Simultaneous lidar and MLS observation, and modeling of a lower stratospheric polar ozone filament over Hawaii

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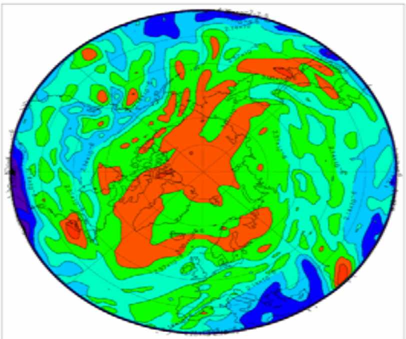
MIMOSA-CHIM

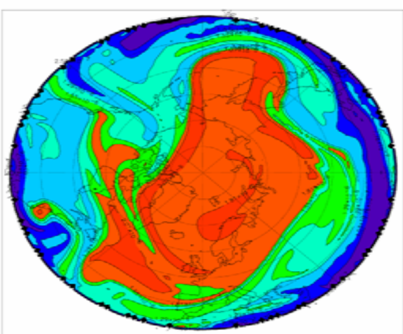
REPROBUS



(2°/2°)

Initialisation

MIMOSA-CHIM



(1°/1°)

ECMWF Winds (2.5°/2.5°) every 6 hr

resolution:
(1 pt/ °)

chemical scheme

15 min

Advection
time step: 1 h

regular grid

advected grid

interpolation
vertical scheme
every 6 h

Diabatic heating rates calculation every 6 hr

MIMOSA-CHIM

- **Initialisation**:
  - **PV calculated from ECMWF (2.5°/2.5°) fields**
  - **Chemical fields from REPROBUS model (2°/2°)**

- **Chemical scheme : REPROBUS (F. Lefèvre):**
  - **evaluation of 55 species mixing ratios**
  - **(chlorine, nitrogen, bromine, oxygen and hydrogen compounds)**
  - **102 gas-phase chemical reactions**
  - **heterogeneous chemistry module (liquid and solid PSCs)**
  - **Equilibrium scheme with constant number density ($5x10^{-3}$)**

- **Diabatic evolution**
  - **relaxation towards ECMWF PV analyses (relaxation time constant 10 days)**
  - **vertical scheme: computation of mass fluxes from diabatic heating rates radiative scheme MIDRAD (Shine)**

- **Boundary conditions:**
  - **-10 to 90 for North Hemisphere and –90 to 10 for South**
  - **forcing by ECMWF PV analyses**
  - **forcing by chemical fields of REPROBUS model**

Advection Model MIMOSA-CHIM

- PV and ozone mixing ratio are well correlated on an isentropic Surface.
- Starts on an orthogonal grid in an azimuthal equidistant projection centred at Pole.
- The PV and chemical fields of each grid point is advected using meteorological wind fields.
- The streched and deformed grid is re-interpolated to original grid after every 6 hours.
- To minimize the numerical diffusion from re-gridding, an interpolation scheme based on the preservation of second order momentum of PV perturbation has been implemented.
- For longer runs the diabatic mass fluxes are computed from heating rates calculated using radiation scheme of SLIMCAT.
- Climatological water vapour, CO2, and interactive ozone fields are used for heating rates calculation.
- Calculated PV and REPROBUS chemical fields are used for the forcing at the boundary of the model.

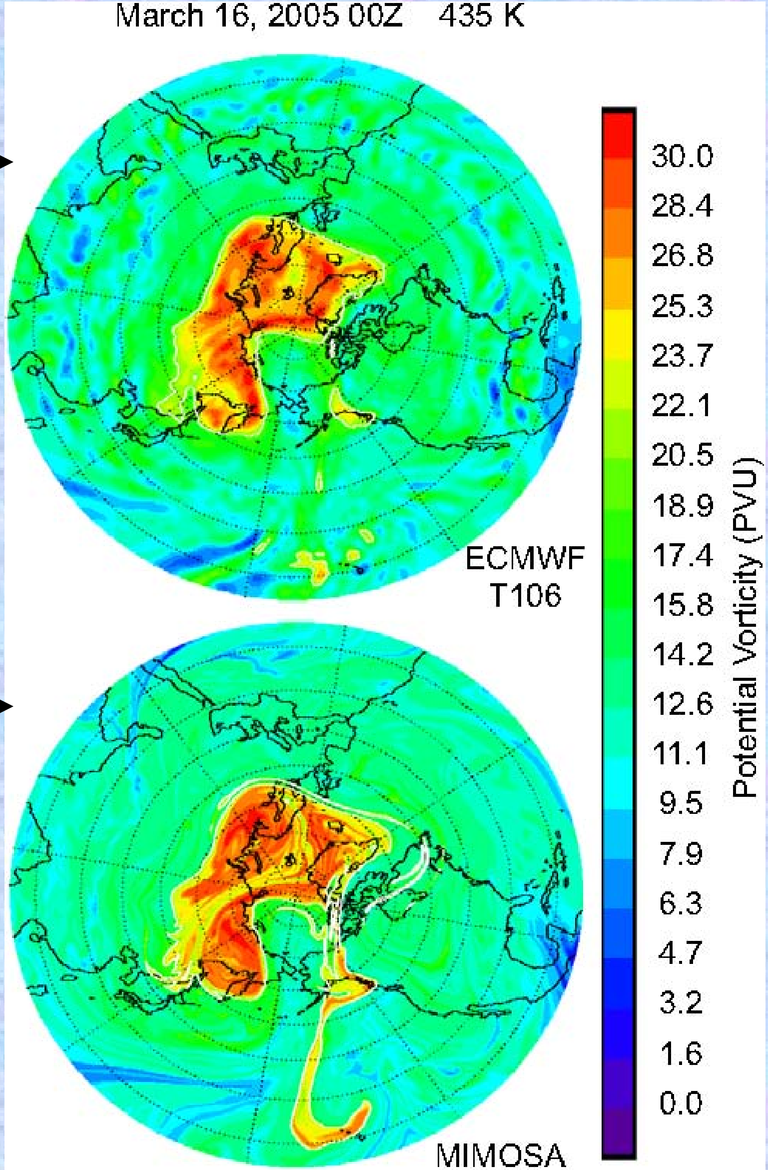
Isentropic PV fields at 435 K on March 16, 2005 at 00:00 UT

