
http://mls.jpl.nasa.gov

# EOS Aura Microwave Limb Sounder Observations of the Antarctic Polar Vortex Breakup in 2004

Gloria L Manney[1,2], Michelle L Santee[1], Nathaniel J Livesey[1], Lucien Froidevaux[1], Hugh C Pumphrey[3], William G Read[1], Joe W Waters[1], Steven Pawson[4]

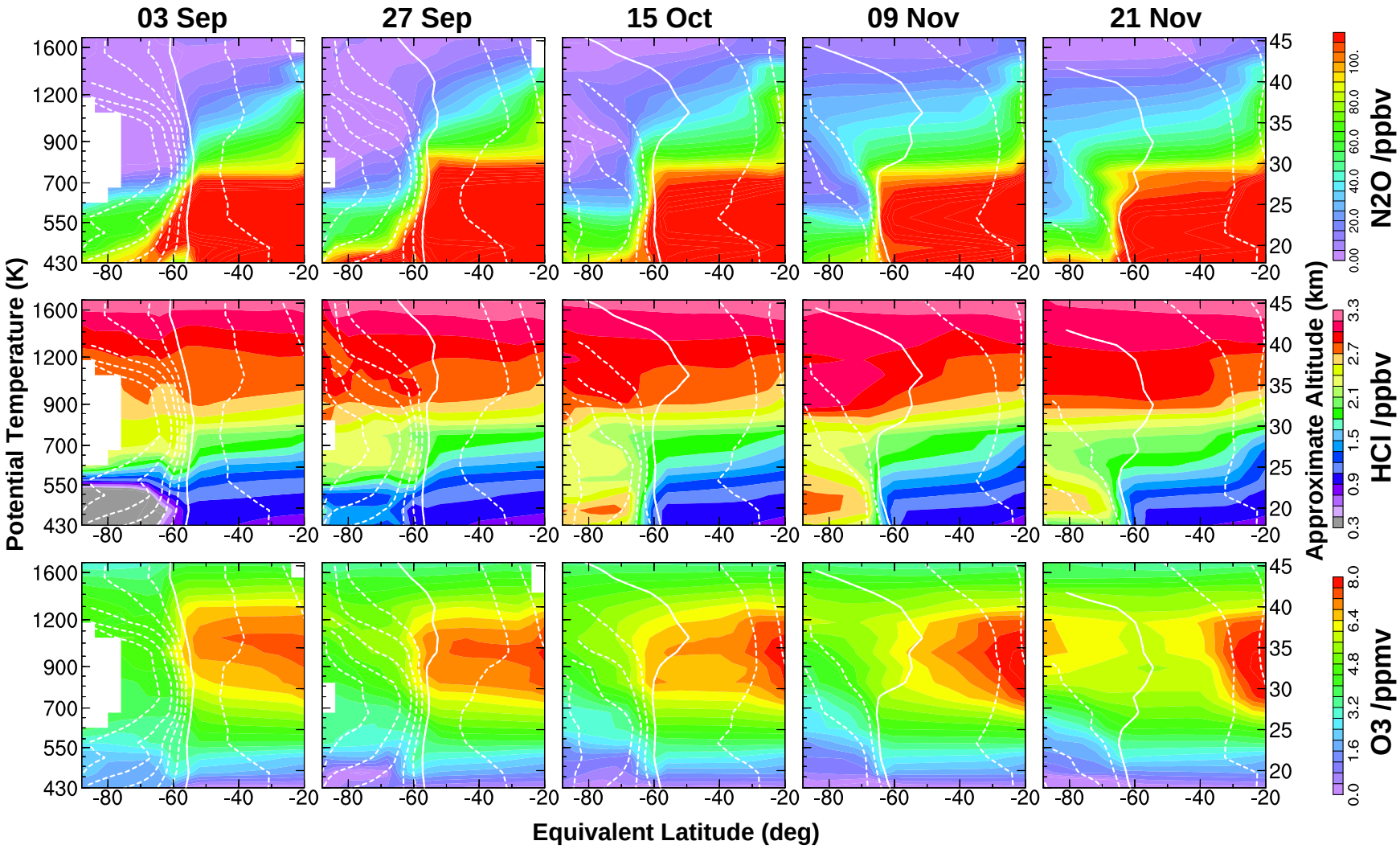
[1]Jet Propulsion Laboratory, California Institute of Technology
[2]New Mexico Highlands University
[3]University of Edinburgh
[4]NASA/Goddard Space Flight Center

## Introduction

- EOS MLS on Aura measures several species that are useful as tracers of transport
- We examine MLS observations of $N_2O$, $H_2O$, $O_3$ and HCl to illustrate the breakup of the Antarctic vortex in 2004
- Initial retrievals are used here; new software now implemented offers substantial improvements, but reprocessing will not be immediate because of computational limitations
- Initial $N_2O$ data in particular show some biases, but exhibit expected morphology
- For timeseries, short data gaps are filled using Kalman smoother [e.g., *Santee et al, GRL, submitted*]; paler colors are used to show periods with sparse or missing data

