Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

Modellistica climatica globale in ENEA: l'Earth System Model EC-Earth

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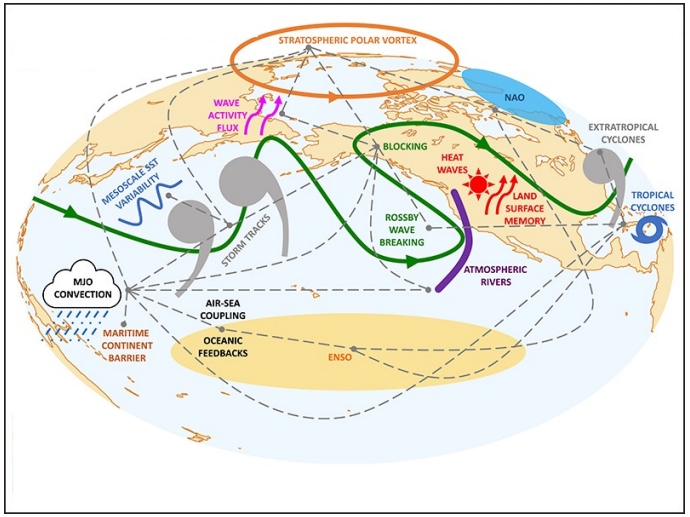
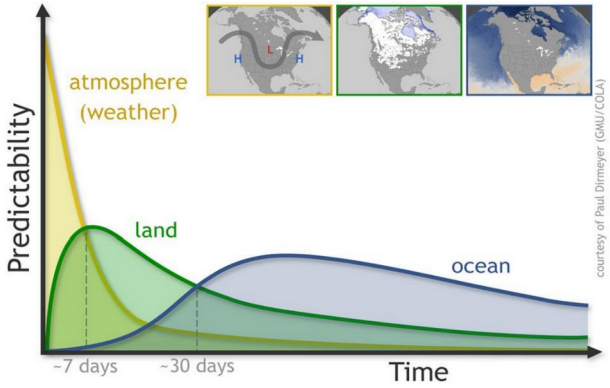
Outline

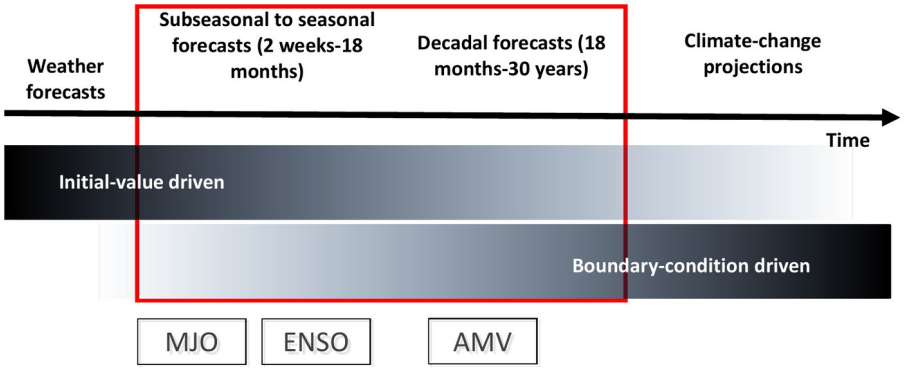
- Introduction on predictability/prediction, scales
- ESM vs GCM
- The Earth System Model EC-Earth
- EC-Earth in CMIP6
- ENEA developments
- Conclusions

Global climate prediction: predictability sources and time scales



Predictability of climate at seasonal and longer timescales stems from the interaction of the atmosphere with slowly varying components of the climate system such as the ocean (e.g. El Niño Southern Oscillation) and the land surface





Earth System Models vs General Circulation models

GCMs

→ Few model components: atmosphere/land and ocean/sea ice

→ NO carbon cycle

→ BUT: **high resolution** (ECMWF: ~36 km seasonal and sub-seasonal, ~9 km NWP)

ESMs

→ more processes/ model components (dynamic vegetation, bio-geo-chemistry, etc)