T106 ECMWF grid (1.125 º x 1.125 º)

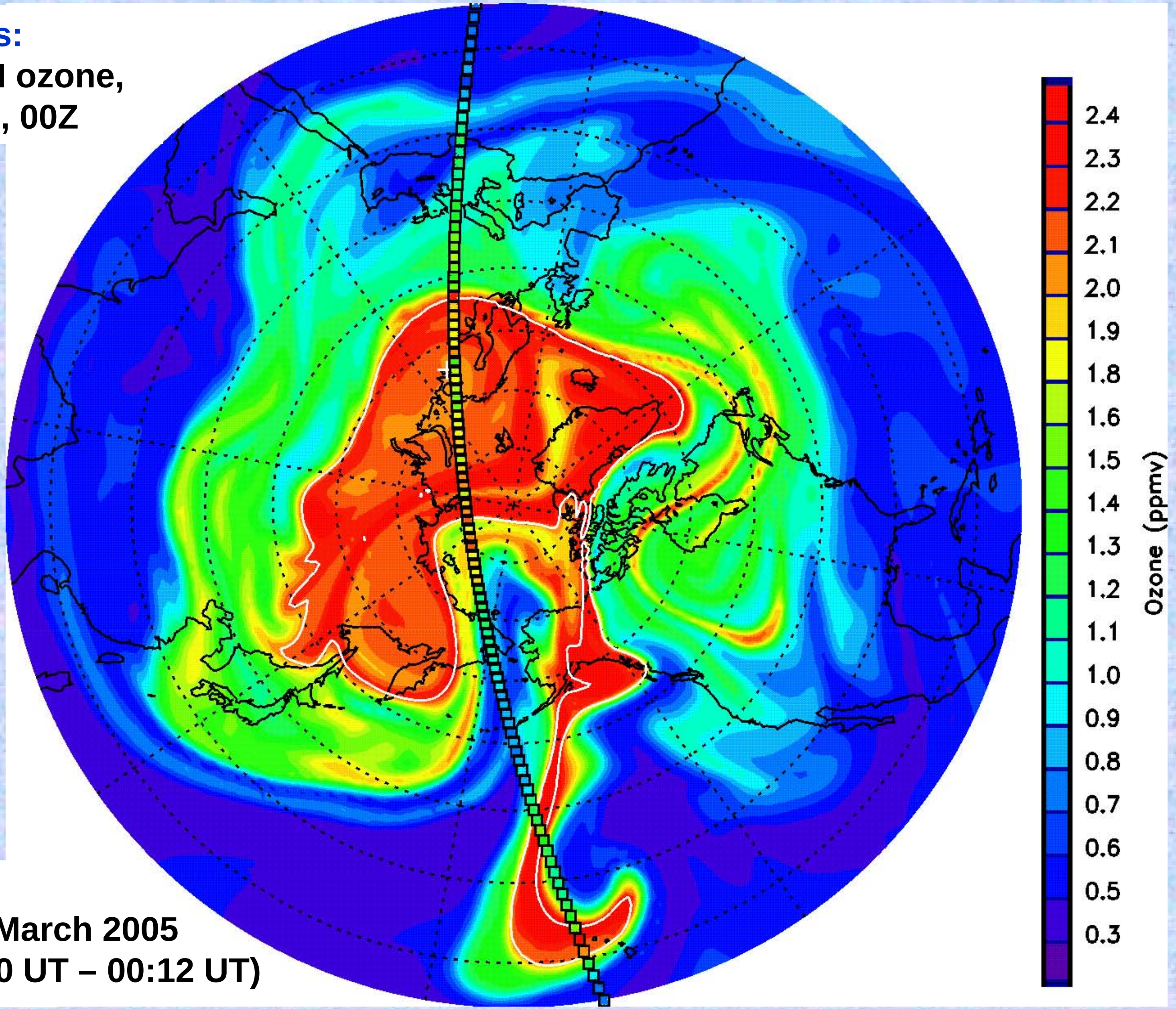
- Filament barely identifiable
- Only a few regions of higher PV

MIMOSA (0.33°/0.33 °)

