# A new European Service to Forecast the High Energy Electron Flux in the Radiation Belts

## www.fp7-spacecast.eu

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Invited talk, US Space Weather week, Boulder USA, 24th April, 2012

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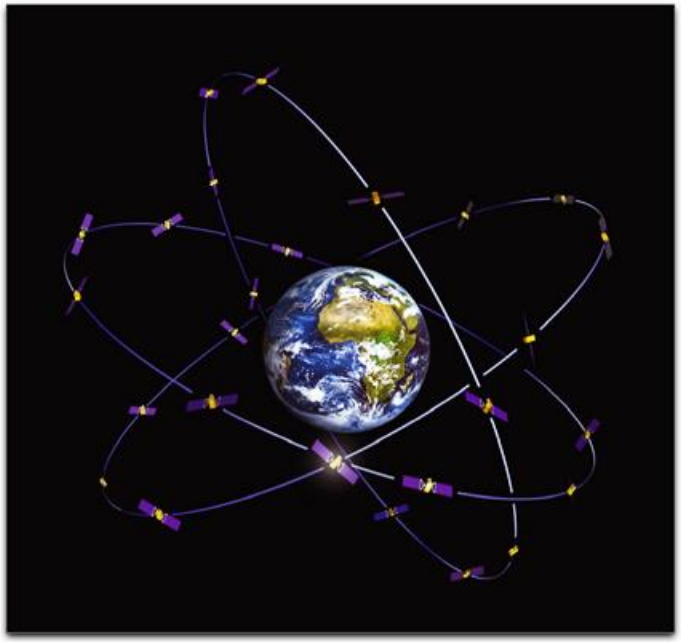
- Space is strategically important for Europe
  - Industry, GMES, Galileo,….
- Space assets are vulnerable to high energy particles
- Vulnerability increasing – new technology
- Risk changes with solar cycle
- High impact low frequency events



Galileo - Courtesy of ESA

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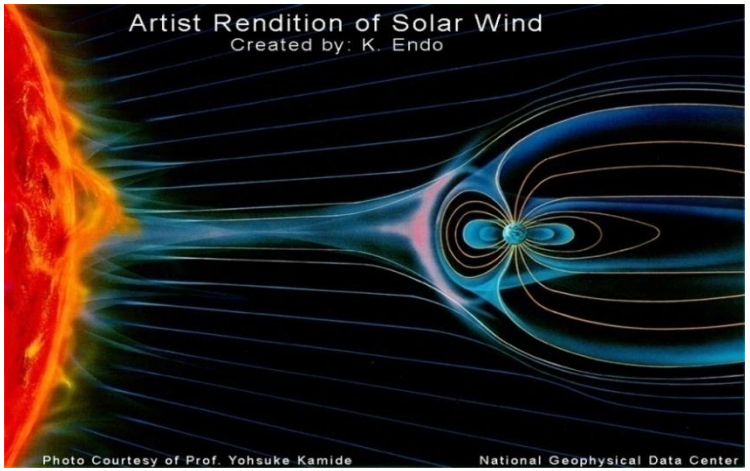
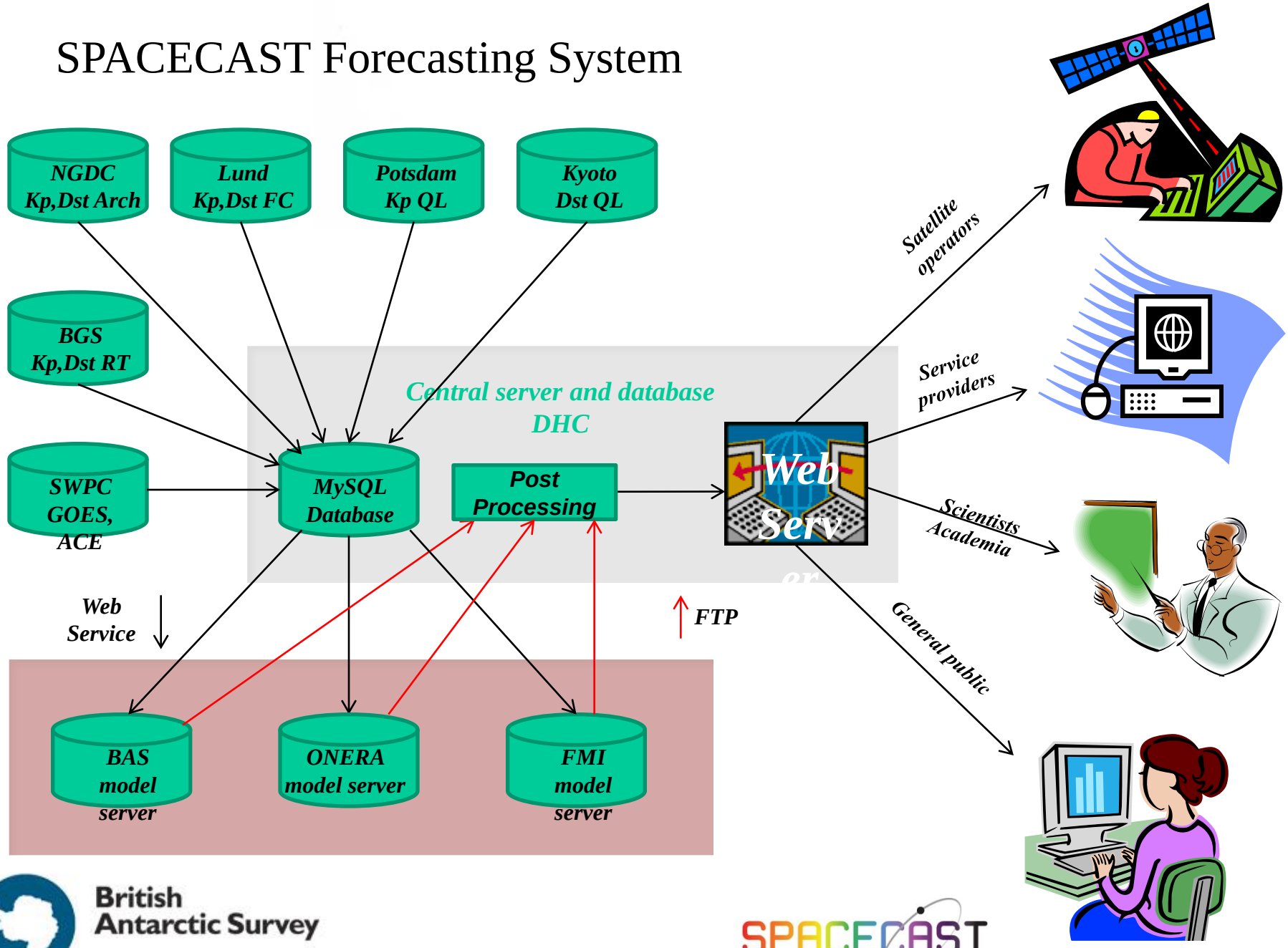
*To protect space assets from high energy particles by developing European dynamic modelling and forecasting capabilities*

