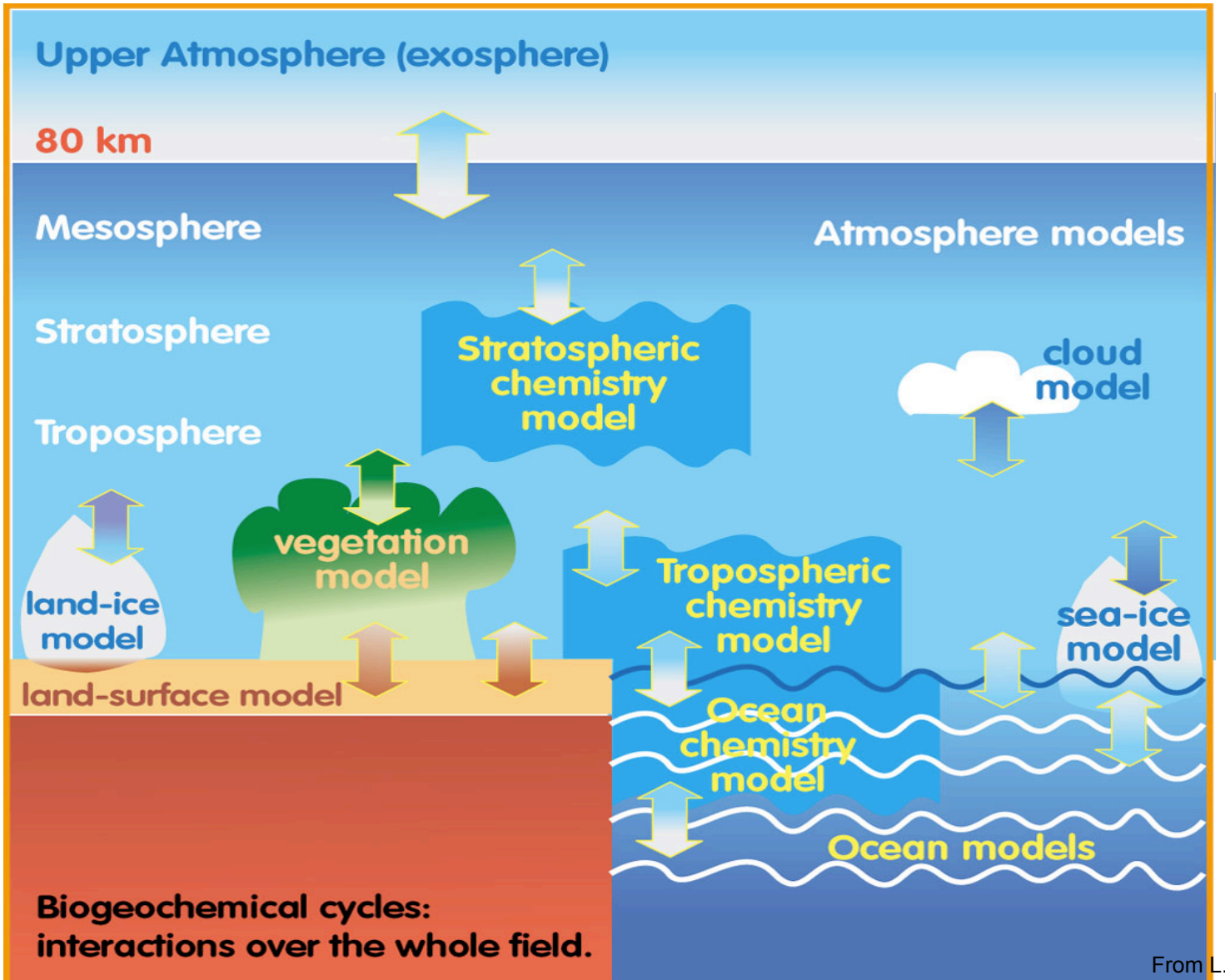
Modellistica Climatica presso ISAC-CNR

Jost von Hardenberg – ISAC-CNR

P. Davini, L. Filippi, A. B. Pieri,
E. Palazzi, A. Parodi, A. Provenzale,

Main components of a global Earth-system model

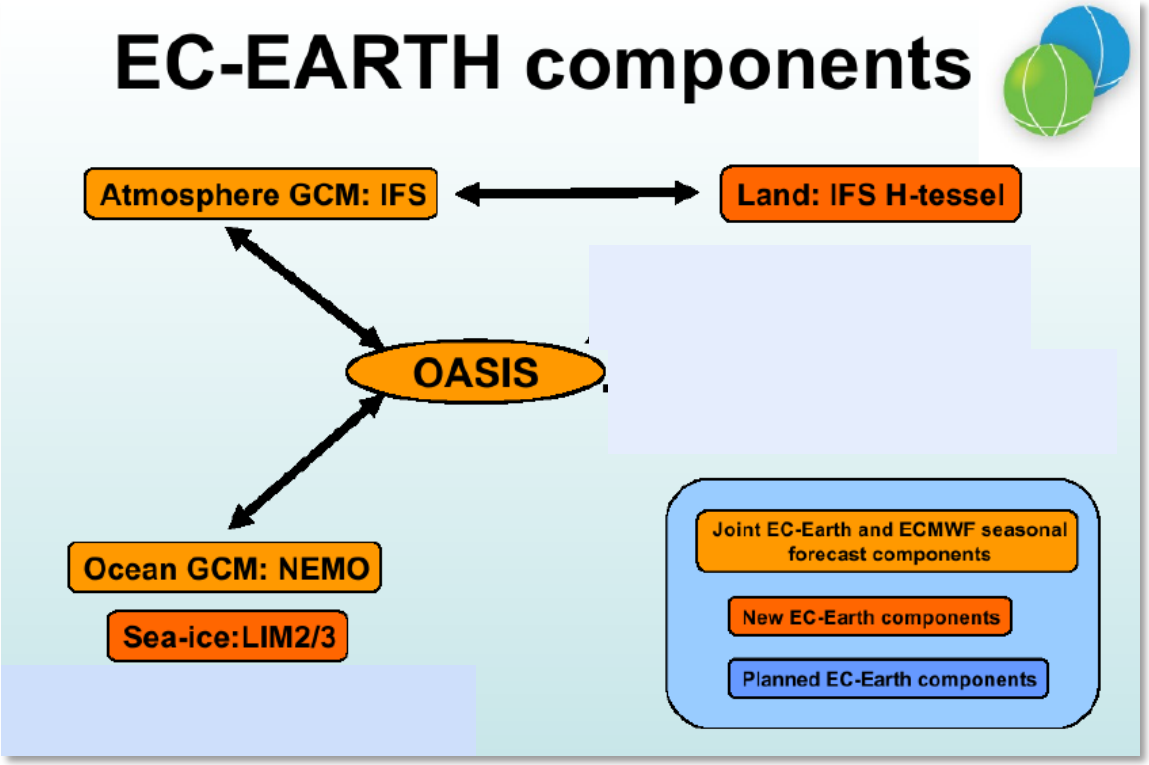


From L. Bengtsson, 2005

The EC-Earth Model

Based on the idea of "seamless predictions"

ECMWF IFS atmosphere (31r1 - T159L62/N80 = 1.125°)+ Land/veg module
+ NEMO2 ocean (OPA/ORCA1) (1° L32)
+ TM5 chemistry/aerosols (6°x4° / 3°x2°)



Integrated Forecast System ECMWF

Nucleus for European Modelling of the Ocean

Louvain La Neuve Ice Model (LIM2 (ECE v2) LIM3 (ECE v3))

H-Tessel Land-surface model

Ref.: Hazeleger, W. et al., 2009. EC-Earth: A Seamless Earth System Prediction Approach in Action. *Bull. Amer. Meteor. Soc.*, in press.

The concept of seamless predictions

- Weather and Climate: Same physical processes (but acting on different space and time scales)
- Initial conditions vs boundary conditions (predictability of the first or second kind)
- From weather → to seasonal → to decadal predictions
- Advantages: climate models profit from advances in NWP and vice-versa

Ref.: * Hazeleger, W. et al., 2010. EC-Earth: A Seamless Earth System Prediction Approach in Action. *Bull. Amer. Meteor. Soc.*, 91, 1357-1363
* Hazeleger W., et al., EC-Earth V2: description and validation of a new seamless Earth system prediction model. Climate Dynamics

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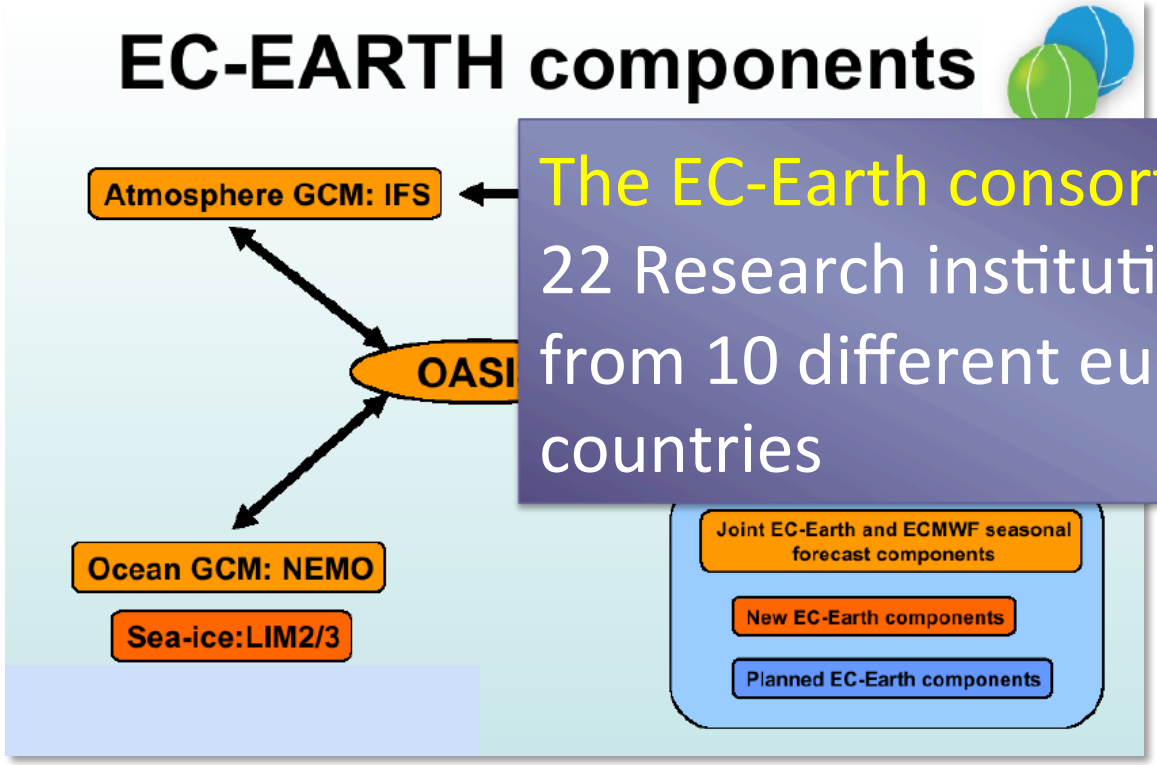