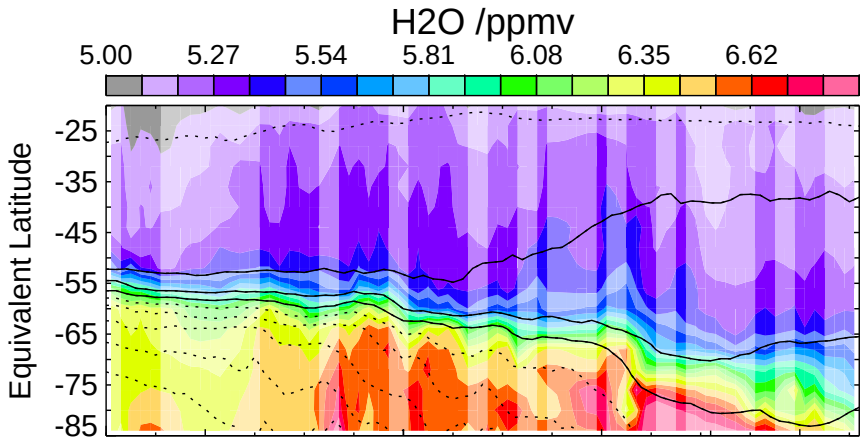
- Potential Vorticity (PV) from NASA's Global Modeling and Assimilation Office's GEOS-4 dataset is used to demark the polar vortex, and as a vortex-centered coordinate (when expressed as equivalent latitude, EqL)
- Effective diffusivity ($K_{eff}$; expressed as the dimensionless quantity log-normalized equivalent length) calculated from the GEOS-4 PV is used to identify mixing regions and transport barriers [e.g., *Haynes & Shuckburgh*, 2000, JGR; *Allen & Nakamura*, 2001, JGR]
- Low $K_{eff}$ values show the polar vortex transport barrier, high values indicate mixing regions

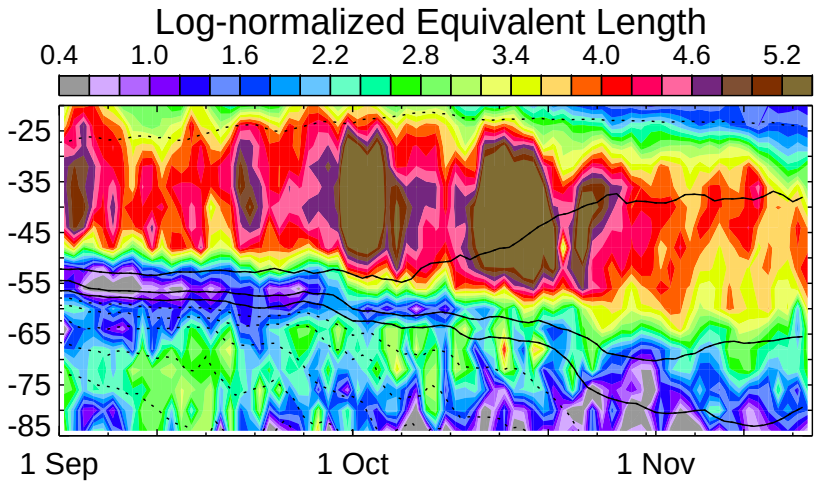
# Overview of Three-Dimensional Vortex Evolution

