Met Office
Hadley Centre

The use and impact of Argo products in seasonal – to – decadal prediction

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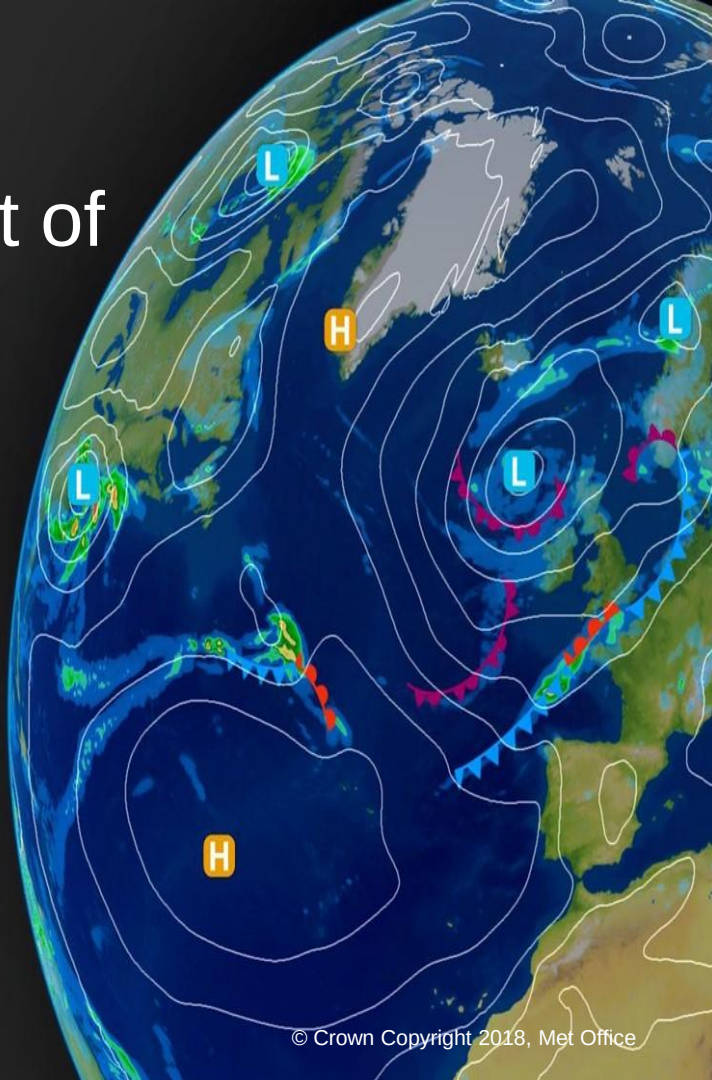
Doug Smith, Nick Dunstone, Rosie Eade, Jeff Knight



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Content

- Introduction to long-range forecasting
- An ocean re-analysis for initialisation
- The impact of Argo's global coverage
- An ensemble of ocean re-analyses
- Implied ocean dynamics
- Summary

Long-range forecasting

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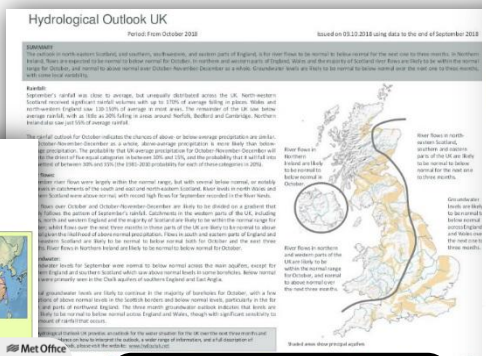
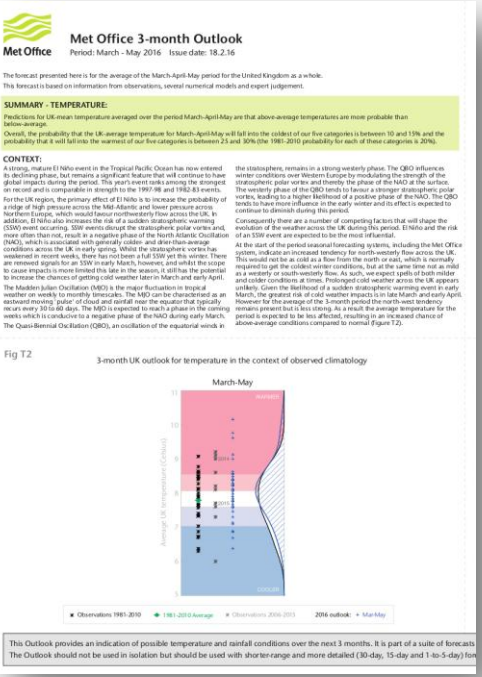
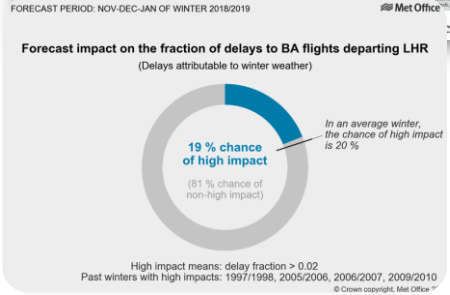
Climate services







