**LPVEx Data Review and Coordination Meeting**

**Helsinki, Finland**

**Oct. 13-14, 2011**

The primary objectives of this 2-day meeting were review the instrument and modeling datasets from during the Light Precipitation Validation Experiment (LPVEx), update their quality and status, establish a timeline for their official release, prioritize top cases for analysis, and consolidate ideas for applying these datasets to validate satellite estimates of high latitude rainfall. One specific focus was to coordinate the collection of ground, aircraft, and satellite observations to "build the column" of hydrometeor and related variables to provide as strict a test of model and algorithm physics as possible.  The meeting provided an open forum for discussing and refining our approach(es) for analyzing the LPVEx data to maximize its impact on CloudSat and GPM precipitation algorithms and advancing our  knowledge of high-latitude precipitation processes in general.

**I What We Collected**

After a warm welcome from Ari-Matti Harri, Director of Radar and Space Technology Group, FMI, the first third of the meeting focused primarily on summarizing and assessing the quality of the datasets collected during LPVEx and identifying specific cases of greatest value to target for future analysis. Approximately ten light precipitation events were sampled by both aircraft and ground observations during the intensive observing period (IOP) and numerous other events were sampled by ground observations during the extended observing period (EOP) through January 2011. From this set of cases, widespread light rainfall events on September 21, 2010 and October 20, 2010, extensive melting-layer sampling on October 19, 2010, and a mixed-phase precipitation event on October 14, 2010 with excellent sampling by the C-band radar and Particle Video Imager (PVI) emerged as the top candidates for further analysis from the IOP. Each of these events provided unprecedented sampling of the melting-layer (both from the ground on Oct. 14 and the air in the other cases) as well as extensive sampling of rainfall microphysics associated with 1-3 mm h-1 rain rates.

Of the numerous light rainfall and snowfall events that were sampled during the EOP, November 9, 11, 13, and 15 provide extensive ground-based observations of rainfall over a range of meteorological regimes that included some sampling of very large raindrops, possibly indicative of snowflakes in the late stages of melting. November 23-24, December 6, 7, 11, 26, and 30, and Jan. 6, 7, and 8 represent excellent targets for snowfall studies. C-band radar and PVI observations acquired on December 3, 2010 may also provide interesting insights into a possible connection between regions of high Zdr and the location of embryo aggregate snowflakes. Each of these cases may be used to provide cold season precipitation microphysics for algorithm development, refine snow scattering tables, and examine our ability to identify snow growth regimes using polarimetric C-band radar. A key to analyzing these EOP observations will be to relate them to high frequency passive microwave observations acquired from the numerous (~1 per hour at this latitude) overpasses of the NOAA and DMSP polar orbiting satellites so creating subsets of these satellite data is a high-priority action item.

*Aircraft:* Data from all King Air probes as well as the Wyoming Cloud Radar (WCR) are processed and available through the LPVEx server and GHRC DAAC. The datasets are described in the release notes along with any known data issues. The CDP, for example, has issues with its baseline voltage at temperatures colder than about -10°C but these instances can usually be identified by comparing against other LWC probes. The PCASP data are also suspect at T < 0°C due to a malfunctioning heating element prior to RF11. The WCR data feature a 150 m blind zone on either side of the aircraft and are susceptible to saturation from bright targets like the surface but saturation is rare for meteorological targets and are generally easy to identify. The WCR calibration is estimated to be robust to +/- 2.5 dB. The WCR data will provide a valuable proxy for CloudSat observations, serve as an anchor point for calculations of Ka/Ku-band reflectivity, and the downward and forward pointing beams may provide a novel way of estimating vertical profiles of attenuation in rainfall as well as constraining two distinct points on ice crystal scattering phase functions.

