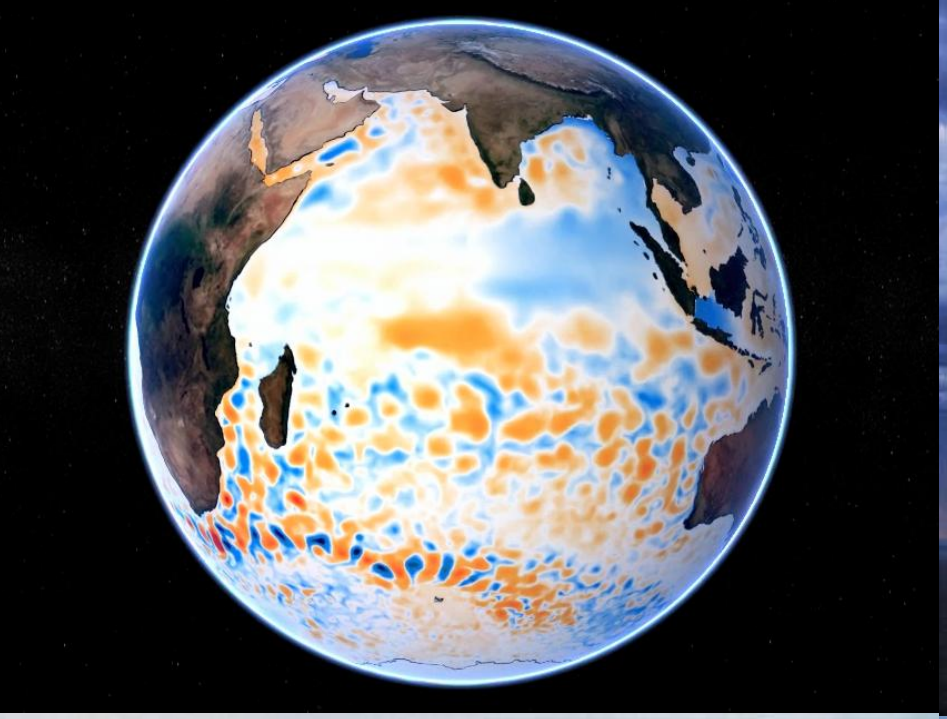


Short- to medium-range coupled prediction
GODAE OceanView Symposium

3-5 November 2013

Baltimore, USA

Co-chairs Gary Brassington, Matt Martin, Hendrik Tolman

Outline

TT-SMRCP status, activities and outcomes

UK Met Office R&D – Matt Martin

Environment Canada, CONCEPTS – Greg Smith

SMRCP goal

Promote research and development in coupled prediction systems as a strategy to improve deficiencies in forecasting of the ocean/wave/sea-ice…

SMRCP goal

Promote research and development in coupled prediction systems as a strategy to improve deficiencies in forecasting of the ocean/wave/sea-ice…and collaborate for complementary research and development within the numerical weather prediction community.

Motivations

- Deficiencies arise in:
  - Prescribed or bulk air-sea fluxes
  - Sub-grid scale turbulence

- Current status
  - bias correction, (NRL implementing a routine 12 month calibration to every NWP upgrade)
  - No conservation constraints
  - Decoupled sub-gridscale turbulence parameterisations

Activities

- GOVST meetings
  - Formation members/objectives
  - Scientific exchange

- Joint GOV/WGNE workshop, 19-21 March 2013
  - Organisers – Bill Lapenta, Glenn White, Gary Brassington
  - Themes
    - Modelling – Eric Chassignet and Paul Sandery
    - Parameterisation – Baylor Fox-Kemper
    - DA – Craig Bishop and Matt Martin
    - Observations – Chris Fairall and Jim Cummings
  - Workshop presentations
  - Breakout discussion
  - Whitepapers – delayed completion

Status

- While Earth System Models have started to use finer eddy-resolving grids for climate projection (Bryan et al., 2010; Gent et al., 2012), they are **not yet used for short-medium range predictions.**
- With the advent of mature **operational ocean forecasting systems** in the last decade, (eg. HYCOM/NCODA, Mercator Ocean, FOAM, MFS, MOVE/MRI, BLUElink, ECCO, TOPAZ, RTOFS) and improved computational resources, it is **now technically possible to run regional/global coupled ocean-atmosphere short to medium range eddy resolving prediction systems**.
- To date most coupled prediction systems for short-medium range have been **regional applications**

- **Coupling is not new to NWP**, coupled atmosphere-land NWP was introduced in the mid nineties (Kalnay et al, 1998). Since then intra-seasonal/seasonal predictions of ENSO based on coupled ocean–atmosphere models are now operational.
- However, many of the ocean models used in these systems are **eddy permitting, not eddy resolving**. In regions of large mesoscale activity, this can lead to excessive smoothing of SST gradients and representation error of ocean forced atmospheric pressure perturbations, heat fluxes, convection, winds etc., particularly in dynamically rich regions (western boundary currents or along the sub-Antarctic front)

- **Ocean initialization** is important for **upper ocean heat content** (eg. Balmaseda and Anderson, 2009; Halliwell et al, 2007; Leipper and Volgenau, 1972) and **coupled mesoscale SST** for hurricane prediction (eg. Yablonski and Ginis, 2008, Bender et al, 2007, Falkovich et al, 2005) and climate downscaling (eg. Bryan et al. 2010, Minobe et al. 2008, Cione et al. 1993).
- **Wind-wave-current coupling** in dynamical models has been shown to be important for surface stress, vertical mixing and improved wave prediction (eg. Fan et al, 2009; Moon et al, 2007).
- Bryan et al. (2010) showed from CCSM downscaling experiments that **positive correlations between surface wind stress and SST are only realistically captured when the ocean component is eddy resolving**.

Impact of coupling

A growing range of impacts. Significant R&D to diagnose significance of coupling. Robust controlled experiments emerging.

