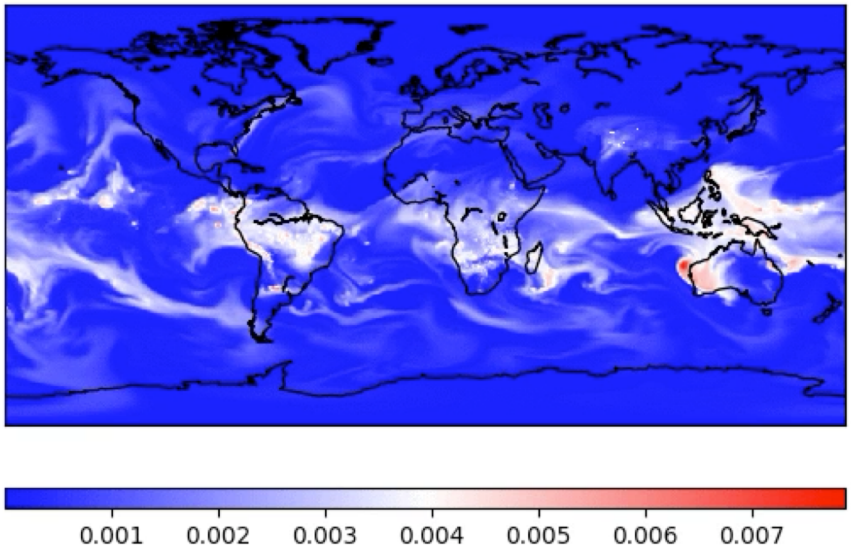
Laboratoire des Sciences du Climat et de l'Environnement
LSCE (UMR 8212)

DYNAMICO: recent progress



ICOLMDZOR AMIP configuration
Resolution: 50 km
Water vapor @ 500 mb

Sébastien Fromang *(CEA, LSCE)*

Yann Meurdesoif *(LSCE),* ***Thomas Dubos*** *(LMD),* ***Arnaud Caubel*** *(LSCE),* ***Josefine Ghattas*** *(IPSL),* ***Masa Kageyama*** *(LSCE),* ***Jerome Servonnat*** *(LSCE),* ***Mickaël Lalande*** *(IGE) & LMDZ Team*

And many LSCE interns in the past few years…
Marie Sicard *(CEA, DRF/LSCE),* ***Stella Bourdin***, ***Thomas Le Corre***, ***Elias Drach***

Outline

1. The ICOLMDZOR configuration

Dynamico & modipsl

Available experiments & validation

2. The effect of horizontal dissipation

Low resolution simulations (δ~200 km)

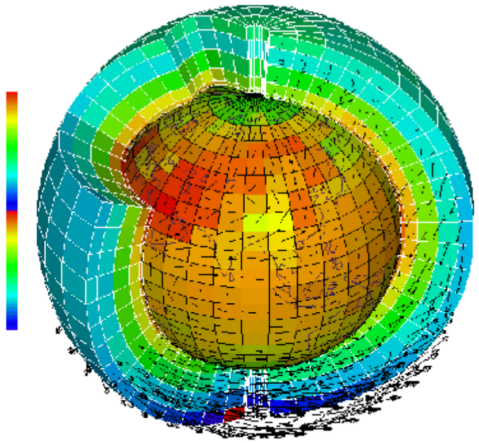
High resolution simulations (δ~50km)

3. Remaining problems…

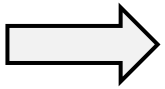
4. Conclusions & Perspectives

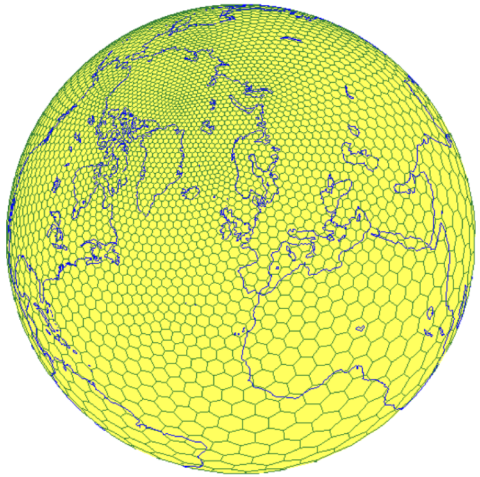
Dynamico: a new dynamical core for the LMDZ

Dubos et al. (2015)



LMD-Z lon-lat core





Lon-lat grid

Pole singularity: => Scalability issues

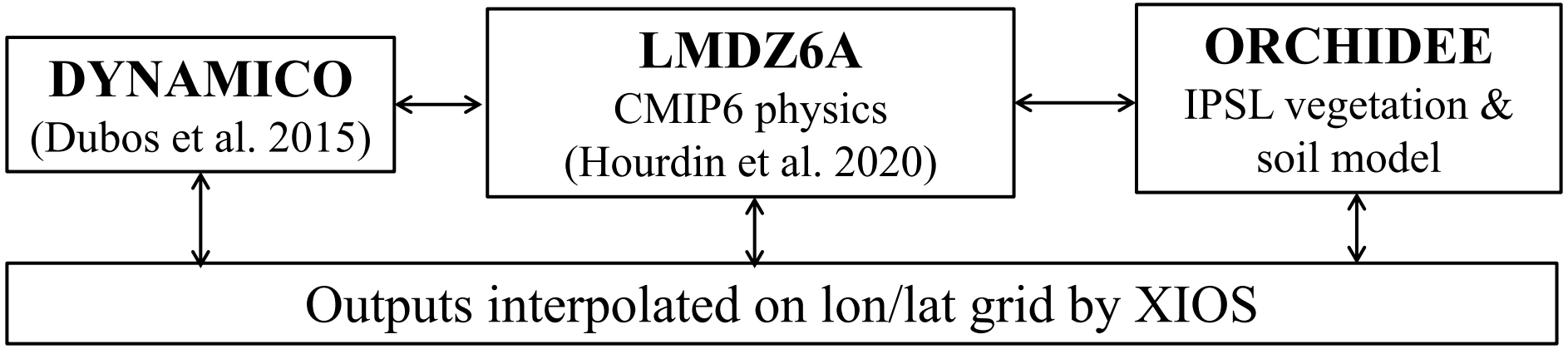
Icosahedrical grid

No pole singularity => better scalability

Uniform resolution

ICOLMDZOR configuration

Recently DYNAMICO has been coupled to the LMDZ physics



ICOLMDZOR configuration

Recently DYNAMICO has been coupled to the LMDZ physics

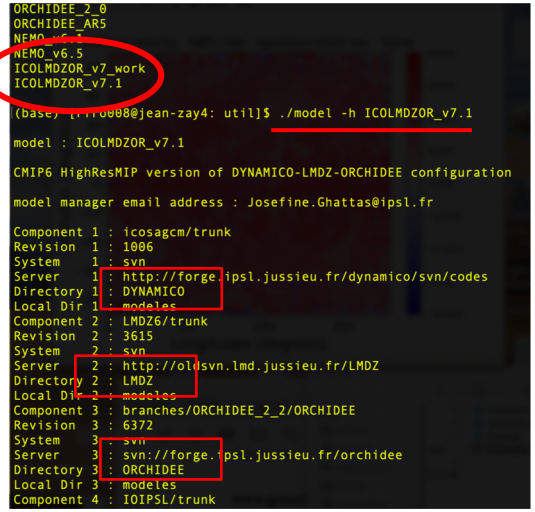
DYNAMICO
(Dubos et al. 2015)

LMDZ6A
CMIP6 physics
(Hourdin et al. 2020)

ORCHIDEE
IPSL vegetation &
soil model

Outputs interpolated on lon/lat grid by XIOS

How do I get the ICOLMDZ configuration?



