Minutes and Action items emerging from the 2nd ECLAT Science and Validation Workshop (SW2) - (Deliverable D600.2)

Space Research Institute, Austrian Academy of Sciences, Graz, Austria
14th-15th April 2013

The 2nd ECLAT Science workshop was held at the Space Research Institute of the Austrian Academy of Sciences in Graz, Austria, 14-15 April 2013, attended by almost 30 scientists (an incomplete attendance list can be found in Appendix 1). The major topic of discussion was the meso-scale science that could be achieved with the datasets collected by the ECLAT project. There follows minutes of the workshop and action items arising from the discussion.

Session 1 - Sunday 14th April 10:00

Session 1 was dedicated to ECLAT dipolarization, current sheet & FAC events, as well as ECLAT dataset summaries.

P. Boakes gave an introduction to the ECLAT Cluster Region and Event datasets
A database of Cluster regions and boundaries in the nightside magnetotail has been produced. Methodology for region boundary determination was presented.
Example region files and quicklook plots were shown, the plots and files can be found on the IWF ECLAT webpage.
In response to reviewer comments, further validation efforts were presented, including individual crossing validation with comparison to OMNI direction particle spectra, comparison with eternally provided PSBL identifications, inter-space craft and instrument region comparison, regions during reconnection events, regions during storms and region statistics. Validation has resulted in further quality/region flags and magnetosheath entry removal.
Three preliminary event lists were presented. Large gradient events (separate lists for large dby/dz, dbx/dz, e.g. thin current sheet events and strong FAC events respectively, 30 events each 2001-2004, extension to later years requires different methods due change in spacecraft separation), dipolarizations (~1000 events), and wavy current sheet events (~140 events).
The IWF ECLAT website, where region and event datasets and quicklooks can be accessed, was demonstrated.

D. Schmid presented detailed methodology of dipolarization list event identification and initial studies using the list.
Introduction to dipolarization events was given followed by details of the ECLAT event list search algorithm, an automated search based on a set of criteria applied to Cluster data in the nightside magnetosphere. Two reference spacecraft are used and if the event is seen at other spacecraft recorded. Total of 1071 events found. Format of event file and example shown.

An initial statistical study making use of the event list was then presented from 50 events. The events where selected to have earthward flows near the neutral sheet and must be observed by all spacecraft. The ratio between post and pre-event temperature was investigated. The findings showed that dipolarization events fall into two categories, events with temperature increasing after dipolarization are flux pileup events, while temperature decreasing events are flux transport events. The two categories appear to have different heating mechanisms. In summary, the preliminary results are very interesting, providing new insight into dipolarization events, warranting further investigation.

A. Nikolaev presented studies of field-aligned current distortions by the substorm current wedge, and its effect on magnetospheric models.

The latest extension of SCW model with two current loops of opposite polarity (R1 and R2-sense) was used to quantify the footprint mapping shifts caused by the SCW and identify the role of different parameters (relevant to WP610). Largest field line distortion and footprint displacement were shown to come from the R1 current system intensity, the I2/I1 ratio, and background field line stretching magnitude.

P. Boakes presented initial studies of FACs mapped from the Cluster spacecraft to the ionosphere, around the time of substorm onset, with the aim determining whether a large scale SCW is observed in the tail, or are Cluster/tail FAC more dependent on local flow.

They present a summary of previous SCW and FAC studies from ground-based and space-based observations. They find no large scale SCW system in Cluster data in the magnetotail. Instead, several examples are shown of local control of the FAC system and its development around substorm onset by local substorm related flow bursts/plasma bubbles. The results are consistent with SCW like wedgelets at each flow burst.

K. Kauristie presented some first statistical studies using the equivalent current data base, and examples of how they can be used.

ECLAT quicklook products were demonstrated. Statistics of horizontal currents and time derivative shown. Summer winter differences were discovered, midnight more pronounced than in winter. Compare curl with CHAMP FAC finding differences in spatial distribution of ‘upward’ currents.

