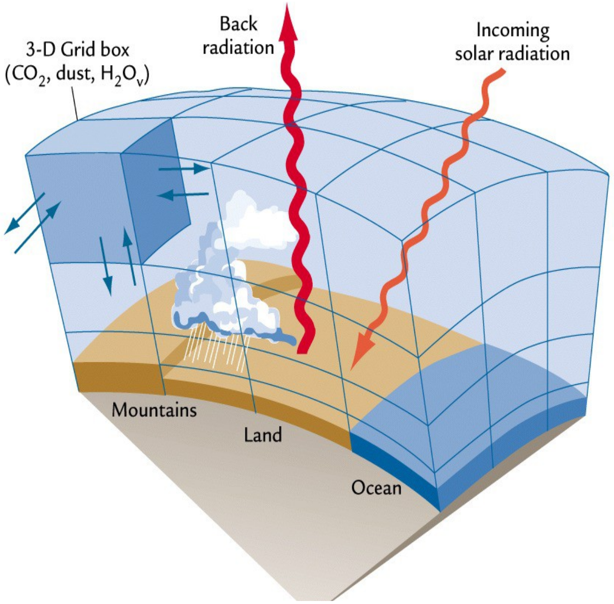
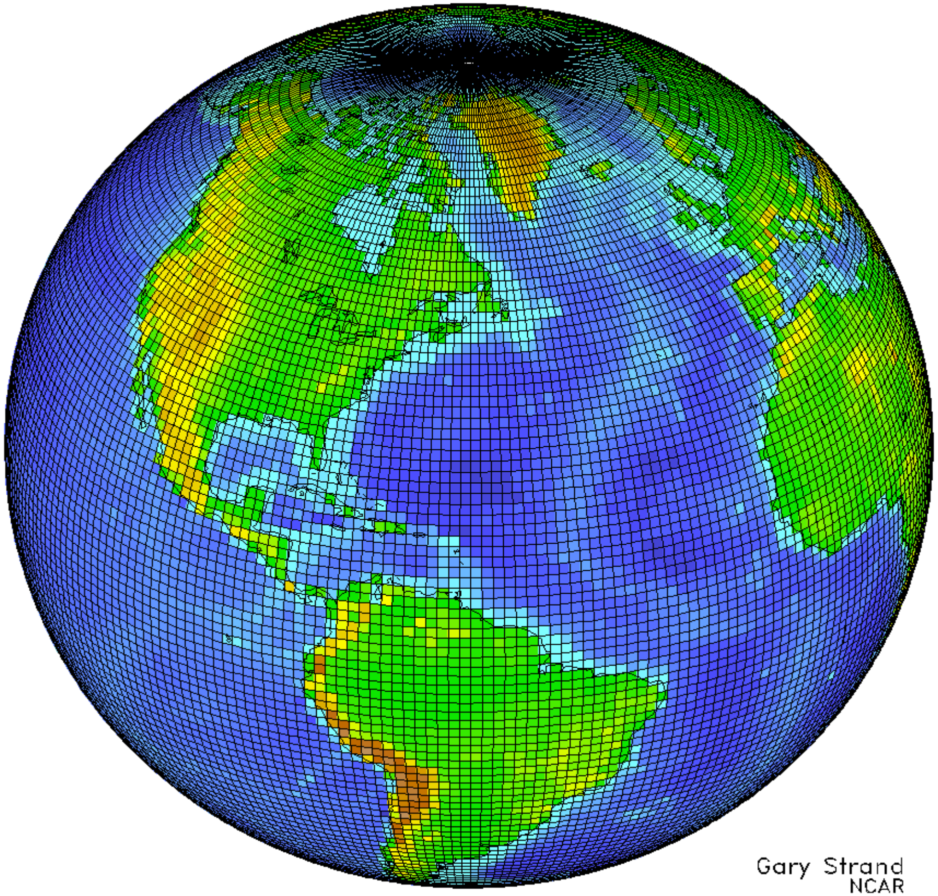
ec-earth.org

From predicting weather to simulating climate

A European Earth System model open to the European climate science community

Ralf Döscher, Rossby Centre, SMHI





Modeling of Climate and Weather

3-D representation of Earth's soil, vegetation, atmosphere, ocean.

In Global Climate Models the entire globe is discretised into a regular grid and the equations governing the evolution of the variables describing the climate system are solved forwards in time. This allows a projection of the future evolution of the climate (e.g. atmosphere, ocean etc) to be made.

3-D model based on fundamental laws of physics:

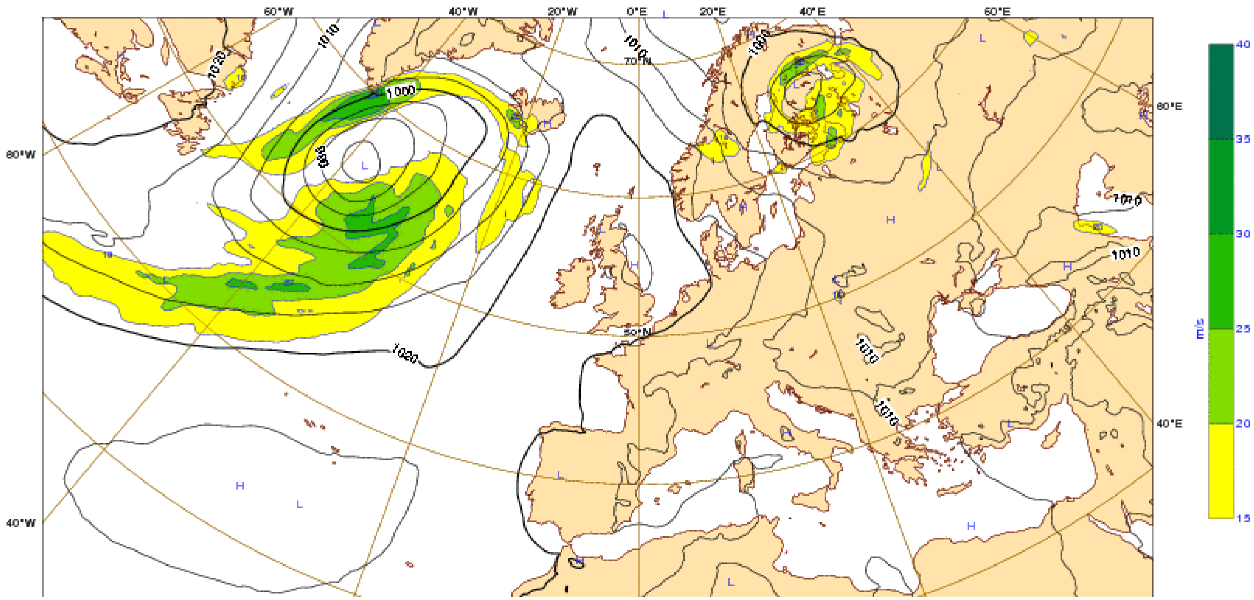
- Conservation of momentum
- Conservation of mass
- Ideal Gas Law (equation of state)
- Conservation of energy

Typical resolutions for climate

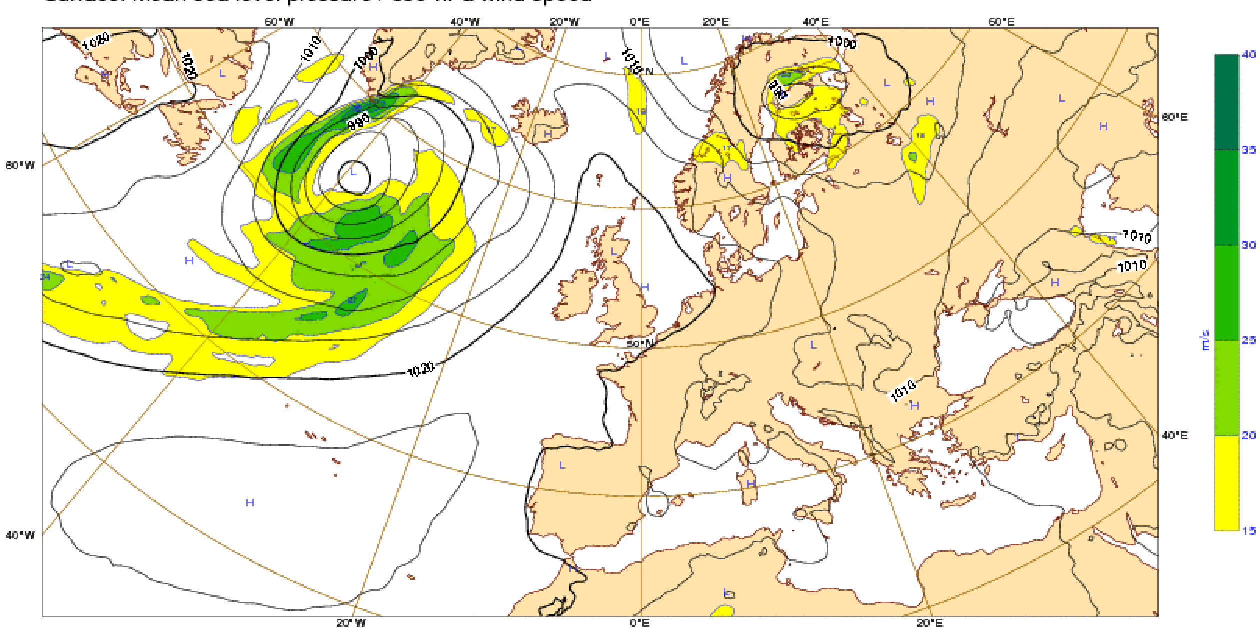
- Recently: 1-2 degrees
- now: Better than 1 degree
- Soon: towards 20 km

ECMWF weather forecasting

Thursday 11 June 2015 12UTC ©ECMWF Forecast t+096 VT: Monday 15 June 2015 12UTC
Surface: Mean sea level pressure / 850-hPa wind speed



