Air Sea Interaction and Ocean Waves

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Outline

- ECMWF Earth System modelling: Coupled atmosphere-wave-ocean-sea-ice system.

-Impact of coupling on tropical cyclone predictions.

-Wave effect on exchange coefficients for momentum, heat and moisture.

Earth system modelling: Different aspects of coupling for ECMWF

Improving weather forecasts

- To improve the representation of relevant processes (tropical cyclones, improved winds, surface fluxes).

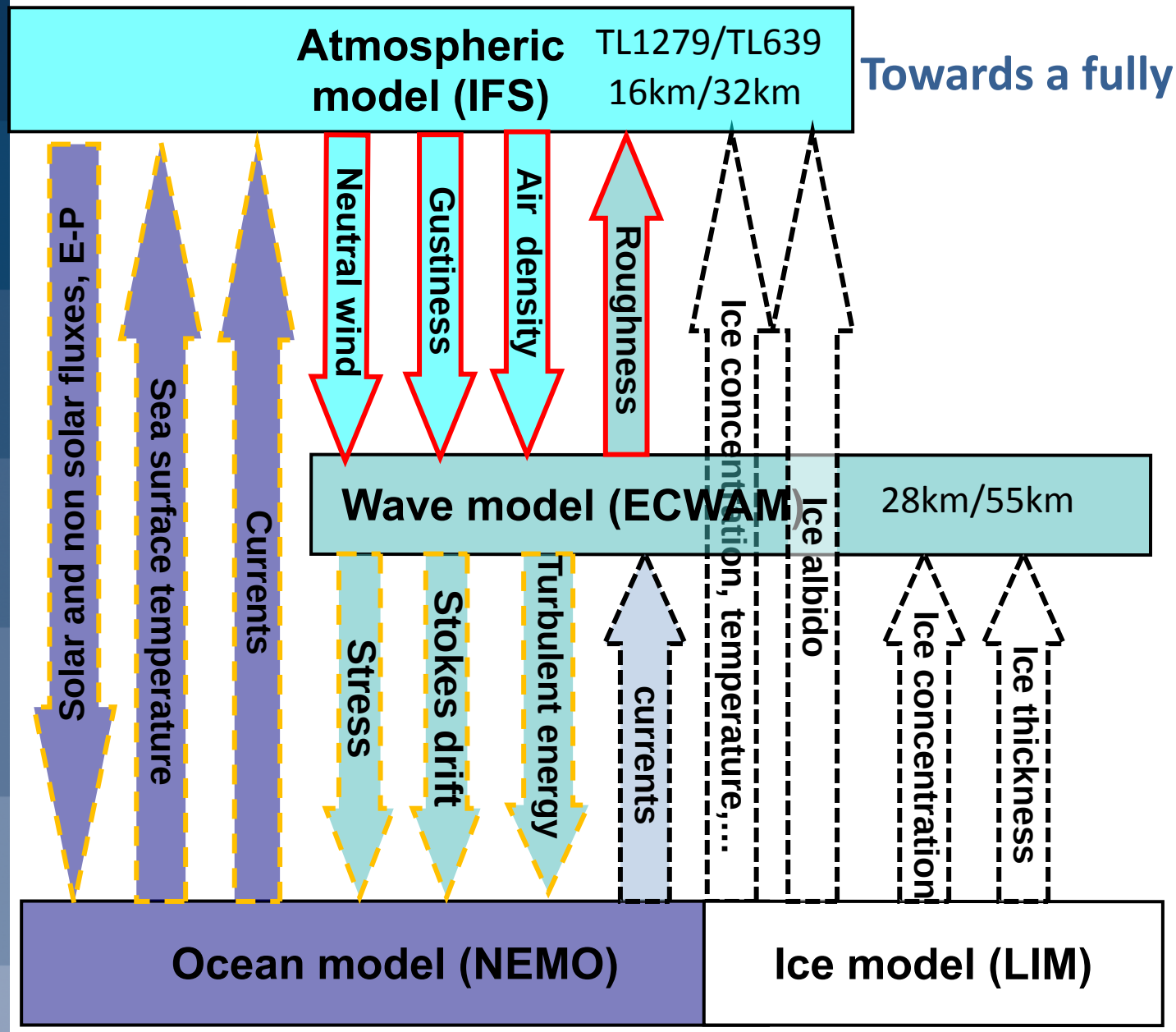
Extending the predictability horizon

- To Monthly-Seasonal and Decadal predictions.
- The focus is on the initialization of the slow component.

Consistent analysis/Reanalysis of the Earth System

- Better use of observations.
- More consistent initialization of coupled forecasts models.

Towards a fully coupled system



All configurations

Ensemble FC

future operational

Spring 2016:

TCo1279/TCo639

9km/18km

14km/28km

End 2016:

