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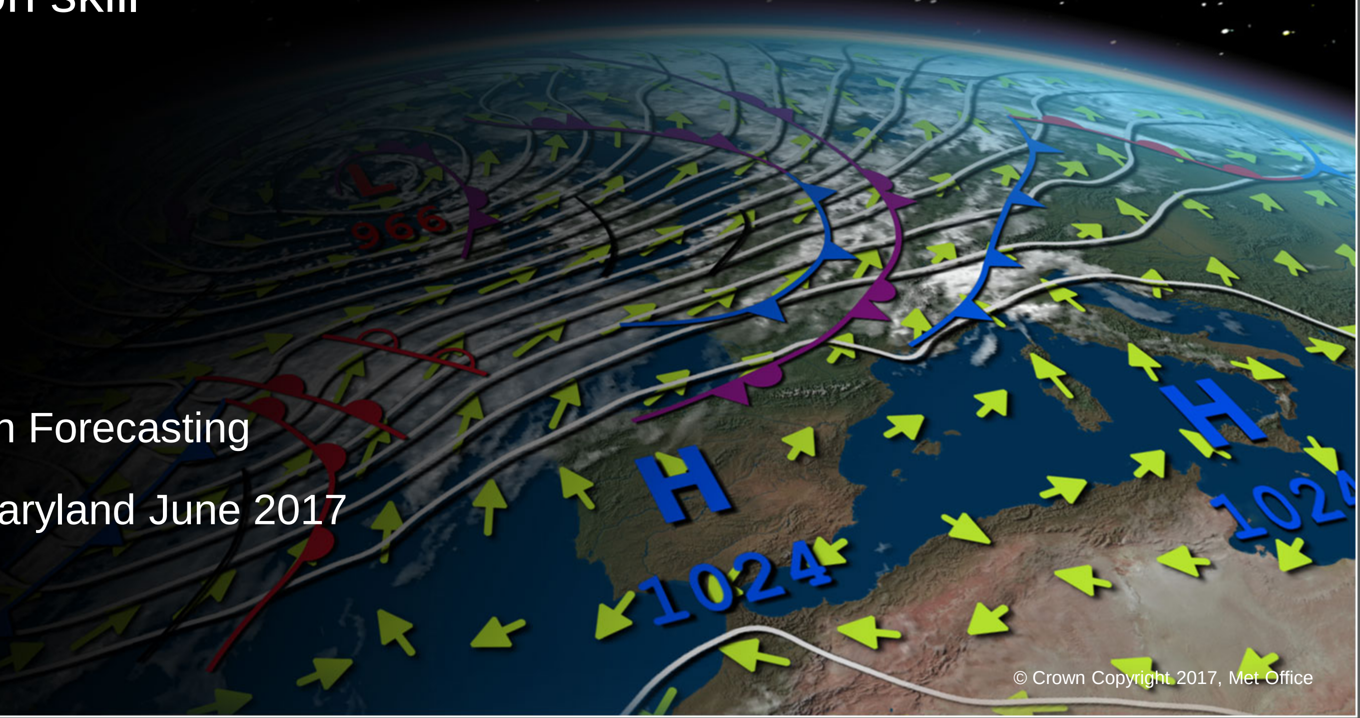
Ocean observations and modelling

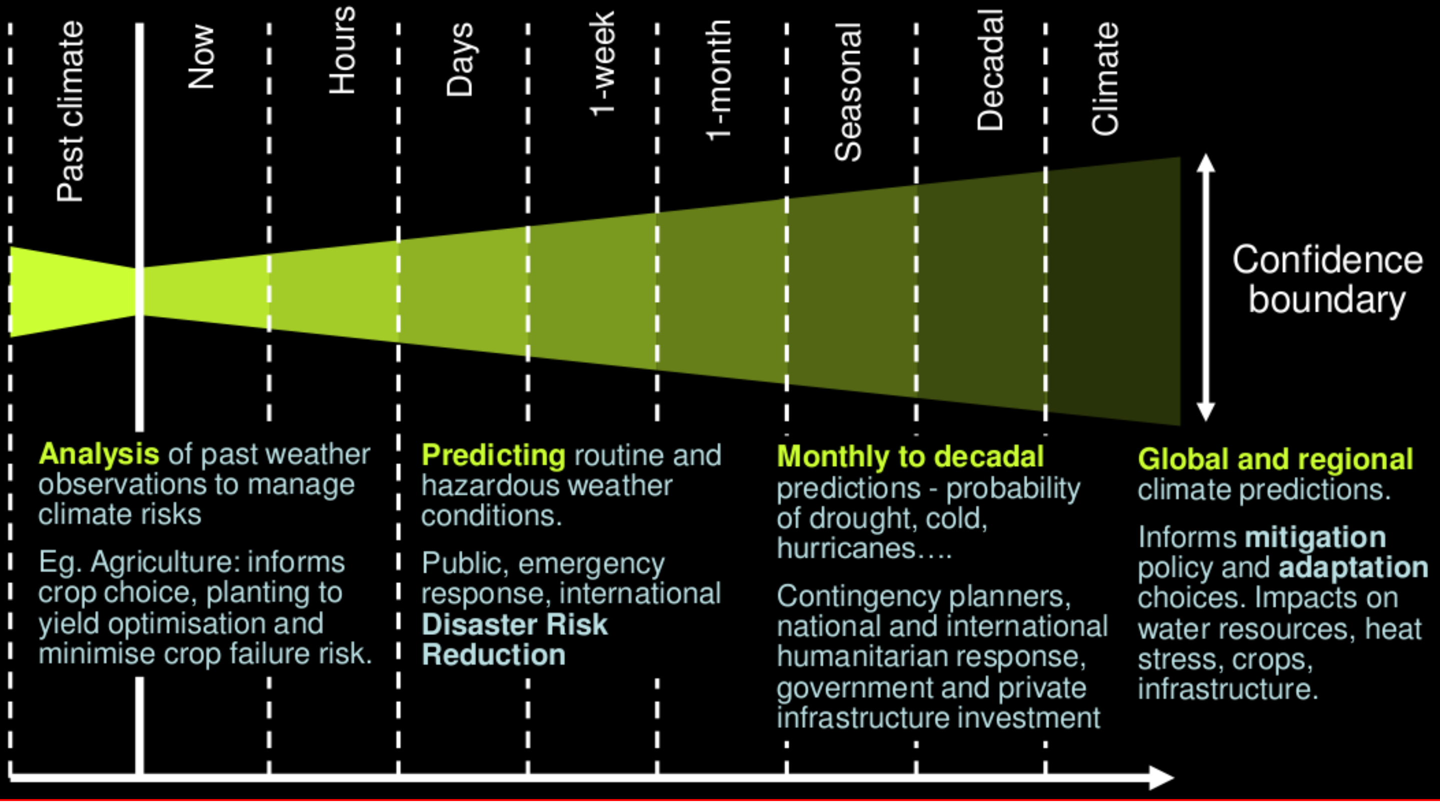
The contribution of ocean observations to weather forecast and prediction skill

