Simulation of Age-of-Air with the Global Climate Model EMAC-ATTILA

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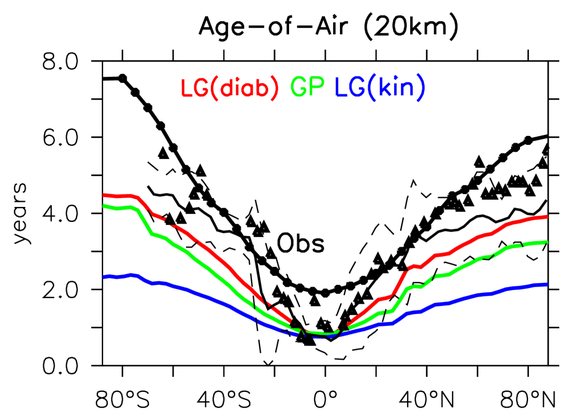
Age-of-Air is a measure of the **speed of the stratospheric circulation**. It is the transit time of a stratospheric air parcel since entering the stratosphere. We applied two ways to calculate Age-of-Air: a.) from parcel clocks and b.) from an inert synthetic tracer (SF6_AoA), nudged by Newtonian relaxation towards a linearly increasing mixing ratio in the lowest model layer.

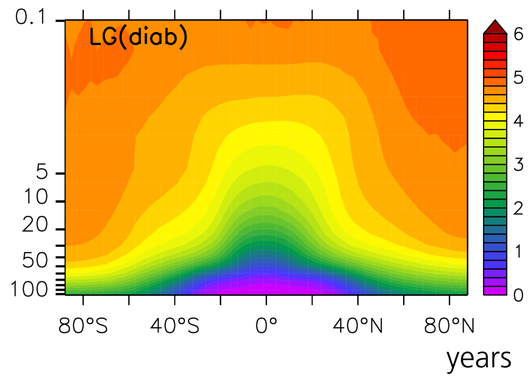
We used the Lagrangian advection scheme **ATTILA** (**A**tmospheric **T**racer **T**ransport in a **LA**grangian model, Reithmeier and Sausen, 2002, Brinkop and Jöckel, 2019), a submodel of **EMAC** (ECHAM/MESSy Atmospheric Chemistry Climate model, Jöckel et al., 2016) with a diabatic vertical velocity scheme and a Lagrangian convection scheme in a transient model simulation from 1950 – 2010 in T42L47MA resolution and with prescribed sea-surface temperatures. The QBO was nudged.

Age-of-Air Compared to Observations



- **Zonal mean Age-of-Air at 20 km height from SF6-AoA tracer over the years 2000-2010.**
- red: LG(diab)=Lagrangian simulation
- green: GP=grid-point simulation
- blue: LG(kin)=Lagrangian simulation
- **MIPAS data black line with circles**: 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, respective, thin black line: mean AoA from CO_2 at 20 km from Andrews et al., (2001).

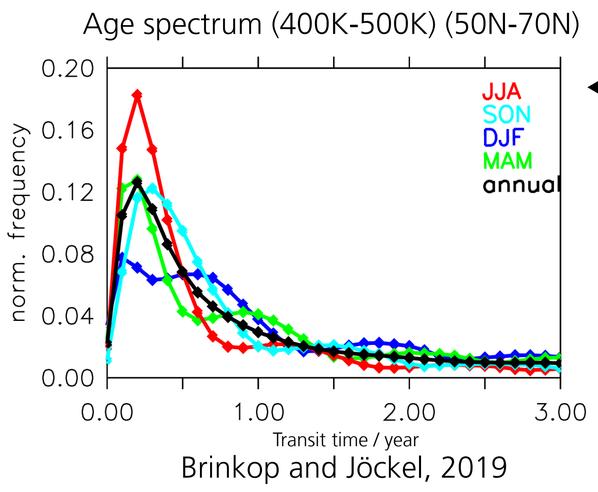
Zonal Mean Age-of-Air



Mean Age-of-Air in (years) from 1960-2010.

A mean Age-of-Air distribution (from SF6-AoA tracer) shows the (zonal mean) Brewer-Dobson circulation with young air entering the statosphere in the tropics and older air descending near the poles. (see also the Figure below.)

Seasonal Age-of-Air Spectra

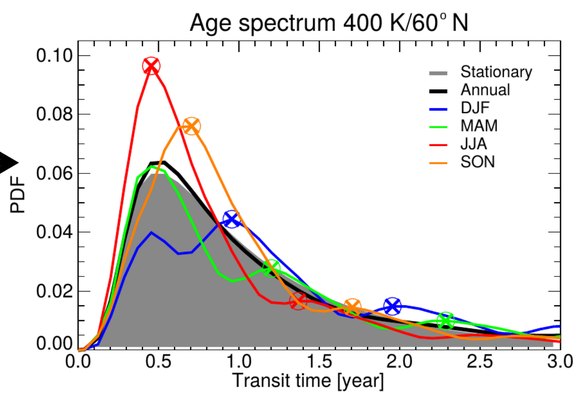


Brinkop and Jöckel, 2019

Simulated Age-of-Air spectra from

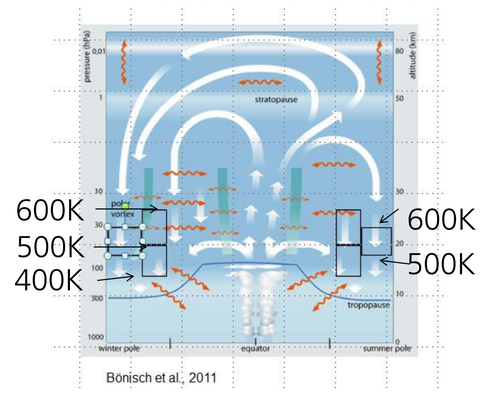
- **(left) clocks on the Lagrangian air parcels simulated with ATTILA**
- **(right) pulse tracer from a simulation with CLaMS**

