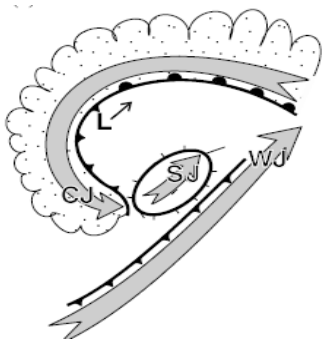
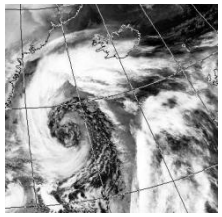
University of Reading





Mesoscale processes in the polar atmosphere – the context

Suzanne Gray University of Reading

February 2013

www.met.reading.ac.uk/~sws98slg

University of Reading

tropopause fold

stratosphere troposphere exchange

numerical weather prediction model

ozone

convection

wave breaking

vertical mixing

radiosonde

mountain wave

particle dispersion model

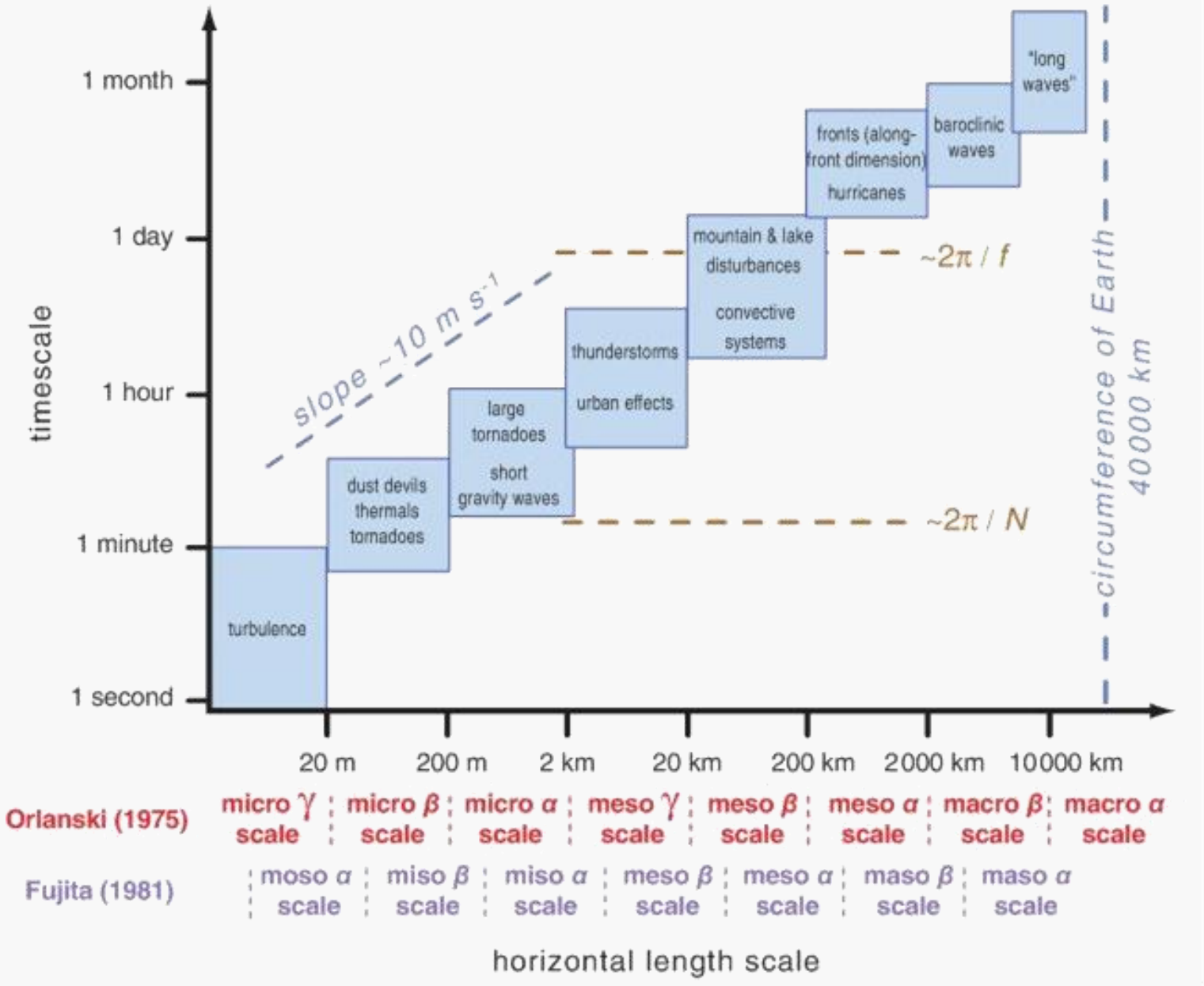
wind profiler radar

potential vorticity

turbulence

Word *It* Out

Mesoscale?



Markowski and Richardson 2010

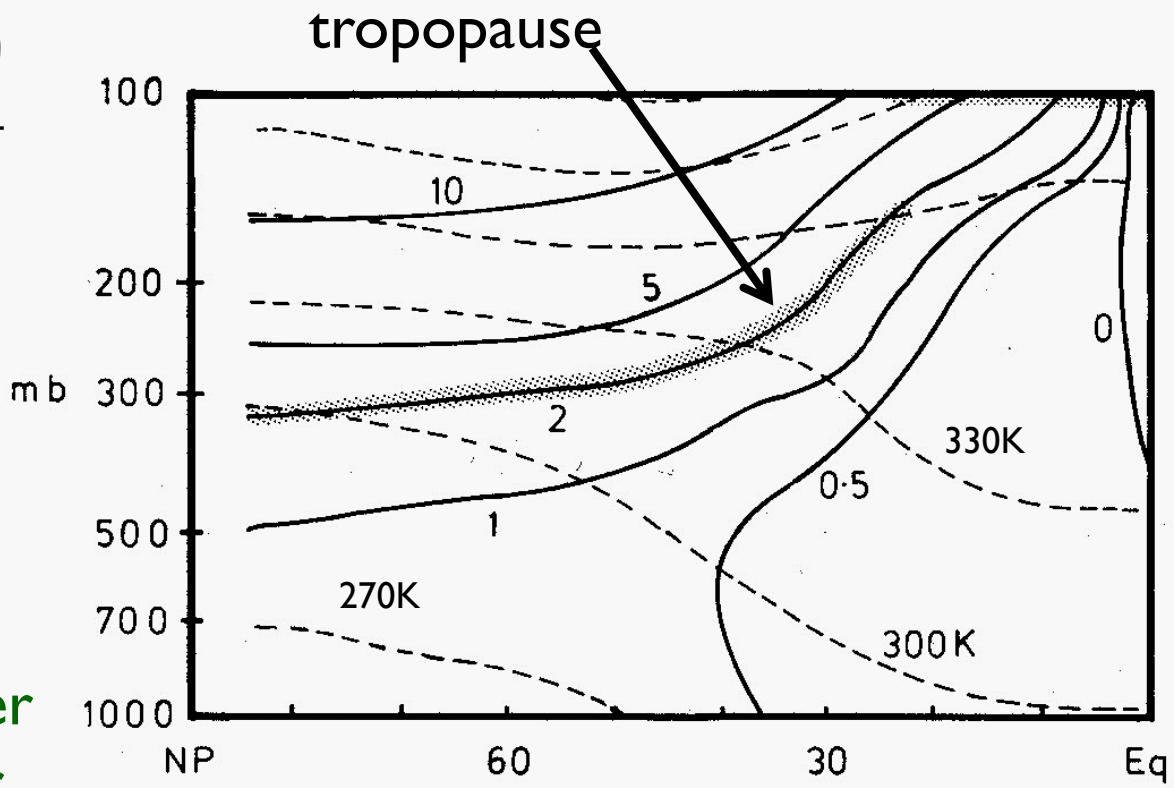
The climatological atmosphere

University of Reading

$$\mathrm{PV} = \frac{(\vec{f} + \vec{\xi}) \cdot \nabla\theta}{\rho}$$

Potential vorticity is conserved following fluid parcels for adiabatic frictionless flow.

This makes it a good tracer for upper-tropospheric air over several days.

