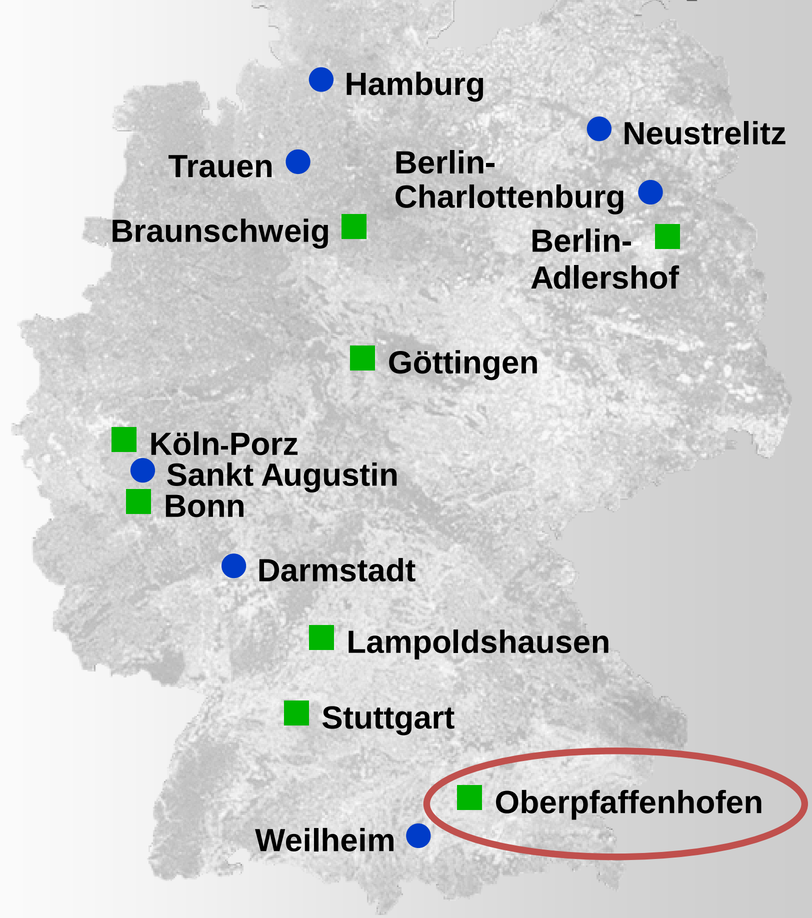
German Aerospace Centre -
Deutsches Zentrum für Luft- und Raumfahrt (DLR)

About 7800 co-workers in

34 research institutes and facilities

- ■ 8 main locations,
- ● 7 branch offices.



DLR

German Aerospace Centre - Deutsches Zentrum für Luft- und Raumfahrt (DLR)

Oberpfaffenhofen

- Deutsches Fernerkundungsdatenzentrum (DFD)
- DLR Earth Observation Center
- DLR-Institut für Hochfrequenztechnik und Radarsysteme
- DLR-Institut für Kommunikation und Navigation
- DLR-Institut für Methodik der Fernerkundung
- ➢ DLR-Institut für Physik der Atmosphäre
- DLR-Institut für Robotik und Mechatronik
- DLR-Institut für Systemdynamik und Regelungstechnik
- DLR Flugexperimente
- DLR Raumflugbetrieb und Astronautentraining
- Robotik und Mechatronik Zentrum

Total about 2000 co-workers in Oberpfaffenhofen

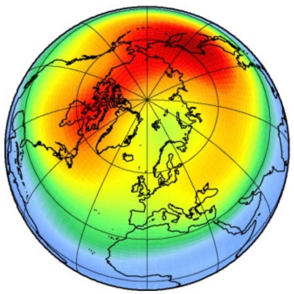
German Aerospace Centre -
Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Institute of Atmospheric Physics

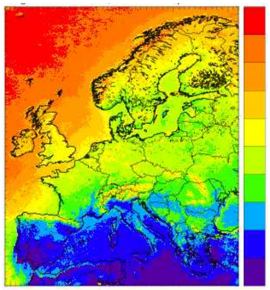
DLR

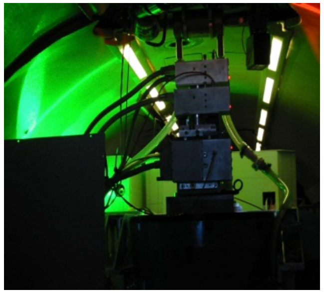
German Aerospace Centre -
Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Institute of Atmospheric Physics

Institut für Physik der Atmosphäre
Prof. Dr. M. Rapp

Atmospheric Dynamics	Atmospheric Trace Substances	Atmospheric Remote Sensing	Weather and Air Traffic	Lidar
Prof. Dr. R. Sausen	Dr. H. Schlager	Dr. R. Meerkötter Prof. Dr. B. Mayer (LMU)	Dr. T. Gerz Prof. Dr. G. Craig (LMU)	Dr. G. Ehret







currently about 120 co-workers

DLR

Impact of wind changes in the upper troposphere lower stratosphere on tropical ozone

