From Surface to Atmosphere – Impact of sea surface temperature on formation of low level clouds and coastal fog

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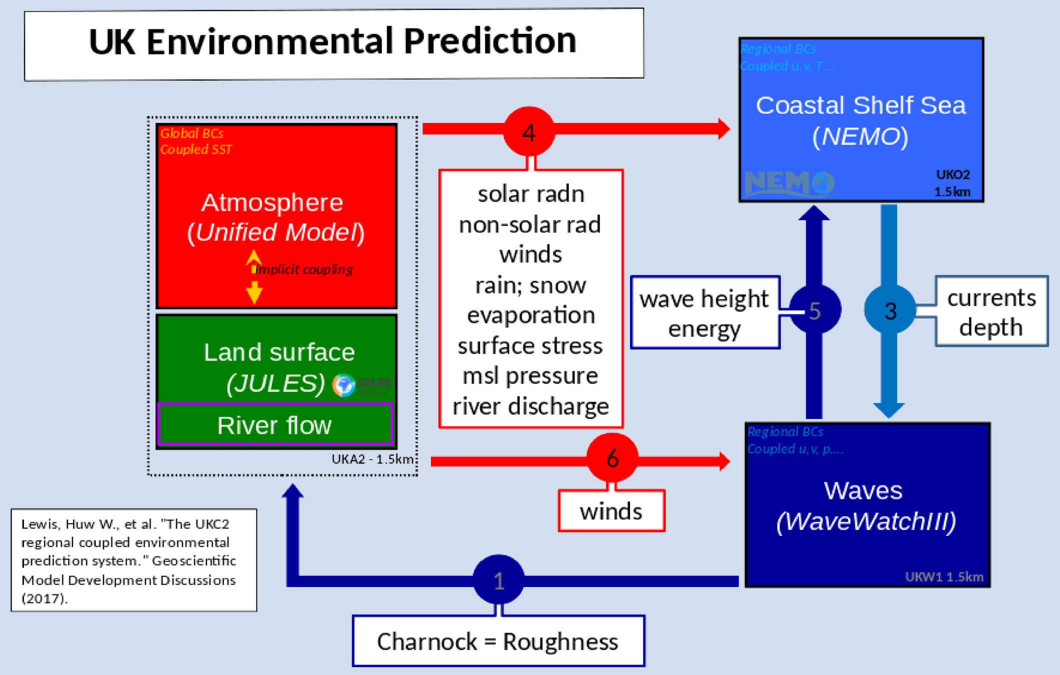
Ocean, Wave, Atmosphere – A coupled view for UK environmental prediction

Accurate prediction and warning of the impacts of severe weather requires an **integrated approach** to forecasting. We develop the first coupled high resolution prediction system for the UK at km-scale. The key components include atmosphere, land surface, ocean, wave and marine ecosystems. The benefits of this approach relative to current uncoupled systems and tools to



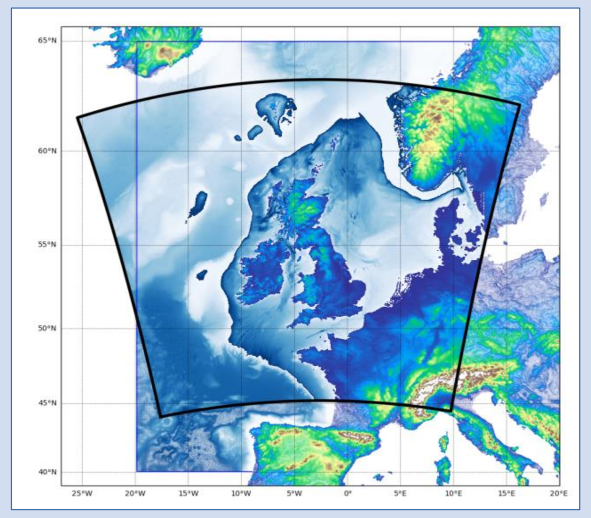
i) improve the accuracy and skill of predictions

ii) provide more relevant hazard advice to users

Iii) better understand the known feedbacks,

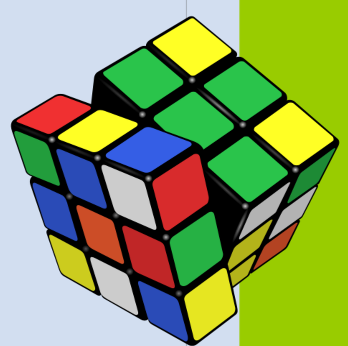
...are to be proven in the UK context

Fully coupled ocean-wave-atmosphere-land prototype system (UKC2), **convective scale** atmospheric model, coupling via OASIS 3-MCT - (**extended UKV domain)** new eddy permitting NEMO ocean component in the **AMM15** domain



ocean initialisation:

