APO-MIP, CATRINE, and diffusion

November 3, 2025

Outline and co-authors

APO-MIP

The Atmospheric Potential Oxygen forward Model Intercomparison Project (APO-MIP1): evaluating simulated atmospheric transport of air-sea gas exchange tracers and APO flux products

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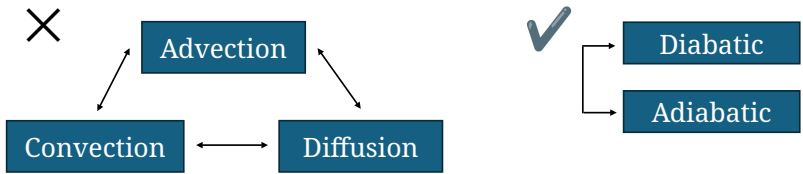
CATRINE WP7

(Frédéric Chevallier, Anna Agustí-Panareda, Maarten Krol, Wouter Peters and Stefan Versick)

CATRINE
Carbon Atmospheric Tracer Research to Improve Numerics and Evaluation

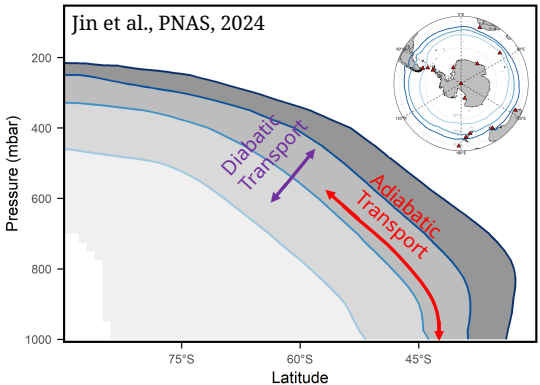
Test with ERA 5 diffusion

1. Diagnosing **transport biases** from a **thermodynamic perspective (moist isentrope)**.



2. Using **tracer observations** to evaluate both **tracer transport models** and **flux products**.

Compensating Errors



- The **mixing rate** of diabatic transport is crucial for determining large-scale tracer distribution
- Diabatic transport is considered a diffusive system, inferred from tracer gradients across isentropes.

Atmospheric Transport Models

- 3-D tracer atmospheric field
- 2-D surface flux field
- 3-D q T P for calculating θ_e ($M_{\theta e}$)
- Daily to sub-daily

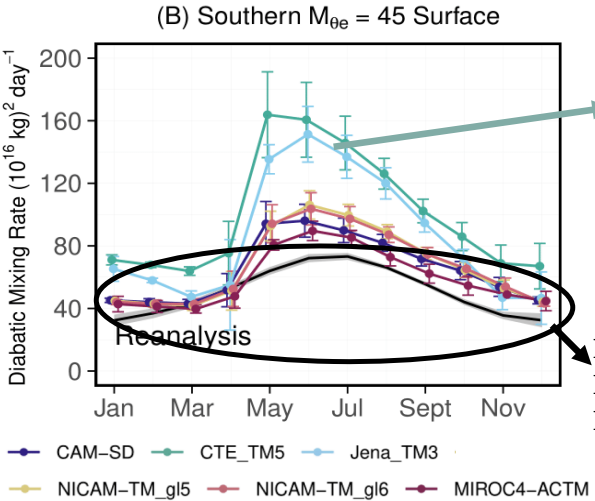
Meteorological reanalysis products

Moist static energy (MSE):

$$MSE = C_p \cdot T + g \cdot z + L_v \cdot q$$

$$MSE \cong C_p \cdot \theta_e$$

Diabatic Mixing Rate ($kg^2\ day^{-1}$)



TM3 and TM5 significantly biased high

Reanalysis really consistent: ERA5, JRA-55, JRA-3Q, MERRA-2

TM3 vs TM5

	TM5	TM3
advection	slopes	slopes
diffusion	Louis (1979)	Louis (1979)
convection	ERA5	Tiedke
resolution	5x4x19	1x1x25
meteo	ERA5	NCEP

both have significantly lower vertical resolution than other participants (> 39)

Conclusions

1. APO-MIP diabatic transport overestimated in TM5 (and TM3)
    1. Vertical resolution? TBD
    2. Problem?

CATRINE development of inter-comparison protocol

1. Prescribed emissions and initial conditions:
   1. ^{222}Rn
   2. SF_6
   3. CO_2
2. simulations cover 2022 to 2024
3. focus on total column transport (CO2MVS)

