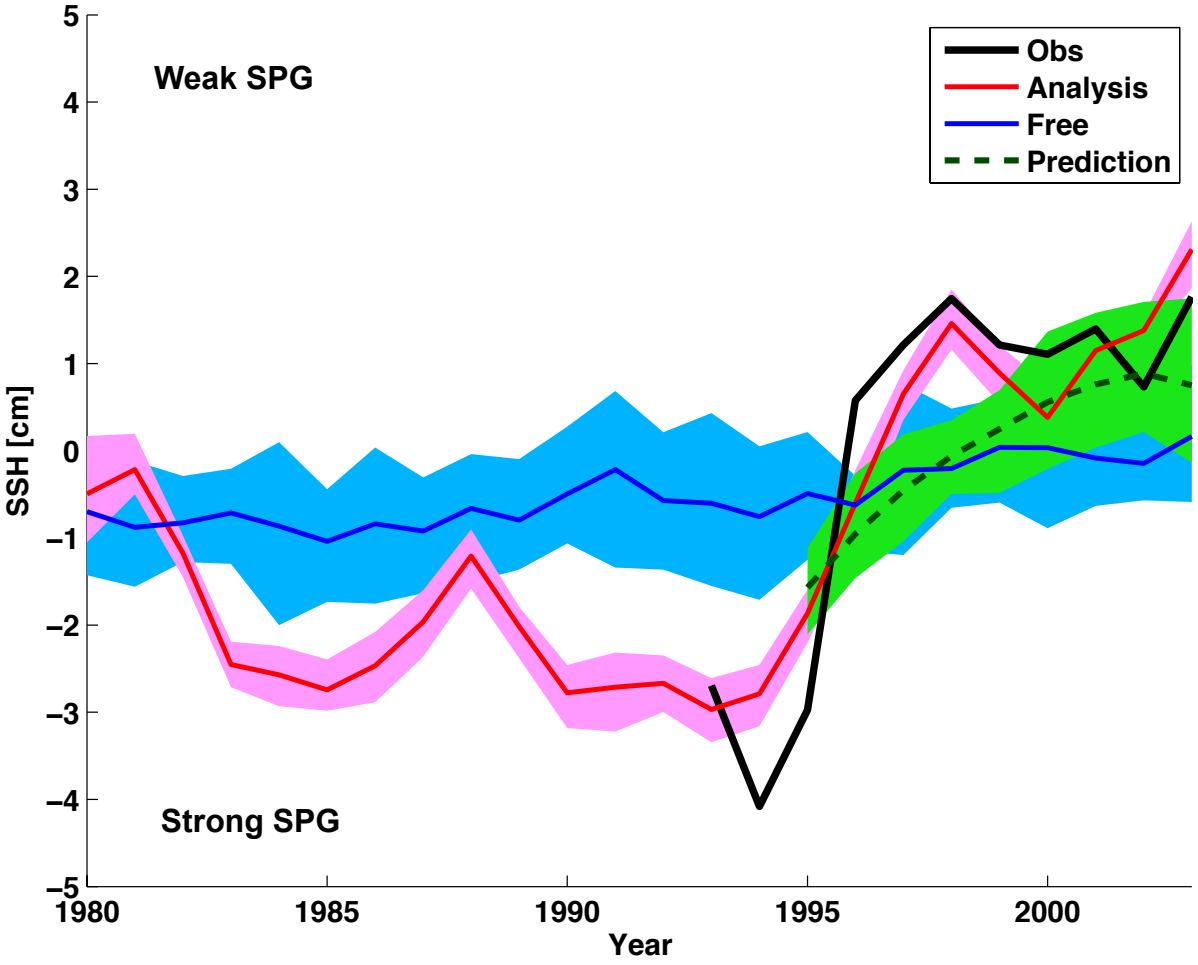

