Mechanisms of ozone enhancement during stratospheric intrusion coupled with convection over upper troposphere equatorial Africa [1]

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Presentation outlines

This presentation is organized under the following four sections

1. Introduction
2. Data and Methodology
3. Results and discussion
4. Conclusions

1.Introduction

- From simultaneous measurement of O_3 and NO_2 in clouds and model studies, three mechanisms are likely to account for O_3 and NO_2 enhancements:

i) convective transport from the boundary layer, ii) stratospheric intrusion, and iii) discharge induced production

- stratosphere to be the main source from which ozone enters the troposphere via tropopause exchange processes

- Tropopause folding and is exchanged with the troposphere via diabatic processes and turbulent diffusion as well as mixing processes and convective erosion during the breakup of stratospheric filaments.

- Synoptic scale instabilities in the upper troposphere can induce transport across the tropopause. Breaking Kelvin waves, or tropical cyclones could episodically transport airmass across the tropical tropopause from stratosphere to the troposphere.

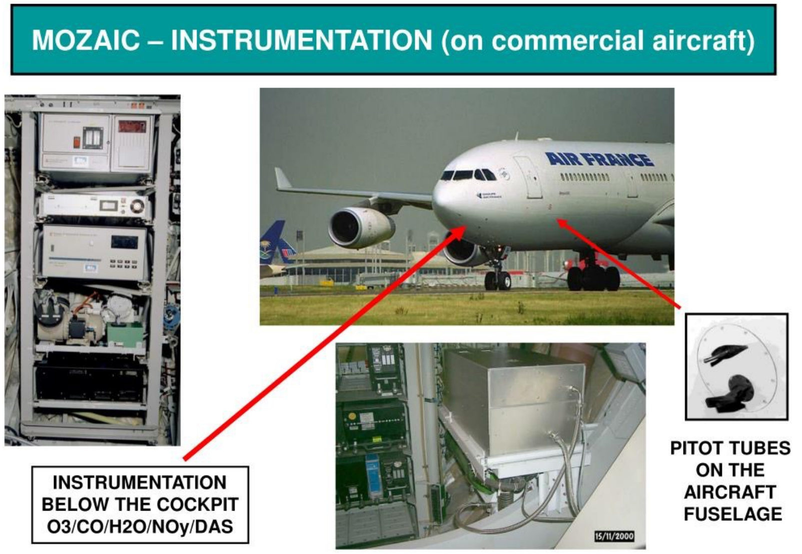
- Regional scale circulation such as cut-off lows that can play significant role in ozone enhancement in tropical troposphere. Rossby wave breaking at the subtropical tropopause in the vicinity of the subtropical jet stream

- Studies confirm that enhanced ozone is introduced into troposphere during thunderstorm events. O_3 enhancement over Equatorial Southern Indian Ocean by Zhang et al. (2012) have shown that upto 62% O_3 tropospheric column could come from O_3 production driven by lightning NOx emissions.

- Funatsu and Waugh (2008) have studied coupling of PV intrusion and deep convection over subtropical eastern pacific based on model and observation.

- Funatsu and Waugh proposed plausible mechanism on the coupling of PV intrusion and deep convection. *The main objective of this work is to investigate whether the enhanced ozone over upper tropospheric equatorial Africa from MOZAIC and ERA-Interim observations can be explained by PV intrusions accompanied by deep convections.*

2.Data and Methodology



- Data: Measurements of ozone in the MOZAIC programme are taken every four seconds from take-off to landing. Based on the dualbeam UV absorption principle (Model 49-103 from Thermo Environment Instruments).

- Data are recorded from aircraft take-off to landing, providing vertical profiles and cruise data between 8 and 12.5 km altitude.

- Reprocessed GOME satellite ozone, part of ECMWF ERA-Interim dataset (Dragani, 2011) over a broader region covering MOZAIC observations, is used to identify whether the observed enhancements in ozone are large scale or isolated small scale events.