Martin Dameris

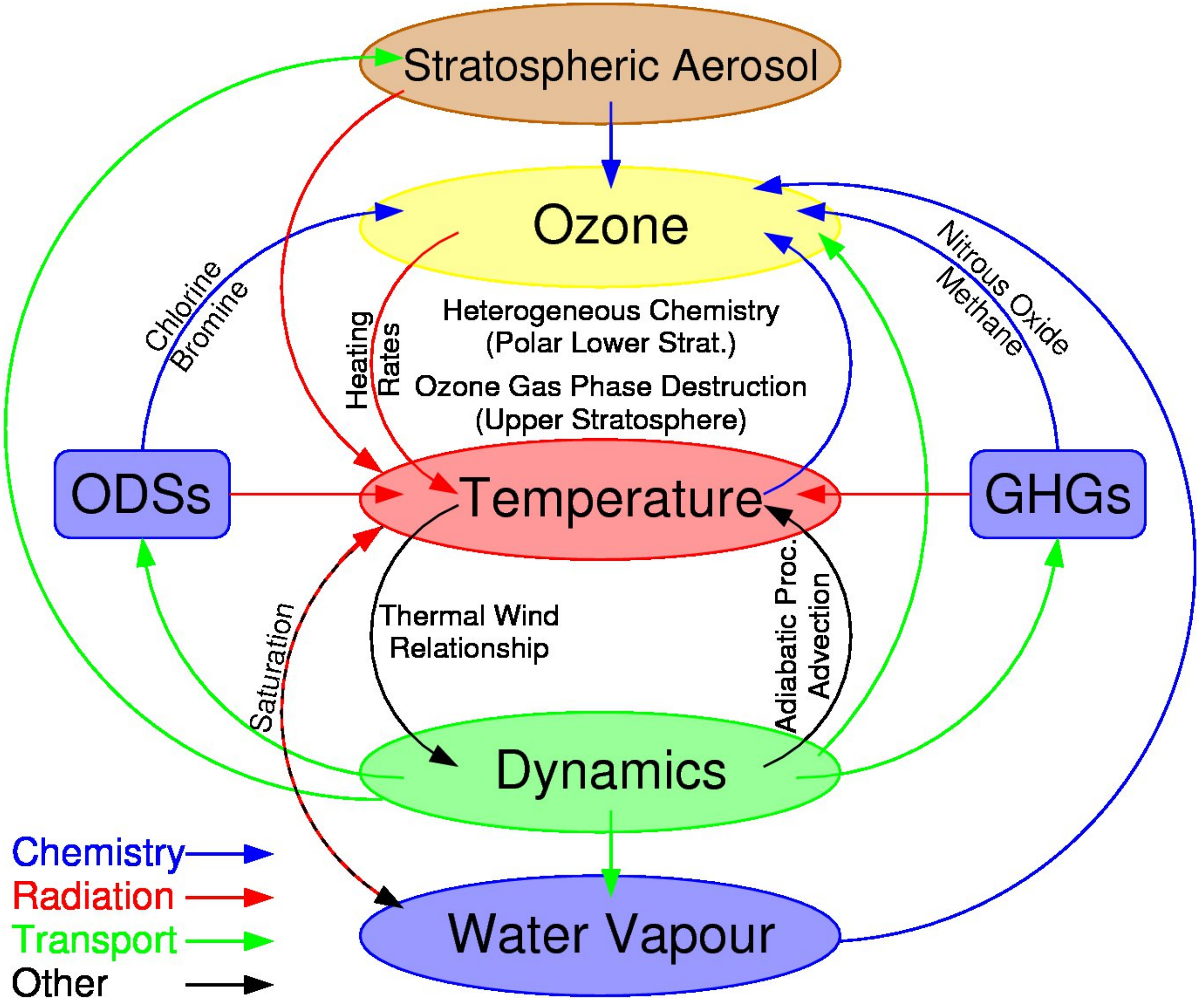
Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Institut für Physik der Atmosphäre, Oberpfaffenhofen

