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agenzia spaziale italiana

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ECRS 2010

SOLAR ENERGETIC PARTICLES IN THE TERRESTRIAL POLAR CAPS

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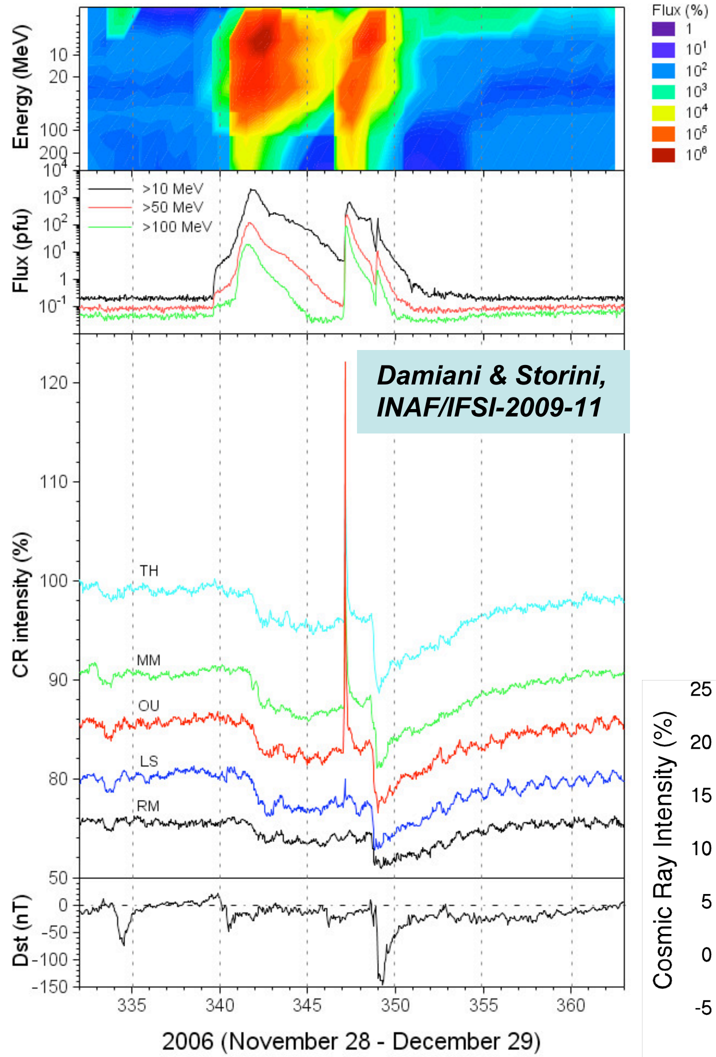
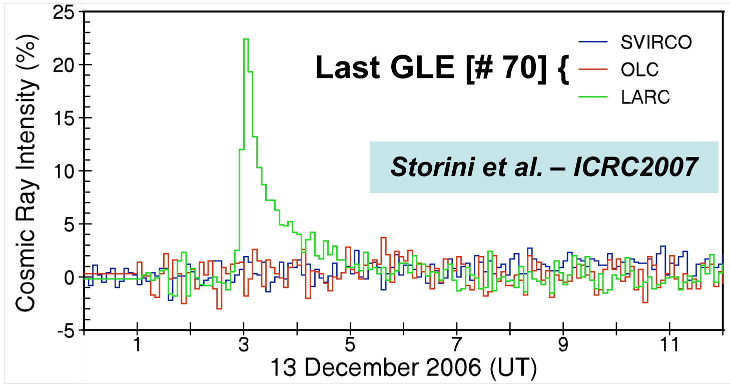
2: UNIChile/FCFM



The short- and medium- term variability of several minor atmospheric components (e.g., O_3, NO, NO_2, OH, ClO, HOCl, HNO_3) have been extensively investigated in connection of the presence/absence of solar energetic particles (SEPs). SEP-induced ionization and/or atypical meteorological phenomena (e.g., stratospheric warming) are the sources of variations in Polar Regions. Progress on the topic is discussed.



ACKNOWLEDGEMENTS

Work partly performed inside ESS2 Project of the Italian Space Agency (ASI contract I/015/07/0) and PNRA of Italy. Work at the Jet Propulsion Laboratory, California Institute of Technology, was done under contract with NASA. Neutron monitor P.I.s are also thanked.

Use of hydroxyl (OH) radicals from MLS-AURA

AURA satellite:

- sun-synchronous orbit at 705 km
- quasi polar orbit (82 N&S)
- inclination 98°
- period 96.8 minutes
- about 3500 profiles per day
- about 14 orbits/day

Microwave Limb Sounder (MLS) instrument:

scans the Earth's limb in the forward direction of flight and detects the microwave emission in different spectral regions. Measurements are performed along the sub-orbital track, and resolution varies for different parameters.

