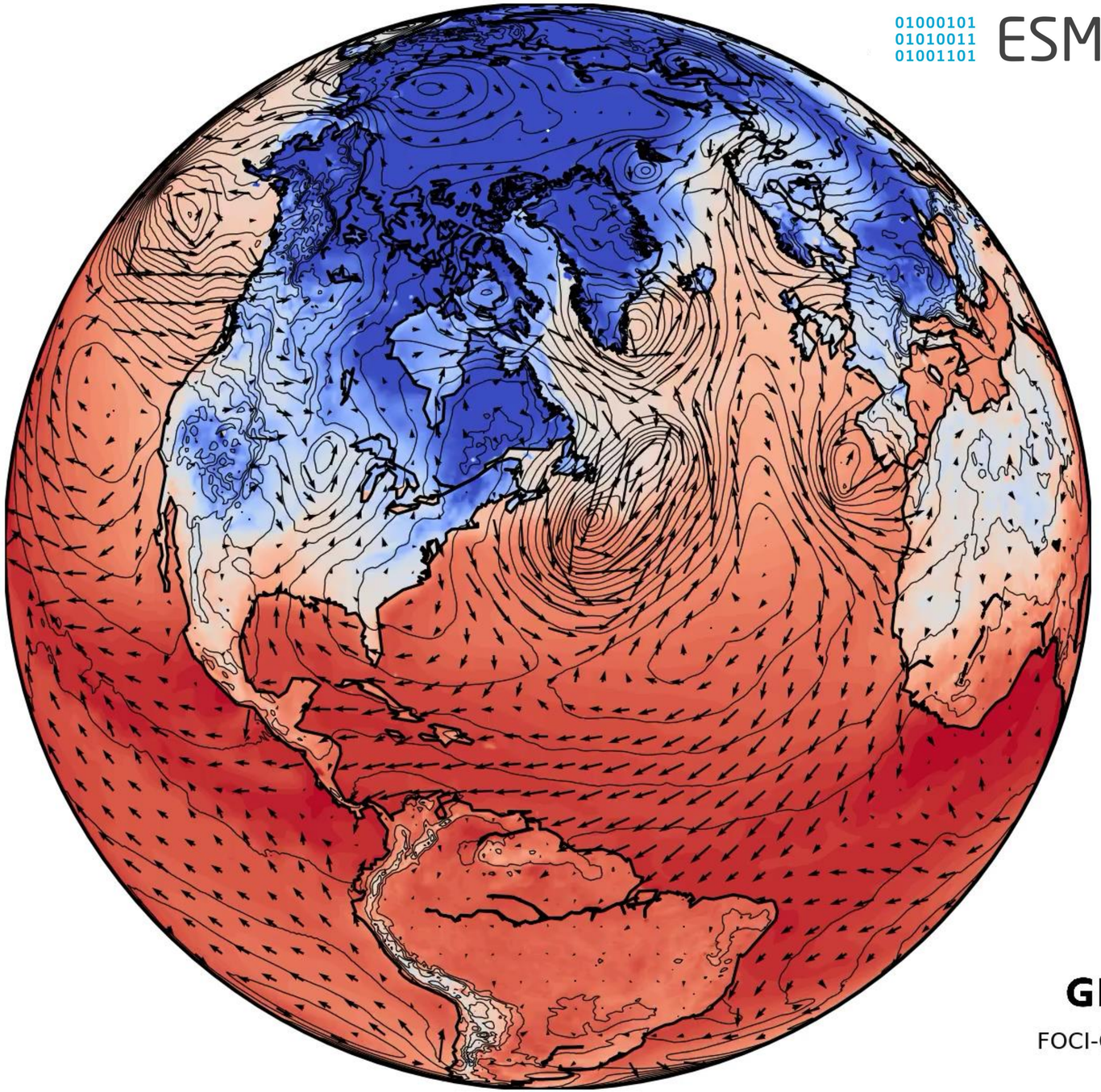


01000101
01010011
01001101 ESM-Tools

FOCI-OpenIFS: A flexible climate model for high-resolution simulations

Joakim Kjellsson, Wonsun Park, Sebastian Wahl, Jan Harlaß, Tobias Bayr, Torge Martin, Mojib Latif, Katja Matthes, Arne Biastoch, etc…
Marine Meteorology / Ocean Dynamics, GEOMAR Kiel