-Tropics, MJO's
-High-latitude sea-ice interactions
-Hurricane/Tropical cyclones
-Extra tropical lows, East Coast Lows

Benefits from the discipline of the coupled physics – instant feedback and improved modelling to resolve flux errors

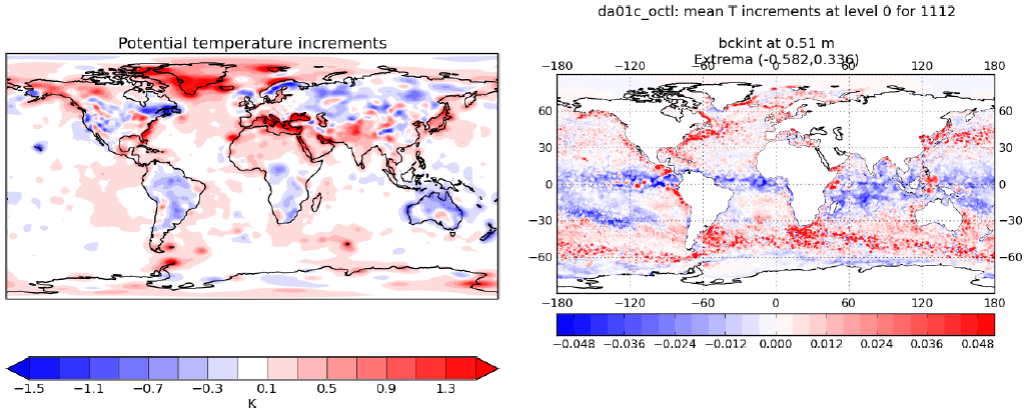
An active area for all groups

Coupled Ocean-Atmosphere-Wave Prediction (SMRCP-TT)

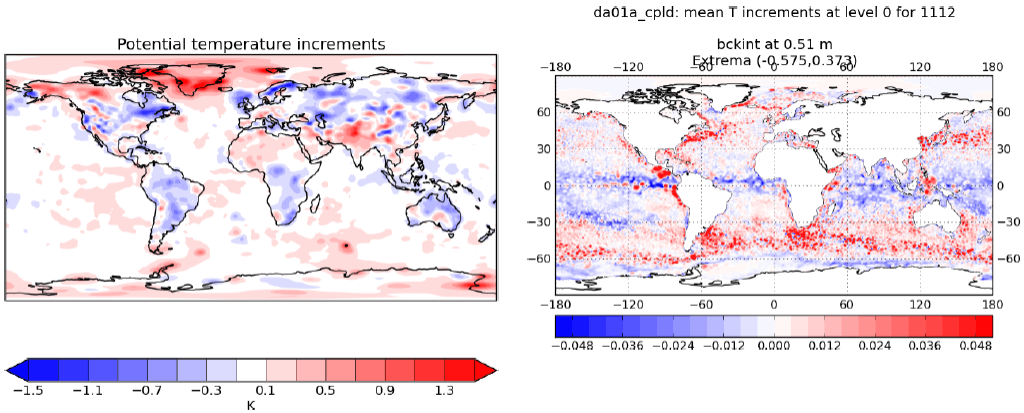
Challenge:
Improving initialisation with coupled data assimilation.

Monthly mean temperature increments for atmosphere (left) and ocean (right).

Coupled data assimilation run has smaller average increments implying improved balance between ocean & atmos.



