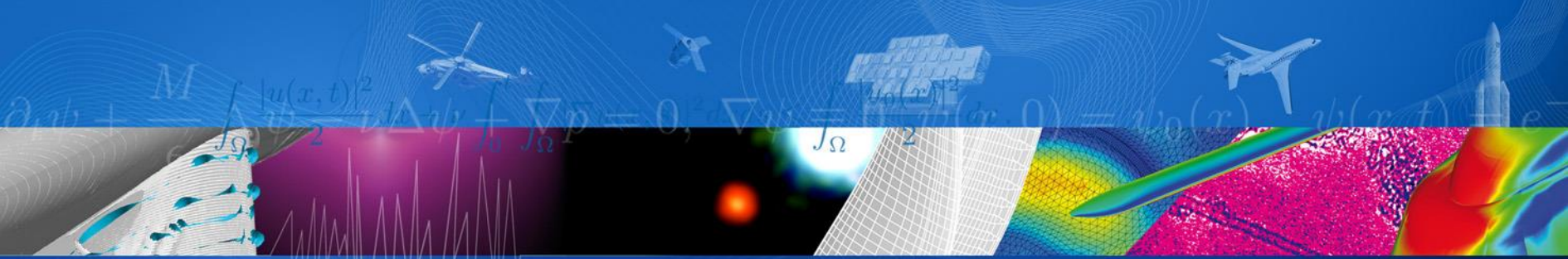

# Highly energetic electrons in the inner zone

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R&T SYSTEMES SPATIAUX

ONERA THE FRENCH AEROSPACE LAB

retour sur innovation

cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

# Purpose of the study

**Who is right, who is wrong?**

- Fennell, J.F. et al., Van Allen Probes show that the inner radiation zone contains no MeV electrons: ECT/MagEIS data, *Geophys. Res. Lett., doi: 10.1002/2014GL062874*, **2015**

- Selesnick R.S., Measurement of inner radiation belt electrons with kinetic energy above 1 MeV, *J. Geophys. Res., doi: 10.1002/2015JA021387*, **2015**

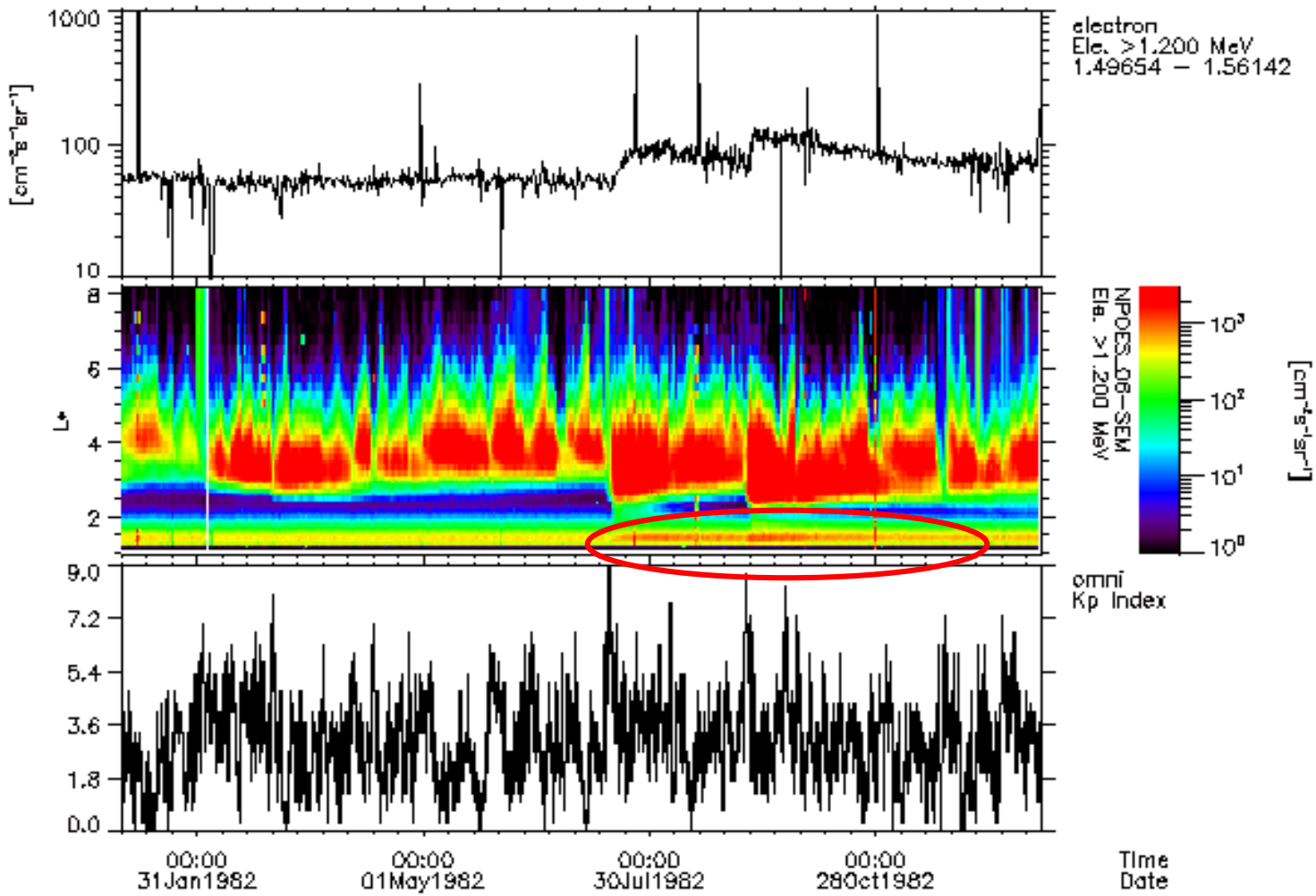
- AE8 shows a high level of >1 MeV electrons in the inner zone

