Observations and Modeling of Composition of Upper Troposphere/Lower Stratosphere (UT/LS): Isentropic Mixing Events and Morphology of HNO3 as Observed by HIRDLS and Comparison with Results From Global Modeling Initiative

J.M. Rodriguez, M. Olsen, Y. Yoshida, S. Strahan, A. Douglass, P. Newman, B. Duncan

NASA/Goddard Space Flight Center

J. Gille, V. Yudin, B. Nardi

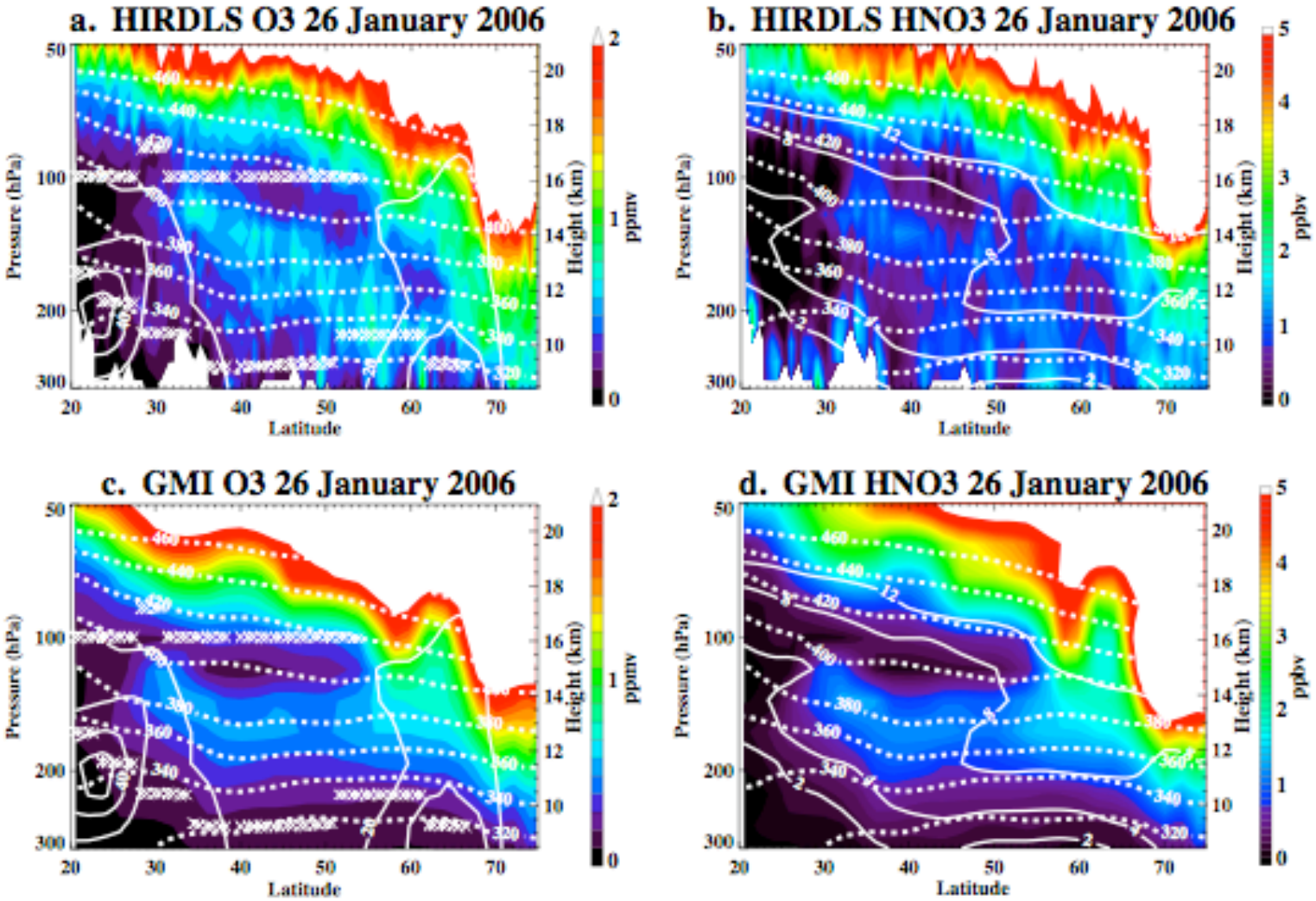
NCAR

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy

Ozone Laminae in Stratosphere

- Described by Dobson (1973)
- Ozone sonde: characterization of laminae and climatologies (Reid and Vaughn, 1973).
- Caused by differential advection by Rossby waves (Newman and Schoeberl, 1995).
- Ozone sonde laminae due to isentropic transport from low latitudes (Vaughn and Timmis, 1998).
- Ozone laminae in ATMOS observations (Manney et al., 2000).
- Ozone sonde lamination frequencies as a diagnostic of horizontal transport in low and high-resolution model (Weaver et al., 2000).
- HIRDLS high-vertical resolution enables observation of laminae over several days, RDF traces laminae back to tropical lower stratosphere (Olsen et al., 2008).

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



From Olsen et al., 2008. Lamina observed for 11 days, and RDF calculations point out both irreversible mixing and return to low latitudes.

