A new approach for a tracer budget of the extratropical lower stratosphere using simultaneous measurements of SF_6 and CO_2

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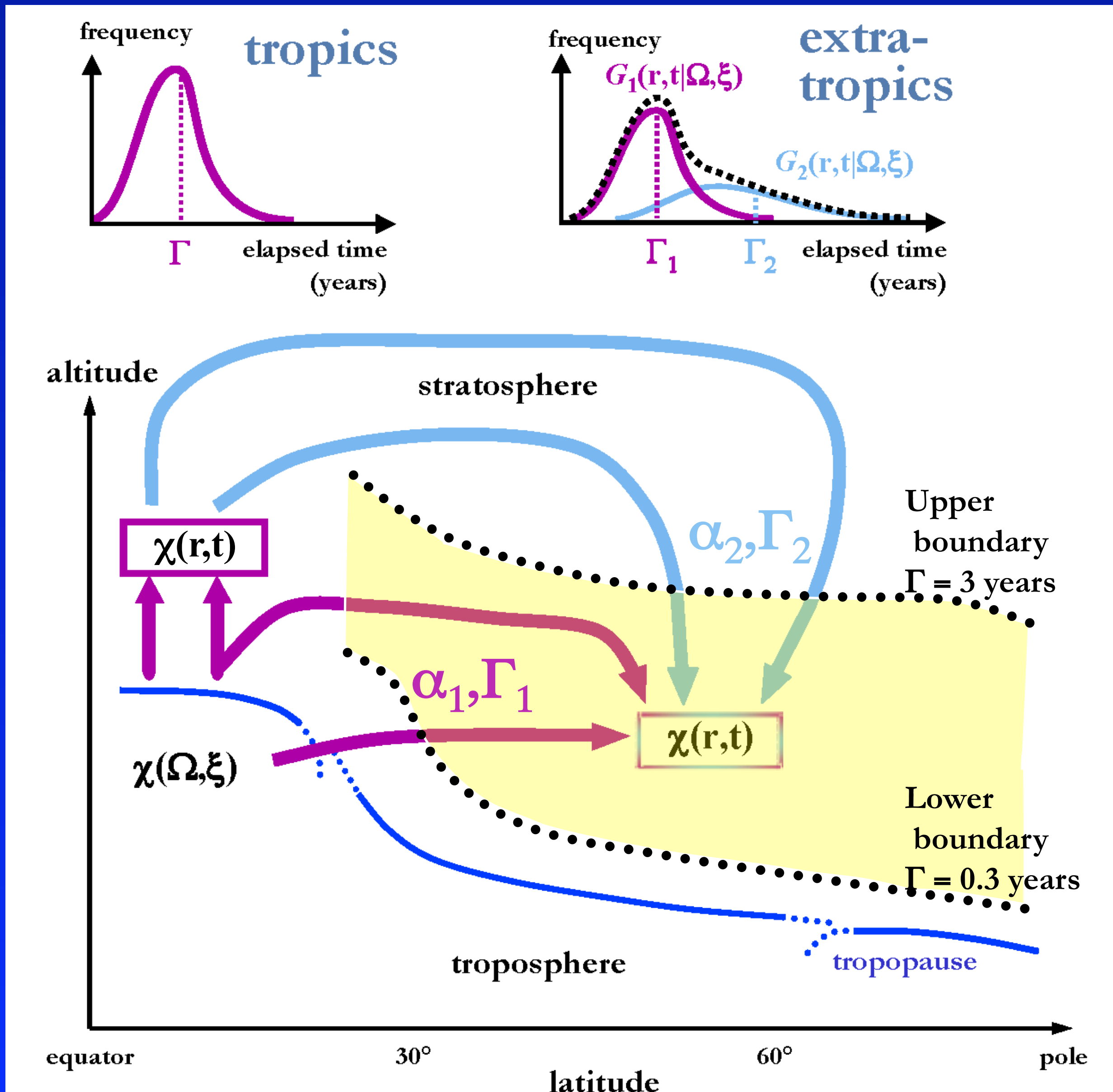
Research Questions

The UTLS is a key region for understanding and predicting future chemical-climate change. [e.g., Forster and Shine, 1997]

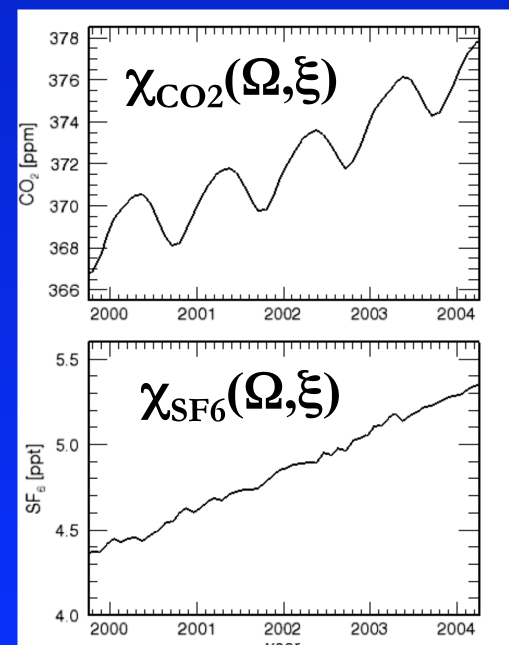
=> Estimate the chemical impact of the transported species on the composition of the lowermost stratosphere (LMS).

=> New approach:
Trace gas budget for the LMS including mean transit times

Trace Gas Budget - Concept



Tropospheric time series of SF_6 and CO_2 in the tropics



Trace Gas Budget - Method

Basic equation for tracer budget calculation

$$\chi(\mathbf{r},\mathbf{t}) = \alpha_1 \int_0^\infty \chi(\Omega,\xi)\cdot G_1(\Gamma_1,\xi)\,d\xi + \alpha_2 \int_0^\infty \chi(\Omega,\xi)\cdot G_2(\Gamma_2,\xi)\,d\xi$$

Subject to the constraints

$$\alpha_1 + \alpha_2 = 1 \quad \text{and} \quad \int_0^\infty G_1\,d\xi = \int_0^\infty G_2\,d\xi = 1$$

Mass conservation

Standardization

Open parameters of the equations system for SF_6 and CO_2

Tropospheric Fraction: $\alpha_1 = ?$
and Mean Transit Time: $\Gamma_1 = ?$

Stratospheric Fraction: $\alpha_2 = 1 - \alpha_1$
and Mean Transit Time: $\Gamma_2 = 3$ years