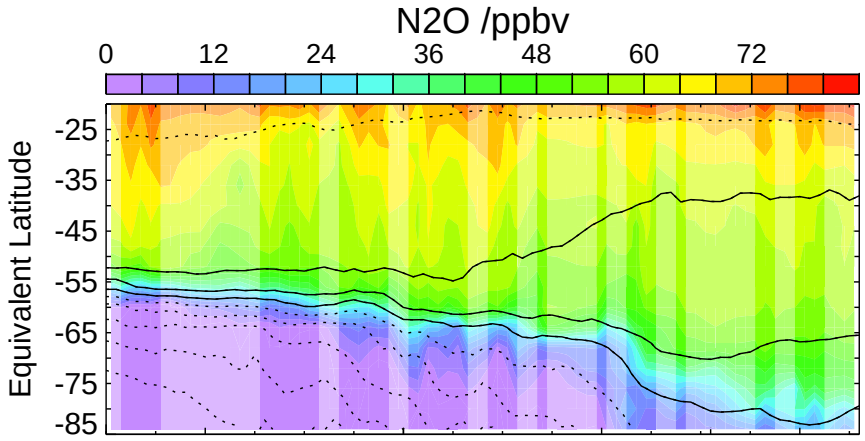


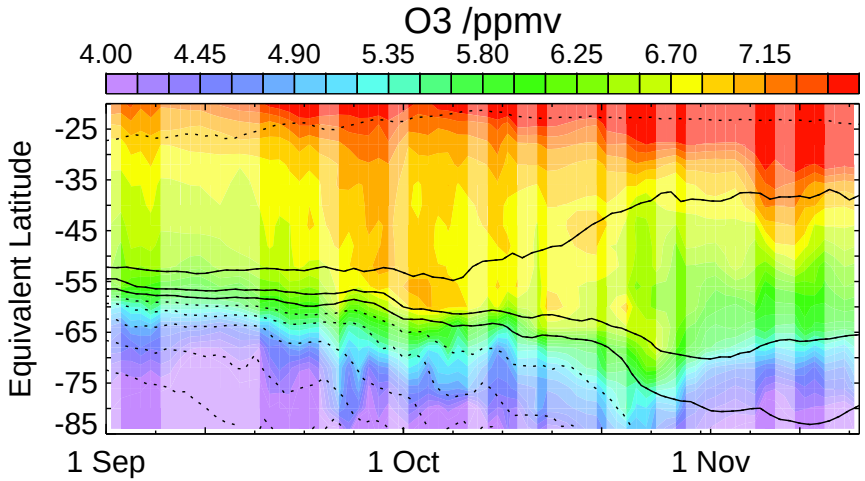

- As vortex decays from top down, extra-vortex air is transported to high equivalent latitudes at progressively lower levels
- $N_2O$ clearly shows descent through mid-November – but ascent suggested in lower stratospheric vortex core after mid-October
- Lower stratospheric vortex ozone increases after mid-October from continued descent and mixing with extravortex air

