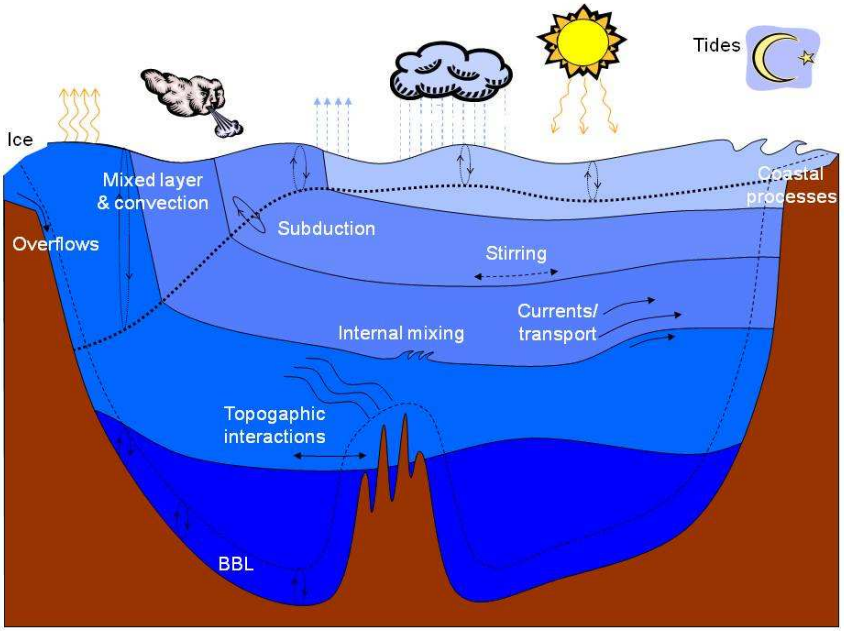
TM5 in EC-Earth & C-IFS

P. Le Sager, T. van Noije, V. Huijnen
R&D Weather and Climate Modeling
KNMI

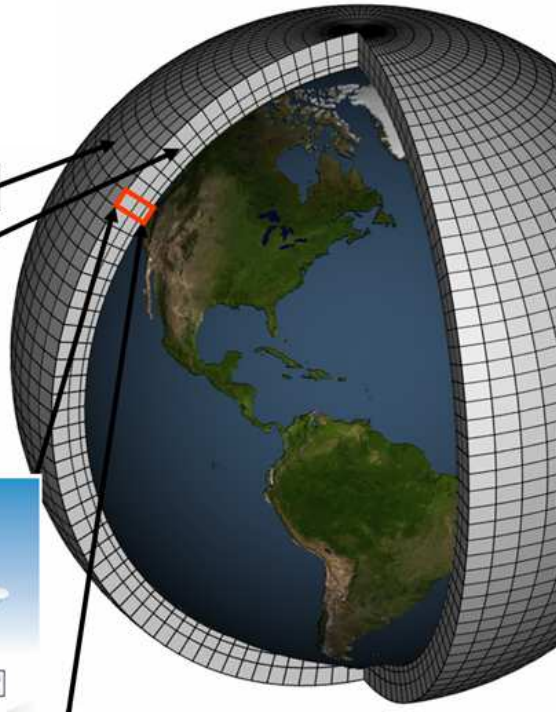


NEMO

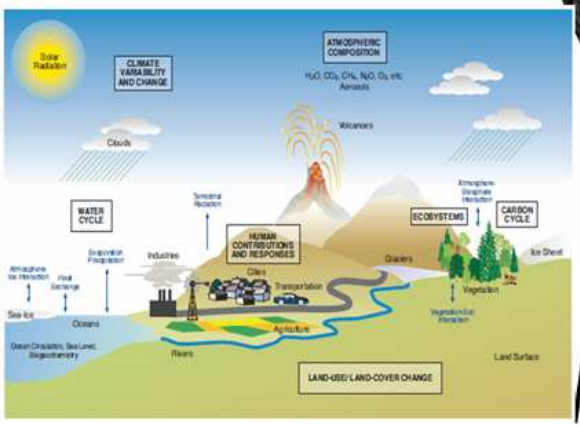
IFS

Horizontal Grid (Latitude-Longitude)

Vertical Grid (Height or Pressure)



Oasis Coupler



EC EARTH 3

A brief history of EC-Earth

- EC-EARTH **2.3** : **CMIP5** (IFS cy31r1, NEMO 2, LIM2) [mid 2010]
- EC-EARTH **2.4** : + Dyn. Land, + Atm. Chemistry [mid 2012]
  (non-interactive)

- EC-EARTH **3.0** : IFS cy36r4, NEMO 3.3, LIM3 [early 2013]
- EC-EARTH **3.1** : some tuning → research [mid 2014]
- EC-EARTH **3.2** : NEMO 3.6, OASIS-MCT [mid 2016]
  - workhorse for **CMIP6**,
  - currently beta (tuning, forcings)

What's new in 3.2?

	2.3 for CMIP5	3.2 for CMIP6
NEMO 2 → 3.6	46 levels	75 levels xios • better conservations (z*) • new equation of state • improved runoff distribution
IFS cy31r1 → cy36r4	T159 (1.125°) L62	T255 (0.75°) L91 convection + microphys. param. (cy40r1) Water mass fixer (cy38r1) Interactive aerosols Better snow treatment
OASIS3 → OASIS3-MCT	executable	library
TM5 → TM5-MP	**cbm4**	**cbm5** **feedback** **performance**
LIM 2 → 3	single ice category	• Multiple (5) ice categories • Multi-layer halo-thermodynamics • EVP rheology on C-grid • More realistic artic sea-ice

What's new in 3.2?