Control run

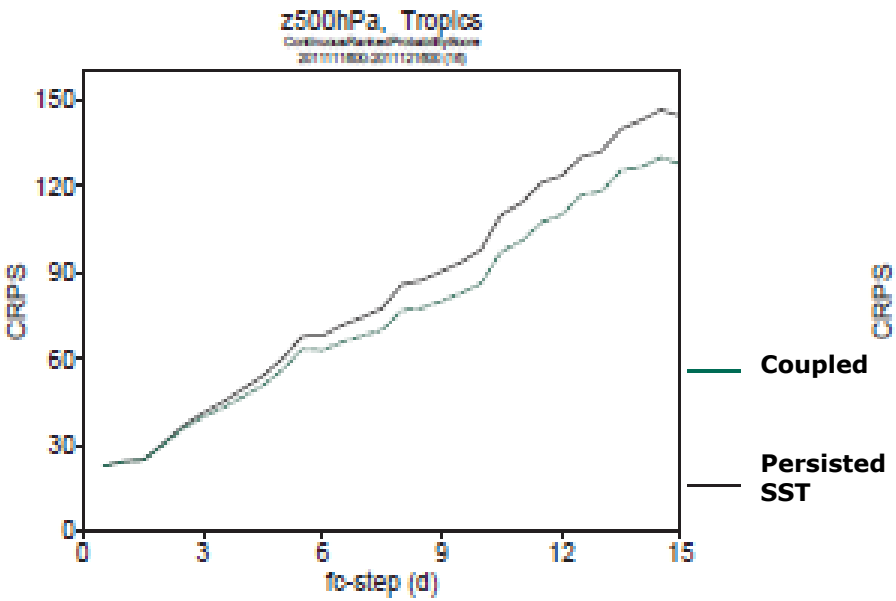


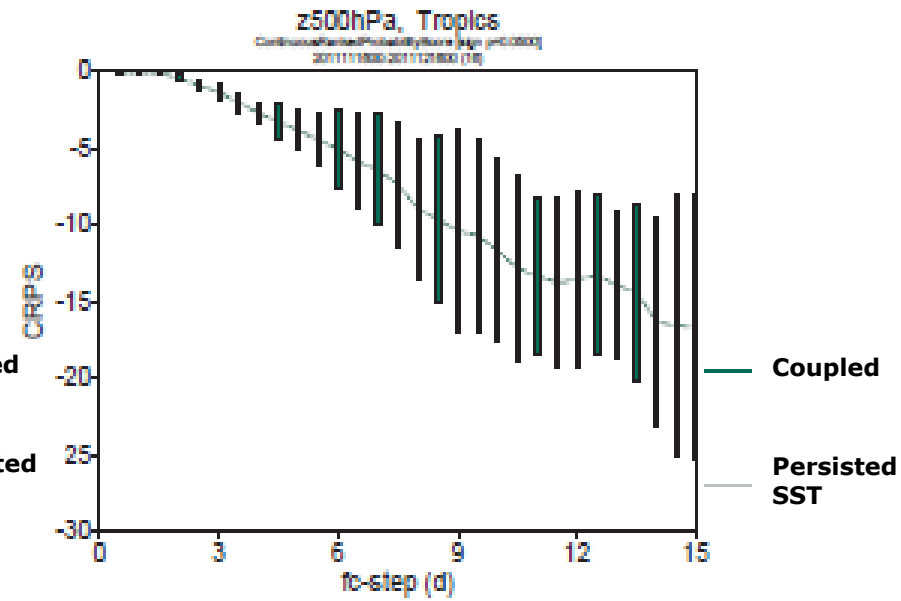
Coupled run

ECMWF - Impact of Coupling in Medium Range Forecasts

CRPS **Coupled-Persisted CRPS**

smaller CRPS is better skill. Bars indicate significance





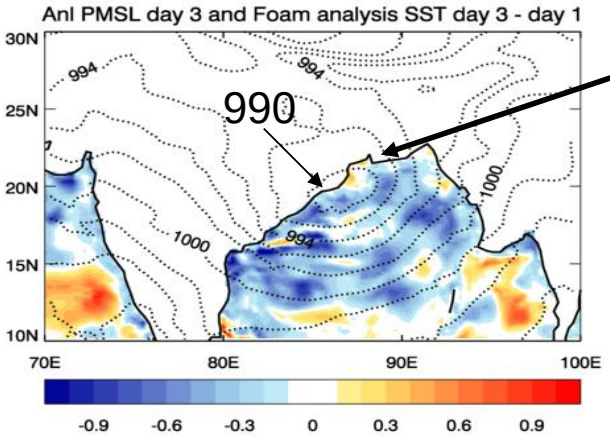
Impact of coupling is positive and robust in tropics (shown) and extratropics (not shown).

CRPS – Continuous Rank Probability Score

Core

Synoptic Case Study:
Bay Of Bengal Tropical Monsoon depression
August 2008 – Day 3 Forecasts

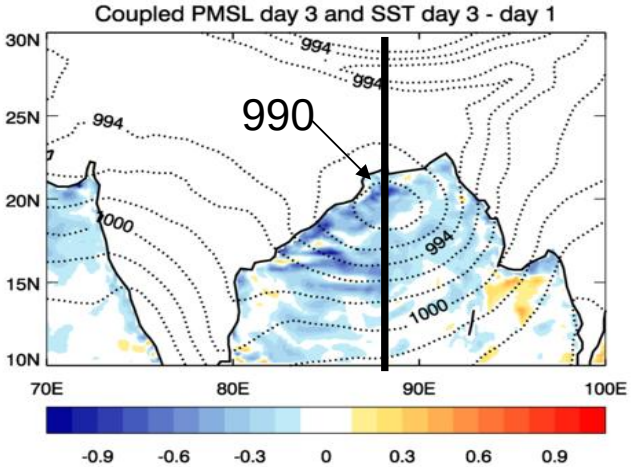
Analysis

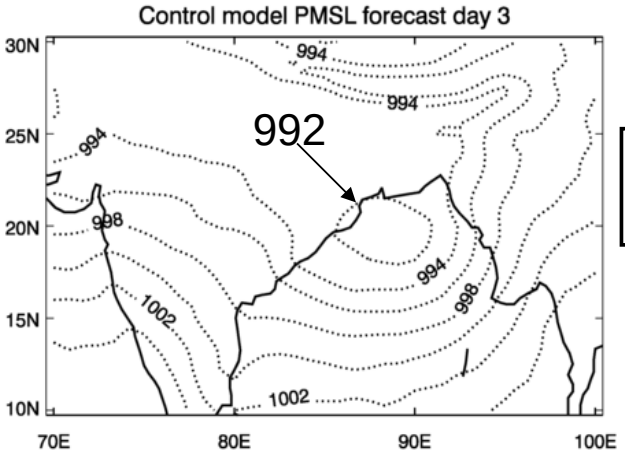


Central pressure (<990hPa) captured by day 3 in coupled model forecast but atmosphere control has shallower depression.

Additional skill comes from interactive ocean – see cooling in BoB in evolution of the SST (day 3-day 1: colour shading)

Coupled Model





Atmos Control

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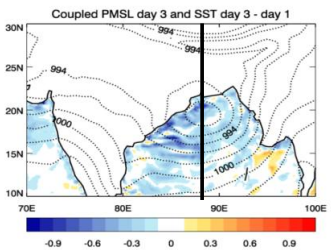
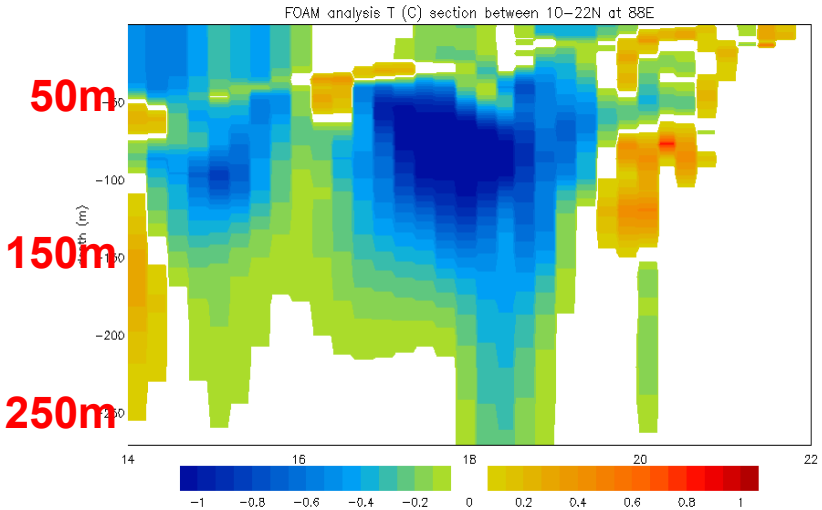
Core

Synoptic Case Study:
Bay Of Bengal Tropical Monsoon depression
Ocean Temperature section along 88E