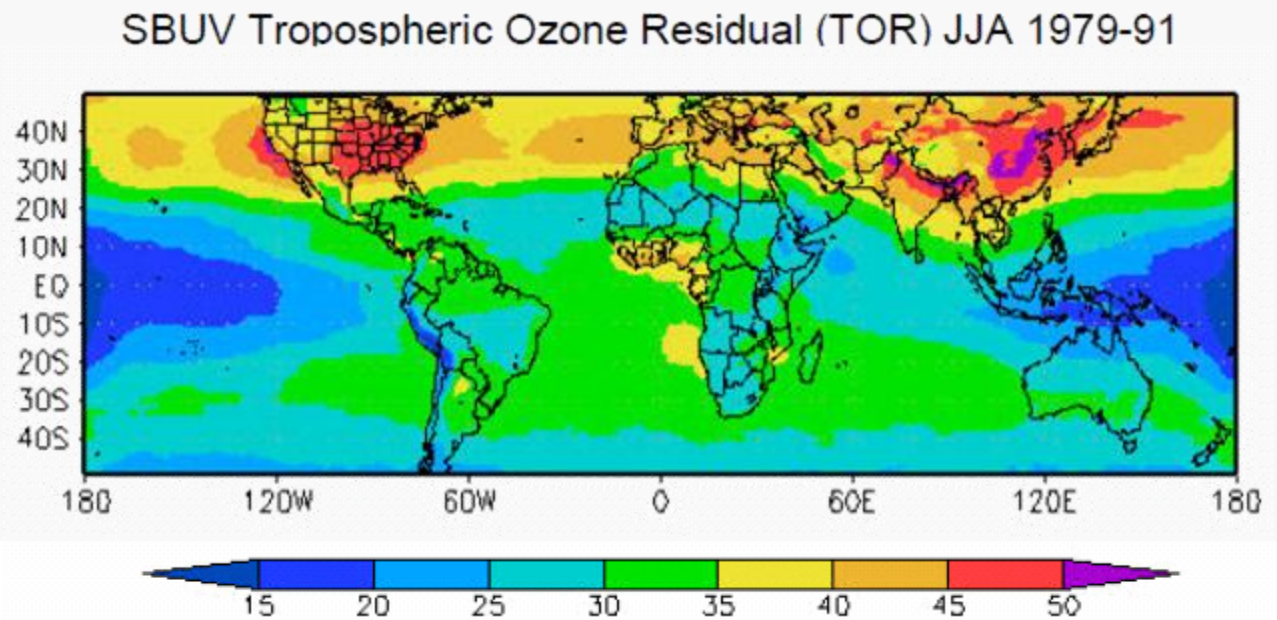


Climatology of PV (in PVU) and θ in NH winter (Hoskins, 1990)

Stratosphere-troposphere exchange

University of Reading

- Defined as the exchange of mass and chemical species between the stratosphere and troposphere.
- Regulates the chemical composition of both stratosphere and troposphere.
- Stratosphere-to-troposphere transport injects ozone and other chemical species into the troposphere.
- Stratospheric ozone absorbs dangerous UV radiation.
- Tropospheric ozone is a greenhouse gas and, at high concentrations, a pollutant with health impacts.



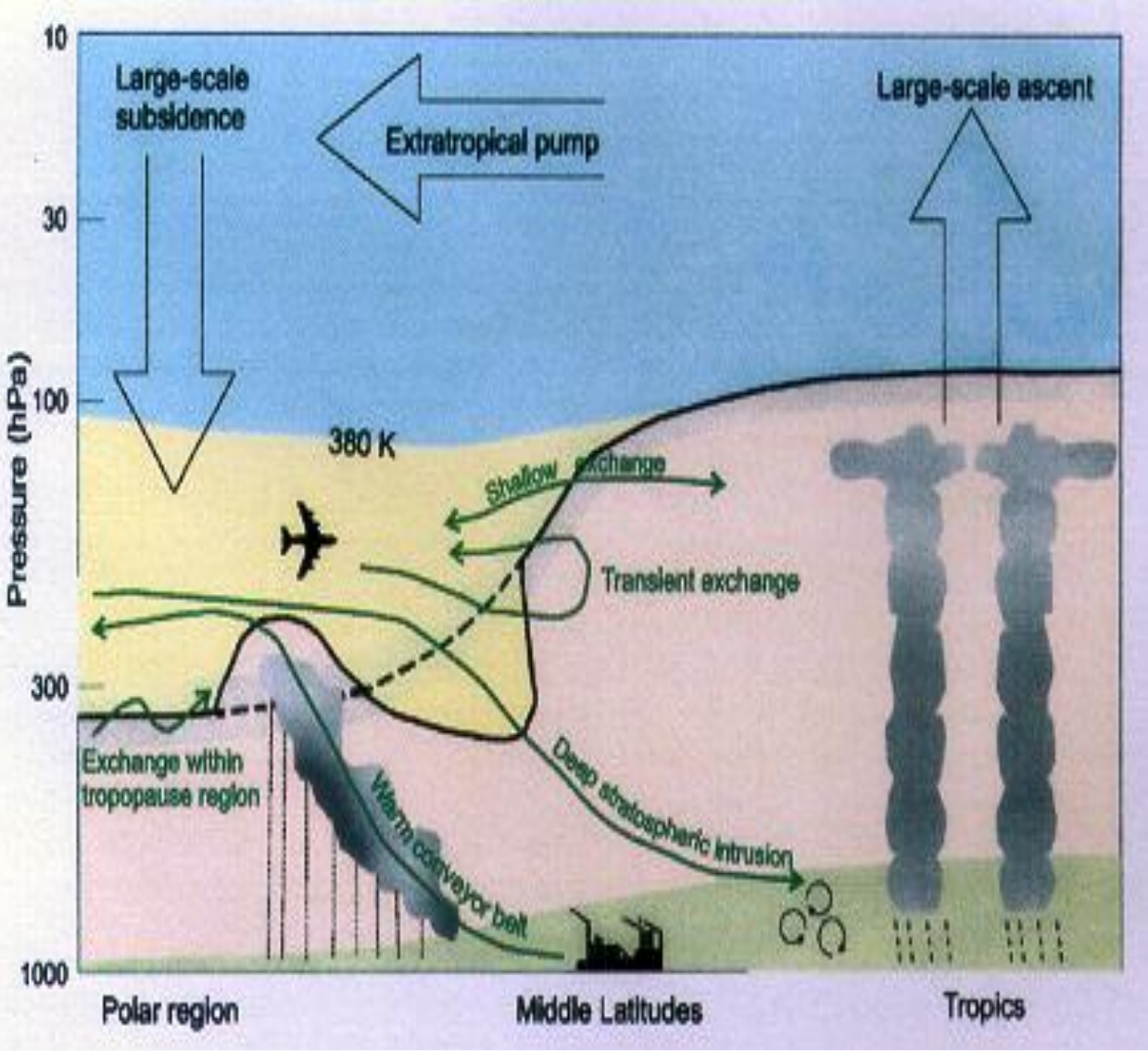
Fishman et al., 2003

Stratosphere-troposphere exchange

University of Reading

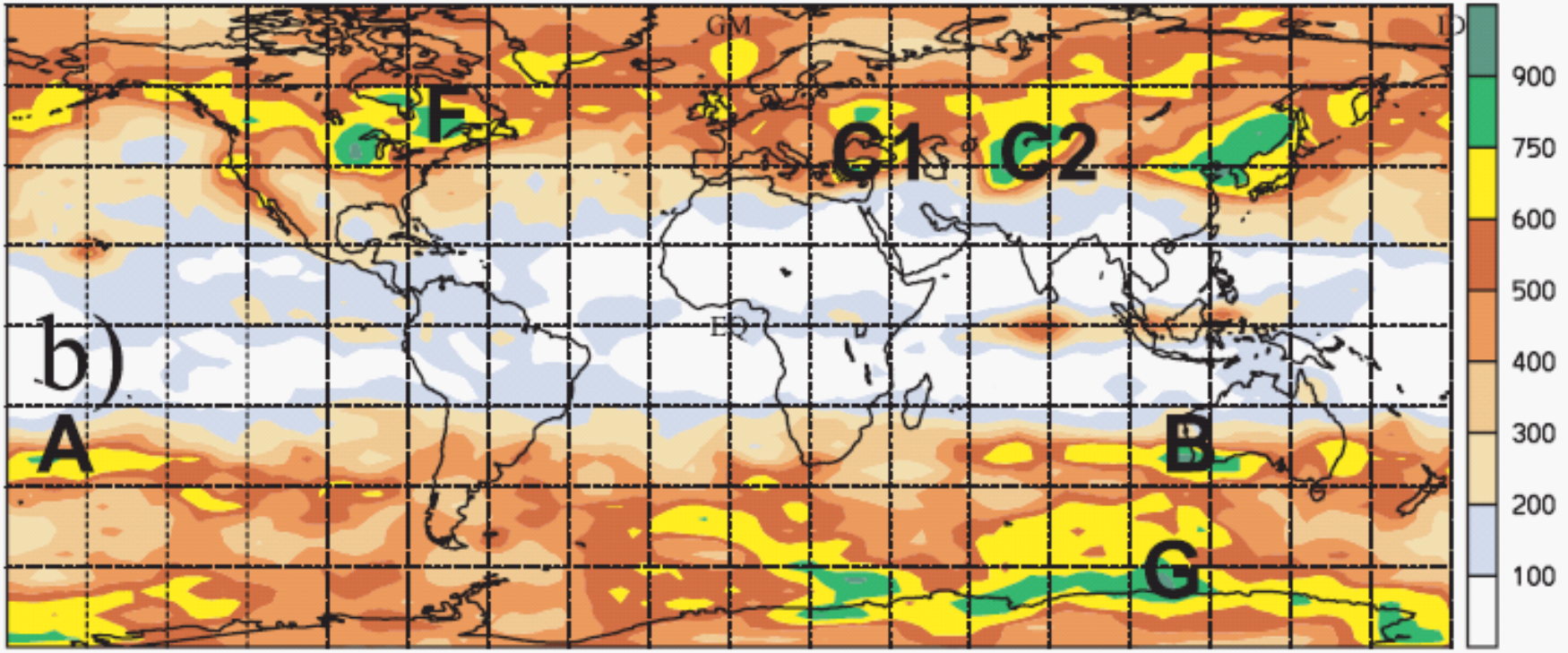
Local exchange across the tropopause is dependent on small-scale near-tropopause processes including folds and cut-off cyclones.