The EC-Earth consortium:
22 Research institutions
from 10 different european countries

ECMWF

ated Forecast System
VF

NEMO

us for European
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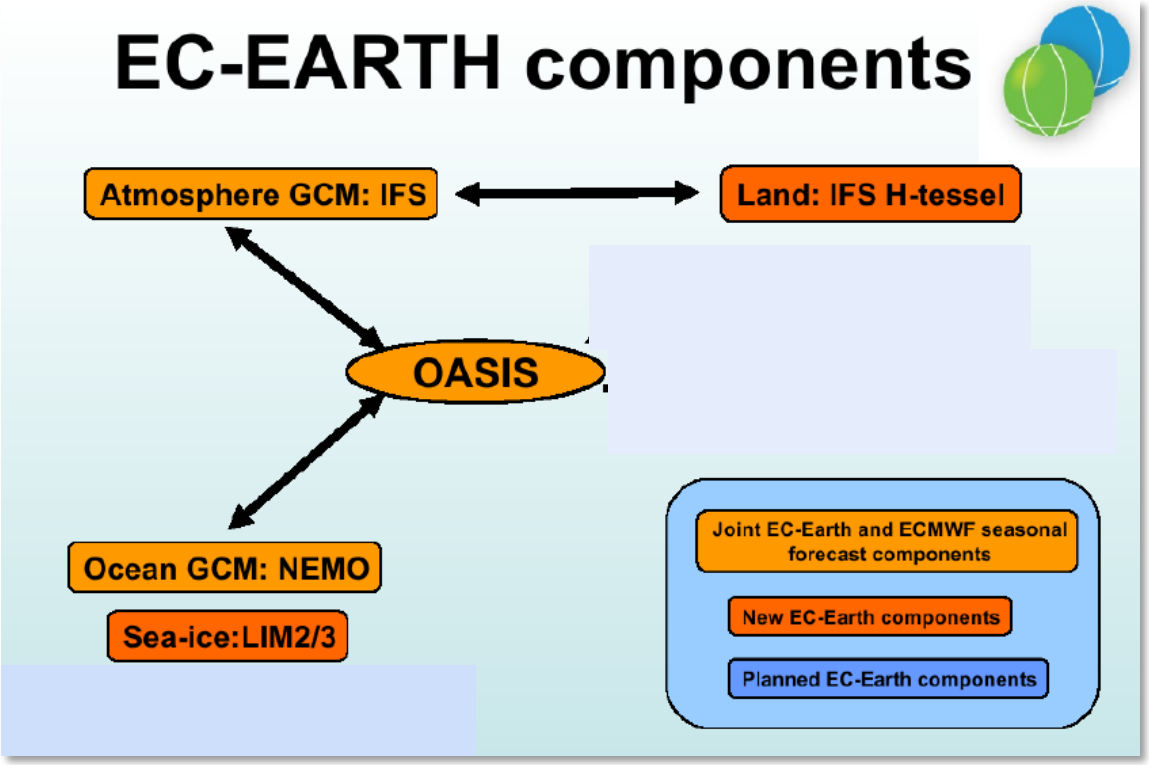

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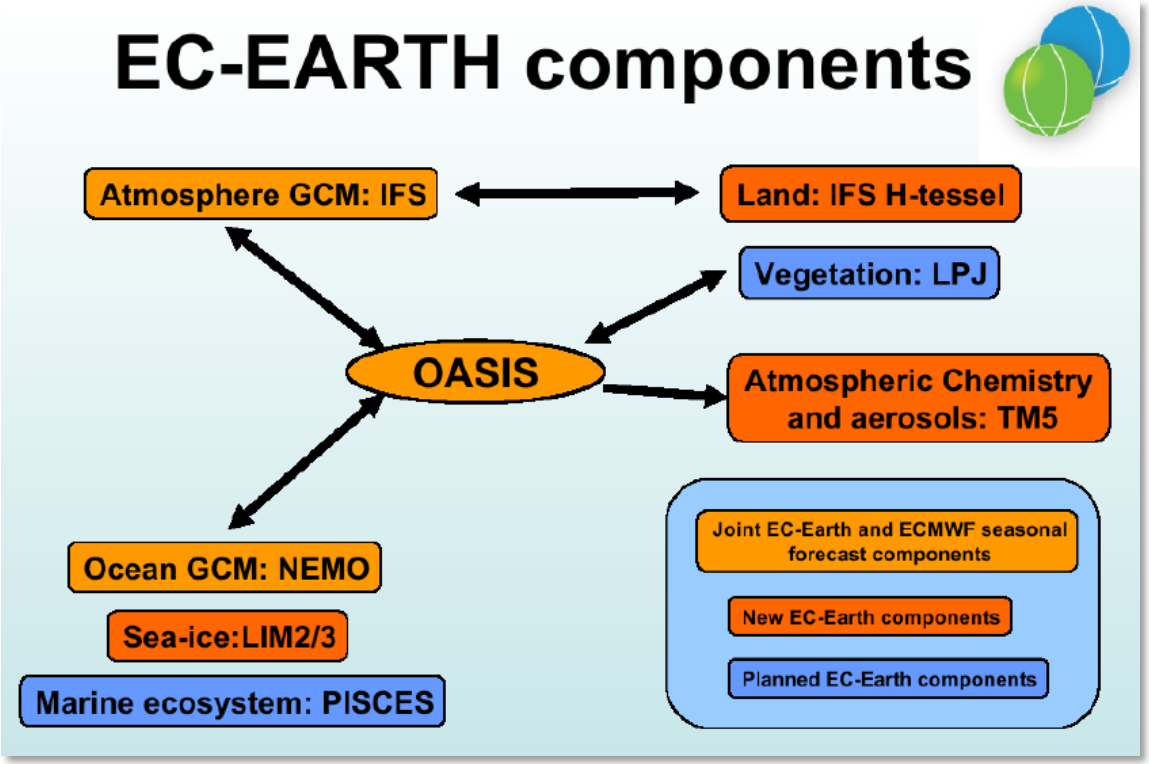

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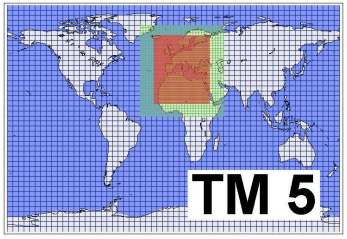


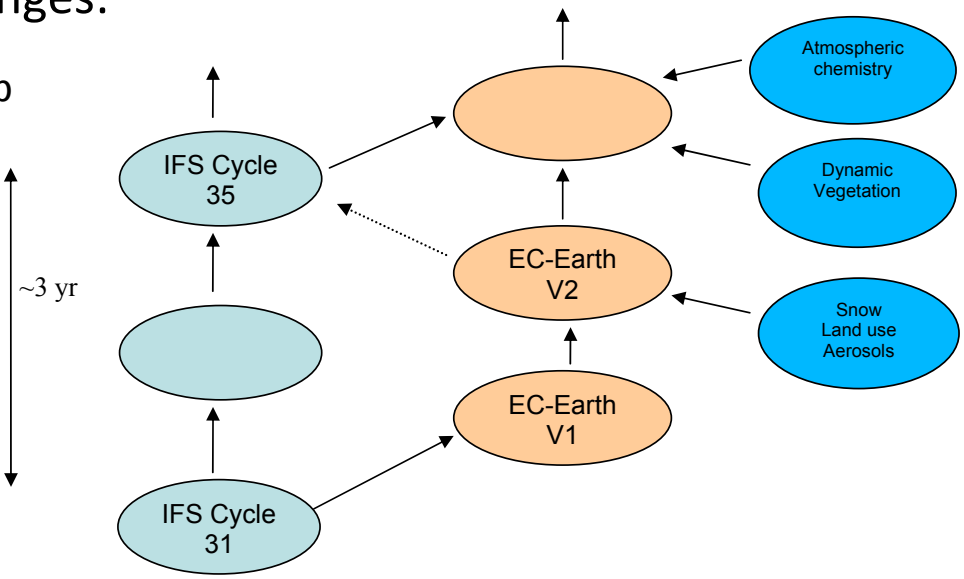
TM5 atmospheric chemistry and transport model

Ref.: Hazeleger, W. et al., 2009. EC-Earth: A Seamless Earth System Prediction Approach in Action. *Bull. Amer. Meteor. Soc.*, in press.

The Atmosphere: IFS

- The "Integrated Forecast System" is the NWP system in use at the European Centre for Medium-Range Weather Forecasts
- Spectral primitive equation model
- Semi-Lagrangian advection , 1h time step
- Current resolution for EC-Earth:
  T159 / N80 (1.125° ~ 125 km) reduced Gaussian grid /
  62 vertical levels up to 5 hPa.
- Cloud and radiation physics + aerosol direct and indirect effects.
- Based on IFS cycle 31r1, some changes:

  - ✓ Better description of entrainment in deep convecting plumes (from cycle 32r3) → better precipitation patterns over tropics
  - ✓ Better mass conservation correction scheme from cy33R2 → better mean atmospheric state
  - ✓ Time-varying aerosols
  - ✓ Ocean wave model not used



Ref.: Hazeleger et al. EC-Earth V2: description and validation … http://ecearth.knmi.nl/index.php?n=PmWiki.Papers

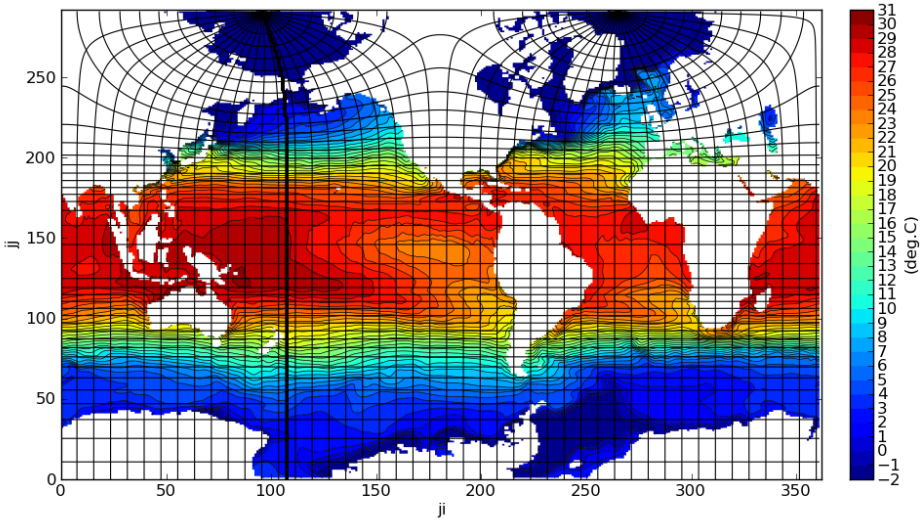
The Ocean:

The “Nucleus for European Modelling of the Ocean” is based on the OPA 9 (Océan Parallélisé) model:

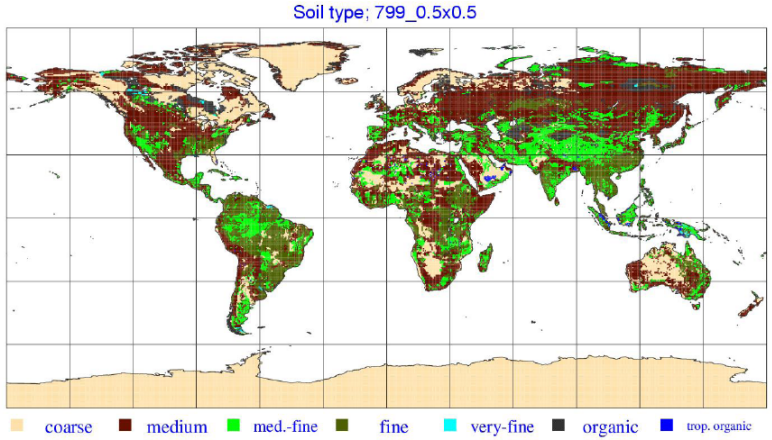
- NEMO2: Primitive equations, free surface, energy and enstrophy conserving momentum advection.
- TVD advection scheme (Zalesak 1979). Free slip lateral BCs.
- Gent and McWilliams (1990) vertical adiabatic mixing scheme for T and S
- Vertical eddy diffusion using TKE scheme (Gaspar et al. 1990).

- ORCA1 grid: Arakawa-C, about 1° resolution (not constant), higher resolution (1/3°) near the equator. Tripolar grid. 42 levels.

- + Louvain La Neuve Ice Model (LIM2) for sea-ice (3-layer thermodynamic model)

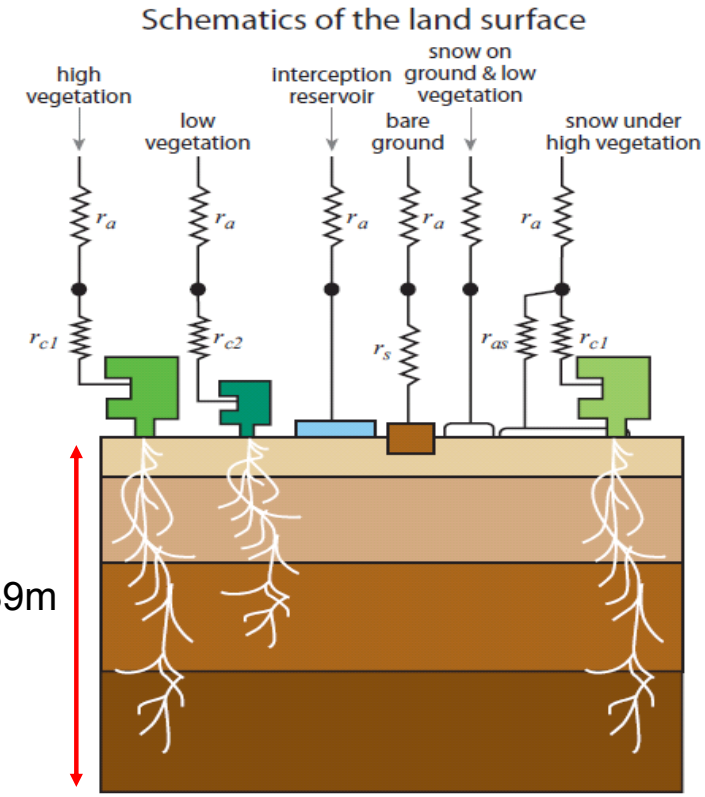


Land Surface: H-TESSEL



- Water + heat exchanges
- 6 land tiles: bare ground, low and high vegetation, intercepted water, shaded and exposed snow

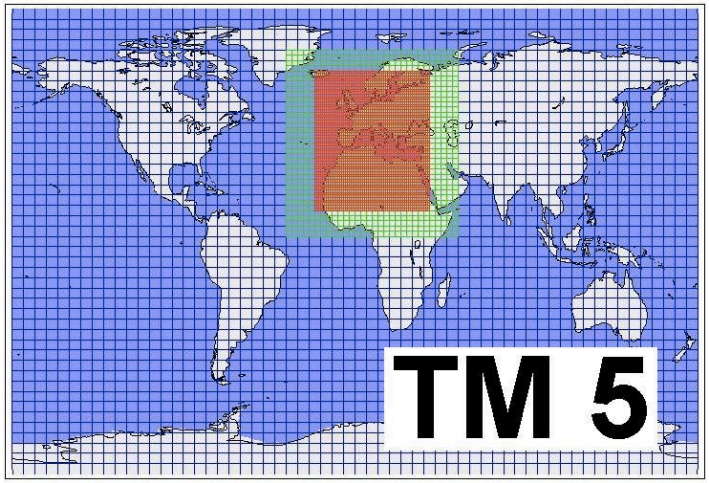
- Energy balance for each tile w/ vegetation evaporation, roughness and snow properties
- Snow albedo and density prognostic
- Parametrization of fast surface runoff
- Spatially varying soil textures + soil hydraulic properties
- Soil water flow: Richard's equation + van Genuchten for conductivity and diffusivity + 4 soil layers
- Instantaneous collection of runoff in river basins.



Refs:: van den Hurk et al. 2000, ECMWF tech. memo 295 + Balsamo et al. 2009, ECMWF tech. memo 563

To be coupled in the next versions:

Atmospheric chemistry and aerosols: TM5



- Tropospheric chemistry + aerosols
- Direct and indirect radiative forcing computed in IFS
- 3°x2° and 6°x4° resolutions
- Tropospheric photochemistry based on CBM (carbon bond mechanism) IV
- Aerosol mass and number concentration computed with M7 (Vignati et al. 2004)
- Online parametrizations for biogenic emissions.

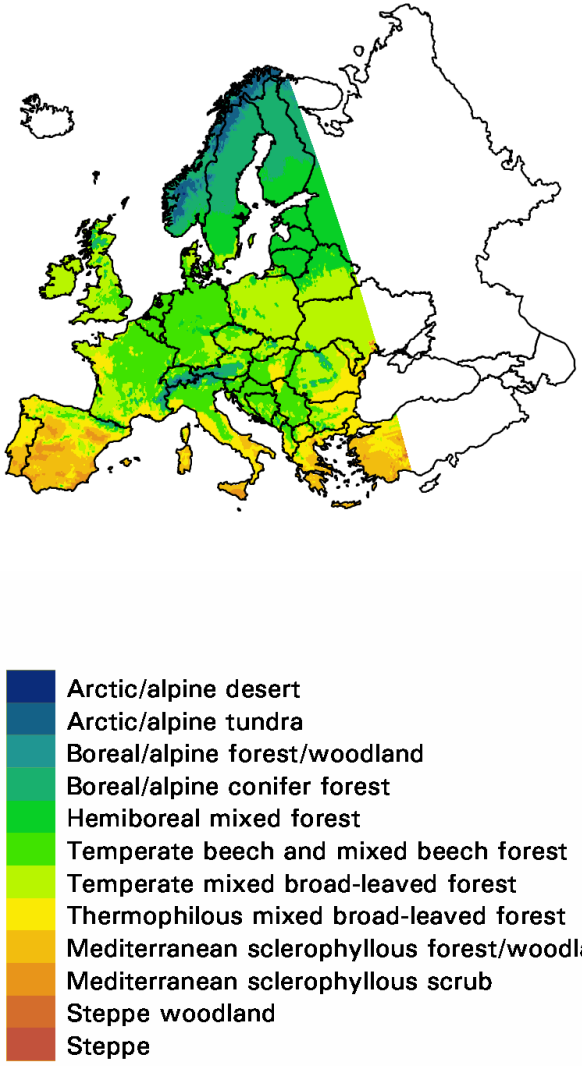
Ref.: Krol et al. 2005 ACP 5, 417-432.

To be coupled in the next versions:

Vegetation and biogeochemistry: LPJ-GUESS

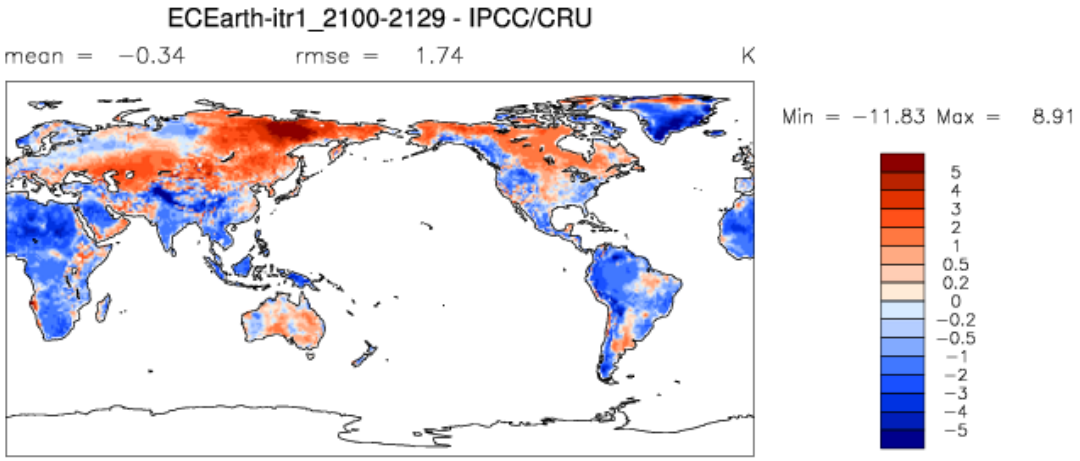
General Ecosystem Simulator (GUESS), +
Lund-Potsdam-Jena Dynamic Global Vegetation Model (LPJ)

- Plant physiology + ecosystem biogeochemistry
- Functional types, vegetation dynamics + canopy structure
- Stochastic establishment, individual tree mortality and disturbances → successional vegetation dynamics
- Process-based description for the main biogenic volatile organic compounds



Ref.: Smith et al. 2001. Global ecology and biogeography, vol 10 (6).