- Reproduce the evolution of fine PV
- Filaments without discontinuity

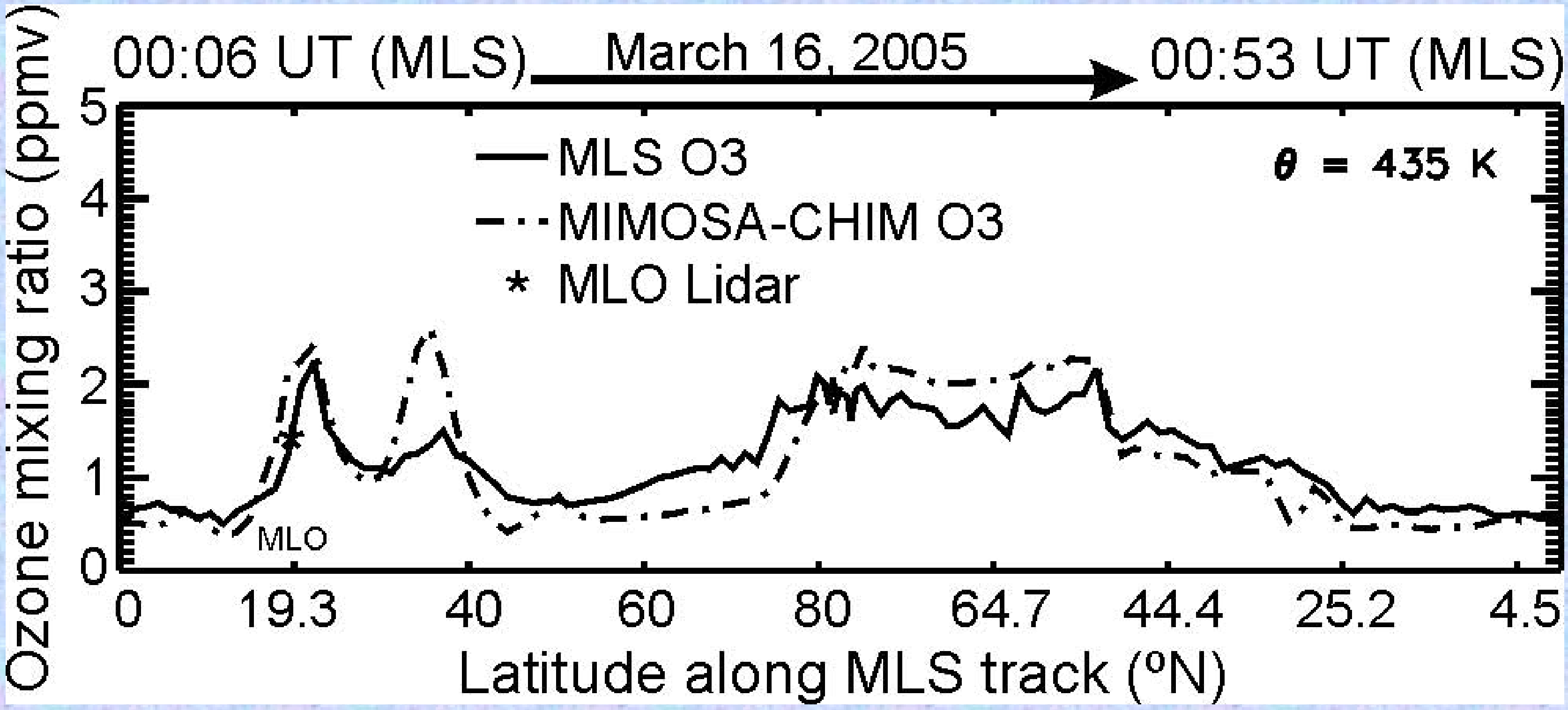


Color contours:
MIMOSA-CHIM ozone, 16 March 2005, 00Z



Color squares:
MLS ozone 16 March 2005 first orbit (00:00 UT – 00:12 UT)

Ozone along the MLS track, measured by lidar at 0700 UT (arterisk), and modeled by MIMOSA-CHIM at 0000 UT along the track at 435 K



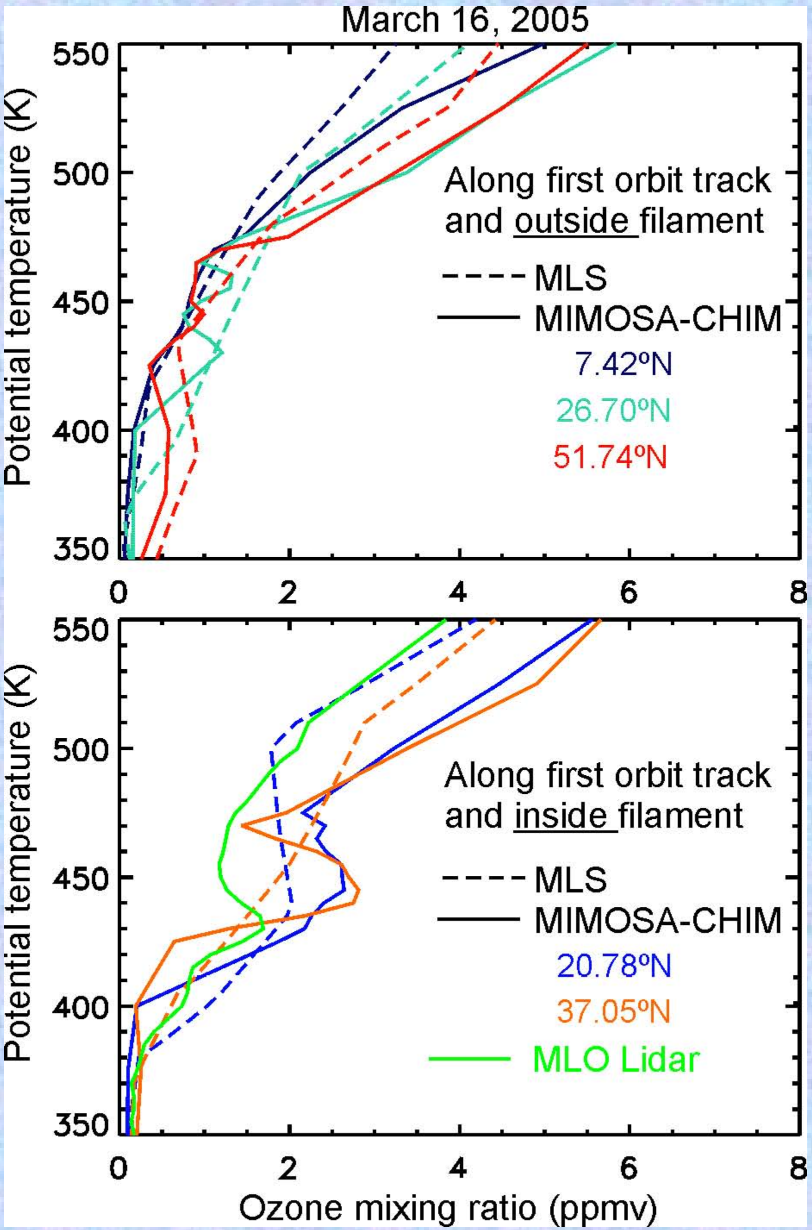
- **Very good qualitative agreement between MLS and MIMOSA-CHIM**
- **Vortex well identified**
- **Two crossings of the MLS track with the filament at 20ºN and 37ºN well captured by MLS**
- **MLS is affected by smoothing and MIMOSA by the uncertainties in advection**

Five selected MLS ozone profiles along the measurement track, with corresponding MIMOSA-CHIM profiles, and MLO lidar