Trace Gas Budget - Example

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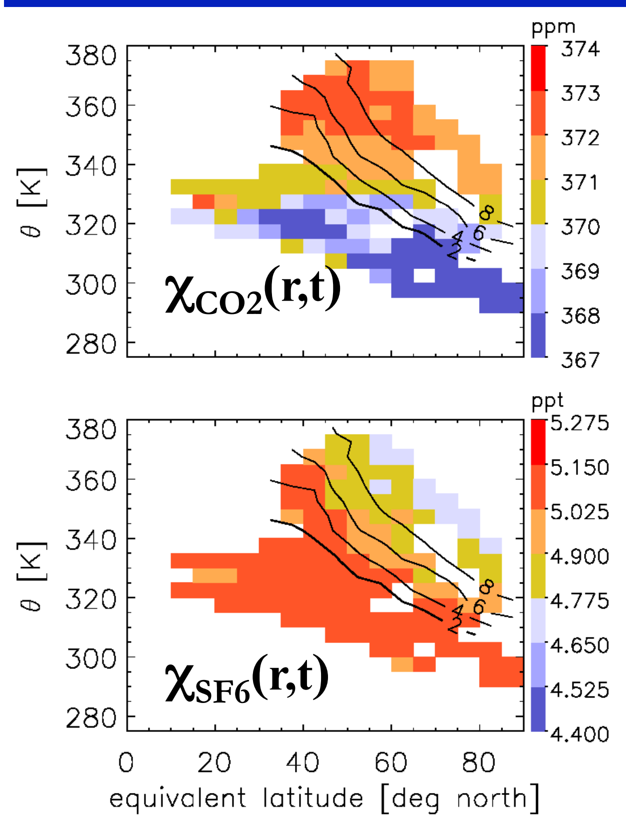
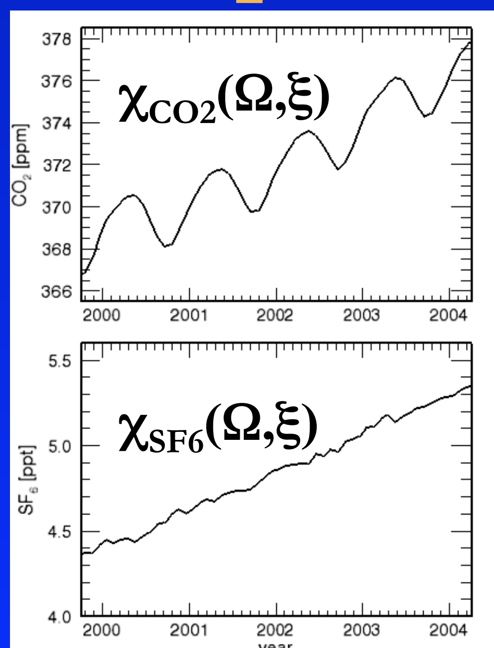
Basic equation for tracer budget

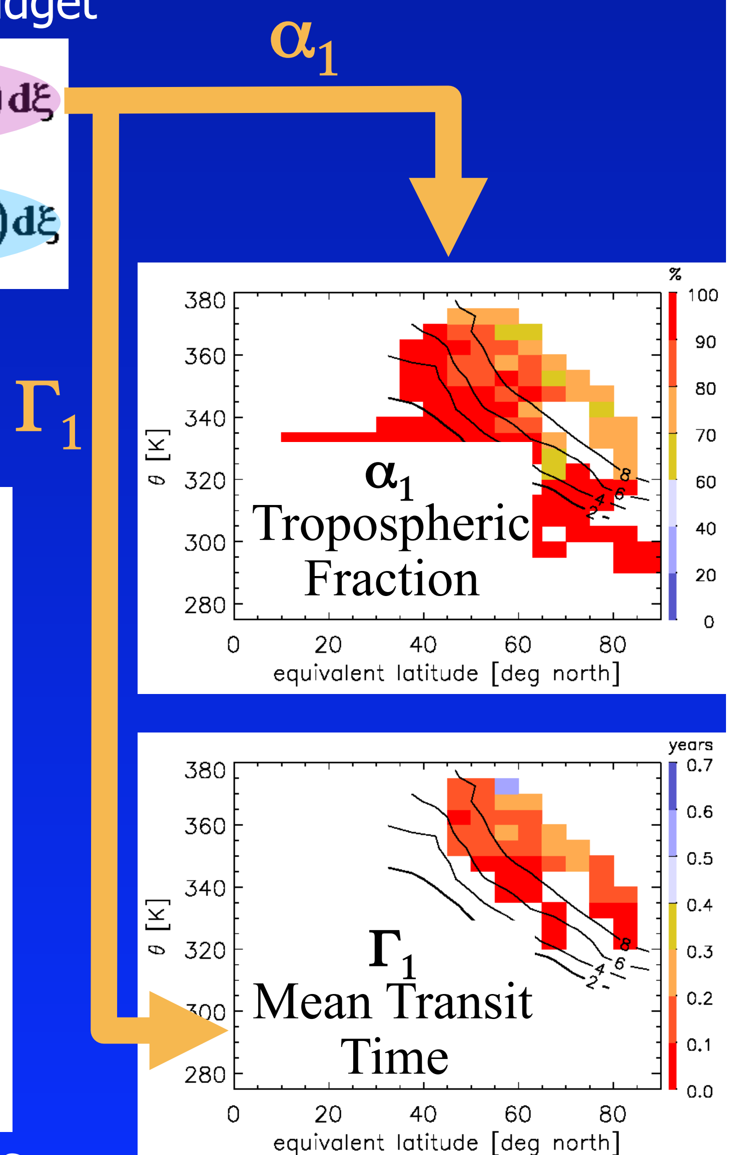
$$\chi(\mathbf{r},\mathbf{t}) = \alpha_1 \int_0^\infty \chi(\Omega,\xi)\cdot G_1(\Gamma_1,\xi)\,d\xi + \alpha_2 \int_0^\infty \chi(\Omega,\xi)\cdot G_2(\Gamma_2,\xi)\,d\xi$$