FOAM analysis

Day 3 minus day 1 sub surface temperature at 88E

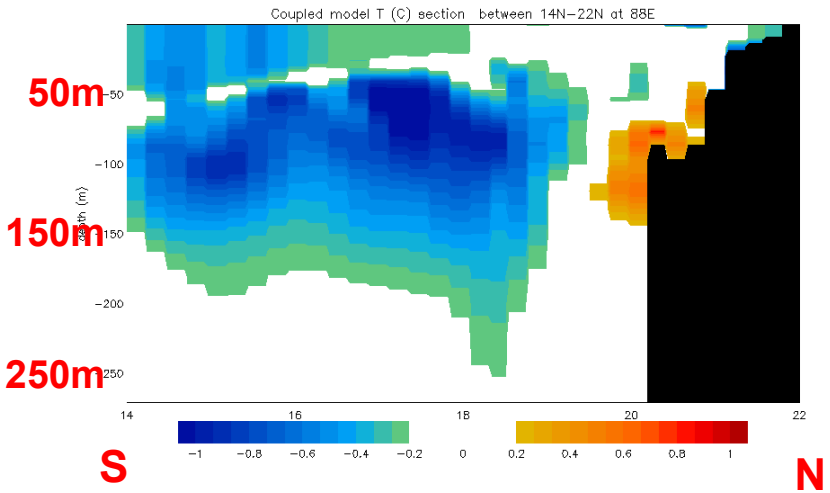




Coupled model

Day 3 minus day 1 sub-surface temperature at 88E

Shows skill in capturing mixed layer temperature evolution out to day 3.



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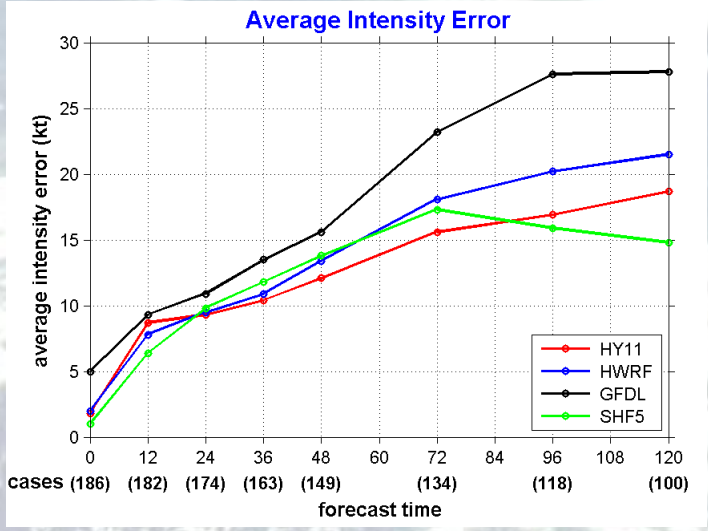
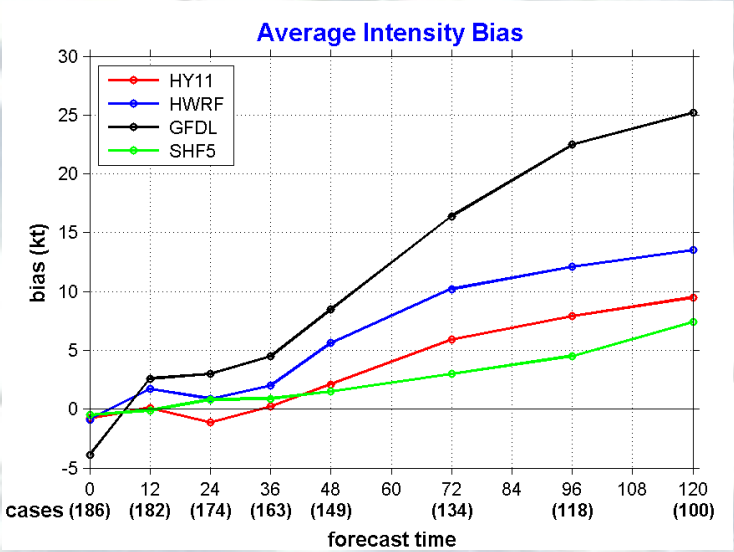
Example of results from parallel pre-operational coupled hurricane runs using HWRF-HYCOM

- Operations is HWRF-POM.
- Implementation driven by HR amongst others

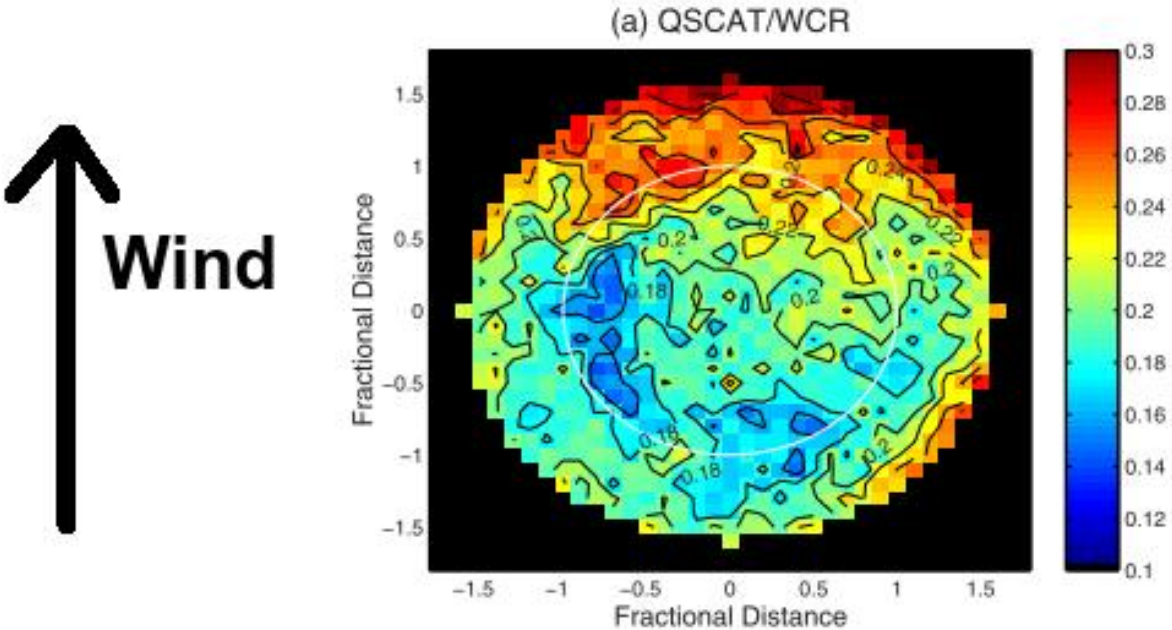
Intensity Forecast for 6 TCs (186 cases): Gert07L, Irene09L, Katia12L, Maria14L, Ophelia16L, and Philippe17L

