Pathway to regular and sustained delivery of climate forcing datasets workshop: 28-31 October 2024, ECMWF Reading

Session 4:
Addressing Gaps and Uncertainties in Forcing Datasets

Chair: Paul Durack

CMIP Climate Forcings | WCRP

Implementation of the CMIP6 forcings in the IPSL-CM6 model: Lessons learned

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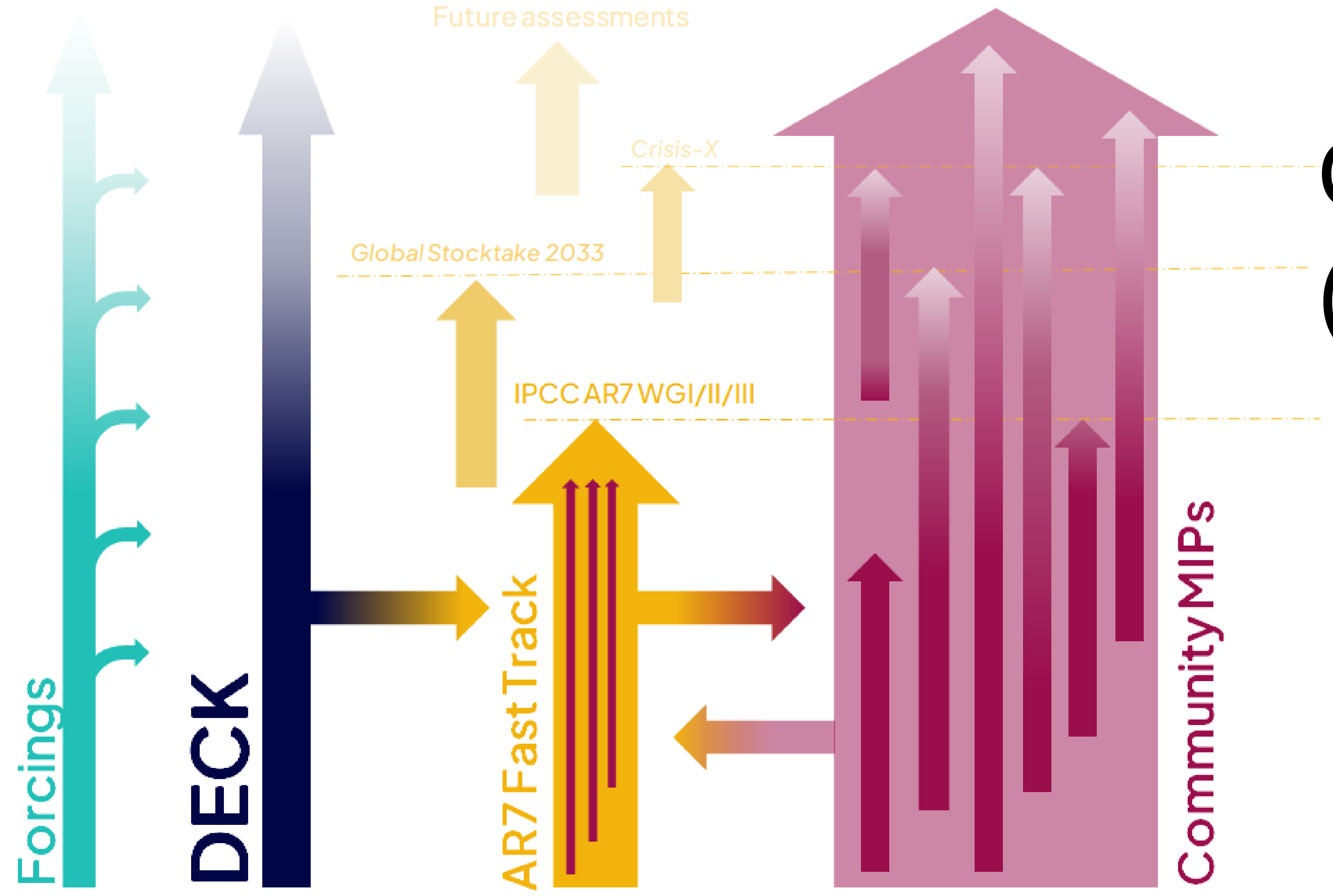

One goal of CMIP is to standardize experiments (which implies standardizing forcings)

Same forcing terms does not mean same radiative forcings!