In-situ measurements of SF_6 and CO_2 in the LMS

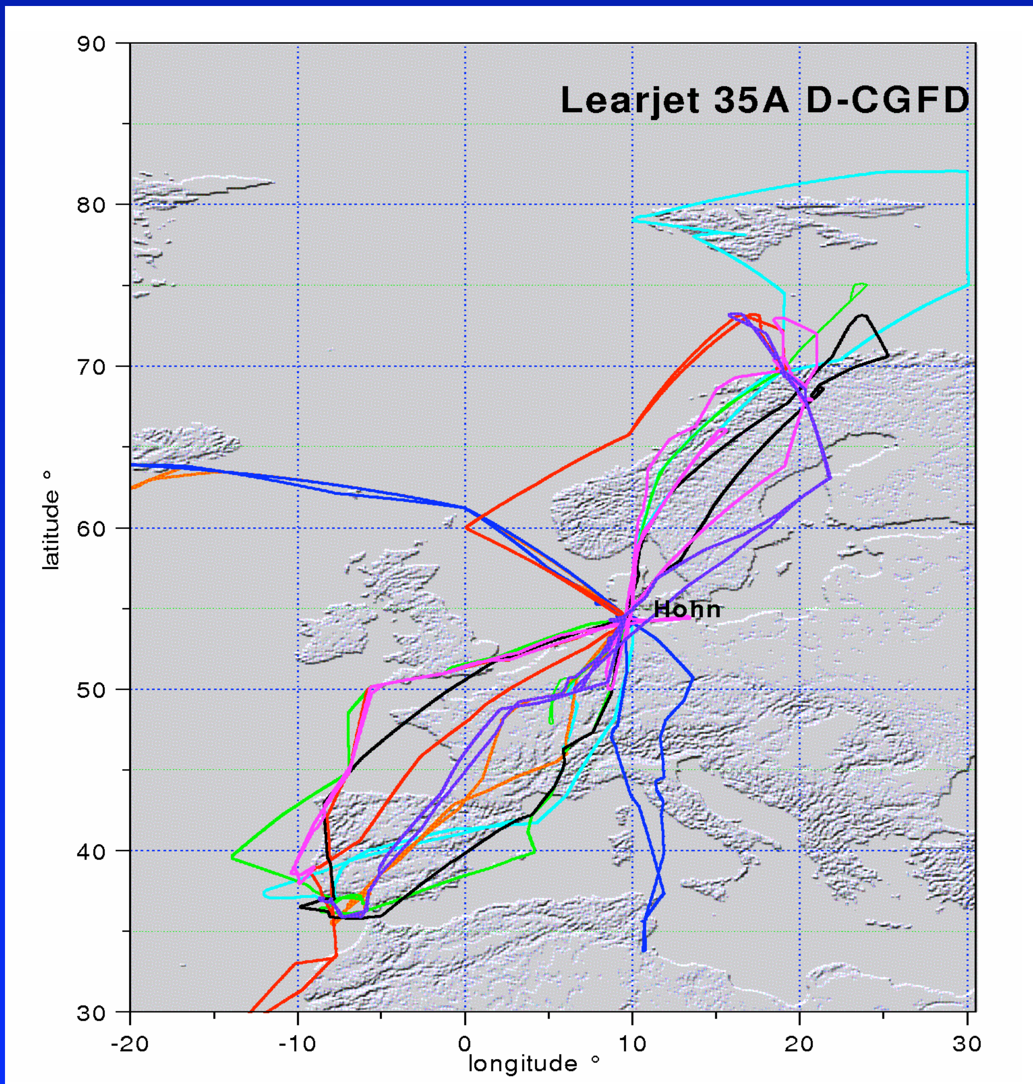


Tropospheric time series of SF_6 and CO_2 in the tropics



SPURT Data Set – UT/LMS Coverage

SPURenstofftransport in der Tropopausenregion



8 campaigns

36 flights

during a time period of two years (2001-2003)

