

# 4D visualisation of the tropopause, identification of air mass exchanges and their fate

Department of Mathematics & Steinbuch Centre for Computing

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MATHSEE MODELING WEEK

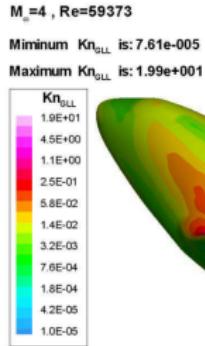
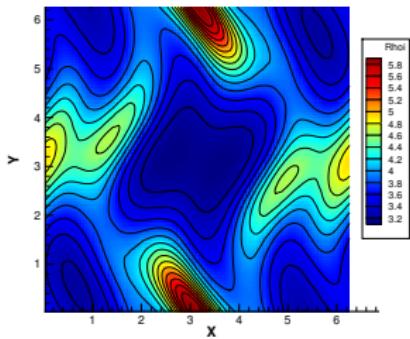


$$\left\{ \begin{array}{l} D(u, u) \geq \alpha ||u||^2 \\ D(u, v) \leq \gamma ||u|| ||v|| \end{array} \right\} \Rightarrow \exists^\exists u : D(u, v) = \rho(v) \quad \forall v, \\ ||u|| \leq \frac{1}{\gamma} ||\rho|| \right.$$

# Self intro

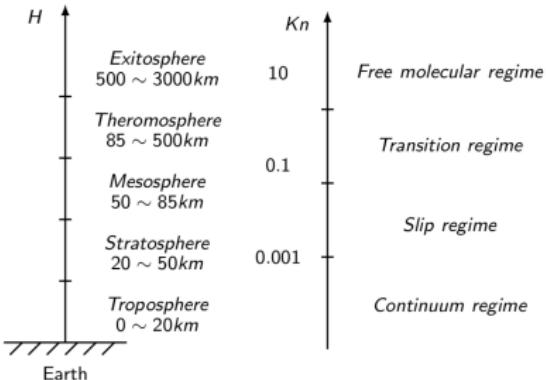
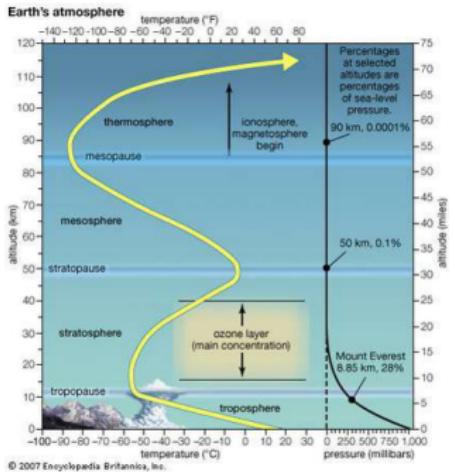
## Tianbai Xiao

- Postdoc in Department of Mathematics and Steinbuch Centre for Computing
- Ph.D. from Peking University and Research Assistant of Hong Kong University of Science and Technology
- 1) numerical and applied analysis, kinetic theory of gases, uncertainty quantification; 2) multiscale modeling and computational study of fluid mechanics, photon transports and plasma physics



# Project intro

Atmospheric structure: multi-layer and multi-physics dynamics  
(roland.ruhnke@kit.edu & jennifer.schroeter@kit.edu)



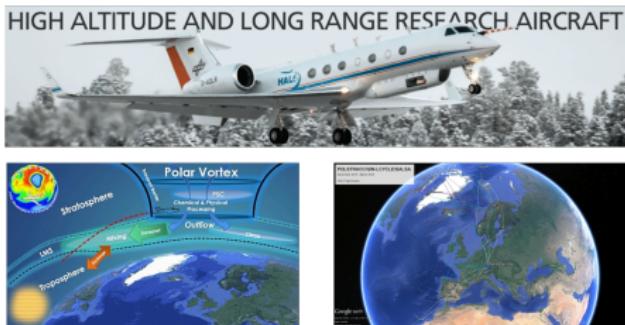
## Tropopause:

- key region for radiative forcing of greenhouse gases
- highly dynamical interface in space and time

# Research facility

The processes at the polar tropopause region have been investigated in a couple of research flights with the German HALO aircraft with the POLSTRACC campaign (see <http://www.halo.dlr.de/science/missions/polstracc/polstracc.html>)

- GLORIA: Gimbaled Limb Observer for Radiance Imaging of the Atmosphere
  - ICON-ART: Numerical Simulator



# Results: wind speed, altitude and qv near 10 km

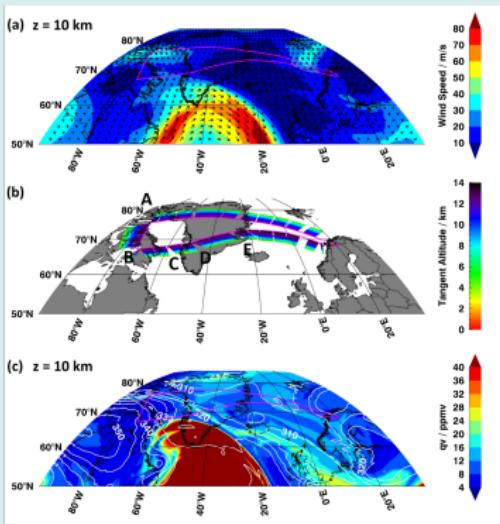


Figure: Meteorological situation and GLORIA sampling during HALO flight N.14 on Feb. 26, 2016. HALO flight track indicated by magenta line in all panels.

