Lagrangian Diagnostics of Large-Scale Transport and Stirring in the UTLS

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Goal of START08 mission is to understand the processes responsible for trace species distributions in the UTLS

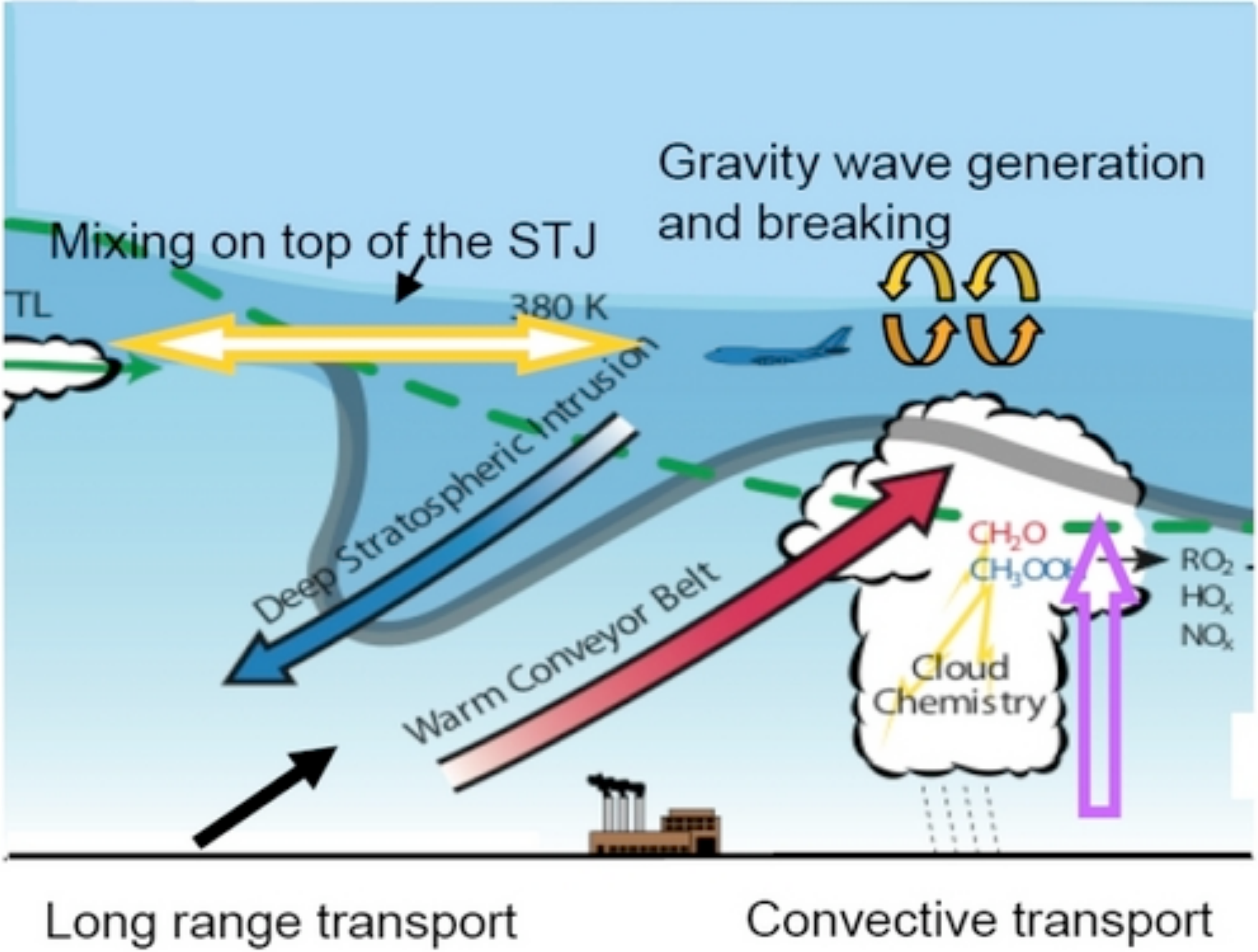
UTLS transport and mixing are the result of processes at a wide range of scales (planetary to molecular)

Definitions

Stirring - irreversible *macroscopic* transport

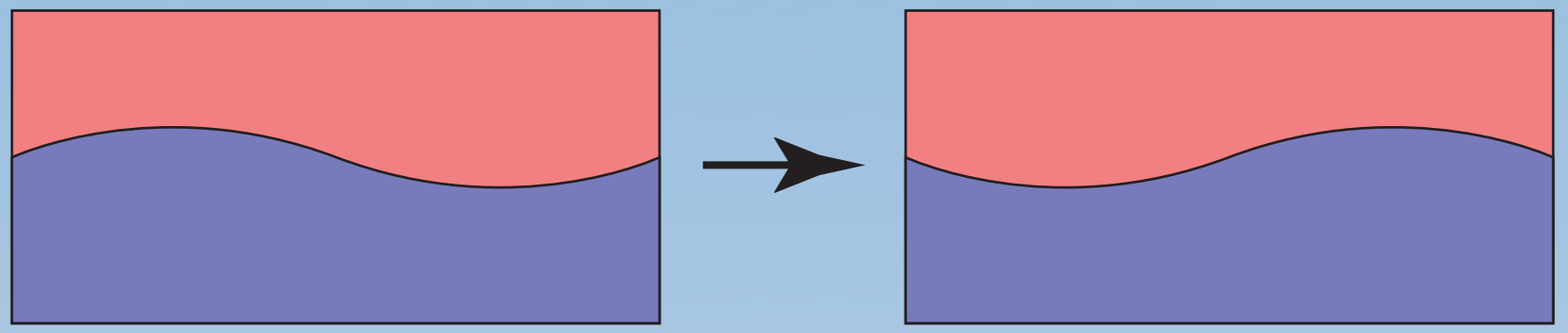
Mixing - irreversible *microscopic* transport (at the molecular level)