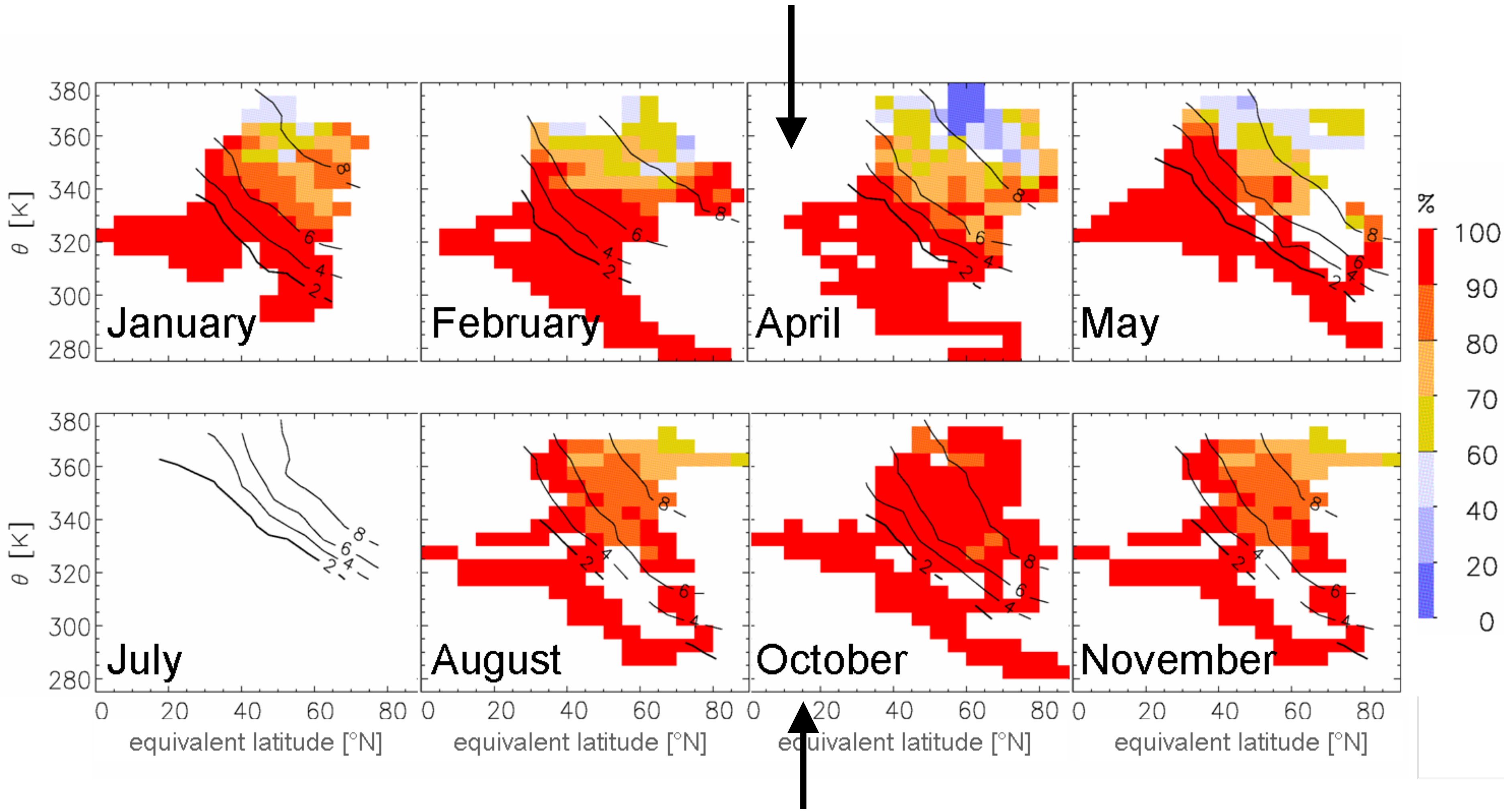
Each season probed twice

SPURT 1 to 8 flight tracks

- Spurt 1: Faro - Kiruna
- Spurt 2: Casablanca - Gran Canaria - Lissabon - Tromsö
- Spurt 3: Jerez - Tromsö
- Spurt 4: Monastir - Keflavik
- Spurt 5: Sevilla - Keflavik
- Spurt 6: Faro - Tromsö - Longyearbyen
- Spurt 7: Kiruna - Lissabon
- Spurt 8: Faro - Tromsö

Trace gas budget – Tropospheric fraction α_1

Minimum tropospheric contribution



Maximum tropospheric contribution

Seasonality of N_2O in the LMS

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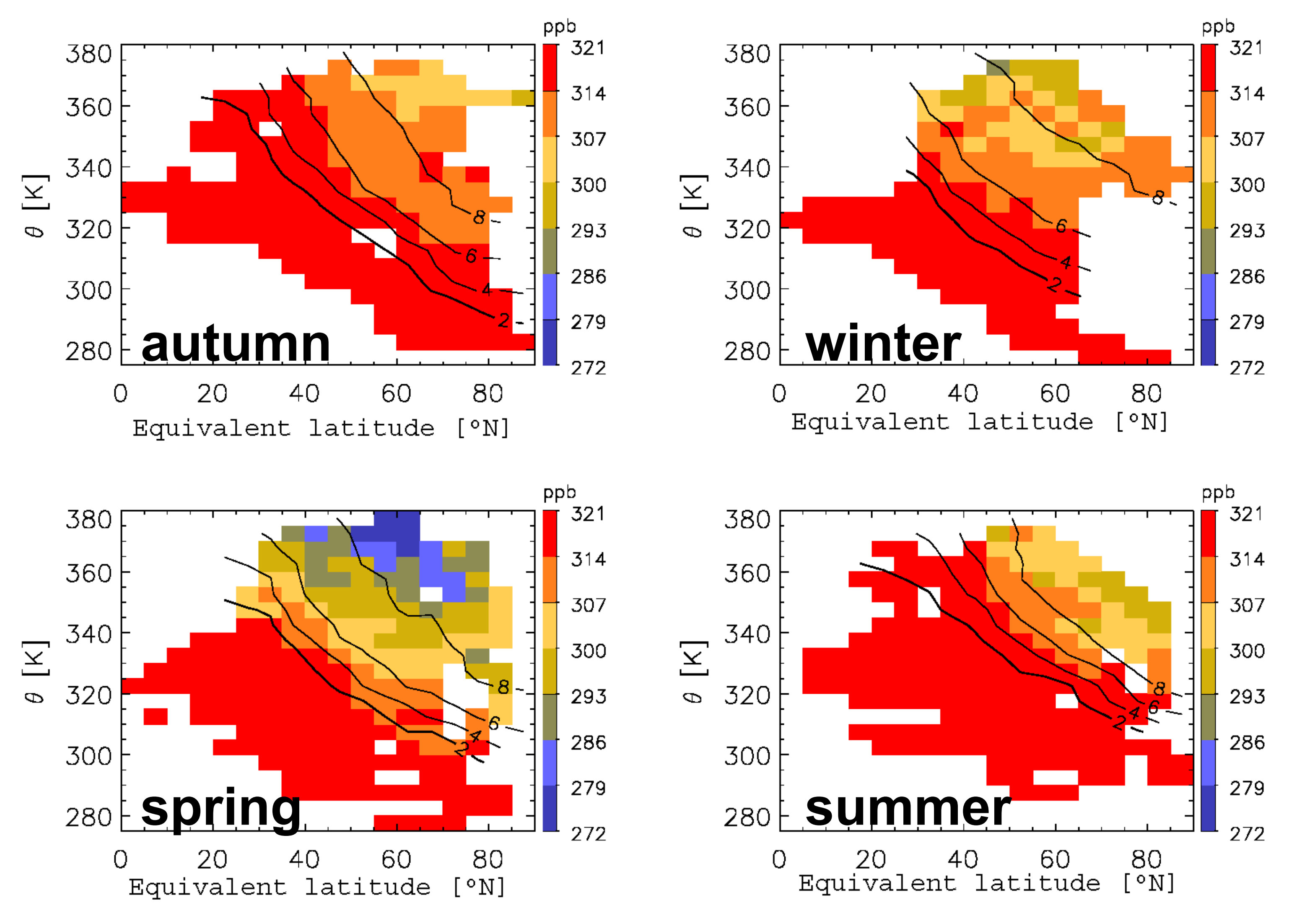
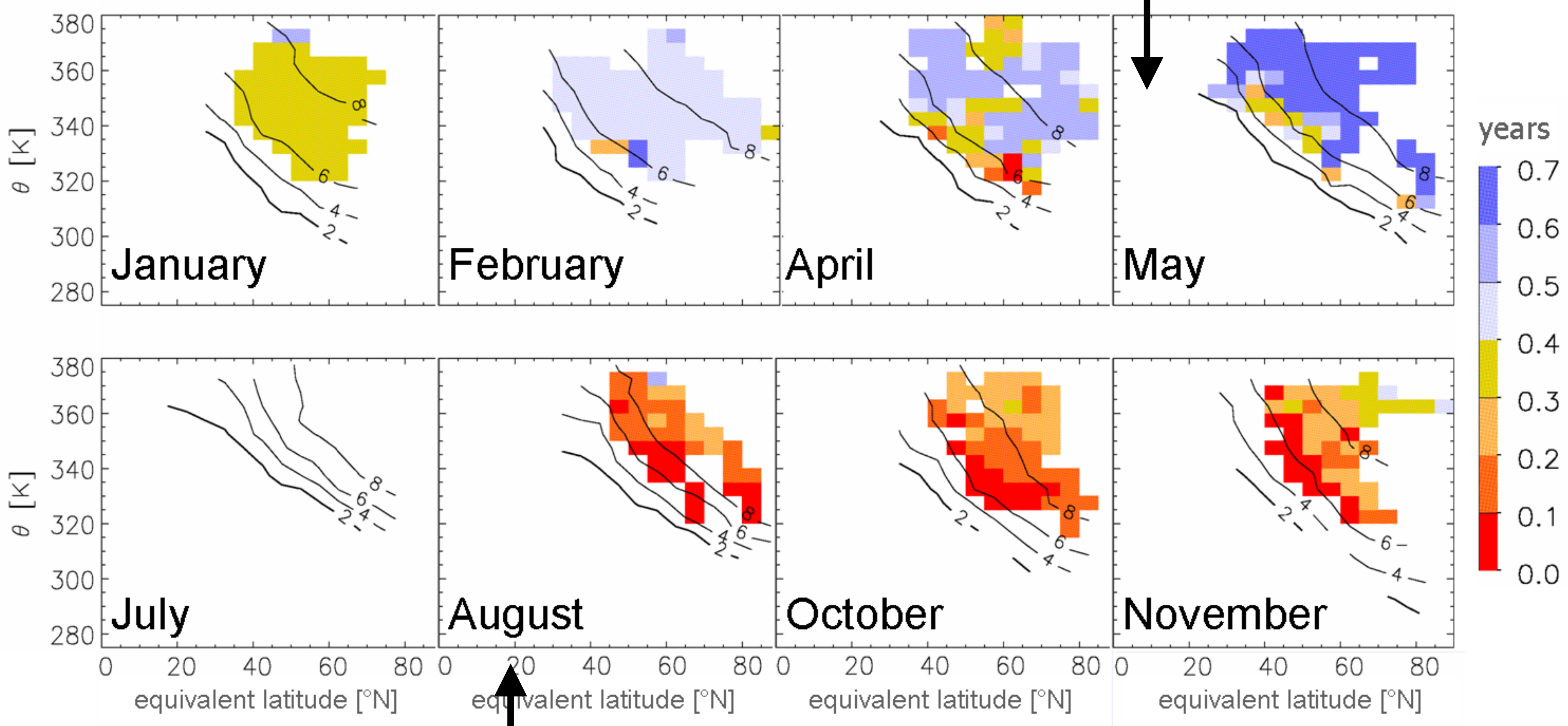


