JÜLICH FORSCHUNGSZENTRUM

esa

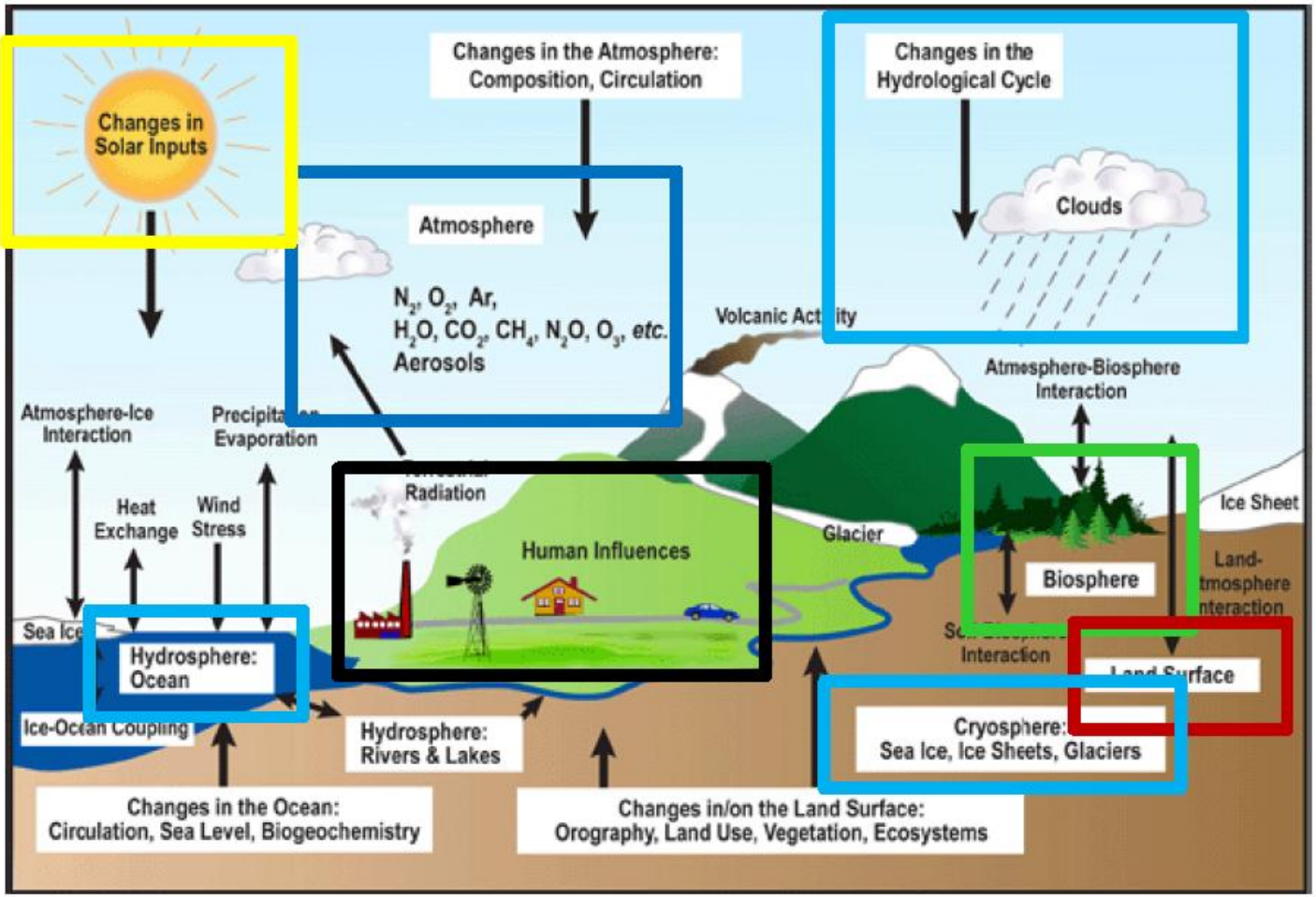
→ ADVANCED ATMOSPHERIC TRAINING COURSE 2014

Atmospheric composition – climate interaction

Martin Riese

Forschungszentrum Jülich (IEK-7)

Schematic view of the components of the climate system, their processes and interactions.



Quelle: IPCC

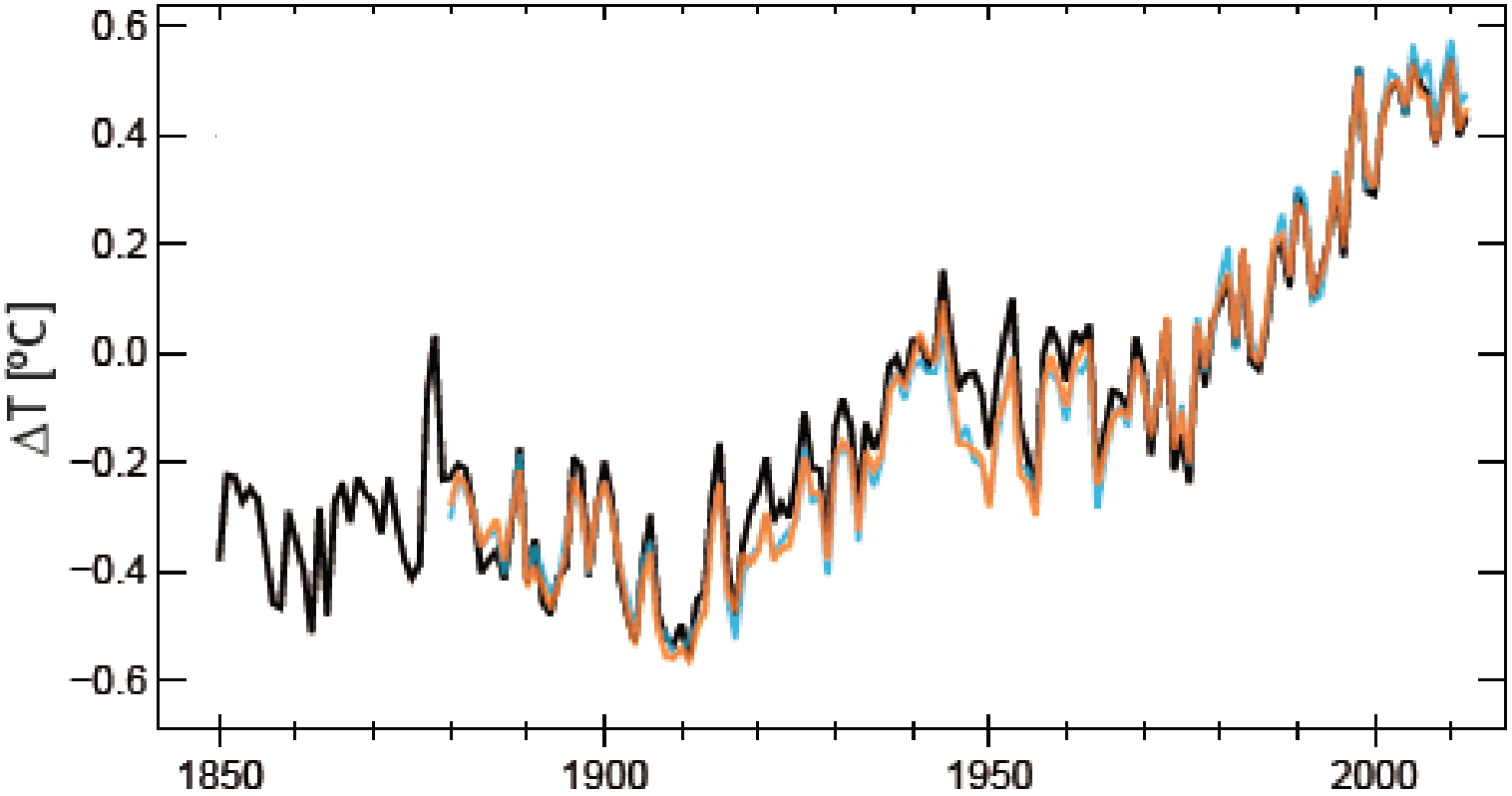
Content

- Radiative effects of composition change
- Atmospheric processes (e. g. role of Asian monsoon)
- Atmospheric circulation changes ?
- Mission concept

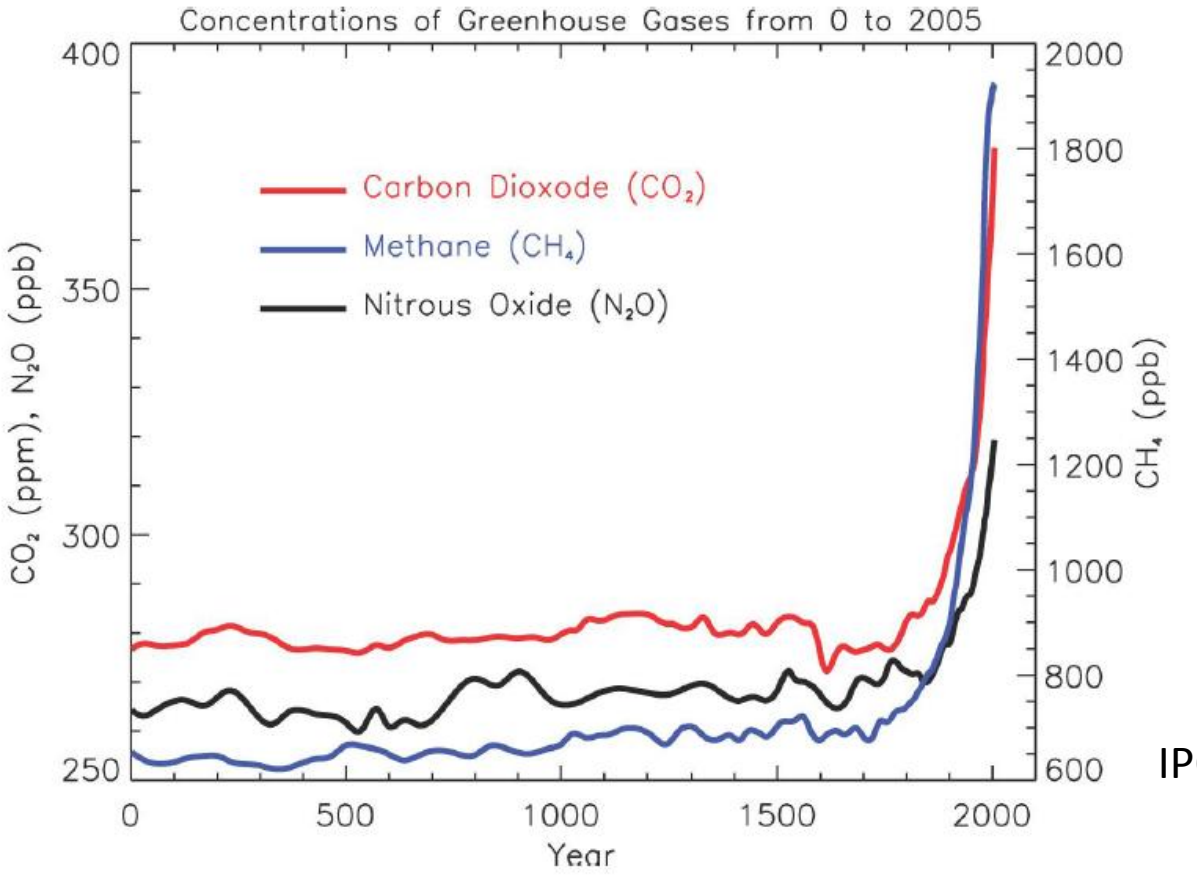
Motivation

Globally averaged surface temperature anomaly (1850 – 2012)

Anomaly relative to mean of 1960 – 1990



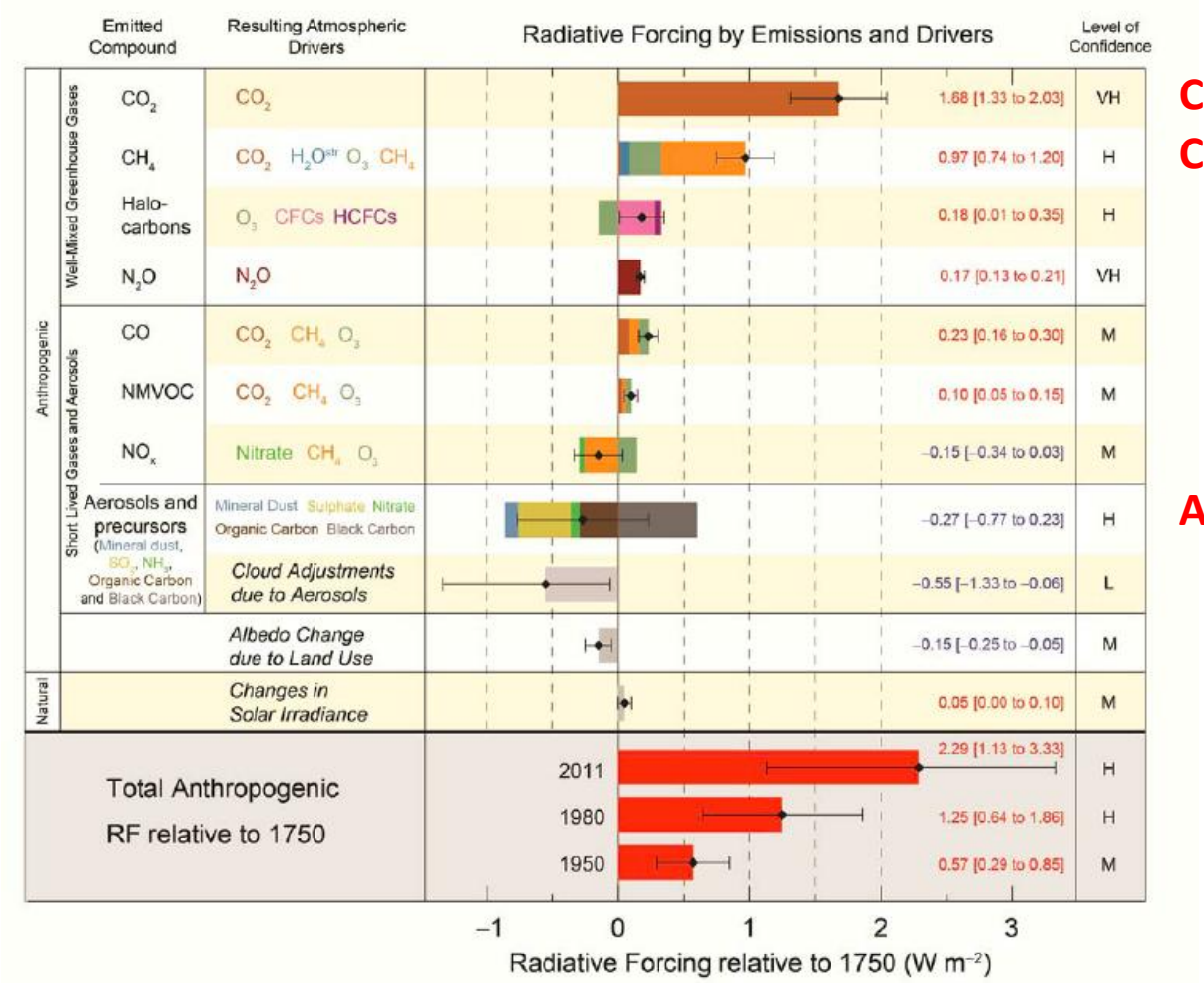
Quelle: IPCC


Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
CO_2 (ppm), N_2O (ppb)
CH_4 (ppb)
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000
Year

