ECMWF forecasting systems

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Coupled Processes Team

ECMWF

Sea Ice in our current forecasting system

High Resolution (~9km) (10 day forecast): Atmosphere + wave model

- Initial conditions of sea ice – use OSTIA (OSISAF)
- Persist ice for the forecast

EPS & Monthly Forecast (15 days (~18km) + 31 days (~36km)) – 51mems Atmosphere, wave + ocean

- Persisted sea ice for first 15 days – use OSTIA (OSISAF)
- Persisted sea ice anomaly – relaxing towards climatology (last 5years)

Seasonal Forecast System 4: (7months ~80km) – 51 members

Atmosphere, wave + ocean

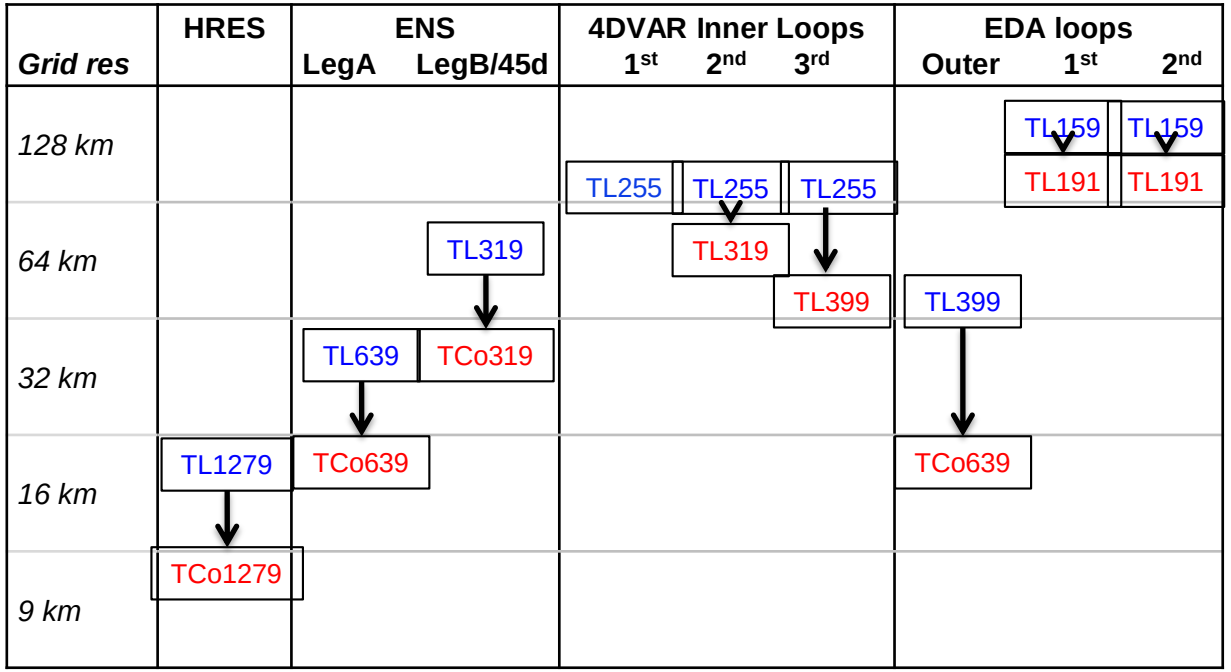
- Sea ice condition selected from previous 5 years
- Sea-ice for the first 10 days of the forecast persists the initial sea-ice analysis; then over the next 20 days there is a transition towards the specified ice conditions from the previous 5 years.

