Project No 637302

Horizon 2020, Call: H2020-PROTEC-2014

PROGRESS: Prediction of Geospace Radiation Environment and Solar Wind Parameters

WP5, Low energy electrons model improvements to develop forecasting products

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PROGRESS Final Review Meeting, 2-3 August 2018

WP5 (led by FMI)

Work package 5

Work package number	5	Start Date or Starting Event			Month 1		
Work package title	Low energy electrons model improvements to develop forecasting products						
Participant number	2	4	1				
Short name of participant	FMI	SIST	USD				
Person/months per participant:	27	8	6				

Objectives

The objectives of WP 5 are:

- Develop an empirical solar wind and IMF driven model for low energy electrons in the plasma sheet;
- Adapt the IMPTAM to include proper diffusion coefficients provided by VERB radiation belts model;
- Provide the low energy seed population to VERB radiation belts model;
- Develop a trial version of forecast model for low energy electrons.

Deliverables

D5.1: Journal paper, ready for submission, on the solar wind and IMF driven model for low energy electrons in the plasma sheet (report, M12)

D5.2: Journal paper, ready for submission, on the results of incorporating of diffusion coefficients from VERB into IMPTAM (report, M24)

D5.3: Report on VERB-IMPTAM low energy seed population provided to VERB radiation belts model (report, M30)

D5.4: Trial version of forecast model for low energy electrons (report, M36)

DELIVERED

Personnel for the project in FMI

1. Leader: **Dr. Natalia Ganushkina**

2. Dr. Stepan Dubyagin and **Dr. Ilkka Sillanpää** (left project in March 2017) are the project's participants.

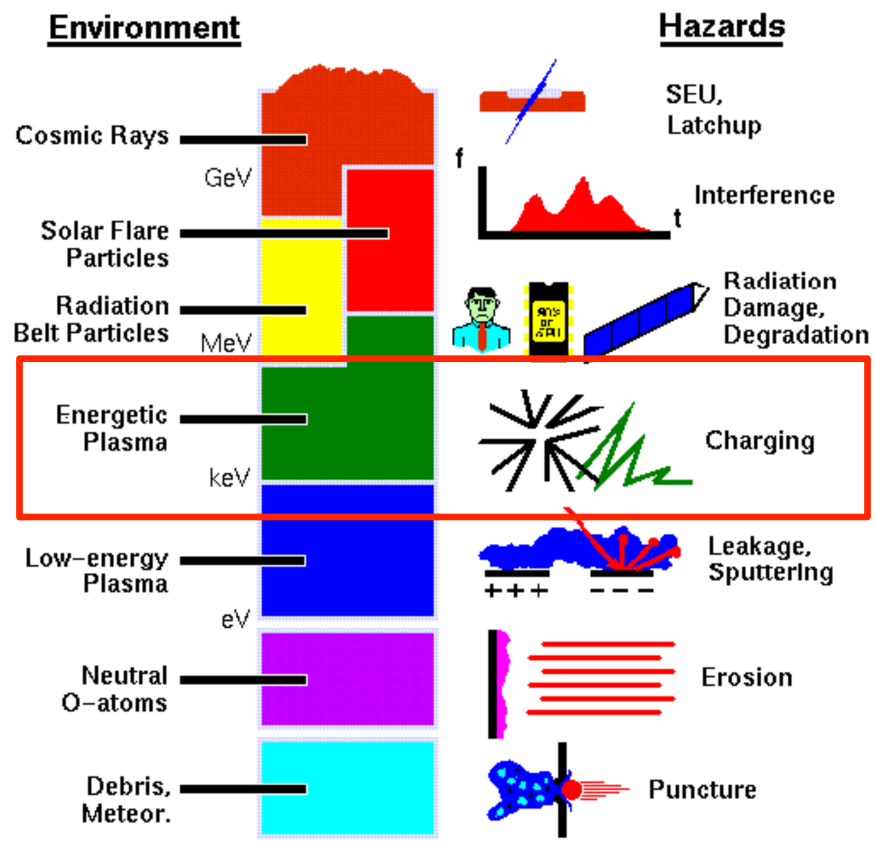
What is the interest in studying keV electrons in the inner magnetosphere?

- The distribution of low energy electrons population (1 to few hundreds of keV) constitutes the **seed population** further accelerated to MeV energies, critically important for **radiation belt** dynamics

  Energetic charged particles trapped in the **radiation belts** are a major source of damaging **space weather effects** on space- and ground-based assets.

- Surface charging by electrons with < 100 keV can cause significant damage and spacecraft anomalies

  electrostatic discharges causing **EM interferences** or local degradations, sustained **arcs** and system or mission destruction in the worst cases.



Source: European Space Agency, Space Environment and Effects Analysis Section

Boundary conditions in the plasma sheet for modeling of keV electrons

Near-Earth plasma sheet is the source for keV electrons in the inner magnetosphere.
In the near-Earth plasma sheet, continuous measurements of plasma sheet electrons are not available, in contrast to geostationary orbit.

The electron flux at the keV energies is largely determined by convective and substorm-associated electric fields and varies significantly with geomagnetic activity driven by the solar wind [*Mauk and Meng*, 1983; *Kerns et al.*, 1994; *Liemohn et al.*, 1998; *Ganushkina et al.*, 2013, 2014].

Studies on keV electrons: *Korth et al*. [1999], *Denton et al*. [2005], *Sicard-Piet et al*. [2008], *Denton et al*. [2015] (LANL MPA and SOPA electron data), *Friedel et al*. [2001] (Polar Hydra instrument), *Kurita et al*. [2011] (THEMIS spacecraft), *Asnes et al.,* [2008], *Burin des Roziers et al.* [2009] (GEOTAIL and CLUSTER data)

No solar wind driven empirical relations for electron fluxes or moments of electron distribution function which can be used easily for radiation belt modeling.

Solar wind driven empirical relations for moments of electron distribution function which can be used easily for radiation belt modeling*: Dubyagin et al.* [2016] (THEMIS)

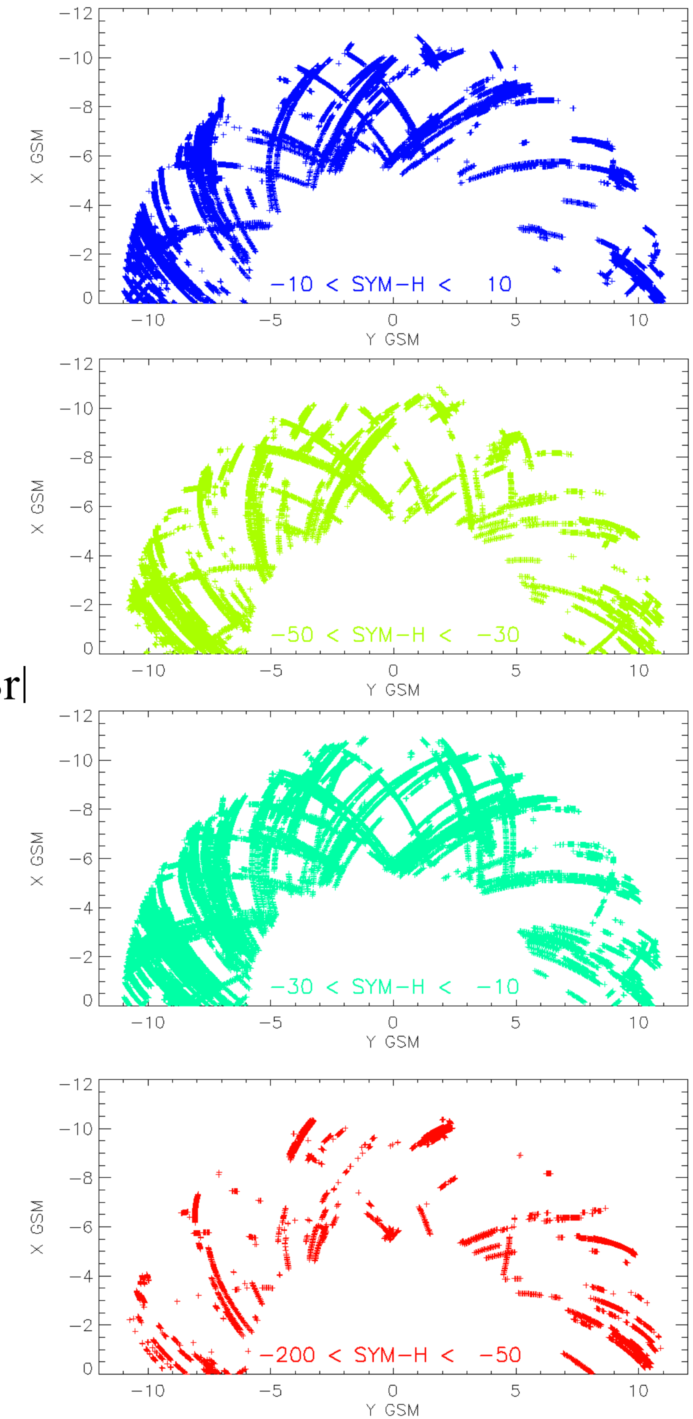
Usage of THEMIS data

THEMIS plasma moments for ions and electrons used:
ESA electrons: 30eV - 30 keV;
ions: 30eV - 25 keV
SST ions and electrons ~25 keV - 300 keV

Data selection:
- THEMIS A, D, E probes
- Probes are in the central part of the plasma sheet |Bz| > |Br|
- Storm-time intervals 2007-2013,
  SYM-H<-50 , 1 day before, 1 day after

