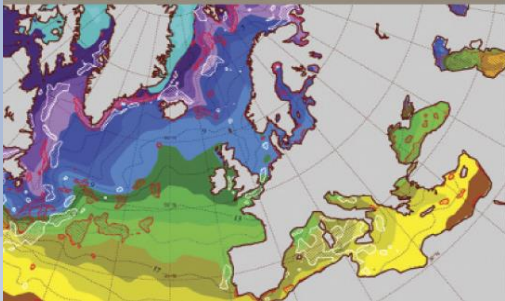


# Earth System Modelling at ECMWF

Nils P. Wedi + ECMWF colleagues

European Centre for Medium-Range Weather Forecasts (ECMWF)

GLOBAL PREDICTION



SEVERE WEATHER



ATMOSPHERIC COMPOSITION



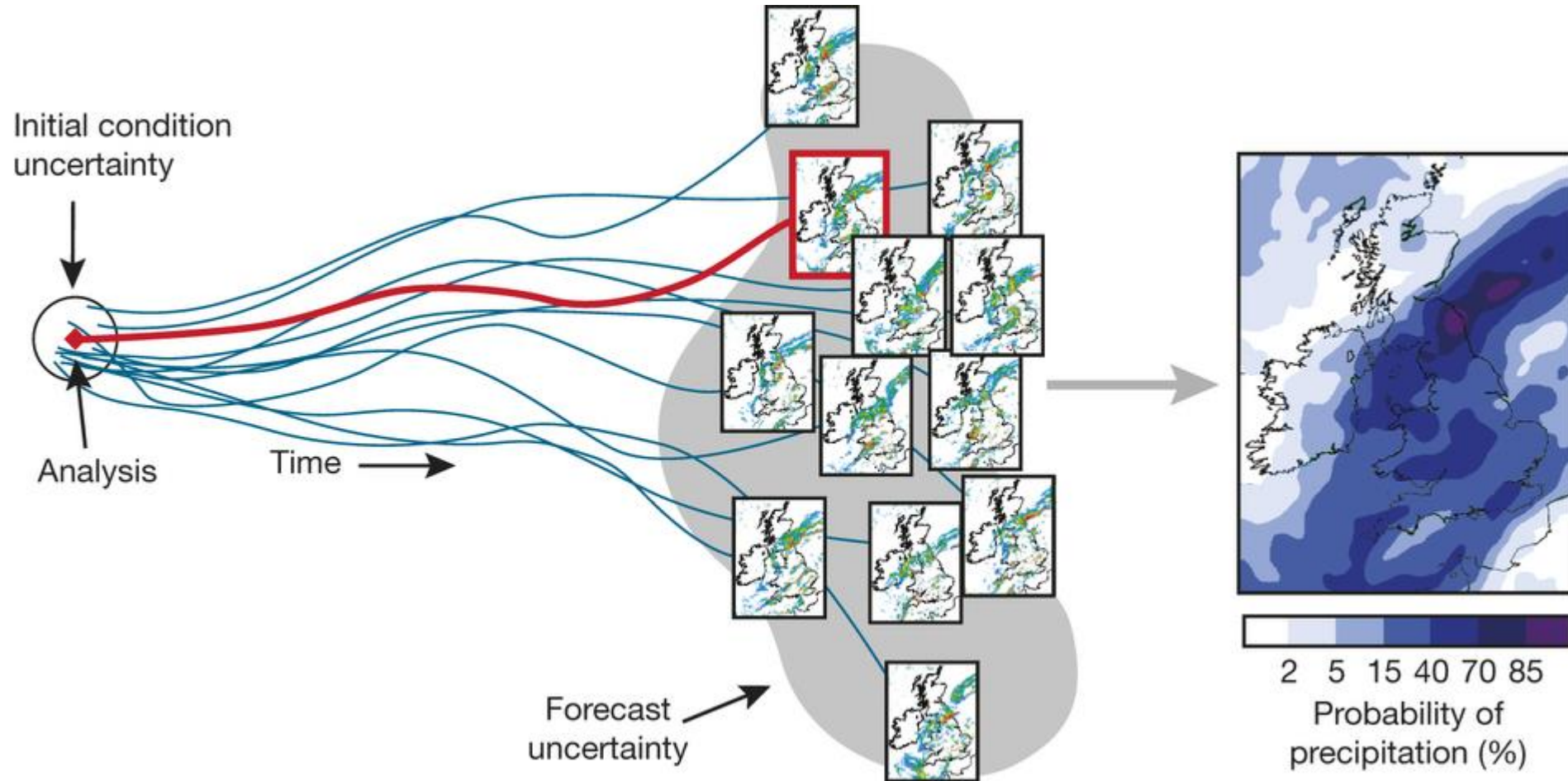
CLIMATE MONITORING



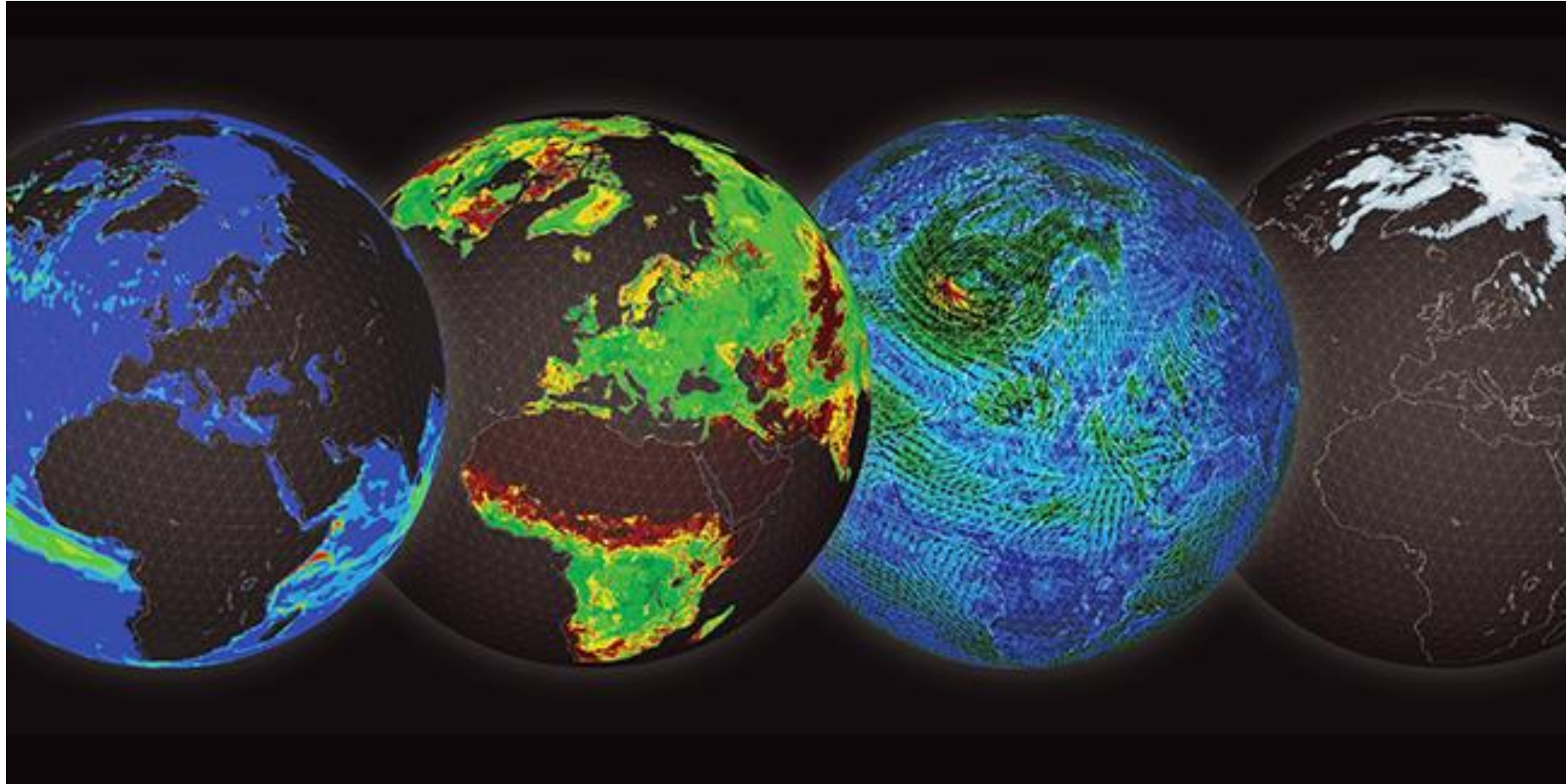
SUPERCOMPUTER CENTRE



# Ensemble of assimilations and forecasts

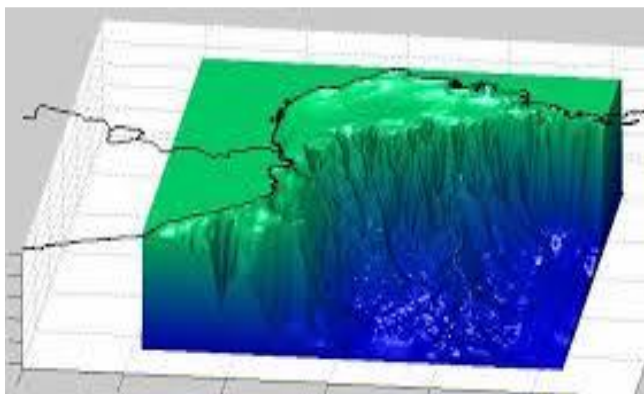


# Ocean – Land – Atmosphere – Sea ice





# Ocean, waves, sea-ice at ECMWF



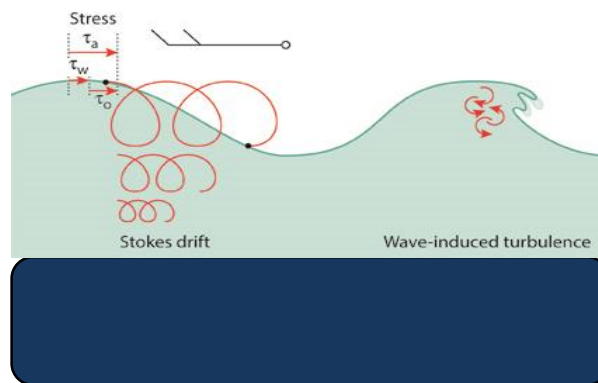