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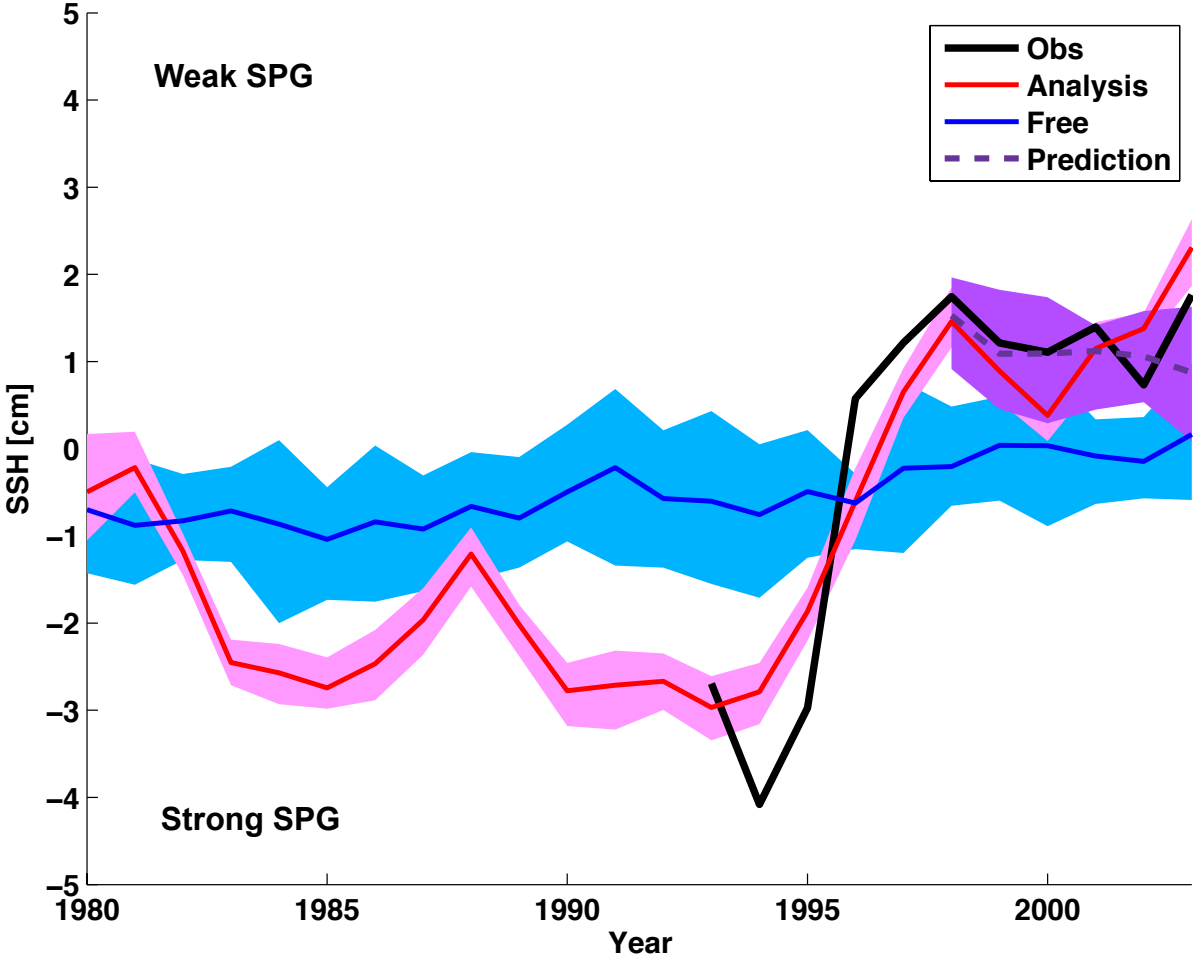