Ni = Ne test: $$N_i / 1.5 < N_e < 1.5 N_i$$

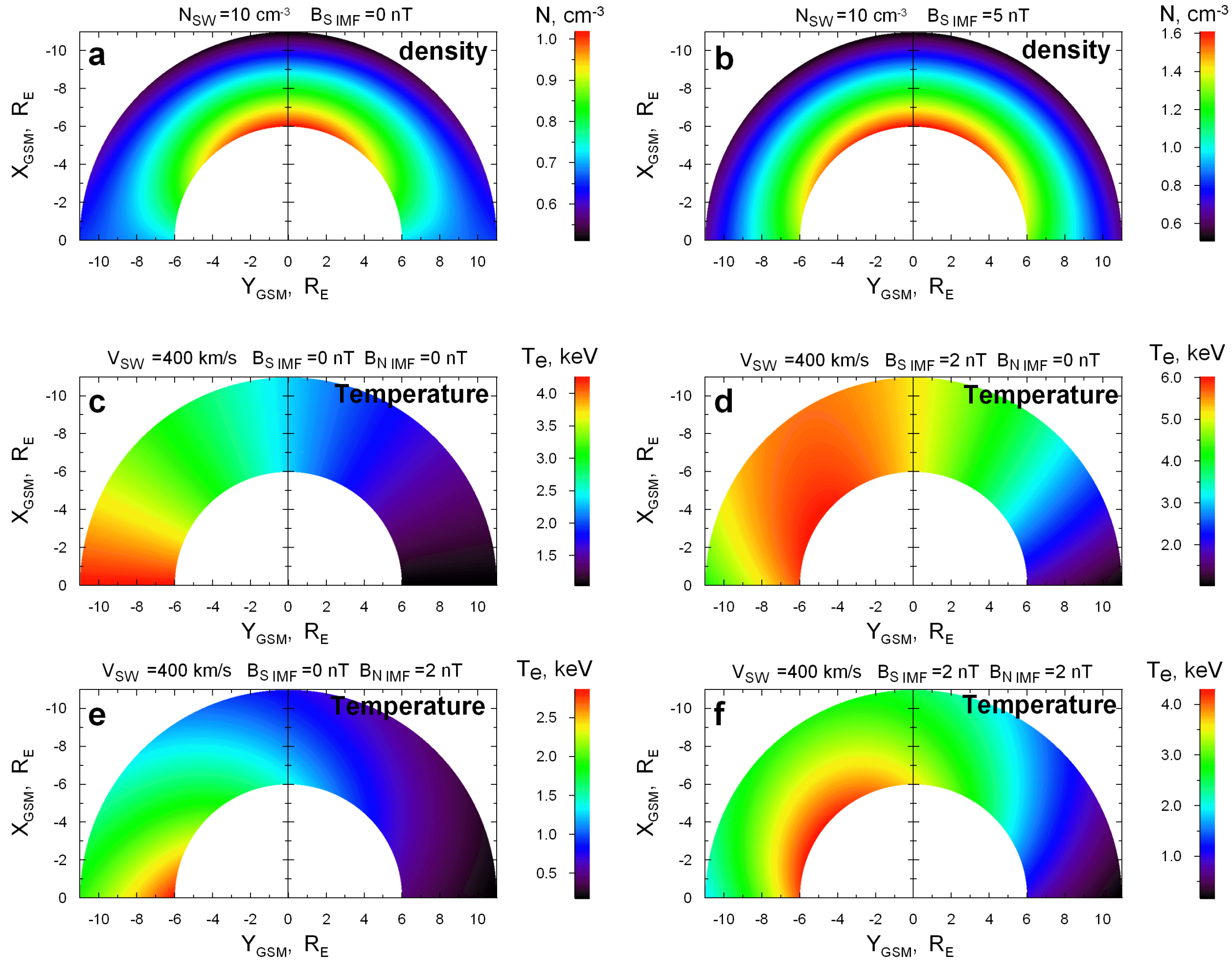
Plasma moments computed using last calibration procedures. After synchronization of the solar wind data with THEMIS plasma moments we got ~45,000 datapoints at 1.6 min resoluton.



Solar wind driven variations of electron plasma sheet temperature and density during storm times

Dubyagin et al. [2016]

THEMIS ESA and SST data



Spatial dependence

$$R = \sqrt{x^2 + y^2 + z^2} \qquad \phi = \arctan(-y/x)$$

Normalization

$$N_{SW} = \langle N_{SW} \rangle / 10cm^{-3}$$

$$V_{SW} = \langle V_{SW} \rangle / 400km/s$$

$$B_S = \langle B_S^{IMF} \rangle / 2nT$$

$$B_N = \langle B_N^{IMF} \rangle / 2nT$$

$$r = R / 10R_E$$

$$\phi = \phi / 90°$$

Electron density model: 7 coefficients

positive

$$N_e = 1.23 - 1.01 \cdot r + 0.874 \cdot r\phi^2 - 0.82 \cdot \phi^2 + 0.392 \cdot N_{SW} + (0.521 - 0.474 \cdot r) \cdot B_S$$

Electron temperature model: 9 coefficients

positive positive negative

$$T_e = [-0.0215 - 0.426 \cdot \phi + 0.874 \cdot V_{SW} + (0.587 - 0.538 \cdot r\phi^2) \cdot B_S^{0.32} - 0.489 \cdot r \cdot B_N^{0.36}]^{2.31}$$

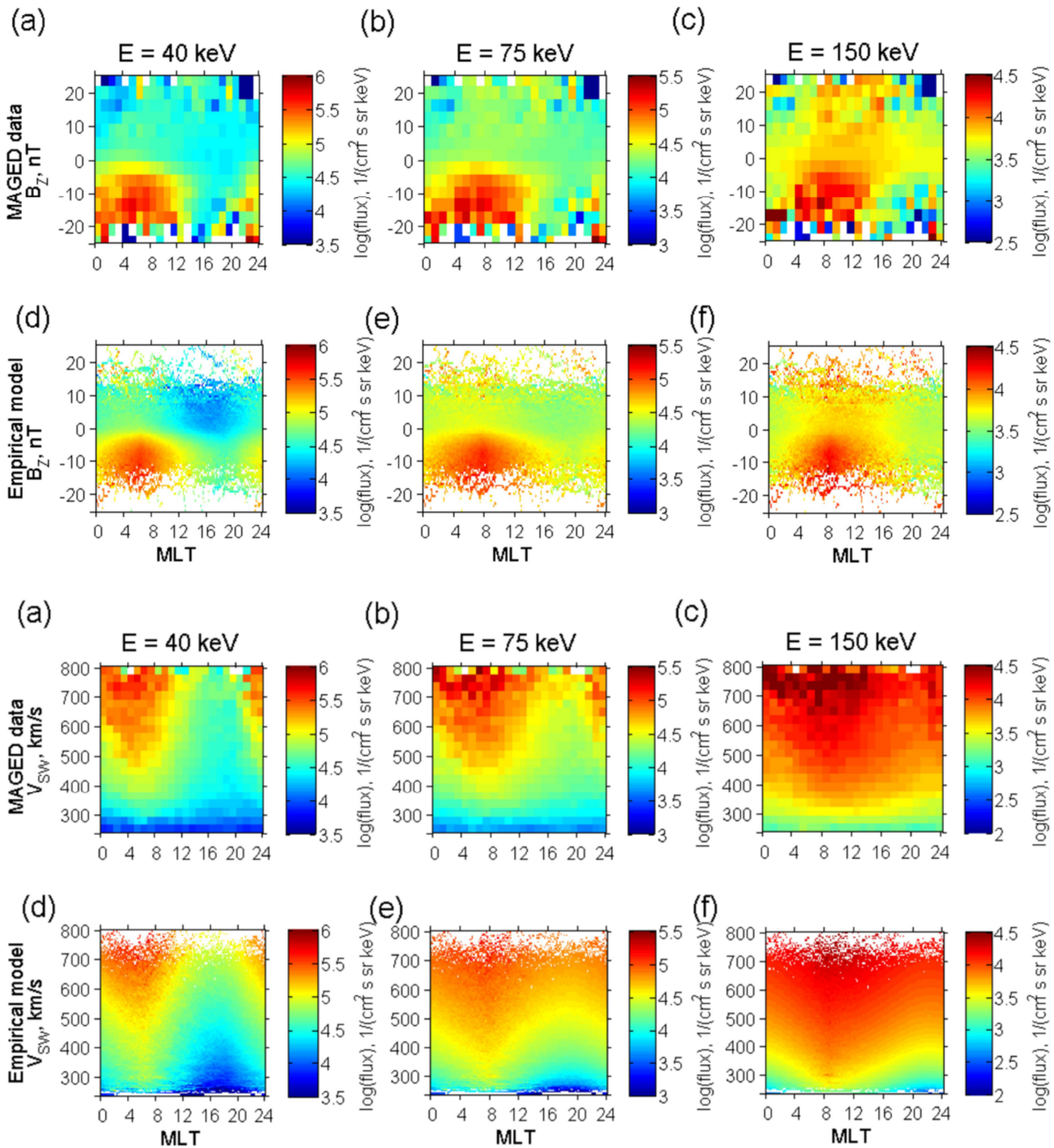
Driving parameters:
N_{SW}, V_{SW}, IMF B_S, IMF B_N

Solar wind driven variations of keV electron fluxes at GEO

GOES-13MAGED data during Jan 2011 – Dec 2015 for 40, 75, and 150 keV electrons analyzed in terms of dependencies on SW and IMF parameters.

Empirical model developed in *Sillanpää et al.* [2017]

Driving parameters: IMF B_Z and V_{SW}



Inner Magnetosphere Particle Transport and Acceleration Model (IMPTAM) for low energy electrons

(*Ganushkina et al., 2013, 2014, 2015*)

- ♦ traces **electrons** with arbitrary pitch angles from the plasma sheet to the inner L-shell regions with energies up to **300 keV** in time-dependent magnetic and electric fields
- ♦ traces a distribution of particles in the **drift approximation** under the conservation of the 1st and 2^{nd} adiabatic invariants. Liouville theorem is used to gain information of the entire distribution function
- ♦ for the obtained distribution function, we apply **radial diffusion** by solving the radial diffusion equation
- ♦ electron losses: convection outflow and pitch angle diffusion by the **electron lifetimes**
- ♦ advantage of IMPTAM: can utilize any magnetic or electric field model, including self-consistent magnetic field and substorm-associated electromagnetic fields.