IPCC, 2007

Anthropogenic forcing

Radiative forcing since 1750



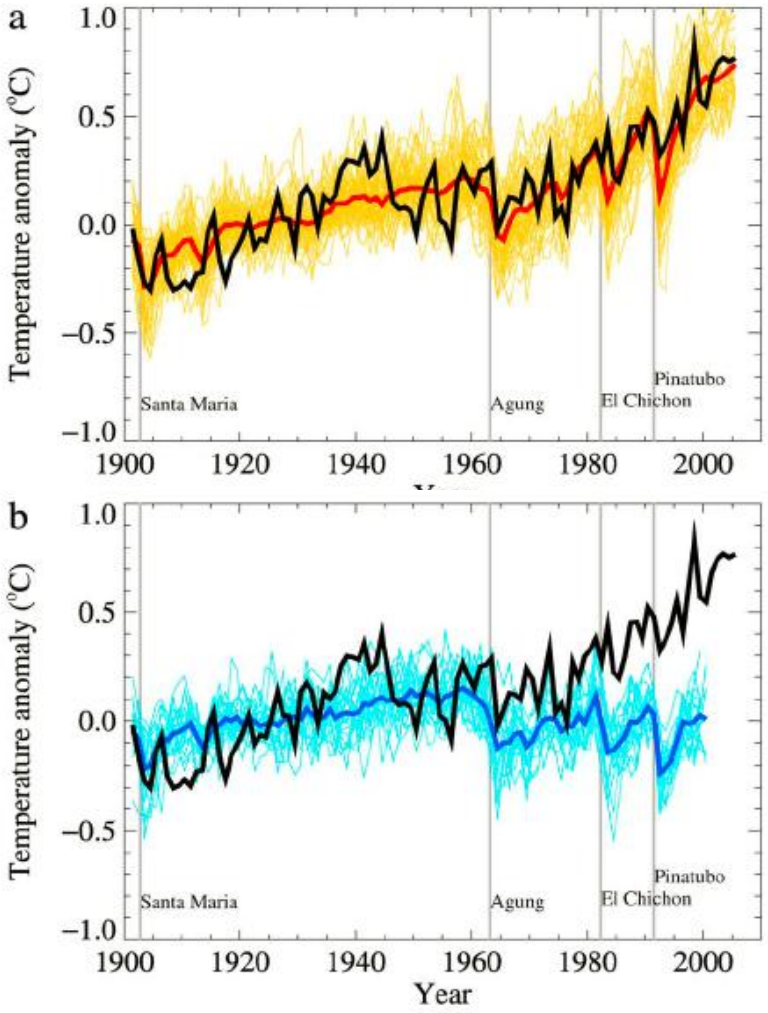
IPCC AR5

CO_2

CH_4

Aerosols

Anthropogenic forcing

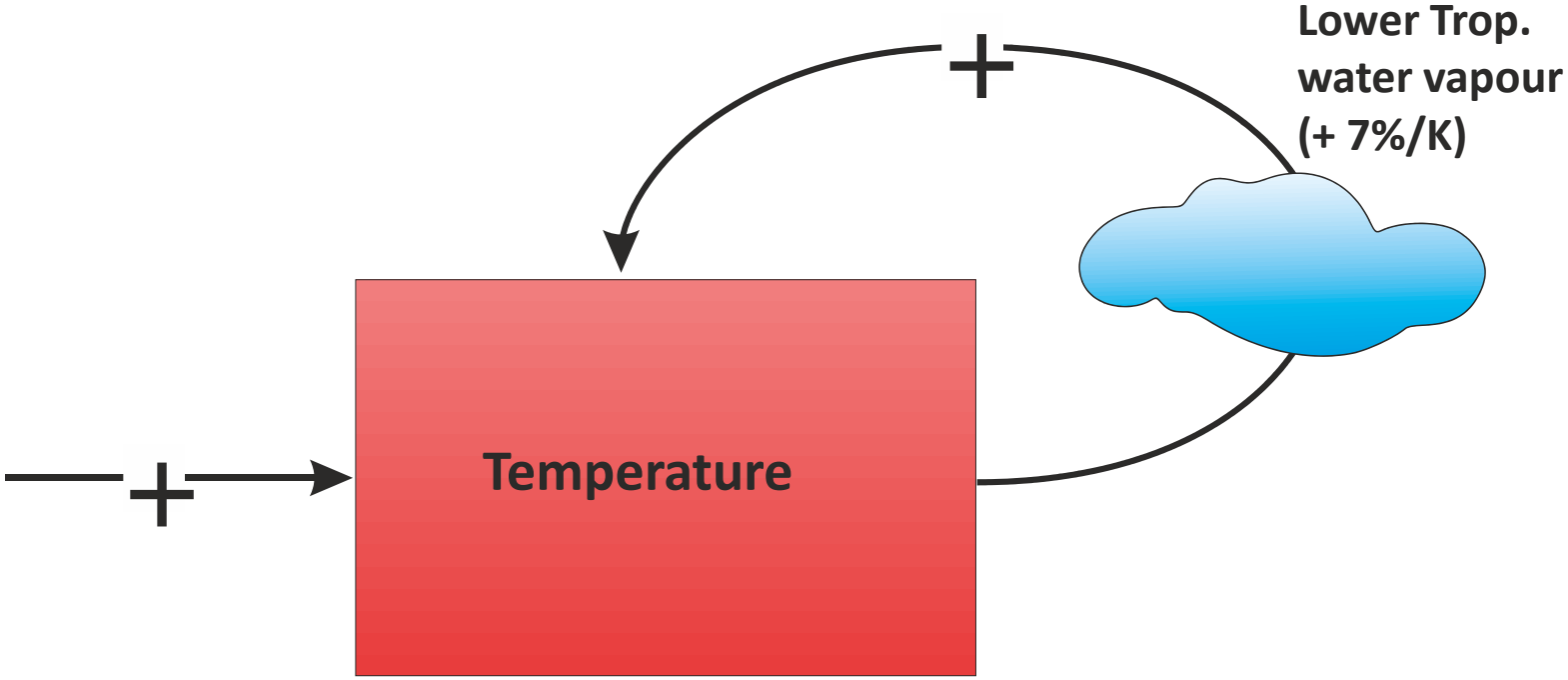


natural + anthropogenic forcing

natural forcing only (solar + volcanic)

from IPCC, 2007

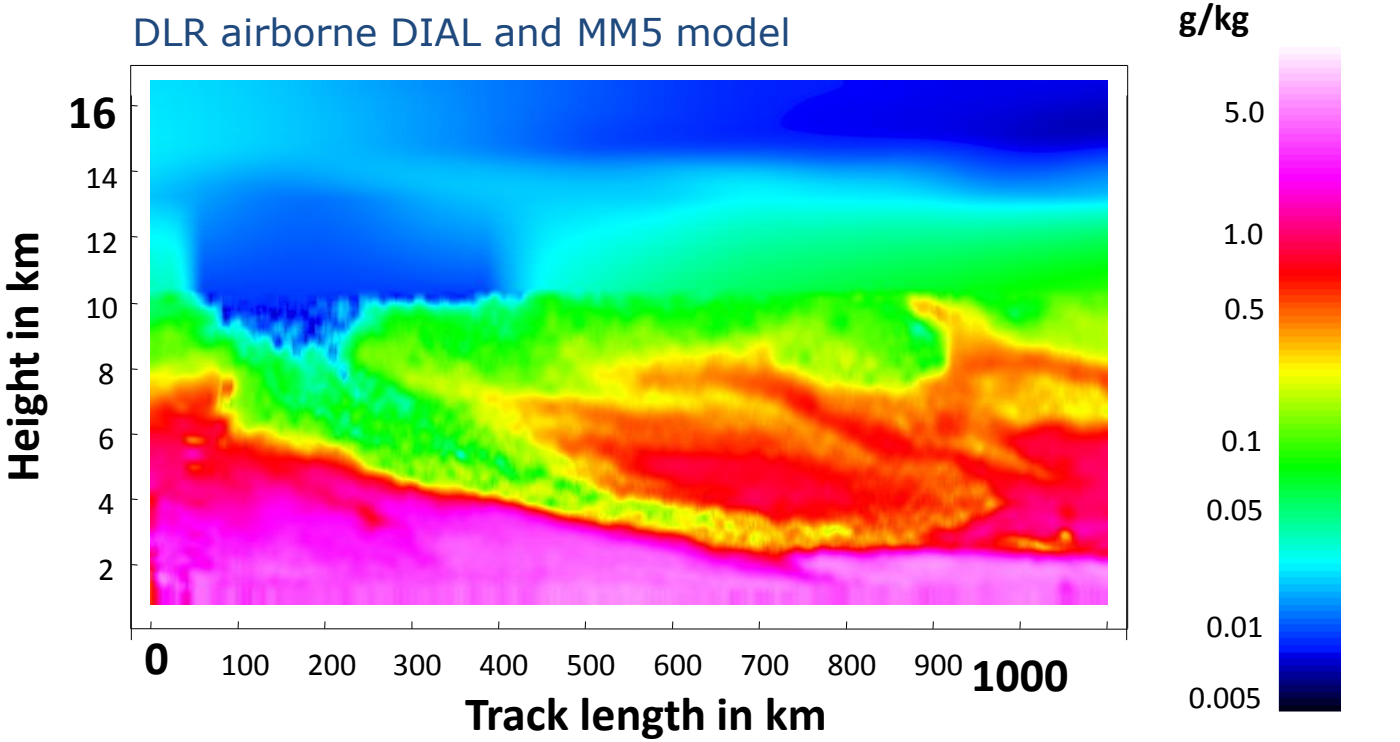
Water vapour feedback



- Water vapour feedback amplifies the radiative forcing of anthropogenic greenhouse gases by a factor of ~2

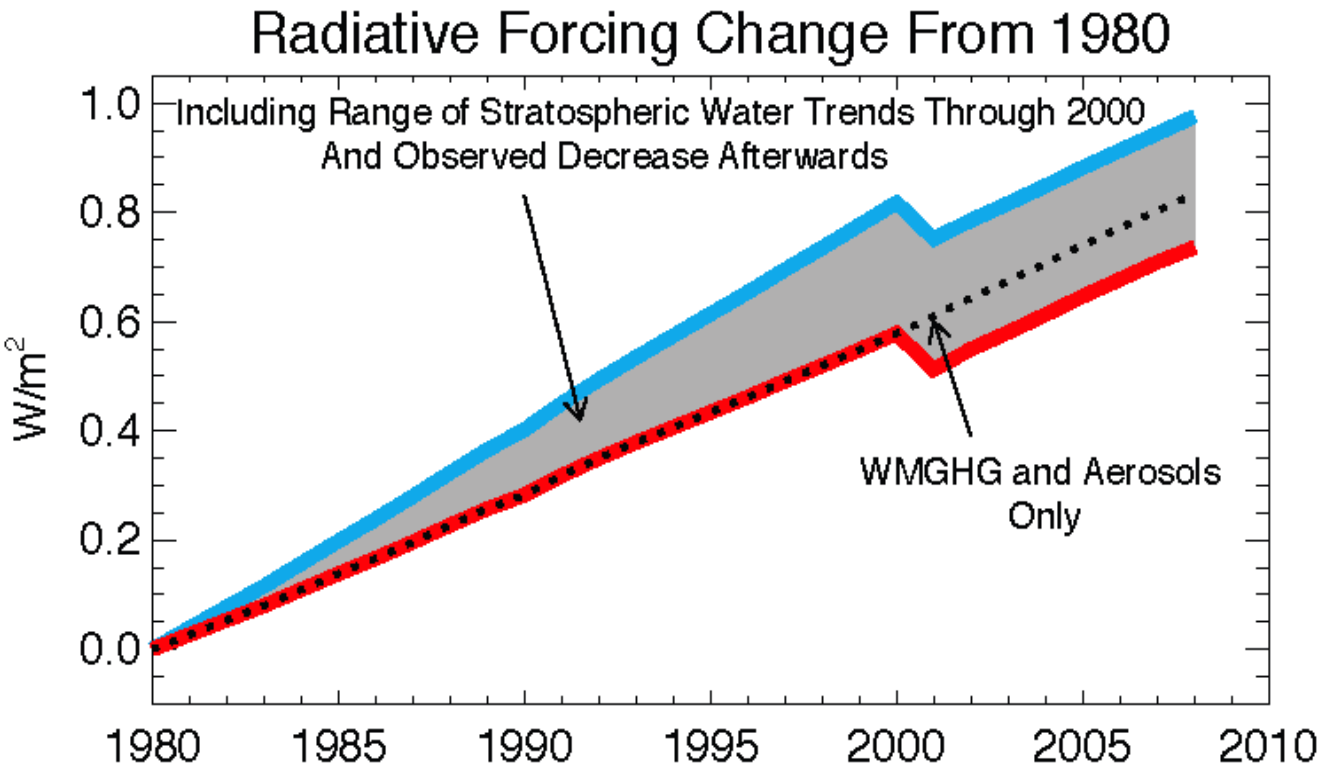
Water vapour in the UTLS

DLR airborne DIAL and MM5 model



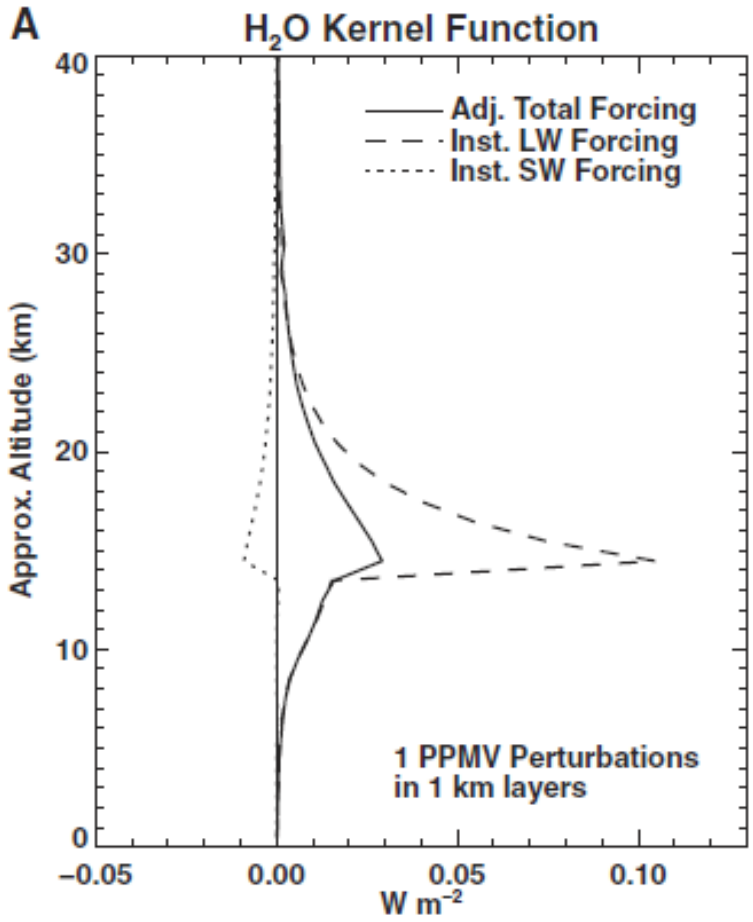
Significant variability in UTLS water vapour arises from its steep gradients and sensitivity to transport and micro-physical processes (and their changes)