OH sources

$H_2O + O(^1D)$ -- > $OH + OH$ (stratosphere/lower mesosphere)

$H_2O + h\nu$ -- > $OH + H$ (upper mesosphere)

OH sinks

Cannibalistic reactions e.g.,

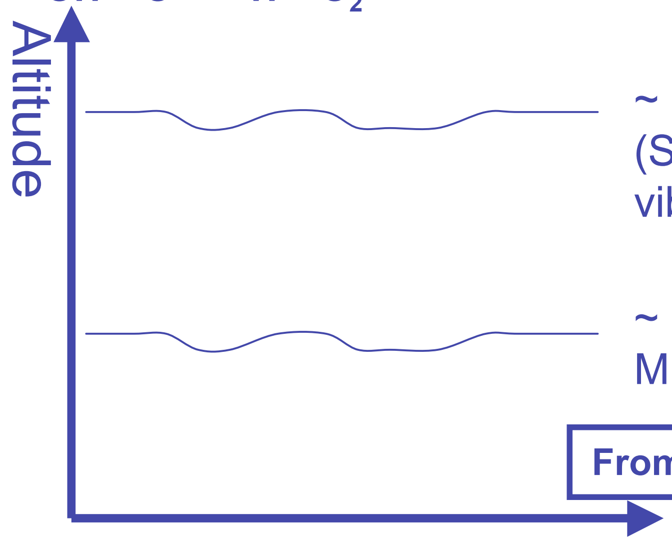
$OH + HO_2$ -- > $H_2O + O_2$

OH layer Source:

$H + O_3$ -- > $OH + O_2$

$OH + O$ -- > $H + O_2$

More details by **Seppälä**: "*SEPs and their effects on the chemistry of the middle and upper atmosphere*"



~ 87 km OH* layer (SABER-Timed airglow vibrational emission)

~ 82 km OH layer (e.g. MLS-AURA; LIDAR)

From Pickett et al., 2006

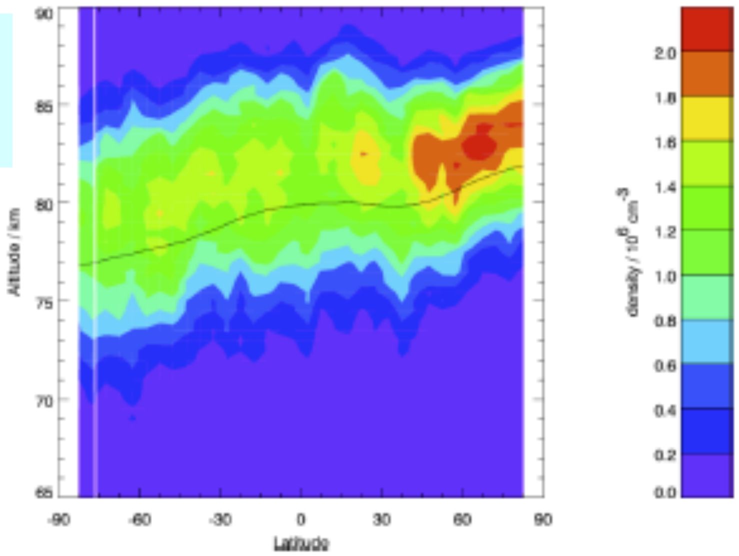
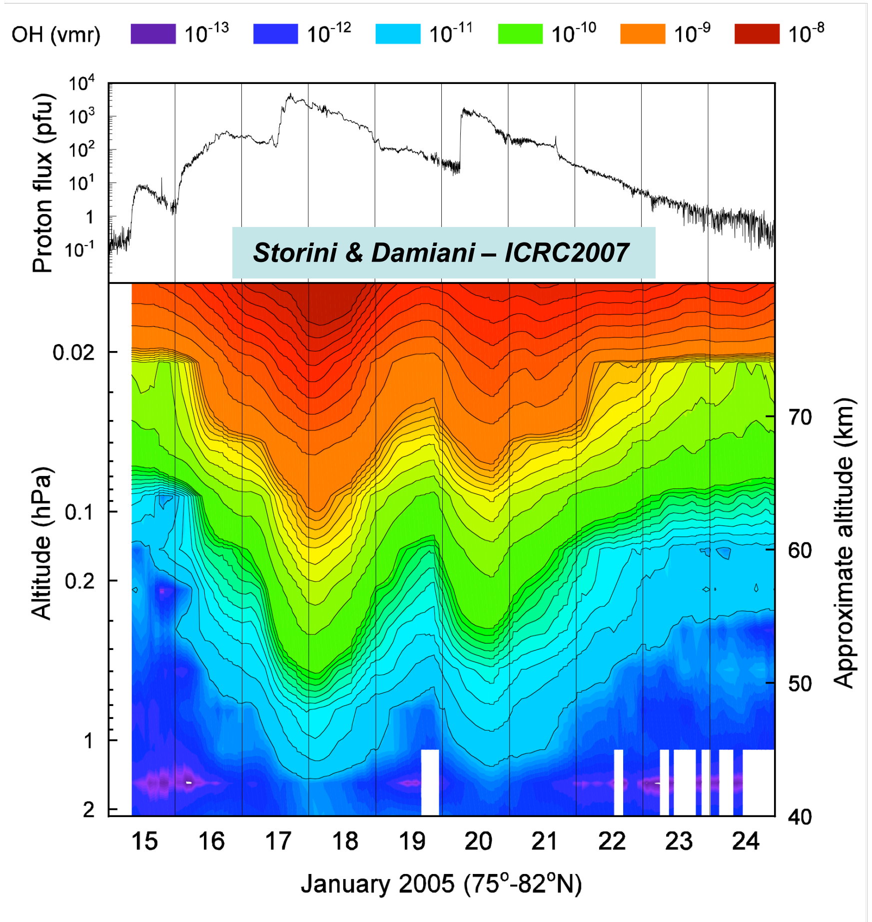