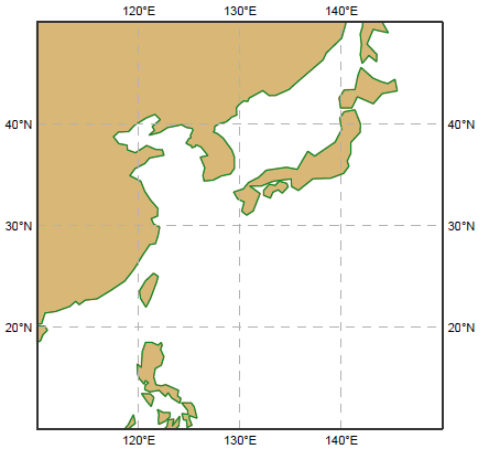
LIM

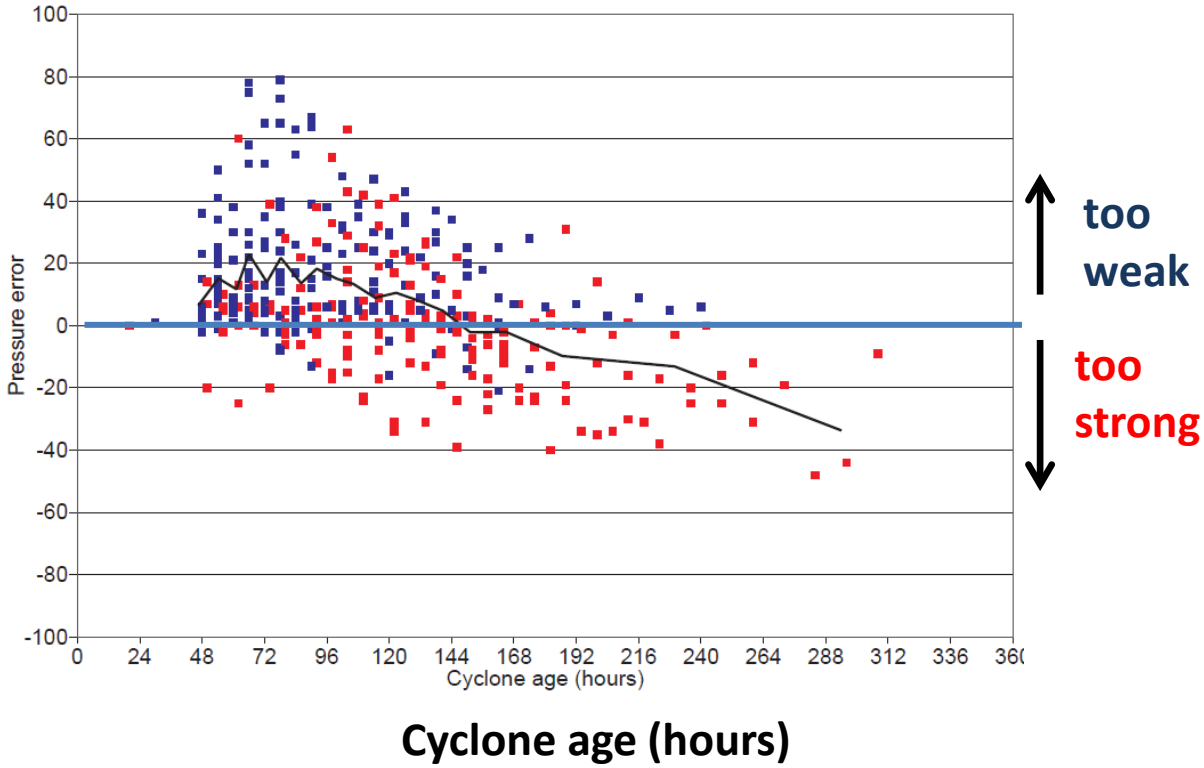
ORCA025_Z75

ORCA1_Z42

Impact of Coupling on tropical cyclone forecast

Tropical cyclone **core pressure mean error** in the western Pacific (hPa)
in the operational high resolution system (HRES)
Blue dots: south of 20°N
Red dots: north of 20°N





Cyclone age (hours)

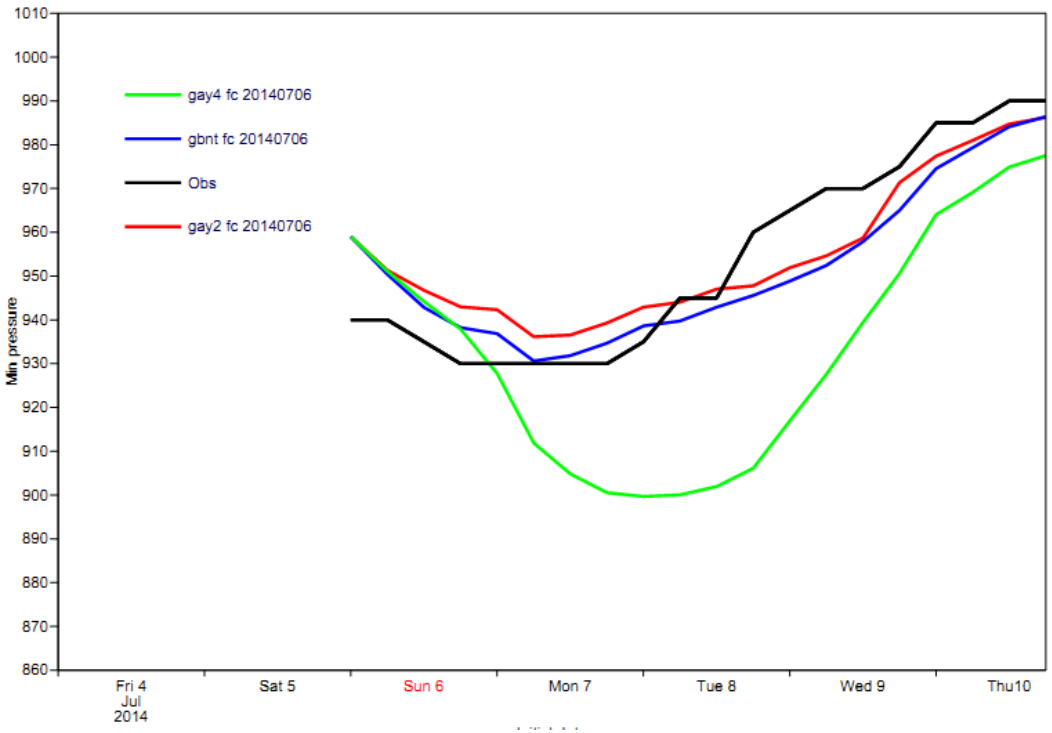
Impact of Coupling on tropical cyclone forecast

For instance Typhoon Neoguri: forecasts from 6 July 2014, 0 UTC

min
MSLP (hPa)

950

900



Black: estimated from observations

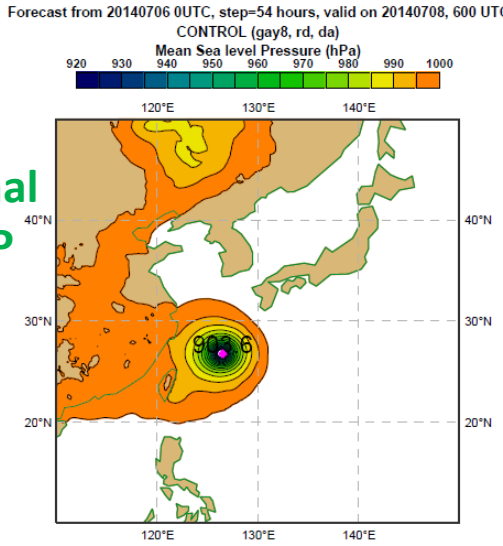
Green: operational HRES configuration (uncoupled) TL1279

Red: experimental: coupled to NEMO (ORCA025_Z75)