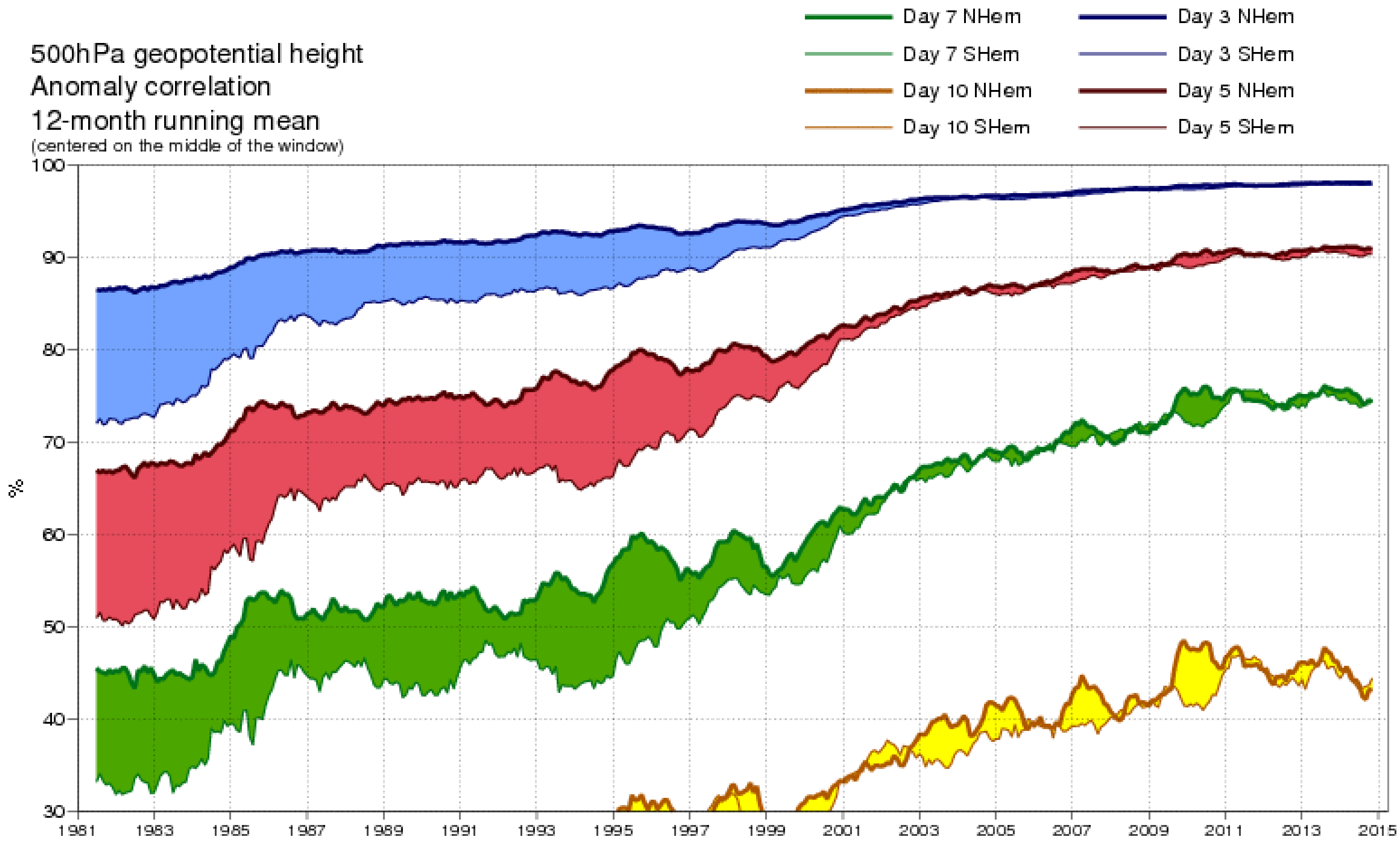
Sunday 14 June 2015 12UTC ©ECMWF Forecast t+024 VT: Monday 15 June 2015 12UTC
Surface: Mean sea level pressure / 850-hPa wind speed



- World leading
- Integrated Forecasting System (IFS)
  - to model the dynamics and physical processes, such as the formation of clouds
  - other processes that influence the weather such as land processes.

ECMWF weather forecasting

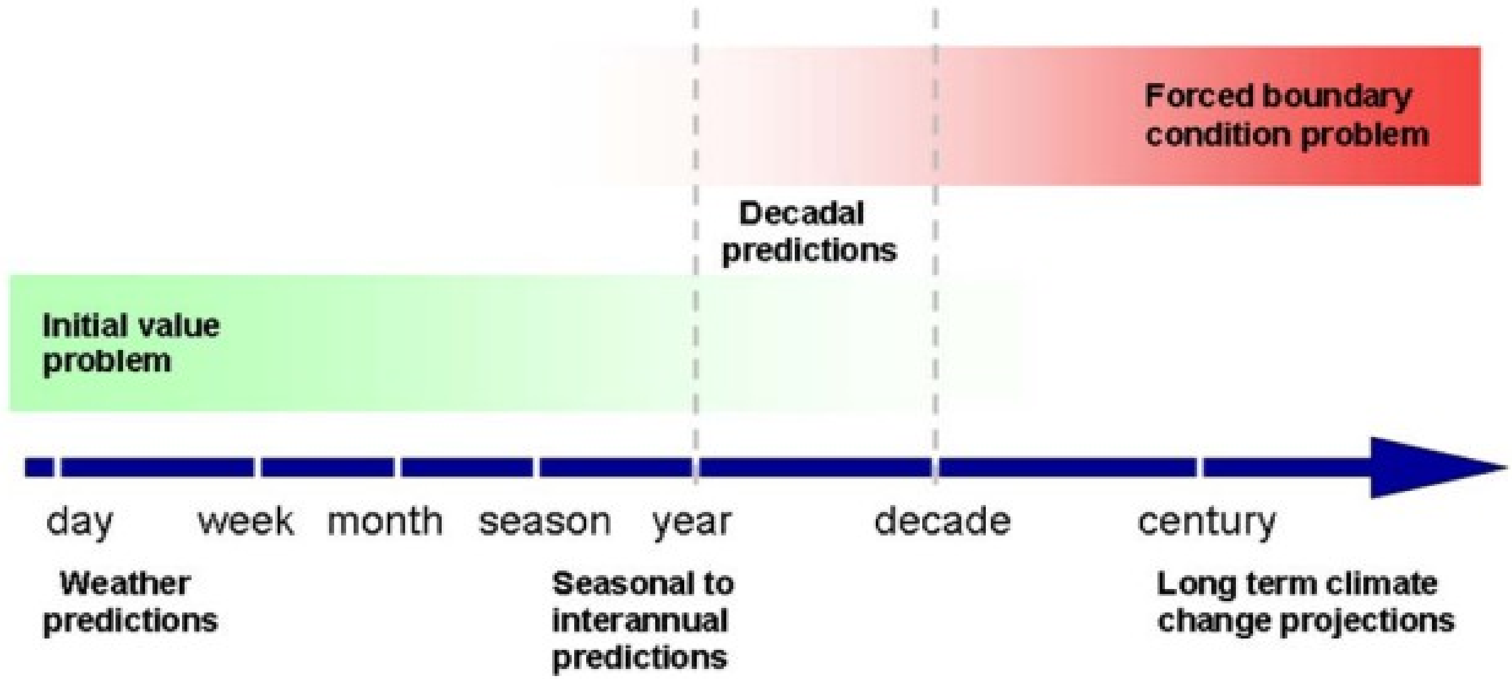
forecast skill



Time series of the annual running mean of anomaly correlations of HRES 500 hPa height forecasts evaluated against the operational analyses for the period January 1981 till present.

From weather to climate

Weather **Climate**



Box 11.1, Figure 2: A schematic illustrating the progression from an initial-value based prediction at short timescales to the forced boundary-value problem of climate projection at long timescales. Decadal prediction occupies the middle ground between the two (based on Meehl et al. (2009b)).

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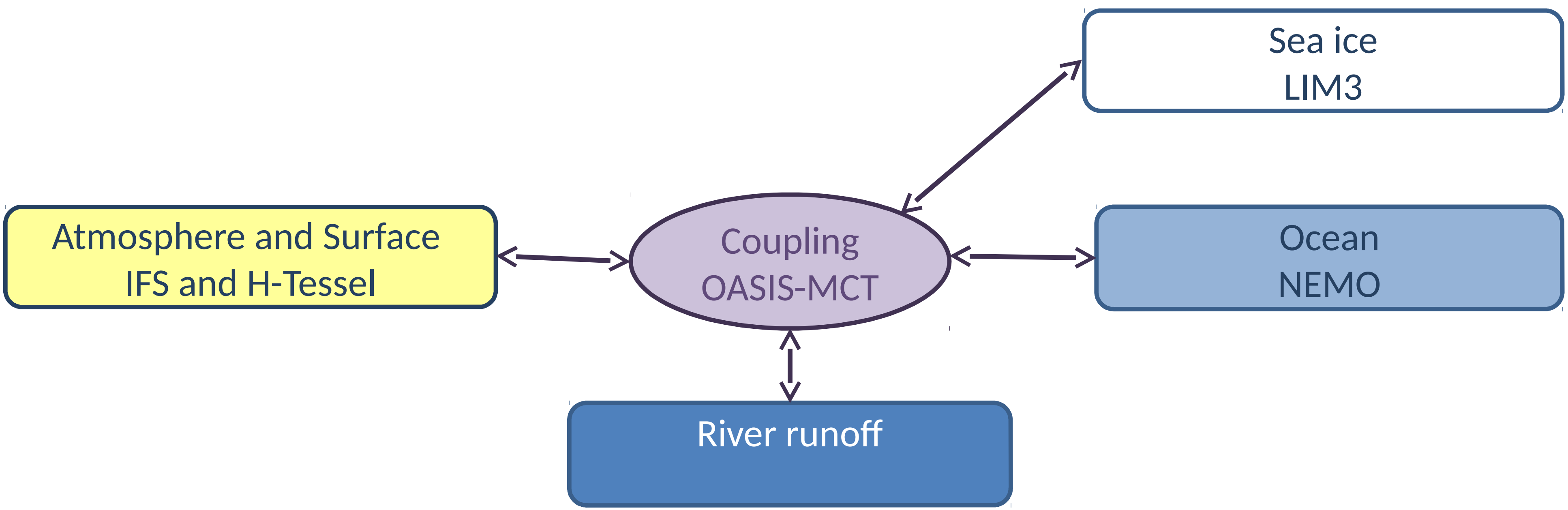
A European Consortium for Earth System Modeling

- 29 partner institutes
  - In Sweden: SMHI, Bolin Centre, Lund university, Gothenburg university, Uppsala university
- 8 core partners
  - KNMI, SMHI, AEMET, DMI, Met Éireann, FMI, IPMA, CNR-DTA
- Steering group
- Work groups
  - Technical
  - Tuning
  - Atmospheric Composition and Land
  - Ocean
  - Millennium scale studies
  - CMIP6
  - Climate prediction (to be started)

The Main objective is “to develop and apply **an Earth System Model** based on ECMWFs ... forecasting system for providing trustworthy **climate information** to climate services and to **advance scientific knowledge on the Earth system, its variability, predictability and long-term changes resulting from external forcing**”. (Science and development plan, 2014)