***CNES R&D 2016 support***

# 1st clue: NOAA-POES measurements

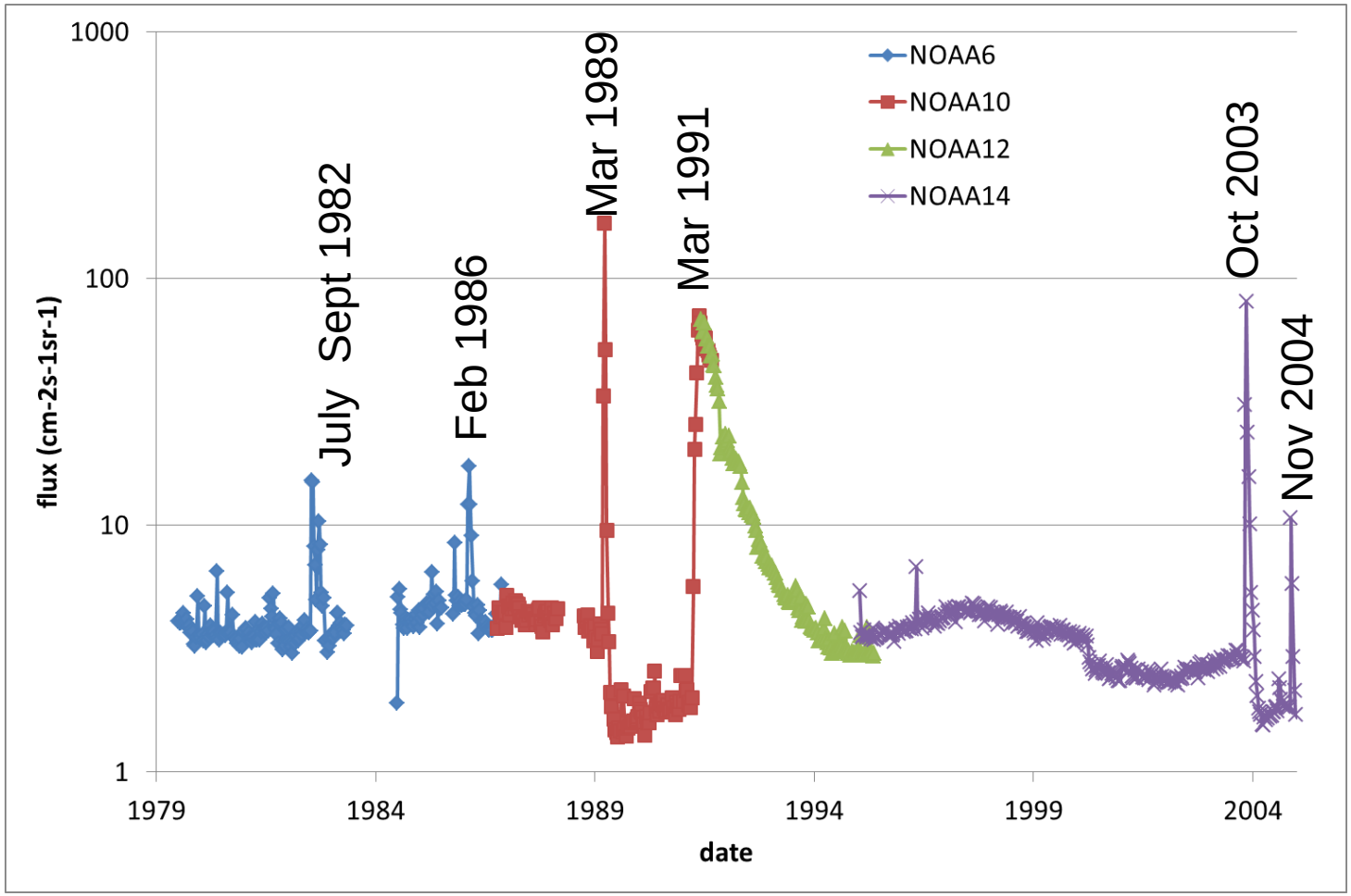
***NOAA-POES 6 measurements:***

***A view of E>1.2MeV electrons (P6 channel) for year 1982***



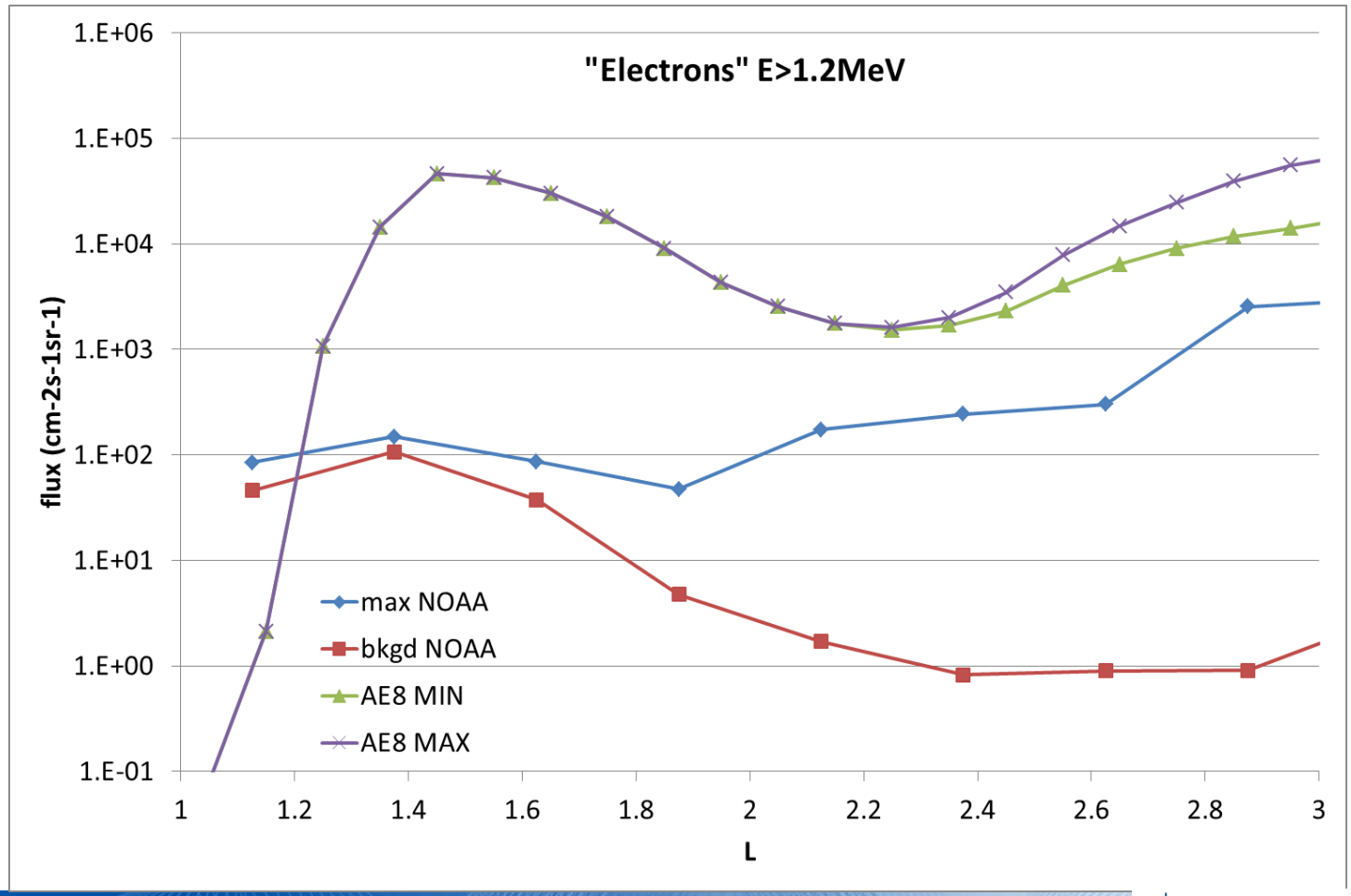
# 1st clue: NOAA-POES measurements

**Search of slot filling from all the