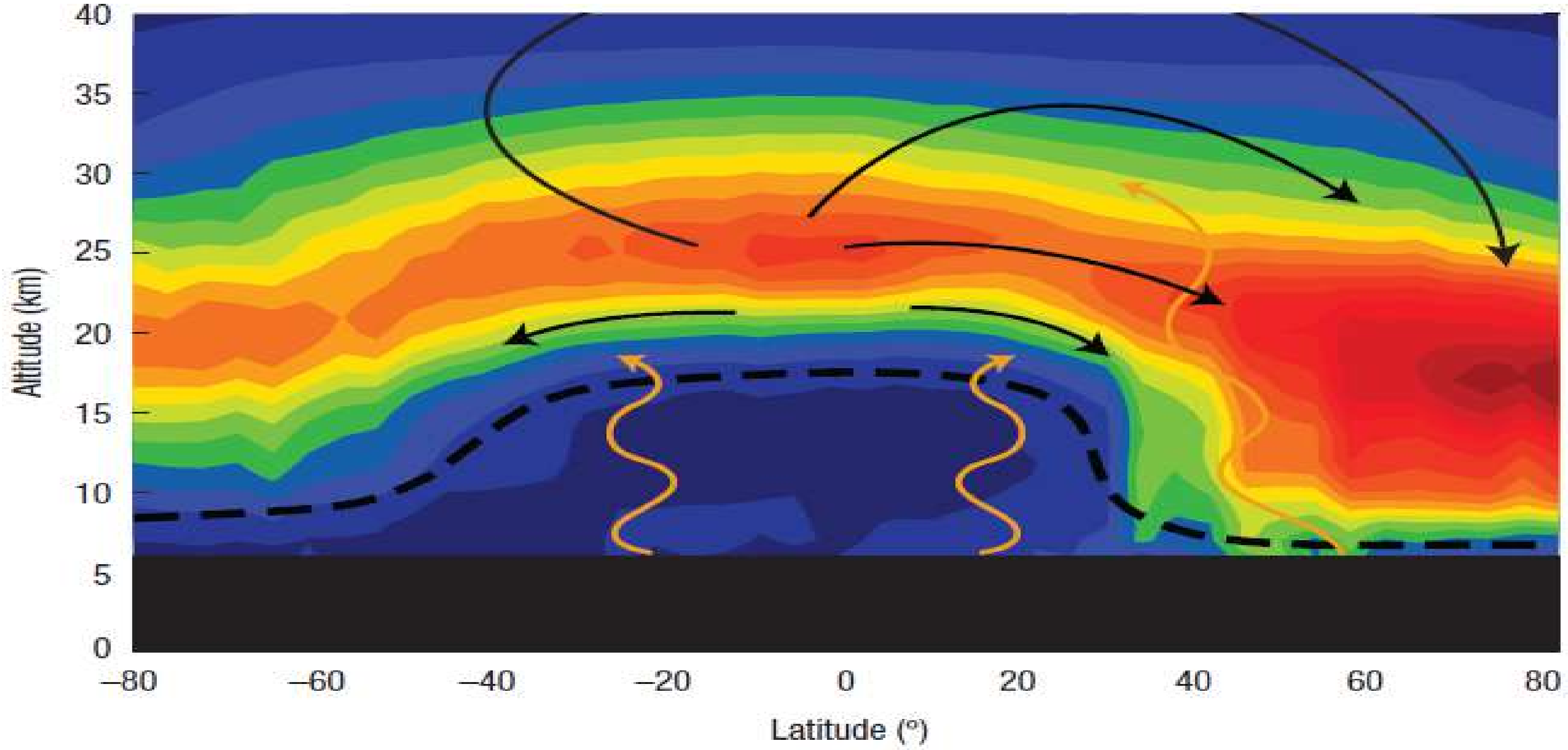
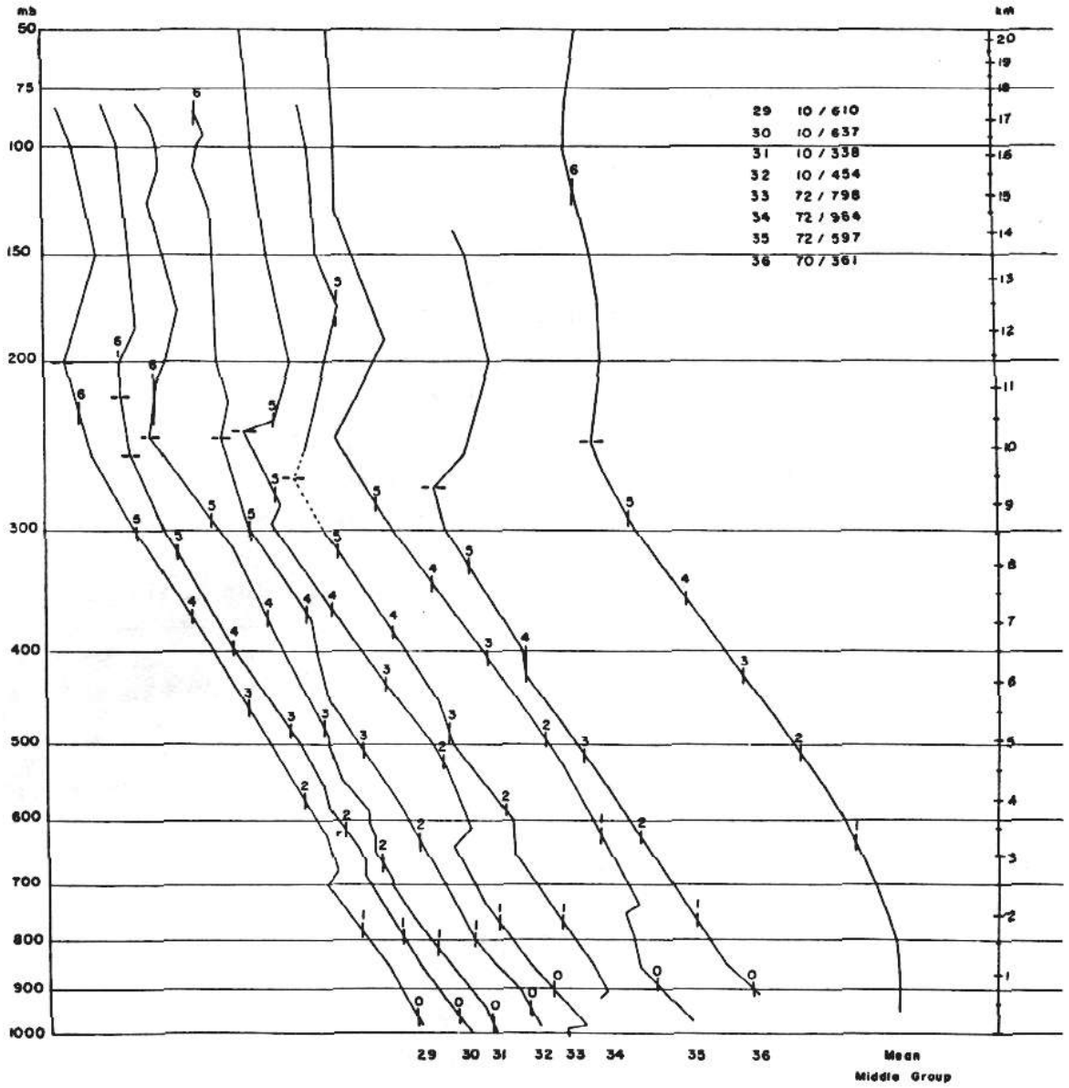
The Tropopause Region in a Changing Atmosphere

The Tropopause



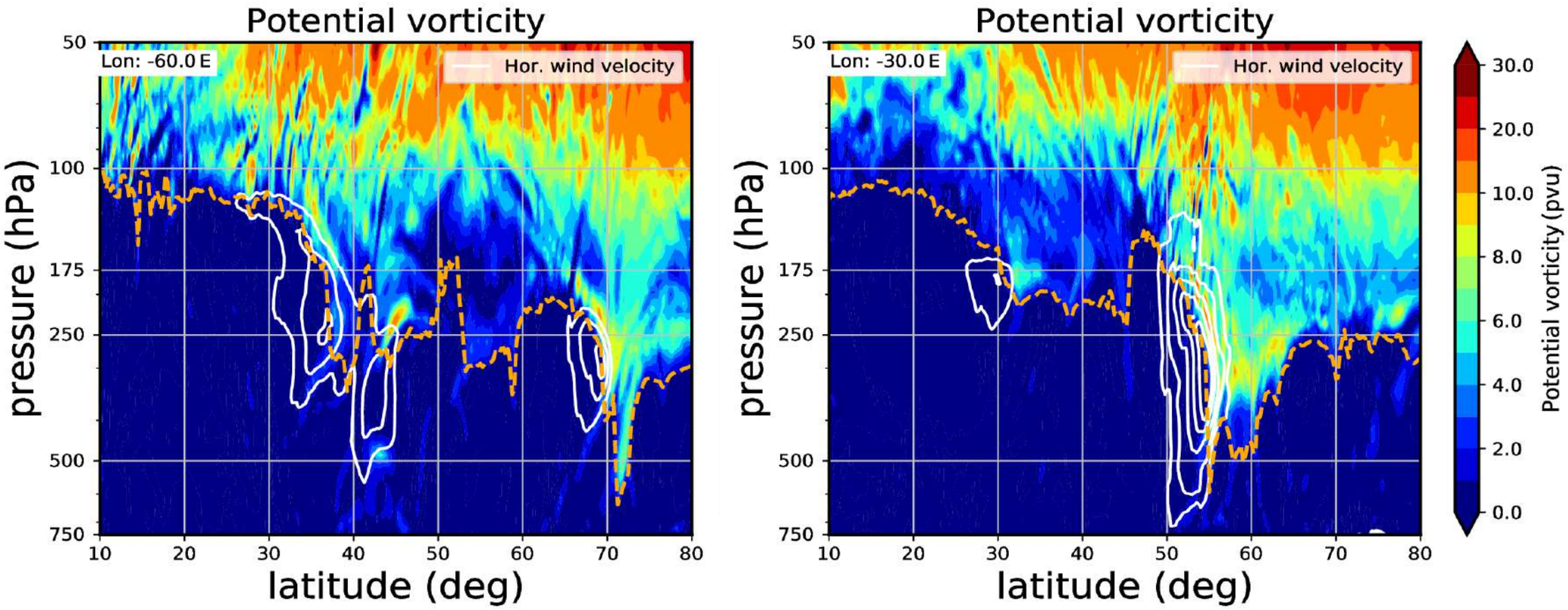
The Tropopause: 1957

Observed temperature Profiles in midlatitudes:
WMO (1957):
dT/dz > -2K/km
and on average
for at least two kilometers



Defant and Taba (1957)