Mitigation measures:

- document how we implement forcings
- document forcing outcomes from the model

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Implementation of the CMIP6 Forcing Data in the IPSL-CM6A-LR Model

Thibaut Lurton, Yves Balkanski, Vladislav Bastrikov, Slimane Bekki, Laurent Bopp, Pascale Braconnot, Patrick Brockmann, Patricia Cadule, Camille Contoux, Anne Cozic, David Cugnet ... See all authors

Outline

I) A brief overview of the IPSL-CM6A-LR model

II) How we treated monthly emissions

III) Prescription of aerosols

IV) Oxidants and scenario correspondence

V) Ozone: tropopause matching and hybrid fields

VI) What worked, what did not work so well...

I) A brief overview of IPSL-CM6A-LR … as used in the CMIP6 exercise

- Atmospheric component:

  LMDz v6: GHG, trop aerosols, strat aerosols, O3, solar

  Resolution: 144 × 143 × 79

  Including atmospheric chemistry: **INCA** to derive aerosol fields

  DECK and most MIP were conducted with monthly prescribed aerosols

- Oceanic components:

  NEMO (blue) + **PISCES** (green) + **LIM3** (white): **dust and Nitrogen deposition**

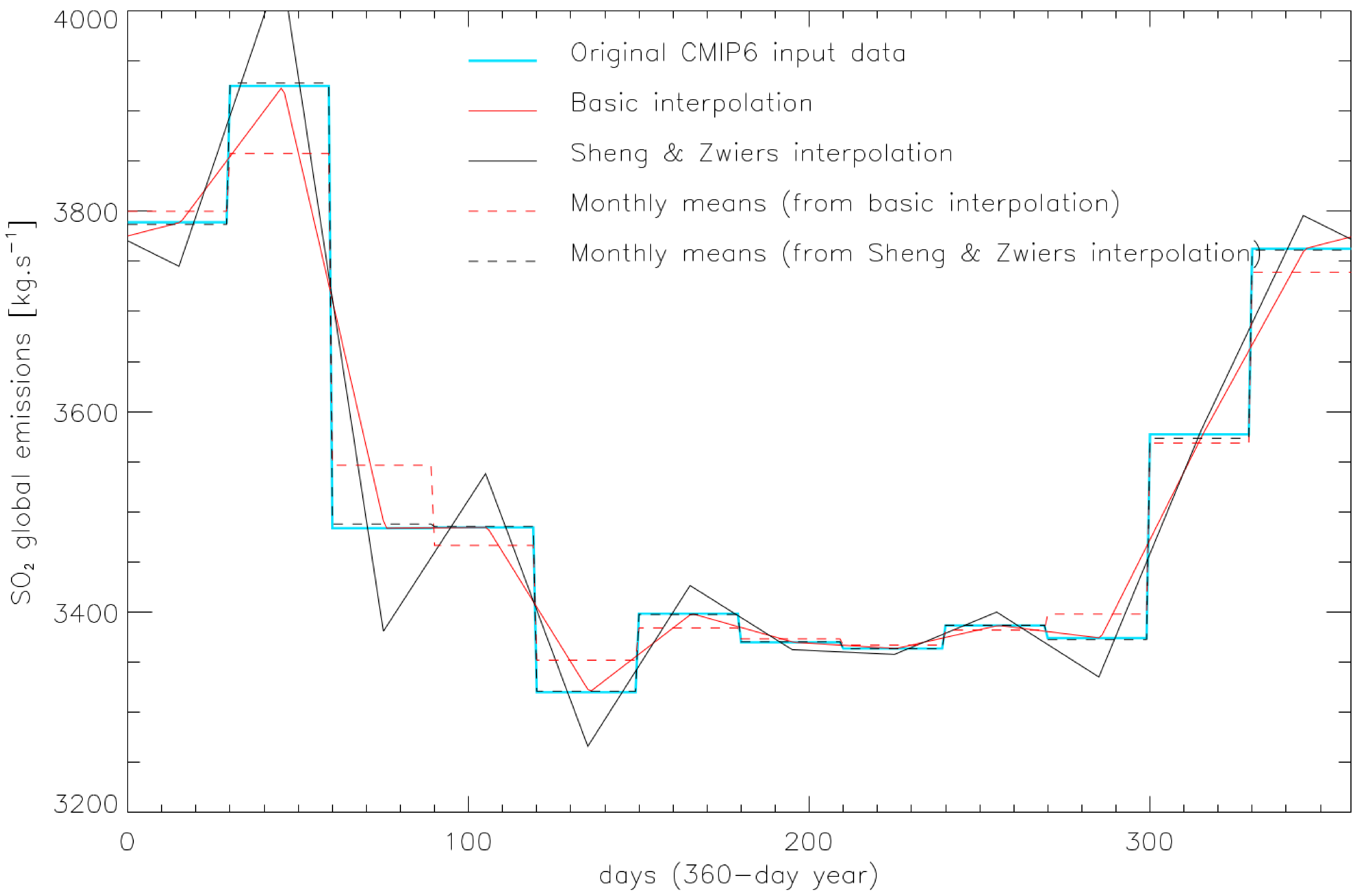
- Continental surfaces:

  ORCHIDEE: land surface types

- Coupler:

  OASIS

II) How we treated monthly emissions: A linear interpolation through time, whilst keeping the prescribed monthly means: how?



CMIP6 provided monthly-mean emissions.

- No time interpolation: monthly emissions are preserved but step changes in emissions every month

- Linear time interpolation: no step change in emissions but seasonal cycle is smoothed out and monthly emissions are not preserved.

Building on the Sheng & Zwiers algorithm, we could reconstruct a continuous evolution of emissions whilst sticking to the CMIP6 monthly means and avoiding negative emissions.

Sheng, J., & Zwiers, F. An improved scheme for time-dependent boundary conditions in atmospheric general circulation models. *Climate Dynamics*, 14 (7), 609–613. doi: 10.1007/s003820050244, 1998.

III) Preparation of tropospheric aerosol fields

Series of LMDZORINCA runs (atmosphere-only) prior to IPSL-CM6A-LR being frozen

For *historical* :

- SST and SIC from input4MIPs;

For *ssp*

- SST and SIC from IPSL-CM5 (i.e. RCP), bias-corrected and interpolated onto *ssp*

INCA was used in AER-only mode (without the whole of the gas chemistry)

Oxidants: from IPSL-CM5 runs, with INCA under AER+CHEM mode

Duration of runs: *historical* period split into 5 (33-yr) segments, each of them starting by a 3-yr spin-up period (eventually discarded); smoothing process to ensure continuity.

Neglected: aviation (3D) emissions

IV) Scenario correspondence for SST, SIC and oxidants

How to make correspondence between 4 RCP in CMIP5 and 8 ssp in CMIP6?

RCP (CMIP5)	RF by 2100	*ssp* (CMIP6)
	1.9 $W.m^{-2}$	ssp119
RCP26	2.6 $W.m^{-2}$	ssp126
	3.4 $W.m^{-2}$	ssp434; ssp534-over
RCP45	4.5 $W.m^{-2}$	ssp245
RCP60	6.0 $W.m^{-2}$	ssp460
	7.0 $W.m^{-2}$	ssp370
RCP85	8.5 $W.m^{-2}$	ssp585

We performed scaling considering the radiative forcings reached in 2100.

Limitations:
- overshoots
- land surface forcing

V) Ozone: tropopause matching

- Two possible definitions of tropopause:
  - *Dynamical*: tropopause lies at level w/ Ertel potential vorticity = 2 PVU and pot. temp. of 380 K;
  - *Chemical* tropopause lies at the first level w/ ozone concentration of 100 ppbv.

CMIP6 ozone forcing data: not provided with necessary fields to compute dynamical tropopause;
Conversely, IPSL-CM has no interactive ozone, so dynamical definition is used.

=> Tropopauses should coincide
=> Use of a vertical stretching process.

Vb) Strat aerosols

Clipped the stratospheric aerosol below the tropopause. No double counting of tropospheric aerosols but we miss stratospheric aerosols sedimenting in the troposphere