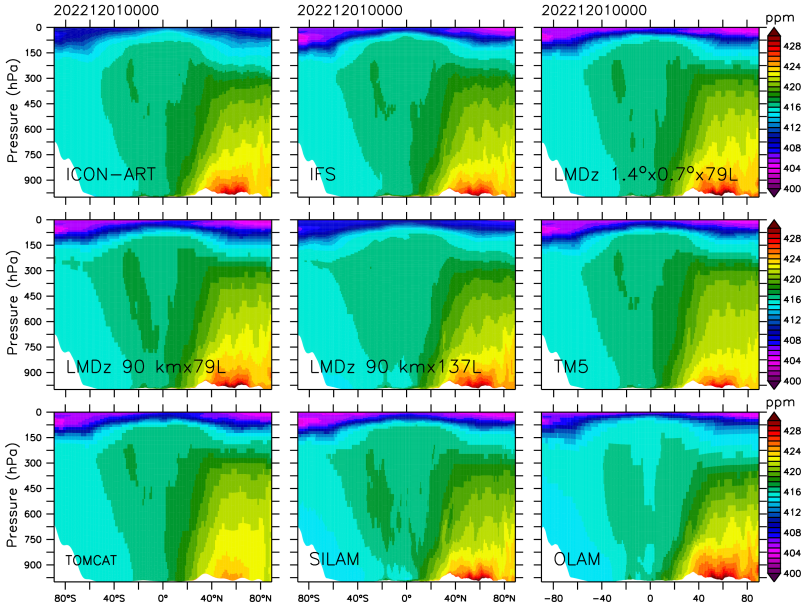
Funded by the European Union

Current participant list

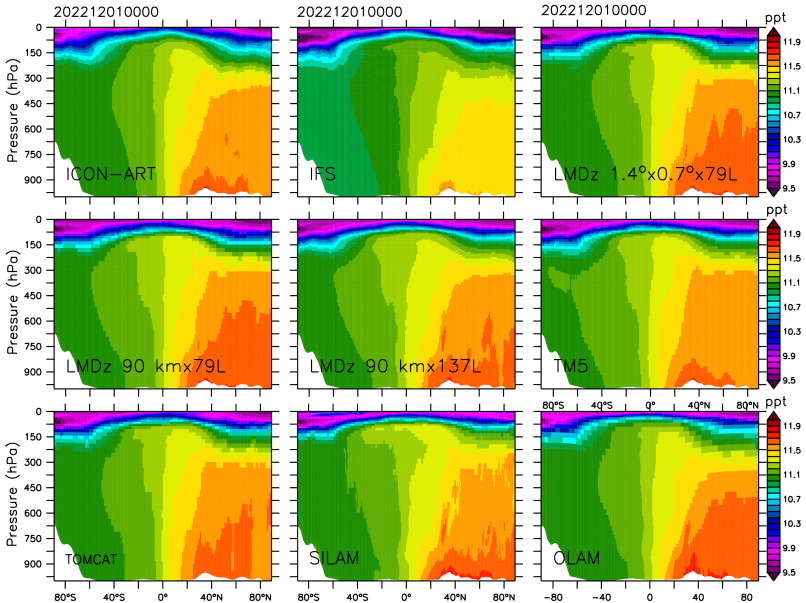
CATRINE
Carbon Atmospheric Tracer Research to Improve Numerics and Evaluation

Model	Institute	Online/ Offline	horizontal	vertical	Driving meteor.	Contact person
ICON-ART	KIT	Online	79 km	120 levels	ERA5	S. Versick
IFS	ECMWF	Online	28 km	137 levels	ERA5	A. Agustí-Panareda
LMDZ-degrees	LSCE	Offline	1.4° × 0.7°	79 levels	ERA5 (nudging)	F. Chevallier and A. Martinez
LMDZ-km	LSCE	Offline	90 km	79 levels	ERA5 (nudging)	F. Chevallier and A. Martinez
LMDZ-era5	LSCE	Offline LMDZ advection with IFS physics	90 km	137 levels	ERA5 (direct use)	F. Chevallier
SILAM	FMI	Offline	0.5° × 0.5°	78 levels	ERA5	R. Kouznetsov
TM5	WU	Offline	1° × 1°	68 levels	ERA5	J. Hooghiem
TOMCAT	Leeds Univ.	Offline	1.125° × 1.125°	60 levels	ERA5	C. Wilson

