The influence of solar activity on the radiation belt relativistic electron dynamics

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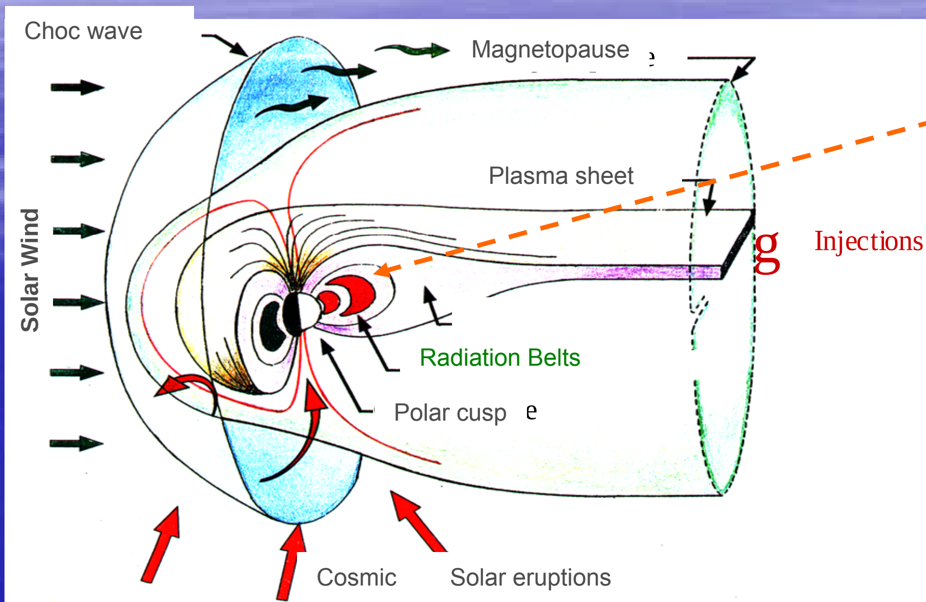
Outline

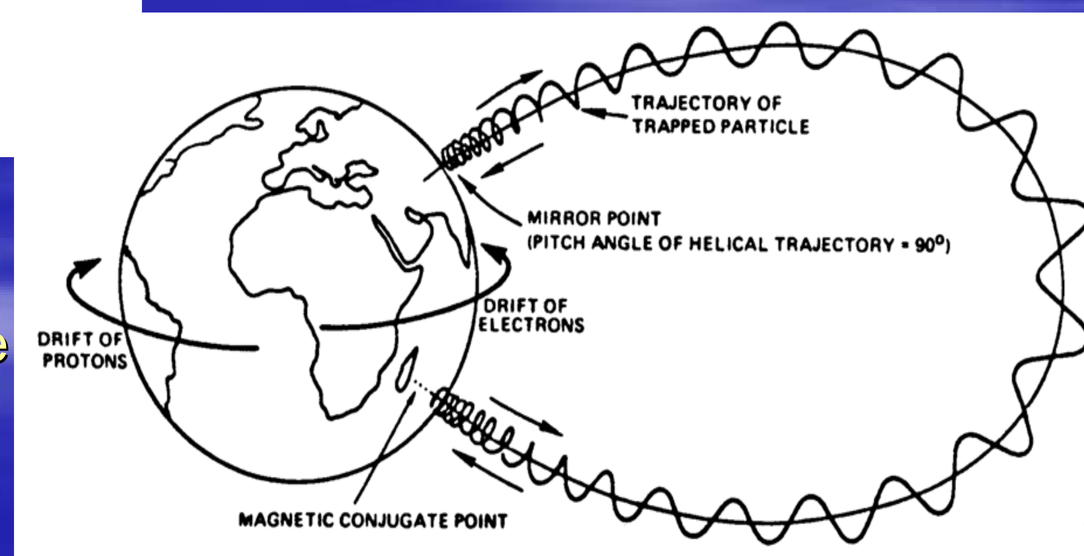
- Introduction
- Radiation belt dynamics:
  - Magnetic storm
  - Solar cycle
  - Correlation with solar wind activity
- Data base at the Los Alamos National Laboratory
- Solar extreme events of the 23rd solar cycle: 2005 and 2006
- Modeling efforts
- Summary

Introduction: The Earth's radiation belts

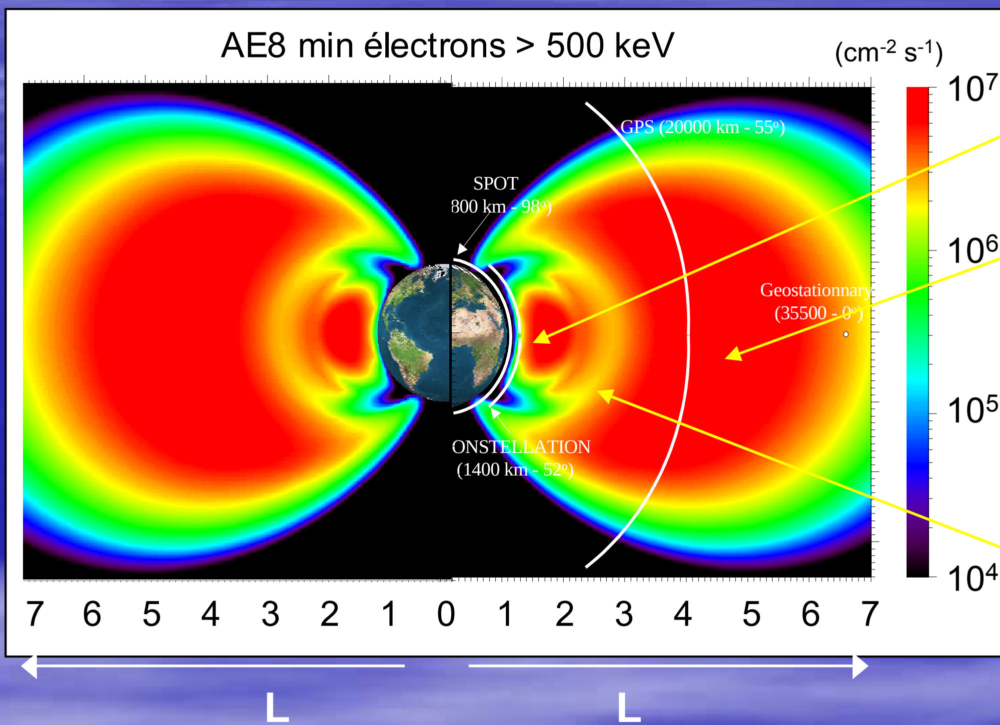


The Radiation Belts, charged particles, trapped by the terrestrial magnetic field.