- Operational analysis of the SST around the UK using the North Atlantic Model at 1/12° (~9km) (NATL12) **'inits',**
- 4 year hindcast of the SST using the NATL12 model **'restart'**
- JULES land surface model with **river routing** to close the water cycle
- wave interaction with **WAVEWATCH III model** on the AMM15 domain

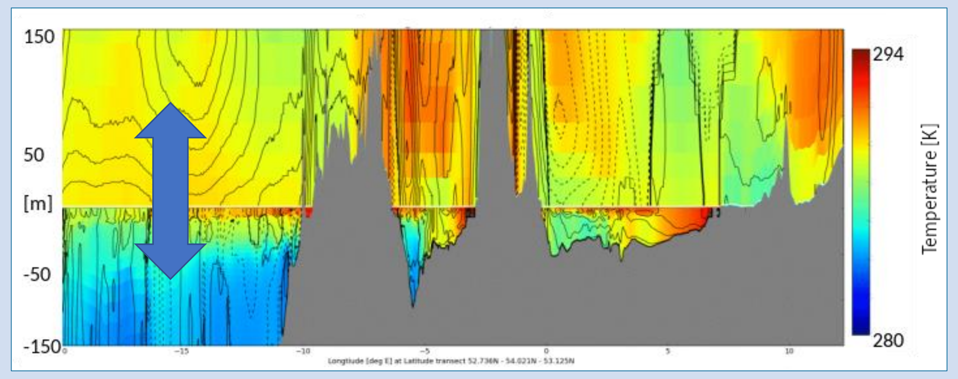


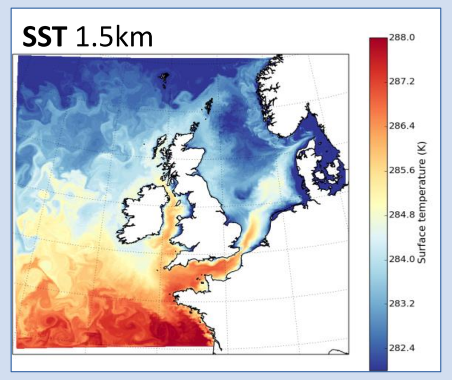
Ocean Atmosphere Feedbacks

Fluxes between thin surface layer and atmosphere.

+

The benefit from **high resolution** SST datasets.





Case Studies

SST control of low level (stratiform) clouds over shallow seas

Case study July 2014 (calm, stable high pressure): **Coupling** of dynamical systems ocean, wave, atmosphere considers **diurnal SST variation**, leading to a significant **warming** of the shallow North Sea (square).

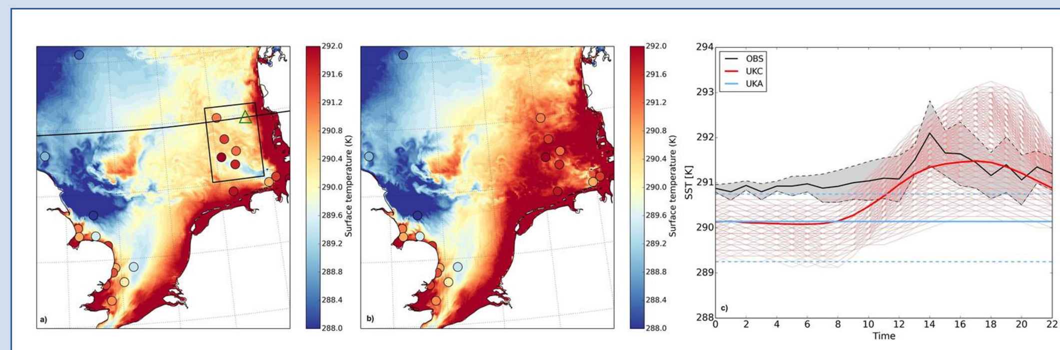


Fig. 5: SST in (a) UKA uncoupled run (persisted SST) and (b) UKC coupled simulation at 1400 h on 16 July 14, both initialized from the same SST at 0000 h. (c) Observed diurnal SST for UKA (blue), UKC (red), and average of SST observations located within the box.