## NEMO3.4

NEMO3.4 (Nucleus for European Modelling of the Ocean)

Madec et al. (2008)

Mogensen et al. (2012)

ORCA025\_Z75 :  $0.25^\circ \times 0.25^\circ$



## EC-WAM

ECMWF Wave Model

Janssen, (2004)

Janssen et al. (2013)

ENS-WAM :  $0.25^\circ \times 0.25^\circ$

HRES-WAM:  $0.125^\circ \times 0.125^\circ$



## LIM2

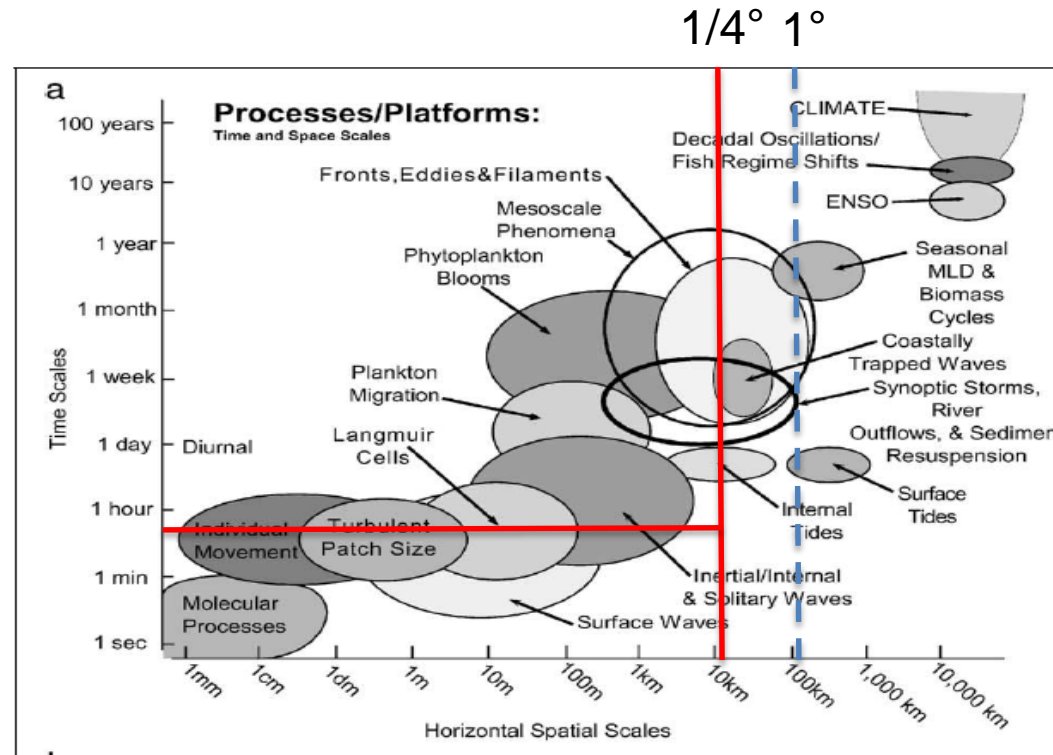
The Louvain-la-Neuve Sea Ice Model

Fichefet and Morales Maqueda (1997)

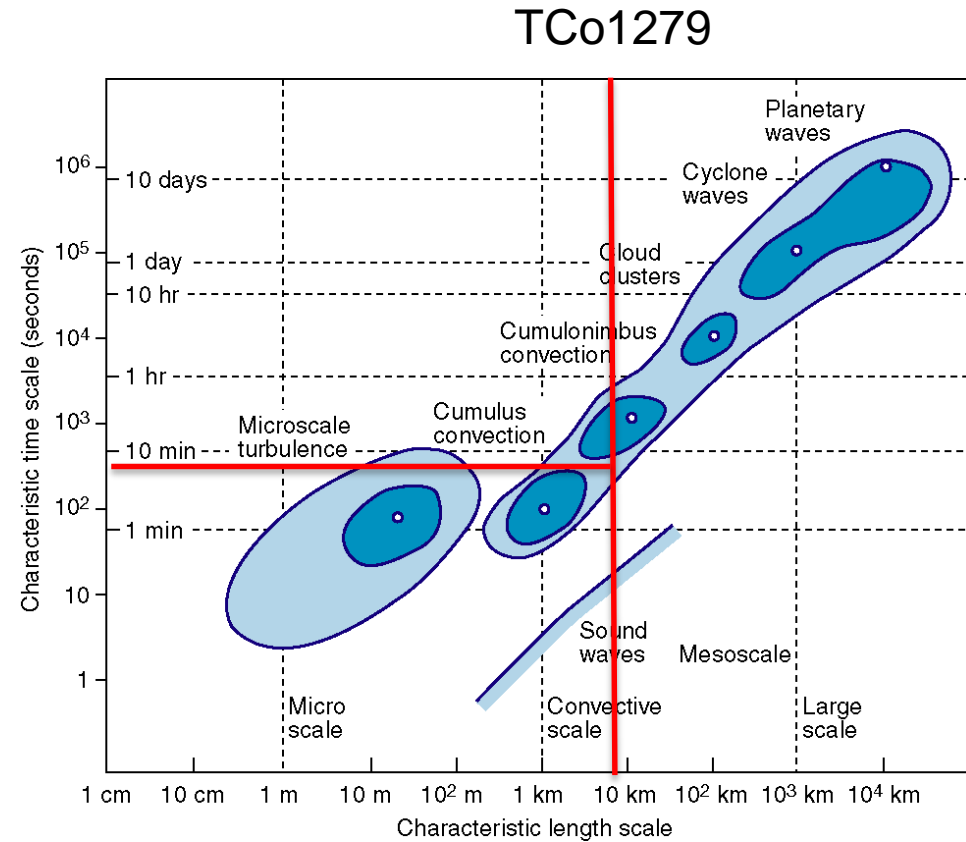
Bouillon et al. (2009)