Long-range forecasting's boundary conditions

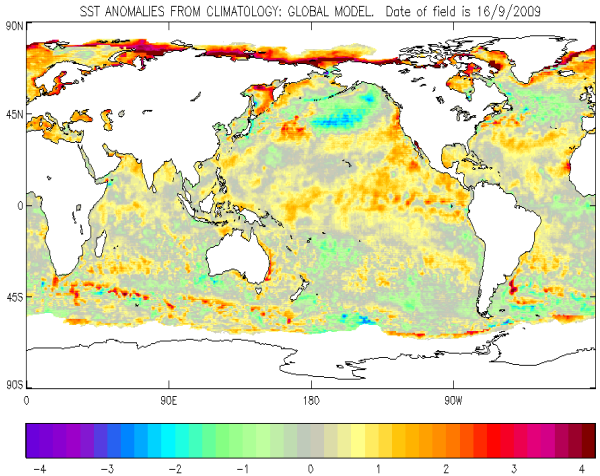
In addition to the atmospheric initial state, the 'boundary conditions' provide the 'memory'

Greenhouse gases & aerosols

Land surface

Ocean

(mainly heat content)



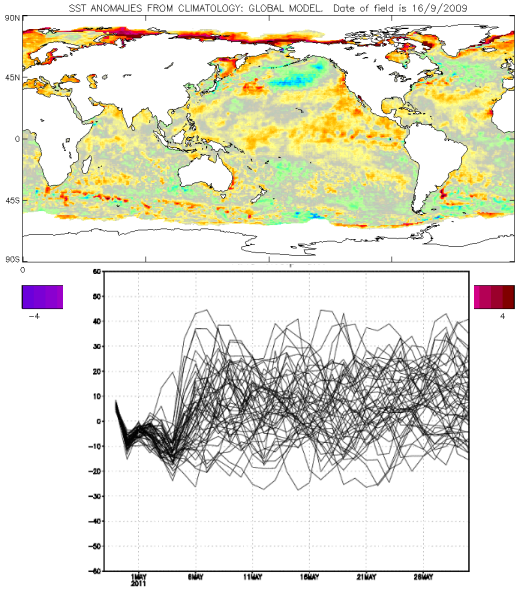
Volcanoes

https://medium.com/starts-with-a-bang/how-much-co2-does-a-single-volcano-emit-bbc045be015d

Cryosphere

https://nsidc.org/cryosphere/quick-facts

Probabilistic forecasting



Systematic effects

Can be quite consistent through the season

Atmospheric spread

Essentially random like rolling a dice

Partial predictability

Like rolling a loaded dice

Predictability for an *instantaneous* state remains low, but *average* conditions across a longer period, such as the season as a whole, are predictable

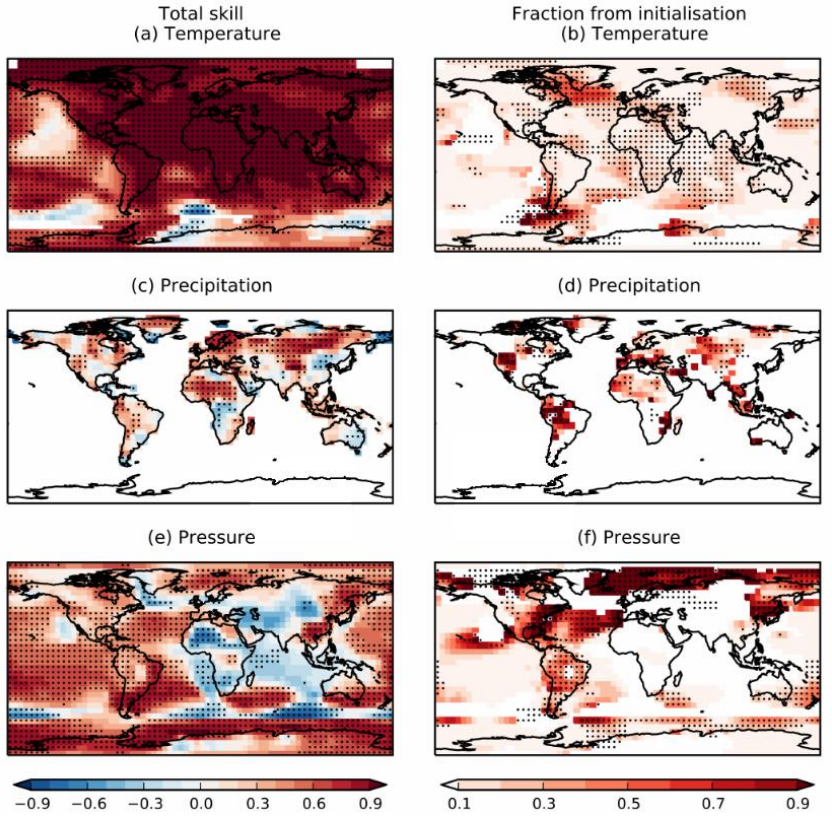
Decadal Prediction

- At the point where initial conditions still matter, but boundary conditions are also important
- Forecast length is 1 – 10 years
- The intention is to model the decadal climate variability
- This variability is an interaction between atmosphere, ocean and cryosphere that provides memory
- Simply put, the ocean integrates the atmosphere on long time scales (many years) and affects the atmosphere on short time scales (seasons)
- The ocean is also important as it stores and persists heat
- To test our decadal prediction system, we run retrospective forecasts (aka hindcasts)
- These are started from re-creations of past climate states (initialisation)