Turbulent heat and moisture flux from a 'warmer' ocean surface into the atmosphere above. Increase of turbulent kinetic energy, vertical velocity and temperature within the MBL leads to **cloud formation** in the area of the MBLH along a selected cross section and vertical profiles.

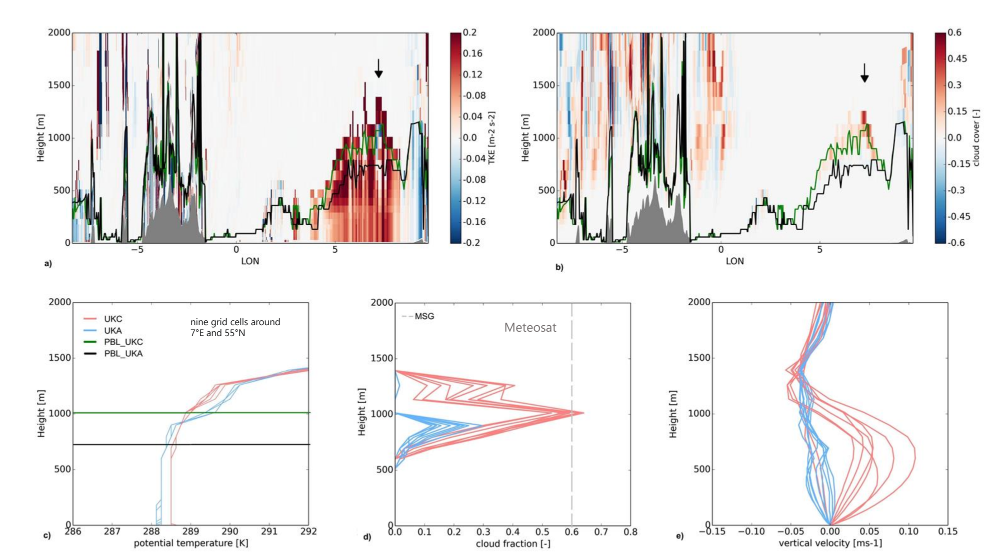


Fig. 6: Cross sections of differences in (a) TKE and (b) cloud fraction between coupled and uncoupled run over cross section (Fig5). PBLH in green (UKC) and black (UKA). Profiles for 3x3 grid cells around green triangle (Fig.5)

Diurnal variation of sensible heat flux, cloud fraction, TOA SWR, MBLH indicate ↑ **SST-Cloud** feedback (figure valid for selected box). Cloud cover can be seen in MSG OBS as well.

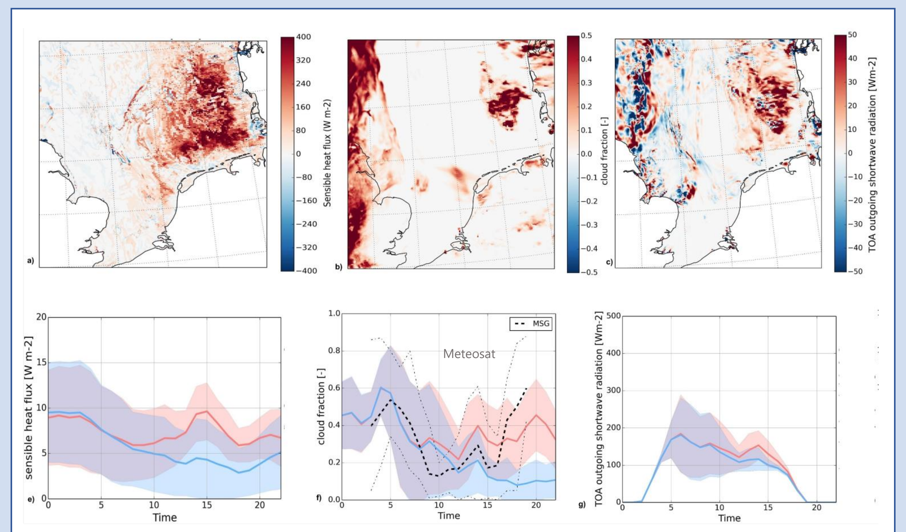
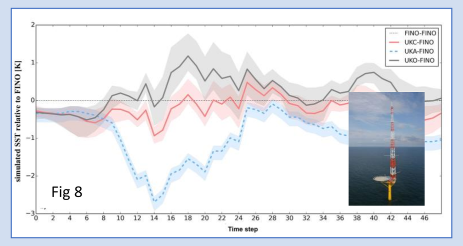