Glenn Carver
ECMWF

Dirk Barbi
Jan Streffing
AWI Bremerhaven

GEOMAR

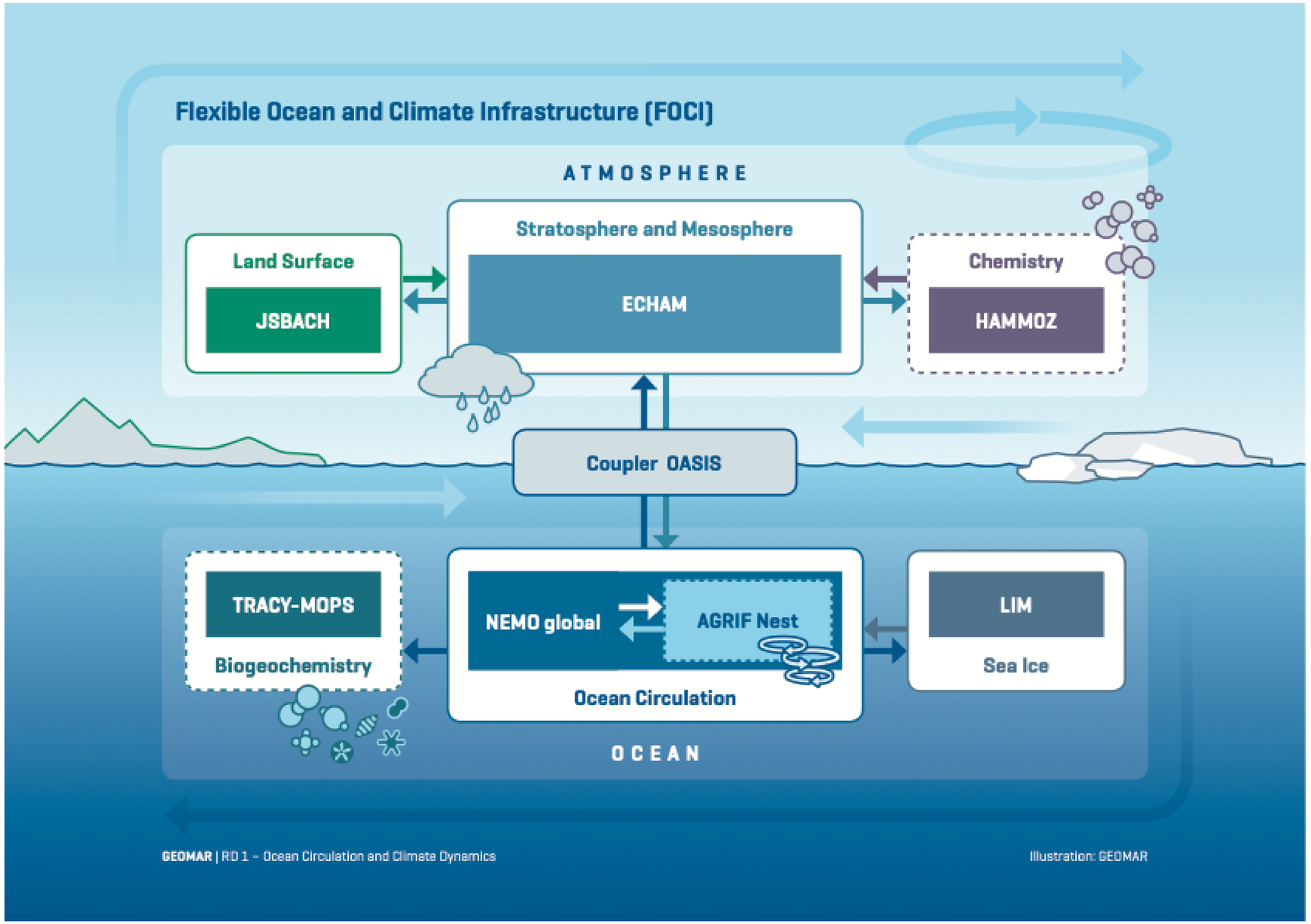
FOCI-OpenIFS T511L91 + ORCA05

GEOMAR

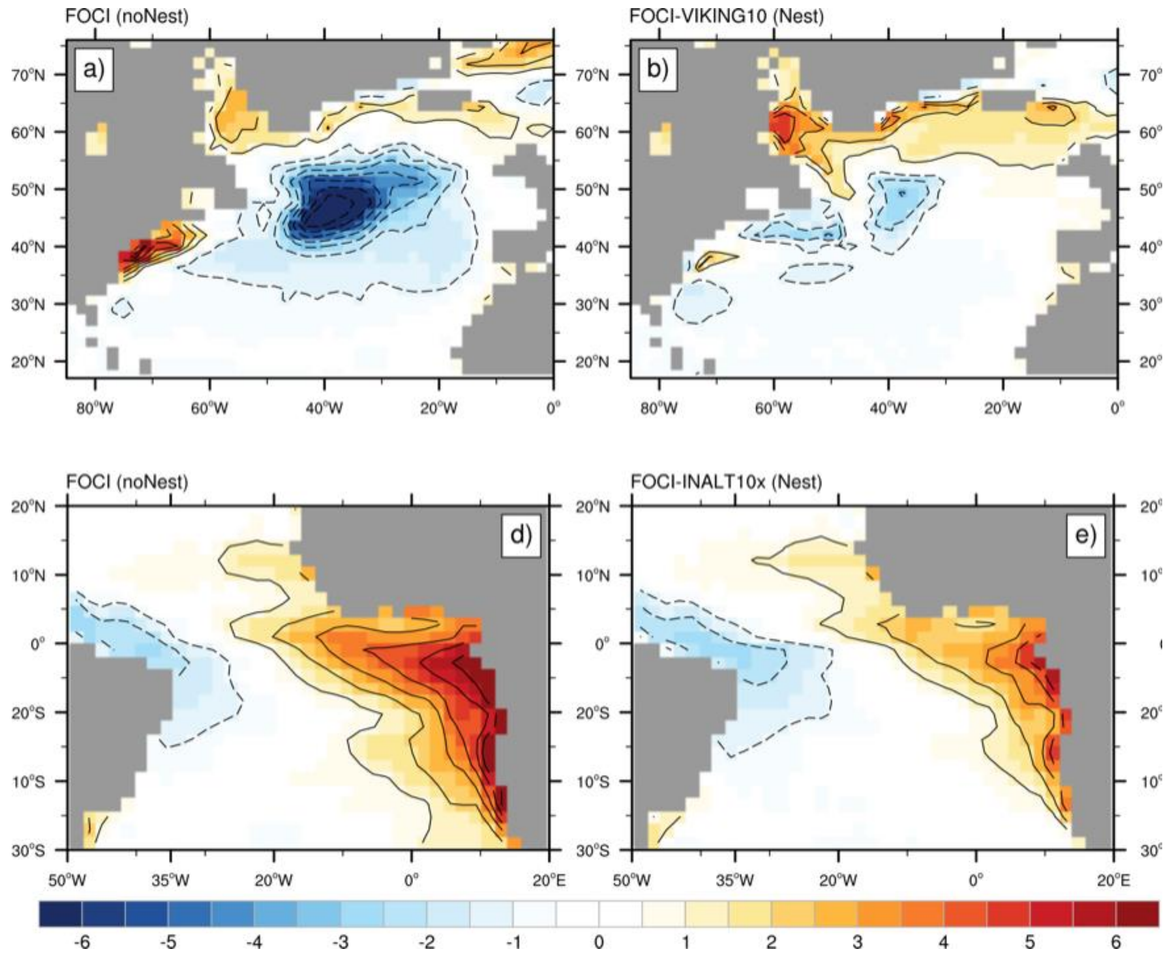
Climate modelling in Kiel

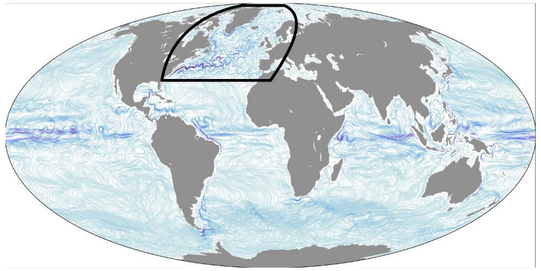
- **KCM. ECHAM5 + NEMO 2/3.4 (Park et al. 2008). T_q31/42/63 + ORCA2/05**
  Long-time workhorse for Meteorology group. No chemistry. No nesting.
- **NEMO v3.6 with AGRIF nesting.**
  ORCA05/025 + INALT10 / INALT60 / VIKING20X.
  Used by Ocean Dynamics group.
- **CESM1 / CAM-WACCM**
  Upper atmosphere dynamics and chemistry modelling in Meteorology group.
- **FOCI (Flexible Ocean and Climate Infrastructure).**
  ECHAM6 + NEMO 3.6, T_q63 + ORCA05 + AGRIF.
  + (HAM)MOZ chemistry, TRACY-MOPS ocean biogeochemistry.
  Currently used in a variety of projects by Meteorology, Ocean Dynamics, and Biogeochemistry groups.
- **FOCI-OpenIFS. T_L159 / T_L511 + ORCA05 (+ AGRIF).**
  OpenIFS cy40 + NEMO 3.6. FOCI without chemistry or biogeochemistry.
  Plans for OpenIFS cy43 & HD.

FOCI 1.0 set up

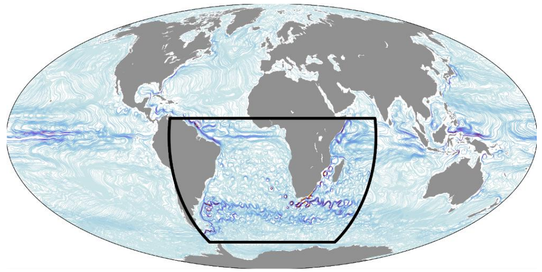


Climate modelling with two-way nesting



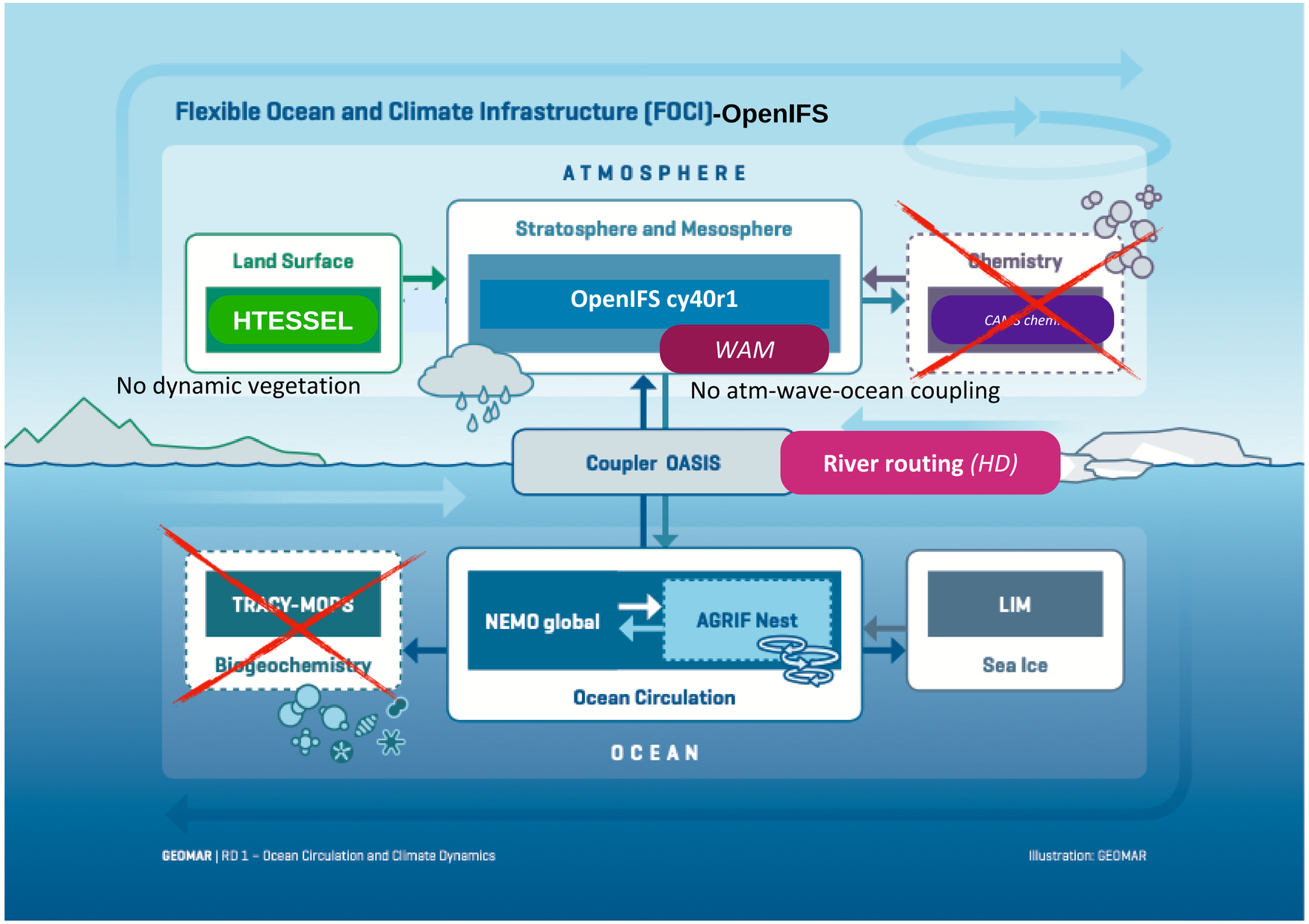


ECHAM6 T63 + NEMO ORCA05 + VIKING10X



ECHAM6 T63 + NEMO ORCA05 + INALT10X

- Global 0.5° with 1/10° locally. Common biases reduce.