John Siddorn, Head Ocean Forecasting

Blueplanet Symposium, Maryland June 2017



Seamless Prediction: Coupled modelling on all timescales



Analysis of past weather observations to manage climate risks

Eg. Agriculture: informs crop choice, planting to yield optimisation and minimise crop failure risk.

Predicting routine and hazardous weather conditions.

Public, emergency response, international **Disaster Risk Reduction**

Monthly to decadal predictions - probability of drought, cold, hurricanes….

Contingency planners, national and international humanitarian response, government and private infrastructure investment

Global and regional climate predictions.

Informs **mitigation** policy and **adaptation** choices. Impacts on water resources, heat stress, crops, infrastructure.

The Forecasting and Prediction Paradigm

- Oceans have high heat content but high latency
  - Seasonal forecasting and climate prediction only
- Weather happens in the (terrestrial, atmospheric) boundary layer
  - Ocean broadly irrelevant, except to mariners and some discrete cases (e.g. coastal flooding)
  - Ocean forecasting is a separate community to weather forecasting

Value of ocean information

- Ensemble wave prediction
- Seasonal forecasting
- Coupled weather prediction
- Coupled impacts modelling

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Making use of wave information in marine operations

Wave forecasting – ascribing value

Cost-loss analysis for marine operations

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The cost-loss model assesses **the relative economic value** of forecasts when both the loss (L) due to adverse weather conditions and the cost (C) of preventing weather damage are known in monetary terms.

These amounts are additional to costs of operation and it is assumed C<L.

The cost-loss model considers a hypothetical decision-maker who must choose whether or not to commit to an operation based only on the forecast available.

- **e.g. an adverse event where Hs > e.g. 3.5m in time span of 24 hours**:

Forecast \ Observed	yes	no
yes	£ C	£ C
no	£ L	£ 0

Perfect forecast

If bad weather is forecast, decision-maker must spend extra money on protection and the expenses associated with delay whether the event occurs or not = C

If bad weather is not forecast (but does occur) losses occur = L

Dr Ed Steele

Met Office Business Group Post Processing Scientist

Calculating the relative economic value of a forecast

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- climatological baseline has a value of V=0
- perfect forecast has a value of V=1.

- Depending on assessment of likelihood of the event (e.g. Hs >3.5m in 24hr), user must **choose to protect** operation or not;

- A monetary **cost, C,** is incurred whenever the decision was made to protect (irrespectively);

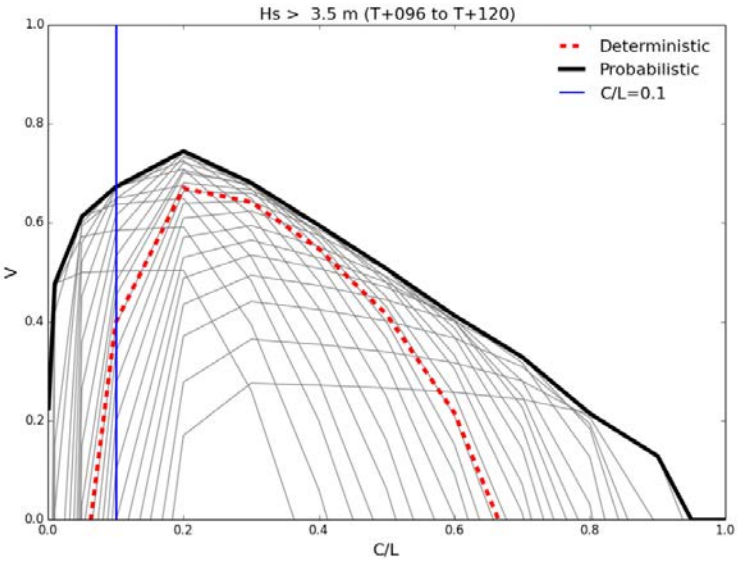
- A monetary **loss, L**, is incurred whenever the event occurs and the decision made not to protect;