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy

QUESTIONS

- **Can we develop climatologies of ozone (HNO_3) laminae from HIRDLS to compare/validate model-derived climatologies?**
- **Seasonal variability of lamination?**
- **We present frequencies of lamination from HIRDLS and GMI for January and July, 2006 (explore methodology).**

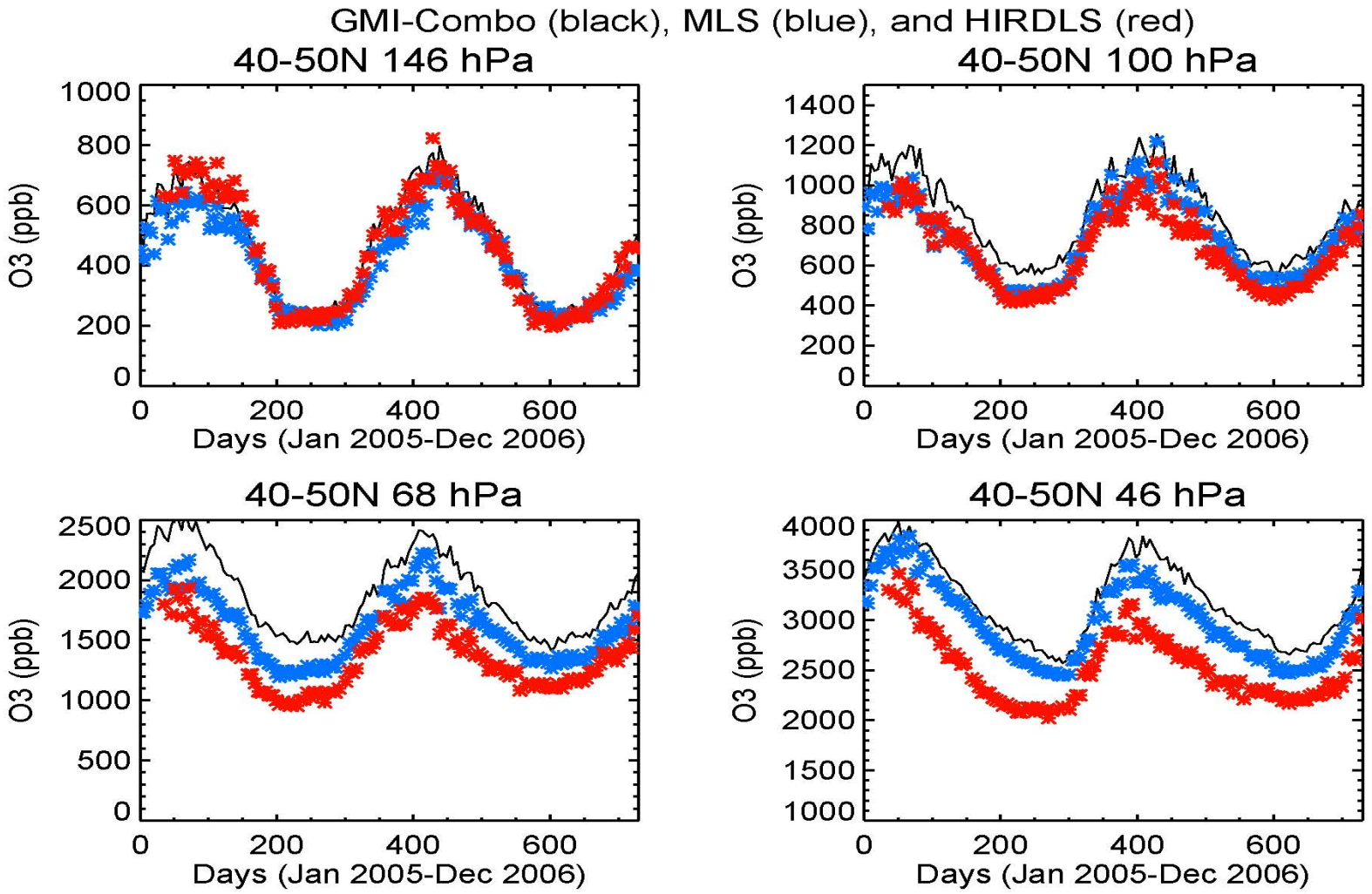
- **Mixing of laminae into lower stratosphere, and contributions to mid-latitude stratospheric ozone budget?**
  - **From HIRDLS**
  - **From GMI (laminae "missed" by HIRDLS).**

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy

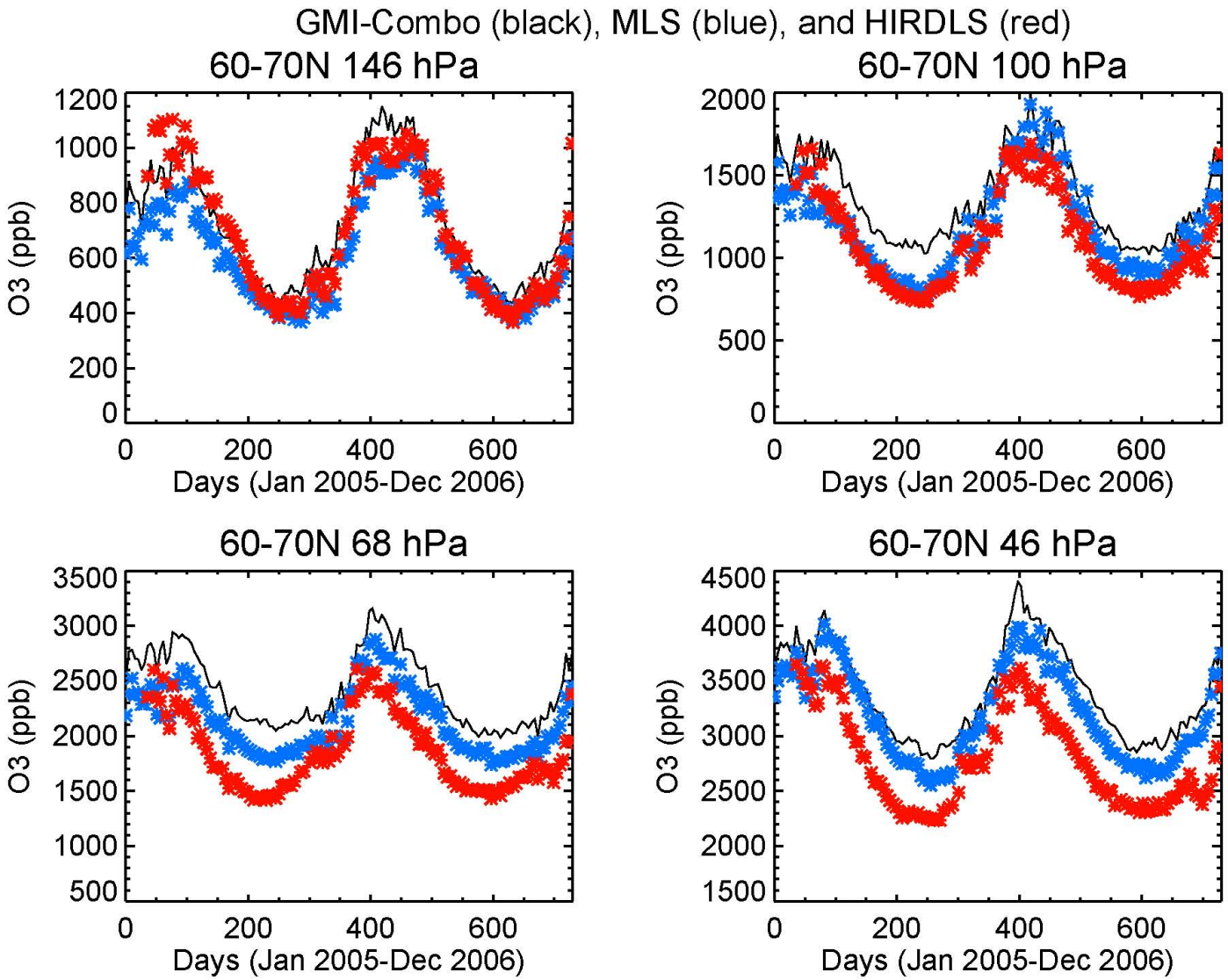
GMI Model
(gmi.gsfc.nasa.gov)