- New 3 year FP7 collaborative project
- Focus on:
  - MeV electron forecast
  - keV electron nowcast
  - SEP event modelling
- 7 European partners
- 4 US partners



# SPACECAST Forecasting System

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# http://www.fp7-spacecast.eu

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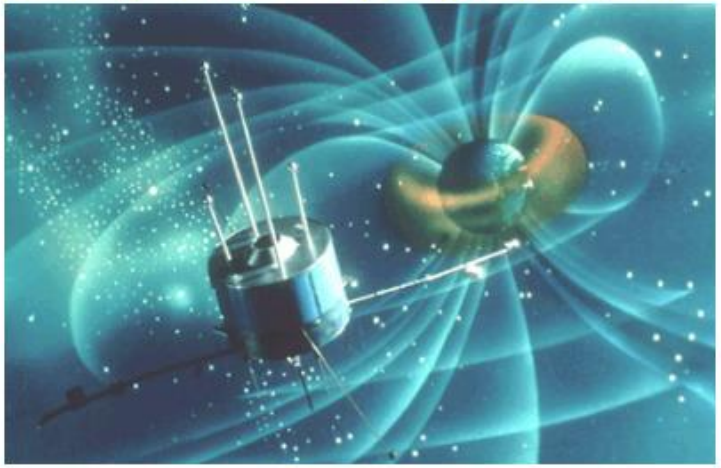
High-Energy Electron Forecasts | Low-Energy Electron Forecasts | Solar Energetic Particles | Radiation Dose | Alerts and Warnings | Animations | Special Events | Archive

**Welcome to the SPACECAST web site, a resource providing support for satellite operators, designers and insurers, and information for the general public. SPACECAST is a Collaborative Project funded by the European Union Framework 7 programme to help protect satellites on orbit by modelling and forecasting particle radiation.**



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**SPACECAST satellite risk index: Low risk**

**Last updated at 05:31 UTC on 24 Apr 2012**
**Next update at 06:35 UTC on 24 Apr 2012**

**Check our latest high energy electron forecast!**

SPACECAST is a three year project which runs until 28 Feb 2014. At present, the web site provides a forecast of high energy electron fluxes and an associated risk index. The underlying models will be improved as part of the research element of the project. In future, we will also provide a forecast of low energy electrons, modelling of Solar Energetic Particles and an alert service. Visit our **site map** for a tour of the site.

Access to the web site is unrestricted, however, future products such as the alert services will require a registered account. You can already sign up for an account, so we can contact you when new products come online.

Please see our **disclaimer!**

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**Last update:** *6 March 2012*

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ONERA

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LEUVEN

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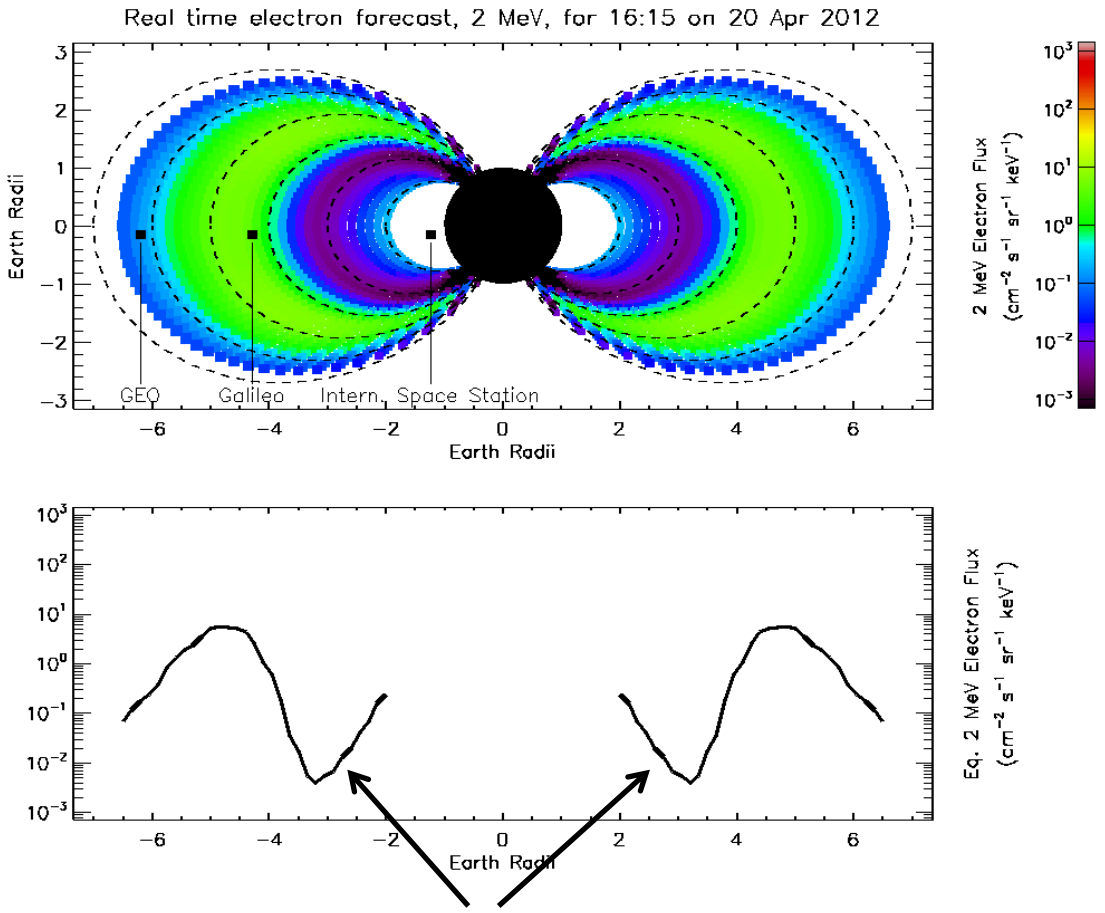
# SPACECAST – Forecast the whole RB




