Project: 1255

Project Title: ESM2025

Principal Investigator: Tatiana Illyna

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1 Outcomes and experiments

WP3/WP6: We analysed the ICON-O-HAMOCC 10km data to investigate the effect of mesoscale eddies in the Southern Ocean on CO_2 fluxes [1]. Our results reveal a heterogeneous influence of eddies depending on the region, driven by regional differences in eddy intensity and the gradients in background properties. The factors controlling CO_2 fluxes within eddies follow the same degree of importance as in background waters, with ΔpCO_2 being the dominant factor. This is driven primarily by changes in dissolved inorganic carbon. Our analysis shows that eddies act as a persistent carbon sink on decadal timescales, while their influence on shorter timescales is more variable and strongly shaped by eddy polarity. Anticyclonic and cyclonic eddies and periphery account for around 10 percent of the Southern Ocean's carbon uptake, with anticyclonic eddies showing the highest carbon uptake per unit area.

The computation time was used to tune HAMOCC in ICON-XPP R2B5/R2B7 configuration. We focused on improving the biological carbon pump by tuning the marine aggregate sinking scheme as well as improving the spatial distribution of the limiting nutrients in the model.

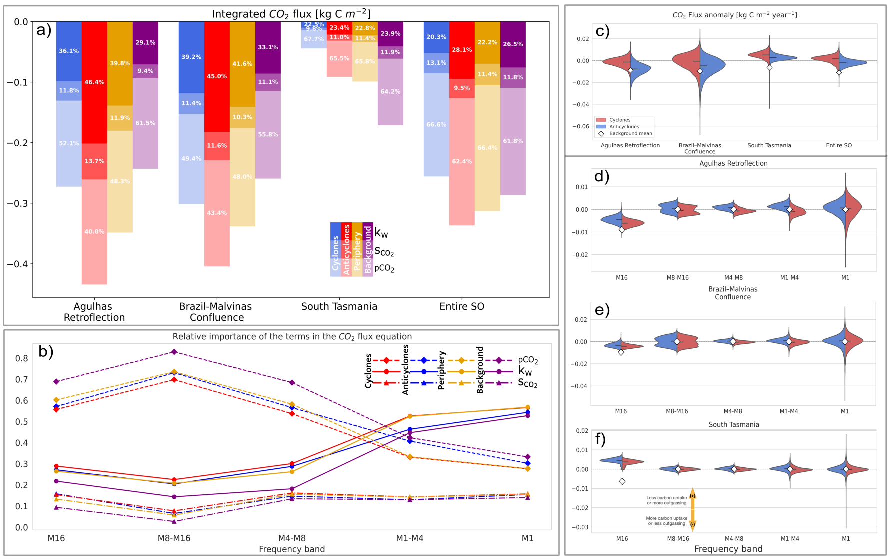

Figure 1: (a) Time-integrated CO2 flux composites for flow regimes across the defined regions, including relative contributions of CO2 flux drivers (solubility, pCO2 and, piston velocity) to the variability. (b) For the Agulhas Retroflection region, though the other regions follow the same pattern, relative contributions of these drivers across different frequency bands (M16: interannual variations above 16 months, M8M16: annual variations between 8 and 16 months, M4-M8: intra-annual variations between 4 and 8 months, M1-M4: intra-annual variations between 1 and 4 months, and M1: submonthly variations). (c) Composite anomalies of total CO2 flux relative to the "background" for anticyclonic and cyclonic eddies. (d–f) Composite anomalies of CO2 flux across different frequency bands in three regions: (d) Agulhas Retroflection, (e) Brazil–Malvinas Confluence, and (f) south of Tasmania.

WP4-WP5: Based on the work with interactive wetland methane emissions [2] presented in last years report, we have taken the next steps towards a fully interactive methane cycle in ICON-ESM. We activated methane as an atmospheric trace gas and coupled this tracer to the atmospheric radiation scheme.