# Tracer Time Evolution in the Middle Stratosphere (850 K, ~30 km)



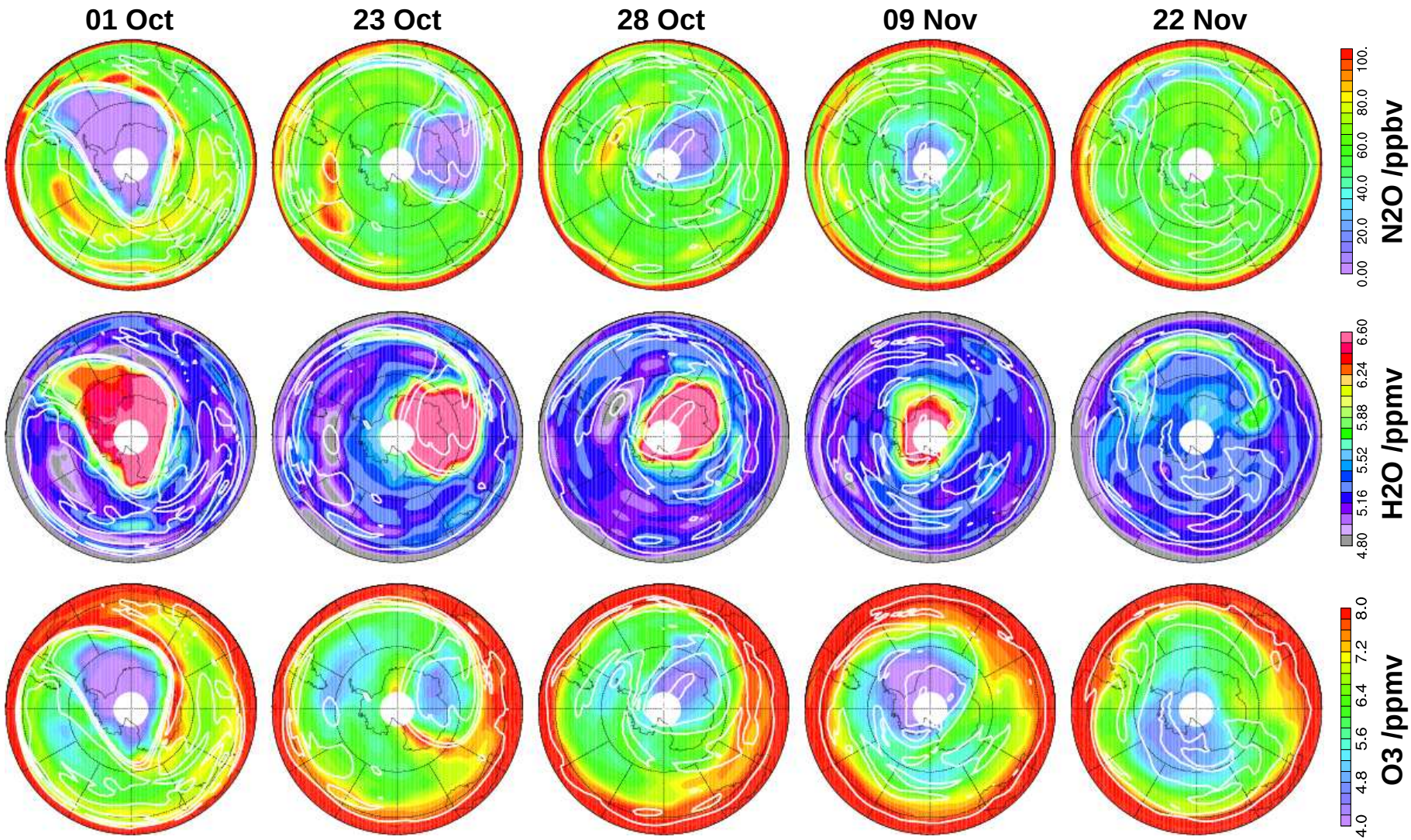



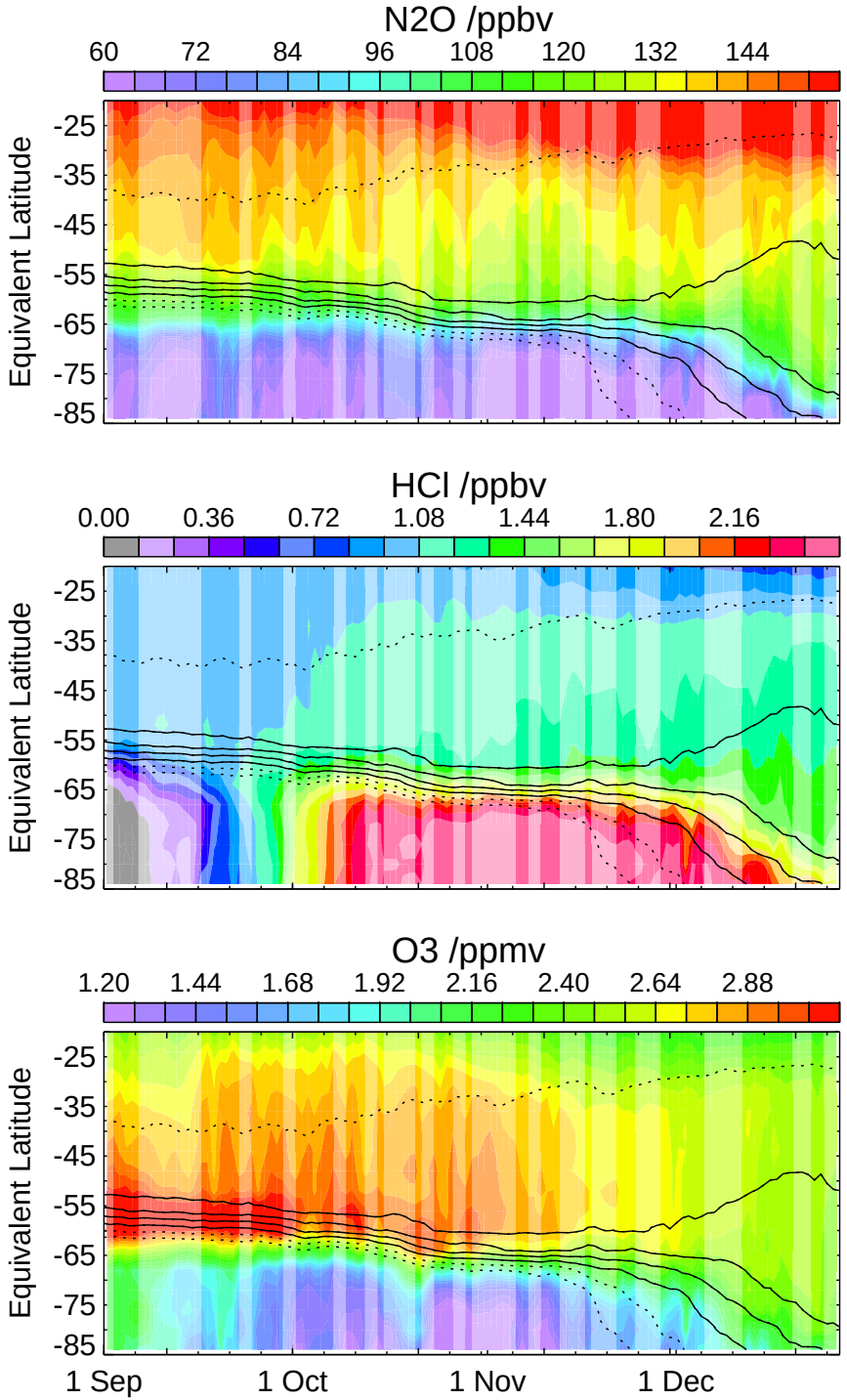

- Midstratospheric vortex breaks up by late October
- Weakened transport barrier, and enhanced midlatitude mixing by end of September
- Ozone shows transport of low-latitude air, “low-ozone pocket” formation (see next slide)
- Decreased high-EqL ozone after vortex breakup due to summer photochemistry

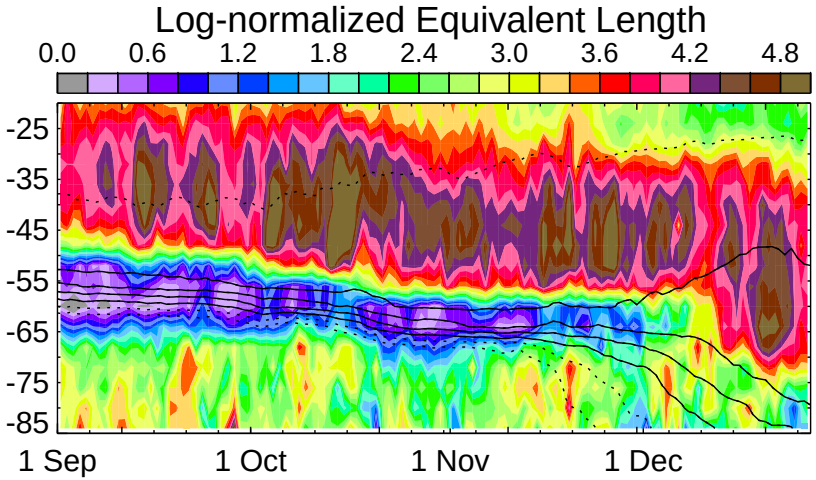
# Daily Snapshots in the Middle Stratosphere (850 K, ~30 km)