Electron losses in the inner magnetosphere

Electron losses occur on the time scales of minutes or hours which is much shorter than those times for ions.

In the inner magnetosphere, the dominating loss process is pitch-angle scattering due to wave-particle interactions.

Chorus waves contribute significantly to the scattering processes of keV electrons **outside the plasmapause**.
Electron pitch angle scattering occurs due to interactions with the plasmaspheric **hiss waves inside the plasmasphere**.

It is difficult to quantify globally the electron losses due to interaction with waves, since the rate of pitch-angle diffusion depends on the wave amplitude, wave frequency, and wave normal distributions, as well as the plasma density and background magnetic field.

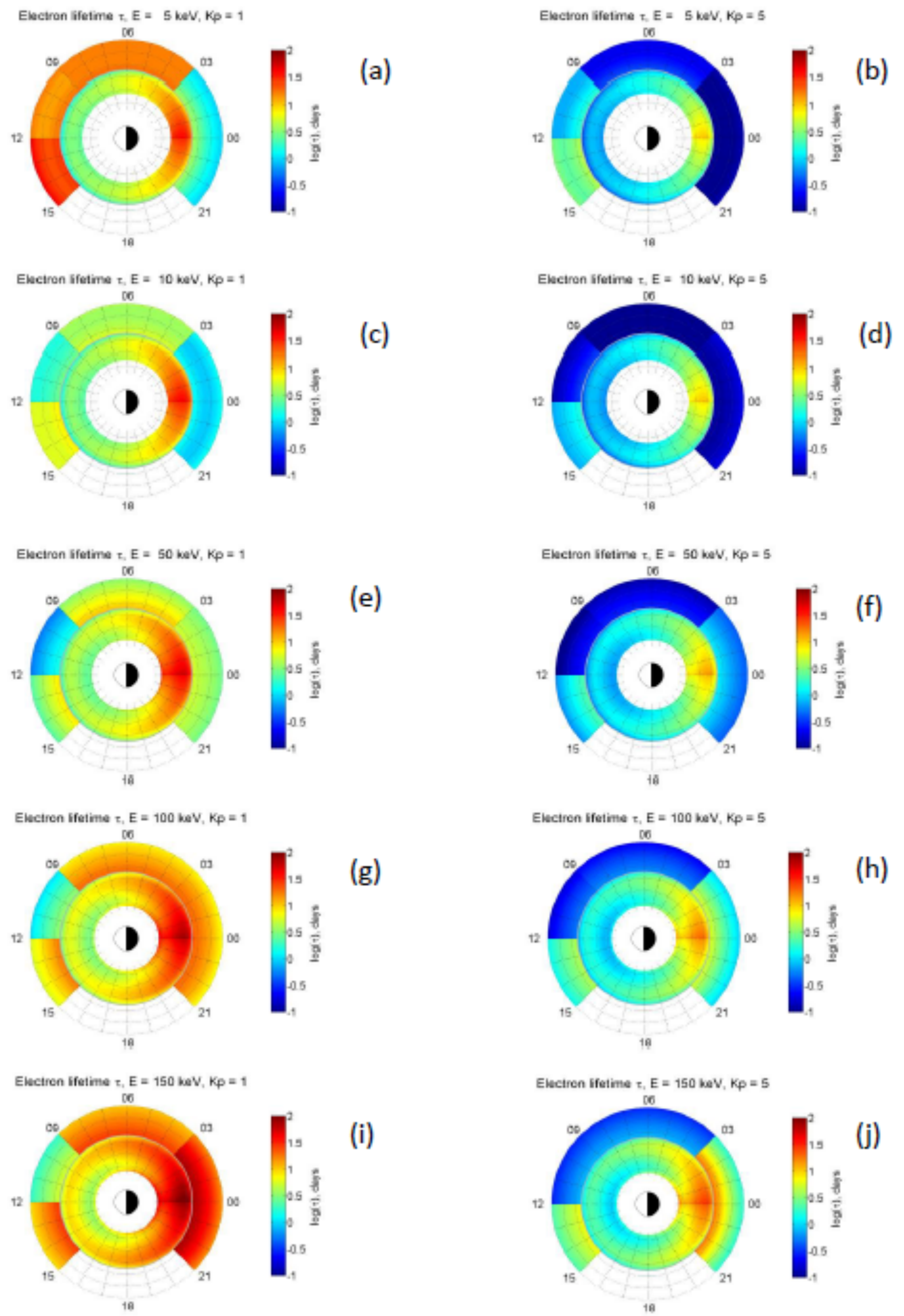
Models used:

1. *Shprits and Orlova* [2014], electron lifetimes due to **chorus waves** at R=3-8 Re.
Activity depedence is parameterized by Kp index.
2. *Orlova et al.,* [2016] electron lifetimes due to plasmaspheric **hiss waves**. Empirical model *Spasojevich et al.,* [2015] of hiss intensity obtained from Van Allen probe data were used at R=1.5-5.5 Re. Activity dependence is parameterized by Kp index.

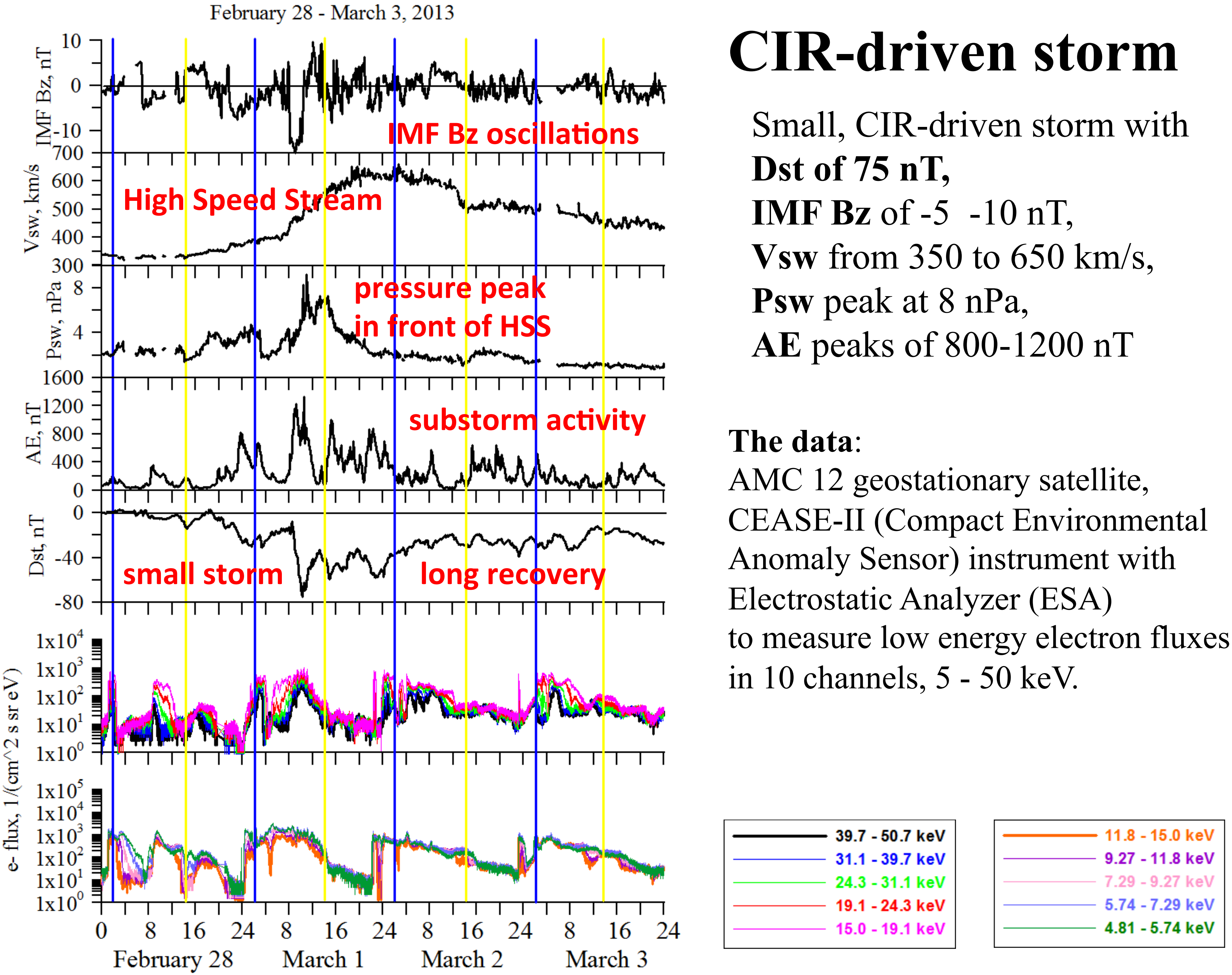
Electron losses in IMPTAM

$$\frac{\partial f}{\partial t} = \frac{\partial f}{\partial \phi} \cdot V_{\phi} + \frac{\partial f}{\partial R} \cdot V_R + S - \frac{f}{\boldsymbol{\tau}}$$

The electron losses due to wave-particle interaction are introduced in IMPTAM as an electron lifetime **τ** given by *Shprits and Orlova* [2014] and *Orlova et al.,* [2016] models