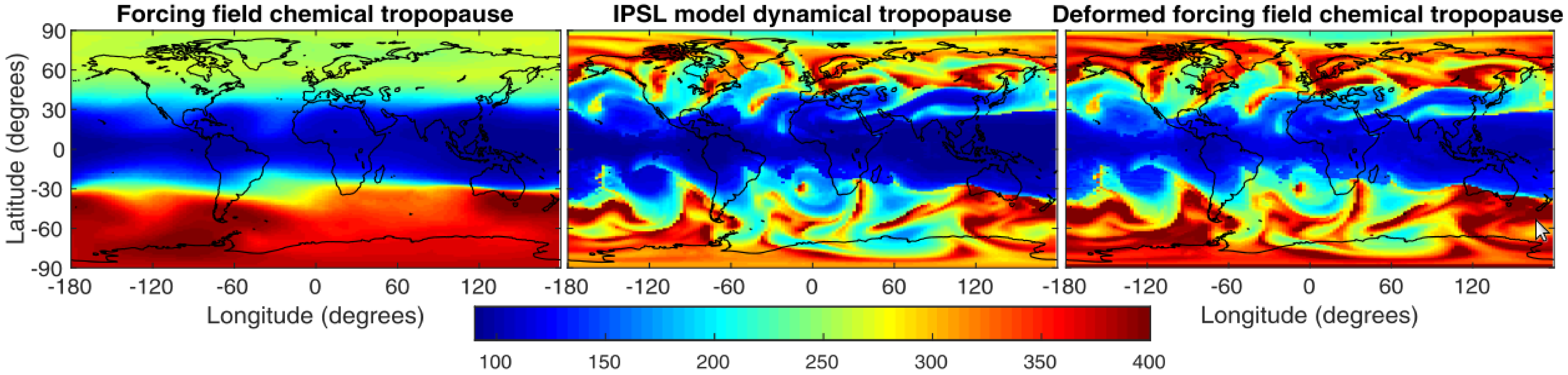


Figure 7. Typical tropopause pressure fields (in hPa) of the original input file (left panel, chemical definition), of our atmospheric model (middle panel, dynamical definition) and of the interpolated field (right panel, chemical definition). The first panel corresponds to the January 1983 mean input data field, while the last two panels are instantaneous fields of the IPSL-CM6A-LR at a particular time in that month.

V) Ozone: hybrid fields

Official tier-2 SSP ozone fields were not available at the time of running simulations by the IPSL. We used “hybrid” fields, yielded by scaling official tier-1 SSP ozone fields and ozone fields from tier-2 ScenarioMIP experiments as output by CNRM-CM6.

Example: for ssp_{434} (∈ Tier 2), we considered two “neighbouring” (in terms of radiative forcing reached in 2100) ozone fields:

$hybrid_{126}$	(low)	(∈ Tier 1)
$hybrid_{245}$	(high)	(∈ Tier 1)

with:

$$hybrid_{low,\ 434} = CNRM_{434} \times UReading_{126} \ / \ CNRM_{126}$$
$$hybrid_{high,\ 434} = CNRM_{434} \times UReading_{245} \ / \ CNRM_{245}$$

and eventually scaling $\quad \mathrm{hybrid}_{434} = \mathrm{f}\,(\,hybrid_{low,\ 434}\,,\,hybrid_{high,\ 434}\,)$

VI) Snags and mishaps

1/ Fairly low ERF for aerosol-cloud interactions Why so?