Figure 3. Zonal Mean MLS observations of OH density with SZA of >100° on June 22, 2005. The black line is the height of the 1 Pa pressure level. The vertical white line is the latitude where the noon SZA = 100°.

OH radicals / MLS-AURA: Selected Geographic band



Discovery of the mesospheric trail of SEP events!

[see also: Usoskin et al., Acta Geophys. 57(1), 88-101, 2009]

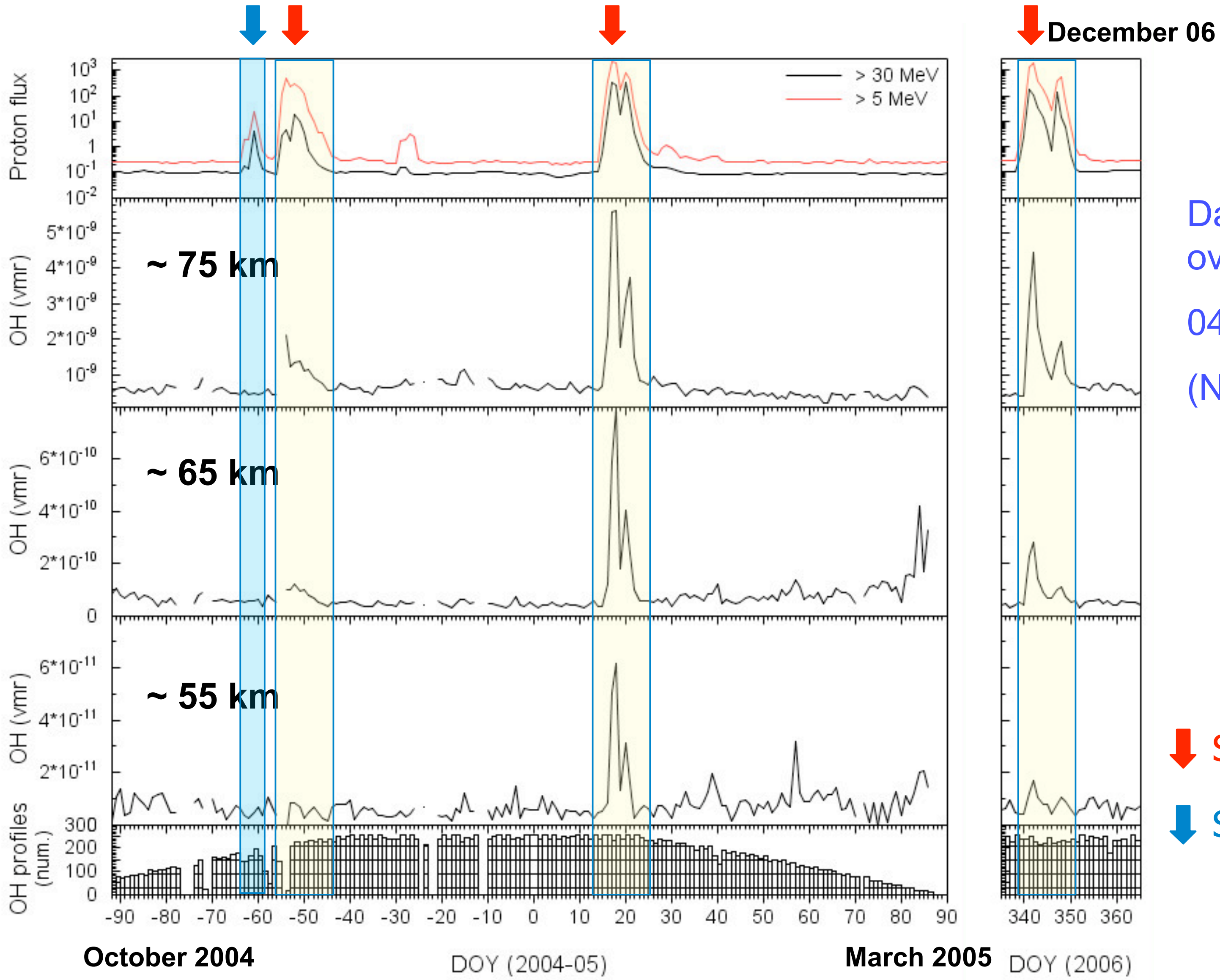
75° - 82° (towards the pole)