Fig. 7. Differences in (a) surface sensible heat flux, (b) 1000 m cloud fraction, (c) TOA outgoing short wave radiation between coupled UKC and uncoupled UKA simulations on 16 July 2014 1400 h. (e-g) Spatial average (box above) and standard deviation.

2-way feedback in a coupled system ↓ **Cloud-SST** - radiative cooling at cloud top 'cools' an uncoupled ocean. Diff between FINO and OBS (Fig 8).



http://www.sunwindenergy.com/sites/default/files/news/56-1.jpg

Surface to Boundary Layer Coupling

SST driven coastal fog formation off the UK East Coast

Case study July 2013: cyclonic high pressure, inflow of cool air masses from the North. In the course of the modelling period**, fog** forms off the East coast of the UK. With regard to model resolution and coupling, the fog layer develops differently (Fig 9. 2300 UTC).

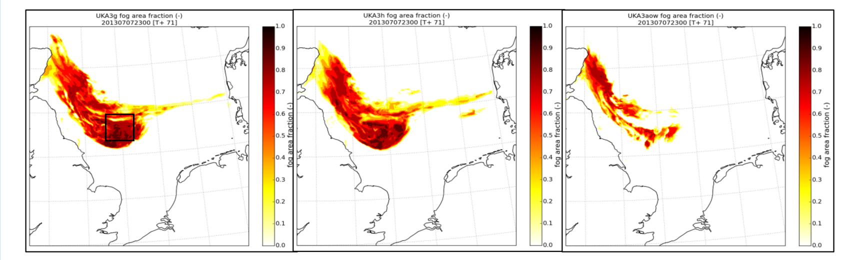


Fig. 9: Fog area fraction for global SST (left), high resolution AMM15 SST initial conditions (middle) and atmosphere-ocean coupled configuration

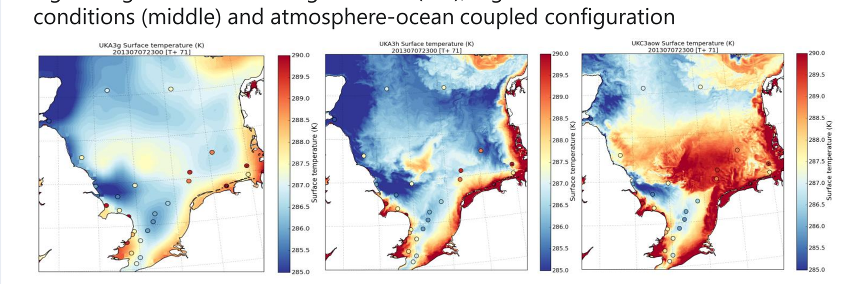


Fig. 10: Sea surface temperature for global SST (left), high resolution AMM15 SST initial conditions (middle) and atmosphere-ocean coupled configuration

Left: global SSTs for model initialisation, persisted throughout the model run. Middle: SSTs from 1.5 km AMM15 data which is as well persisted throughout the run. Right: In the coupled run, a diurnal cycle is added to the SST by coupling.

Averaged over all OBS (Fig. 11) **SST underestimated** for both configurations with ~1 K for UKC (a) and ~2 K for UKA (b) on a daily mean. The error in 2m air temperature fluctuates around zero (c), **drifts away** during the simulation with persisted SST (d).