- The Global Modeling Initiative (GMI) CTM uses a chemical mechanism that includes a standard stratospheric mechanism and the tropospheric mechanism from Harvard University's GEOS-CHEM model (117 species, 322 chemical reactions, 81 photolysis reactions).
- Photolysis frequencies are calculated using the FAST-Jx algorithm [M. Prather, UCI].
- The CTM simulations shown here utilized met. fields from the GEOS-4-DAS system from NASA GMAO (Calculations carried out for the AURA period).
- The horizontal resolution of the fields are 2º latitude x2.5º longitude.
- Original analysis has 55 levels from ground to 0.015 hPa; mapped to 42 levels (11 above 10 hPa) to reduce number of levels of middle stratosphere.
- Interpolate to HIRDLS orbit.

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



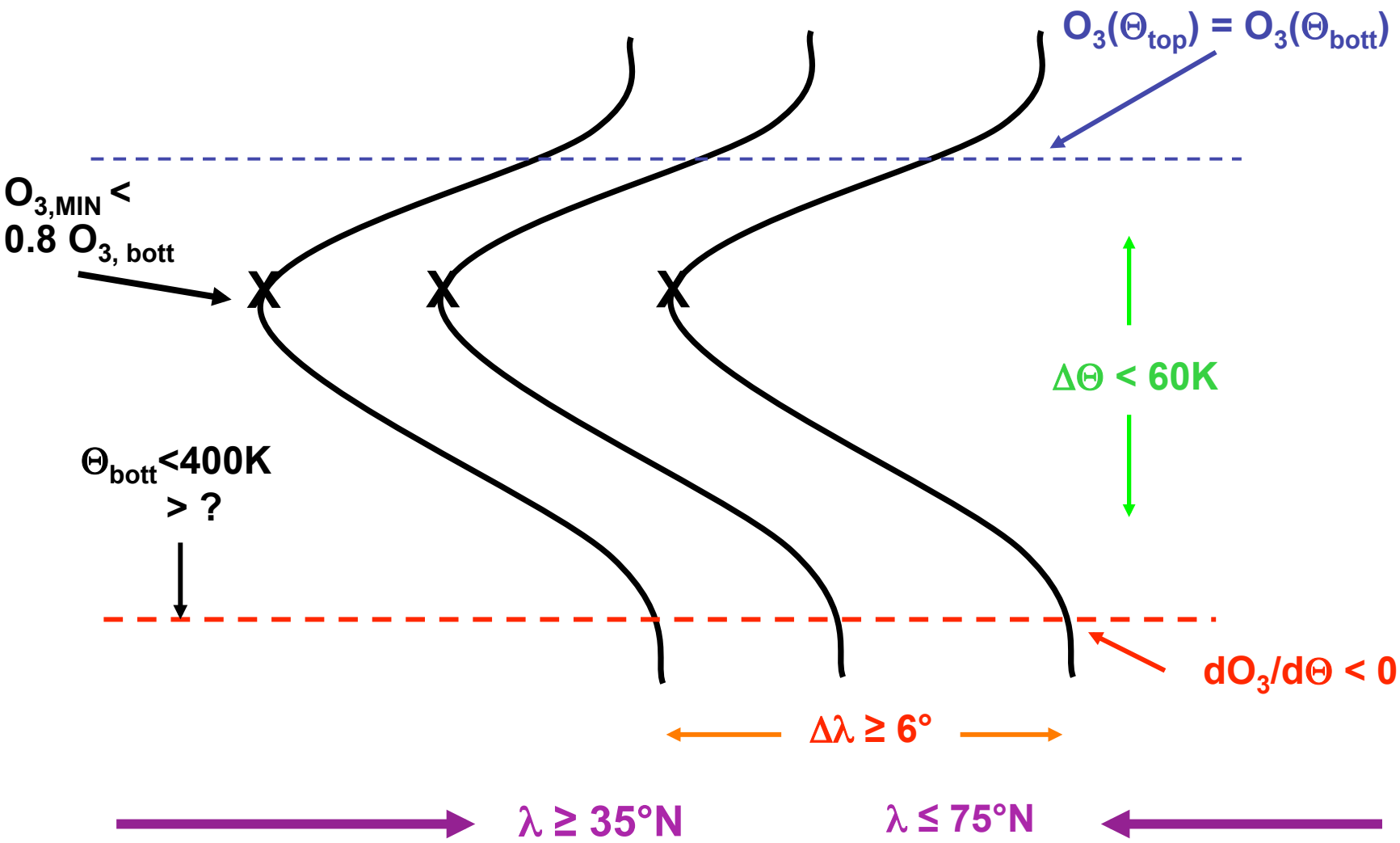
SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy