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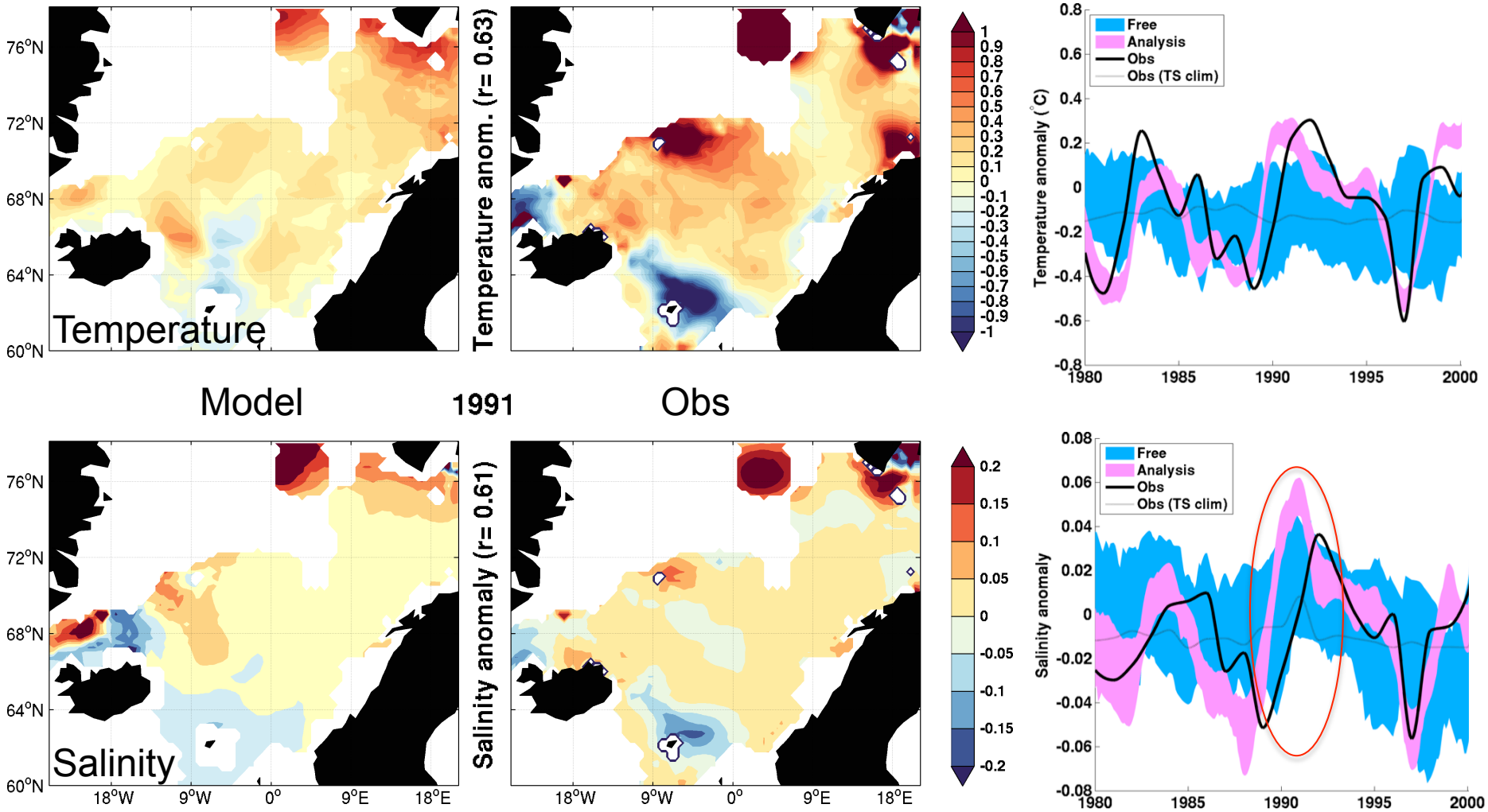
SST anomaly assimilation (1980-present)