Mixing processes including mountain waves and convection can bring stratospheric air to the surface.



Stohl et al., 2003

Stratosphere-to-troposphere transport



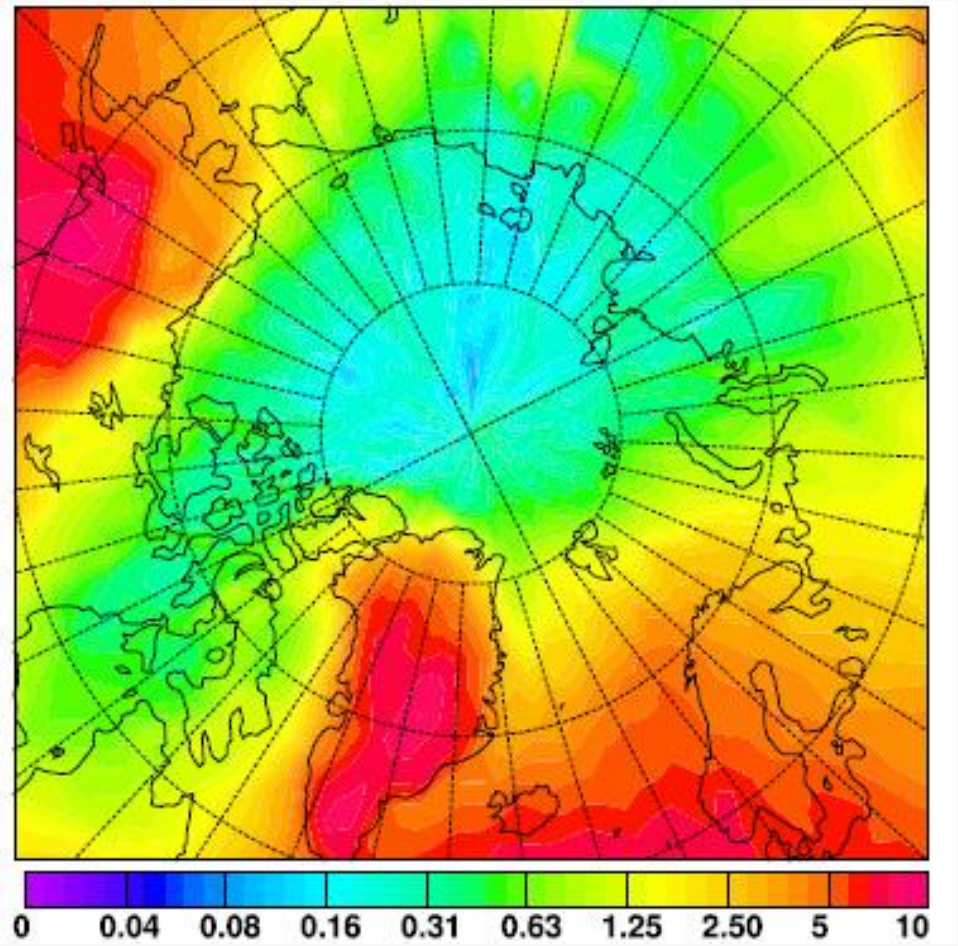
JJA transport

Deep STE occurs predominantly over Atlantic and Pacific storm tracks in winter.

Sprenger et al. (2003)

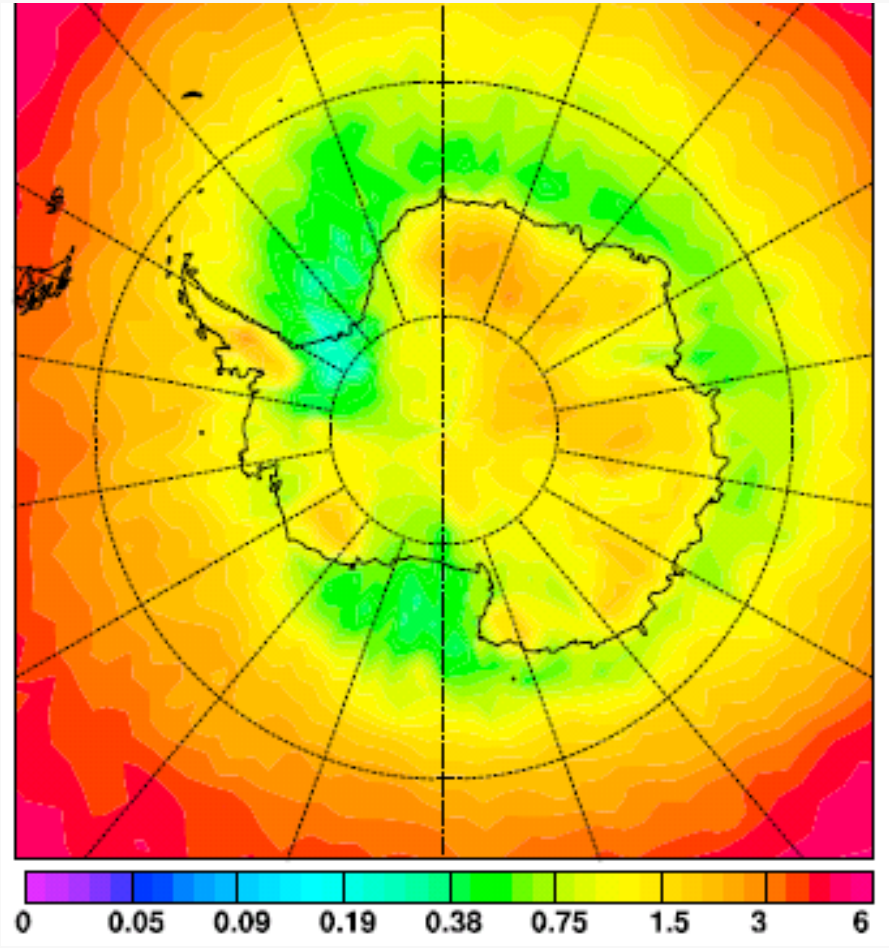
Polar stratosphere-to-boundary layer transport

University of Reading



Winter in the Arctic (%)

Stohl (2006)



Autumn in the Antarctic (%)

Stohl and Sodemann (2010)