DLR

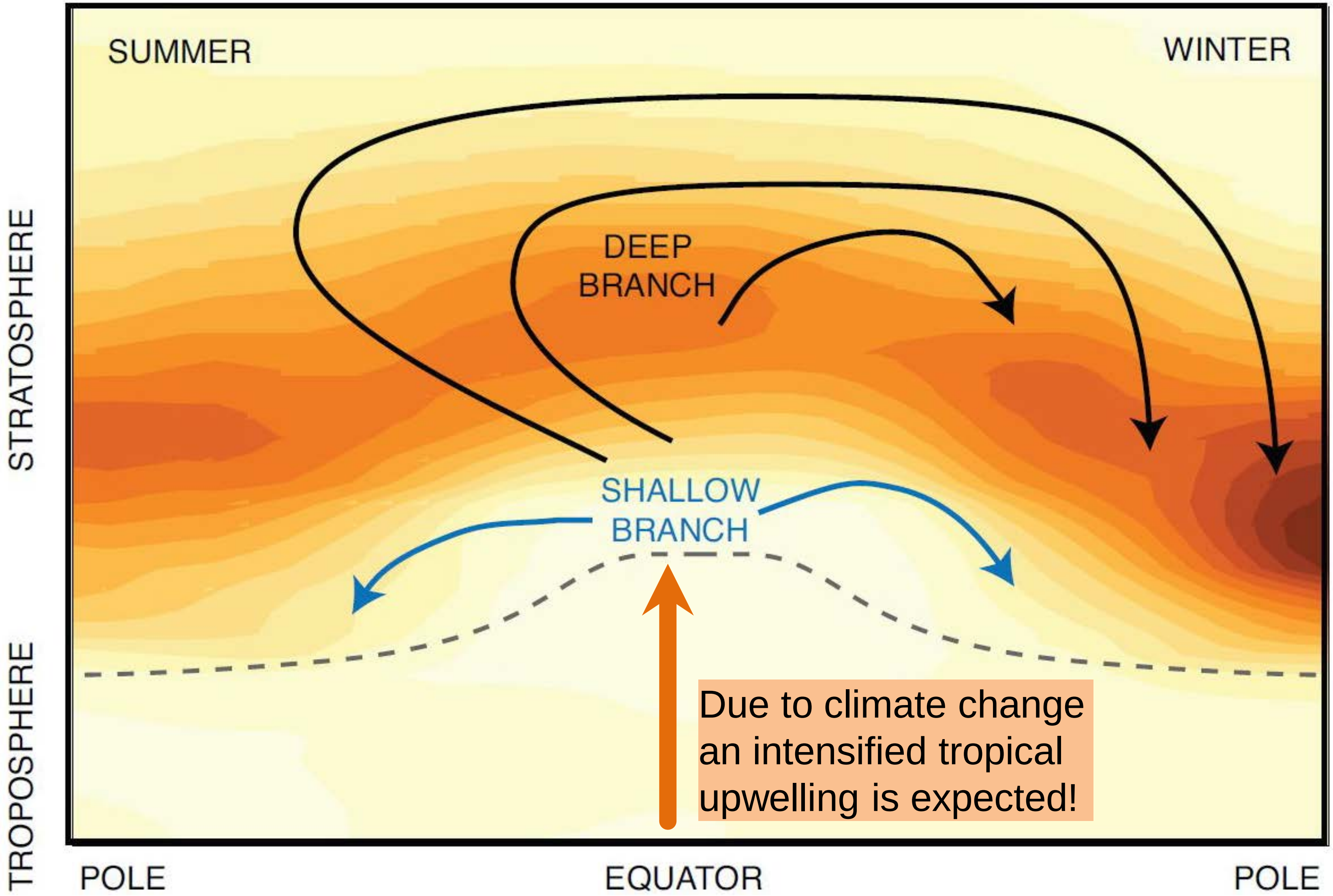
Role of winds in a changing climate

- Changes of the zonal flow and vortices have a strong impact on climate and weather. Therefore **global information is needed, in particular of the UTLS wind field** for investigations of related (dynamic) processes relevant for explaining changes in chemistry and climate.
- The characteristics of the zonal flow in the upper troposphere lower stratosphere (UTLS) are important to be known for
  - finding out the dynamical coupling / exchange of air between the stratosphere and troposphere and especially
  - determining stratospheric ozone concentrations.
- Currently largest **uncertainties** are existing **in the tropics**.