- The relative **economic value, V**, compared to a **climatological baseline**, as a fraction of the maximum obtained from using a perfect forecast is:

$$V = \frac{Ec - Ef}{Ec - Ep}$$

- ***Ec*** *- expense if using climatology*
- ***Ep*** *- expense if using perfect forecast system*
- ***Ef*** *- expense of the forecast system studied*

- Calculated from operational forecasts for **ten locations** in the North Sea
- Forecasts using **one year of ensemble** data:
- **Adverse event:** Hs > 3.5 m in 24 hr;
- The **C/L ratio** determines the scale of the benefit

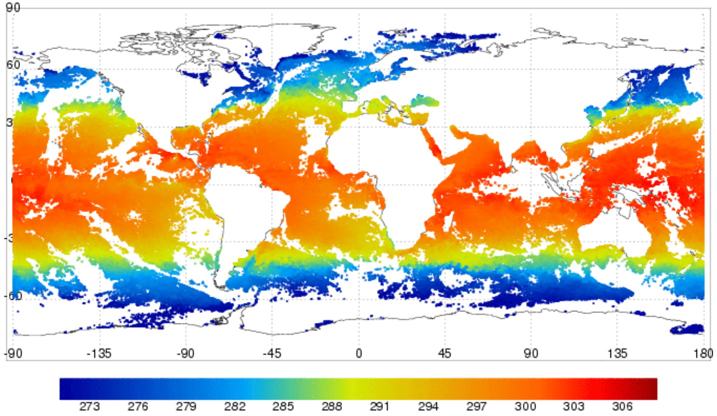


Coupled ocean atmosphere

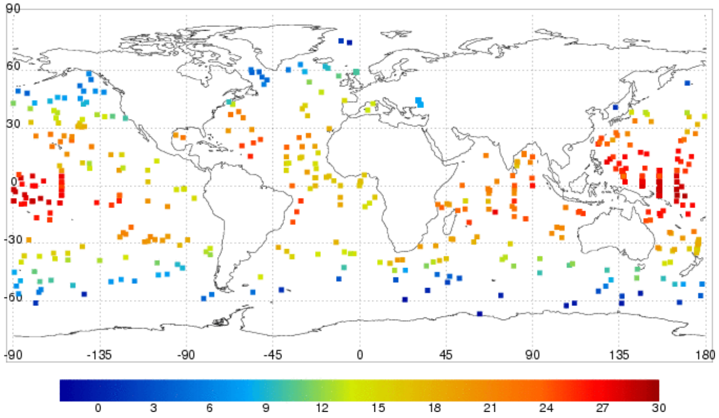
Observations assimilated into coupled atmosphere-ocean system

Ocean

- T/S profiles
- SST
- SLA
- Sea-ice concentration



Satellite SST data for 1-day (NOAA/AVHRR, MetOp/AVHRR)



Temperature profiles at 100m depth for 1-day (Argo, moored buoys, XBTs, CTDs, marine mammals, gliders)

Atmosphere

- Temperature, wind, humidity and radiances from AIRS, IASI, ATOVS, GPSRO, SSMI, aircraft, radio-sondes, Surf-Scat
- Already well-constrained

Seasonal Prediction

A ‘breakthrough’ in long range forecasting

THE TIMES

Super Fruit & Veg Guide

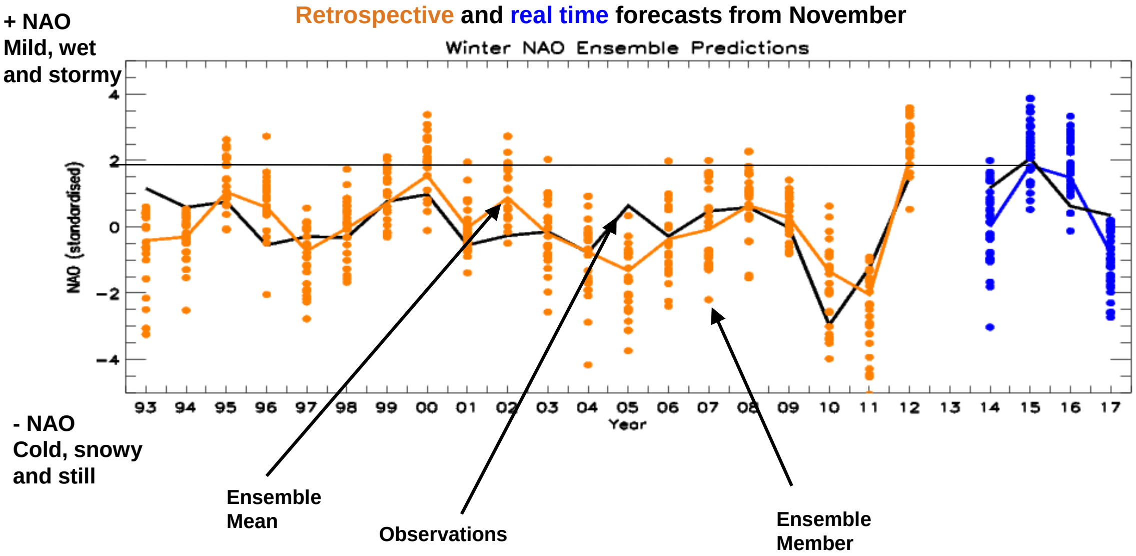
Are you getting enough?

