Lifecycle of the 'Frozen-in Anticyclone' in the 2005 Arctic Summer

Paper 527

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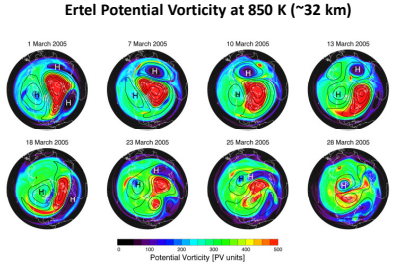
Summary

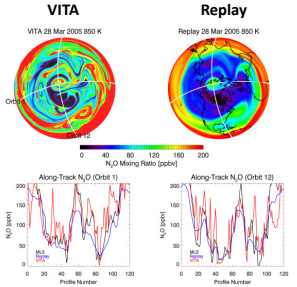
Immediately following the breakup of the 2005 Arctic spring stratospheric vortex, a tropical air mass, characterized by low potential vorticity (PV) and high nitrous oxide (N_2O), was advected poleward and became trapped in the easterly summer polar vortex. This feature, known as a "Frozen-In Anticyclone (FrIAC)", was observed in Earth Observing System (EOS) Aura Microwave Limb Sounder (MLS) data to span the potential temperature range from ~580 to 1100 K (~25 to 40 km altitude) and to persist from late March to late August 2005. This study compares MLS N_2O observations with simulations from the Global Modeling Initiative (GMI) chemistry and transport model, the GEOS-5/MERRA Replay model, and the Van Leer Icosahedral Triangular Advection (VITA) isentropic transport model to elucidate the processes involved in the lifecycle of the FrIAC, which is here divided into three distinct phases, as described below.

Phase 1: Spin-Up Phase (March to Early April 2005)

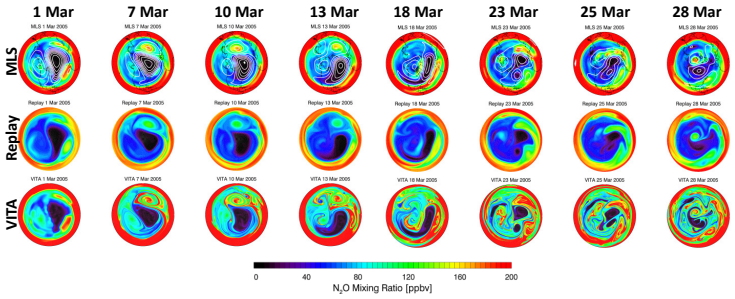
During the "spin-up phase" (March to early April), strong poleward flow resulted in a tight isolated anticyclonic vortex at ~70–90°N, marked with elevated N_2O. GMI, Replay, and VITA all reliably simulated the spin-up of the FrIAC, although the GMI and Replay peak N_2O values were too low.



Northern Hemisphere Ertel potential vorticity at 850 K potential temperature for select days in March 2005 (colored contours). PV units are used, where 1 PVU = 1.0 x 10^{-6} m^2 s^{-1} K kg^{-1}. Black lines indicate 10 hPa geopotential height at 25-m contour intervals. The black "H" marks the location of the Aleutian anticyclone and the white "H"s mark the locations of other anticyclones.



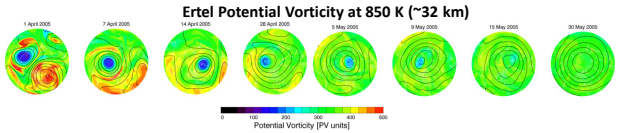
Top row: Northern Hemisphere VITA (left) and Replay (right) N_2O at 850 K on 28 March 2005. Overlaid are two EOS Aura orbit tracks for this day. Second row: MLS, Replay, and VITA N_2O at 850 K along the selected orbit tracks. Replay and VITA data are interpolated linearly in space and time to the MLS data points.



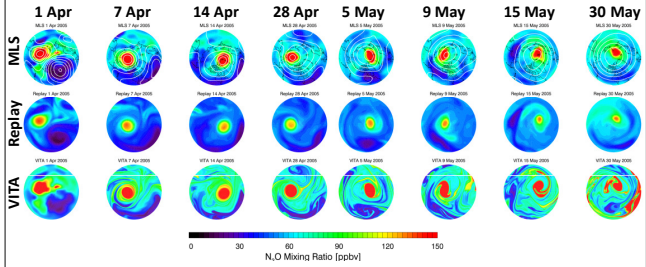
Northern Hemisphere EOS Aura MLS N_2O mixing ratio at 850 K for select days in March 2005 overlaid with contours of 10 hPa geopotential height at 25-m intervals (first and third rows). Replay N_2O simulations for the same days (second and fifth rows). VITA N_2O simulations initialized on 1 March 2005 (third and sixth rows).