- suitable region to perform investigations by using *zonal means* on a daily basis;
- completely located inside the *polar cap* (geomagnetic latitude greater than 60°);
- mainly outside the *auroral belt*;
- the *winter night* is roughly maintained for many months;
- region inside the core of the *polar vortex*;
- region less disturbed by *planetary waves*.

NOTE:

1. *Low background values at nighttime for the mesospheric hydroxyl (OH) radical.*
2. *GOES data for the proton flux level.*

MLS OH: Oct. 2004 - March 2005 and Dec. 2006



Daily OH zonal mean over 75˚N - 82˚N

04.00<LST<11.30

(Nighttime SZA > 95°)

SEP > 330 pfu

SEP < 134 pfu

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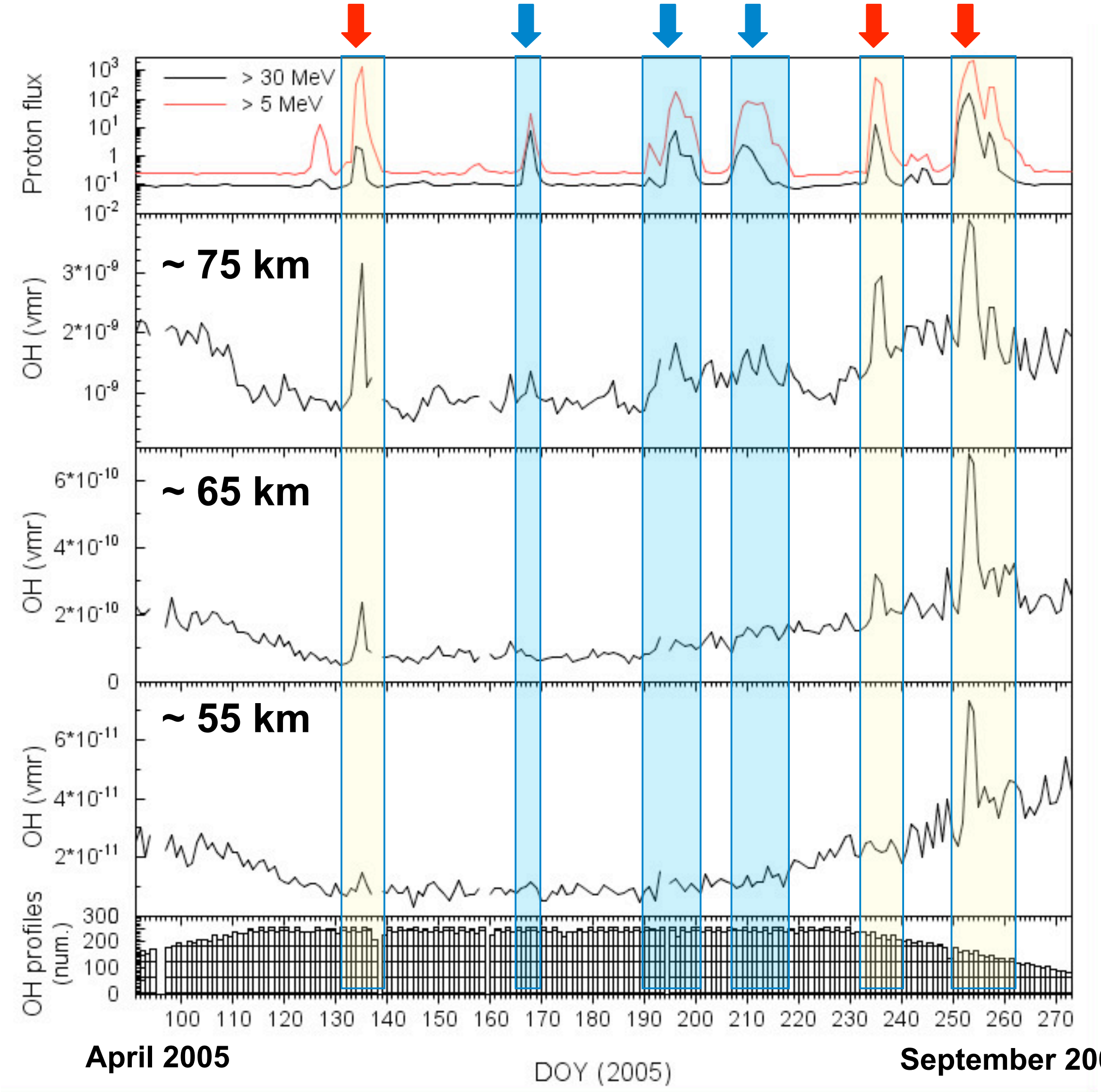
MLS OH: April - September 2005