- For this purpose, geopotential height, potential vorticity, zonal and meridional winds, temperature and pressure from ECMWF ERA-Interim dataset are additionally used. Meteosat satellite imageries are also used to identify deep convection and major circulation features that support the convection

Study Area Description and Methodology

- The tropopause levels were calculated using the methodology proposed by Hughes (1981).
- Equivalent latitude calculated from PV for diagnosis of transport and identification of origin of airmass, we have used equivalent latitude calculated using PV.
- Space-time Fourier decomposition of meridional averaged zonal wind field is used to determine the different atmospheric waves prevalent at the time of ozone enhancements captured by MOZAIC.
- MTM-SVD method has also been used to investigate joint spatio-temporal variability of climate drivers and climate signal

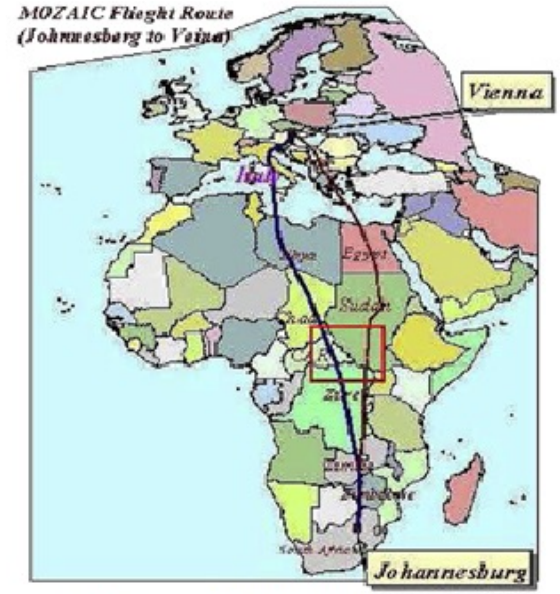


Fig.1 Freqent MOZAIC flight route from Johannesburg to venna.Ozone enhancements observed wihin the red-rectangular box

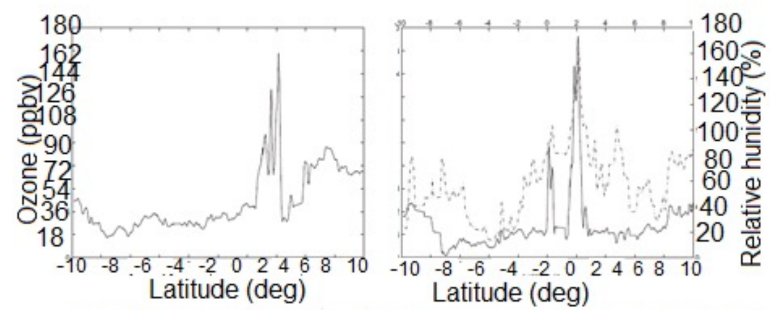


Fig.2Ozone (solid line) and relative humidity (dash-dot)

3. Results and discussion

- At about 240 hPa approximate flying altitude (tropopause heights being at 88 hPa) with in 3.14-4.20^{0}N latitude, MOZAIC flight records O_3 volume mixing ratio of exceeding 100 ppbv were observed. (April 06, 1996 and March 27, 1997 selected for this case study)

- The question to be addressed where do high O_3 VMRs of upto 170 ppbv originate?
- There are only three possibilities: horizontal transport, in-situ production and vertical transport through troposphere stratosphere exchange processes.

- In-situ chemical production in the troposphere in this case may not lead to O3 VMRs of upto 170 ppbv

- ERA-Interim Ozone observation show a progressively decreasing ozone concentration towards the lower altitude. However, the observed concentration at 250 hp is far less than 100 ppbv. Therefore, vertical transport does not justify the cause of the enhancement.

- Equator ward propagation of extratropical wave activity favors stratospheric intrusion is the.Fig. 4 shows the geopotential height (contour) and horizontal winds (arrow) at 50 hPa pressure level for April 6-7, 1996 before and after MOZAIC instrument captured enhanced ozone event.

