

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

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- 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

Met Office Long-range forecasting



0-7 days 7-15 days 2-6 weeks 3-9 months 1-10 years 30-100+ y

Initial conditions

Boundary conditions

Met Office Climate services

Hydrological Outlook UK Period: From October 2018

issued on 03:10:2018 using data to the end of Sectomber 201

names. September's califul was close to average, but unequality distributed across the SK. Nexth-nextern Section received applicant safetal valueme with up to 1005 of average follog in places. Walks and methodentess fingland size: 120-150% of average in most areas. The remainder of the UK size betwee sectorgranning, but as 100 a 2005 falling in areas around holds, fielding and Carrindge. Rechtum

outposh for October indicates the chances of above or herve veryage procipitation are similar, and/secretize discretizer as a white, above varyage procipitation is more fieldly than being segmetation. The probability that this varyage procipitation of October Asservative Sciencelo with or disks of the expand categories in between 20% and 12%, and the probability that it willful area (or deriver all States). The or discretizer area is the expension in 20%.

are flown work largely within the normal range, but with several below normal, or notable In contrast two access access to many cards maked high threads for generative results of the first two two cares of totals and two cares of two cares of the second secon

and and southern Scotland which saw above normal levels in some bornholes. Below normal interfy seen in the Chalk againers of southern English and East Anglia.

and parts of northwest England. The three march groundwater outlook indicates that levels are listly to be normal to below normal across England and Wales, thoogh with significant sensitivity to

Met Office Main

let Offic



Met Office 3-month Outlook Period: March - May 2016 Issue date: 18.2.16

The forecast presented here is for the average of the March-April-May period for the United Kingdom as a whole. This forecast is based on information from observations, several numerical models and expert judgement.

SUMMARY . TEMPERATURE

Predictions for UK-mean temperature averaged over the period March-April-May are that above-average temperatures are more probable than below-average

Overall, the probability that the UK-average temperature for March-April May will fall into the coldest of our five categories is between 10 and 19% and 10 probability that it will fall into the warmest of our five categories is between 25 and 30% (the 1981-2010 probability for each of these categories is 20%). en 10 and 15% and the

CONTEXT:

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3-month UK outlook for temperature in the context of observed climatology



This Outlook provides an indication of possible temperature and rainfall conditions over the next 3 months. It is part of a suite of forecast The Outlook should not be used in isolation but should be used with shorter-range and more detailed (30-day, 15-day and 1-to-5-day) for

This document provides forecasts for the Yangtze river region in 2018. The region used is shown on the right. The location of the Three Gorges Dam is marked with a star. Forecasts are for area-averaged seasonal precipitation accumulations, or river flow. The current headline results are: For the coming 3-month period (ASO): . There is a 60% chance of above-average rainfall FORECAST PERIOD: NOV-DEC-JAN OF WINTER 2018/2019

02 July 2018

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Forecast impact on the fraction of delays to BA flights departing LHR

INTERNAL USE ONLY

2018 Yangtze River Forecasts





Prospects for El Niño in the coming months Jeff Knight and Sarah Ineson, Met Office Hadley Centre

21st August 2018

Fig T2

Met Office Long-range forecasting's boundary conditions

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

Greenhouse gases & aerosols



Land surface





Volcanoes



https://medium.com/starts-with-abang/how-much-co2-does-asingle-volcano-emitbbc045be015d

Cryosphere



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

Met Office Probabilistic forecasting



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



- 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)

Met Office Hadley Centre 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

A Starter

(a) Temperature

(c) Precipitation

Fraction from initialisation (b) Temperature



(d) Precipitation



(e) Pressure



(f) Pressure



Smith et al, in prep

[≪] Met Office 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

Met Office Hadley Centre 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

Met Office Iterations: Hadley Centre Example anomalies for May 1980

Observations

obs qump pot 1980 05 995.5m





Initial iteration

iter00 qump pot 1980 05 995.5m



Iteration 1

iter01 qump pot 1980 05 995.5m



Iteration 2

iter02 qump pot 1980 05 995.5m





-2.0-1.6-1.2-0.8-0.4 0.0 0.4 0.8 1.2 1.6 2.0

-2.0-1.6-1.2-0.8-0.4 0.0 0.4 0.8 1.2 1.6 2.0



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



- 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

Met Office 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)

Met Office Perturbed Parameter Ensemble Hadley Centre An ensemble created by changing the parameters for the unresolved physics



Figure from Kuniko Yamazaki

Met Office Hadley Centre Integrated temperature and salinity



Met Office Hadley Centre Integrated temperature and salinity



∞ Met Office Where are differences in Hadley Centre ocean heat content?

Std Devn NEMO covs 1960s



Std Devn NEMO covs 1970s



00 02 04 06 08 10 12 14 16 18 20

meter-kelvin

Std Devn NEMO covs 1980s





Std Devn NEMO covs 1990s

00 02 04 06 08 10 12 14 16 18 20

meter-kelvin





meter-kelvin

Maps of 700m ocean heat content. Units: 10⁴ J RMSE of temperature at all depths



RMSE: 0.75 K

Impact of Argo?

RMSE: 0.60 K

Met Office Why do analyses diverge more with better coverage?

Is it because better coverage means stronger anomalies?

Number of observations

(a) 2000s



(c) 1990s



Standard deviation of heat content

Std Devn NEMO covs 2000s

Typical temperature anomalies

ppe2868-02 2000s



ppe2868-02 1990s





0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 -3.0-2.4-1.8-1.2-0.6 0.0 0.6 1.2 1.8 2.4 3.0 meter-kelvin meter-kelvin

Met Office Hadley Centre Atlantic transport at 45°N

Smoothed anomaly AMOC at 45N (Sv)



Met Office Hadley Centre Deep Atlantic density 1200 – 3000m





The biggest differences are in the salinity



- 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



Questions?

www.metoffice.gov.uk

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Met Office Hadley Centre AMOC 45N (absolute)