I'd like a fifth child
What Jools Oliver did next

Tighter visa curbs drive away foreign students

Forecasters crack formula to predict long-range weather

Greater accuracy will boost health and economy



Our original tests are shown in orange and indicate a correlation skill of 62%

More ensemble members => more skill and ~0.8 may be possible

So far so good with real time forecasts...

Prof Adam Scaife

Head Seasonal 2 Decadal

Seasonal predictability: hydrology

Comparing predictability from a seasonal forecasting system and persistence

Application of seasonal forecasts is now feasible

Hydrology is an obvious example

skilful winter river flow predictions

UK winter river flows

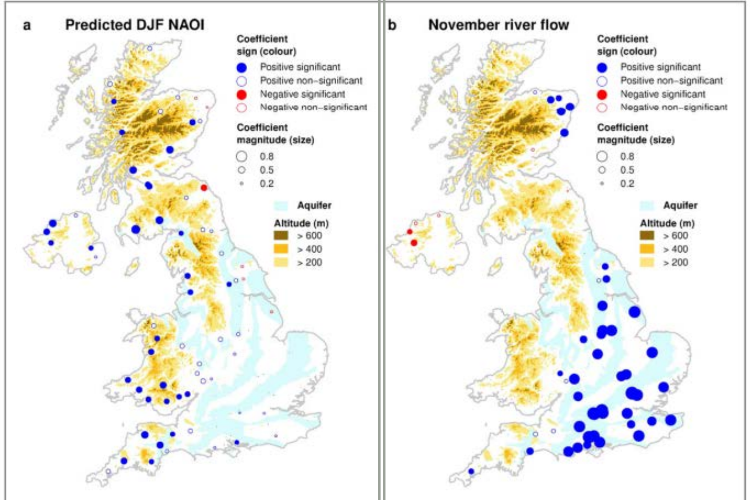


Figure 2. Sources of predictability of winter river flows as reflected by the coefficients for a regression model of winter river flow on either or both of two predictors: long-range forecasts of atmospheric circulation over the North Atlantic as characterized by the NAO index (a), and observed monthly mean river flow for November (b). The aquifer outcrop areas (light blue shading) show where groundwater makes an important contribution to river flows.

Correlations (predictability) from DJF seasonal prediction of NAO

Correlations (predictability) from Nov river flows

Svensson et al ERL 2015

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Coupled Numerical Weather Prediction (NWP)

2010 hypothesis: Coupling may provide benefits to Weather

- Short-range deterministic NWP global forecasting
  - Extra-tropical cyclones
- Short-range deterministic high resolution NWP forecasting
  - Sea fog and showers
  - Sea breezes
- Surge modelling (not really NWP but …)
- Ensemble prediction systems
  - Increase perturbations by using coupled ensemble members