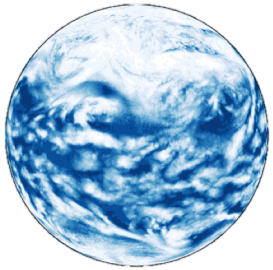
On Irene-skl or Jean-Zay:

svn co http://forge.ipsl.jussieu.fr/igcmg/svn/modipsl/trunk modipsl
cd modipsl/util
./model -h
./model –h ICOLMDZOR_v7.1
./model ICOLMDZOR_v7.1
=> install all the required components…

More information: http://forge.ipsl.jussieu.fr/igcmg_doc/wiki/Doc/Install#Downloadingmodipsl

Available experiments

Atmosphere only experiments – no coupled configurations yet available



Aquaplanet experiments: no continents, no topography, no seasonal cycle – diurnal cycle & imposed SST

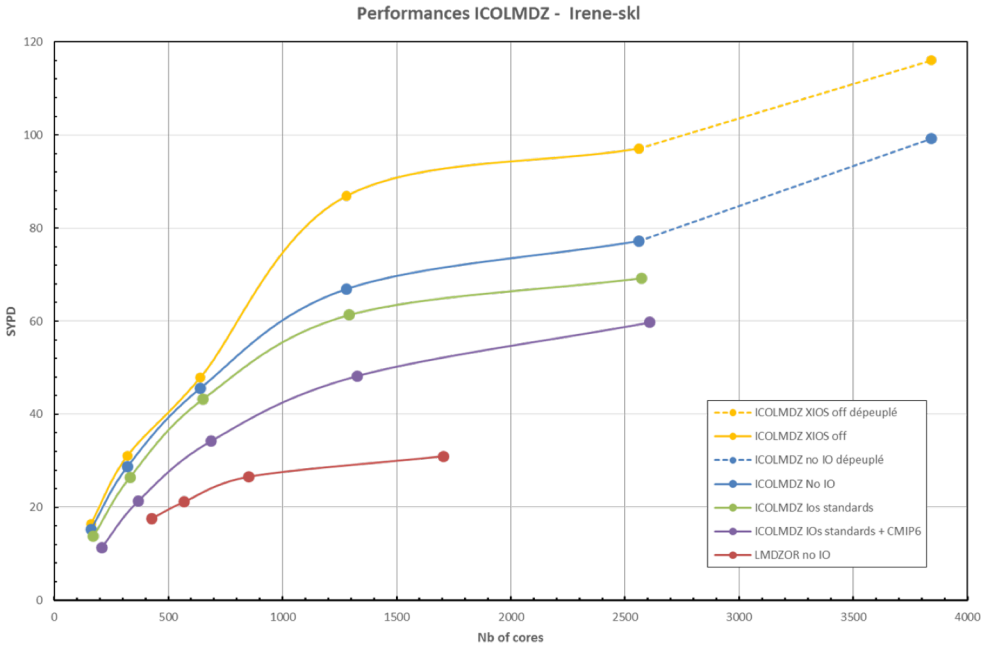
AMIP experiments: continents, topography, diurnal & seasonal cycle, aerosols, imposed SST (in this talk: 1979-2008 averaged SST)

Historical experiments: continents, topography, dirunal & seasonal cycle, imposed time-varying SST (period 1950-2014)

Typical performances

Low resolutions (*δ~200 km):*

⇒ Outputs interpolated on 144x143 lon/lat grid (identical to LMDZOR-v6)
⇒ Standard configuration: 160 MPI x 4 OMP: 35 yrs/days with standard I/O
⇒ **Perfs up ~ 80 yrs/days when using 320 MPI x 8 OMP w/o IO**



High resolutions (*δ~50 km):*

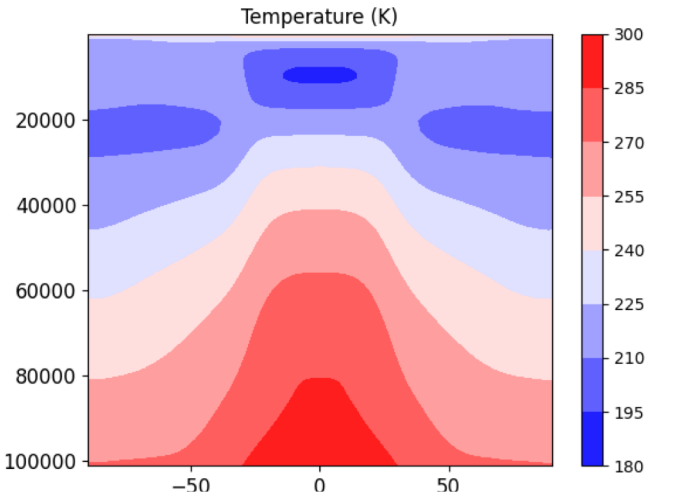
⇒ Outputs interpolated on 720x360 lon/lat grid (about ½ degree)
⇒ Standard configuration: 640 MPI x 4 OMP: *~2500 process total*
⇒ **Perfs: ~ 6-10 yrs/days**

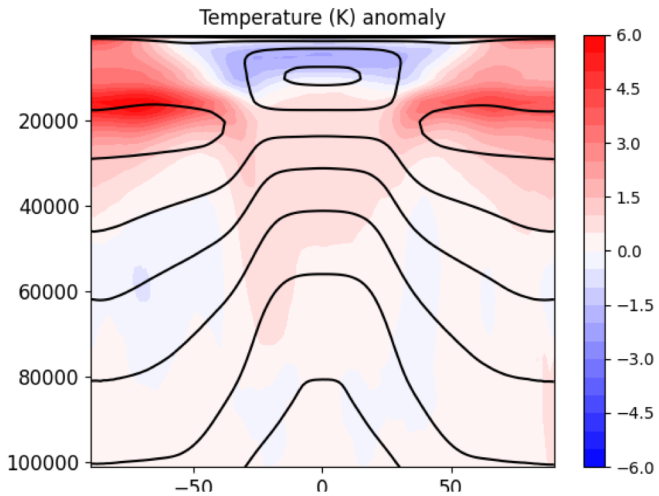
Examples & validation

Aquaplanet experiment (δ=240 km)

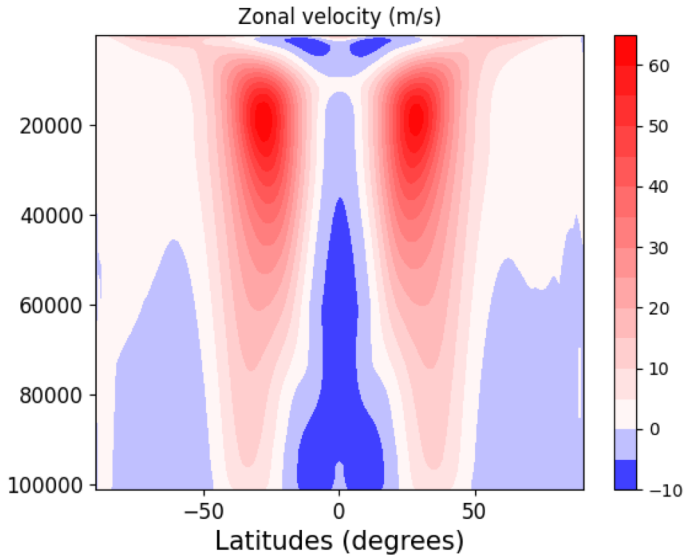
LMDZ | **ICOLMDZ anomaly**

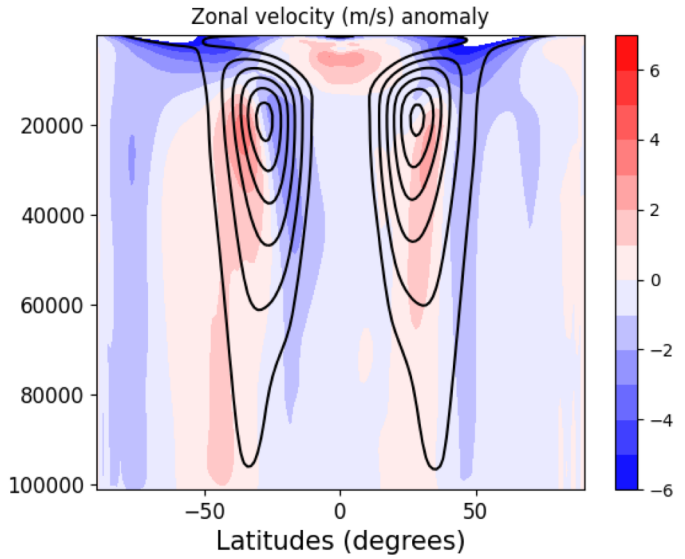
Temperature





Zonal wind





Zonal & time [illegible]

Agreement between LMDZ vs. DYNAMICO: coupling OK!