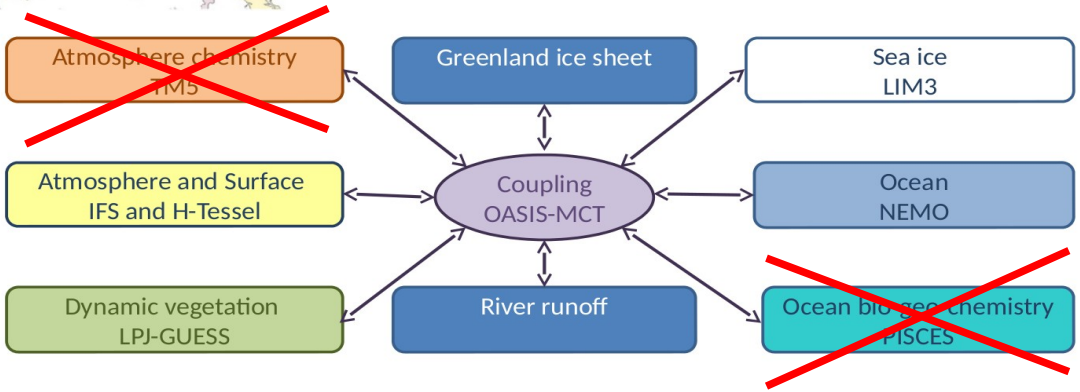
→ interactive carbon cycle (in atmosphere, vegetation, soil and ocean)

→ BUT: **coarser resolution** (usually >100 km)

The Earth System model EC-Earth: an overview

EC EARTH ESM

Earth System Model



Configuration:

Atmosphere: IFS cycle 36r4

Ocean: NEMO 3.6

Vegetation: LPJ-Guess 4

Coupler: OASIS 3

Resolution:

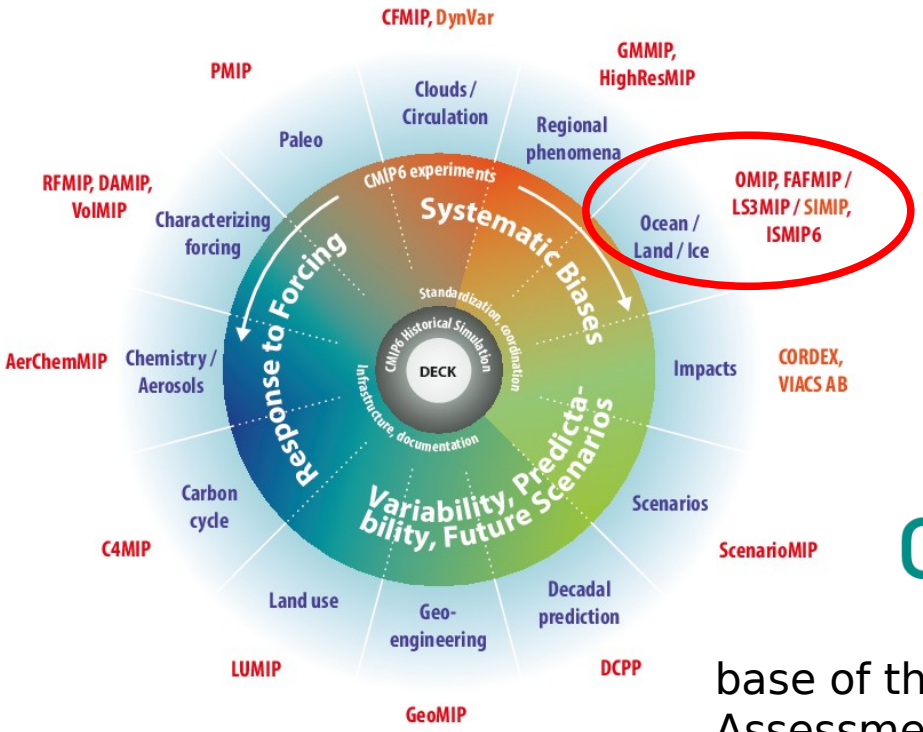
Atmosphere: IFS (T255 L91) ~ 80km

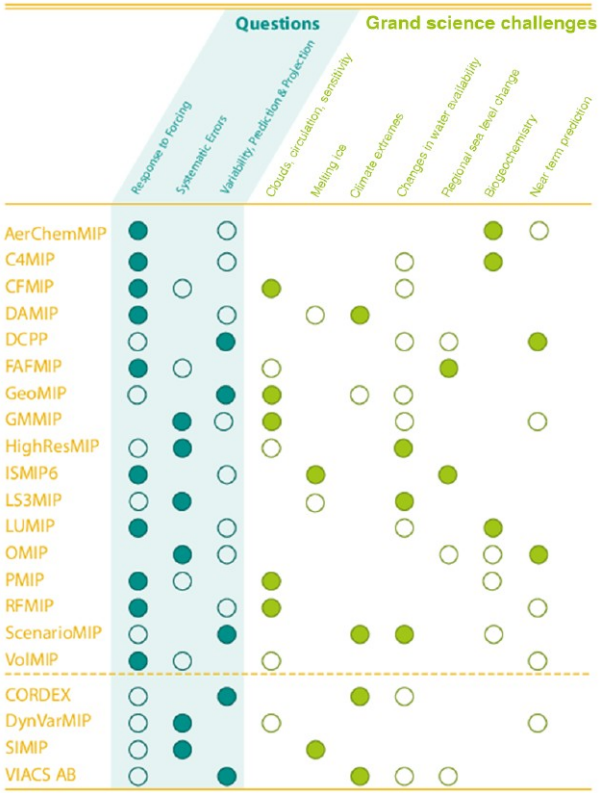
Ocean: NEMO (ORCA1 L46)