- $H_2O$ and $N_2O$ show low-latitude air drawn up and entrained into anticyclone
- Low-ozone pockets form photochemically in air confined in anticyclone
- Remnant of vortex air apparent on 22 Nov in $N_2O$ and $H_2O$; remnants linger through December

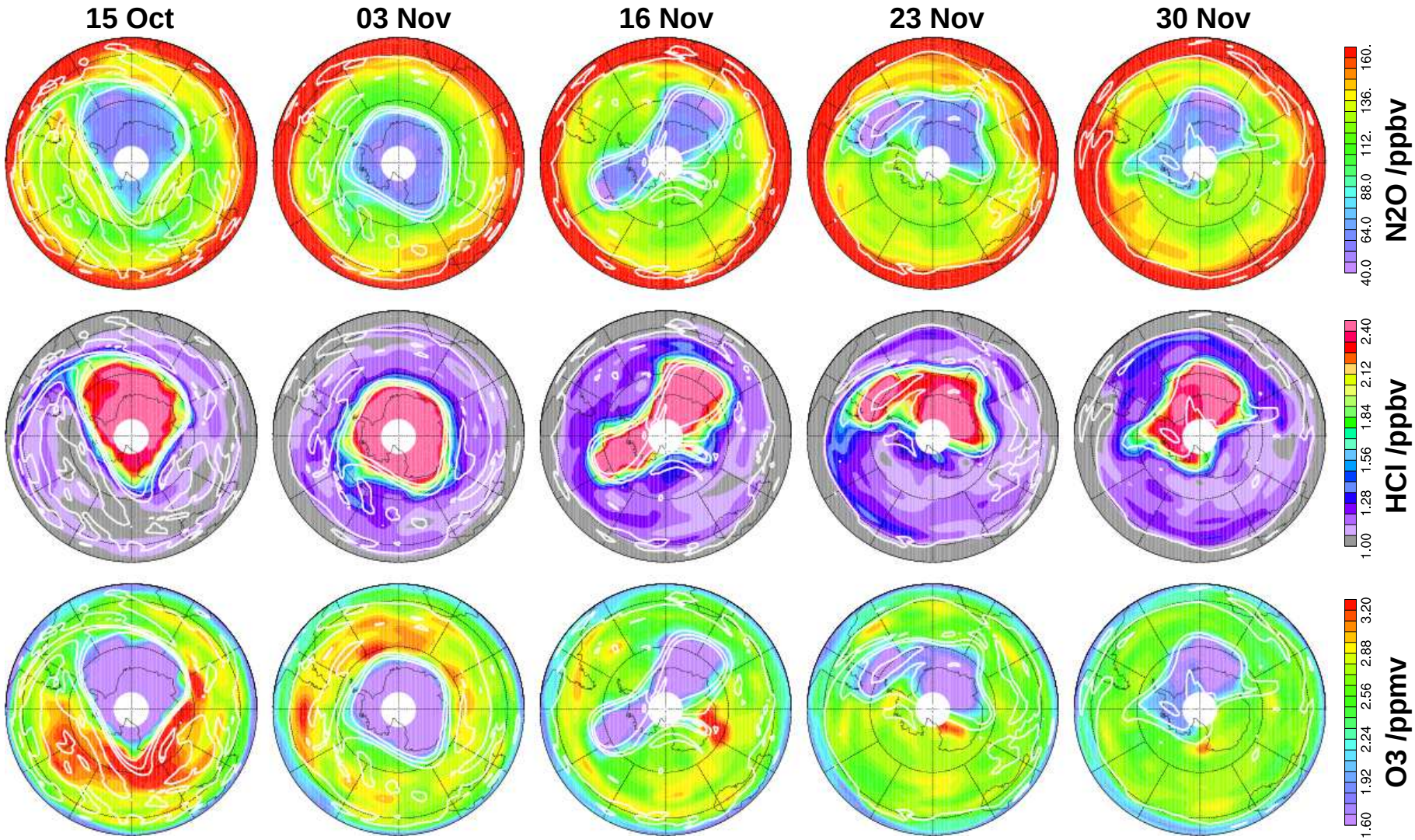
# Tracer Time Evolution in the Lower Stratosphere (520 K, ~19 km)