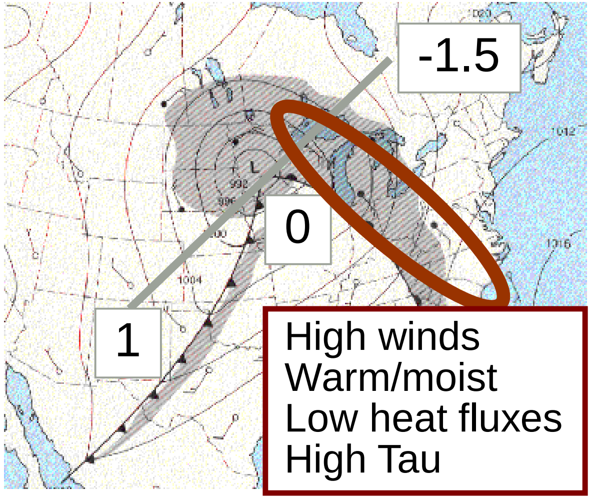
Coupled forecasting systems

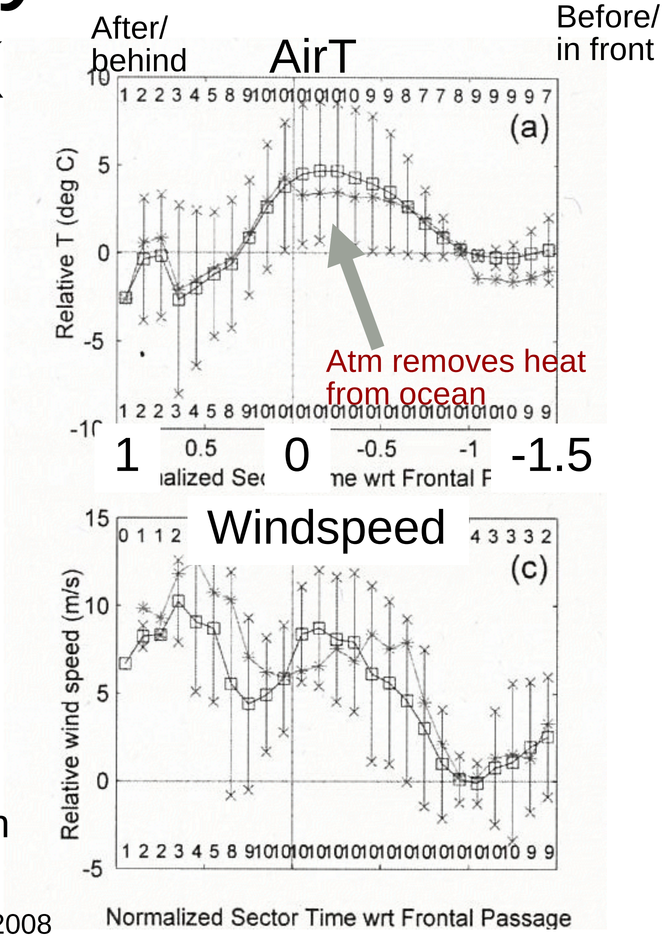
- Global NWP - moving from Research 2 Operations
  - Already have coupled **climate/seasonal systems**; new science but well-developed infrastructure
  - Weakly coupled **data assimilation**
  - Science/cost case accepted for **transition to operations**
  - Met Office deterministic/ensembles global **weather forecasting** **10**/20 km atmos coupled to 0.25^{o} Ocean by **March 2019**
  - Increased resolution deterministic ocean (~10 km) by **March 2020**
- Regional Environmental Prediction
  - Developing **coupled infrastructure** has been significant effort
  - Forecast experiments now producing **interesting science**
  - Aspirations broader than global (**impacts** and **weather**)
  - Not yet in R2O pathway; 3 – 5 years behind global

Tropical Cyclone Case Study

Demonstrating ocean benefits upon weather prediction

Mid-latitude cyclones - a naïve look

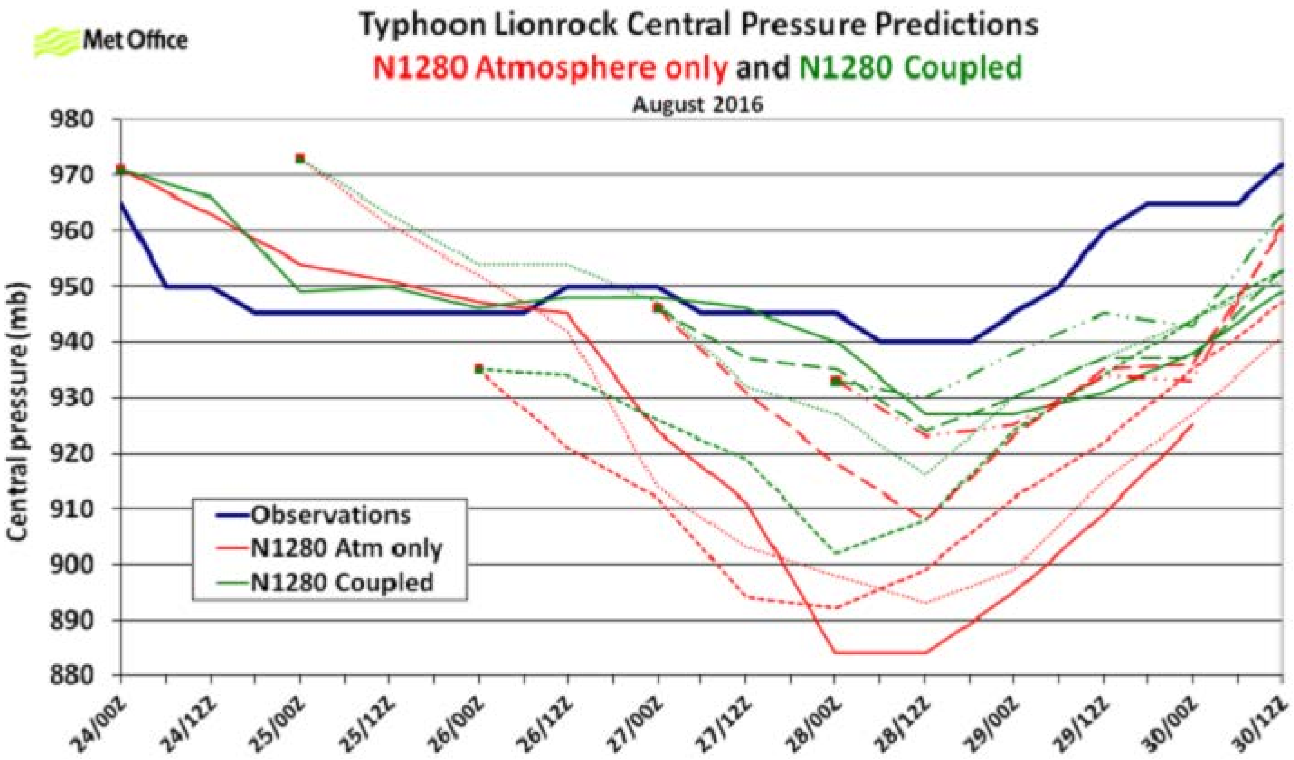




- Non-interactive SST is expected to keep an “unlimited” source of heat to cyclone and thus overestimate storm intensity
- Recent generations of high resolution NWP systems over-deepen lows