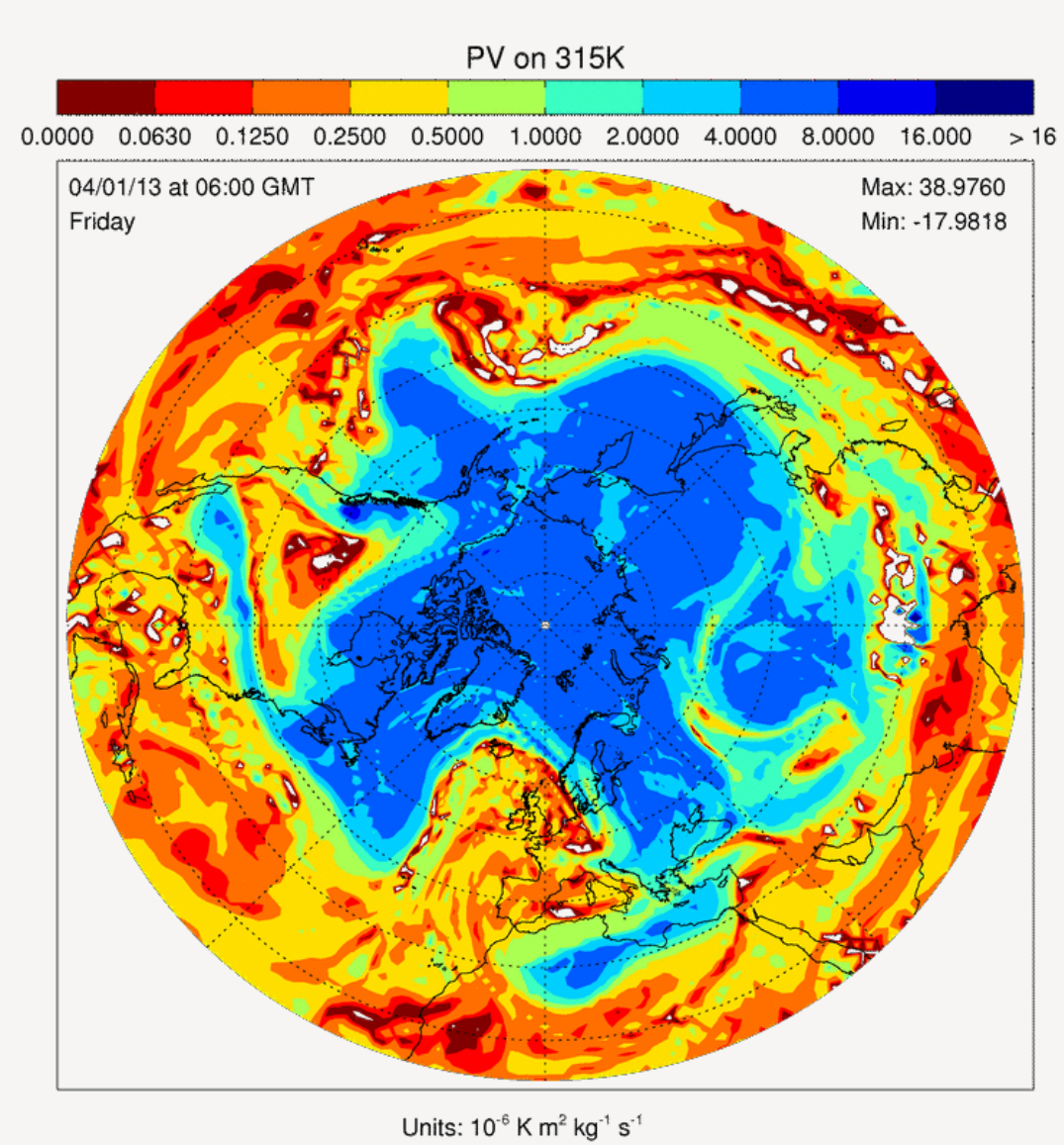
Weather systems and potential vorticity

University of Reading

$$\mathrm{PV} = \frac{(\vec{f} + \vec{\xi}) \cdot \nabla\theta}{\rho}$$

Potential vorticity is conserved following fluid parcels for adiabatic frictionless flow.

This makes it a good tracer for upper-tropospheric air over several days.

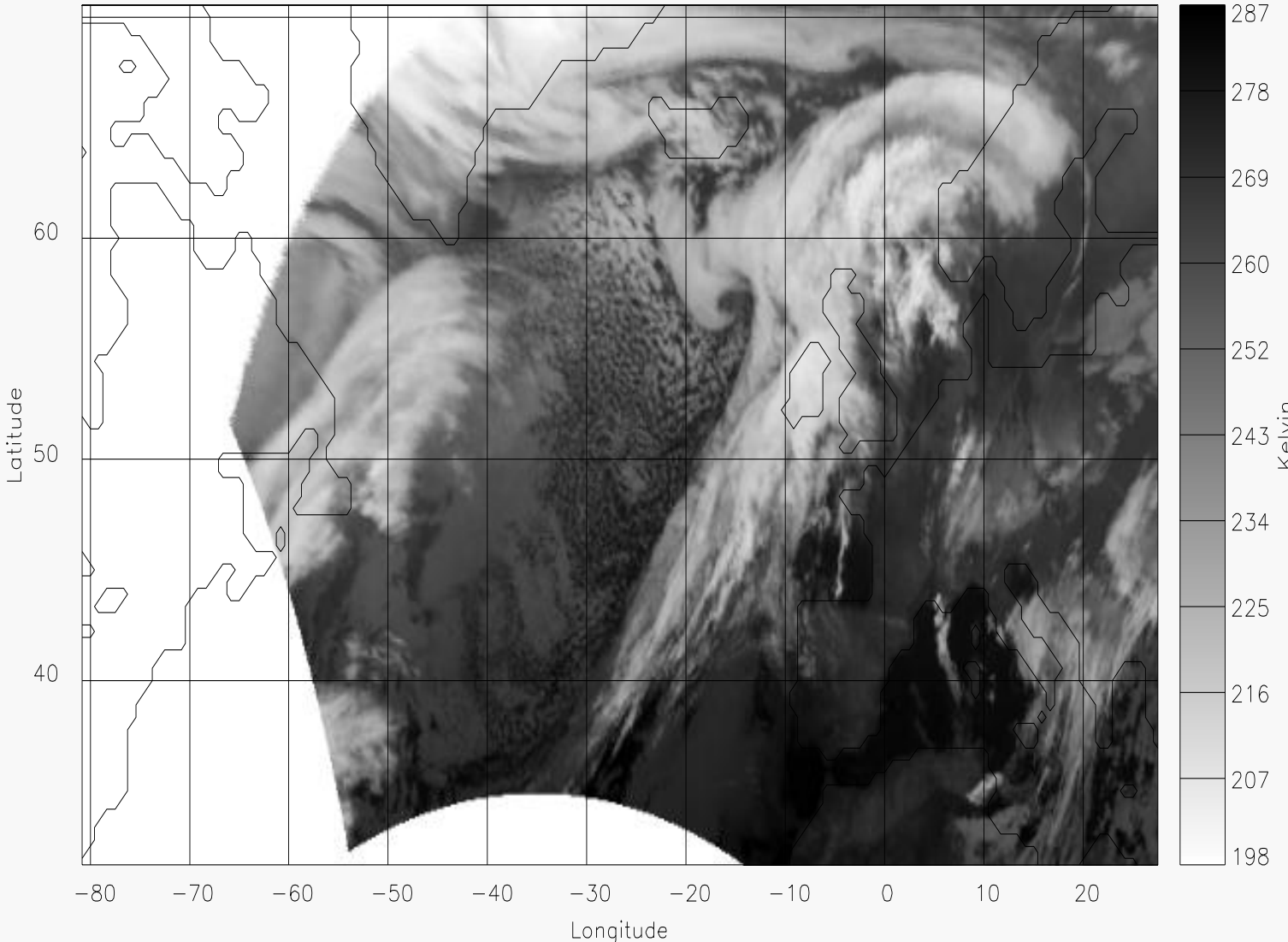


ECMWF analyses of PV on 315K isentrope.

Stratosphere-to-troposphere transport in folds

University of Reading

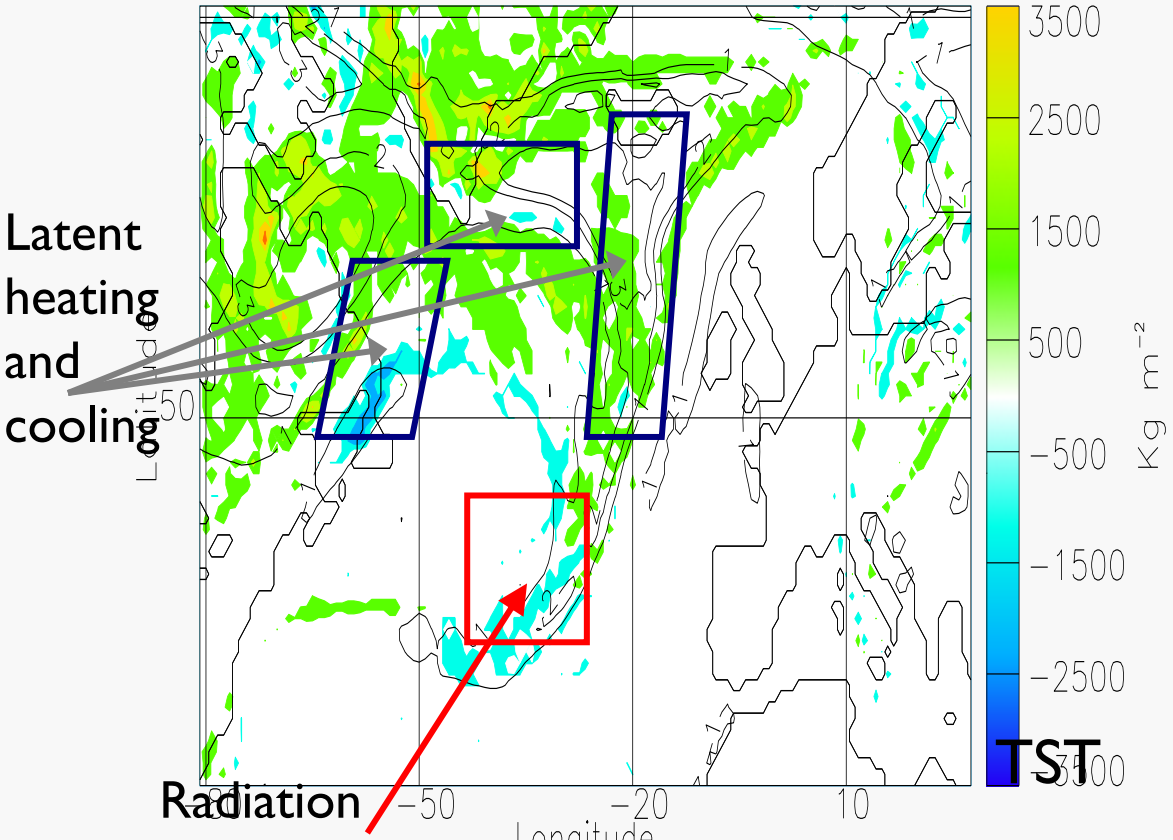
IR image: 0Z
10/2/00



Gray (2006)