1) Three-dimensional climatological transport
2) Large-scale two-dimensional stirring by transient waves

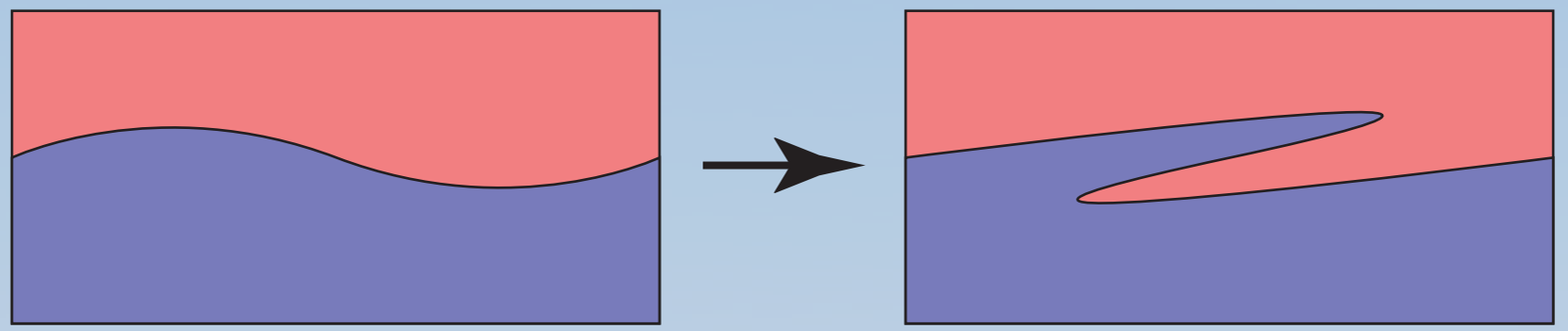

Gravity wave generation
and breaking
Mixing on top of the STJ
TL
380 K
Deep Stratospheric Intrusion
Warm Conveyor Belt
CH_2O
CH_3OOH
RO_2
HO_x
NO_x
Cloud
Chemistry
Long range transport
Convective transport

Reversible vs. Irreversible Transport

Reversible transport



Irreversible transport (stirring)