Gridding of HIRDLS data

- **Version 003**
- **Gridded to potential temperature surfaces using HIRDLS p, T, at 5°K intervals, above 320K.**
- **In determining laminae, gridded results below about 150 hPa are not considered.**
- **Average over 2° latitude (about 3-4 profiles) to compare to GMI.**

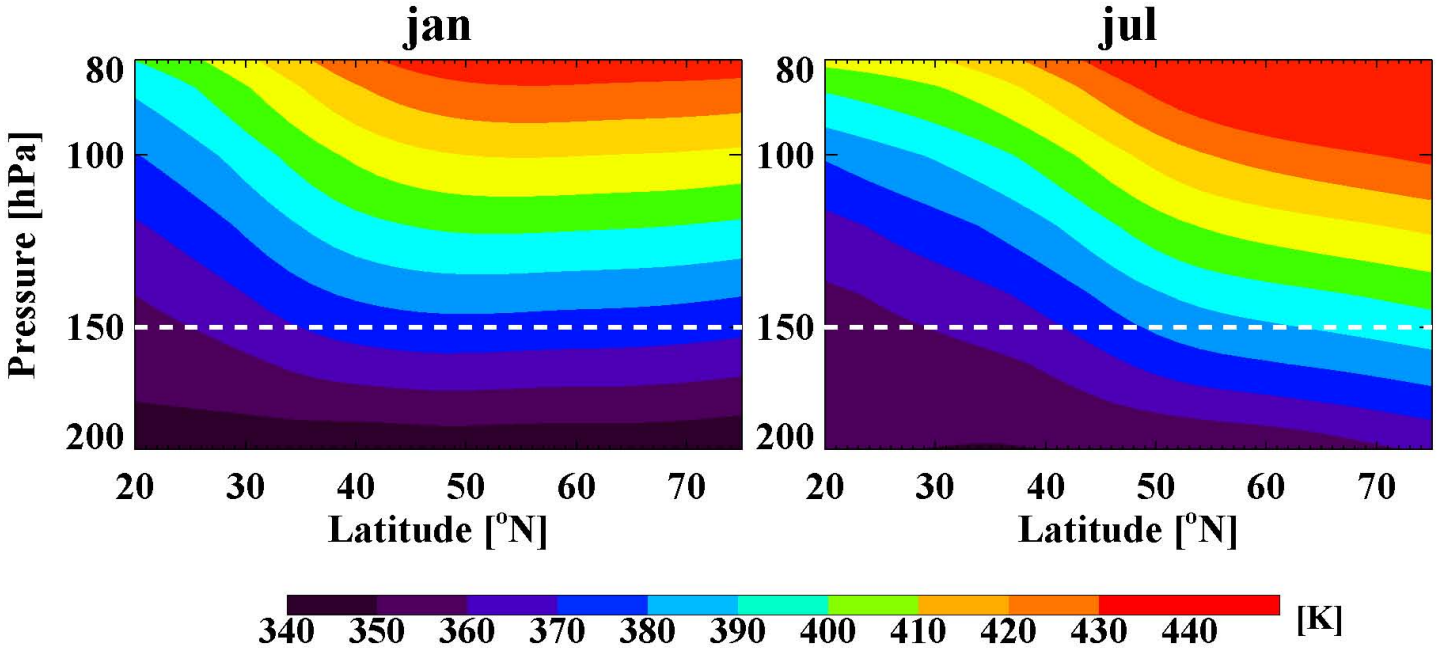
SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy