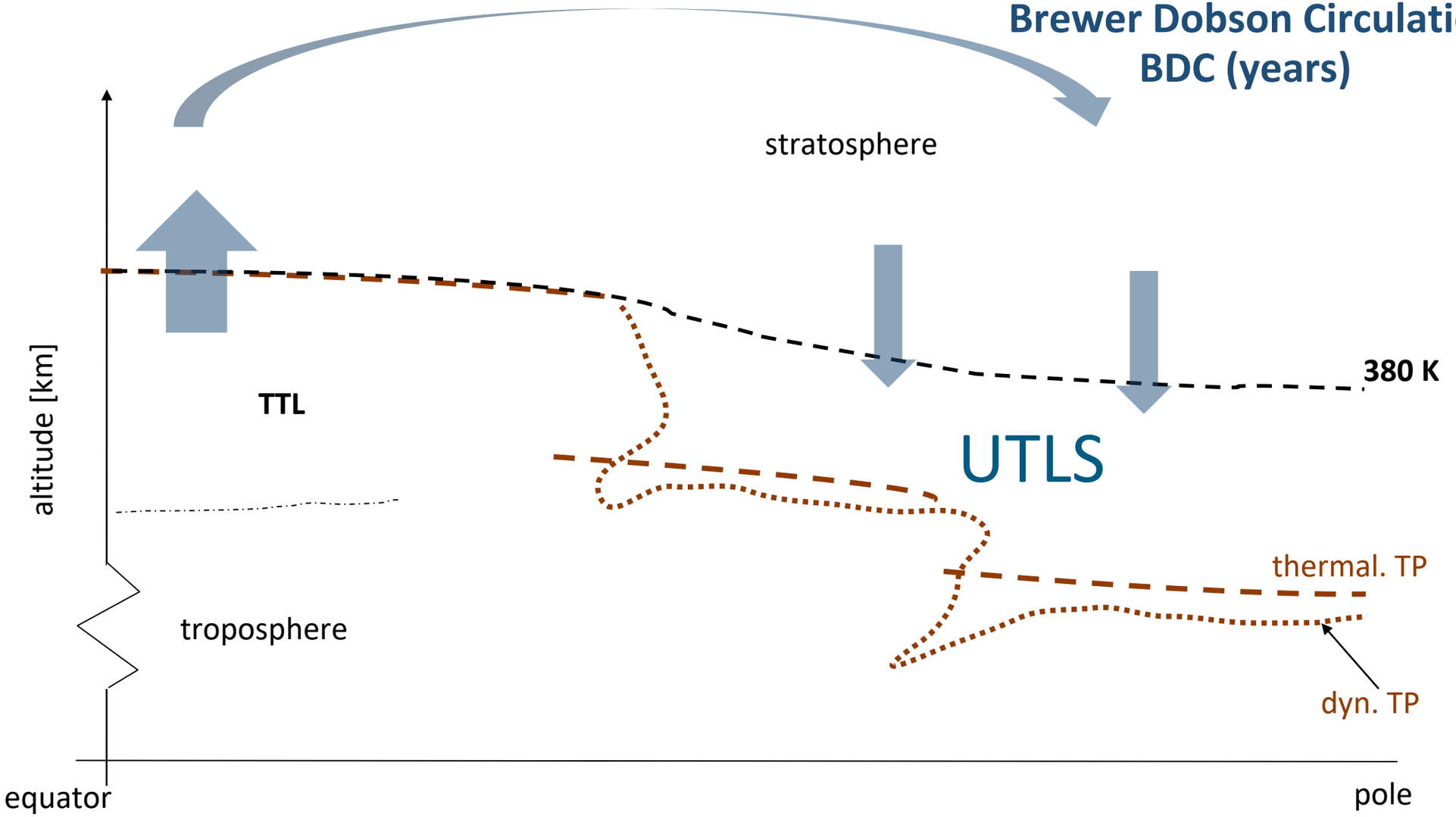
The Tropopause



Large spatial and temporal variability of the tropopause location and jets

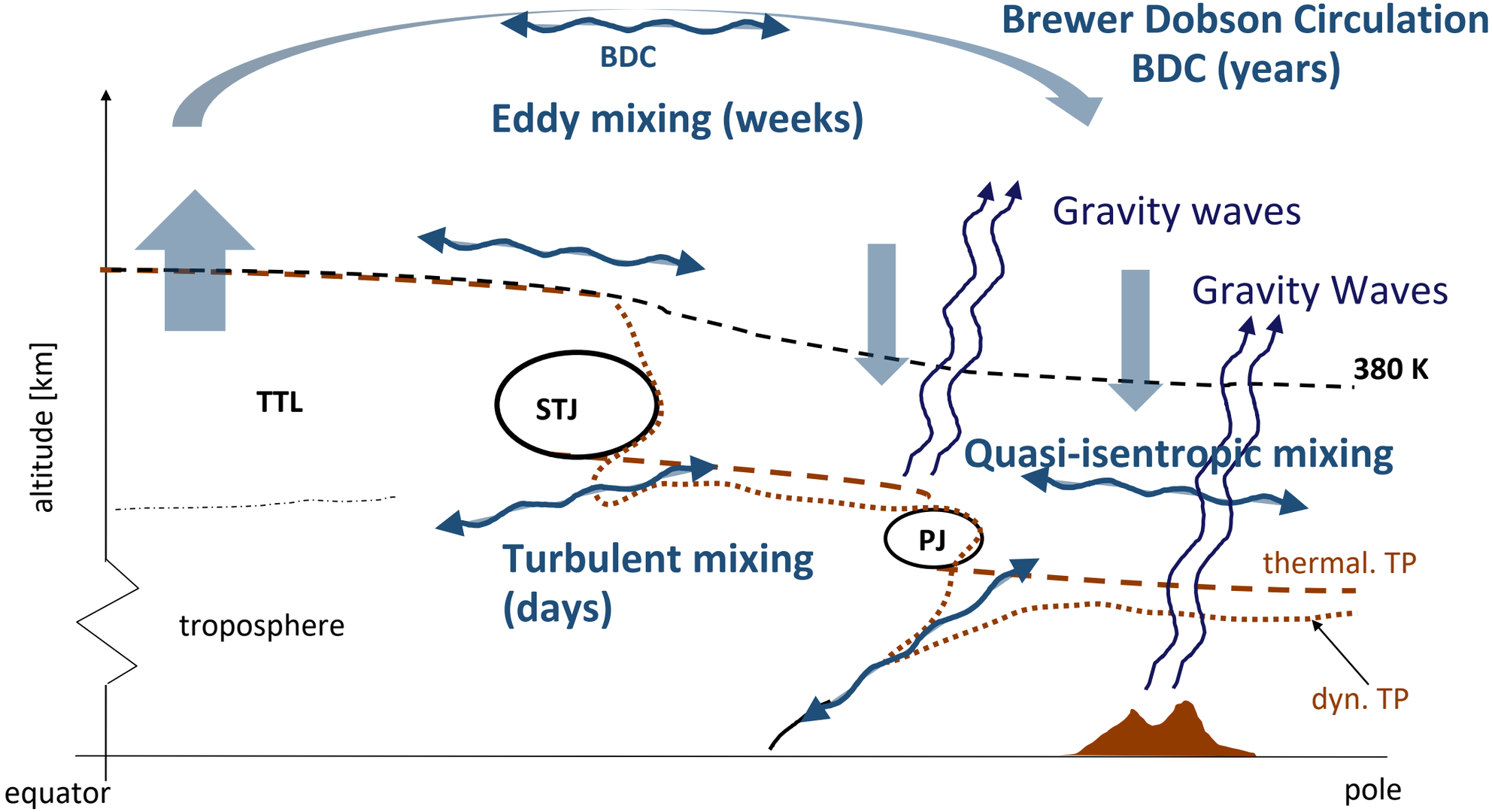
The UTLS as a transition region of scales

Large scale impact of the stratospheric circulation (global scale, years)



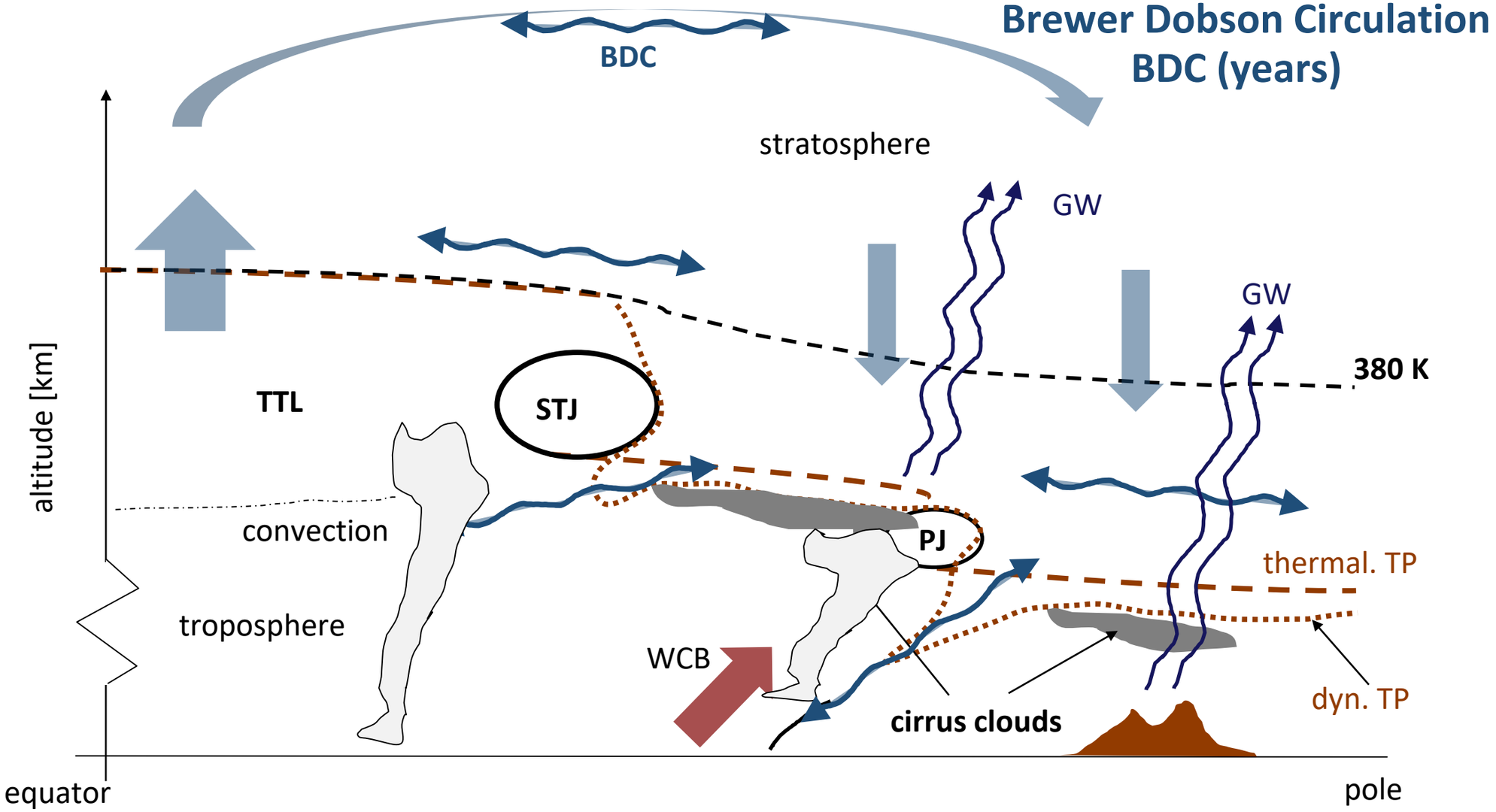
The UTLS as a transition region of scales

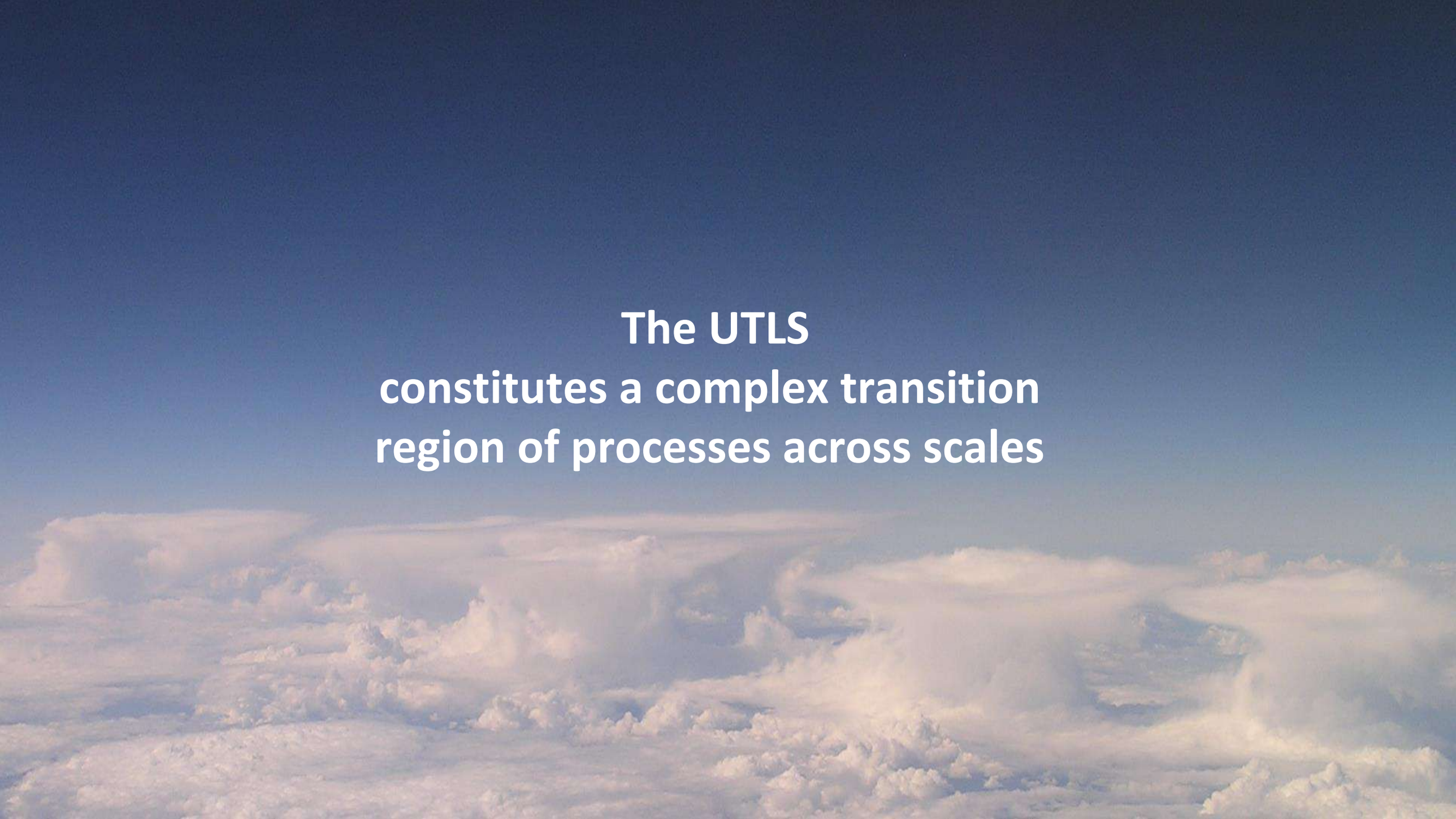
Rapid dynamical processes leading to mixing (synoptic scale to local, subseasonal scale to days)