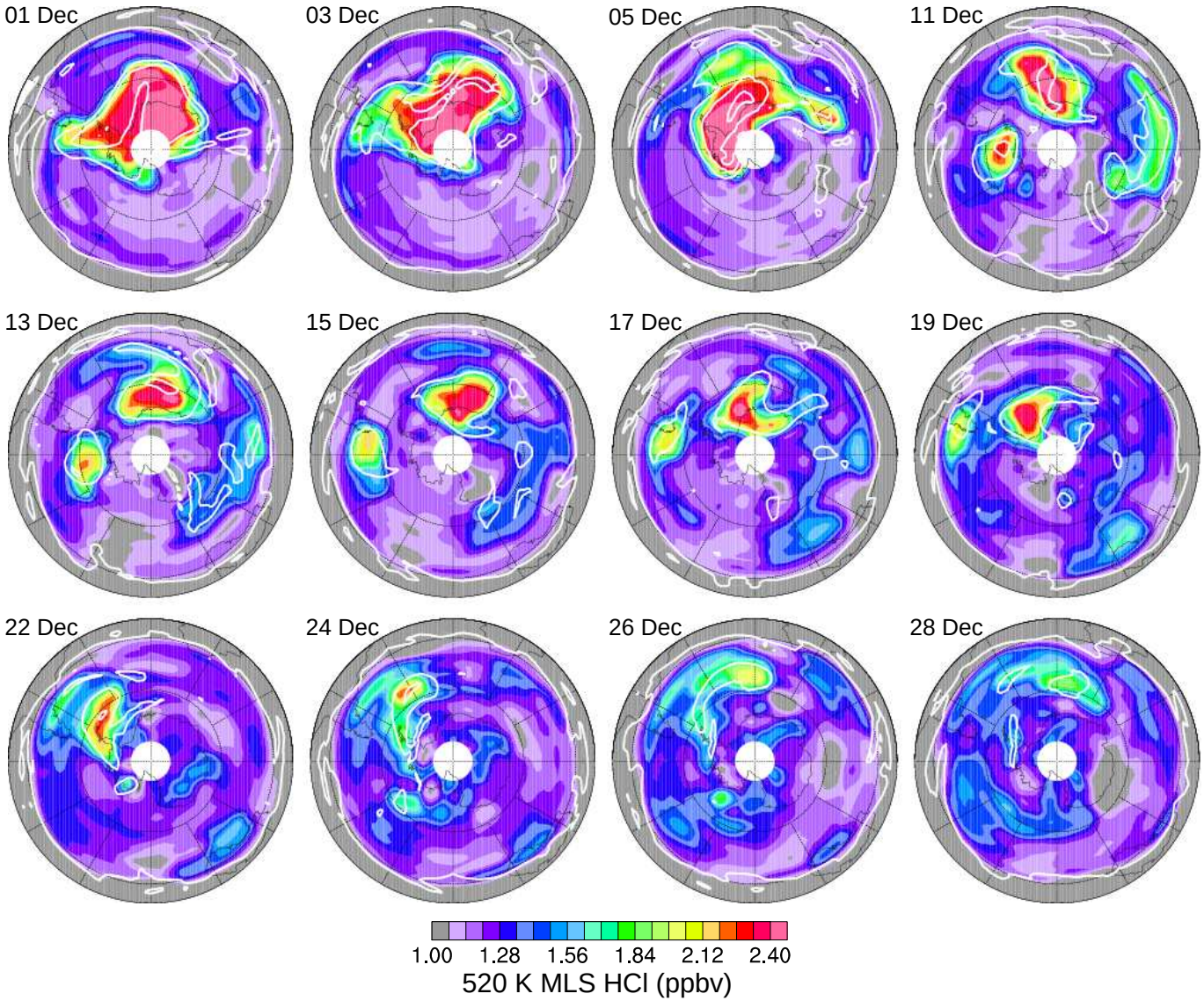

- Vortex shrinks slightly in mid-October
- Transport barrier weakens in mid-November, but vortex remains large
- Transport barrier disappears and vortex shrinks rapidly beginning in early December
- MLS tracers reflect evolution and breakup of vortex