Daily OH zonal mean over 75˚S - 82˚S

Satellite passage at 16.00<LST<23.30

(Nighttime SZA > 95°)

⬇ SEP > 330 pfu

⬇ SEP < 134 pfu

SEP EVENTS and MLS/AURA MEASUREMENTS

The number of OH profiles used for the daily zonal means are ~250-200 in mid-winter, decreasing to ~50 (100) at the beginning/end of the winter in NH (SH) owing to the incoming illumination. In this way, the relative error of the means is ~5% for most of the analyzed periods.

Features of the analyzed SEP events. First four columns: SEP event start, time of its maximum flux, proton flux and number of samples per SEP utilized in the correlations of Fig. 2 (see the text). Last three columns: OH increase (%) at 55 km, 65 km and 75 km (referred to the pre-SEP day).

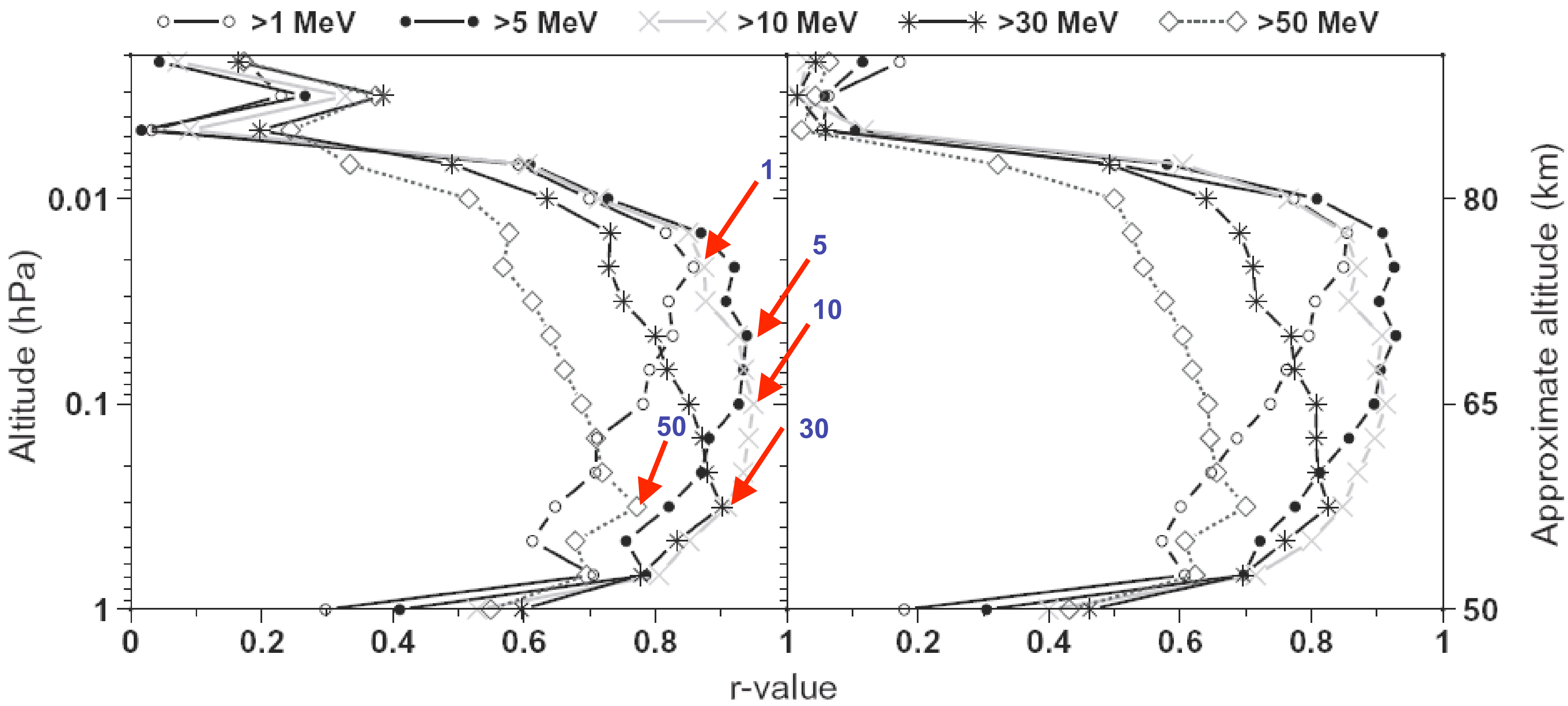
SEP events (pfu unit)				OH increase (%)		
Start (YY, MM DD/UT)	Maximum (Day/UT)	Proton flux at >10 MeV	Number of samples per SEP	~55 (km)	~65 (km)	~75 (km)
04, November 01/0655	01/0805	63	0	–	–	–
04, November 07/1910	08/0115	495	9	–	99	397
05, January 16/0210	16/1840	365	2	76	234	279
05, January 17/1240	17/1750	5040	3	1221	2131	894
05, January 20/0650	20/0810	1860	4	575	1030	448
05, May 14/0525	15/0240	3140	4	160	379	328
05, June 16/2200	17/0500	44	0	–	–	–
05, July 14/0245	15/0345	134	6	–	–	–
05, July 27/2300	29/1715	41	8	–	–	–
05, August 22/2040	23/1045	330	4	–	93	110
05, September 08/0215[a]	11/0425	1880	0	171	198	104
05, September 14/0040[a]	15/0905	235	0	–	–	–
06, December 06/1555	07/1930	1980	7	110	954	940
06, December 13/0310	13/0925	698	4	–	315	543