"WORKING DEFINITION" OF LAMINAE



SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy

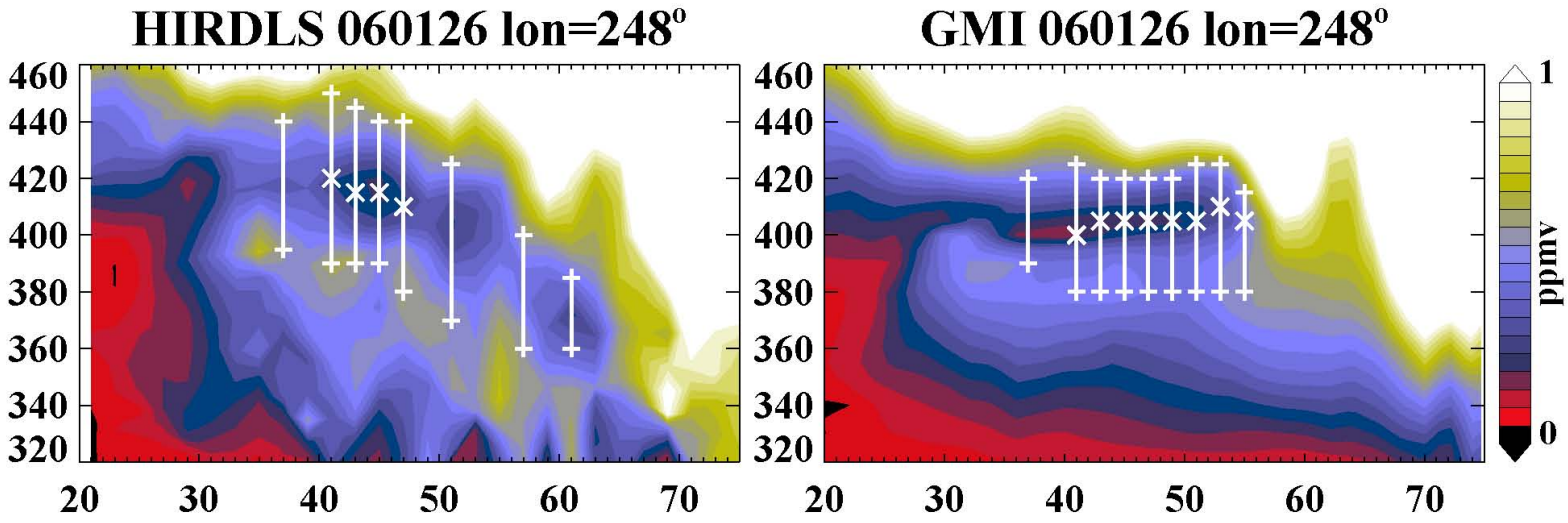
CONTOURS OF CONSTANT Θ AS FUNCTION OF PRESSURE AND LATITUDE



Using T and P from GEOS-4, what is the "bottom" potential temperature below which we should not use current HIRDLS data for defining laminae. (General assumption is that data below 150 hPa at mid-latitudes does not have required accuracy/precision. In addition, laminae in January occur at lower latitudes than in July).

$\Theta_{bott} \approx$ 360K for January, 380K for July. (Need to do this profile by profile).

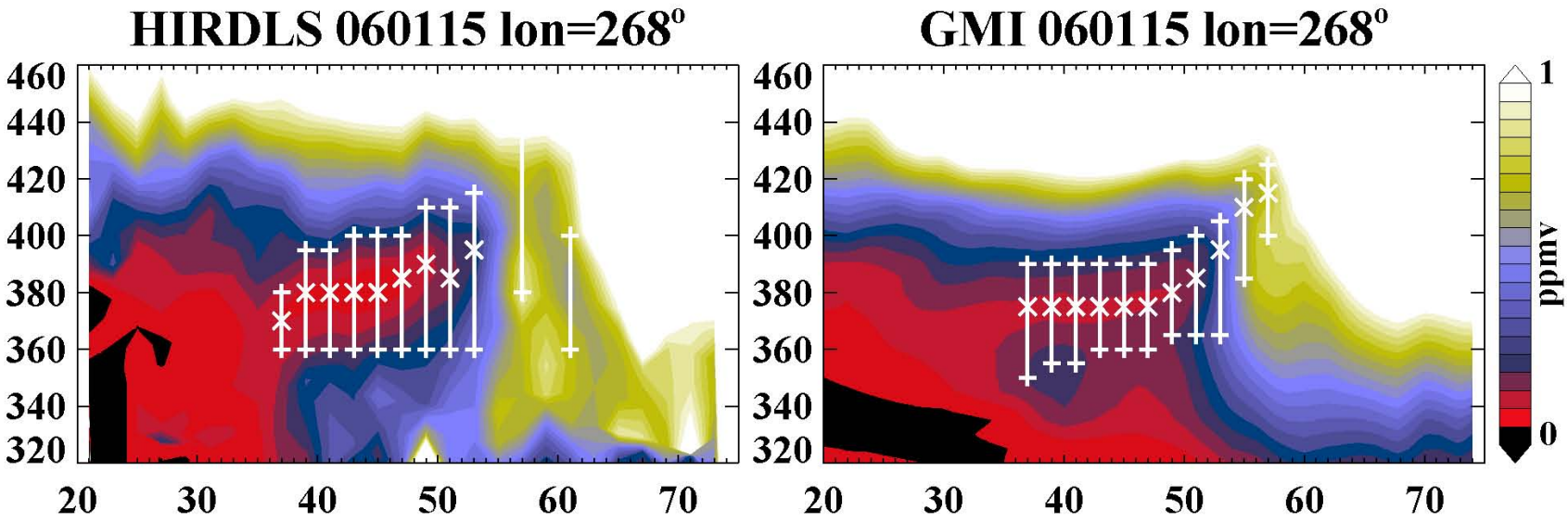
SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



Lamina in Olsen et al., 2008. Our criteria for contiguous vertical laminae over at least 6° latitude do not extend HIRDLS lamina to high latitudes.

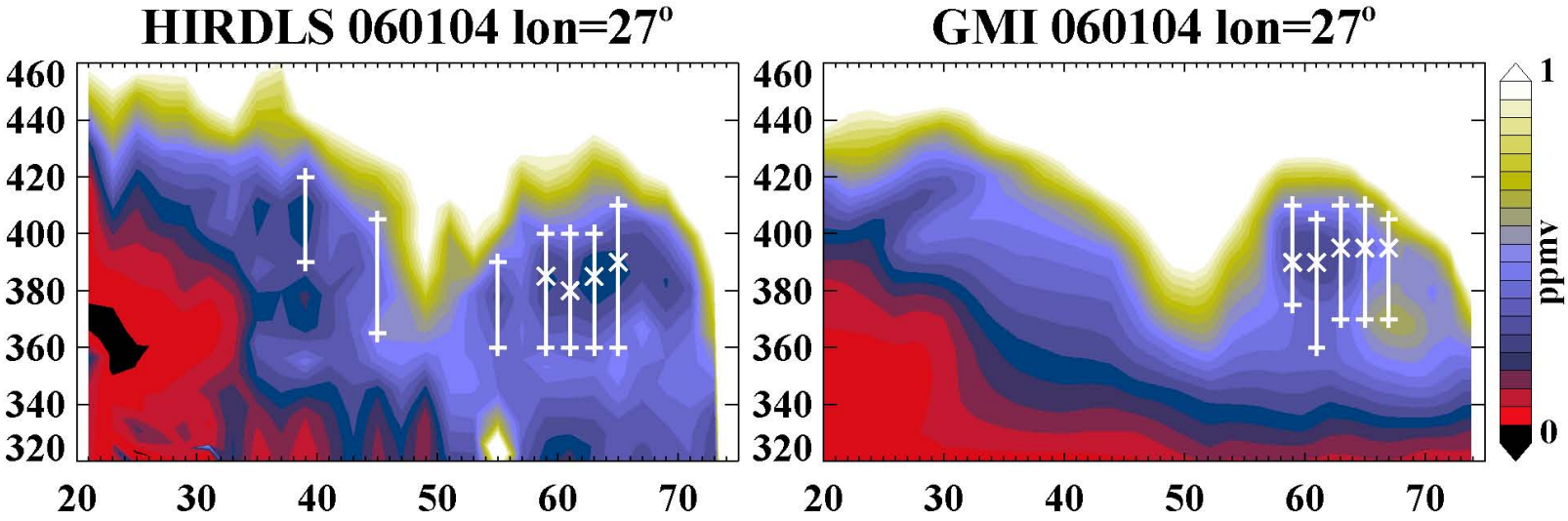
Note: Vertical bars denote laminar vertical extent. X denote lamina minimum. Bars without x are lamina-like, but fail one of the other criteria (in this case continuity in latitude).