- Trapped particle movements:
  - gyration around the field line
  - bounce between two mirror points
  - drift around Earth



Introduction: The electron radiation belts

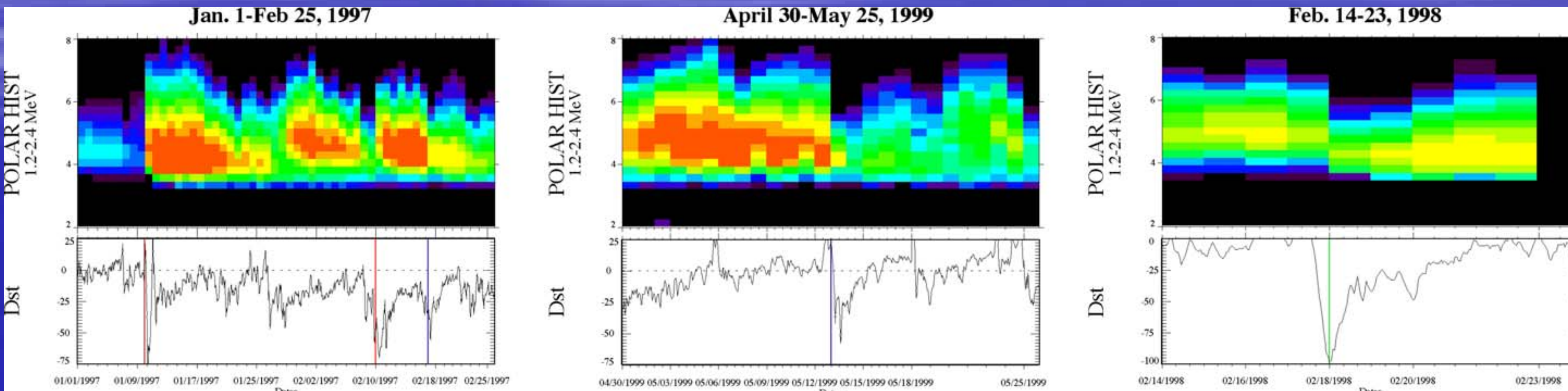


- Two belts:
  - **- Inner-belt** stable (1< L <3)
  - **- Outer-belt** very dynamic (3< L <10)
- Energies from ~1 keV to ~7 MeV
- Separation of the two belts by the **« slot » region** ⇒ precipitation of electrons from electromagnetic waves of very low frequency is very effective.

- Trapped electrons interact also with:
  - plasmaspheric cold electrons
  - high atmosphere particles