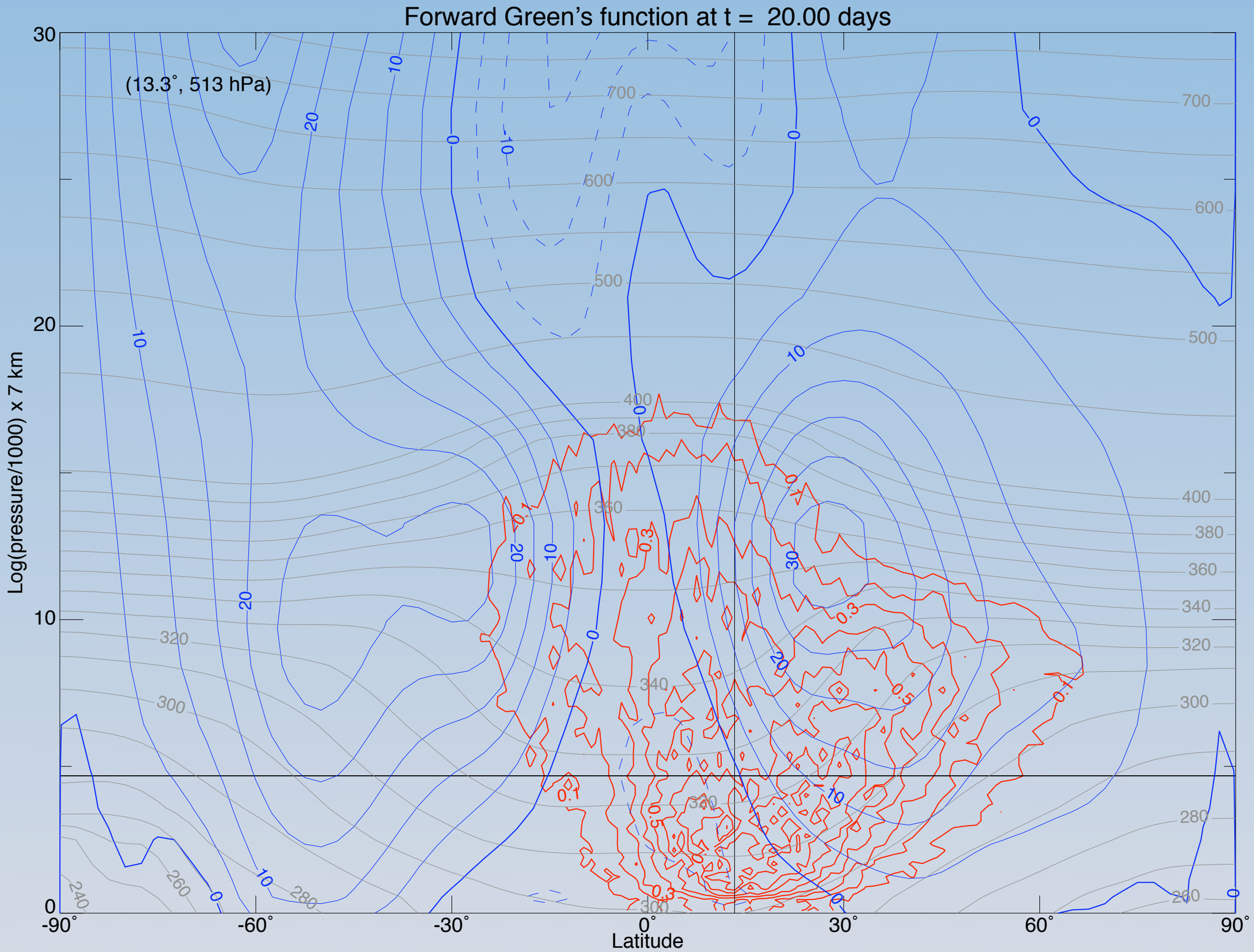


Large-scale stirring by folding and stretching produces filaments with large surface areas. Repeated stretching and folding rapidly produces thin layers (~ few days). These layers can be acted on by smaller-scale processes (e.g., gravity wave breaking and turbulence).

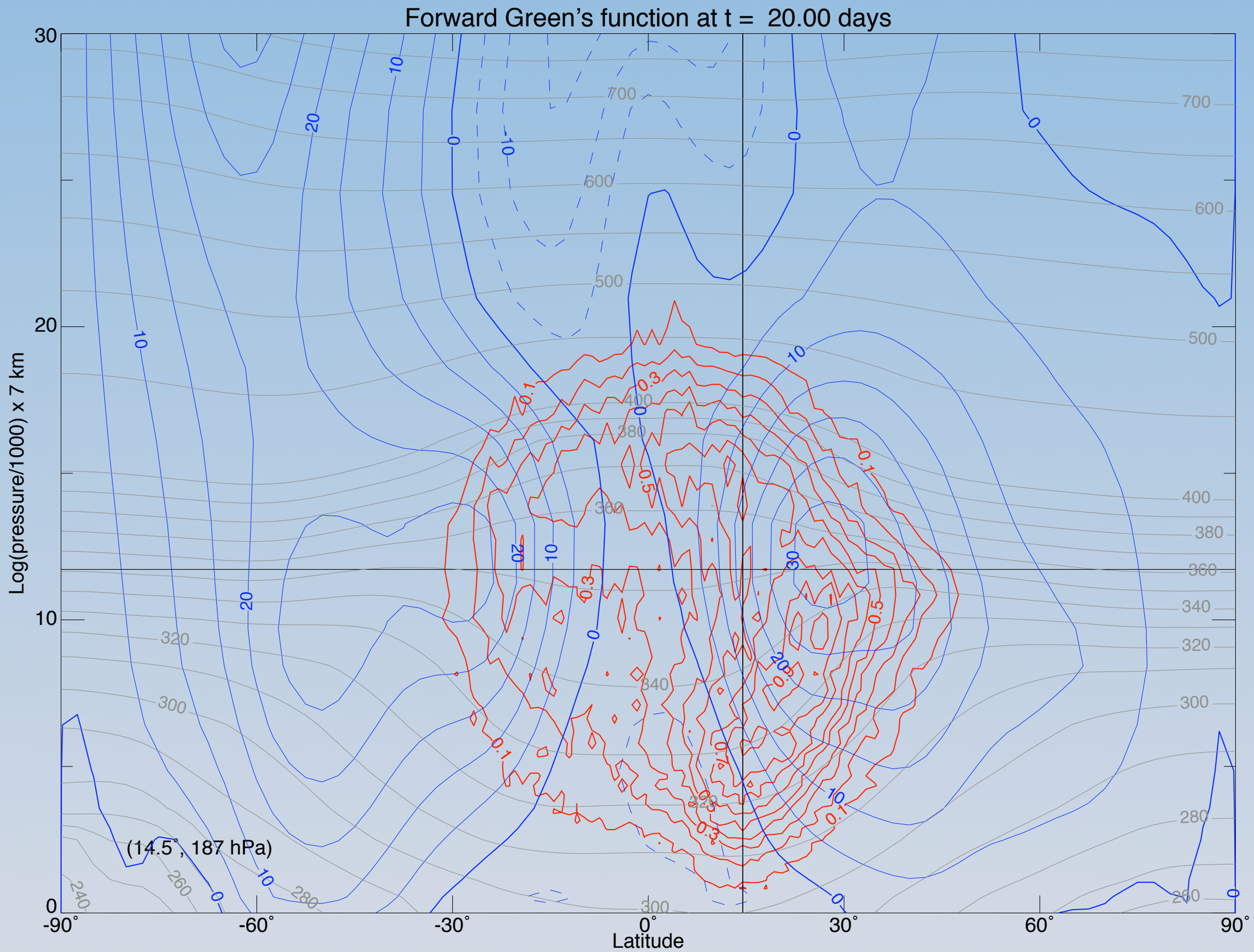
1. Climatological Transport Characteristics

- Release particles at a particular location in the atmosphere at many different times
- Examine the climatological *distribution* of particle locations after some time