The UTLS as a transition region of scales

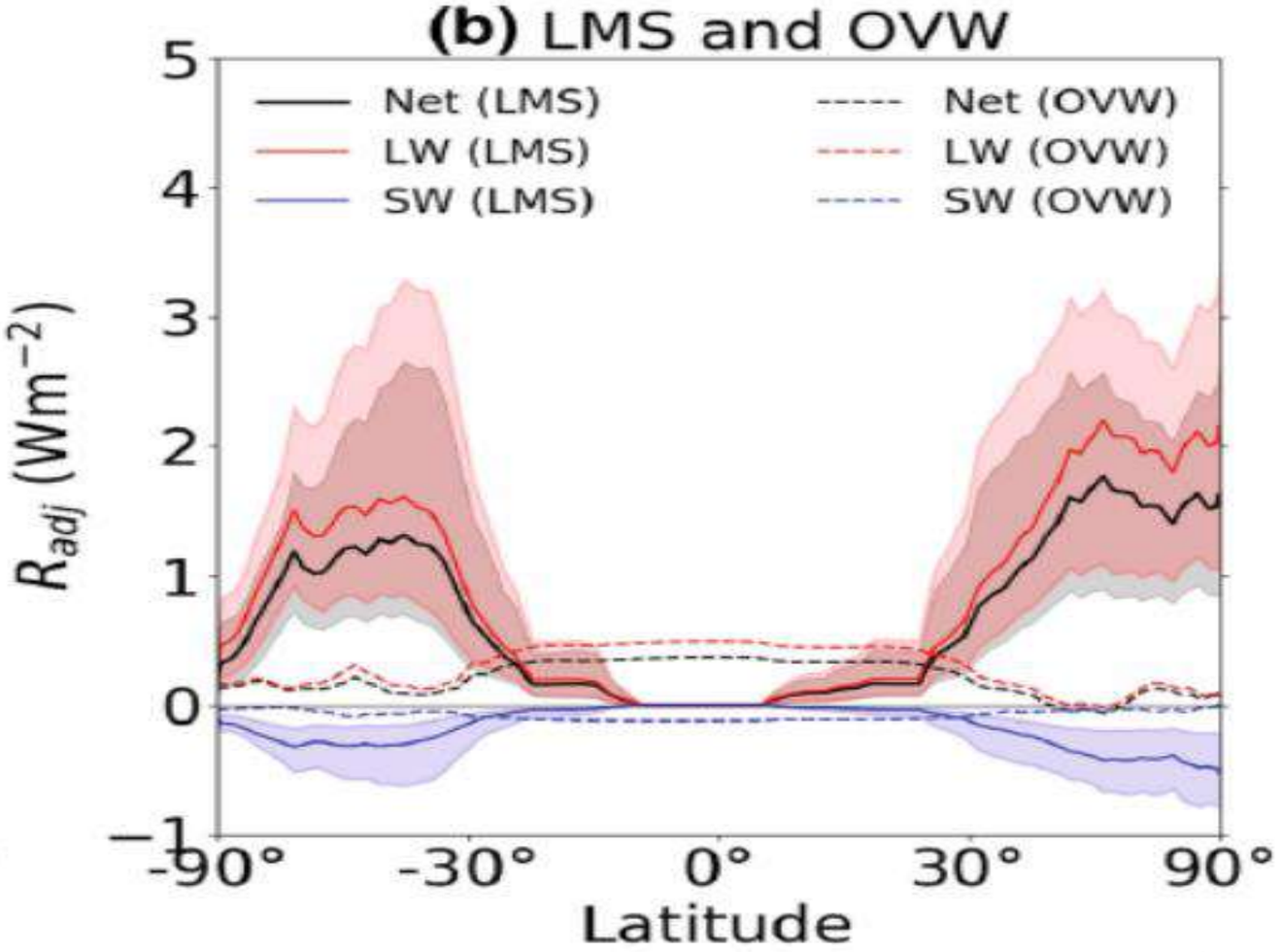
UTLS-composition:
Coupling of transport, microphysics, aerosol properties and dynamics




The UTLS
constitutes a complex transition
region of processes across scales

The effect of unresolved processes

Radiative forcing from stratospheric H_2O in CMIP5

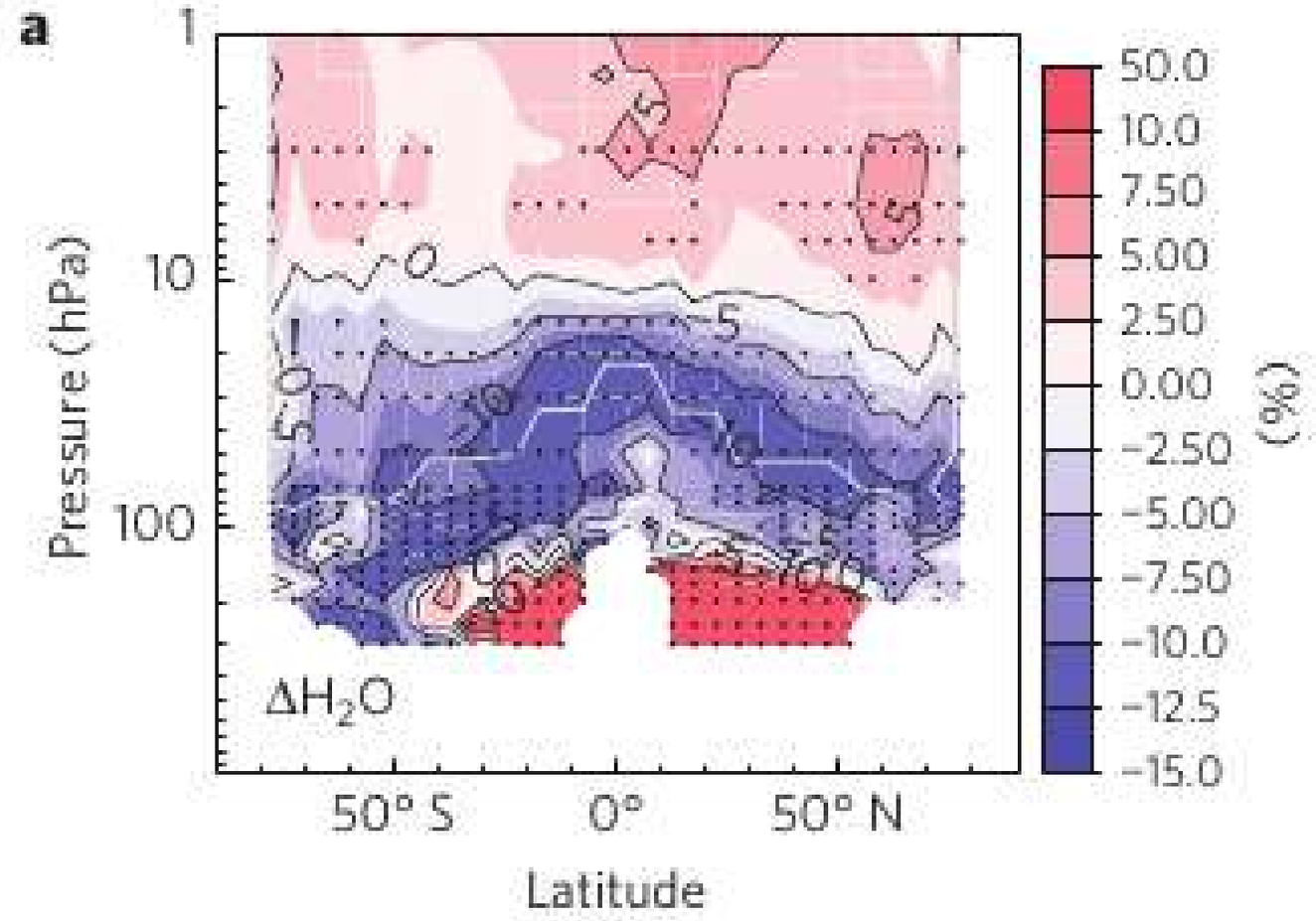


Bannerjee et al., 2019

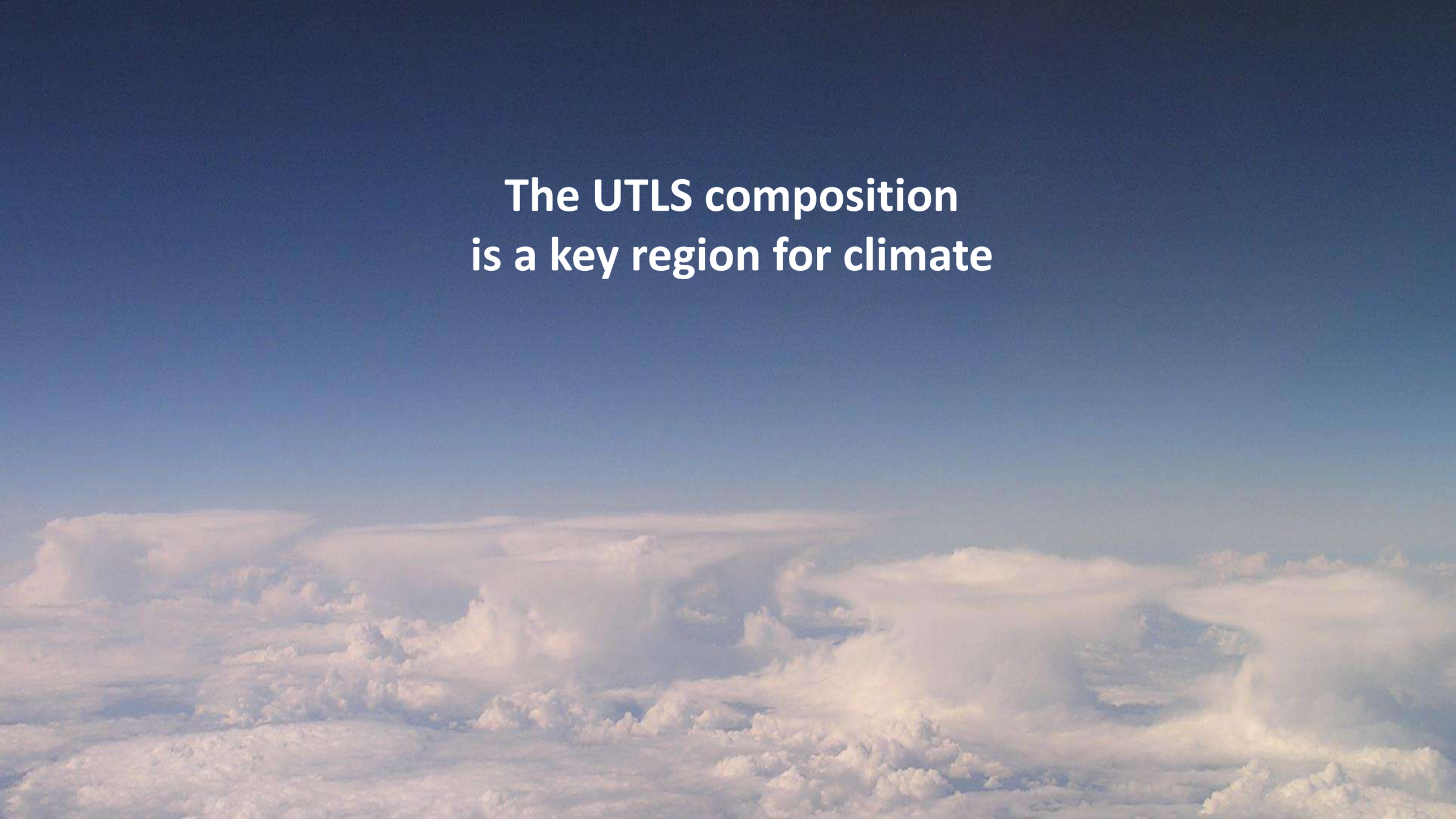
LMS water vapour plays a crucial role for radiative forcing and ist uncertainties