Climate-Chemistry-feedbacks in the stratosphere

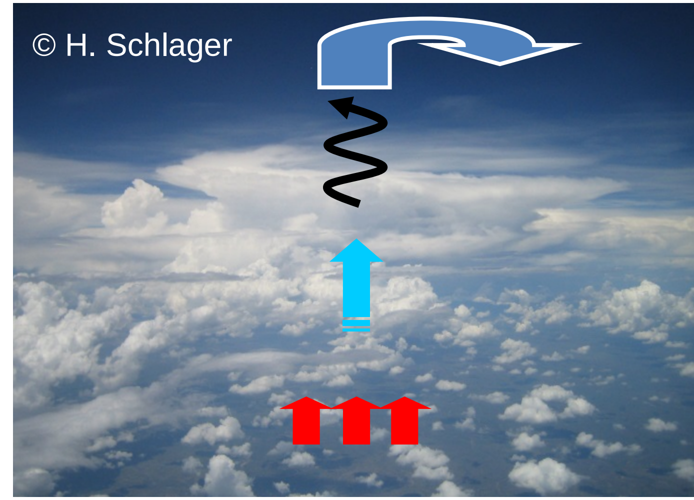


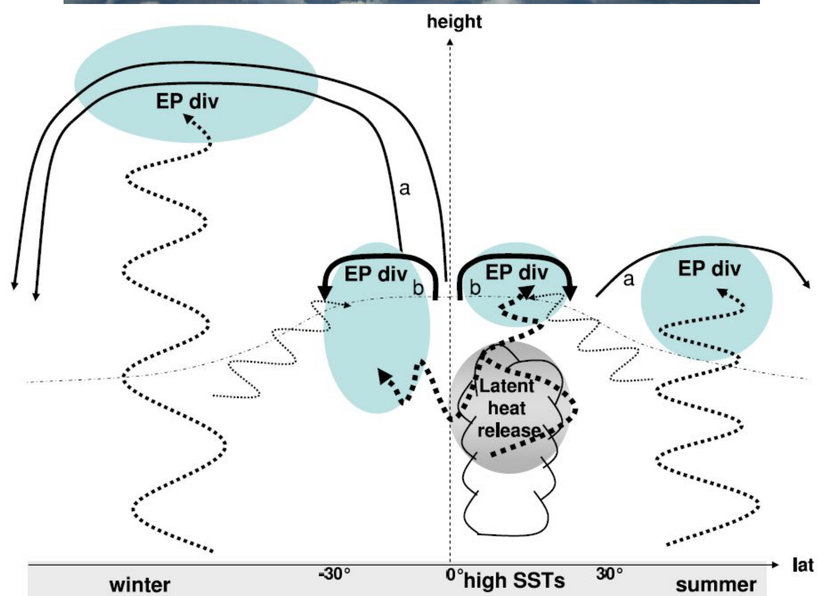
The Brewer-Dobson circulation



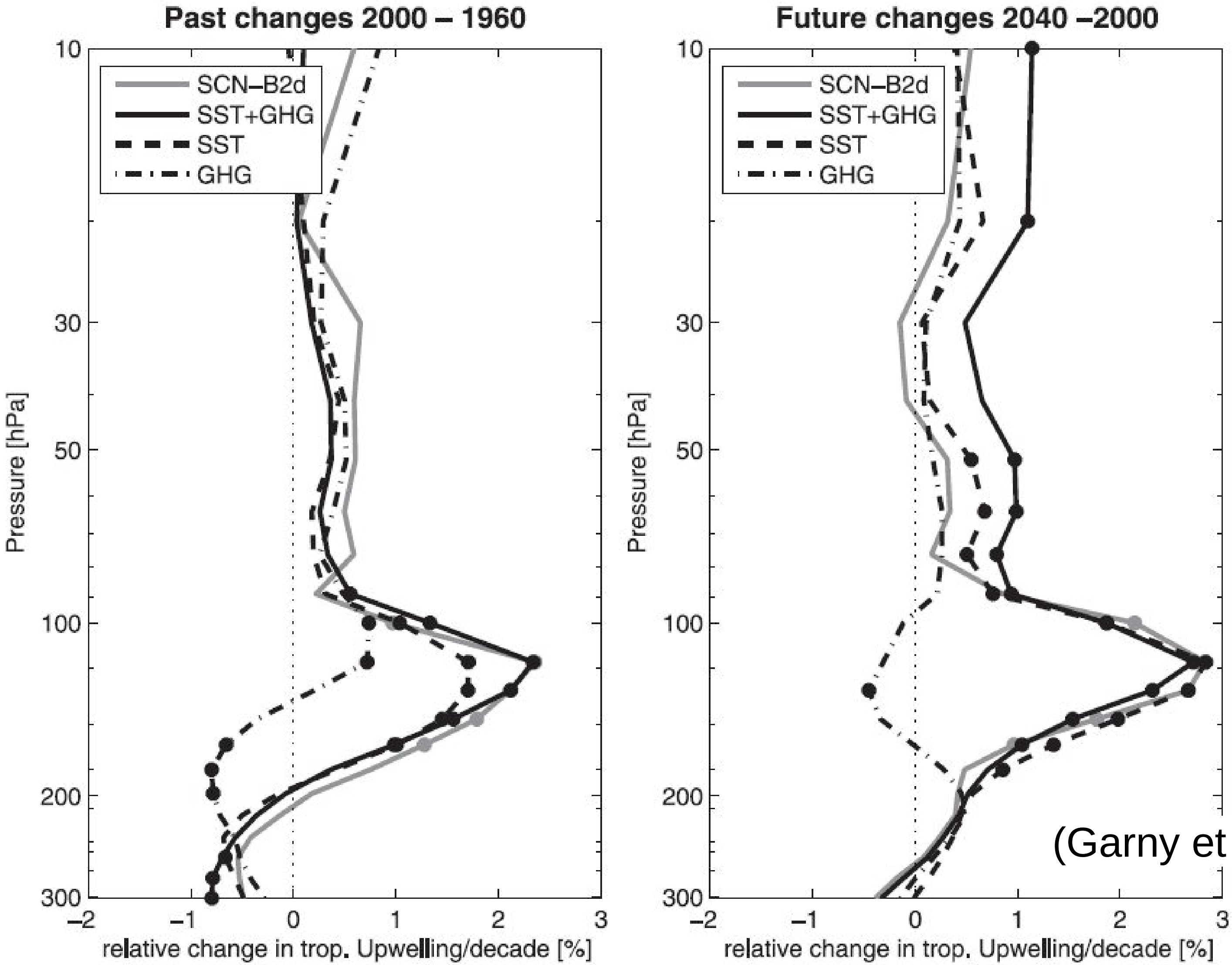
Role of the tropical sea-surface temperatures

- Enhanced tropical sea-surface temperatures (SSTs) lead to
  - a strengthening of deep convection,
  - increased release of latent heat which is connected with additional generation of quasi-stationary planetary waves,
  - intensified upwelling of tropical air masses (Deckert and Dameris, 2008a;b).
- Impact of prescribed SSTs on climatologies and long-term trends in CCM simulations were studied by Garny et al. (2009), in particular
- dynamically forced increase of tropical upwelling in the lower stratosphere (Garny, 2010; Garny et al., 2011).





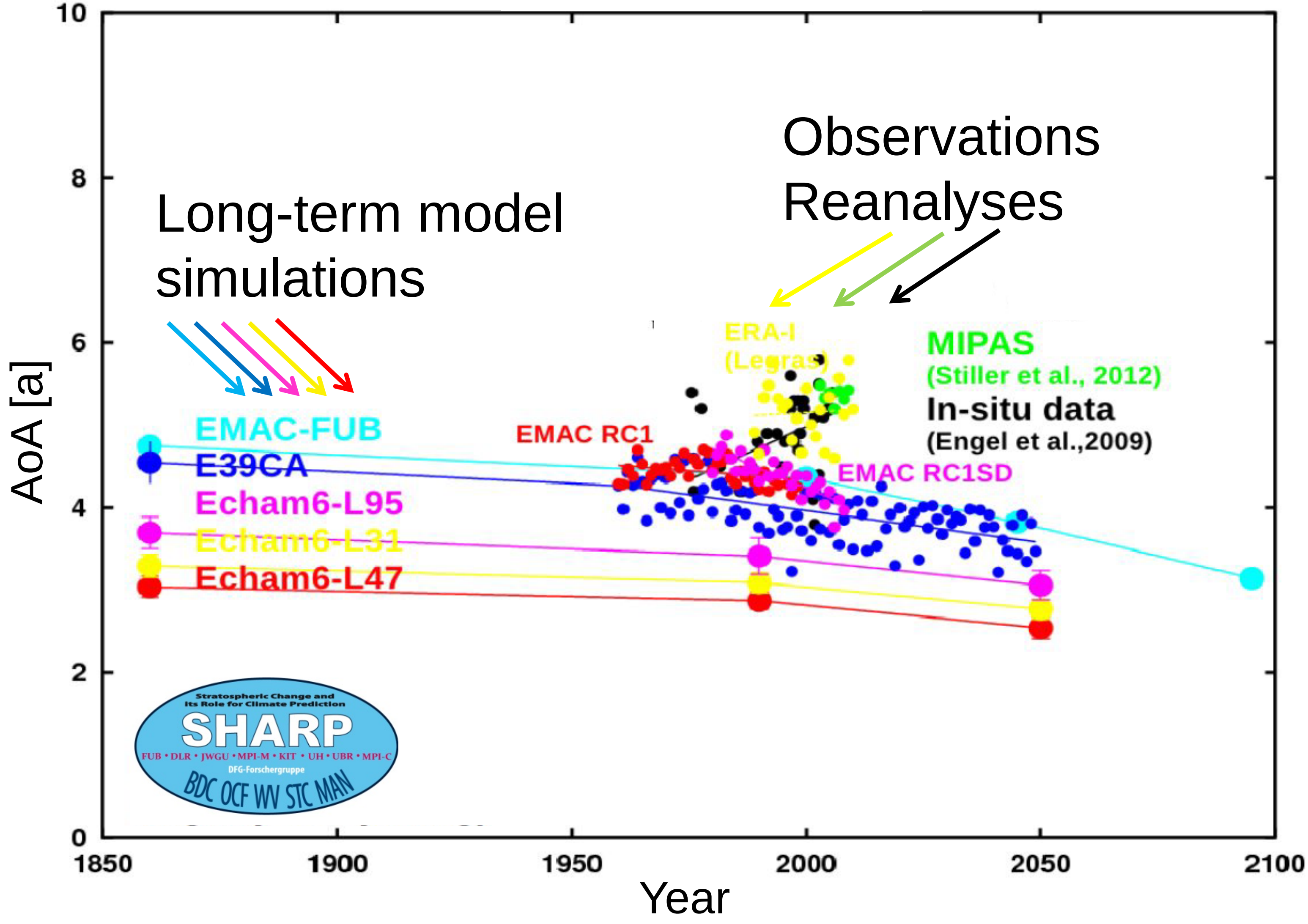
Annual mean relative changes in tropical upwelling