	2.3 for CMIP5	3.2 for CMIP6
software management	Old fashioned: ad-hoc scripts - tar files -	Modernized: ec-conf utility runtime environment version control project management + tracking issues
Runoff mapper	-	more robust & flexible
PISCES	-	Biogeochemistry
LPJ-Guess		Feedback (LAIs)
PISM	-	Parallel Ice Sheet Model
XIOS	-	Output server

Components of 3.2

Greenland ice sheet
PISM

Atmospheric Chemistry
TM5

Bio-geo-chemistry
(PISCES)

Sea Ice (LIM3)

Ocean
NEMO 3.6

Atmospheric Dynamics

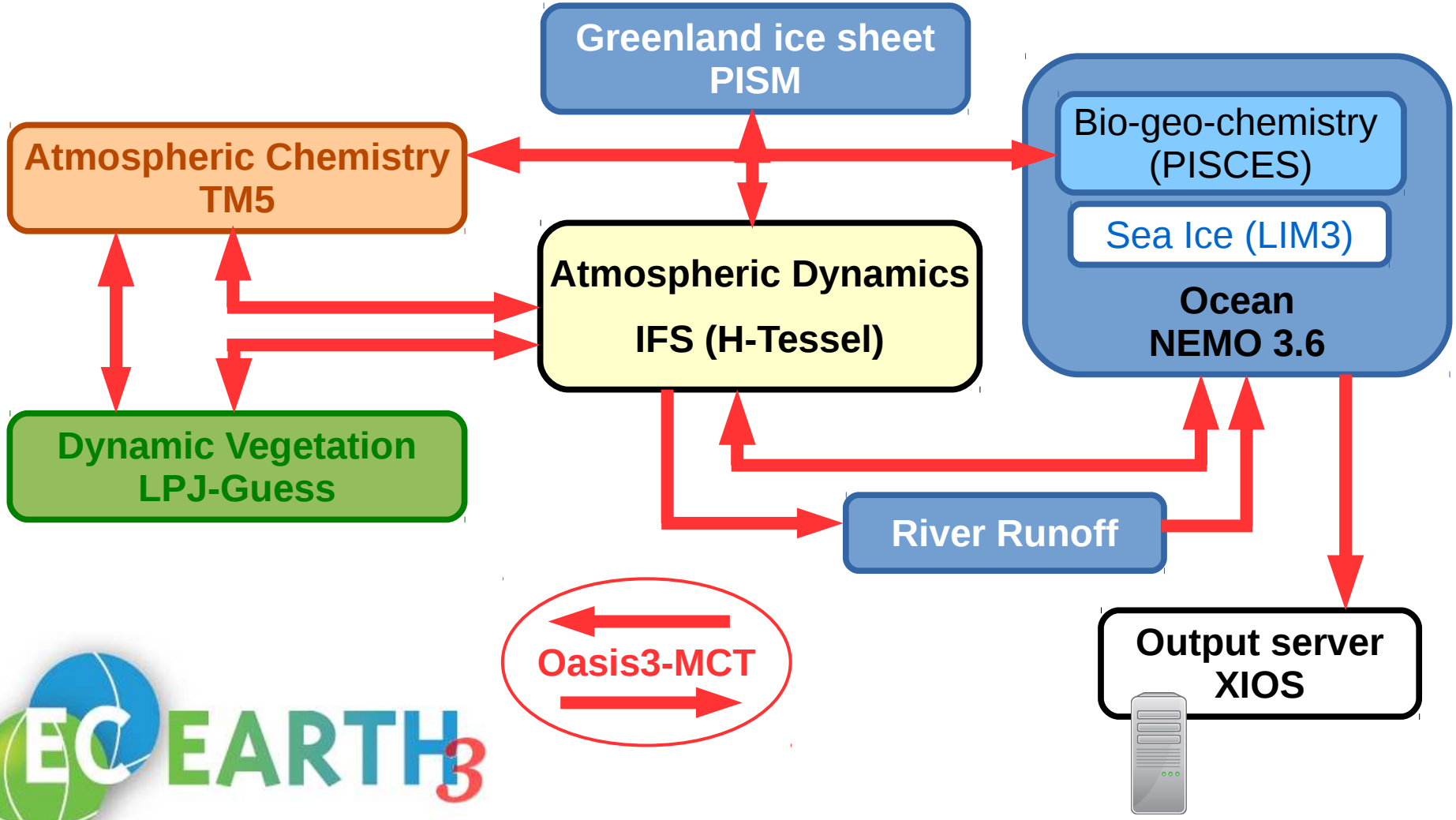
IFS (H-Tessel)