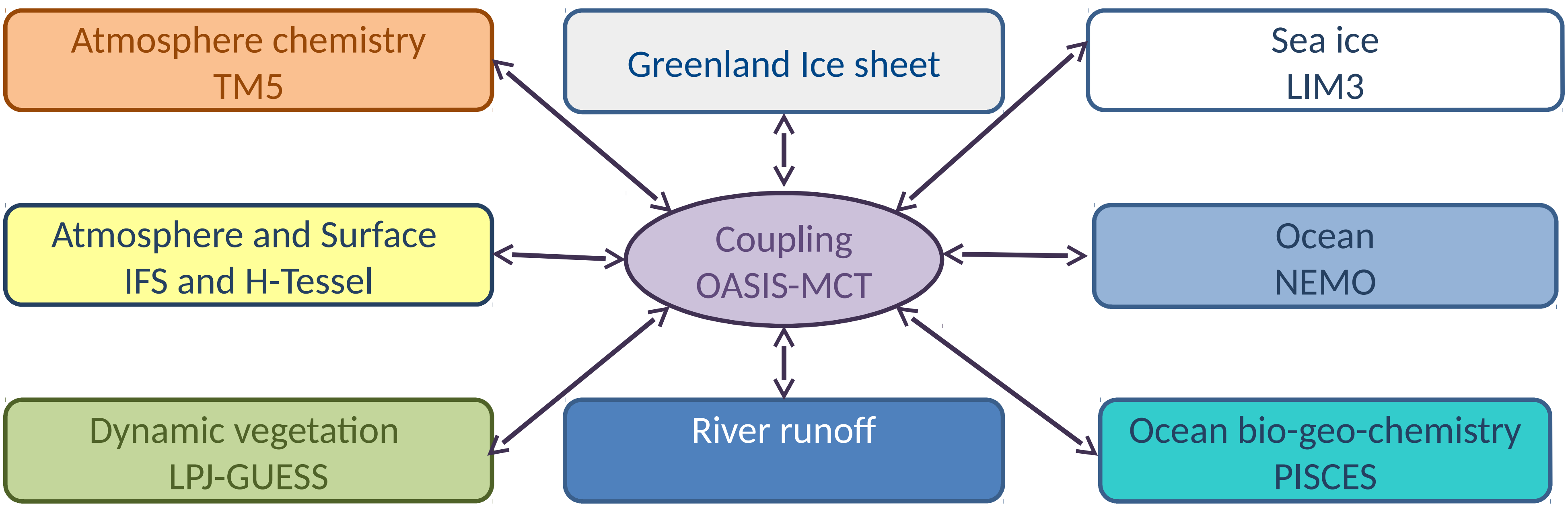
GCM

Global Climate Model



ESM

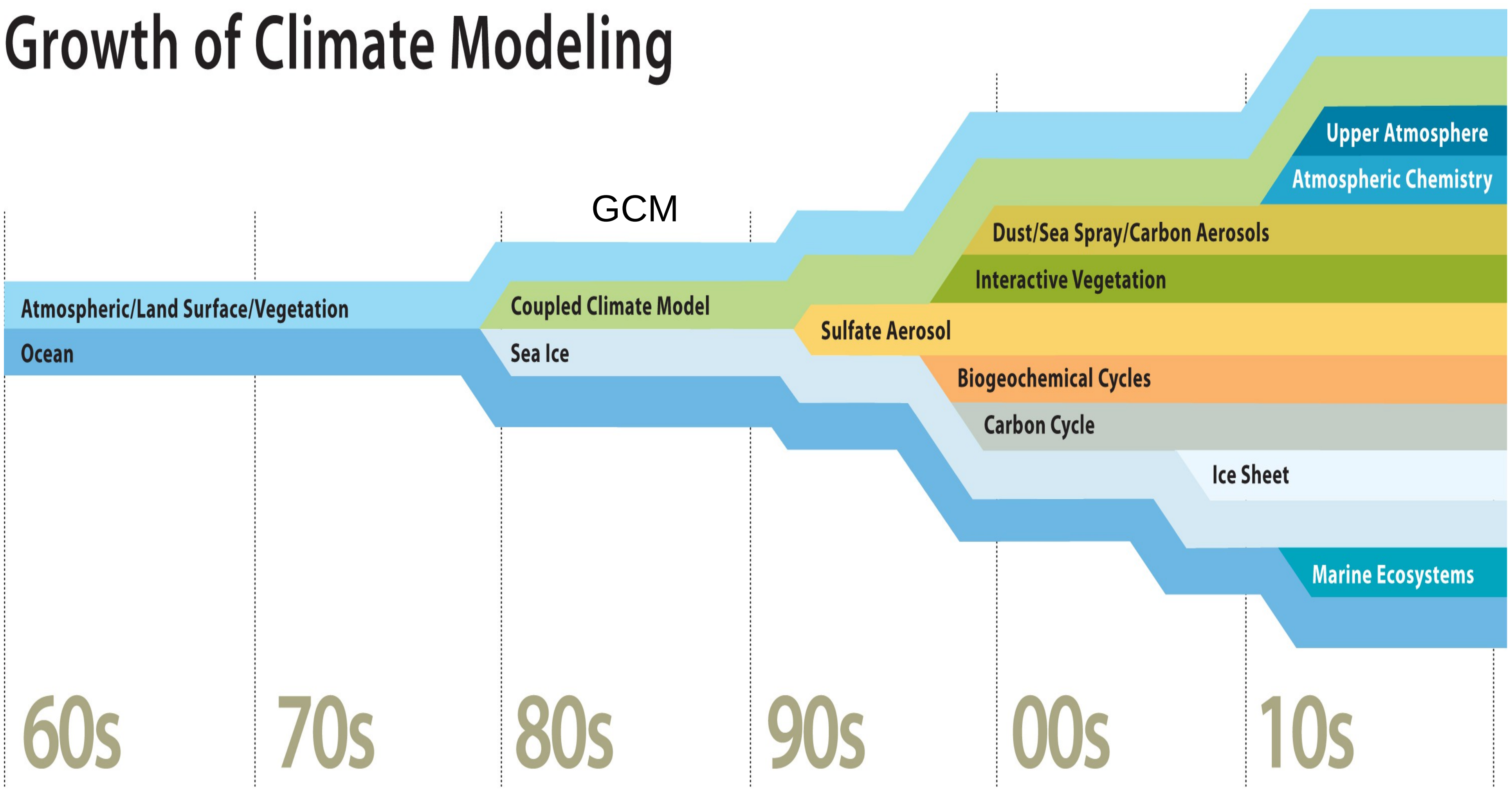
Earth System Model



ESMs add

- A more complete system including more feedbacks
- Interactive carbon cycle
- More variables of direct relevance for users
- ...

From GCM to ESM

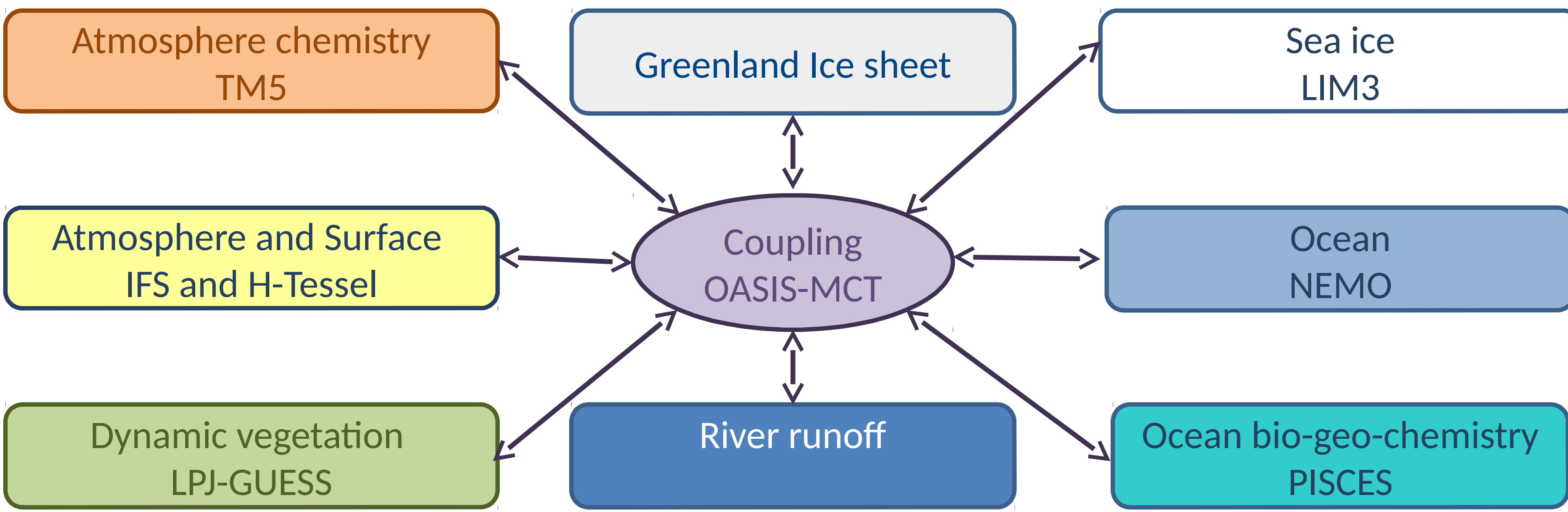


+ Nitrogen cycle
+ small glaciers
+ permafrost
+ methane
+ economical impact and feedbacks

EC-EARTH Consortium members

ESM

Earth System Model



ESMs add

- A more complete system including more feebacks
- Interactive carbon cycle
- More impact variables of direct relevance for users
- ...