Stratosphere-to-troposphere transport in folds

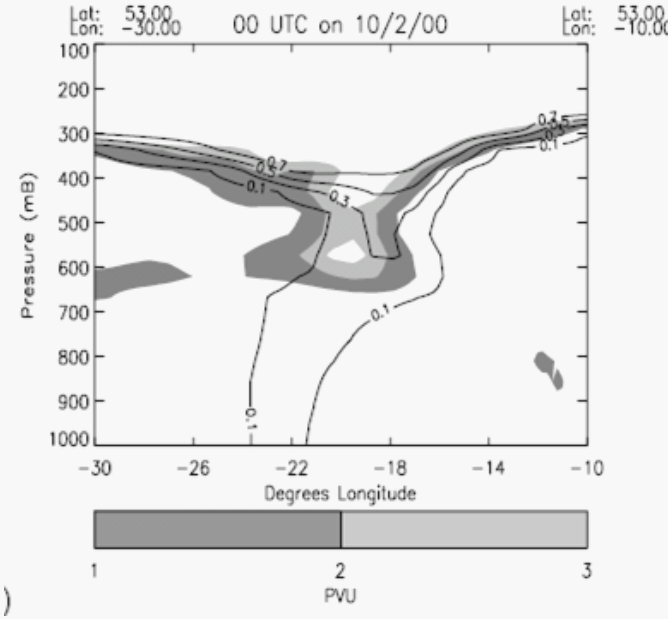
STT



Latent heating and cooling

Radiation

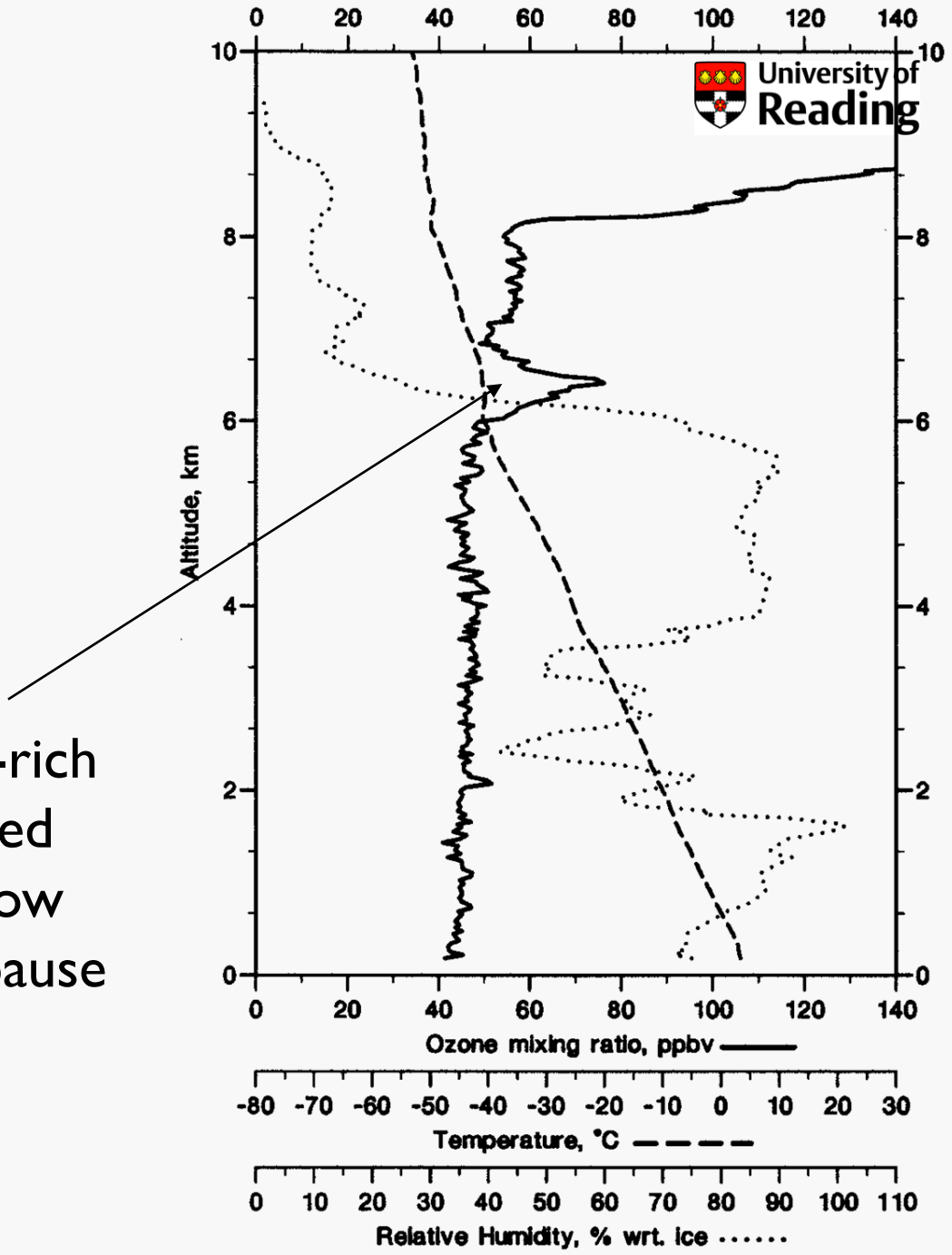
TST



Exchange across the 1 PVU surface diagnosed using PV tracers

Gray (2006)