AMIP experiment (inc. ORCHIDEE)

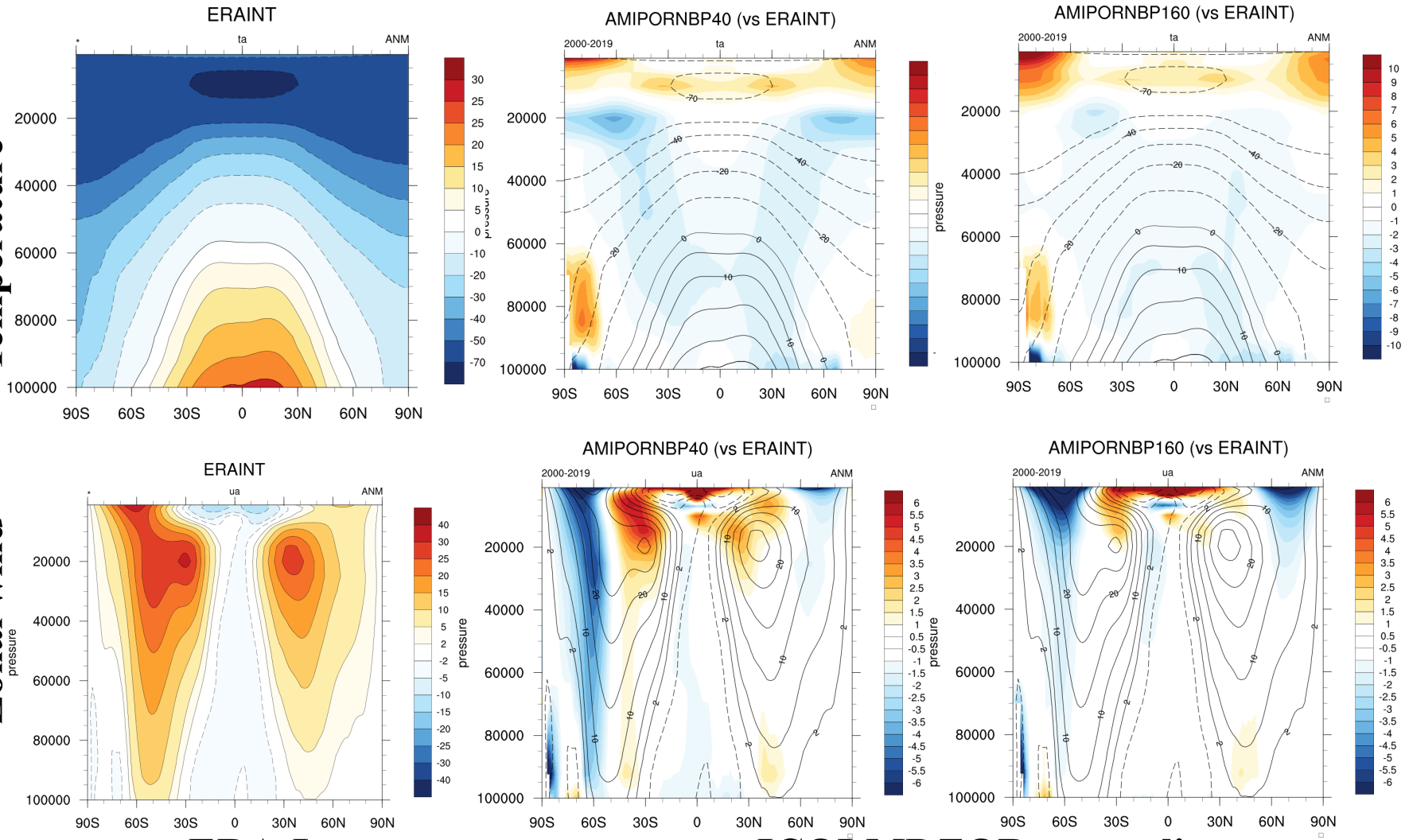
δ=240 km

δ= 50 km

Temperature

Zonal wind

Zonal & time average (20 yrs)



Bias vs ERA-I comparable with those obtained using LMDZOR

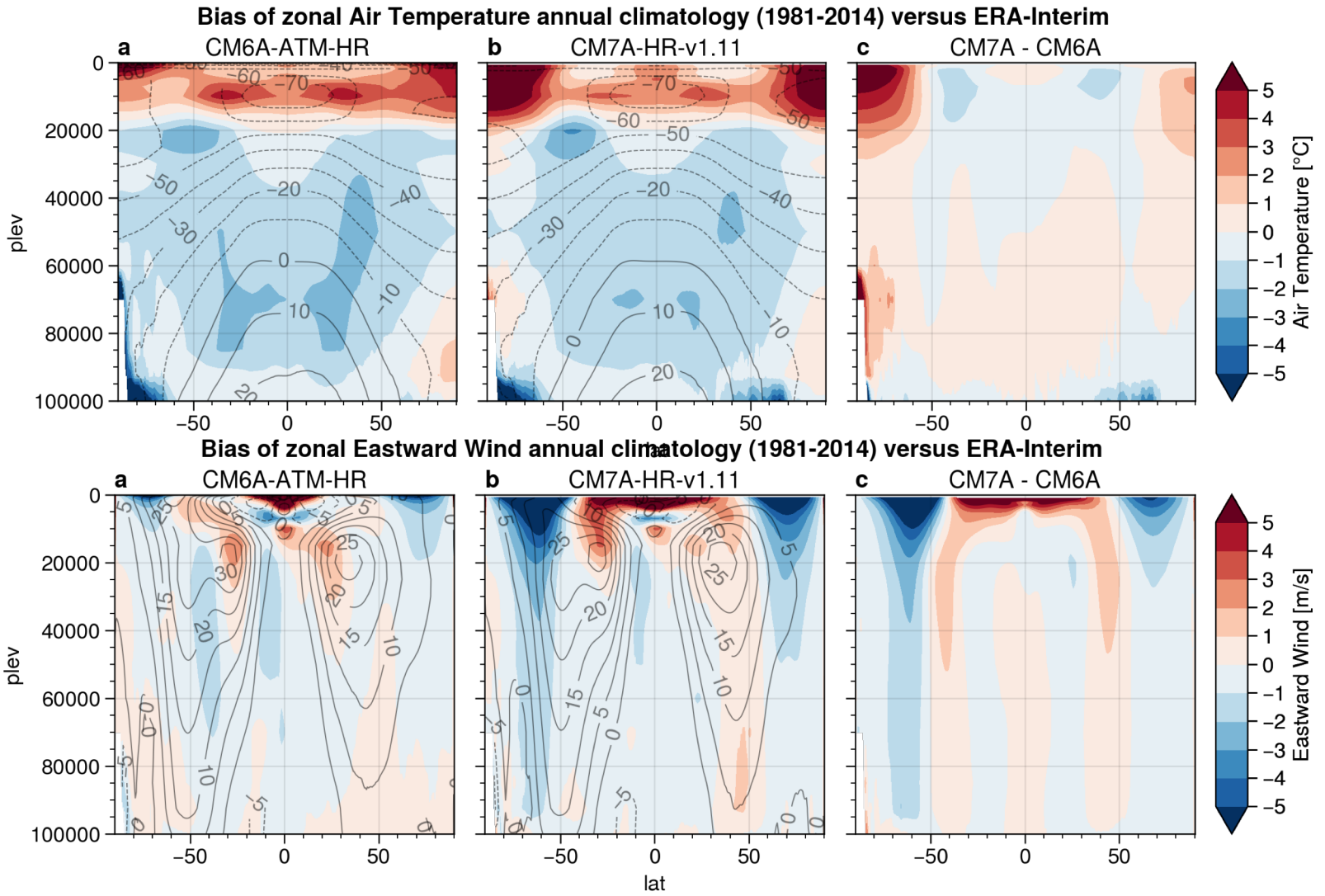
highResMip experiment (δ=50 km)

(Thanks to Mickaël Lalande)

Temperature

Zonal wind

Zonal & time averaged (1981-2014)



Main differences between LMDZ & ICOLMDZ: <u>hotter polar stratosphere</u> & <u>jet slightly equatorward</u> in ICOLMDZ

Differences with LMDZOR-v6.1.11?

Two differences:

$\Rightarrow$ Sponge layer

LMDZOR-v6 : u,v,theta relaxed to their zonal mean

ICOLMDZOR: u,v relaxed to zero

$\Rightarrow$ Horizonal dissipation

ICOLMDZOR scheme is intrisically dissipative

Smaller dissipation may be used…

Differences with LMDZOR-v6.1.11?