Dynamic Vegetation
LPJ-Guess

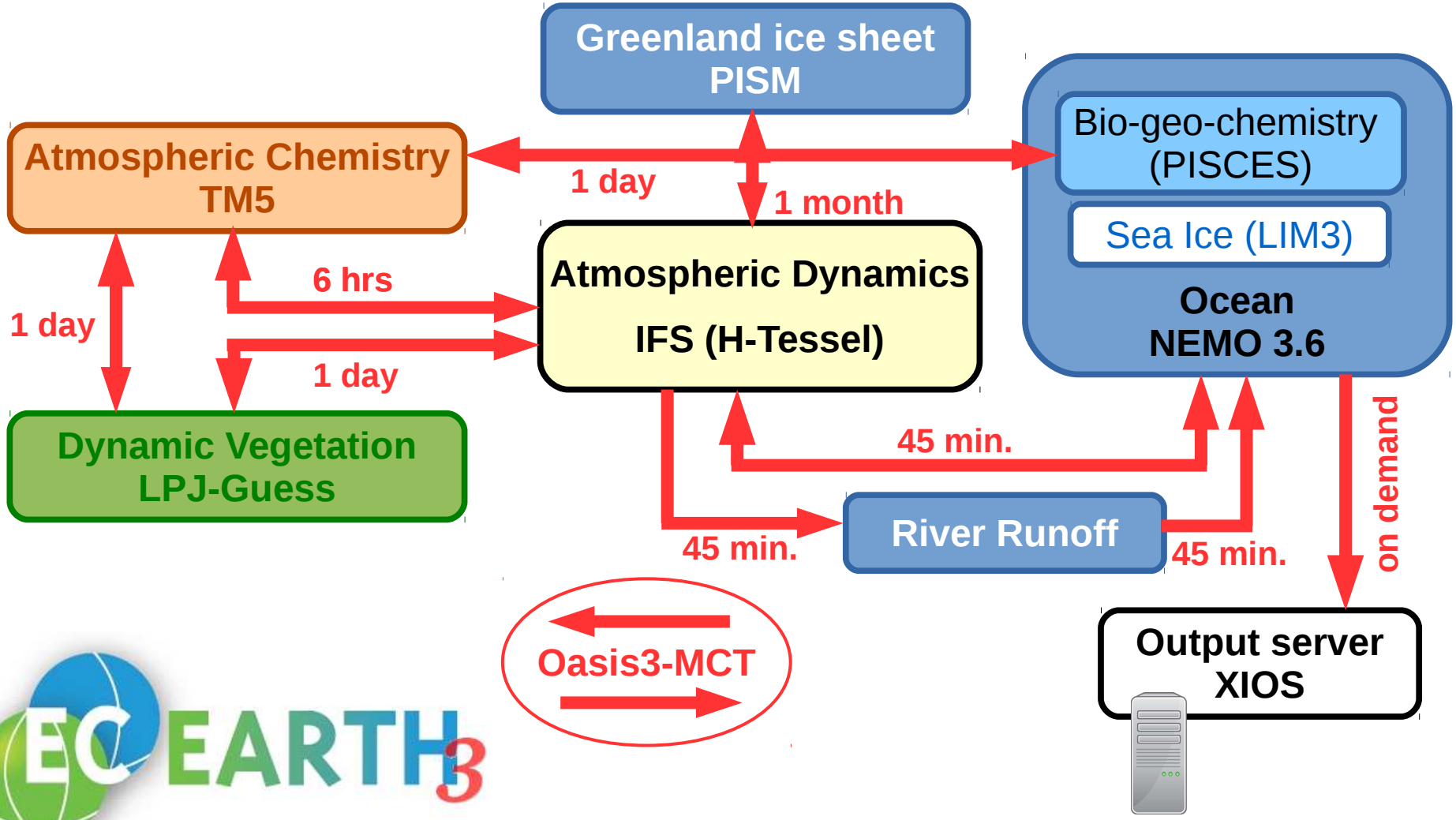
River Runoff

Output server
XIOS

Components of 3.2



Components of 3.2



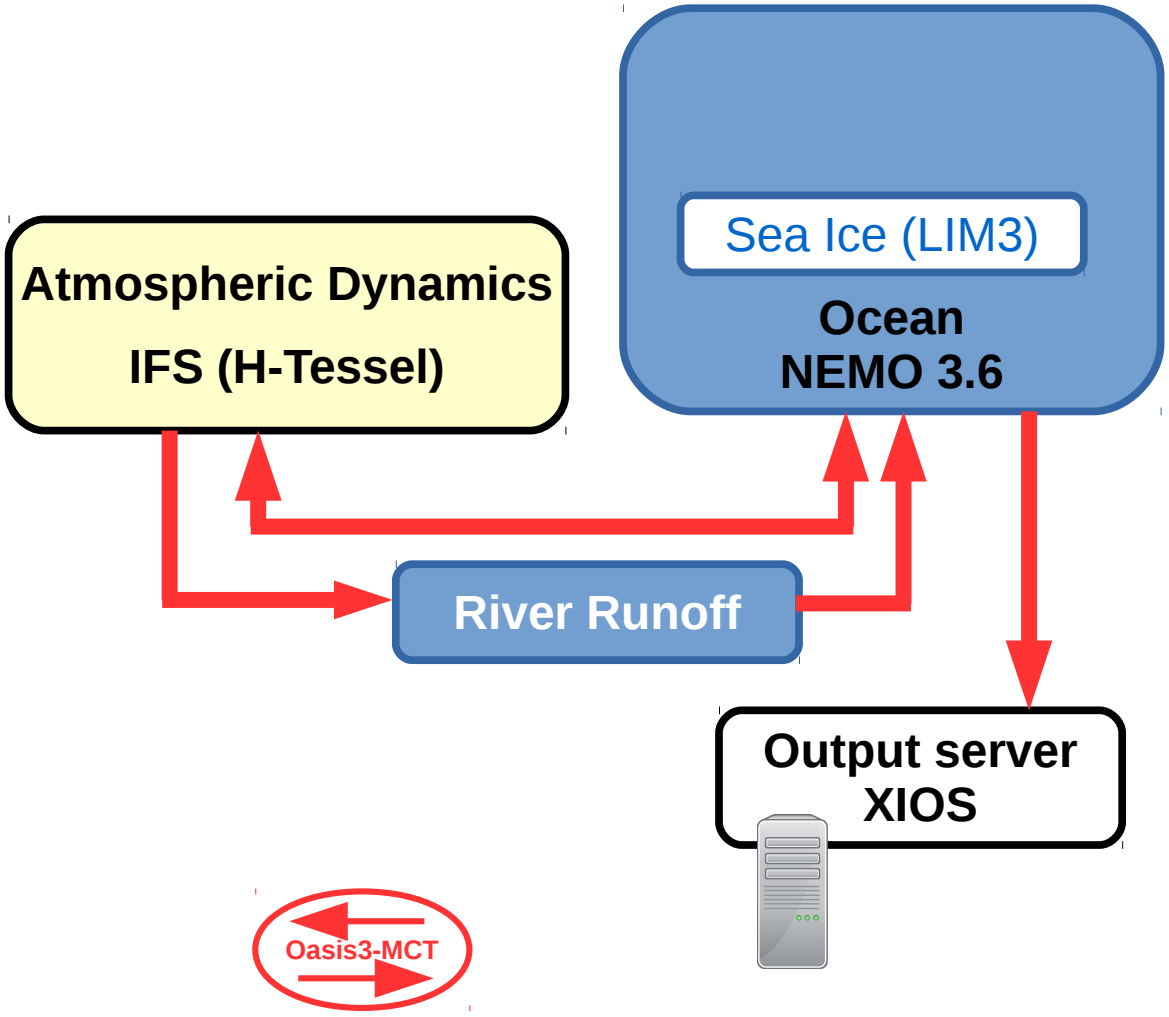
GCM configurations

Resolutions

- Low
  T159L62, ORCA1L75
- Standard
  T255L91, ORCA1L75
- High
  T511L91, ORCA025L75