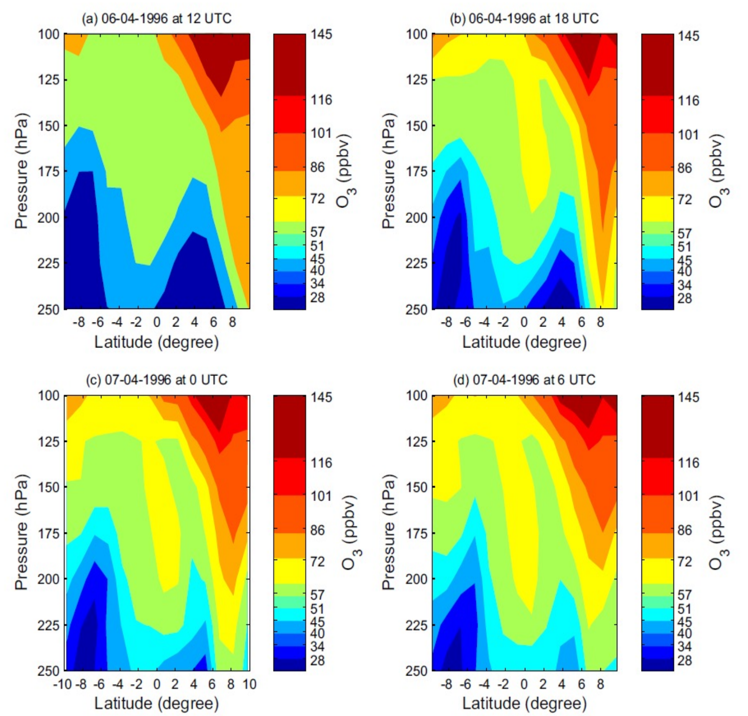


Fig. 3 ERA-Interim Ozone observation at 25 E

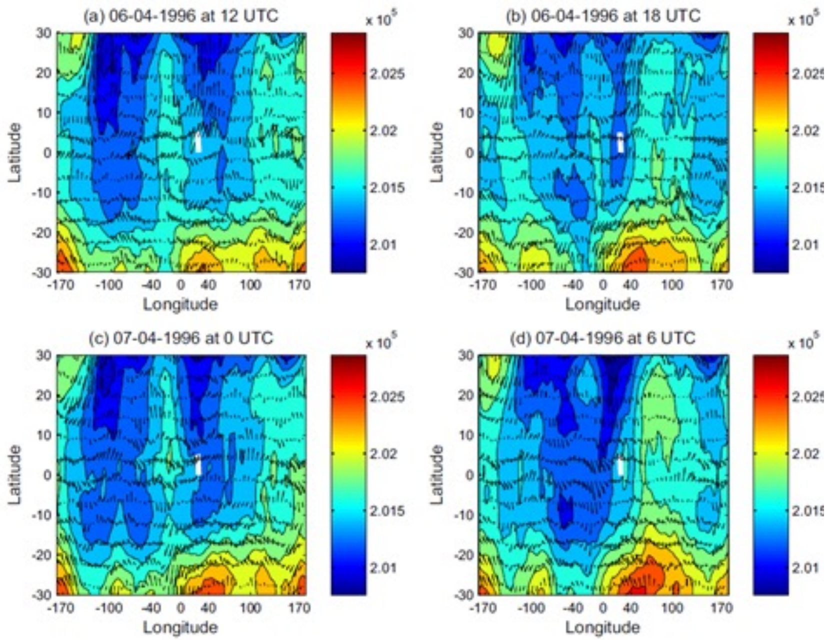


Fig.4 Circulation pattern at 50 hPa pressure level MOZAIC observation of high ozone. Geopotential field depicted by color code in unit of m2 /s2 is overlaid by the wind field shown in arrow. The white solid line is MOZAIC flight route

