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International Advanced School
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Effects in the Earth Environment

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ICTP-COST-CAWSES-INAF-INFN
International Advanced School on Space Weather

Lecture 4. EFFECTS IN THE EARTH ENVIRONMENT

- Terrestrial effects of CRs:
  An overview
- CR data:
  Direct use in Space Weather
- CR data:
  Indirect use in Space Weather

TERRESTRIAL EFFECTS OF CRs

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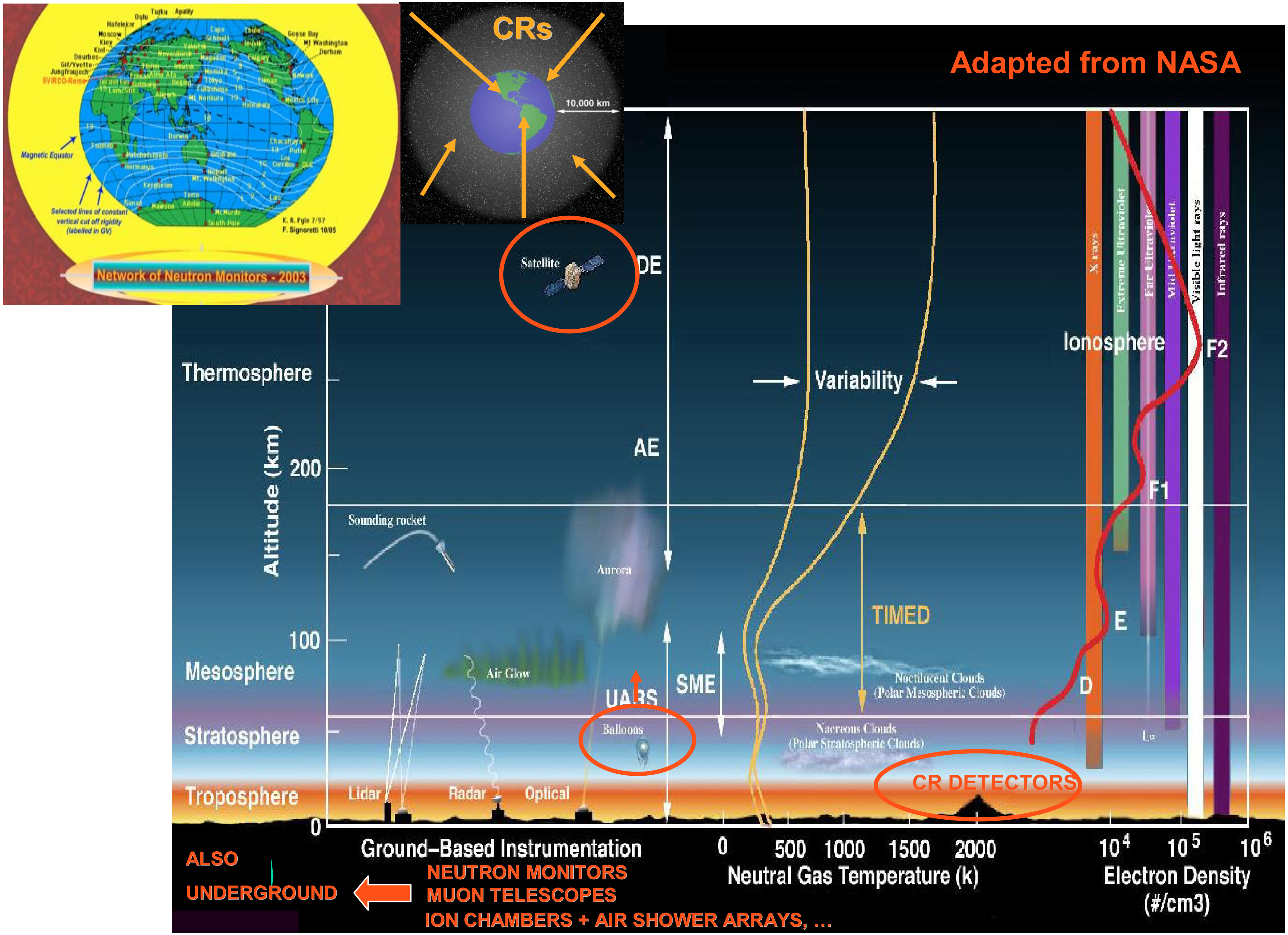