SEM measurements: L=2, E>1.2MeV**



# 1st clue: NOAA-POES measurements

**NOAA-POES data consistent with AE8 in outer zone but not in the inner zone**



# 2nd clue: CRRES (1990-91) and SAMPEX measurements

## Residual effects of Starfish experiments

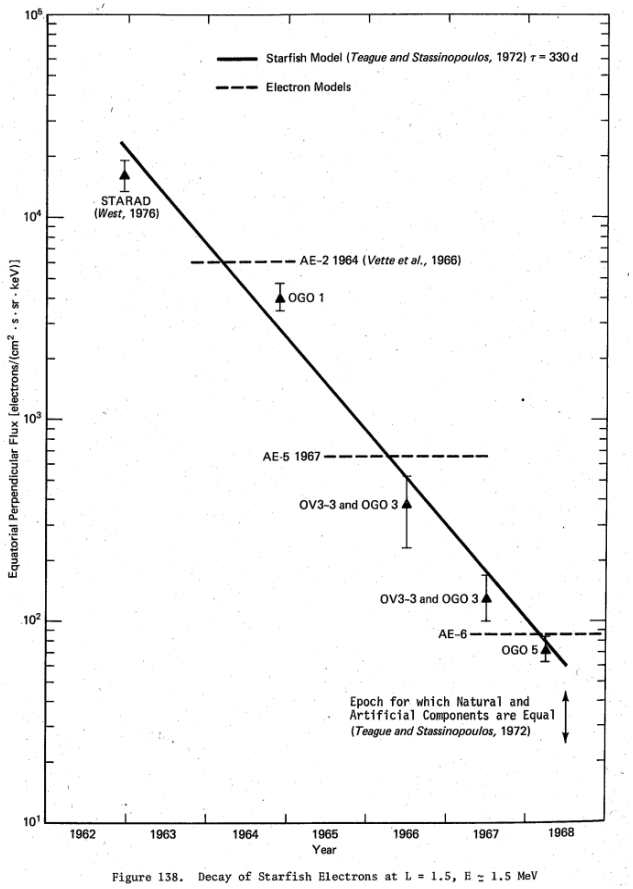
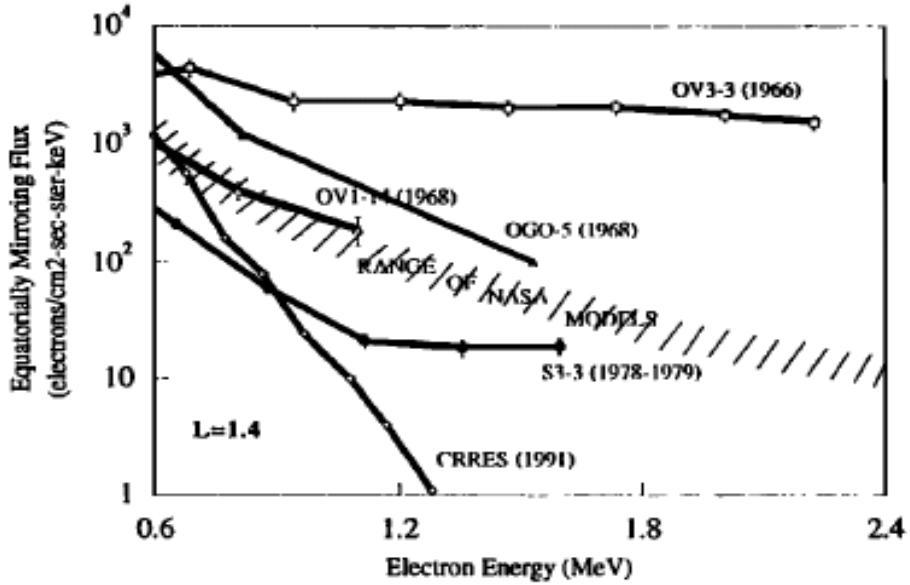