Ocean model: NEMOv3.4 1deg resolution 42 levels

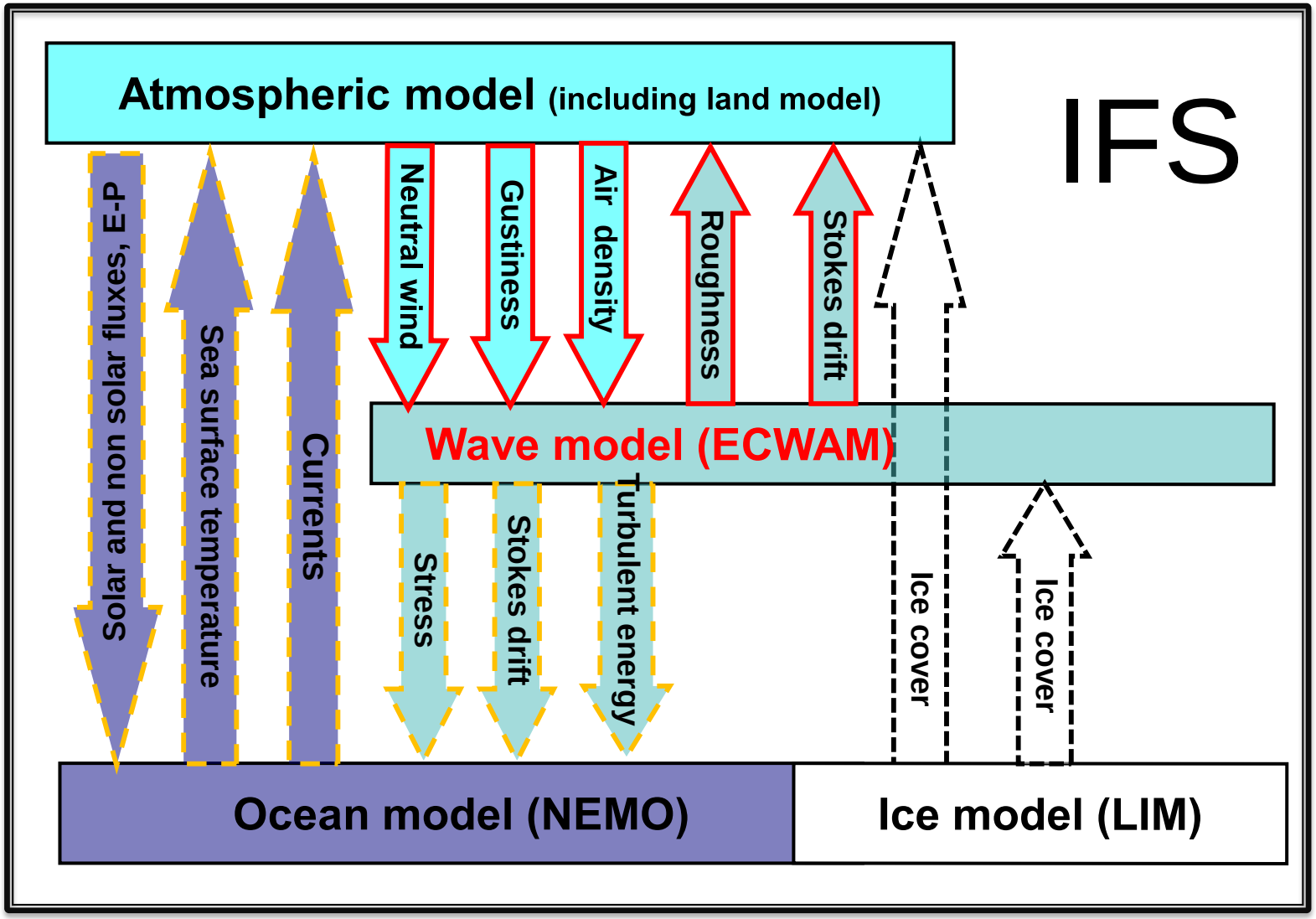
ECMWF

Changes to our forecast system

2016 atmos resolution upgrade: 41r1 → 41r2
from linear (L) grid to cubic octahedral (Co) grid



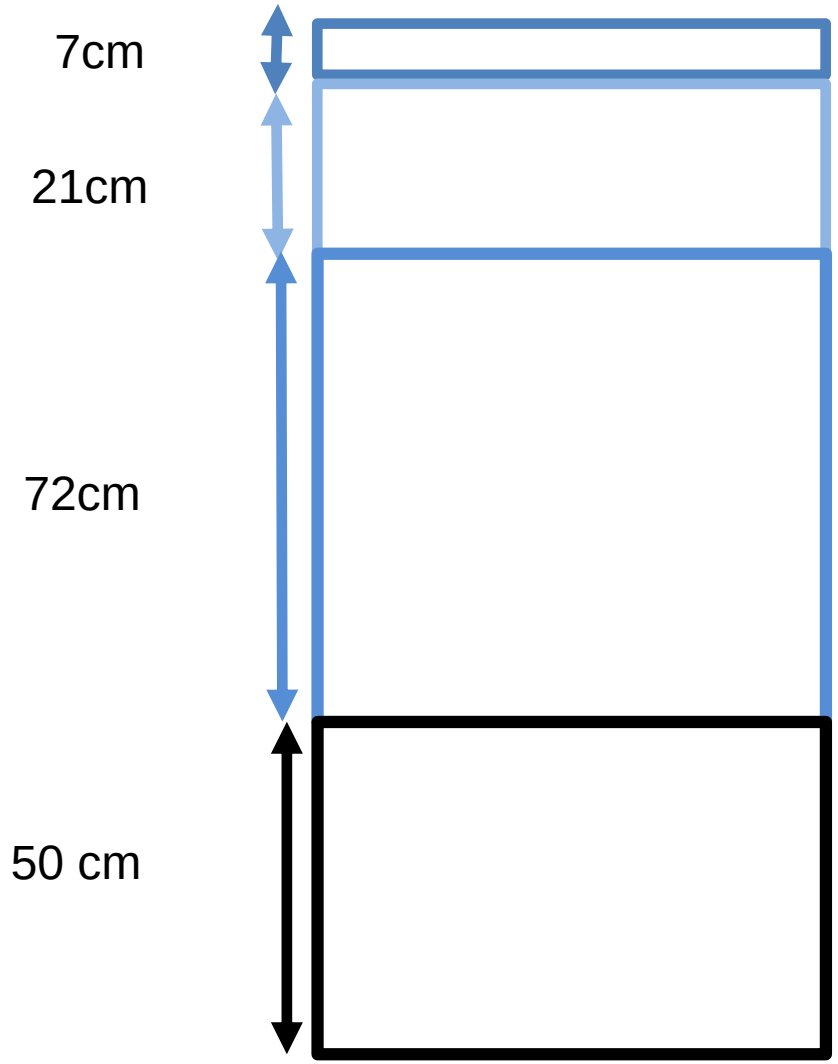
Ocean model upgrade in 22 Nov 2016
(NEMO 3.4): from 1.0º/42 lev to 0.25º/75 lev
Add dynamic sea ice model


Atmospheric model (including land model)
IFS
Solar and non solar fluxes, E-P
Sea surface temperature
Currents
Neutral wind
Gustiness
Air density
Roughness
Stokes drift
Wave model (ECWAM)
Stress
Stokes drift
Turbulent energy
Ice cover
Ice cover
Ocean model (NEMO)
Ice model (LIM)

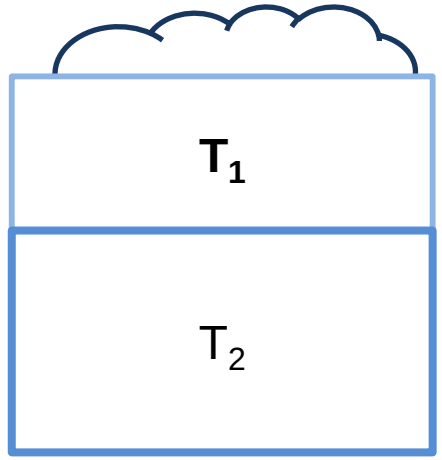
Ice model in the IFS (atmosphere-land)

- 4 level model
- 1.5 m in thickness -fixed
- No snow on top
- Albedo climatology