Radiative effects of decadal variations of stratospheric water vapour



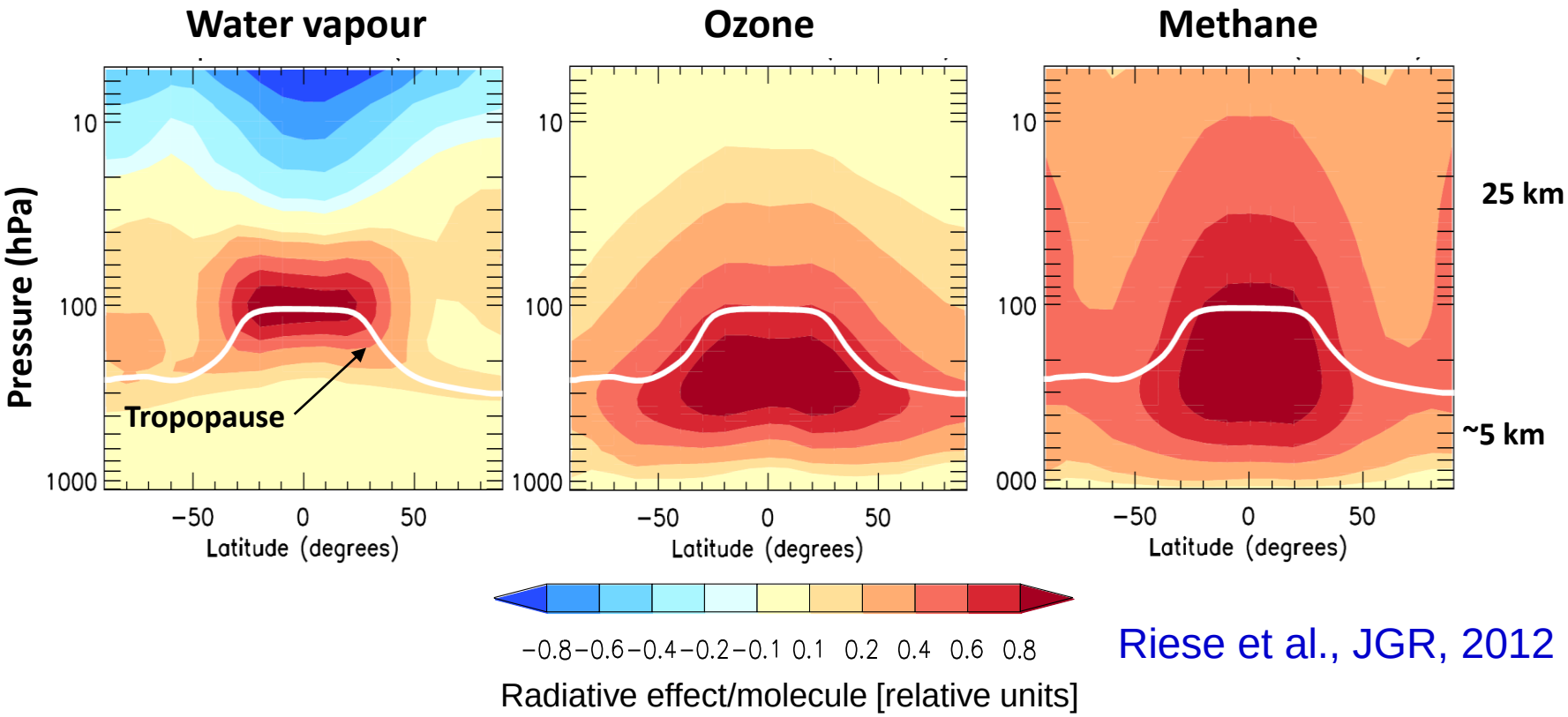
Solomon et al., 2010

Sensitivity of forcing to changes in the UTLS



Solomon et al., 2011

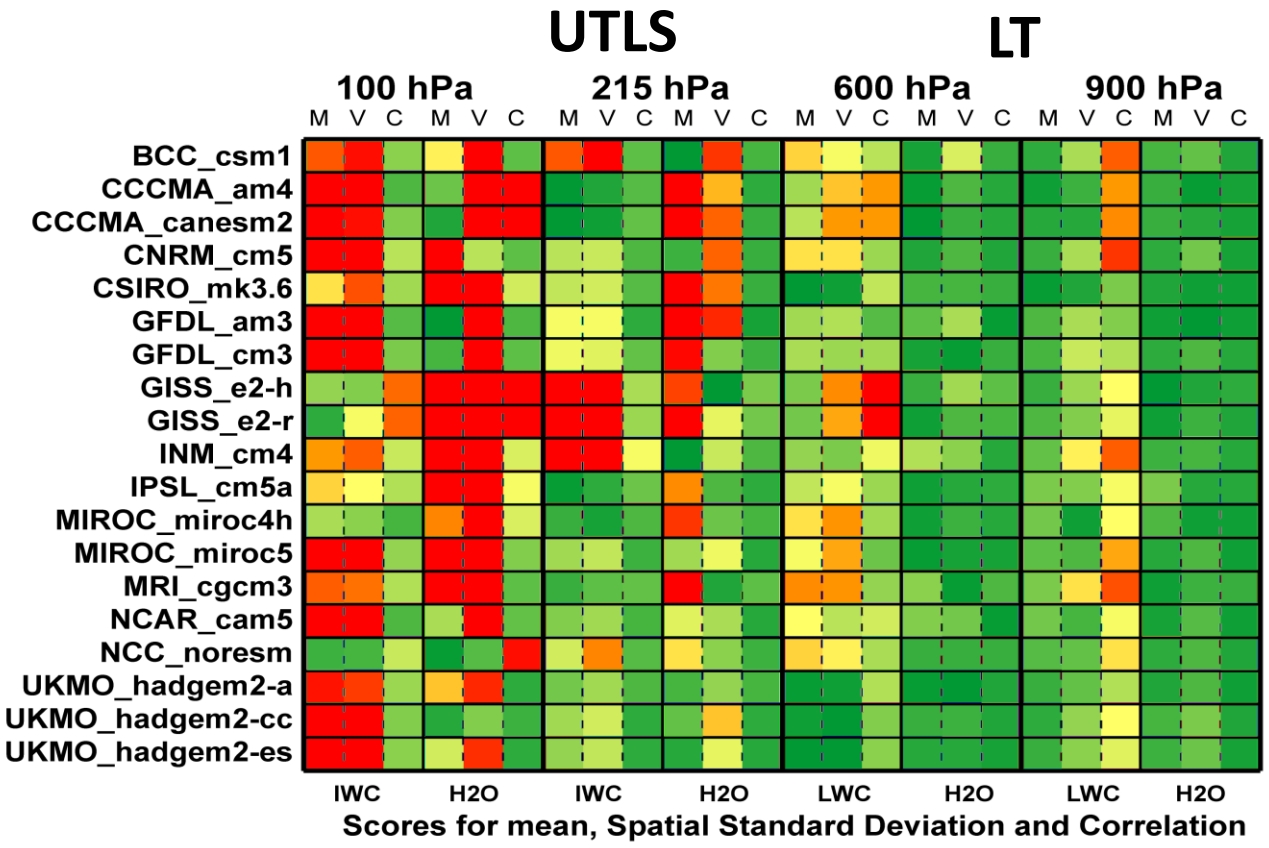
Two-dimensional sensitivity functions

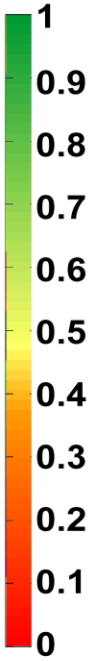


Riese et al., JGR, 2012

The sensitivity of surface temperature to changes in the UTLS requires quantitative understanding of the underlying processes !

Modelling UTLS water vapour and ice water content





Comparison to A-train observatrions

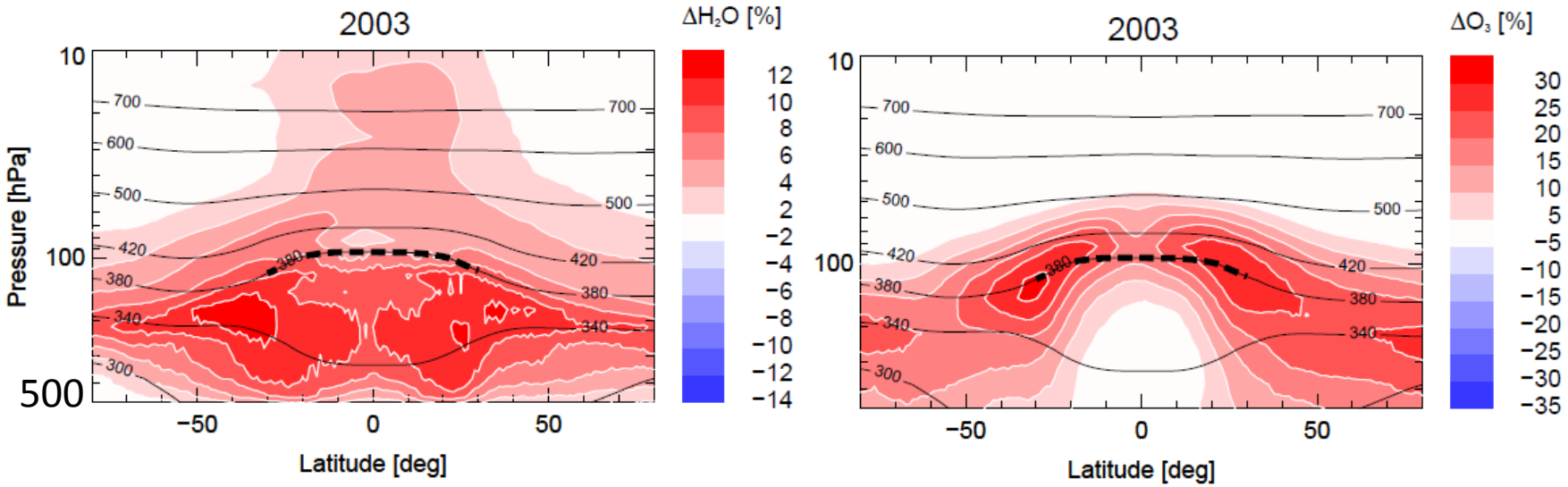
Good

M = Mean Value
V = Variability
C = Correlation

Poor

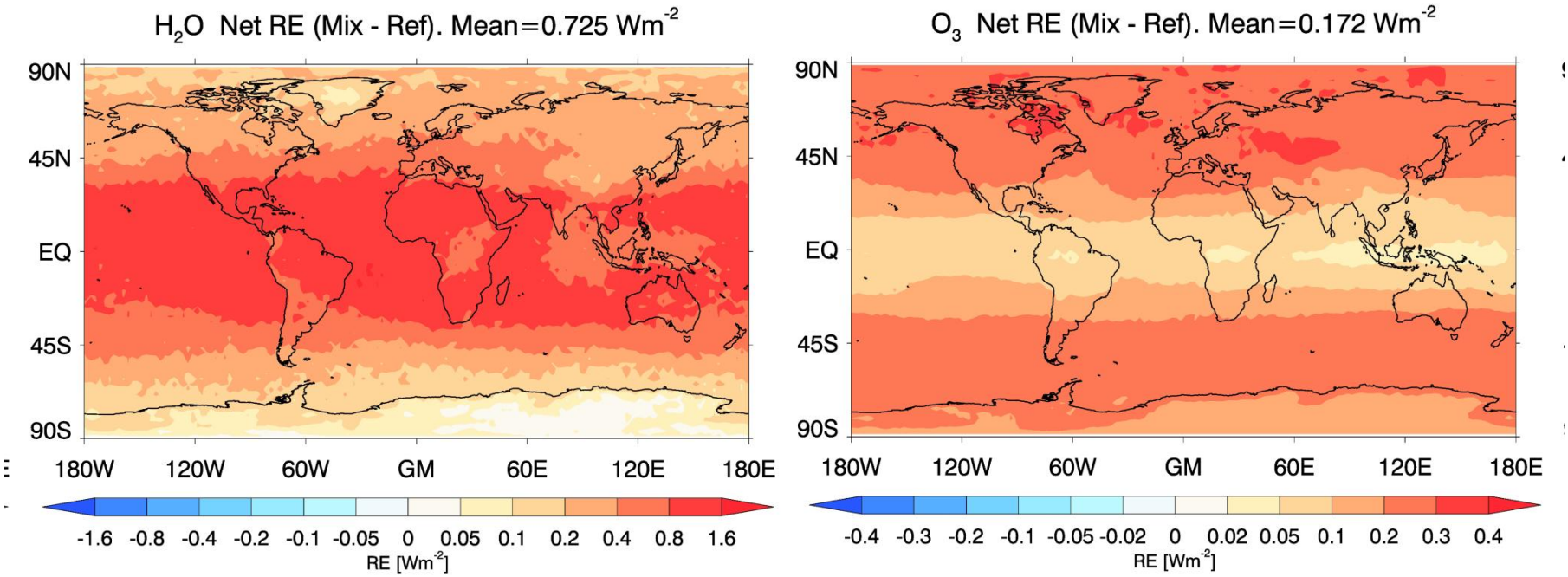
Jiang et al., JGR, 2012

Impact of mixing uncertainties on simulated UTLS water vapour and ozone



Riese et al., JGR, 2012

Associated uncertainty in radiative effects



- Simulated RE for trace gases with steep gradients in the UTLS (H_2O, O_3, …) are very sensitive to uncertainties of representation in models !
- Effects for CH_4 and N_2O are 2 orders of magnitude smaller.