Flexible Ocean and Climate Infrastructure (FOCI)-OpenIFS
ATMOSPHERE
Land Surface
HTESSEL
No dynamic vegetation
Stratosphere and Mesosphere
OpenIFS cy40r1
WAM
No atm-wave-ocean coupling
Chemistry
Coupler OASIS
River routing (HD)
TRACY-MOPS
Biogeochemistry
NEMO global
AGRIF Nest
Ocean Circulation
LIM
Sea Ice
OCEAN
GEOMAR | RD 1 – Ocean Circulation and Climate Dynamics
Illustration: GEOMAR

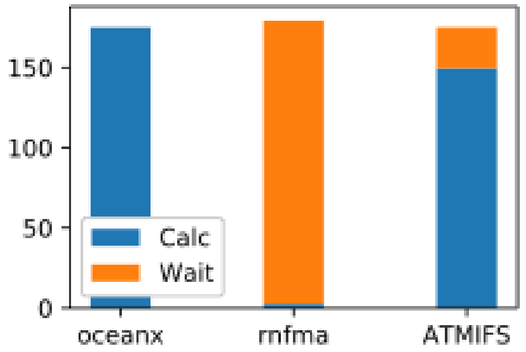
Why OpenIFS?

- ECHAM development is discontinued. ICON is future for MPI-M.
- We want to go finer than 0.5° resolution, especially when coupled to AGRIF.
  dx < 50 km not feasible with ECHAM6.
  OpenIFS uses half the CPUs for double resolution compared to ECHAM6.
- OpenIFS can take a lot longer time steps than ECHAM6. Reduced grid.

HLRN-IV: Intel Skylake Gold 6148 (40 CPU/node)

	CPUs	CPU-h
FOCI-OpenIFS T159L91 + ORCA05	279+1+480 (IMPI 2018)	570
FOCI T63L95 + ORCA05	600+480 (IMPI 2019)	540

FOCI speeds up greatly from IMPI 2019,
but FOCI-OpenIFS slows down!
We need IMPI 2019 for XIOS in detached mode.



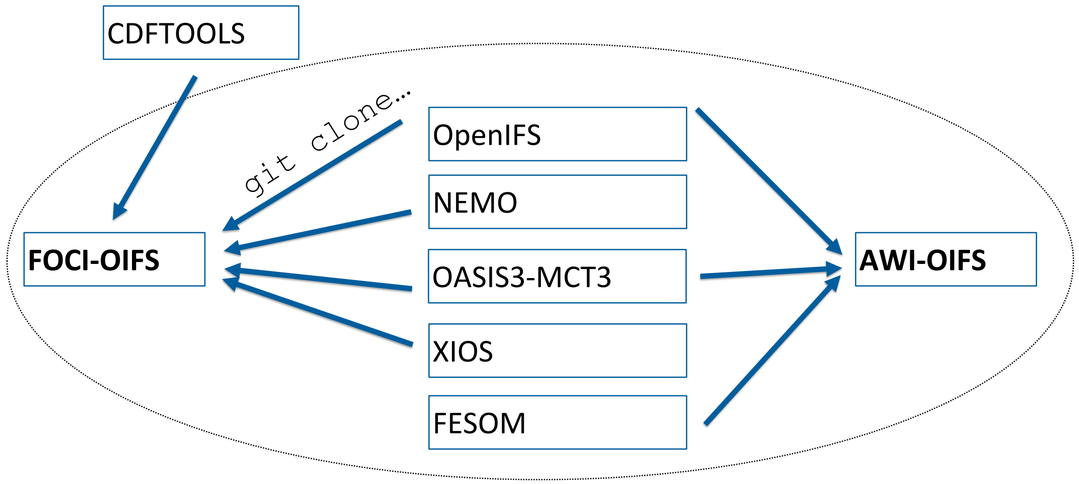
OpenIFS, T159L91 @ 279 CPUs
NEMO, ORCA05L46 @ 480 CPUs
River routing @ 1 CPU

ESM-Tools

Typical ESM

FOCI 1.13
- ECHAM
- NEMO
- XIOS
- OASIS
- etc.

With ESM-Tools



- Developed at AWI by Dirk Barbi et al. Allows the same infrastructure (compiling, fetching forcing files, restarting, storing output) for a variety of ESMs.
- Groups using different coupled models can co-develop individual model components, e.g. OpenIFS for AWI-CM3, FOCI-OpenIFS, and standalone.
- Used for standalone OpenIFS and coupled FOCI-OpenIFS, for FOCI (next week), and NEMO (future).

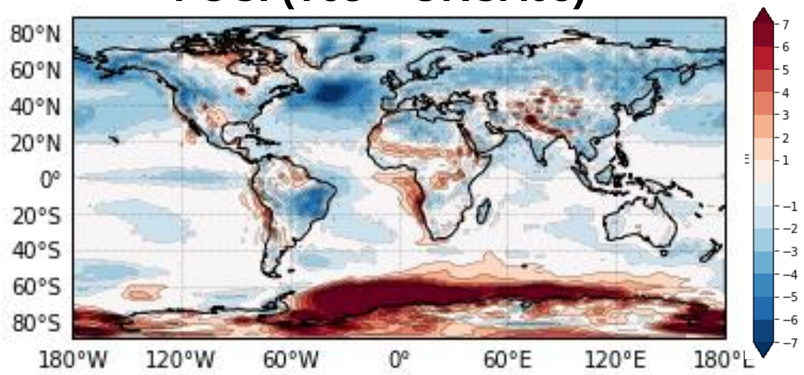
Current & Planned configurations

	OIFS	NEMO	Run time	Settings
FOCI-OIFS LR	T_L159L91	ORCA05 L46	32 SYPD @ 760 CPU ~ 570 CPUh	No WAM
FOCI-OIFS MR	T_L511L91	ORCA05 L46	LUCIA analysis in progress	No WAM
FOCI-OIFS ORION	~0.25°?	ORCA05 L46 (+ "ORION12")	Planned for SO-CHIC	AGRIF nest over Southern Ocean
FOCI-OIFS VIKING	~0.25°?	ORCA05 L46 (+ VIKING10X)	Planned for new project	AGRIF nest over North Atlantic

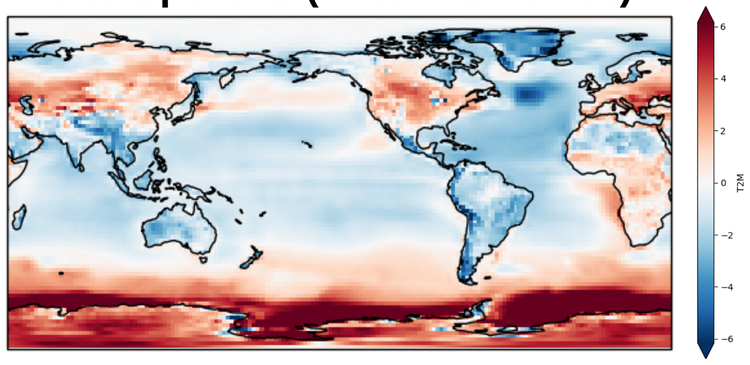
- "MR" configuration still needs testing.
- "ORION" and "VIKING" configurations require work on coupling (this autumn).
- Will switch to CY43 and new grid.