Radiation belt dynamics: Magnetic storm

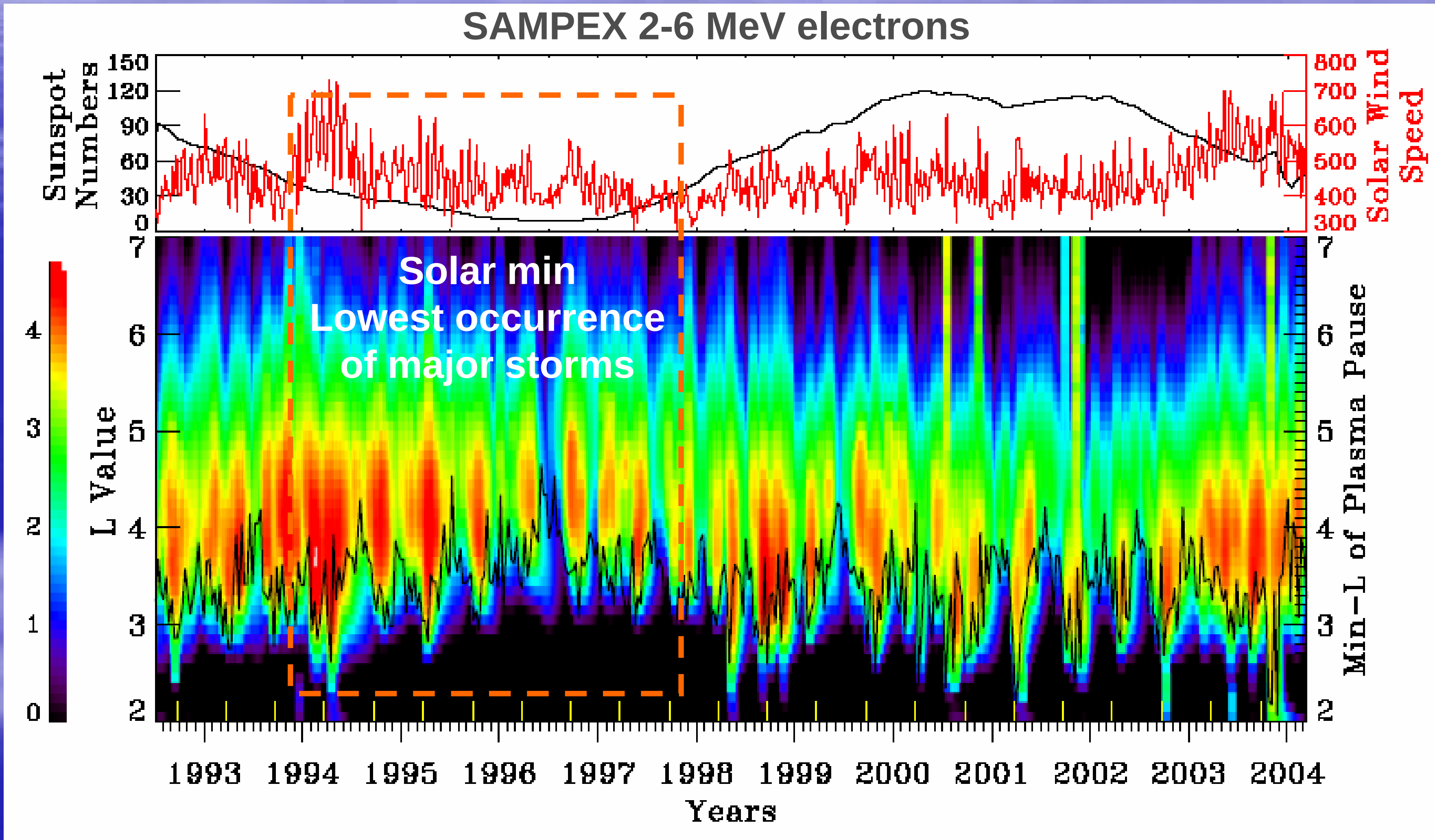
Reeves et al., GRL, 2003



Increase Decrease No change

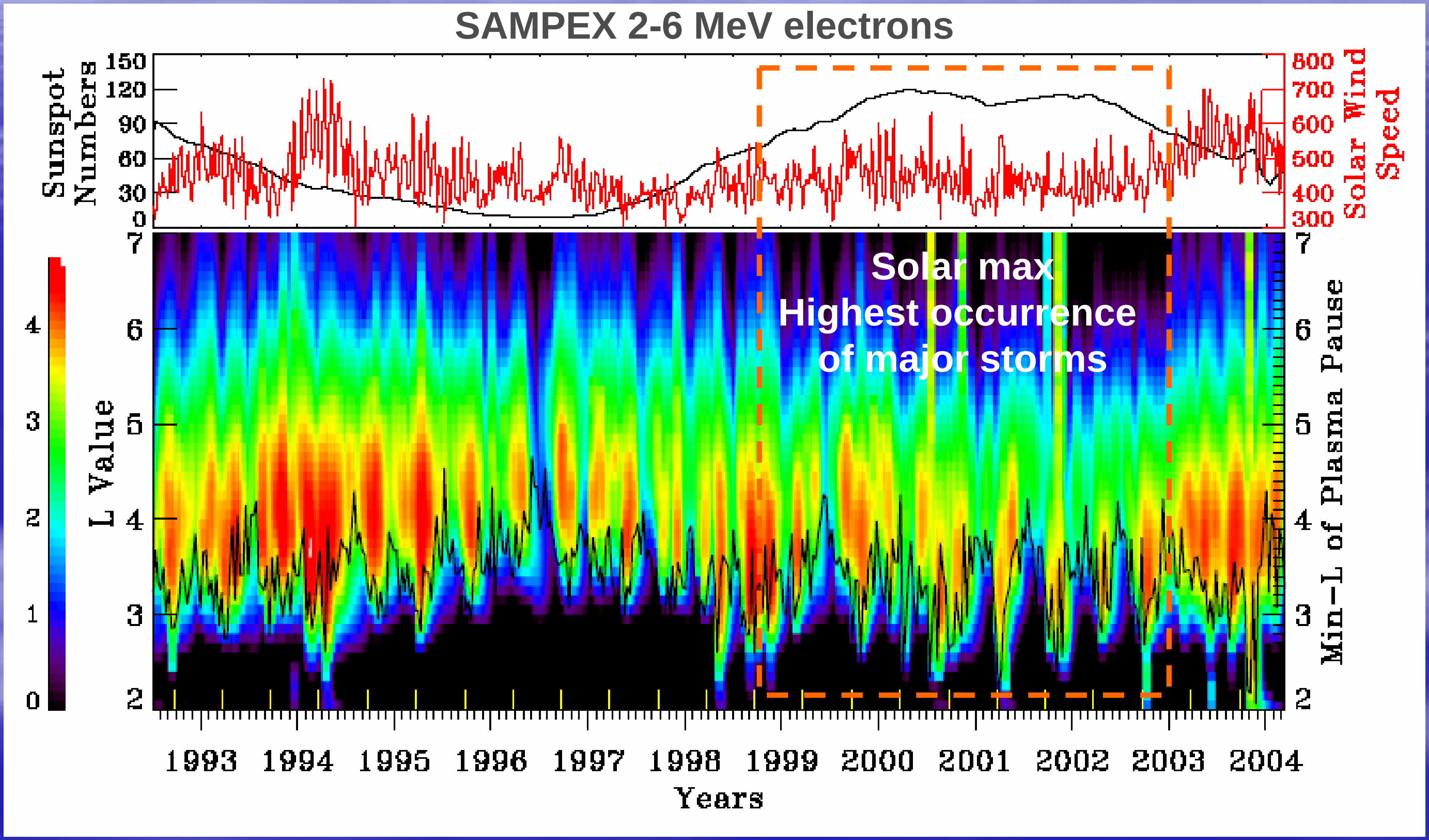
- During storms particle loss and acceleration processes are enhanced. The evolution of the electron fluxes after the storm main phase depends on the balance between these processes.

Radiation belt dynamics: Solar Cycle



Li et al., GRL, 2006

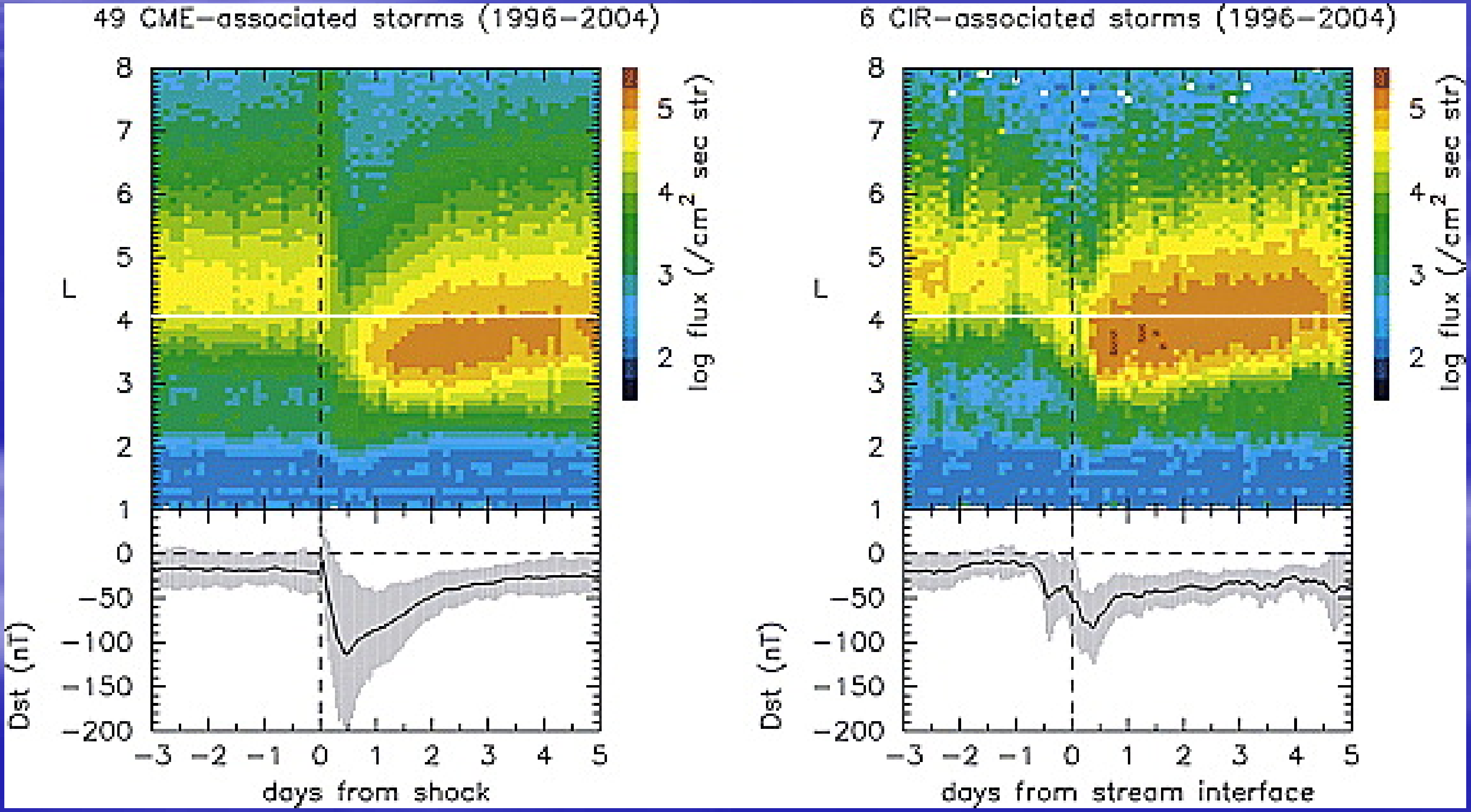
Radiation belt dynamics: Solar Cycle



Li et al., GRL, 2006

Radiation belt dynamics: Correlation with solar wind activity

• Response to ICME and CIR driven storms



Kataoka and Miyoshi, Sp. Weather, 2006

Radiation belt dynamics: Correlation with solar wind activity

- Key parameters during the recovery phase of magnetic storms
  - high solar wind speed
  - prolonged periods of southward fluctuating IMF