Also available

- Atmosphere only
- Ocean only



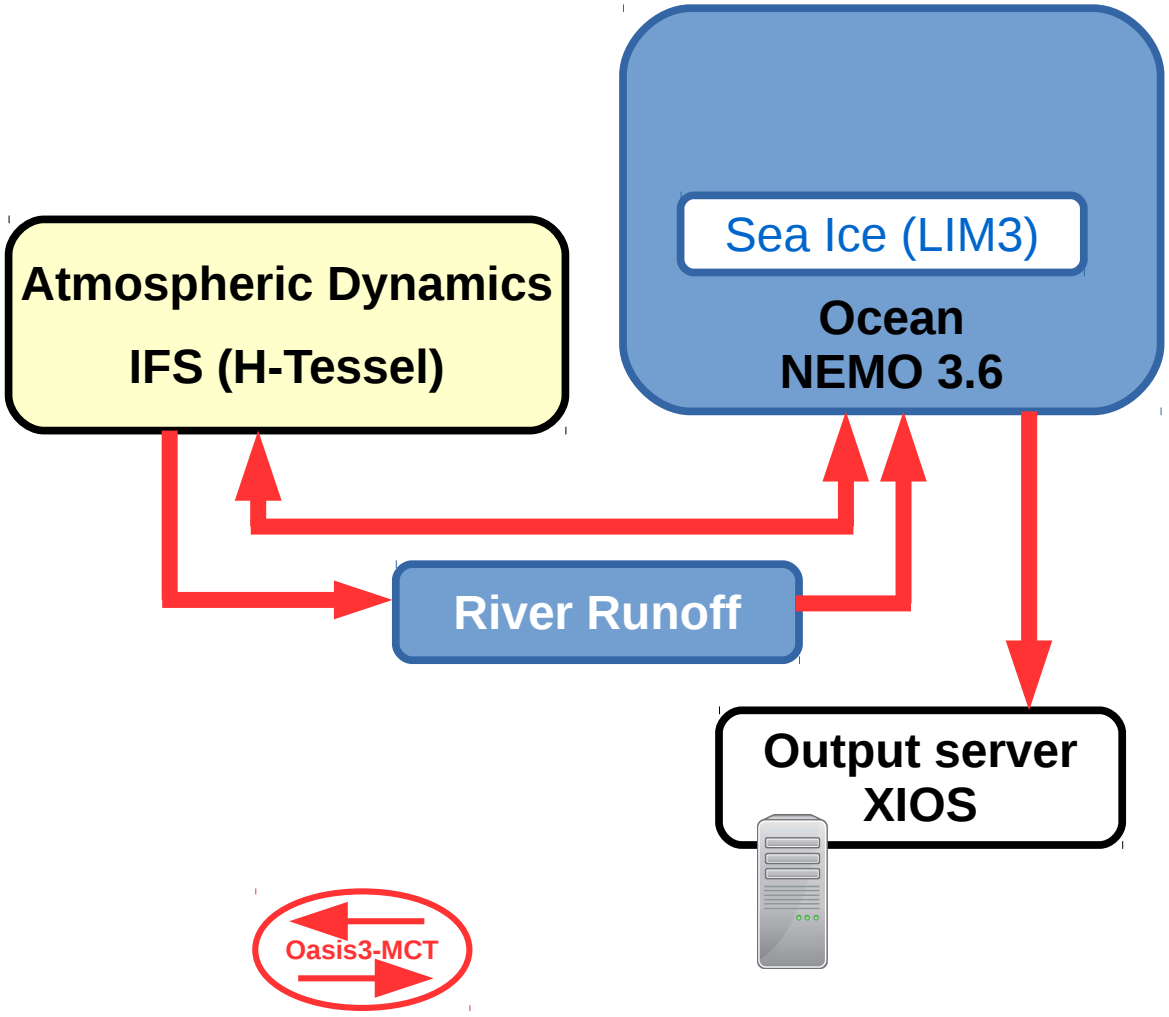
GCM configurations

Status: beta

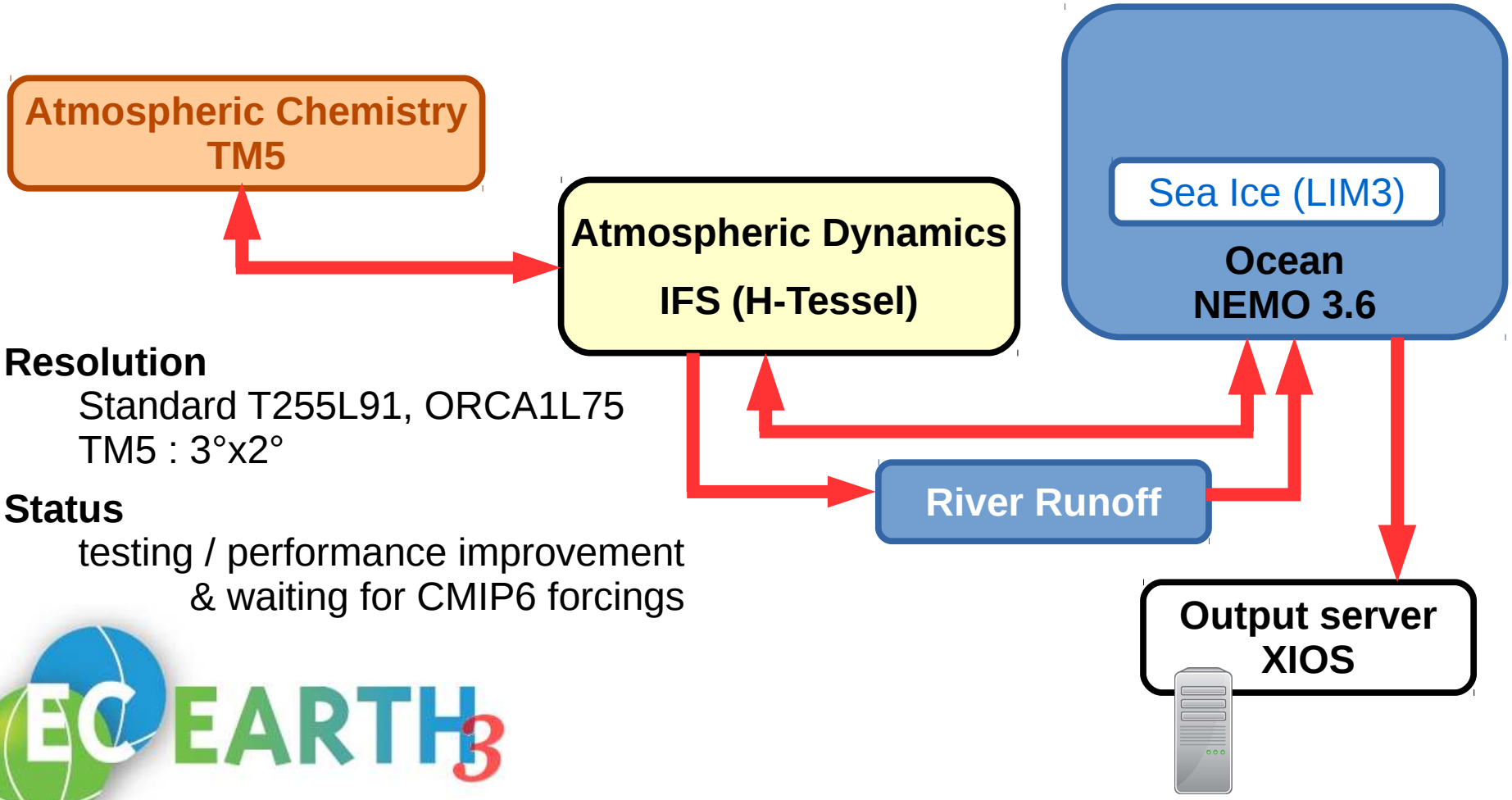
- **consolidation**
- **waiting for forcing fields → tuning**