Vancoppenolle et al. (2009) ORCA025\_Z75 :  $0.25^\circ \times 0.25^\circ$

# Scales of motion



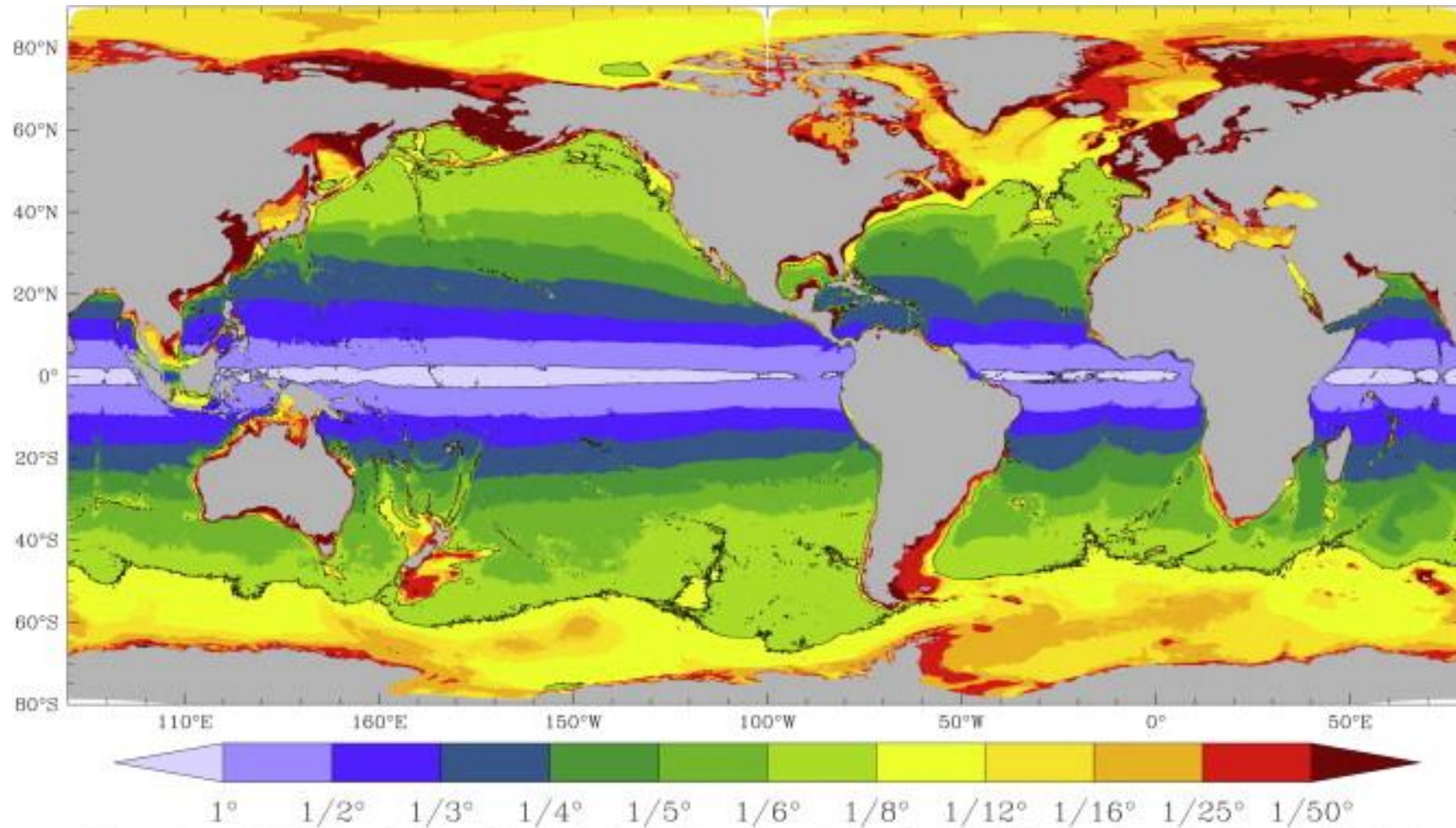
From Dickey (2003)



**Target: 4-6 dx effective resolution!**

# Ocean resolution requirements

Hallberg 2013

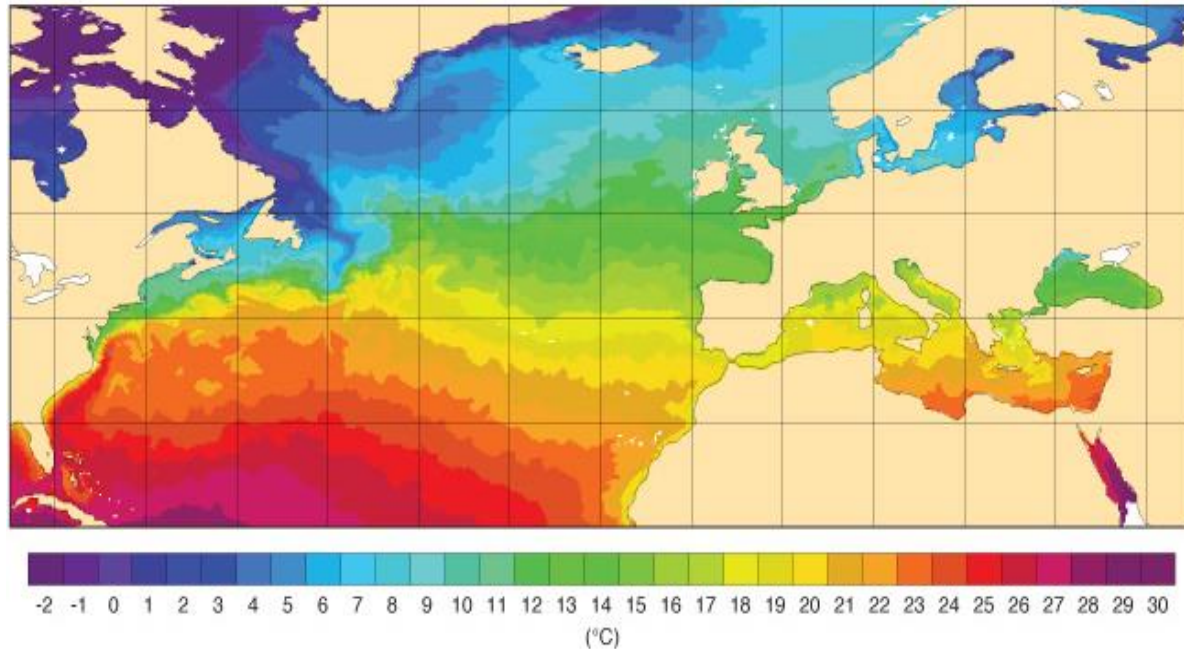


Mercator Grid Resolution Required to Resolve Baroclinic Deformation Radius with  $2 \Delta x$

From the presentation of H. Hewitt, at ECMWF (2016)