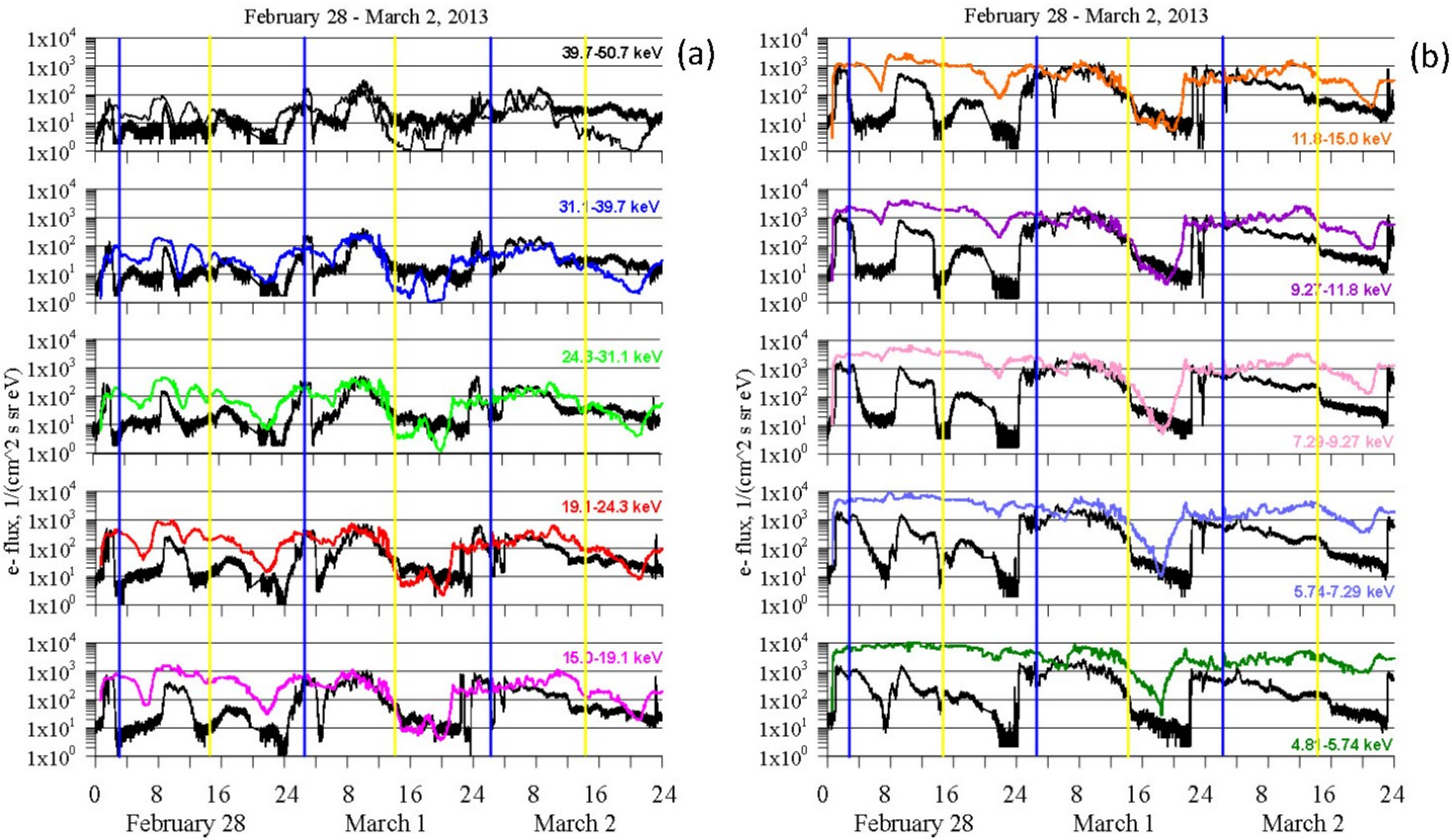
CIR-driven storm



Small, CIR-driven storm with
Dst of 75 nT,
IMF Bz of -5 -10 nT,
Vsw from 350 to 650 km/s,
Psw peak at 8 nPa,
AE peaks of 800-1200 nT

The data:
AMC 12 geostationary satellite,
CEASE-II (Compact Environmental Anomaly Sensor) instrument with Electrostatic Analyzer (ESA)
to measure low energy electron fluxes in 10 channels, 5 - 50 keV.

IMPTAM output along AMC 12 satellite orbit



Ganushkina et al. [2017], submitted to JGR, still under review

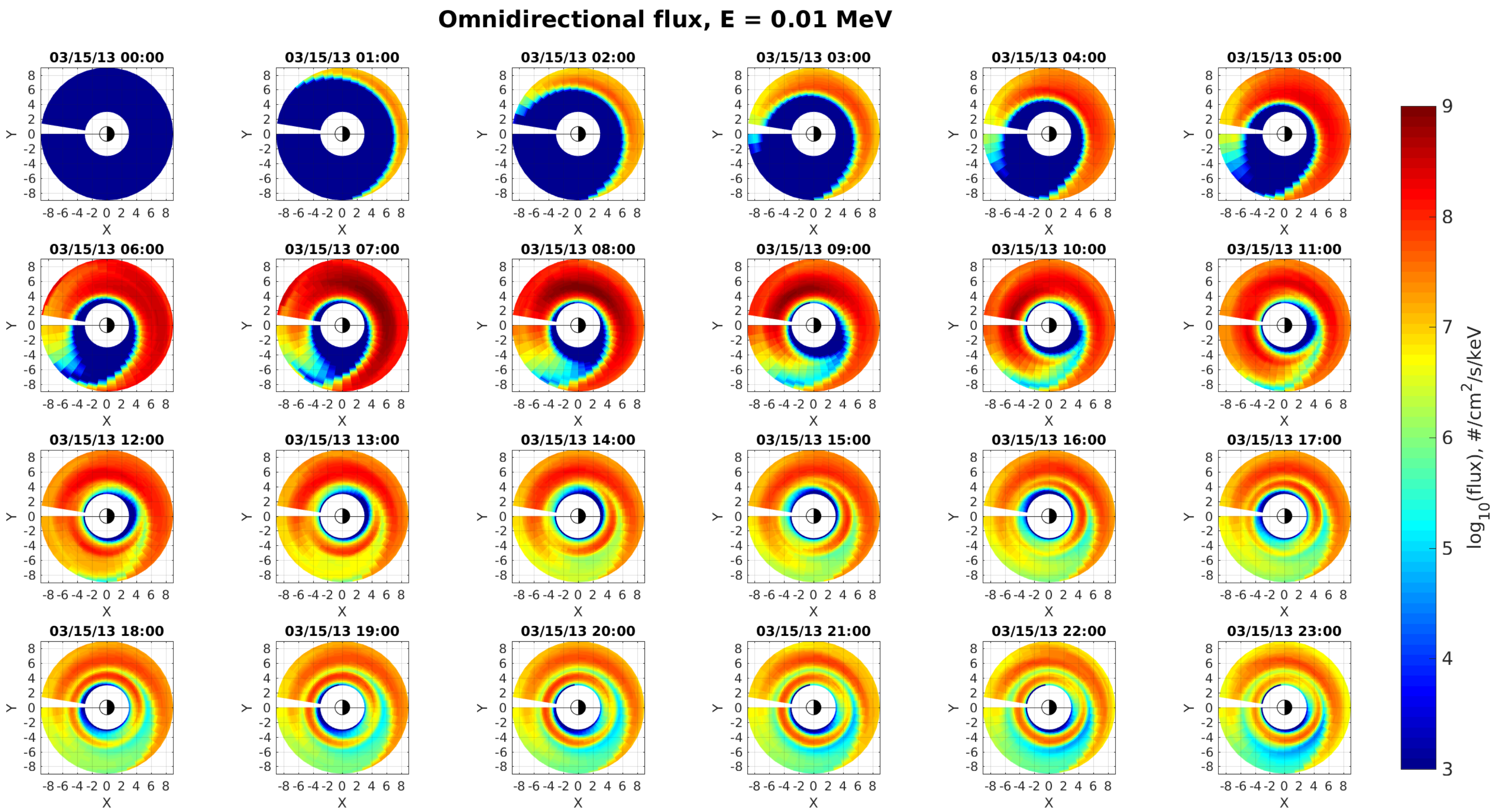
Low energy seed population to VERB radiation belts model

IMPTAM output for VERB: maps in (L, MLT, pitch angle, energy) of low energy electrons
Provided to GFZ as seed keV population for VERB for further accelerations to MeV energies, format explained.

```
<header
    step="480"   INSIDE STEP
    timeRun="57600"   TIME IN SECONDS
    time="1054224000"> UNIX TIME
    <data type="grid">
        <grid
            info="Rs, Re" RADIUS, ACTUALLY, L*, UNITLESS
            node="{1 30 3 9}"> 1-LINEAR GRID, 30-NUMBER OF INTERVALS IN R, 3-MIN IN R, 9-MAX IN R
            <grid
                info="Longitude, deg" LONGITUDE, NOT MLT, STARTS AT NOON, LONGITUDE=0 AT NOON
                node="{3 60}"/> FROM 0 TO 2PI, 60-NUMBER OF INTERVALS IN LONGITUDE
        </grid>
        <data
            type="grid">
            <grid
                info="PitchAngle, deg"
                 node="[90 88 86 84 82 80 78 76 73 70 67 64 60 55 50 45 40 35 30 25 20 15 10]">
                <grid
                    info="Energy, keV"
                     node="{2 30 1 300}"/> 2-LOGARITHMIC, 30-NUMBER OF INTERVALS IN ENERGY FROM 1 KEV TO 300 KEV
            </grid>
            <data
                type="unit"
                info="flux, 1/cm^2*sec*keV*sr"/>
        </data>
    </data>
</header>
```

4D arrays of electron flux in 1/(cm2 s sr keV) in (L, MLT, pitch angle, energy). Energy is the innermost index. The dimension of the array is [31][60][23][31].
All explanations are in the headers of each .dat file, output is provided every 30 minutes during the simulation.

Illustration of omnidirectional fluxes for 10keV as a function of R and MLT



VERB-IMPTAM coupling results

VERB code utilizes the seed population and make its own verification. Coupled VERB and IMPTAM are validated against observations in the heart of the outer radiation belts. VERB-IMPTAM will form alternative to NARMAX-VERB combination of codes.