Skill and impact of initialisation: years 2-9

- High skill for temperature
- Skill for rainfall over land in many regions
- Skill for pressure (with some exceptions)
- Improved skill from initialisation

➢ especially rainfall and pressure



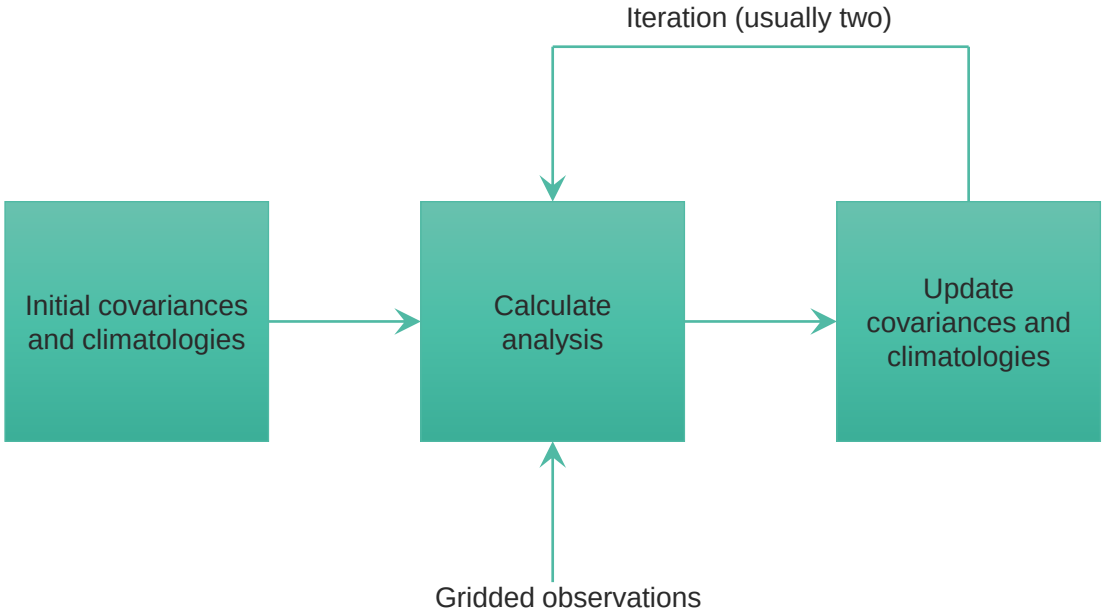
Smith et al, in prep

Met Office Statistical Ocean Re-Analysis (MOSORA)

- 4-D potential temperature and salinity analysis
- Starting 1950, monthly means up to present
- Regular latitude / longitude grid:1.25˚ x 1.25˚ 20 levels
- Uses profiles of temperature and salinity from EN4 (Argo, XBTs, etc. see Rachel Killick's talk)
- Also uses SST (HadISST1.1 from 1982, HadSST2 before)
- Global covariance optimal interpolation (Smith & Murphy, 2007)
- Initial covariances are taken from a model control run (smoothed fields)
- The first-guess analysis then provides the covariances for the next analysis and this is iterated

Smith et al, 2015 GRL

Iteration procedure for MOSORA

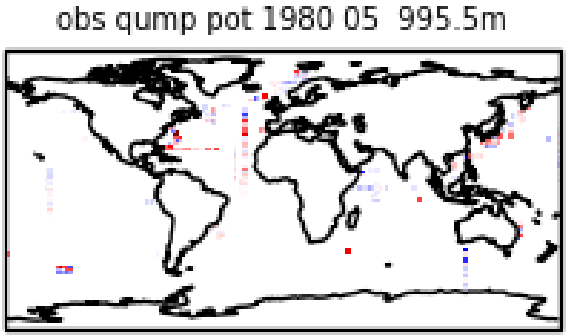


- There is an improvement in RMSE between the initial and first iteration
- The second iteration generally has larger anomalies, but no better RMSE

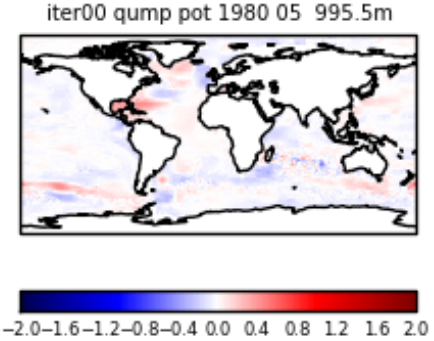
Iterations: Example anomalies for May 1980