(Garny et al., 2011)

DLR

"Age-of-Air" at 24 km, 30°-50°N



DLR

WMO Ozone Assessment 2014 (Chapter 4)

- **<u>Climate models</u> consistently predict a long-term increase in the strength of the Brewer-Dobson circulation due to greenhouse gas increases, with important impacts on stratospheric and tropospheric composition.**
  - The predicted increase in the strength of the Brewer-Dobson circulation extends throughout the depth of the stratosphere.
  - **<u>Observations</u>** of changes in temperature, ozone, and trace gases over the past three to five decades are suggestive of increased upwelling in the tropical lower stratosphere, consistent with a strengthening of the shallow branch of the Brewer-Dobson circulation predicted by models. There is **<u>large uncertainty in changes</u>** in the deep branch of the Brewer-Dobson circulation inferred from observations in the mid and upper stratosphere.

Another open point / question

The upward transport of air in the tropical upper troposphere lower stratosphere (UTLS) region (e.g. the **Asian monsoon circulation**) is modified by climate change and therefore the entry of trace gases and particles (aerosols) in the strato-sphere are changed and also the chemical composition.

? Which processes determine the transport of air, and with that the entry of trace gases and -substances in the stratosphere? What is the most important process? (For instance: over-shooting convection over continents or the Asian summer monsoon.)

➔ The EU-project ***StratoClim**** – a joint activity of European research groups including **CNR-ISAC** and **DLR-IPA**.

[* Stratospheric and upper tropospheric processes for better climate predictions]

StratoClim: Objectives

- Improve our quantitative knowledge of **air mass transport pathways between the troposphere and stratosphere**, including chemical processing along these pathways, with particular **focus on the Summer Asian Monsoon**;
- understand chemical composition, dynamical and thermal structure in the upper troposphere and stratosphere (UTS) within the **context of climate change**; <u>in particular</u>:

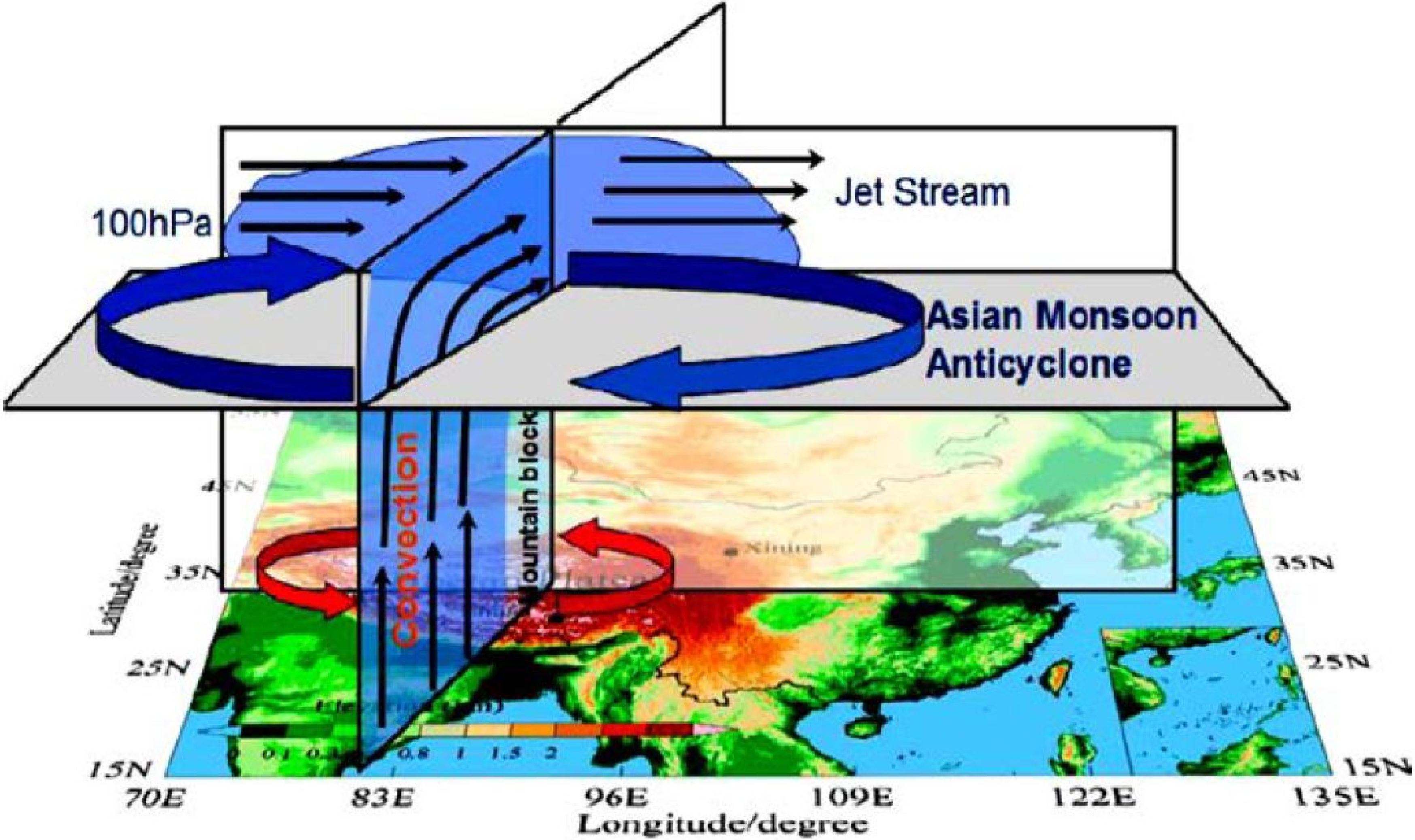
➔ upgrade the understanding of intra-seasonal, inter-annual, and decadal **variability of water vapour** in the UTS;