- JJA age spectrum: highest frequency for young air → relatively high amount of young air
- DJF age spectrum: lowest frequency of young air, but the distribution is the broadest → less young air is mixed in



Plöger and Birner, 2016

Brewer-Dobson-Circulation



Latitude and isentrope zonal bands, for which the **mean annual age spectra have been** estimated

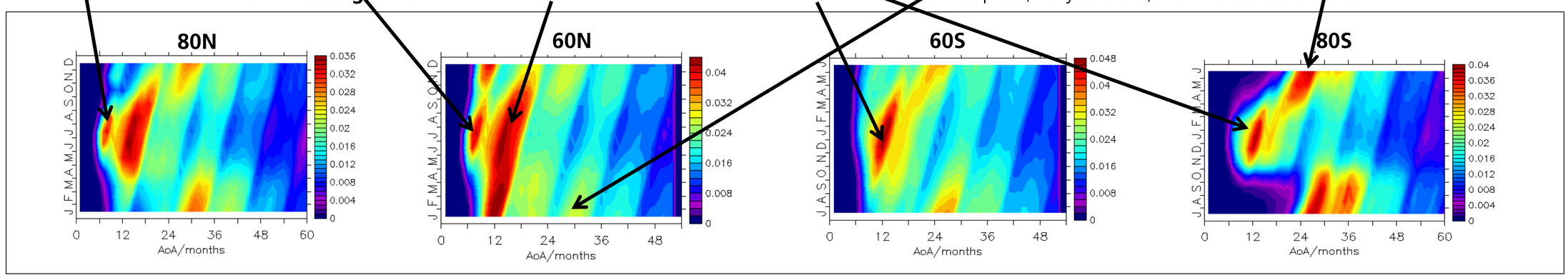
Mean Annual Cycle of Age Spectra – Origin of Air Masses Dependent on Age

0.5-year old air masses: They come directly from the tropics and there from levels between the tropopause and 500 K.

1- year old air masses: 0.5 years before, the air mass was in the same isentropic level but mainly in the tropics. One year ago the air mass was in the tropics, too, but below 500K.

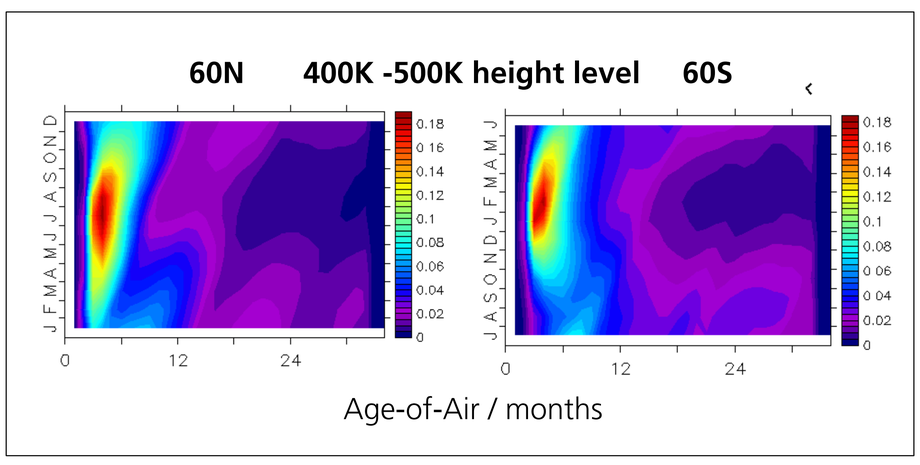
2.5-year old air masses: They are transported downwards from a broad range of levels between 400K and 1000K. Via the Brewer-Dobson circulation they came originally from the mid-latitudes (2 years old) from the (same) 500K-600K level, and before from the tropics (1.5 years old) from levels below 500 K.

500K-600K height level



In **the polar and mid-latitudes** the annual cycle of the Age-of-Air spectrum is **different** in the **500K-600K height level,**

However, the annual cycle of the Age-of-Air spectrum is **similar in mid-latitudes at the 400K-500K** height level showing a maximum of young air masses in the respective summer months →



References:
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Jöckel, P.. et al..: Earth System Chemistry integrated Modelling (ESCiMo) with the Modular Earth Submodel System (MESSy) version 2.51, Geoscientific Model Development, 9, 1153-1200, doi: 10.5194/gmd-9-1153-2016.
Ploeger, F., T. Birner, Characteristics of lower stratospheric transport as inferred from the age of air spectrum, Atmos. Chem. Phys., 16, 10195-10213, doi:10.5194/acp-16-10195-2016, 2016.
Reithmeier, C. and Sausen, R.: ATTILA: Atmospheric Tracer Transport in a Lagrangian Model, Tellus, 54B , 278-299, 2002.

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