Content

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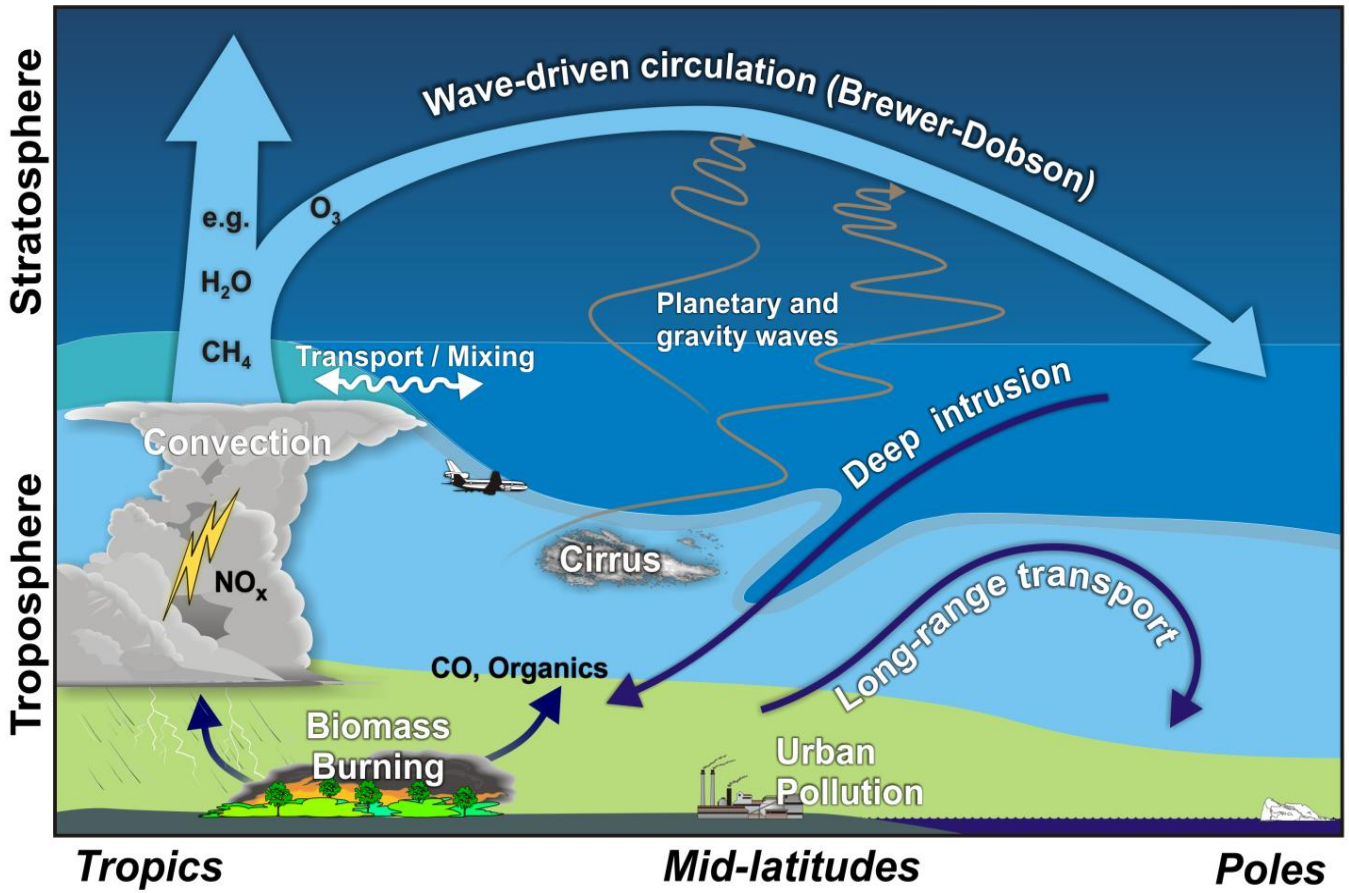
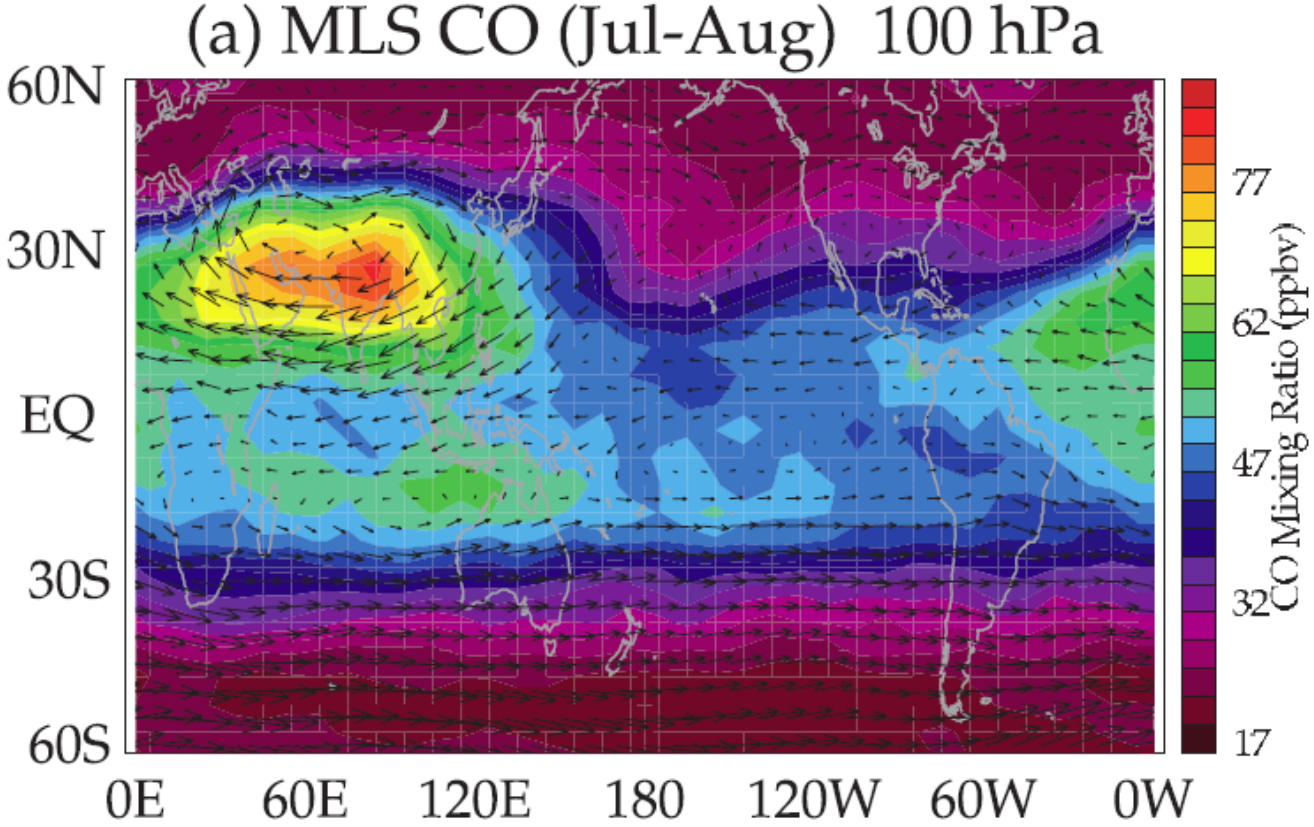
- Atmospheric processes (e. g. role of Asian monsoon)
- Atmospheric circulation changes ?
- Mission Concept

Role of the upper UTLS in climate



Uplift by the Asian Monsoon

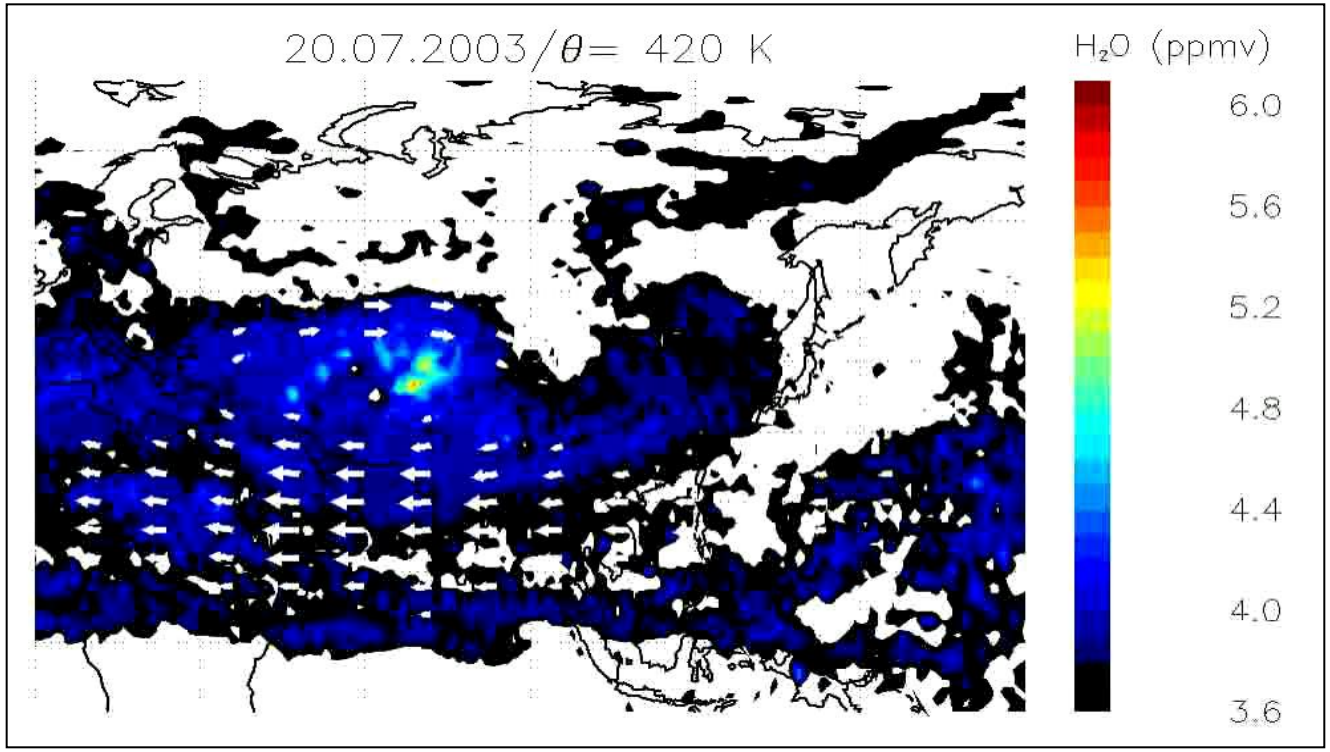
Confinement of pollution by the AM anti-cyclone



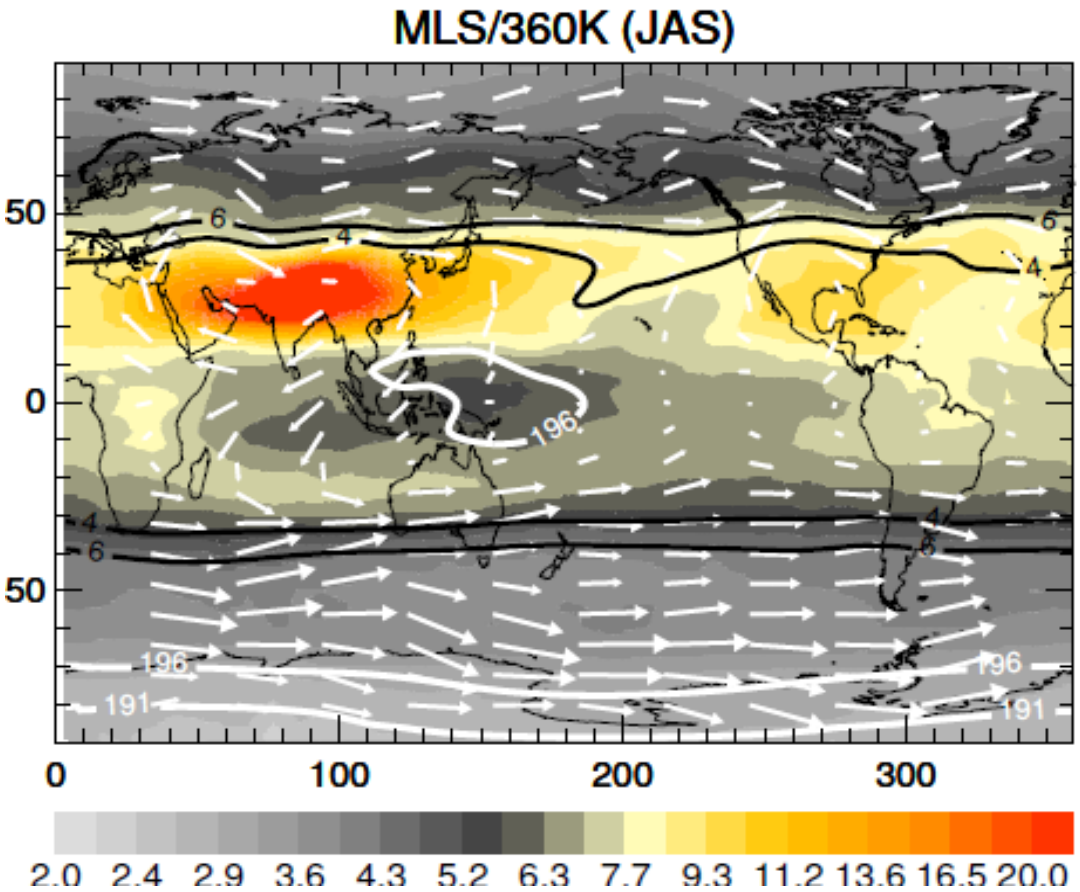
Park et al., JGR, 2007

Transport of water vapour from the tropical UT into the extra-tropical LMS

CLaMS H_2O simulation at 18 km altitude from July until Dec'03



- Upward transport during summer in the region of the AM
- Important for propagation of moisture towards higher latitudes.

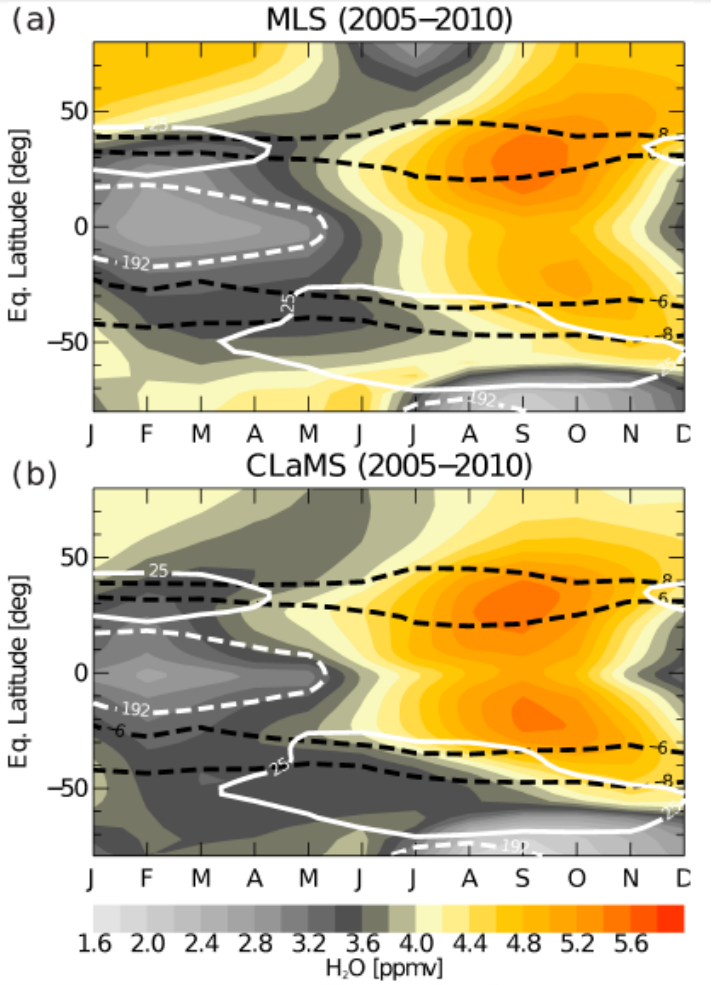


~ 14 km

Plöger et al., JGR, 2013

- Convective uplift by AM important for moistening the tropical UT

Propagation of moist air (390 K, ~16 km) into the extra-tropical LMS



- ★ good agreement CLaMS ⇔ MLS
- ★ highest H_2O in subtropics
- ★ NH moistened in summer/fall