Losses due to wave-particle interactions – form the slot region

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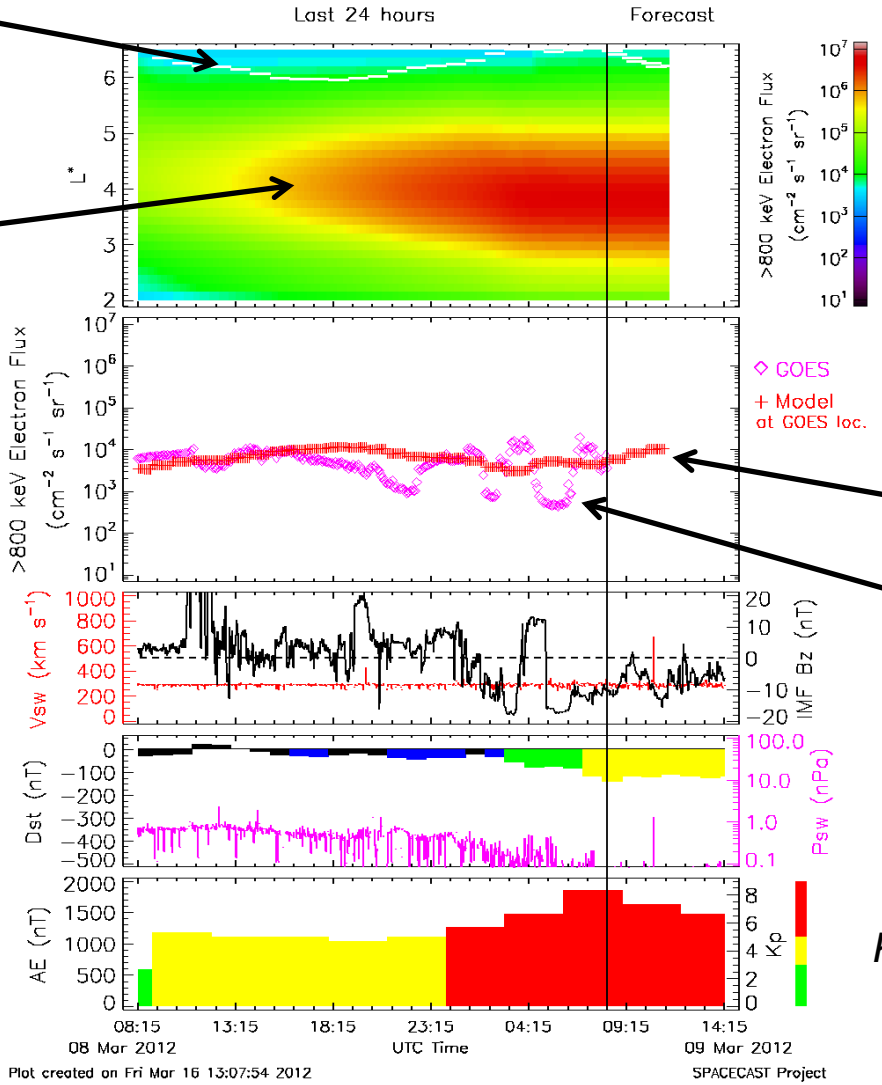
# SPACECAST – Forecast >800 keV electrons