Model tuning effort



- ISAC-CNR is coordinating a consortium-level tuning effort of the EC-Earth v3 model. The goal is to reach mid-2014 with a tuned and optimized version, ready for CMIP6.
- Current activities include coordinated experiments among the different participants in the consortium, based on a common reference baseline (in progress) and on performance metric tools based on Reichler and Kim (2008) (developed)
- Several long experiments (> 1500 years total) with permanent 2005 conditions in progress/done. Under exploration: changes in ocean albedo and fixes for conservation of atmospheric humidity during advection.

Boundary conditions

- Land and vegetation:
  - ✓ Low and high vegetation cover prescribed: GLCC database
  - ✓ Land-use scenarios for RCPs
  - ✓ Monthly varying albedo for each veg. type

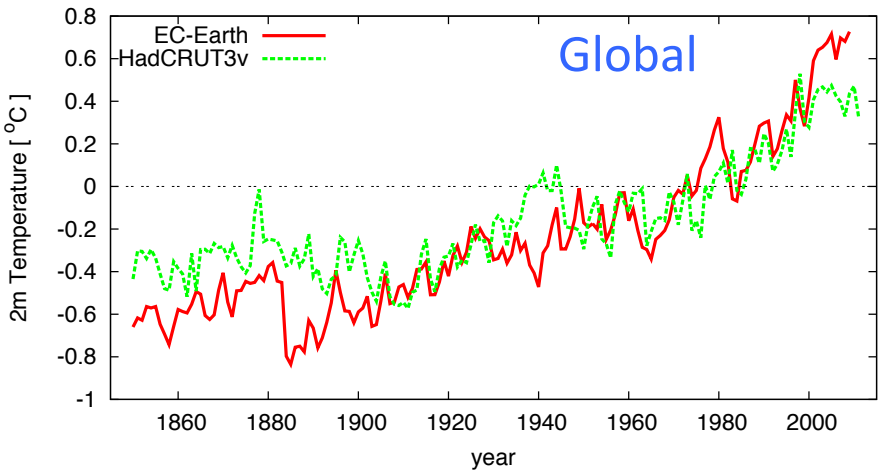
- Anthropogenic and natural aerosols:
  - ✓ Sulfates, BC, OC, Sea-salt and desert dust concentrations are taken from the Community Atmosphere Model with IPCC emissions.
  - ✓ Monthly averages, 26 levels, 35x71 points.

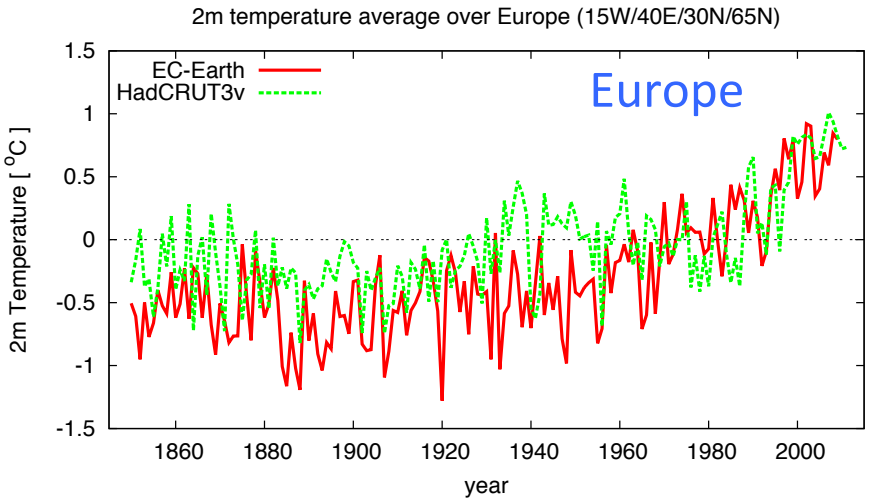
- Volcanic aerosols:
  - ✓ Monthly fields of volcanic AOD based on GISS data (1850-2010) including major eruptions.

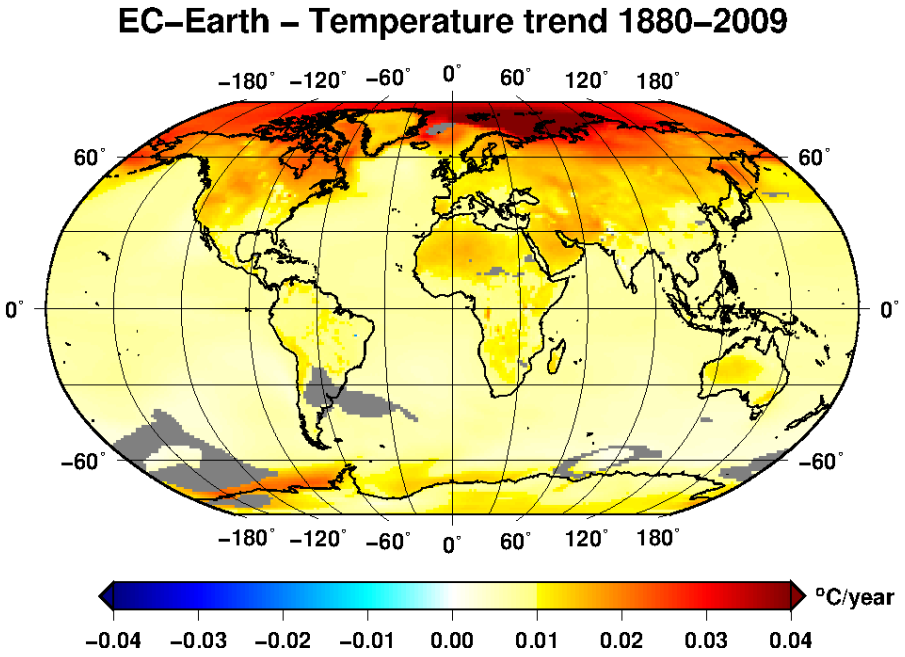
- Greenhouse gases:
  - ✓ Global averaged annual values for CO2, CH4 and N2O based on IIASA concentrations.
  - ✓ CFC-11 and CFC-12 computed based on annual emissions.

- Solar forcing:
  - ✓ Forcing data (SPARC) based on reconstruction w/ solar flux model based on sunspot and facular timeseries. Before 1850 mean of reconstructed 1844-1856 irradiance. After 2008 last solar cycle is repeated.

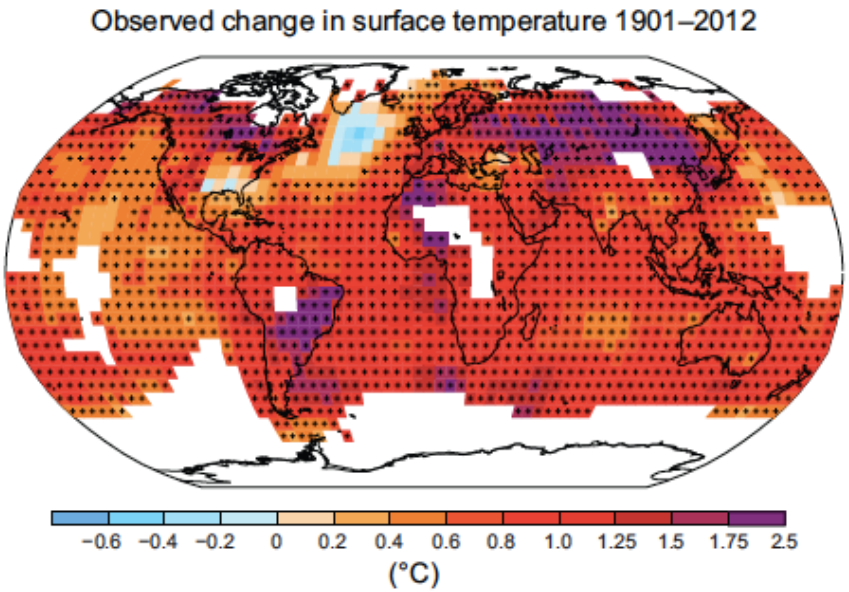
Historical run: surface temperatures



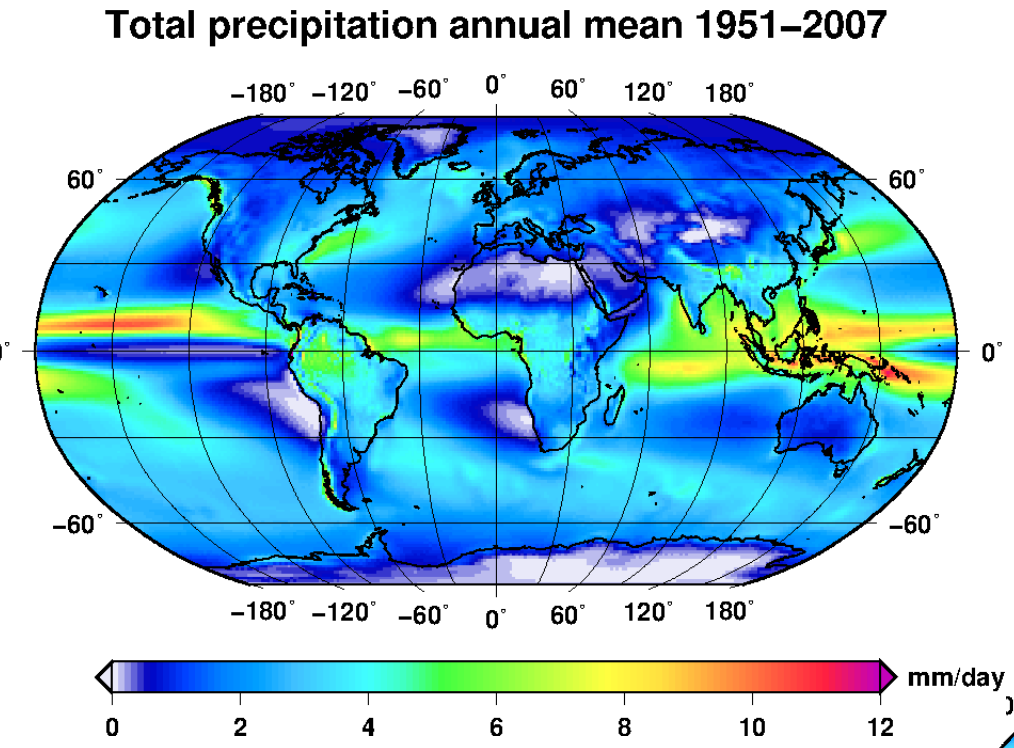




(b)