Wetland emissions is only one source of methane, and we implemented other sources necessary for a balanced methane budget by prescribing them in a framework making it easy to — for individual sources — to switch them off, prescribe or — if possible — calculate interactively.

The atmospheric sink of methane is simulated by scaling a prescribed climatology (lat, height, time) from the EMAC-atmospheric chemistry model by a function dependent on actual emissions of reactive carbon (CO, isoprene) and reactive nitrogen (NO). These a emitted by plant metabolism and wildfires, and the latter is additionally produced by lightning, so that we needed to implement a lightning scheme with NO-production. Additionally we added the water produced by decay of methane. Though unimportant in the troposphere, this may contribute a significant part to the stratospheric water content and thus have influence on the radiation budget.

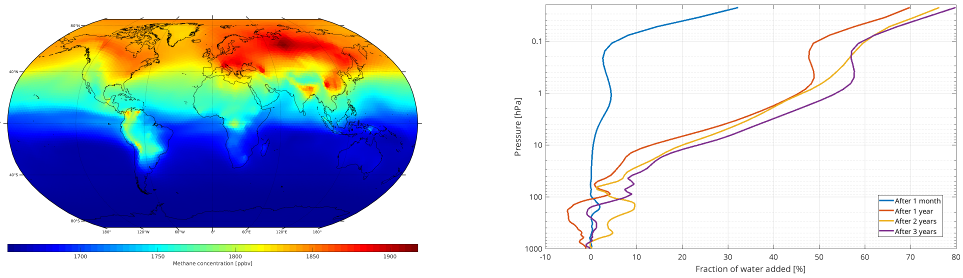

Figure 2: Left: Mid tropospheric (layers 75-85) methane concentration for year 1981 (year 3 of experiment). Right: Fraction of water added at different heights by methane decay after 4 different periods of the experiment.

The DKRZ-resources have been used to develop and run first test with this scheme. Still some calibration is needed, since our atmospheric sink is too low by $\approx 20\%$.

WP10: In WP10 we advanced with the implementation of a new parameterization scheme for the representation of anthropogenic land cover change in JSBACH4 that promotes a more wholistic representation of carbon relocation. The current default scheme ("maps scheme") relies on maps of annual land-cover states as forcing and determines carbon relocation from the year-to-year differences in these maps. Direct information on transitions between land-cover states is missing, and e.g., carbon relocation from cyclic conversions is not taken into account. In contrast, the new scheme ("transition scheme") is based on annual land-cover transition rates as forcing data, and these transition rates determine carbon relocation, including cyclic conversions. The implementation of the new scheme for anthropogenic land-cover change in JSBACH4 is based on the transition scheme in JSBACH3 but applies some updates, such as the omission of a rule that prefers pasture to expand into grassland over forest.

In addition to the implementation of the transition scheme, simulations with the new scheme also require adequate forcing data. Here, we developed the pre-processing procedure of transition rates from the updated LUH3 V1 dataset (Land-use Harmonization project) that are available via input4MIPs for the use in CMIP7 simulation. The pre-processing included aggregation of LUH3 land-cover classes to three broader land-cover states (natural, crop, pasture) as well as conversion and remapping to match the forcing requirements of JSBACH4.

DKRZ resources have been used for test simulation with JSBACH4 stand-alone as part of the implementation process and for the development of the pre-processing routine for the required forcing data.

2 Publications and Presentations

References

[1] Mariana Salinas-Matus, Nuno Serra, Fatemeh Chegini, and Tatiana Ilyina. Mesoscale eddies heterogeneously modulate co 2 fluxes in eddy-rich regions of the southern ocean. *EGUsphere*, 2025:1–20, 2025.

[2] **S. Wilkenskjeld**, T. Kleinen, T. Stacke, and V. Brovkin. Natural wetland methane emissions simulated by icon-xpp. *Biogeoscience preprints*, 2025.