*GOES orbit*

*>800 keV electron flux increases*




*Note whole rad belt: GEO + MEO*

*3 hour forecast at Geo*

*GOES data*

*Solar wind*

*Dst and SW pressure*

*Kp index*

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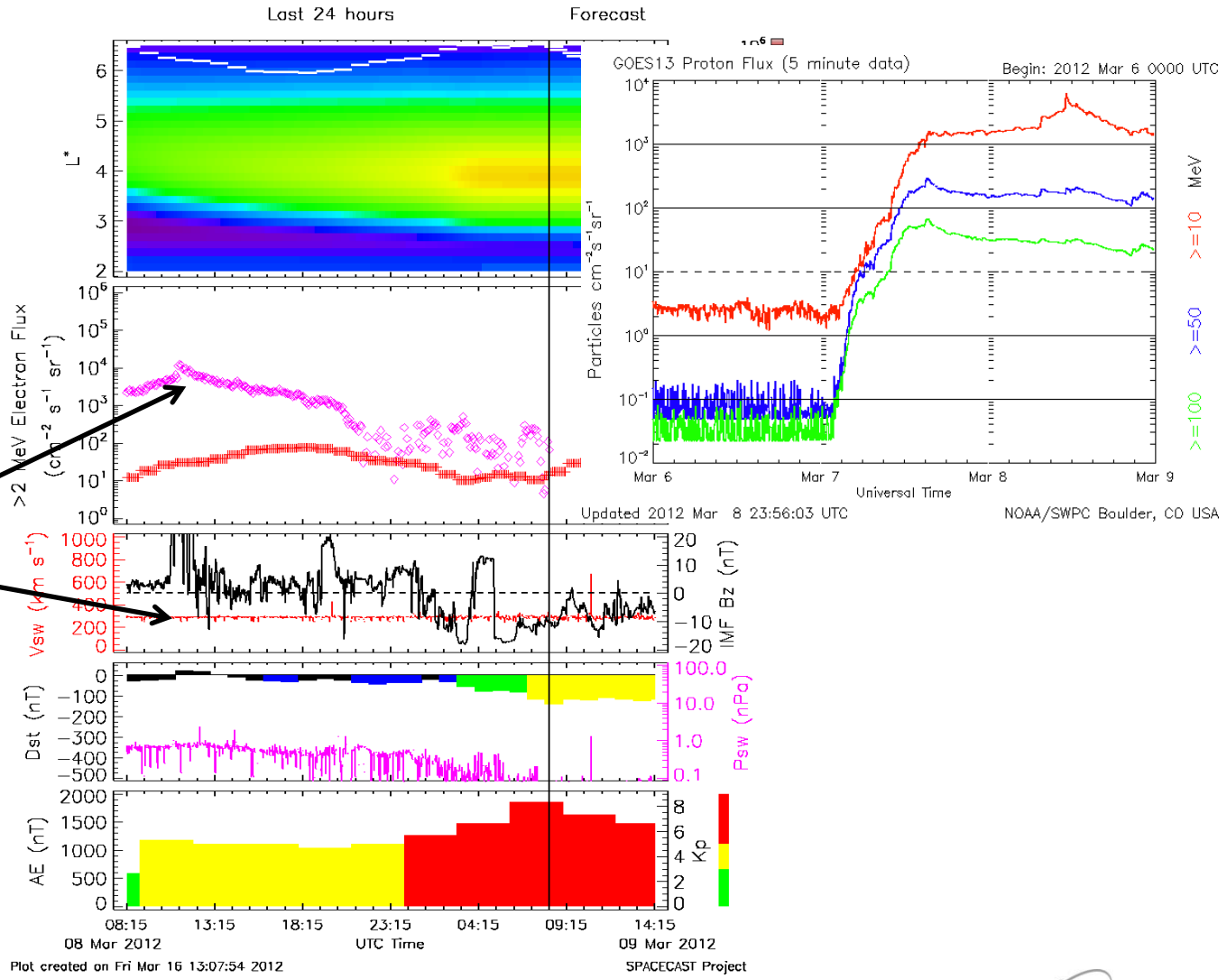
# SPACECAST > 2 MeV Electrons




*Satellite data affected by SW*

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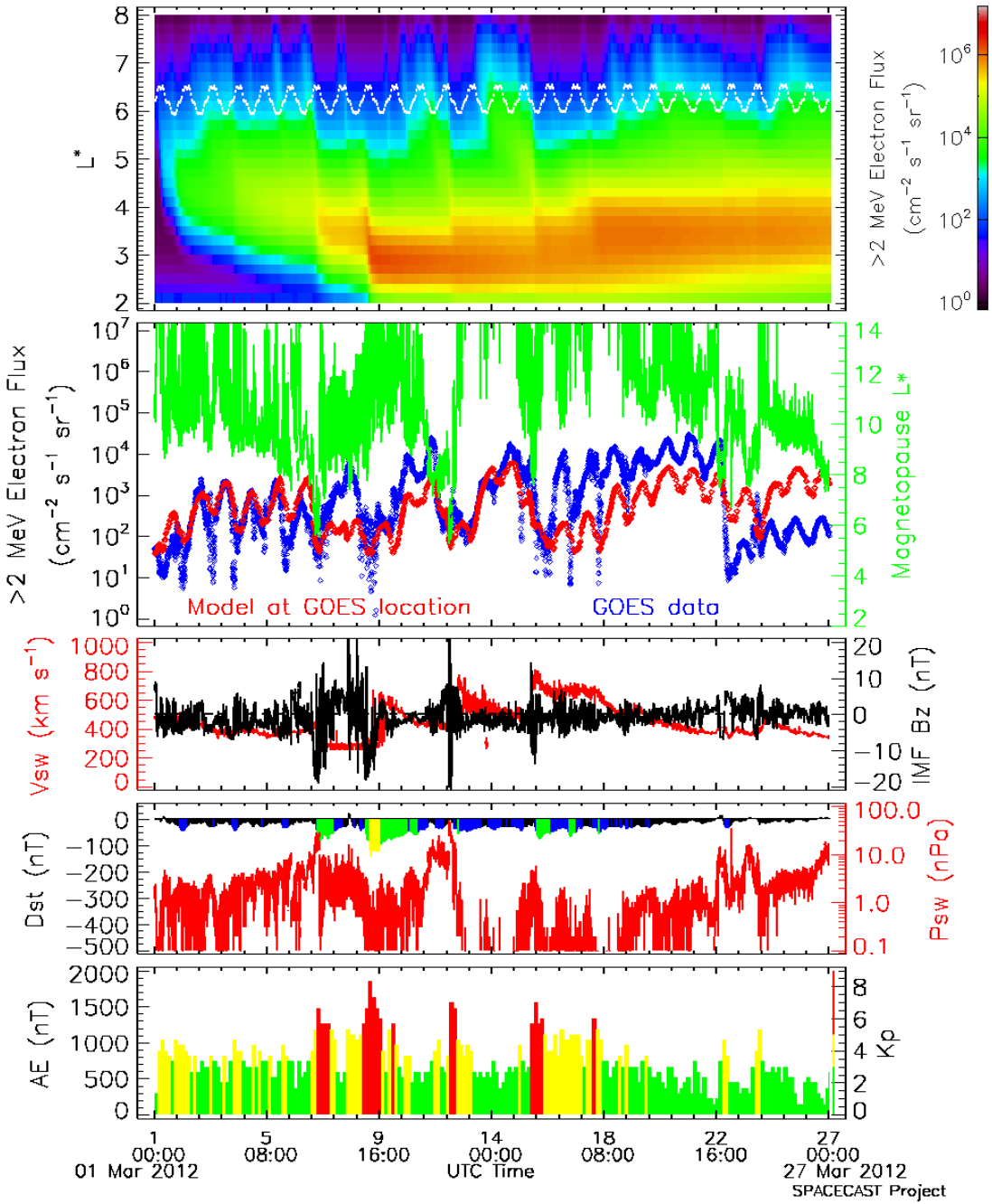
# March 2012