Figure: N_2O distribution in the LMS as a function of equivalent latitude and potential temperature derived from SPURT in-situ measurements. Black solid lines mark PV-Isolines.

Trace gas budget – Mean transit time Γ_1

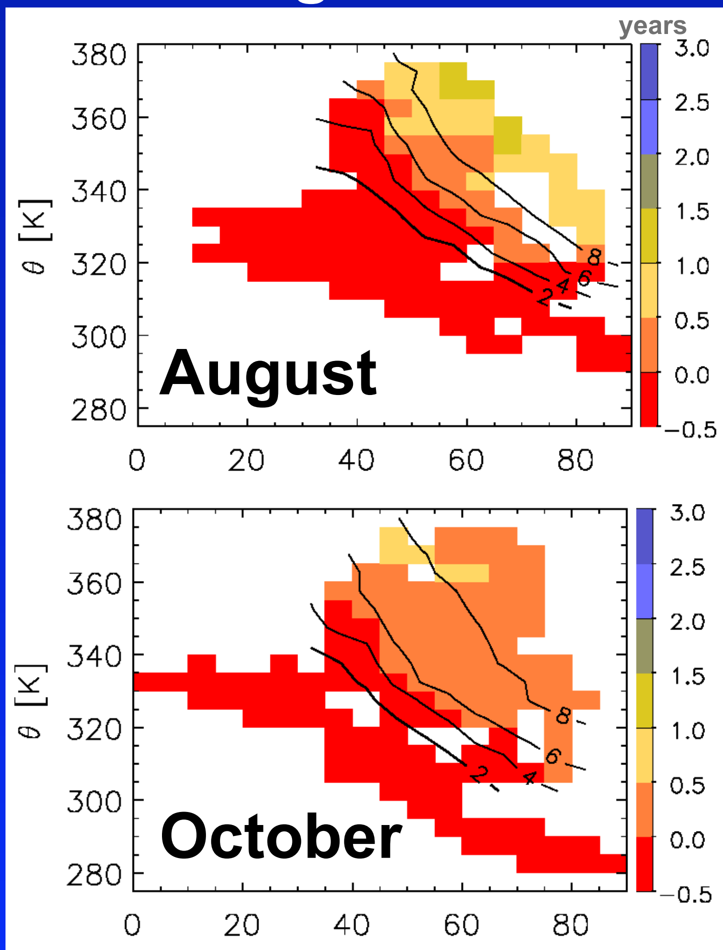
longest transit times



shortest transit times

Changing trace gas composition between summer and autumn

Mean Age of Air



Water Vapor

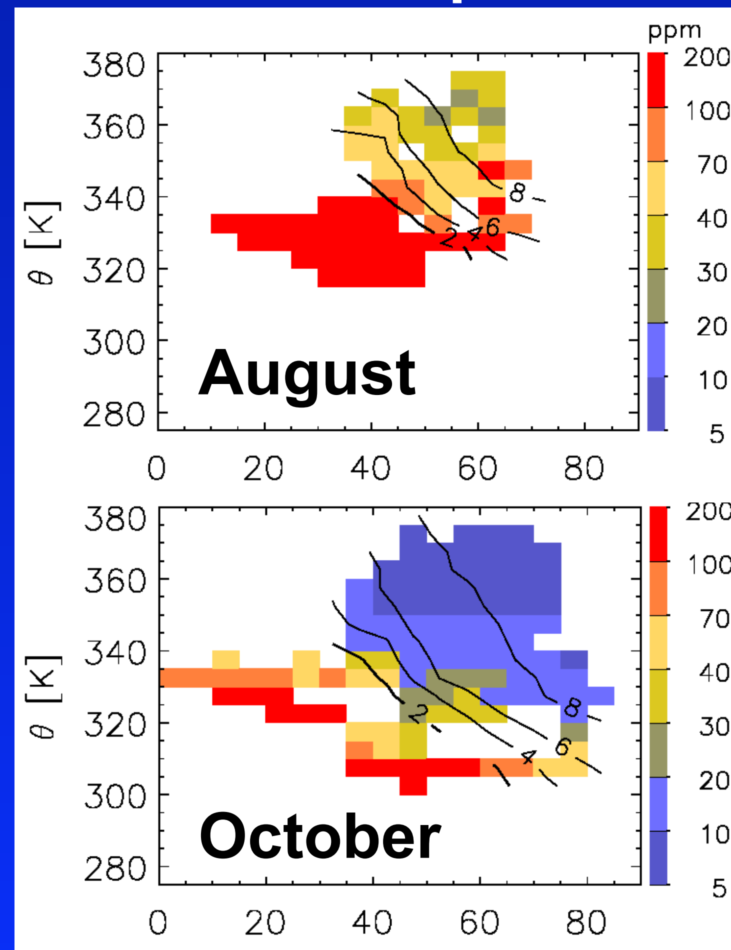


Figure: Mean age of air (left panel) and water vapor (right panel) distribution in the LMS as a function of equivalent latitude and potential temperature derived from SPURT in-situ measurements. Black solid lines mark PV-Isolines.

Conclusions

- Tropospheric contribution in the LMS maximize in October (on average: α_1>90 %) and minimize in April (lowest values: α_1<20 %)
- During all seasons tropospheric fractions α_1>60% can occasionally be found in the LMS, even for PV>8 pvu