HY11=HyHWRF2011; HWRF=operational HWRF





Effect of SST gradients on cloudiness, rainfall and thunderstorms

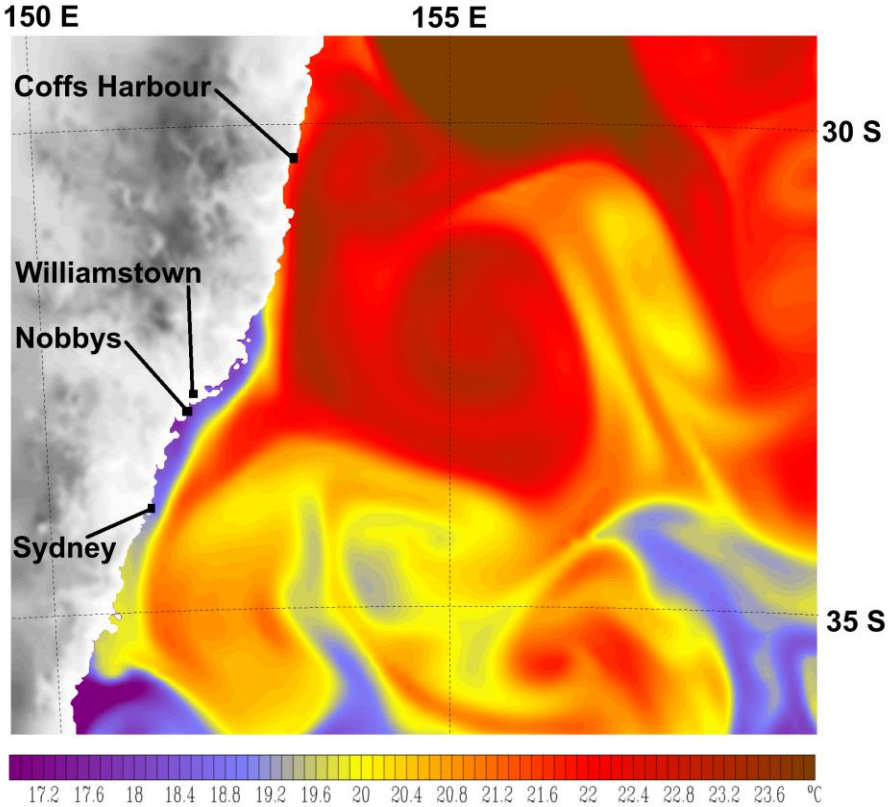


Cloudiness over Gulf Stream rings from an average of 403 warm-core rings (Park et al 2006)

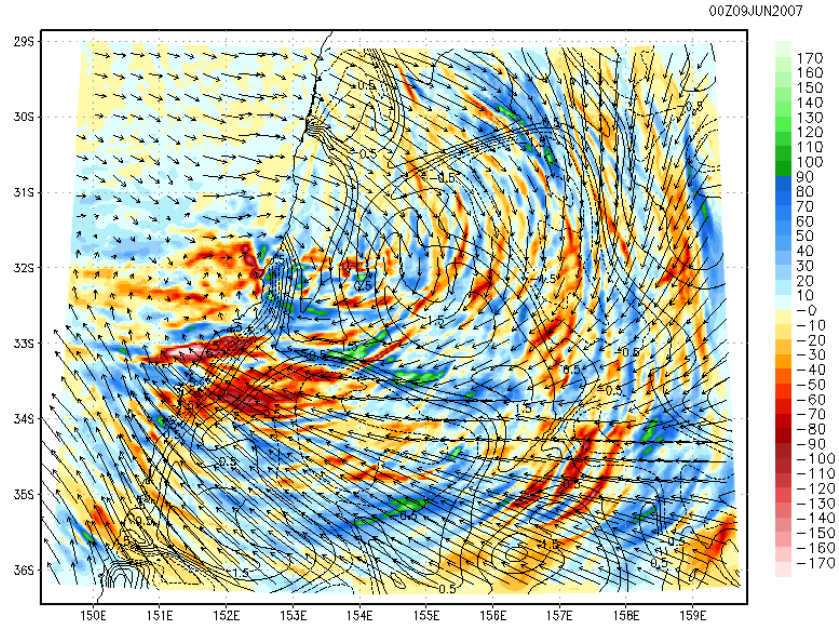
Cloudiness increases downwind of warm eddy rings.

Precipitation Changes Due to Eddy-Resolved SST's in simulations of East Coast Lows

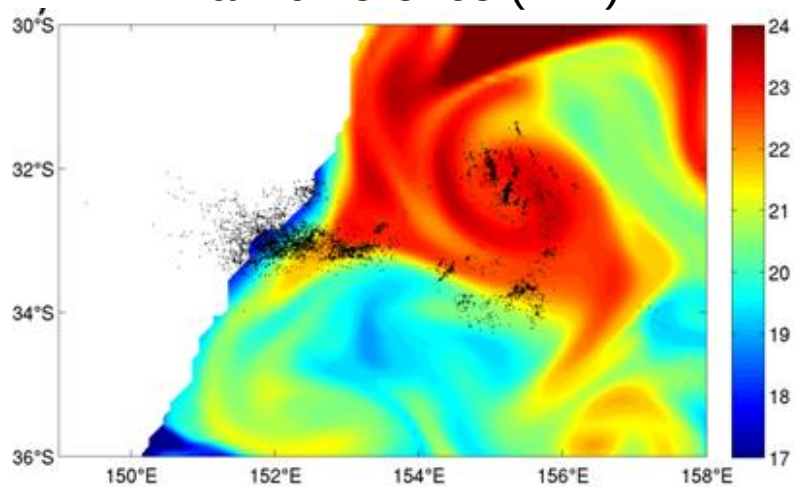
Chambers, Brassington, Walsh and Simmonds