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



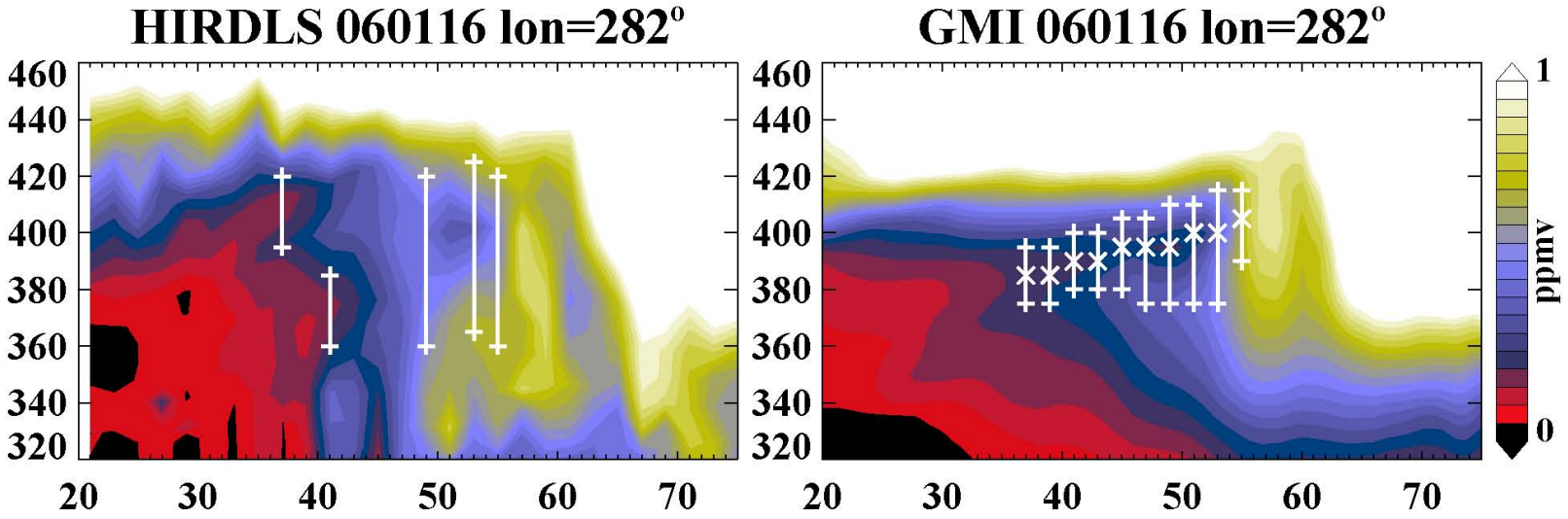
Example of other well-defined laminae in January in both HIRDLS, GMI.

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



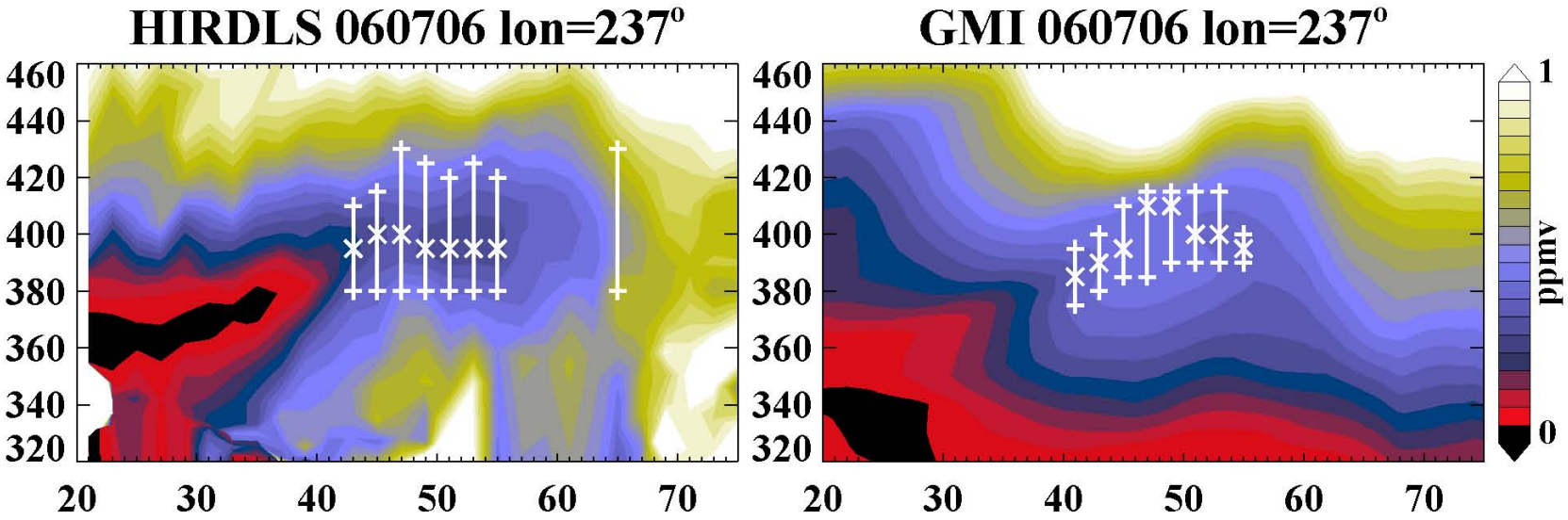
High-latitude laminae. Origin?