Forecast in red
Data in blue
Mpuase in green

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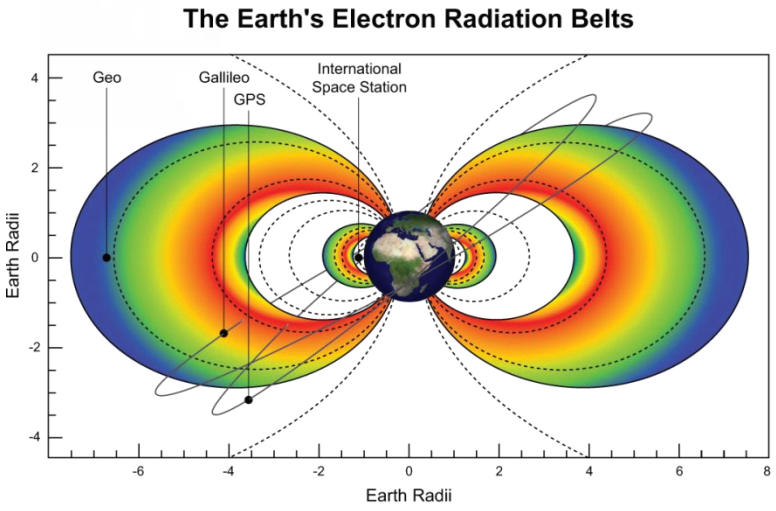
# BAS Global Dynamic Radiation Belt Model




physics-based model

solve a Fokker-Planck equation

***Pitch angle diffusion*** ***Energy diffusion***

$$\frac{\partial f}{\partial t} = \frac{1}{T(\alpha)\sin(\alpha)}\frac{\partial}{\partial \alpha}\left( T(\alpha)\sin(\alpha) D_{\alpha\alpha}\frac{\partial f}{\partial \alpha}\right)\Bigg|_{EL} + \frac{1}{E(E+2E_0)}\frac{\partial}{\partial E}\left( E(E+2E_0) D_{EE}\frac{\partial f}{\partial E}\right)\Bigg|_{\alpha L}$$

$$+ L^2\frac{\partial}{\partial L}\left(\frac{1}{L^2} D_{LL}\frac{\partial f}{\partial L}\right)\Bigg|_{\mu J} - \frac{f}{\tau}$$