- Mean transit times in the LMS minimize in August (Γ_1<0.2 years) and maximize in May (Γ_1>0.5 years), whereby Γ_1 increases continuously.

In summary, we conclude that the LMS is flushed with tropospheric air during summer and that this in-mixing can be traced back till the end of spring the following year.

Outlook

- Implementing both passive tracers SF_6 and CO_2 in model experiments in order to evaluate modelled transport into the LMS (Boenisch et al., 2008)

And

- Applying the trace gas budget method on model simulations of both tracers

(see Poster P7 : "First results of a model evaluation based on a tracer budget of the extratropical lower stratosphere applied on simulated and measured SF_6 and CO_2").

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Downward mass flux into the LMS

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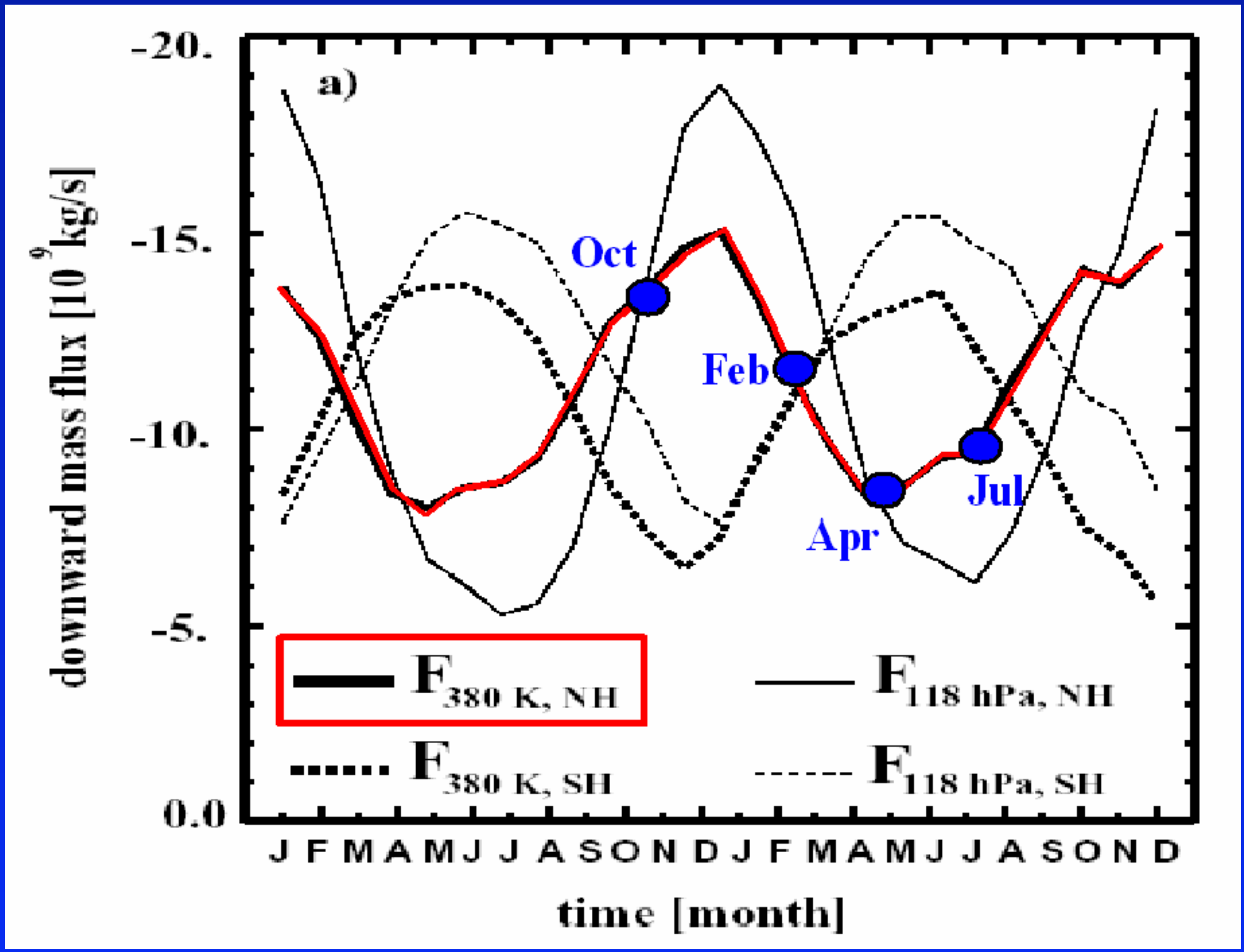
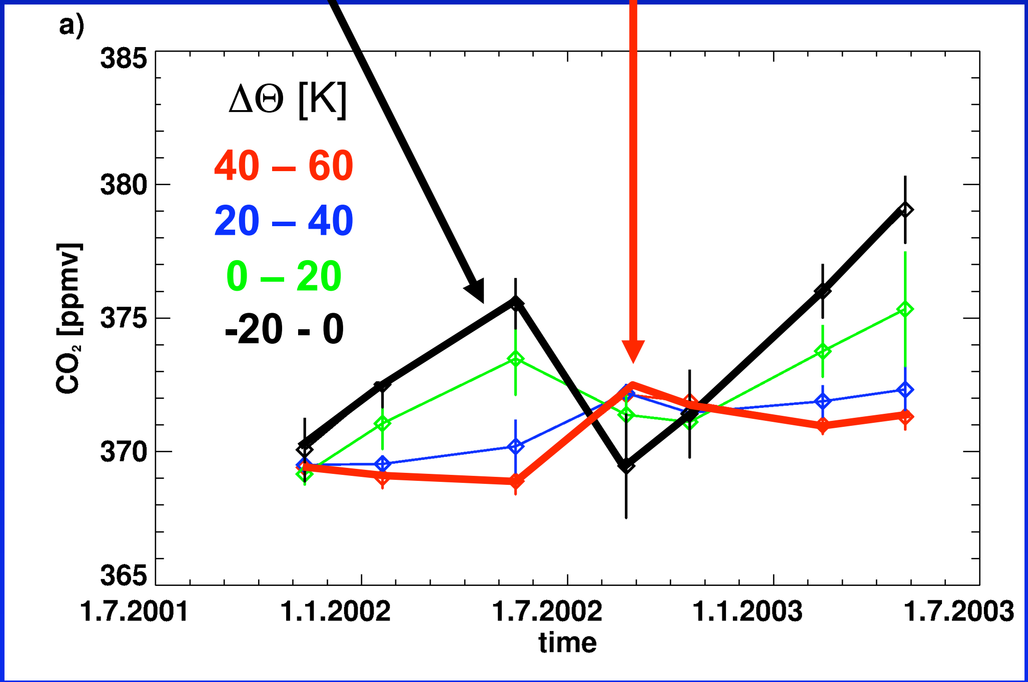