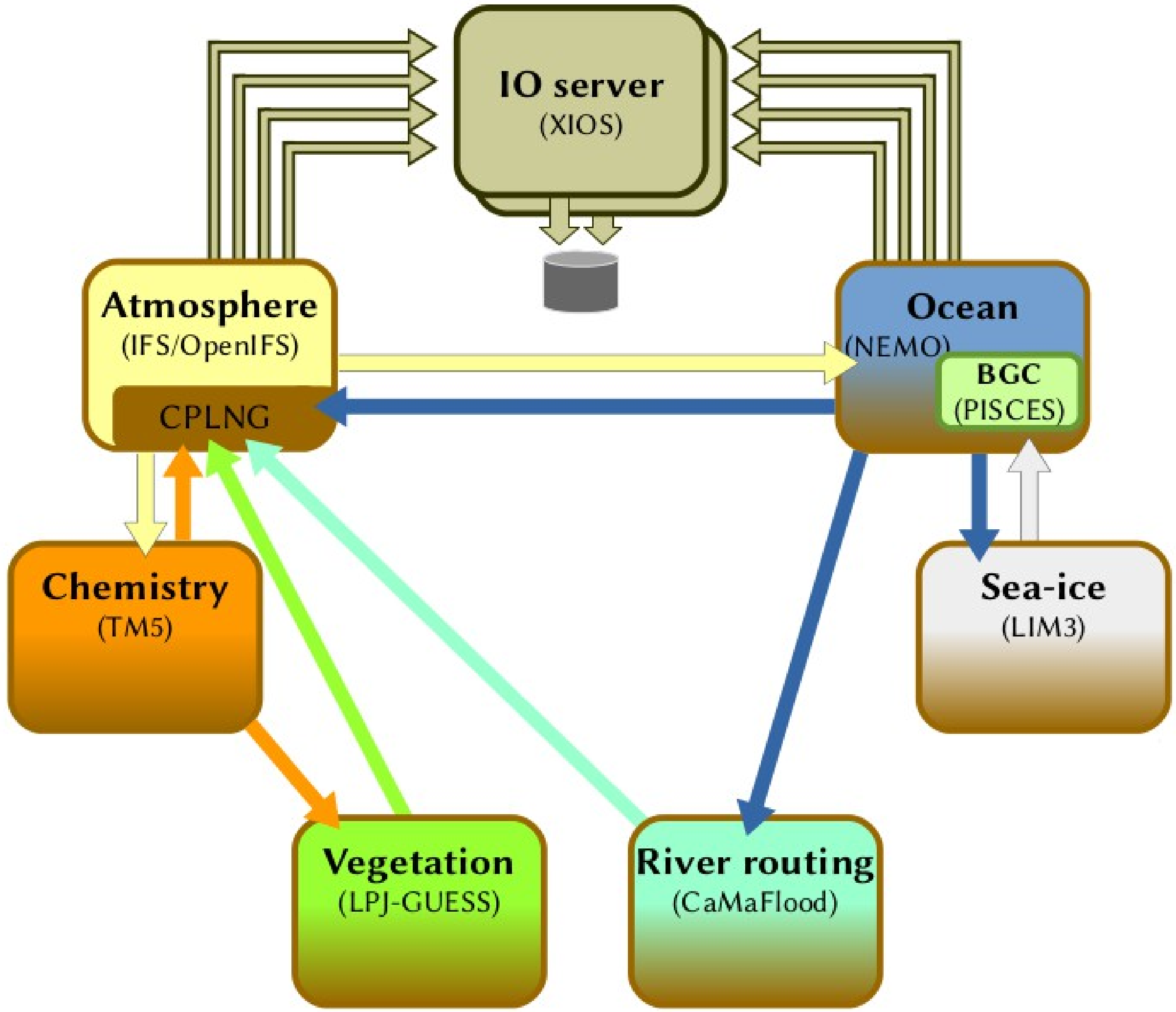
The coupler

Coupling
OASIS-MCT

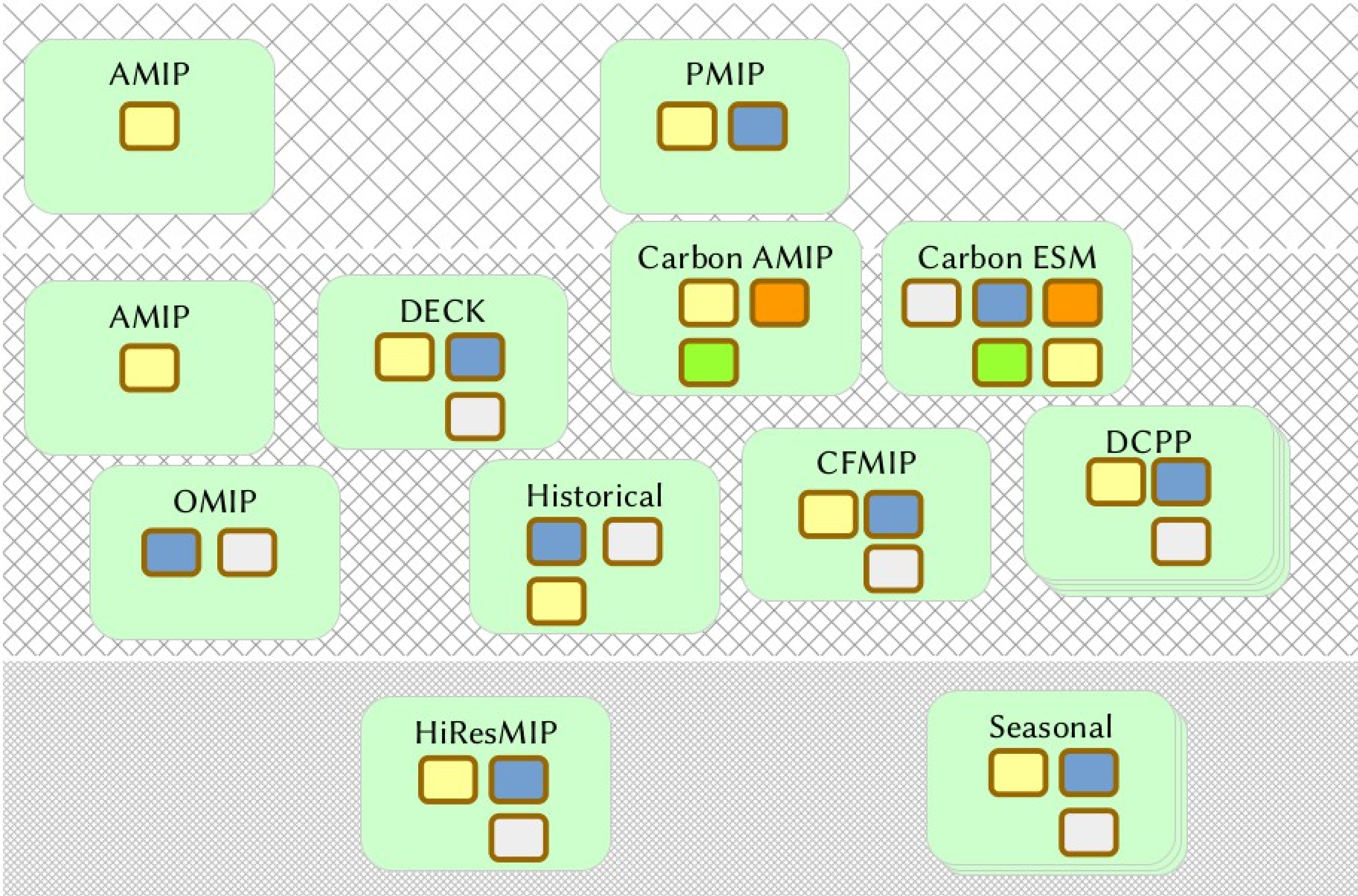
The coupler

EC EARTH Consortium members

Coupling
OASIS-MCT



Configuration zoo

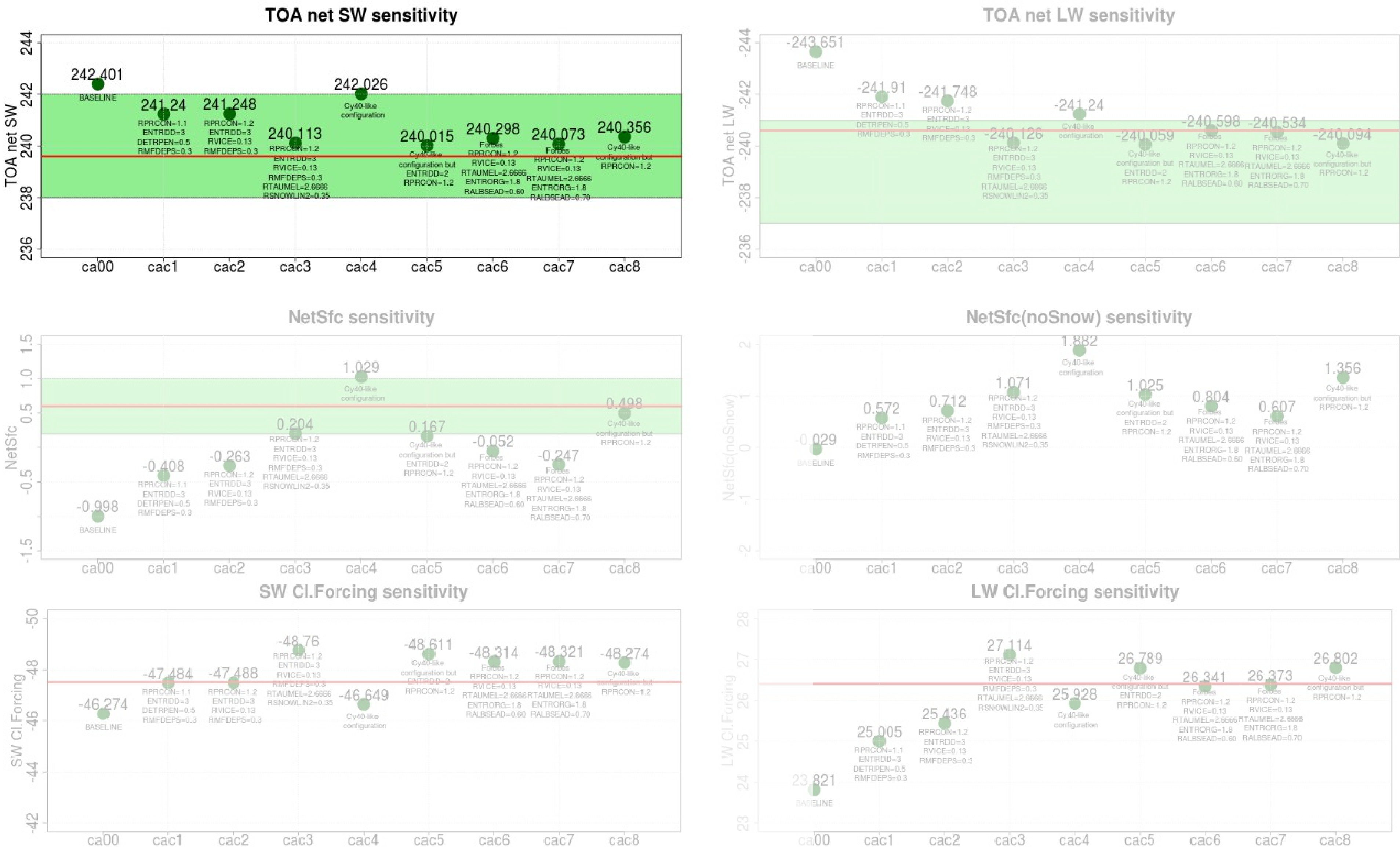