***Transport*** ***Loss***

requires appropriate boundary conditions

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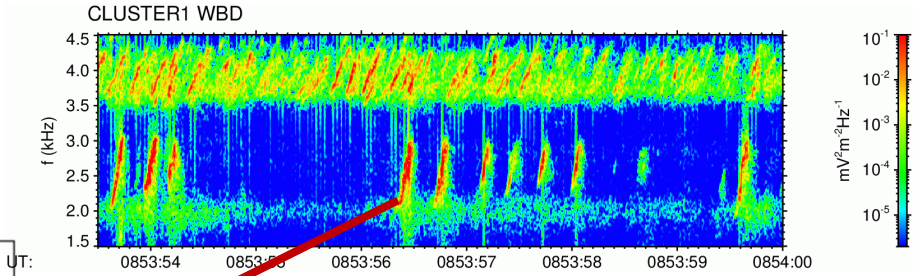
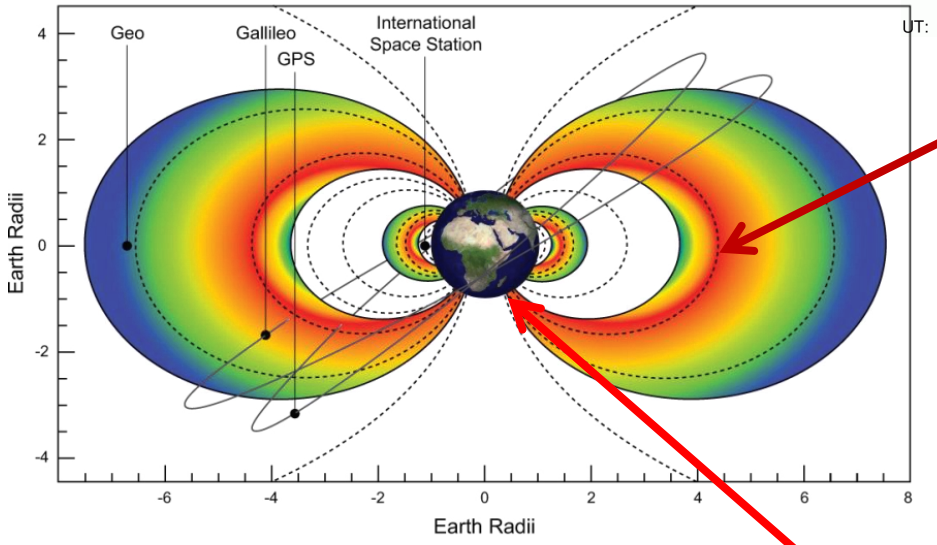
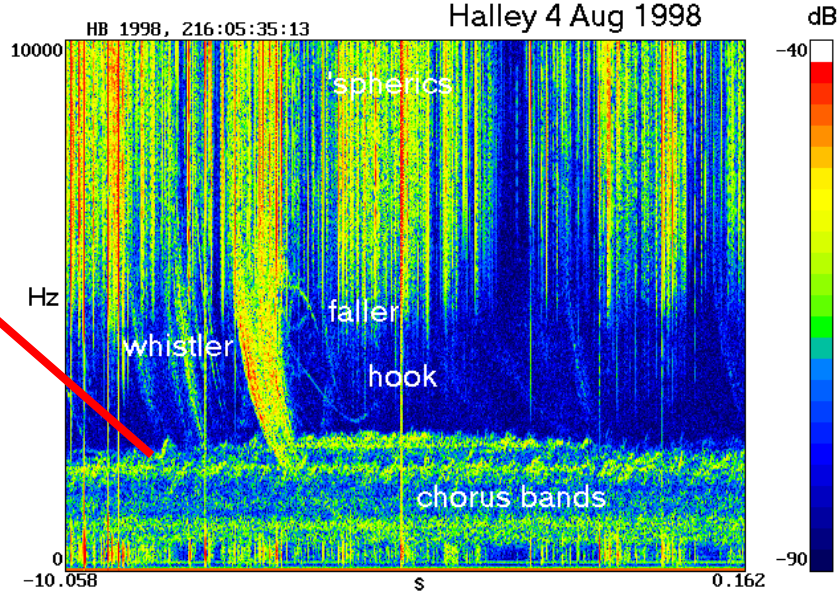
# Wave-Particle Ineractions : Antarctic Connection




- Shown that waves accelerate electrons in radiation belts
- Changed ideas lasting 40 years
- Now included in global models

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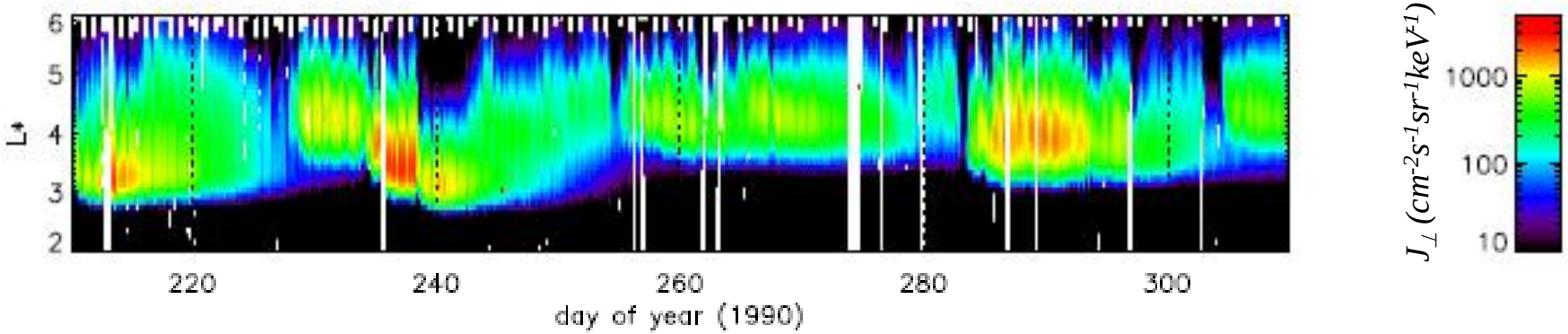
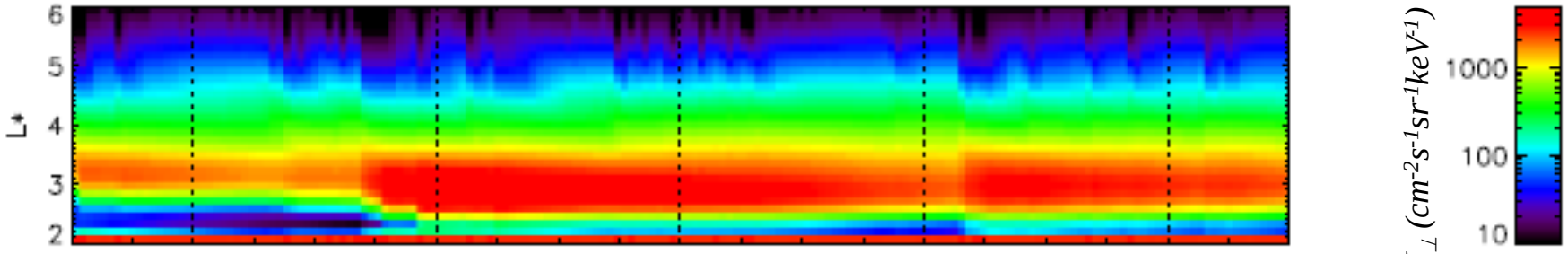
# BAS Radiation Belt Model