**Session 2 - Sunday 14th April 14:30**

Session 2 was dedicated to ECLAT relevant science. Session two was an opportunity for both ECLAT and external scientists to present studies relevant to ECLAT.

W. Teh presented Current Density Estimation for PSBL: Results from Ideal MHD Reconstruction
An introduction to MHD model reconstruction methods was given. Reconstruction for two Cluster PSBL encounters in the magnetotail where shown, and the magnetic topology of the PSBL considered given the reconstruction results.

**A. Aikio** presented an invited talk on BBFs in the ionosphere/magnetosphere

Background to the EISCAT radar and measurements, and their use was given. Followed by introduction to BBFs and the bubble model. Two event studies were presented, combining EISCAT and Cluster data. The 1st event showed evidence for duskside return flows of a bubble measured simultaneously in the magnetosphere and ionosphere. The duskside showed a decrease in plasma density but the dawnside an increase, unexplained result. Event 2 suggested that polar cap flow channels may trigger BBFs after interaction with the polar cap boundary. Can support the idea of an empty flux tube hitting the polar cap boundary and triggering onset. Further study is needed on how polar cap flow channels are created and what are there typical properties, as well as what physical interaction mechanism in the tail they could have on the effect the reconnection process.

**A. Yoshikawa** M-I coupling theory, cowling channel coupling to the shear Alfvén wave.

Theory of the Alfvén wave interaction to the ionosphere presented. The effect of Pederson and Hall polarization field on the ionospheric potential is separated and derived from model equations. Results are summarised as Hall polarization fields can be identified from observable data, Hall polarization fields causes clockwise of convection stream line, Hall polarization fields possibly confines the electric field inside the high-conductivity band, in the uniform conductance case Hall and Pederson currents are only crossing each other while in the non-uniform case they are really closing each other and this way the Cowling channel is produced.

**E. Panov** presented studies of oscillatory flow braking of BBFs.

The theory of Wolf et al., 2012 is applied to 25 events, a function is fit to velocity measurements to obtain oscillation frequencies and damping rates, as well as calculated flux volume and entropy. The background plasma sheet is also obtained from Tsyganenko field model (AM-03) and parameters collected for the 25 events. Comparing observed results with MHD predictions shows good agreement. The results suggest the simple 2D geometry of the Wolf model may be applied to the 3D magnetosphere with error less than 50%. The hypothesis that the THEMIS observations of periodical plasma flows may be due to flux tube oscillation back and forth during the BBF braking is now confirmed by a good statistical agreement with the theory. Further, it is shown that the plasma sheet current also oscillates, in associated with FAC oscillations, auroral streamers and Pi2 pulsations. A delay of 50 seconds is found between plasma sheet current oscillations and ground FAC oscillations, consistent with the Alfenic transit time. Also coincident with streamer events-ps current oscillations are related to streamers, streamer evolves with oscillating upward part of the current wedge. Ionospheric FAC may be represented by sum of slow changing larger current related to dipolarization and a faster changing alternating current related to BBF flow braking.

**R. Nakamura** presented observations of multiple dipolarization fronts (DF) before flow bouncing.

Event 20070907. BBF features observed consistent with bubble model. Cluster near midnight, major westward electrojet. Particle injection is observed at DF front time. DF shape was discussed-last ones are bigger scale (large scale at flow bouncing). Cluster observations: Dipolarization fronts (DFs) with flow braking features and additional Ey due to “local dipolarization”
confined to inner sc. Multiple-DFs and “local dipolarization” led to create a “wall” of pressure gradient & magnetic configuration enabling the flow bouncing. Major energetic electron enhancements took place associated with dipolarizations near flow bouncing. Ionospheric response showed major auroral onset at bouncing time. Suggest event for more ECLAT study.