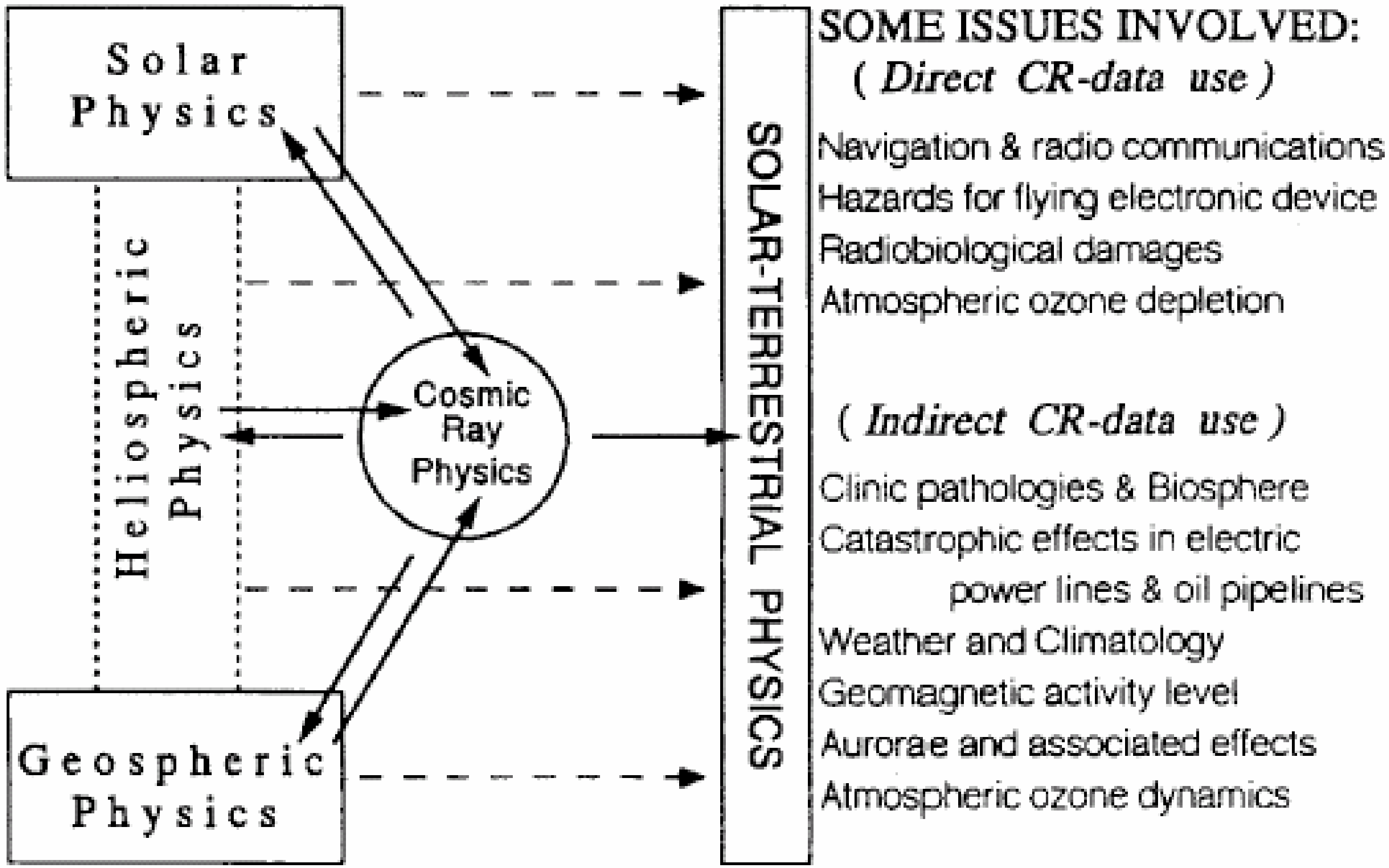

Figure 1. The interlacement of CR physics with other physical branches (*left side*) and issues for CR data uses in geospheric physics (*right side*). (From Storini and Cordaro, 1997.)

Il Nuovo Cimento, 20C, 1027-1032, 1997.

CR DATA: DIRECT USE

Space Weather requires the development of algorithms and codes to forecast dangerous effects in the terrestrial environment. From previous lectures it is clear that CRs have their room inside the field. This is true not only for their direct effects but because, being probe of the heliosphere, they can tell us in advance the arrival of outstanding “space storms”.

Cosmic ray data are also used for creating:

- numerical models of the ionization-radiation environment (use: space dosimetry, CR effects on materials, atmospheric process including the role in cloud formation,…);

- codes able to reproduce SEP effects on the ozone layer;

- catalogues of worst cases.