- Thermodynamics considered



Coupling of a dynamic sea ice model



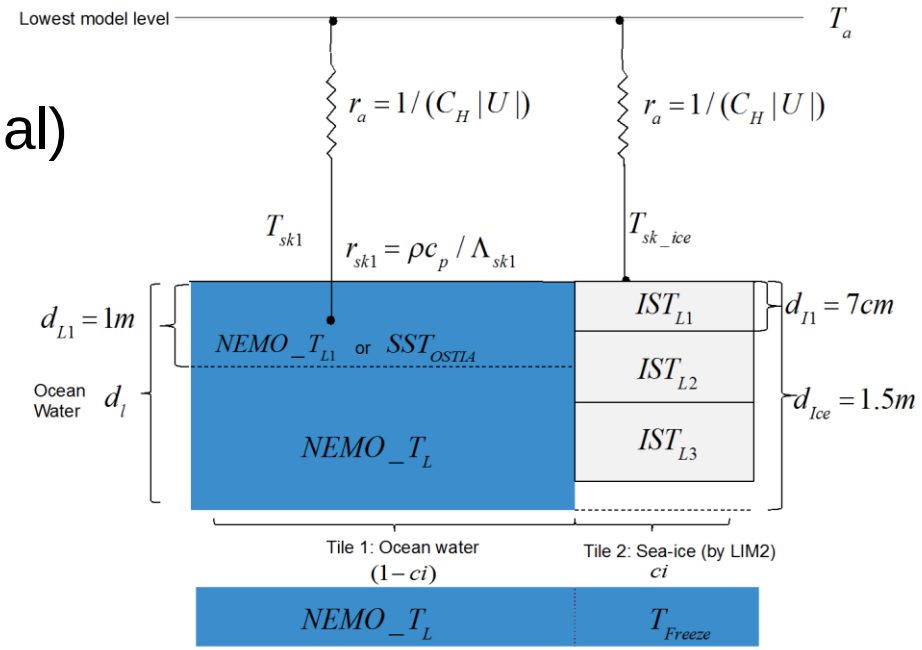
Ice Model

- Louvain-la-Neuve Ice Model (LIM 2)
- 3 thermodynamic layers (two ice layers and snow layer)

Coupling to atmospheric model

Ice to ice coupling

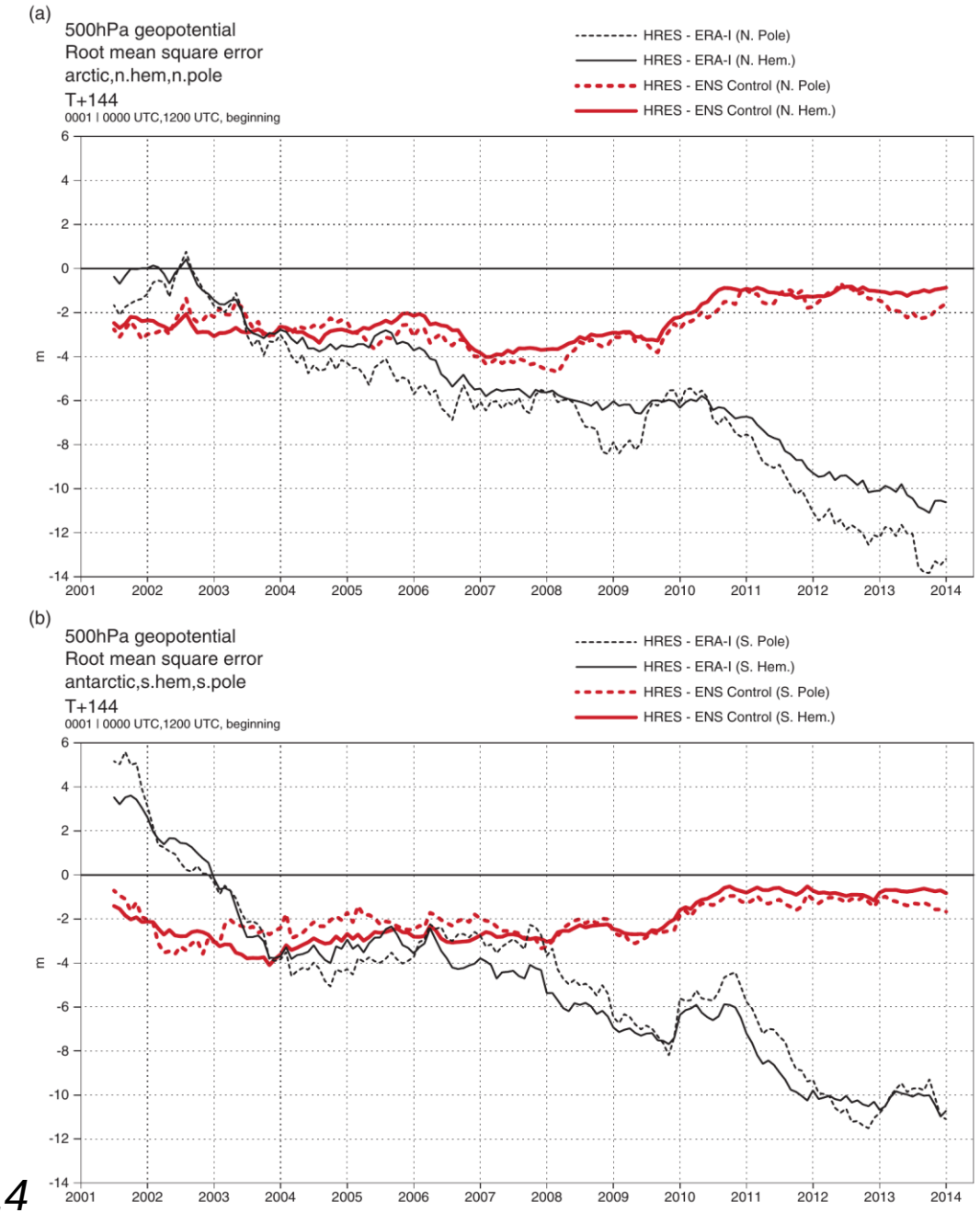
- Ice fraction
- surface temperature of ice (or snow if present) (optional)
- albedo (optional)