➔ quantify depletion/recovery of the **stratospheric ozone layer** in response to changing concentrations of ozone depleting substances (ODSs) and greenhouse gases (GHGs), **focussing on the Arctic region and the tropics**;

StratoClim: Objectives

- evaluate **feedbacks** between the **stratospheric ozone layer** (polar variability, polar long-term depletion, global variability and future super recovery), **climate and surface** weather patterns;
- improve the understanding of the **interaction between stratospheric changes and tropospheric composition**, including surface processes;
- improve the knowledge of **dynamical interactions between the stratosphere and the troposphere**, particularly mechanisms of coupling in the Arctic and North Atlantic-European region from intra-seasonal to decadal and centennial timescales;

Asian Monsoon



DLR

The stratosphere in the climate system

It is evident that climate change is not only affecting the troposphere (the greenhouse effect: $\Rightarrow$ warming) but is also modifying the stratosphere (e.g. cooling).

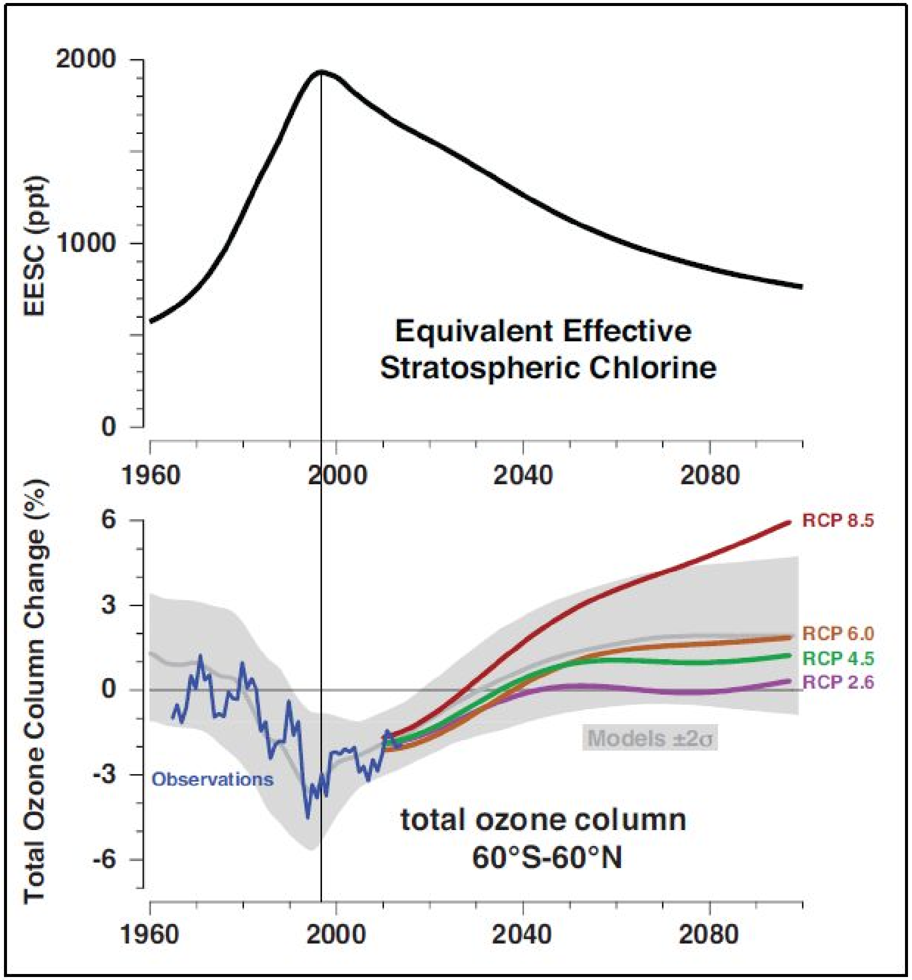
? How are the interactions between climate change and modifications of the circulation and chemical composition of the stratosphere?

? How is climate change influencing the stratospheric ozone layer?