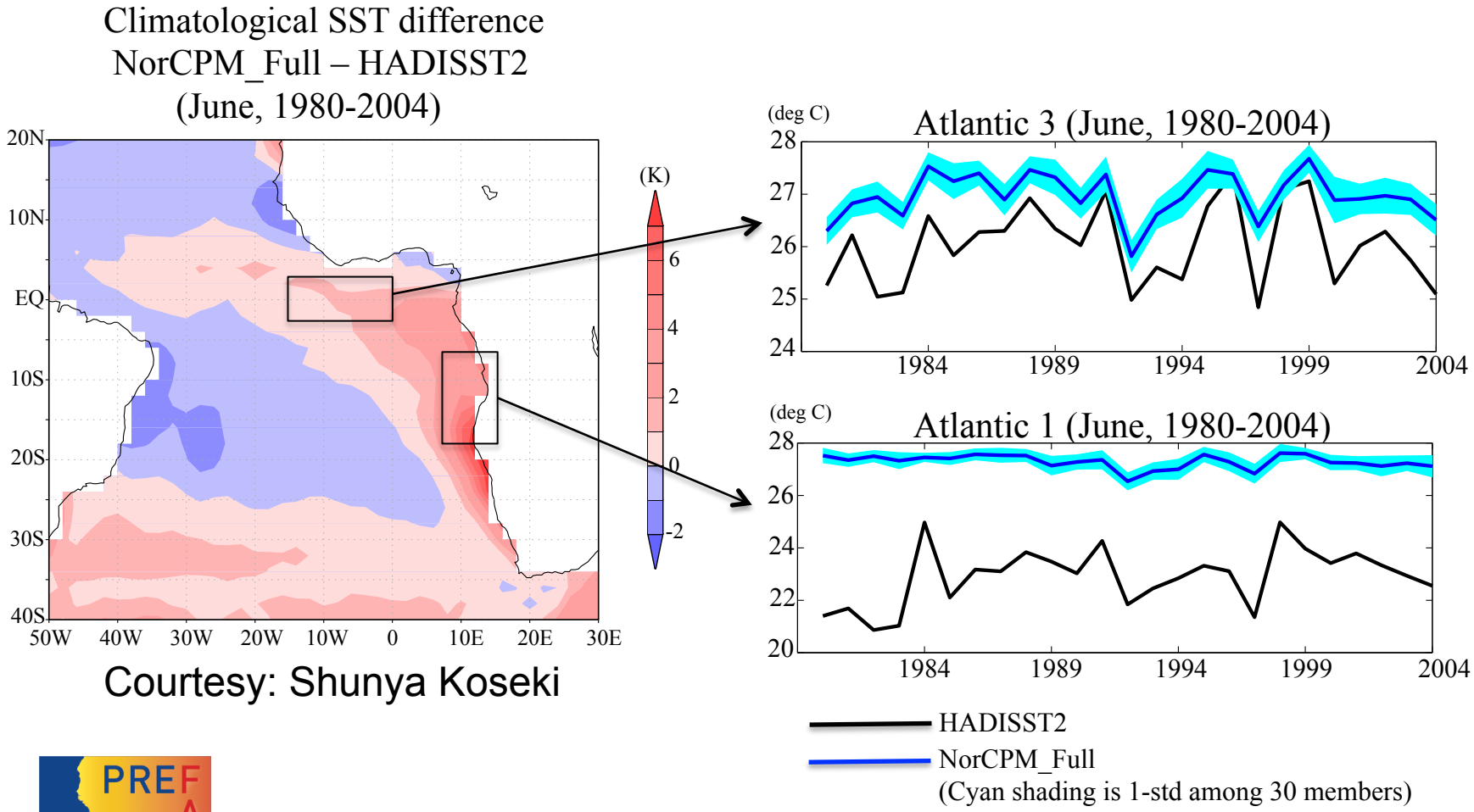
Temperature and salinity averaged over Atlantic Layer (~0-300m)



analysis leads observations!