Two differences:

⇒ Sponge layer

LMDZOR-v6 : u,v,theta relaxed to their zonal mean
ICOLMDZOR: u,v relaxed to zero

⇒ Horizonal dissipation

ICOLMDZOR scheme is intrisically dissipative
Smaller dissipation may be used…

Horizontal dissipation in DYNAMICO (and LMDZ)

Dissipation operator for the variable X: $(\delta^{2q}/\tau)\ \Delta^q X$

Example: *q=1* $\Longleftrightarrow$ *standard diffusion – e.g. kinematic viscosity)*

Interpretation: $\tau \sim$ timescale to diffuse X over gridscale δ

Dissipation applied on:

compressive component of velocity (q=1): τ_{div}
rotational component of velocity (q=2): τ_{rot}
potential temperature (q=2): τ_{temp}

Two questions

Q1: How do we choose τ_{div}, τ_{rot} and τ_{temp} at low resolution?

Q2: How do we change τ_{div}, τ_{rot} and τ_{temp} with resolution?

Two questions

Q1: How do we choose τ_{div}, τ_{rot} and τ_{temp} at low resolution?

A1: do the same as LMDZ

τ_{div}=3600 sec
τ_{rot} =20400 sec
τ_{temp} =10800 sec

Q2: How do we change τ_{div}, τ_{rot} and τ_{temp} with resolution?

A1: Decrease LMDZ values in proportion with resolution
(ex: Jablonowsky & Williamson 2008)

Option used in previous slides

Two questions

Q1: How do we choose τ_{div}, τ_{rot} and τ_{temp} at low resolution?

A1: do the same as LMDZ

τ_{div}=3600 sec
τ_{rot} =20400 sec
τ_{temp} =10800 sec

A2: investigate weaker dissipation

Q2: How do we change τ_{div}, τ_{rot} and τ_{temp} with resolution?

A1: Decrease LMDZ values in proportion with resolution
(ex: Jablonowsky & Williamson 2008)

A2: investigate weaker dissipation

Option used in previous slides

Explored in following part using aquaplanet simulations

Rationale to choose dissipation timescales

1: Large scales insensitive to dissipation (this is the goal)

Aim for the largest dissipative timescales possible

2: Stability

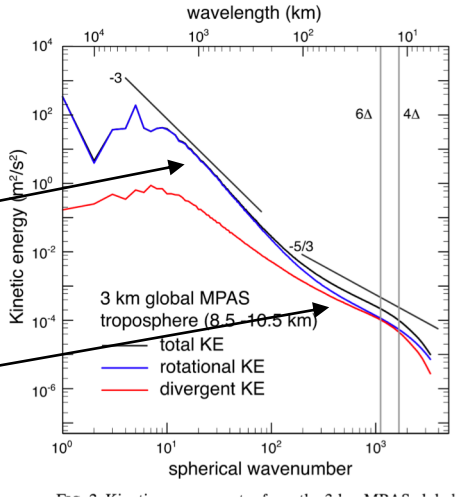
τ_{div}<10000 sec regarless of resolution

No stability constraints found regarding τ_{rot} and τ_{temp}

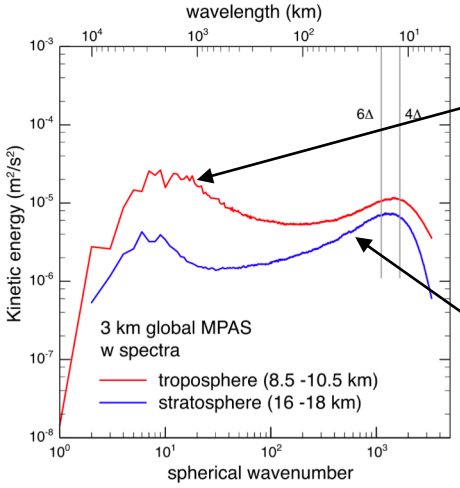
In practice, little effect of τ_{temp}. Took $\tau_{rot}=\tau_{temp}$

3: EKE and vertical velocities power spectra well behaved at small scales

Eddy Kinetic Energy



Vertical velocity



-3 exponent at large scales

-5/3 exponent at small scales

Peak at synoptic scales

Rather flat at small scales (due to gravity waves)

From Skamarock et al. (2014) using MPAS

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High resolution simulations (δ~50km)

3. Remaining problems…

4. Conclusions & Perspectives

Low resolution case – nbp=40 (δ=200 km)

CMIP6 dissipation

τ_{div}=3600 sec

τ_{rot} =20400 sec, τ_{temp} =10800 sec

Low resolution case – nbp=40 (δ=200 km)

More dissipation

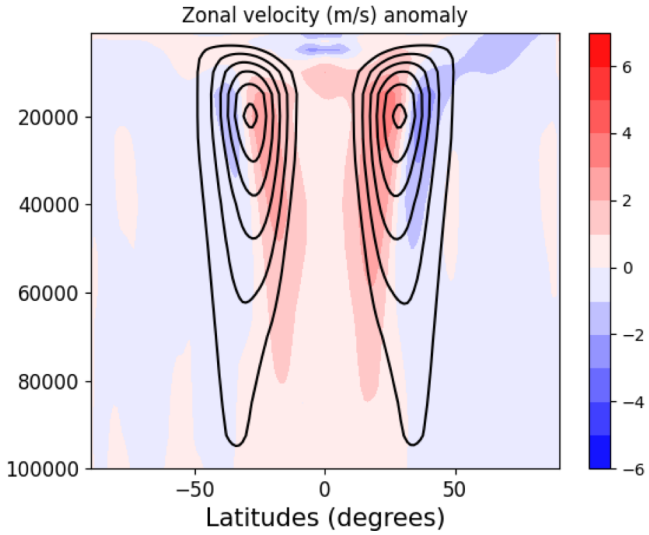
τ_{div}=1000 sec

τ_{rot} =τ_{temp} =5000 sec

CMIP6 dissipation

τ_{div}=3600 sec

τ_{rot} =20400 sec, τ_{temp} =10800 sec

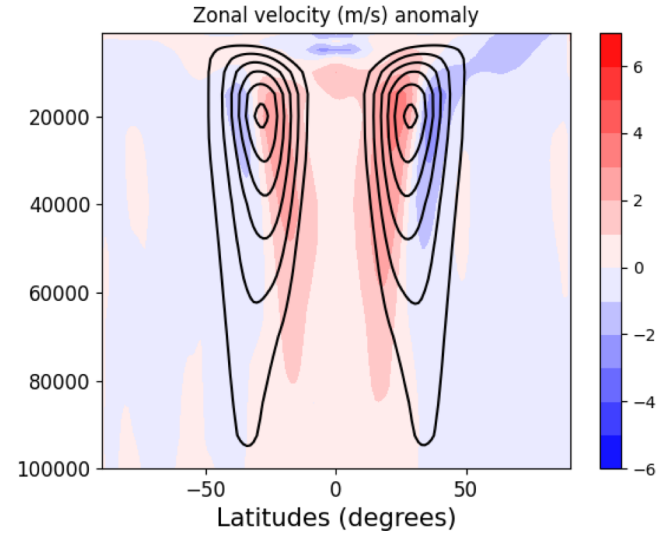


⇒ Midlatitude jets equatorward shift

Low resolution case – nbp=40 (δ=200 km)

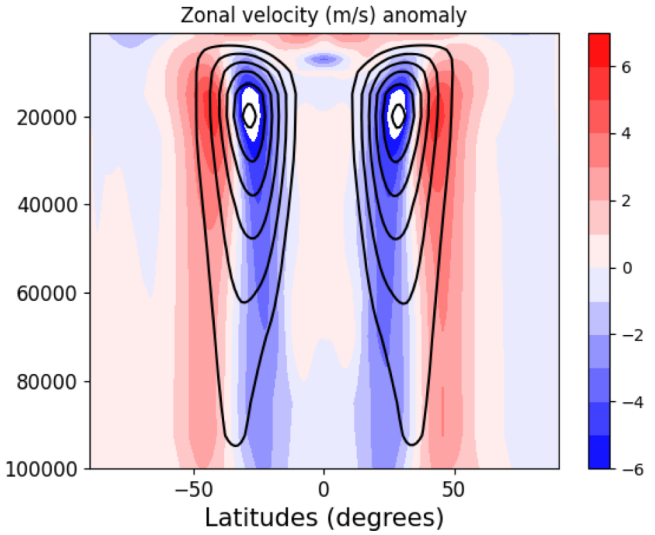
CMIP6 dissipation
τ_{div}=3600 sec
τ_{rot} =20400 sec, τ_{temp} =10800 sec