External homepage
ec-earth.org

Development portal

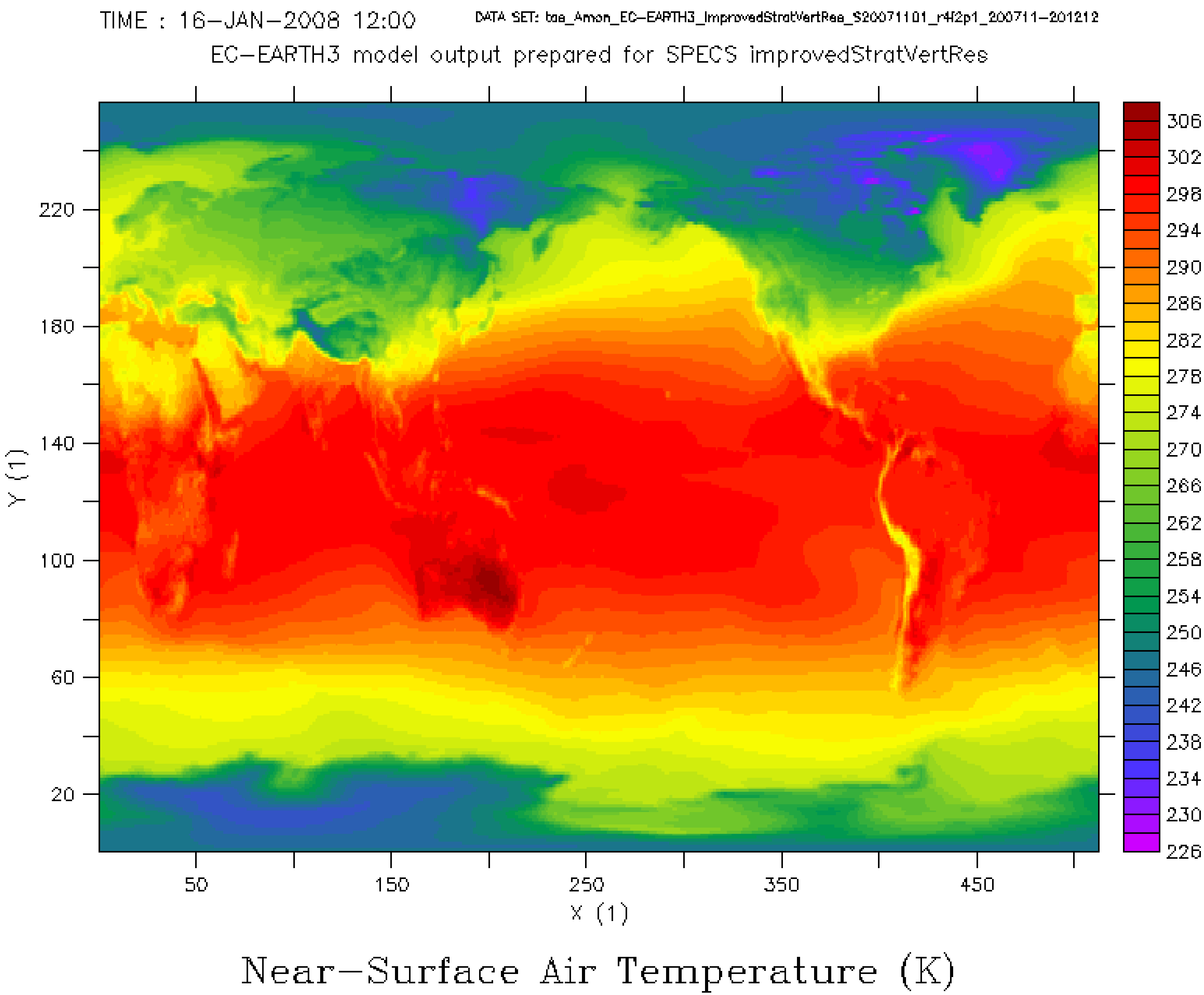
for distributed model development

Tuning

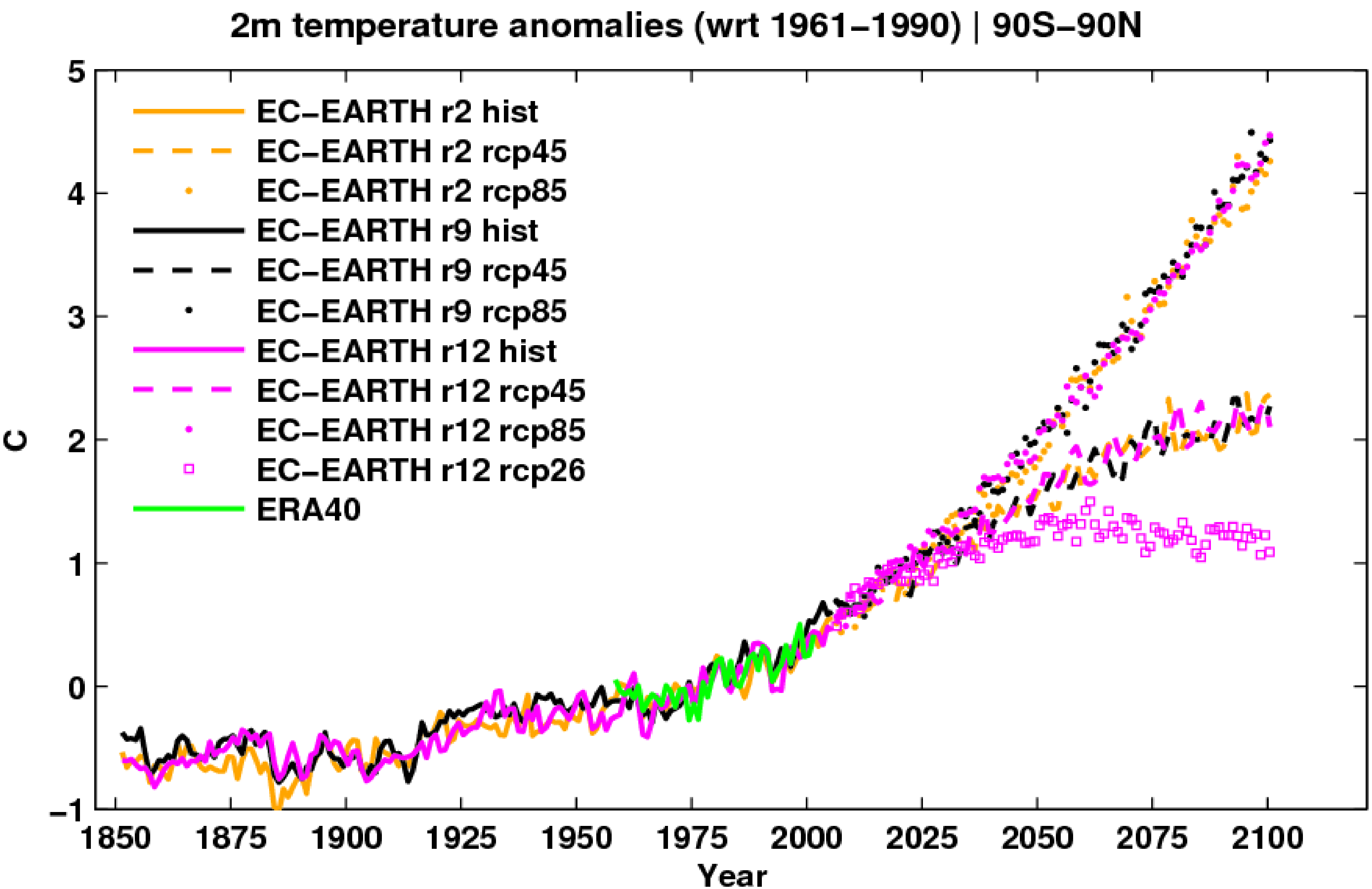


(Davini and von Hardenberg, 2014, CNR-ISAC)