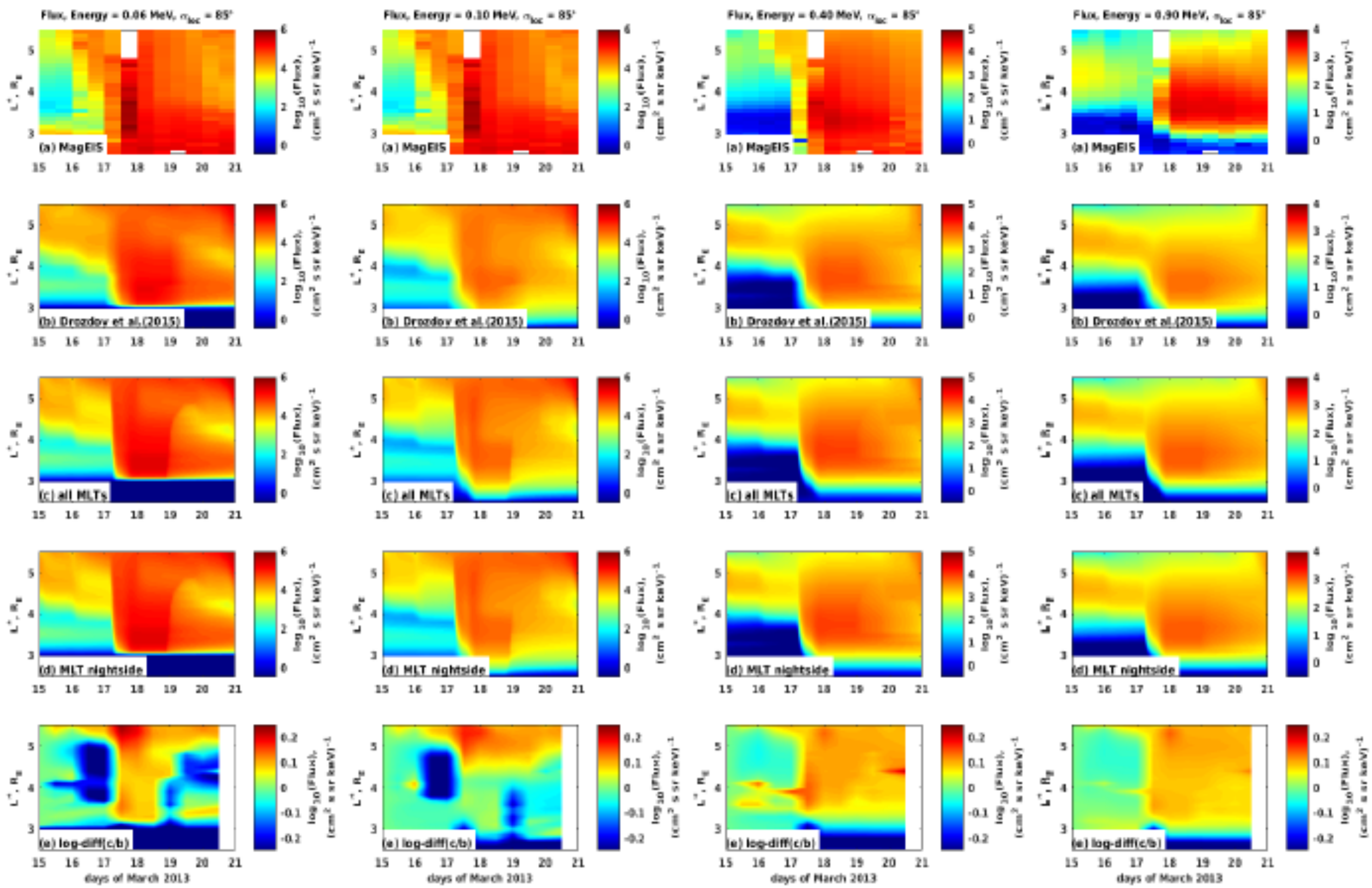
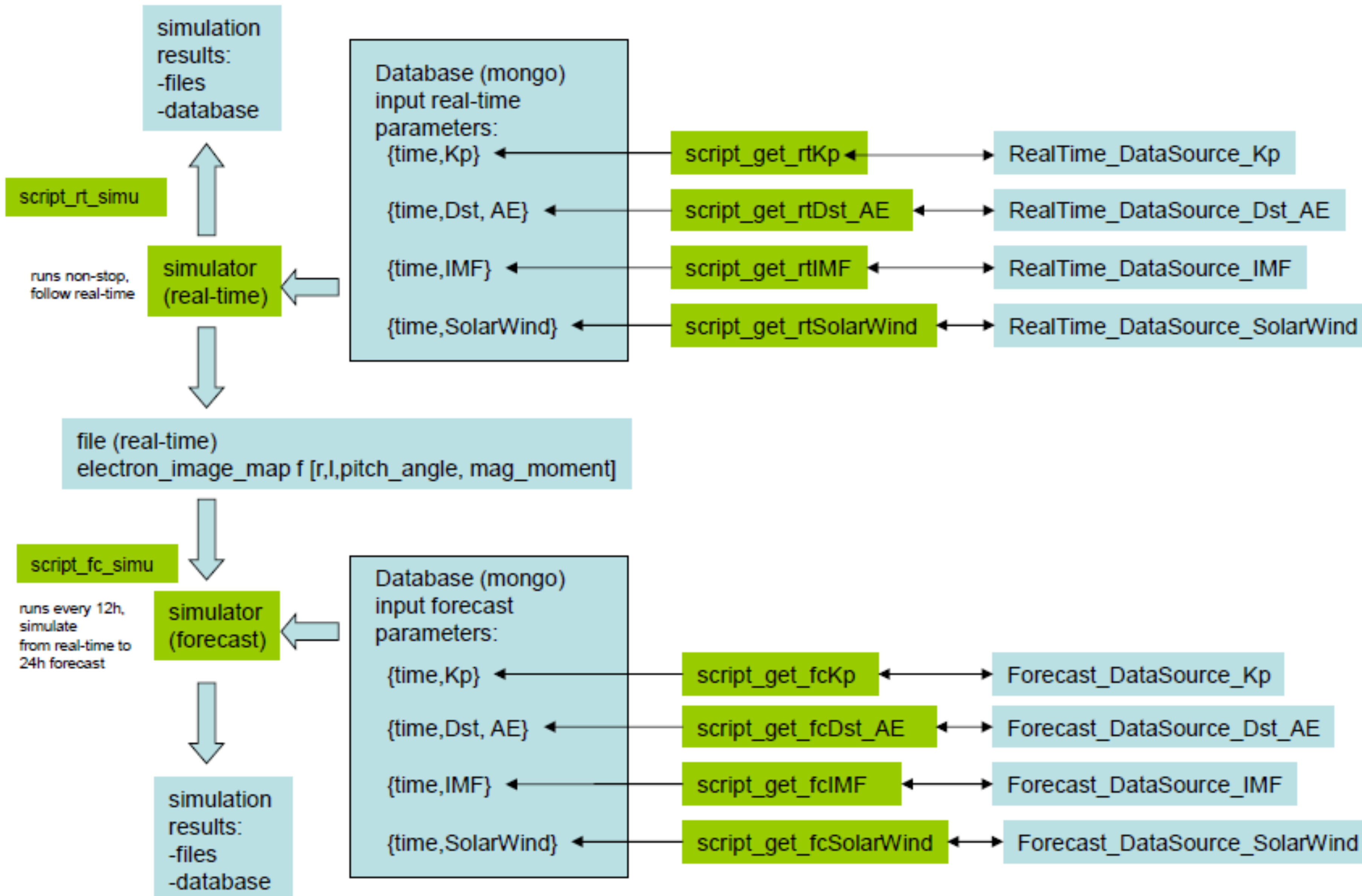


Figure 1: Electron fluxes as function of L^* and time. Each column displays the results of our simulation for local pitch angle $\alpha_{loc} = 85°$ at fixed energies 0.06 MeV, 0.10 MeV, 0.40 MeV and 0.90 MeV. The panels in each column show: a) MagEIS data, b) base simulation from Drozdov et al. (2015), c) VERB-simulation using IMPTAM-fluxes averaged over all MLTs, d) VERB-simulation using IMPTAM-fluxes averaged over the night side, e) logarithmic difference calculated between panels b) and c) for the corresponding energy.

IMPTAM as a forecasting tool architecture



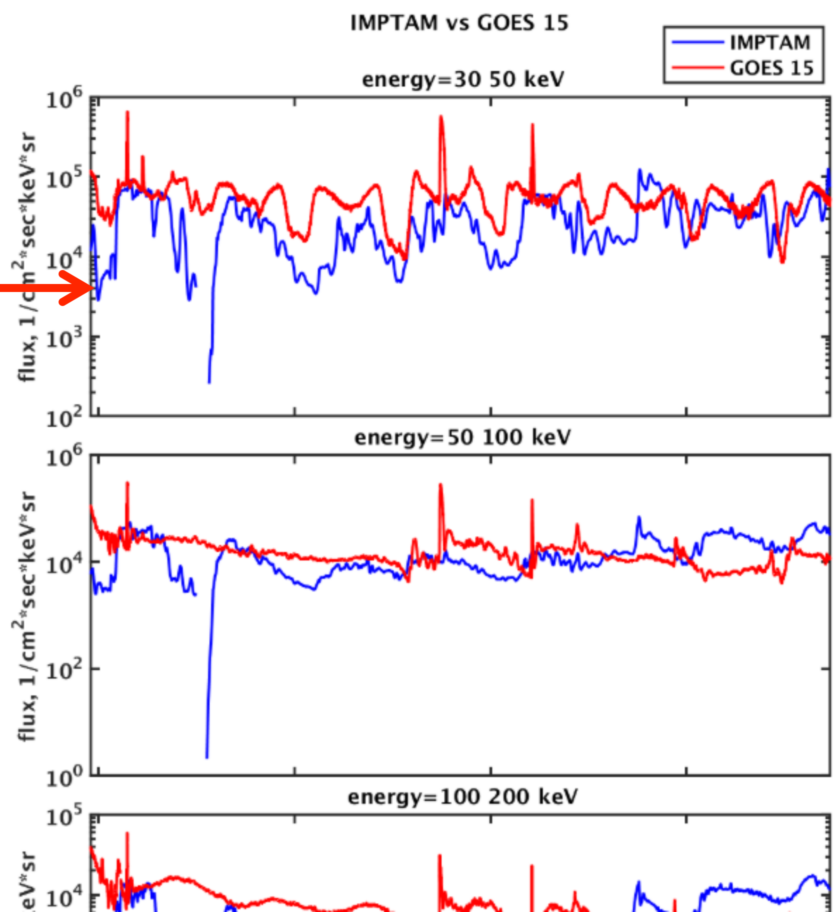
https://ssg.group.shef.ac.uk/progress2/html/imptam_results_ivg15.phtml