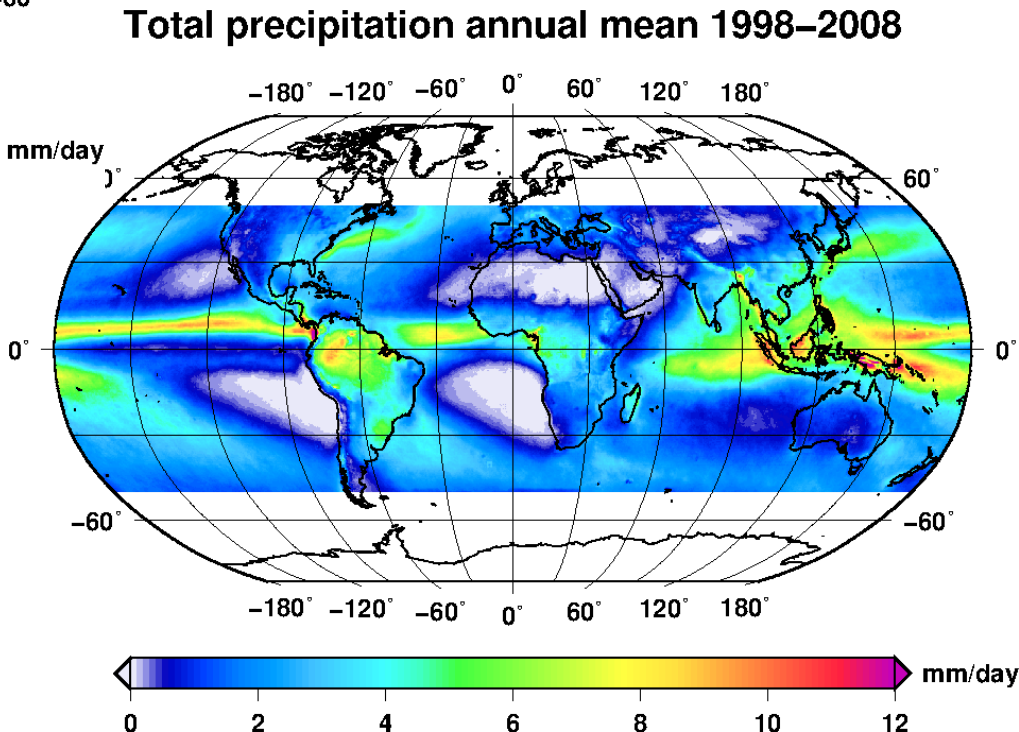
EC-Earth 2.3 climatology: Global precipitation

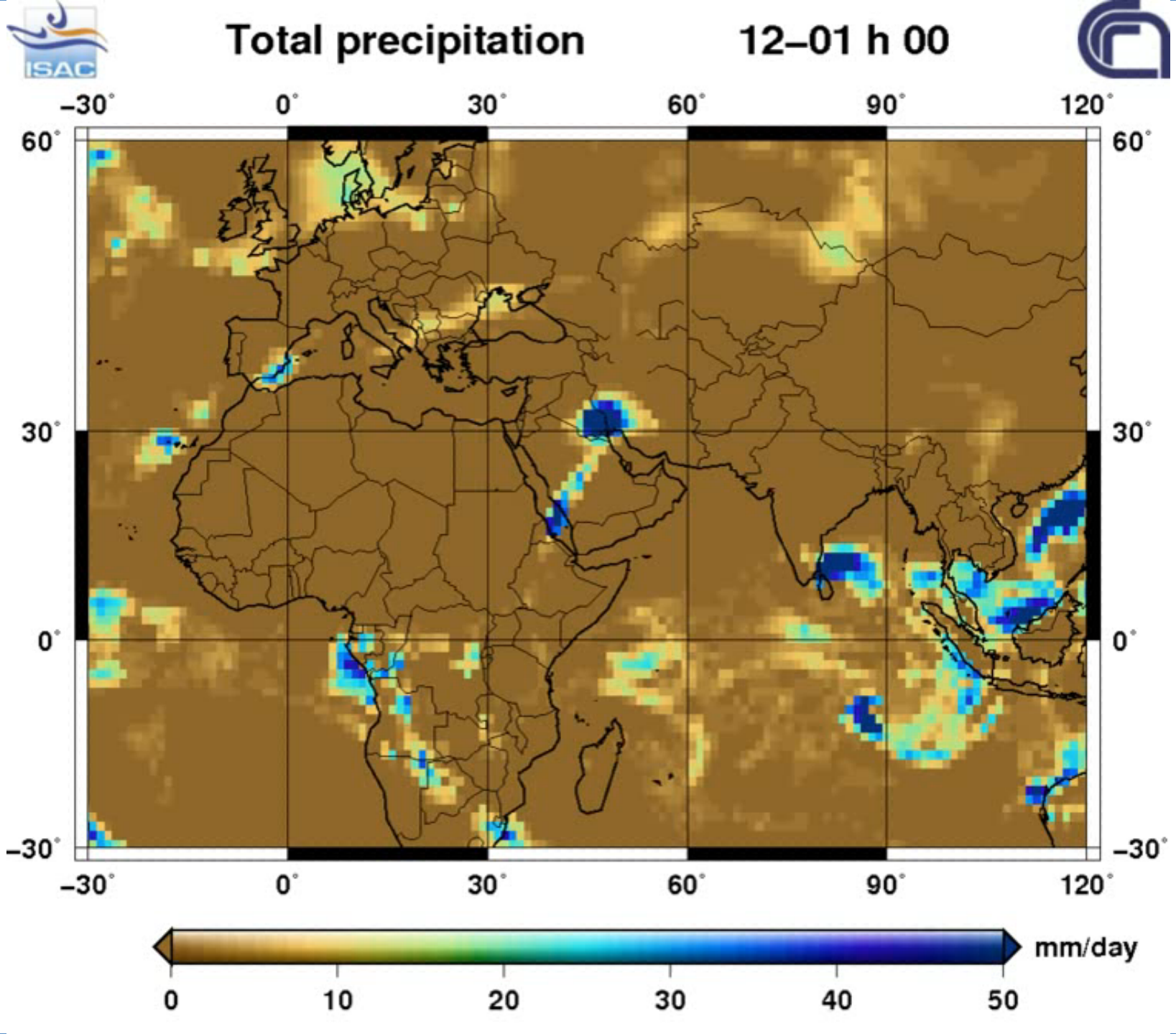


EC-Earth 2.3

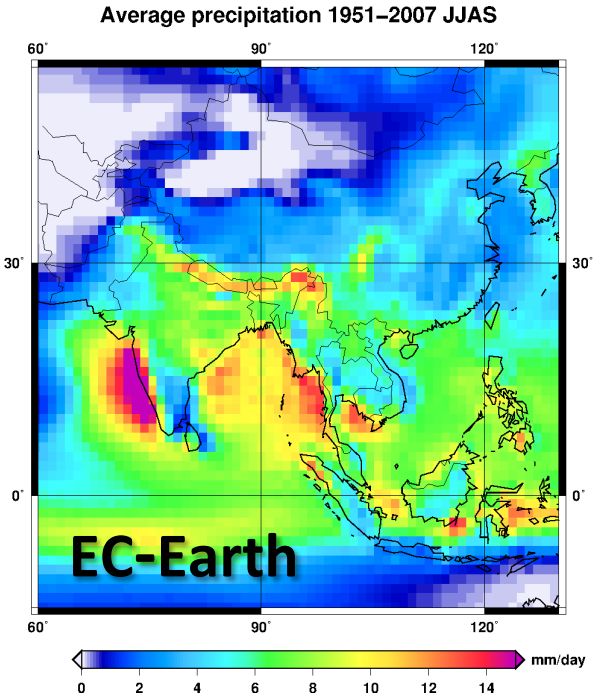
TRMM (Tropical Rainfall Measuring Mission)

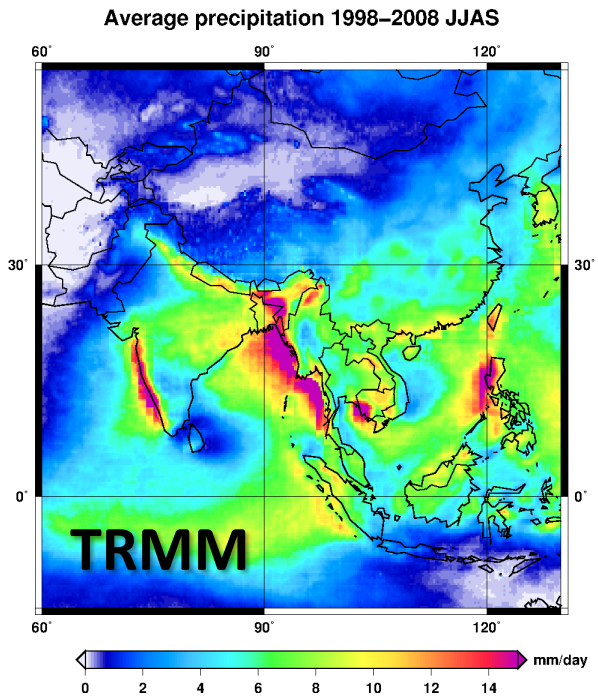
Product: 3B42: 3-Hour 0.25 x 0.25 ° (30x30 km) from 50°S-50°N