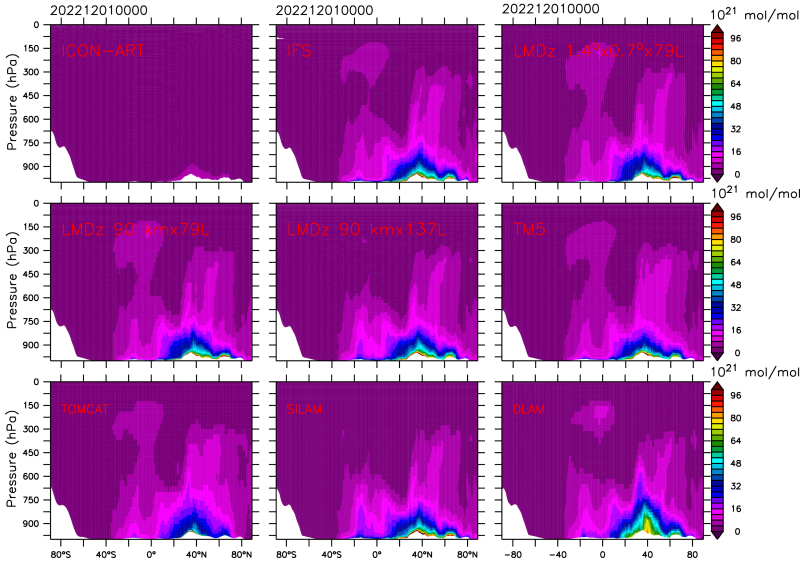
CO_2 distribution



SF_6 distribution



^{222}Rn distribution



Vertical profiles LEF tower

Funded by the European Union

CATRINE Carbon Atmospheric Tracer Research to Improve Numerics and Evaluation

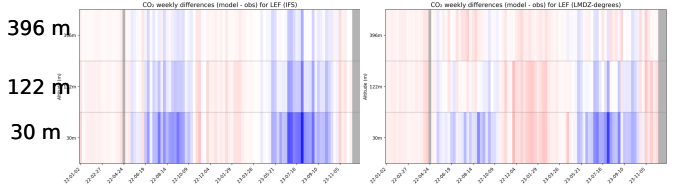
IFS

LMDZ

396 m

122 m

30 m

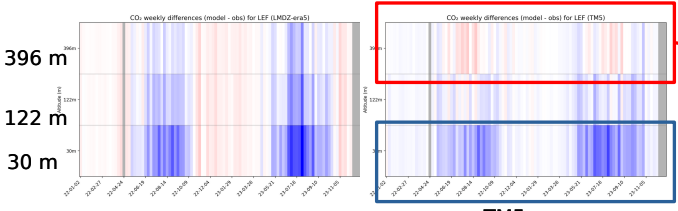


ObsPack GV+ 10.1
co2_lef_tower-insitu_1_allvalid-30magl.nc
co2_lef_tower-insitu_1_allvalid-122magl.nc
co2_lef_tower-insitu_1_allvalid-396magl.nc

396 m

122 m

30 m



Model biased high

Model biased low

LMDZ (era5)

TM5

Conclusions

1. APO-MIP: diabatic transport overestimated in TM5 (and TM3)
    1. Vertical resolution? TBD
    2. Problem?
2. CATRINE: (ongoing) TM5 within ensemble of models
    1. but also indication of strong upward mass flux

Test with TM5 diffusion

Compute diffusive mass flux through top (`dkg` in `diffusion.F90`) using

1. Heat diffusivity K from TM5
2. Heat diffusivity K from ERA5

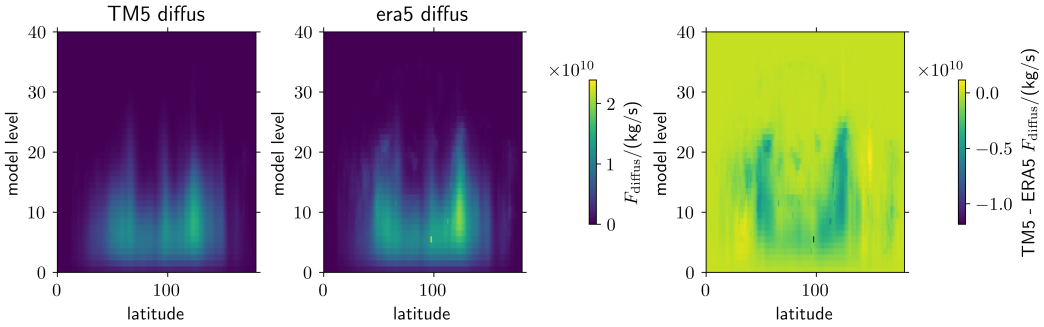
1. Are there significant differences?
2. Computational benefit? (yes; but small compared to other operators)
3. Improved?