Performance

- Std : 8-12 SYPD
- High: 2-4 SYPD



ESM configuration #2 – EC-EARTH3-CHEM



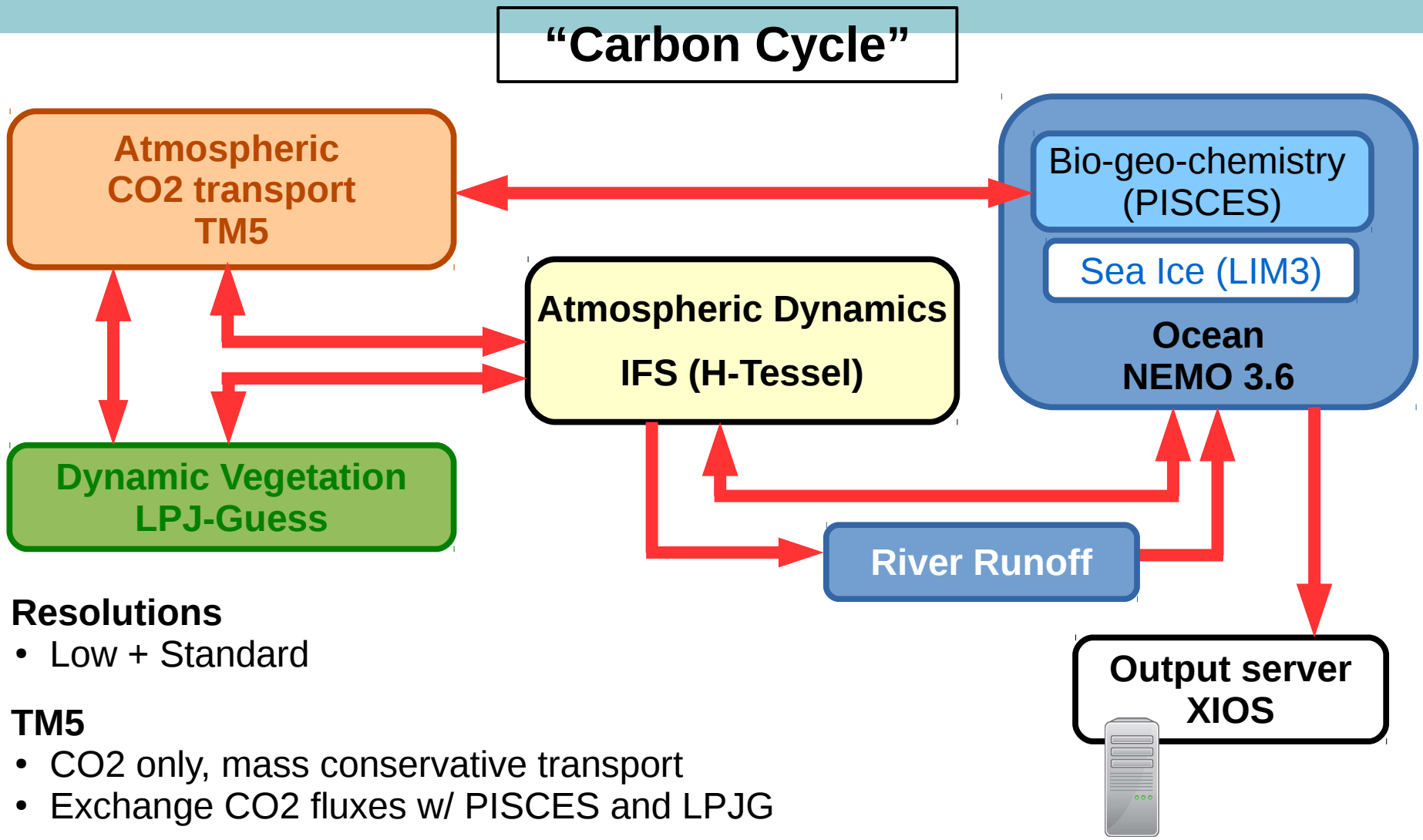
Resolution

Standard T255L91, ORCA1L75
TM5 : 3°x2°

Status

testing / performance improvement
& waiting for CMIP6 forcings

ESM configuration #4 – EC-EARTH3-CC



Resolutions

- Low + Standard

TM5

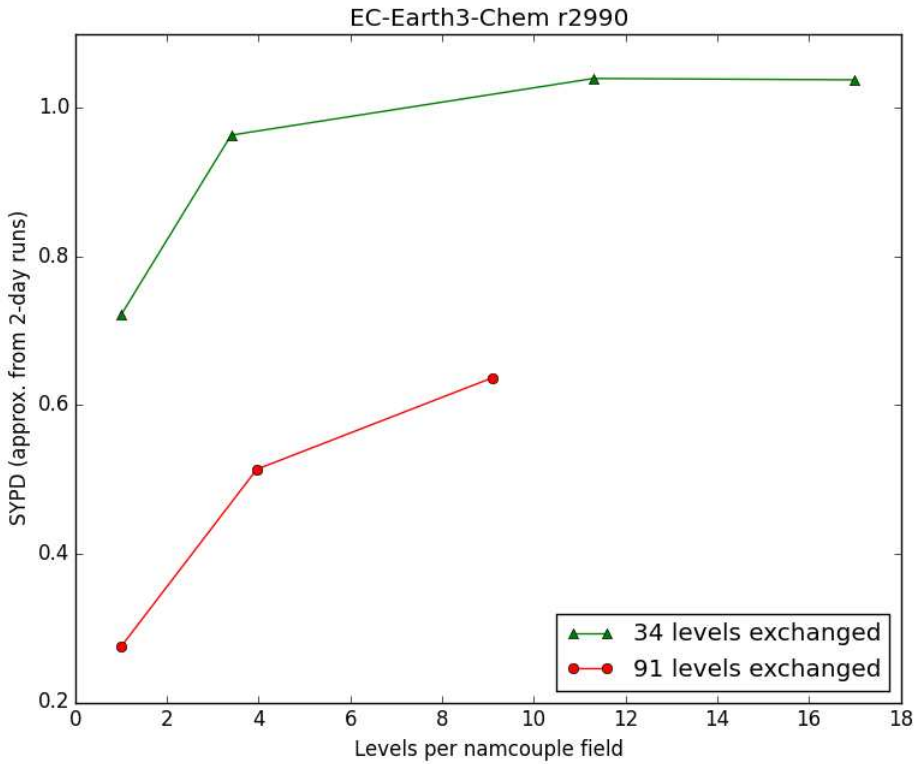
- CO2 only, mass conservative transport
- Exchange CO2 fluxes w/ PISCES and LPJG

Status

Components ready. Exchanges to be implemented.