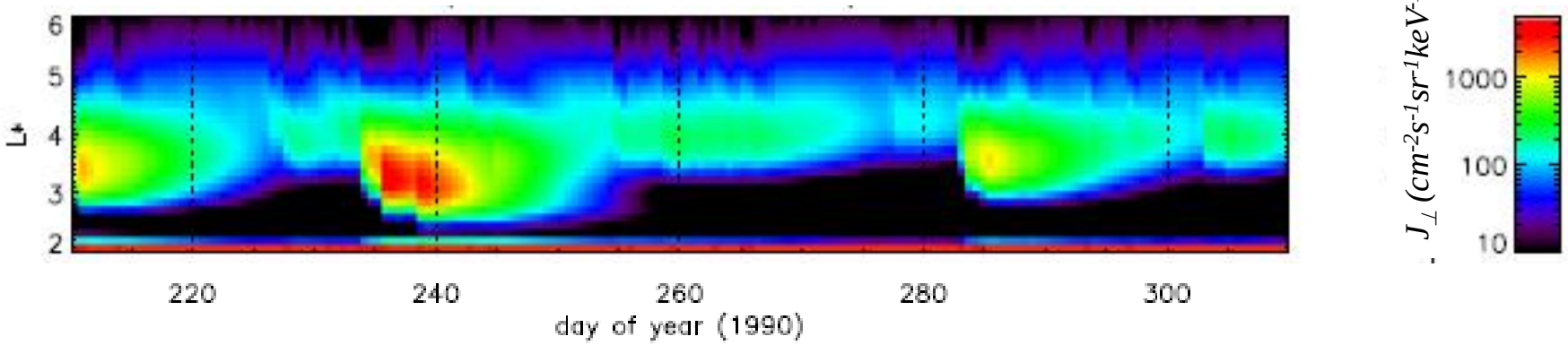
*CRRES Relativistic Electrons*




*BAS Model with Radial Diffusion only*




*BAS Model with Radial Diffusion and Waves*



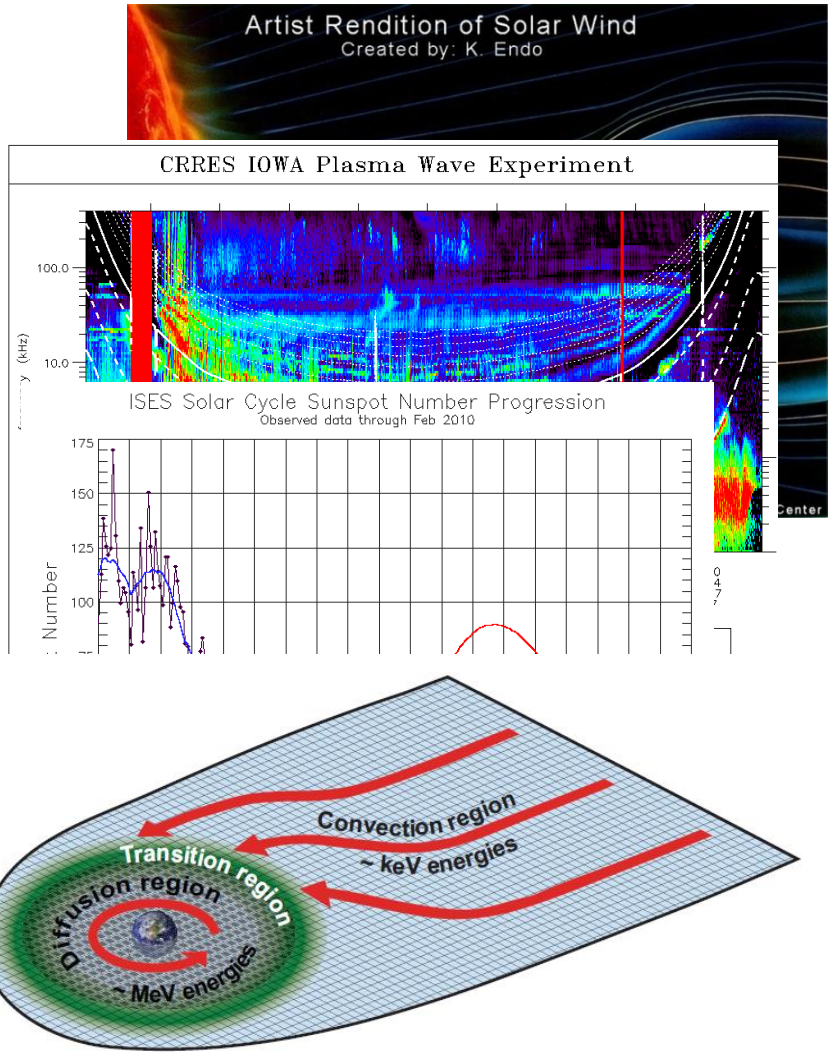
# Uses

Physics based model - we can:

- Predict what is likely to happen in the next few hours
- Results for orbits where there are no data
- Calculate average and extreme conditions
- Reconstruct what happened in the past – for satellite anomalies
- Calculate particles precipitating into the atmosphere

# SPACECAST - Research to Improve Dynamic Models

- Magnetopause boundary
- Develop better wave models
- Better radial diffusion models
- Include solar cycle effects
- Develop low energy electron models
- Couple low and high energy electron models