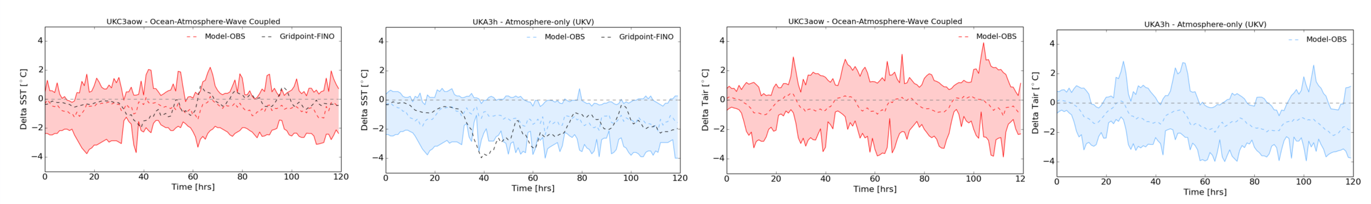


Fig. 11: ΔModel-OBS SST averaged over all points and for single FINO OBS for both (Fig 11. a,b) coupled (UKC) and uncoupled (UKA) configuration. Same is done for 2m air temperature (c,d)

Fig.12: Initial **low level clouds forming/advecting** from the north and transported over the North Sea. Increase of SST in the coupled run ,increase of **sensible heat flux** from a relatively warmer SST. **Fog removal at the basis**.

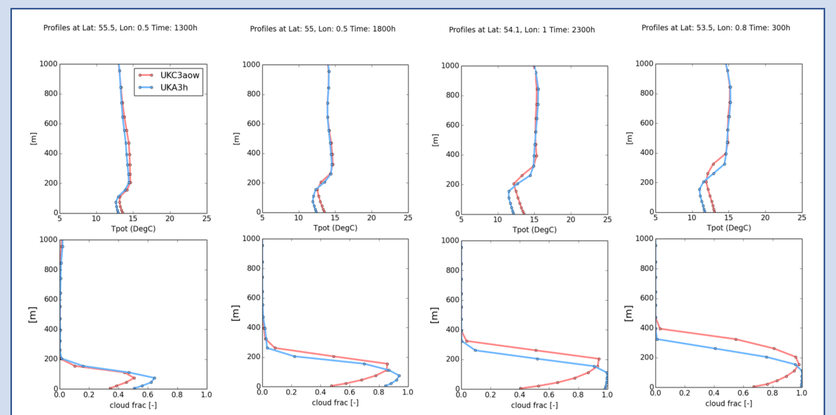


Fig. 12: Profiles following air parcel moving over the North Sea over 14 hrs (7 July)

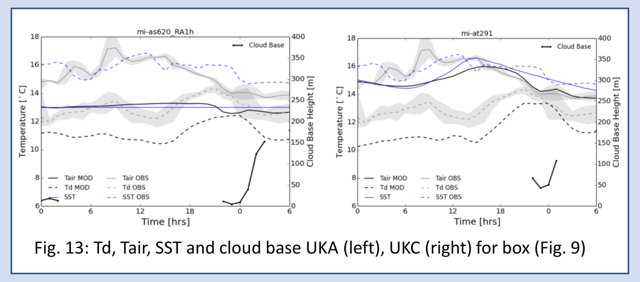
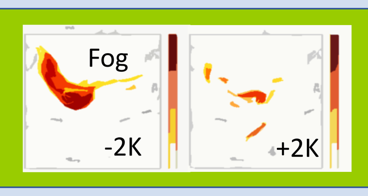


Fig. 13: Td, Tair, SST and cloud base UKA (left), UKC (right) for box (Fig. 9)

Elevation of low level cloud layer in the coupled run, fog persists in the uncoupled setting. Around midnight fog is forming (**Tair=Td**) and the cloud base is attached to the surface (Fig 13)

Sensitivity to initial SST



coupled

	UKA_Base	UKCaow	UKA_plus1	UKA_plus2	UKA_minus1	UKA_minus2
SST [°C]	15.9	17.19	16.91	17.25	14.93	14.35
Fog area fraction [%]	8.2	4.3	6.1	4.7	10.2	12.4
1.5m Tair [°C]	15.65	16.92	16.65	16.65	14.85	14.15
1.5m wind speed [ms^{-1}]	3.7	3.92	3.7	3.41	3.73	3.32
1.5m Visibility [km]	14.7	17.2	15.3	16.3	14.5	13.5

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