  [*Iles et al*., Ann. Geophys., 2002; *Vassiliadis et al*., JGR, 2005; *Kataoka and Miyoshi*, Sp. Weather, 2006; *Tsurutani et al.,* JGR, 2006]

⇩

High speed CIR related storms are more effective in producing enhanced MeV electron fluxes

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MeV electron flux enhancements are mostly observed during the declining phase of the solar cycle

The LANL geosynchronous satellites

- Circular 6.6 Re (~36.000 km) orbit at geographic equator.
- 24-hour period- satellites at fixed longitude.
- Data from eV to MeV electrons- whole spectrum of source.
- Continuous data acquisition from 1976.
- Currently, instruments on 5 satellites are in operation.

Satellite	Operation Period
1989-046	1989/09/22 - today
1990-095	1990/11/16 – 2005/11/09
1991-080	1991/11/27 – 2004/11/18
1994-084	1994/12/30 - today
LANL-97A	1997/07/16 – today
LANL-01A	2000/10/14 – today
LANL-02A	2002/01/16 – today

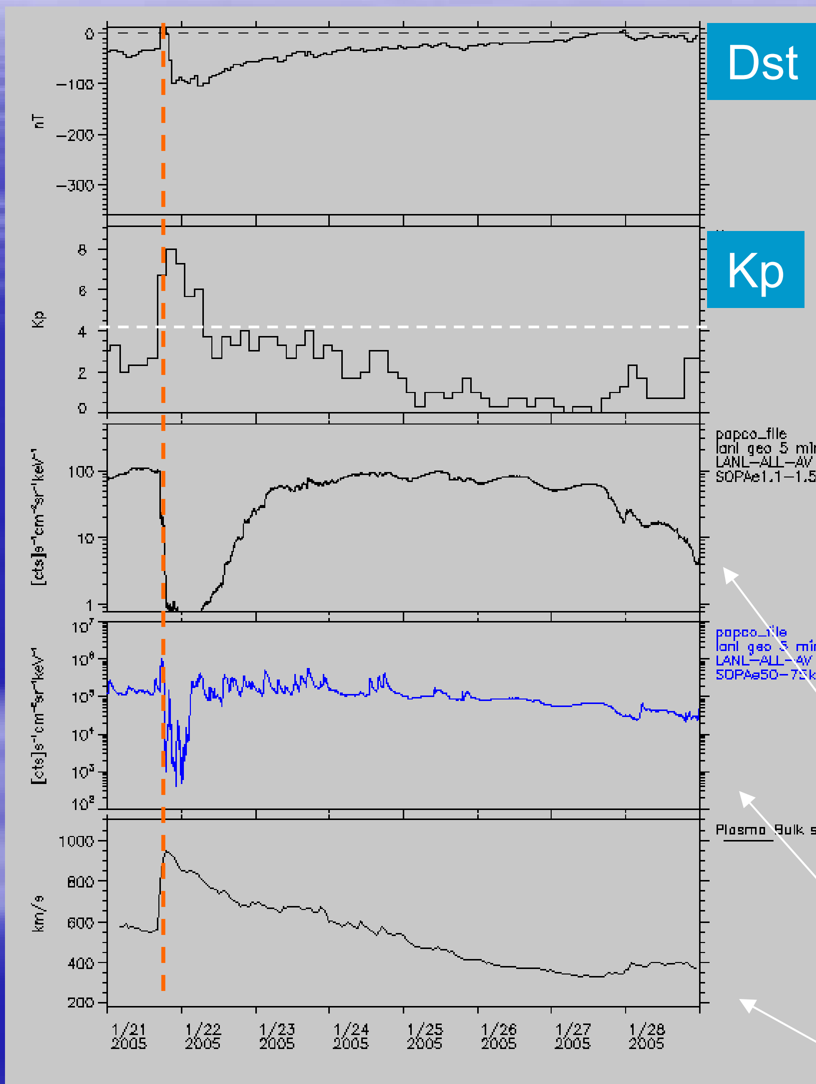
- Calibration techniques have been developed.

The GPS satellites

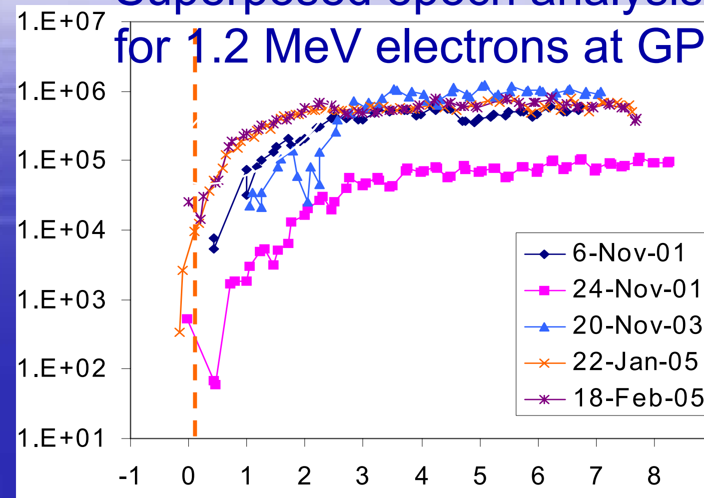
- Circular 4 Re (~20.000 km) orbit with 12 hour period.
- 50 degrees inclination.
- L ≥ 4 – Equator at L=4.2.
- Data for 100keV-10MeV electrons.
- At the present time there are 8 energetic particle instruments in space- a real constellation mission in the inner magnetosphere.
- Calibration and contamination techniques have been developed.