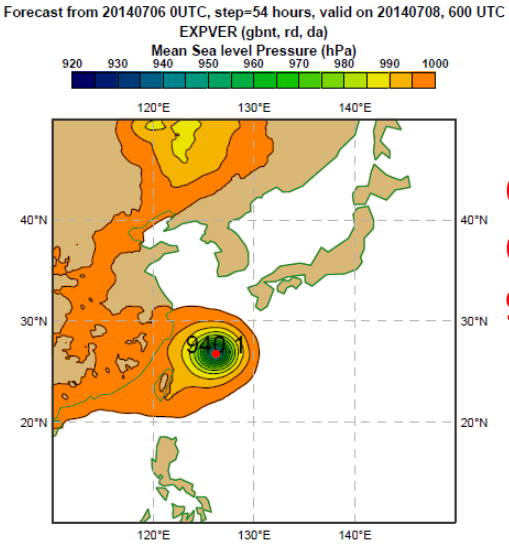
Blue: coupled to NEMO + new physics

Impact of Coupling on tropical cyclone forecast

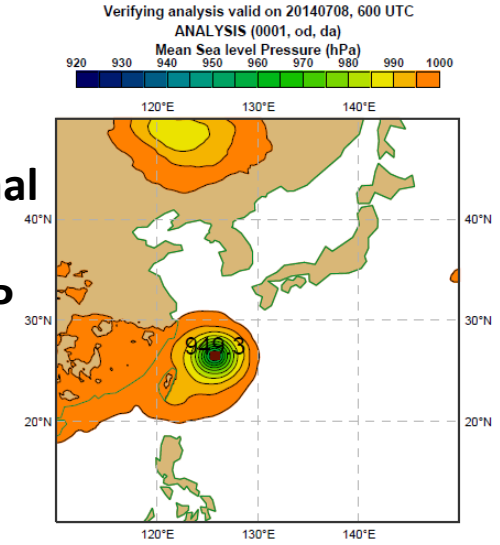
Operational Core MSLP 903.6 hPa



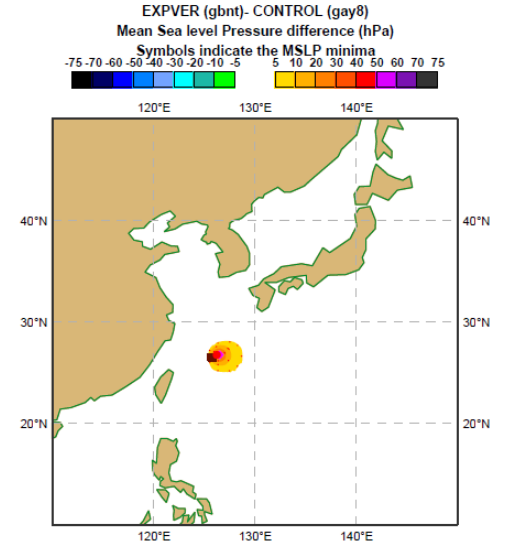
Coupled Core MSLP 940.1 hPa



Operational Analysis Core MSLP 949.3 hPa

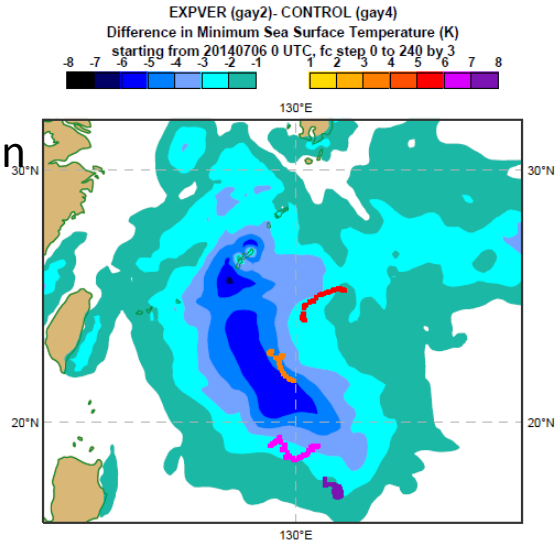


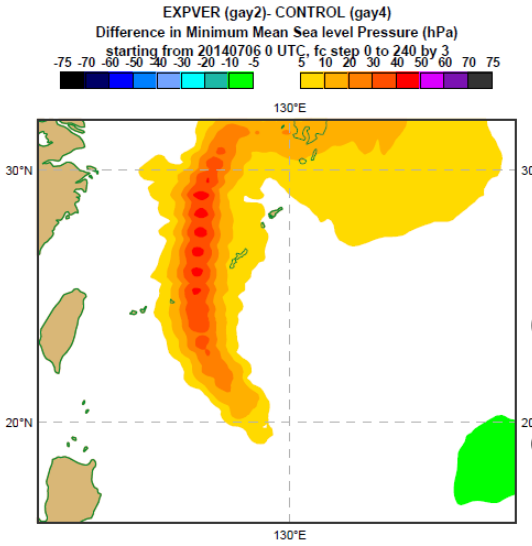
Coupled minus operational



Impact of Coupling on tropical cyclone forecast

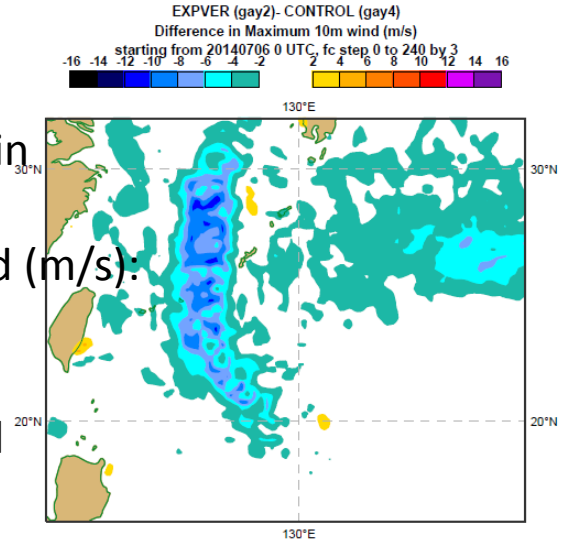
Difference in Minimum SST (K): Coupled minus operational