–: No evaluation (see the text)
[a] Excluded from the correlation analyses.

Please cite this article in press as: Damiani, A., et al. The hydroxyl radical as an indicator of SEP fluxes in the high-latitude terrestrial atmosphere. J. Adv. Space Res. (2010), doi:10.1016/j.asr.2010.06.022

SEP EVENTS and MLS/AURA MEASUREMENTS

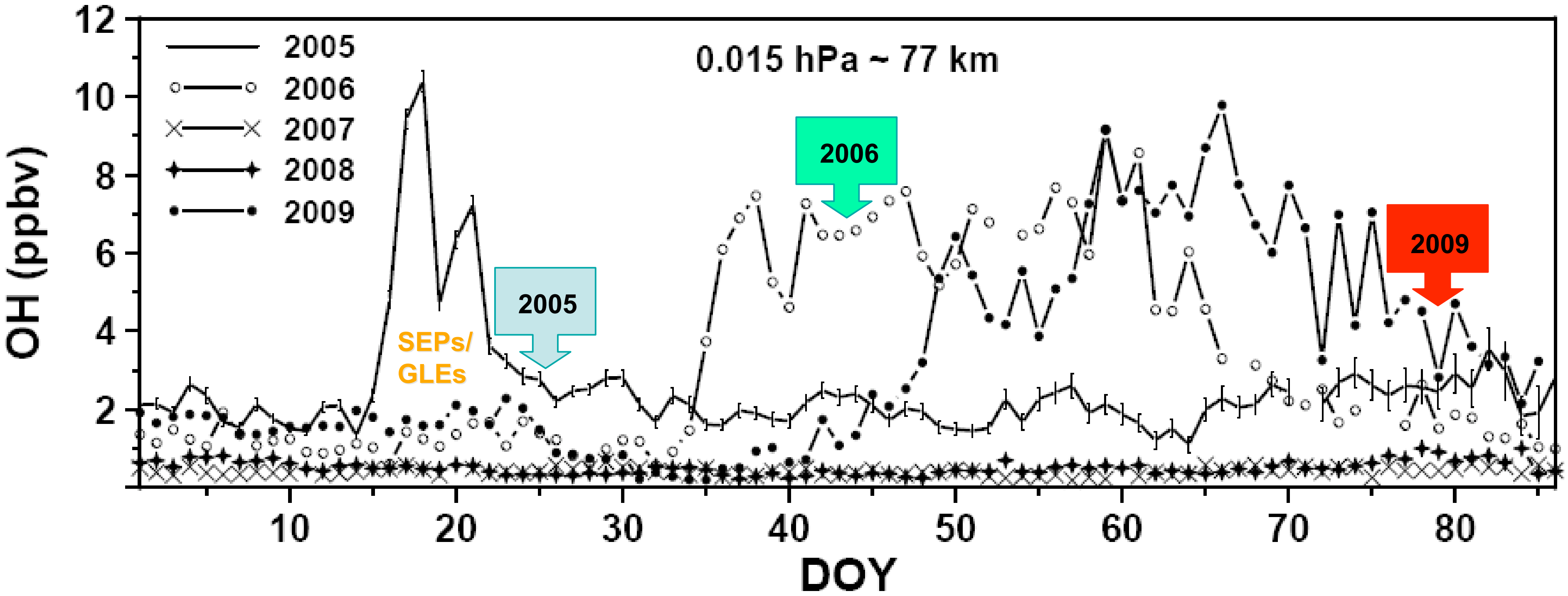
The quite similar results of the correlations on the right and left sides indicate that, normally, the SEP-induced variations are deeply dominant over the day to day variability.



