Three-dimensional radiative transfer around a tropopause fold

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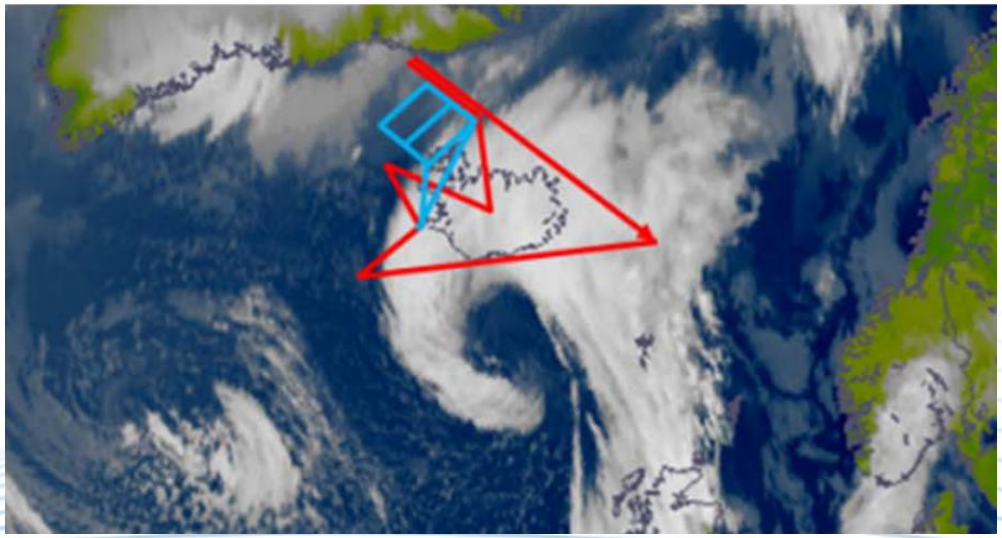
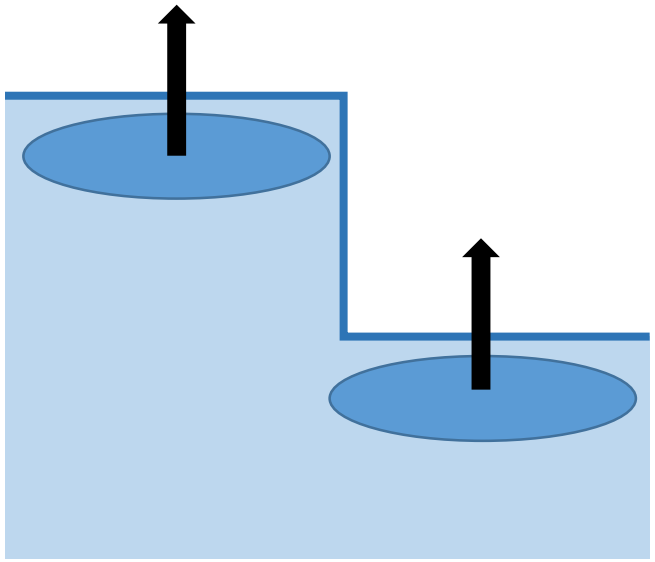
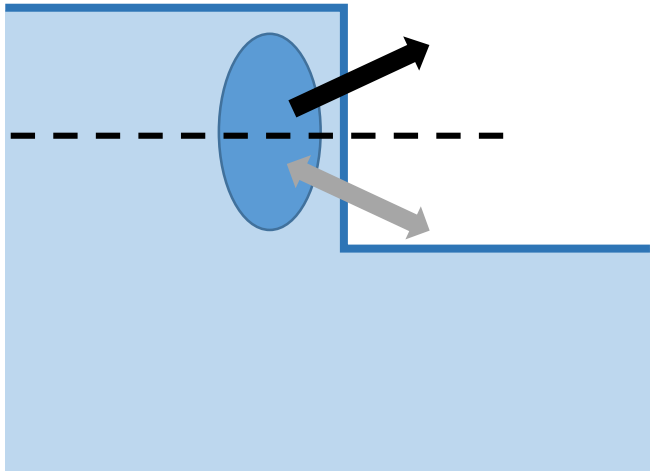


