







## Representation of the Terrestrial Carbon Cycle in CMIP6

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Contact: gier@uni-bremen.de EGU Session CL4.9 Vienna, 02.05.2025







International

**ESMValTool** 

development team



18 funded projects

## Earth System Model Evaluation Tool

 Open source tool for fast and easy routine evaluation and analysis of Earth system models including provenance records for all results (traceability and reproducibility)

Universität

Bremen

 Was used in support of production of a subset of figures of the IPCC WGI AR6, part of REF for CMIP7



Eyring et al., GMD, 2016



Righi et al., 2020

**Technical overview** 

Eyring et al., 2020

Large-scale diagnostics

Lauer et al., 2020

**Diagnostics for emergent** 

Weigel et al., 2021



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Website:	Documentation:
<u>www.esmvaltool.org</u>	https://docs.esmvaltool.org/
GitHub:	Zenodo:
tps://github.com/ESMValGroup/	https://zenodo.org/records/1497
ESMValTool	<u>4718</u>
PyPI:	conda-forge:

https://pypi.org/project/ESMValTo ol/ conda-forge: https://anaconda.org/condaforge/esmvaltool

# **Curious about ESMValTool?**

**Cookies** available in

liability for addiction to

cookies or ESMValTool

limited supply. No

after the splinter

meeting. Warning:

are found to exhibit

strange addiction to

coffee, beer, tanks,

plushies, work, etc.

Community members

splinter session during today's lunch break!

JOIN ME!

SPM69: 12:45 – 13:45



Proceed with caution. Image: https://madhav-malhotra.medium.com/come-to-the-dark-side-we-have-cookies-f71507791785

ESMValtool

SIDE



Schematic for carbon cycle representation in ESMs (ORCHIDEE land model used in IPSL-CM6A-LR)

1 GPP	10	P uptake
2 Ra	11	N retrans
3 NPP	12	P retrans
Litter production	13	N minera
5 6 7 Litter decomposition	14	P immobi
⑧ Rh	15	P biologic
In uptake	16	P biocher
Weathering P release		24 N Ie

- 18 N deposition
- Biological N fixation
- 20 P deposition
- 21 N emission
- 22) N fertilization (mineral + manure)
- 23 P fertilization (mineral + manure)

- N retranslocation
  P retranslocation
  N mineralization / immobilization
  P immobilization
  P biological mineralization
  P biochemical mineralization
  N leaching
  - 5 P leaching
  - P desorption / adsorption

Evapotranspiration

Absorbed radiation by canopy















#### **Gross Primary** 140 **Productivity (GPP)** 120 [PgC/yr] 001 **GPP** represents CO<sub>2</sub> uptake through photosynthesis 80 GPP GLASS 1986-2005 FLUXCOM 60 MTE Ncycle MMM CMIP5e non-Ncycle MMM CMIP5e 40 Ncycle MMM CMIP5c non-Ncycle MMM CMIP5c 20 Ncycle MMM CMIP6c non-Ncycle MMM CMIP6c Ncycle MMM CMIP6e non-Ncycle MMM CMIP6e Month

6

12

10

8











**Bettina Gier** 

## Global NBP Mean & Trend



NBP = Net Biome Productivity, Net Flux of Carbon between Atmosphere and Land. Positive = Uptake of Carbon by Land

- CMIP5e Ncycle
- CMIP5e non-Ncycle
- CMIP5c Ncycle
- CMIP5c non-Ncycle
- CMIP6e Ncycle
- CMIP6e non-Ncycle
- CMIP6c Ncycle
- CMIP6c non-Ncycle

CMIP5c Ncycle MMM CMIP5c non-Ncycle MMM CMIP5c Ncycle MMM CMIP5c non-Ncycle MMM CMIP6c Ncycle MMM CMIP6c non-Ncycle MMM CMIP6c Ncycle MMM CMIP6c non-Ncycle MMM OBS





- Good global agreement due to **compensating errors**:
  - NH carbon sink underestimated
  - SH, Tropics carbon sink overestimated
- CMIP5e Ncycle
- < CMIP5e non-Ncycle
- CMIP5c Ncycle
- < CMIP5c non-Ncycle
- CMIP6e Ncycle
- CMIP6e non-Ncycle
- CMIP6c Ncycle
- CMIP6c non-Ncycle
- CMIP5c Ncycle MMM CMIP5c non-Ncycle MMM CMIP5c Ncycle MMM CMIP5c non-Ncycle MMM CMIP6c Ncycle MMM CMIP6c non-Ncycle MMM CMIP6c non-Ncycle MMM OBS











**Bettina Gier** 

02.05.2025

## **Overall Model Performance**



- Normalized relative spacetime Root Mean Square Difference (RMSD) of climatological seasonal cycle centered on ensemble median
- Blue labels denote models with interactive nitrogen cycle

Variable	Main Reference	Alternate Reference
LAI	LAI4g	GLASS
GPP	FLUXCOM	GLASS
NBP	CarboScope	CAMS







## Conclusions

How do **CMIP6** models **compare** to **CMIP5** models in simulating **terrestrial carbon cycle** variables, on the basis of observational and reanalysis data?

- **CMIP6** models as a whole perform **better** than **CMIP5** models in reproducing terrestrial carbon cycle variables, but improvement not consistent between variables
  - Several biases remain, e.g. seasonal cycle of LAI (see paper), allocation of NBP

What **effect** does increased process complexity, through the inclusion of interactively coupled **nitrogen cycle** and the **forcing of carbon emissions** instead of carbon concentrations, have on **model performance**?

- Large improvement in simulating GPP for models with coupled nitrogen cycle, with no adverse effects in other variables
- Similar performance for concentration and emission driven simulations

# Thank you for your attention!

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### **Representation of the terrestrial carbon cycle in CMIP6**

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## **ESMValTool Community Meeting:**

### **SPM69**

Friday 12:30-13:45 **Room 2.96** 



# **Additional Slides**







## Land Carbon Fluxes







Hatching shows agreement on sign of data

Europe generally known as carbon sink for start of 21<sup>st</sup> century, CAMS shows source

Discrepancies attributed to differences in inversion models and atmospheric  $CO_2$ measurements used (Kou-Giesbrecht et al. 2023)