# Prelude to the Lower Stratospheric Vortex Breakup



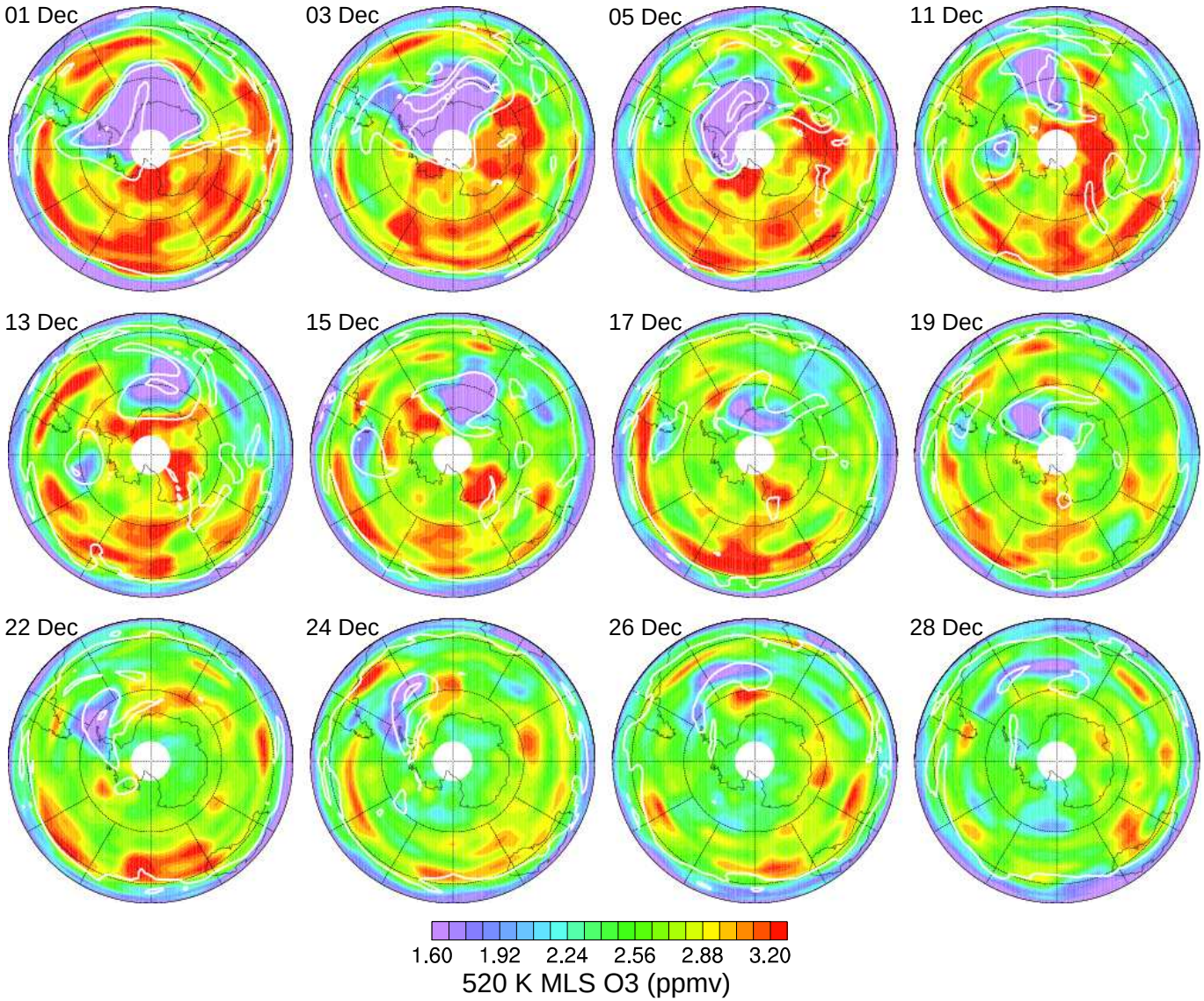

- Vortex shrinks and weakens moderately from mid-Oct through Nov, but well-confined region of vortex air persists
- Filamentation and vortex-edge erosion (e.g., 15 Oct, 23 Nov)
- Some intrusions into vortex (e.g., 23 Nov)
- Increased mixing of vortex-edge air into midlatitudes apparent from early Nov