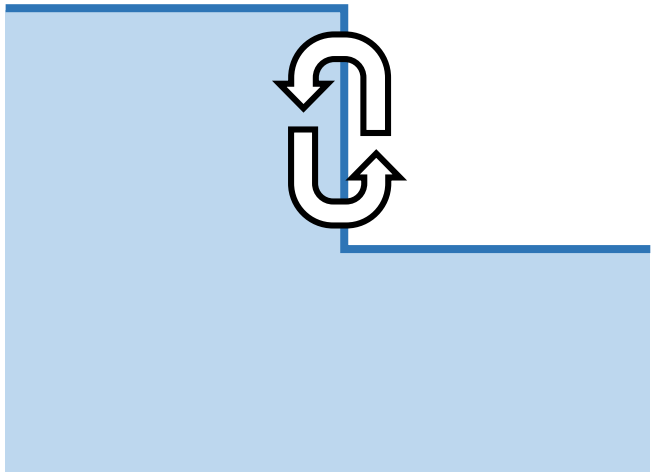
Why 3D radiation might be important at tropopause folds



- 1D radiation leaves gap at vertical tropopause



- 3D radiation at vertical boundary to upper quadrant cools

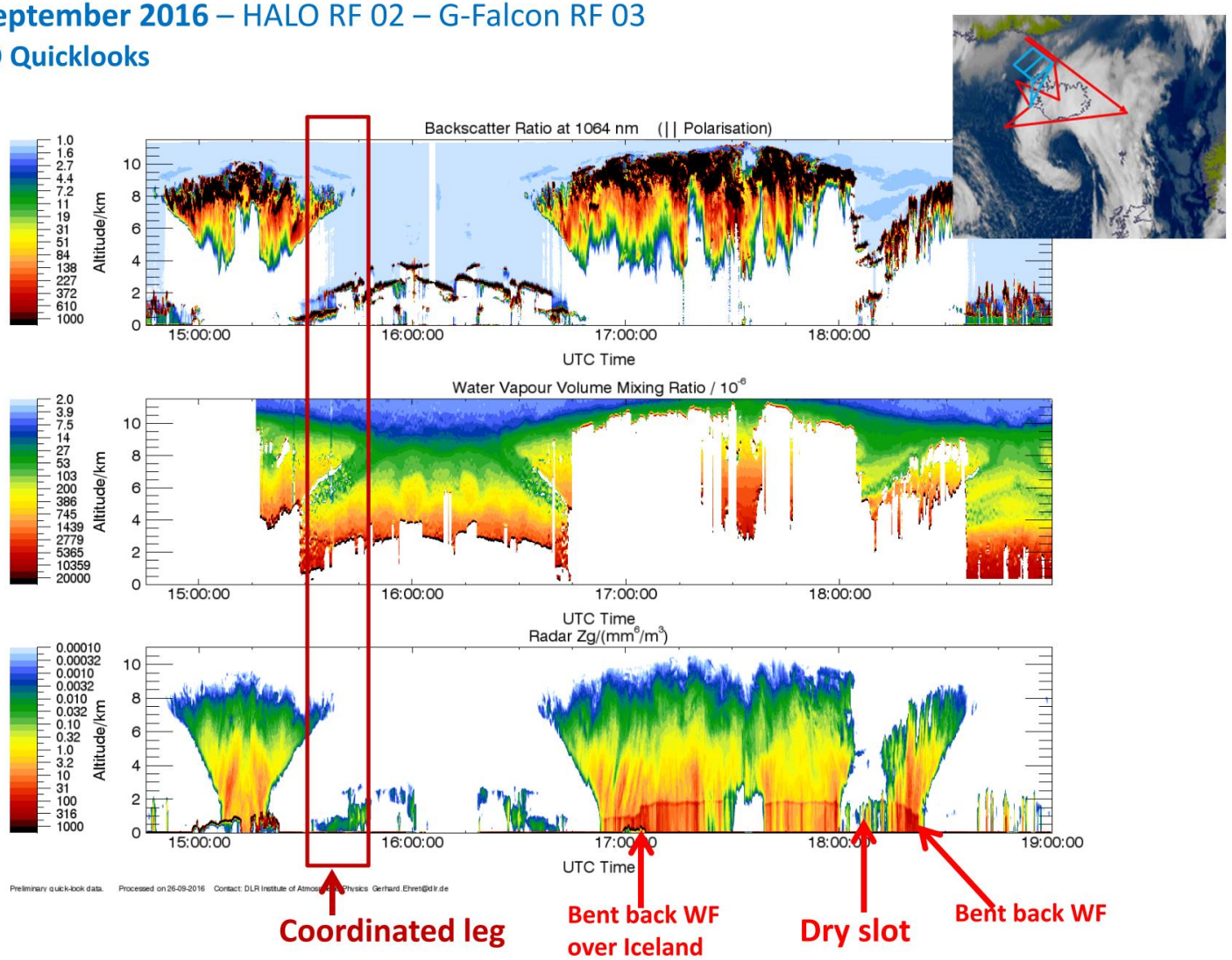


- Horizontal cooling gradient drives circulation, weakens front

High Resolution Information

21 September 2016 – HALO RF 02 – G-Falcon RF 03

HALO Quicklooks



Ingredients:

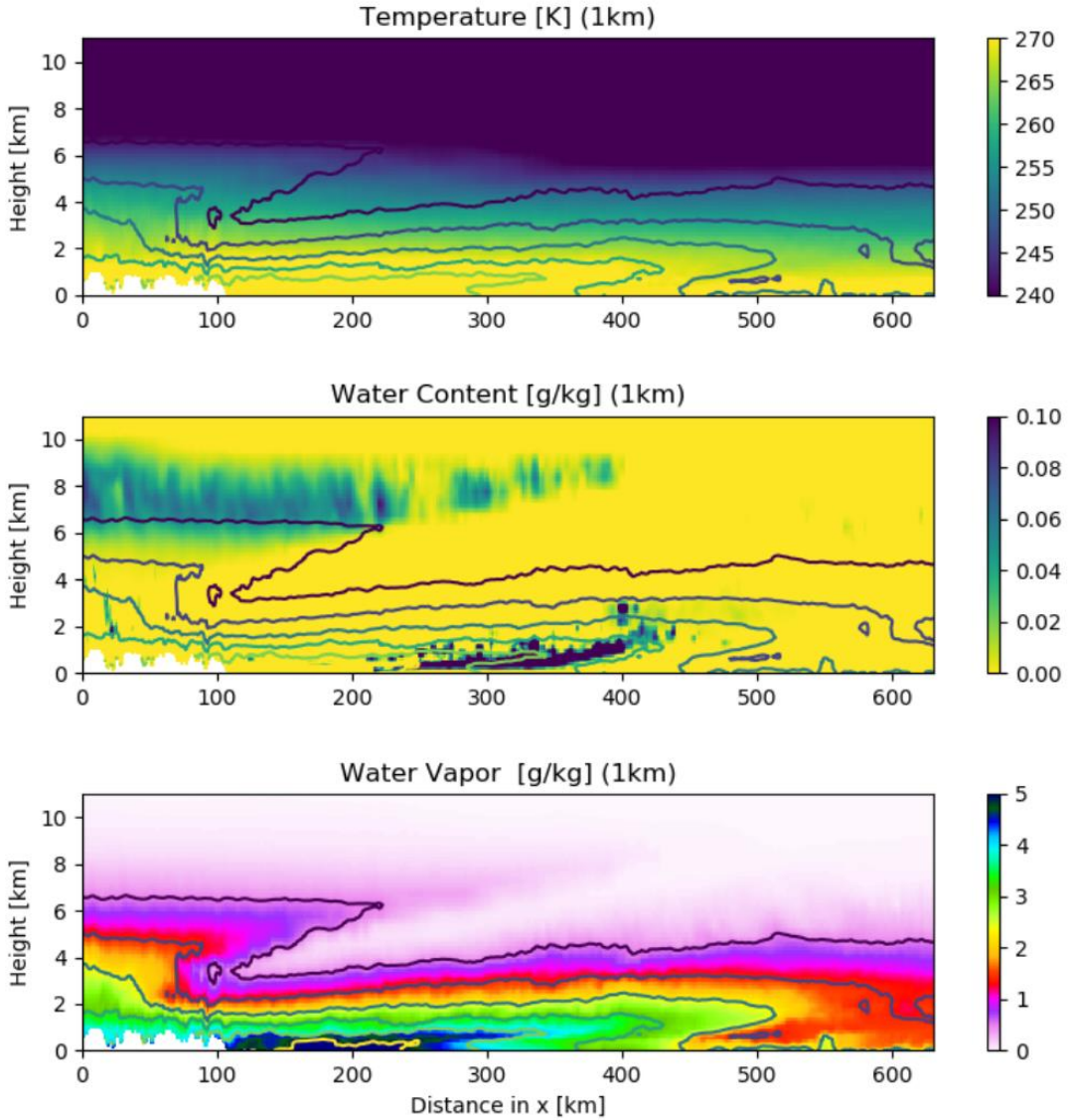
- 3D Radiative transfer: MYSTIC (Mayer et al)
- High-resolution data: NAWDEX airborne remote sensing

Simulated Atmospheric State

Temperature

Cloud water content

Water vapour



COSMO simulations

- 1 km resolution
- ECMWF initial and boundary conditions.