- (a) ICON-ART simulated horizontal wind speed (colour-coded contour and arrows) at 10 km altitude
- (b) GLORIA measurement tangent points, colour-coded with altitude
- (c) ICON-ART simulated specific humidity qv (colour-coded contour) and potential temperature (white contour lines) at 10 km altitude

The area within the strong horizontal wind gradient is associated with high values of specific humidity indicating tropospheric air at 10 km altitude.

# Results: Potential Vorticity at different altitudes

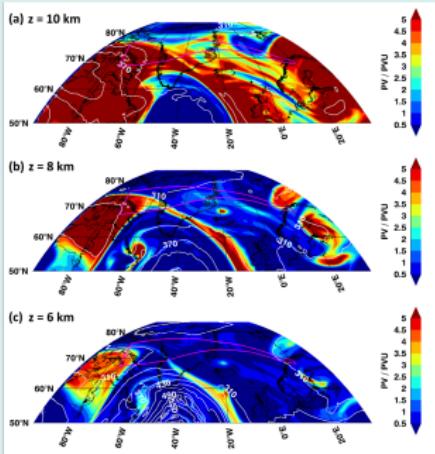
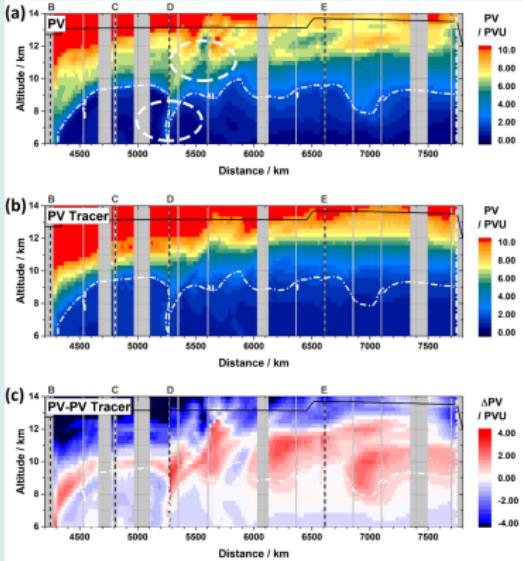


Figure: ICON-ART potential vorticity (colour-coded contour) and equivalent potential temperature (white contour lines) at different altitudes. HALO flight track indicated by magenta line in all panels.

- A PVU value of 2 can act as a measure for the tropopause.
- The high values of specific humidity corresponds to low values of PV at 10 km altitude.
- Below 10 km high values of PV are visible indicating stratospheric air at these altitudes.

# Results: vertical cross-section of PV



- Dash-dotted white lines indicate the  $PV = 2$  PVU level as indicator for the dynamical tropopause
- HALO flight altitude indicated by black line in all panels
- The two white circles shows features of interest along the flight track. A fast and sharp decrease in altitude of the tropopause accompanied by an uplift in short distance

Figure: Vertical cross-sections of (a) potential vorticity PV, (b) PV tracer, and (c) PV - PV tracer.

# Results: air uplift and exchange

- This uplift of air masses with tropospheric characteristics above the dynamical tropopause is seen in measurements as well as in the model simulations
- The question is **where does this exchange is generated** and **what is the fate of it**

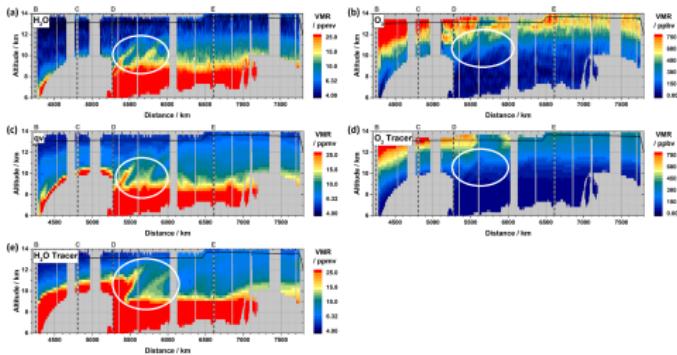


Figure: Fine-structures in GLORIA measurements and ICON-ART simulations. Vertical cross-sections along east-bound flight section. GLORIA (a) water vapour and (b) ozone, and ICON-ART (c) specific humidity, (d) ozone tracer, and (e) water vapour tracer at 18 UTC. HALO flight altitude indicated by black line in all panels.

# Conclusion and work plan

- 4D visualisation of tropopause represented by the simulated PV
- Automatic identification of air masses of tropospheric origin above the tropopause, e.g. by analysing the qv and the PV fields (Q: where is the origin of this exchange of tropospheric air through the tropopause into the stratosphere)
- Tracking of these air masses in time and space to visualise their atmospheric fate (Q: is the exchange reversible or not?)
- English speaking group
- My utmost to help (but no REPLACEMENT)