From Persson 2008

A severe over-deepening case



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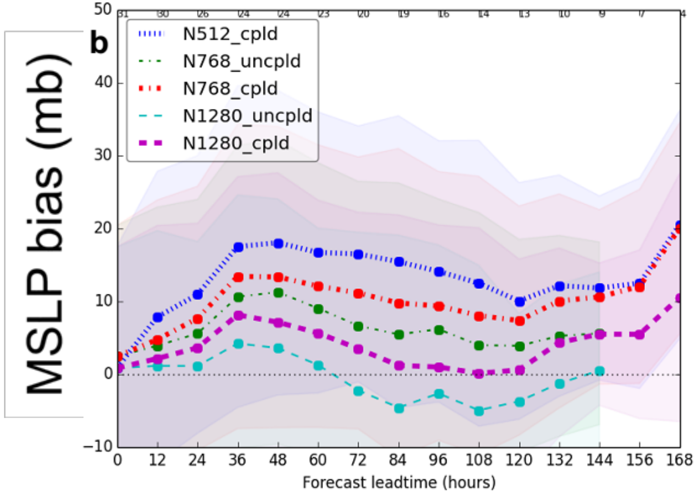
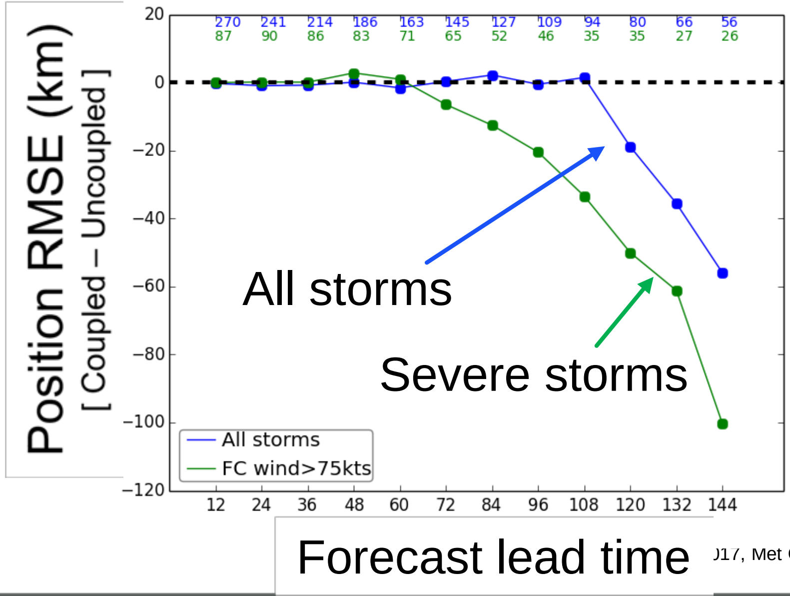
Tropical Storm forecast performance

Coupled vs Uncoupled at 10,17 and 35 km atm resolutions



31 Storm cases. Forecast errors were calculated for position, wind speed and MSLP of the storm core



- N1280 UNCPLD suffers from over-deepening from T+72
- virtually eliminated between T+84 and T+120 through interactive coupling
- Still missing processes – waves?

Michael Vellinga et al

Case study conclusions

- At lead times ≤ T+60 tropical storm track error are the same
  - Atm resolution is more important than coupling
- At lead times ≥T+60 interactive air-sea coupling reduces the track error for a given resolution.
- AND coupling is more important than resolution (for N768/17km vs. N1280/10km)

Environmental Prediction

Demonstrating ocean benefits upon weather and prediction

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Environment Agency's Flood Incident Management Investment Review (FIM IR)

- Three (baseline, improved, enhanced) 10 yr investment scenarios in Weather prediction
- "Enhanced" scenario made up of 4 areas:
  - **Risk-based, local UK forecasts**
  - **Research demonstration projects**
  - **Nowcasts**
  - **Impact forecasts -** Coupling traditional weather forecasting models with river-flow and ocean surge/wave models will allow new operational hazard impact services to be developed.
- Uses an estimate of the ***Average Annual Damage (AAD)*** due to fluvial and coastal flooding (forecast by NWP and surge/wave models)
- Assessment provides financial benefits **directly (below)** and indirectly (much larger) as a result of investment in Flood Forecasting

England, Wales & Scotland					
	2015/16	2016/17	2017/18	2018/19	2019/20
'Improved' flood forecasts/warnings	$30 Mill	$60 Mill	$90 Mill	$130 Mill	$160 Mill
'Enhanced' flood forecasts/warnings	$80 Mill	$160 Mill	$260 Mill	$360 Mill	$450 Mill