Döscher, R., Catalano F., et al., 2022: The EC-Earth3 Earth system model for the Coupled Model Intercomparison Project 6, Geosci. Model Dev., 15, 2973–3020, https://doi.org/10.5194/gmd-15-2973-2022, 2022

World Climate Research Programme (WCRP) CMIP6

21 CMIP6-Endorsed MIPs





CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

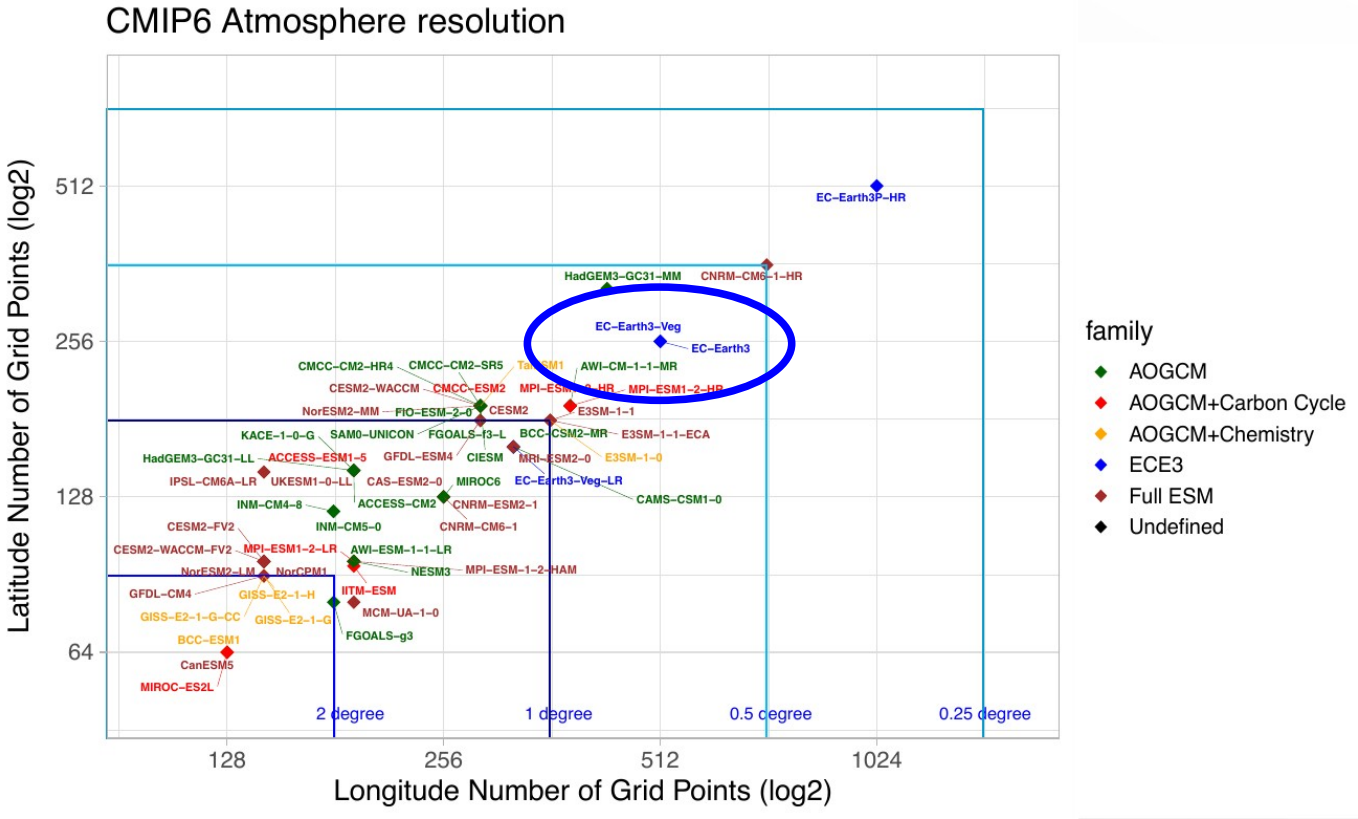
base of the IPCC 6th Assessment Report on Climate Change (AR6)