Figure 138. Decay of Starfish Electrons at L = 1.5, E ≥ 1.5 MeV

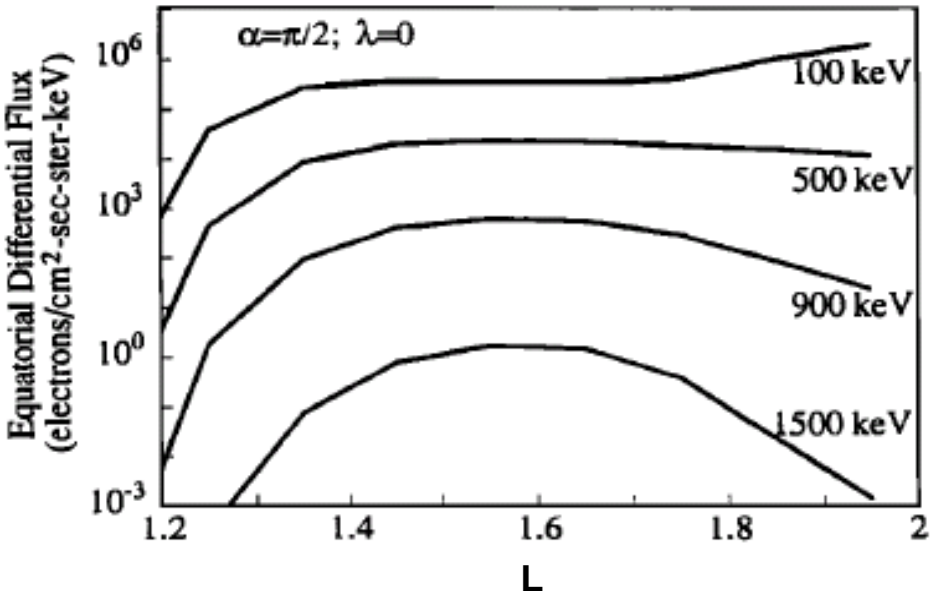
Teague, M.J., N.J. Shofield, K.W. Chan, J.I. Vette, A study of inner zone electron data and their comparison with trapped radiation models, NASA Technical report NSSDX/WDC-A-R&S 79-06, 1979.