Due to lower stratospheric temperatures, chemistry is directly affected; for example the content of ozone (O_3) in the

- middle and upper stratosphere is enhanced, while in the
- polar lower stratosphere is reduced.

Evolution of the stratospheric ozone layer

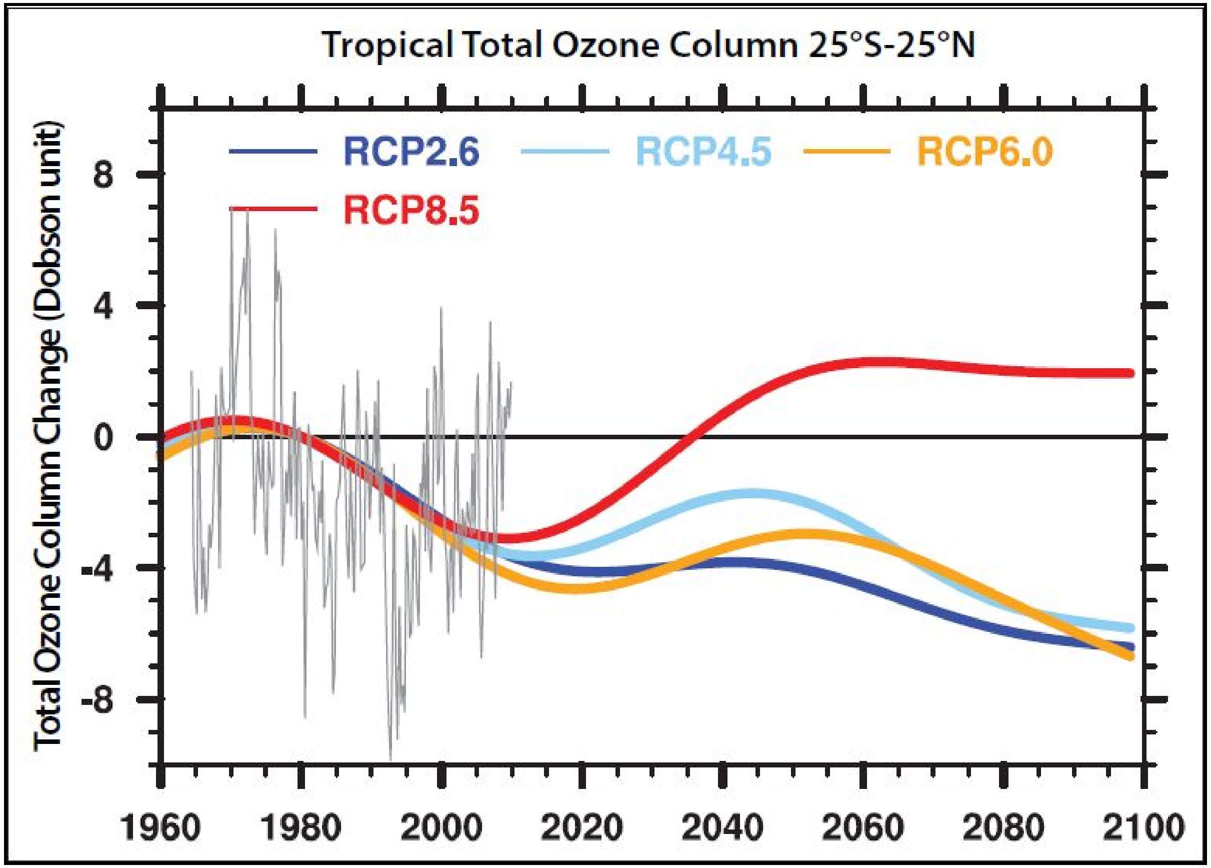


<u>Top figure</u>:
Variation of EESC in midlatitudes from 1960 to 2100.

<u>Bottom figure</u>:
Evolution of the total ozone column depending on (four) different greenhouse gas scenarios (with different concentrations of CO_2, CH_4 and N_2O):
The four scenarios correspond to a global radiative forcing of +2.6 (blue), +4.5 (green), +6.0 (brown), and +8.5 (red) in W m^{-2}.

(WMO, 2014)