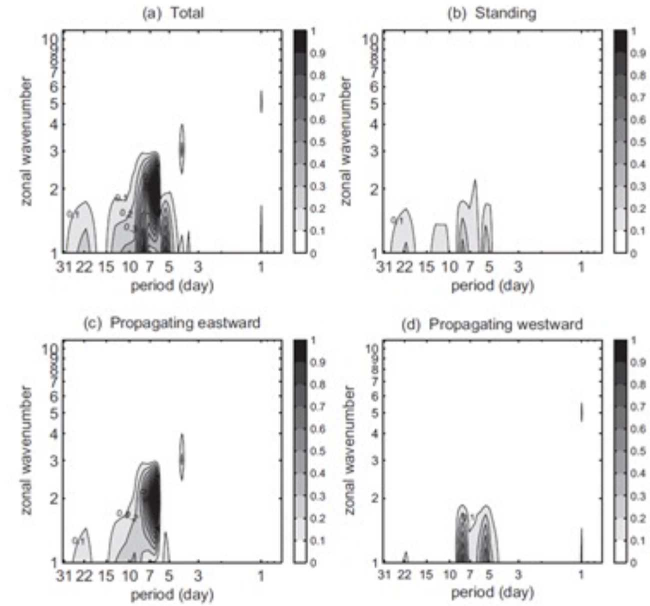


Fig.5 Hayeshi spectra for the period centred on enhanced ozone event of April 6, 1996.

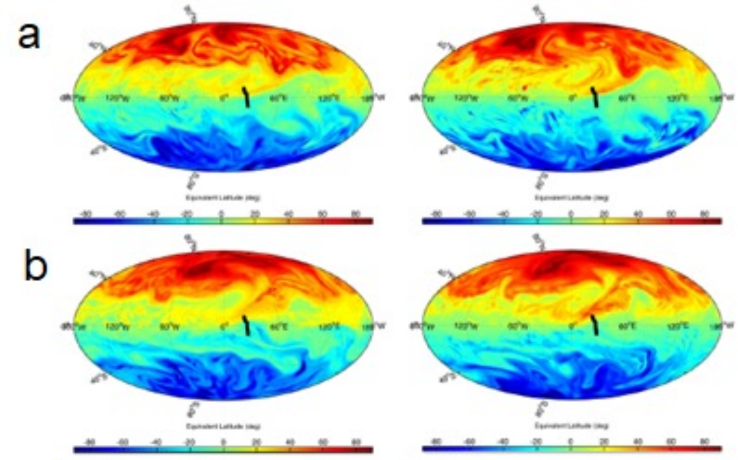
- Relative humidity content of the stratosphere is very low, therefore in conjunction with stratospheric intrusion there has to be deep convection leading to thunderstorm (Fig.2)
- This is part of a large amplitude planetary wave of wavenumber 2. Hayeshi spectra in Fig. 5 is constructed from zonal wind at 50 hPa pressure level over the equatorial latitude band.
- Presence of westward and eastward propagating waves are indicated by the significant power spectra. This is in agreement with previous signal shown in Fig.4

-Equivalent latitude as zone tracer:

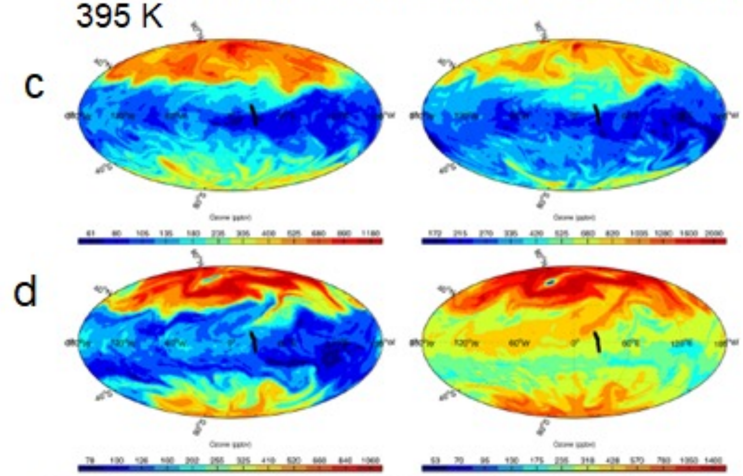
Equivalent latitude on isentropic level (a,b) at 370 and 395 K levels were used as a dynamical tracer to show ozone transport.
-On April 06, 1996 at 18 UTC just before captures ozone record. (a)370 K left and 395 K right panel. Similarly for March 27, 1997 panel (b).

-Panel (c) and (d) shows the corresponding ozone concentration at the same isentropic levels.
The black line over the equator show the MOZAIC flight route.