Observations

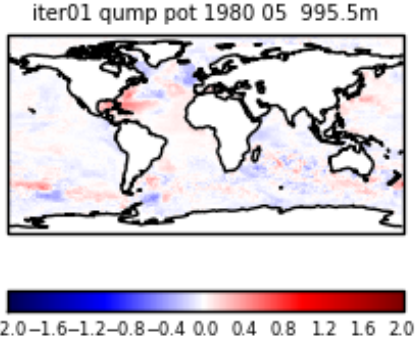
1000m



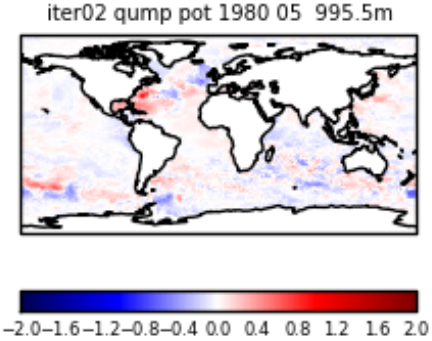
Initial iteration



Iteration 1

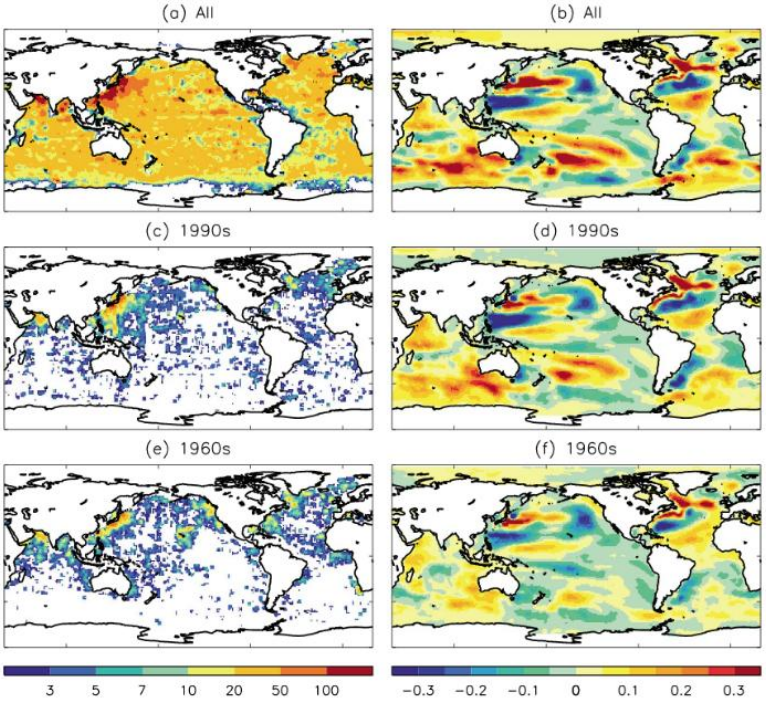


Iteration 2



Impact of observational coverage on trends in heat content 2008 - 2012

Number of observations | Ocean heat content trends



- The estimated trends depend on the observational coverage
- With the global coverage of Argo, the trends are strongest
- Sub-sampling the observations to the observational coverage of the 1990s or 1960s reduces the estimated trend

Smith et al, 2015 GRL

An ensemble of analyses

- The next Met Office Decadal Prediction System has 10 member forecast ensembles
- Each member has initial conditions from different analyses
- The difference between analyses is in the origin of the initial covariances:
  - one analysis uses HadGEM3-GC2 (current version of coupled model)
  - one analysis uses an ocean-only integration GO5 (current ocean version)
  - eight analyses use perturbed parameter integrations of HadGEM3-GC3 (next version of the coupled model)