Satellite	Operation Period
GPS ns41	12/00 – today
GPS ns54	12/02 – today
GPS ns56	02/03 – today
GPS ns60	07/04 – today
GPS ns61	11/04 – today
GPS ns59	12/04 – today
GPS ns53	10/05 – today
GPS ns58	12/06 - today

January 21, 2005

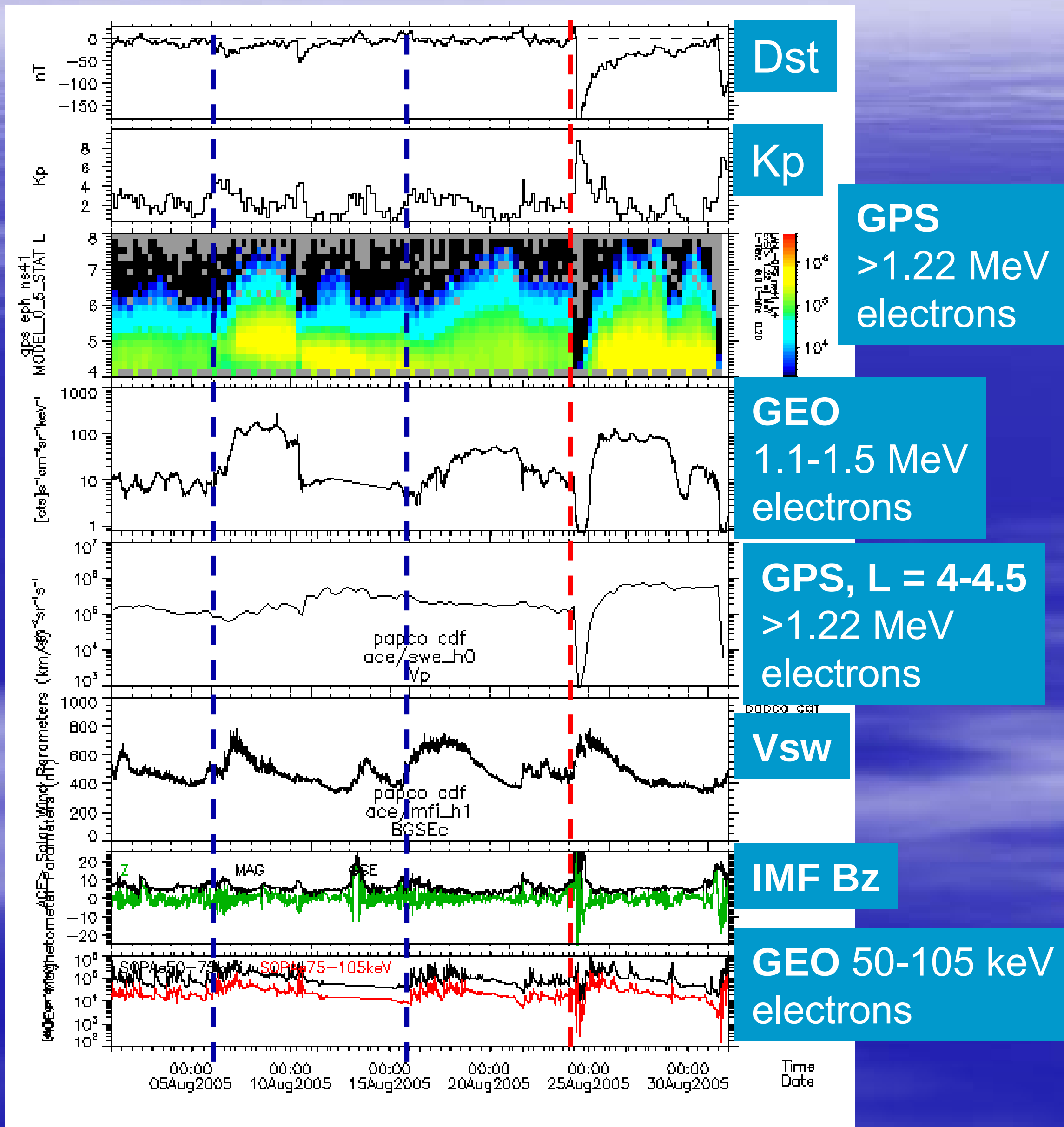


Superposed epoch analysis for 1.2 MeV electrons at GPS



- Dst_min = -105 nT for 11 hours.
- Kp_max = 8, Kp > 6 for more than 1 day.
- GEO 1.1-1.5 MeV fluxes at background level for ~1/2 day and then fast recovery.
- Low energy (75-100 keV) injections.
- High solar wind speed (~1000 km/h).

August 24, 2005



- Dst_min = -216 nT
- Kp_max = 9 –

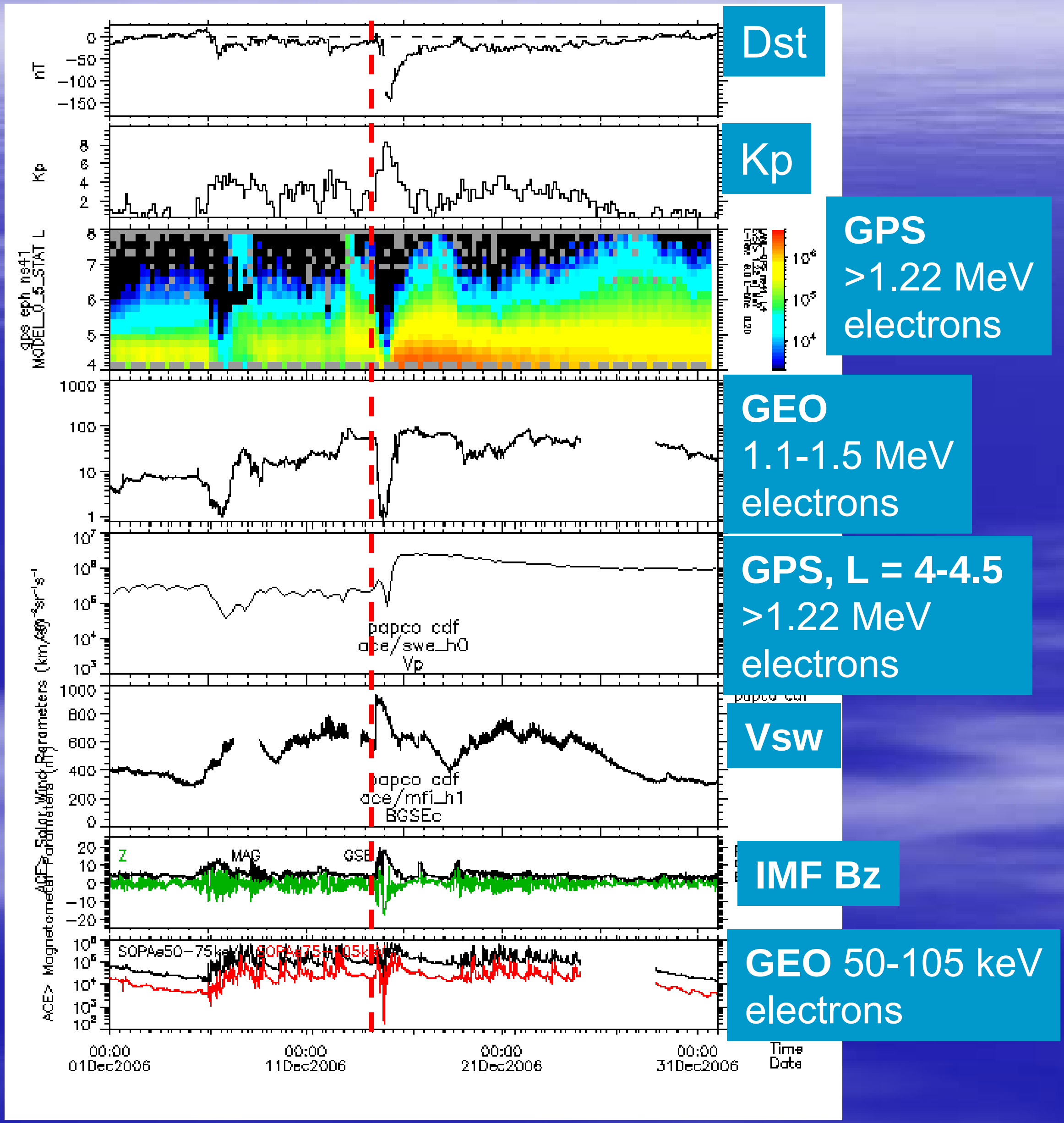
- GPS fluxes drop and then increase fast.