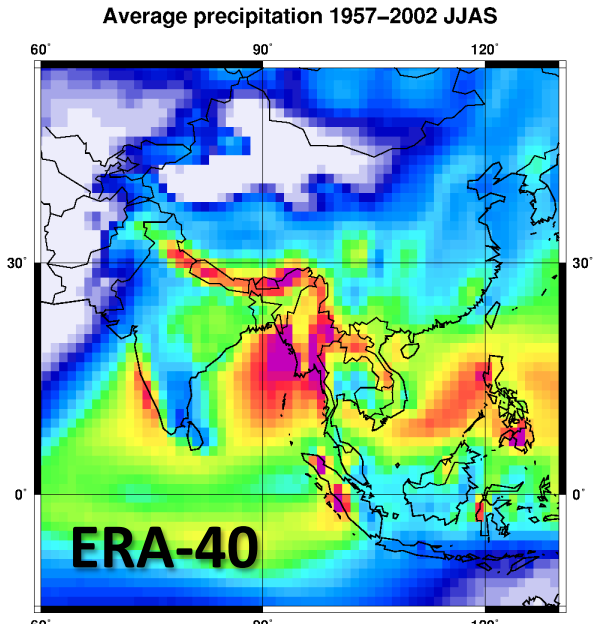


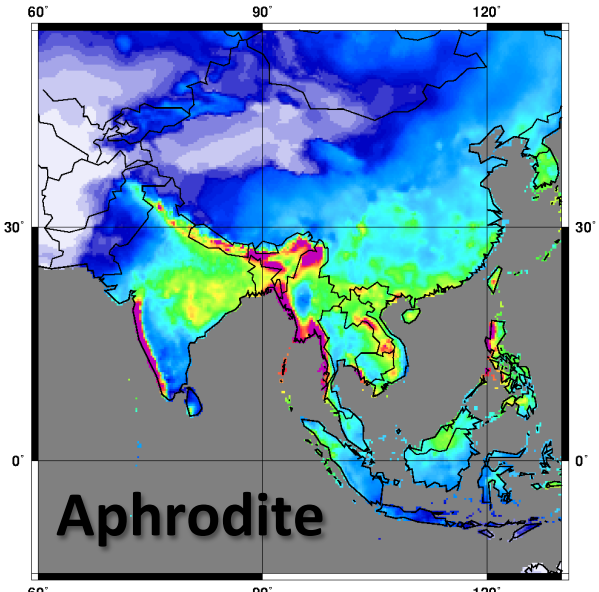

Total precipitation
12–01 h 00
ISAC
–30°
0°
30°
60°
90°
120°
60°
30°
0°
–30°
0
10
20
30
40
50
mm/day

Summer precipitation in the Indian monsoon area

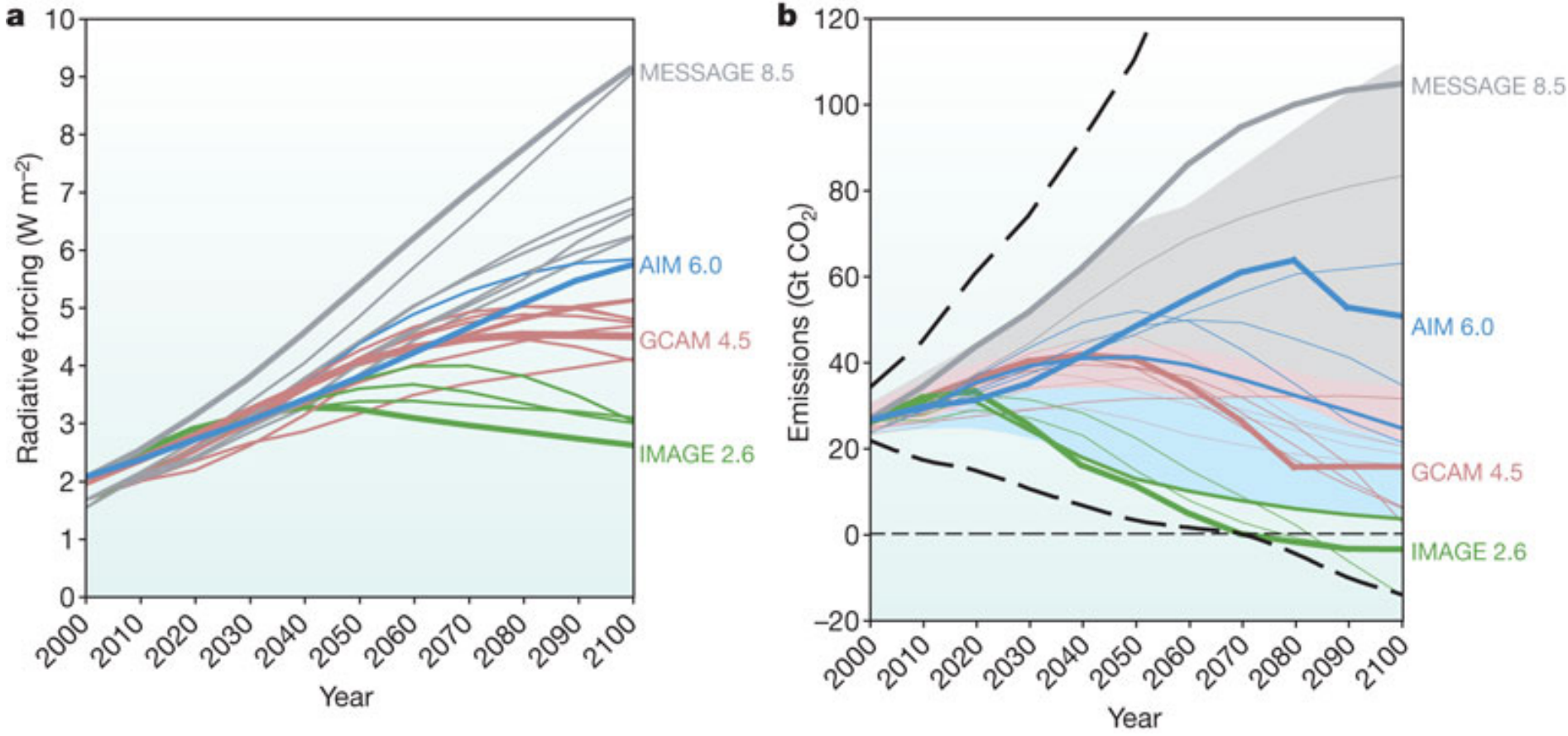








Future projections: CMIP5 and Representative concentration pathways



RH Moss *et al. Nature* **463**, 747-756 (2010) doi:10.1038/nature08823

nature

Scenario runs:

RCP 4.5

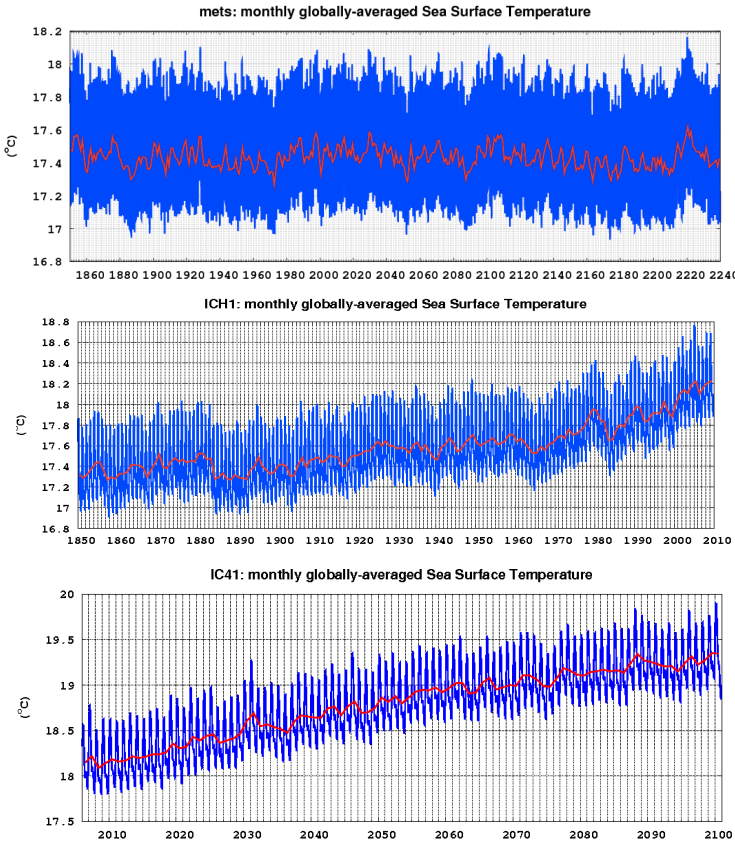
(stabilization of anthropogenic radiative forcing at 4.5 W/m^2 wrt to pre-industrial in 2100)

RCP 8.5

(increase of anthropogenic radiative forcing to 8.5 W/m^2 wrt to pre-industrial in 2100)

Current simulations (ISAC)
Historical runs and scenarios (CMIP5)

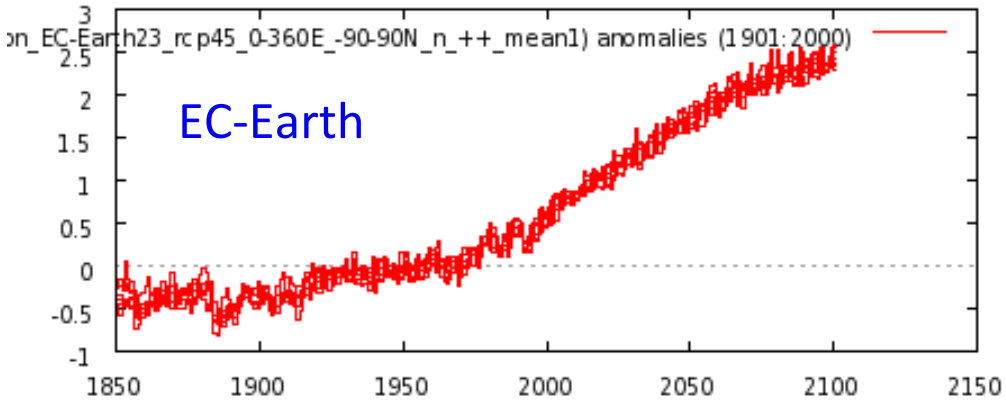
- Pre-industrial spin-up and control run (700 yrs – by MetEireann)
- Industrial simulation 1850-2005 (using historical GHG and aerosol concentration fields)
  (16 member ensemble created by consortium partners)
- RCP 4.5, RCP 8.5 + RCP 2.6 scenarios 2006-2100

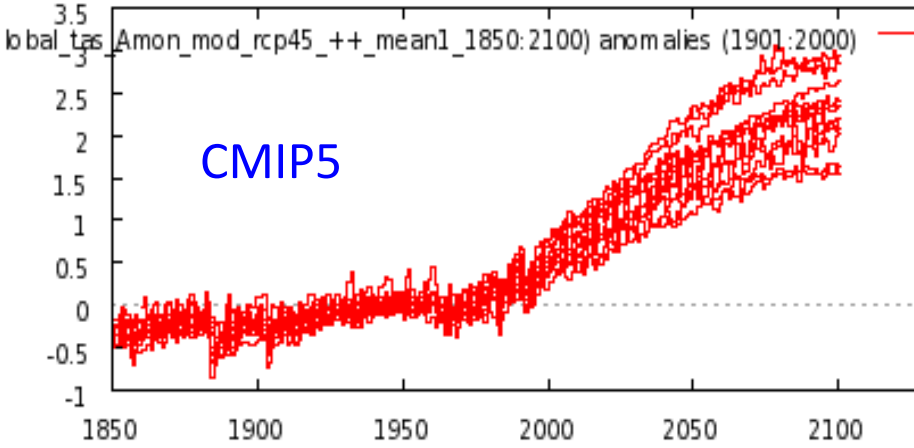


Data produced (historical): 15TB+ 30TB (scenarios)