# A partially coupled system in the extra-tropical regions

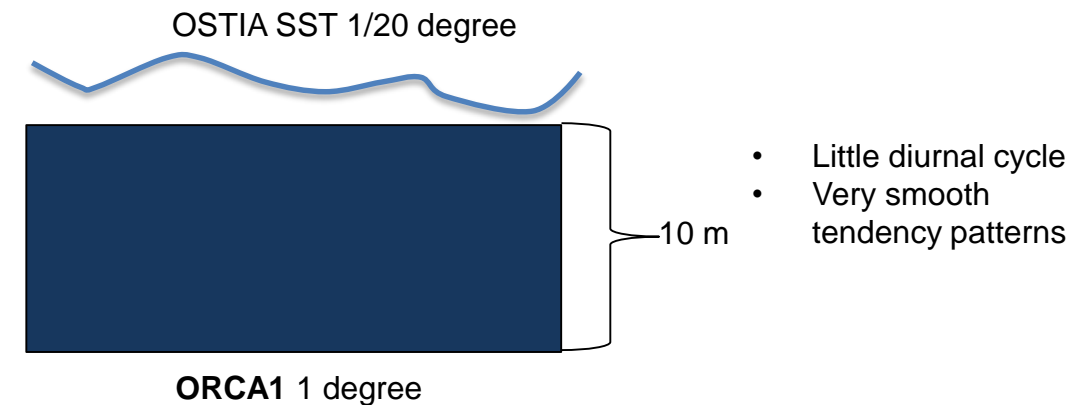
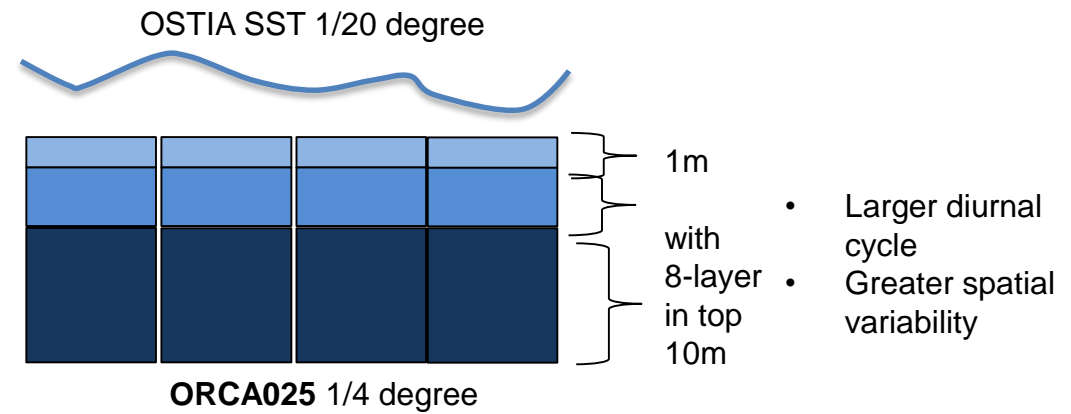
- **RESOLUTION Enhancement**



(Mogensen et al, 2017)

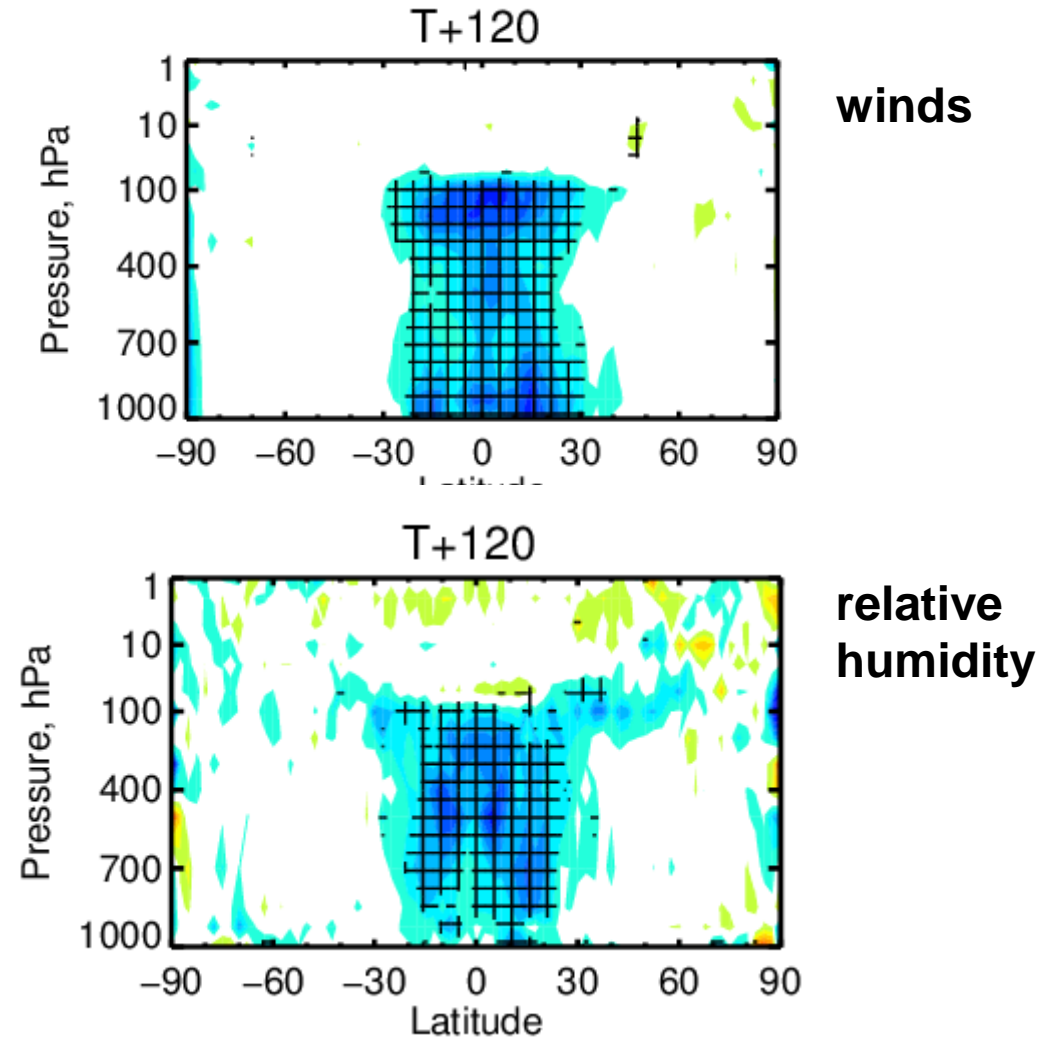
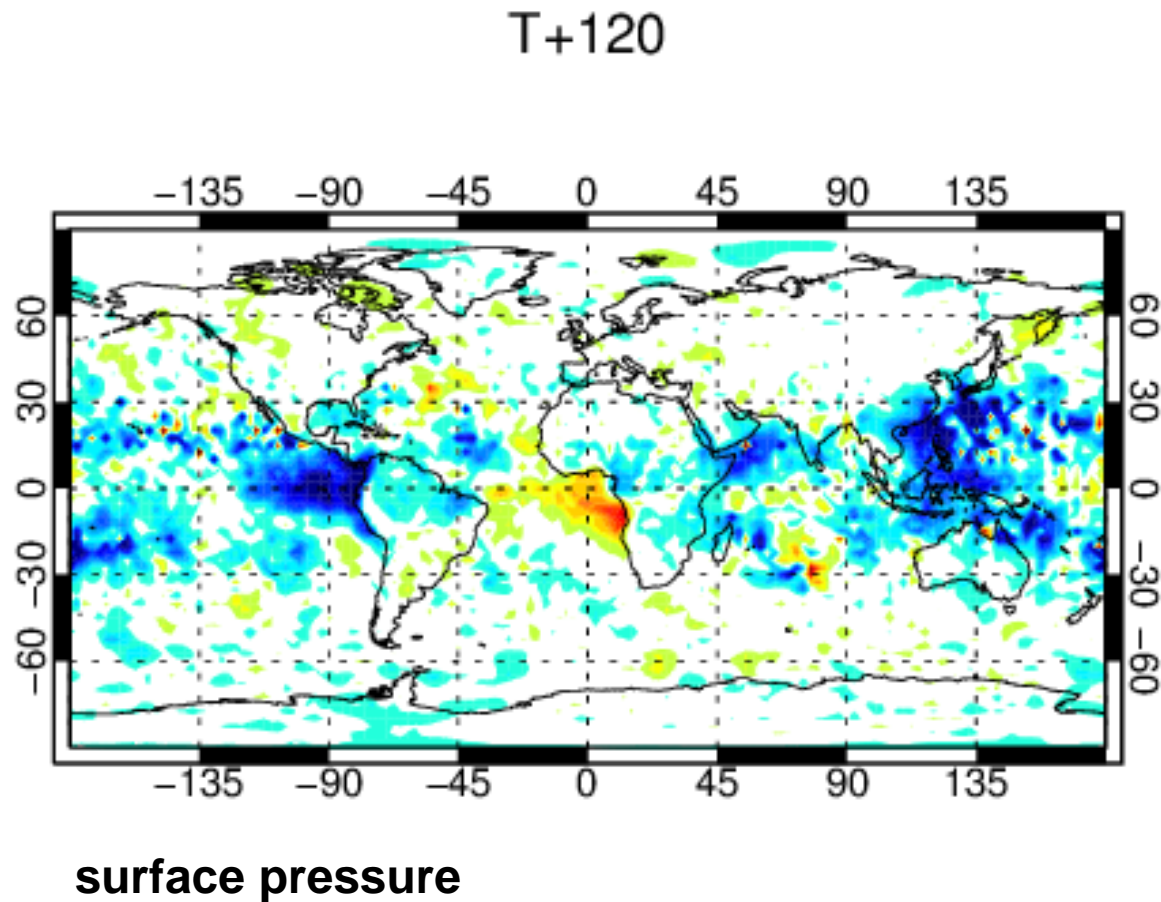
- **COMBINED approach for SST**