Perturbed Parameter Ensemble

An ensemble created by changing the parameters for the unresolved physics

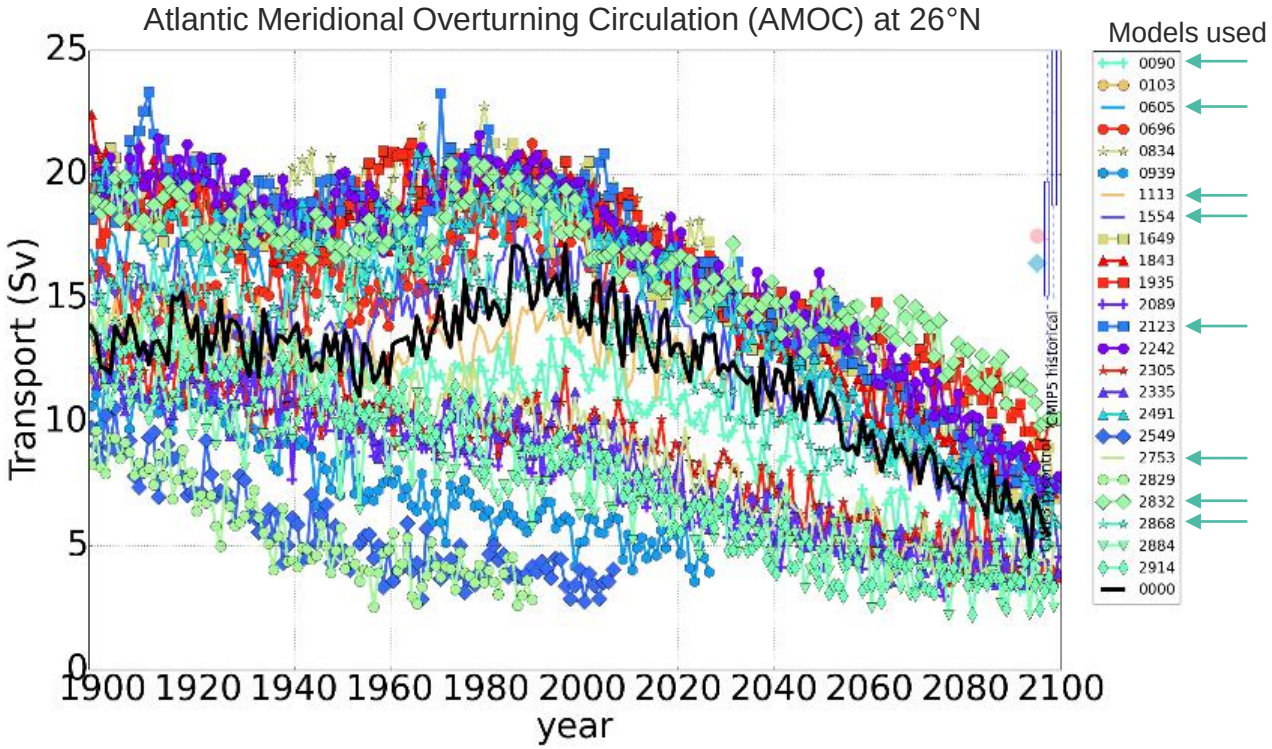
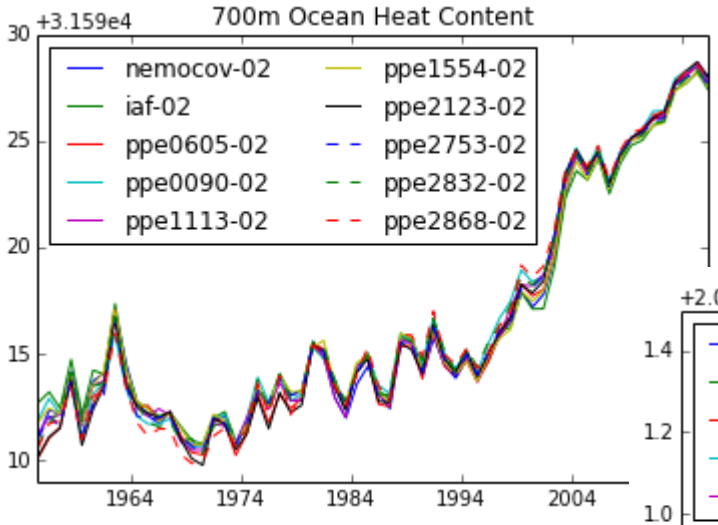
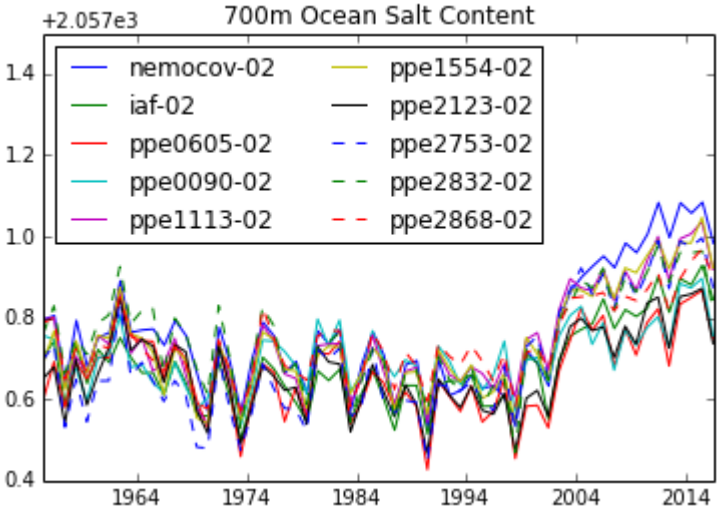