Abel, B., R.M. Thorne, A.L. Vampola, Solar cycle behavior of trapped energetic electrons in Earth's inner radiation belt, J. Geophys. Res., vol 99-A10, pp. 19427-31, 1994.

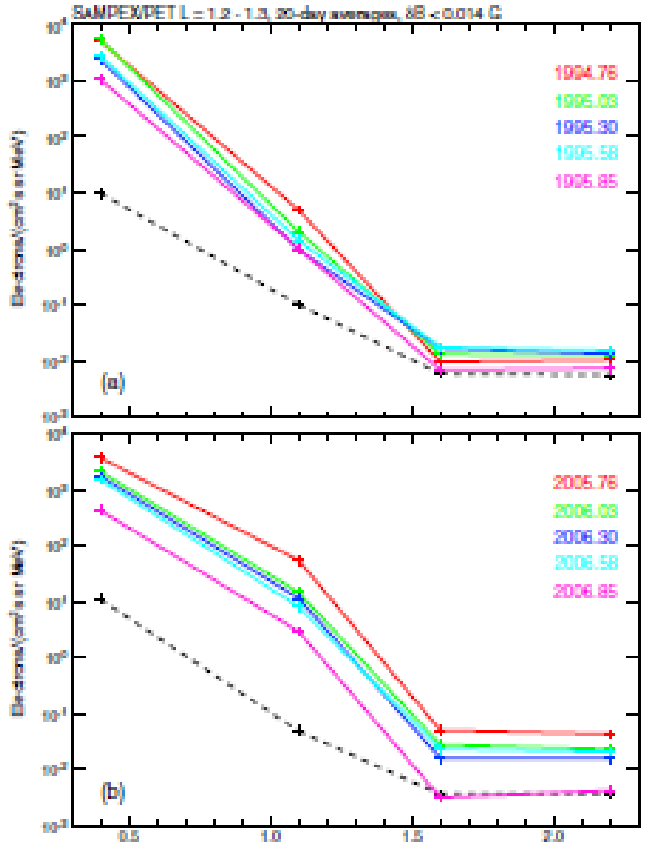
# 2nd clue: CRRES (1990-91) and SAMPEX measurements

## CRRES before March 1991 event




Abel, B., R.M. Thorne, A.L. Vampola, Energetic electron precipitation from the inner zone, *Geophys. Res. Lett. , vol 24-16, pp. 1983-6*, 1997.