benefit of a high resolution initial condition by OSTIA SST are combined with ORCA025





# Day +5 forecast (rms) error reduction due to the (partially coupled) **ocean coupling to the TCo1279 forecast model**





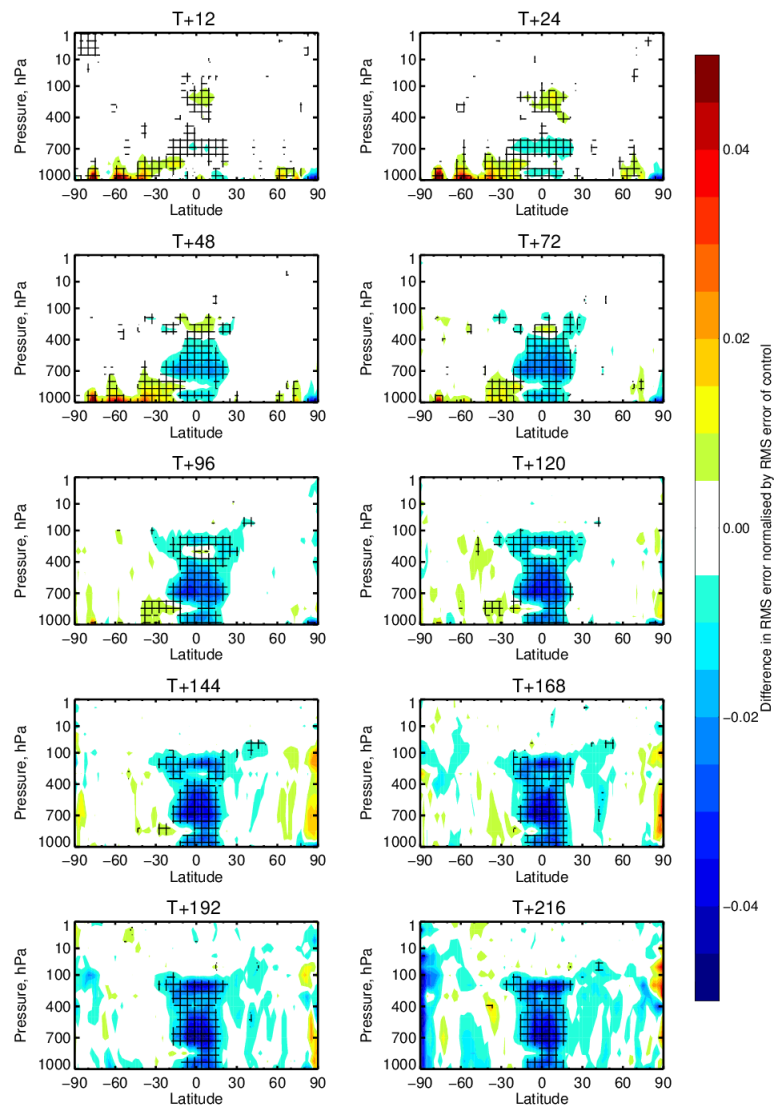
## Impact from ocean initial condition

## Additional impact from dynamical coupling to the ocean

45r1 Coupled HRES

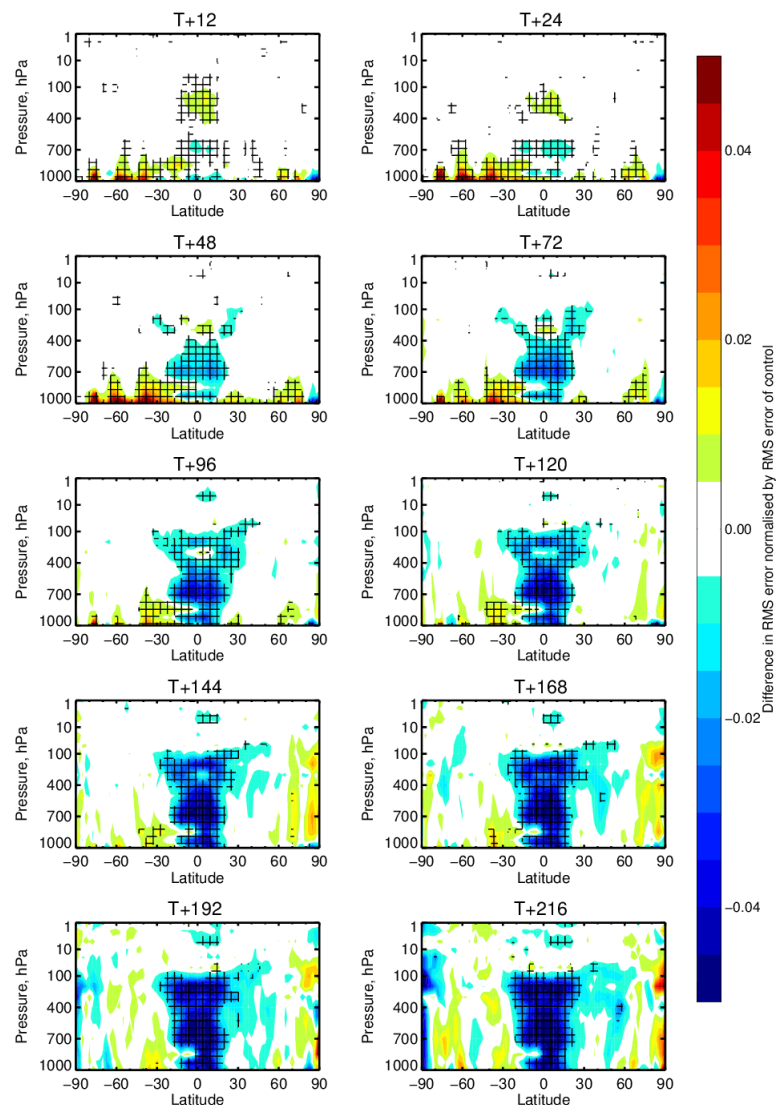
Change in error in T (ORAS5 SST–Oper SST)

1–Dec–2014 to 30–Nov–2015 from 356 to 365 samples. Cross-hatching indicates 95% confidence. Verified against 0001.