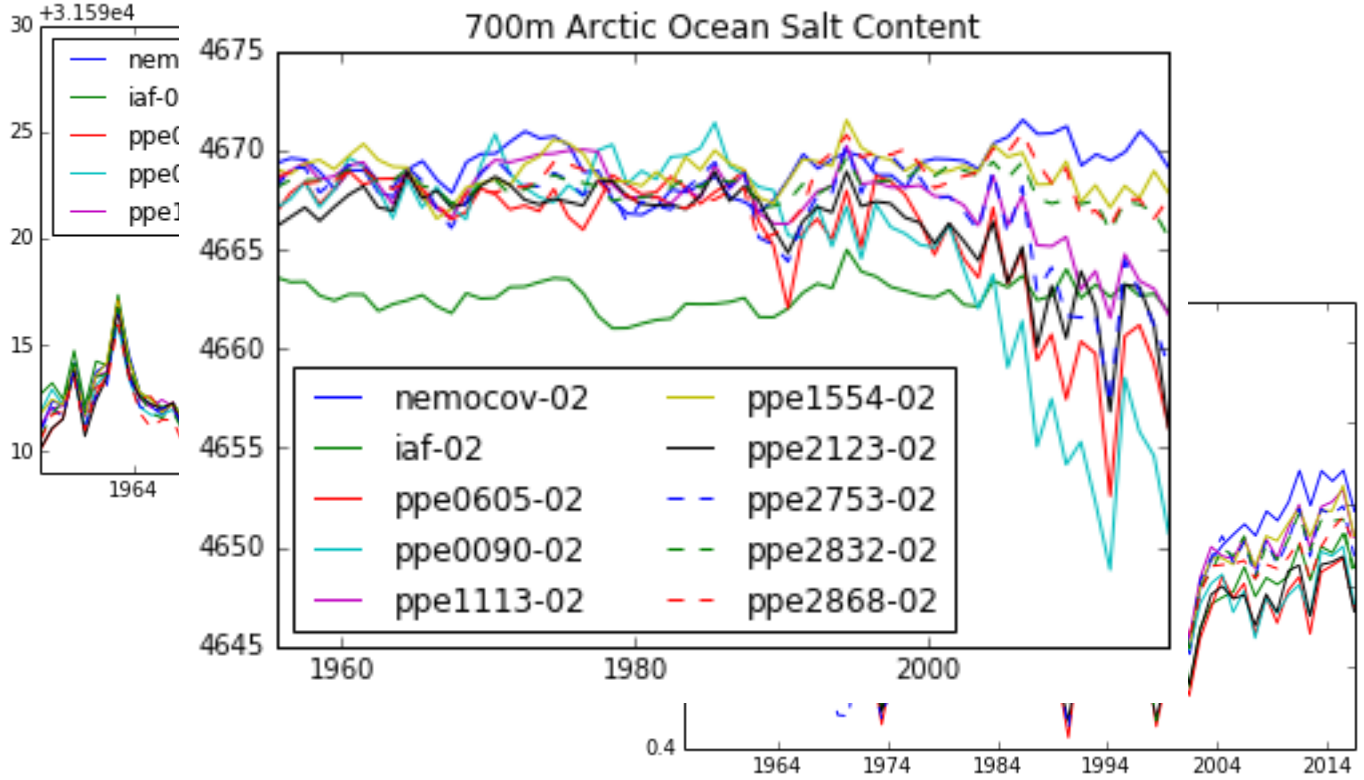
Figure from Kuniko Yamazaki

Integrated temperature and salinity

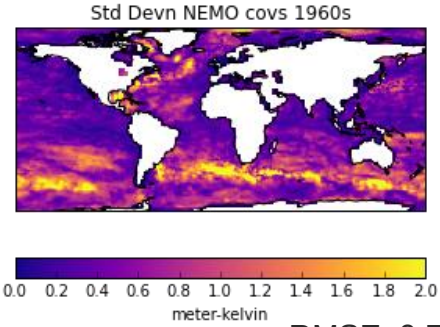




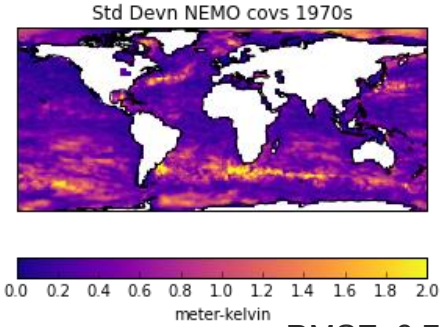
Integrated temperature and salinity



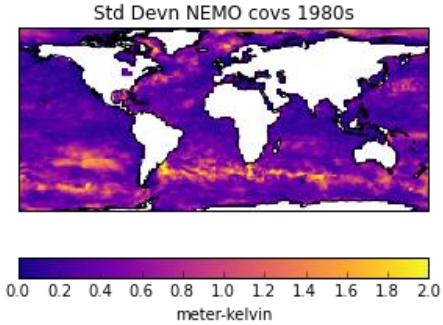
Where are differences in ocean heat content?