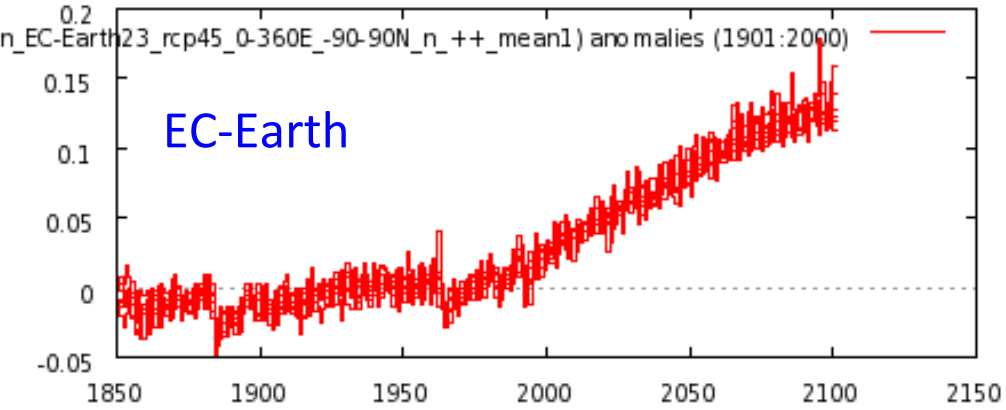
Future projections: comparing EC-Earth with other 12 CMIP5 models (RCP 4.5)

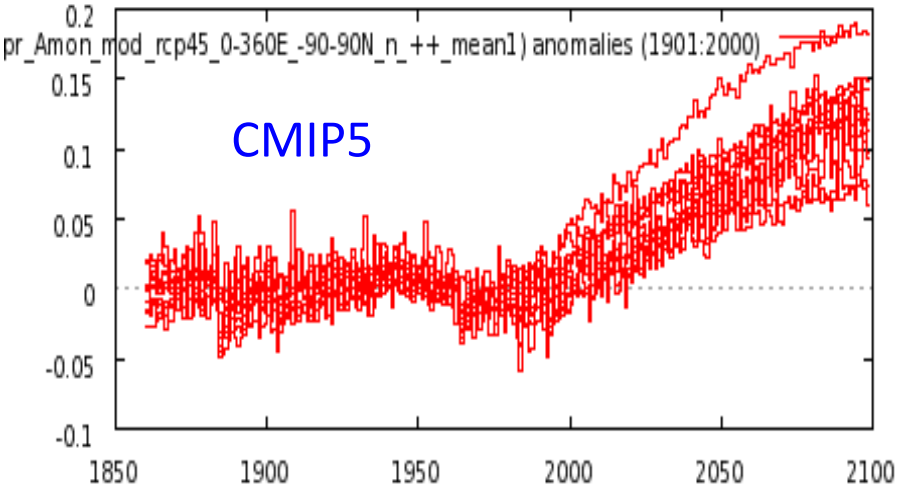
Temperature at soil



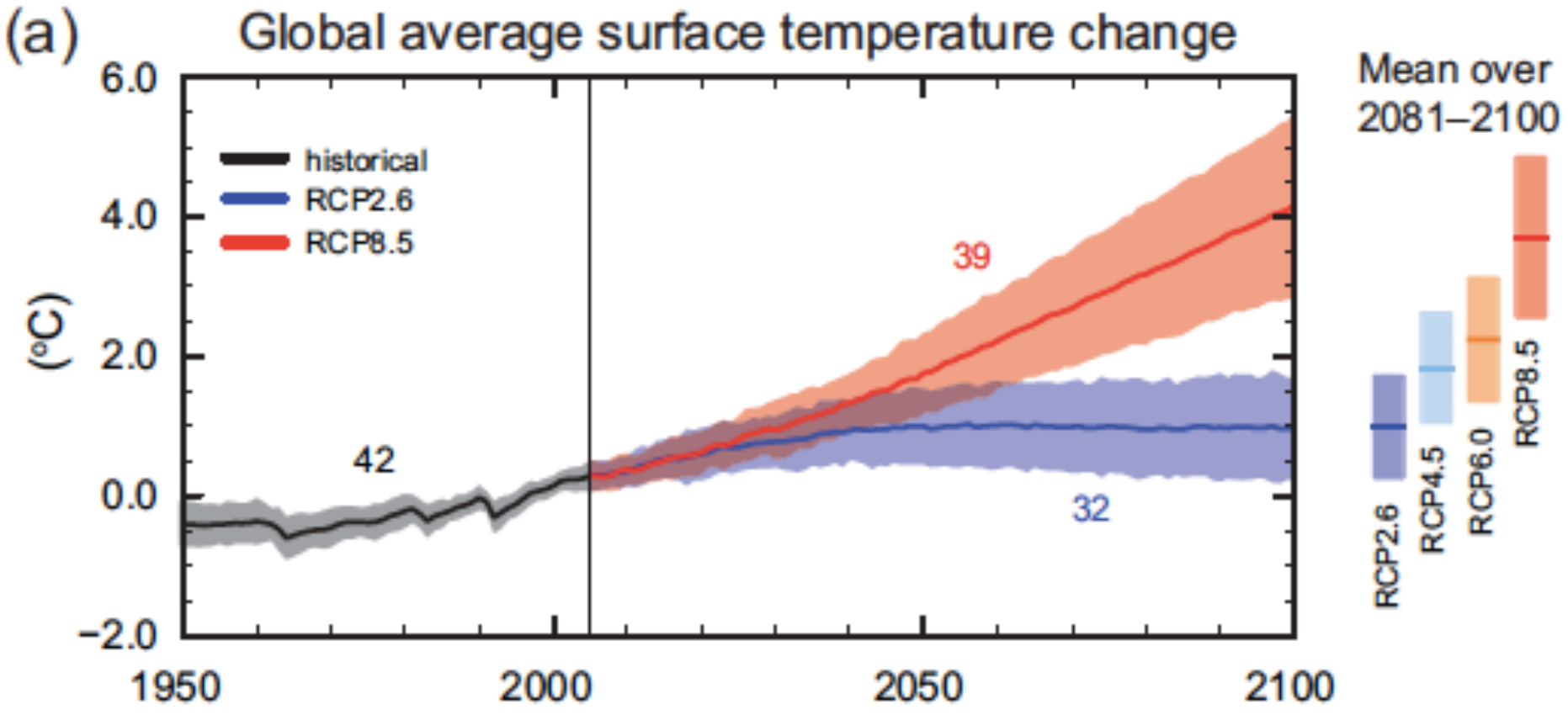


Precipitation

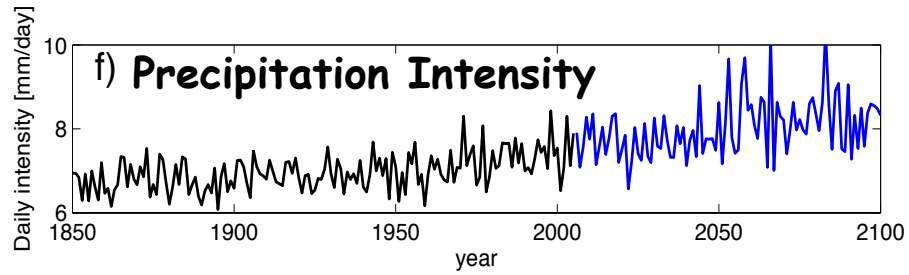


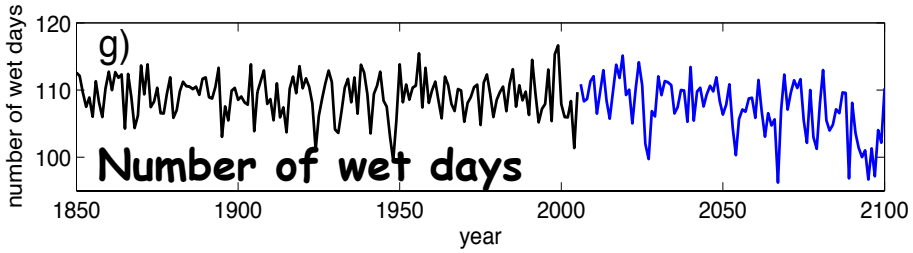


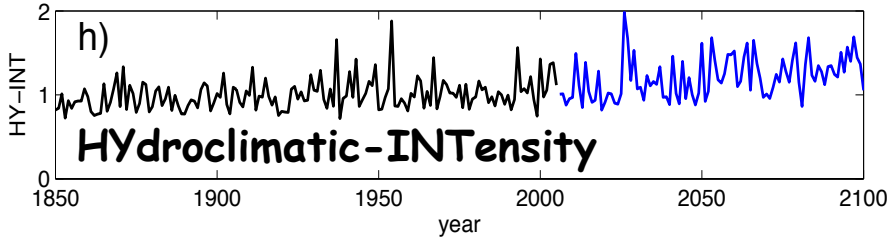
Future projections (IPCC AR5)