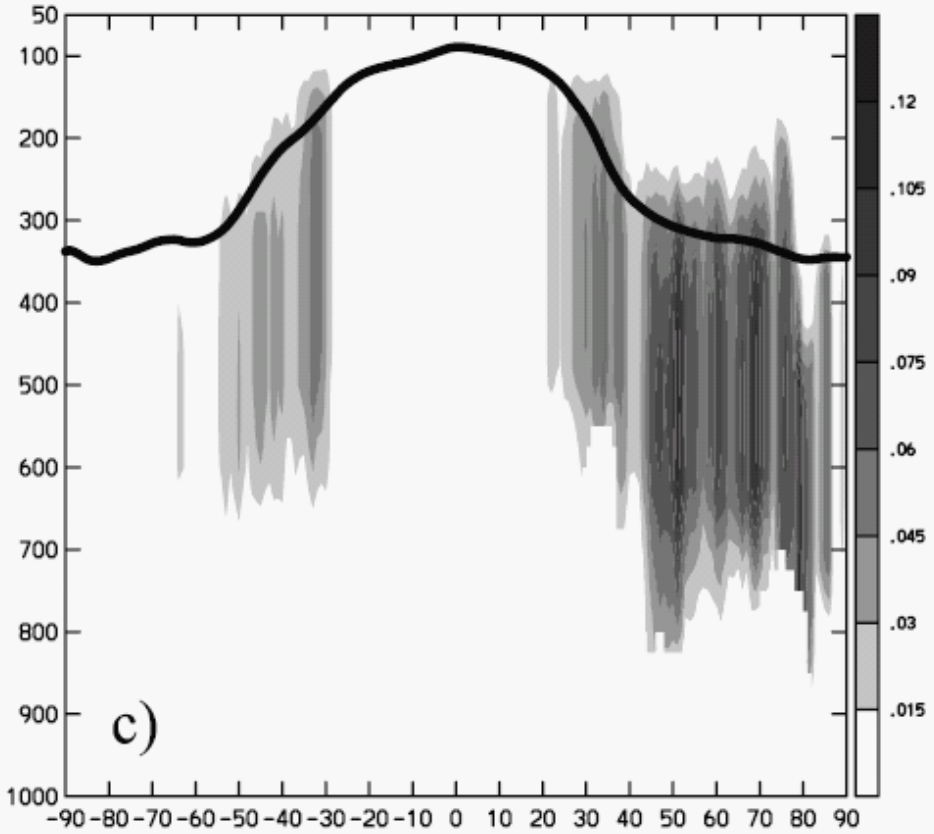
Observations of tropopause folds



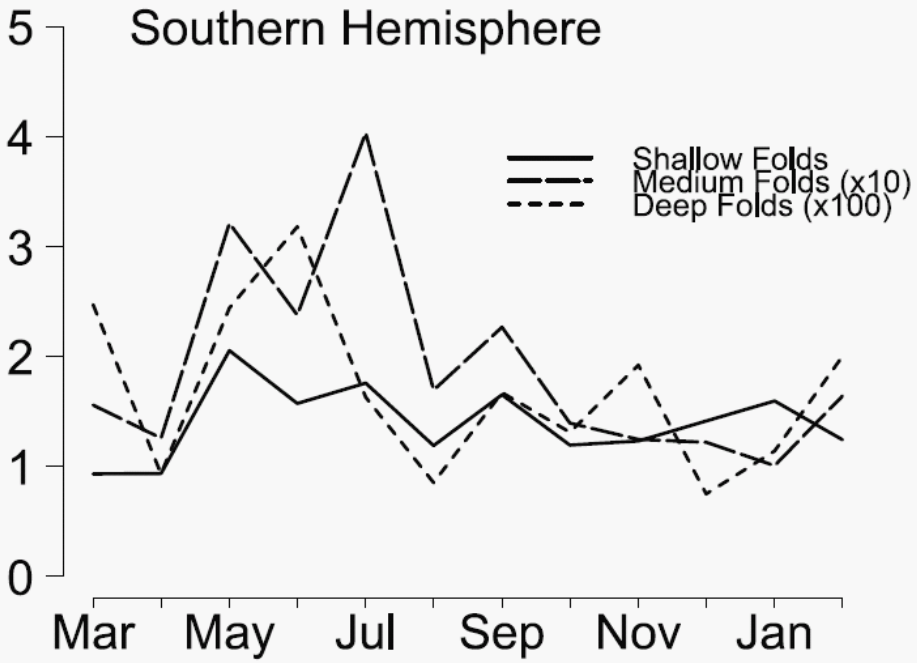
Fold – dry ozone-rich layer with enhanced static stability below the ozone tropopause

Reid and Vaughan, 2004

Tropopause fold climatology



DJF deep fold frequency (%)



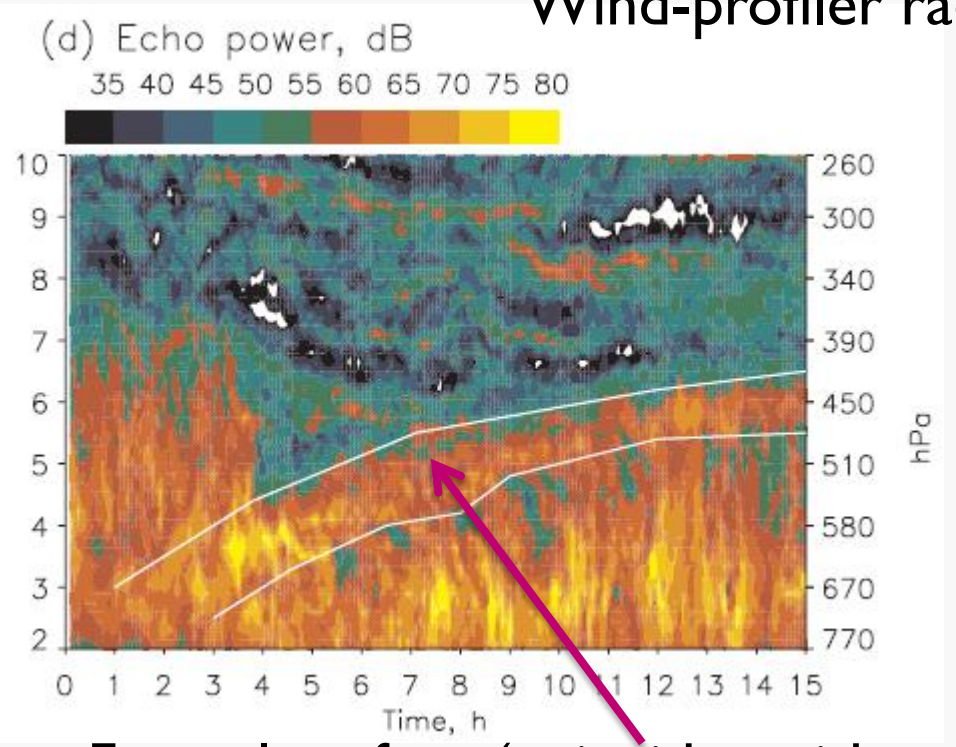
Annual variability of folds

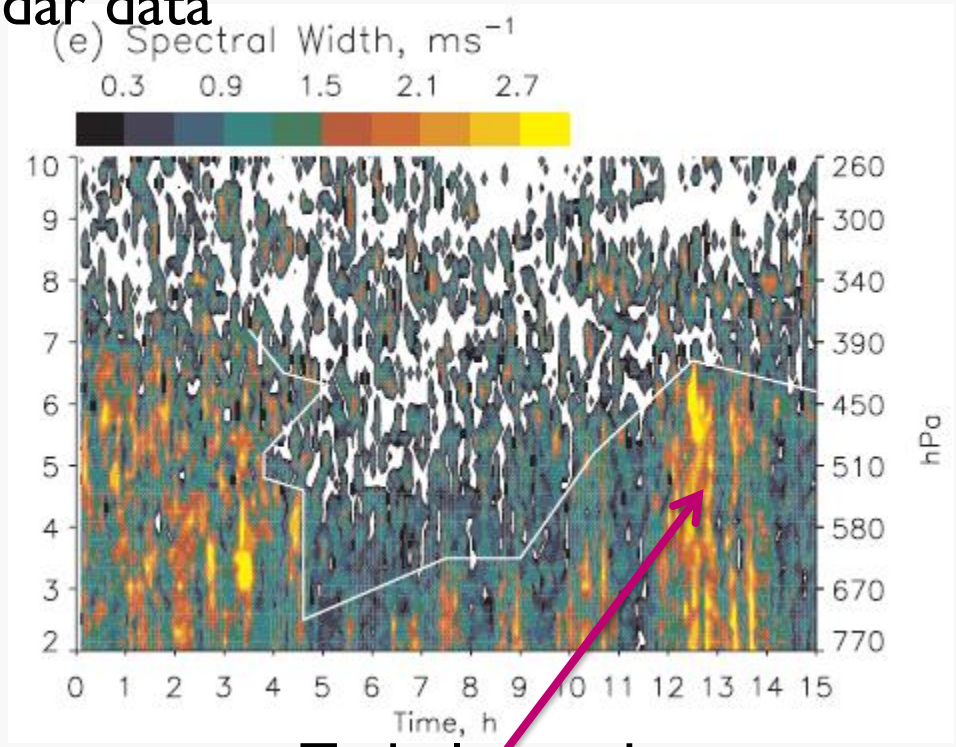
Sprenger et al. (2003)

Convection induced vertical transport

University of Reading

Wind-profiler radar data





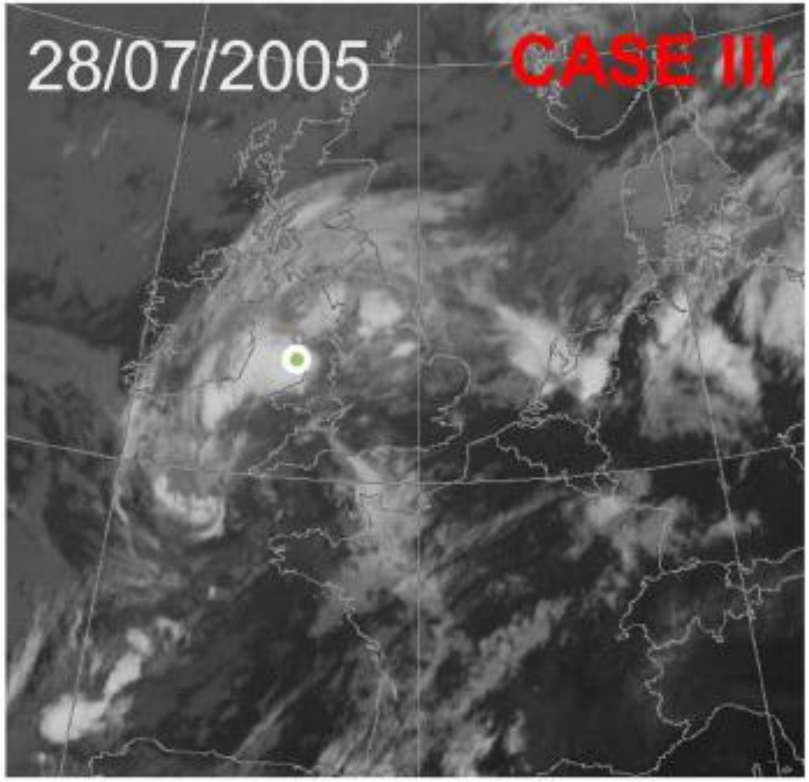
Frontal surface (coincides with tropopause fold at upper levels)