- **Layer of enhanced ozone extends vertically from 410 K to 460 K, peaking around 435 K**

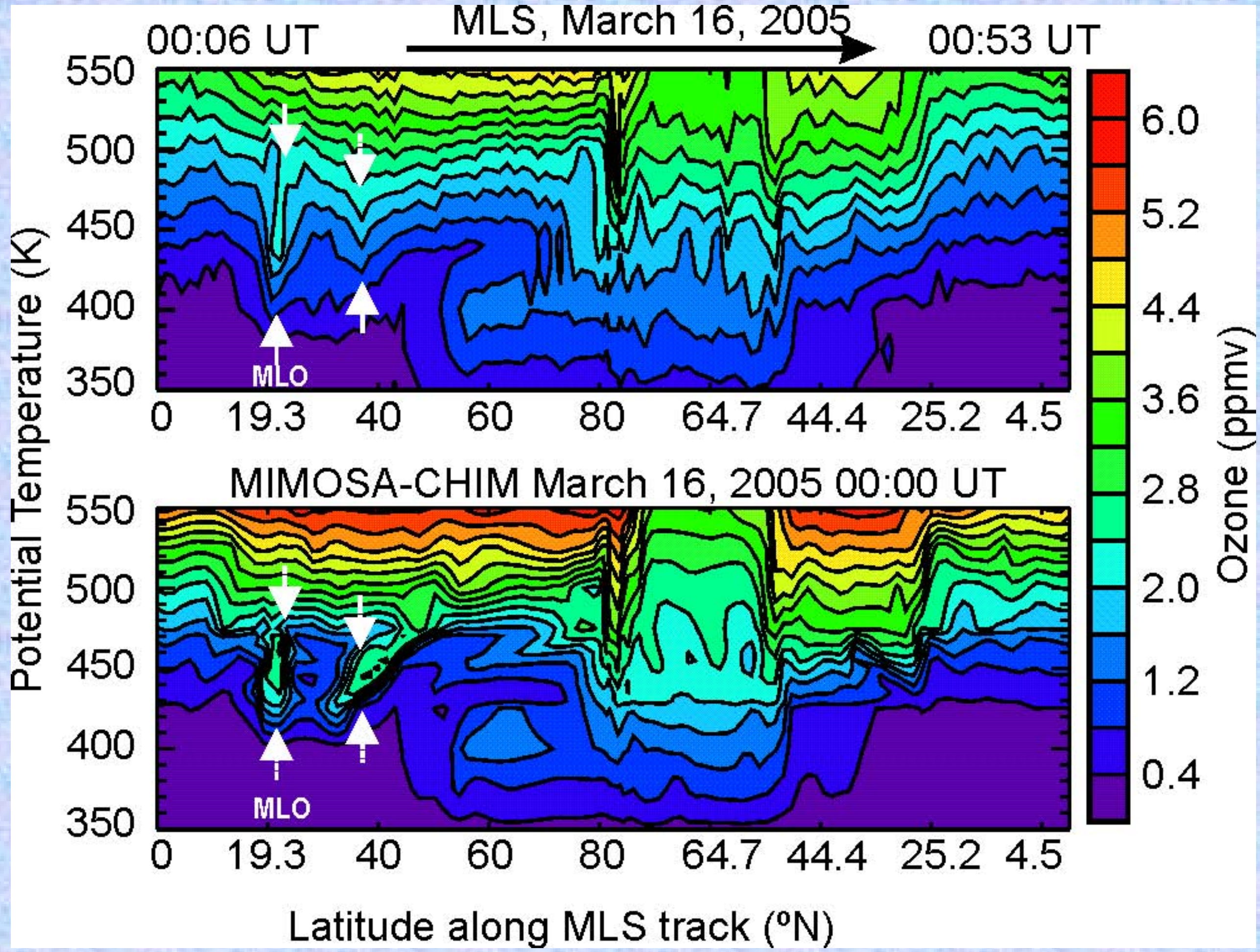
- **Width and shape of the peak varies depending on the measuring/modeling technique and the position along the track**

- **Model ozone overestimated above 475-500 K, causing a contamination to lower levels, and affecting the shape of the ozone layer at 435 K**



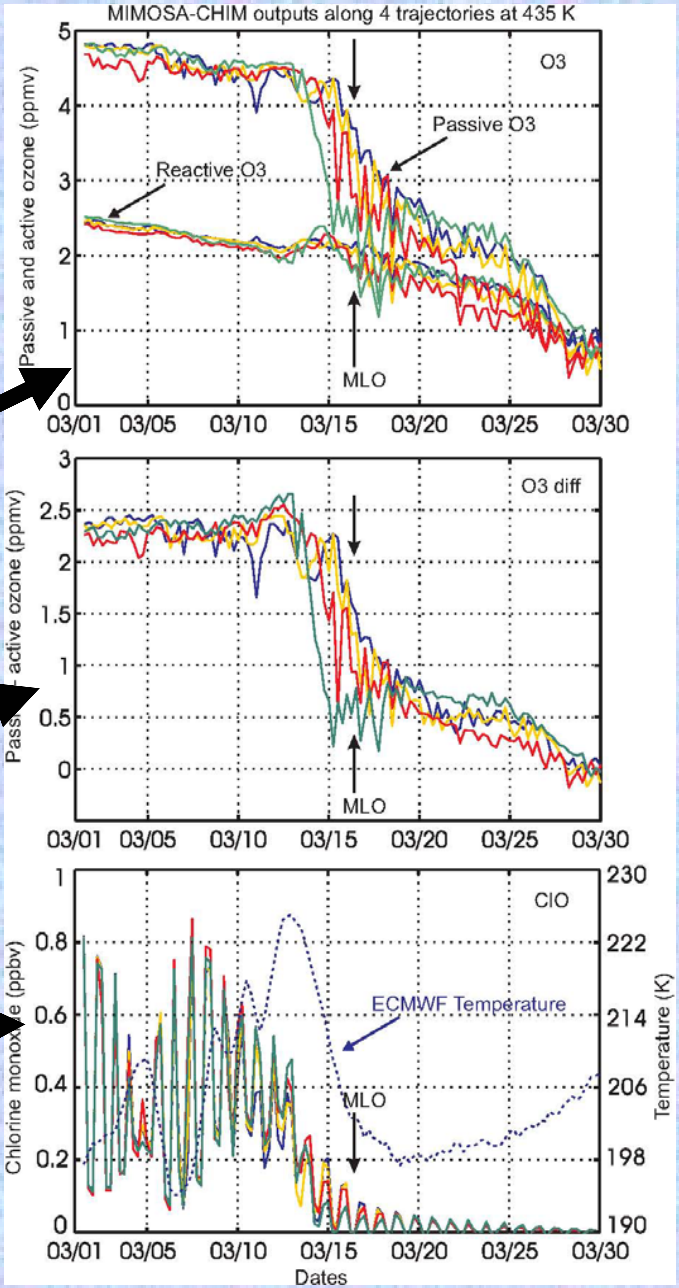
Latitude-altitude 2D cross-section of ozone measured by MLS along its suborbital track (top), and the corresponding MIMOSA-CHIM ozone output