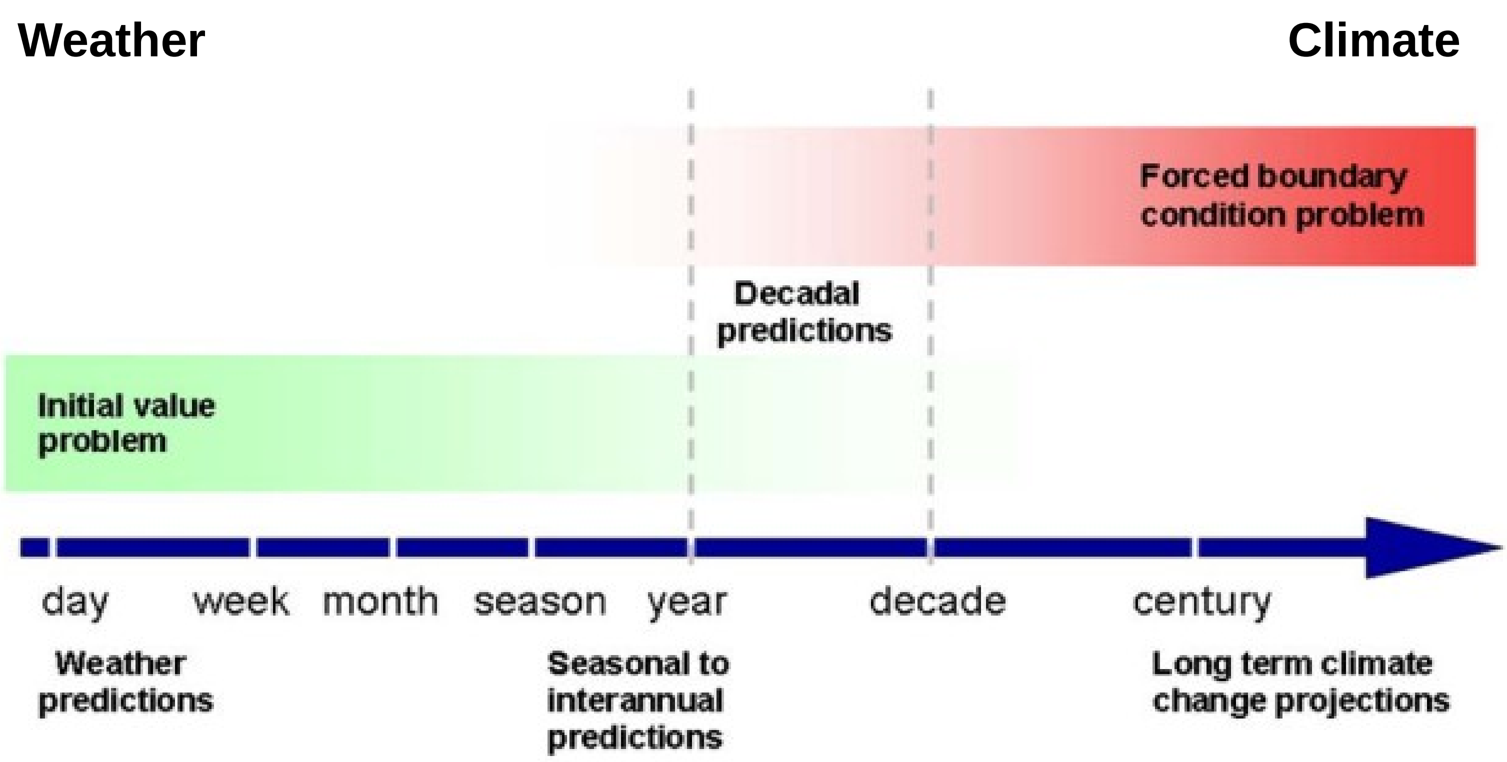
Surface air temperature



Future climate scenarios

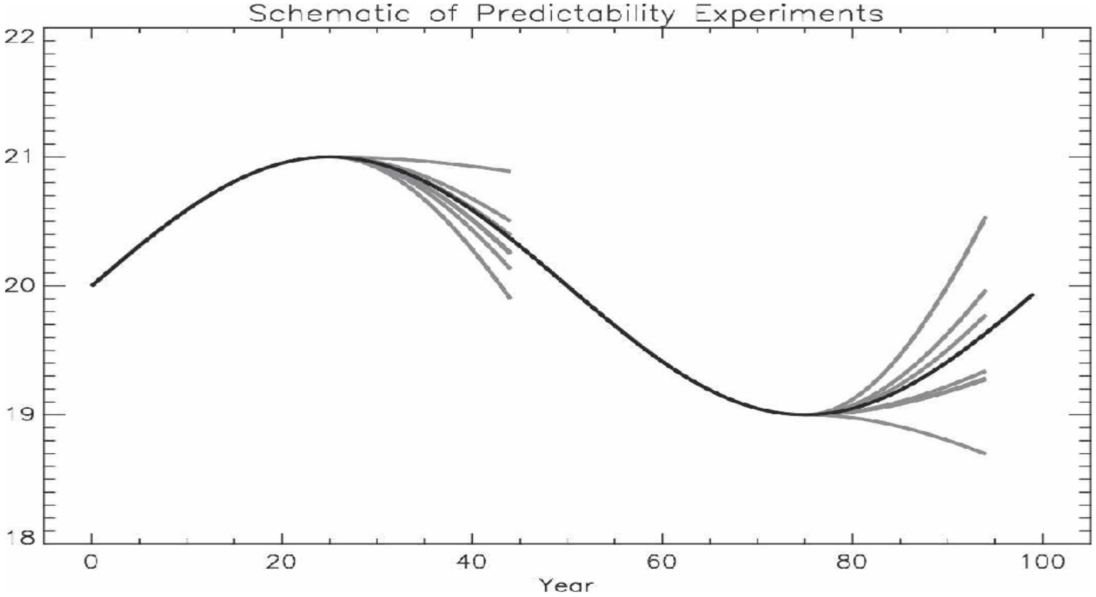


From weather to climate

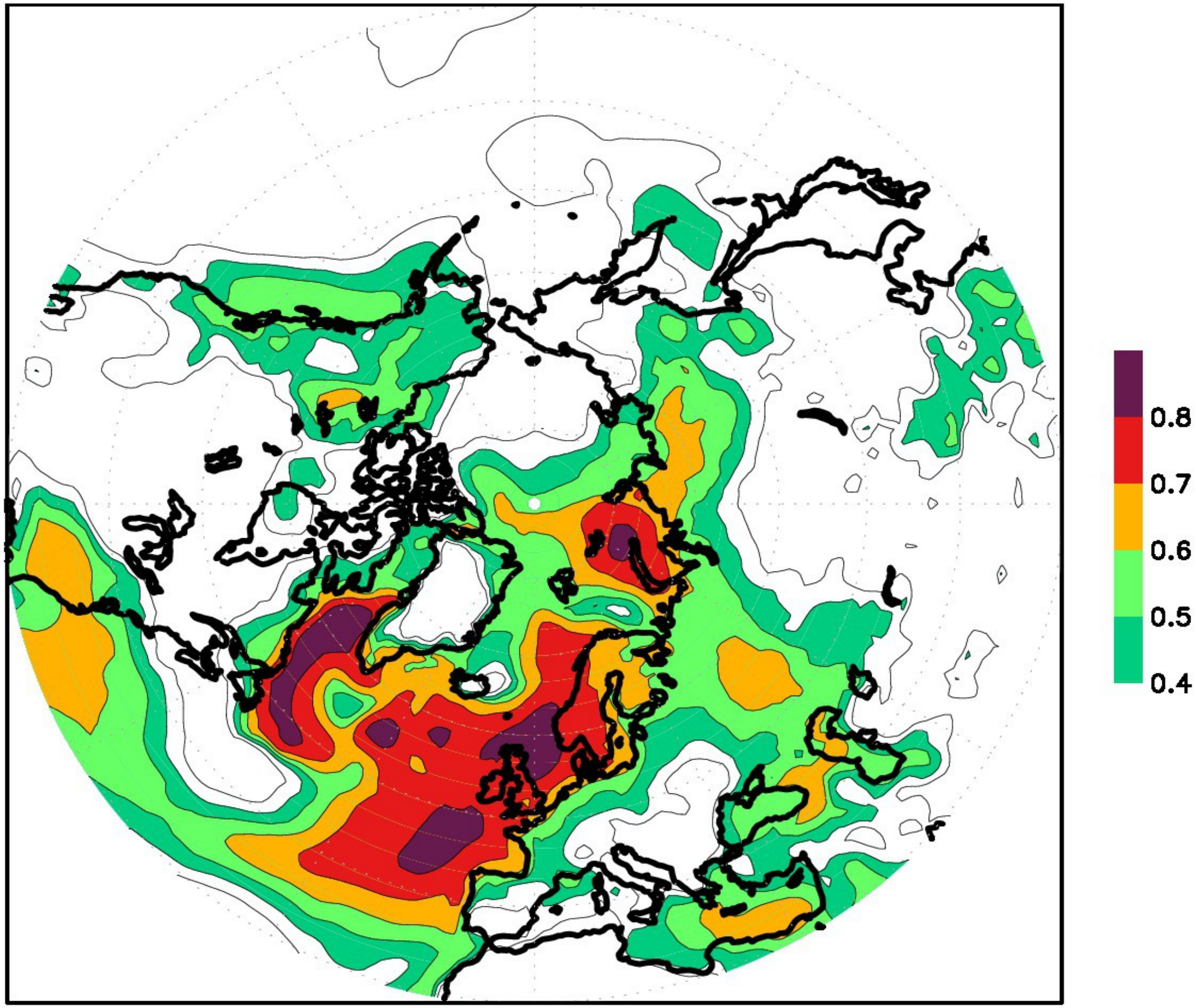


Box 11.1, Figure 2: A schematic illustrating the progression from an initial-value based prediction at short timescales to the forced boundary-value problem of climate projection at long timescales. Decadal prediction occupies the middle ground between the two (based on Meehl et al. (2009b)).

Climate prediction



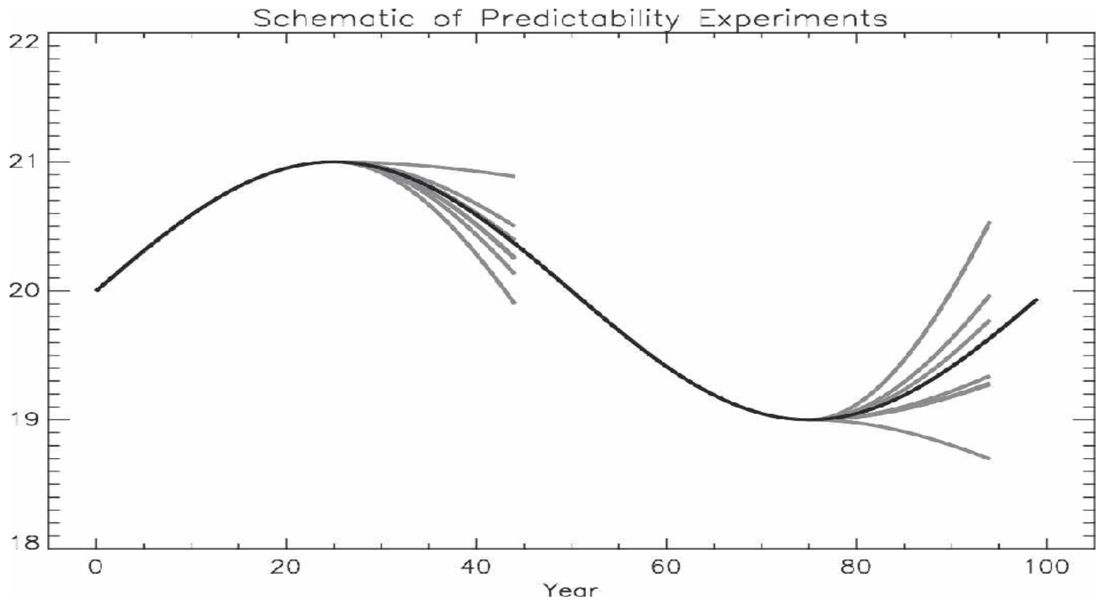
EC-Earth: climate predictability



Prognostic potential predictability for surface air temperature in perfect ensemble experiments with EC-Earth 2.1 using present day climate conditions. Values between 0.4 and 0.9 display the scale from low to high predictability. Shown is the potential predictability of the mean of the first 10 years after initialization. The figure is based on Koenigk et al. 2012 (their Fig. 11). Note that all values have been detrended before calculating the predictability. The potential predictability of local decadal mean surface air temperature is significant over entire Europe with exception of the South and South-west.

Koenigk, SMHI

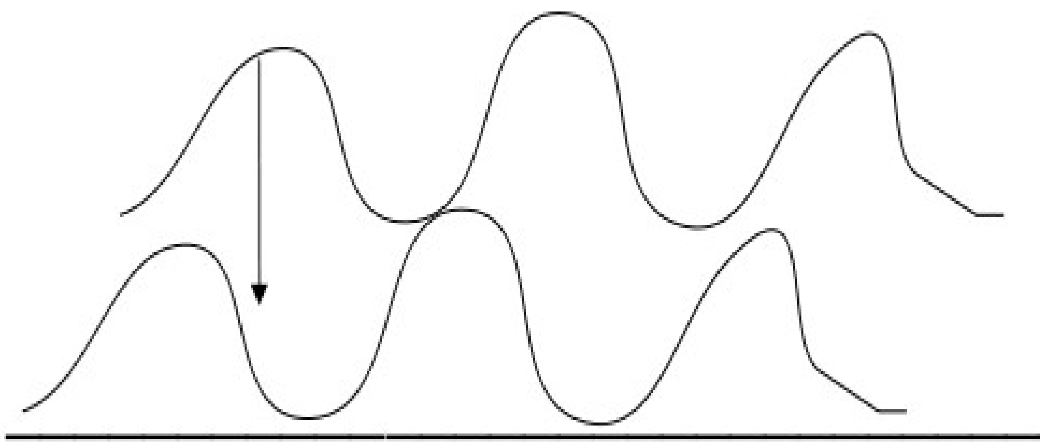
Climate prediction



- Ensembles of
  - low/high resolution
  - Different initialization methods

Example for improvement of skill:
Phase anomaly initialization

Phasing ("process" projections):



EOF decomposition of observations and model.

Observation fields are recomposed with modified amplitude and phase, derived from the model signal, and then used for initialization.

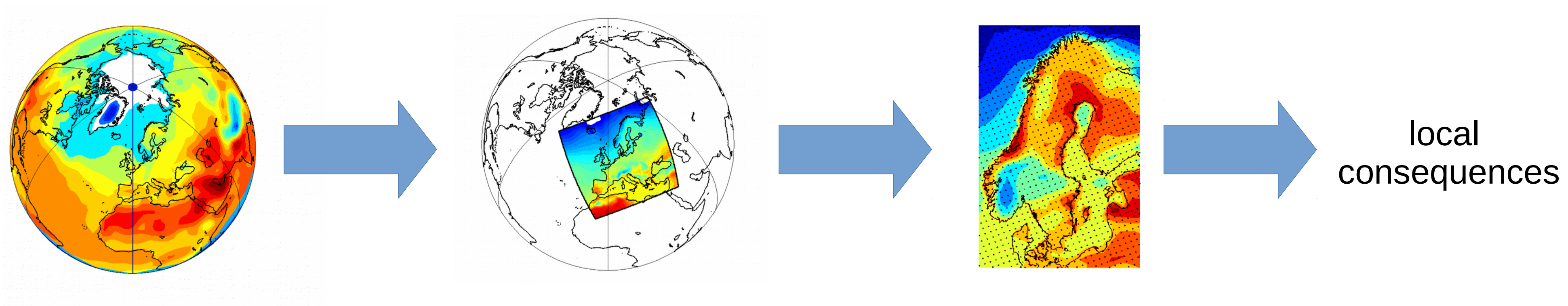
Anomaly correlation skill:

AN 95	0.35 (p1)	0.22 (p2)	0.35 (p3)	0.62 (p4)	0.56 (t)	**0.71 (ts)**	0.47 (tsuv)	0.41 (anaice)

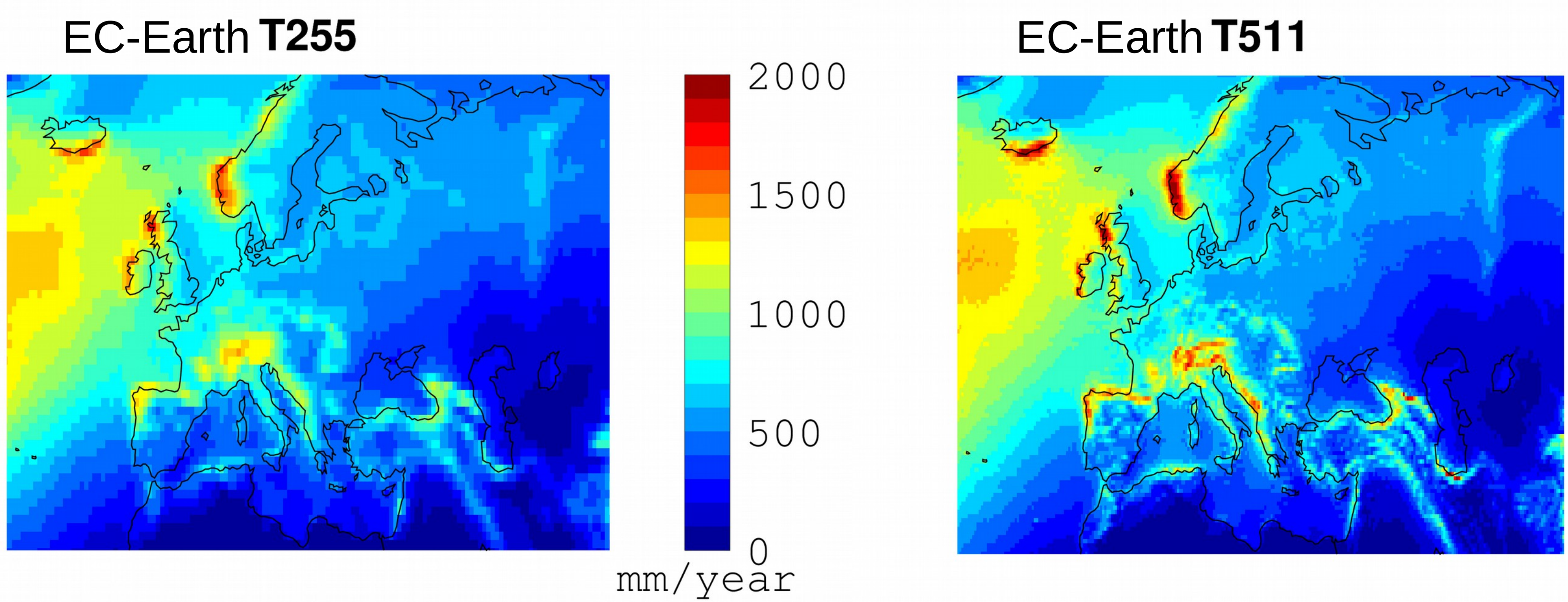
Best skill for T and S phase initialization at all levels. (Robust finding, Tested for several decades)