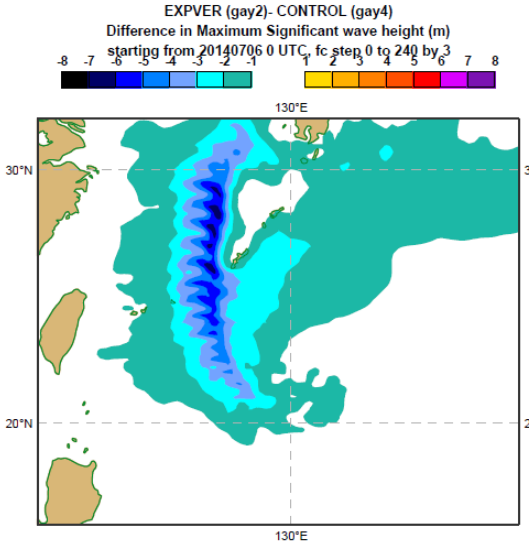




Difference in Minimum MSLP (hPa): Coupled minus operational

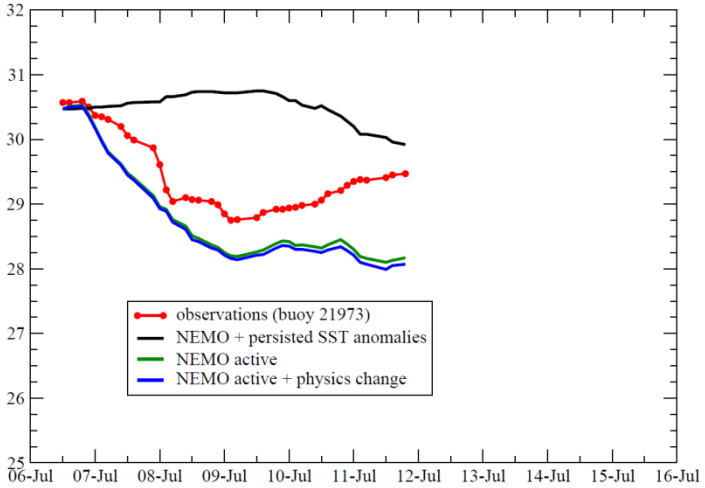
Difference in Maximum Wind speed (m/s): Coupled minus operational

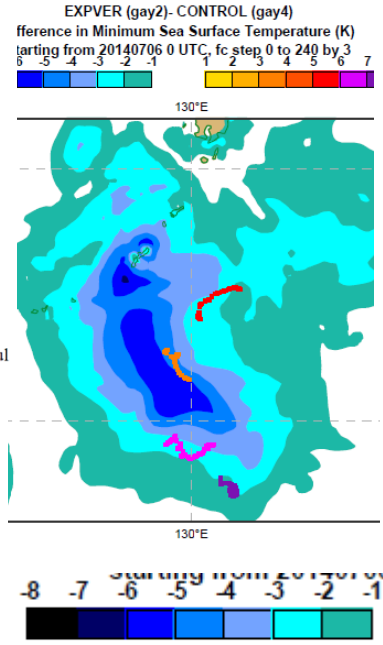


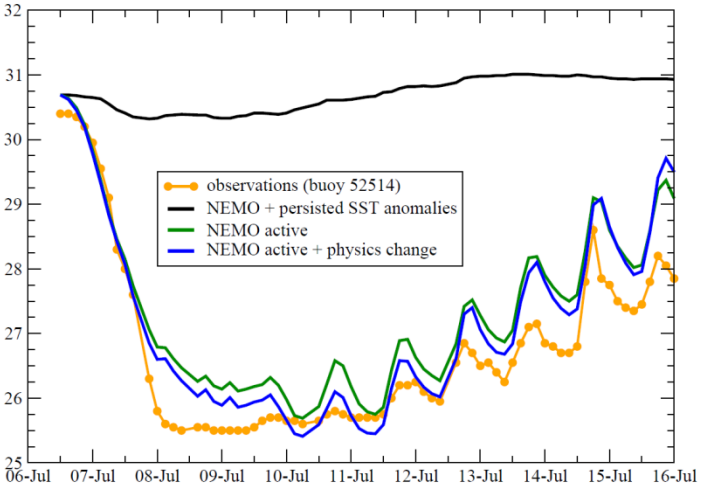


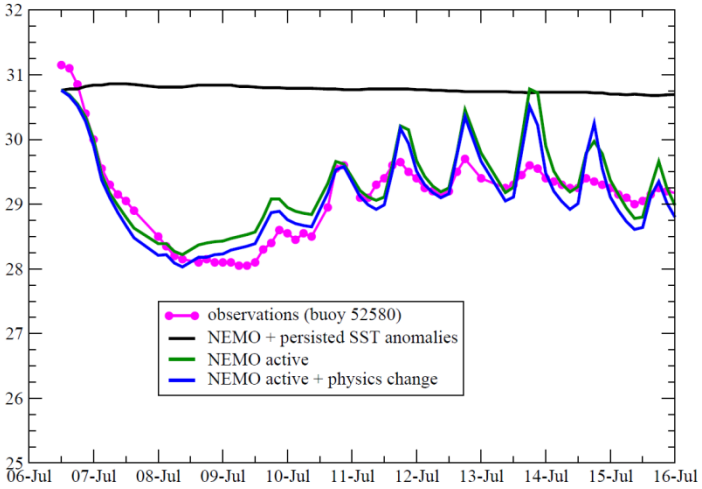
Difference in Maximum SWH (m): Coupled minus operational

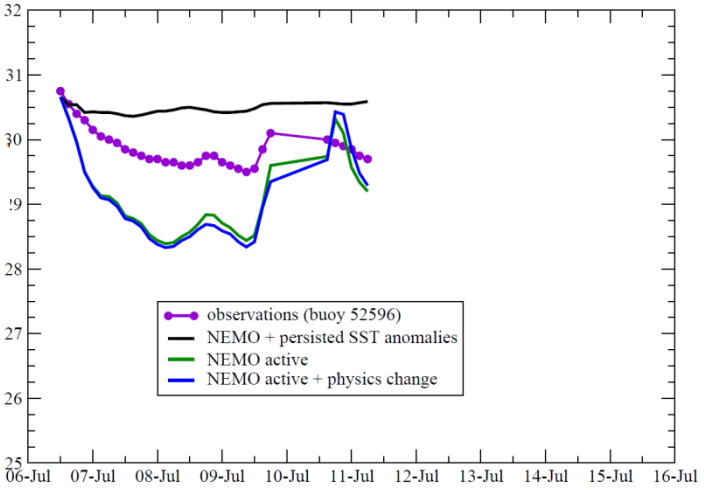
Impact of Coupling on tropical cyclone forecast