-These figures clearly illustrate MOZAIC captures ozone of stratospheric origin.



Equivalent latitude on isentropic levels of 370 K and 395 K



Ozone on isentropic levls of 370 and 395 K   Fig. 6 and 7

- Cloud cover and streamlines overlaid for April 06,1996 Upper panels just before and after MOZAIC flights (Upper two panels)
- Similarly for March 27,1997 (Lower panels)
- Both pair of panels illustrates convection during after the MOZAIC flights.
- convection also demonstrated using OLR (not shown here)

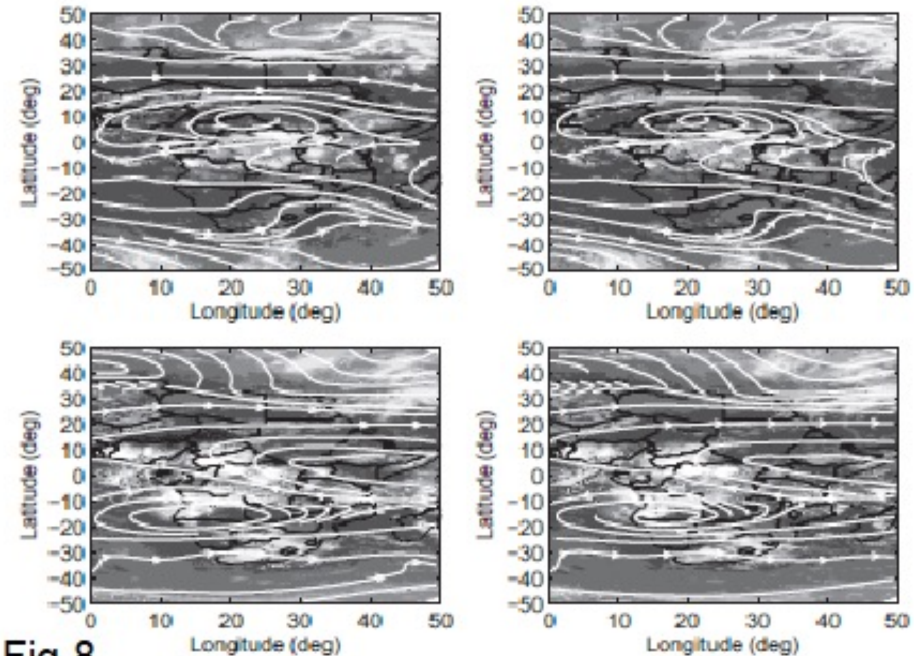


Fig.8

Cloud cover stremlies ovelayed before and after MOZAIC flights for the two case days

4. Conclusion

- The possible cause and source of enhanced ozone and water vapor from MOZAIC cruise measurements, which also reflected in ERA-Interim ozone, over equatorial Africa (10 S-10 N) at altitude range of 300-200 hP investigated.

- Equivalent latitude computed from PV used as a dynamical tracer of atmospheric transport has given clear indication that the transport during the two considered events captured by MOZAIC is dominated by airmass transport along isentropic surfaces from higher latitude stratosphere into equatorial upper troposphere.

- The use of Space-time Fourier decomposition of meridional averaged zonal wind field based on procedure formulated by Hayashi(1971, 1979), used to quantitatively identify the wave activities revealed in equivalent latitudes.

- The MTM-SVD spectral technique is used to determine how these waves modulate stratospheric PV intrusion, and the coupling relationship between the intruded PV and accompanying deep convective activity using OLR as its proxy.
- Stratospheric PV intrusion adiabatically along isentropic surface from mid-latitude stratosphere and descent over tropics can likely trigger convective activity. As a result, there is a possibility to observe enhanced ozone in the troposphere coupled with high water vapor.
- The phase relationship between OLR and ozone in the stratosphere and troposphere are found to be different. In the stratosphere there is a positive correlation at this temporal cycle while in the troposphere, ozone decreases with enhancement in OLR, a likely indicator of convection.
- The possible explanation for the observed difference might be linked to scavenging of ozone by lightening inside a thunderstorm clouds in the upper troposphere

Thank you for your attention