MYSTIC: Monte Carlo radiative transfer

- 2D vertical cross section
- Long-wave only

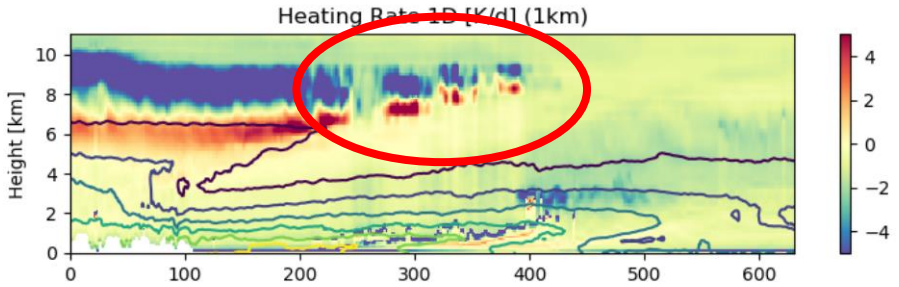
Radiative Cooling Rates

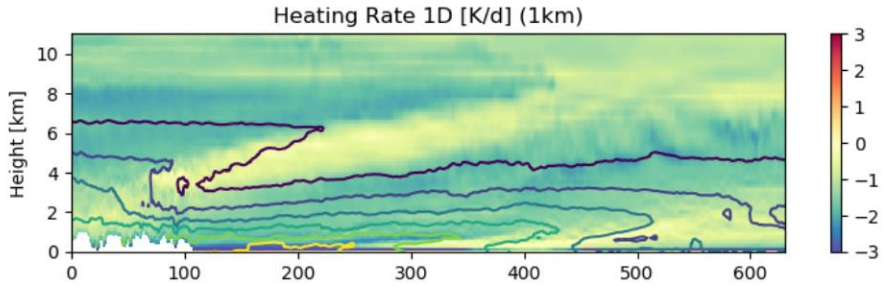
With clouds

1. Cloud in fold is broken

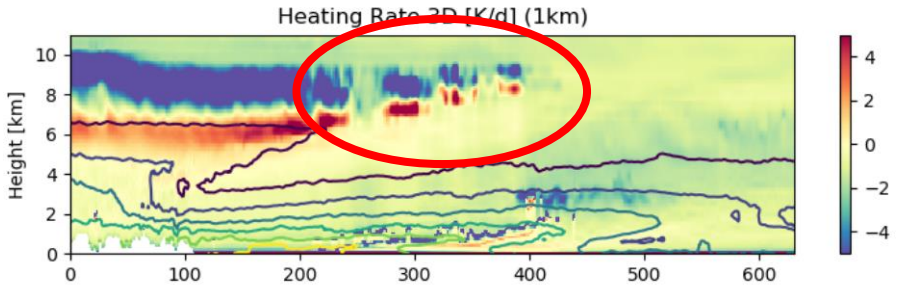
Without clouds