Performance of ESM-CHEM (1) nb of fields exchanged

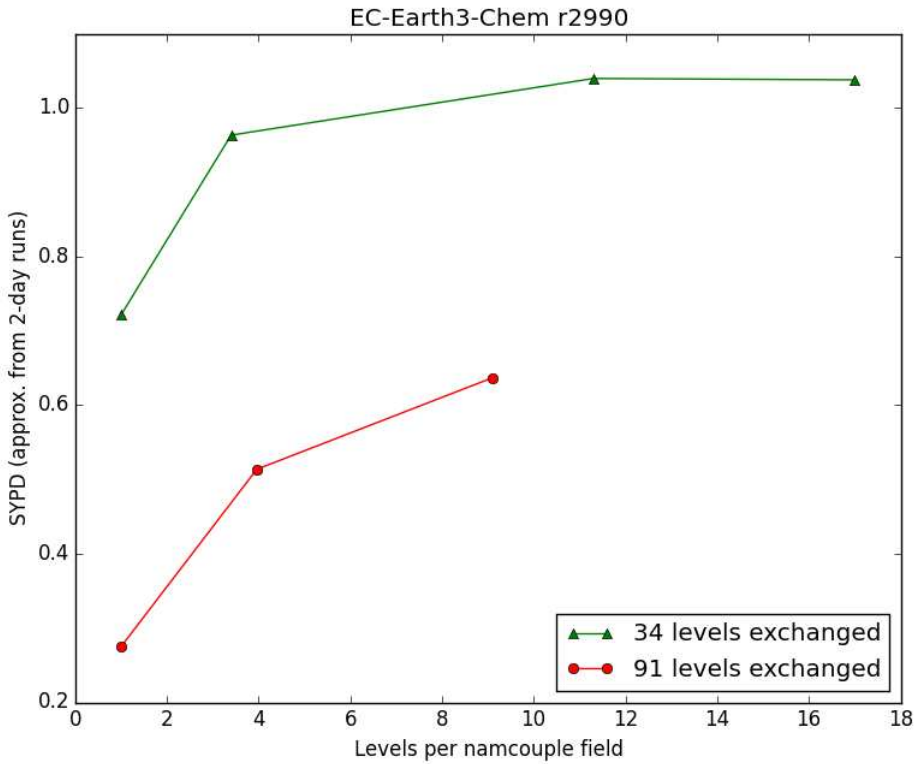
- **82** 3D fields are exchanged
  - 13 met. fields
  - 69 aerosols prop.
- **39** 2D fields are exchanged
- Total of 2D fields
  - **2827** (34 levels)
  - **7501** (91 levels)
- **<u>Limit the number of levels exchanged!</u>**



Performance of ESM-CHEM (2) bundles

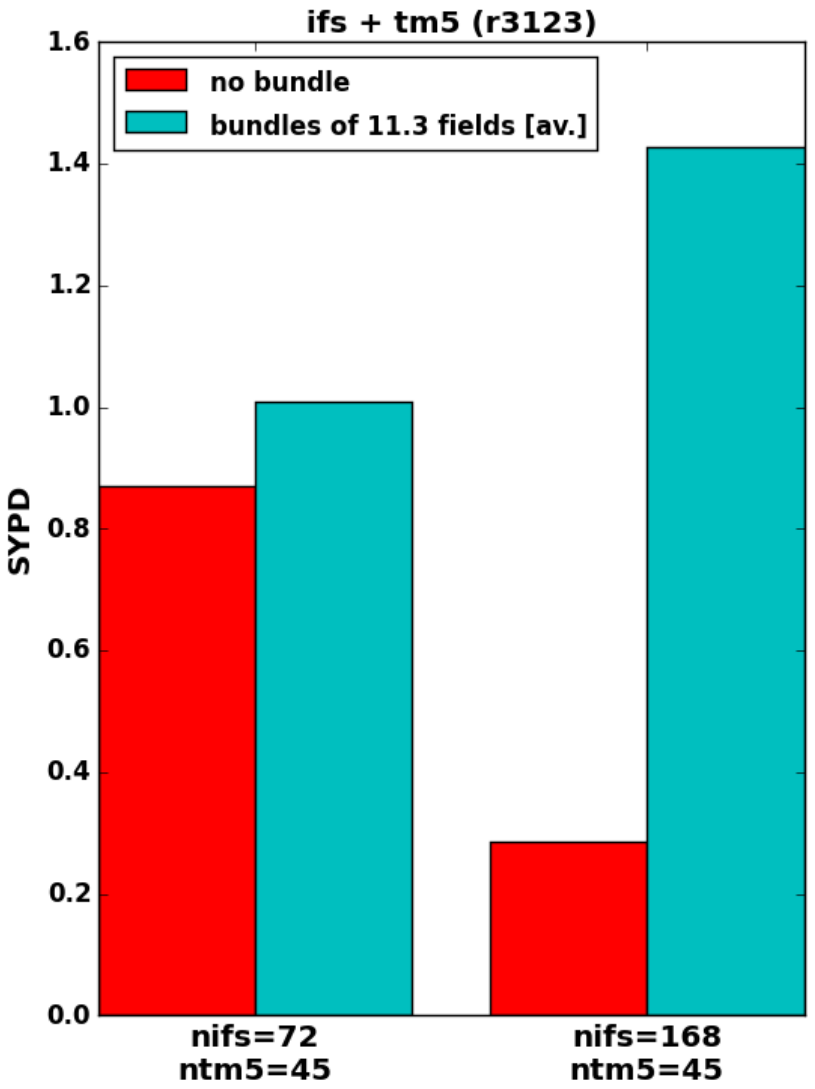
- **82** 3D fields are exchanged
  - 13 met. fields
  - 69 aerosols prop.
- **39** 2D fields are exchanged
- Total of 2D fields
  - **2827** (34 levels)
  - **7501** (91 levels)
- **Limit the number of levels exchanged!**

- pseudo 3D = bundle
- **Bundle as much as you can!**



Performance of ESM-CHEM (3) load balancing

- **Balanced configuration depends on bundle size**
- **Further right (resp. left) bar is balanced for bundle of 11-12 (resp. 1) fields**



Performance is SYSTEM DEPENDENT

best configs on ECMWF Cray: XC30 vs XC40

	Intel-IvyBridge	Intel-Broadwell
Cores per node	24 (2.7 GHz)	36 (2.1 GHz)
Memory per node	64 (1866 MHz DDR3)	128 (2400 MHz DDR4)
FP Instruction set	AVX	AVX2
IFS cores	144	108
TM5-MP cores	1x45	2x36
SYPD	1.4	1.85
10-year sim. runtime	7d 9h	**5d 10h**

TM5-MP standalone: 2 SYPD (3x45 cores on XC40)