More dissipation
τ_{div}=1000 sec
τ_{rot} =τ_{temp} =5000 sec



⇒ Midlatitude jets equatorward shift

Less dissipation
τ_{div}=10000 sec
τ_{rot} =τ_{temp} =50000 sec



⇒ Subtropical jet weakened: -10 m/s
⇒ Eddy driven jet shift poleward: ~ 5°

Less dissipation => more fluctuations => larger poleward eddy momentum flux => jet shift poleward

See also Guemas & Codron (2011)

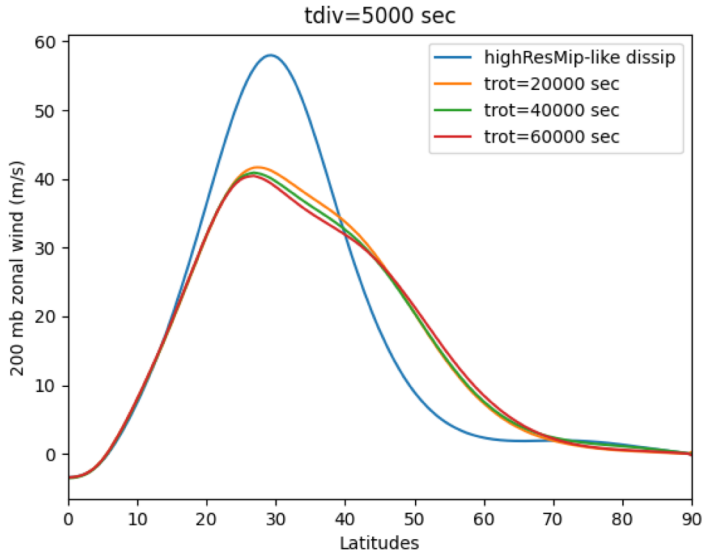
Strong sensitivity of the circulation to horizontal dissipation in aquaplanet setup

High resolution case - nbp=160 (δ=50 km)

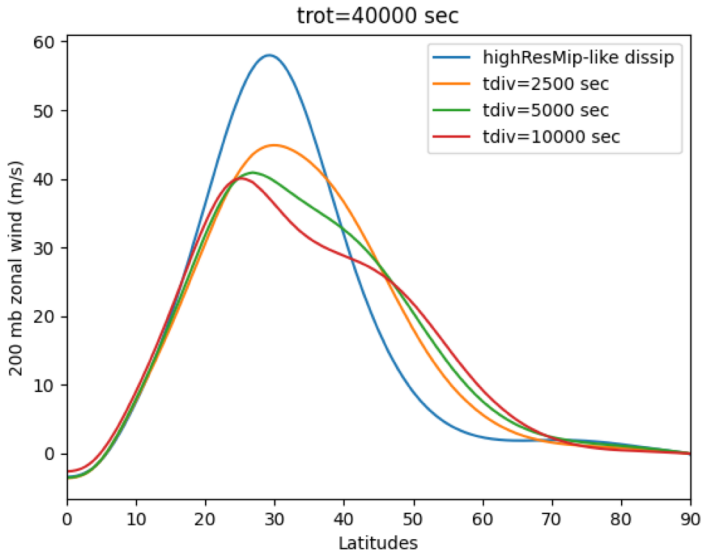
Option 1 (highResMip-like dissipation):
Same result is obtained (strong sensitivity to dissipation)

highResMip dissipation
τ_{div}=900 sec
τ_{rot} =5400 sec, τ_{temp} =2700 sec

Option 2 (weaker dissipation)
Some signs of large scale convergence found *(see also Chen et al. 2018)*



Global circulation **insensitive** to τ_{rot} for 20000 s< τ_{rot} <60000 s

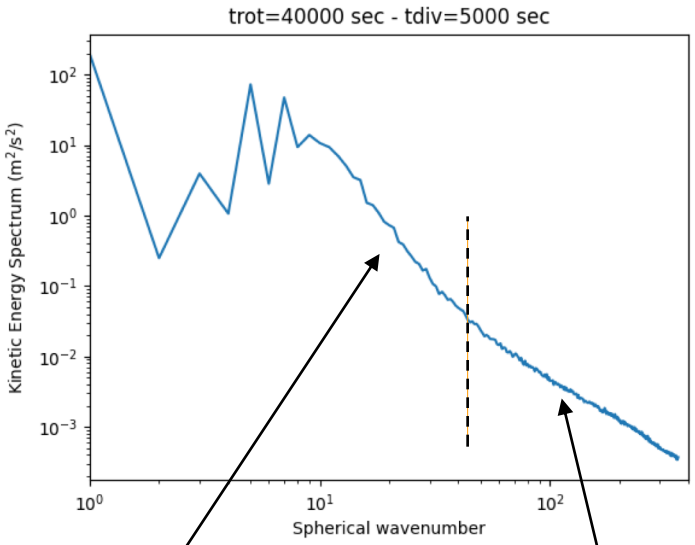


Global circulation **still sensitive** to τ_{div} for 2500 s< τ_{div} <10000 s

Is it reasonnble to take such high dissipative timescales?

Power spectra: $t_{rot}=t_{temp}=40000$ s & $t_{div}=5000$ s

200 mb EKE power spectrum

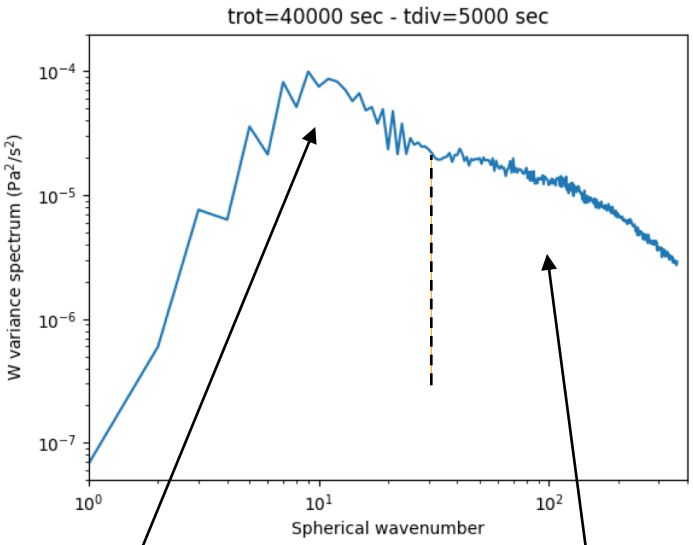


Steep spectrum at large scales

Spectrum flattens at small scales (expt => -5/3)