ECMWF

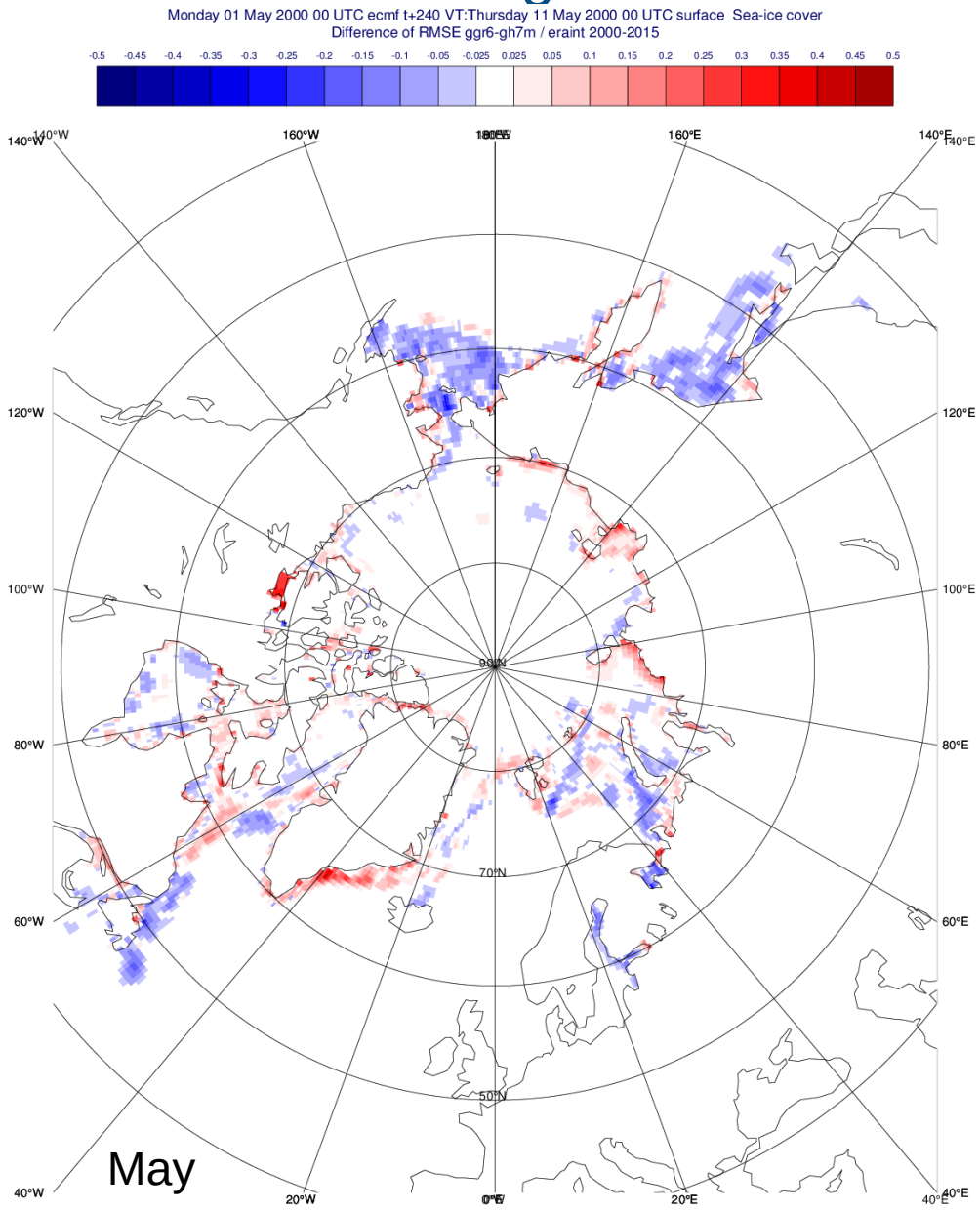
Polar Region Forecasts (Day 6)

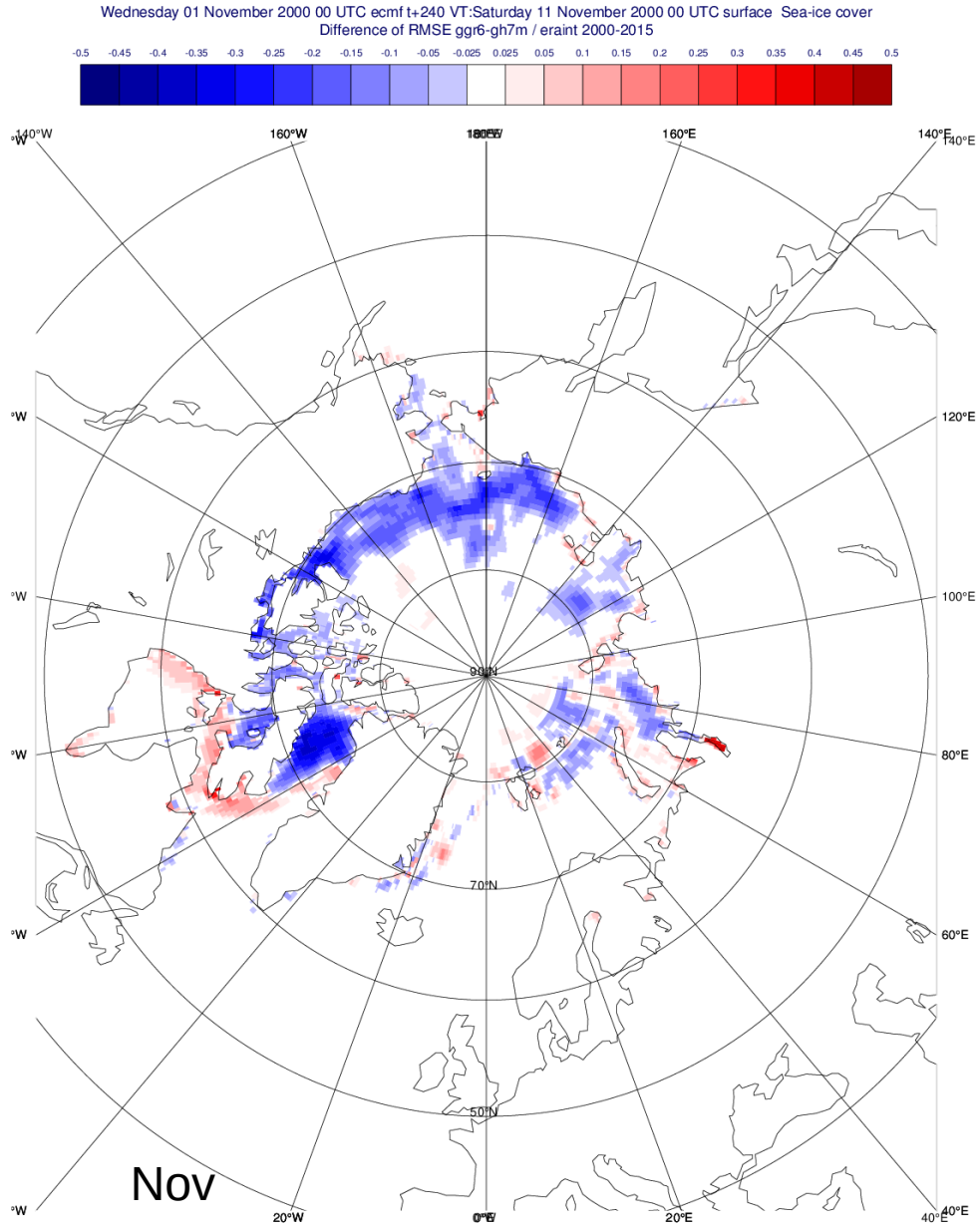
- General error reduction over the past decade
- Improvements in model and data assimilation systems
- Higher resolution does help to reduce some of the errors in the forecast