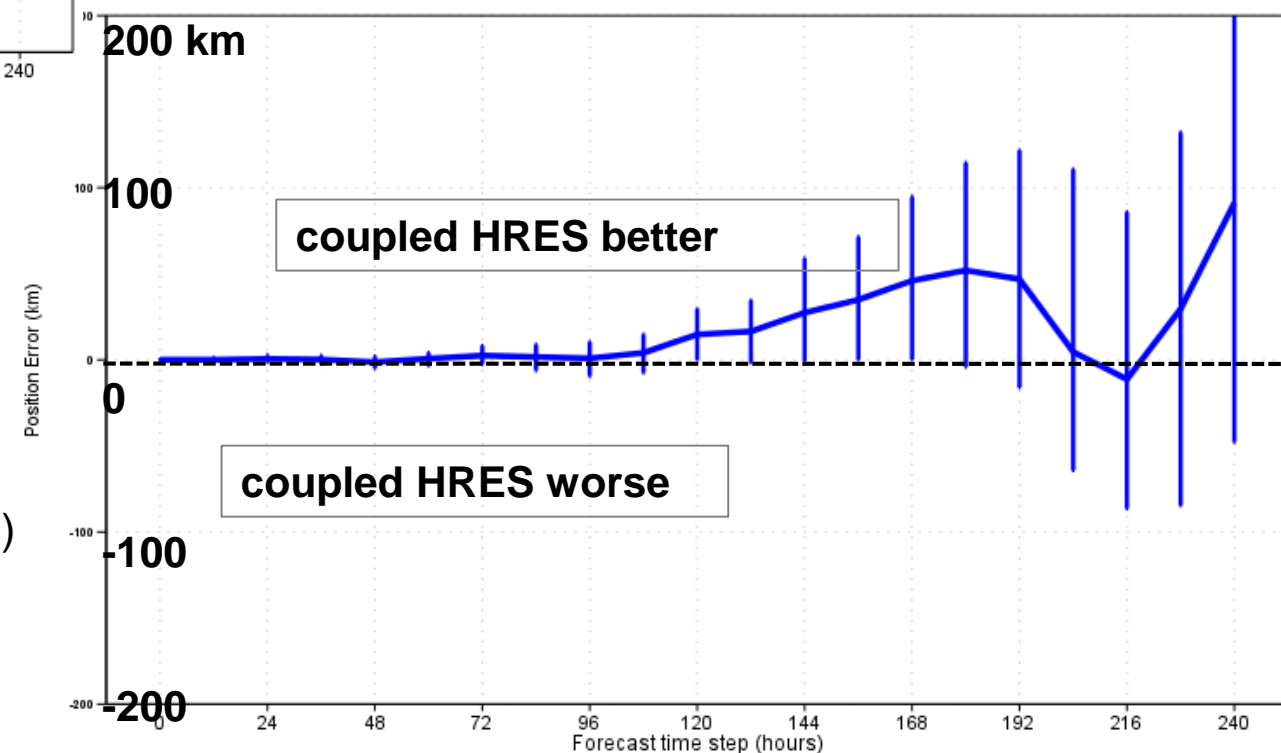
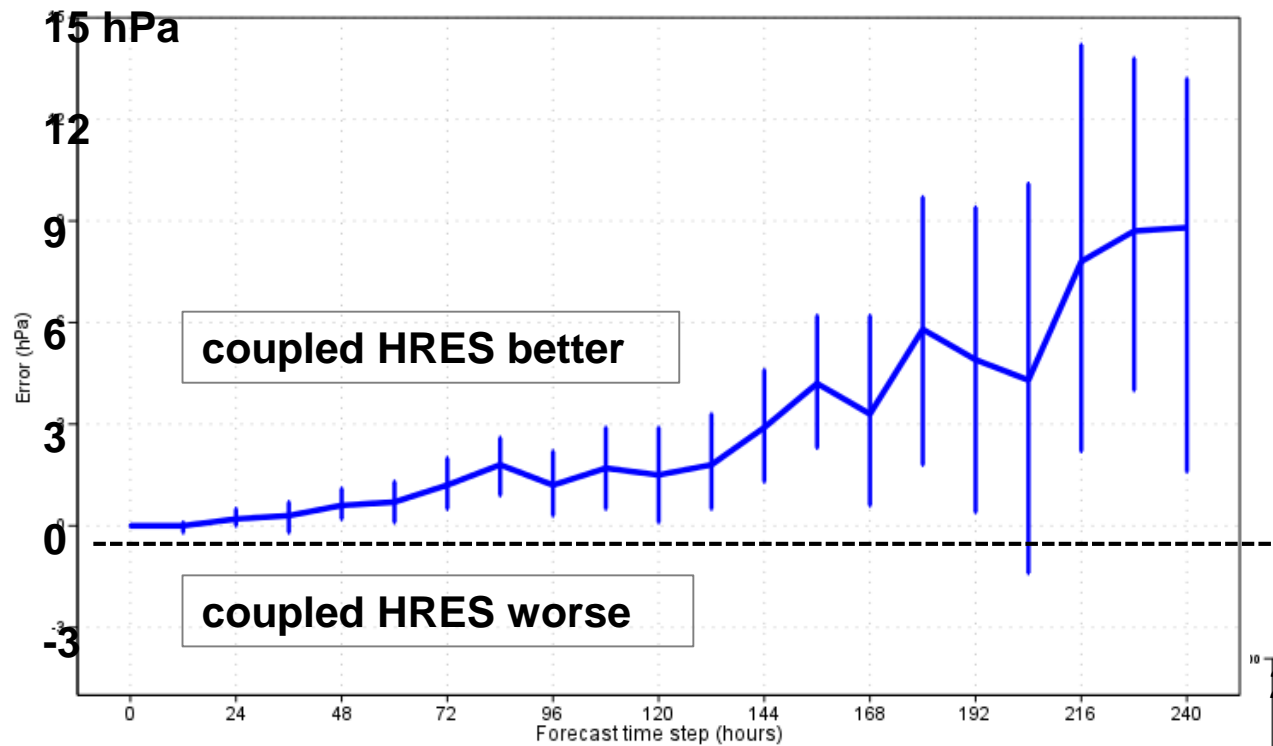
Change in error in T (Fully coupled–Oper SST)

1–Dec–2014 to 30–Nov–2015 from 356 to 365 samples. Cross-hatching indicates 95% confidence. Verified against 0001.