ENEA among CMIP6 modeling groups

https://pcmdi.llnl.gov/CMIP6/

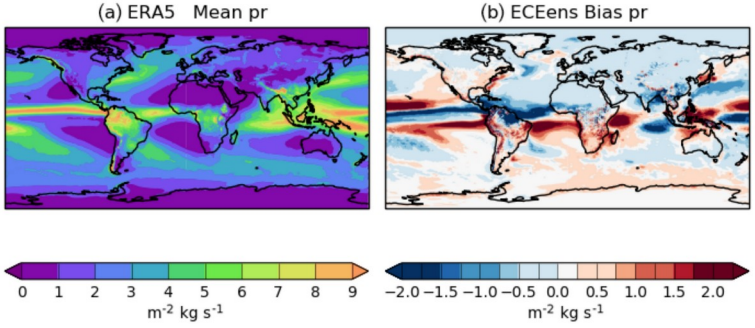
CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

Among the highest resolution CMIP6 models for the atmosphere

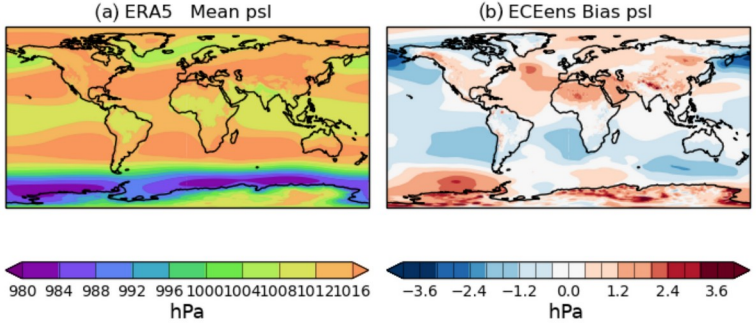


Mean bias

Precipitation

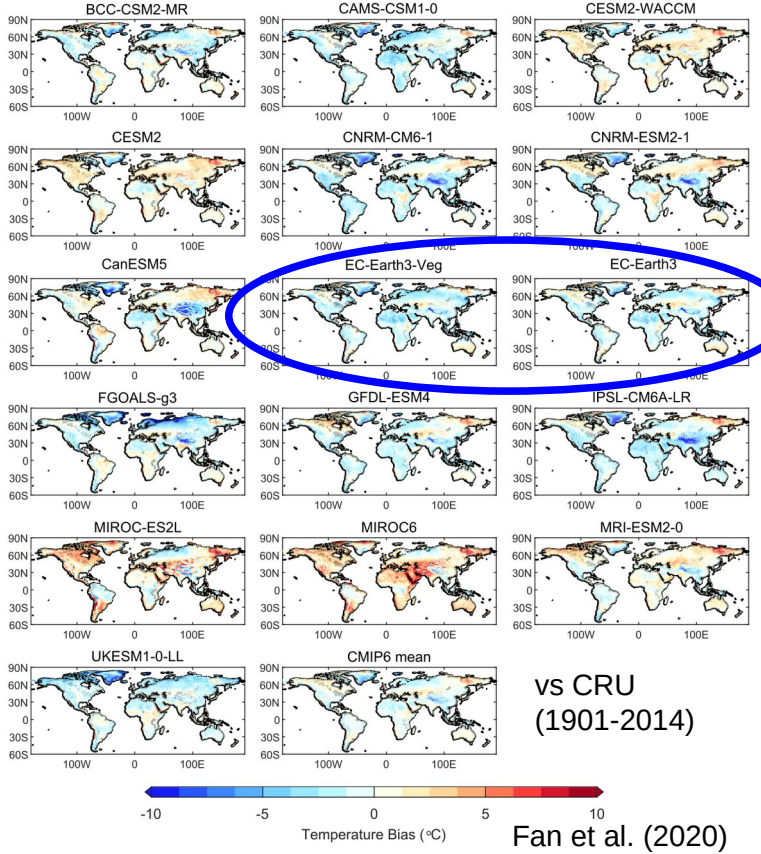


mean sea level pressure



Döscher et al. (2022)