- GEO 1.1-1.5 MeV fluxes at background level for ~1 day and then fast recovery.

- High solar wind speed (~800 km/h).

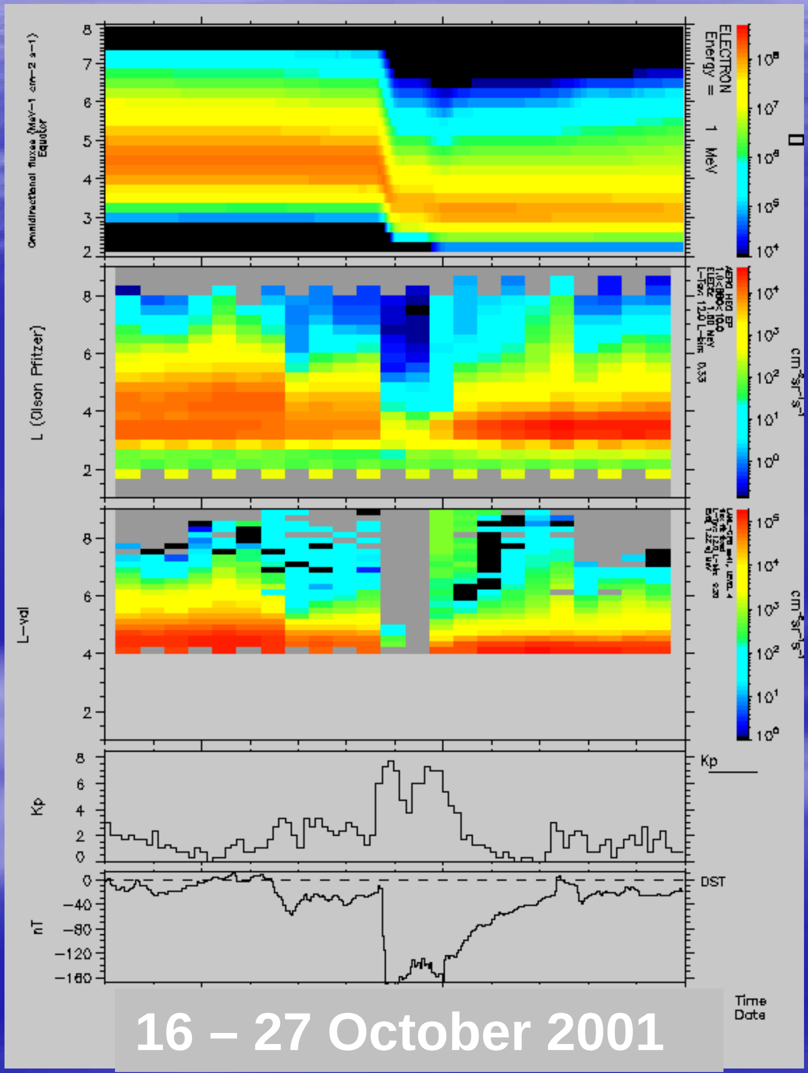
- Low energy (75-100 keV) injections.

December 14, 2006



- Intense geomagnetic storm.
- GPS fluxes increase by an order of magnitude.
- GEO 1.1-1.5 MeV fluxes at background level for ~1/2 day and then fast recovery.
- High solar wind speed (~900 km/h).
- Low energy (75-100 keV) injections.

Modeling efforts: storm simulations with a physical model



Salammbô + GEO boundary conditions: omnidirectional fluxes for 1 MeV

HEO 3 integral fluxes for E >1.5 MeV.

GPS ns41 integral fluxes for E >1.22 MeV.