Kudela K., et al., Cosmic rays in relation to Space Weather,
Space Sci. Rev., 93, 153-174, 2000.
Kudela K., Storini M., Cosmic Rays: Basic characteristics and relations to Space Weather,
in Sun-Earth Connection and Space Weather, SIF Conf. Proc., 75,101-118, 2001.

CR DATA: DIRECT USE

Navigation and radio communication failure in their performances are well documented since the discovery of the PCA effect (Polar Cap Absorption).

See Cander L. & Kersely L. Lectures

Radiobiological damages are the same described for the man-made space journey, but now concerns flights, specially over polar areas (Dosimetry is strongly improved).

See Kudela K. Lecture

Ozone is monitored by terrestrial satellites and a high statistic confirms that SEP events are related to an ozone depletion at least in the mesospheric region. Modeling of such effects are in progress. The role of GCRs still has several controversies, as the one of auroral particle precipitations.

See Marsh D. Lectures

[also Storini M., Adv. Space Res. 27 (12), 1965-1974, 2001; Krivolutsky A.A., Adv. Space Res. 31 (9), 2127-2138, 2003; Lastovicka J. And Krizan P., Adv. Space Res. 31 (9), 2139-2144, 2003 ; Krivolutsky A.A. et al., JASTP 67, 105-117, 2005, among others]

There is a scientific work/debate on the ability of cosmic rays to active cloud formation.

See Hamilton K. & Haigh J. Lectures

(e.g. Svensmark H., Friis-Christensen E., JASTP, 59, 1225, 1997;

Svensmark H., Phys. Rev. Lett. 81, 5027, 1998; Kristjánsson J.E., Kristiansen J., JGR 105, 11851, 2000; Marsh N.D., Svensmark H., Phys. Rev. Lett. 85, 5004, 2000; Marsh N.D., Svensmark H., Space Sci. Rev. 94, 215, 2000; Carslaw K.S., Harrison R.G., Kirkby J., Science 298, 1732, 2002; Marsh N.D., Svensmark H., JGR 108 (D6), art. 2002JD001264, 2003; Kniveton D.R. and Tinsley B.A., JGR 109, D11201, doi:10.1029/2003JD004232, 2004; Usoskin I.G. et al., GRLett. 31, L16109, doi:10.1029/2004GL019507, 2004 among others)

Relationships with water precipitations are also under study.

e.g. Stozhkov Y.I. et al., Il Nuovo Cim. 18C, 335, 1995.

It was proposed a link between CRs and terrestrial climate derived from exposure ages of Iron meteorites (periodic modulation of CRs by spiral arm dynamics of the Milky way).

See Shaviv N.J., IJMPA 20 (29), 6662-6665, 2005 and references therein.

Most of the Space Weather effects are related to geomagnetic storms occurrence.