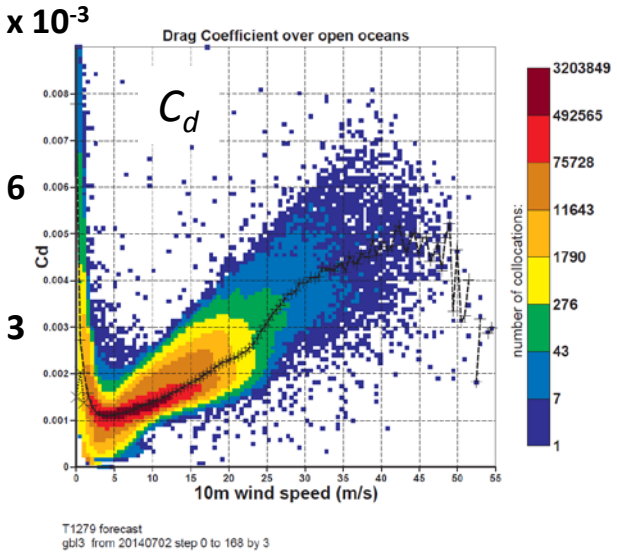




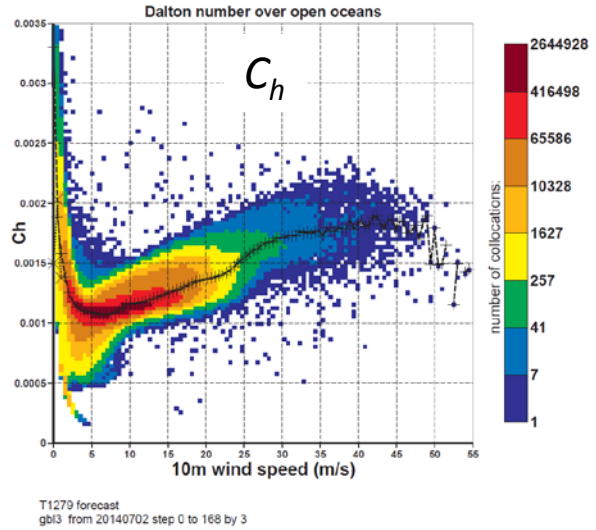




Impact of Coupling: revisit parameterisations?



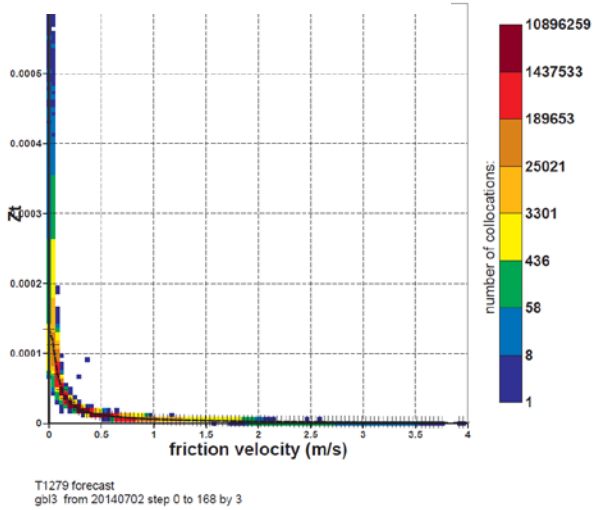
Exchange coefficients dependency on wind speed
Left: for momentum (Cd)
Right: for heat (Ch)



$$C_h = C_D^{1/2} \frac{\kappa}{\ln(10/z_T)}$$

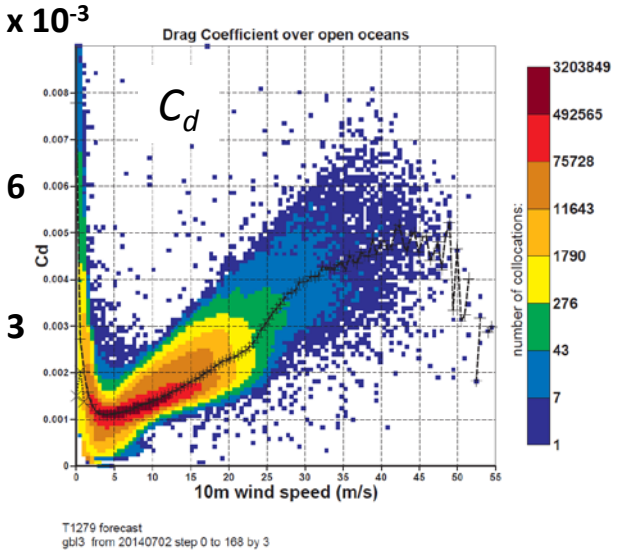
C_d is sea state dependent

Z_T



$$Z_T = \frac{\delta v_z}{\kappa u_*}$$

Impact of Coupling: revisit parameterisations?



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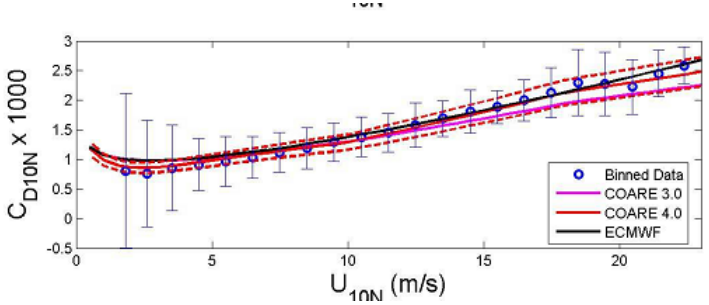
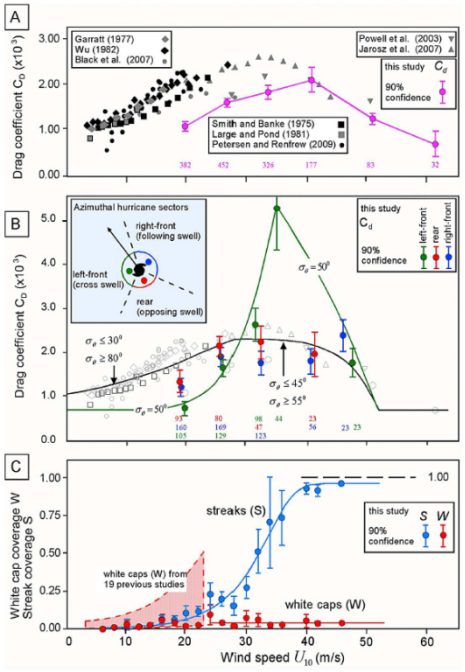
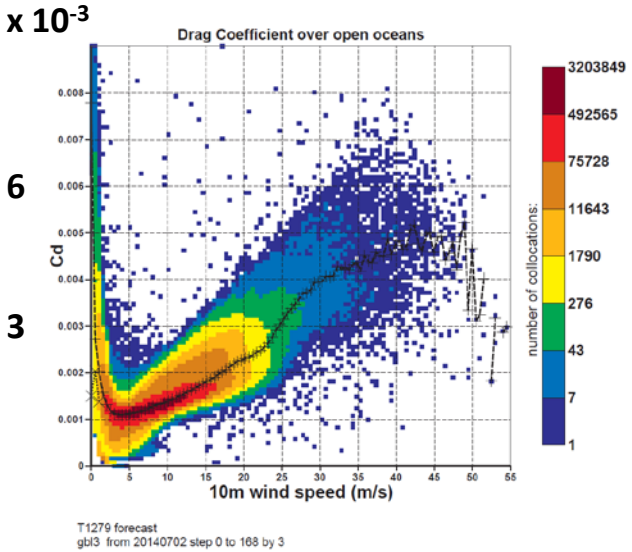