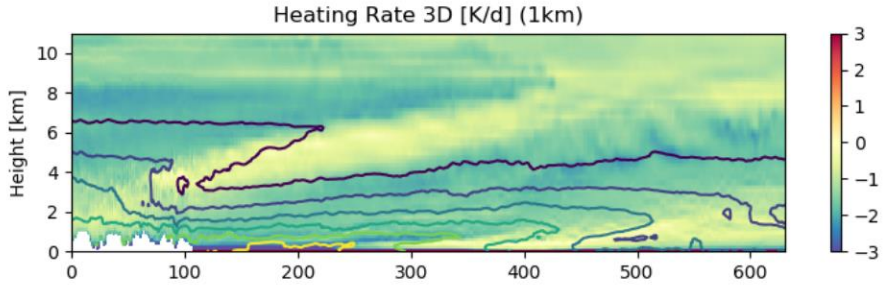
1D radiation



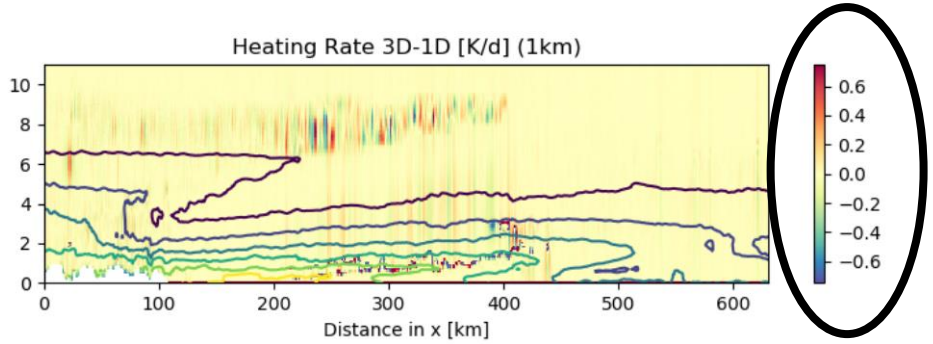


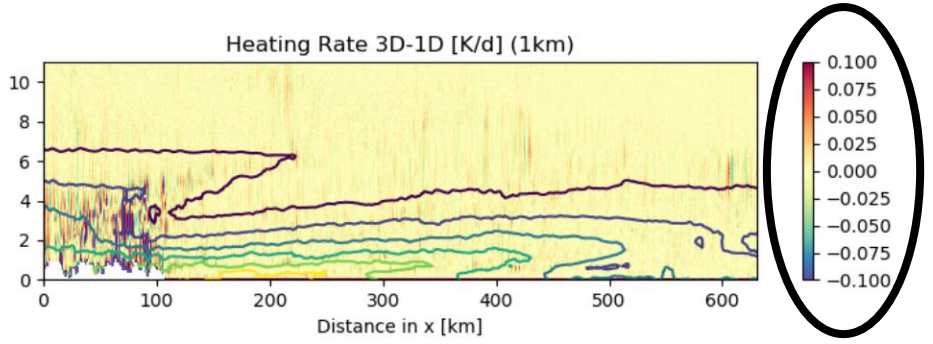
3D radiation





Difference



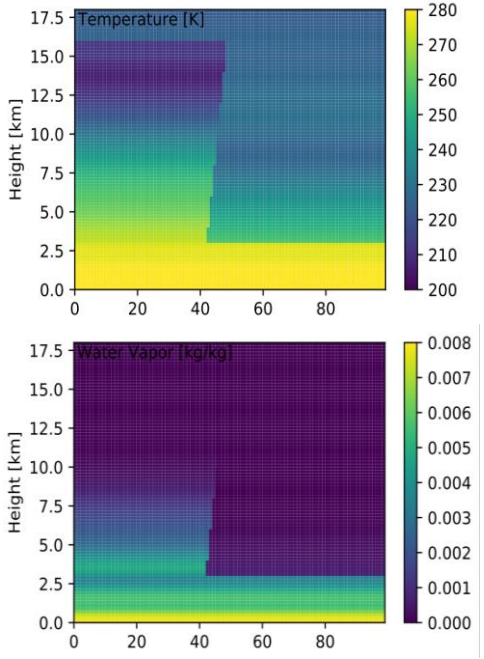


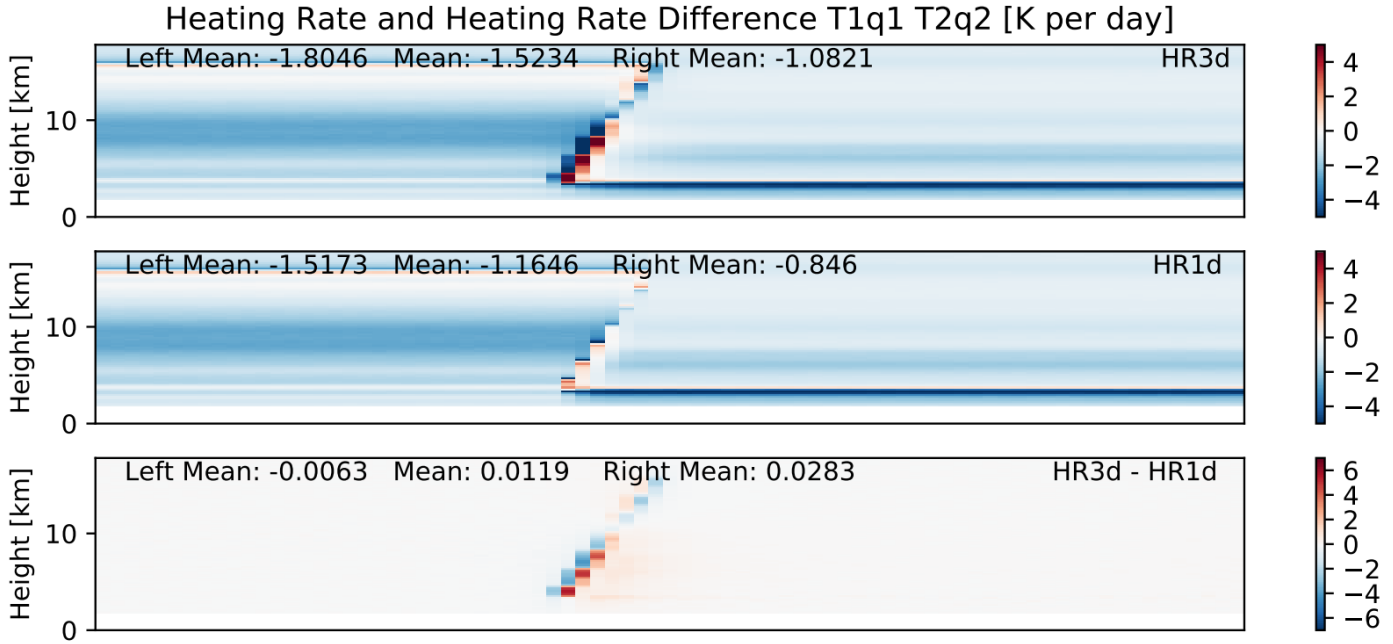
Maximum difference is 1-10% - why?