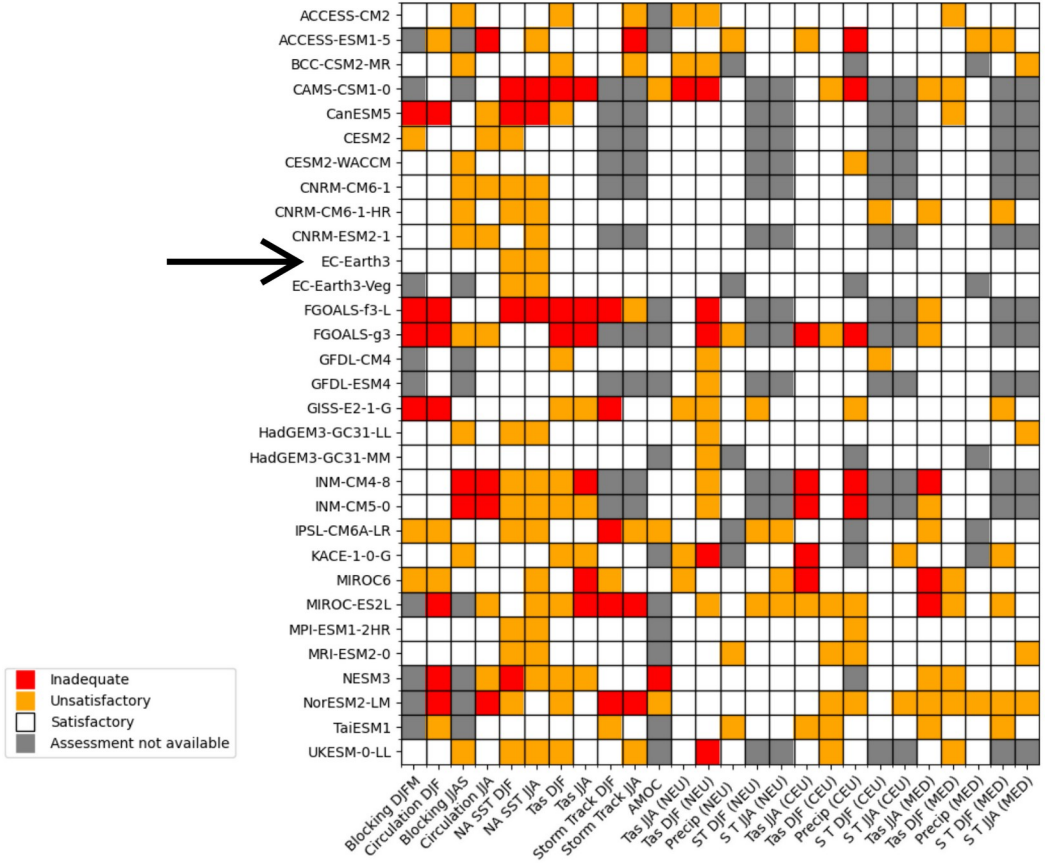
Surface temperature



vs CRU (1901-2014)

Fan et al. (2020)

Performance comparison over Europe



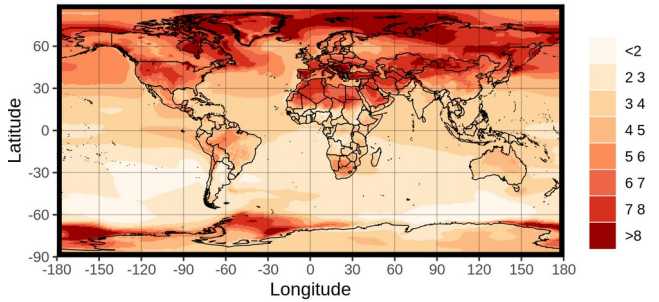
Palmer et al. (2023)

ENEA contribution to CMIP6

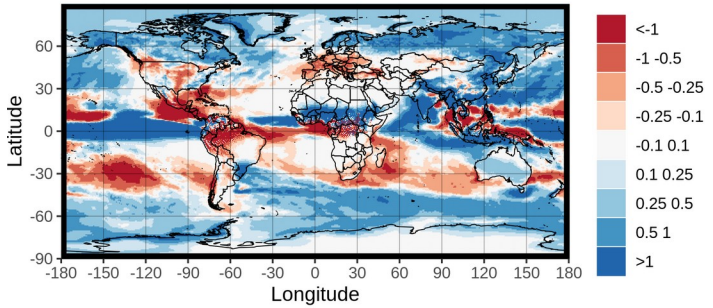
ENEA EC-Earth3 projections in CMIP6

scenario SSP5-8.5, JJA

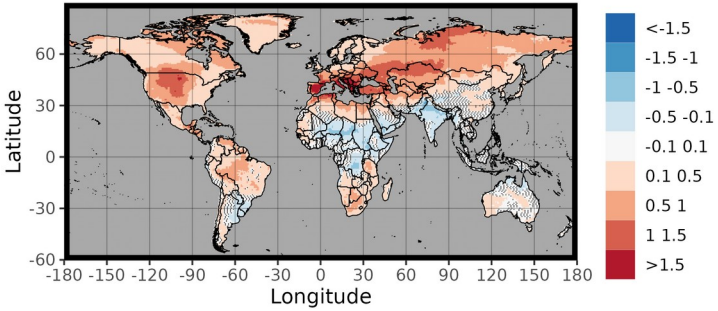
Climate warming over 21st century (K)