Plöger et al., JGR, 2013

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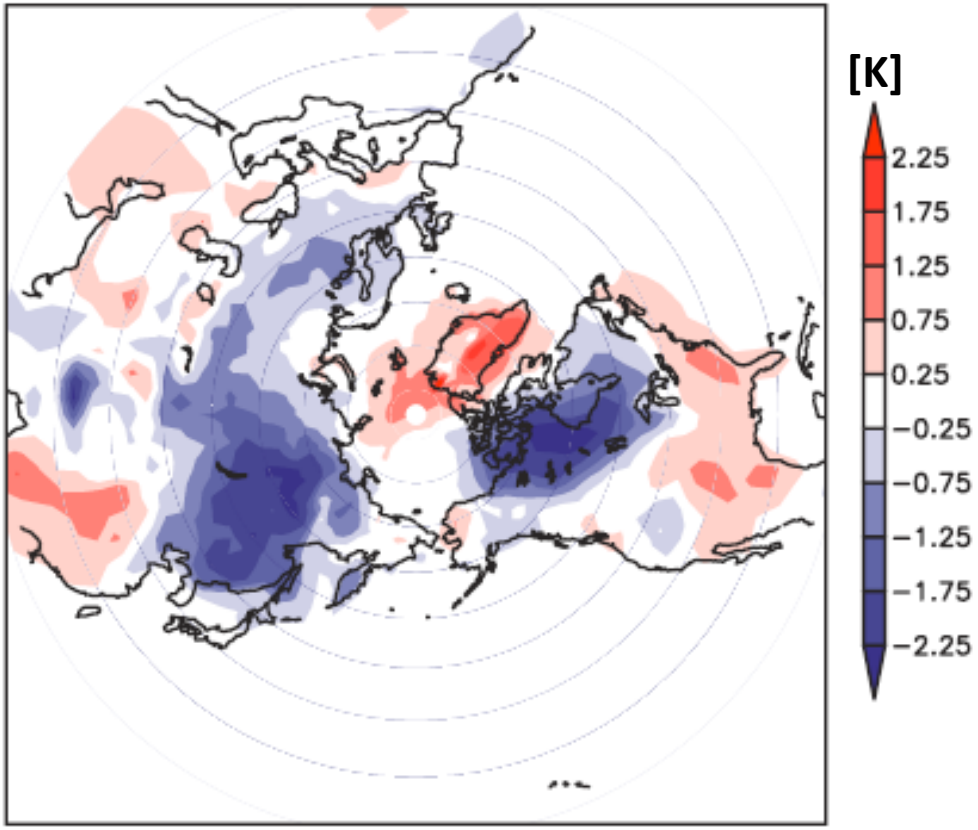
Dynamic coupling - stratospheric circulation

Surface temperature difference

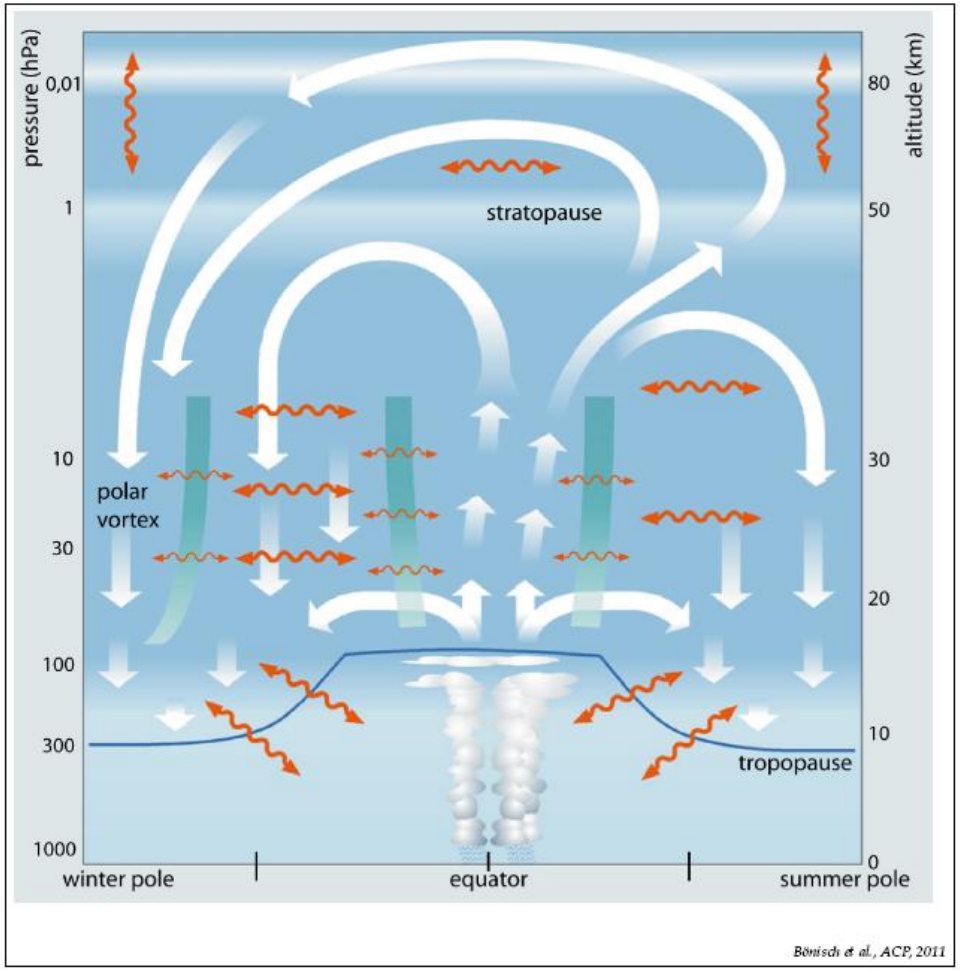


Climate simulations with CO_2-doubling (21. century)

Only diffence is gravity wave parameterisation (circulation)

Scinocca et al., 2010

Meridional mean circulation



Residual mean circulation

$$(\overline{v}^*, \overline{Q}^*)$$

$$\overline{v}^* = (\overline{\sigma v})/\overline{\sigma}$$

$$\overline{Q}^* = (\overline{\sigma Q})/\overline{\sigma}$$

σ : density

Eddy mixing

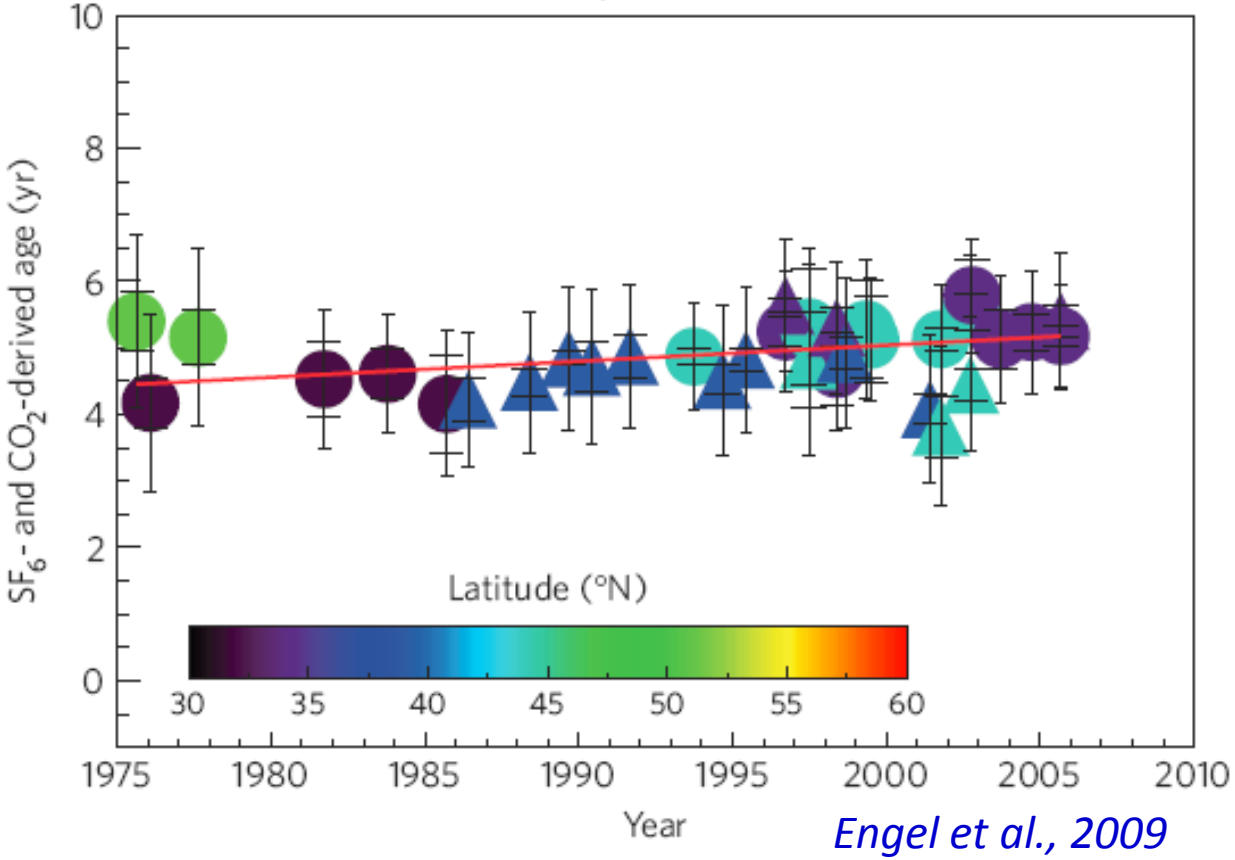
$$M_\phi = -\overline{(\sigma v)'\Gamma'}$$

$$M_\theta = -\overline{(\sigma Q)'\Gamma'}$$

Γ : Tracer mixing ratio

In-situ observations of age-of-air

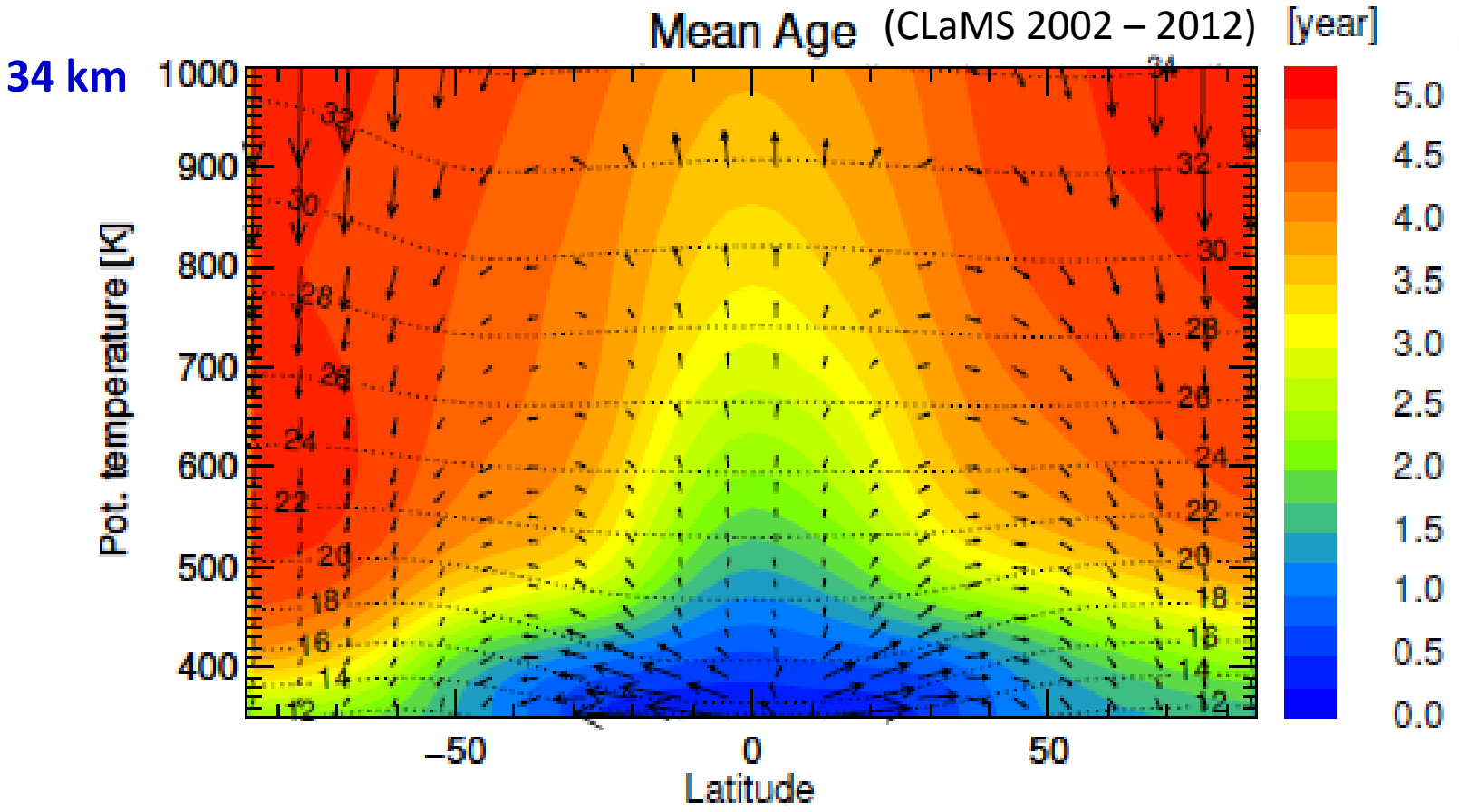
Evolution of mean age of air in NH at ~25km

