Observations of vertical air mass exchange and new particles formation at Everest-Pyramid GAW Station

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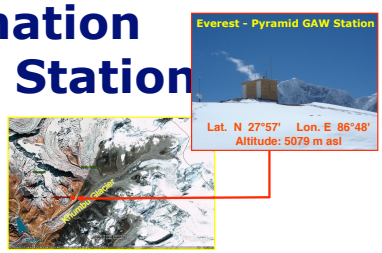


BACKGROUND - In the framework of the Ev-K2-CNR SHARE (Stations at High Altitude for Research on the Enviroment) and UNEP ABC (Atmospheric Brown Clouds) projects, the Everest-Pyramid monitoring station is active since March 2006 in the Khumbu valley (Nepal), at 5079 m asl in order to make up for a lack of information at high altitude in Himalayan region. The measurements describing the behaviours of aerosol, ozone and GHGs showed that this remote area can be affected by local, regional or long range transports of air masses, as well as frequent vertical air exchanges. Air mass intrusions from stratosphere or upper troposphere are characterized by simultaneous rise of ozone content and diminution of relative humidity. During several of Lower Stratosphere/Upper Troposphere (LS/UT) transport events a sudden increase of ultrafine particles number was observed at the end of the event. The interface between very clean LS/UT air and the more polluted air masses transported by valley wind breeze, has been identified as an efficient mechanism for new particles formation.

Methodology

In order to identify LS/UT transport events at the Everest-Pyramid station, days characterised by (1) high surface ozone (O_3) values; (2) high potential vorticity (PV) values; (3) high total column ozone (TOC O_3) values; (4) atmospheric pressure (PP) significant variations, were considered.

TOC O_3: total column ozone measured by OMI provides information about possible intrusions from stratosphere. **70 days** were characterized by significant (>75th centile) increases of TOC O_3 residuals (compared with seasonal values).

PP: downward transport of stratospheric air into the troposphere are often related with synoptic processes (i.e. fronts, upper level trough, cut-off lows, subsiding anticyclonic areas). **116 days** show significant (90% confidence level) atmospheric pressure variations (residuals in respect to seasonal mean).

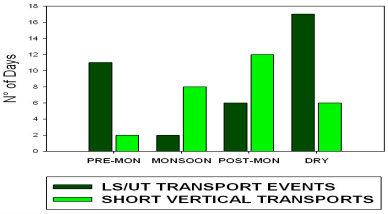
PV: air mass PV were deduced by the LAGRANTO back-trajectories calculated every 6 hours. PV has been used to trace stratospheric air in the troposphere (PV is greater in stratosphere than in troposphere). **127 days** show at least one trajectory with PV > 1.6 pvu (at altitude higher than 5000 m asl).

Considering only the days characterized by surface O_3 increase (dark green in graph at right side) and at least 2 of 3 variables listed above, **35 days** with possible LS/UT transport events were identified.
In addition, **28 episodes of Short Vertical Transports** (SVT; few hours duration) with simultaneous O_3 increase and relative humidity decrease, probably testifying short vertical transports from the upper clean troposphere (green in graph at right site) were also recognized.
37% of days with possible LS/UT transports and **47%** of SVT are characterized by presence of **nucleation particles**, generally appearing at the end of episode.

Analysis of LS/UT transport event seasonality

During the **first year of measurement at Everest-Pyramid station**, we identified 35 days "stratospheric influenced" (LS/UT) which represent **10%** of the considered data-set. In addition 28 Short Vertical Transport (SVT) events have been also considered in this study.

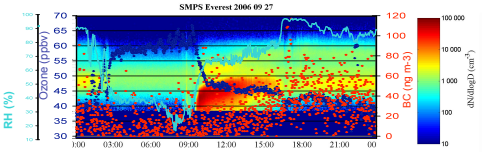
Seasonal distribution of vertical transports



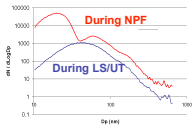
The seasonal LS/UT transport event frequencies showed minimum value during the Monsoon period, while the highest event occurrences were recorded during Dry and Pre-monsoon seasons. This seasonal behaviour could be related with the different position of the "Tibetan High", a strong thermal anticyclone forming in the upper troposphere during summer season and on strength and location of the Subtropical Jet Stream.