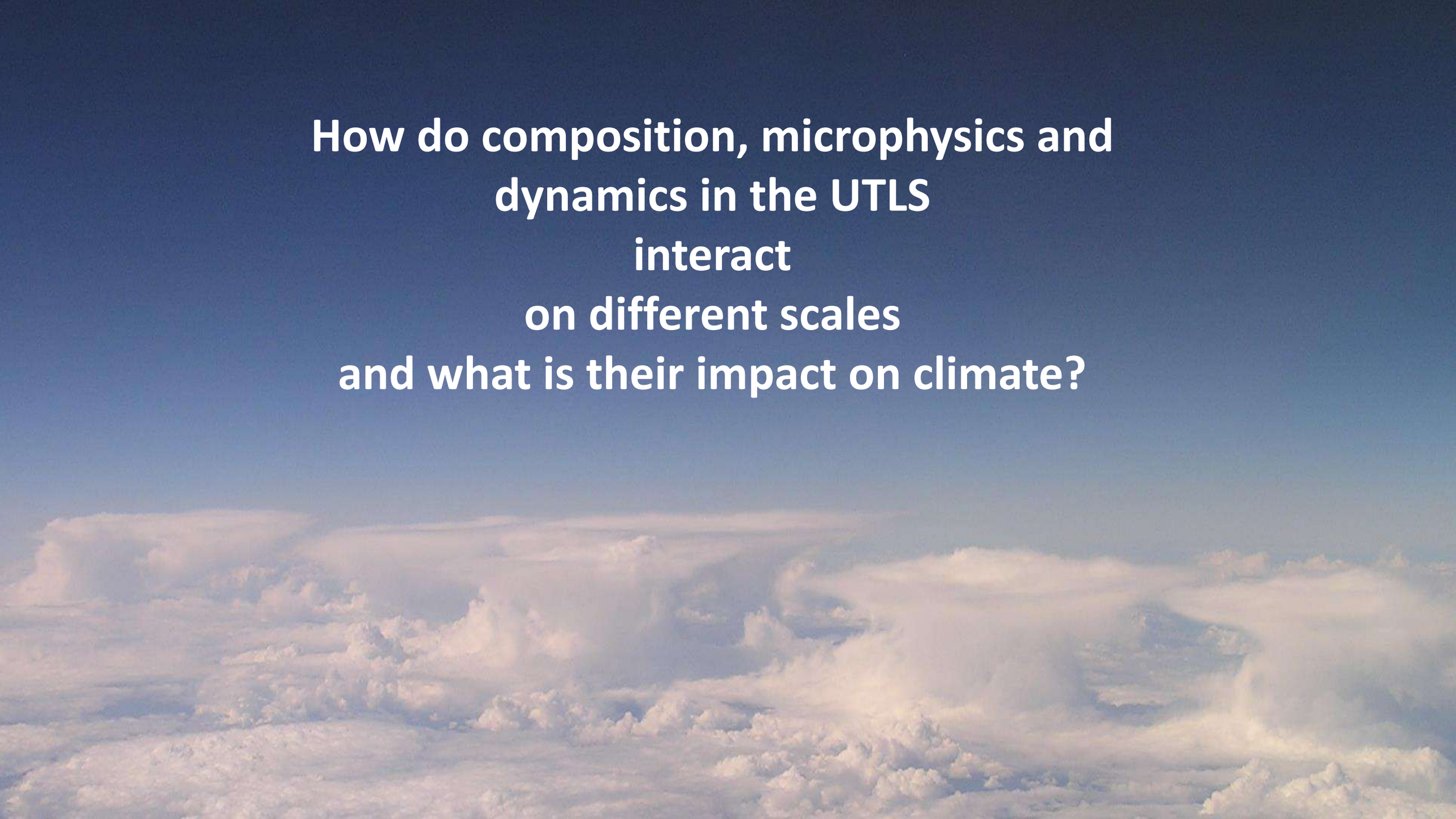
Large scale distribution and impact

Observed H_2O change from (1988-2010) from ACE-FTS

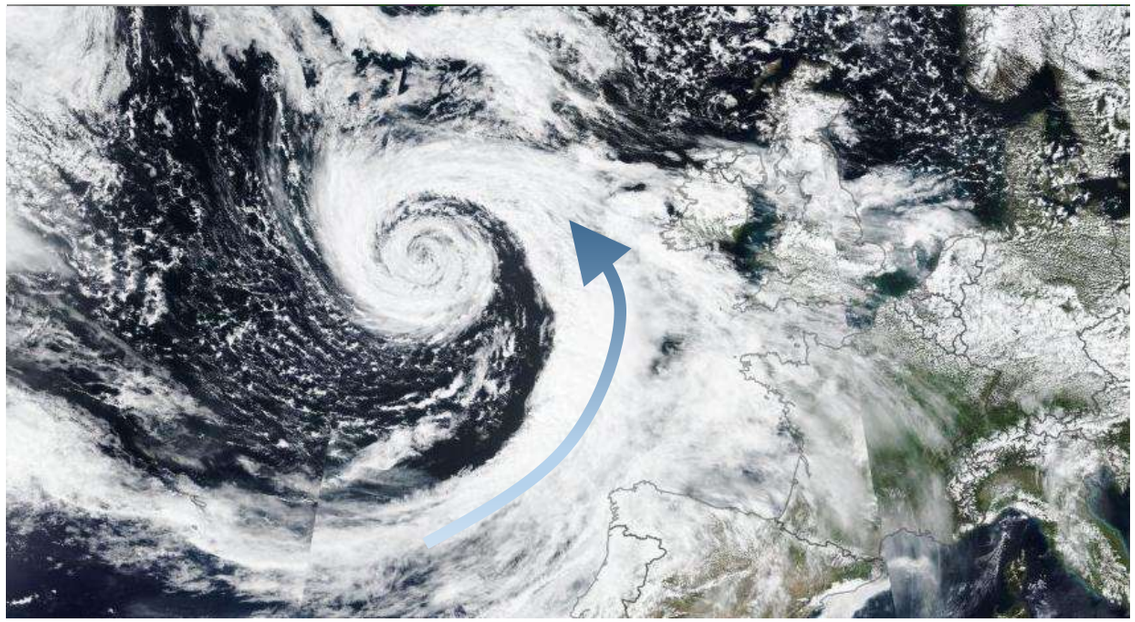


Hegglin et al., 2014


The UTLS composition
is a key region for climate

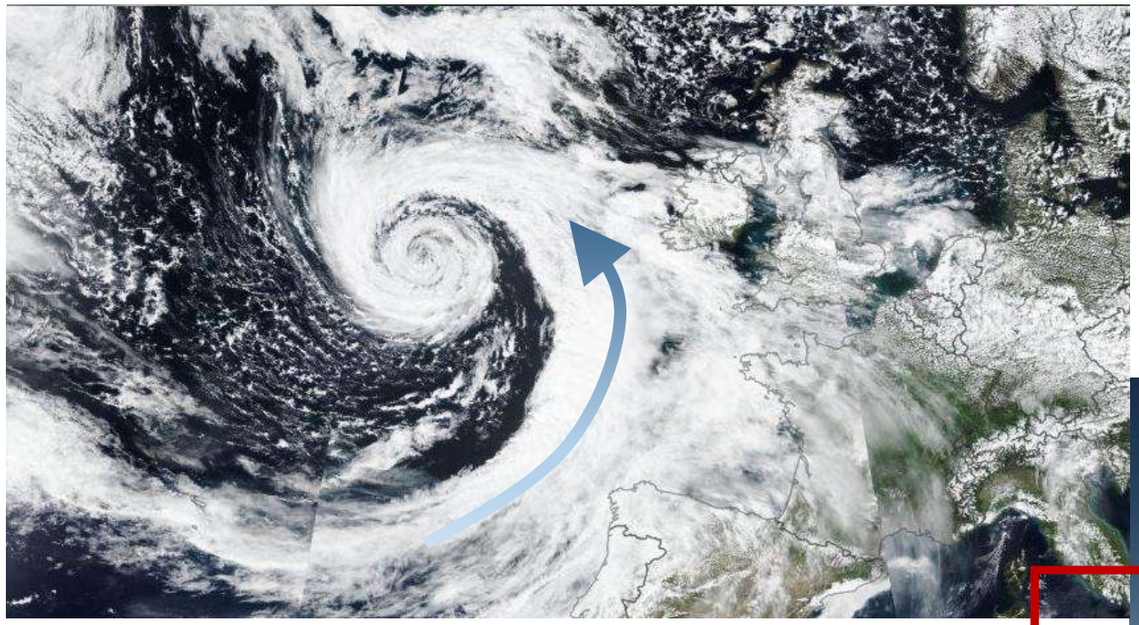

How do composition, microphysics and
dynamics in the UTLS
interact
on different scales
and what is their impact on climate?

Dynamics and microphysics



1. Vertical transport and redistribution of aerosols, moisture and other trace gases
2. Cirrus formation and aerosol cloud interaction

Dynamics and microphysics

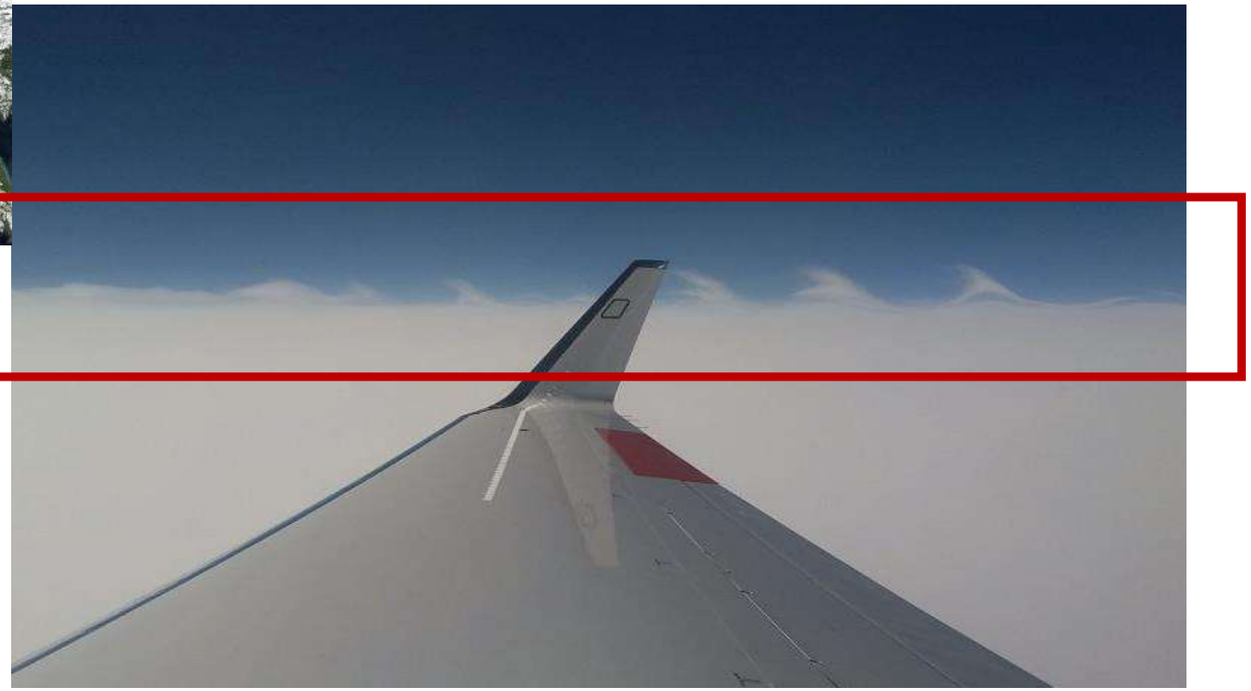


1. Vertical transport and redistribution of aerosols, moisture and other trace gases
2. Cirrus formation and aerosol cloud interaction

3. Turbulence and mixing

Coupling of processes

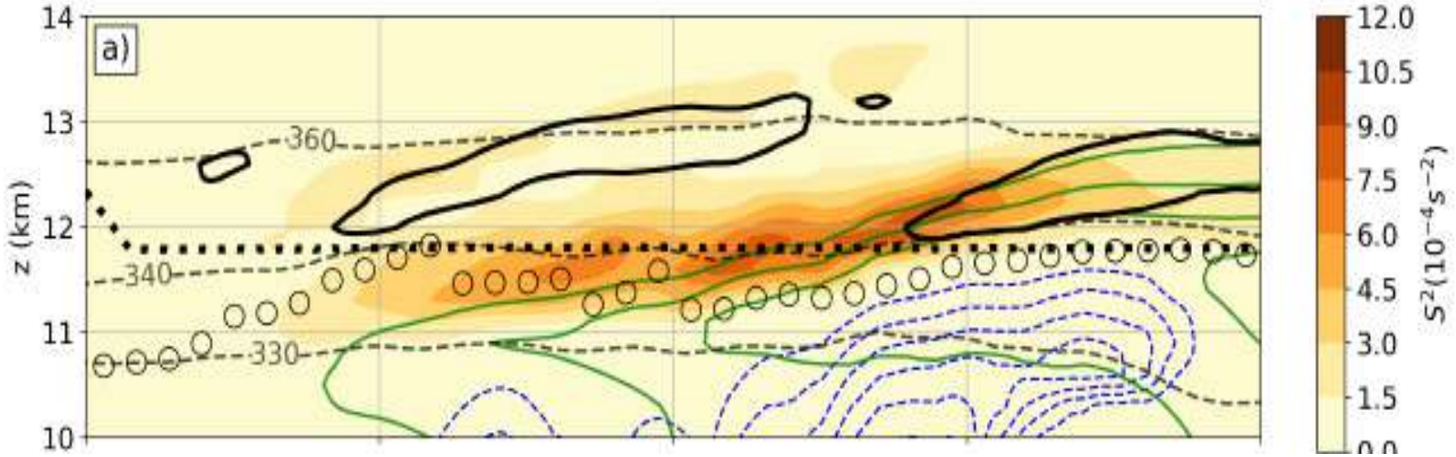
(transport, composition, microphysics, dynamics) across scales



Kunkel et al., 2019

Dynamics and microphysics

Shear occurrence in operational ECMWF data :
High shear above the tropopause
(also in regions of high static stability!)