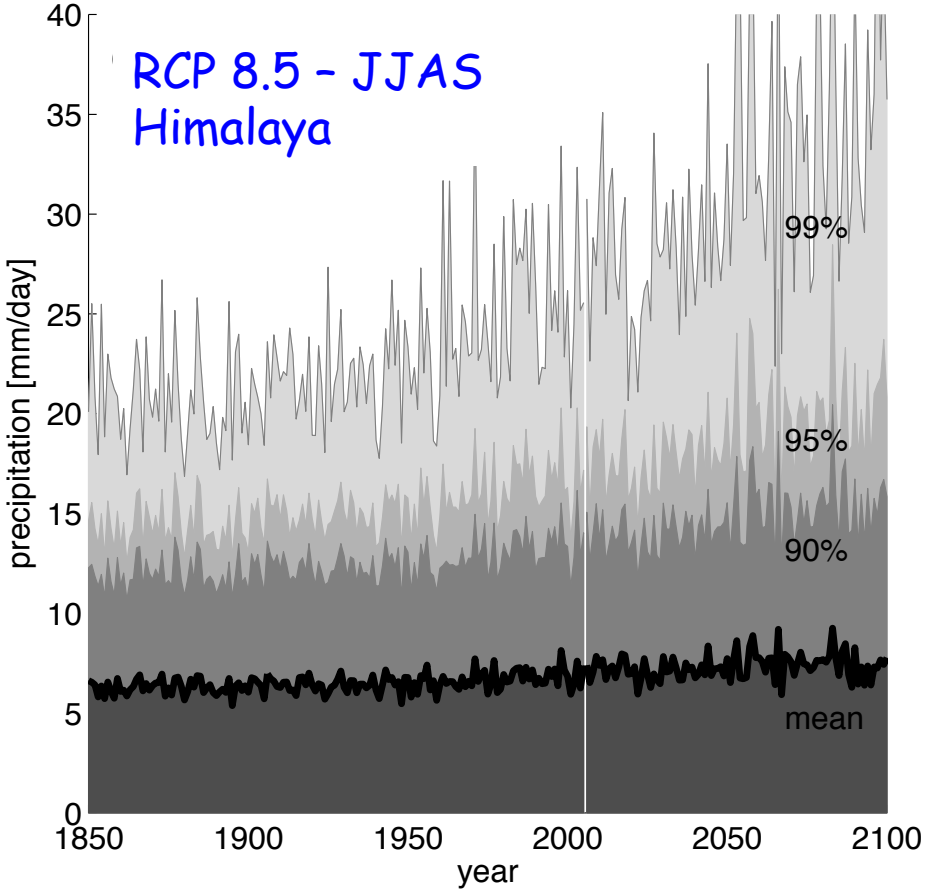
EC-Earth simulations and projections (Precipitation Extremes)







Himalaya box – RCP 8.5 – JJAS



WRF - The Weather Research & Forecasting Model

http://www.wrf-model.org/index.php

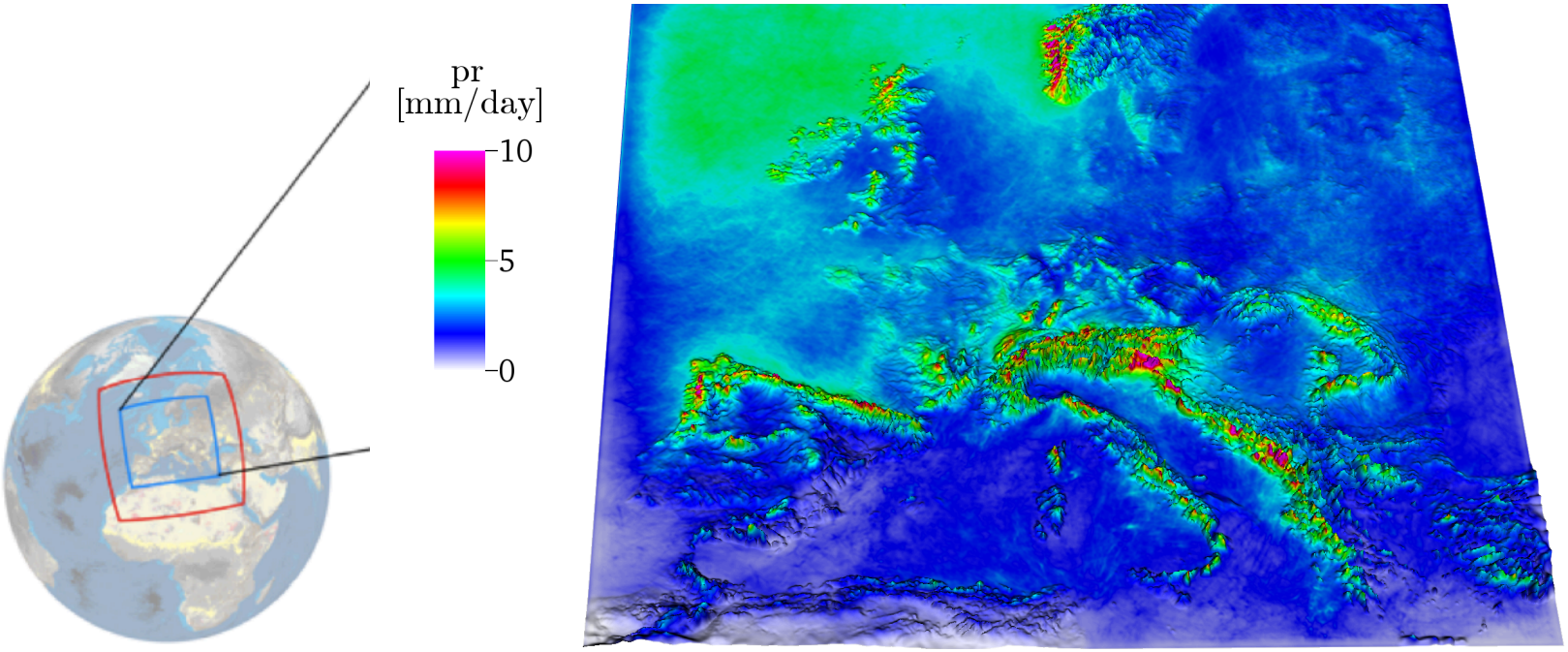
- Non-hydrostatic regional model → high resolution → small-scale processes usually neglected or parameterized in coarser-scale models are treated explicitly

- Simulation of individual events (e.g., extreme events such as floods) and climate simulations

- We are using WRF nested into both global reanalyses and the EC-Earth GCM

High-resolution dynamical downscaling of global scenarios over Europe

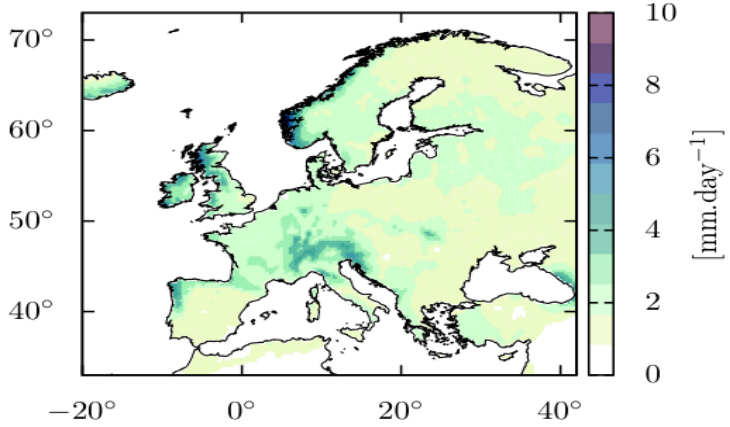
- 30-yr present (1979-2008). Large scale driver ERA-Interim at 3.5 km resolution (done)
- present, RCP 4.5 and RCP 8.5 projections, large scale driver EC-Earth at 11 km resolution (will be finished by the end of the year)



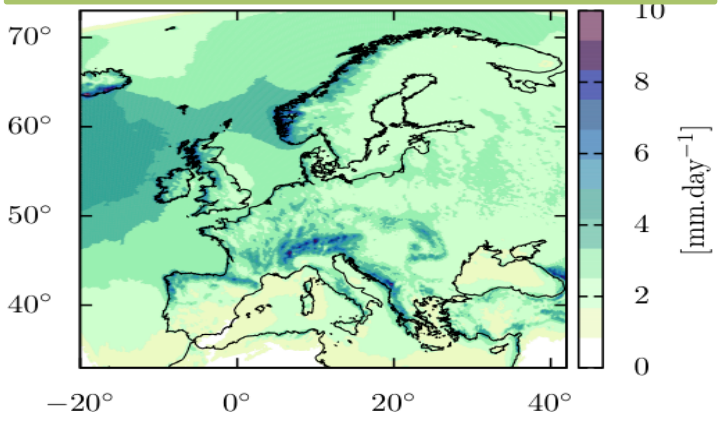
Simulations @ LRZ/SuperMUC, Munich

Precipitation climatology

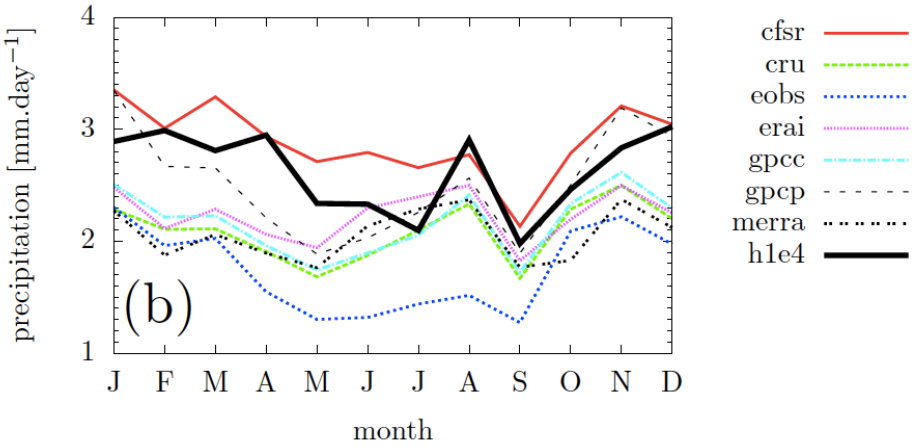
E-OBS



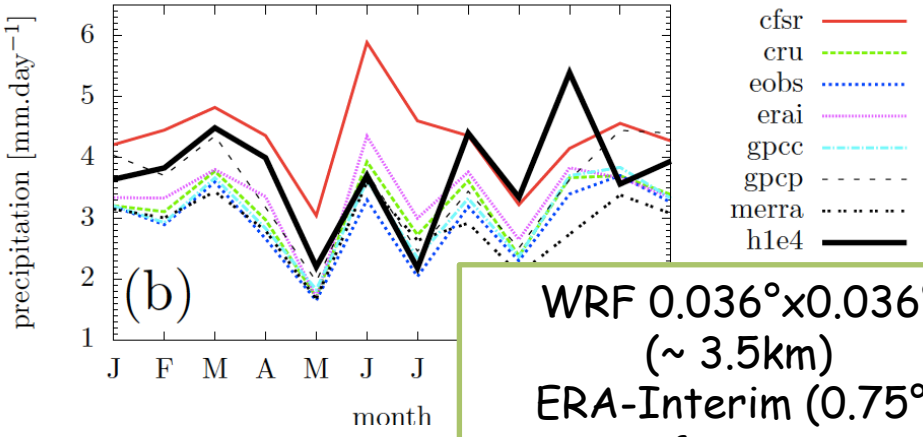
WRF 0.11°x0.11° (~ 10km)
ERA-Interim (0.75°) forcing



EURO-Cordex area



GAR area



WRF 0.036°x0.036°
(~ 3.5km)
ERA-Interim (0.75°)
forcing

High resolution runs (3.5 km), explicit convection

WRF 0.036°x0.036°
(~ 3.5km)
ERA-Interim (0.75°)
forcing