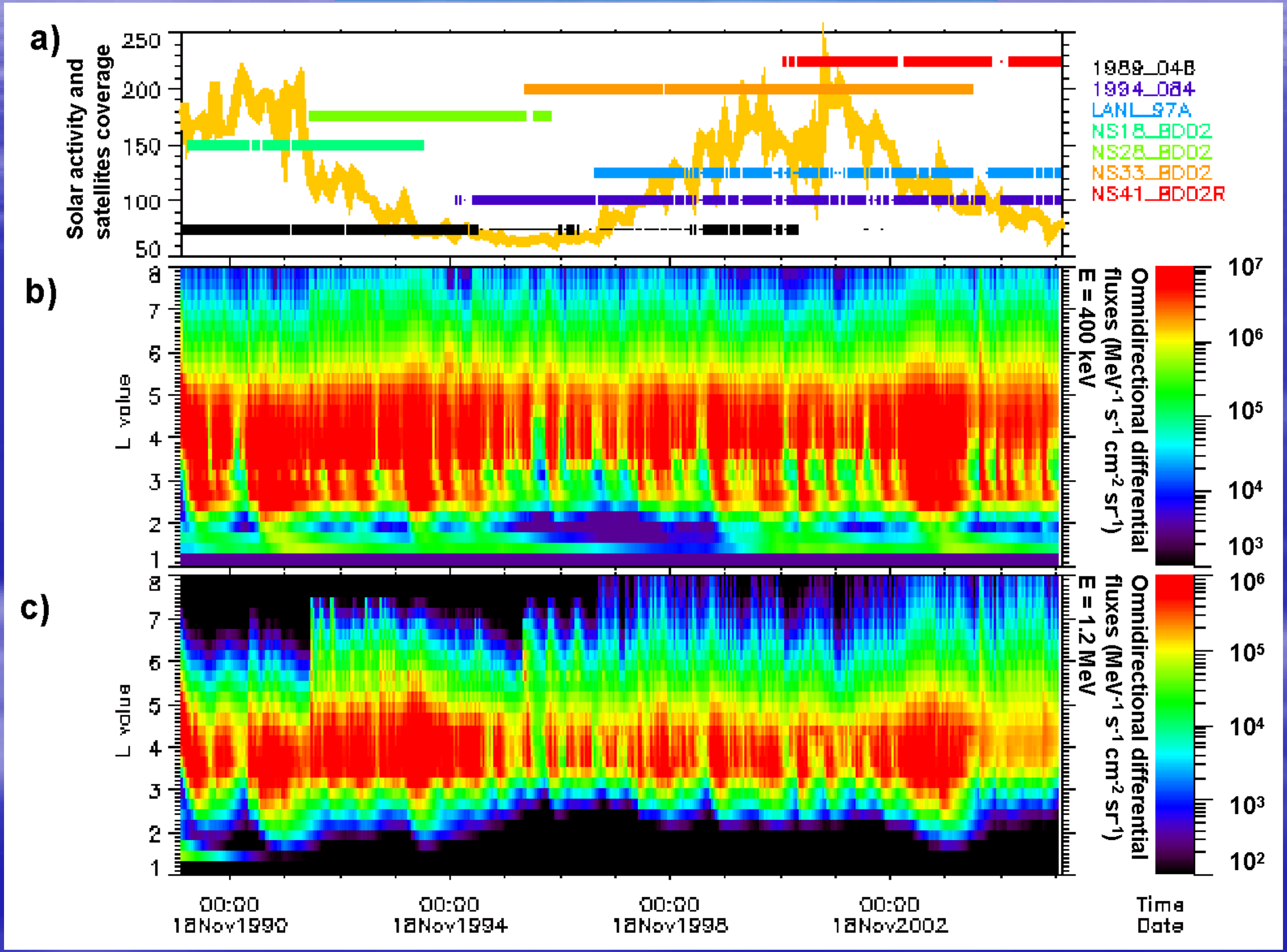
Kp

Dst

(ICME related storm)

Modeling efforts: direct data assimilation

Salammbô + GEO and GPS



Maget et al., 2007

Summary

- We have access to a large data base of satellite measurements.
- We know that effects/dynamics can be very important/violent.
- We have the means to trace variation from the Sun to the Earth.

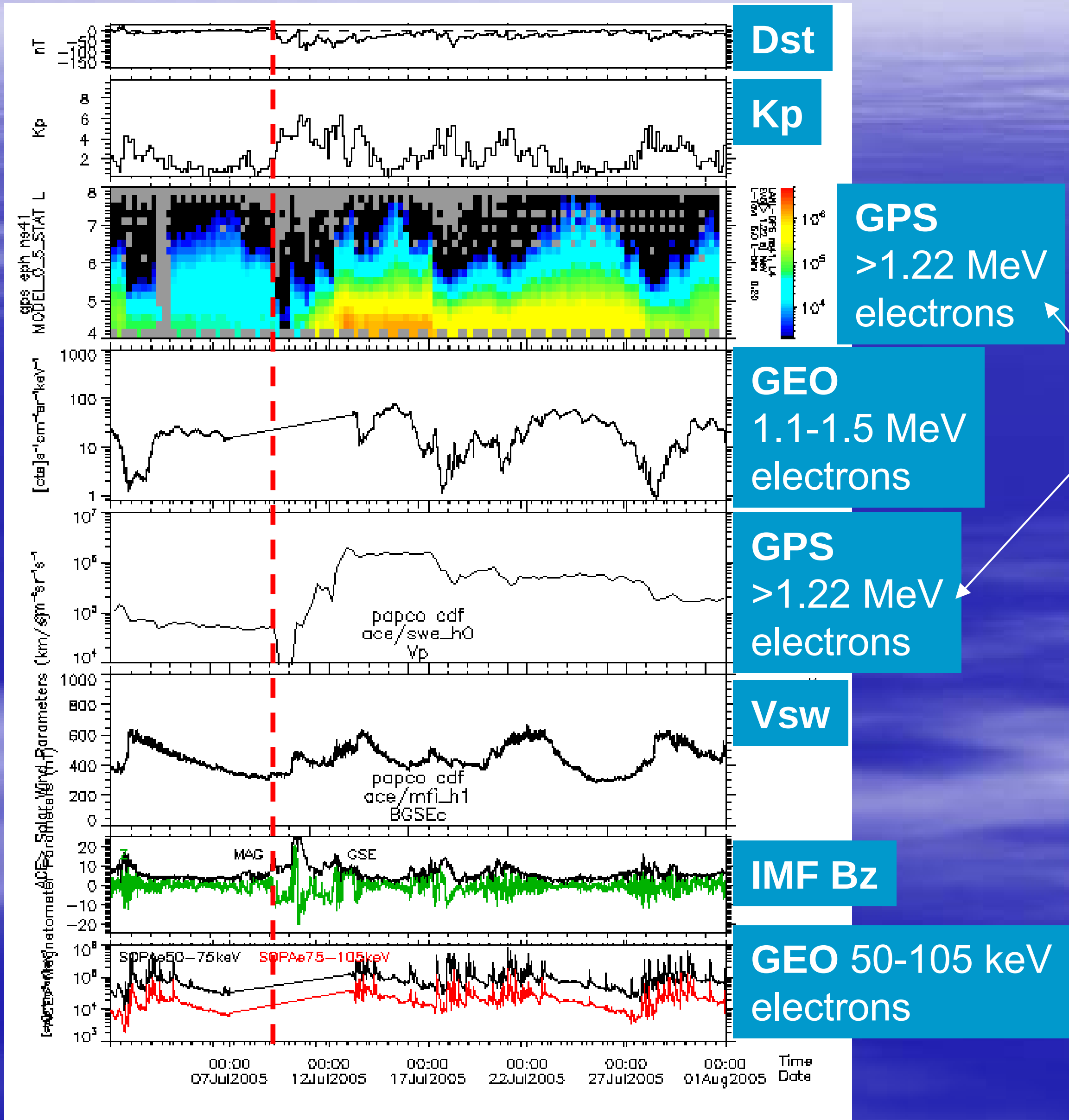
- We still need to understand how the system works, which processes are involved.

- New data will be available in the future.
- Modeling and data assimilation techniques can help.