- **White arrows : Two crossings with filament**
- **400-475K : Apparent discrepancy in shape and extent.**
- **MIMOSA-CHIM filament at 37ºN tilted (southward-downward) while MLS is purely vertical.**



Likely causes for observed difference: misrepresentation of filament by MIMOSA above 475 K, and two-dimensional smearing effect due to MLS smoothing

Forward and backward isentropic trajectories, starting at each grid point within +/-1º of longitude and latitude from MLO location



Evolution of passive ozone (i.e., advected since December 1, 2004 at the level of reactive ozone at that time) and chemically processed ozone, as modeled by MIMOSA-CHIM along the four trajectories best centered to the "core" of the filament during its MLO overpass.

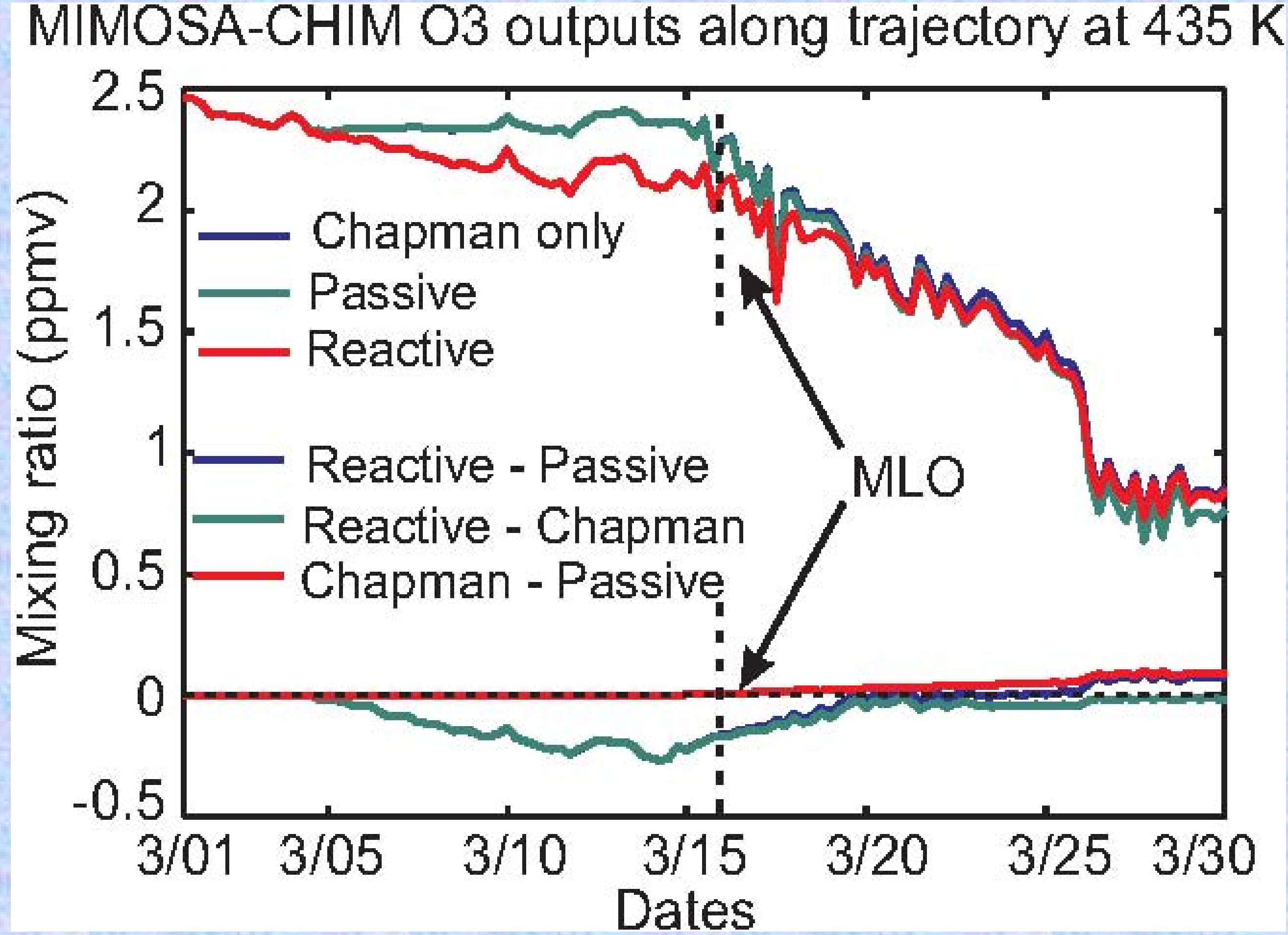
Difference between passive and active ozone (ozone loss in the air –parcel)

Chlorine monoxide (ClO) and temperature modeled along the same four trajectories.