Other features of interest

- **COSP** (CFMIP Observation Simulator Package)
  - compare simulated clouds with observations
- **Nudging**
  - IFS (from cy38r1)
  - NEMO
- **Stochastic parameterization of small scales**
  - perturbations applied to 3D fields tendencies
    - 3.1 → 150 TB data to mine

Atmospheric nudging explained

$$\frac{\partial X_i}{\partial t} = F_{\text{model}}(\{X_i\}) + \frac{X_{i,\text{target}}(t) - X_i}{\tau_i}$$

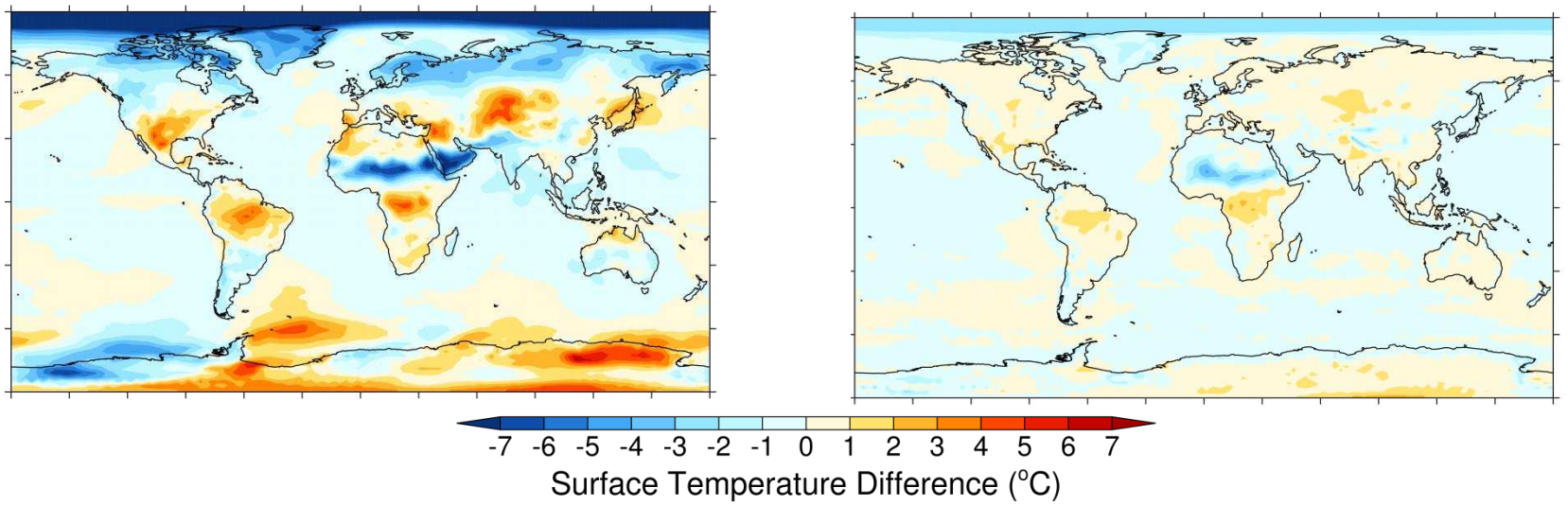
- X_i: temperature *T*, vorticity *VOR*, divergence *DIV*, surface pressure *SP* (humidity, cloud cover, cloud liquid & ice water content also possible)
- $X_{i,\text{target}}$: 6-hourly ERA-Interim fields; linear time interpolation in IFS
- τ_i: nudging time scales; range of values proposed/applied in literature:
  - *Jeuken et al.* (JGR, 1996):
    2.8 h (*VOR* & *SP*), 5.6 h (*DIV*), 27.8 h (*T*)
  - *Hourdin & Issartel* (GRL, 2000); *Hauglustaine et al.* (JGR, 2004):
    2.5 h (*T*, *VOR*, *DIV*)
  - *Telford et al.* (ACP, 2008)
    recommend $\tau_i \sim$ inverse frequency of the target data (6 h in our case).
- Test simulations with EC-Earth (IFS@T255L91) show best performance for $\tau_i \sim 6$ h (*T*, *VOR*, *DIV*, *SP*)

Atmosphere-only simulations with prescribed SSTs and sea ice (2005-2006);