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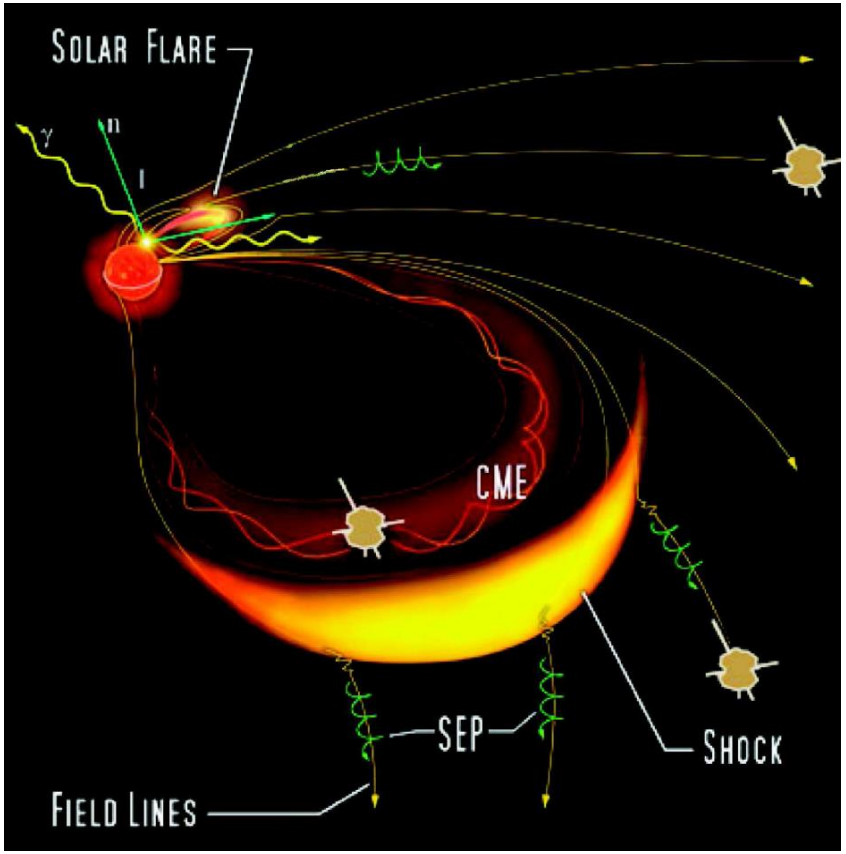
# SPACECAST - Research on Solar Energetic Particles

- Extend SEP models to higher energies ~ 200 MeV
- Simulate shocks with MHD models
- Model the transport of shock accelerated protons
- Use the shock and transport model to predict proton flux
- Construct better parameterisations for SEP prediction models
- Determine the radiation dose

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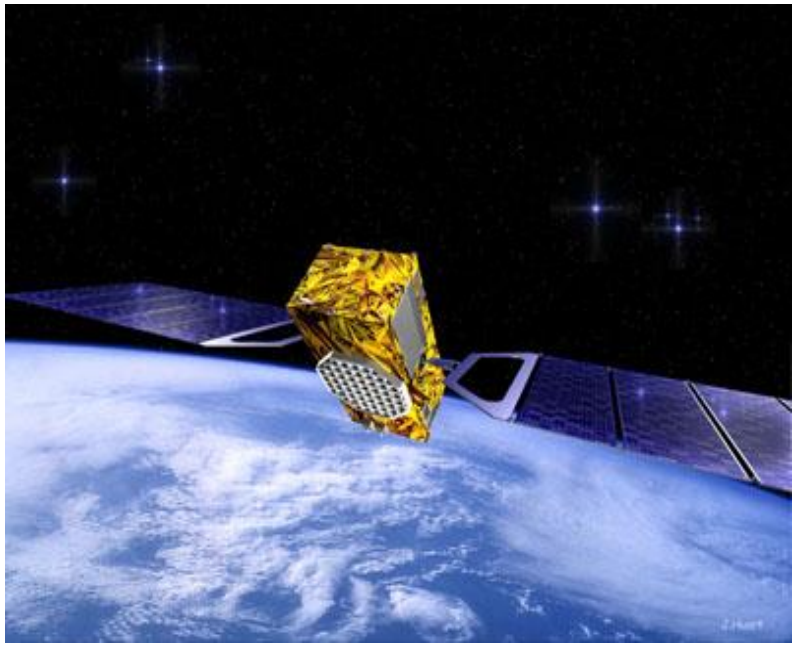
# SPACECAST - Develop a Stakeholder Community

- Spacecraft Operators
- Satellite designers
- Space Insurance

- Policy makers
- The public
- Other scientists



- We will deliver a European space weather forecasting capability that will last beyond the project and which will lay the foundation for an operational system

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# Conclusions

- SPACECAST - real time forecasts of the radiation belts for satellite operators
- Will issue warnings and alerts to stakeholders
- Pre-operational, freely available
- Will provide a nowcast of low energy ~keV electrons
- Modelling of solar energetic particle events to help develop forecasts
- Research to improve forecasts, reduce uncertainty
- Would like feedback on user needs, displays, thresholds…
- The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no 262468

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# Satellite Anomalies – When SW Conditions Disturbed

- 20th Jan 1994 Intelsat 4, Anik E1 and Anik E2
  - Intelsat 4 and Anik E1 were recovered in a few hours
  - Anik E2 - Loss of service for 6 months
- 11th January 1997
  - Telstar 401 - Total loss – Insurance payout $132m
- 19th May 1998
  - Galaxy IV - Total loss – Insurance payout $165m
- 23rd Oct to 6th Nov 2003
  - 47 satellites reported malfunctions
  - Midori 2 - Total loss - US$640m – scientific satellite
- 5th Apr 2010
  - Galaxy 15 - Loss of service for 8 months - drifted around GEO – risk of collision
- 7th March 2012,
  - Sky Terra 1 - Safe mode, loss of service for a few days

- Very difficult to say if Space Weather was the cause – or rule it out