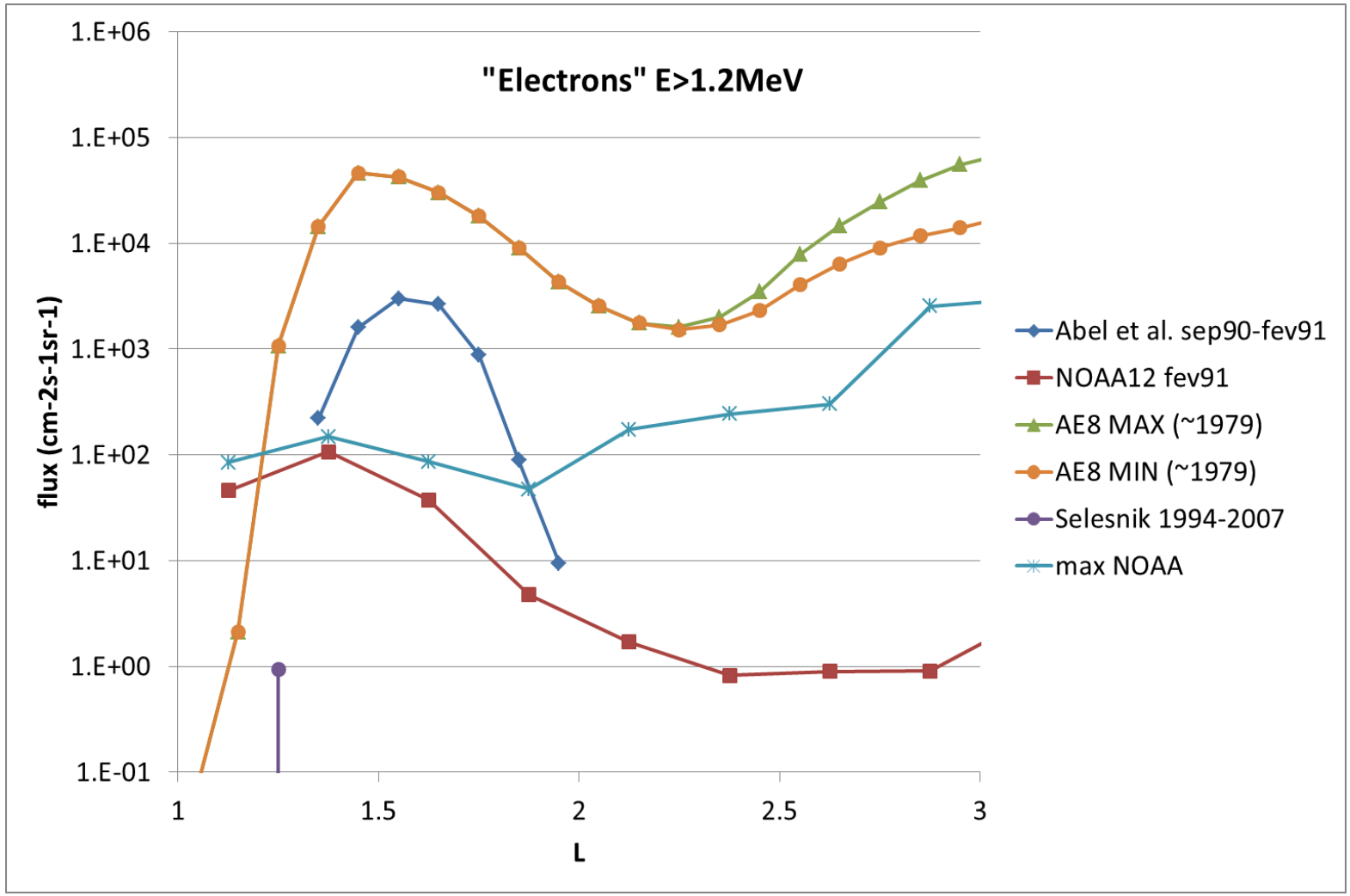
## SAMPEX observations over years




Selesnick R.S., Measurement of inner radiation belt electrons with kinetic energy above 1 MeV, *J. Geophys. Res., doi: 10.1002/2015JA021387*, 2015.

# 2nd clue: CRRES (1990-91) and SAMPEX measurements

## CRRES and SAMPEX measurements consistent together and with NOAA



# 3rd clue: Salammbô

- Simplified radiation belt modelling: **2D (E,L) + time**

  → *make possible to simulate several solar cycles quickly*

- Boundary condition L=8 (from **CNES R&D 2015**) :

  $$J\ [MeV^{-1}cm^{-2}s^{-1}sr^{-1}] = 4.3195.10^{10}exp^{-E[MeV]/0.002085}$$

- Radial diffusion depends on Kp and L: $D_{LL}[s^{-1}] = 1.198.10^{-14}exp^{1.0362Kp}L^{10.2}$

- Wave-particle interactions modelled using losses time constants (from **CNES R&D 2011**)

- **Calculation performed between 1976 (beginning of solar cycle #21, with an empty magnetosphere) and 2016**