CR DATA: Indirect use in SW

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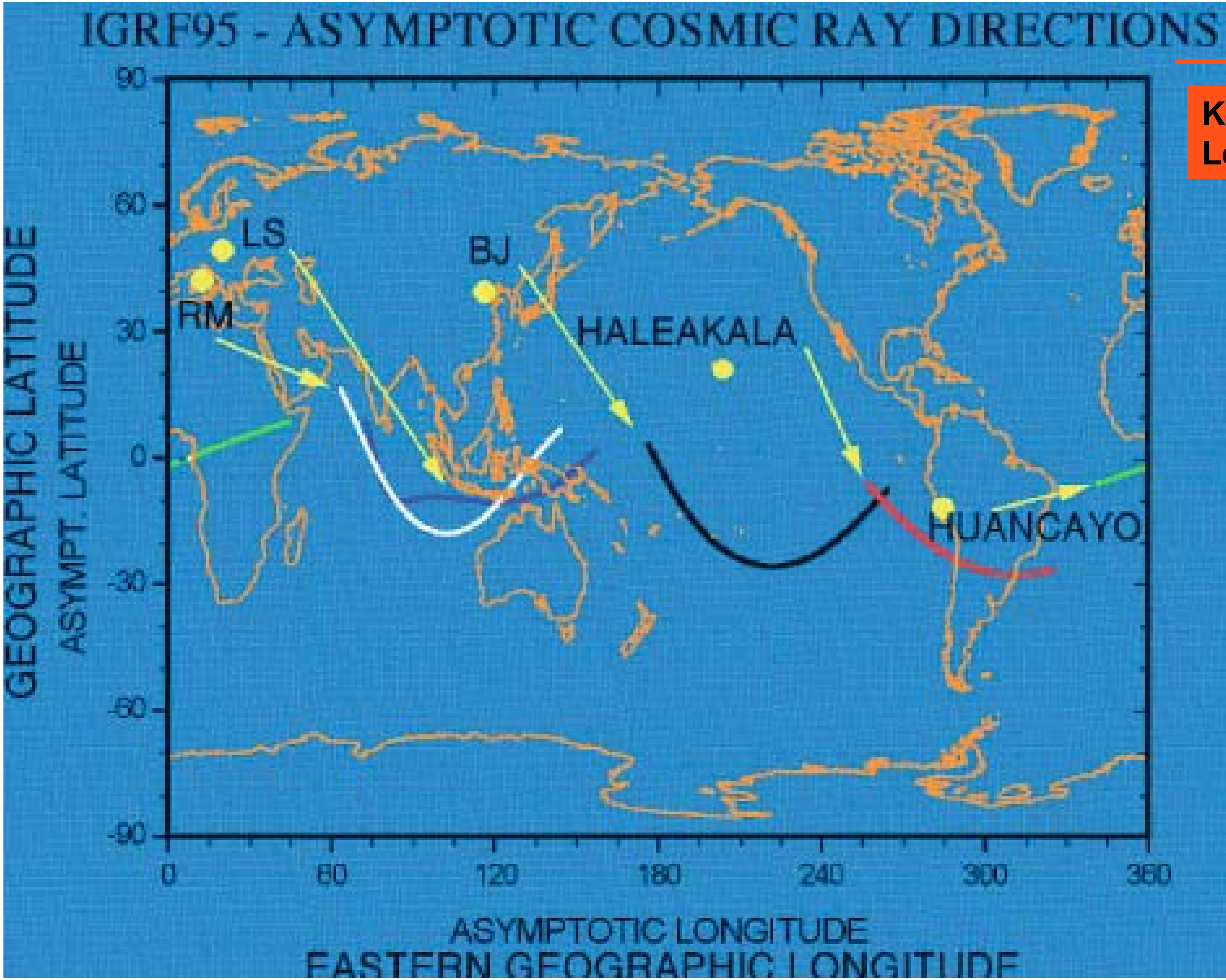
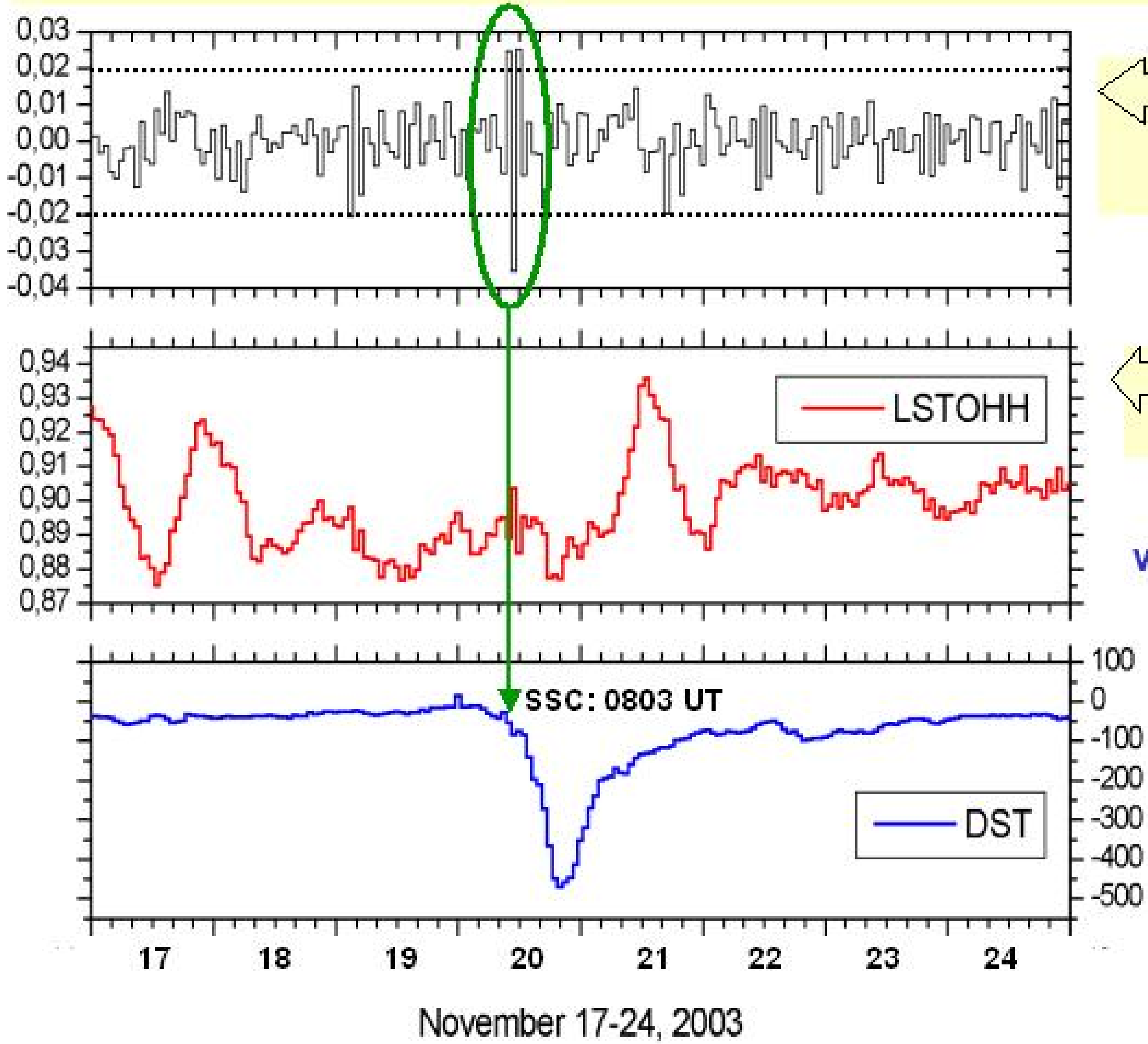