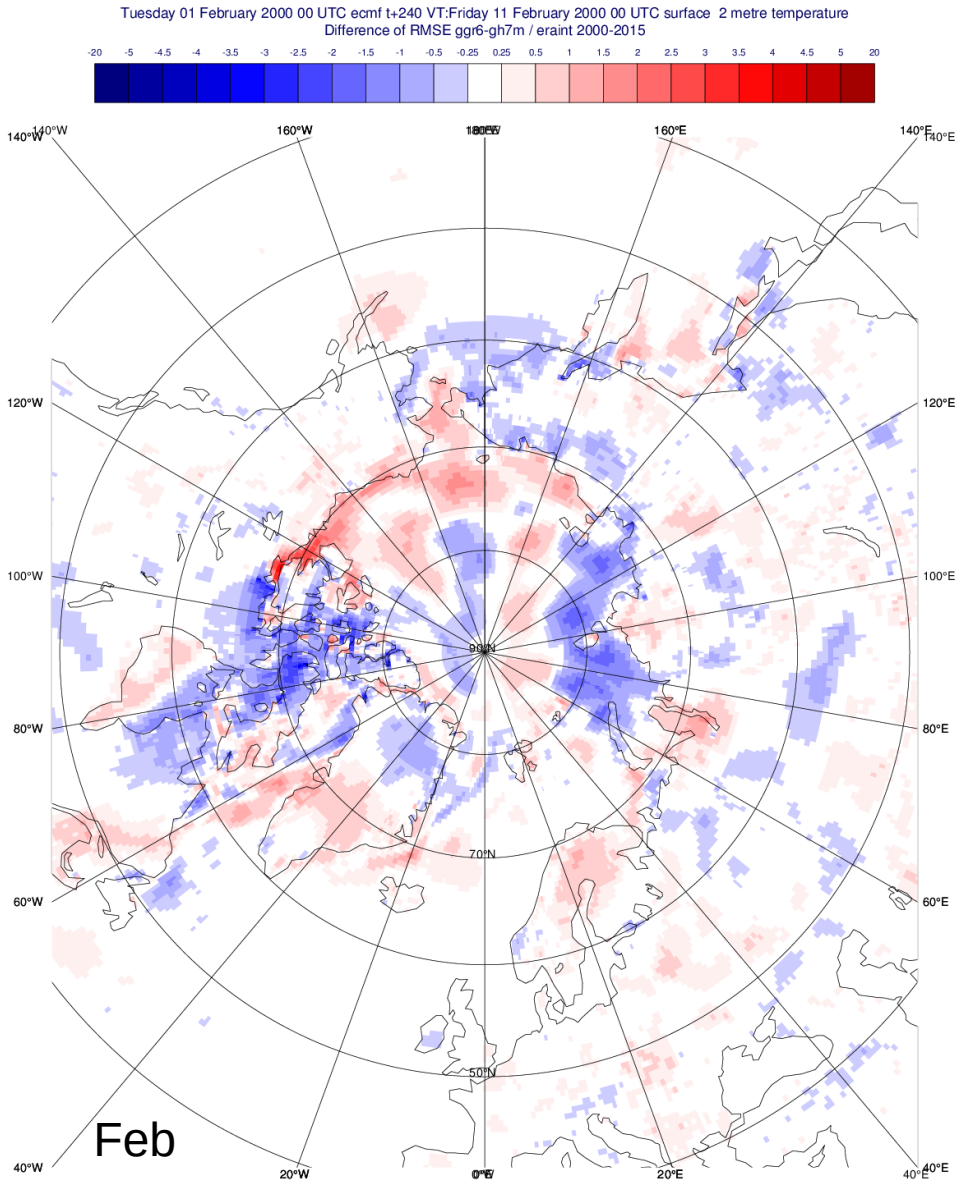
Bauer et al. 2014

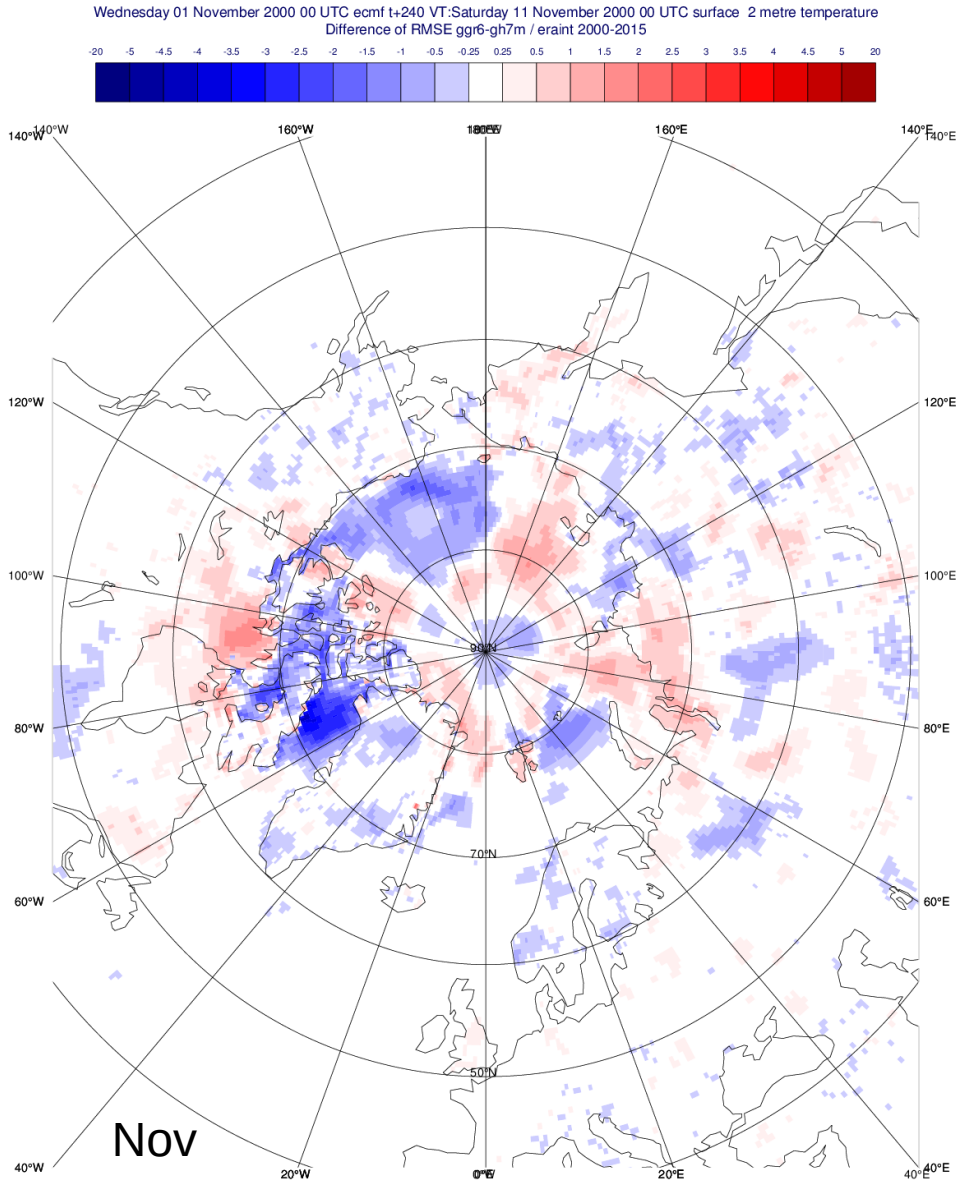
Change in RMSE for sea ice cover at day 10 during





Change in RMSE for winter months for 2mT – when sea ice has the strongest influence