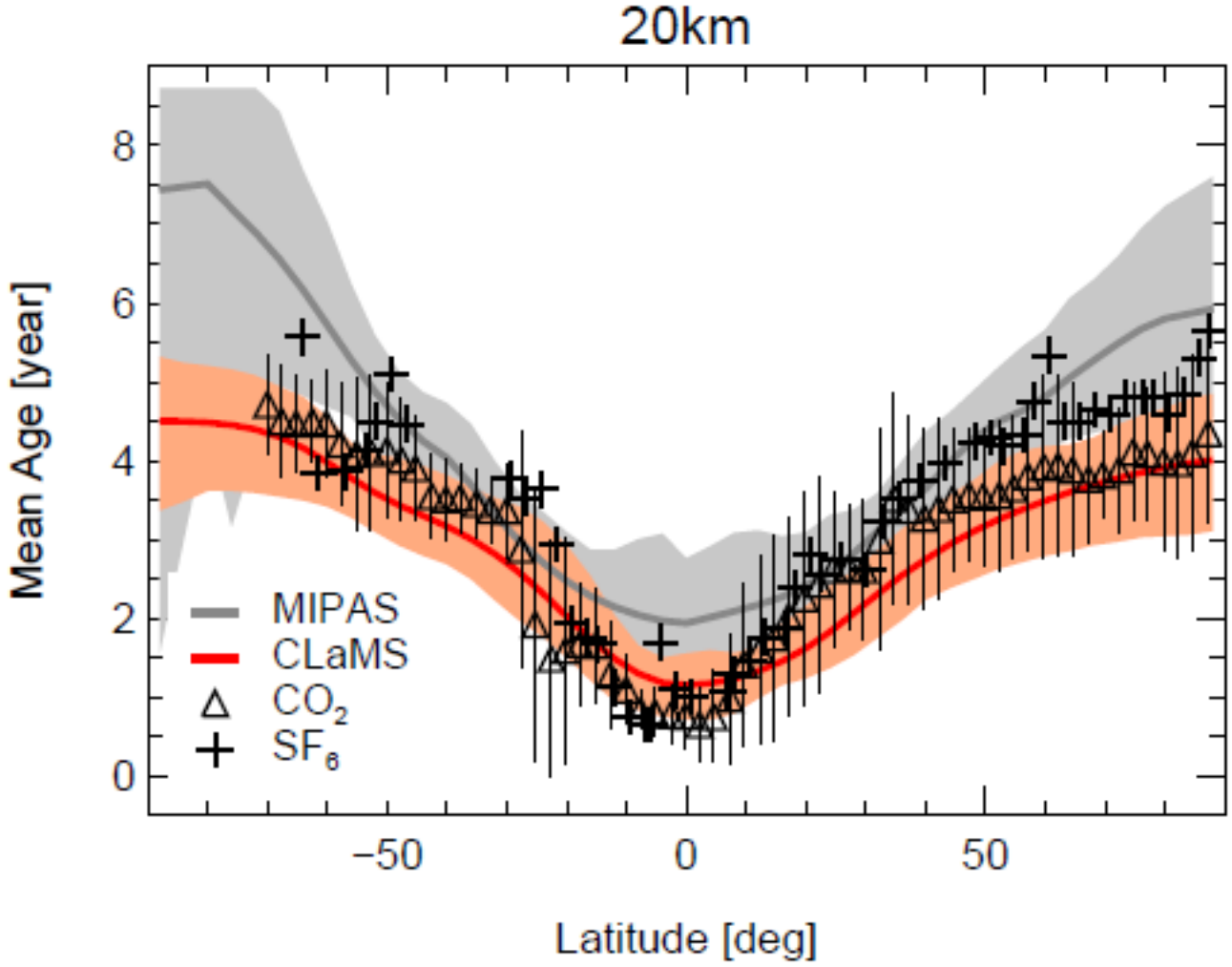


Engel et al., 2009

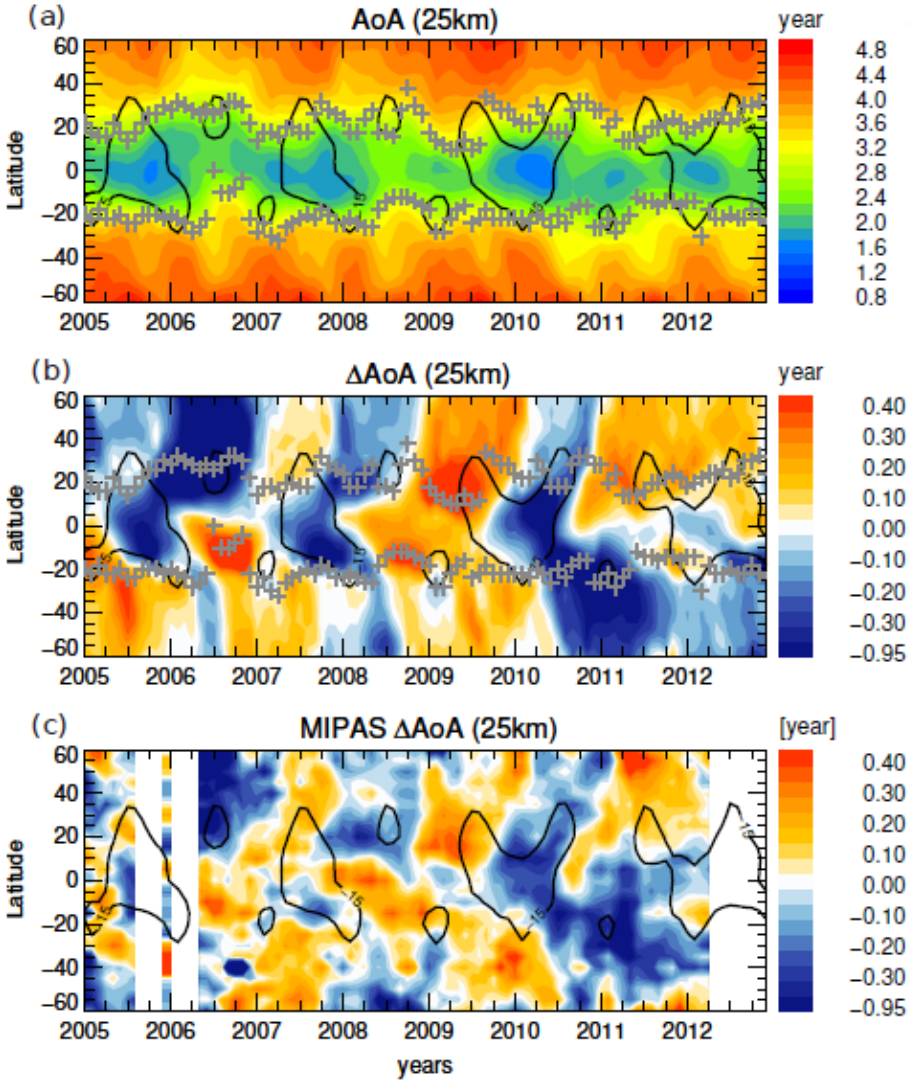
- GCMs consistently simulate a decrease of AoA in the stratosphere
- Contradiction between observations and models?

Age-of-air as transport tracer




20km
Mean Age [year]
0
2
4
6
8
−50
0
50
Latitude [deg]
MIPAS
CLaMS
CO2
SF6

CLaMS – MIPAS comparison at 25 km



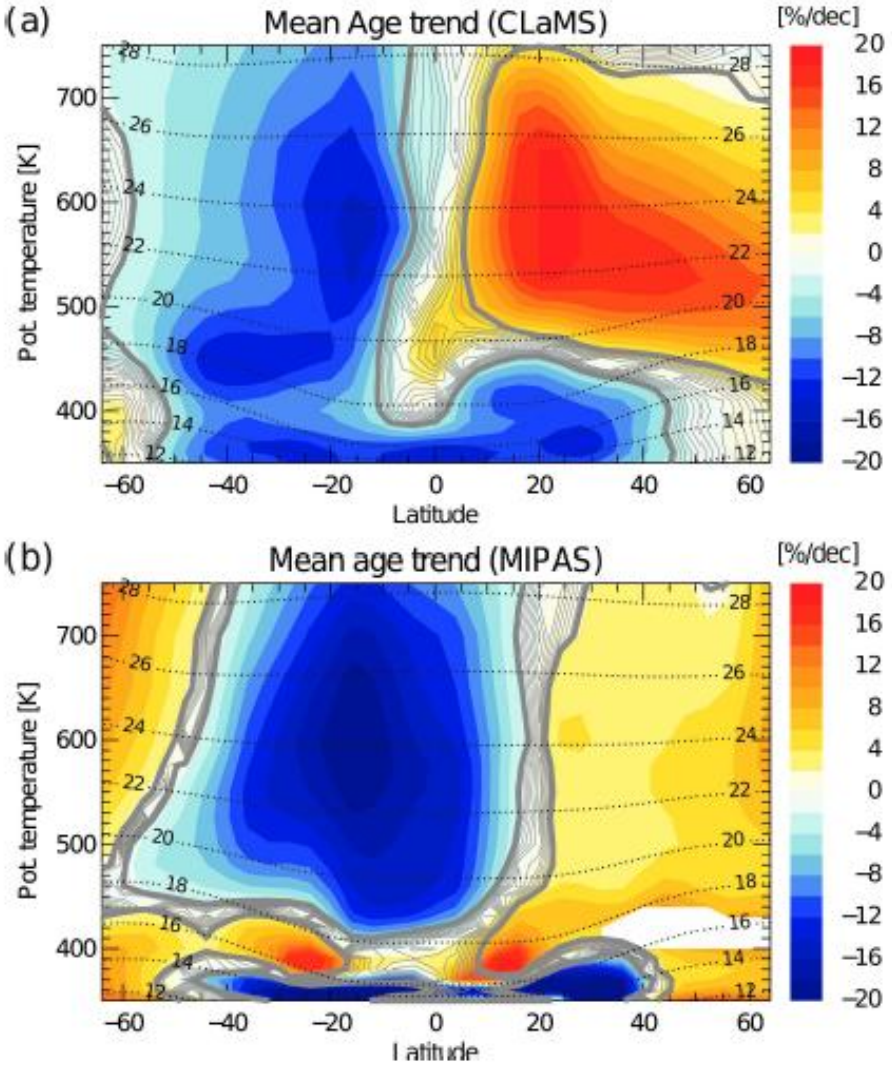
CLaMS

CLaMS anomalies

MIPAS anomalies

Plöger et al., submitted

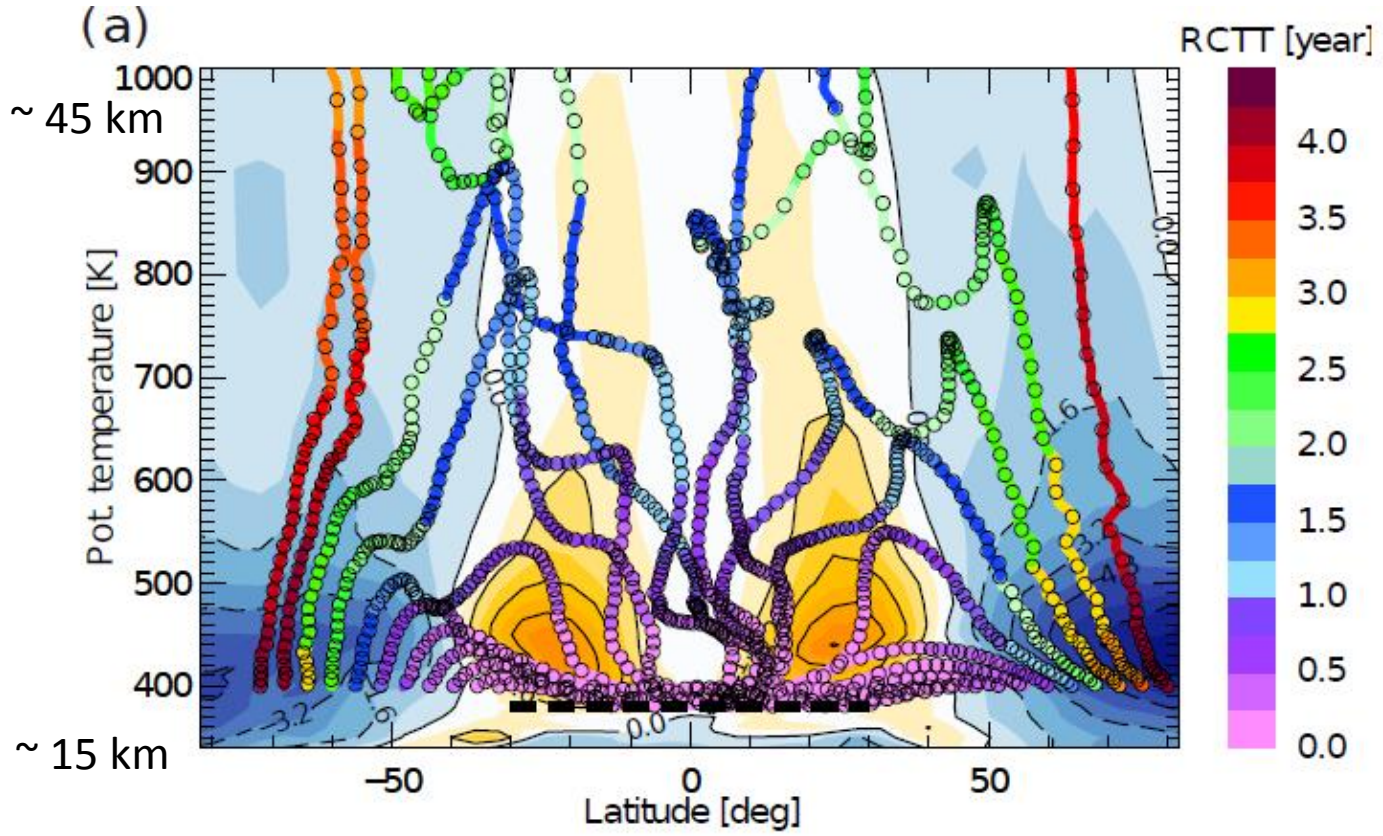
Decadal-scale age of air change (2002 to 2012)



Modell (CLaMS)

Messung (Satellit)

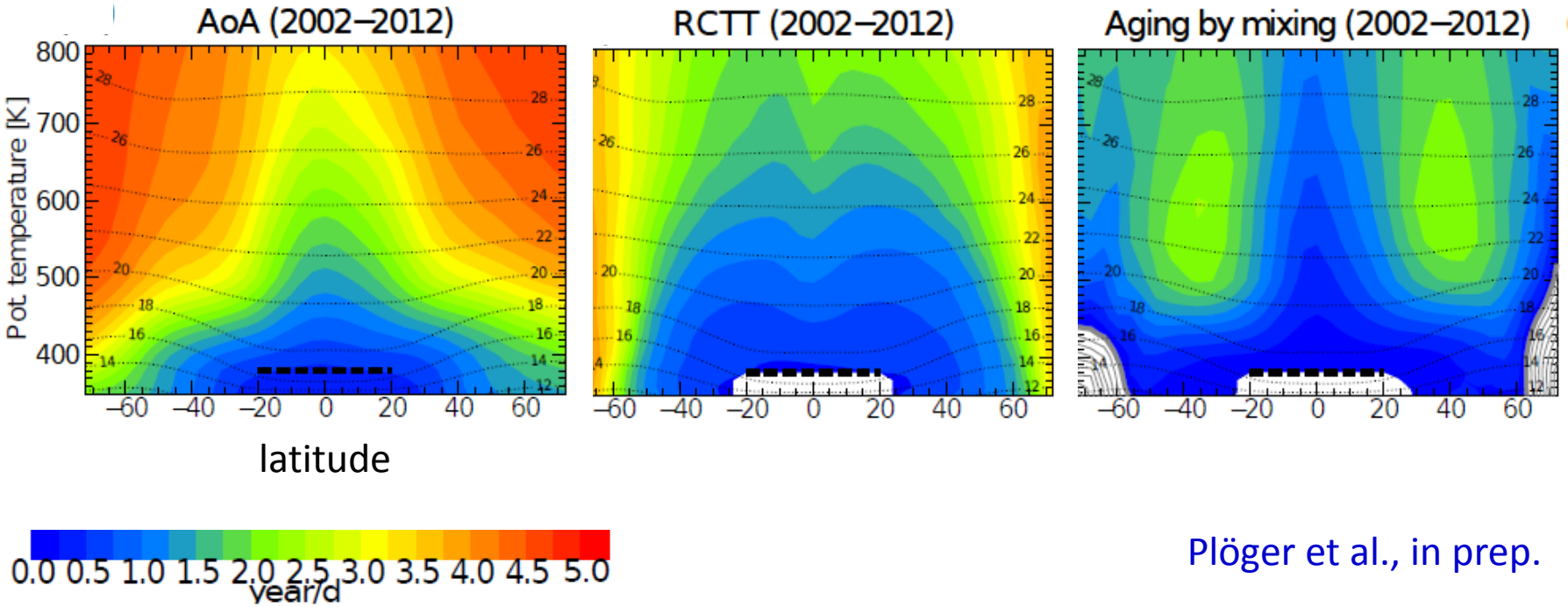
Plöger et al., submitted



$$\overline{\Gamma}(x,t) = \tau_{\mathrm{RCTT}}(x,t) + \int_{t_0}^{t} \mathscr{M}(x,t)\,\mathrm{d}t' \qquad \mathscr{M} = \frac{1}{\overline{\overline{\sigma}}}\nabla \cdot M$$