Precipitation change over 21st century (mm/d)

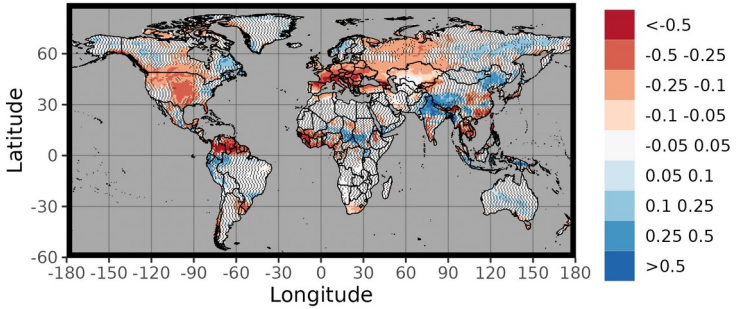


Temperature sensitivity to SM change (K)



LS3MIP

Precipitation sensitivity to SM change (mm/d)



ENEA CMIP6-LS3MIP simulations published on ESGF (SSP1-2.6, SSP5-8.5)

- https://doi.org/10.22033/ESGF/CMIP6.4544
- https://doi.org/10.22033/ESGF/CMIP6.4542

ENEA developments in EC-Earth

interactive soil/vegetation fractions

improvement of DJF surface temperature climate change - 20th century

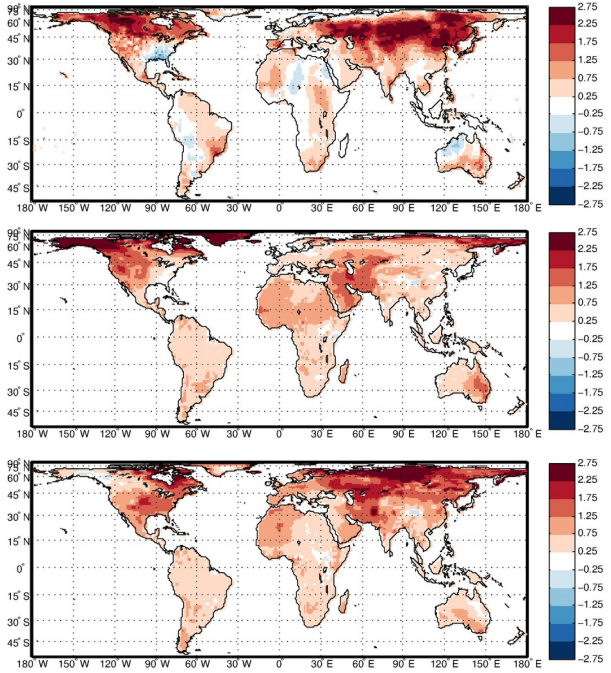
OBSERVATION CRU

EC-Earth

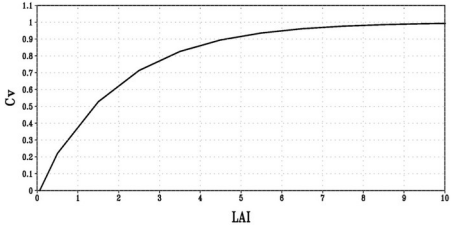
CMIP5 version

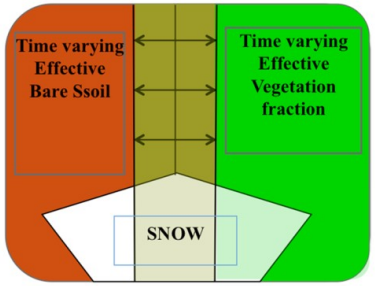
EC-Earth with ENEA improvements

included in CMIP6 version

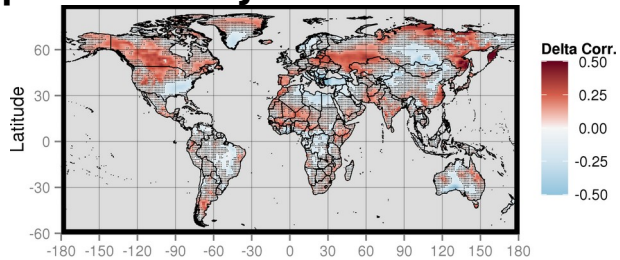