Kaluza, phd-thesis, 2021

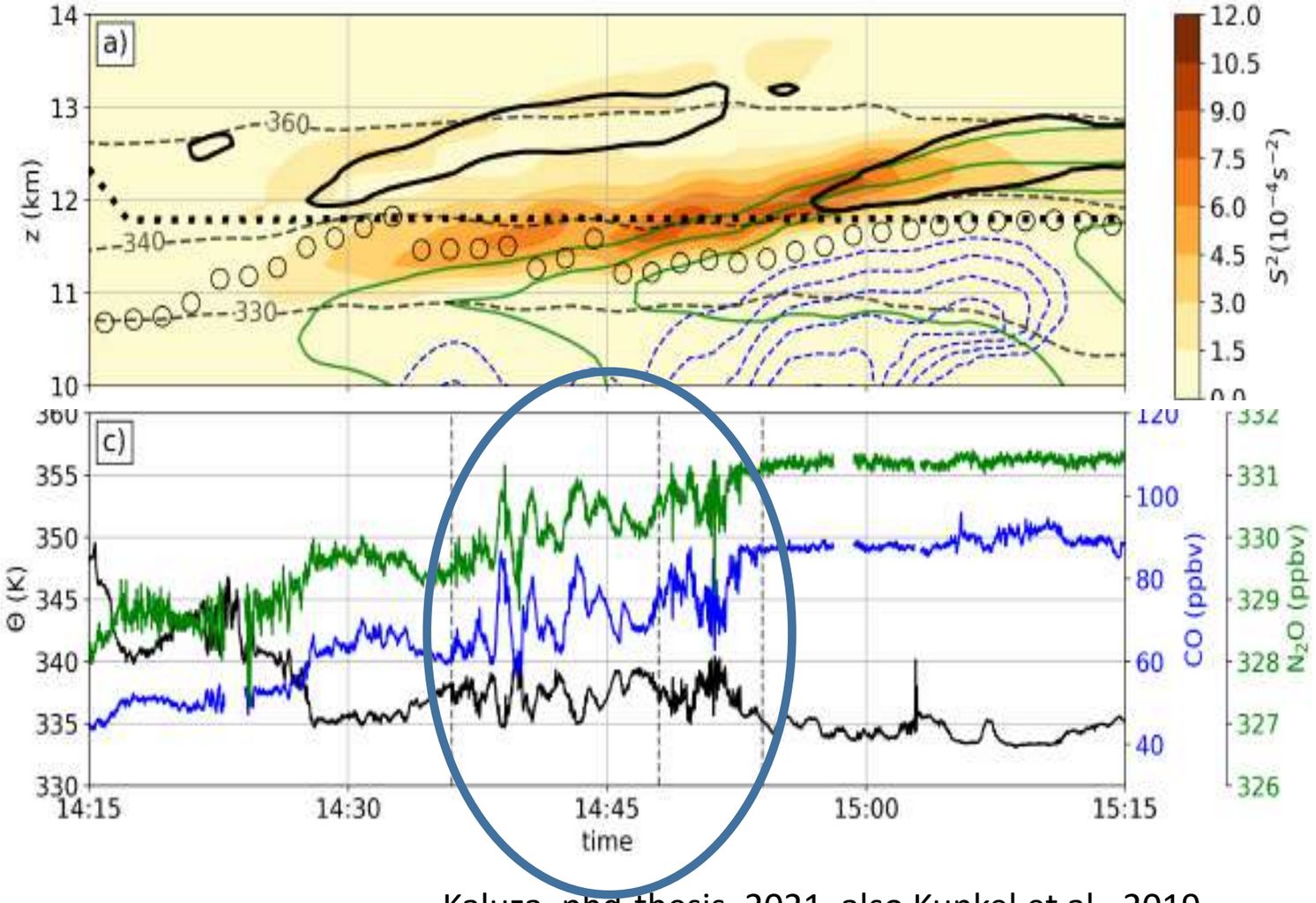
Kaluza, phd-thesis, 2021

Dynamics and microphysics

Shear occurrence in ECMWF operational data :
High shear above the tropopause
(also in regions of high static stability!)

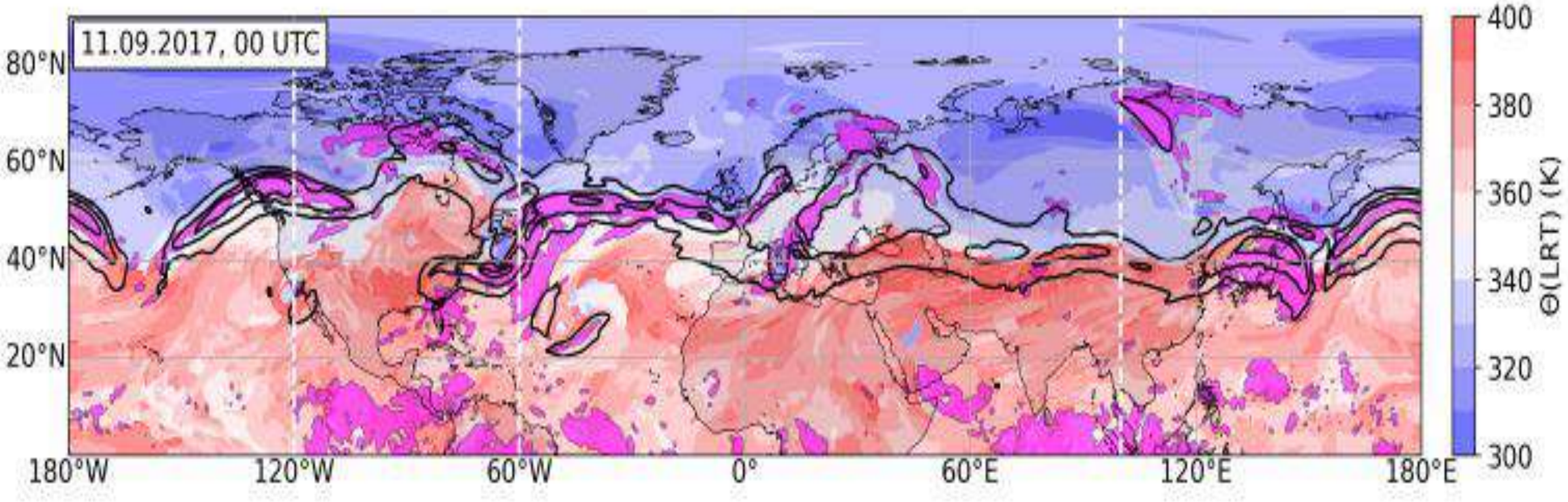
and regions of enhanced tracer variability and turbulence occurrence:

Mixing!



Kaluza, phd-thesis, 2021, also Kunkel et al., 2019

Dynamics and microphysics



ERA-5: Snaphot of shear occurrence (magenta) at 1-2 km above the tropopause from ERA5

Small scale mixing has a potential global impact

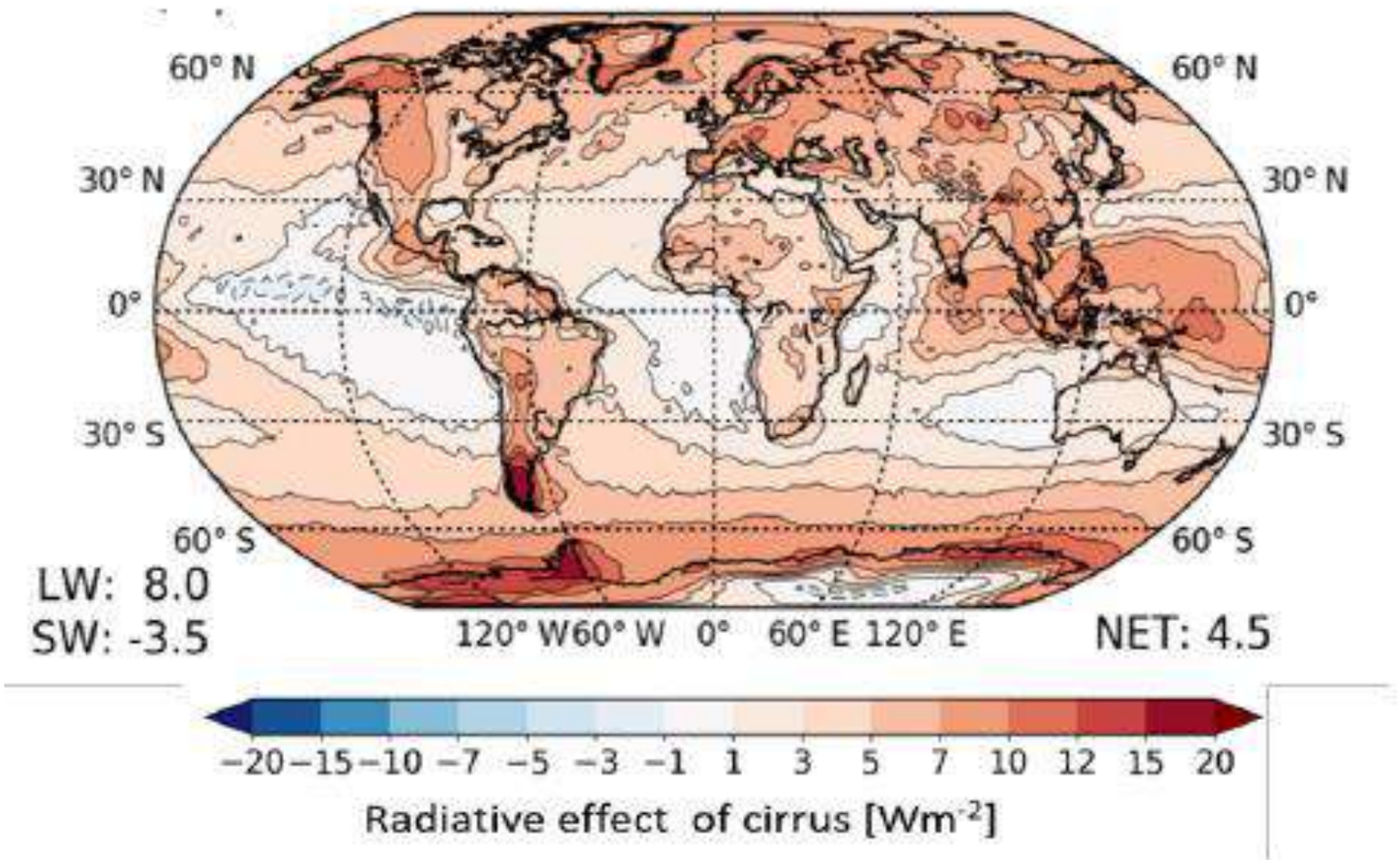
Kaluza et al., 2021

Aerosol, clouds and chemistry

UTLS cirrus occurrence has large impact on forcing and the energy budget of the atmosphere

But:

Depending on formation process the radiative impact of cirrus particles is highly variable and can even change sign



Gasparini et al., 2017

The Tropopause Region in a Changing Atmosphere

TP CHANGE

Spokesperson Prof. Dr. Peter Hoor

Applying universities Johannes Gutenberg-Universität Mainz
Goethe-Universität Frankfurt am Main