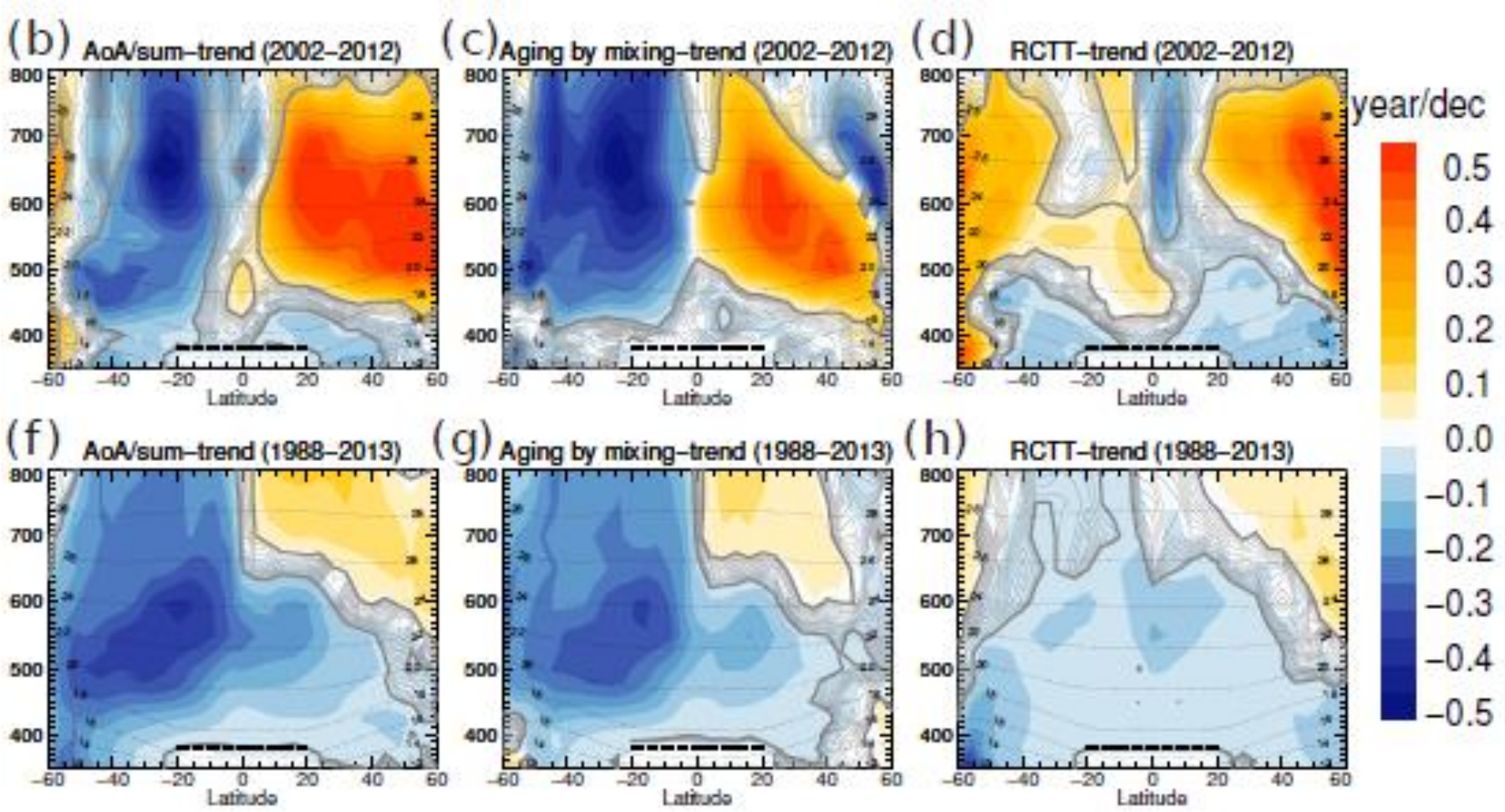
Plöger et al., in prep.

Contributions of mixing and residual mean circulation to age-of air



Plöger et al., in prep.

Contributions to AoA trends by mixing and residual circulation



Plöger et al., in prep.

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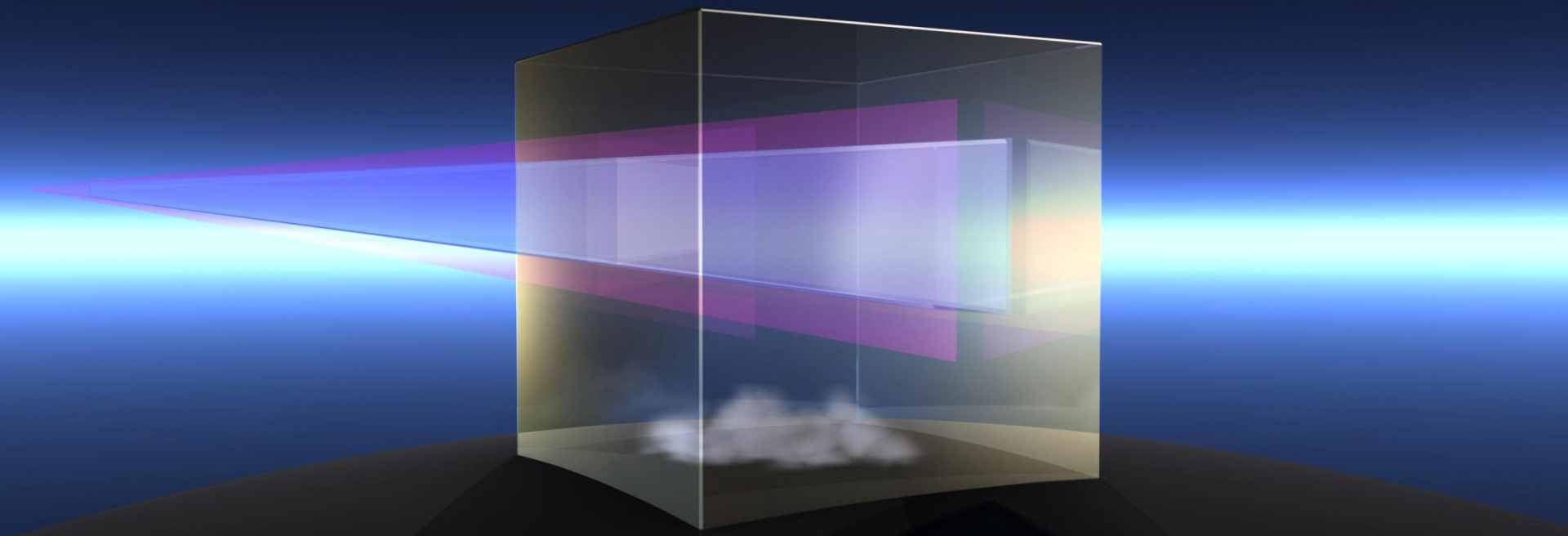
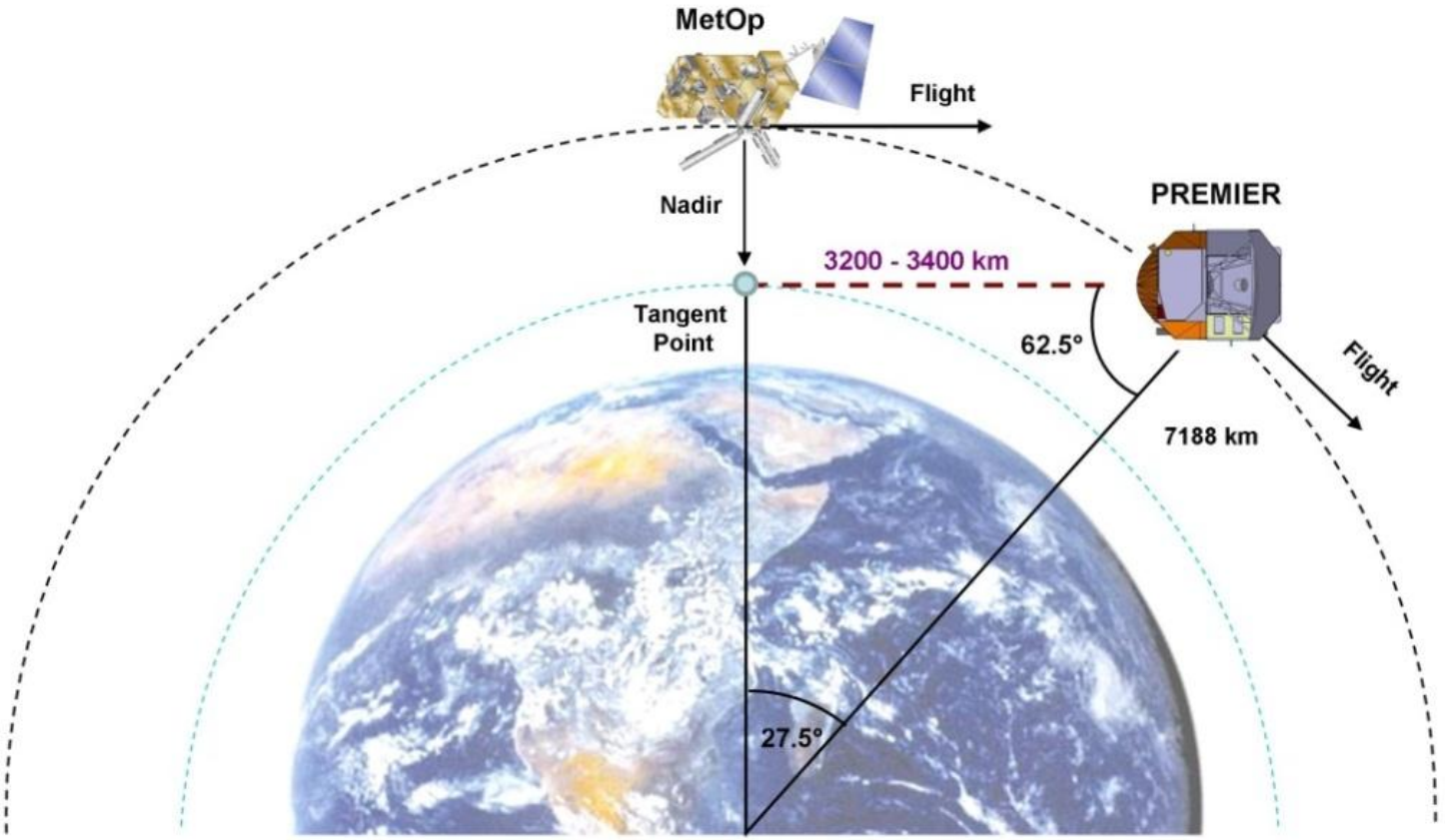
premier –

process exploration through measurements of infrared and millimetre-wave emitted radiation

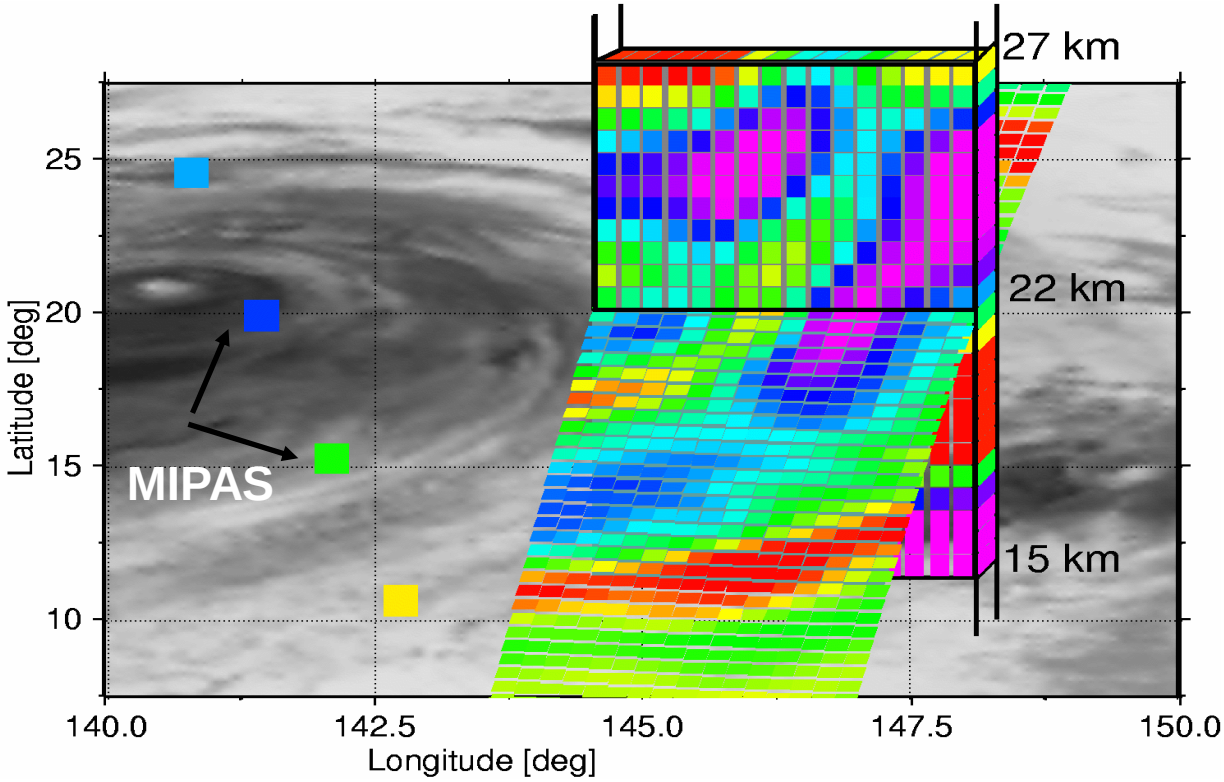


TO OBSERVE ATMOSPHERIC COMPOSITION FOR A BETTER UNDERSTANDING OF CHEMISTRY-CLIMATE INTERACTIONS

Formation flight with MetOP

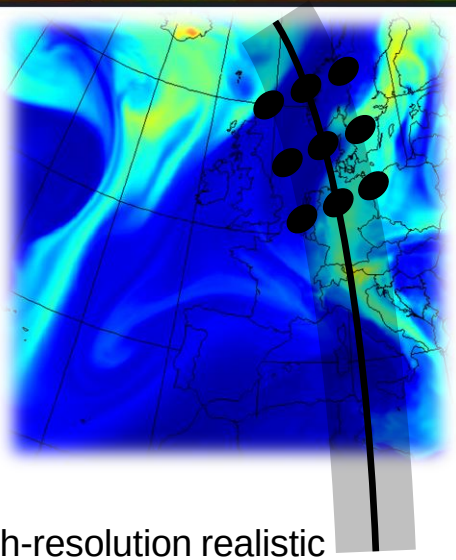


Sampling of gravity wave temperature structures



0.75 km x 25 km x 50 km (vertical x across track x along track

Assessment of scientific performance

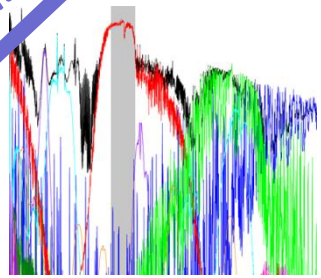


High-resolution realistic 3D model output ("Nature Run")