King Air data from the IOP target dates should provide extensive information about the microphysical processes in the melting layer as well as the partitioning of cloud and rain liquid water below it and the presence of super-cooled liquid water above it. The sampling strategy of combining stacked level legs with racetrack spirals provides a combination of excellent vertical resolution with the ability to enhance sampling at select levels by integrating longer flight legs. For example preliminary analysis of the spiral data suggest that the assumption of mass conservation across the melting layer in melting layer models is robust. The King Air dataset provides one of the first opportunities to compare the performance of 5 different LWC probes simultaneously on the same platform. Such comparisons are now underway and will provide insights into the performance of each probe under different conditions. The combination of Nevzorov liquid and ice water content observations and particle size distributions observed by the CIP and 2DP may provide a way of accessing particle density with relatively high confidence. Early results provide clear evidence of microphysical processes like aggregation above the melting layer and suggest that mass seems to be conserved across the melting layer even as density, phase, and particle sizes change dramatically. Some evidence of splashing is evident in the 2DP observations of liquid precipitation that will be addressed in later processing. Interestingly, the behavior of the DSD slope profile in light stratiform events, for example, suggests that the LPVEX precipitation character may not differ that much in its primary variability properties from other regions of the world (including the tropics) previously studied. Collectively it was agreed that the King Air data will provide a useful resource for testing the physics in the models used to generate high latitude rainfall databases for Bayesian retrieval algorithms. Fundamental properties such as the melting layer height and thickness statistics as well as Dmax vs. T can also be created for future algorithm development.

*Surface Datasets:* Despite some issues in acquiring data during the first week of the experiment, high quality Parsivel, 2DVD, Pluvio, and PVI data (note: PVI observations are confined to Jarvenpaa site) were obtained from all sites during the experiment. In general the 2DVD, JW and Parsivel datasets are in excellent qualitative agreement from a correlation perspective although relative to the 2DVD and JW the Parsivel seems to have a slight positive bias in DSD parameters (0.25 mm) and more persistent 30% bias in rain rates, consistent with previous deployments. Raw data,1 minute DSD integrations, and 2DVD drop by drop files have been processed for all ground instruments and are available through the GHRC DAAC and the LPVEx server with corresponding README. Work is underway to compare DSD observations from the 2DVD and Parsivel and this will lay the foundation for documenting the DSD properties associated with light rainfall at high latitudes. Precise measurements of freezing level differences between Sept. 21 (2.5 km), Oct. 20 (1 km), and Oct. 14 (intersecting the ground) may provide a means for quantifying differences in rainfall DSD as a function of freezing level height. Throughout the EOP, a wide range of meteorological regimes were sampled leading to great variety in surface wind speeds that could be used to explore the sampling characteristics of particular sensors in different wind speed environments. One important question, for example, concerns the ability of the PVI to provide useful data in all wind conditions where the sampling volumes of the 2DVD and Parsivel make those data less reliable in high wind regimes. Similarly, data from the Parsivel and the ODM deployed on the RV Aranda can be used to assess the importance of disdrometer orientation with respect to the wind on ship-based platforms although it appears that ODM data is only available for the Sept. 21, 2010 event.

 Each ground site was also equipped with a Precipitation Occurrence Sensor System (POSS) and one or more Micro-Rain Radars (MRR) during LPVEx. Data from these instruments are undergoing final quality control at this time and initial results suggest that most of the data is of sufficient quality for research. POSS products will include X-band reflectivity, precipitation type, rate, and D0. Research is ongoing to determine the extent to which POSS power vs. Doppler velocity spectra can be used to infer microphysics information such as phase and degree of riming. The combination of this data with Parsivel, 2DVD, and PVI imagery may provide a useful tool for inferring particle volume, cross-section, and density at the surface.

The MRR provides K-band reflectivity and Doppler velocity at 100m vertical resolution and a derived rainfall intensity. Analysis is underway to assess the closest usable MRR bin to the surface and to compare MRR intensity estimates against ground-based disdrometer measurements. Initial results suggest that the Emasalo MRR may have had a consistent low bias that could be corrected. MRR observations are also available from an experimental deployment aboard the RV Aranda that spent time at sea during the first 2 weeks of the campaign. This data can be compared with that from the Parsivel and ODM disdrometers to assess the future feasibility of using MRRs on ocean platforms.