Southern Ocean biases, JJA

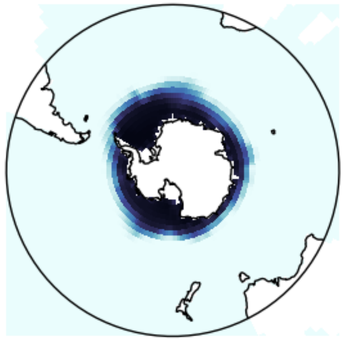
FOCI (T63 + ORCA05)



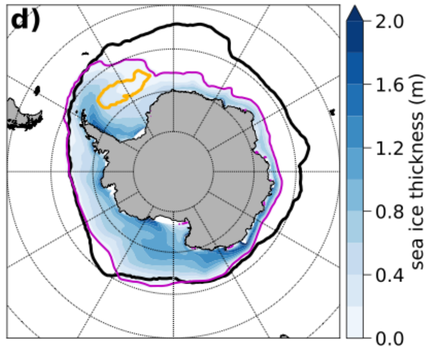
FOCI-OpenIFS (T159 + ORCA05)



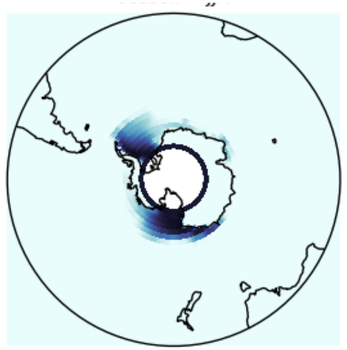
HadISST



FOCI

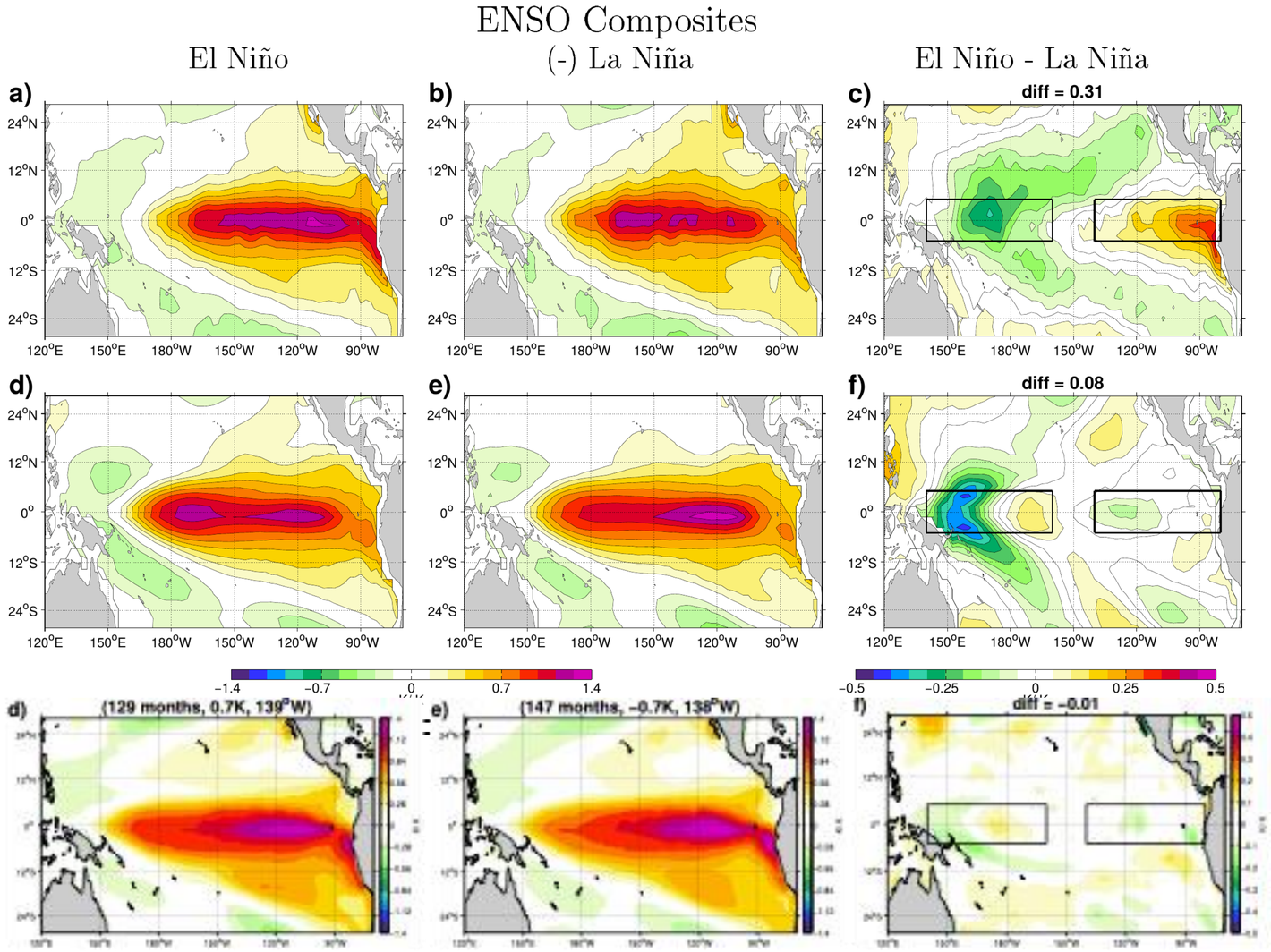


FOCI-OpenIFS



- Warm bias closely linked to sea-ice bias.
- FOCI-OpenIFS worse than FOCI.
  But better for tropical Atlantic
  (due to resolution?)
- Caused by errors in cloud scheme?
- Weak ACC in FOCI, FOCI-OpenIFS and forced ORCA05 runs.