UK Environmental prediction

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

PML | Plymouth Marine Laboratory

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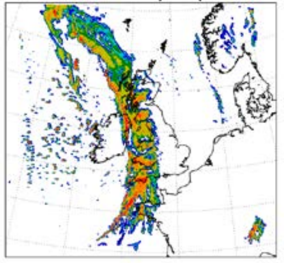
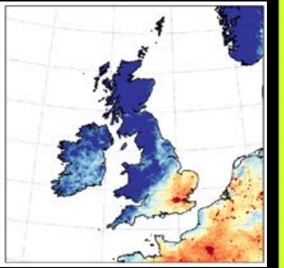
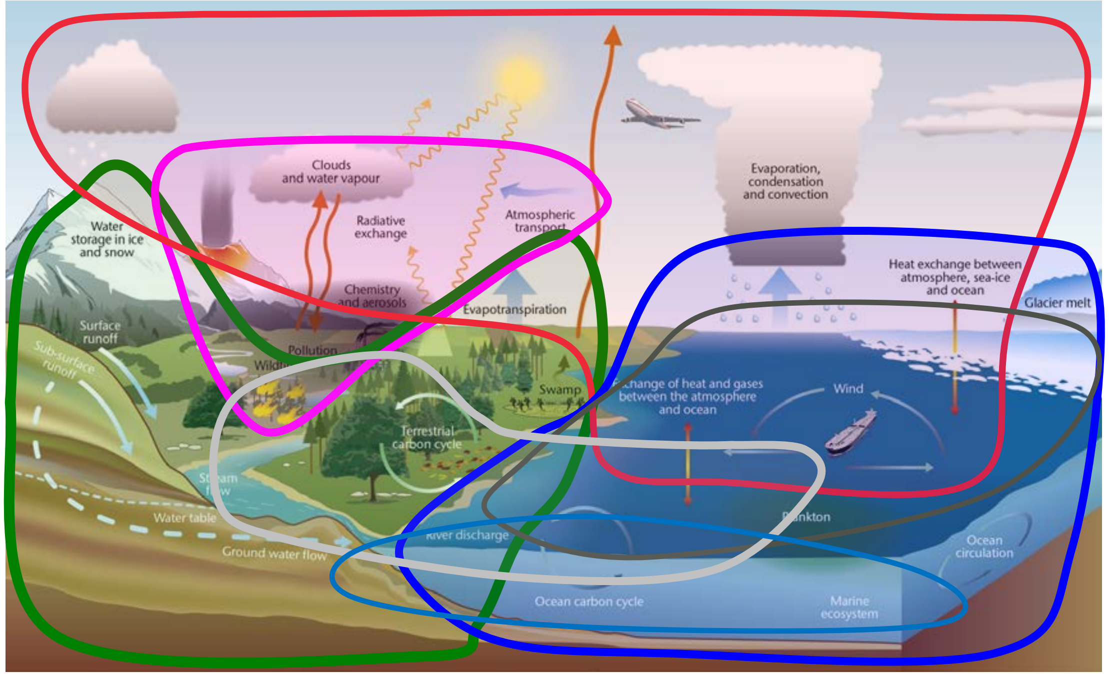
'[...] develop the first coupled high resolution [...]atmosphere-marine-land surface-composition-ecosystem prediction system for the UK at 1km scale'

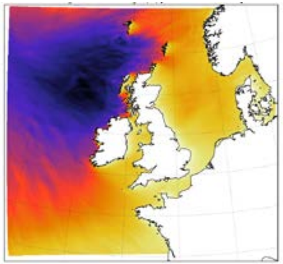
COMPOSITION
ATMOSPHERE



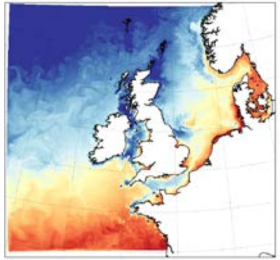
LAND SURFACE







WAVES



OCEAN
BIOGEOCHEMISTRY

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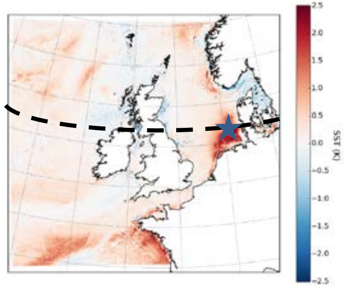
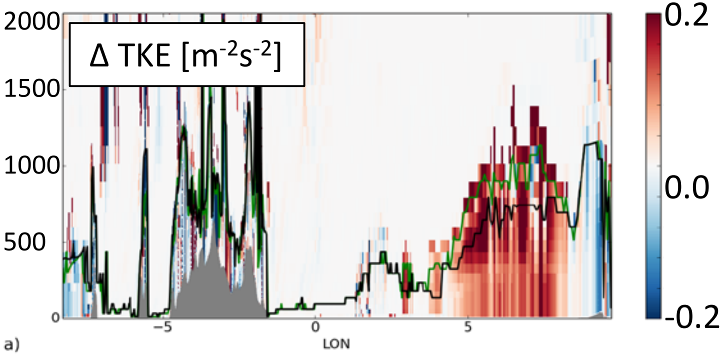
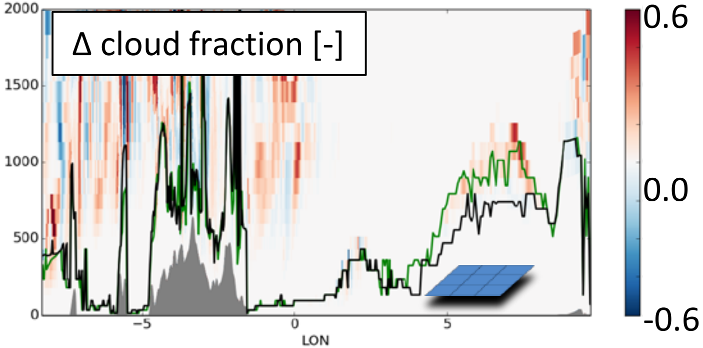
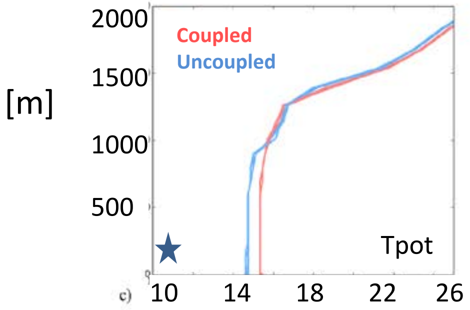
Air-sea interaction – an interactive diurnal cycle