Ground-based estimates of total column water vapor, cloud liquid water path, and rain liquid water path along the axis of the Kumpula radar have also been inferred from the ADMIRARI located at the Emasalo site. Based on a ceilometer and MRR cloud mask, the ADMIRARI backs out the presence of rainfall and estimates the cloud to rain water ratio (an important component in both PMW and W-band rainfall retrievals) using surface-based multi-frequency passive microwave observations. These data are currently being quality controlled but will be uploaded to the LPVEx server shortly. One open question worthy of further research is the need to assess the sensitivity of ADMIRARI retrievals to the Bayesian database used. Currently the algorithm employs a predominantly tropical database that leads to occasional unphysical retrievals but it should be possible to adapt the LPVEx WRF and AROME model simulations to create a database that is more appropriate for higher latitudes.

*C-band Radar:* A total of four C-band radars regularly collected data during LPVEx. The operational Vantaa radar made regular full volume scans throughout the experiment providing broader context for all operations. The Kumpula and Kerava research radars performed a combination of narrow swath sector RHIs and PPIs above ground sites and coincident with aircraft operations. Finally, a vertically pointing C-band radar collected high vertical resolution reflectivity and Doppler velocity spectra at the Jarvenpaa site throughout the experiment. All of the data from these radars has been quality controlled and will be made available in both raw iris format and UF format though the LPVEx data server. A potential ZDR bias of -0.2 dB may exist in the Kerava radar data, but is still being investigatd to determine the final value. Additional data from the Korpoo radar in western Finland will be acquired from FMI to provide context for the melting layer sampling flight in the Gulf of Bothnia on October 19, 2010.

To facilitate future analyses, the MGRAD matching algorithm is being used to create a matched dataset along aircraft tracks of airborne microphysics and W-band reflectivity curtains with corresponding ground-based C-band radar observations. Matches will be created for every 1-second time-step of the aircraft probes and integrated to produce 5 second PSD matches. Derived products such as hydrometeor ID and raindrop DSD can easily be added to the matched datasets as they become available.

Ultimately these matched datasets will provide a useful resource for constraining larger-domain C-band microphysics retrievals, examining dual wavelength ratios, simulating reflectivities at other wavelengths, and simulating passive microwave observations. Another specific question of interest concerns the degree to which the multi-dimensional ice crystal scattering problem can be collapsed to a more manageable number of free parameters. The combination of W-band/C-band reflectivity (occasionally MRR K-band as well) and ice crystal mass/cross-sectional area from the Nevzorov and 2D probes may provide a way of addressing this question.

Given the wealth of ground-based measurements that were collected outside research flight times, it will also be important to assess how well C-band retrievals can be constrained using ground-based disdrometer observations alone. Provided this can be accomplished with some degree of confidence, the resulting microphysics estimates over the radar volumes may be used to quantify variability of the DSD in the column.

*Satellite Overpasses:* As anticipated, there were a large number of satellite overpasses during the experiment that may help fill the gap due to a lack of coincident passive microwave measurements during the campaign. Between the AMSU-B and MHS instruments aboard the NOAA polar orbiting satellites and the SSMIS instruments aboard the DMSP satellites, high frequency passive microwave observations are available approximately once an hour over the Gulf of Finland. Subsets of these observations from NOAA-15, NOAA-16, NOAA-17, NOAA-18, NOAA-19, F-16, F-17, and F-18 will be created to augment the LPVEx data archive. In addition, rainfall estimates based on 150 and 183 GHz PCT will be provided for comparison against ground observations. Finally, CloudSat made a number of overpasses of the region, particularly during the EOP. Cross-sections of W-band reflectivity and all related precipitation products will also be extracted and added to the LPVEx data server for future comparisons.

**III Modeling Activities**

Cloud resolving modeling activities are also underway to augment the LPVEx datasets. The WRF-SBM has been run on both the Sept. 21 and Oct. 20 cases and results are being evaluated against in situ and radar observations. The results highlight the value of the LPVEx measurements for evaluating model physics. Initial findings suggest that model melting layers are too shallow, particle number concentrations appear to be too high, and particle sizes too small. These disagreements appear to be reduced by increasing ice nuclei concentrations in the model but additional work is necessary to identify potential improvements to microphysical processes in the model. WRF simulations with single-moment microphysics are also being compared against LPVEx observations. The results suggest that N0 is overestimated in rain and underestimated in snow but that changes in the microphysics scheme can improve the agreement with observations.