First test with CATRINE protocol

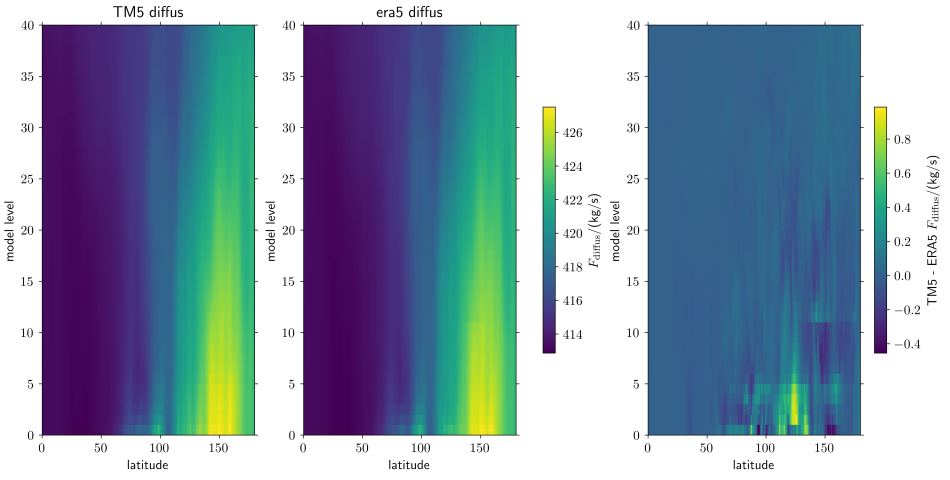
1. 1x1 x 68 layers tm5 diffusion
2. 1x1 x 137 layers tm5 diffusion
3. 1x1 x 137 layers era5 diffusion

Result: dkg

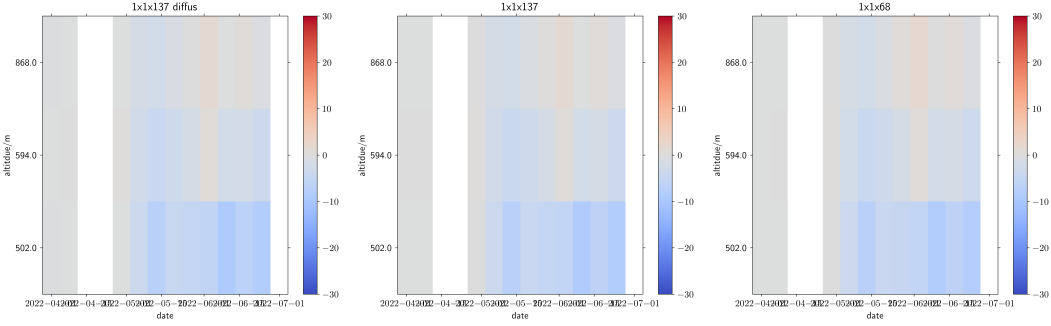
Upward diffusive mass flux in kg/s through



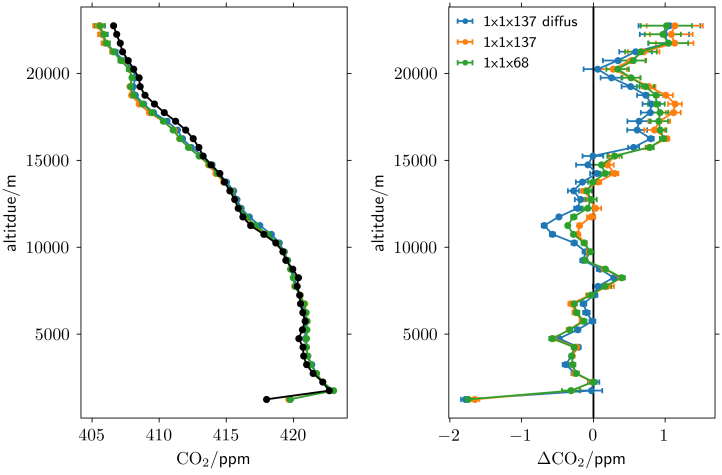
Effect on CO_2tracer distribution NOTA BENE: wrong label at the colorbar



LEF tower no noticeable difference yet



AirCore Jan-Jun 2022; 500 m bins



Conclusions

1. APO-MIP: diabatic transport overestimated in TM5 (and TM3)
2. CATRINE: (ongoing) TM5 within ensemble of models
3. TM5 diffusion vs ERA5 diffusion
    1. Significant differences? Yes
    2. Improved? (no conclusion)
        1. Emissions error vs transport error (Moist isentropic mass coordinate!)
    3. Computational benefit? Yes

Outlook

1. Apply moist isentropic mass coordinate
2. Participate in the SF_6 MIP by Jacobson et al.
   1. N-S gradient
   2. Atom data
3. Convection?

Thanks to Yuming Jin, Frédéric Chevallier, and Anna Agustí-Panareda (and all co-authors of the APO-MIP and CATRINE) for sharing their slides

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