Kudela K. Lecture

CR NOWCAST FOR OUTSTANDING GEOMAGNETIC STORMS



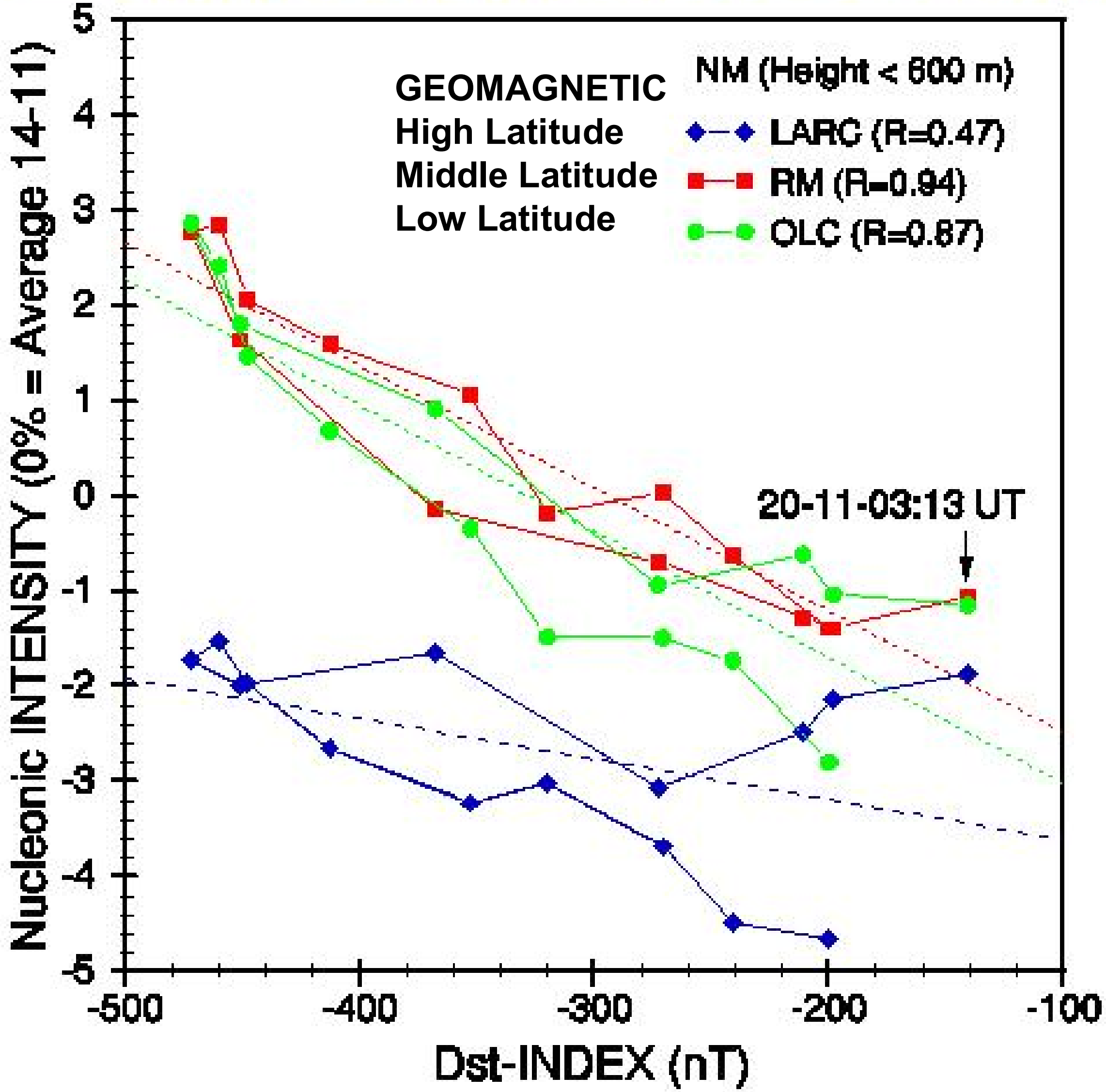
LS/HH Derivate (taken from 2 h before and 1 h after)