BRAN SST



Rain difference (mm)



12 hourly GPATS lightning strike locations

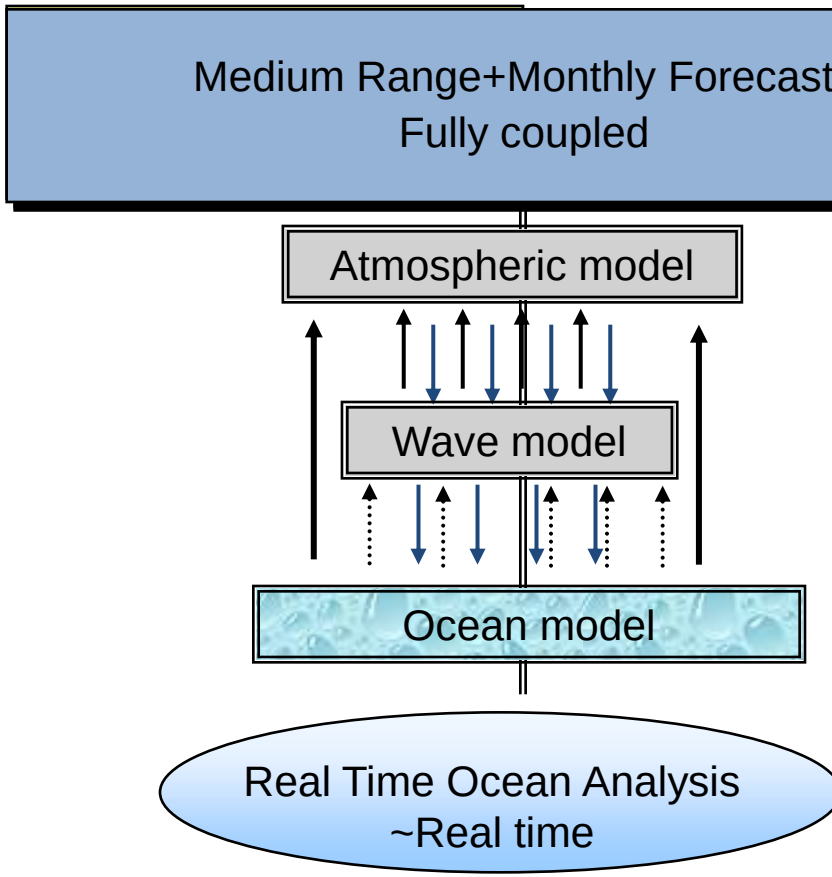
Downwind SST gradients induce enhanced CAPE leading to enhanced localised precipitation as observed by lightning data and rain gauge totals

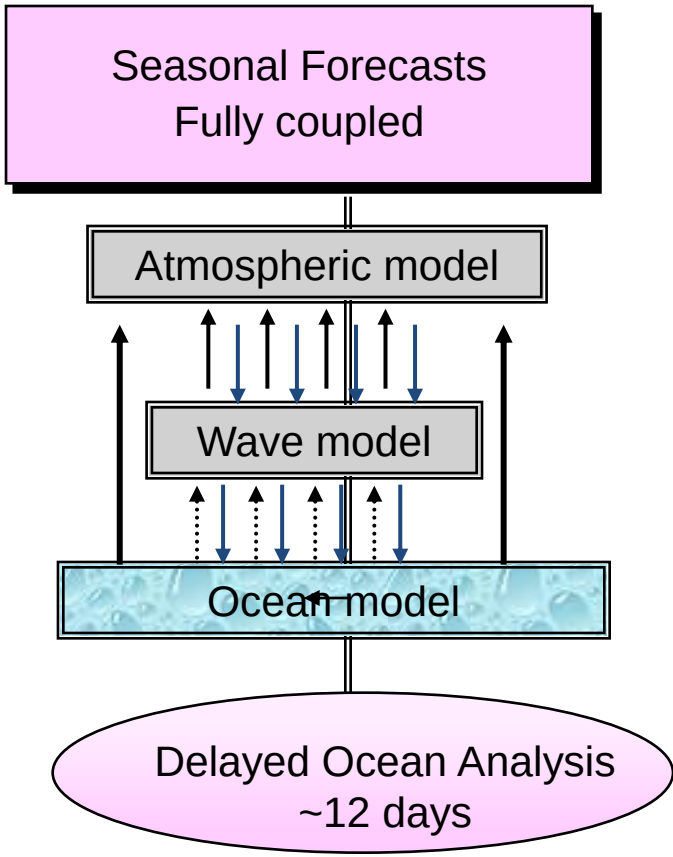
Progress

Many groups have committed to research and development to implement coupled prediction systems

ECMWF – Long standing R&D program, medium-range will move to full coupled system
NRL – COAMPS systems and committing to ESPC based on 1/12 HYCOM, 2018
UKMet – Strategic R&D program
NOAA – Coupled Hurricane forecasting R&D and wave-coupling
Environment Canada – CONCEPTS, sea-ice and weather forecasting
CAWCR – Regional coupled model (CLAM)