PRediction Of Geospace Radiation Environment and Solar wind parameterS

Caution: PROGRESS test web site

Results

IMPTAM Electron Fluxes at Geosynchronous Orbit



Developing a trial version of forecast model for low energy electrons

IMPTAM is driven by the real time solar wind and IMF parameters, such as,
Nsw, PSW, VSW, IMF BY, BZ, and B_IMF

AWSoM + SWIFT Predictions
https://warwick.ac.uk/fac/sci/physics/research/cfsa/people/bennett/swift-data/results3/

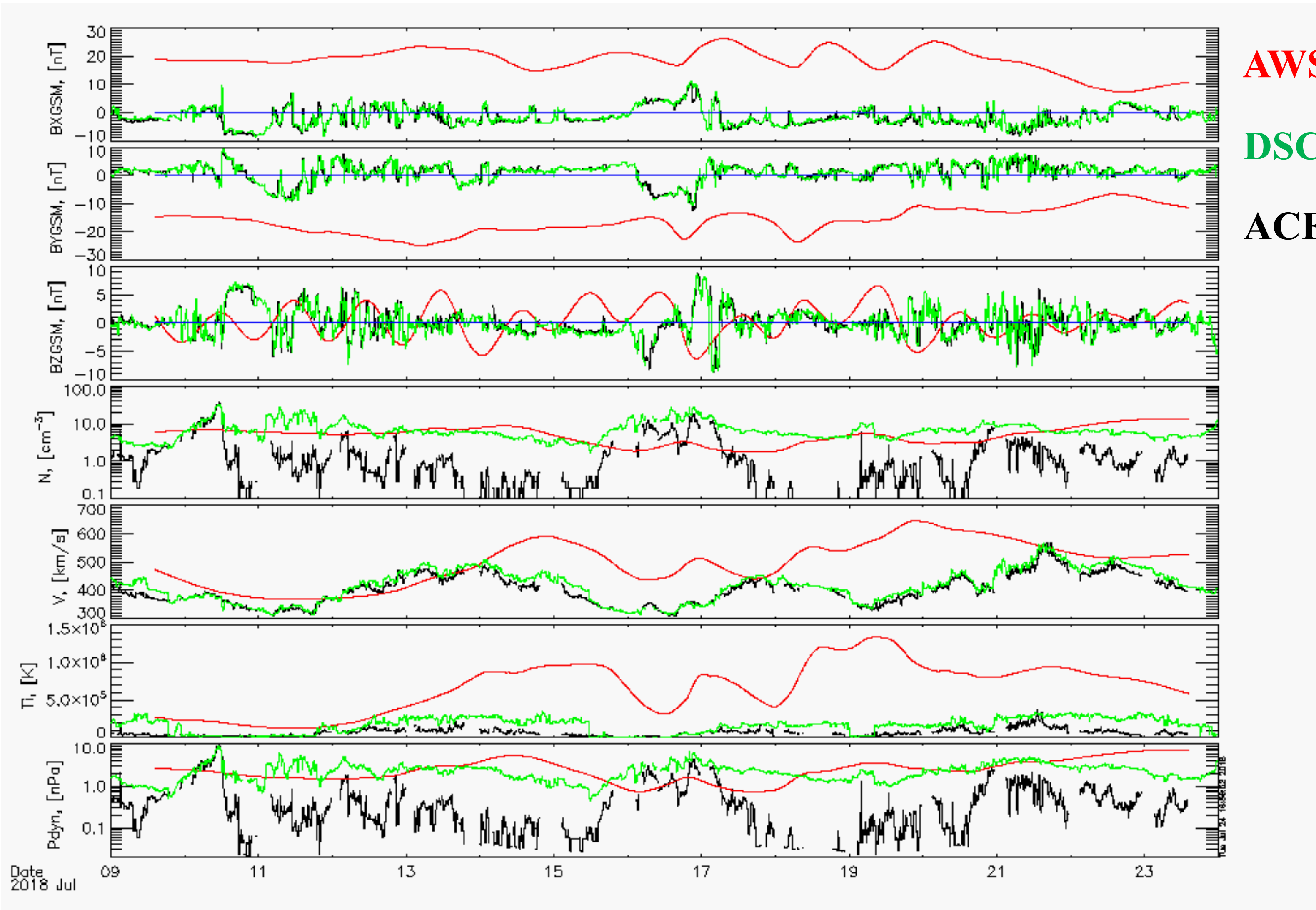
At present:
Getting the predictions correctly in real time

No long-term predictions for geomagnetic indices available

Near future: Kp and Dst long-term predictions using Sheffield models

satellite	"Earth"
end_date	"2017-12-07T12:08"
arrays	
Temperature_ion	{...}
Energy_electron	{...}
Time	{...}
Y_Position	{...}
Z_Position	{...}
Temperature_electron	{...}
Energy_ion	{...}
Unix time	{...}
Pressure	{...}
Pressure_ion	{...}
Rho	{...}
Bx	{...}
By	{...}
Bz	{...}
Vx	{...}
X_Position	{...}
Pressure_electron	{...}
Cs	{...}
Vy	{...}
Vz	{...}
co-ordinates	"Cartesian"
swift_version	"0.1.4"
start_date	"2017-11-23T12:04"
output_version	2
magnetogram_date	"2017-12-03T12:03"
co-ordinate system	"GSM"
swift_run_date	"Sat Nov 25 05:01:17 2017"
swift_commit_id	"v0.1.4-616-gdb0248c-dirty"