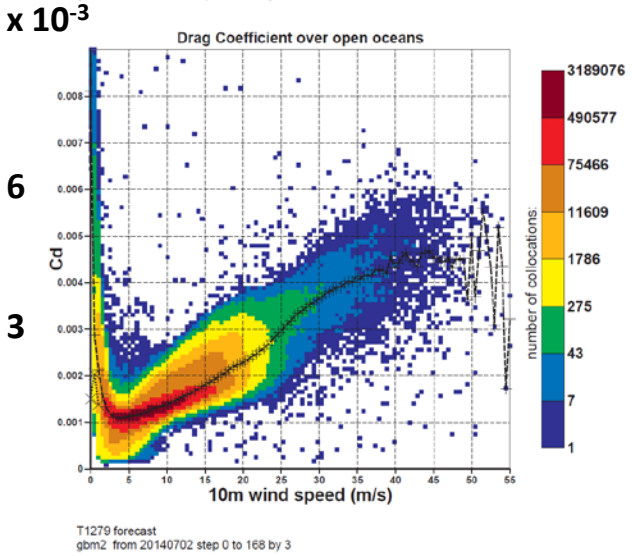
Edson et al., 2013



Holthuijsen et al. , 2012

Impact of Coupling: revisit parameterisations





In ECWAM, from about 1.3 times the peak frequency the model has an omega−4 spectrum which is caused by the nonlinear interactions pumping energy from the low frequency waves to the high frequency waves. In fact, we have the model spectra take the form of the Toba spectrum in that frequency range.

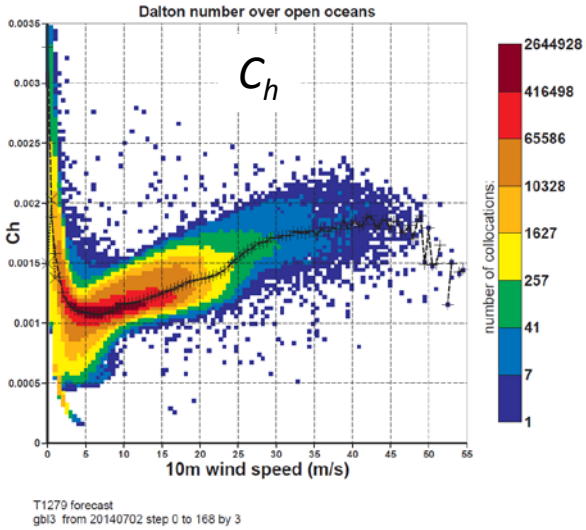
$$F(\omega) = \alpha_t \, g \, u_* \, \omega^{-4}$$

However, clearly for strong winds, hence large u∗, the Toba spectrum cannot hold because the waves in that frequency range become too steep and breaking should happen. Therefore, the idea in this note is to impose a limitation to the high frequency part of the spectrum based on a limiting Phillips spectrum

$$F_{max}(f) = \alpha_{max} \, g^2 \, (2\pi)^{-4} \, f^{-5}$$

Impact of Coupling: revisit parameterisations?

Exchange coefficients dependency on wind speed
Left: for momentum (Cd)
Right: for heat (Ch)



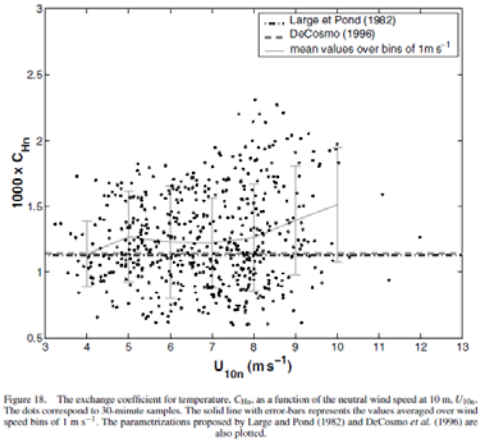


Figure 18. The exchange coefficient for temperature, C_{Hn}, as a function of the neutral wind speed at 10 m, U_{10n}. The dots correspond to 30-minute samples. The solid line with error-bars represents the values averaged over wind speed bins of 1 m s^{-1}. The parametrizations proposed by Large and Pond (1982) and DeCosmo *et al.* (1996) are also plotted.

Brut et al. 2005

Impact of Coupling: revisit parameterisations?