Ratio between the counting rate (LS/HH)

Nowcast from two NMs with opposite asymptotic longitudes (LS: L-Stit & HH:Haleakala)

Kudela & Storini, Adv. Space Res. 2006 (in press).

THE NOVEMBER 20, 2003 GEOMAGNETIC STORM & CRs



Scatter plot for 15 hourly averages of NM data vs. Dst-index from November 20, 2003 at 13 UT (R: correlation coefficient).

The better anticorrelation refers to SVIRCO NM (RM).

Search for cut-off changes by using geomagnetic field models. See Kudela K. Lecture

Storini et al. – EGU 2006

CR DATA: Indirect use in SW

M. Storini / Trieste - 5 May 2006

Flückiger and Desorgher, 2005

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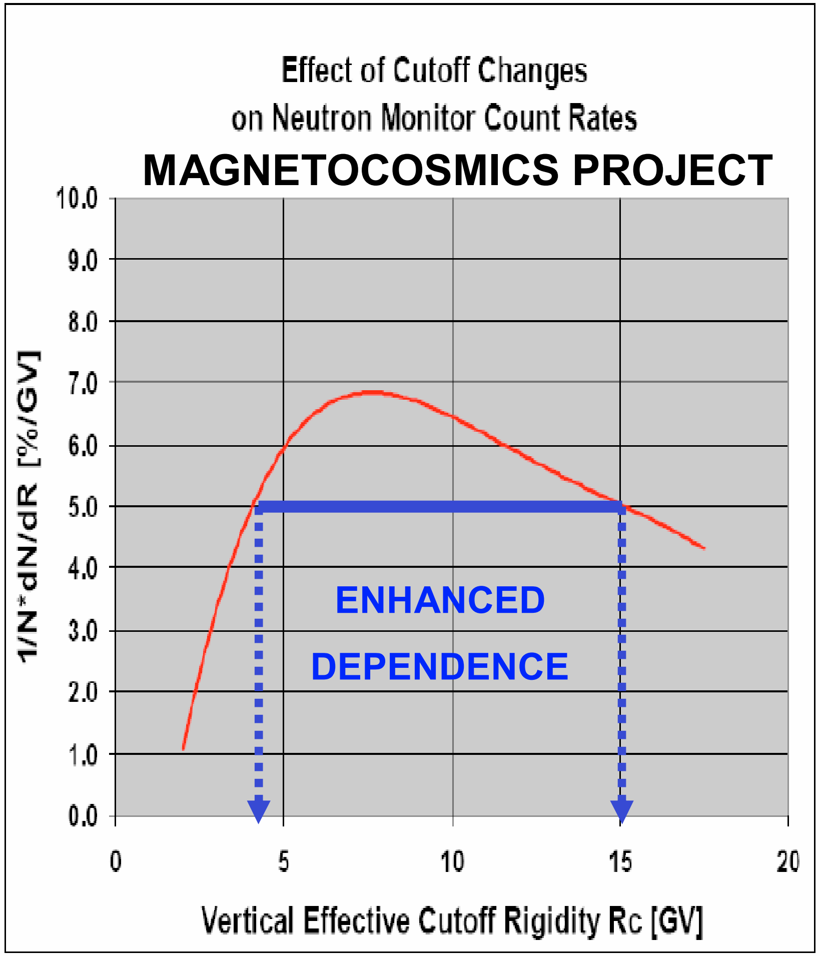