Turbulence due to convection

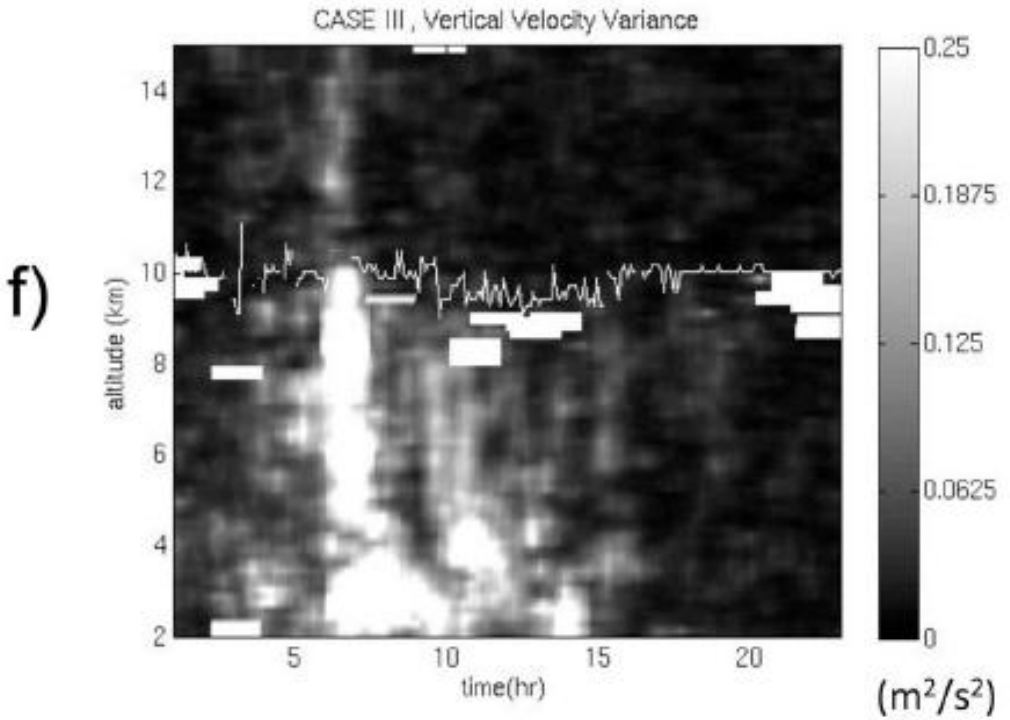
4×10^{12} kg of stratospheric air estimated to be diluted by convection