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

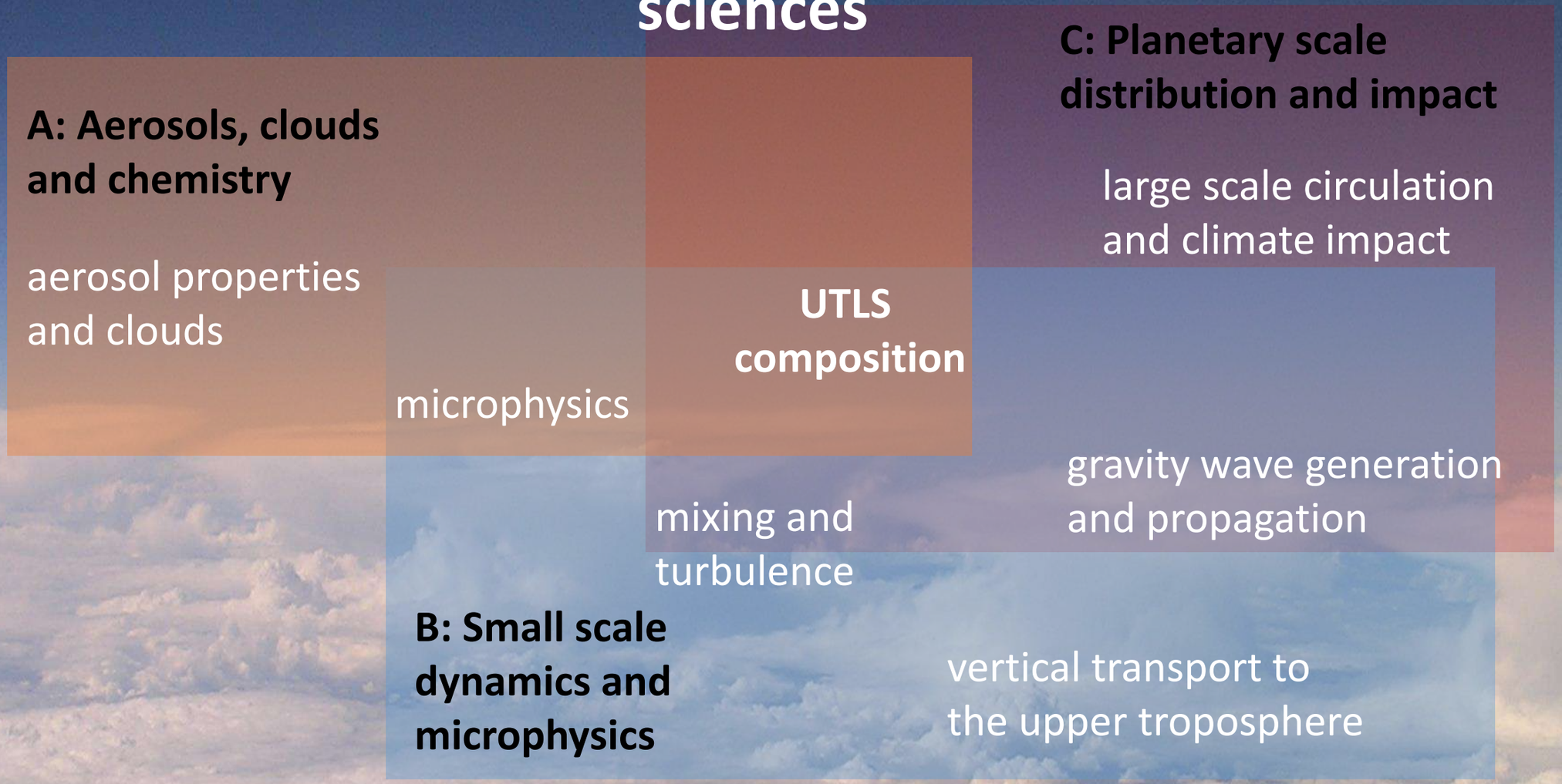
TECHNISCHE UNIVERSITÄT DARMSTADT

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

JÜLICH Forschungszentrum

DLR Deutsches Zentrum für Luft- und Raumfahrt

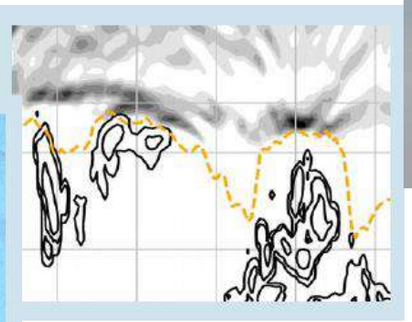
TPChange
will bring together a broad range of expertise from different disciplines of atmospheric sciences



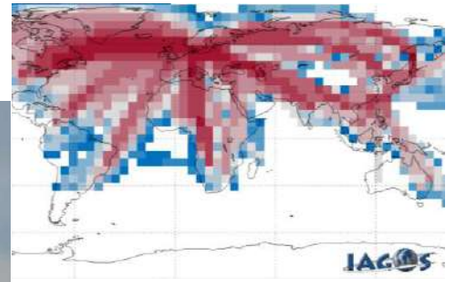
Approach and project structure

The tools…

Process scale
Vertical wind tunnel and particle electron microscopy



Regional and synoptic scale
HALO-SPP 1294
Falcon, Lear-Jet



Global scale
IAGOS-Core / CARIBIC
Satellite data (MSG, Seviri)

CM1, PincFloit

MECO(n)

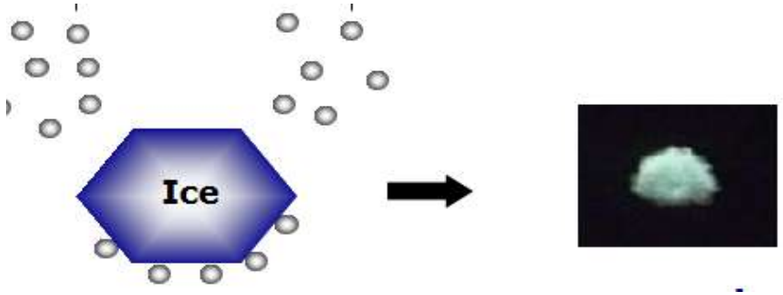
CLaMS

MS-GWaM, EMAC, **ICON**

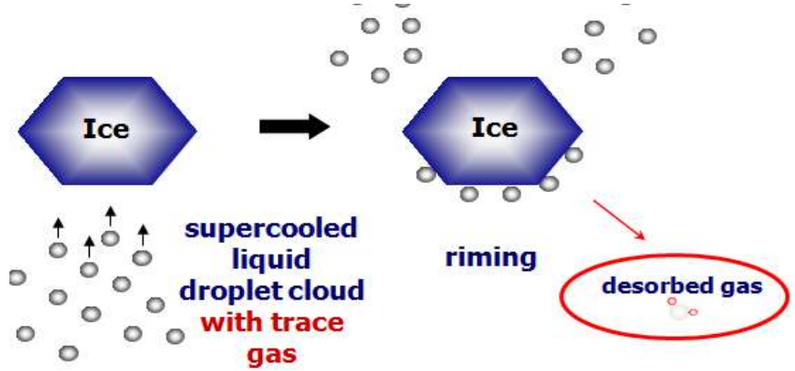
Modelling and theory

Laboratory studies

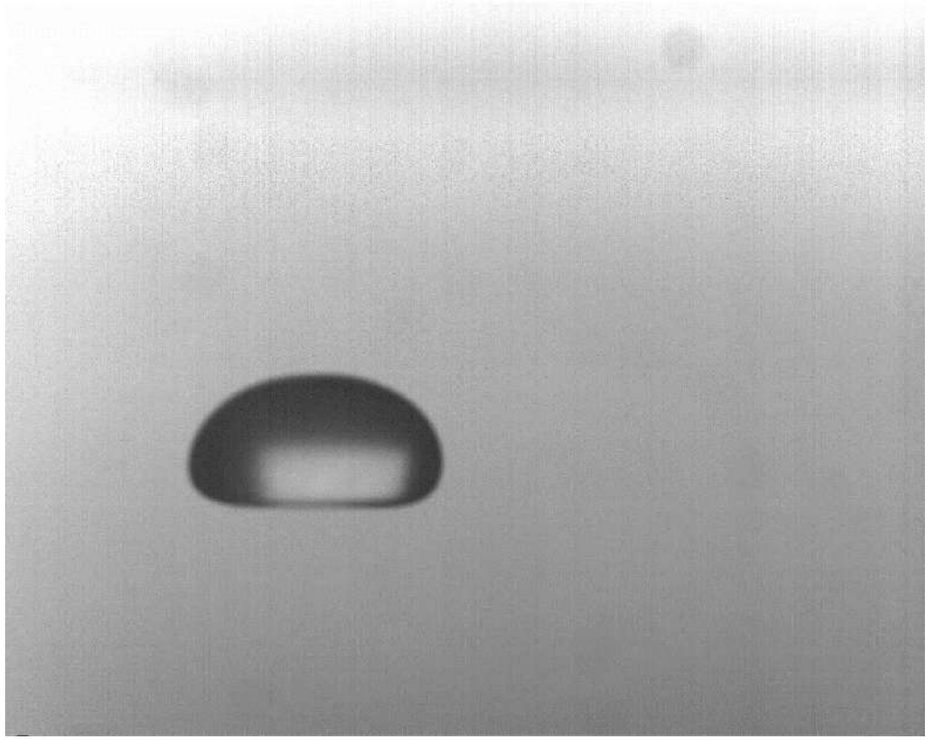
– Vertical Wind tunnel – microphysics and cloudchemistry



formation and growth of hail



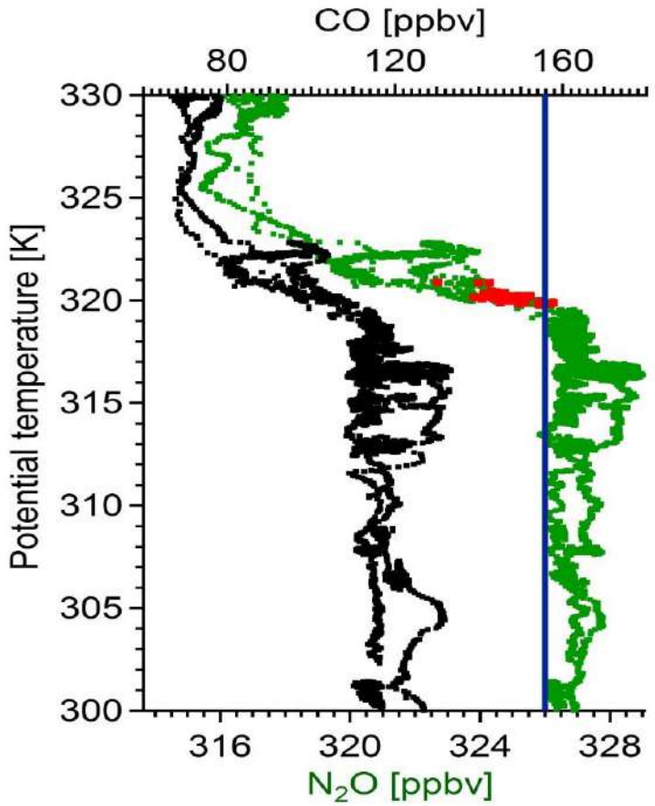
Retention coefficients



shape oszillation and collision of droplets

M. Szakall

Field experiments

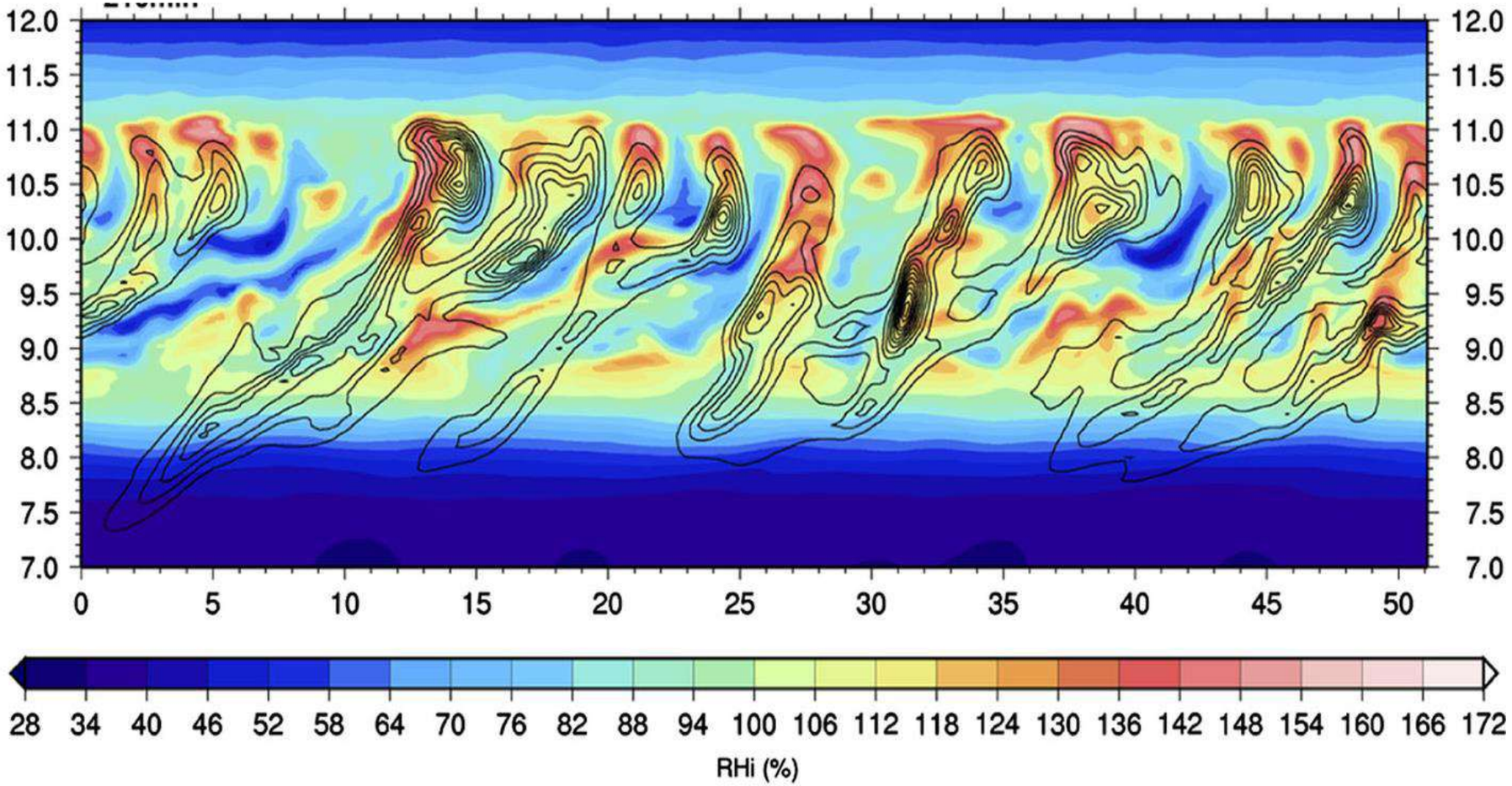


Cirrus properties: Measurements above and within / below the cirrus with a dual platform approach: Effects of cirrus on radiation and water vapor