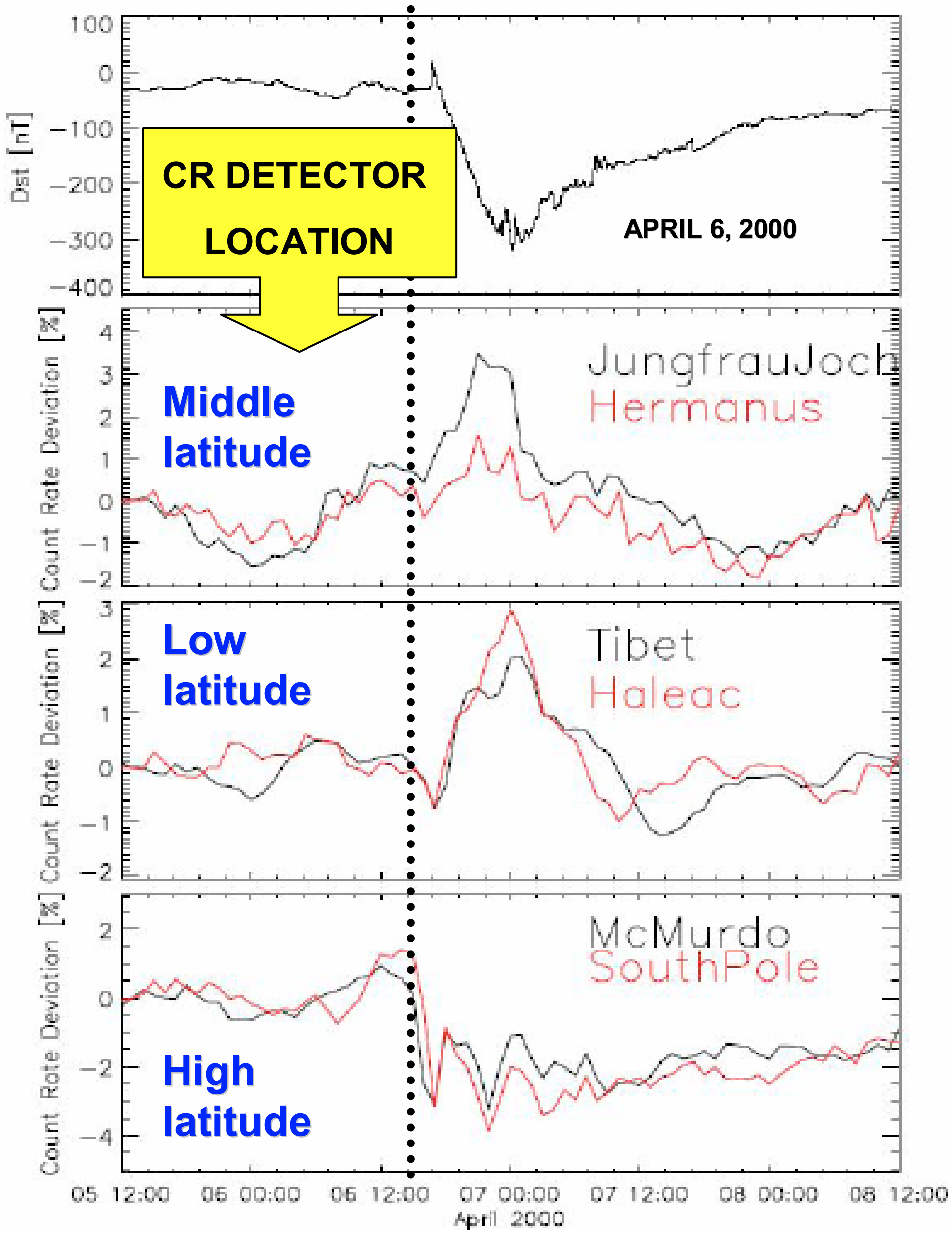

Desorgher, L., MAGNETOCOSMICS: Geant4 application for simulating the propagation of cosmic rays through the Earth's magnetosphere, http://reat.space.qinetiq.com/septimess/magcos/, 2004