Lack of skewness in FOCI-OpenIFS ENSO



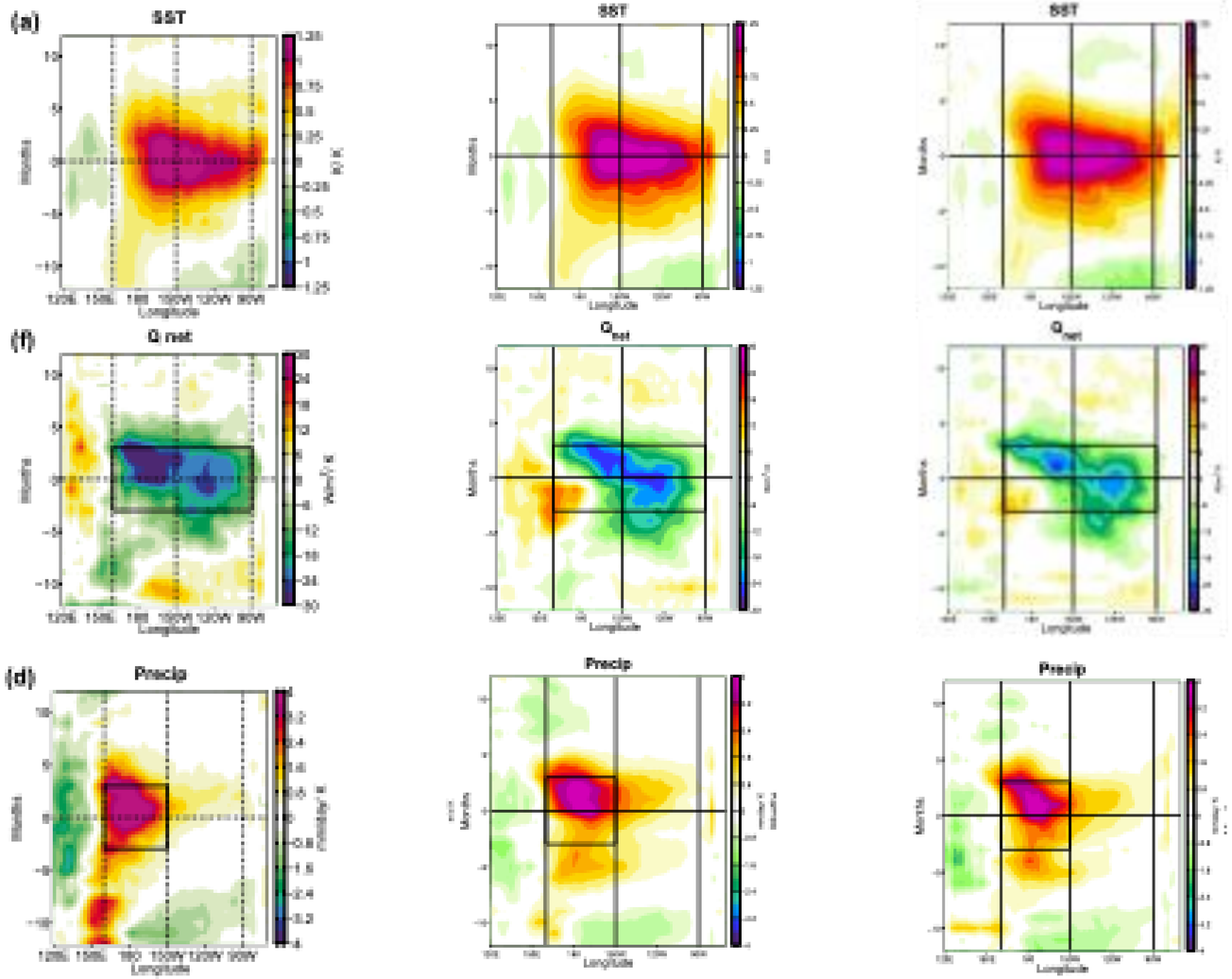
HadISST

ECHAM6+NEMO

OpenIFS+NEMO

Atmospheric ENSO feedbacks in AMIP runs

Obs + ERA-Interim | **AMIP T159L91** | **AMIP T511L91**



SST

Heat flux

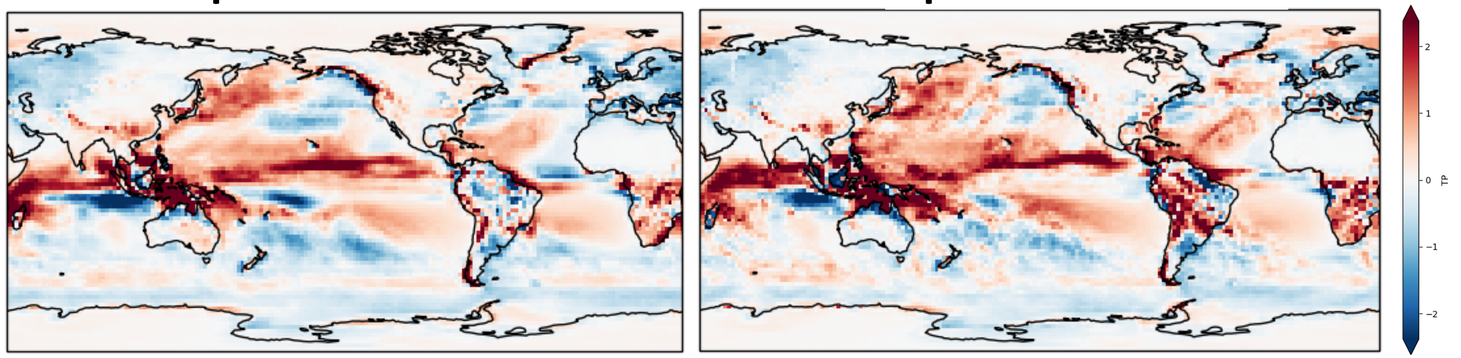
Precipitation

- Forced by obs SST/SIC 1982-2016.
- T159 has an easterly wind bias.
  T511 slightly better.
- No improvement of feedbacks in T511.
- SPPT / SKEB.
- Tuning exercise in progress.

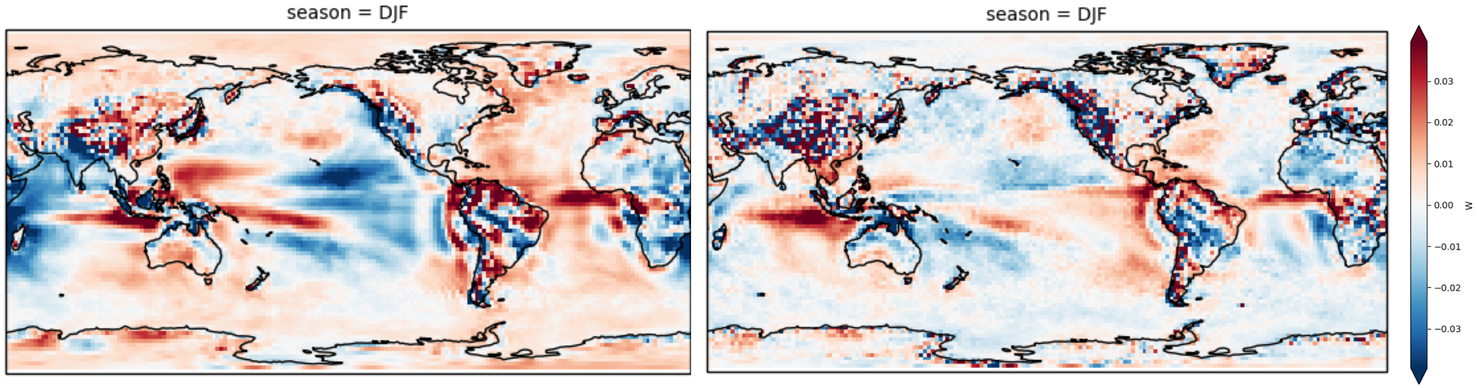
Bayr et al. (CD, 2018)

Biases in precip, W500 and CRE in AMIP runs, DJF

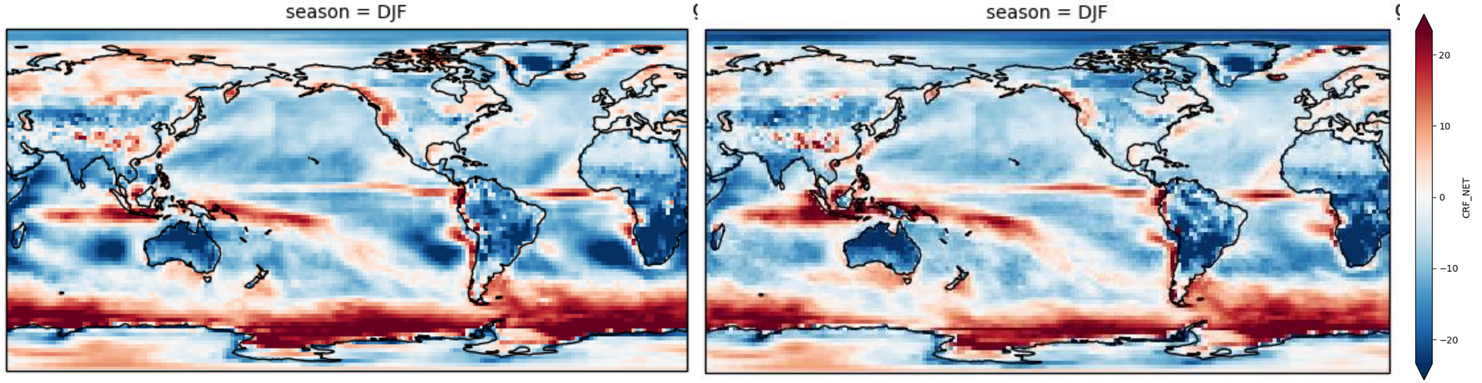
OpenIFS T159 | **OpenIFS T511**



Precip



W (500 hPa)



Cloud rad. effect

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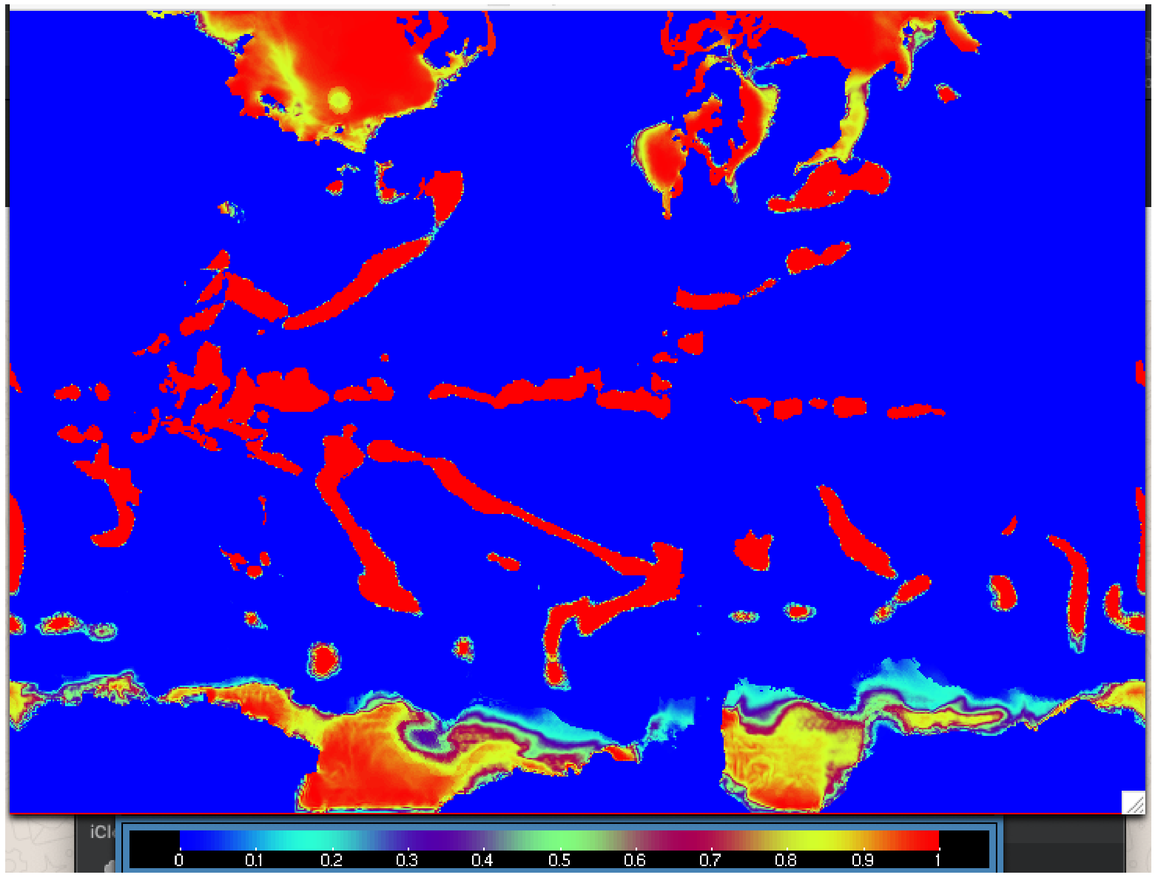
Summary & Outlook