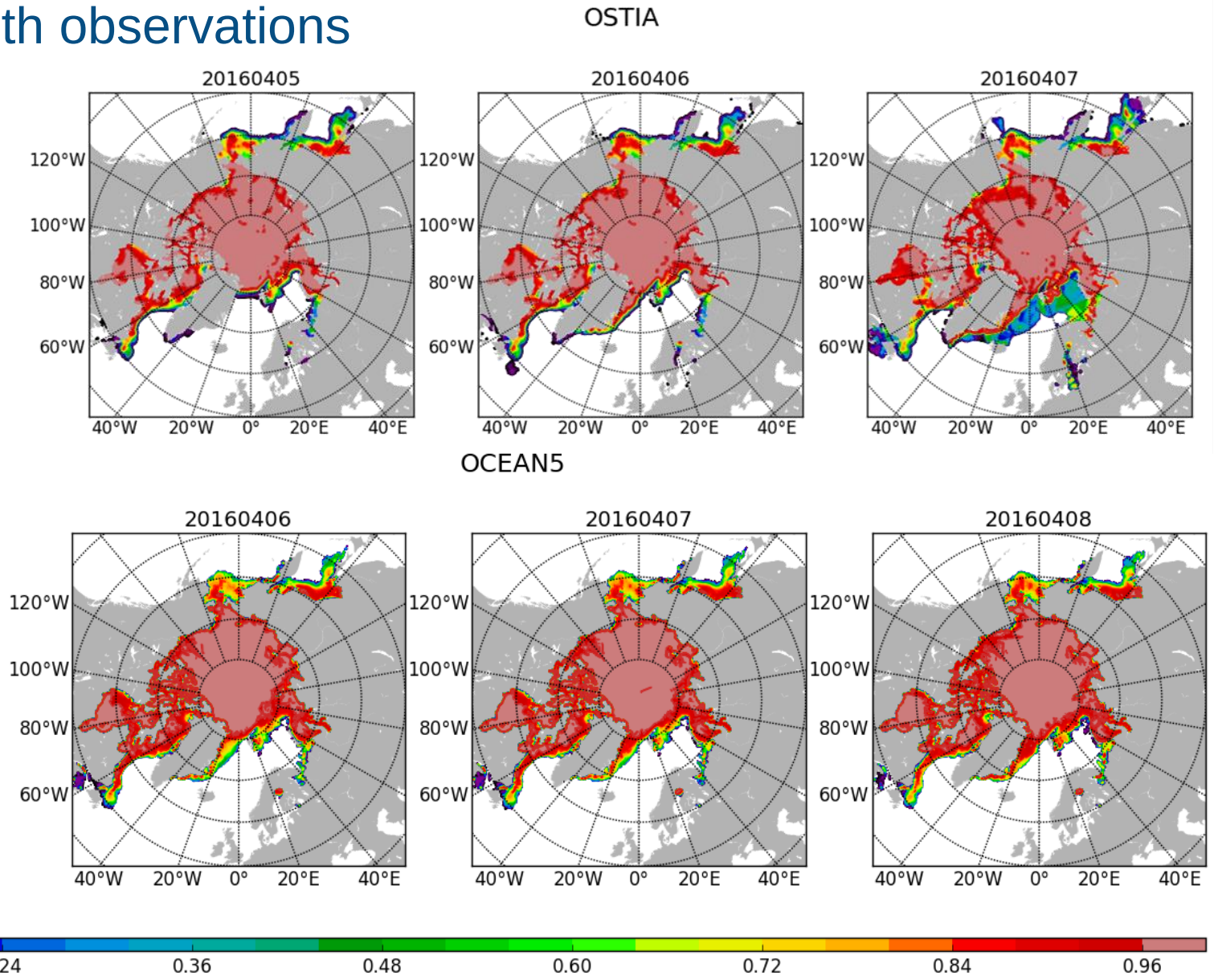




Data assimilation working with observations

Gridded satellite sea ice concentration product used with a day delay

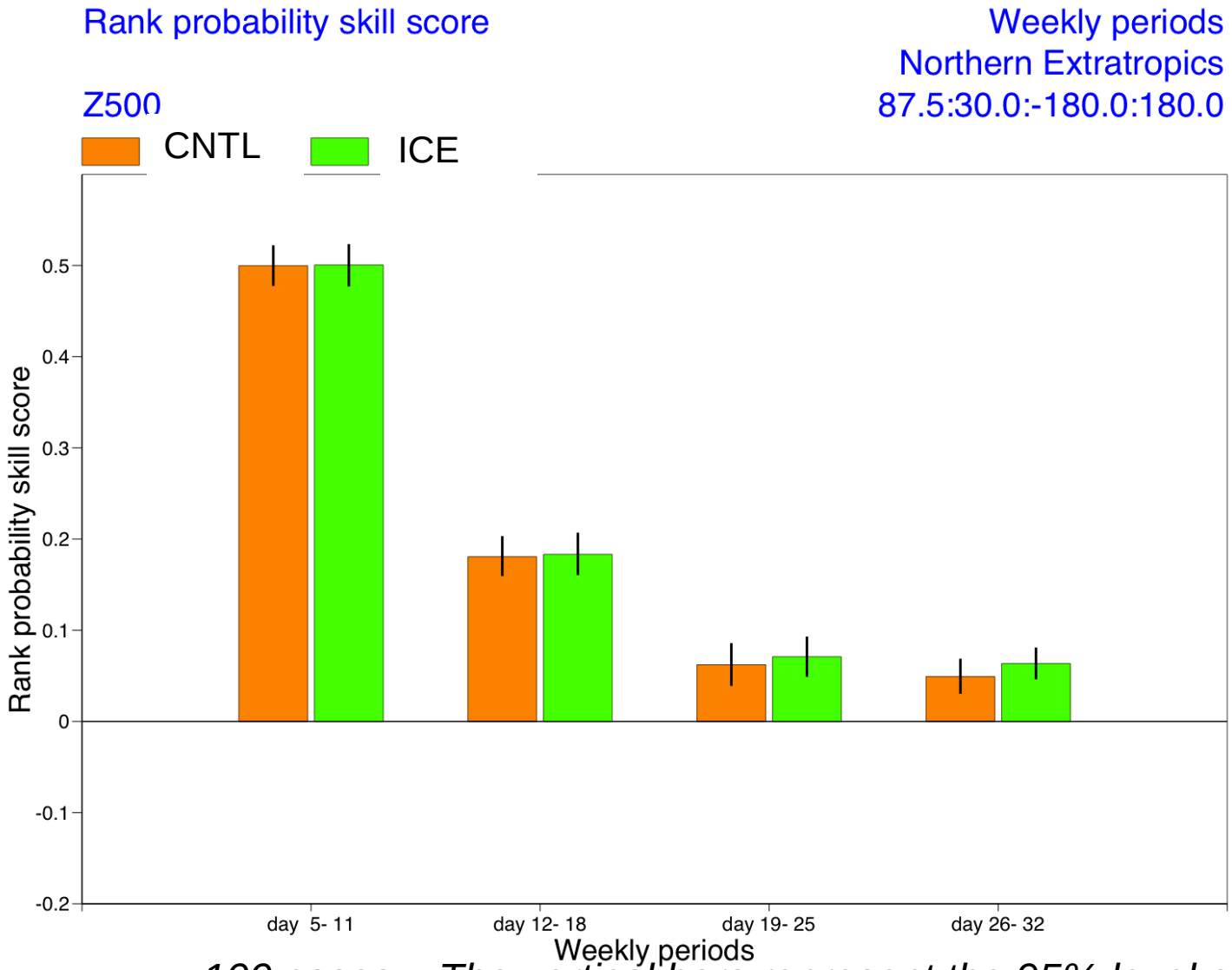
3DVar assimilation system reduces the exposure to data issues



Ensemble experimental set up

- 15 member ensemble
- Coupled T639(T319) atmos 91 levels to NEMO3.4 ORCA025 75 levels
  - Control (old ice formulation Persistence – damped anomaly)
  - Ice using Ice model (LIM2 VP)
- Uses ensemble of initial conditions from ORAS5 (3DVAR ocean-ice assimilation)
  - 5 different ocean-ice states
- Start dates 1st of Month (46 day forecast)
  - February, May, August, November
- Run for preiod 1989-2014

Headline scores comparing ERA-I with: CNTL (persisted – climate ice) and LIM2



100 cases – The vertical bars represent the 95% level of confidence

S5 overview

- No official announcement yet, the following is expected but subject to change

- SEAS5 will be implemented in 2017, using Cy43r1
- Testing is taking place now to determine the configuration to be used

- Indicative timetable:
  - Dec 2016: Finalize decisions on configuration
  - Jan 2017: Start production of re-forecasts
  - Mar 2017: Start real-time suite in test mode
  - 1 July: earliest possible switch of operations to S5

Drivers for S5 decision

- S4 is now 5 years old (Nov 2011). Maintenance is a significant issue.

- Latest IFS cycles show improvements in model climate and forecast performance. As always, newer is not automatically better, and not everything will improve.
- Ongoing research has focussed on identified weaknesses and limitations of S4 (land initialization, NH predictability, QBO). Significant progress has been made, but as ever, research continues.
- ORCA025 (1/4 deg) ocean is available, plus corresponding analysis (ORAS5).