Well behaved at all scales

200 mb vertical velocity spectrum



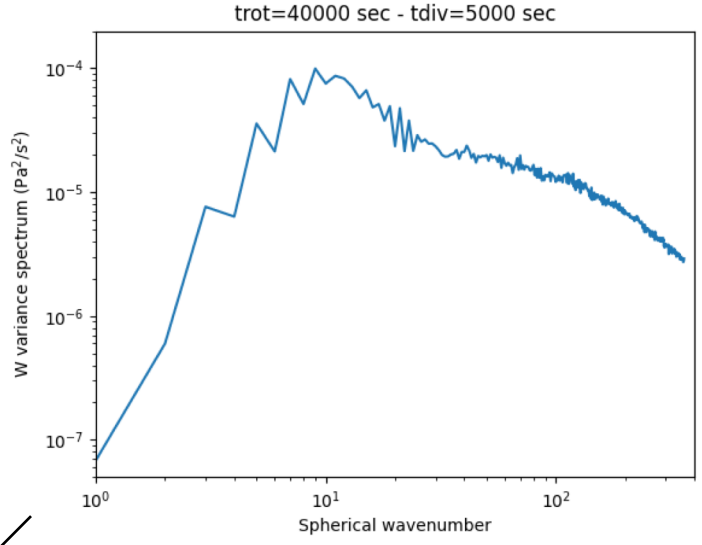
Peak at synoptic scales

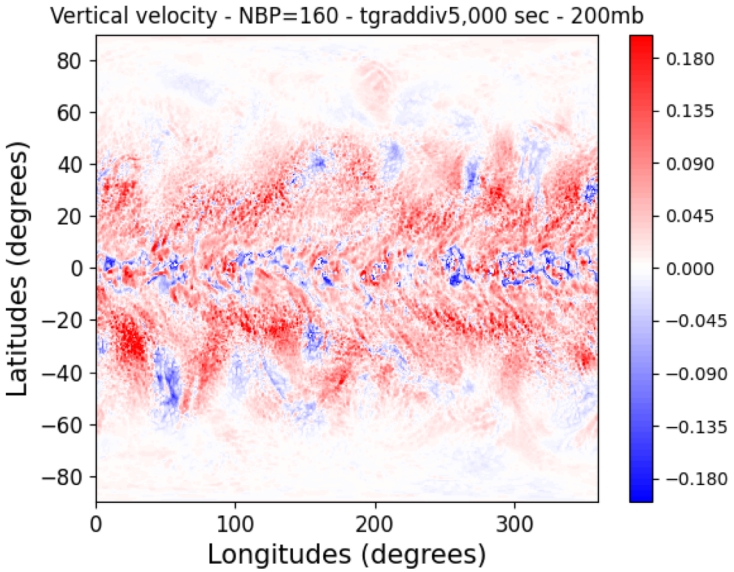
Flat spectrum at intermediate scales

Well behaved at all scales

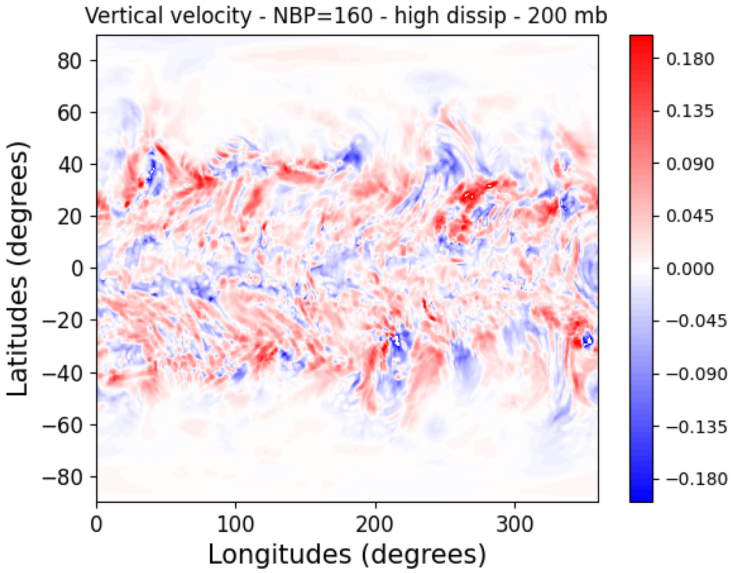
Power spectrum: trot=40000 s & tdiv=5000 s

Vertical velocity power spectrum

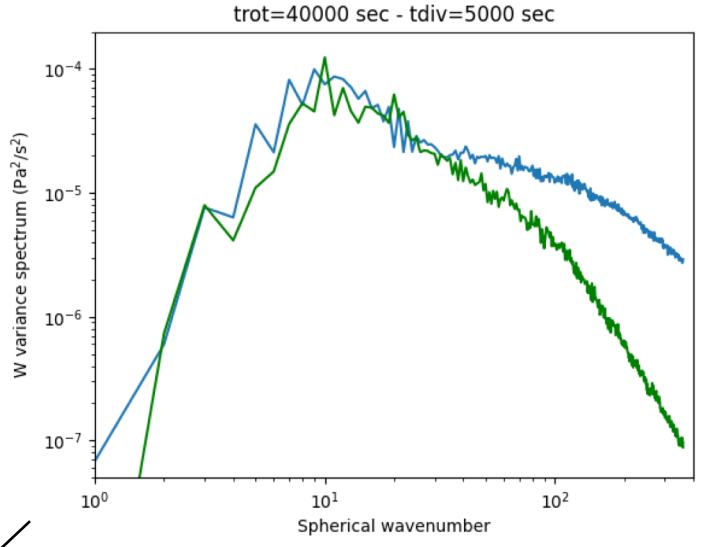




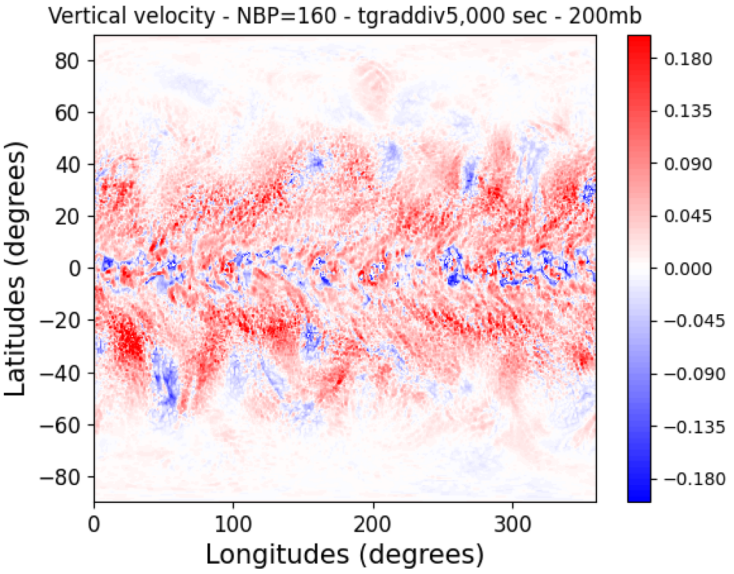
Power spectrum: trot=40000 s & tdiv=5000 s