- AMIP with standalone T_L159, T_L511, T_L1279.
- Coupled T_L159 + ORCA05 & T_L511 + ORCA05.
- SO-CHIC simulations coming. OpenIFS + NEMO + AGRIF.
  Requires direct OpenIFS -> AGRIF coupling (dedicated OASIS support).
- Some large biases (Southern Ocean, ENSO) but nothing out of the ordinary.
  Biases reduce somewhat at T511. Tuning of cloud parameters in progress!
  Test new supercooled liquid cloud water scheme from CY45?
- We like OpenIFS! We are eagerly awaiting CY43R3, XIOS and full/reduced chemistry.
- Run with any SST/SIC. Start from ERA-I or ERA5?
  Metview scripts for post processing, i.e. grib->netcdf & spectral transforms.
  CDO is really slow, and might not handle new grids.
- Ref. paper for FOCI (Matthes et al.) in prep.

Can you see anymore model bugs?
No, but I’m sure they’re out there…

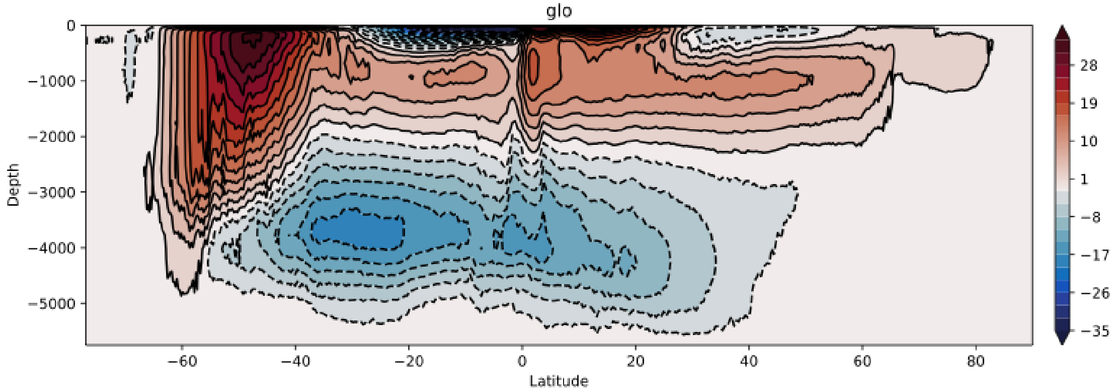
How do you run OpenIFS coupled?

- Make OASIS interfaces (or steal from CY43).
- Lakes are treated as ocean!
- Can not run longer than 44 years (integer overflow).
- GRIB limits the run period to 1900 - 2155.
- Reduce output as much as possible.
- Pray…

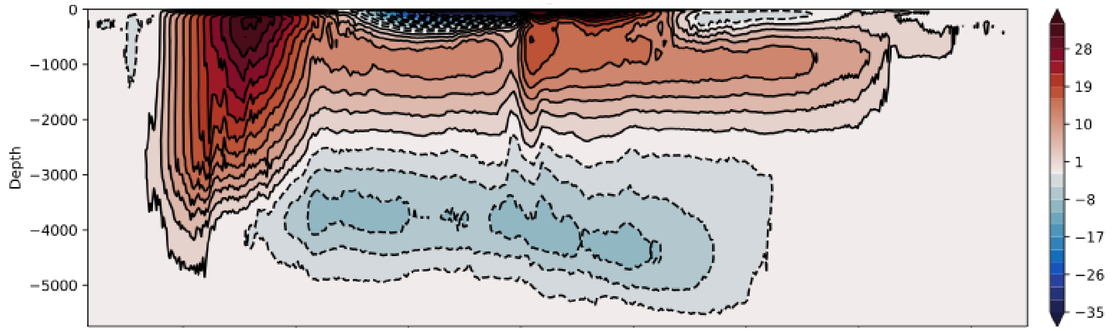


~ 20 m thick sea-ice suddenly grows in the tropics!
Creates massive SST/SSS gradients and insane velocities.
OpenIFS error / NEMO error / HPC error