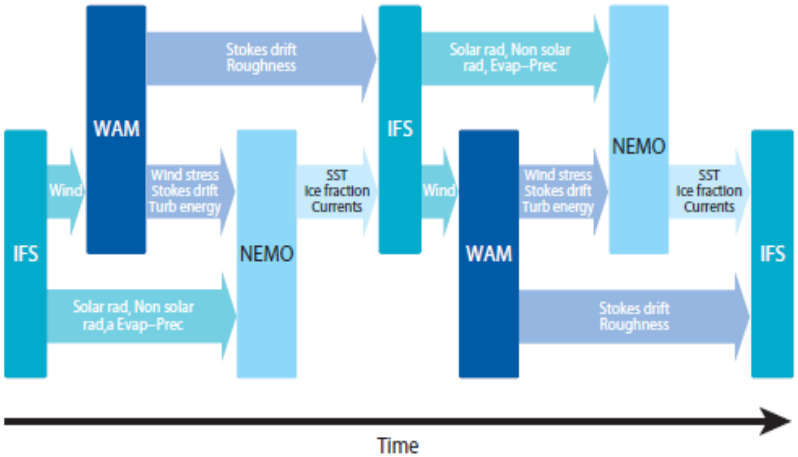
ECMWF:
Seamless Forecasting System





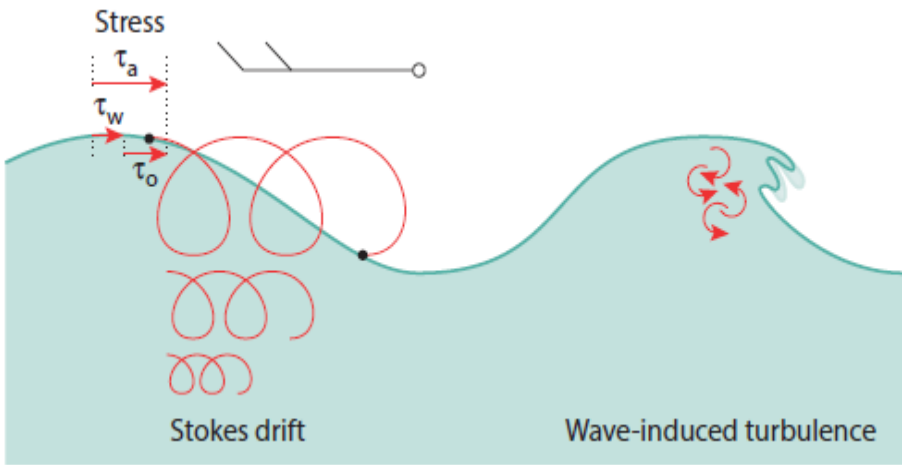
ECMWF - Recent Developments

1) Single Executable



Single executable time step

2) Coupling WAM to NEMO

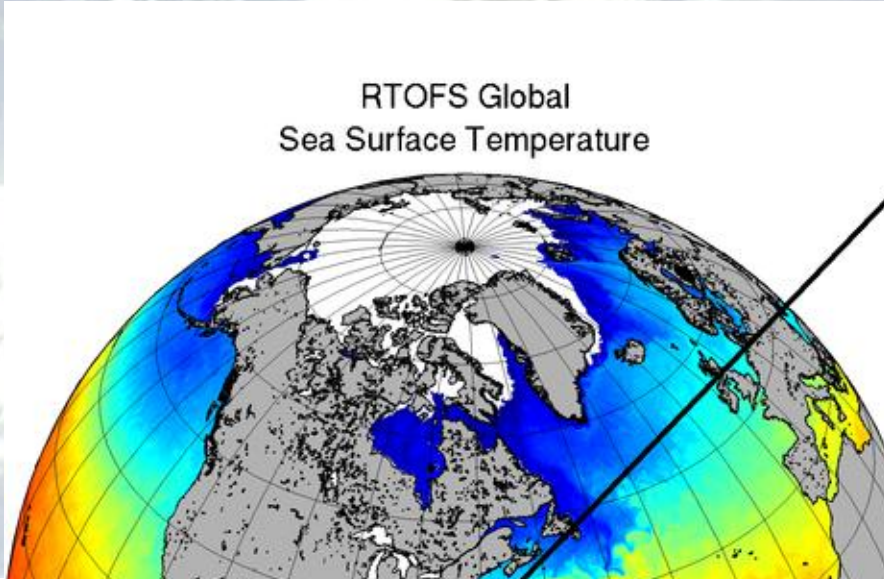


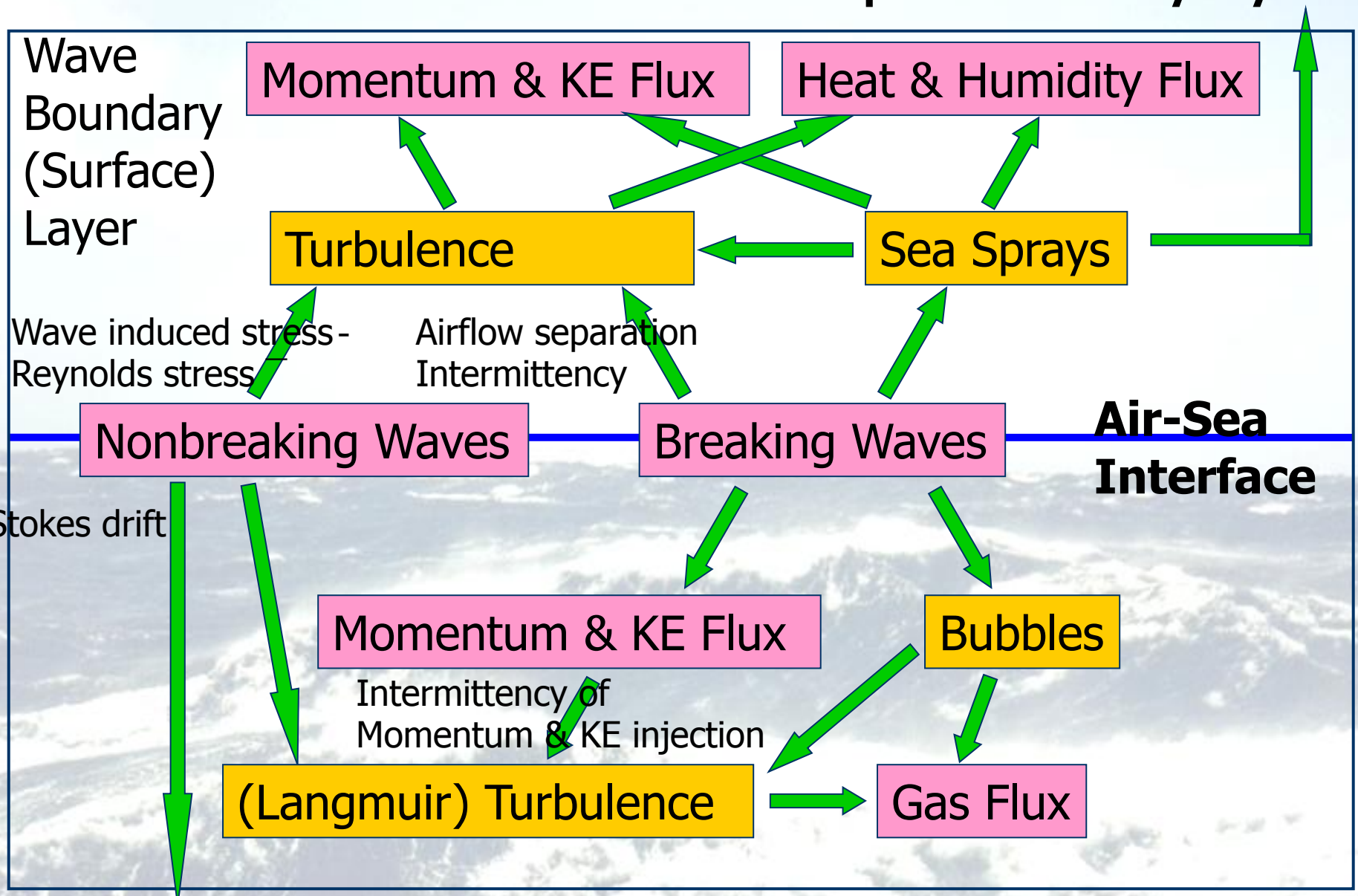
Coupling from Day0

Ocean Wave Ice interactions from many publications.

- Wave-current interactions in Gulf Stream and wave-driven circulation.
- Effects of waves (Langmuir / Stokes circulation) on upper ocean mixing and mixed layer physics.
- A good weather time scale ice model is essential for a good coupled ocean atmosphere model.
- Effects of waves on air-sea fluxes …

- Service req. for the Arctic
- Possible NOPP project
  - HYCOM
  - WAVEWATCH III
  - Ice …





Courtesy Isaac Ginis

Recommendations / Challenges

Many….

Summary: ideas/questions for future coupled ocean-atmosphere EnKF

- Toy model: coupled assimilation and short windows are more accurate for LETKF even if ocean has longer time scales.
- Running in Place (RIP) extracts more information from the observations and allows the use of shorter windows.
- A new hybrid LETKF+simple 3D-Var would make the system more robust with fewer ensemble members and observations.
- For the coupled (India Monsoon Mission) CFS system, we will test the use of 6hr (short) windows for the ocean as well as the atmosphere assimilation.
- Assimilate SST and SSH observations directly.
- Localization of observations near the surface should allow for atm.-ocean interaction through the background error covariance

Summary & further works

Summary

- ⋆ Coupled ECMWF ReAnalysis (CERA) has been launched
  $\longrightarrow$ ocean observations can immediately affect the atmospheric analysis (and conversely)
- ⋆ Some milestones have already been successfully implemented

Further works

- ⋆ Start merging the milestones to produce the full CERA system
- ⋆ Develop proper metrics to assess the skill of coupled data assimilation

CONCLUSIONS

- For some time now there has been the expectation, based on physical considerations, that sea state effects could be relevant for upper ocean mixing and dynamics. This might be indeed the case.
- At ECMWF, we have developed an efficient tool to study these effects and first results are promising so that by the end of this year a coupled ensemble prediction system+monthly forecasting system, using sea state information from the WAM model, will be introduced operationally.
- Clearly, at the moment we are just at the beginning of a exciting new development. And still a lot of work needs to be done: higher resolution, sea-ice, weakly coupled data assimilation,....

Hyun-Sook Kim and Hendrik Tolman, NOAA/NCEP

Summary:

1. Overall, HYCOM provides better forecast skill in hurricane prediction than POM.
2. Details –
   A. Mesoscale dominant SST fields, e.g. eddies and fronts.
   B. SST cooling close to observations.
   C. Better upper layer responses to hurricane winds, e.g. inertial waves and upwelling.