AWSoM + SWIFT predictions as compared to ACE and DSCOVR data

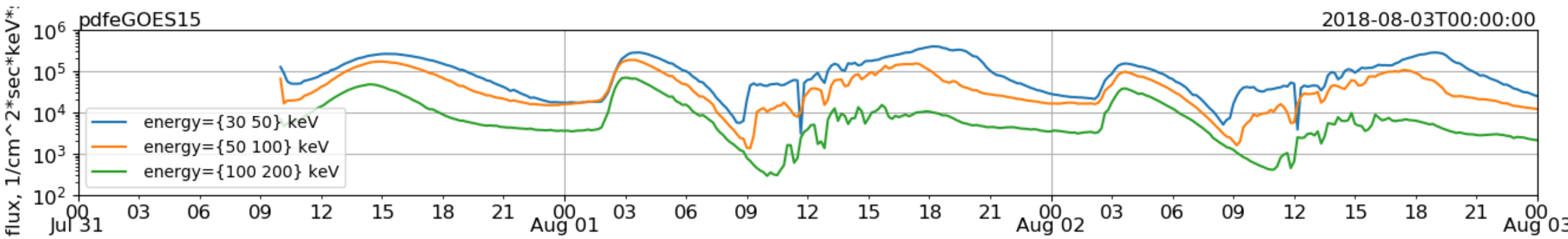


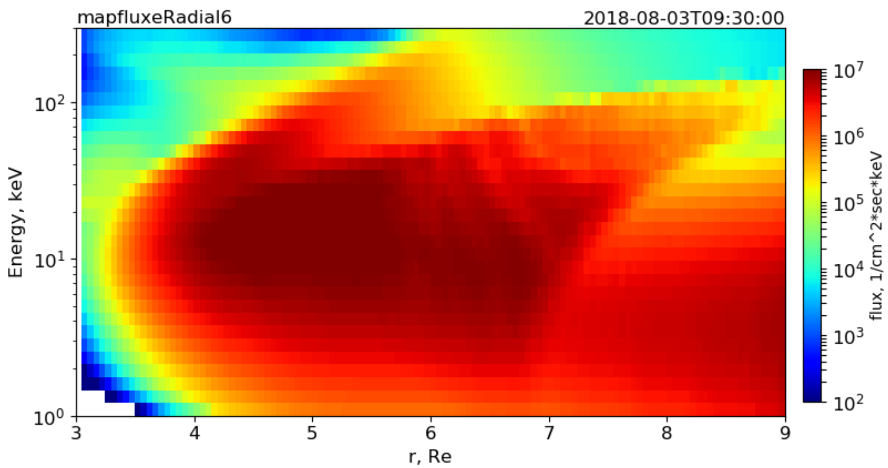
AWSoM + SWIFT

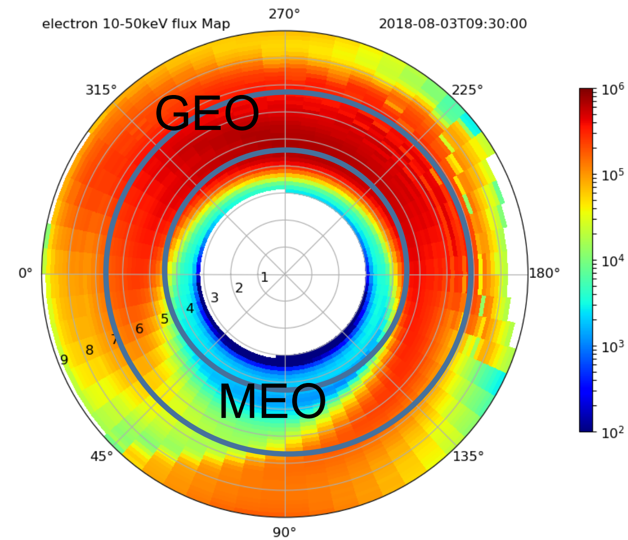
DSCOVR

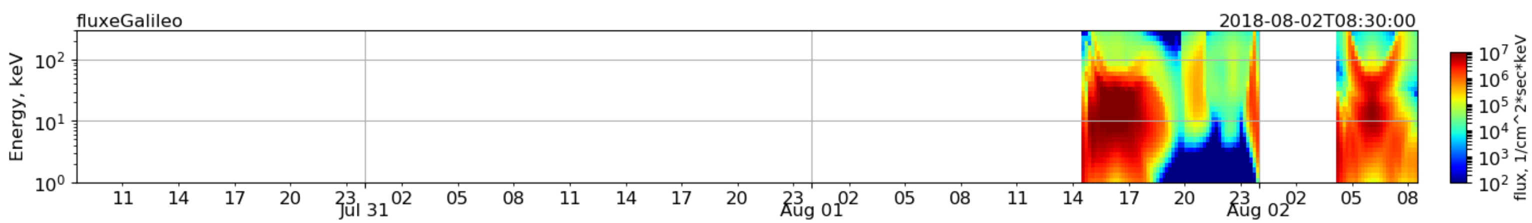
ACE

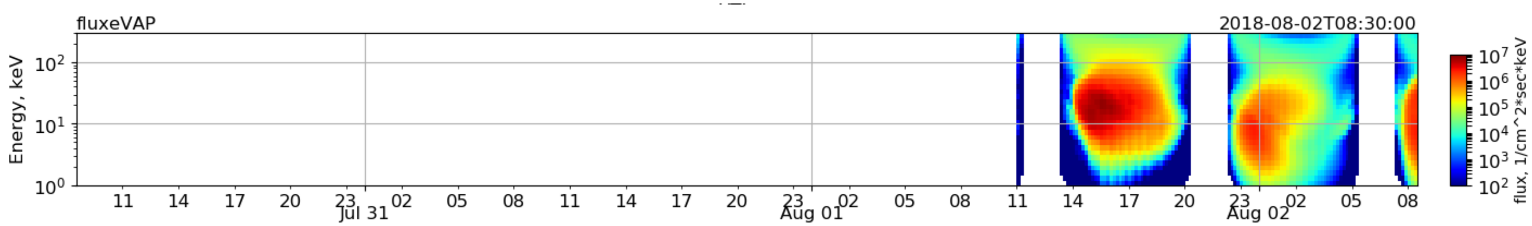
IMPTAM prediction examples











Dissemination activities (January 2015 – July 2018)

Published papers	17
Submitted papers	4
Invited Oral Presentations	16
Contributed Oral Presentations	16
Poster Presentations	3

Dissemination activities, FMI (1)

<u>Papers, published:</u>

1. Ilie, R., **M. W. Liemohn**, G. Toth, **N. Yu Ganushkina**, and L. K. S. Daldorff (2015), Assessing the role of oxygen on ring current formation and evolution through numerical experiments, *J. Geophys. Res. Space Physics*, 120, doi: 10.1002/2015JA021157.
2. **N. Y. Ganushkina**, **M. W. Liemohn**, **S. Dubyagin**, I. A. Daglis, I. Dandouras, D. L. De Zeeuw, Y. Ebihara, R. Ilie, R. Katus, M. Kubyshkina, S. E. Milan, S. Ohtani, N. Ostgaard, J. P. Reistad, P. Tenfjord, F. Toffoletto, S. Zaharia, and O. Amariutei, Defining and resolving current systems in geospace, *Ann. Geophys*., 33, 1369–1402, 2015, doi:10.5194/angeo-33-1369-2015. http://www.ann-geophys.net/33/1369/2015/angeo-33-1369-2015.pdf
3. **Dubyagin, S., N. Ganushkina**, **M. Liemohn**, and M. Kubyshkina (2015), Can ring current stabilize magnetotail during steady magnetospheric convection?, *J. Geophys. Res. Space Physics*, 120, doi:10.1002/2015JA022003.
4. Ilie, R., **N. Ganushkina**, G. Toth, **S. Dubyagin**, and **M. W. Liemohn** (2015), Testing the magnetotail configuration based on observations of low altitude isotropic boundaries during quiet times, *J. Geophys. Res. Space Physics*, 120, doi:10.1002/2015JA021858.
5. **Dubyagin, S., N. Y. Ganushkina, I. Sillanpää**, and A. Runov (2016), Solar wind-driven variations of electron plasma sheet densities and temperatures beyond geostationary orbit during storm times, J. Geophys. Res. Space Physics, 121, doi:10.1002/2016JA022947.
6. Grigorenko, E. E., E. A. Kronberg, P. W. Daly, **N. Y. Ganushkina**, B. Lavraud, J.-A. Sauvaud, and L. M. Zelenyi (2016), Origin of low proton-to-electron temperature ratio in the Earth’s plasma sheet, J. Geophys. Res. Space Physics, 121, doi:10.1002/2016JA022874.

Dissemination activities, FMI (2)

Papers, published:

7. **Liemohn, M. W**., **N. Y. Ganushkina**, R. Ilie, and D. T. Welling (2016), Challenges associated with near-Earth nightside current, J. Geophys. Res. Space Physics, 121, 6763–6768, doi: 10.1002/2016JA022948.
8. **Walker, S. N**., A. G. Demekhov, S. A. Boardsen, **N. Y. Ganushkina**, D. G. Sibeck, and **M. A. Balikhin** (2016), Cluster observations of non–time continuous magnetosonic waves, J. Geophys. Res. Space Physics, 121, doi:10.1002/2016JA023287.
9. **Boynton, R. J., M. A. Balikhin**, D. G. Sibeck, **S. N Walker**, S. A Billings, and **N. Ganushkina** (2016), Electron flux models for different energies at geostationary orbit, Space Weather, 14, doi:10.1002/2016SW001506.
10. **N. Ganushkina**, A. Jaynes, **M. Liemohn**, Space Weather Effects Produced by the Ring Current Particles, Space Science Reviews, Volume 212, Issue 3–4, pp 1315–1344, DOI 10.1007/s11214-017-0412-2, 2017.
11. John D. Haiducek, Daniel T. Welling, **Natalia Y. Ganushkina**, Steven K. Morley, and Dogacan Su Öztürk, SWMF Global Magnetosphere Simulations of January 2005: Geomagnetic Indices and Cross-Polar Cap Potential, Space Weather, 15, https://doi.org/10.1002/2017SW001695 accepted, 2017.
12. **I. Sillanpää, N. Yu. Ganushkina, S. Dubyagin**, and J. V. Rodriguez, Electron fluxes at geostationary orbit from GOES MAGED data, Space Weather, 15, https://doi.org/10.1002/2017SW001698, 2017.
13. Grigorenko, E. E., **Dubyagin, S.,** Malykhin, A. Y., Khotyaintsev, Y. V., Kronberg, E. A., Lavraud, B., & **Ganushkina, N. Y.** (2018). Intense current structures observed at electron kinetic scales in the near-Earth magnetotail during dipolarization and substorm current wedge formation. Geophysical Research Letters, 45. https://doi.org/10.1002/2017GL076303

Dissemination activities, FMI (3)

<u>Papers, published:</u>

14. **Ganushkina, N. Y., Liemohn, M. W., Dubyagin**, S. (2018). Current systems in the Earth's magnetosphere. Reviews of Geophysics, 56. https://doi.org/10.1002/2017RG000590
15. Kubyshkina, M., Semenov, V., Erkaev, N., Gordeev, E., **Dubyagin, S., Ganushkina, N**., & Shukhtina, M. (2018). Relations between vz and Bx components in solar wind and their effect on substorm onset. Geophysical Research Letters, 45. https://doi.org/10.1002/2017GL076268
16. **S. Dubyagin, N. Yu. Ganushkina**, and V. Sergeev (2018), Formation of 30 keV proton isotropic boundaries during geomagnetic storms, Journal of Geophysical Research: Space Physics, 123. https://doi.org/10.1002/2017JA024587.
17. Andrey Y. Malykhin, Elena E. Grigorenko, Elena A. Kronberg, Rositza Koleva, **Natalia Y. Ganushkina**, Ludmila Kozak, and PatrickW. Daly, Contrasting dynamics of electrons and protons in the near-Earthplasma sheet during dipolarization, Annales Geophysicae, 36, 741–760, 2018. https://doi.org/10.5194/angeo-36-741-2018

Dissemination activities, FMI (4)

<u>Papers, submitted, under review:</u>

1. **M. Liemohn, N. Yu. Ganushkina**, D. L. De Zeeuw, L. Rastaetter, M. Kuznetsova, D. T. Welling, G. Toth, R. Ilie, T. I. Gombosi, and **B. van der Holst**, Real-time SWMF at CCMC: assessing the Dst output from continuous operational simulations, submitted to *Space Weather*, May 2018.

2. J. D. Haiducek, **N. Y. Ganushkina, S. Dubyagin**, D. T. Welling, On the accuracy of adiabaticity parameter estimations using magnetospheric models , submitted to *JGR Space*, June 2018.

3. A. J. Halford, A. C. Kellerman, K. Garcia-Sage, J. Klenzing, B. A. Carter, R. M. McGranaghan, T. Guild, C. Cid, C. J. Henney, **N. Yu. Ganushkina**, A. G. Burrell, M. Terkildsen, B. J. Thompson, A. Pulkkinen, J. P. McCollough, S. A. Murray, K. D. Leka, S. Fung, S. Bingham, B. M. Walsh**, M. W. Liemohn**, M. M. Bisi, S. K. Morley, D. T. Welling, Application Usability Levels: A Framework for Tracking a Project's Progress, submitted to *Space Weather*, June 2018.