Ice particles in stratospheric air mass

Frey et al., 2009, Müller et al., 2015

Process modelling

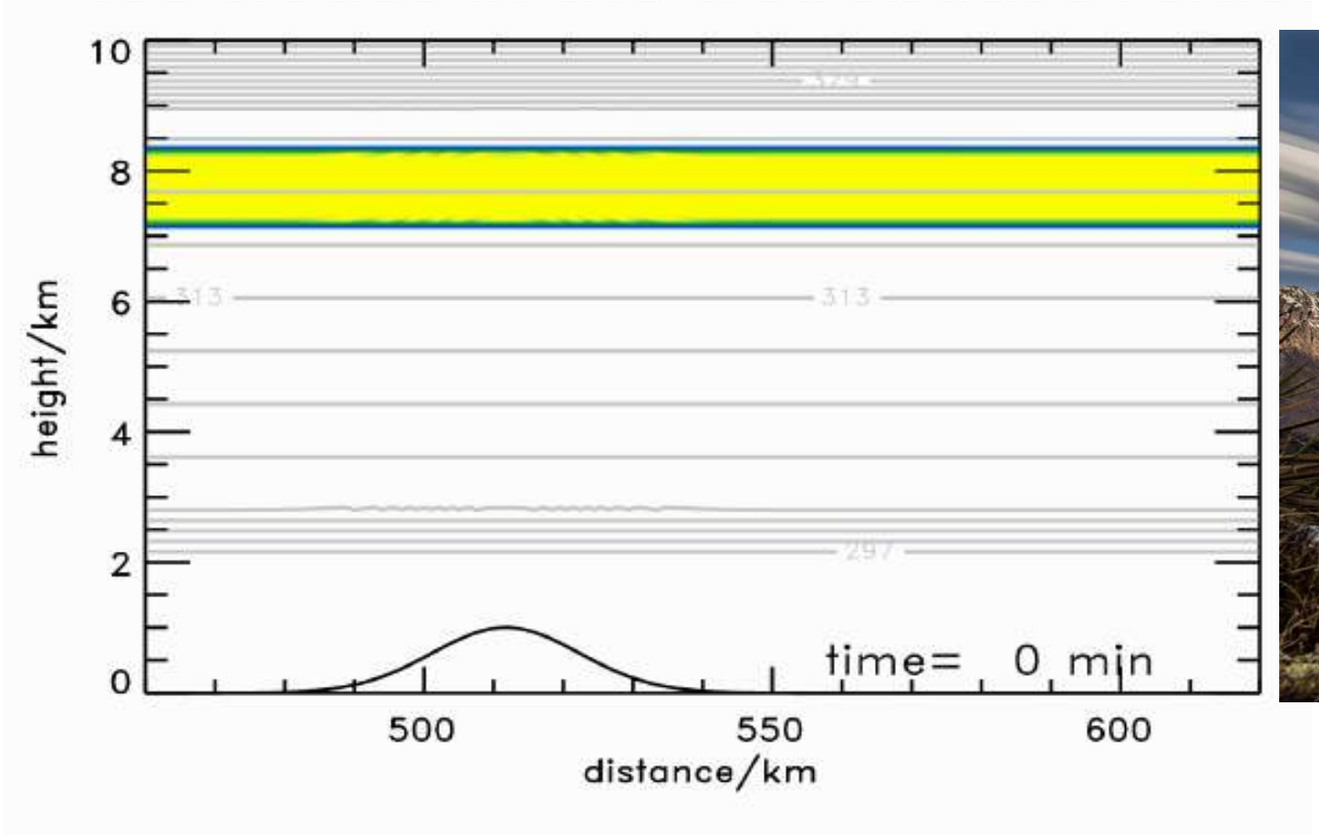


Impact of cirrus convection on tropopause gradients

Spichtinger, 2014

Process modelling

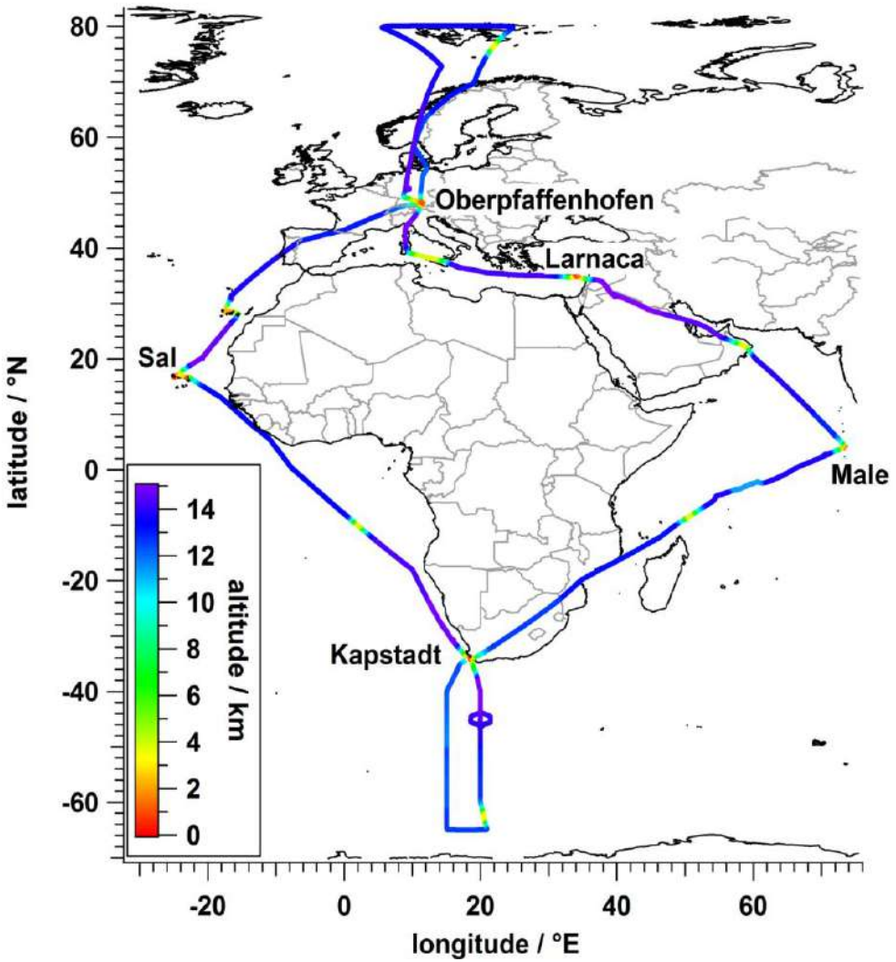
–Ice clouds in the tropopause region



P. Spichtinger

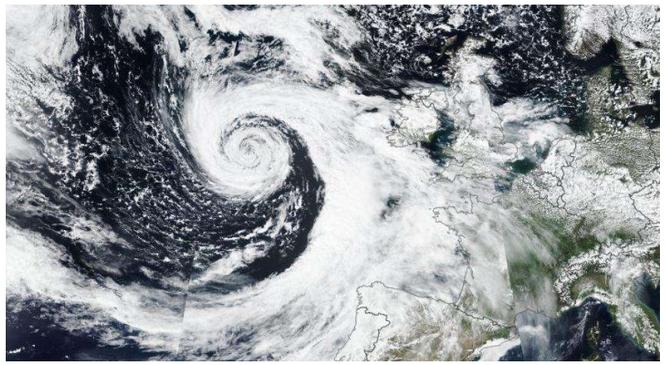
Ice clouds and orographic waves

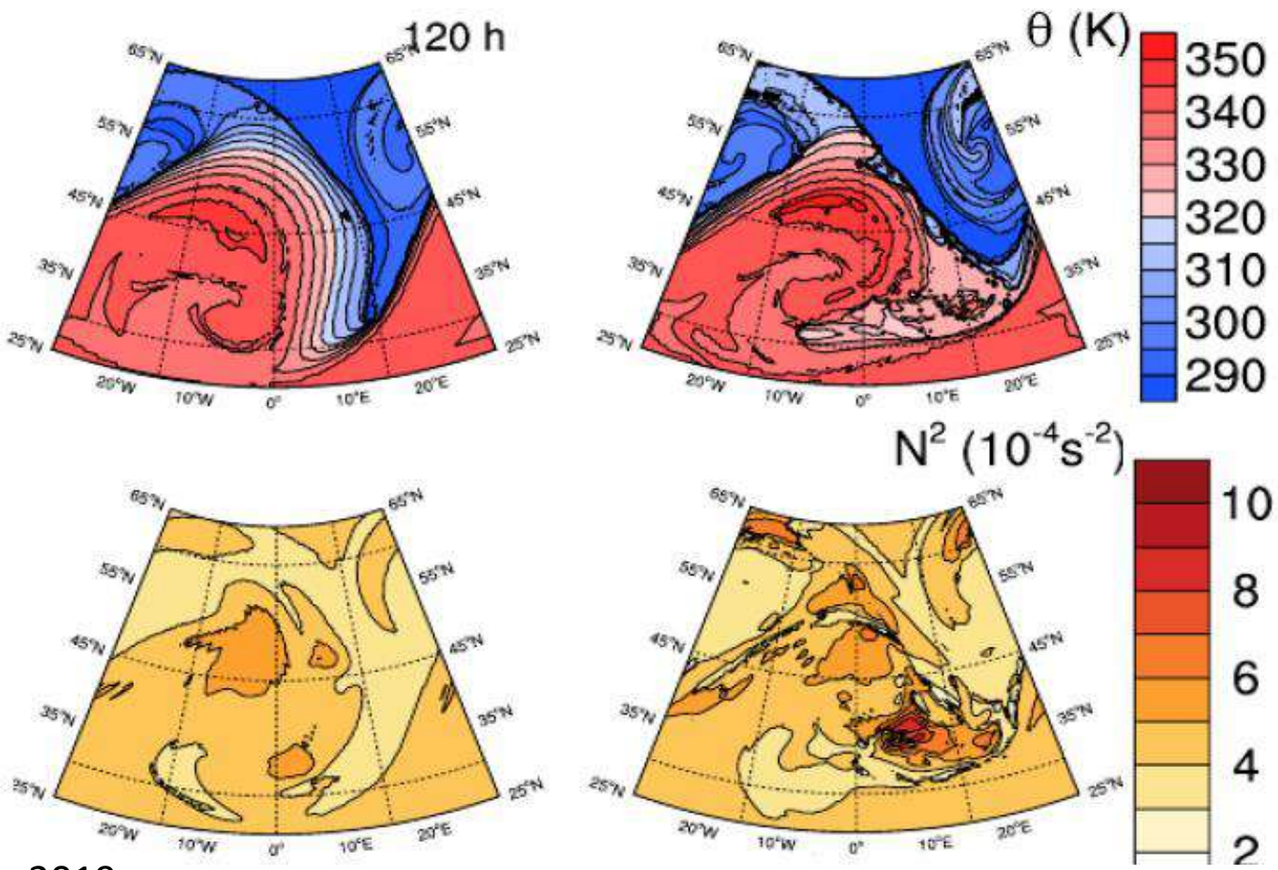
Large scale measurements



Global distribution and transport of air masses in the tropopause region from in-situ airborne measurements of CO, N_2O, CH_4 and CO_2