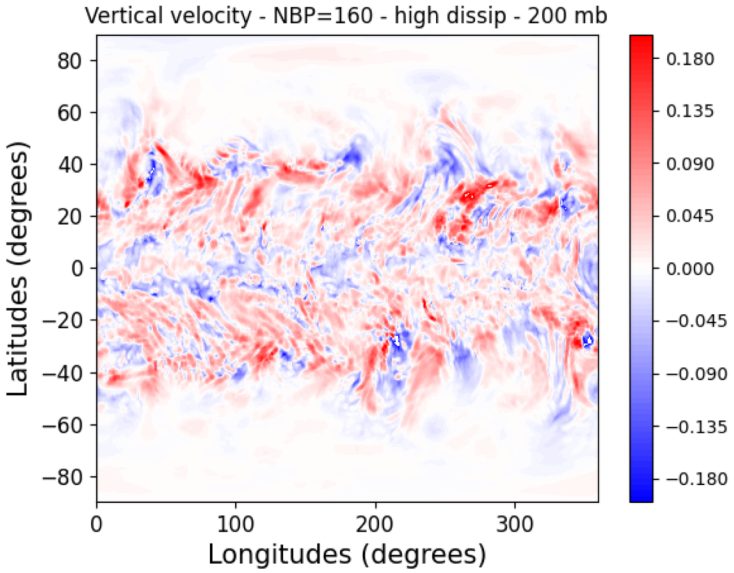
Vertical velocity power spectrum



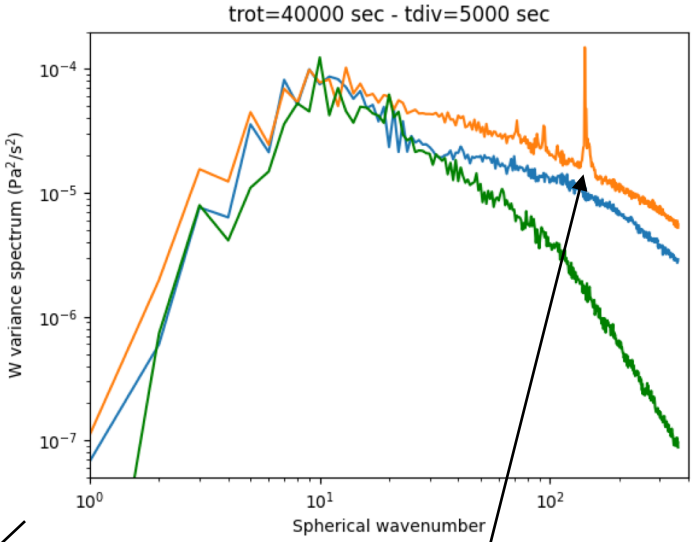
highResMip-like dissipation

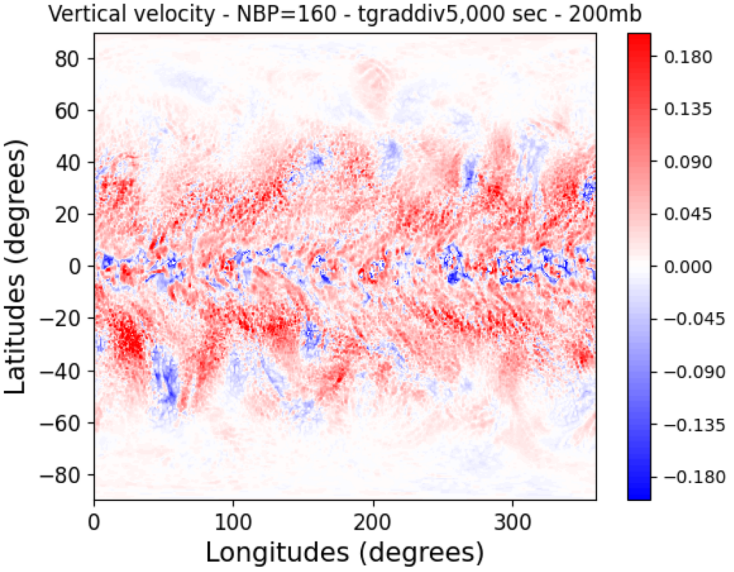


Power spectrum: trot=40000 s & tdiv=5000 s



Vertical velocity power spectrum





Spurious peak at small scales when tdiv=10000 s

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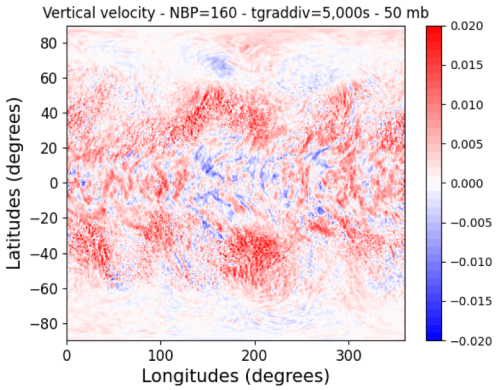
Remaining issues at low resolution?

None!

Please go ahead and use it!

Remaining issues at high resolution?

1/ Strong vertical velocities oscillations in the stratosphere.



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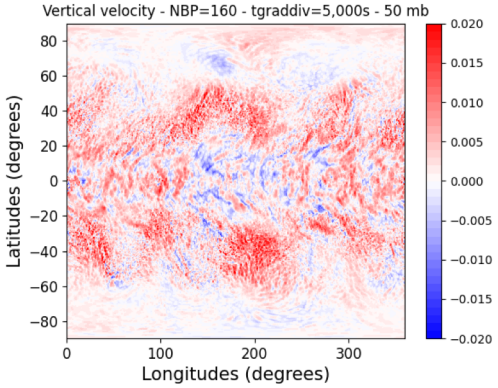

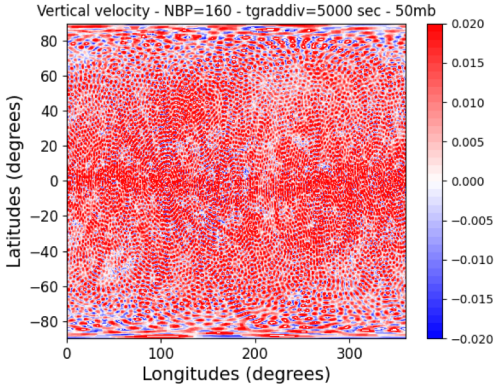

- Amplitude: ~1 cm/s
- Present in CM6 highResMIP run
- Identical climatology (same QBO)

Remaining issues at high resolution?

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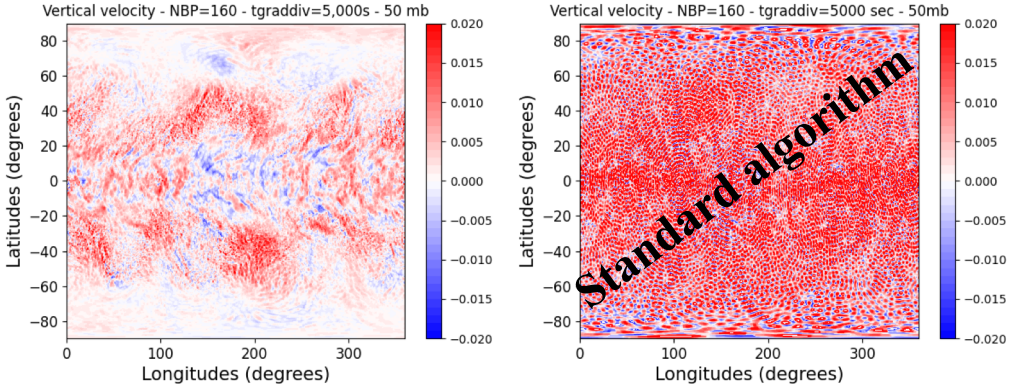

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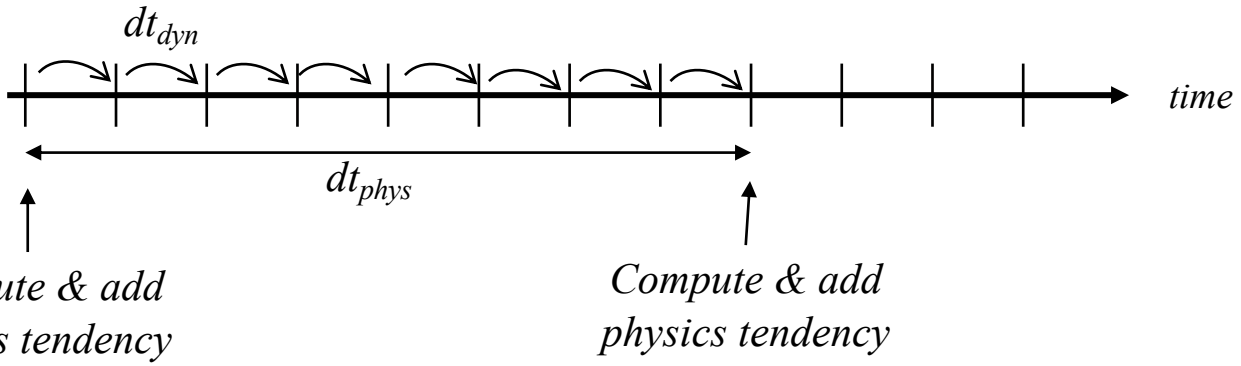
Problem associated with the physics/dynamics coupling…



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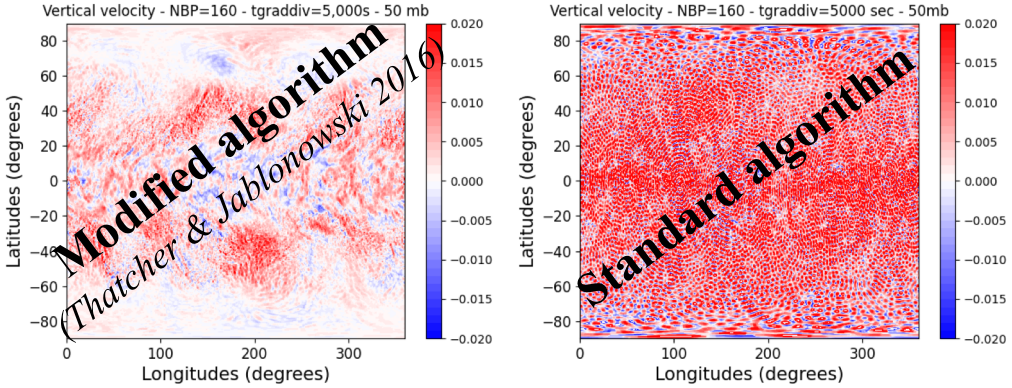

