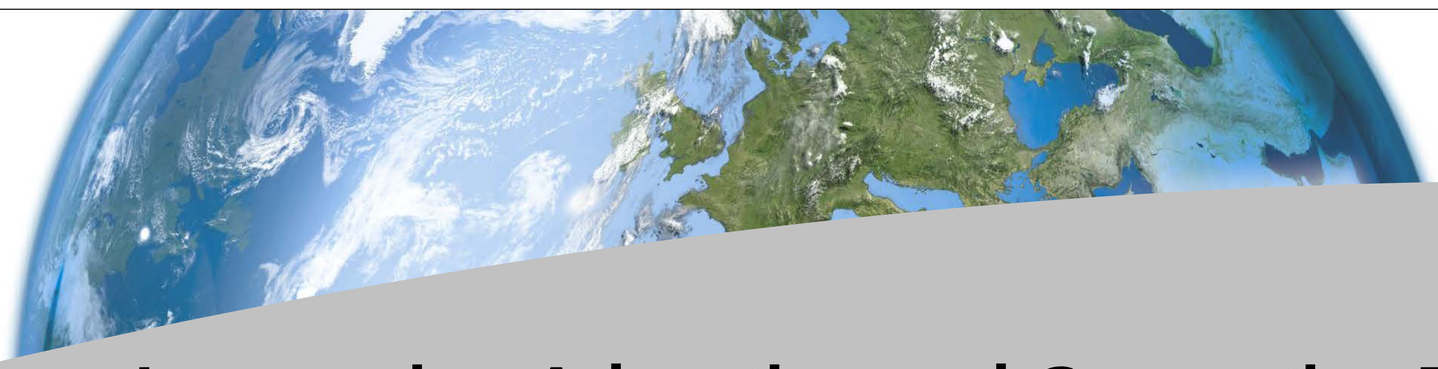


Lagrangian Advective and Convective Transport of Passive Tracers Within the EMAC Chemistry Climate Model

S. Brinkop and P. Jöckel

We introduce the extended and improved Lagrangian (LG) advection scheme **ATTILA** (**A**tmospheric **T**racer **T**ransport in a **LA**grangian model, *Reithmeier and Sausen (2002)*), which was parallelised, modularised and rewritten as a submodel for the **EMAC** (ECHAM/MESSy Atmospheric Chemistry) model (*Jöckel et al., 2010*).

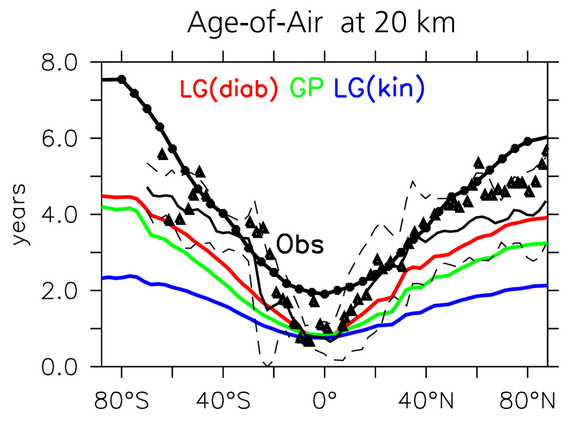
ATTILA is complemented by a new infrastructure (pseudo random number generators, parallelisation, transformation and transposition methods), **new physical** (*air parcel mixing, Lagrangian convection, diabatic vertical velocity*) and new diagnostic submodels.

Model Simulations

3 transient simulations from 1950 – 2010 in T42L47MA resolution with EMAC/ATTILA similar to CCMI free running hind-cast simulations:

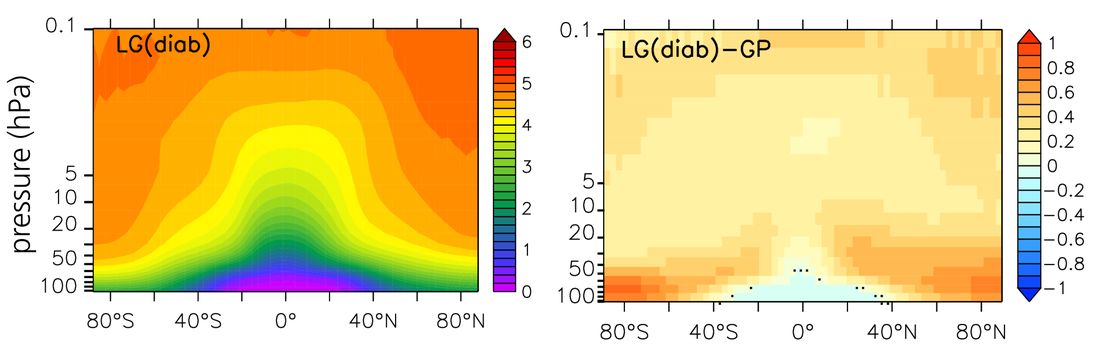
1. Grid point **GP**
2. Lagrangian with diabatic vertical velocity **LG(diab)**
3. Lagrangian with kinematic vertical velocity **LG(kin)**

Simulation of Age-of-Air



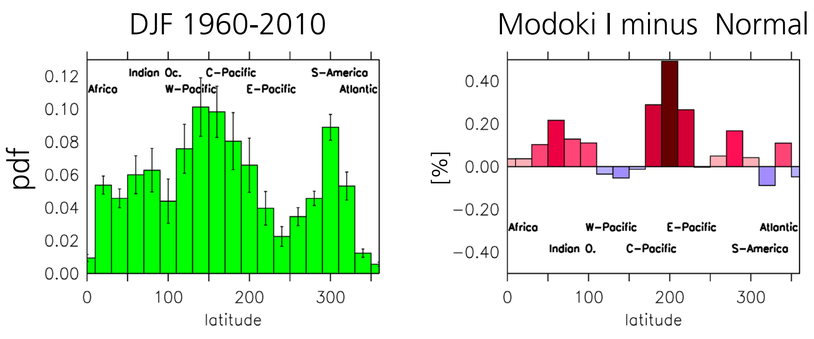
- **Zonal mean AoA at 20 km height from SF6 AoA tracer**
- red: LG(diab),
- green: GP,
- blue: LG(kin), mean over the years 2000-2010.

- **Black line with circles**: MIPAS data; mean over the years 2003, 2007, 2008, 2009, 2010, 2011 from *Stiller et al. (2012), Haenel et al. (2015)*
- **Triangles:** AoA from SF6 at 20 km, from *Waugh and Hall (2002)*
- **Black dashed thin lines**: minimum and maximum AoA, respectively; thin black line: mean AoA from CO_2 at 20 km from *Andrews et al., (2001)* and *Scheele et al. (2005)*



LG(diab) simulation shows older air throughout the stratosphere, most pronounced at high latitudes between 100 and 50 hPa compared to the GP simulation. → LG(diab) less diffusive

Lagrangian Convection Example: Histogram Composites of Deep Updrafts During DJF (1960-2010) in the Tropics

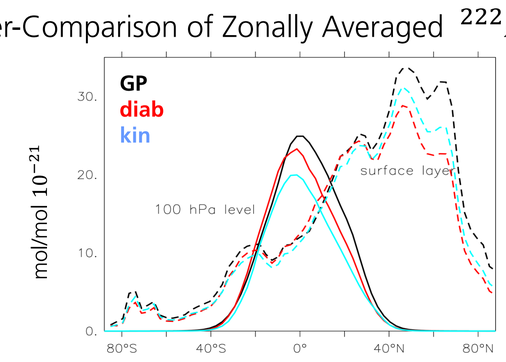


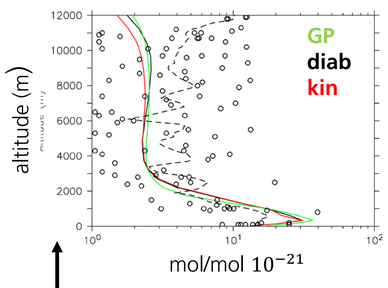
- **Composites of histograms for DJF for LG parcels that jump vertically over more than 10 model levels**

- **Normal years** (without El Niño or La Niña, 21 events)
- **El Niño years** (11 events)
- **El Niño Modoki I years** (central pacific EL Niño, 6 events)
- **La Niña years** (13 events)
- Note the shift and increase in deep convective updrafts during EL Niño and La Niña conditions.