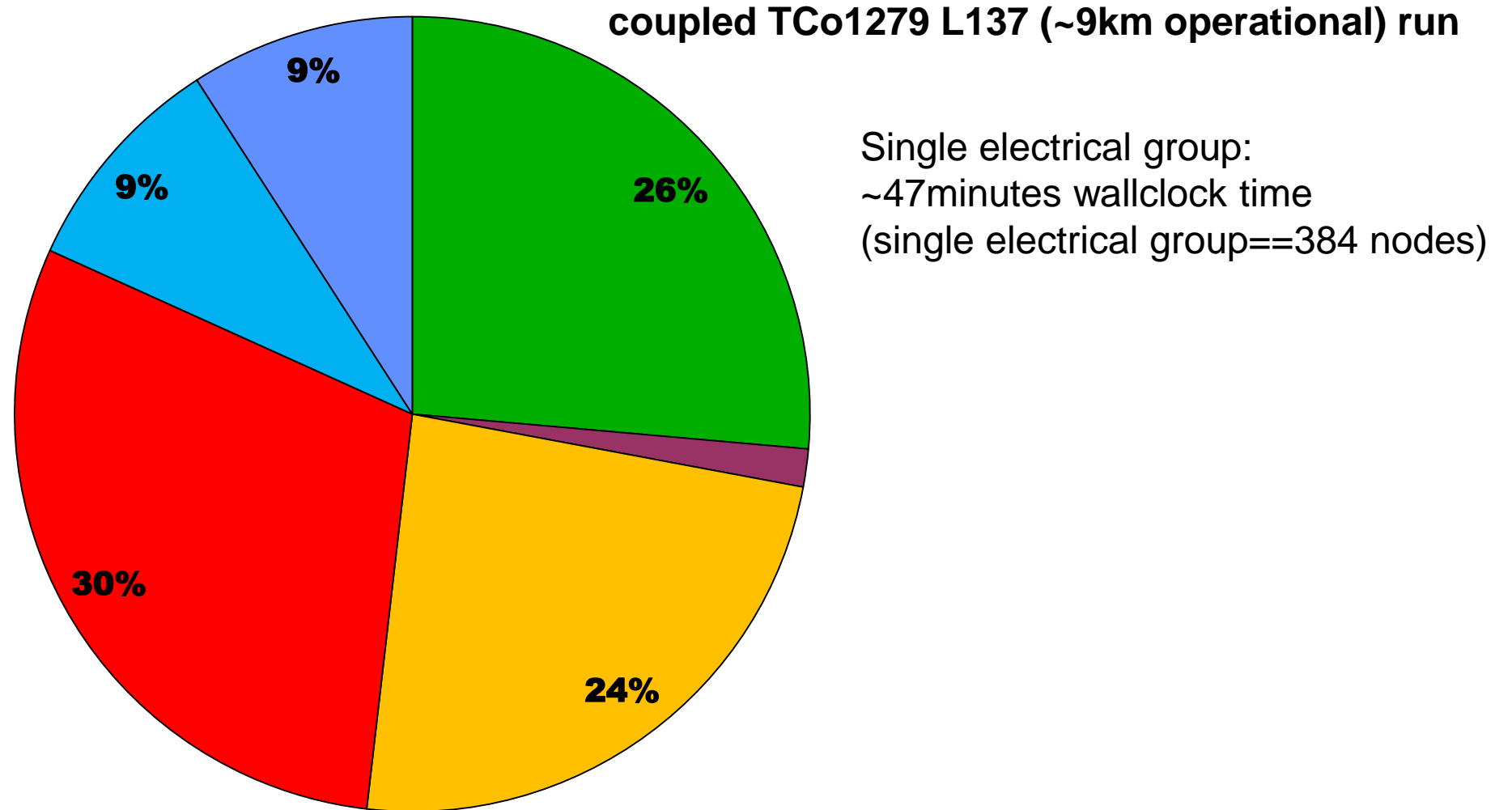
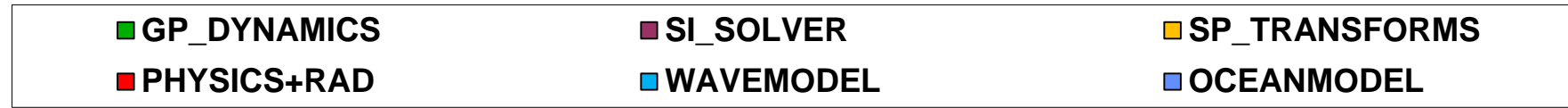
## Improvement of tropical cyclones

**Difference of the mean absolute intensity errors (hPa)**  
VT: 2016-05 to 2017-01 (homogeneous samples/all basins)  
**Bars: 95% confidence interval**



**Difference of the mean position error (km)**  
VT: 2016-05 to 2017-01 (homogeneous samples/all basins)  
**Bars: 95% confidence interval**

## Where do we spend the time ?

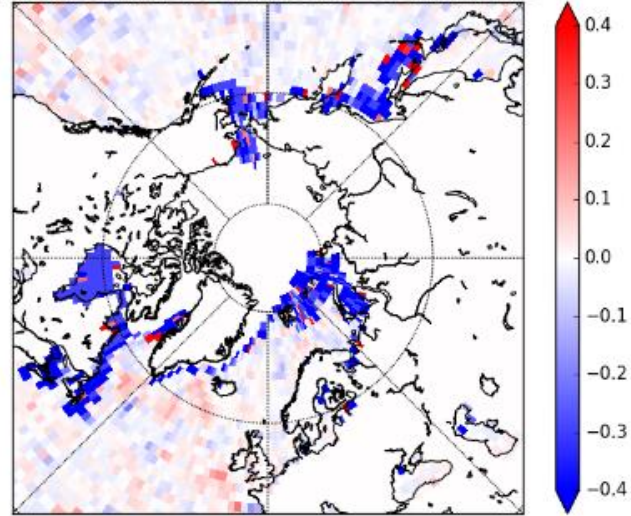




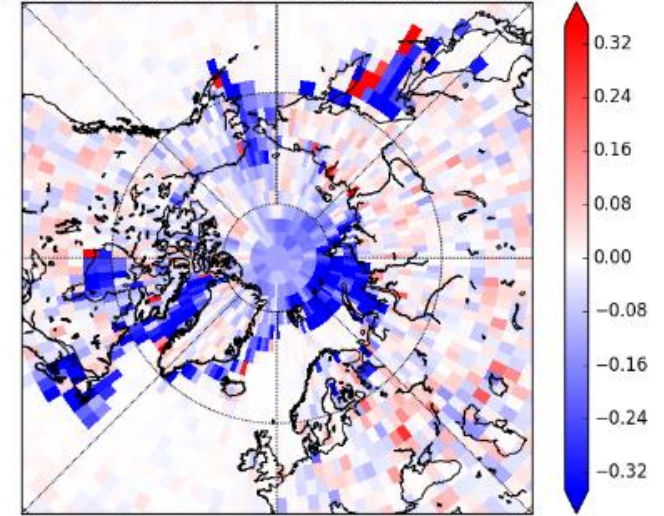
## 45r1 Sea-ice initialisation

*Normalised surface wave height and temperature RMS difference, computed for December 2016 to February 2017, between an experiment using OCEAN5 to initialise sea ice conditions and a control experiment using OSTIA sea ice.*

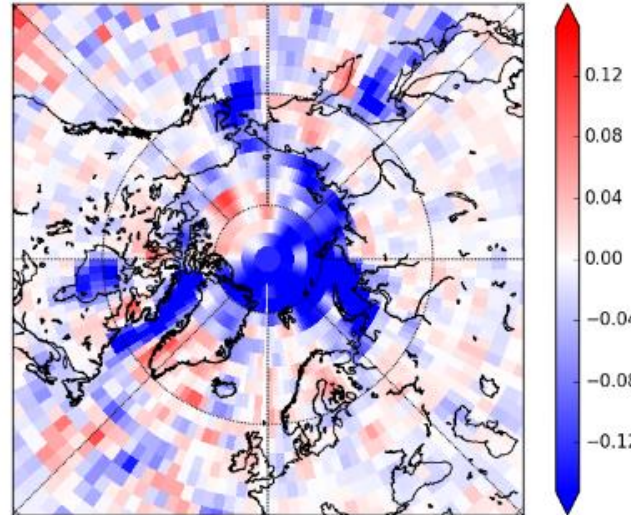
Normalised difference in RMS error of SWH T+24hrs



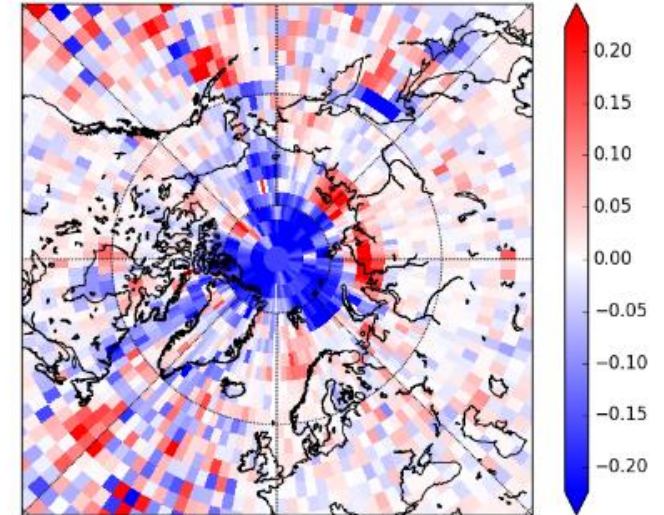
Normalised difference in RMS error of SKT T+24hrs