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



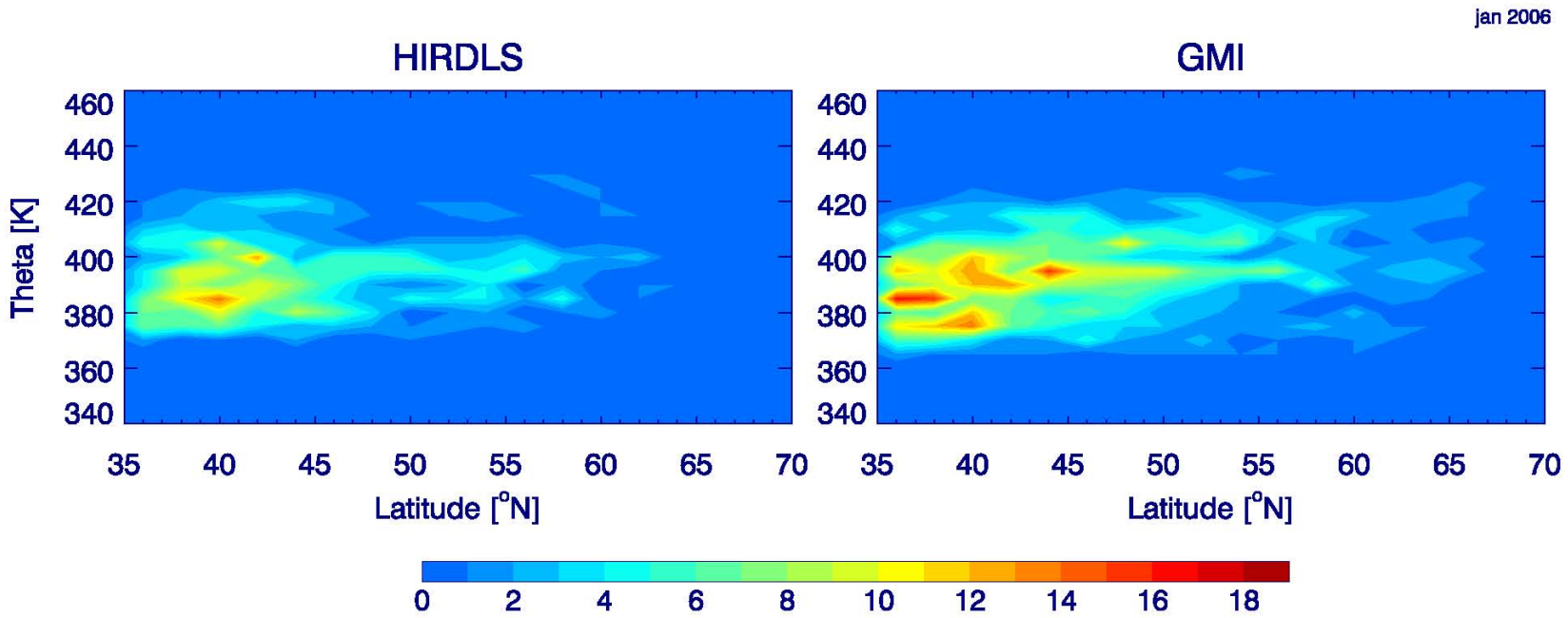
Lamina in GMI, only indications in HIRDLS