Thank you

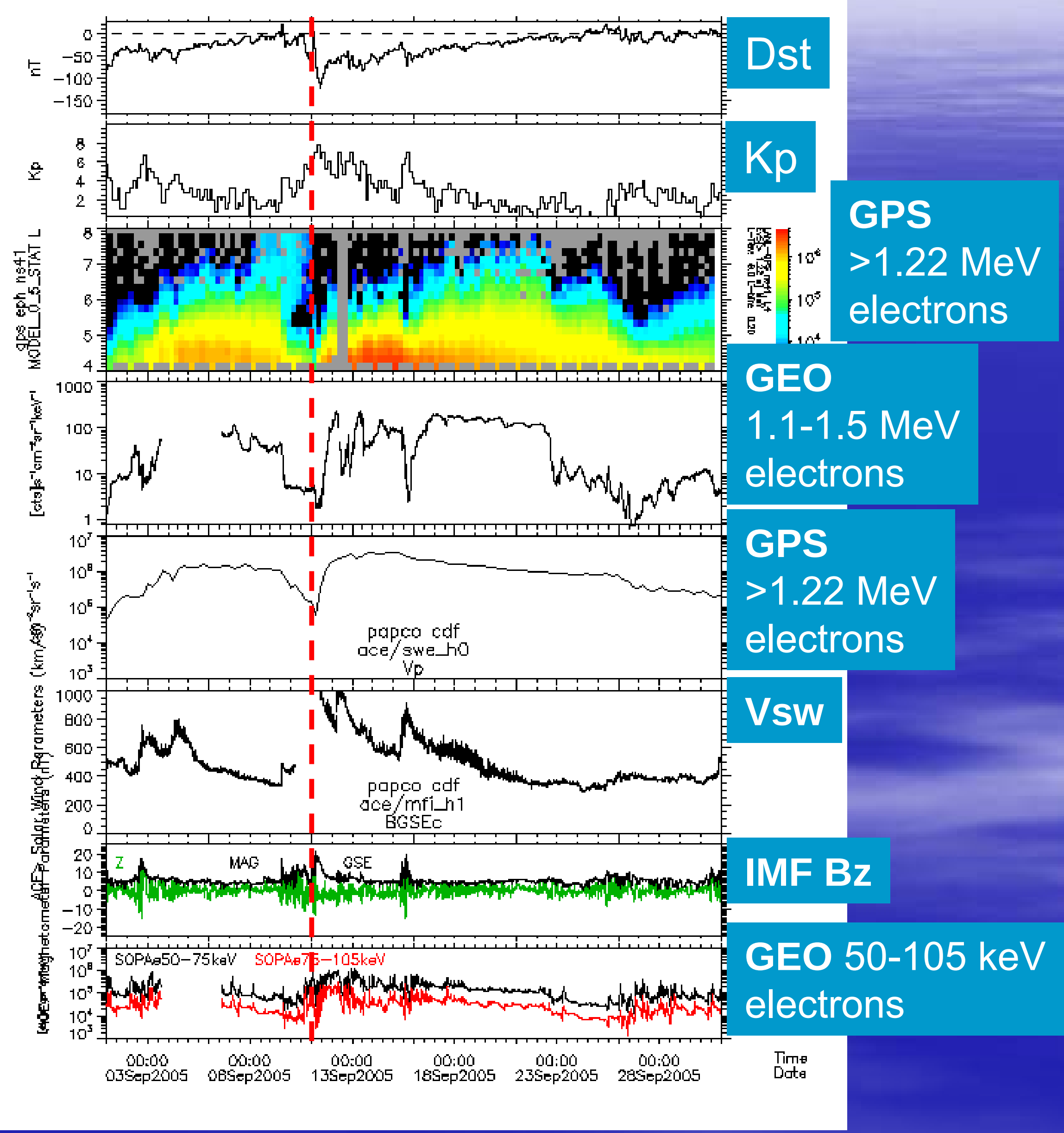
Please contact me for any question, information: athina@lanl.gov

July 9, 2005



- Moderate storms (Dst)
- Kp > 4 for ~ 5 days
- Fluxes at GPS drop for ~ 1 day, then increase by ~2 orders of magnitude
- Data gap for GEO satellites

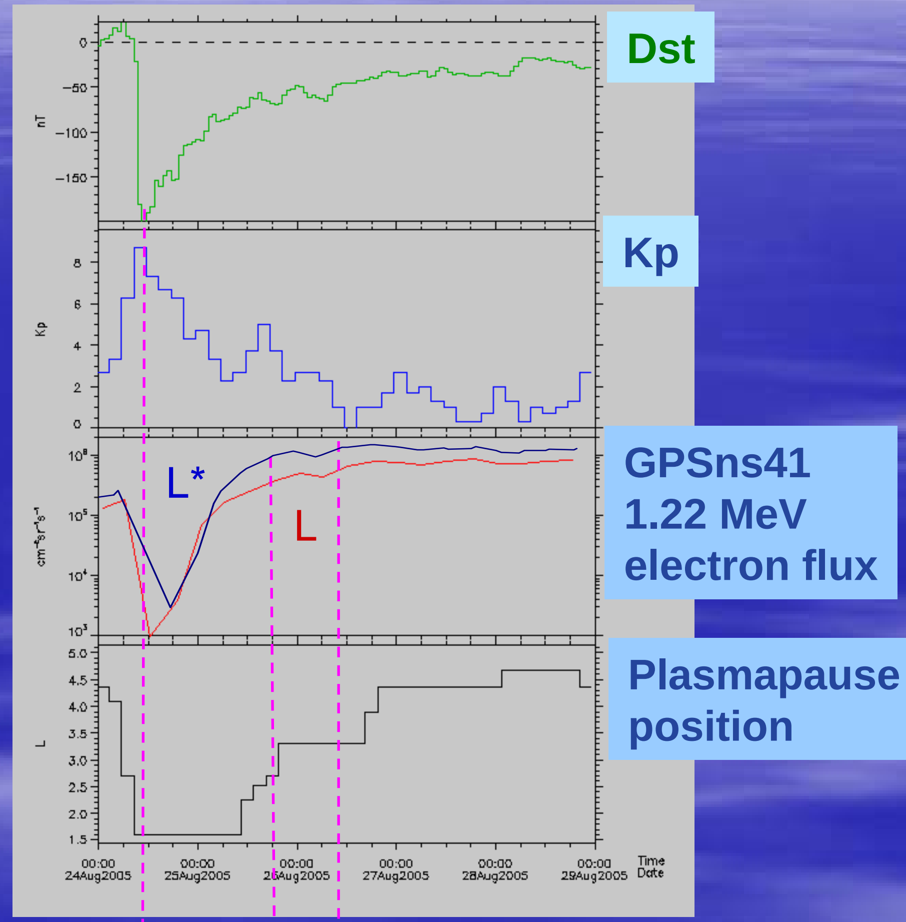
September 11, 2005



- Dst_min = -123 nT
- Kp_max = 8 –
- GPS fluxes drop and then increase fast.
- GEO 1.1-1.5 MeV fluxes at background level for ~1 day and then fast recovery.
- High solar wind speed (~800 km/h).
- Low energy (75-100 keV) injections.

Statistical study of relativistic electron flux rise times

- Data from GPS n41 satellite for the period 2001-2006:
  - Only equatorial fluxes: L*=4-4.5. (T01 storm was used)
  - One energy channel: E=1.22 MeV.
- Time=0 at Dstmin.
- We have studied 41 events:
  - 21 are CME related



Varotsou et al., 2007, submitted