Caian et al., in prep, SMHI

Regional climate and impact

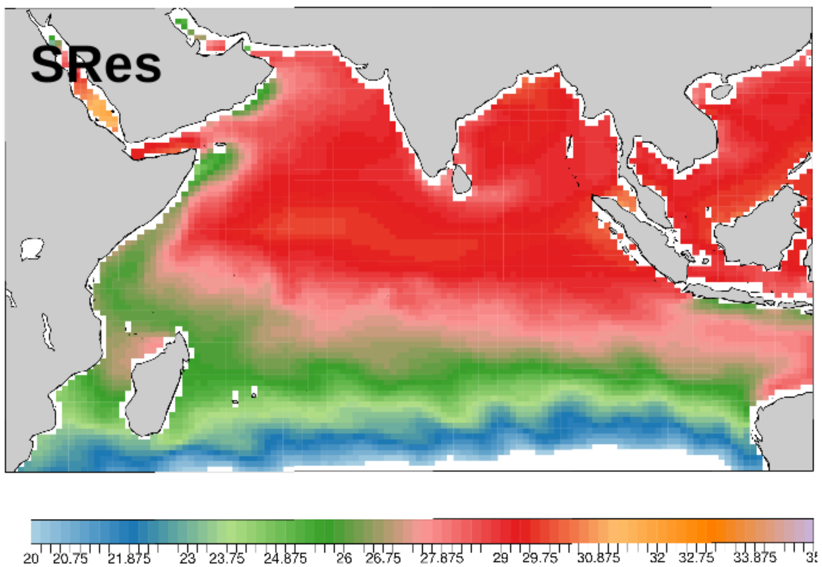


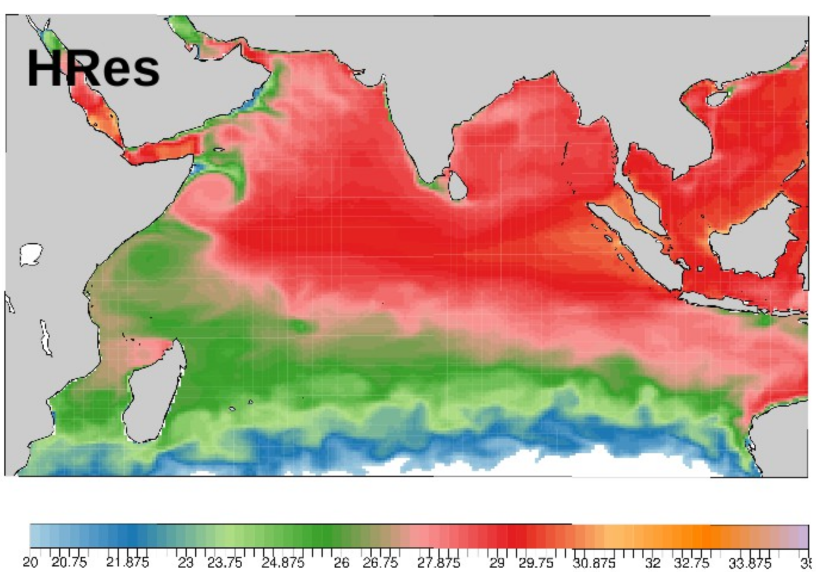
Precipitation over Europe



Resolution in the ocean

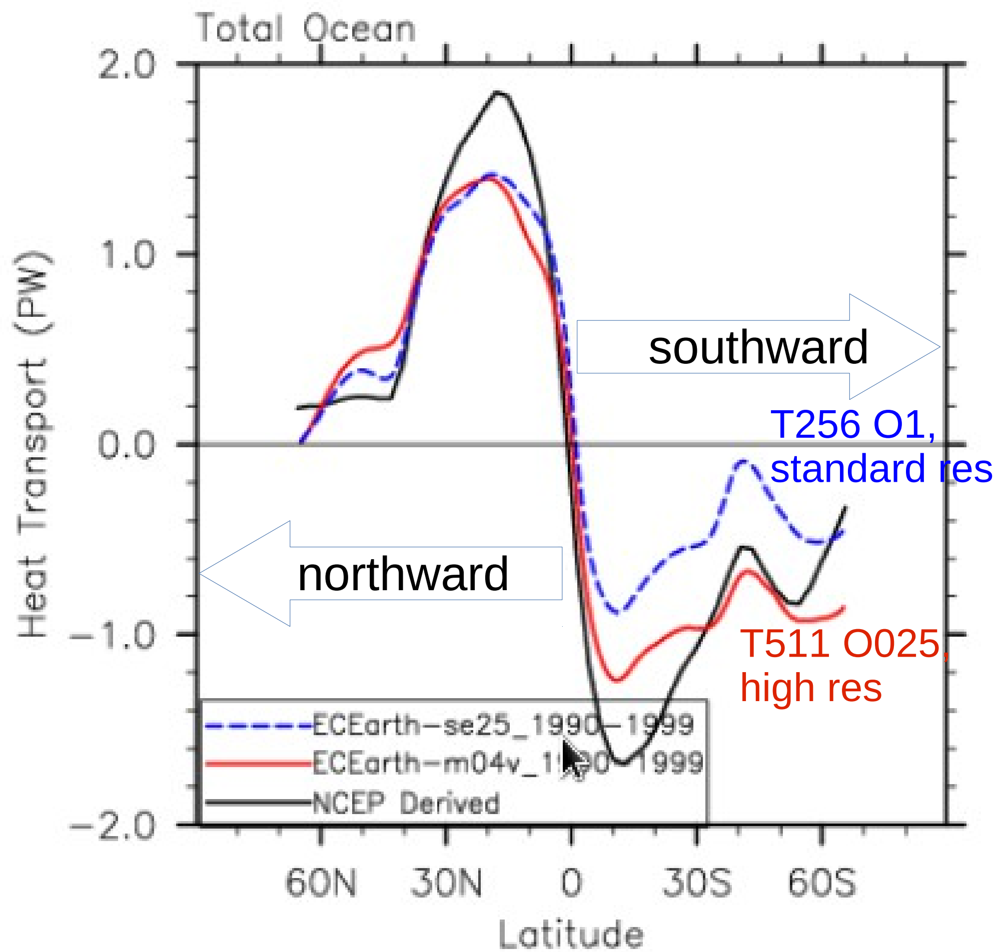
Sea Surface Temperature in the Indian Ocean





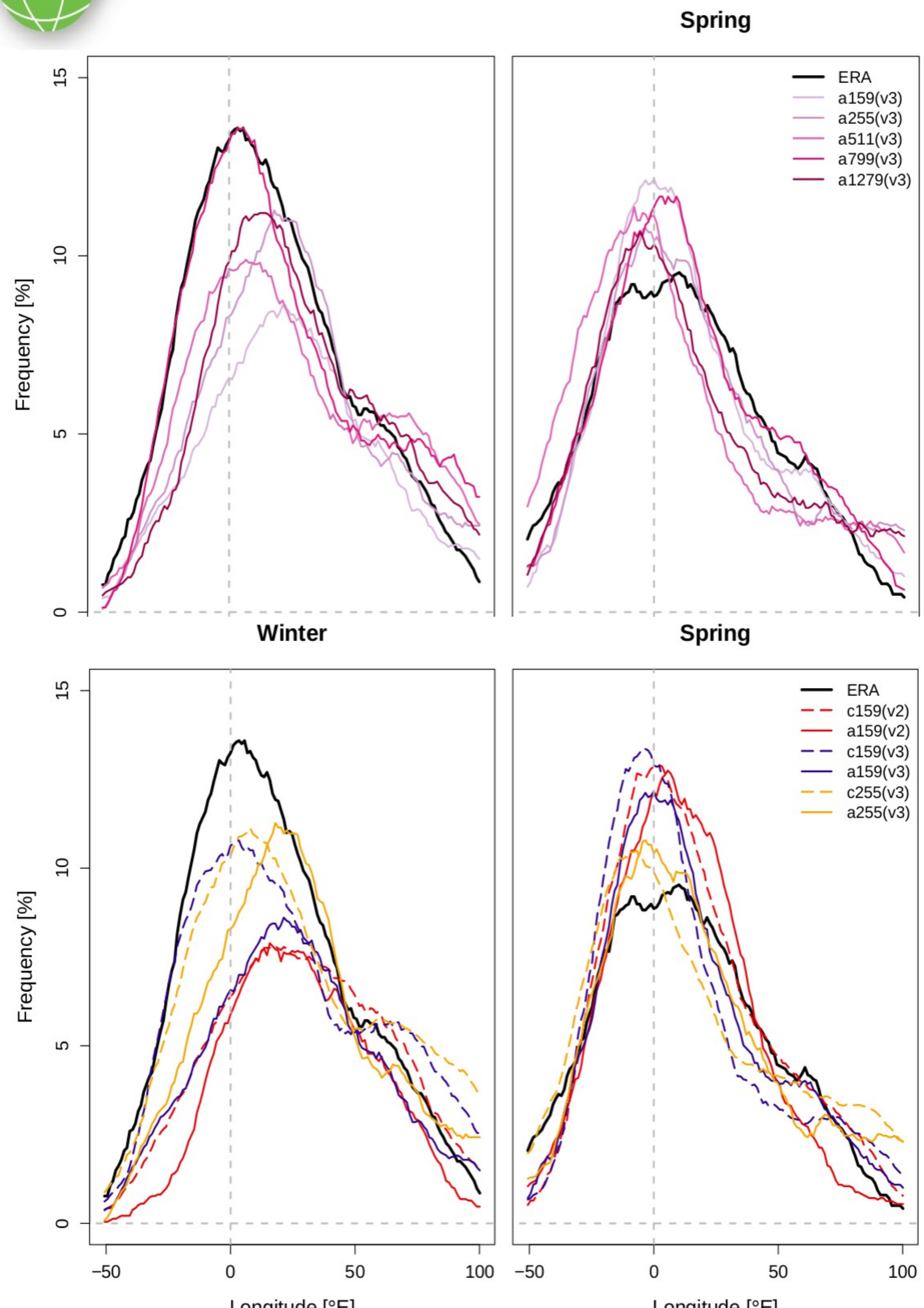
Prodhomme et al., IC3/BSC

Ocean transport of heat from the tropics towards the poles



Increased resolution gives better heat transports

Blocking, Resolution and Coupling



- Tibaldi-Molteni Index
- High resolution improves the simulation (mostly for winter and uncoupled)
- Role of coupling and model version is less clear (for coupled runs, v3 is better; with less influence of resolution)