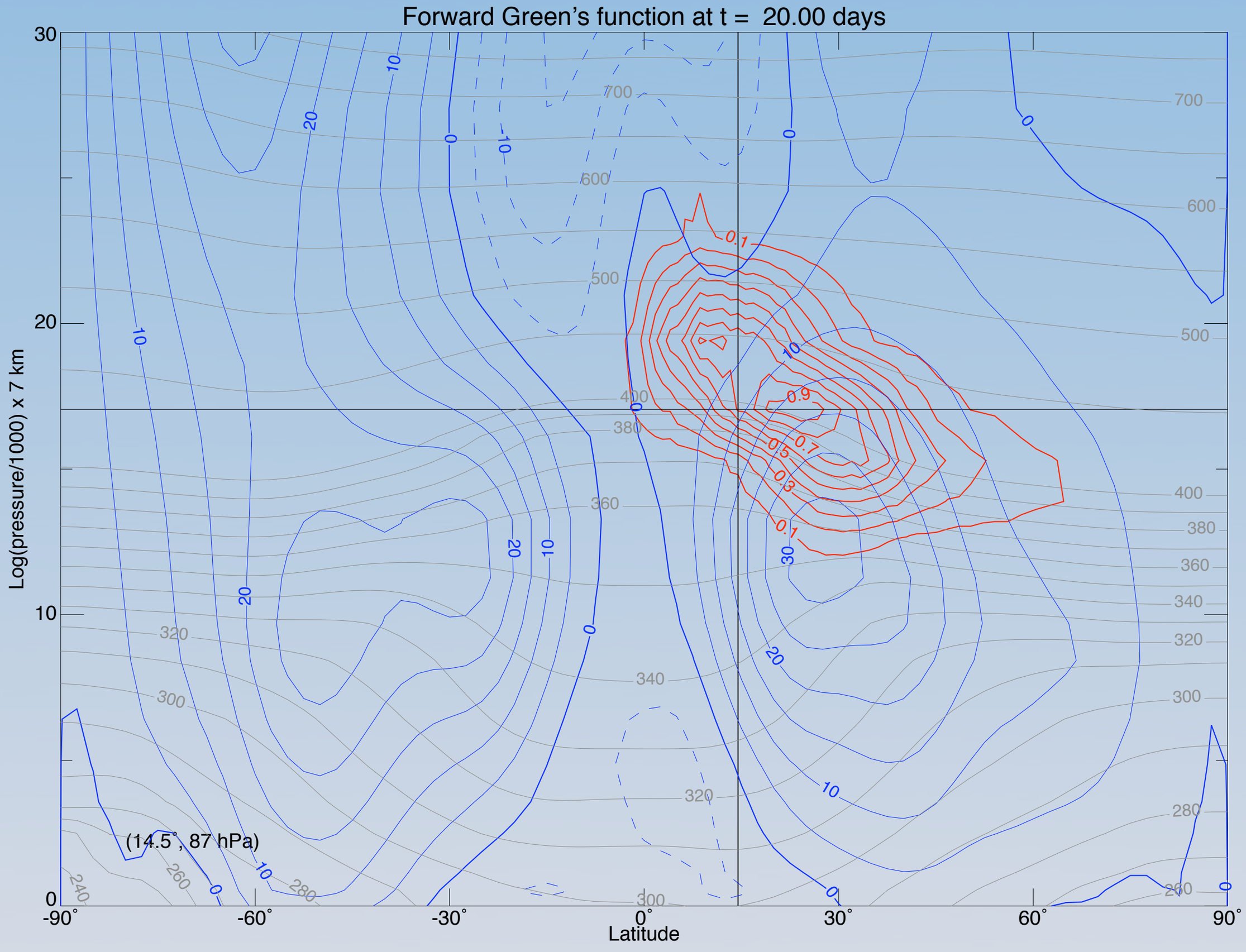
April Climatological Transport



April Climatological Transport

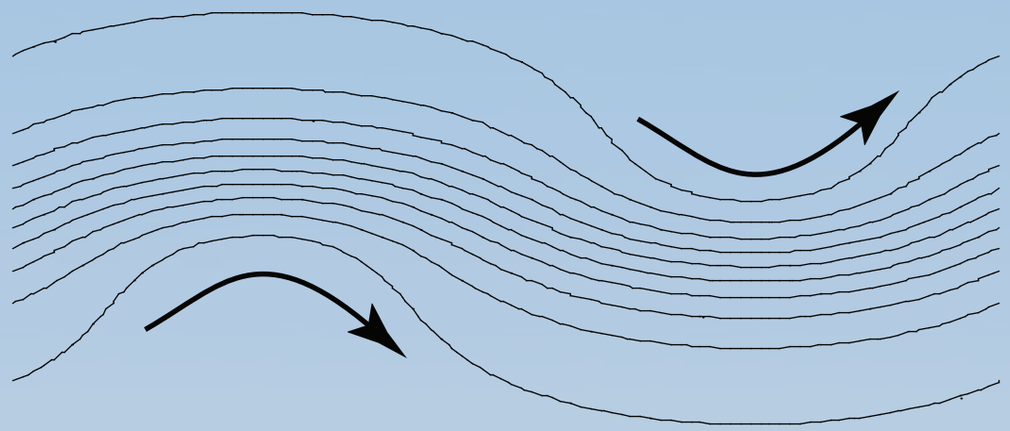


April Climatological Transport



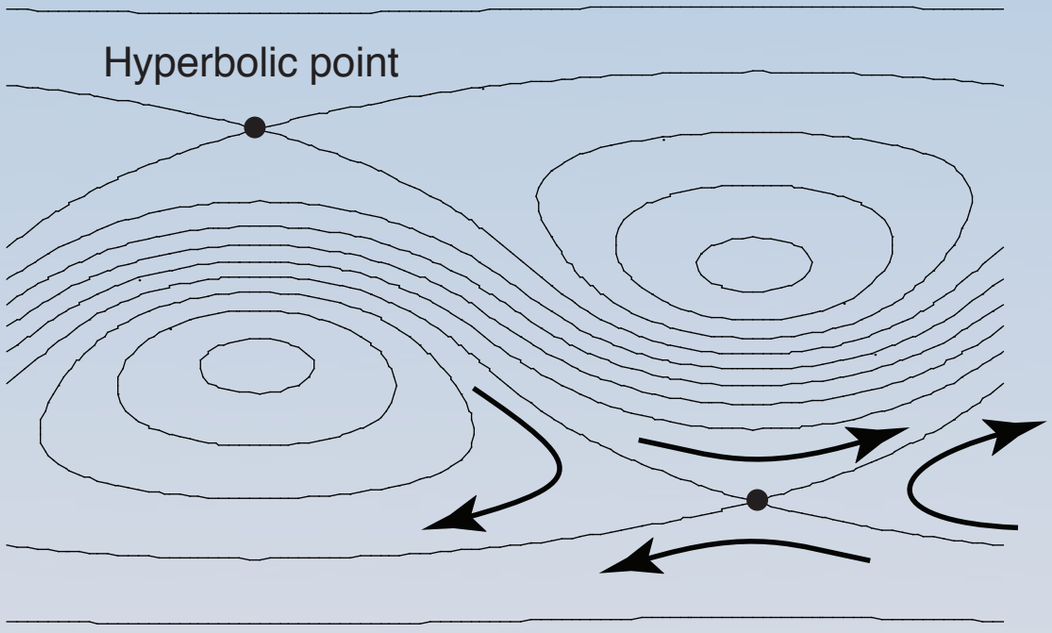
2. Stirring by transient large-scale waves

- Well-developed theory for the 2-D, non-divergent case (Hamiltonian system)