**S. Imber** presented a summary of the SuperDARN ECLAT products and studies of the HMB over one solar cycle.

Introduction to SuperDARN and map potential technique for creating global convection pattern is presented. Data provided from 1996 to August 2011. ECLAT products provided include SuperDARN map potential coefficients for plotting data convection maps, quicklook plots with Cluster footprints and MIRACLE field of view, ionospheric potential, the Heppner Maynard Boundary. A demonstration of how the SuperDARN quicklooks can be used to find interesting intervals is given.

Initial studies of HMB over a solar cycle. HMB is equatorward boundary of convection pattern. Comparison of HMB latitude to the average latitude of the auroral oval suggests the HMB can be used as a proxy for the size of the auroral oval/polar cap, and therefore activity. Comparing the HMB lat over a solar cycle show a decrease in lat during the declining phase of the solar cycle (2003), consistent with increased solar wind driving of magnetosphere for declining phase. HMB latitude peaks in 2009, during the extended solar minimum (solar wind driving low). A yearly variation in the number of radar backscatter data points is clearly seen in the northern hemisphere, consistent with the solar activity cycle. Such a variation is not seen in the southern hemisphere, warranting further investigation.

**R. Nomura** presented ground-based observations of EMIC waves.

Two growth theories, linear and non-linear, for EMIC waves. The first observations of ground signature of non-linear EMIC wave is shown. Two types of motion are observed in the aurora, in the auroral oval and isolated proton aurora at sub-auroral latitudes. Good correlation is found between PC1 wave and isolated proton aurora. More events are needed for study.

**F. Plaschke** presented High Speed Jets (HSJ) in the subsolar magnetosheath

A dataset of HSJs has been created using a set of selection criteria. Statistical comparison of solar wind and magnetosheath conditions during HSJs vs. average conditions is presented. Cone angle seems to be the only SW variable controlling HSJ occurrence. HSJs have lower more isotropic temperatures, suggesting HSJ driver linked to quasi-parallel bow shock and/or upstream foreshock. Lack of solar wind variation suggests not driven by rotational discontinuities or reconnection in this study. In future good to look at effect HSJ in magnetosphere and on the ground.

**Session 3** - Monday 15th April 09:00

Session 3 was dedicated to plasma boundaries and modeling

**N.A. Tsyganenko** presented details of the new data-based field model

This new model is needed to improve several aspects of existing models, including: insufficient flexibility in equatorial current, lack of shape dependence of magnetopause on IMF Bz, increasing validity region (i.e. >12-14 Re), better time dependence on external drivers is needed, FAC are
largely underestimated, partial ring current, forecasting can be improved and new data helps to improve modeling.

Magnetopause is now parameterised by P, IMF Bz and psi. Equatorial current sheet is a linear combination of 3 modules. Symmetric and partial ring currents are now included and for the first time R2 FACs, which are calculated from plasma pressure in inner magnetosphere, based on Cluster, Polar, Geotail and Themis data. R1 FACs results till strictly empirical. Solar wind data sets are taken from the Omni 5 min database (1996-2012). Magnetospheric B data covering 123 storm events - goal to model over an entire storm cycle. Data needs to be weighted in R due to non-uniform data density. Model is fitted to data, 42 unknown parameters. Compare model vs. observed Bx good correlation R>0.96. Compare angular difference between observed and model B, and compare different models. Show that new models are getting better. Show model FAC for quiet time and storm. New model FAC is increased. Field evolution during several Cluster events shown. Time scales for modelled currents are now 30 mins several hours and 12 hours.

Summary-beta version is in place, yields reasonable B and J distributions. Magnetopause size and flaring rate now variable. R1 and R2 currents have larger magnitudes compared to previous models.

What is needed next: external driving (nonlinear response to V, effects IMF Bz>0), delayed response to Pdyn pulses, due infinite tailward propagation, dayside cusps.