Evolution of the tropical stratospheric ozone layer

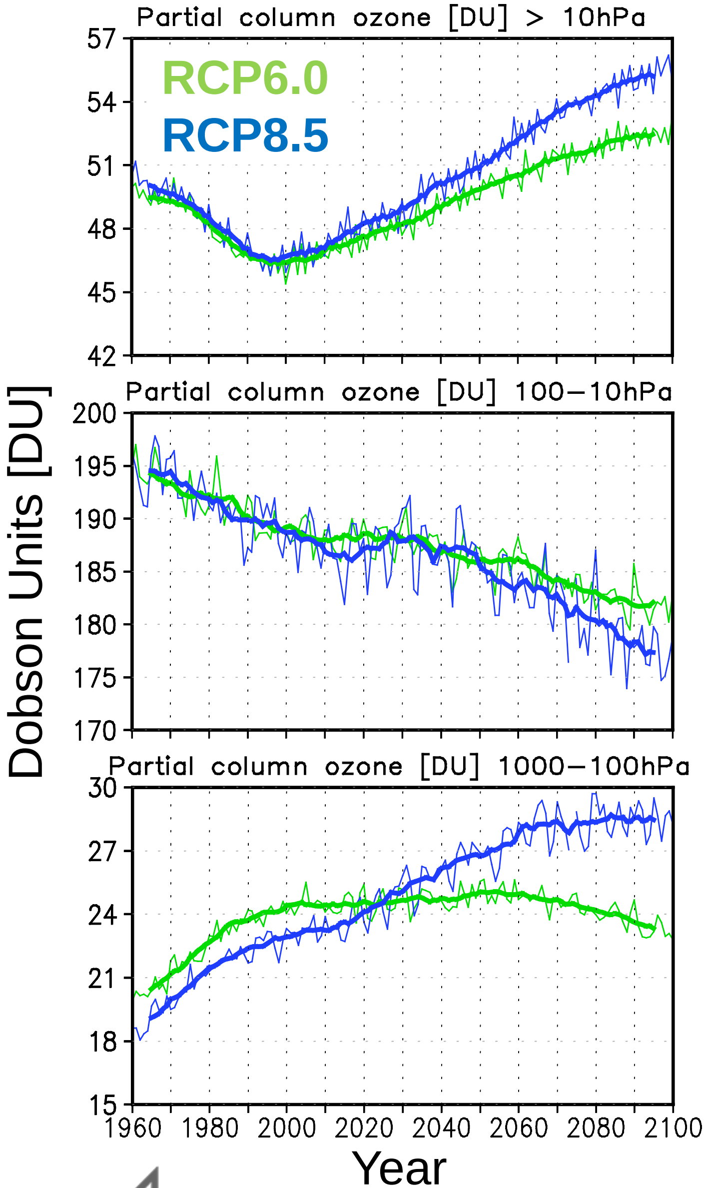


Evolution of total ozone column in the tropics (25°S-25°N) for the four greenhouse gas scenarios.

(WMO, 2014)

DLR

Evolution of the tropical stratospheric ozone layer



Evolution of partial ozone columns in the tropics (20°S-20°N) at different high regions for two greenhouse gas scenarios (preliminary results!):

Top: Above 30 km – future increase due to stratospheric cooling (chemistry).

Middle: Between about 30 to 15 km – future decrease due to enhanced upwelling (dynamics).

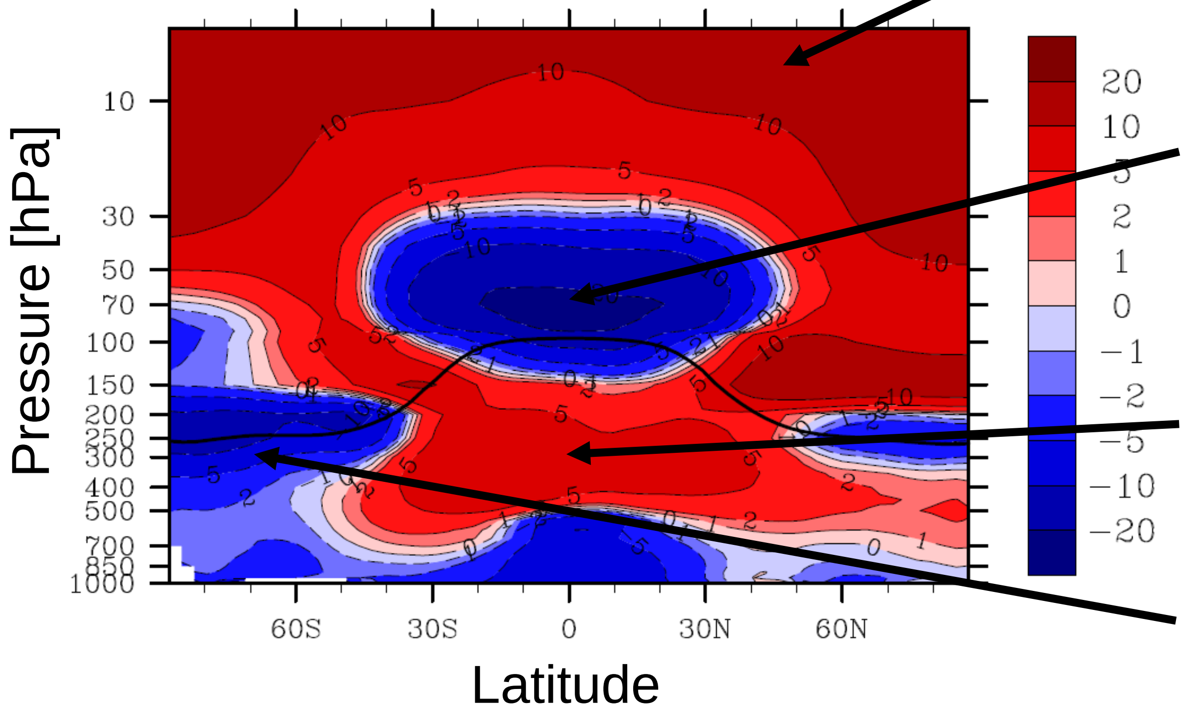
Bottom: Between about 15 km and the surface – more ozone due to anthropogenic NO_y emissions (chemistry).

(in cooperation with S. Meul and U. Langematz, FU Berlin)

DLR

Ozone feedback in CO_2 increase simulations

Ozone concentration change [in %] under CO_2 doubling



- Ozone destruction is reduced in the middle and upper stratosphere due to cooling.
- **Ozone reduced due to tropical upwelling which increases as troposphere warms.**
- Increased NO_y controls ozone response in the upper troposphere.
- Polar ozone reduced due to enhanced PSC formation.

(Dietmüller et al., 2014)

DLR

Tasks and goals

There is an urgent need, both for

- **atmospheric research** of dynamic processes and for
- **evaluation purposes** of atmospheric circulation models (AGCMs), climate models (AOGCMs) and climate-chemistry models (CCMs). [Currently used models are representing the stratosphere with a horizontal resolution of about 150-300 km and a vertical resolution of 1-2 km.]

In particular, adequate tropical observations are scarce to provide a robust foundation for model evaluation.

Especially, having wind profile observations in the tropics would help considerably in advancing understanding of tropical dynamics and its consequences for climate.

Investigations of these **changes of dynamics and ozone** will be in the focus of atmospheric research in the coming years.