- Atmospheric resolution: multiple studies (including MINERVA) have shown improvement in structure of N. Atlantic winter predictability with high atmospheric resolution
- Increased HPC resources are available, in particular due to funding by C3S

- Long term desire to “converge” extended and seasonal range systems. Upgrade allows us to take steps in that direction

Comparison between S4, expected S5 and ENS Leg B

	S4	SEAS5	ENS Leg B (15-45 days)
HRES	TL255 / N128	TCo319 / N320	TCo319 / N320
Grid spacing	80km	32km	32km
Timestep	2700s	1200s	1200s
VRES	L91	L91	L91
Ocean res	ORCA1/L42	ORCA025/L75	ORCA025/L75
Sea-ice	Prescribed, last 5 years	LIM2	LIM2
Stochastic physics	SPPT3+SKEB	SPPT3	SPPT3+SKEB (conv only)
NOGWD	Custom tuned	GGAUSSB=-0.95	GGAUSSB=-0.25
Ozone	Interactive/Cariolle	Interactive/BMS	Climate
Tropospheric sulphate aerosol	Fixed climate	Decadally varying (CMIP5)	Fixed climate
Land sfc ICs	Offline/ops	Hi-res offline/ops	Hi-res offline/ops

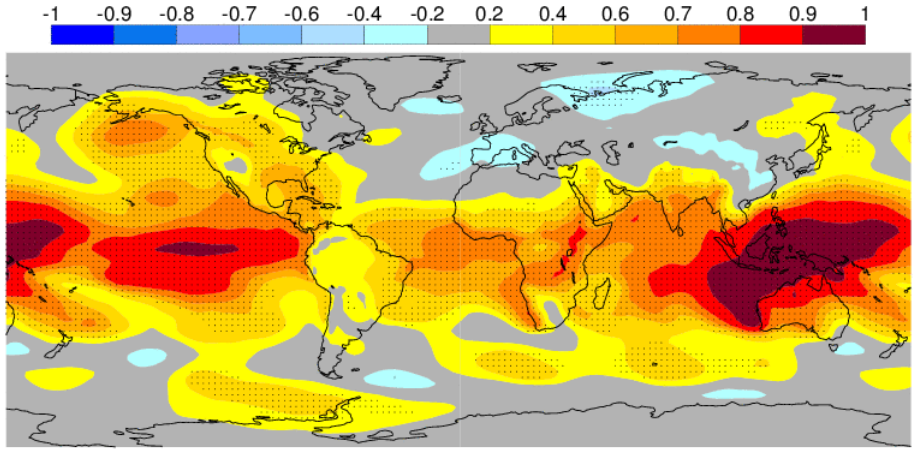
- Land surface initialization believed to be significantly improved
- Higher horizontal resolution (TCo399/N400, 25km) is still a possibility
- Re-forecast set will differ from S4: 25 members instead of 15, calibration probably from 1993 instead of 1981

Summary

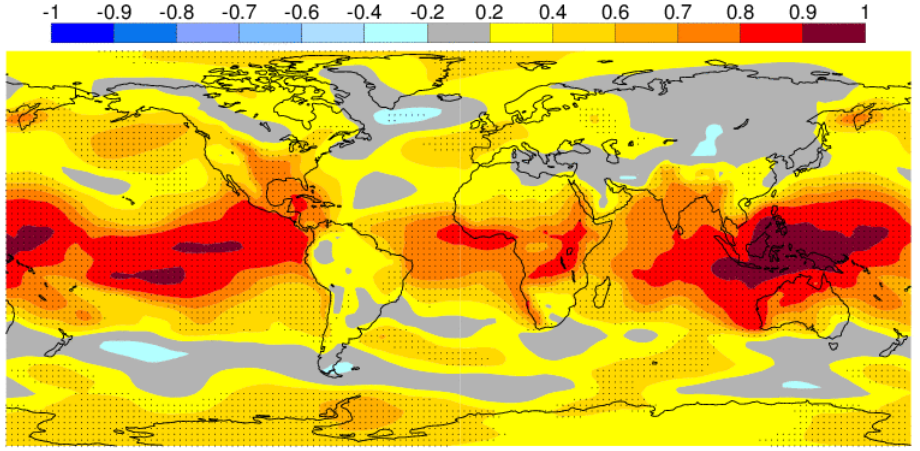
- S5 will become operational in 2017
  - initial re-forecast set should be complete by summer
  - additional re-forecast runs may be made later (eg extension of some dates to 51 members)
- Resolution:
  - ORCA025 instead of ORCA1 (expensive)
  - TCo319/N320 (at least)
  - Stick with 91 levels for now – compatibility with ENS
- Cy43r1
  - Improved tropical biases, ENSO
  - Improved land surface and initialization
- S6 just over the horizon
  - C3S resources allow more frequent updates, maybe 2-3 years instead of 5 years
  - Stratosphere / stochastic physics improvements are targeted for S6

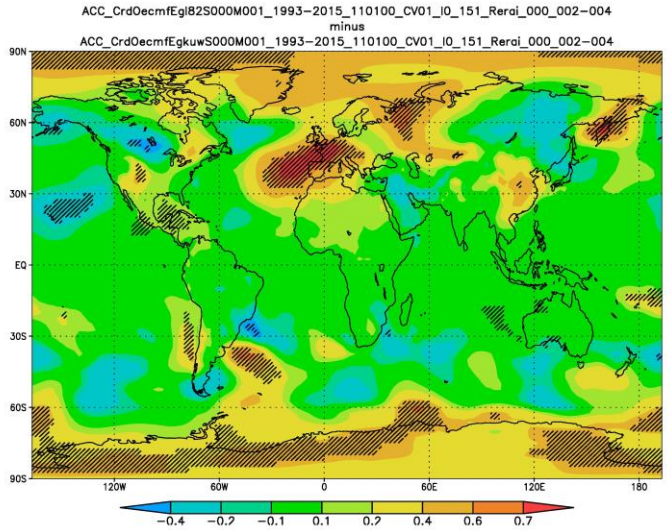
Tropospheric scores

Anomaly Correlation Coefficient for ECMWF gkuw with 5 ensemble members
Mean sea level pressure
Hindcast period 1993-2015 with start in November average over months 2 to 4
Black dots for values significantly different from zero with 95% confidence (1000 samples)



Anomaly Correlation Coefficient for ECMWF gl82 with 5 ensemble members
Mean sea level pressure
Hindcast period 1993-2015 with start in November average over months 2 to 4
Black dots for values significantly different from zero with 95% confidence (1000 samples)





Future developments

- Coupling:
  - More complex/update coupling interface with IFS
    - Confront model with observations
    - Understand energy budgets in polar regions
  - Snow on ice
    - Radiation
    - Sea ice thickness measurements
  - Waves and ice model
- More complex ice model – LIM3
  - Improvements to albedo – melt ponds vs prescribed values
  - Initialisation of multicategory system
- Robust metrics for assessing the model changes