Phase 2: Anticyclonic Phase (April - June 2005)

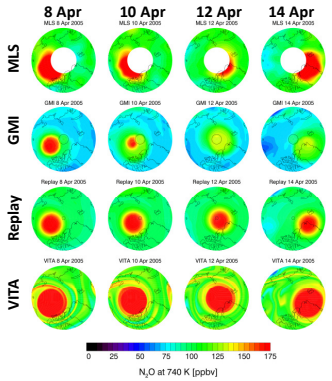
The FrIAC became trapped in the developing summer easterly flow and circulated around the polar region during the "anticyclonic phase" (early April to the end of May). During this phase, the FrIAC crossed directly over the pole between the 7th and 14th of April. The VITA and Replay simulations transported the N_2O anomaly intact during this crossing, in agreement with MLS, but unrealistic dispersion of the anomaly occurred in the GMI simulation due to excessive numerical mixing of the polar cap. The vortex associated with the FrIAC was apparently resistant to the weak vertical shear during the anticyclonic phase, and it thereby protected the embedded N_2O anomaly from stretching.



Ertel potential vorticity at 850 K potential temperature from 50–90°N for select days in April and May 2005 (colored contours). Black lines indicate 10 hPa geopotential height at 10-m contour intervals.



MLS N_2O mixing ratio at 850 K from 50–90°N for select days in April–May 2005 overlaid with contours of 10 hPa geopotential height at 10-m intervals (first and fourth rows). Replay N_2O simulations for the same days (second and fifth rows). VITA N_2O simulations initialized on 1 April 2005 (third and sixth rows).



MLS N_2O mixing ratio from 70–90°N at 740 K potential temperature for 8, 10, 12, and 14 April 2005 along with simulations from GMI, Replay, and VITA. Black circles indicate the extent of the polar mixing cap in the GMI and Replay simulations.

Acknowledgments

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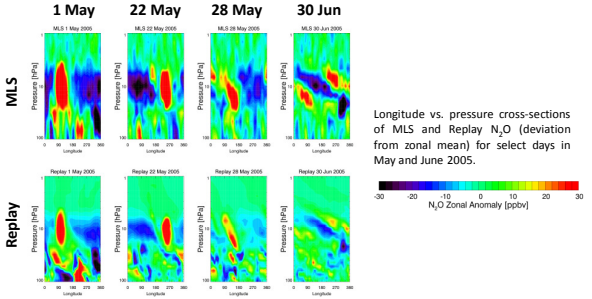
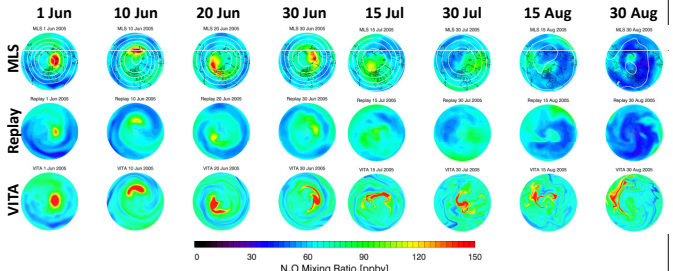
Phase 3: Shearing Phase (July - August 2005)

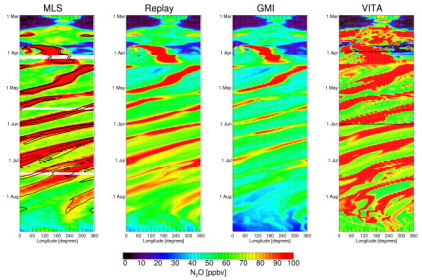
The vortex decayed in late May due to diabatic processes, leaving the N_2O anomaly exposed to horizontal and vertical wind shears during the "shearing phase" (June to August). The observed lifetime of the FrIAC during this phase is consistent with time-scales calculated from the ambient horizontal and vertical wind shear. Replay maintained the horizontal structure of the N_2O anomaly similar to MLS well into August. The VITA simulation also captured the horizontal structure of the FrIAC during this phase, but VITA eventually developed fine-scale N_2O structure not observed in MLS data.



Longitude vs. pressure cross-sections of MLS and Replay N_2O (deviation from zonal mean) for select days in May and June 2005.



MLS N_2O mixing ratio at 850 K from 50–90°N for select days in June–August 2005 overlaid with contours of 10 hPa geopotential height at 10-m intervals (first and fourth rows). Replay N_2O simulations for the same days (second and fifth rows). VITA N_2O simulations initialized on 1 June 2005 (third and sixth rows).



Longitude vs. time Hovmöller plots of N_2O at 850 K, 78°N for MLS, Replay, GMI, and VITA. The black contours on the MLS plot are the 75 and 100 ppbv contours of the Replay simulation, for direct comparison with MLS. White regions on the MLS plot indicate no data available during that time period. The VITA contours are produced from a composite of three runs of the model, initialized with MLS N_2O on 1 March, 1 April, and 1 June, as indicated by the horizontal black line.