Lambert-Beer formulation for Cv as a function of LAI





Improved seasonal prediction of surface temperature in DJF

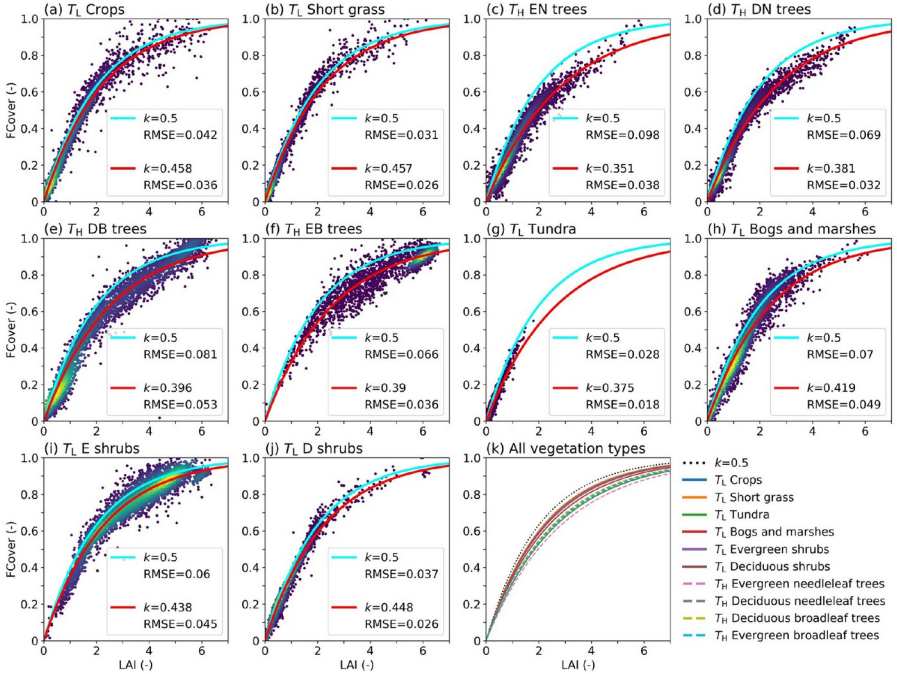


Similar improvements on decadal scale and for precipitation

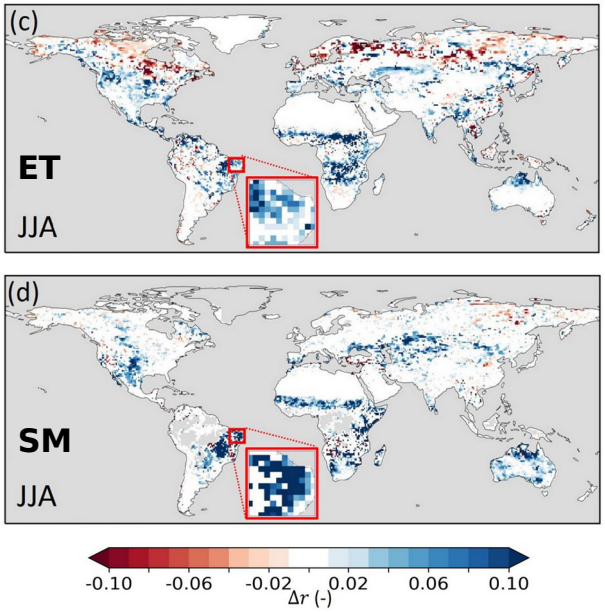
- Alessandri A., Catalano F., De Felice M., van den Hurk B., Doblas-Reyes F., Boussetta S., Balsamo G., Miller P. A., 2017: Multi-scale enhancement of climate prediction over land by increasing the model sensitivity to vegetation variability in EC-Earth. Clim. Dyn., 49, 1215-1237, doi:10.1007/s00382-016-3372-4

Vegetation fractions from state-of-the-art observations

Vegetation fraction coeff. estimated from COPERNICUS LAI for each type



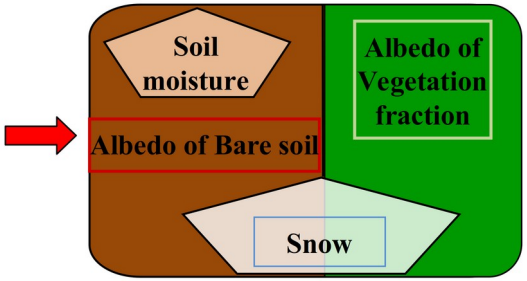
improvement of JJA evaporation and soil moisture