- Good approximation for the large-scale UTLS flow for short times scales (~ days)



Jet and traveling wave in conventional stationary reference frame

Transport *appears* to be reversible



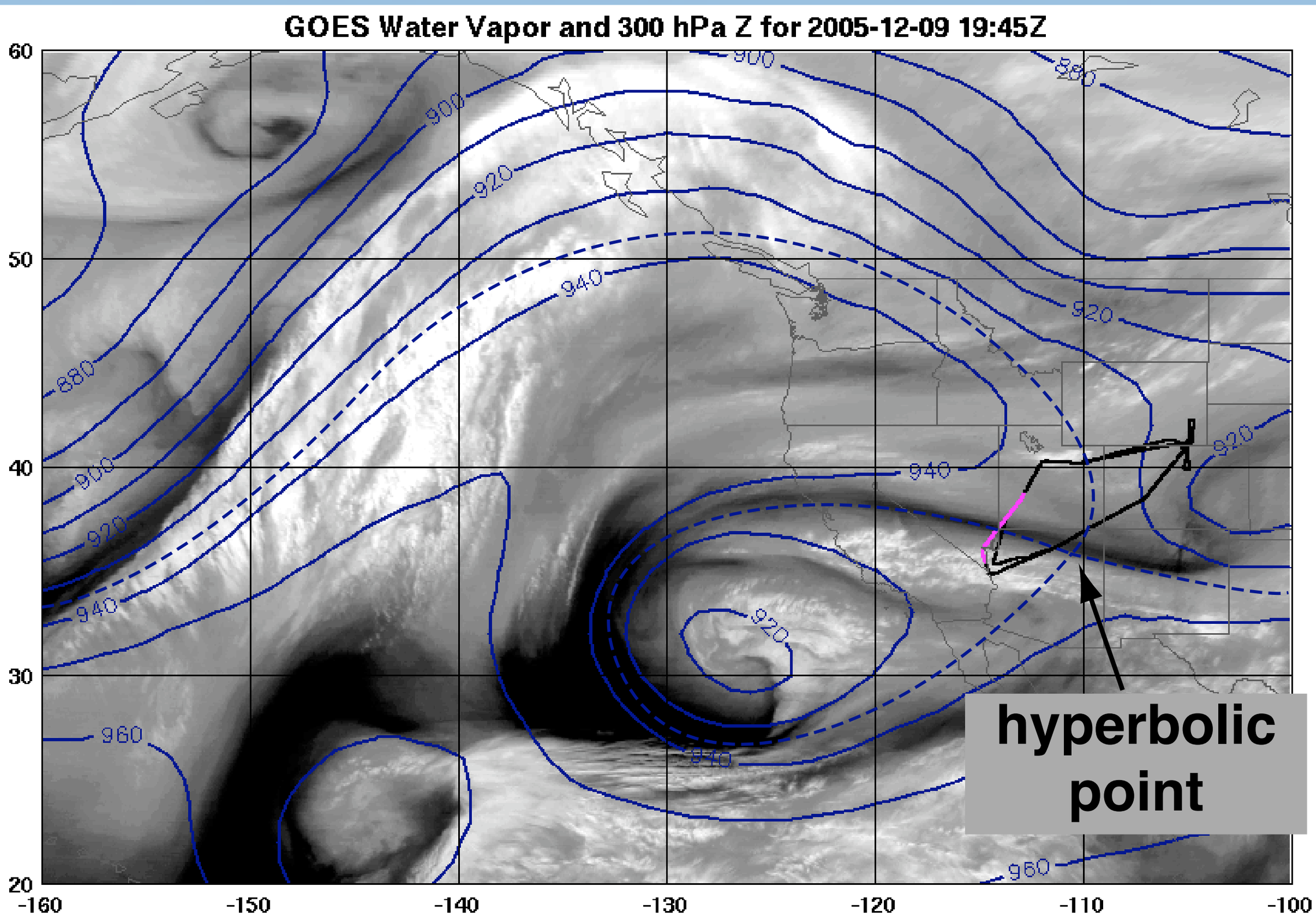
Jet and traveling wave in reference frame moving with wave