Sampling according to (future) satellite track & swath

Synthetic (reference) profiles for meteorology (T, q…) and composition parameters (O_3, CH_4…)

Radiative transfer model and application of (future) instrument characteristics



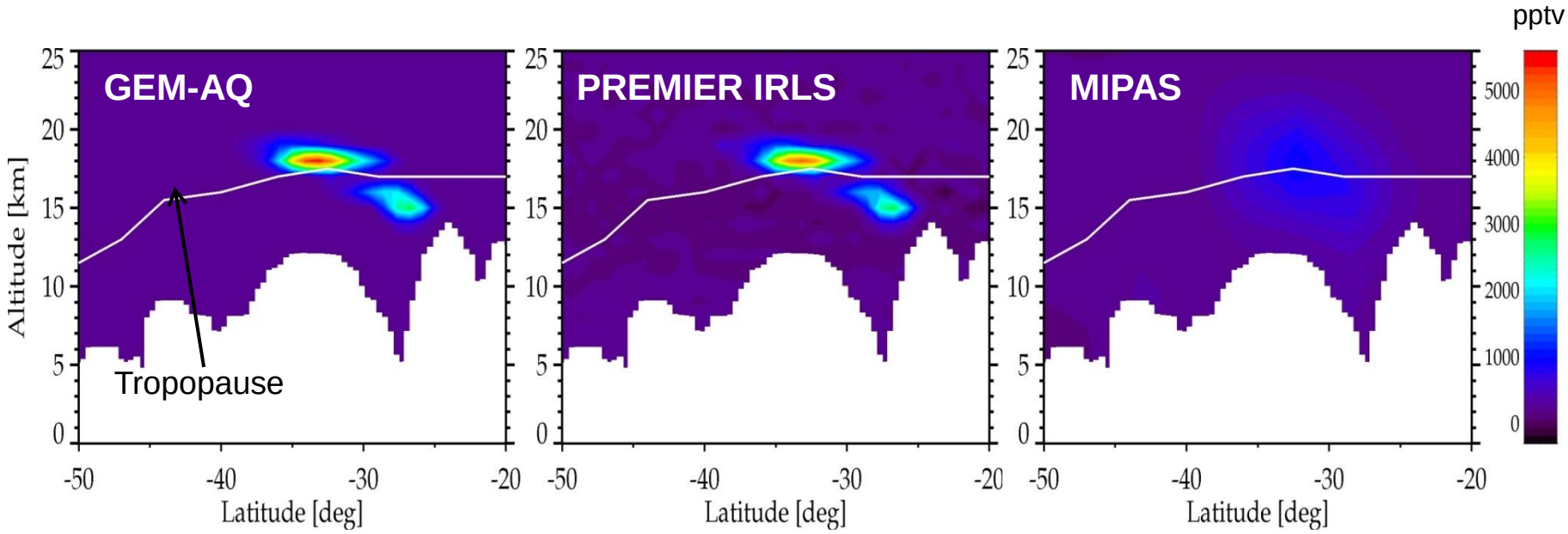
Evaluate (future) instrument capabilities

Synthetic (L1) spectra as would be seen by the (future) instrument if "nature run" was the reality.

Retrieval / inversion system

Retrieved synthetic (L2) profiles

High vertical and along-track resolution: HCN in double plume from Australian bush fires

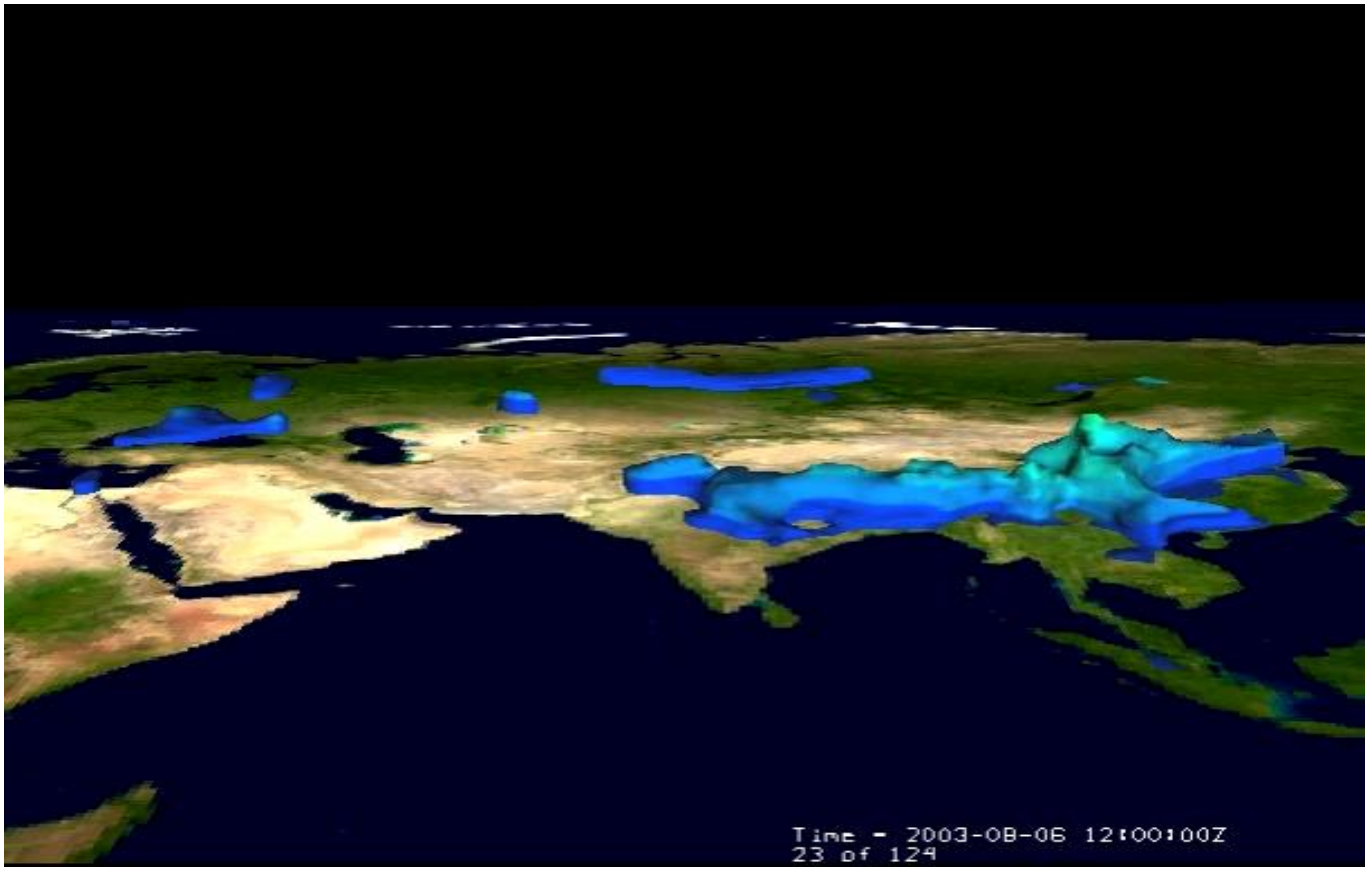


Courtesy of N. Glatthor

→ *IR Limb Imager will track ozone precursors and HCN in plumes to quantify ozone production and radiative forcing from pyroconvective sources*

Rapid upward transport of increased CH_4 emissions from South-East Asia

ECMWF / GEMS CH_4 – Aug to Oct 03



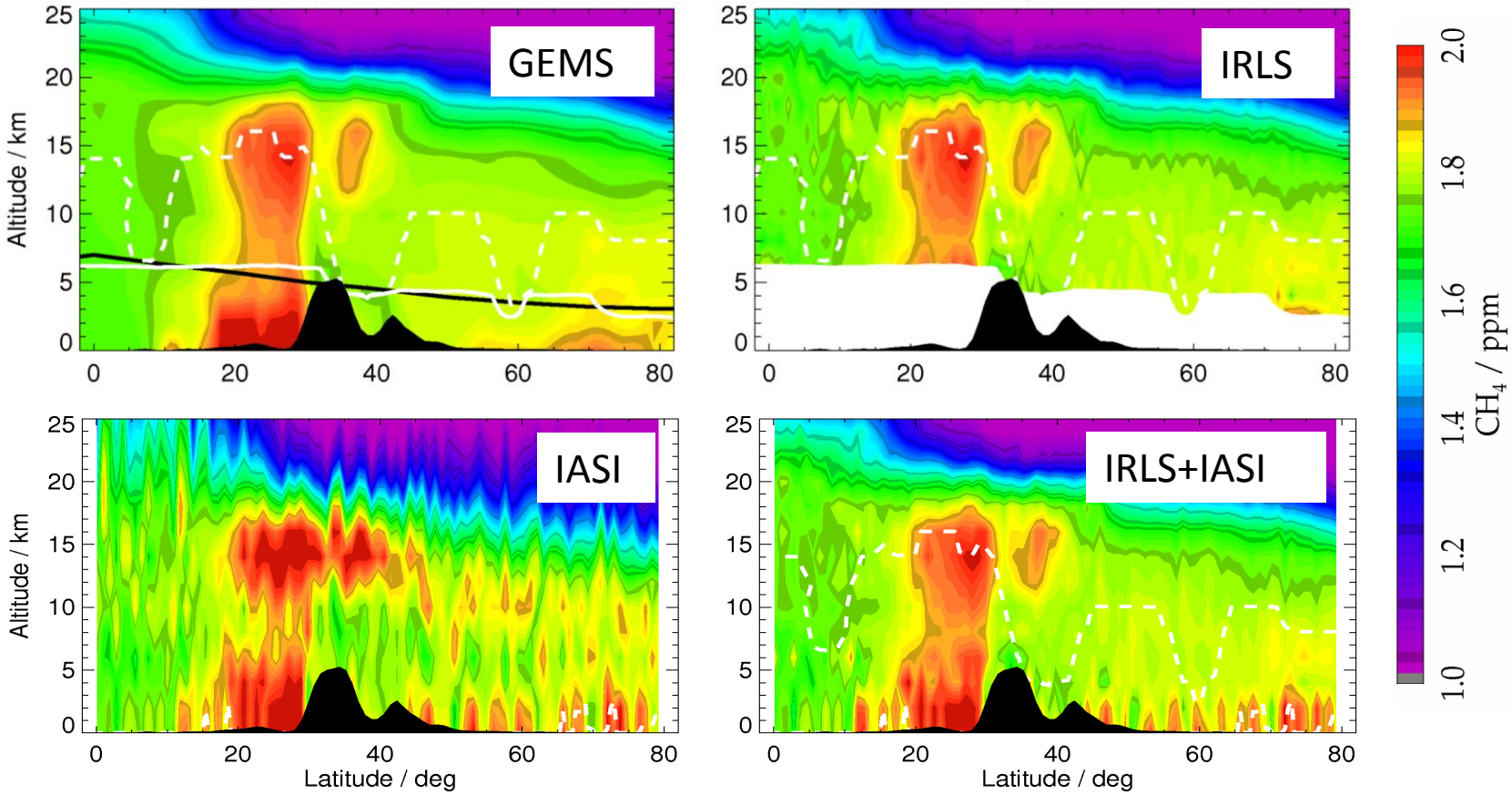
Height of 1.9 ppmv Contour

18 km

0 km

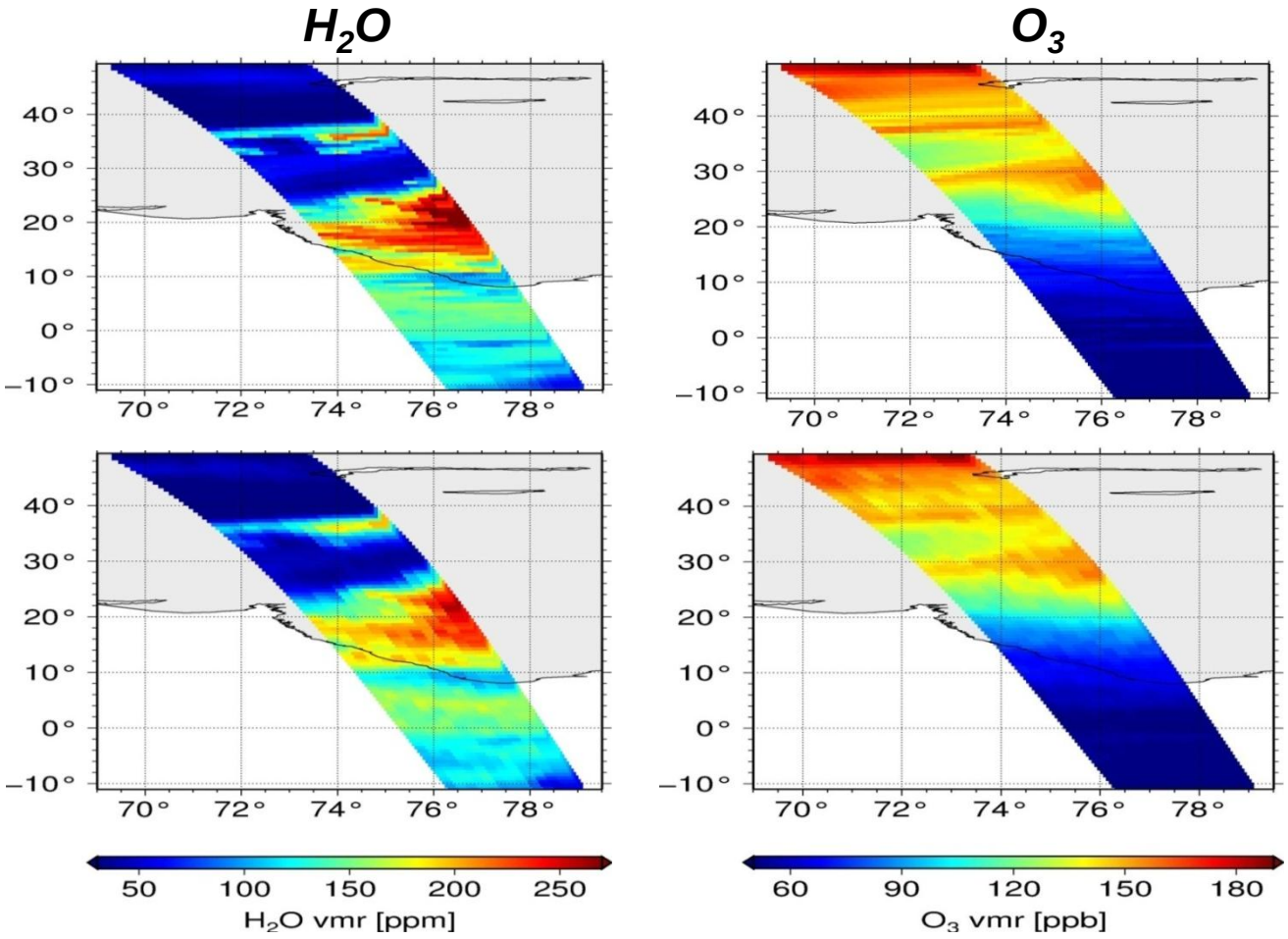
Results of retrieval simulations

Courtesy Alison Waterfall



- IR limb imager captures the structure of the plume in the UTLS.
- IASI-type instrument provides the extension to the sources.

Across-track capability
- monsoon periphery (12km) -



GEM-AQ

Infrared Limb Imager

Courtesy of Lars Hoffmann

Thanks for your attention!