**Question Steve Milan:** are R1 FAC symmetric - yes for a start, but can be adjusted dawn-dusk north-south

V. Sergeev presented validation studies of magnetospheric models and assessment of mapping accuracy. (WP 610 – footprint validation)

Assessment/validation models still an open problem. Approach benchmarking the models. Only two attempts previously to point compare tail and expected auroral counterpart with model location. Will use initially isotropy boundaries and later SCW in order to validate new SCW module. Example isotropy boundary identification shown, usually clear in data. Use adaptive model to compare with expected position. Database 18 half day events 2005-2008, Cluster, GOES, Geotail. Run adaptive models, T96, TS05, T12. Isotropic boundaries from NOAA. 330 Proton IBs, 170 electron. Compare B field predictions by different models with observations.

Generally AM02 performs best, and T12 is better than T96 and TS05. All models are overstretched in the tail.

Provide objective measure for quantitative benchmarking the different models, demonstrate relative strength and shortcomings of specific models. In the inner magnetosphere all models are overstretched. Compare model and observed IB location. For protons, similar scores all models. Electrons more problematic due sensitivity in small Beq tail where all models not very good. All models have shifted distributions. Summary-created testing database covering large range SW conditions, and different magnetospheric regions. Benchmarking B-field predictions of different models, also in different tail regions. Benchmarking proton isotropy boundaries for different models.

**Question Harri Laakso:** why is sometimes T12 worse –then the adaptation to must be wrong and the
adaptation should be adjusted by user...

**M. Kubyshkina** presented studies on possibility of mapping error estimations from plasma sheet boundaries data.

Using ECLAT tail region dataset boundary region crossings map, and various models to compare model data with latitude of PCB observe by NOAA spacecraft at low-altitude. 309 NOAA boundaries in 18 events, well mixed in latitude and MLT. Not much difference in comparison for all models in statistical sense. Cluster latitudes are shifted higher and lower end, but peaks are same location as NOAA. Case studies show on average a 4 degree difference in model Cluster boundary and NOAA boundary, however the projected latitude is normally lower than observed. Projections are usually very close in all three models used.

**Question Olaf Amm:** From a user perspective can you say which model is best to use? - Wait and use T12.

**Comment Harri Laakso:** One should not use 5 minute average, too long when you are off the equatorial plane...

Also: there seem to be two populations in the mapping error, corresponding to two populations of data groups, Cluster at 18 Re and Cluster at 15 Re.

**S. Milan** presented a study mapping magnetospheric boundaries to the ionosphere

ECLAT tail region dataset mapped to ionosphere using ECLAT models - 5 minute footprints of regions obtained. N and S maps show regions from clear auroral oval, but T96 field lines are clearly mapping north of the auroral oval. There is quite some asymmetry between northern and southern hemisphere, with the latter having much more results mapping into the auroral oval.

**Comments Minna Palmroth/Harri Laakso:** they think there could be a solar wind directional bias from using 2005 autumn data

There are cases when model believes field lines are closed. but Cluster region is in the lobe (open). Some data points of PS identification from Cluster are found at high latitudes, apparently inside the polar cap, could be transpolar arcs.

**Later Comment Steve Milan:** when he uses updated region and mapping files most of the plasma sheet points in the polar cap disappear...

All footprints plotted on average auroral oval for quiet event and active events - show good correlation auroral oval and regions in quiet, not many Cluster points in active auroral oval region, but expected as most Cluster data will be in quiet time. Worse correlation in the flank regions-possibly due to no Cluster observations outside Y-15 Re. Future works need to investigate individual events, and plotting of region footprints on auroral image data for disturbed and active times. Bin data by IMF direction or Tail X,Y,Z.

**S. Milan** presents initial science topics for combined ECLAT SuperDARN and IMAGE FUV data analysis

Quicklooks allow users to gain overview of interval (aurora and SuperDARN). 10 min plots of IMAGE with MIRACLE FOV and footprints, also 10 min plots of SuperDARN global convection pattern,
plus hourly keograms. Cluster footprint through one day on model oval, both southern and northern hemisphere plots and both geographic and magnetic co-ordinates. Studies are combining expanding/contraction substorm cycle auroral oval motions with SuperDARN radar measurements of reconnection rates. Studies can be done combining AMPERE FAC with SuperDARN reconnection rate-correlation depending on activity level. Combining SuperDARN and IMAGE to study cusp spots, dual lobe reconnection and transpolar arcs.