Corr. Coeff. of proton flux vs. OH mixing ratio (left: flux vs. daily OH increment; right: flux vs. actual daily OH for SEP days).

[from: Damiani et al., Adv. Space Research, in press, 2010]

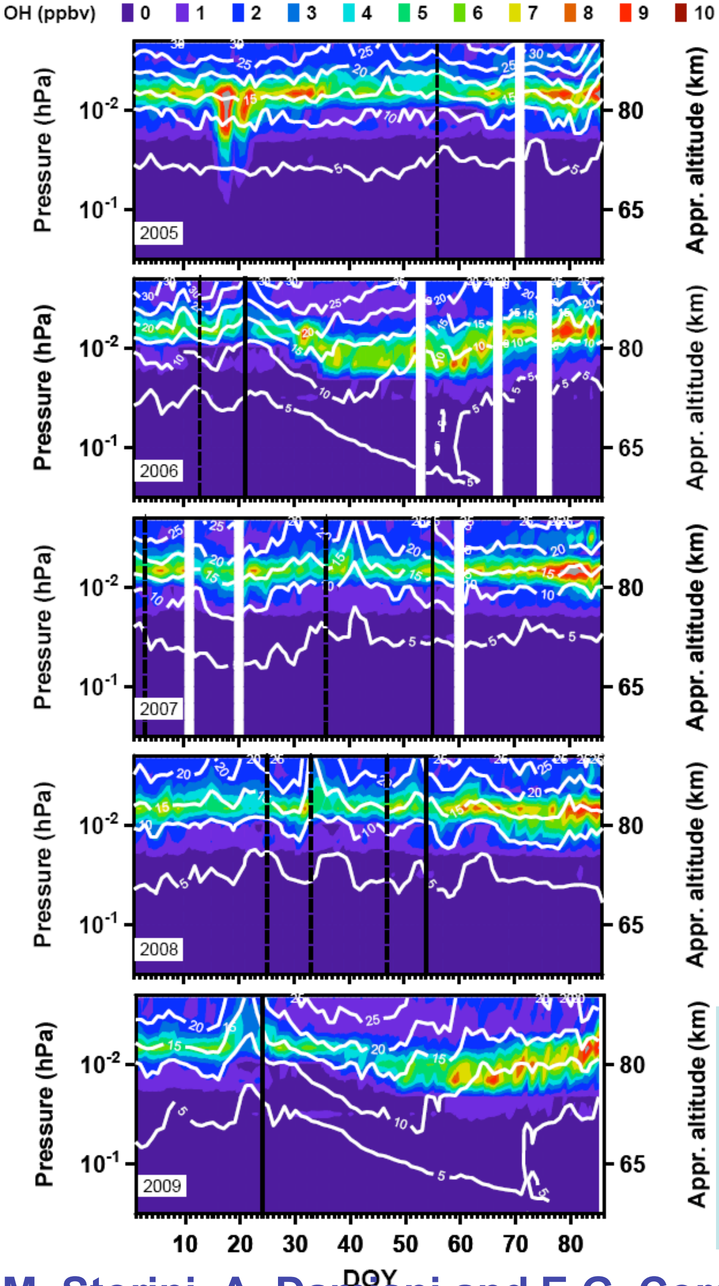
TO NOTE: February 2006 and 2009 !



Daily zonal mean nighttime OH (75°N - 82°N) from 1 January to 27 March (years: 2005 to 2009) at ~ 77 km [from: Damiani et al., Atmos. Chem. Phys. Discuss., 10, 14583-14610, 2010]

The main features of the figure are the sudden and short-lived OH increases related to the SEP events of 17 and 20 January 2005 and the long-lasting OH enhancements during February 2006 and February/March 2009 (for them no SEP events are identified in GOES data).

TO NOTE: February 2006 and 2009 !



The OH layer inside the polar vortex (nominal altitude: 82 km) descended during Feb. 2006 and Feb./Mar. 2009 by ~ 5-7 km, and its density increased to more than twice January values. In these periods and location the abundance of the OH layer is *comparable* with the OH values induced by SEP forcing (see Jan. 2005) at the same altitudes. Moreover, in both years, the OH layer drop was coupled with *increased mesospheric temperatures, elevated carbon monoxide and an almost complete disappearance of* O_3 at the altitude of the descended layer.