Closed circulations cause folding, shear from jet causes stretching, result is *irreversible* stirring

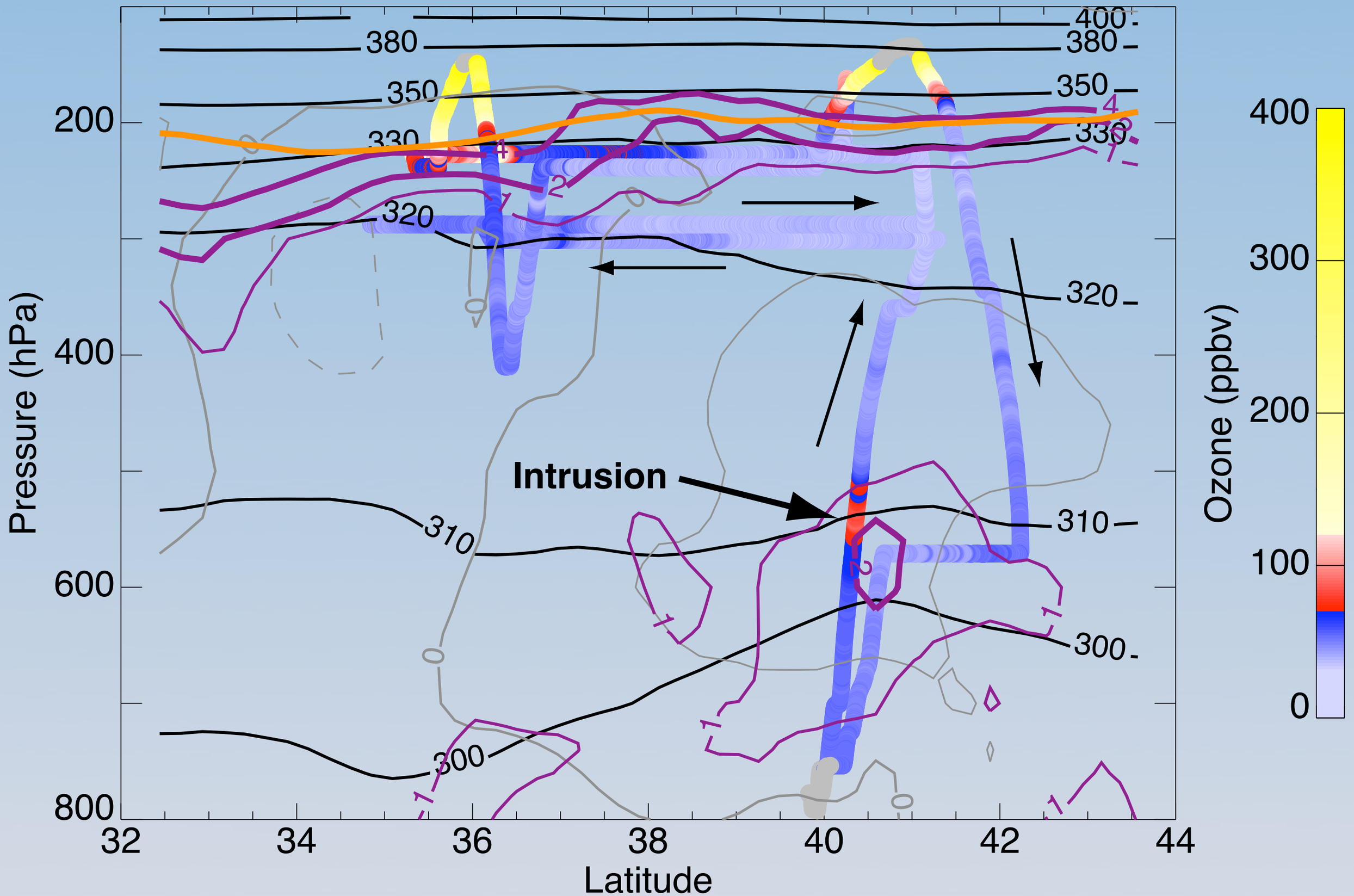
Hyperbolic regions are the essential geometric features