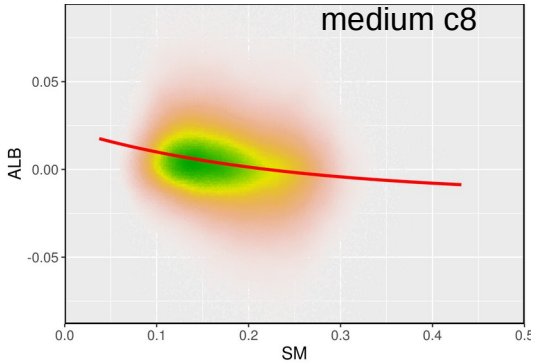


- van Oorschot F., van der Ent R., Hrachowitz M., Di Carlo E., Catalano F., Boussetta S., Balsamo G., Alessandri A., 2023: Inter-annual land cover and vegetation variability based on remote sensing data in the HTESSEL land surface model: implementation and effects on simulated water dynamics. Earth System Dynamics, 14, 1239-1259, doi:10.5194/esd-14-1239-2023

Interactive soil albedo

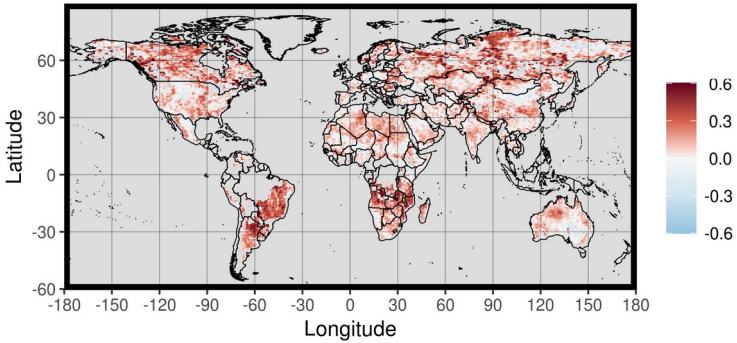
Soil albedo dependence upon soil moisture from observational constraint using ESA SM and COPERNICUS ALB for each soil type and color





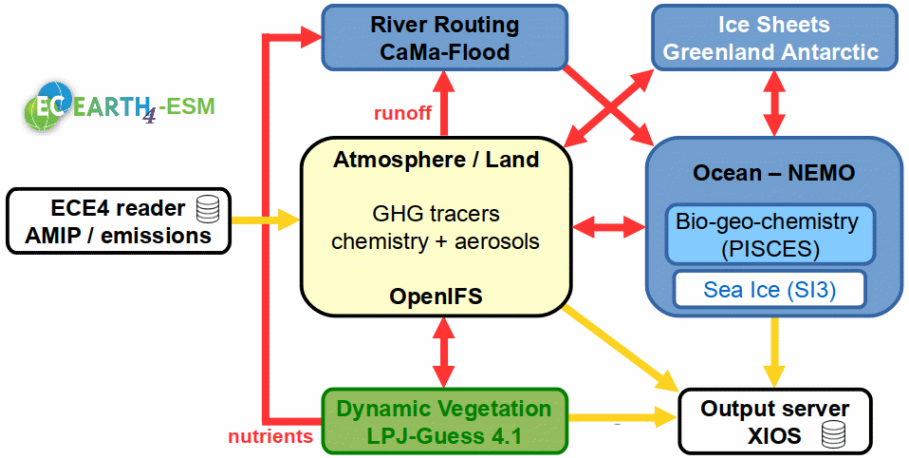
Preliminary offline evaluation against independent albedo dataset (GLASS):

More realistic soil albedo variability



ICSC-Spoke4
Earth & Climate

towards EC-Earth4 ESM...



- OpenIFS cy48r1
- NEMO 4.2 with SI3 sea-ice model
- OASIS3-MCT with improved conservative coupling rdy2cpl
- XIOS for model outputs

- M7 for chemistry + aerosols
- PISCES for Ocean biogeochemistry
- CaMaFlood for river routing
- Ice sheet model PISM for Greenland and Antarctic ice sheets

Conclusions

- We are contributing to the development of the european global ESM EC-Earth
- We have contributed with EC-Earth3 to CMIP6. Data published on ESGF
- EC-Earth3 is one of the highest resolution CMIP6 models
- Good performance (bias and variability), also thanks to a more realistic land-surface representation (ENEA developments)

→ particularly suited to be used for downscaling

(SSP3-7.0 will be downscaled with ENEA-REG for MED-CORDEX)

- New developments coming in EC-Earth4


Grazie per l’attenzione
e buona festa d’inverno

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