Exchange coefficients dependency on wind speed
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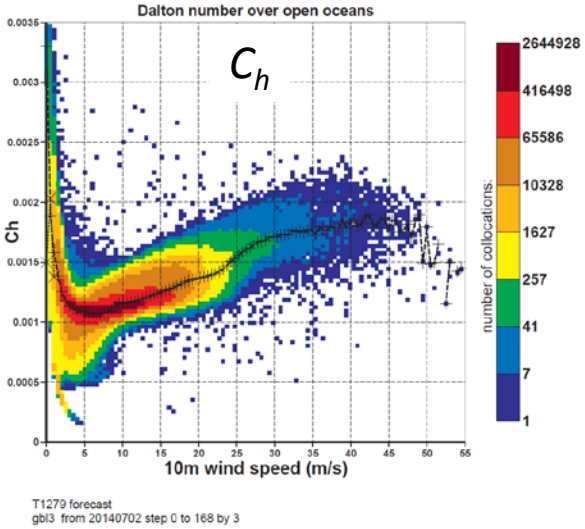
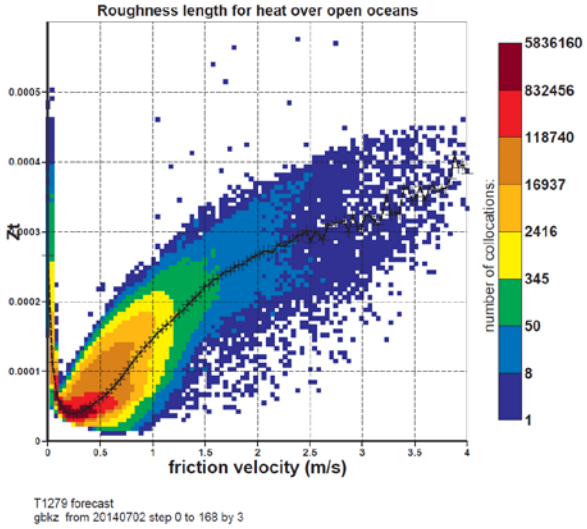


$$C_q = C_D^{1/2} \frac{\kappa}{\ln(10/z_T)}$$

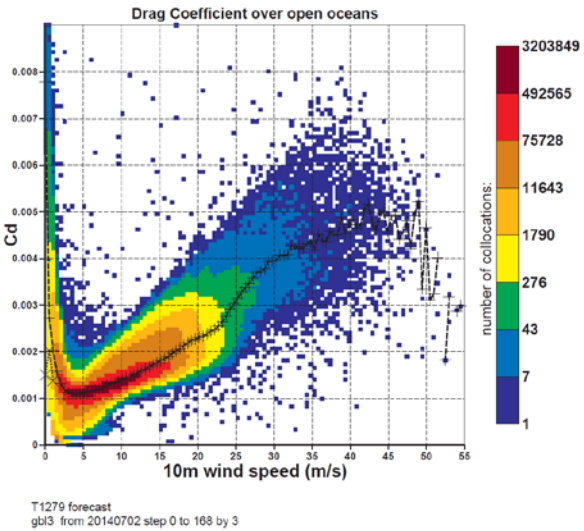
Janssen, 1997:
Effect of surface gravity waves on the heat flux
ECMWF Tech memo 239: z_T

z_T function of sea state and

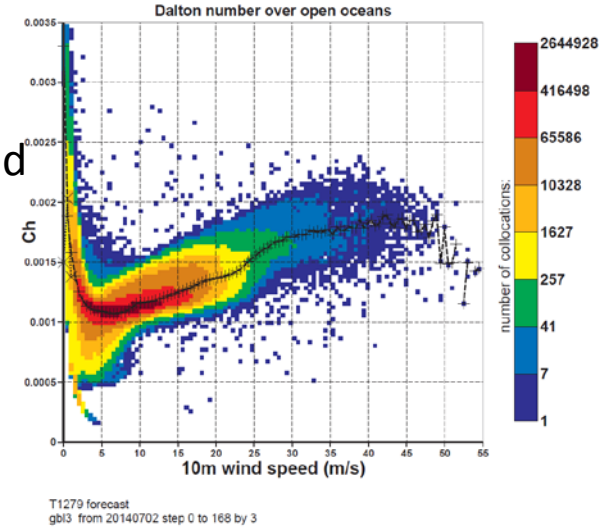
$$z_v = \frac{\delta v_z}{\kappa u_*}$$

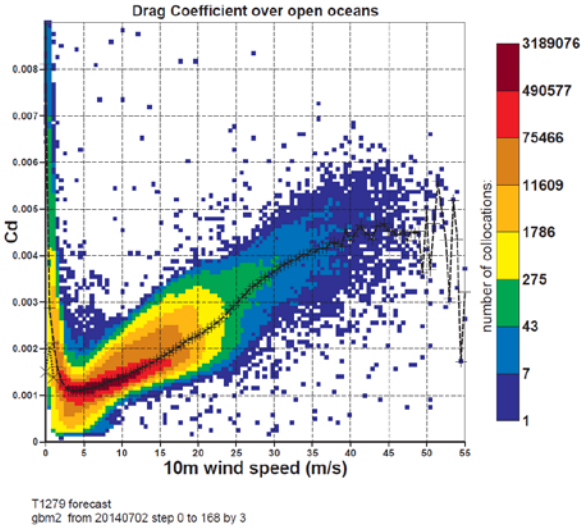


Impact of Coupling: revisit parameterisations



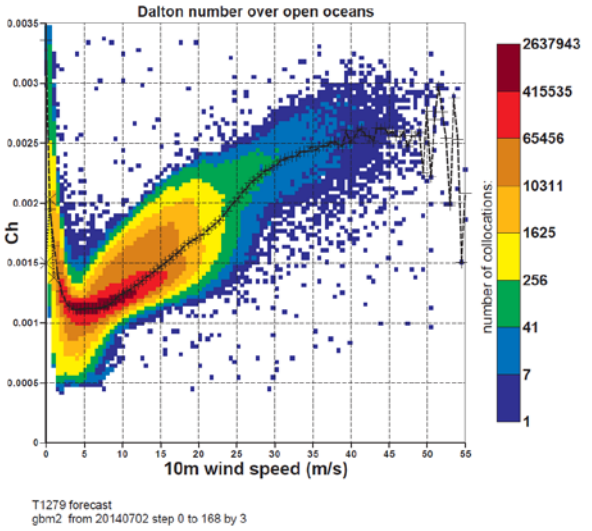
Exchange coefficients dependency on wind speed
Left: for momentum (C_d)
Right: for heat (C_h)
Operational version





Experimental version

Sea state depend C_h
and
Maximum wave spectral limitation.