The seasonal SVT episodes, characterized by surface ozone rise with very low pollution levels and decrease of RH, show a trend with maxima during Post-monsoon and Monsoon season.

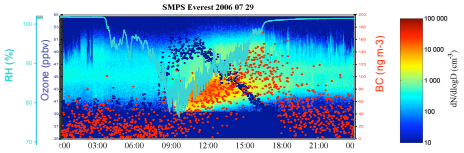
An episode of LS/UT transport with new particle formation



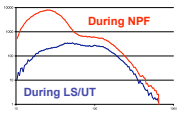
On September 27 2006, during LS/UT event, the O_3 increase (20 ppbv around 1 AM) was associated with a strong and rapid decrease of pollution tracers (BC, fine particle) revealing the presence of clean and dry air masses (RH reaches 15%). The end of the event suddenly appears around 10 AM, while the pollutants show a moderate increase after 6 PM (linked with valley breeze). Size distribution during the LS/UT event shows a monomodal distribution around 45nm, while after NPF process, besides the occurrence of nucleation particles, 45nm mode shifts to 60nm, probably due to gases condensation. Particles number rises from 570 to 16300#cc^{-1}.



A short episode of vertical transport with new particle formation



During the short vertical transport event of July 29, 2006 injection of air mass from higher tropospheric levels bring at the measurement site low concentrations of aerosols: BC 20 ng m^{-3}, PM1 0.4 μg m^{-3}, particles number 260 # cc^{-1}, with a dimensional distribution around 50 nm, with a second less pronounced mode in the accumulation size range (120 nm).
During the new particles formation event, the concentrations of particles reaches 7000 #cc^{-1} and the original 50 nm mode growth until accumulation size range.



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CONCLUSIONS - Aerosol characterisation during UT/LS events

	O_3 ppbv (LS/UT)	O_3 ppbv (SVT)	Principal Diameter (nm)	Particles N (# cm^{-3})	BC (ng m^{-3})	PM_1 (μg m^{-3})
LS/UT events	**68.8**±11.4	**51.9**±7.9	**50**±12	**510**±212	**57**±23	**0.8**±0.4
Annual average	**45.8**±26.9		--	**875**±956	**148**±342	**1.9**±1.8

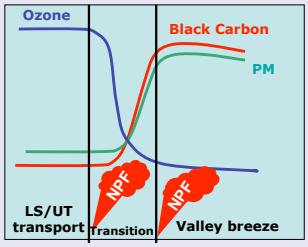
During LS/UT transports, aerosol properties are characterised by very low concentration in number (510±212# cc^{-1}) and mass (PM1=0.8±0.4 μg), as well as low black carbon fraction (57±23 ng m^{-3} corresponding to 7.1% of PM1) and a typical monomodal distribution around 50 nm. These values are calculated non considering the periods with new particles formation.

Table with data seasonality out of LS/UT transport events

	RH (%)	T (°C)	O_3 ppbv	Particles N (# cm^{-3})	BC (ng m^{-3})	PM_1 (μg m^{-3})
MAM	**67.2** ±29.0	**-4.5** ±3.8	**56,4** ± 29	**1193** ±1012	**328** ±544	**4.3** ±7.1
JJA	**94.8** ±7.7	**2.1** ±1.9	**35,7** ± 22	**632** ±784	**76** ±123	**0.4** ±0.3
SON	**69.7** ±29.0	**-3.1** ±3.8	**40,2** ± 28	**989** ±803	**112** ±117	**1.2** ±1.3
DJF	**29.1** ±27.4	**-6.3** ±4.6	**49,4** ± 20	**685** ±661	**131** ±173	**1.2** ±2.1

Typical behaviour of new particles formation (NPF) at the end of LS/UT transport events.

NPF takes place during 40% of these events, generally at the starting or at the end of transition between LS/UT and valley breeze air masses. A change of wind direction is always simultaneous with NPF.



No significant difference were found for aerosol properties between LS/UT and SVT events, while the mean O_3 concentration was significantly higher in LS/UT.