Ongoing work: full-field assimilation and bias assessment

Tackling model error in the Tropical Atlantic

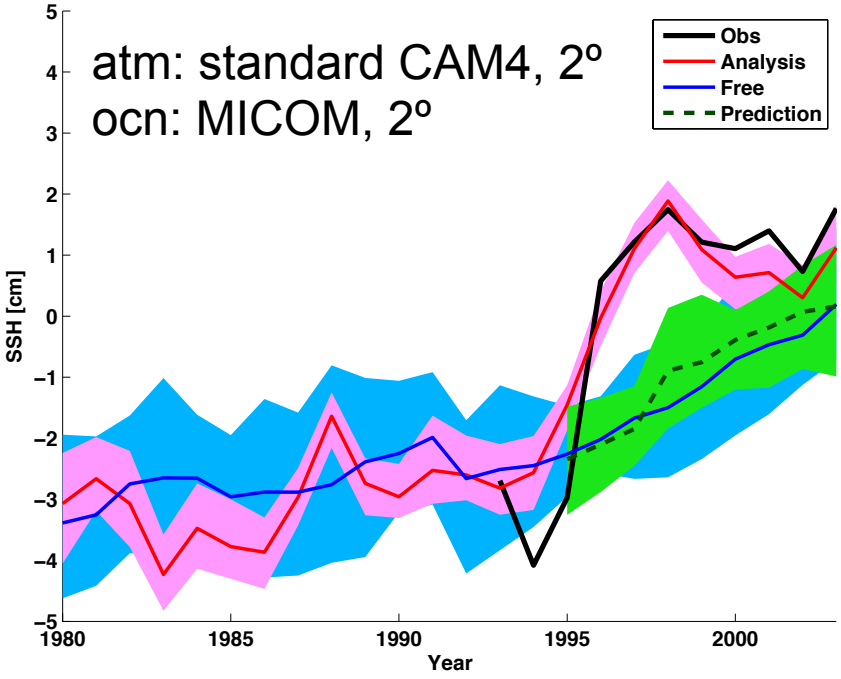


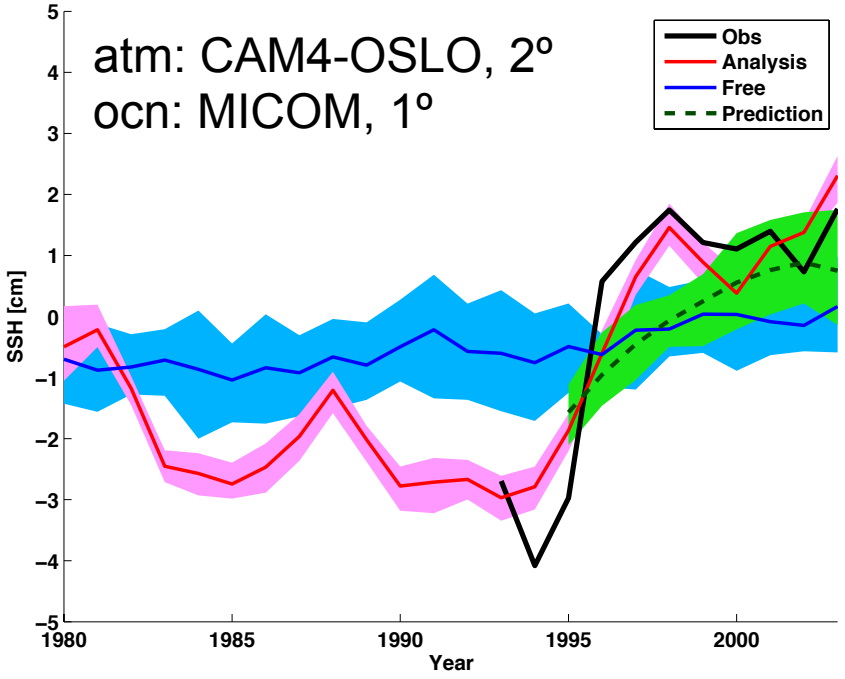
Courtesy: Shunya Koseki

Predictions are used in the EU-PREFACE project to understand and reduce model errors

Ongoing work: sensitivity to model resolution and physics

SPG index = box-averaged SSH [60W-15W,48N-65N]