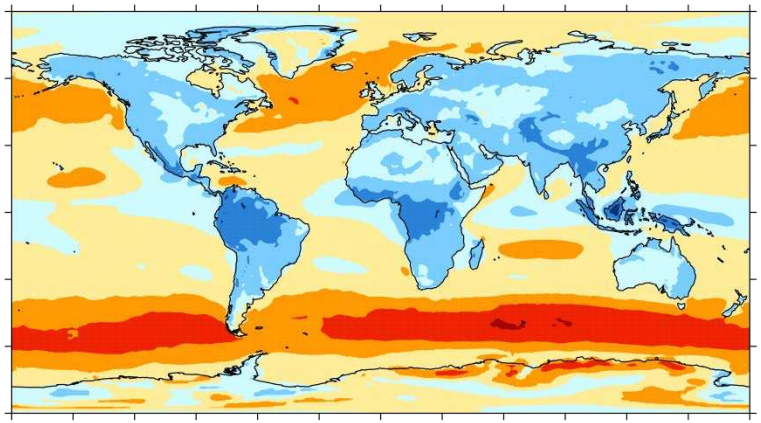
Untuned EC-Earth version 3.2-beta

Free – ERA-Interim, JJA 2006

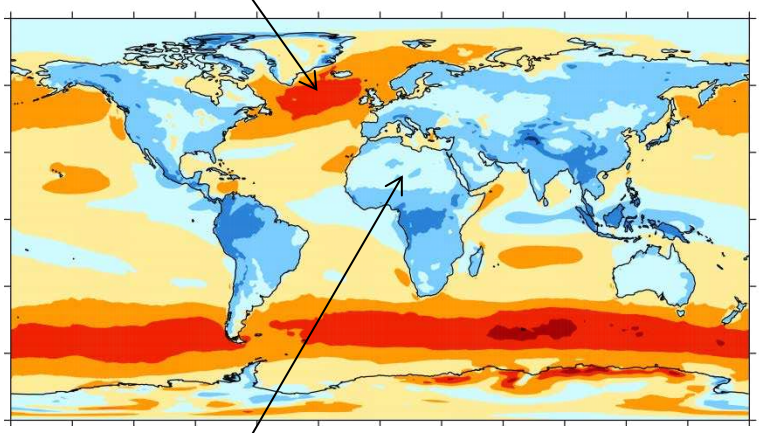
Nudged – ERA-Interim, JJA 2006



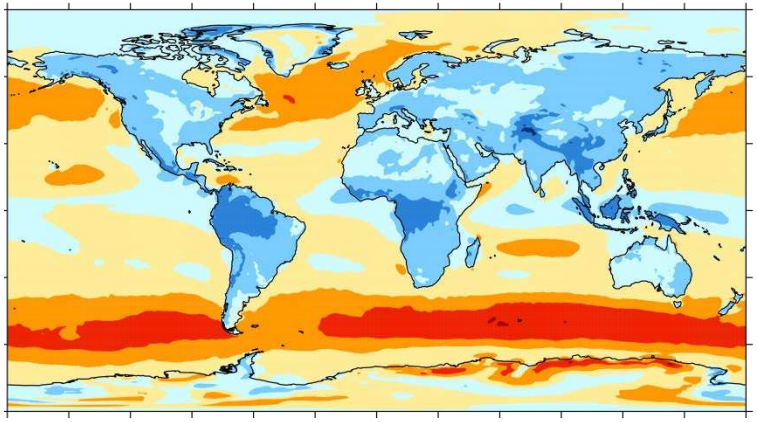
ERA-Interim



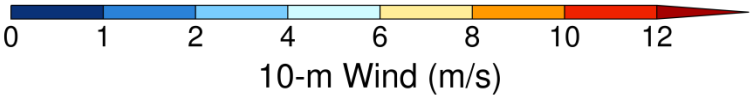
Free



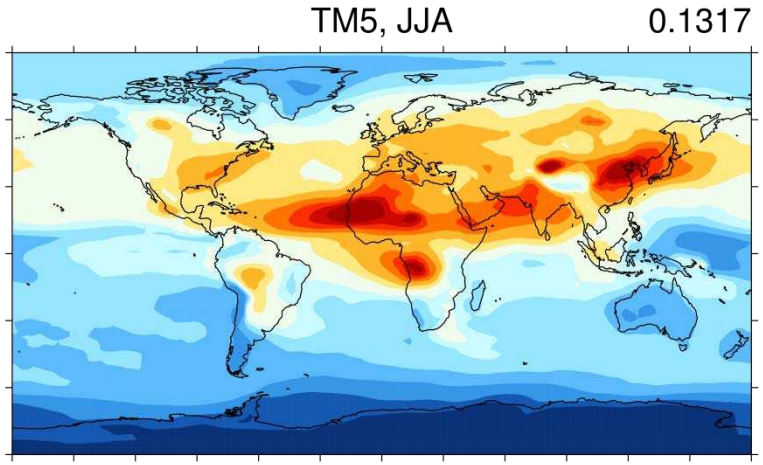
Nudged



Higher wind speeds in parts of Sahara and Bodélé depression

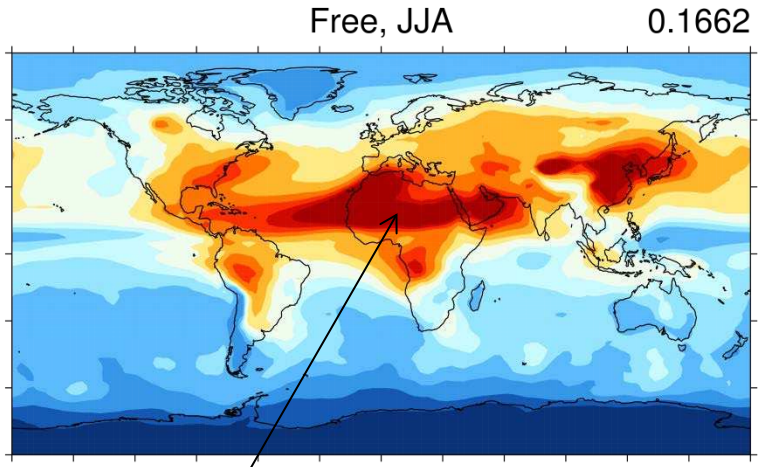


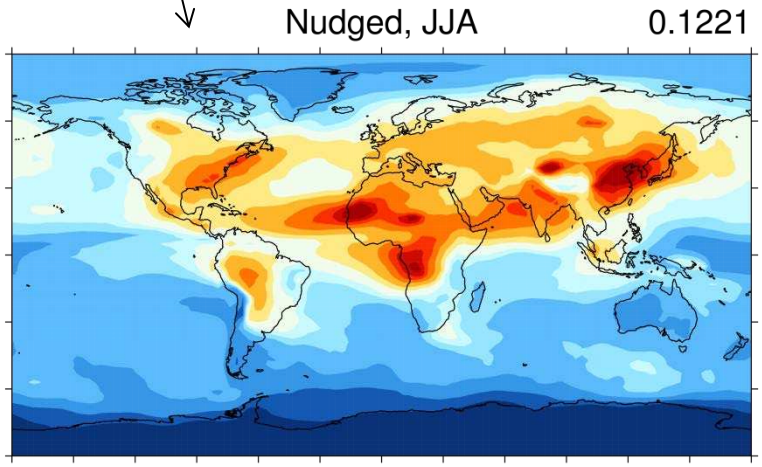
EC-Earth vs. standalone TM5



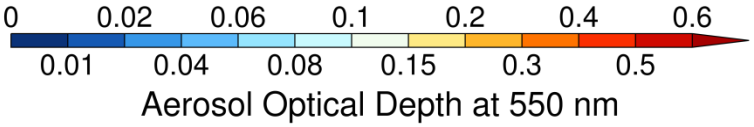
Remaining differences due to:

- Improvements in model physics (e.g. convection) from IFS cycle 31r2 (ERA-I) to 36r4 (EC-Earth)
- IFS resolution (T159L60 vs. T255L91)
- Details of coupling (frequency; time interpolation)





Retuning of dust emission source is possible using existing scale factor for threshold wind speed



C-IFS developments: a very brief update

- C-IFS-CB05 has been used for CAMS Interim-Reanalysis (Flemming et al. *in preparation*), and will be used for upcoming CAMS-Reanalysis (2003-2016), expected to start this autumn.

- CIFS-CB05-BASCOE, (extension with stratospheric chemistry & kpp), in review for GMD. Ongoing: revision of PSC parameterization, extension of evaluation.

- Quick study on total CO_2 emitted during 2015 Indonesian fires based on *hand-guided* optimization of CO emissions in C-IFS (Huijnen et al., *Sci. Rep.* 2016)

- KNMI participates in CAMS tender on Reactive Gases:
  - Review tropospheric chemistry (e.g. isoprene)
  - Closer links to aerosol (nitrate, sulfate precursors)
  - Revision of stratospheric chemistry
  - intercomparison study of trop. chemistry mechanisms.

  Start of tender is delayed.