Sloping Boundary

Radiative transfer on idealized states

- Vary slope of boundary and compare 3D vs 1D cooling rates
- Resolution 1km x 200m
- Horizontally averaged T, q on warm and cold sides

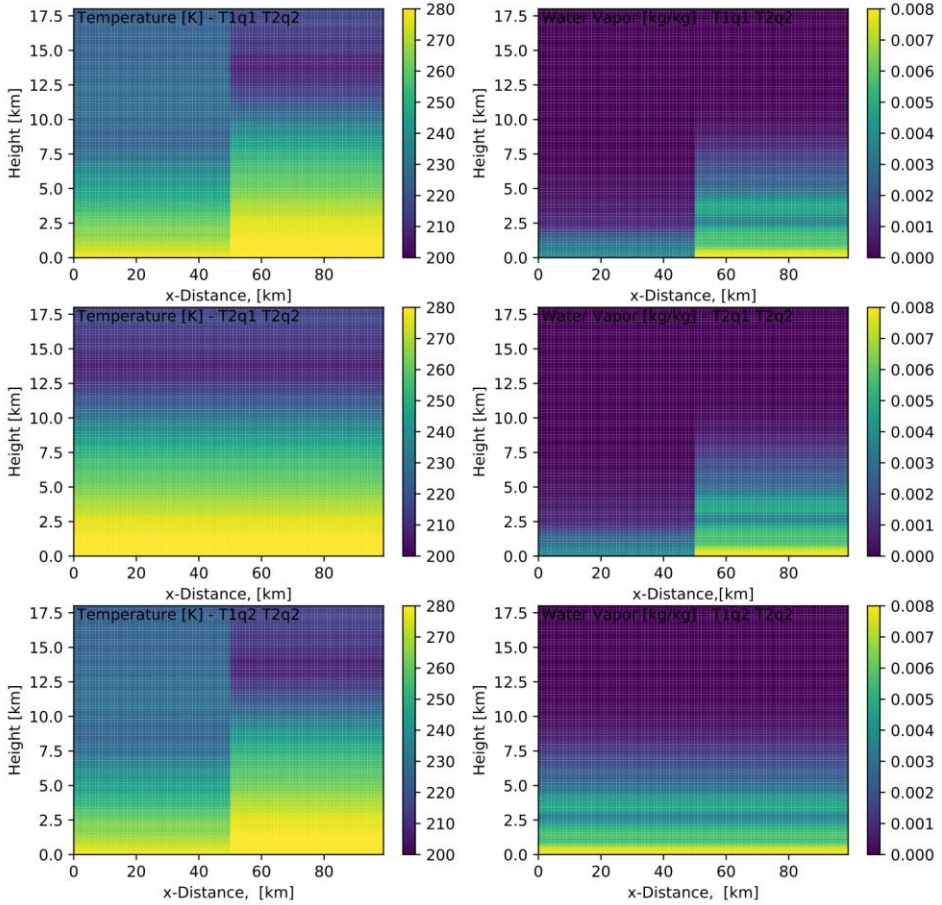




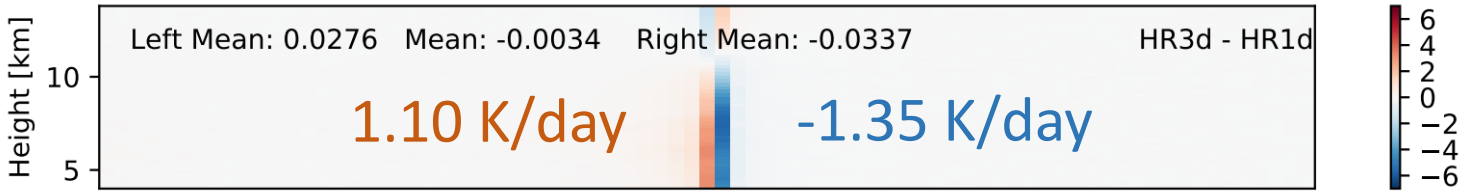