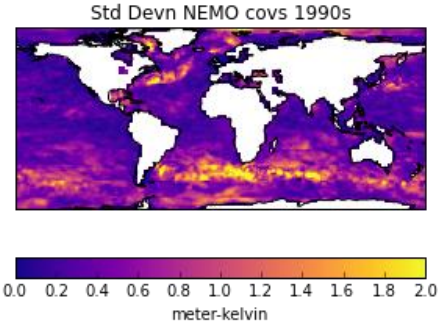
RMSE: 0.75 K



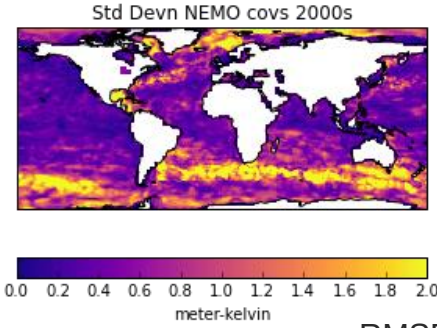
RMSE: 0.72 K



RMSE: 0.69 K



RMSE: 0.68 K



RMSE: 0.60 K

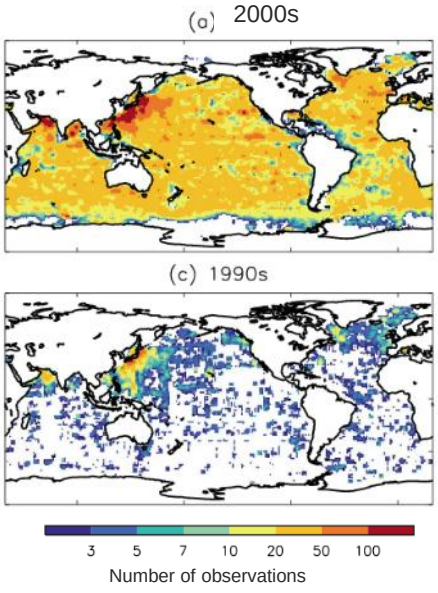
Maps of 700m ocean heat content.
Units: 10^4 J
RMSE of temperature at all depths

Impact of Argo?

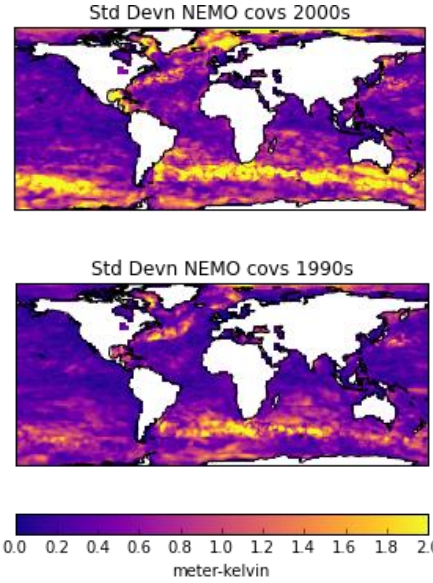
Why do analyses diverge more with better coverage?

Is it because better coverage means stronger anomalies?