**M. Shukhtina** presented Tail magnetic flux calculation using Cluster and its application in different tail domains

Model used to obtain total tail flux from single spacecraft measurement in the tail. ECLAT task to apply 3 types of tests to Cluster data.

1. CCMC MHD simulations – results: Tail flux from spacecraft \( F_t \) exceeds model flux by 0.2 Gwb, near neutral sheets \( F_t \) breaks down after substorm onset. Influence of Pd-causes some variation but regression \( F_t(F_{MHD}) \) fairly stable. Modification made to the algorithm to remove dipole part of tail field such that \( F_t \) correlates more to open flux \( F_{cor} \). Further modification made from virtual pressure balance (previous model real) \( F_{virt} \). \( F_{virt} \) broadens scope of method.

2. Compare with IMAGE determined open flux (integrated mag field through area enclosed by auroral oval). Intervals show similar magnitudes, statistics give generally a linear correlation, other factors may create spread, like e.g. s/c position, dipole tilt, general activity level. Investigate effect of spacecraft position - correlation rather stable in \( R > 10 \) Re. Inside 10 Re the virtual algorithm is better, but at all Re correlation is not so great. Other factors - larger solar wind parameters cause more scatter. Tilt and Ma have no effect. Larger dependence of model flux on sym-H than IMAGE.

3. Comparing poleward edge of R1 with APERE yields that during large sym-H \( F_{cluster} \) exceeds \( F_{AMPERE} \). Attempt to apply algorithm to ARTEMIS. All three tests give satisfactory result (correlation >0.7). Modified algorithms allow larger scope to apply method. Large errors for large IMF \( V_z, B_x \) and \( B_y \). Algorithm strongly overestimates \( F \) for large sym-H, reason unknown.

**E. Gordeev** presented a test of GUMICS global MHD code using empirical relationships.

How realistic are solutions of global MHD?

Still there is no successful approach to systematic evaluation

Present new approach for model evaluation is based on static GMHD runs (static SW) instead of events, and empirical relationships instead of time series. The final goal is to verify GUMICS global MHD model.

Carried out 162 2 hour runs with steady IMF inputs - give stationary magnetosphere/ionosphere solutions.

Comparison of magnetopause position to Shue et al empirical relation yields good agreement of subsolar magnetopause, except for large southward IMF.

Good agreement for tail magnetopause during northward IMF, for south and horizontal IMF the GUMICS magnetopause is 10% smaller than empirical predictions. Lobe mag field-underestimated 10-30% compared to empirical values, and there is a significant discrepancy for large northward IMF.
Plasma sheet pressure - nearly corresponds for northward IMF, but lower during southward IMF by 20%
Neutral sheet shape - typically good agreement
Cross-polar cap potential - low range of variation
Tail flux - 25-30% reduction in GUMICS. Generally depressed convection.

Quote: “In general GUMICS-4 simulation results reproduce the empirical relationships reasonably well for an ideal MHD simulation.”

Session 4 - Monday April 15th 14:00

Session 4 was dedicated to discussions on GUMICS and GUMICS assimilation events.

M. Palmroth started the session by summarising ECLAT 2nd year activities of GUMICS
Year long run now carried out in 12 slices per orbit (4.75 hour slots). Mapping cluster using simulated magnetic field and making quick-looks plots are still outstanding action items.
Website for quicklooks demonstrated