Evaluation with $^{222}Radon$

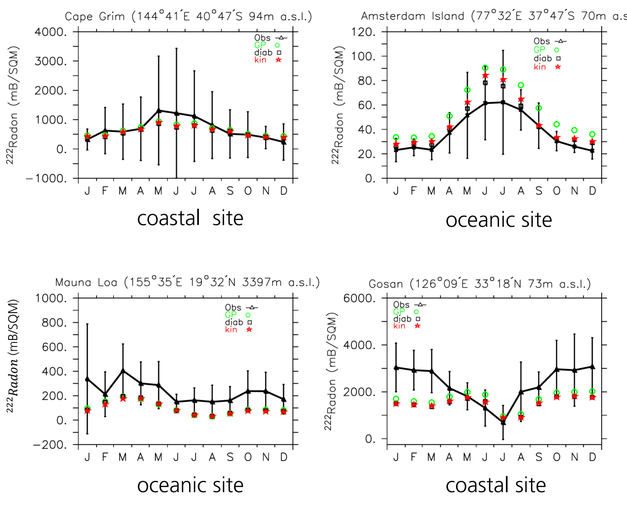
Inter-Comparison of Zonally Averaged $^{222}Radon$ Distributions





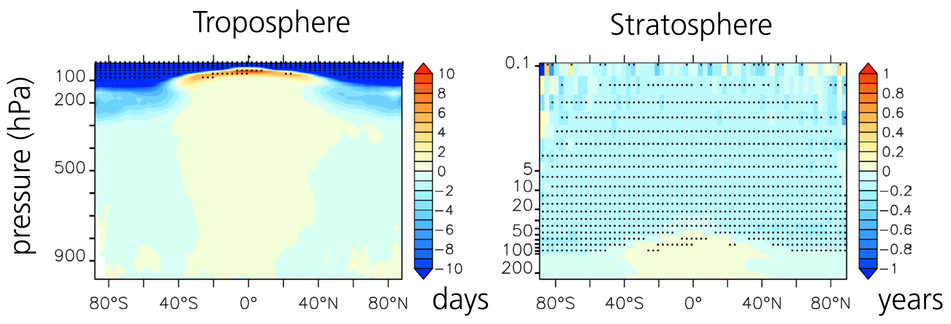
Vertical profiles of $^{222}Radon$ during the MOFFET campaign in California (*Kritz et al., 1998*, data from June to August 1994)

Annual Cycle of $^{222}Radon$ in the Surface Layer



Evaluation of the annual cycle of $^{222}Radon$ against in-situ measurements (*Zhang et al., 2008*). A continental influence can be seen, when $^{222}Radon$ exceeds 1000 mBeq/m^2.

Inter-Parcel Mixing: Influence on Age-of-Air in LG(diab)

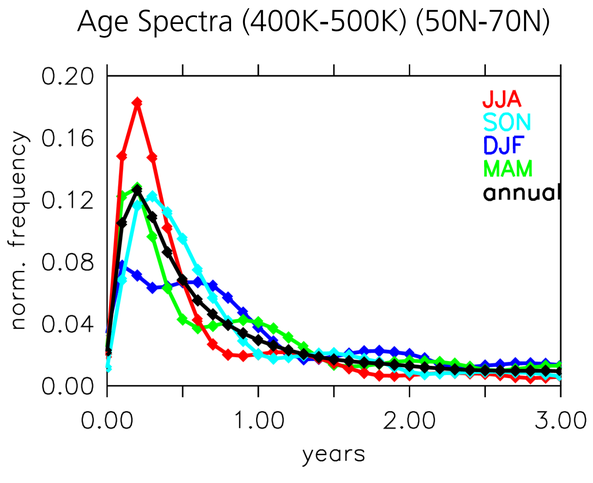


with minus *without* inter-parcel mixing

Inter-comparison of a tracer *with* and *without* inter-parcel mixing of simulation LG(diab).
Stippled area is statistically significant (t-test, 99%)

- Inter-parcel mixing makes air at the tropical tropopause older by ~10 days
- Inter-parcel mixing makes stratospheric air younger by ~3 months

Seasonal Spectra of Age-of-Air from LG(diab) Simulation



- Age spectrum from LG clocks
- LG clocks start with time zero at the tropopause
- JJA age spectrum shows the highest frequency for young air → relatively high amount of young air
- DJF shows the lowest frequency of young air compared to the other seasons
- DJF has the widest age distribution → less young air is in-mixed

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