Remarks:

The TC forecasting has gone through from non-coupled, coupled to 1-D ocean, and to 3-D ocean. What is presented is to provide an insight for next generation model, e.g., 3-way coupling with Wave model.

A take-home message is:
The TC forecasting should couple to eddy-resolving ocean model for better forecast skill.

Summary and Challenges

Status

- Evolving sea ice cover affects regional weather forecasts on very short timescales
  - Details matter!
- Arctic leads have a large impact on Global coupled forecast skill

Challenges

- Evaluating and improving the representation of leads
- Including wave-ice interactions
- Atmosphere-ice-ocean momentum transfer
- Constraining sea ice thickness
- Sea ice forecast verification
- Separation of coupled effects from differences due to IC

Conclusions - workshop

•Strong statement being requested for promoting the notion that the evidence is now overwhelming/compelling for coupled modelling for short- to medium-range forecasting
•A positive message for the advantage of the coupled framework for putting some spotlight into the air-sea interaction problem
•Communication/dialogue amongst a more diverse set of groups will be a challenge. BUT WE MUST DO THAT SMARTER, WITHOUT ADDING SIGNIFICANTLY TO THE GROWING SET OF MEETNGS.
•Coupled modelling will introduce additional requirements on the observing system both for air-sea parameterisation, systematic bias. Dialogue required to specify those requirements. Enhancements or new platforms.
•Do not reinvent the wheel for parameterisation. Much already exists that should translate to the coupled high res modelling.
•It was acknowledged that for various reasons it may or may not be advantageous to conserve interfacial fluxes in a coupled model. However it was also viewed that the coupled framework provided greater control and discipline over the decision for what to exchange.
•The latency and coverage for observations of the coupled boundary layers was identified as limiting progress. It was suggested that the requirements of observing the coupled boundary layer were unique and might give rise to different designs. The autonomous engineering community should be presented with the requirements to determine if a cost effective solution can be achieved.

Final remarks

Coupled prediction is being pursued by several centres with both ocean prediction and NWP capability (some with waves and sea-ice)

Research in coupled prediction for short to medium-range has clearly accelerated

GOV/WGNE workshop was timely and a great success

Critical to complete whitepapers to document the outcomes

GOV Symposium whitepaper will provide another deadline to push the whitepapers along

Keeping regular contact between the various communities and national activities is critical

Initiating a dialogue with the observational community require for progress

Outlook is for R&D in this area to continue throughout a GOV follow-on