In conclusion the mesospheric OH abundance can be used as *indicator for SEP presence in the terrestrial environment,* provided that meteorology is also taken into account.

Zonal mean nighttime OH (75°N-82°N) for Jan.1-Feb. 27 of 2005-2009. White contours refer to zonal mean nighttime CO mixing ratio, as tracer for atmospheric motion (e.g. Zafra and Muscari, 2004). [from: Damiani et al., Atmos. Chem. Phys. Discuss., 10, 14583-14610, 2010]

Strong polar **vortex** in 2004, 2006, 2009 with intense air descent! - Useful research papers

On recent interannual variability of the Arctic winter mesosphere: Implications for tracer descent

David E. Siskind,[1] Stephen D. Eckermann,[1] Lawrence Coy,[1] John P. McCormack,[1] and Cora E. Randall[2]

Large increase of NO_2 in the north polar mesosphere in January–February 2004: Evidence of a dynamical origin from GOMOS/ENVISAT and SABER/TIMED data

Alain Hauchecorne,[1] Jean-Loup Bertaux,[1] Francis Dalaudier,[1] James M. Russell III,[2] Martin G. Mlynczak,[3] Erkki Kyrölä,[4] and Didier Fussen[5]

Ionospheric evidence of thermosphere-to-stratosphere descent of polar NO_X

Mark A. Clilverd,[1] Annika Seppälä,[2] Craig J. Rodger,[3] Pekka T. Verronen,[2] and Neil R. Thomson[3]

Satellite observations and modeling of transport in the upper troposphere through the lower mesosphere during the 2006 major stratospheric sudden warming

G. L. Manney[1,2], R. S. Harwood[3], I. A. MacKenzie[3], K. Minschwaner[2], D. R. Allen[4], M. L. Santee[1], K. A. Walker[5,6], M. I. Hegglin[5], A. Lambert[1], H. C. Pumphrey[3], P. F. Bernath[7,6], C. D. Boone[6], M. J. Schwartz[1], N. J. Livesey[1], W. H. Daffer[1], and R. A. Fuller[1]

Mesospheric N_2O enhancements as observed by MIPAS on Envisat during the polar winters in 2002–2004

B. Funke[1], M. López-Puertas[1], M. García-Comas[1], G. P. Stiller[2], T. von Clarmann[2], and N. Glatthor[2]

THE STRATOSPHERIC AND MESOSPHERIC NO_y IN THE 2002–2004 POLAR WINTERS AS MEASURED BY MIPAS/ENVISAT

M. LÓPEZ-PUERTAS[1,*], B. FUNKE[1], T. VON CLARMANN[2], H. FISCHER[2] and G. P. STILLER[2]

Aura Microwave Limb Sounder observations of dynamics and transport during the record-breaking 2009 Arctic stratospheric major warming

Gloria L. Manney,[1,2] Michael J. Schwartz,[1] Kirstin Krüger,[3] Michelle L. Santee,[1] Steven Pawson,[4] Jae N. Lee,[1] William H. Daffer,[1] Ryan A. Fuller,[1] and Nathaniel J. Livesey[1]

The evolution of the stratopause during the 2006 major warming: Satellite data and assimilated meteorological analyses

Gloria L. Manney,[1,2] Kirstin Krüger,[3] Steven Pawson,[4] Ken Minschwaner,[2] Michael J. Schwartz,[1] William H. Daffer,[1] Nathaniel J. Livesey,[1] Martin G. Mlynczak,[5] Ellis E. Remsberg,[5] James M. Russell III,[6] and Joe W. Waters[1]

Arctic and Antarctic polar winter NO_x and energetic particle precipitation in 2002–2006

Annika Seppälä,[1] Pekka T. Verronen,[1] Mark A. Clilverd,[2] Cora E. Randall,[3]

Johanna Tamminen,[1] Viktoria Sofieva,[1] Leif Backman,[1] and Erkki Kyrölä[1]

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Thank you !

OH layer characteristics during unusual boreal winters of 2004 and 2006

J. R. Winick,[1] P. P. Wintersteiner,[2] R. H. Picard,[1] D. Esplin,[3,4] M. G. Mlynczak,[5] J. M. Russell III,[6] and L. L. Gordley[7]

Enhanced NO_x in 2006 linked to strong upper stratospheric Arctic vortex

C. E. Randall,[1,2] V. L. Harvey,[1] C. S. Singleton,[1] P. F. Bernath,[1] C. D. Boone,[3] and J. U. Kozyra[4]