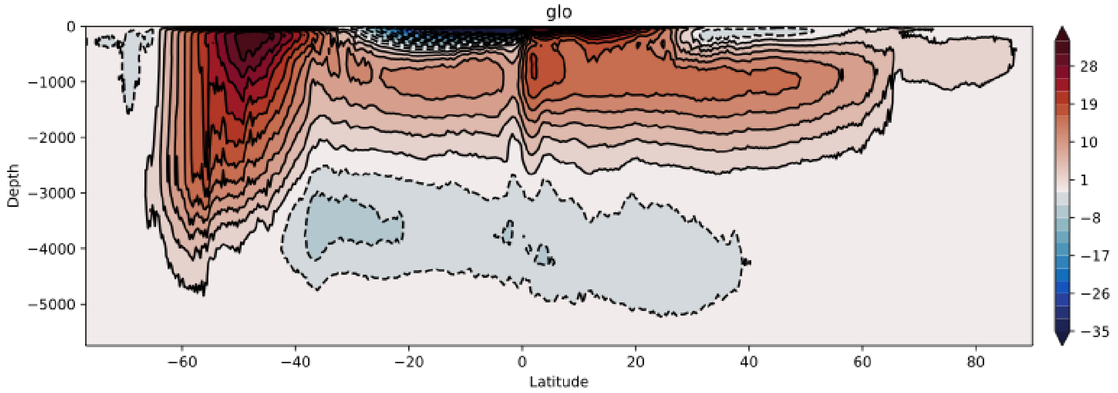
AMOC trends



Year 10-20

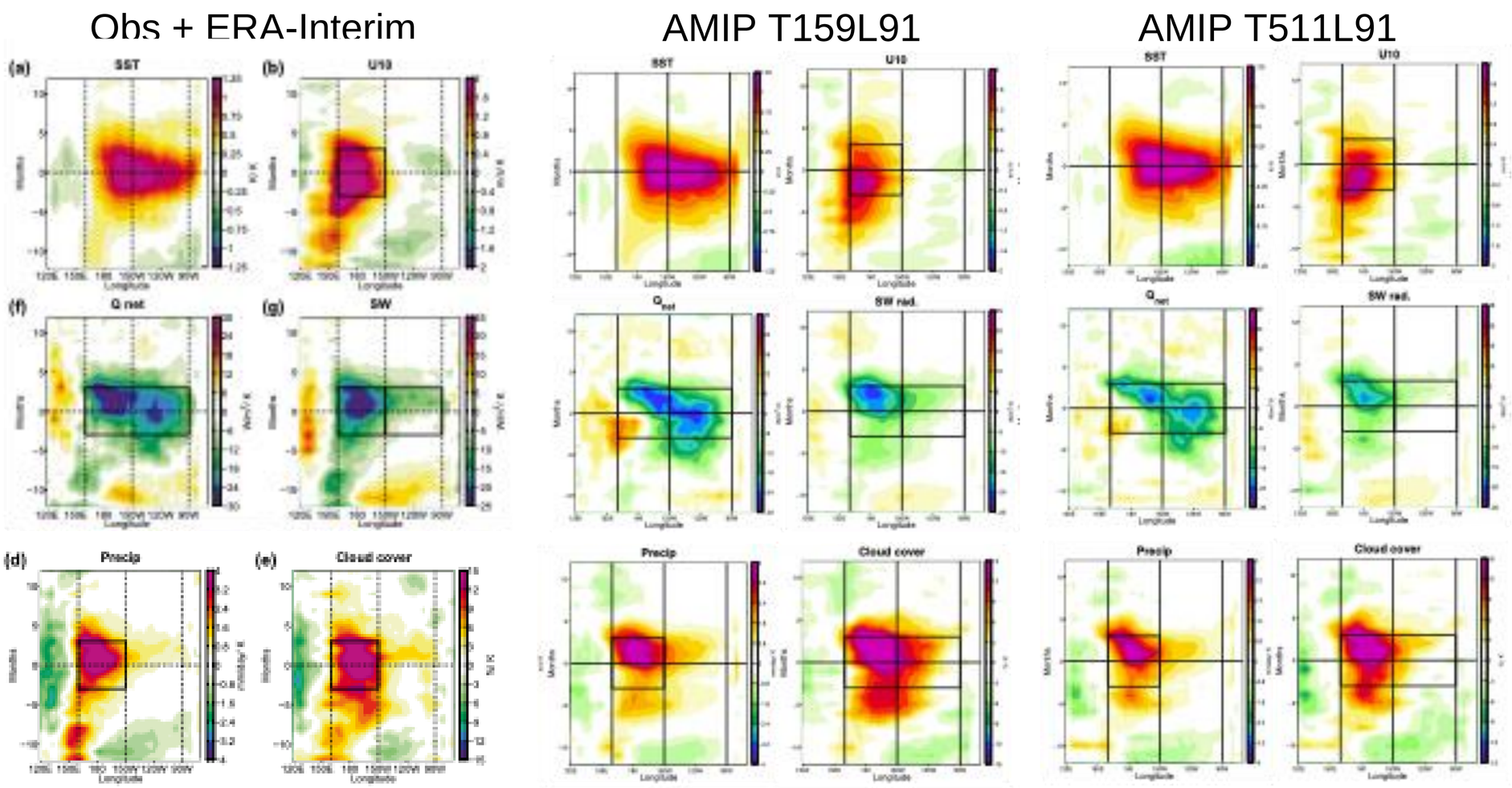


Year 70-80



Year 140-150

ENSO feedbacks (AMIP)



Bayr et al. (CD, 2018)

- Too weak wind feedback. Precip and cloud feedbacks are too late!
- T511 worse than T159!

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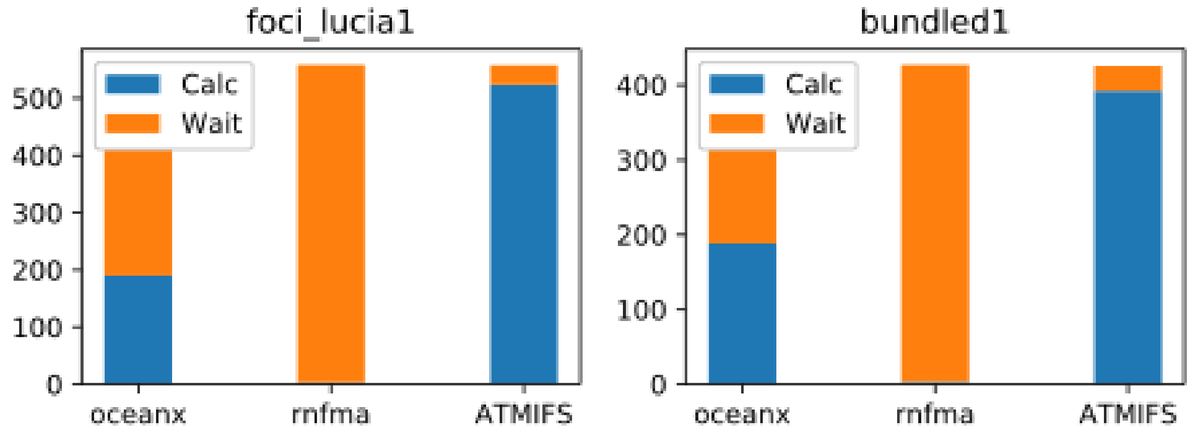
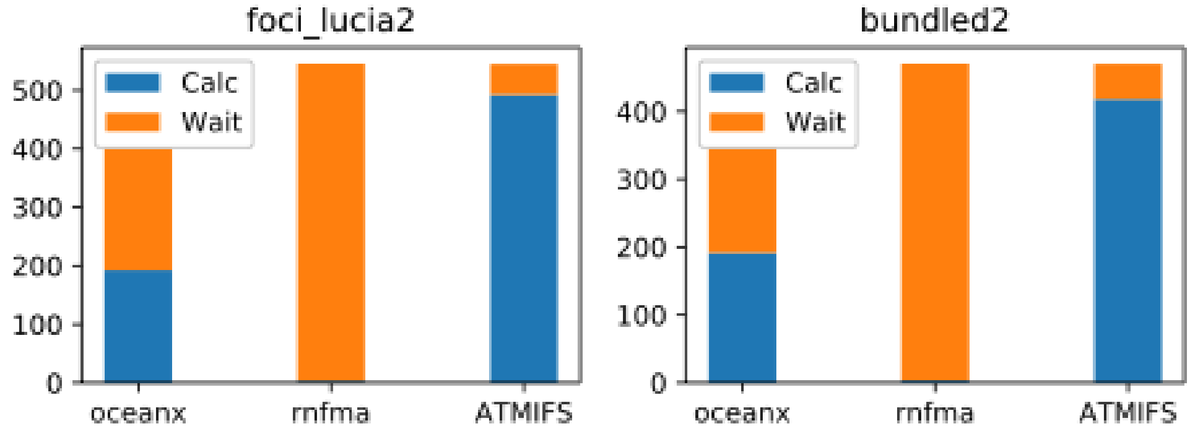
Run time tuning