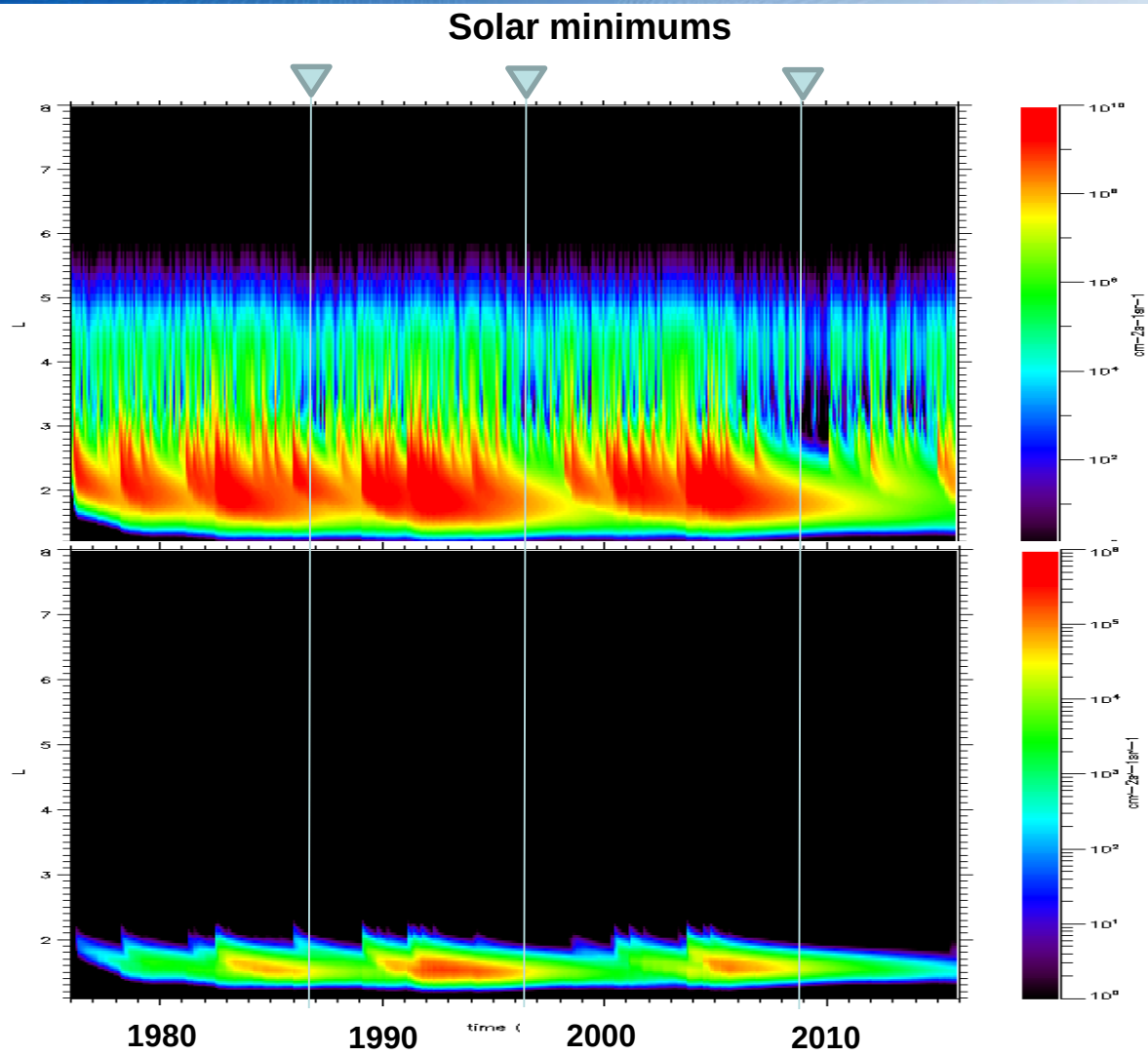
# 3rd clue: Salammbô

**E>100keV**

- Electrons are accelerated only by radial diffusion
- The slot is induced  by losses time constants
- The solar cycles are more or less observed

**E>1MeV**

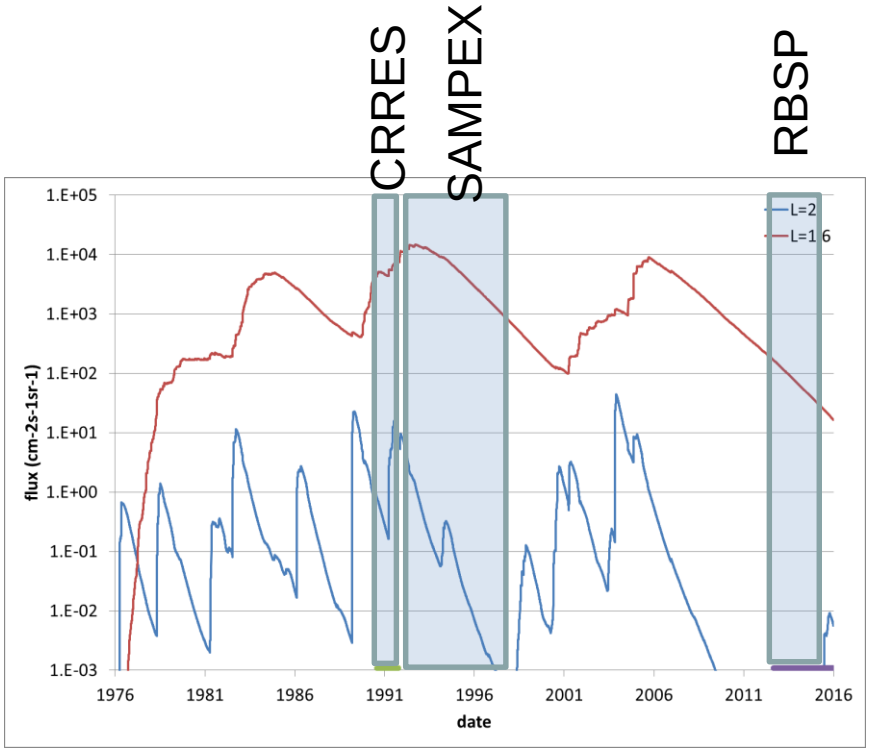
- Electrons are accelerated by radial diffusion
- There is no outer belt as no energy diffusion included
- The solar cycles are more or less observed

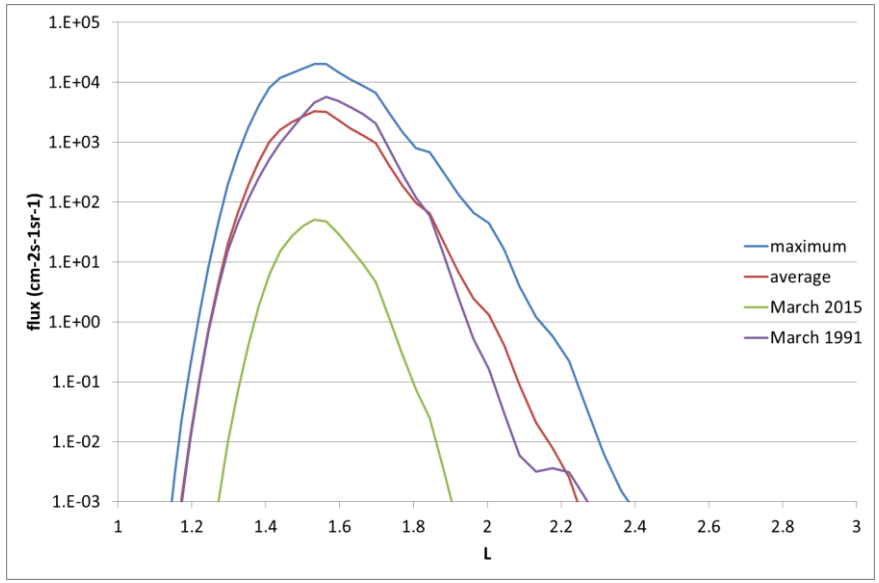



E>1MeV electrons in the inner zone have a strong inertia. They increase only following intense events