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



July laminae

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy

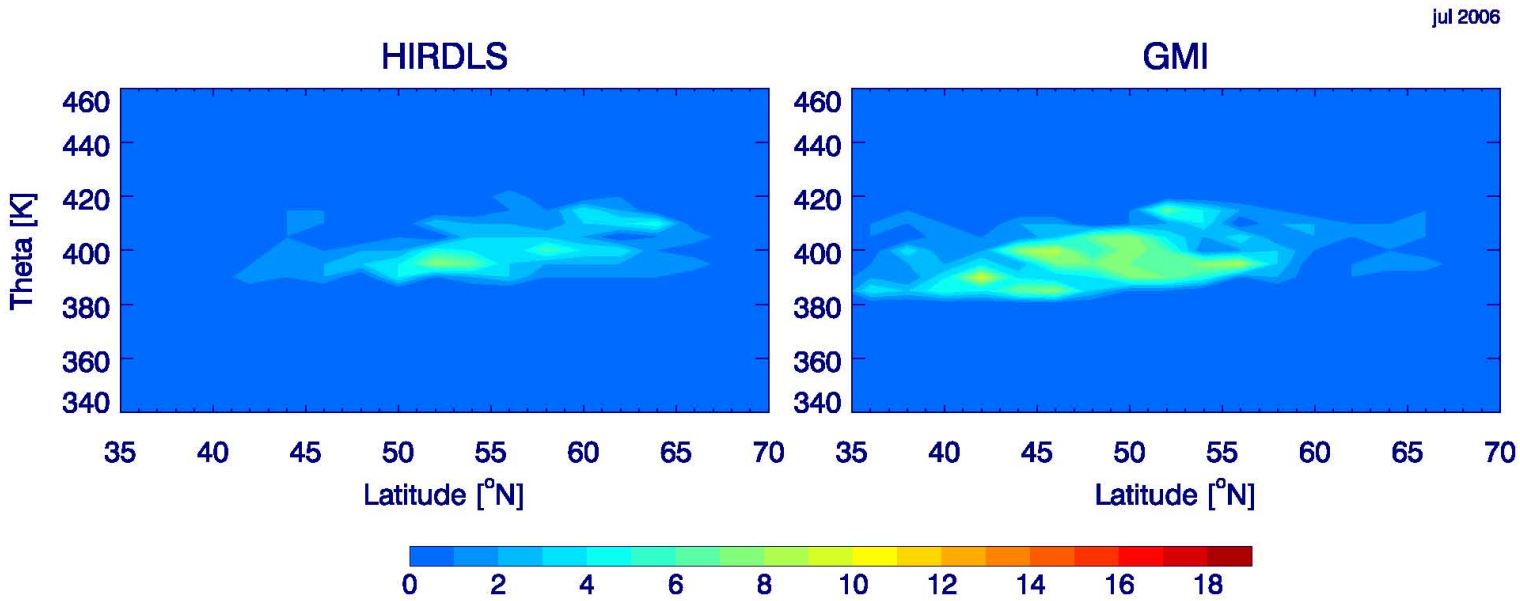


Distribution of number of laminae (per 2° latitude) observed by HIRDLS and calculated by GMI for January, 2006, using Θ_{bott}=360 ° K and $\Delta\Theta$=60°K.

NOTE: We show number of occurrences of vertical laminae in each 2° latitude grid (i.e., the distribution of the "x's" at lamina minimum).

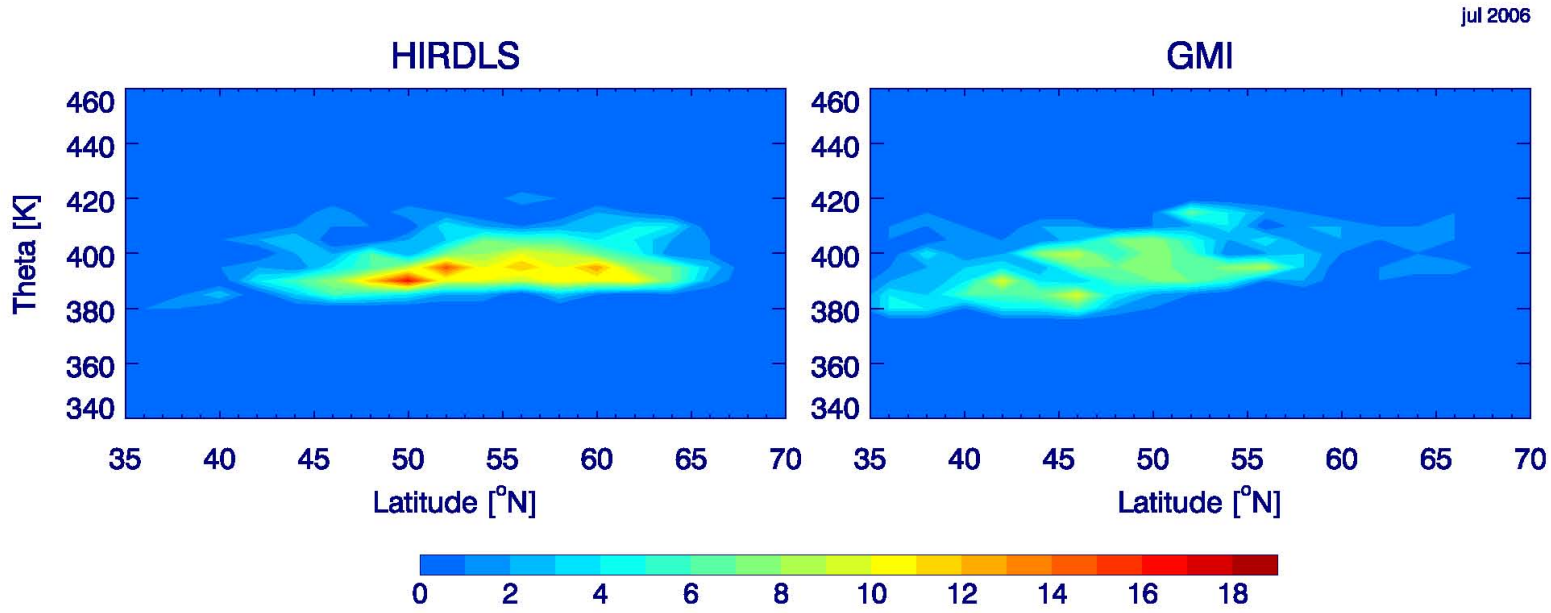
A two-dimensional lamina can thus give more than one occurrence in different latitude grids. (Shows average lamina morphology better?).

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



Distribution of number of laminae (per 2° latitude) observed by HIRDLS and calculated by GMI for July, 2006, using Θ_{bott}=380 ° K and $\Delta\Theta$=60°K

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy



Distribution of number of laminae (per 2° latitude) observed by HIRDLS and calculated by GMI for July, 2006, using Θ_{bott}=375 ° K and $\Delta\Theta$=60°K

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy

CONCLUSIONS AND FUTURE WORK

- **Frequency and spatial distribution of ozone laminae observed by HIRDLS in good agreement with those in GMI/GEOS-4 calculations for January, 2006.**
- **Frequency of occurrence during July exhibits fairly good agreement between GMI and HIRDLS, and smaller values than in January.**
- **However, frequency of occurrence in HIRDLS is very sensitive to location of minimum potential temperature for "accurate" HIRDLS measurements.**
- **We need to**
  - **Carry out better gridding of HIRDLS data taking into consideration measurements statistics on a per-orbit basis.**
  - **Version 004? GEOS-5?**
  - **HNO_3**
  - **Extend analysis to other months.**
  - **RDF calculations to determine evolution and mixing of laminae.**

SPARC 4th General Assembly
Sept. 2, 2008
Bologna, Italy