Test run – I: Passive ozone (or tracer) were initialized on March 5 using the values of reactive ozone on that day.

Test run – II: Ozone was passed only through the Chapman reactions

- **Up to March 15 : continuous decrease of fully reactive ozone relative to passive ozone and Chapman-only ozone.**
- **From March 15 to March 19- 20: pure mixing process**
- **After March 20: fast mixing leading to concentrations typical of the tropical background.**



Time series of the meridional gradient of MIMOSA - PV (435 K) with respect to equivalent latitude for the past four consecutive winters.

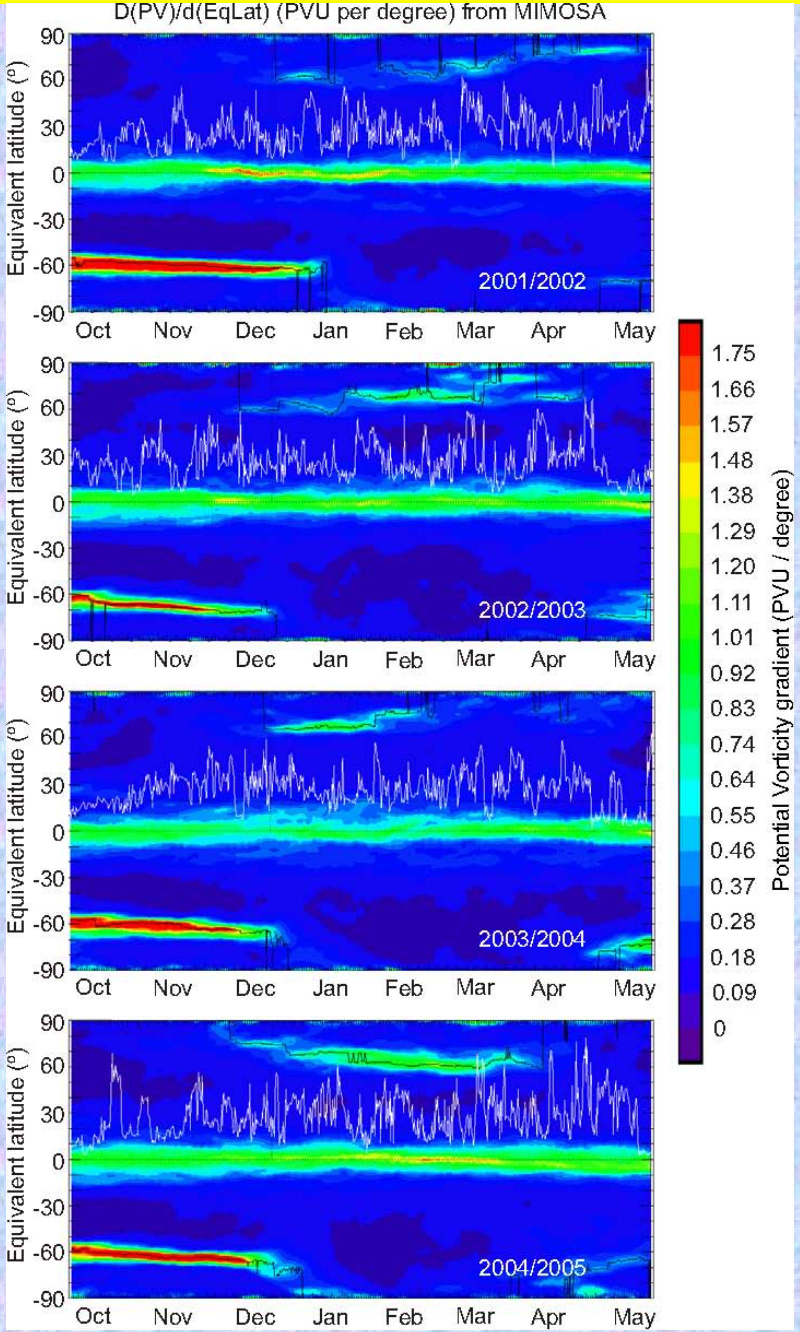
- **High gradients (green to red) = transport barriers**

- **White curve : MLO equivalent latitude at 435 K**

- **White curve not situated at the average latitude of 20ºN but instead at average latitude of 30ºN**

➔ dynamical regime at MLO during boreal winter is more subtropical than tropical

- **March 2005 event is the only one in the four years shown**



Conclusion

➢ **First filament observed simultaneously by lidar and EOS MLS over HI**

- **Vertically centered at 435 K**
- **O3 vmr peak at 1.5-2 ppmv in a region (20ºN) where climatological values are typically 0.5-1 ppmv.**
- **Despite known differences in measuring techniques and vertical resolutions, excellent agreement found between all three datasets.**

➢ **MLS able to capture thin structures such as filaments.**

➢ **Such an event was not observed in any of the past winters since 1999/2000.**

➔ **Very rare event. Will it happen again? How often?**

➔ **How significant impact on local reservoir?**

➔ **Despite current "low" vertical resolution, EOS MLS is a promising instrument to validate future high-resolution modeling studies.**

Thank You

MIMOSA-advected PV maps over the Northeastern Pacific Region on March 16 at 0600 UT and 425 K

- **Remarkable consistency of position and timing in both the forecasts**
- **ECMWF analysis using MIMOSA agrees well with the forecasts**
- **The filament first passed over the Big Island of Hawaii on March 16, during the main vortex stretching event**
- **Then the "elbow" of the filament (i.e., its southwestern edge, located west of the islands) passed on March 19**
- **It remained stationary for a few hours over the island and then initiated a high speed eastward motion towards Southern California.**
- **The quality of the forecast allowed the JPL personnel to anticipate optimal ozone lidar measurements on the night of March 16, and on the following three nights.**