Reid and Vaughan, 2004

Convection induced vertical transport



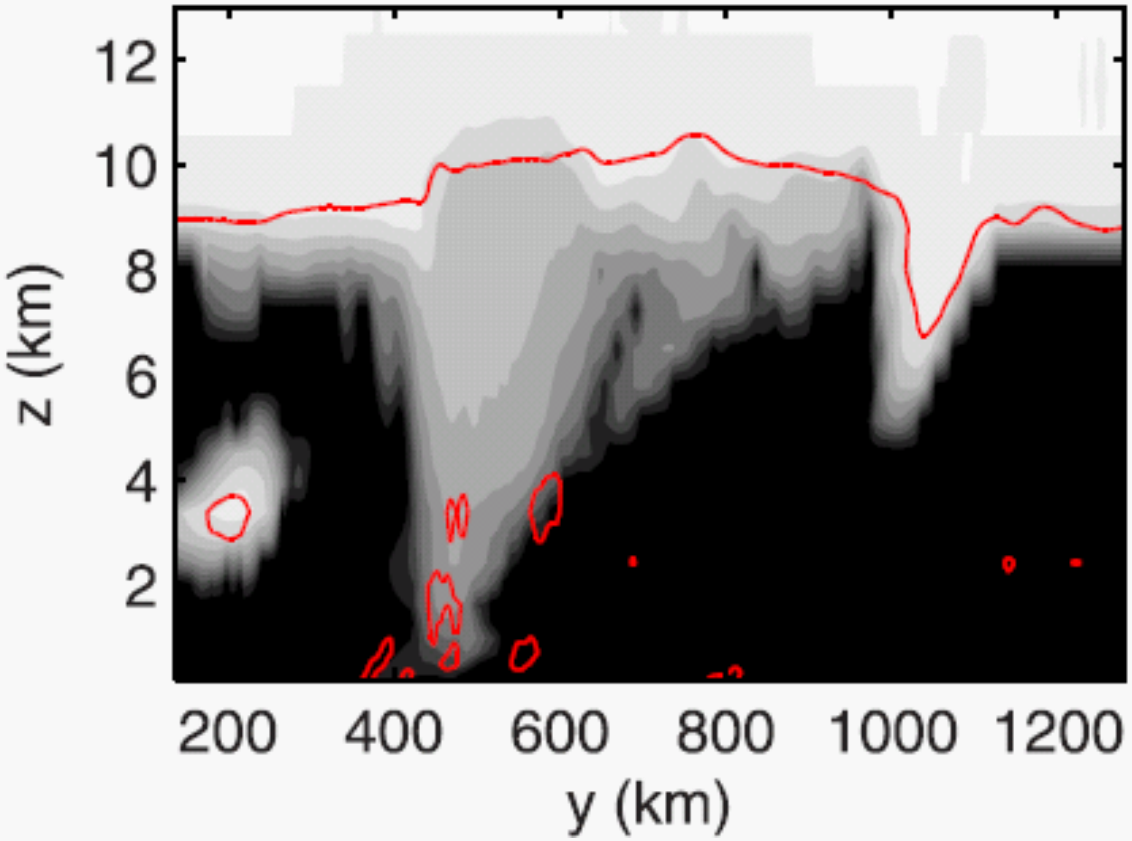
IR satellite imagery

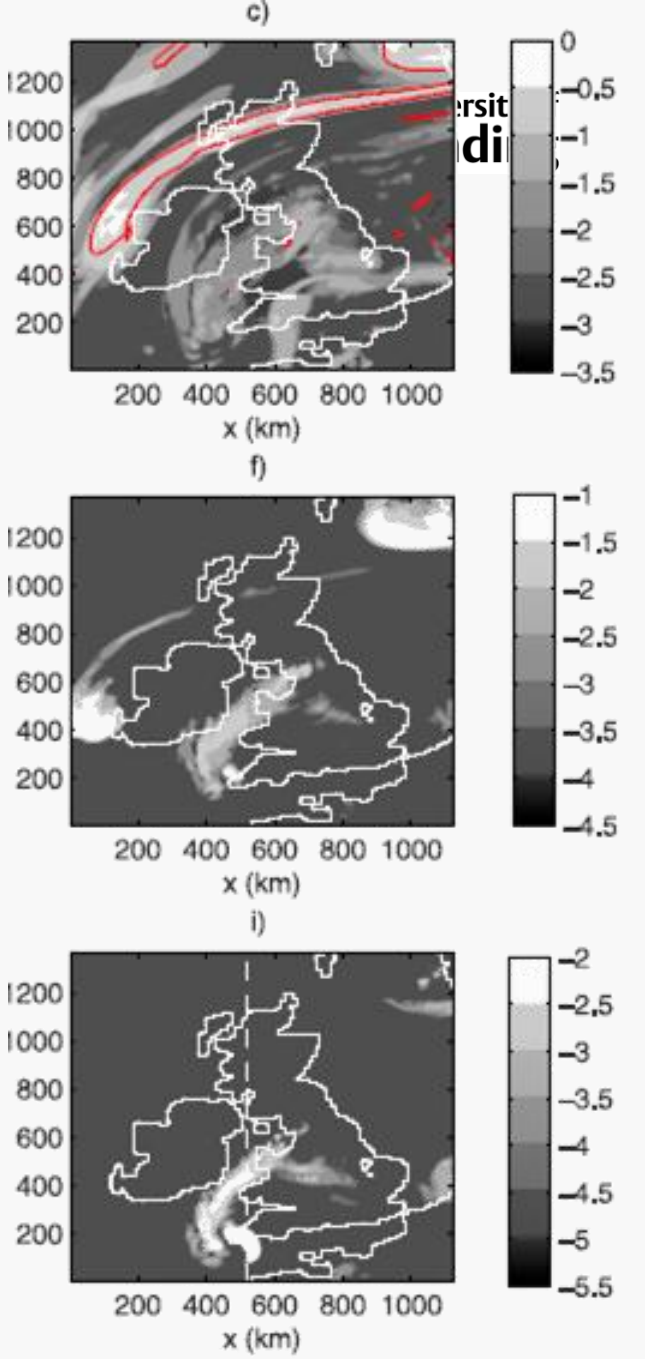


Wind profiler radar

Chagnon and Gray, 2010

Convection induced vertical transport





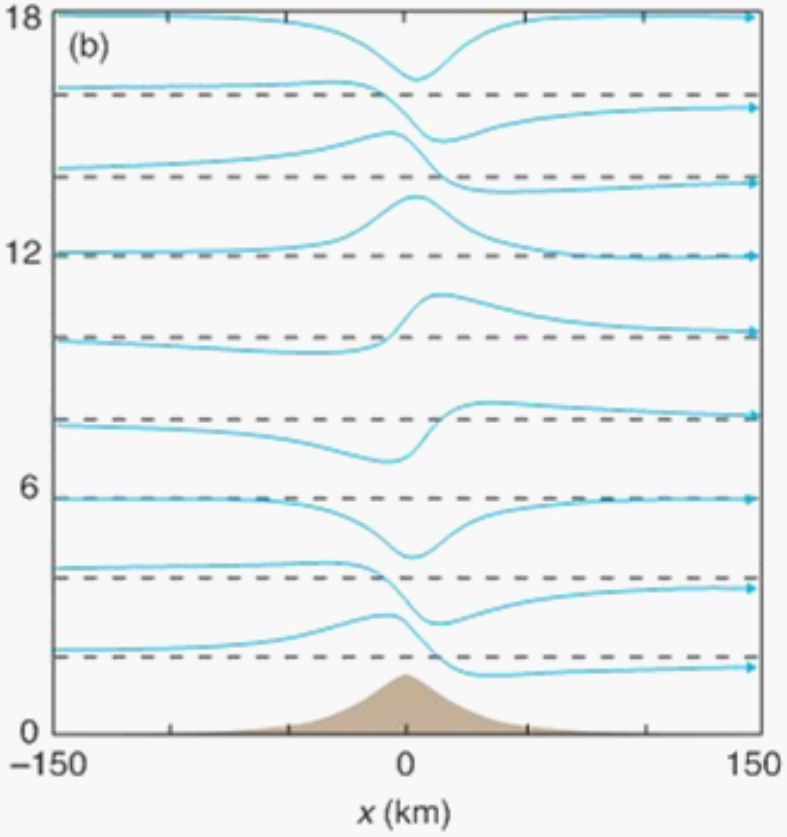
5-20% of total mass within 2 km above the tropopause is transported to troposphere (3 cases). Only 1% of this reaches the boundary layer

Chagnon and Gray, 2010

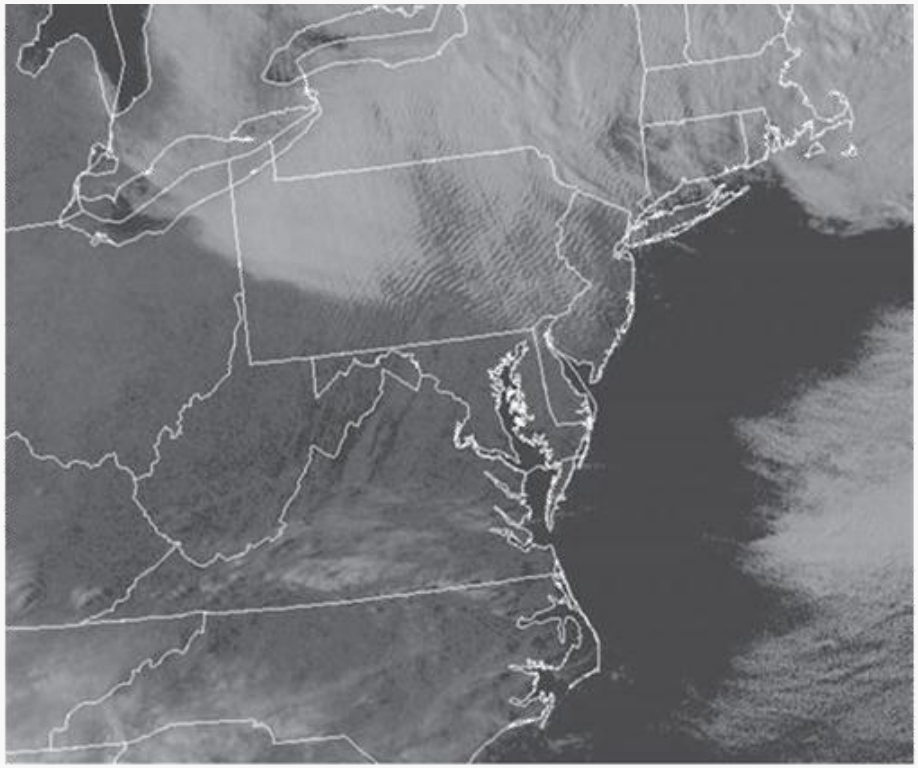
Mountain waves

University of Reading

Vertically propagating mountain wave



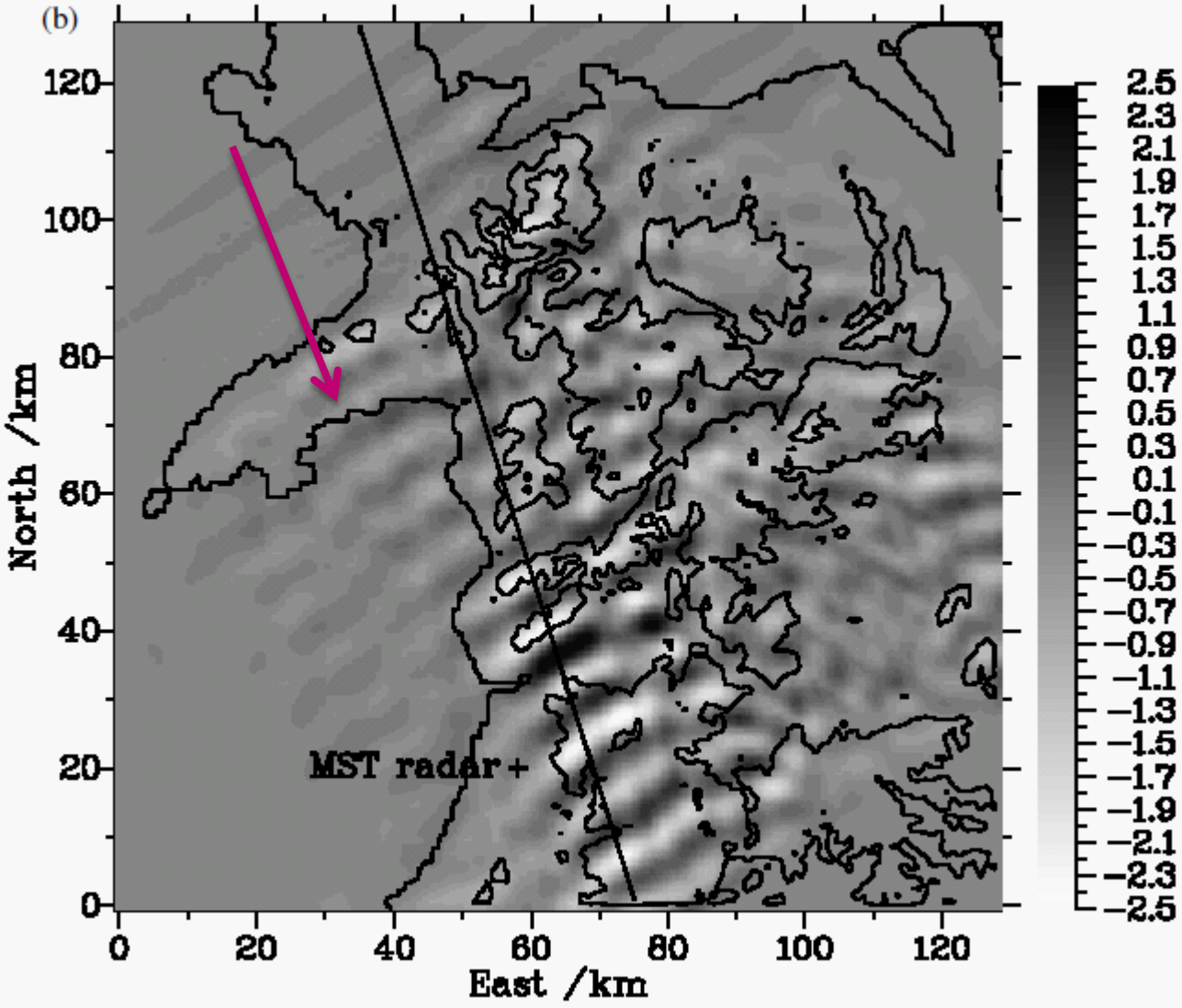
Trapped lee waves



Markowski and Richardson 2010

Mountain wave: Model simulations

University of Reading



Vosper and Worthington (2002)

Questions

University of Reading

- How much mass is transported from the stratosphere to the troposphere (and boundary layer) in polar regions?
- What are the processes by which this occurs?

And specifically

- What processes cause turbulence and the vertical transport of tropospheric air near the Scandinavian mountain chain? How important are mountain waves?
- What is the climatology and importance of tropopause folding events in Antarctica?

This thesis presents the answers to these questions using new analysis of radar and sonde data combined with analysis from operational numerical weather prediction model output and research model simulations.