M. Palmroth then present a summary of ECLAT GUMICS reanalysis objectives and description of work, discussion to follow on reanalysis event selection.
Aim: Scientific investigations and initial testing during a selected event, where the GUMICS-4 magnetospheric magnetic field is forced to match that of several magnetospheric spacecraft observations.
Main MI coupling in GUMICS FAC and precipitation.
Step 1 - replace GUMICS electric potential with measured and see how this affects modeling, need a couple hour event with reliable SuperDARN data, not extreme conditions
Step 2 - replace GUMICS electric potential and electron precipitation with measured one from e.g. IMAGE.
Step 3. Replace FAC distribution with measured one.
She would prefer reliable global estimates on potential, precipitation and FAC.
It is noted that assimilation of MHD code results has not been done before.
The general idea is that an event could last from 2-10 hours - not too active, moderate.
Needed for assimilation are good observations (for a couple of hours) on either or all of the following parameters : Ionospheric conductances (Pedersen & Hall), field-aligned currents, ionospheric potential (SuperDARN), precipitation (IMAGE FOV)
All teams are asked to identify possible assimilation events/interval.

P. Boakes presented three possible events where data from all ECLAT products were available. A working group was formed in the event workshop to study these events in more detail, but they were too active for the assimilation interval.
A lively discussion was held to discuss how to select an assimilation event, what is needed, and what to choose as a metric. MP was tasked to produce a list of priority for what is needed while teams will use to identify possible intervals. A working group was formed as part of the event workshop to discuss this further?
General Criteria and Conditions for Assimilation events (R. Nakamura notes):
Best SuperDARN (best during the winter months in the northern hemisphere)
Best IMAGE data (best during the winter months due to dayglow problems)
Best Cluster tail during the summer months.
--> Compromise to be made
19th October 2001: Suzie/Steve/Garbo/Herman
Solar wind & GroundGB in page 4-5
Excellent SuperDARN data coverage, and IMAGE WIC and SI12 auroral images.
Suzie Imber would provide SuperDARN
Steve Milan would provide IMAGE keograms.

Candidate events from list of "IMAGE Frey-onset + Cluster within 4MLT" IMAGE+Cluster+MIRACLE
20020802002056, 20021028183523, 200111001193420 (IMAGE+Cluster: very complicated)
20020820223625 (Without Cluster FGM data), 20011001193420, 20010831210633
Appendix 1 – Attendance list (incomplete)
<table>
<thead>
<tr>
<th>Name and Institution</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGEP, TU Braunschweig</td>
<td>Reiko Nomura</td>
</tr>
<tr>
<td>Reiko Nomura</td>
<td></td>
</tr>
<tr>
<td>David Stückel (SELK)</td>
<td></td>
</tr>
<tr>
<td>Akinaka Yoshikawa</td>
<td></td>
</tr>
<tr>
<td>Hanni Laakie</td>
<td></td>
</tr>
<tr>
<td>Vladimir Semenov</td>
<td></td>
</tr>
<tr>
<td>Sergey Apatenkov (SPbSU)</td>
<td></td>
</tr>
<tr>
<td>Evgeny Gordeev (SPbSU)</td>
<td></td>
</tr>
<tr>
<td>Lisa Jansson (FM1)</td>
<td>Minna Palmroth (FM1)</td>
</tr>
<tr>
<td>Mark Lester (Leicester)</td>
<td></td>
</tr>
<tr>
<td>Steve Milne (Leicester)</td>
<td></td>
</tr>
<tr>
<td>Anica Aikio (U Oulu)</td>
<td></td>
</tr>
<tr>
<td>Susie Inmar (Leicester)</td>
<td></td>
</tr>
<tr>
<td>Kirsti Kavršte (FM1)</td>
<td></td>
</tr>
<tr>
<td>Arnaud Masson (ESA)</td>
<td></td>
</tr>
<tr>
<td>Marina Kuzishkina</td>
<td></td>
</tr>
<tr>
<td>SPb University</td>
<td></td>
</tr>
<tr>
<td>Kjellmar Oksavik (Univ. Bergen)</td>
<td></td>
</tr>
<tr>
<td>Maram Shakh'ting(SPSU)</td>
<td></td>
</tr>
<tr>
<td>Nicolaev Alexander</td>
<td></td>
</tr>
</tbody>
</table>