# Lower Stratospheric Vortex Breakup Detailed in MLS HCl



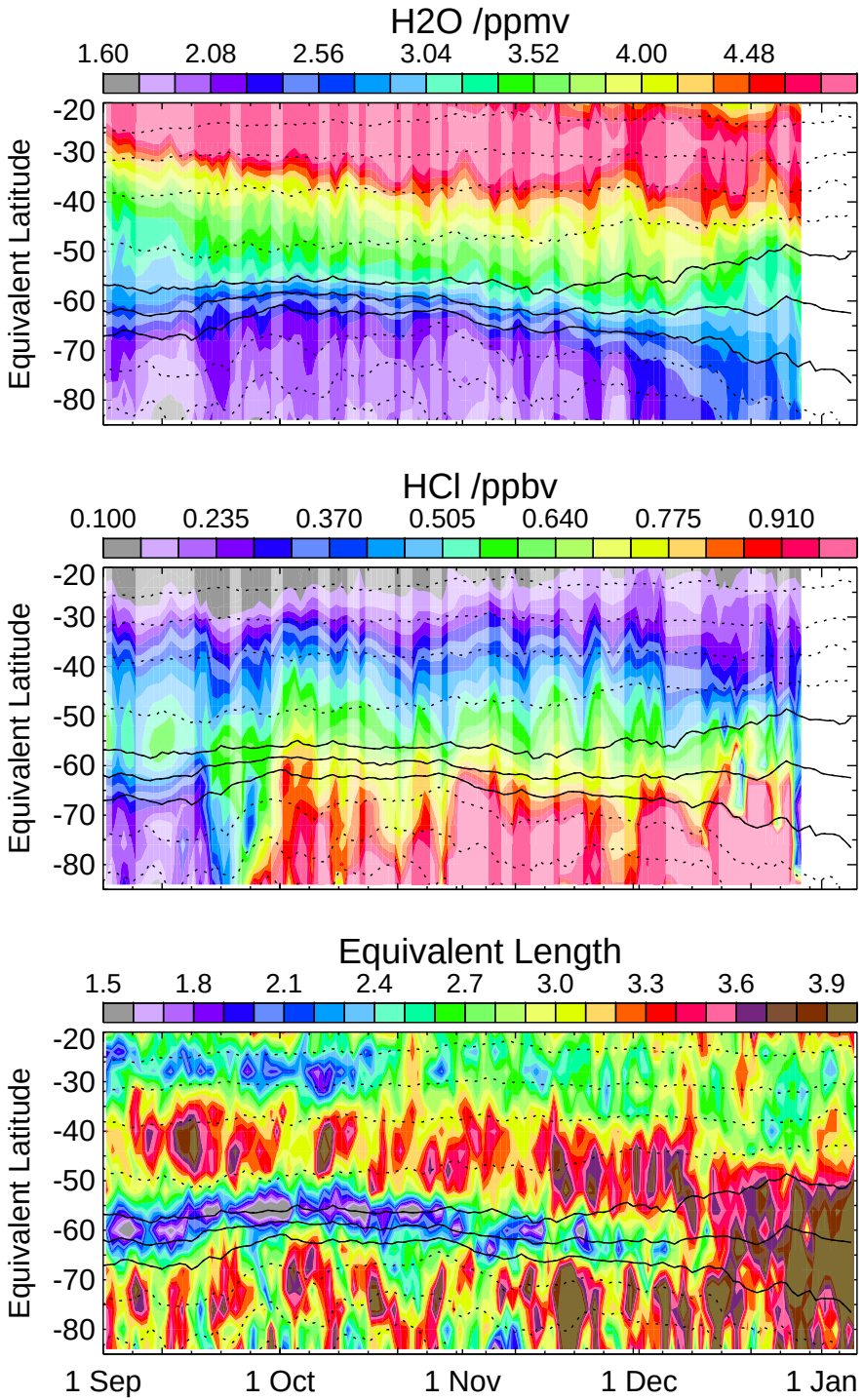

- Vortex still well-confined at beginning of December, but weakens rapidly
- Between 5 and 11 December, vortex breaks into three fragments
- Vortex remnants weaken in December, and can be identified only through early January

# Lower Stratospheric Vortex Breakup Detailed in MLS Ozone

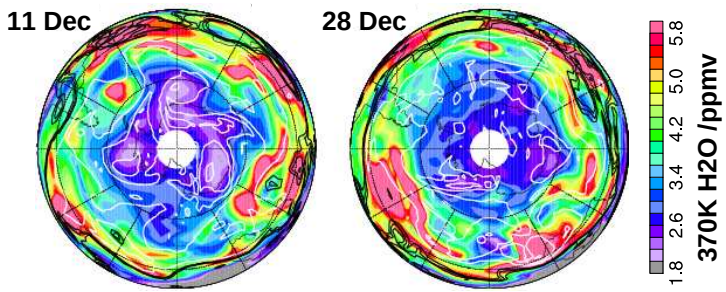



- $O_3$ maps at 520 K show dispersion of ozone depleted air during vortex breakup
- Mid-EqL $O_3$ decreases during the breakup from mixing (both with vortex and low-latitude air)
- Low-$O_3$ vortex fragments identifiable into early January

# The Subvortex and Lowermost Stratosphere (370 K, ~12 km)




- NOTE: MLS started V1.5 processing in 2005; new data (not shown) confirm patterns of transport
- 370 K is in the troposphere in the tropics, in the stratosphere at higher latitudes
- New retrievals in UTLS region are improved – but subvortex (and tropopause) transport barriers are clearly defined and coincide with minima in $K_{eff}$
- Subvortex breaks up abruptly, a few days after the lower stratospheric vortex – no confinement apparent by early January
- $H_2O$ (and $O_3$, HCl, not shown) maps show synoptic evolution consistent with GEOS-4 PV fields; vortex fragments underlie those in lower stratosphere



## Summary:

- EOS MLS trace gas and GEOS-4 meteorological data give a consistent picture of the breakup of the 2004 Antarctic vortex throughout the stratosphere
  - Descent continued through mid-November in the outer part of the lower stratospheric vortex; ascent began in vortex core by mid-October; consistent with previous studies [e.g., *Manney et al*, 1994, JAS]
  - The mid-stratospheric vortex broke up by late October, following an early October breakup in the upper stratosphere
  - The lower stratospheric vortex weakened and shrank modestly in November, but remained well-confined at beginning of December
  - Starting in early December, lower stratospheric vortex eroded rapidly, then fragmented between 5 and 11 December
  - Vortex remnants in lower stratosphere remained only through early January
  - Sub-vortex broke up abruptly and almost simultaneously with lower stratospheric vortex
- Even in these preliminary retrievals, the EOS MLS dataset provides a wealth of information on transport processes and vortex evolution
  - Compared to UARS MLS, addition of $N_2O$ and HCl measurements, and extended coverage for and improvements in $O_3$ and $H_2O$, enhance our ability to track transport processes during the vortex breakup using EOS MLS data
  - The MLS observations show the breakup of the 2004 Antarctic vortex in unprecedented detail
- Paper submitted to GRL, available on MLS website (http://mls.jpl.nasa.gov)