CR DATA: Indirect use in SW

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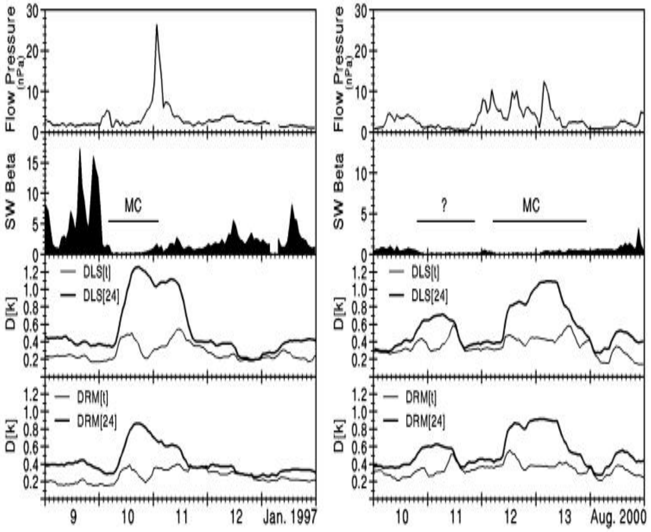
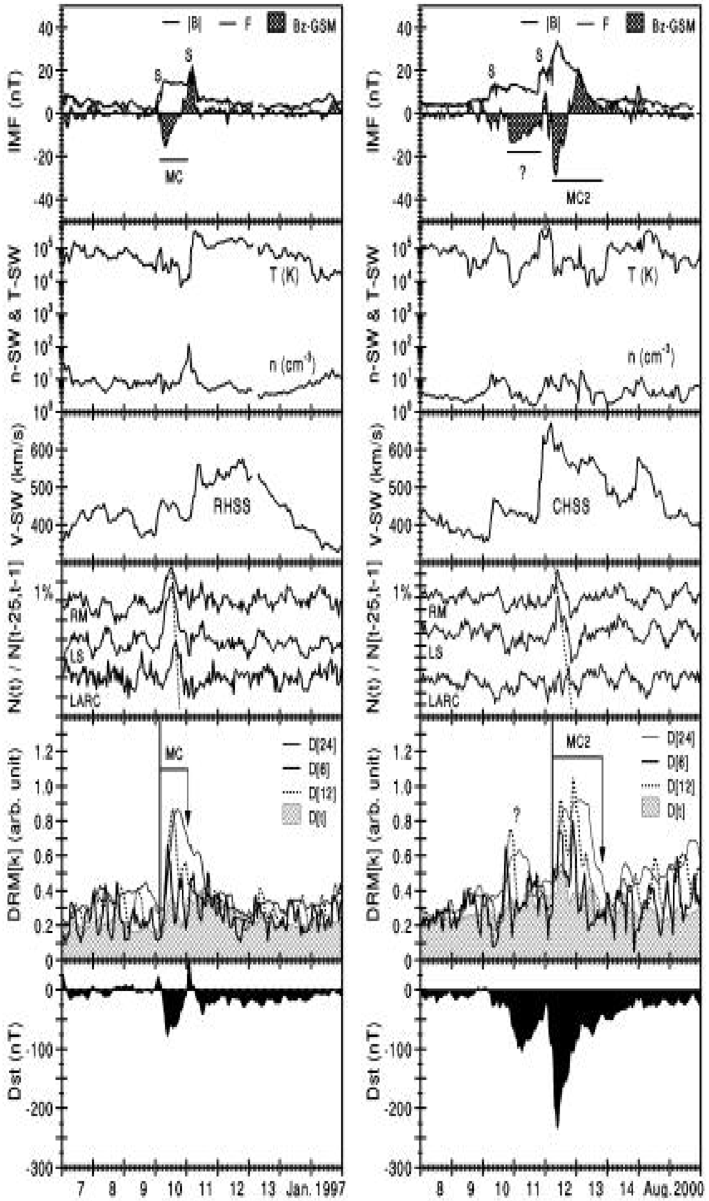
MCs - Case studies: January 10-11, 1997 & August 10-13, 2000

Are these CR signatures relevant for the ICME identification ?



Time history of some SW hourly parameters (flow pressure and plasma beta), D[t] and D[24] for LS and RM detectors during 9-13 January, 1997 (left) and 10-14 August 2000 (right).



MCs: Two case studies

Solar wind (SW) parameters (|B|: field magnitude average, F: magnitude of average field vector, Bz-GSM: z-component of the field in the geocentric solar-magnetospheric [GSM] coordinate system; T: proton temperature, n: proton density and V: flow speed), CR indices (see previous sheet) and Dst values for 7-15 January 1997 (left) and 8-16 August 2000 (right). S stands for Shock and/or SSC occurrence, and MC for "magnetic cloud" identification by using the variance matrix technique.

Derived from NM data:

- **the hourly nucleonic intensity normalized to the past 24 hours, i.e. I(t) =N(t)/N[t-25,t-1].**
- **the CR variability over 24 h without the diurnal wave: D[t].**
- **the CR variability over different time scales: D[k],** i.e. **D[3] for [t-4,t-1],... D[24] for [t-25, t-1].**

Storini et al., 29th ICRC, 2, 413-416, 2005

CONCLUSION

These lectures intend to give only the background knowledge of the field. No completeness should be expected due to the few hours allowed.

Students are encouraged to visit the web site of COST 724