c = coupled

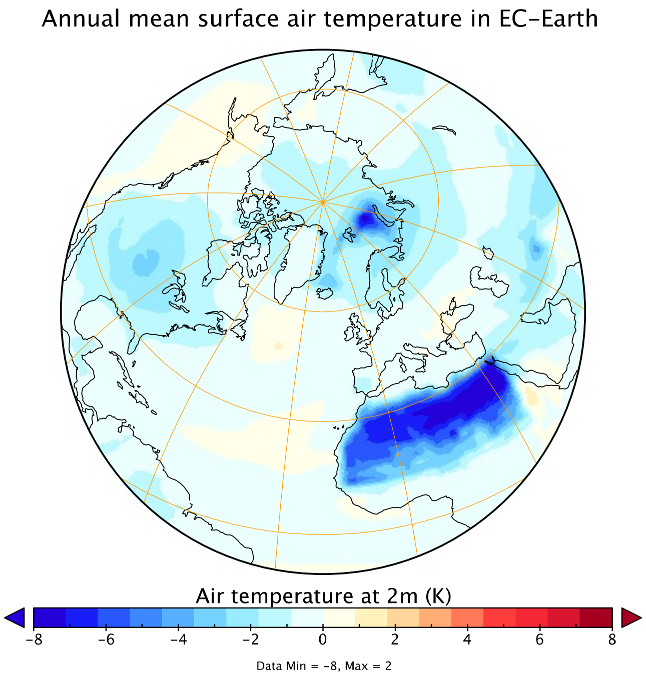
a = atmosphere-standalone

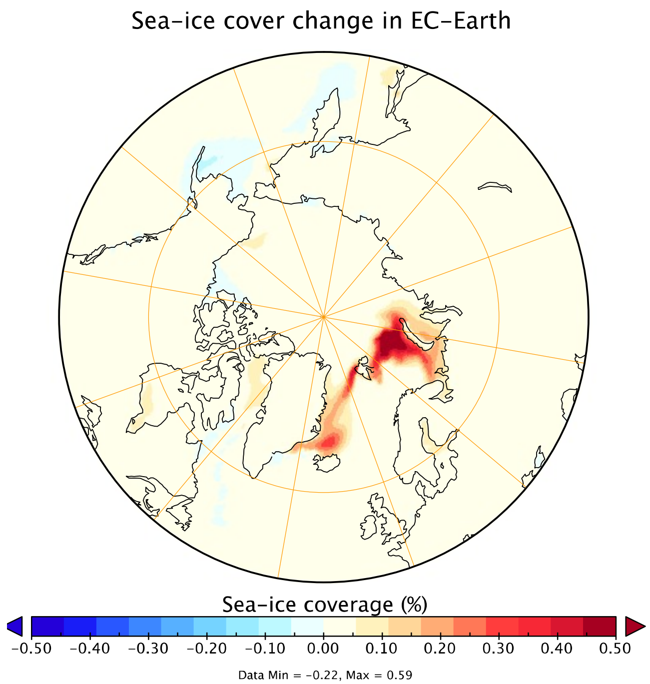
Bolin Centre for Climate Research

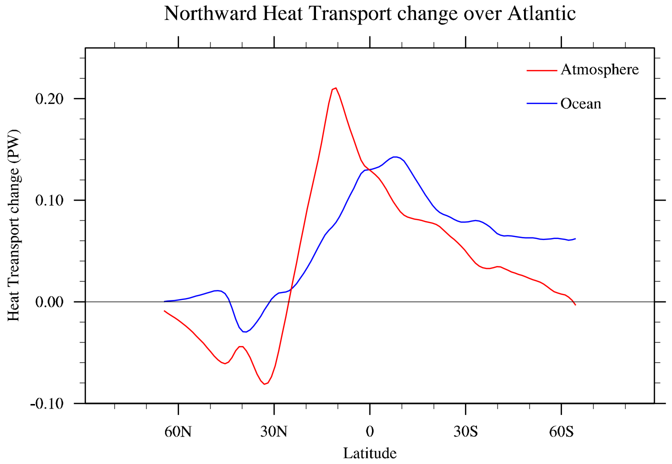
Stockholm University

Kerstin Hartung, MISU

Cooling response over Arctic due to Sahara desertification







- Model: EC-Earth 3.1, T159-ORAC1-LIM3
- Climate condition: Mid-Holocene, 6000 yrs BP
- Climate forcing: Orbital forcing, slight change in CH4 compared to pre-industrial (PI)
- Initial conditions: PI (1850) spin-up
- Sensitivity experiments:
  - Albedo effect due to collapse in vegetation, "Green Sahara" and "Desert Sahara" in northern African domain
  - Dust effect, less dust (20% less) emission in green Sahara, more dust emission in desert Sahara
  - Simulations are run for 200~300 years, last 100 years are used for analysis.

Large area cooling over Arctic is observed in EC-Earth due to Sahara desertification, which is consistent with indication from paleo-proxy data. Largely extended sea-ice coverage is found over Barents Sea and Fram Strait.

The weakened northward heat transport (both in atmosphere and ocean)

Muschitiello et al., submitted to Quaternary Science Review

Bolin Centre for Climate Research

Stockholm University

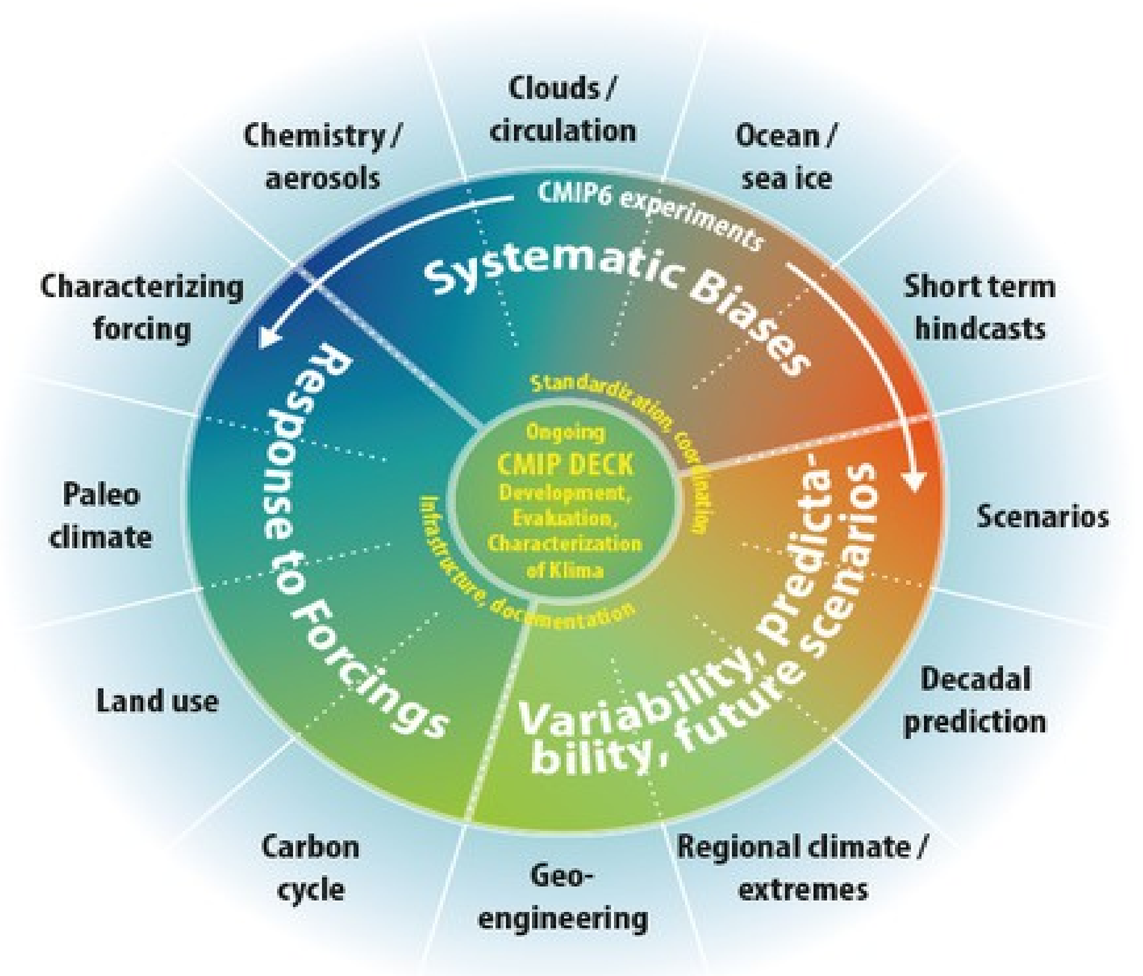
Coming challenge: CMIP6

Climate Model Intercomparison Project 6

WCRP World Climate Research Programme

CMIP6 underlying questions

- How does the Earth system respond to **forcing**?
- What are the origins and consequences of systematic model **biases**?
- How can we assess **future climate changes** given climate variability, climate predictability, and **uncertainties** in scenarios?



Computing performance and resources

Performance

- using 4000 cores (Triolith)
  - GCM std. res. (T256O1)
    - 2.6 simulated years per day, 25 - 125 Gb per simulated year
  - GCM high res. (T511O025)
    - 0.7 simulated years per day, 125 Gb per simulated year
  - ESM std. res. (T256O1), full atmospheric chemistry and ocean bio-geo chemistry
    - 0.2 simulated years per day
- using 16000 cores (MareNostrum, PRACE)
  - GCM high res. (T511O025)
    - 1.25 simulated years per day, 125 Gb per simulated year

Resources

- Bi (9 mill. core-h/year)
- SNIC (~13 mill core-h/year (2015))
- PRACE (x core-h/year)

For CMIP6 simulations we currently estimate an overall amount of **340 mio core-hours** (estimates based on Triolith units) over a period of 5 years (2015-2019). 40 mio core-h for 2015

MareNostrum: With the last upgrade (2012-2013), MareNostrum has a peak performance of 1,1 Petaflops, with 48,896 Intel Sandy Bridge processors in 3,056 nodes, and 84 Xeon Phi 5110P in 42 nodes, with more than 104.6 TB of main memory and 2 PB of GPFS disk storage. At June 2013, MareNostrum was positioned at the 29th place in the TOP500 list of fastest supercomputers in the world. 94.21 Teraflops

To take home

- EC-Earth
  - is an open community of balanced partners for Earth System Modeling in Europe
  - Is interacting with the world-leading weather centre
  - provides a viable framework for distributed development and integration
  - is preparing for CMIP6
  - Is a base for studies in various configurations
    - Processes
    - Climate change
    - Climate prediction
  - Heterogeneous science application areas fosters robust development
- Earth System Modelling requires resources for computing and data management

End