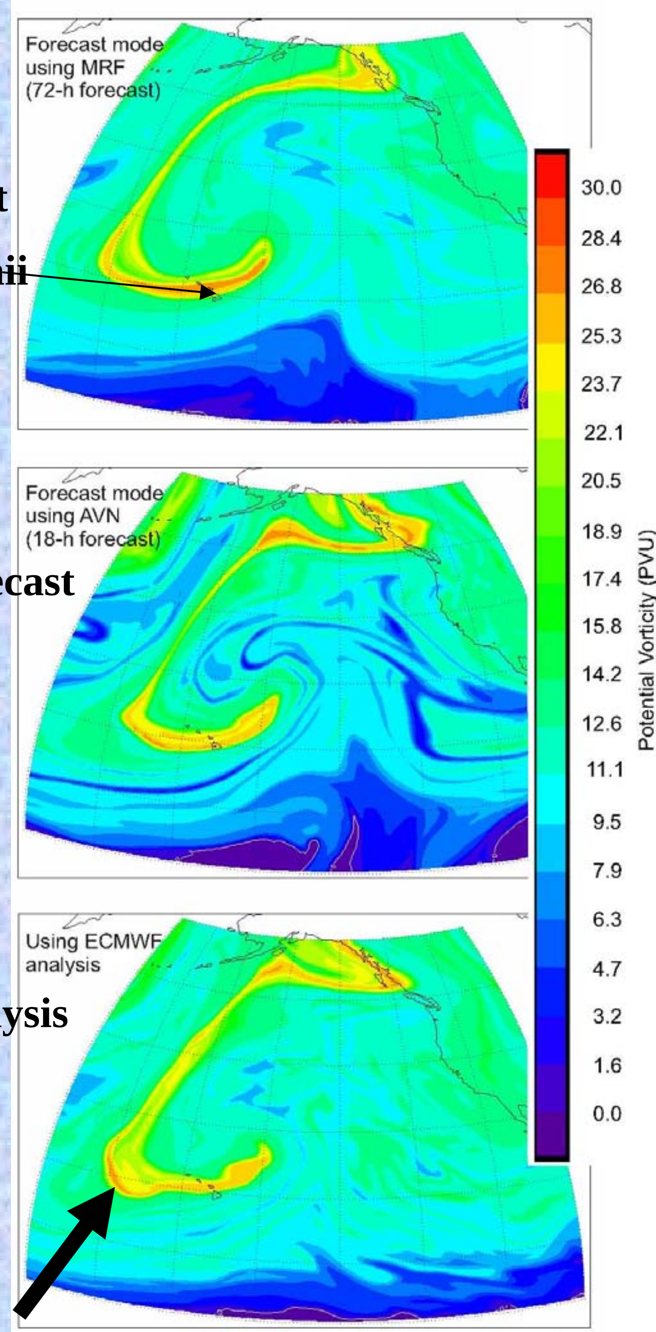
MRF 72h forecast

Big Island of Hawaii

AVN 18h forecast

ECMWF analysis

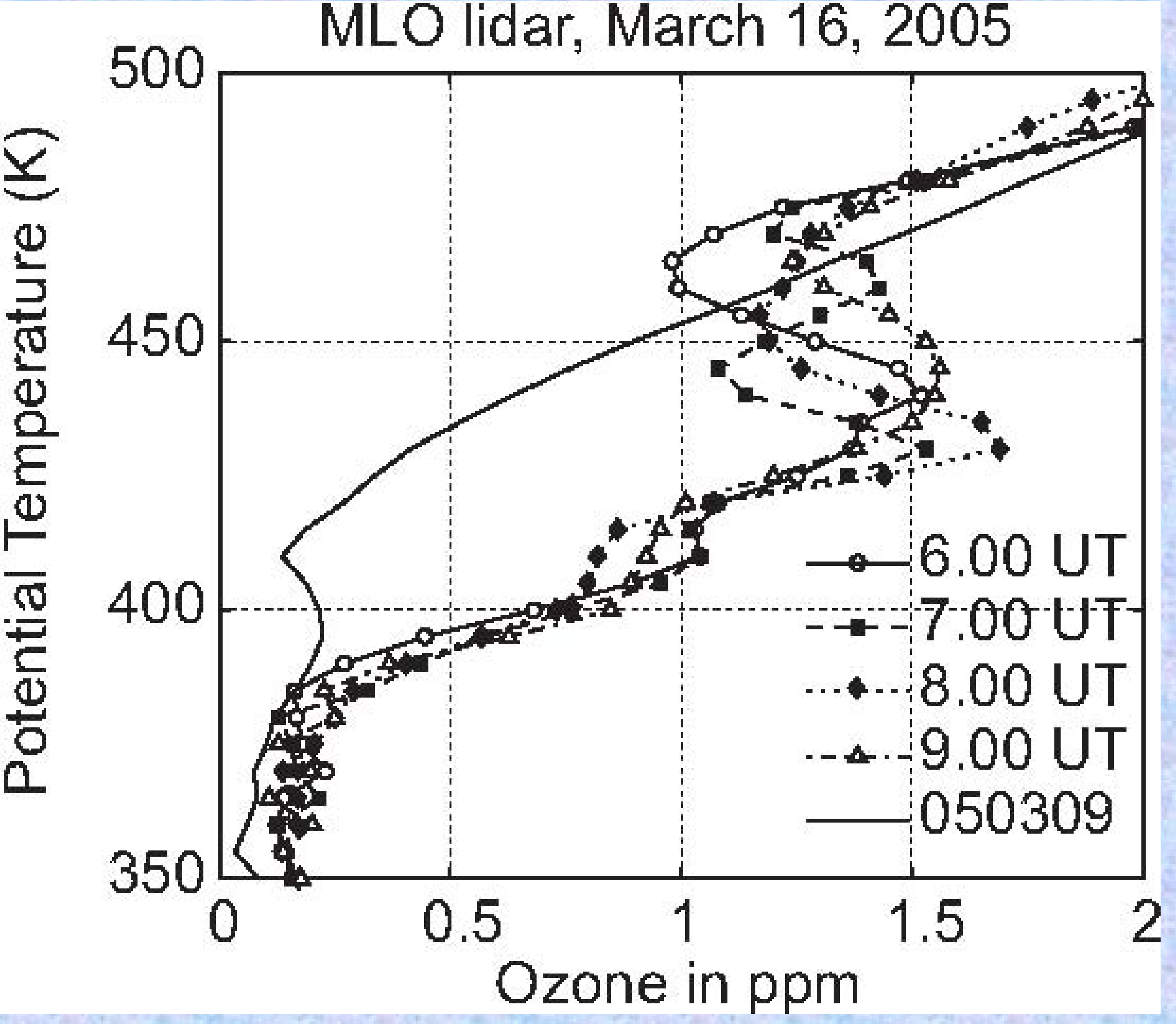
Elbow that passes on March 19



All three maps: MIMOSA outputs: March 16, 2005 0600Z, 435 K

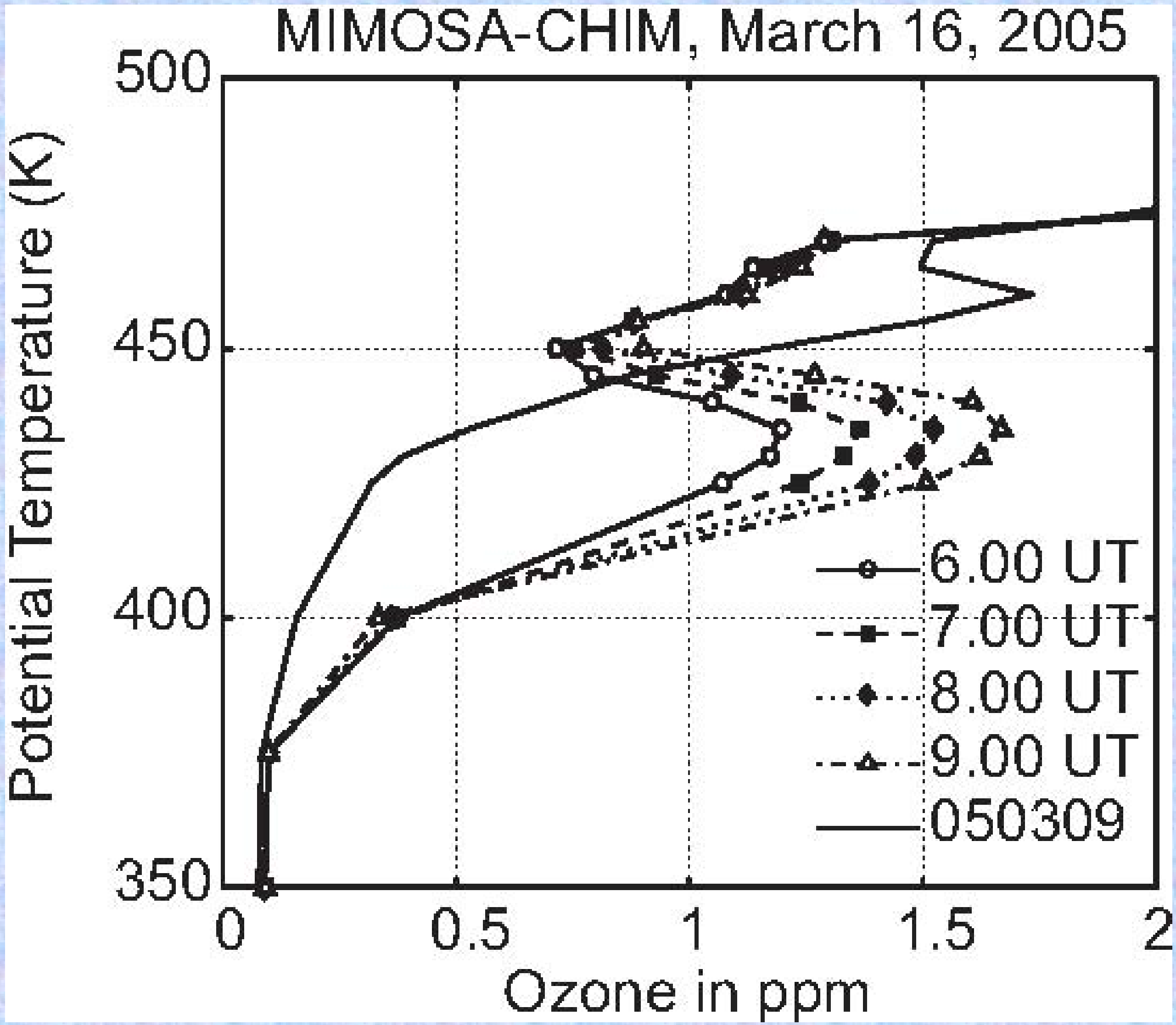
One-hour integrated (centered at the time indicated) ozone profiles from Lidar

- The filament is a layer of enhanced ozone reaching about 1.6 ppmv, as compared to typical climatological values of 1 ppmv (as measured, for example, on March 9).
- The local ozone peak is reached at 435 K, but this level actually varied from 425 K to 450 K over the few days between the beginning and the end of the event (not shown). Even over the course of one night.
- Lidar detected the filament at varying isentropic levels (between 425 K and 435 K).



- **Additional run was started on March 15, 2005 at 00 UT, with both re-gridding and output every 1-hour.**
- **Initialized from the 6-hour MIMOSA-CHIM output on March 15, 2005 at 00 UT.**
- **The ozone filament centered near 435 K was actually approaching MLO during the first hours of March 16, reached MLO at around 0600 UT, and remained above MLO until after 1200 UT.**
- **Three-dimensional displacement of the filament with time. The filament can be pictured as a 3D vortex fold that approached and passed over Hawaii on the night of March 16.**

MIMOSA-CHIM ozone profiles modeled at the same times and location as that measured by lidar



Evolution of ClO in the air parcels within the filament during its development and “ejection” out of the vortex at 435 K from MIMOSA-CHIM.

- **Air mass in the filament that left the polar vortex on March 13 was chemically active containing significant amount of ClO.**
- **The chemically active air mass is transported all the way to the tropics, and chlorine deactivated as the filament passes over MLO.**