Figure: Downward mass flux through 380 K isentrope (index 380) and 118 hPa isobar (index 118) surface for Northern (index NH) and Southern (index SH) hemisphere (Appenzeller et al., 1996). The figure is taken from Hegglin et al. (2004).

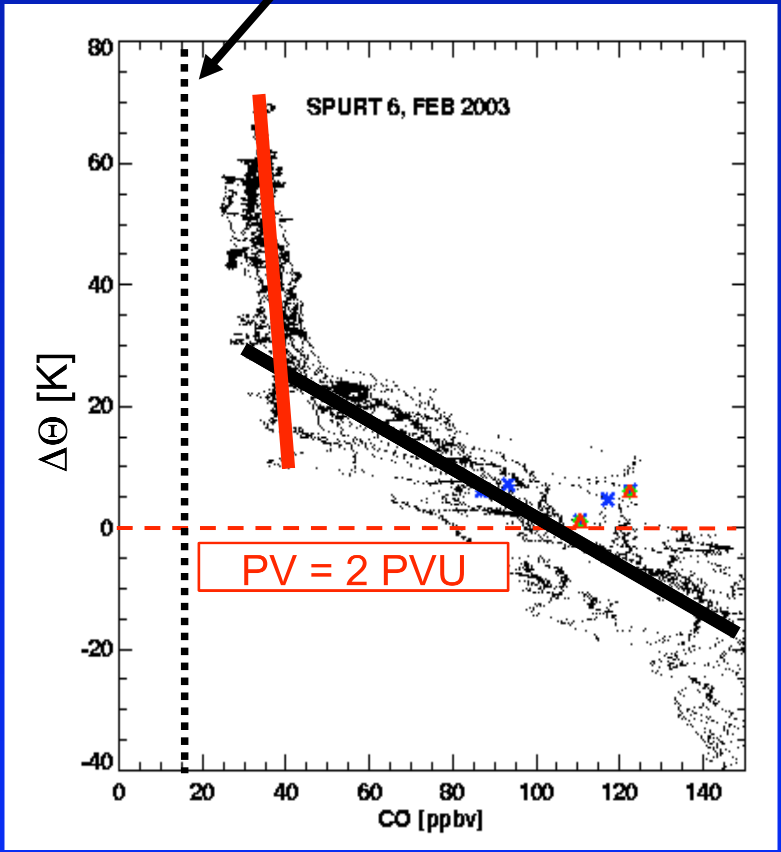
Structure of the LMS – Tropopause following mixing layer