No transport *through* the jet core

GOES Water Vapor, 300 hPa Z, and HIAPER Flight Track

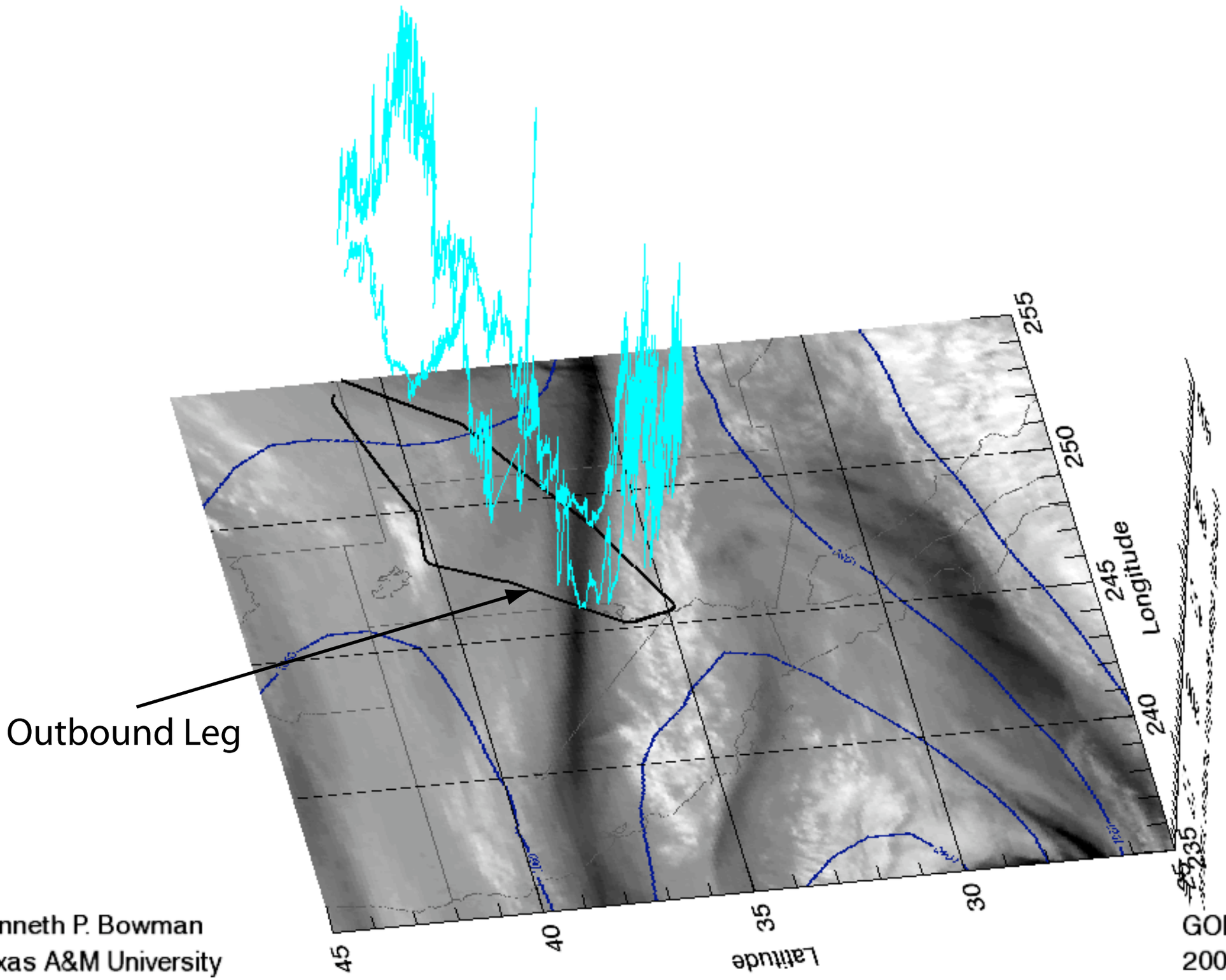


START05 HIAPER Flight 5



HIAPER Water Vapor for Flight 502rf05

2005-12-09 18:40Z to 2005-12-09 21:27Z



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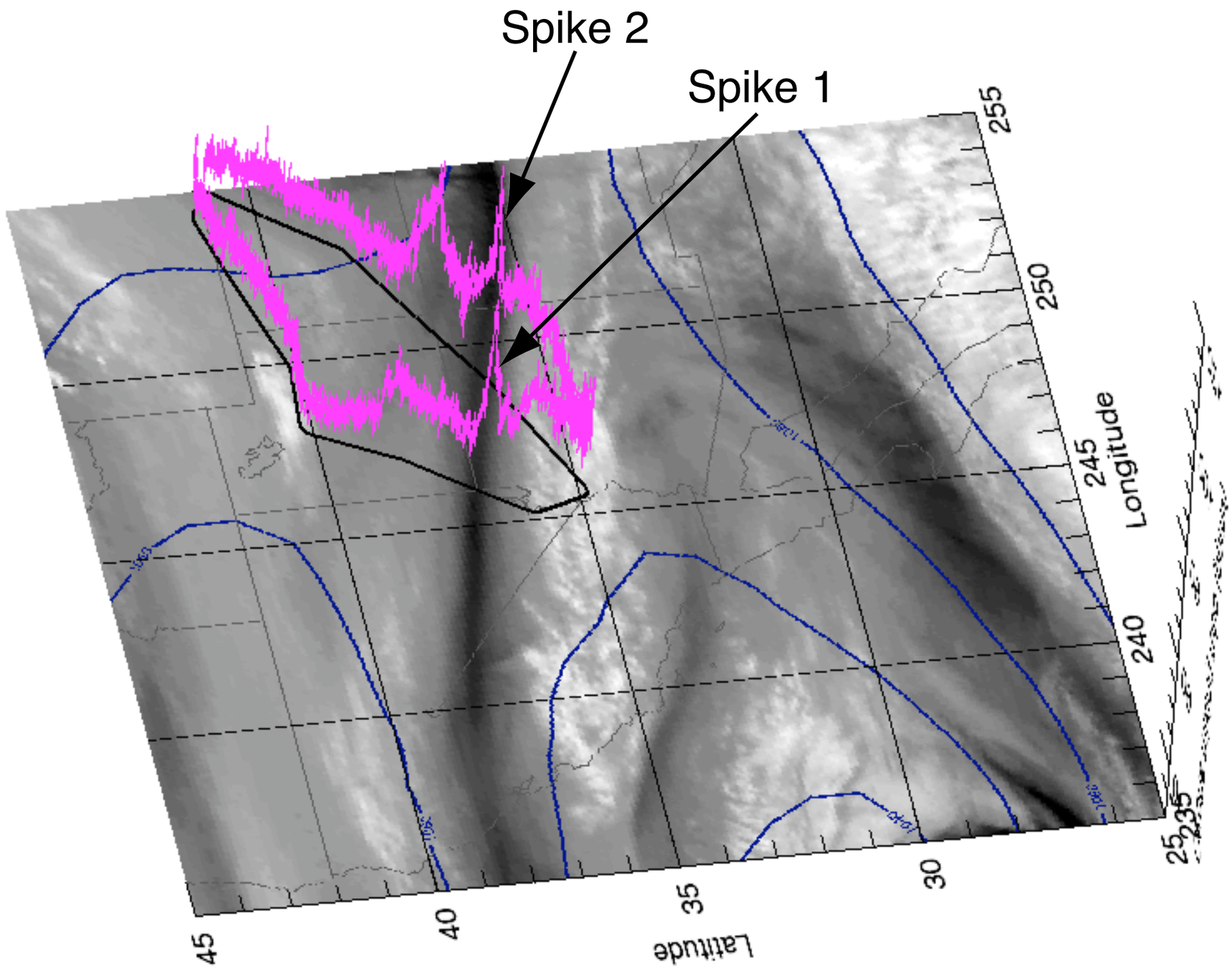
GOES water vapor
2005-12-09 19:45Z