Atmospheric dynamics modelling and analysis



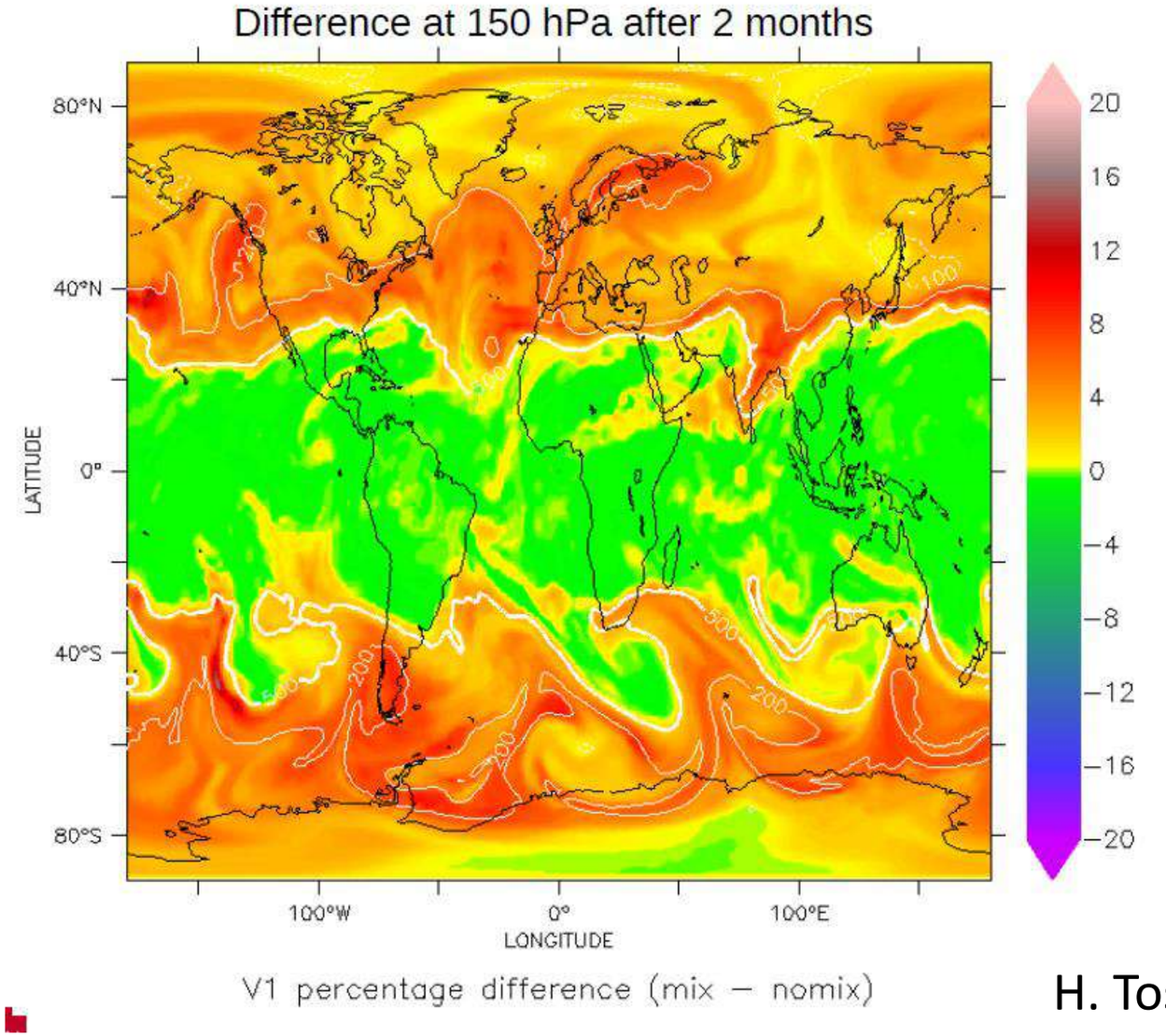


Kunkel et al., 2019

Baroclinic life cycles, and mixing at the tropopause: Which processes are relevant for tropopause sharpness or turbulence occurrence?

Large scale measurements

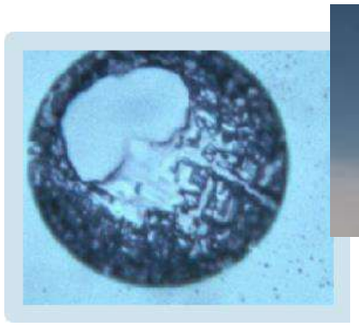
Simulated change of artificial tracer at 150 hPa from mixing



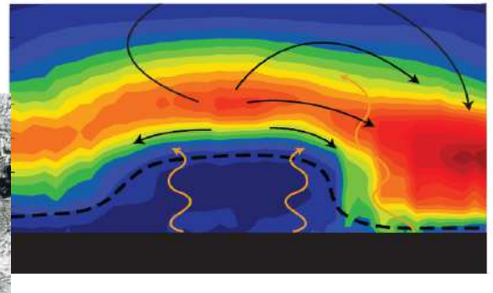
H. Tost

The UTLS as a transition region of scales

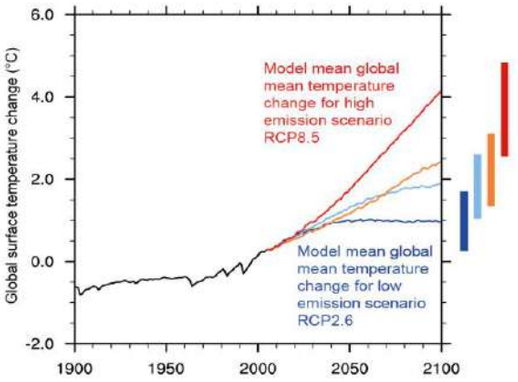
Process scale
understanding of aerosol processes and their role as INPs and CCNs



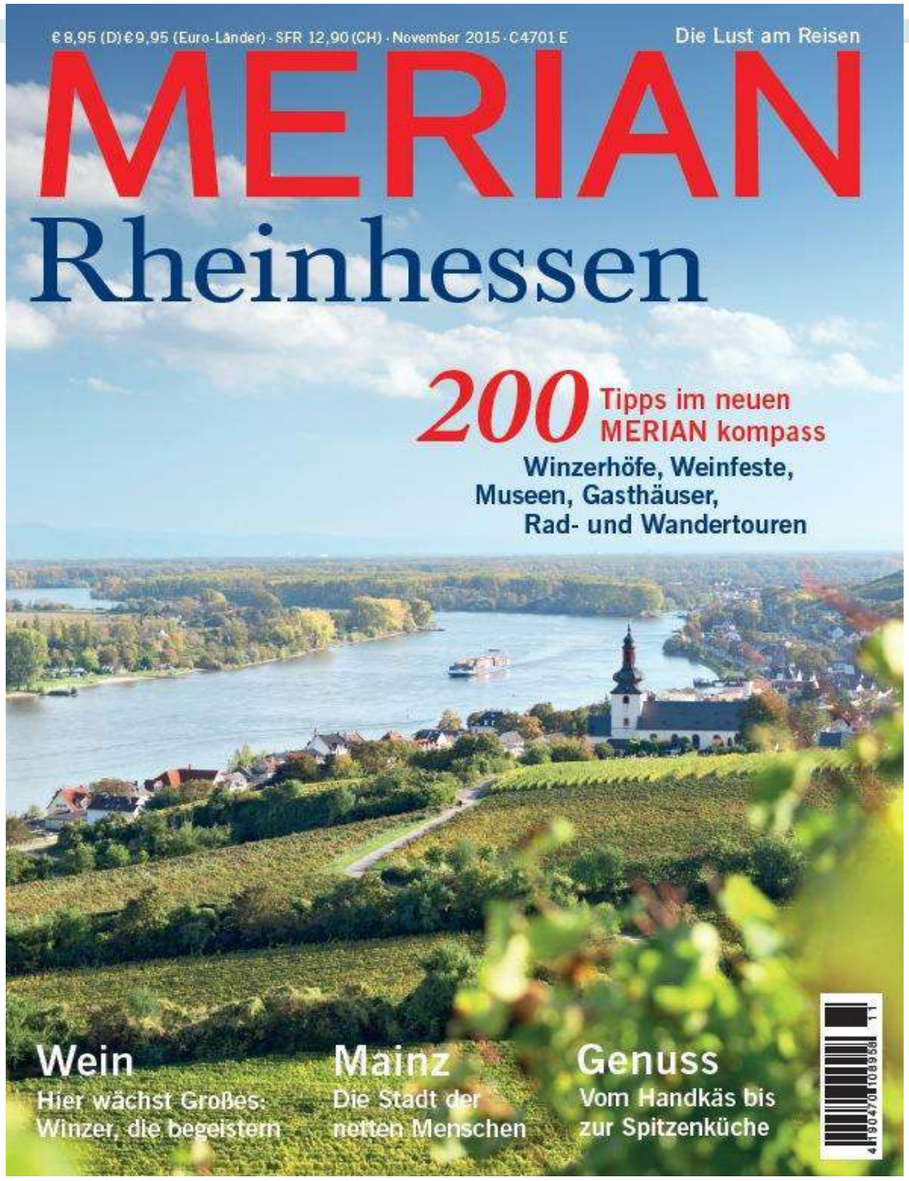
Regional and synoptic scale
Gradients, dynamics and mixing at the tropopause

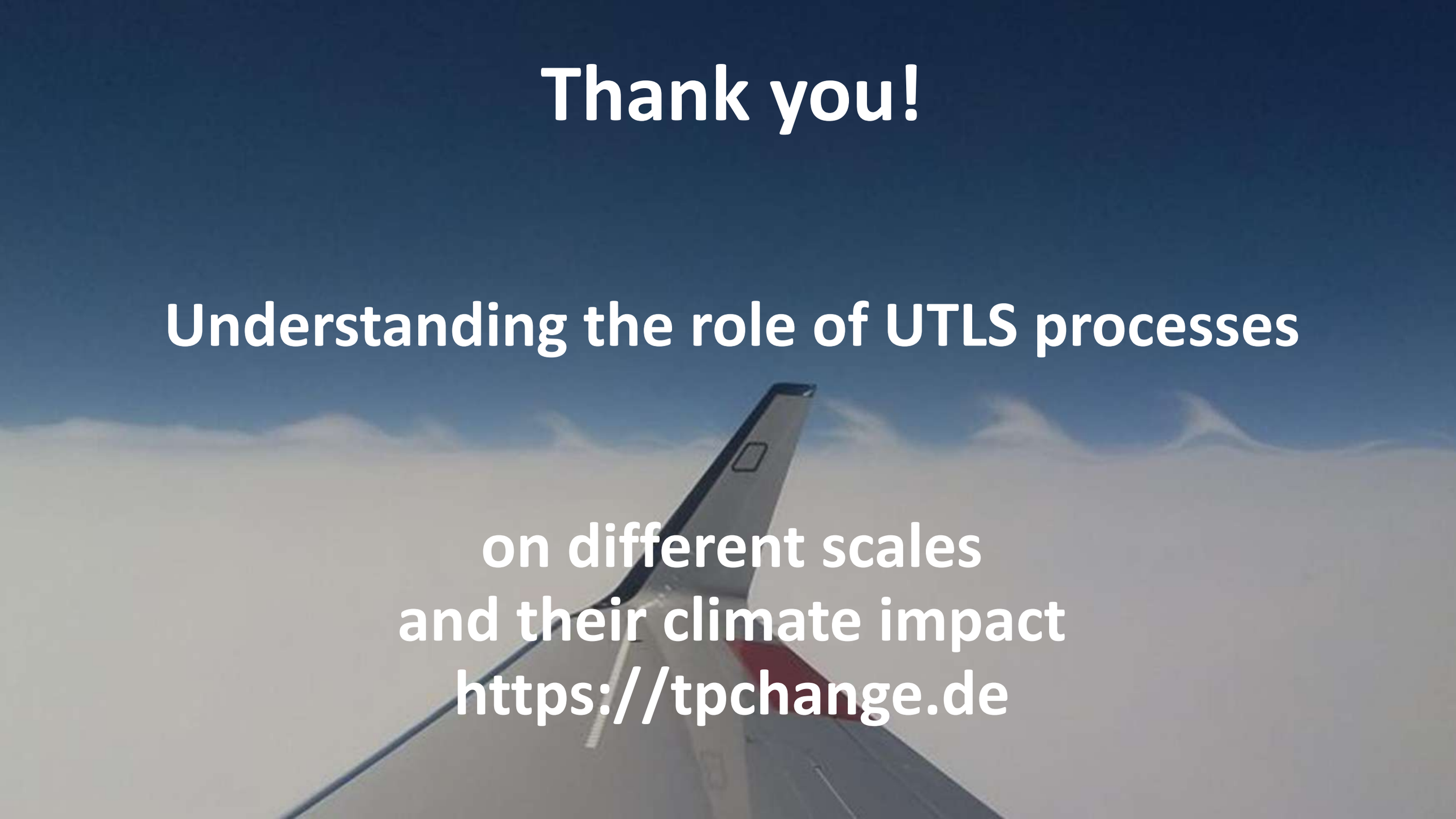


Global scale UTLS composition and impact



Further advantages of Mainz …




Thank you!
Understanding the role of UTLS processes
on different scales
and their climate impact
https://tpchange.de