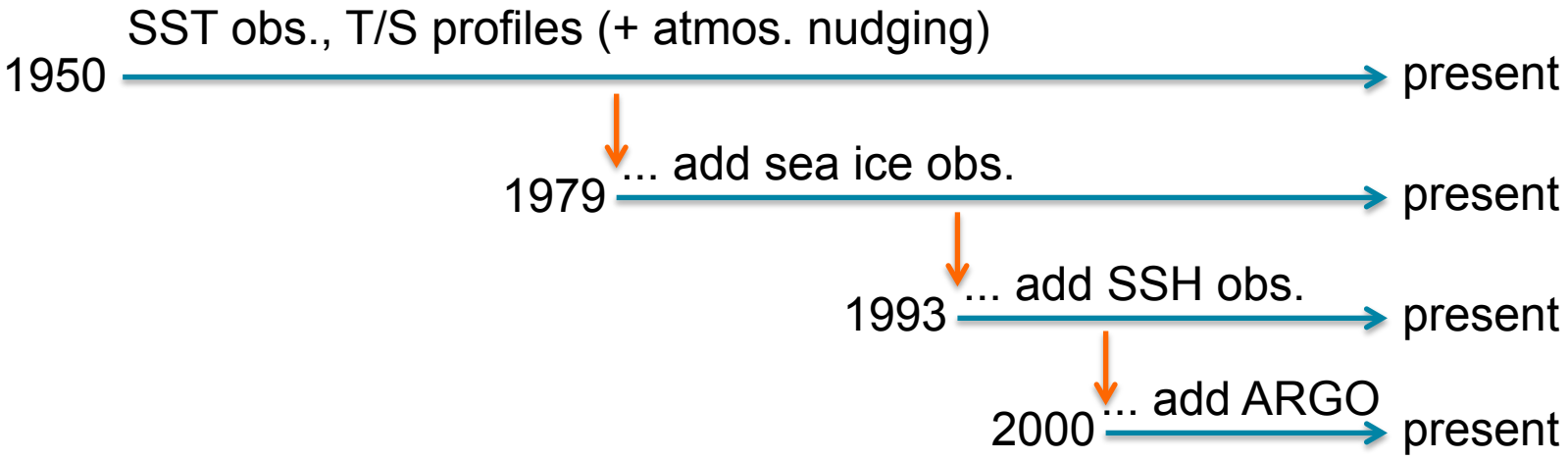




- physics and resolution matter!
- high-top WACCM configuration (L66) will be evalutated for seasonal prediction

Ongoing work: more data + atmospheric nudging

Assess benefit from assimilating more data



Atmospheric nudging

- future goal: coupled EnKF assimilation (ocean, atmosphere, land, sea ice)
- for now: nudging to re-analysis products
- constraining atmospheric state should improve ocean, sea ice and snow cover initialisation, **BUT** can easily lead to collapse of ensemble spread

Plans for CMIP6 DCPP

#	Experiment	Notes	# of years	
PRIORITY 1: basic forecast information				
1.0	Ensembles of 10-year hindcasts and forecasts	- coupled models initialized based on observations - initial dates on or before 31 Dec of the year preceding the forecast period (start date on or before Nov 31 allows DJF seasonal forecast results and is recommended) - all years from 1960 to end of CMIP6 period - 10 ensemble members if possible - projected radiative forcing but *no information from the future* (such as volcanoes, solar etc.)	60x10x10=6000	definitely
1.1	Ensemble of 10-year current forecasts	- as above but from the end of the CMIP6 period up to the time of AR6	~300	definitely
PRIORITY 2: enhancement of forecast information				
2.0	Ensembles of 10-year uninitialized cases	- forced climate simulation up to start date of corresponding forecast using historical forcing - simulation parallel to corresponding forecast with projected radiative forcing but *no information from the future* (such as volcanoes, solar etc.) - all years from 1960 to end of CMIP6 period - 10 ensemble members if possible	60x10x10=6000	perhaps not
2.1	Increase ensemble size for Experiment 1.0	- m additional ensemble members to improve skill and examine dependence of skill on ensemble size	mx10x10=mx100	maybe
PRIORITY 3: possible coordinated experiments benefiting association with CMIP protocols				
3.1	Ensembles of 10-year predictability runs	- m start dates from 20th century historical runs - perturbed initial condition - n ensemble members	mxn	perhaps not