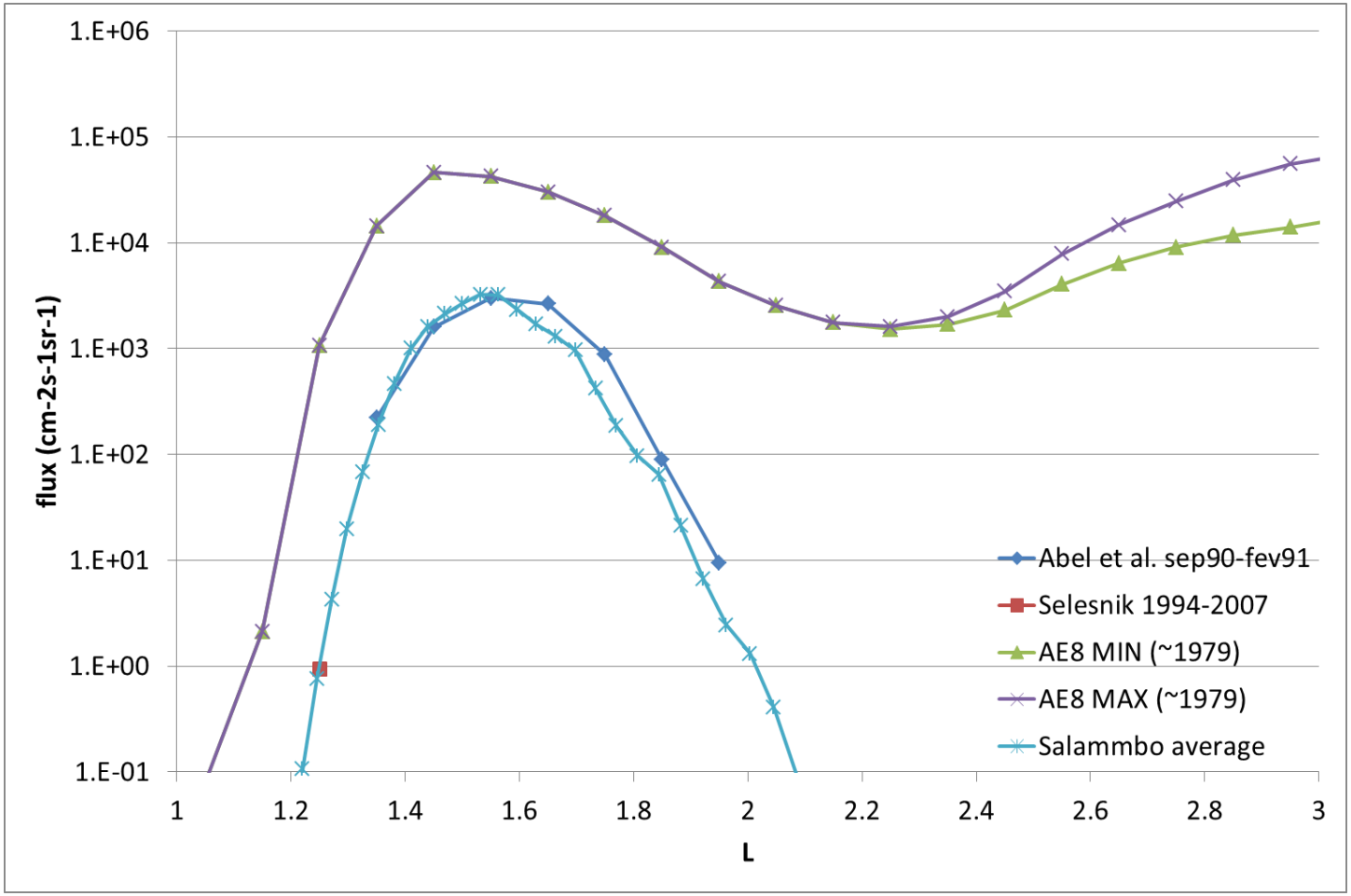
# 3rd clue: Salammbô

**> 1 MeV electrons simulated dynamics compared to time periods of measurements**



# 3rd clue: Salammbô




**Conclusion**: Salammbô consistent with CRRES

Salammbô shows large variations in the inner zone electrons (3 orders of magnitude)

# General conclusions

- **High energy electrons are present in the inner zone**
- ***They can vary*** at their maximum by several orders of magnitude
- They were nicely measured by CRRES and SAMPEX
- **The increase observed in the NOAA 6 flux in 1982 can be explained by the combined effect of intense storms and Starfish residuals**
- They are presently higher than claimed by RBSP
- In average, they are 10 times lower than as modelled in AE8
- A physical model as Salammbô is very powerful for understanding such measurements over solar cycle timescales