HIAPER Ozone for Flight 502rf05

2005-12-09 18:40Z to 2005-12-09 21:27Z



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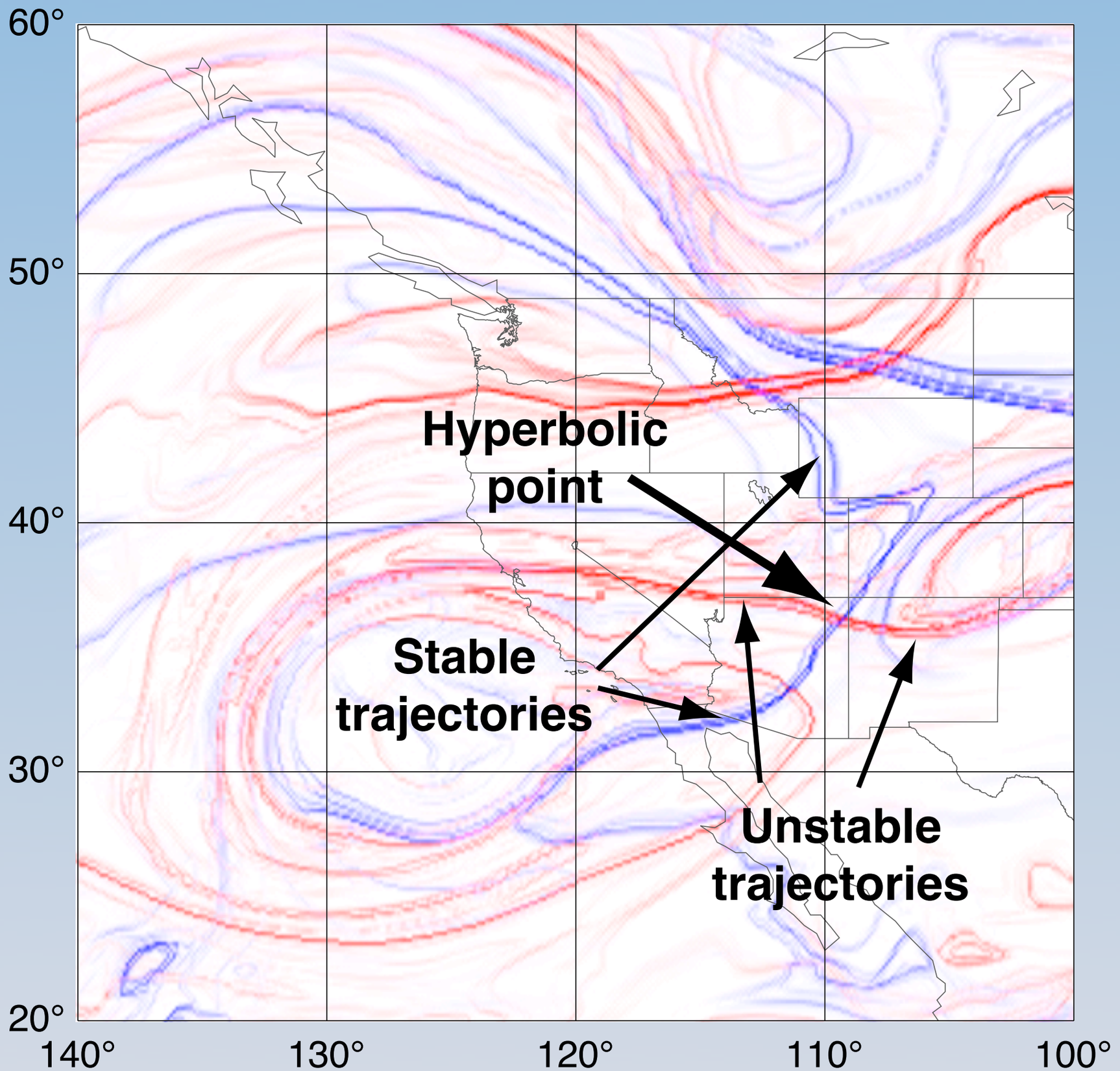
GOES water vapor
2005-12-09 19:45Z

Mapping the Flow Structure



Summary

- Climatological transport analysis indicates poleward transport above the jet, possibly related to multiple tropopause formation
- Trajectory analysis shows the rapid stirring (stretching and folding) by the large-scale flow in the UTLS that produces small-scale layering
- Vertical shear, gravity wave breaking, and turbulence can then operate on this fine structure to produce true mixing
- For case studies we will map the stirring structure at multiple levels in the UTLS (below, through, and above the jet)
- Flow analysis will be done as part of flight planning using GFS forecast winds