OIFS 400
NEMO 400



Send oce->atm
in one call

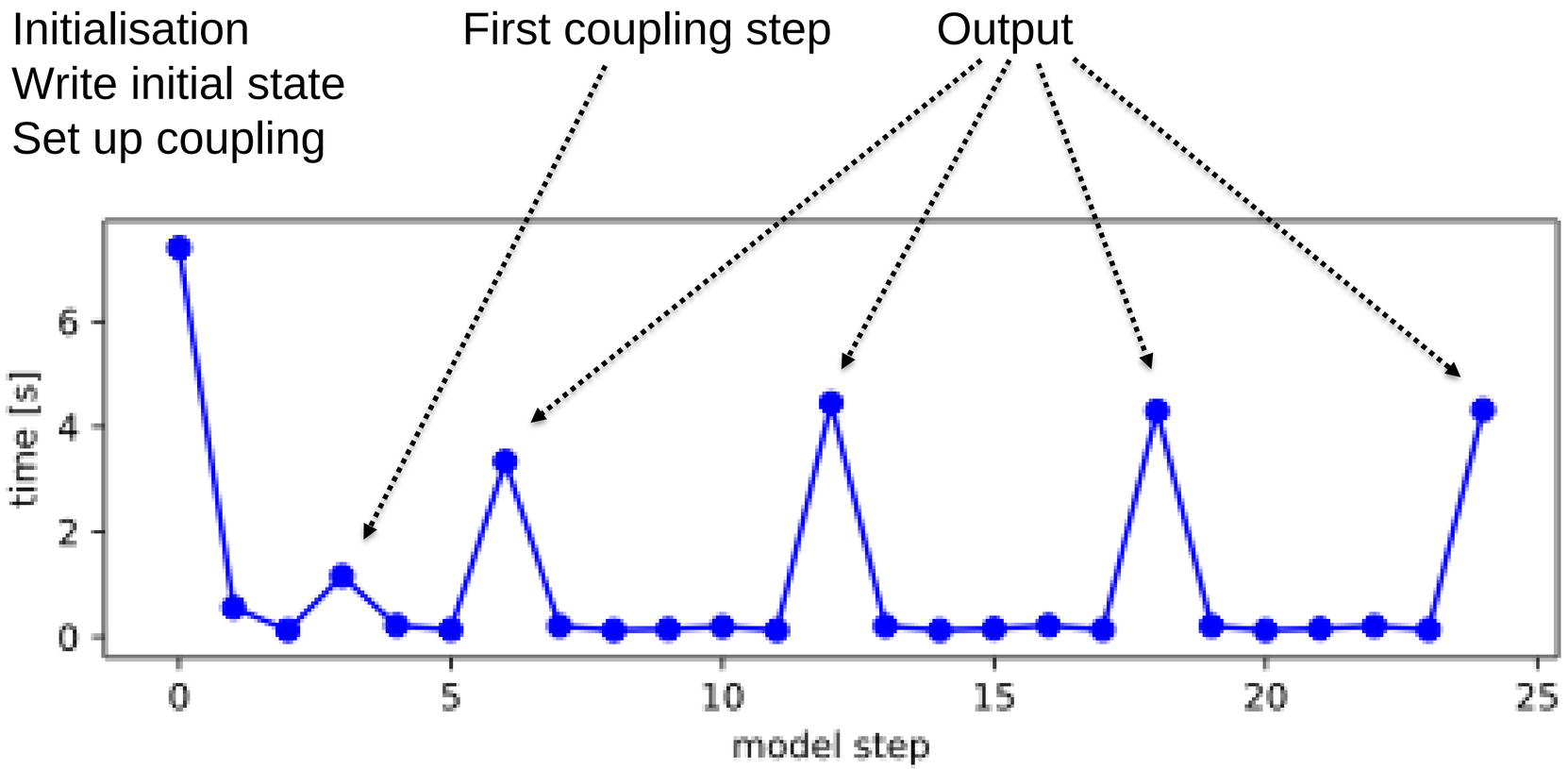
OIFS 800
NEMO 400



Send oce->atm
in one call

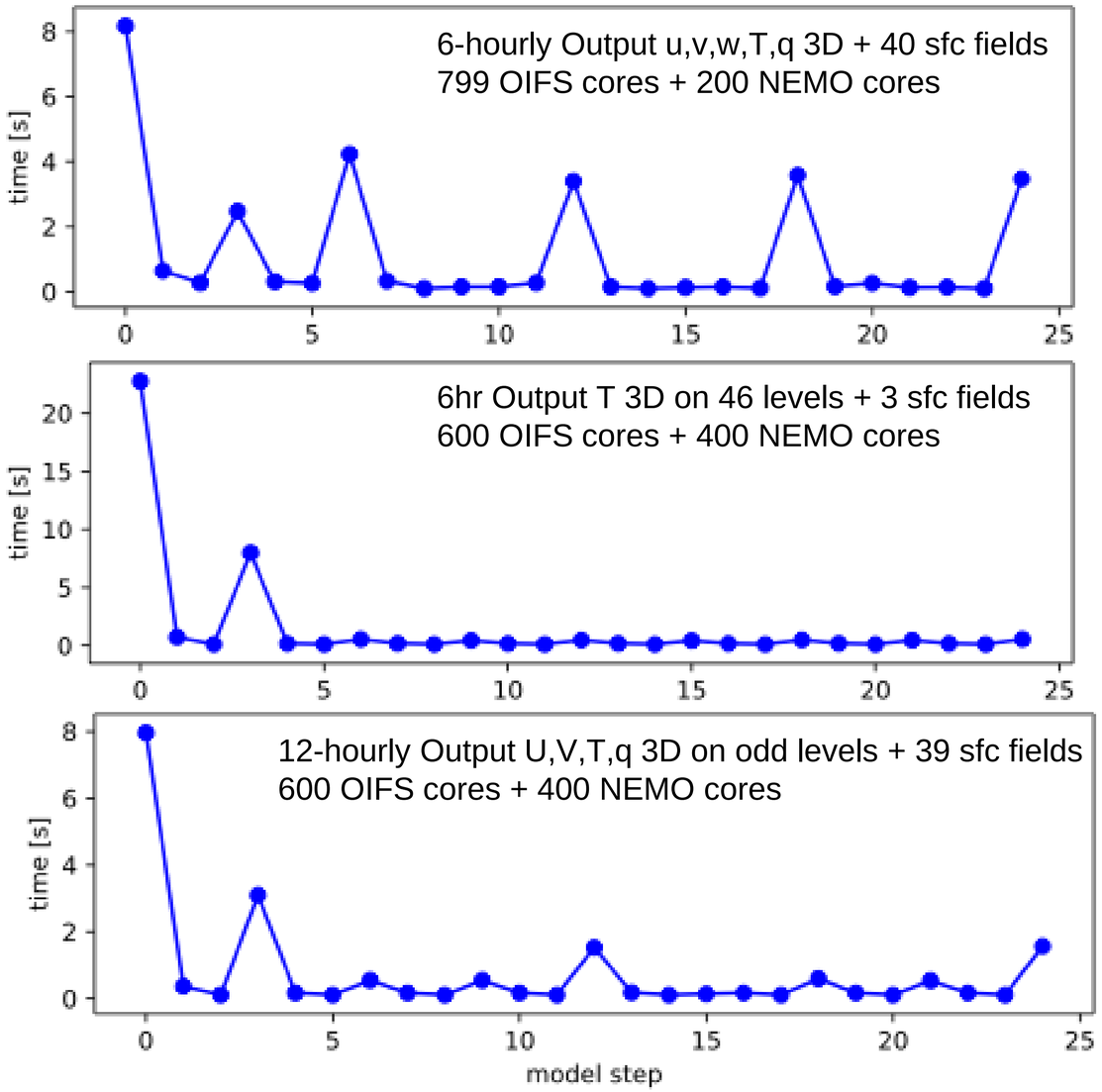
Bundling oce->atm fields reduces run time by ~ 20%

Output from ifs.stat



One time step takes ~ 0.2s
One output step takes ~ 4s
Number hardly change when doubling OIFS cores.
Are we at the limit of speed already at 400 OIFS cores?
We don’t need U,V,W,T,q,O3 on all 91 levels…

Reducing model output



OIFS CY40R1 T159L91
+ NEMO ORCA05
+ OASIS3-MCT3

1 month = 744 OIFS steps,
first 25 steps shown here.

Reducing output to 12-hourly and only odd levels leads to 2.5 - 3x speed up!

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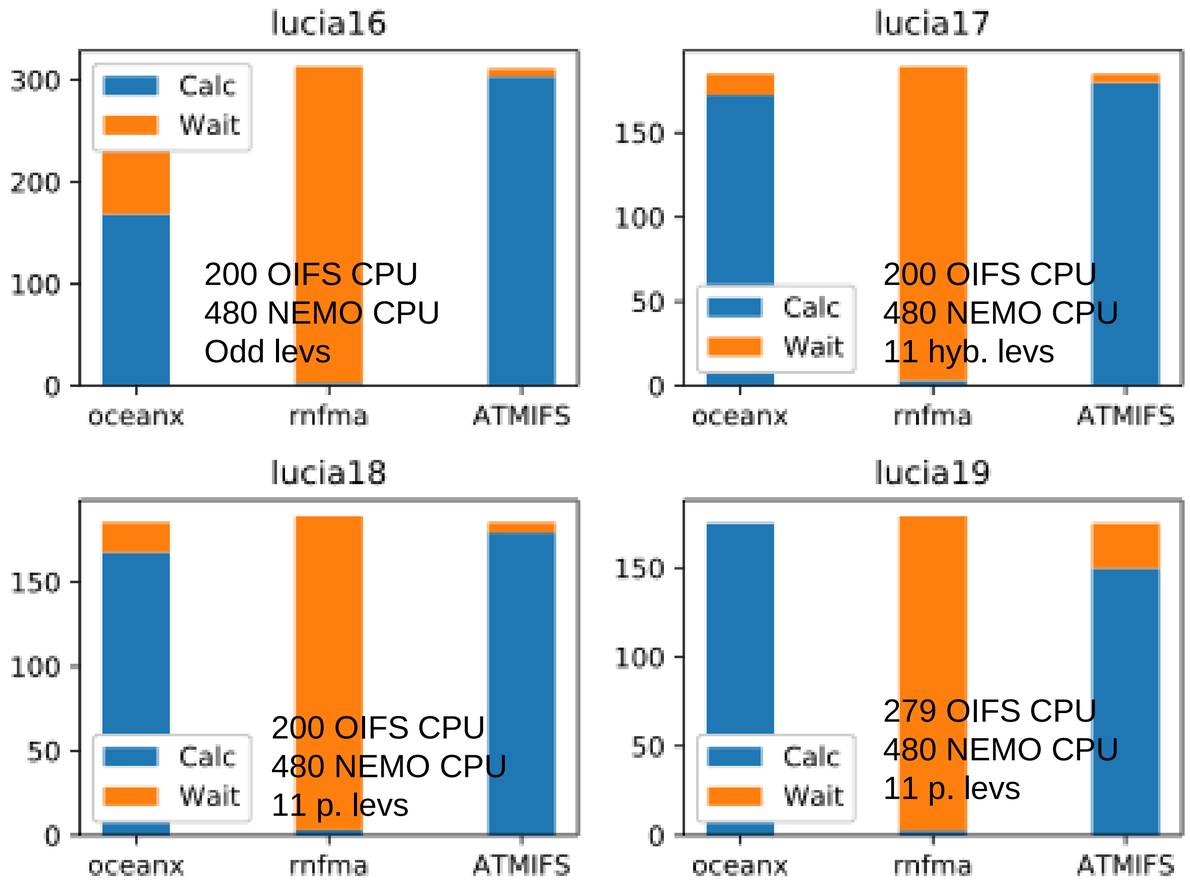

Reducing output has a huge impact!

Using 279 CPUs lets us use all CPUs for calculations, but total NPLs are unchanged.

(There's also a lot of overhead for only 1 month run!)