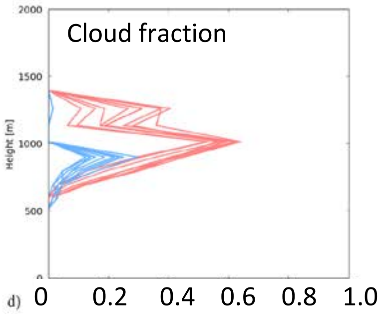
- Atmospheric boundary layer characteristics through cross sections and vertical profiles
- SST to cloud, boundary layer coupling

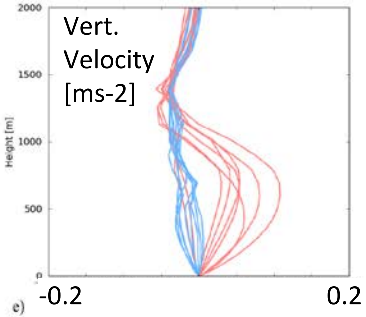










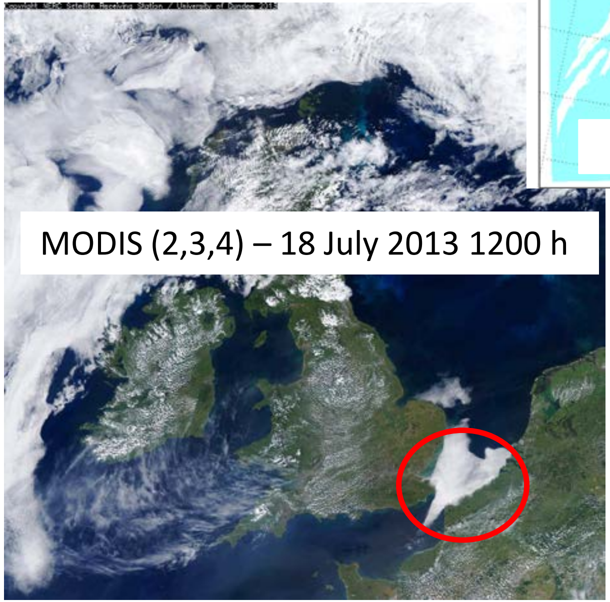


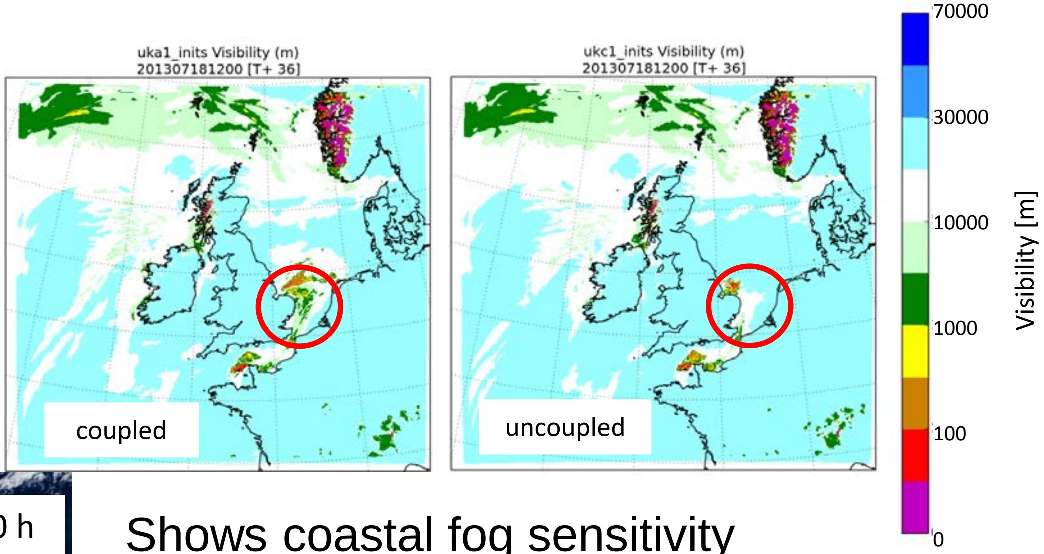
Joachim Fallmann

Coastal fog and ocean-atmosphere coupling

36 h forecast 1.5 km models
Coupled ocean-atmosphere (EP)
vs
forced atmosphere (UK NWP)

http://www.sat.dundee.ac.uk





Shows coastal fog sensitivity

But still need:

- More case studies
- Improved experimental design
- Coupled initialisation

Joachim Fallmann

To conclude

Conclusions

- Ocean observations have a direct impact upon the marine economy through **ocean forecast services**
- Ocean observations/modelling are well-established as impactful in understanding and prediction **future climate**
- Ocean observations/coupled modelling are increasingly demonstrating value for decision making (on land and sea) at **monthly to seasonal timescales**
- Ocean observations/coupled modelling are increasingly becoming a source of value for **weather and impacts services**

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Thank you