2. Need nearly vertical slope (eg. 2:1) for horizontal component of flux to be significant

Temperature and Moisture Gradients

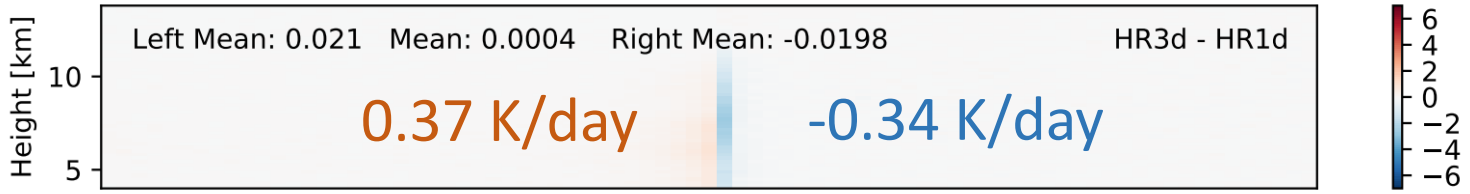
Warm and cold sides reversed!



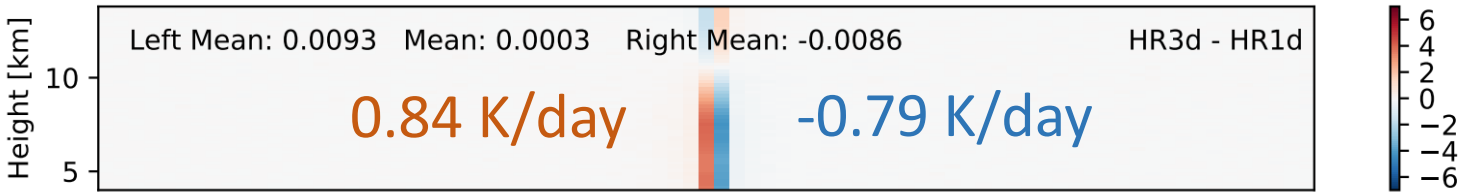
Column-averaged heating rates within 1km of boundary