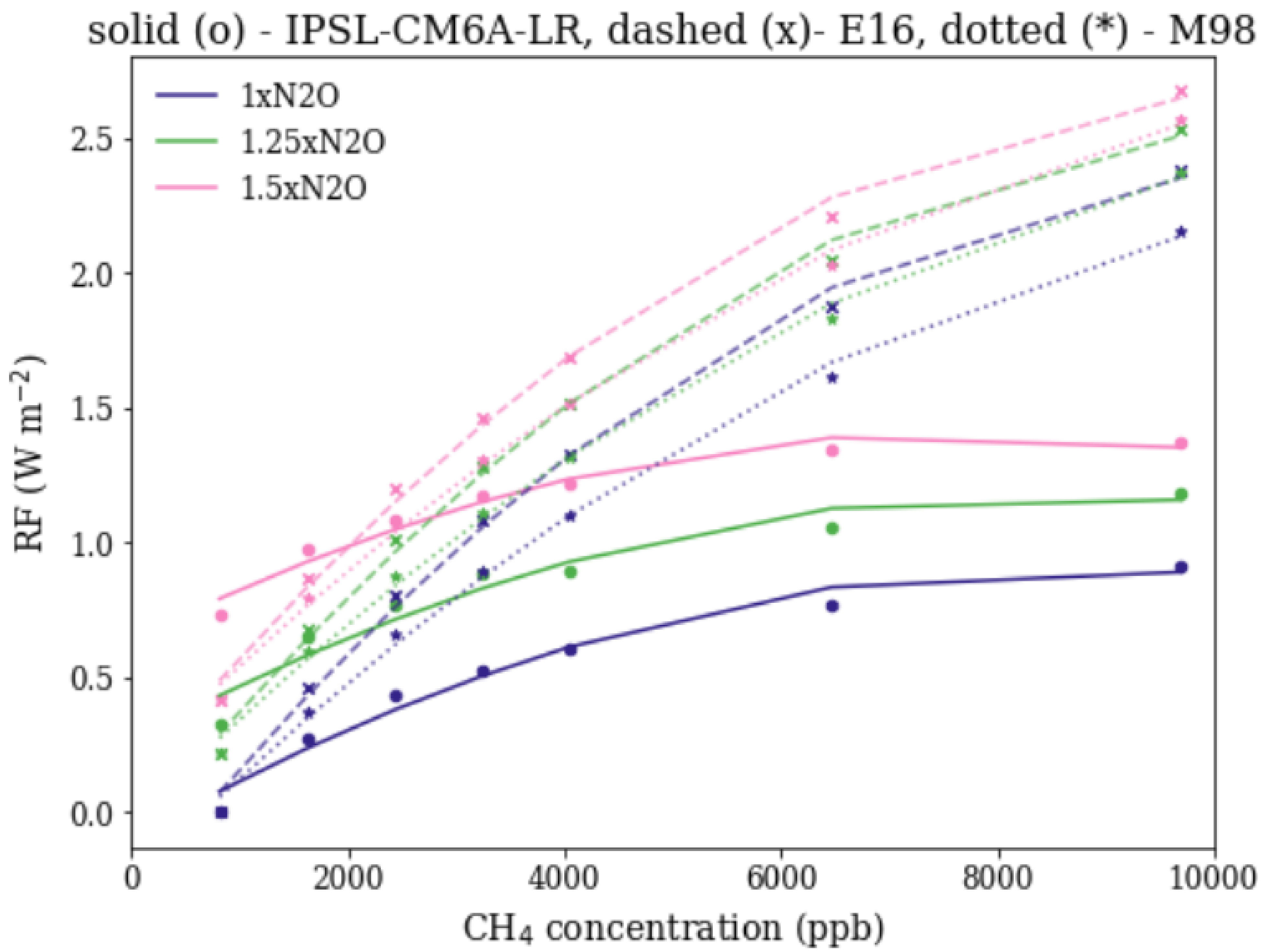
- LMDZ6 now undergoes a systematic "tuning" procedure to match a number of features in the present-day climate. Matching the historical warming trend was not a tuning target.
- Cloud parameters are used to tune LMDZ6, which had a overly impact on the aerosol-cloud ERF

Workaround: restrict range of parameters, add ERF as a tuning target

2/ Too weak CH_4 forcing and too strong N_2O forcing

- RRTM radiative module leads to too weak CH_4 forcing and, conversely, too strong N_2O forcing (w.r.t. expected values, cf. Etminan et al., 2016). Known issue (Robin Hogan) but we did not know!

Workaround: we can input modified (effective) CH_4 and N_2O concentrations to the radiation scheme in order to yield equivalent radiative forcing values. (Melnikova et al., preprint, 2024)



Melnikova, I., Ciais, P., Tanaka, K., Shiogama, H., Tachiiri, K., Yokohata, T., and Boucher, O. Carbon cycle and climate feedback under CO2 and non-CO2 overshoot pathways, *EGUsphere doi:* 10.5194/egusphere-2024-1553, preprint, 2024.

Figure A3. The ERF of CH_4 and N_2O from IPSL-CM6A-LR idealised experiments (points and fitted solid lines) and estimated from M98 (* and fitted dotted lines) and E16 (x and fitted dashed lines) equations, fitted to polynomial regressions for three levels of N_2O concentrations.

$$[CH_4]^{effective} = [CH_4]_{t=0} + a \times ([CH_4]^{actual} - [CH_4]_{t=0})^c \qquad a = 19.447 \quad ; \quad c = 0.496$$

$$[N_2O]^{effective} = [N_2O]_{t=0} + b \times ([N_2O]^{actual} - [N_2O]_{t=0})^d \qquad b = 0.849 \quad ; \quad d = 1.139$$

Thank You

Lurton T., Balkanski Y., Bastrikov V., Bekki S., Bopp L., Braconnot P., Brockmann P., Cadule P., Contoux C., Cozic A., Cugnet D., Dufresne J.-L., Éthé C., Foujols M.-A., Ghattas J., Hauglustaine D., Hu R.-M., Kageyama M., Khodri M., Lebas N., Levavasseur G., Marchand M., Ottlé C., Peylin P., Sima A., Szopa S., Thiéblemont R., Vuichard V. and Boucher, O.: Implementation of the CMIP6 forcing data in the IPSL-CM6A-LR model, *Journal of Advances in Modeling Earth Systems* (JAMES), 18, 2020.