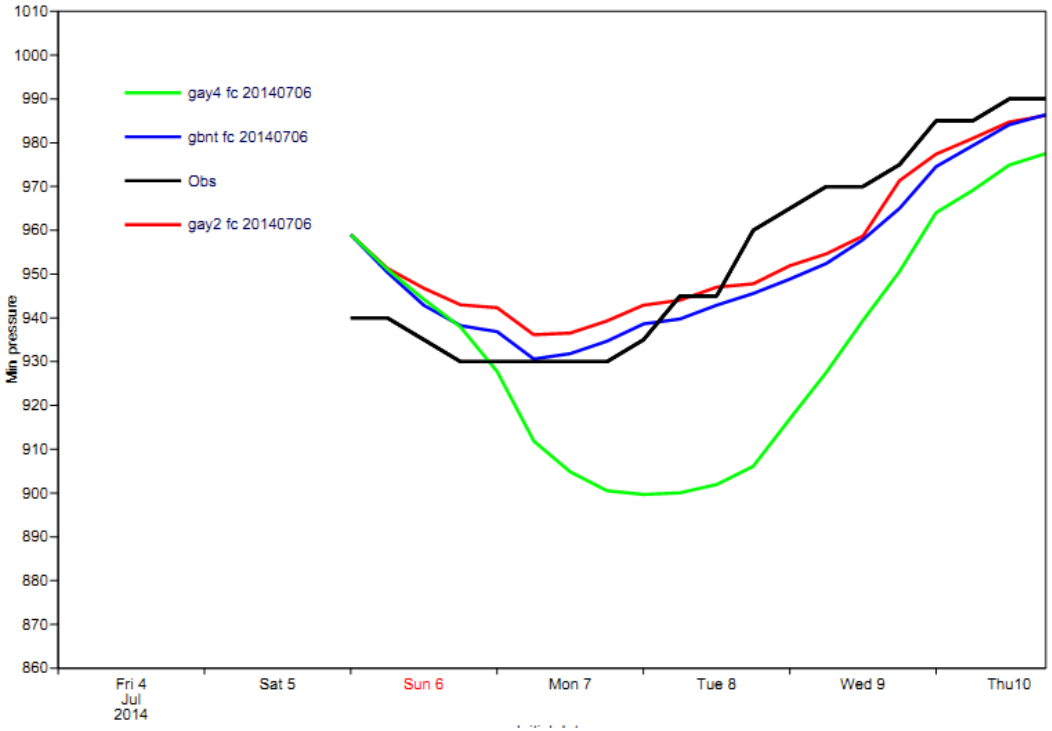


Impact of Coupling on tropical cyclone forecast

min
MSLP (hPa)

950

900



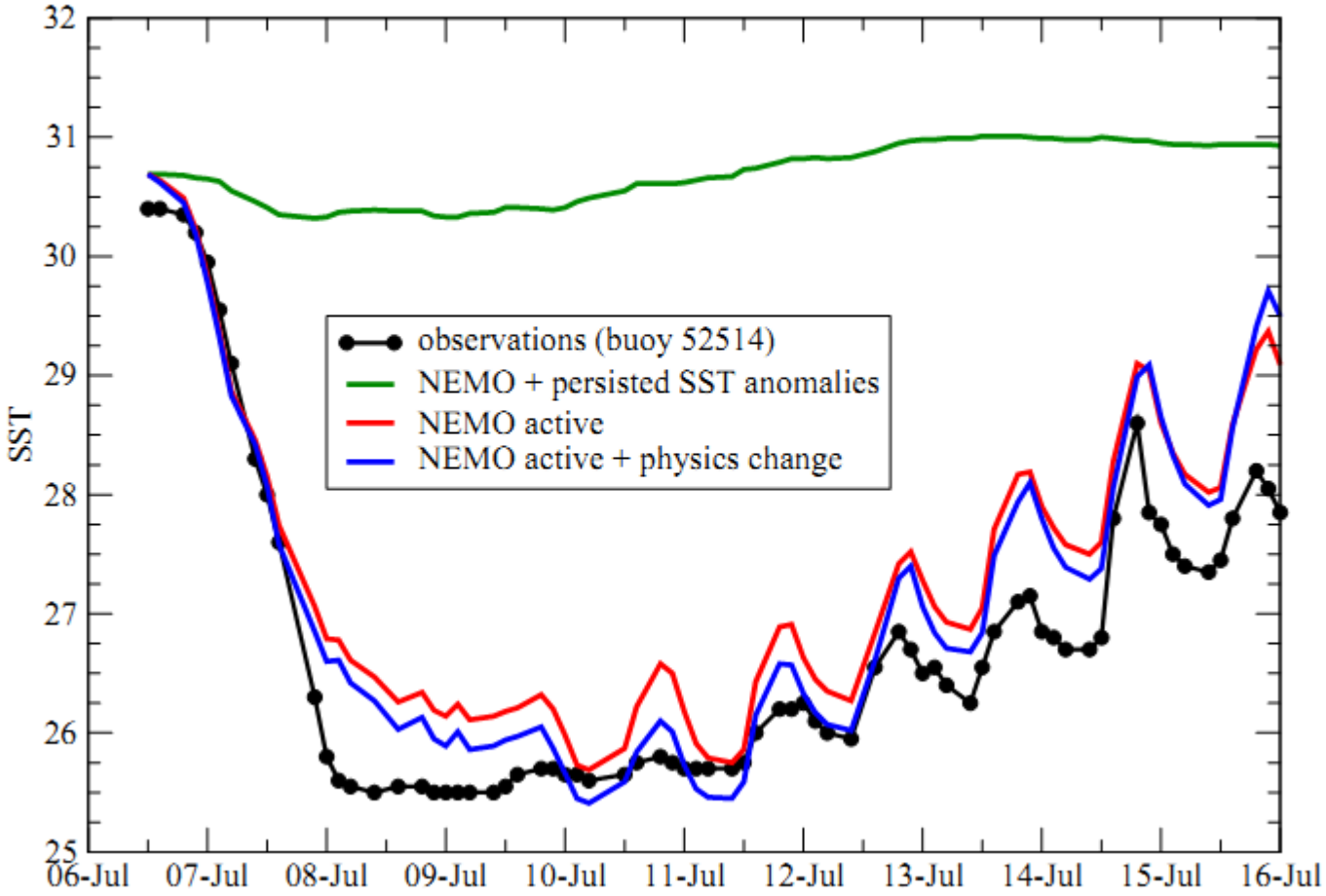
Black: estimated from observations

Green: operational HRES configuration (uncoupled) TL1279

Red: coupled to NEMO (ORCA025_Z75)

Blue: coupled to NEMO + new physics

Impact of Coupling on tropical cyclone forecast



Conclusions:

- ECMWF has a fully coupled atmosphere-wave-ocean circulation forecasting system, currently operational in the Ensemble Prediction System.
- The wave model act as an agent between the atmosphere and the oceans.
- Work is ongoing on using a higher resolution ocean components (ORCA025z75).
- There are clear benefit in coupling the different models, but challenges as model parameterisations will need revisiting.