4. **N. Yu. Ganushkina, I. Sillanpaa**, D. Welling, J. Haiducek, **M. Liemohn, S. Dubyagin**,

J. V. Rodriguez, Validation of Inner Magnetosphere Particle Transport and Acceleration Model (IMPTAM) on the long-term GOES MAGED measurements of keV electron fluxes at geostationary orbit, submitted to *Space Weather*, July 2018.

Dissemination activities, FMI (5)

<u>**Presentations**</u>:

<u>**Orals, invited**</u>

1.N. Ganushkina, S. Dubyagin, I. Sillanpää, Recent revisions of the IMPTAM model, **EGU General Assembly 2015**, Vienna, Austria, 12 – 17 April 2015.

2. **N. Ganushkina, S. Dugyagin, I. Sillanpää**, D. Pitchford, Substorm-associated effects in the variations of low energy electron fluxes in the inner magnetosphere: Does the substorm's strength matter? **Unsolved Problems in magnetospheric physics**, 6-12th September, 2015, Scarborough, UK.

3. **N. Ganushkina** and **S. Dugyagin**, Near-Earth plasma sheet as a seed population for the outer radiation belt, **Cluster 15th and Double Star 10th anniversary workshop**, 12-16 October 2015, Venice, Italy

4. **N. Ganushkina**, Low energy electrons in the inner Earth's magnetosphere, **Dynamical Processes in Space Plasmas**, April 3-10, 2016, Ein Bokek, Israel.

5. **N. Ganushkina, I. Sillanpää, S. Dugyagin**, D. Pitchford, J. Rodriguez, A. Runov, Low energy electrons in the inner Earth's magnetosphere, **European Geosciences Union General Assembly 2016**, Vienna, Austria, 17–22 April 2016.

6. **I. Sillanpää, N. Ganushkina, S. Dubyagin**, IMPTAM Runs at CCMC, **8th CCMC Workshop**, Annapolis, MD, USA, April 11-15, 2016.

7. **N. Ganushkina**, Space weather effects in the ring current, **The Scientific Foundation of Space Weather, International Space Science Institute Workshop**, Bern, Switzerland, 27 June – 1 July 2016.

8. **N. Ganushkina and S. Dubyagin**, Forecasting the keV-electrons in the inner Earth's magnetosphere responsible for surface charging, **International Symposium on Recent Observations and Simulations of the Sun–Earth System III**, Golden Sands, Bulgaria, September 12–16, 2016.

9. N. Ganushkina, S. Dubyagin, I. Sillanpää, Modeling of the low-energy near-Earth electron environment using IMPTAM, **Global Modelling of the Space Weather Chain**, 24 – 28 October 2016, Aalto University, Espoo, Finland.

Dissemination activities, FMI (6)

Presentations:

Orals, invited

10. **Natalia Ganushkina, Stepan Dubyagin, Ilkka Sillanpää**, From studying electron motion in the electromagnetic fields in the inner magnetosphere to the operational nowcast model for low energy (< 200 keV) electron fluxes responsible for surface charging, **Thirteenth European Space Weather Week**, November 14-18, 2016, Oostende, Belgium.

11. **N. Ganushkina** and SPACESTORM and PROGRESS teams, Understanding the radiation environment in the Earth's inner magnetosphere, **Fourth Joint Cluster-THEMIS Workshop, incorporating ARTEMIS**, 7-12 November 2016, Palm Springs, CA, USA.

12. N. Ganushkina, S. Dubyagin, M. Liemohn, Storm-time near-Earth magnetotail dynamics examined using 30 keV proton isotropic boundaries, **The Magnetosphere: New Tools, New Thinking, New Results**, November 12-17, 2017, Puerto Varas, Chile.

13. **Natalia Ganushkina**, Low energy electrons in the inner Earth's magnetosphere, **Fundamental Physical Processes in Solar-Terrestrial Research and Their Relevance to Planetary Physics ESSE18**, 8-12 January 2018, Kona, Hawaii.

14. **N. Ganushkina**, Specification of electron radiation environment at GEO and MEO for surface charging estimates, **Isradynamics 2018 "Dynamical Processes in Space Plasmas",** Ein Bokek, Israel, 22-29 April 2018.

15. **N. Ganushkina**, Transport of keV electrons in the large- and small-scale electromagnetic fields in the inner Earth's magnetosphere, **50th Anniversary International Symposium of Center for Space Science and Radio Engineering (SSRE)**, 25-26 June 2018, UEC, Chofu, Tokyo, Japan

16. **N. Ganushkina**, Variability of keV electrons in the Earth's magnetosphere, **42nd COSPAR Scientific Assembly 2018**, July 14 - 22, 2018, Pasadena, California, USA.

Dissemination activities, FMI (7)

Orals, contributed:

1. **Natalia Ganushkina**, Wave-particle interactions for low energy electrons in the inner Earth's Magnetosphere, ISSI International Team "Analysis of Cluster Inner Magnetosphere Campaign data, in application the dynamics of waves and wave-particle interaction within the outer radiation belt", January 19-23, 2015, Bern, Switzerland.
2. **Ganushkina, N. and S. Dubyagin**, Magnetospheric current systems as inferred from SYM and ASY mid-latitude indices, **EGU General Assembly 2015**, Vienna, Austria, 12 – 17 April 2015.
3. **N. Ganushkina, S. Dubyagin, I. Sillanpää**, Low energy electrons in the inner magnetosphere: Recent revisions of IMPTAM model, **GEM 2015 Workshop**, Snowmass CO, USA, 15-19 June 2015.
4. **S. Dubyagin, N. Ganushkina**, Empirical model for plasma sheet electrons: Initial results, THEMIS data, **GEM 2015 Workshop**, Snowmass CO, USA, 15-19 June 2015.
5. **N. Ganushkina, I. Sillanpää**, J. V. Rodriguez, Metrics of model performance for electron fluxes (<200 keV) at geostationary orbit**, 12th ESWW**, November, 23-27, 2015, Ostend, Belgium
6. N. **Ganushkina, S. Dugyagin**, I. Sillanpää, J.-C. Matéo Vélez, D. Pitchford, Advanced modeling of low energy electrons responsible for surface charging, **12th ESWW**, November, 23-27, 2015, Ostend, Belgium.
7. **N. Ganushkina, S. Dubyagin, I. Sillanpää, D. Pitchford**, Forecasting keV-electrons in the inner Earth's magnetosphere responsible for surface charging, AGU Fall Meeting, December 14 - 18, 2015, San Francisco, CA USA.
8. Natalia Ganushkina, Modeling of the ring current with IMPTAM, First meeting of ISSI Team “Ring current modeling: Uncommon Assumptions and Common Misconceptions” (leaders R. Ilie and N. Ganushkina), March 7-11, 2016, Bern, Switzerland.
9. Natalia Ganushkina, Stepan Dubyagin, Ilkka Sillanpää, Losses of keV electrons as electron lifetimes in IMPTAM, Second meeting of ISSI International Team "Analysis of Cluster Inner Magnetosphere Campaign data, in application the dynamics of waves and wave-particle interaction within the outer radiation belt", May 9-13, 2016, International Space Science Institute, Bern, Switzerland.

Dissemination activities, FMI (8)

Orals, contributed:

10. **S. Dubyagin, N. Ganushkina**, A. Runov, Solar Wind Control of the Plasma Sheet Thermal Electrons at r=6-11 Re: Empirical Model, International Symposium on Recent Observations and Simulations of the Sun–Earth System III, Golden Sands, Bulgaria, September 12–16, 2016.
11. **Ilkka Sillanpää, Natalia Ganushkina, Stepan Dubyagin**, Juan Rodriguez, IMPTAM verification and validation on GOES MAGED data for long-term variations of electron fluxes at geostationary orbit, Thirteenth European Space Weather Week, November 14-18, 2016, Oostende, Belgium.
12. **Natalia Ganushkina, Ilkka Sillanpää**, Jean-Charles Matéo-Vélez, **Stepan Dubyagin**, Angélica Sicard-Piet, Low energy electrons at MEO during observed surface charging events, Thirteenth European Space Weather Week, November 14-18, 2016, Oostende, Belgium.
13. **N. Ganushkina**, Isotropic Boundaries Observed at LEO as a Proxi for SWMF Magnetic Field, 2nd SWMF User Meeting, February 27 - March 1, 2017, University of Michigan, Ann Arbor, USA
14. **N. Ganushkina, S. Dubyagin**, Low energy electron radiation environment for extreme events, ESWW, November 27 – December 1, 2017, Ostende, Belgium.
15. **N. Ganushkina, S. Dubyagin**, Jean-Charles Matéo-Vélez, Specification of electron radiation environment at GEO and MEO for surface charging estimates, AGU Fall meeting, 11-15 December 2017, New Orleans, LA, USA.
16. **Natalia Y Ganushkina, Stepan Dubyagin**, and Michael Liemohn, Probing storm-time near-Earth magnetotail dynamics using 30 keV proton isotropic boundaries as tracers of precipitating and trapped populations, AGU Fall meeting, 11-15 December 2017, New Orleans, LA, USA

Dissemination activities, FMI (9)

<u>Posters</u>:

1. **Ilkka Sillanpää, Natalia Ganushkina, Stepan Dubyagin**, Jean-Charles Matéo-Vélez, Case studies with van Allen Belt Probes and IMPTAM modeling, Global Modelling of the Space Weather Chain, 24 – 28 October 2016, Aalto University, Espoo, Finland.
2. **Stepan Dubyagin, Natalia Ganushkina**, Andrei Runov, Solar wind driven empirical model of electron plasma sheet densities and temperatures beyond geostationary orbit during storm times, Thirteenth European Space Weather Week, November 14-18, 2016, Oostende, Belgium.
3. **Natalia Ganushkina, Stepan Dubyagin**, Andrei Runov, Solar Wind Driven Variations of Electron Plasma Sheet Parameters Beyond Geostationary Orbit During Storm Times, Session: SM51B Magnetotail Dynamic Processes: Recent Progress in Observations and Simulations, AGU Fall meeting, 12-16 December 2016, San Francisco, CA, USA.