Phase lag between
Troposphere and Stratosphere



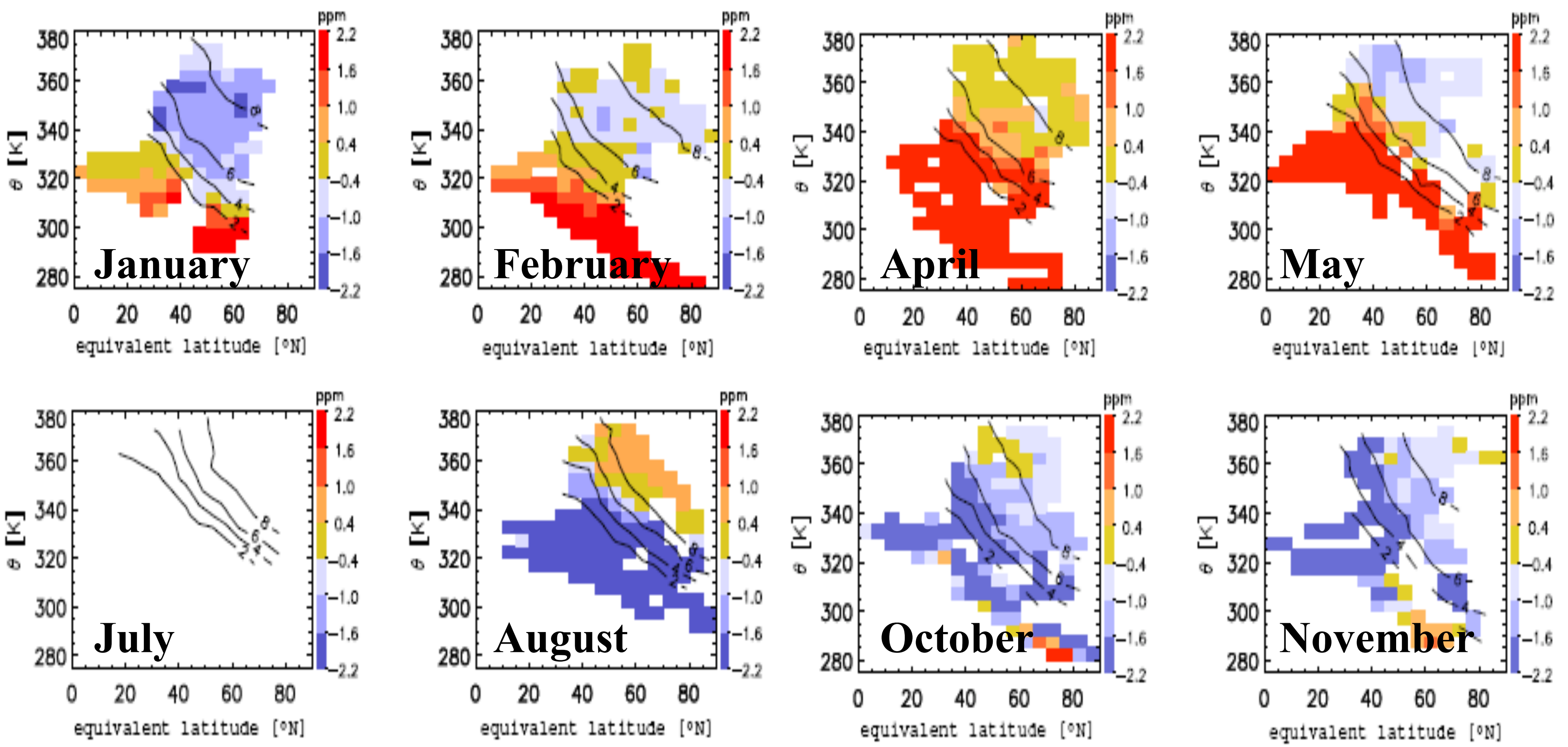
Hoor et al. 2004

CO equilibrium value



Hoor et al. 2004

Propagation of tropospheric CO_2 amplitude into LMS



Water vapour in the LMS

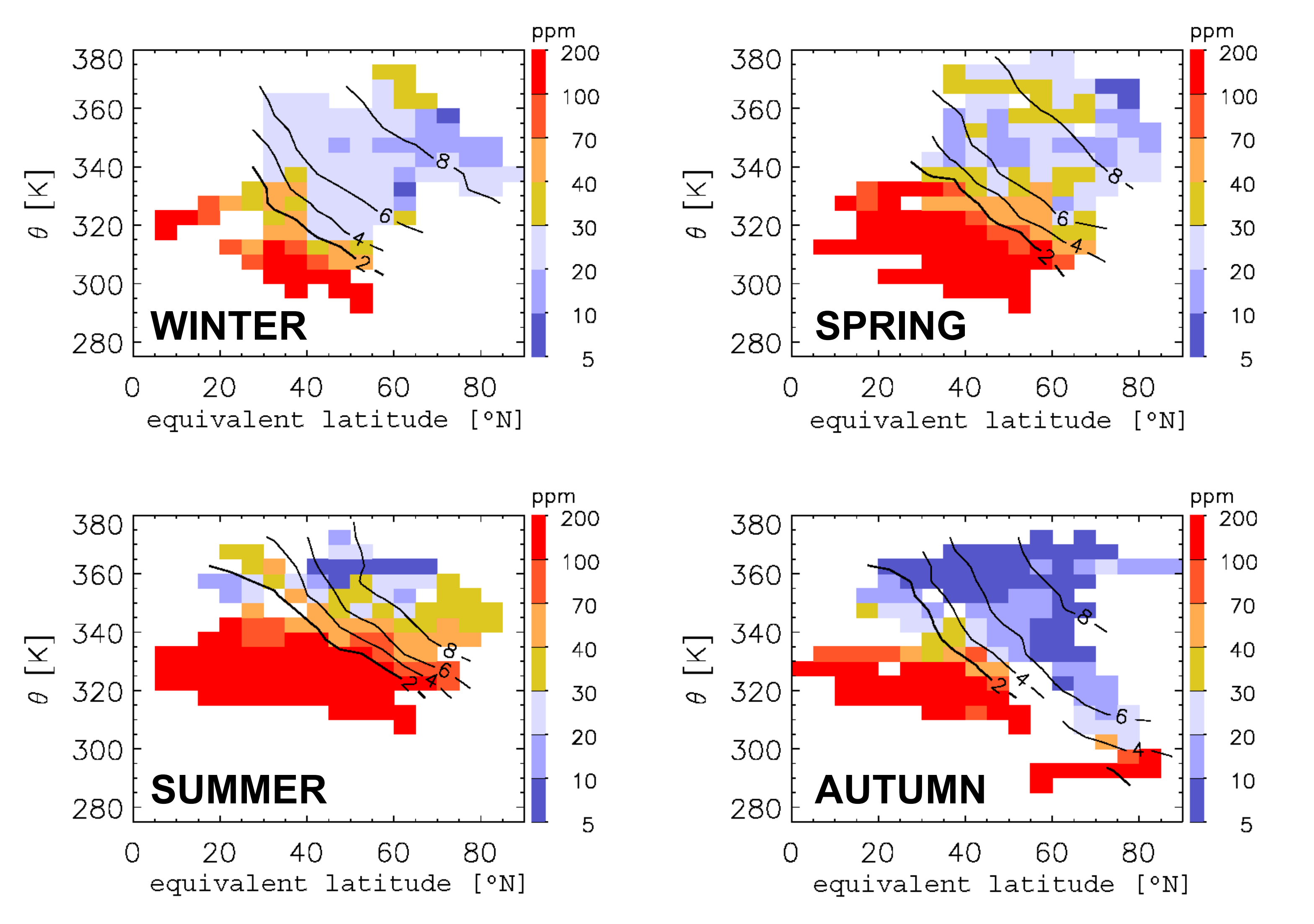


Figure: Seasonal variation of the water vapour distributions in the LMS (Engel et al. 2006). The curves indicate the PV-isolines.