Temperature and humidity contrast



Humidity contrast only



Temperature contrast only

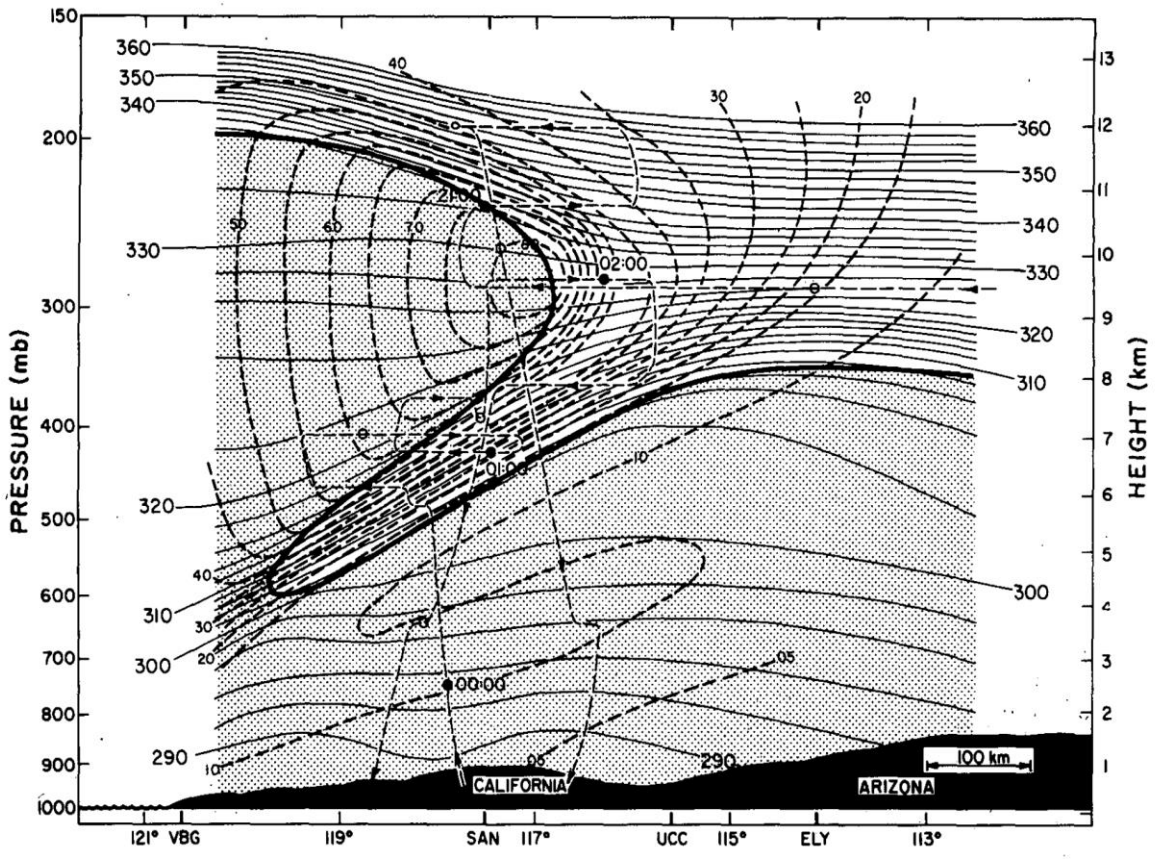
3. Temperature effect more important than humidity, but small near tropopause

Conclusion

Impact of using 3D radiative transfer is smaller than expected

1. Broken clouds in WCB outflow, so lack of strong cooling at tropopause.
Locally, boundary may be sharp

2. Tropopause must be nearly vertical for horizontal fluxes to matter.
Typical slope is f/N ~ 1/100



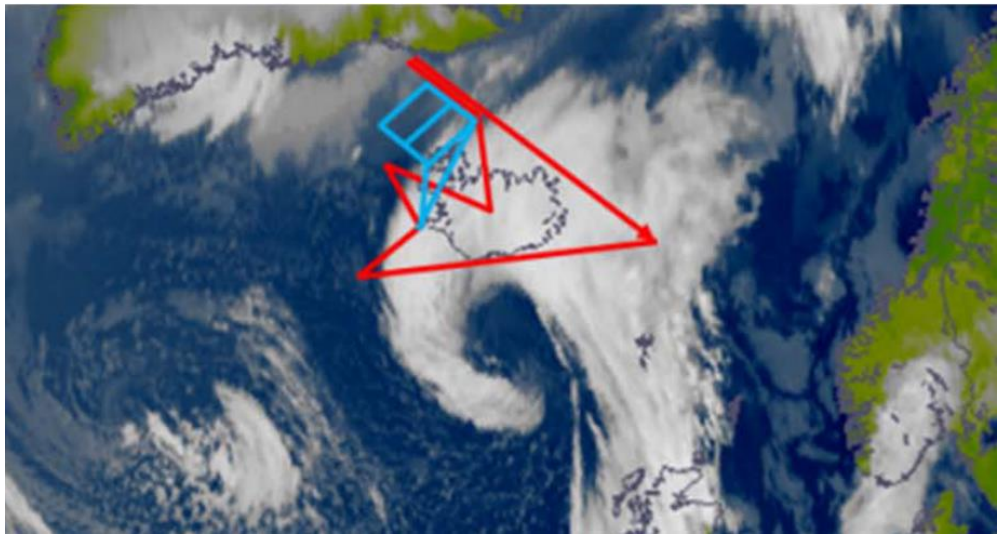
Shapiro (1980)

3a. T-gradient more important than humidity near tropopause.
And...

3b. Horizontal T-gradient is small where tropopause is vertical.
Consequence of thermal wind equation at height of maximum wind speed!

Future Work

3D effects may be important where the cloud boundary is sharp



Waves to Weather project B4

(Bernhard Mayer, Aiko Vogt)

- 3D radiation effects as part of general investigation of impact of radiation on mid-latitude cyclones