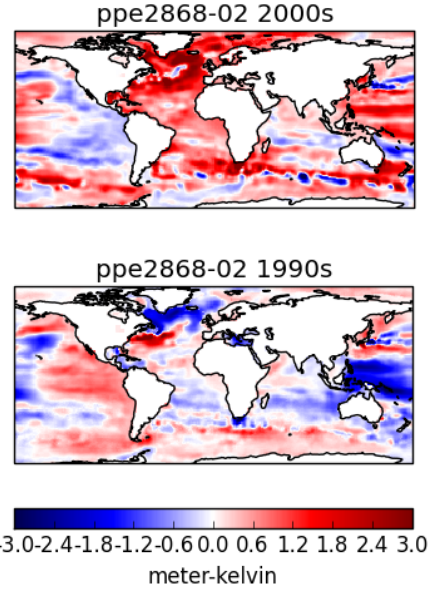
Number of observations



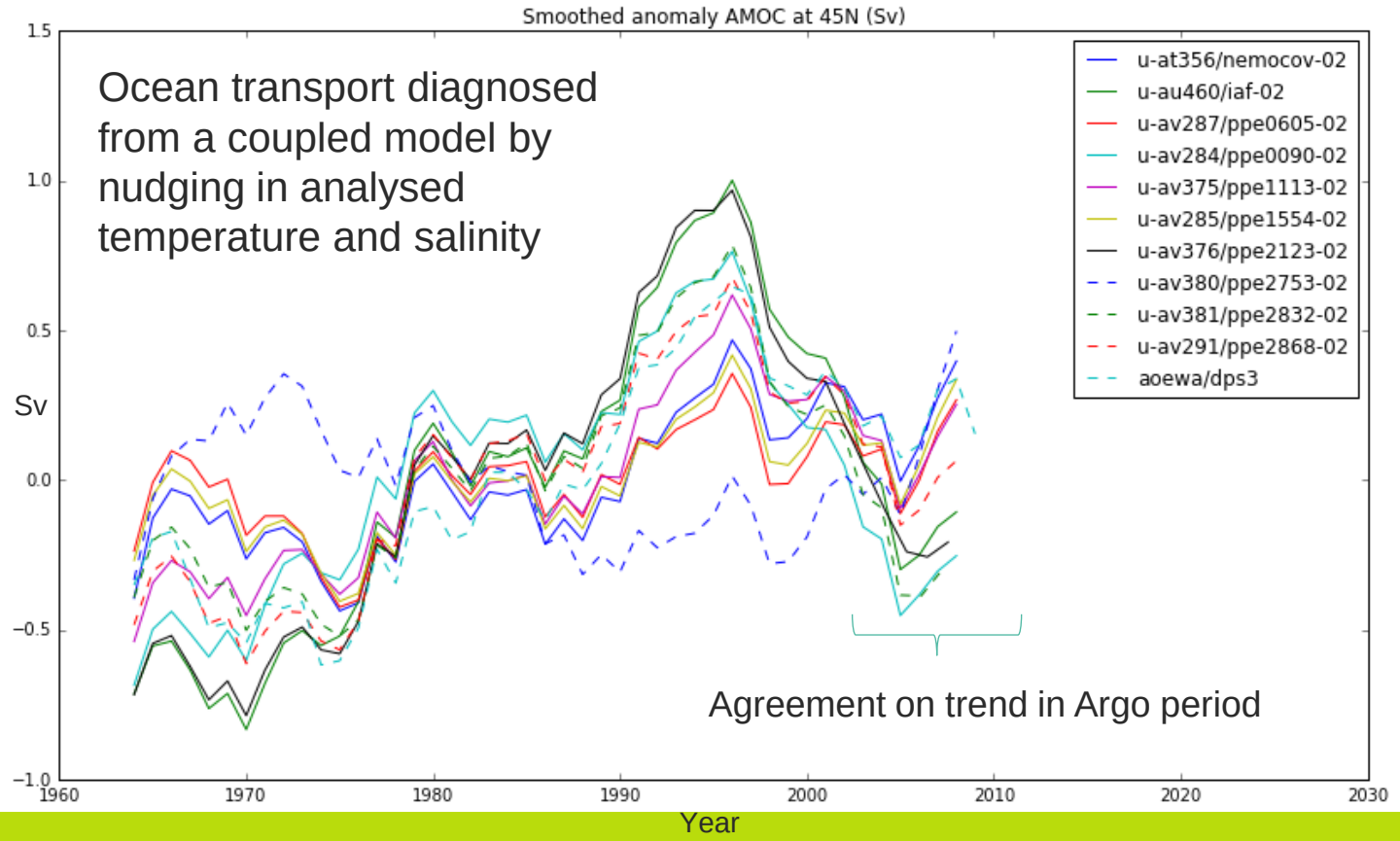
Standard deviation of heat content



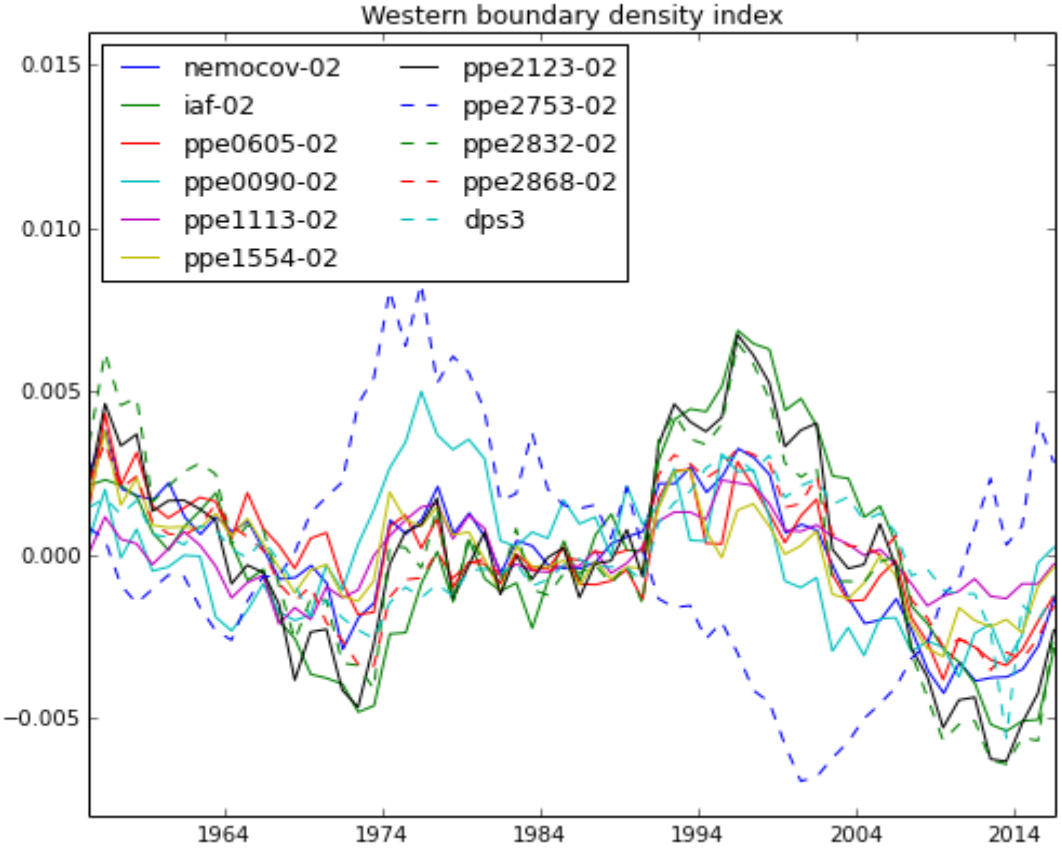
Typical temperature anomalies



Atlantic transport at 45°N



Deep Atlantic density 1200 – 3000m



The biggest differences are in the salinity

Summary

- Prediction further ahead than a few months is dependent on processes that vary on time scales longer than the weather in the atmosphere
- The primary source of predictability is the ocean
- The global coverage provided by Argo means better estimation of five-year trends of ocean heat content
- It also leads to lower errors in the analysis of temperature and salinity
- It may reduce the uncertainty in the estimation of ocean dynamics
- Perhaps paradoxically, the disagreements between ocean analyses increases in some regions with the introduction of Argo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