Normalised difference in RMS error of T at 1000hPa T+24hrs



Normalised difference in RMS error of Z2T T+24hrs



# Coupled assimilation: ready for science evaluation to begin in HRES

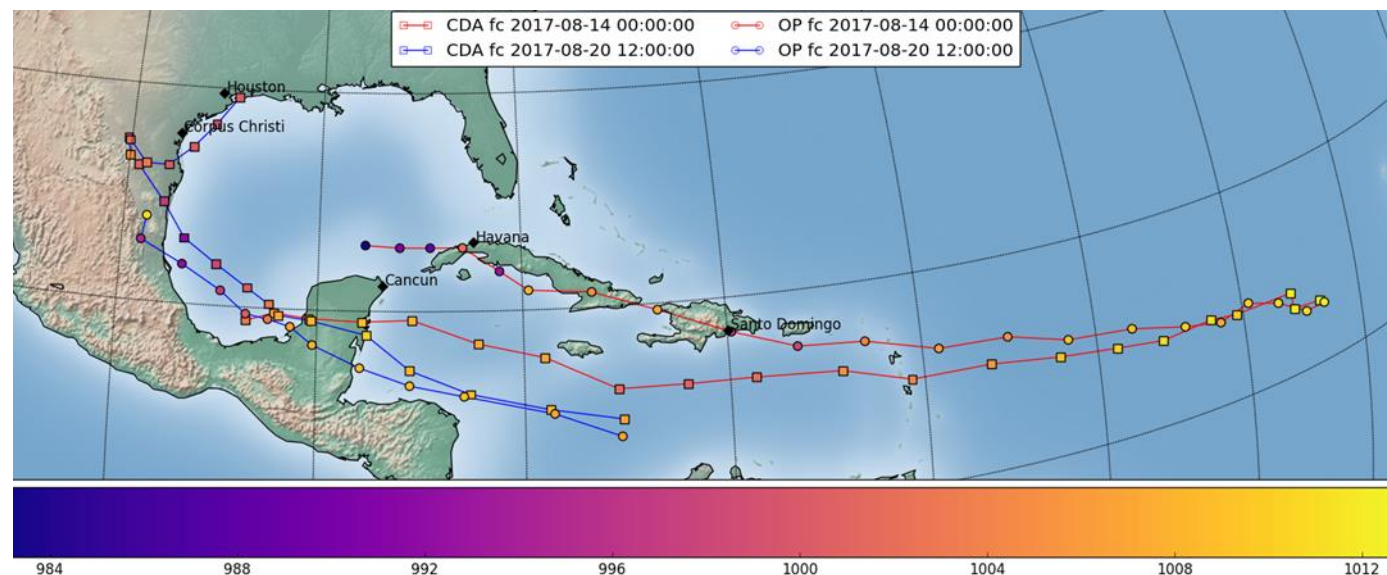
Weak coupling in 45r1 with coupled forecast changes

Outer-loop coupling tested in CERA-20C and CERA-SAT

Outer-loop coupling being evaluated in HRES IFS

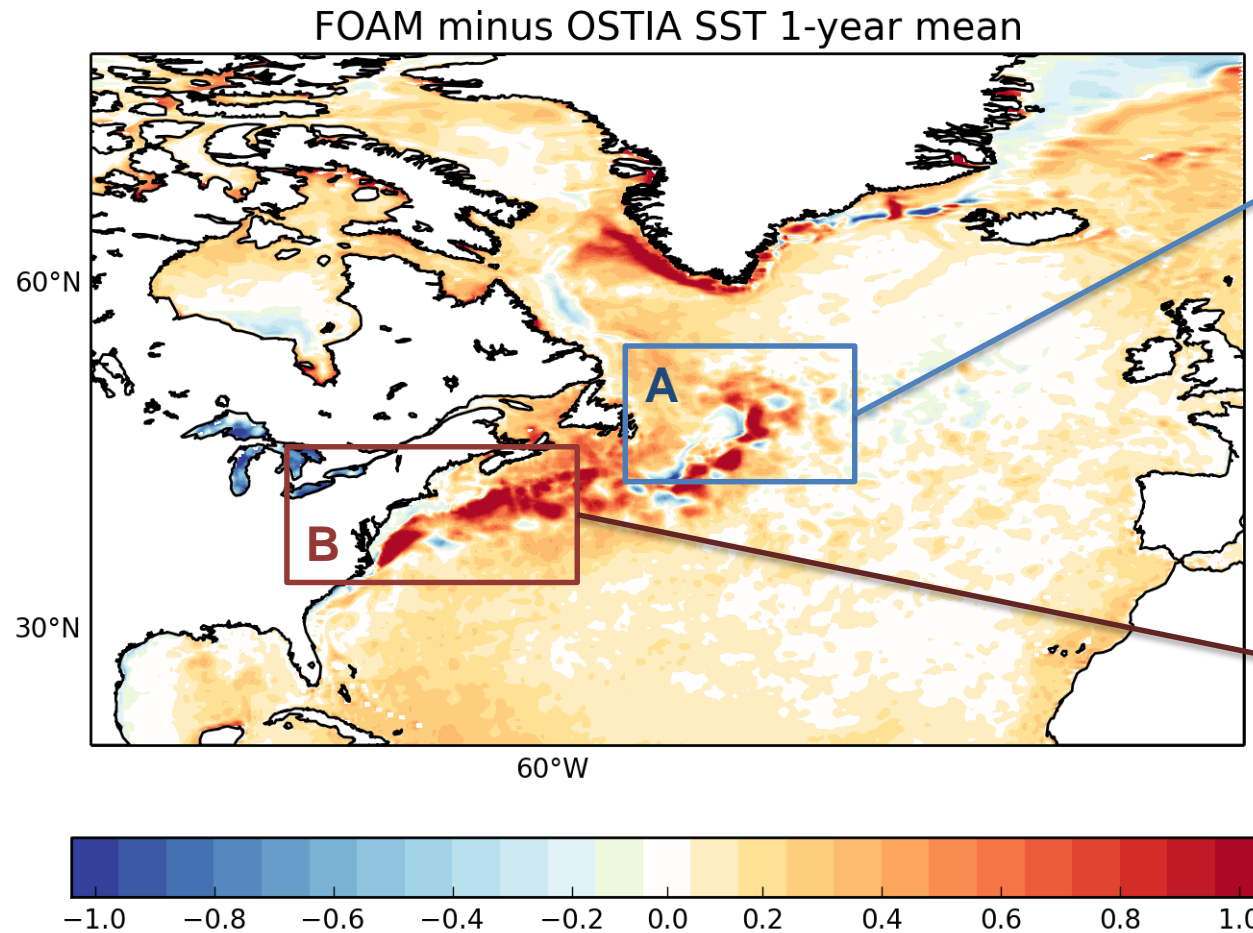
Research demonstration

Technical infrastructure



*Hurricane Harvey tracks are modified by using coupled DA – but **this is only the beginning of the scientific evaluation phase***

# Focus theme: North Atlantic SST errors



## A: Transition Zone

Flow-dependent errors in SEAS5  
(decadal modulation)

Objective: Remove the problem in ORAS6-  
SEAS6

## B: Gulf Stream Separation

High impact on prediction skill at all lead  
times

When can it be sorted out? (next 4 or next  
10 years? )

Implication for forecast strategies



# Conclusions

- Increasing complexity with coupling to ocean and sea-ice model
- Positive impact from both ocean and sea-ice initial conditions and dynamics
- Reduced intensity error in tropical cyclones
- Coupled assimilation research
- Boundary currents and Gulf stream separation