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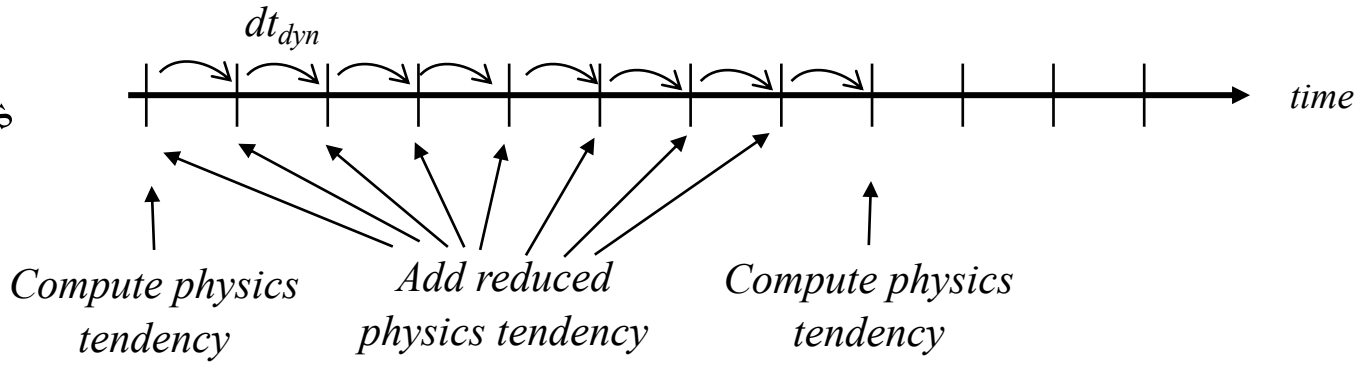

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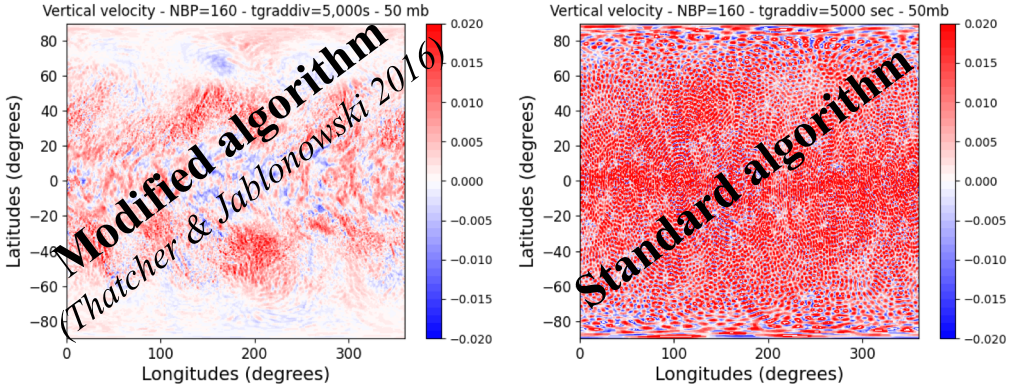
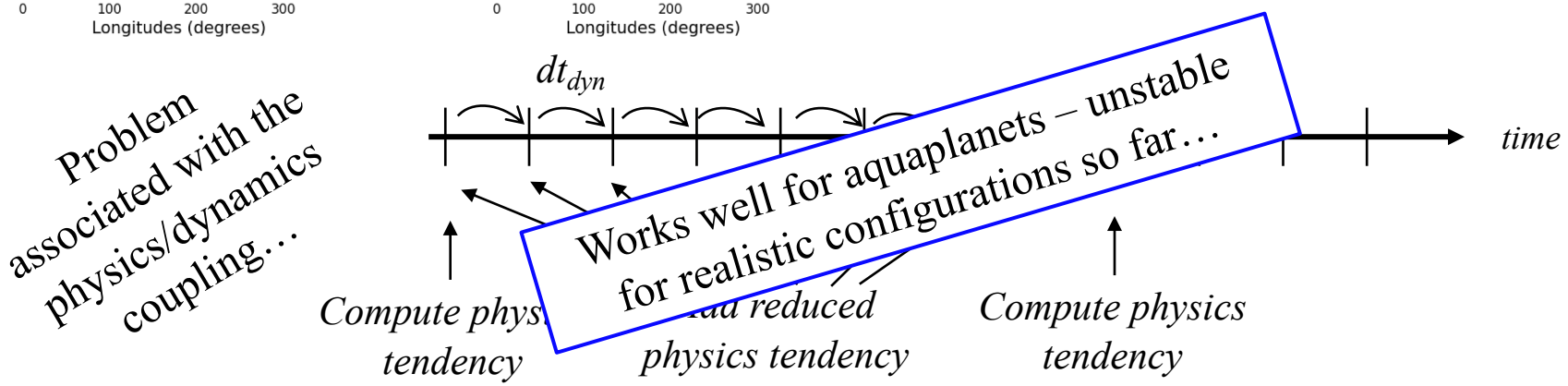
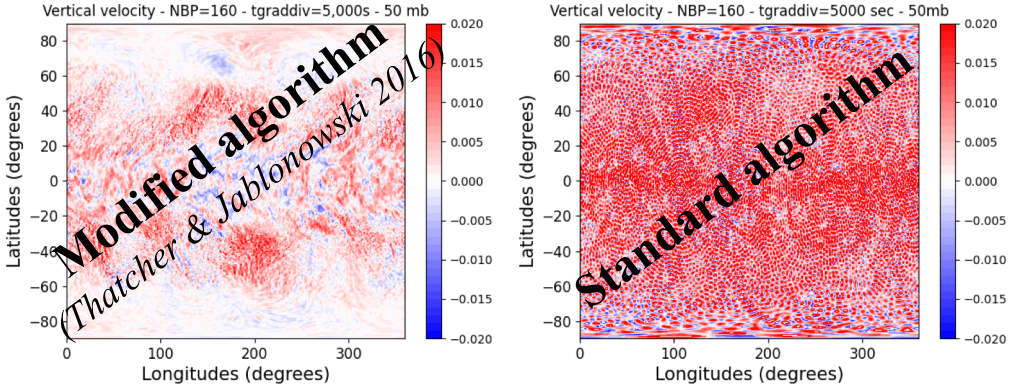


- Amplitude: ~1 cm/s
- Present in CM6 highResMIP run
- Identical climatology (same QBO)



Remaining issues at high resolution?

1/ Strong vertical velocities oscillations in the stratosphere.



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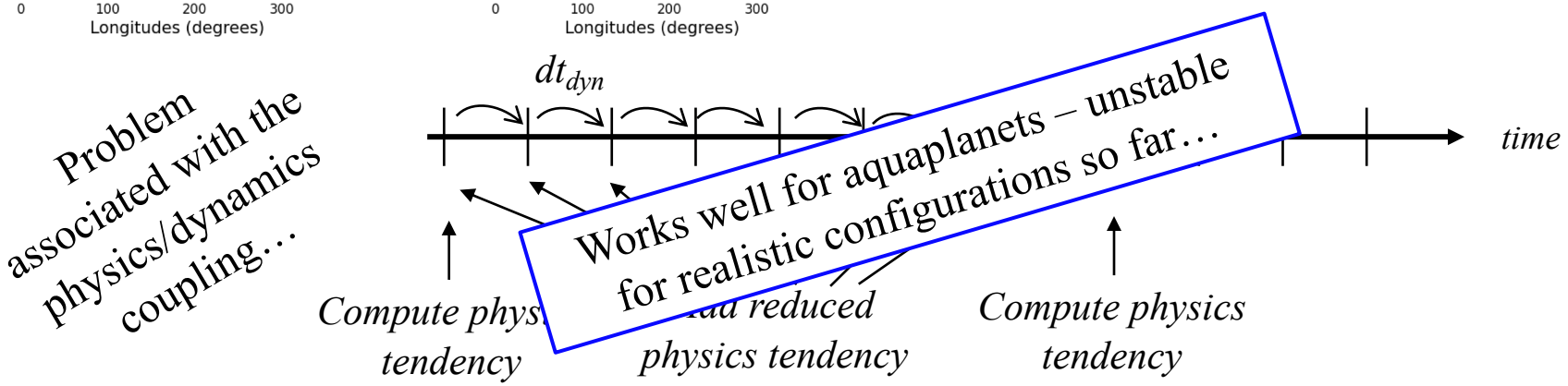

2/ Crashes (hgardfou) in AMIP runs @ 50 km

=> more problematic as resolution improves…

=> associated with strong convective events above land

=> fix: reduce values of oliq_max & oice_max in physics.def

=> long term solution needed…

Conclusions

⇒ ICOLMDZOR configuration available & working through modipsl

- **Low resolution: up & running**
  - ⇒ Aquaplanets, AMIP & historical configuration
  - ⇒ AMIP runs with various dissipation coefficient (re-tuning needed?)

- **High resolution**
  - ⇒ Various issues (crashes, vertical velocity oscillations in stratosphere
  - ⇒ Perspective 1: highResMip @ 25 km (PhD thesis starting Nov 1st at LSCE on extremes events)
  - ⇒ Perspective 2: coupled model

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Thank you for your attention!