 Together these studies represent progress toward another important goal of using LPVEx data to evaluate and ultimately improve the databases at the root of satellite rainfall algorithms. These studies will soon be augmented to include additional LPVEx datasets, span a greater range of cases, and further evaluate simulated radar and passive microwave observations. The October 20 event, in particular, will be a significant challenge for models but may provide an excellent target for evaluating and improving shallow freezing level rainfall databases.

The LPVEx observations will also be used to establish constraints on scattering table calculations. One key action item will be to use airborne and ground-based DSD observations to define the maximum diameter used for creating and integrating scattering tables. In addition, collocated PSD and ice water content observations will be used to verify and refine assumptions of snow density used in ice crystal scattering models. Each of these assumptions can be tested against reflectivity observations matched to the aircraft sample volume.

**III Analysis Plans: Building the Column**

It was emphasized that a central component of the LPVEx analysis plan is ensuring that the datasets collected are of maximum value to algorithm developers. Toward this goal, the group formulated a plan for bringing various components of the LPVEx observations and analyses together to create a number of volumes or ‘columns’ with as complete a description of atmospheric properties, microphysics, surface rainfall, and remote sensing observations as possible from the datasets collected during the experiment. In so doing we hope to create a sufficiently comprehensive description of all aspects of a few profiles of high latitude precipitation that can be directly compared to existing Bayesian algorithm databases, used to evaluate bulk characteristics of model simulations, employed as constraints for passive microwave and Ka/Ku-band radar simulations, and used as the basis for synthetic retrievals.

The second spiral descent by the King Air over the Emasalo site between 0957Z and 1019Z on September 21, 2010 was selected as an initial target case to develop this product with the goal of extending the methodology to other aircraft spirals acquired over the course of the campaign. The aircraft spiral itself defines relevant length and time scales for averaging such that the resulting profile will represent the mean conditions over the ~5 km diameter column sampled by the King Air over the ~20 minute period of the sampling. Variability in aircraft and ground-based reflectivity profiles and surface DSD and rainfall measurements provide measures of heterogeneity over the course of the observations.

This effort will involve contributions from all investigators who participated in the experiment as follows:

* Petersen/Tokay – integrated DSD and mean rainfall rates from all Emasalo disdrometers and standard deviations obtained from 1 min. samples as measures of heterogeneity;
* Heymsfield/Bansemer – aircraft microphysical observations integrated to an appropriate vertical resolution with associated size, phase, and particle density estimates;
* Nesbitt – collocated C-band/W-band radar curtains: reflectivity, polarimetric parameters (Kdp, Zdr, etc.), W-band Doppler velocity matched to the 1 Hz aircraft microphysical observations; these can then be integrated to the same time step as the aircraft microphysics;
* Nebitt/Moisseev – profiles of DSD moments derived from polarimetric radar variables
* Dolan – Column hydrometor ID consistent with airborne data.
* Kidd – K-band reflectivity and Doppler velocity from the Emasalo MRR (corrected for under-reporting issue)
* Chandra/Leinonen – Ka/Ku-band reflectivity derived from collocated C/W-band
* L’Ecuyer/French – aircraft temperature, humidity, and winds from spiral and following slant sounding
* L’Ecuyer/Kidd – extract closest pixel (or 2x2 pixels) of SSMIS/AMSU-B/MHS from NOAA/DMSP satellites to ‘cap the column’
* Saavedra/Battaglia – ADMIRARI derived quantities (RLWP, CLWP, and TPW)
* Von Lerber – simulations of the melting layer using multiple models and comparison with obsevations
* Kirstin – background environment from ECMWF, NCEP, AROME, and HIRLAM
* Matsui – average rainfall structures from WRF-SBM over similar region/time period for comparison

The immediate goal is to assimilate all of this data into a single data file consisting of a single representative vertical profile (and standard deviation where appropriate) of all relevant parameters as a function of height within the column that can be distributed to algorithm developers, modelers, and simulator developers to evaluate CRM-derived databases and scattering tables in the context of observed W/C-band reflectivities and TOA passive microwave brightness temperatures.

**IV Team Analysis Framework**

Much of the second day of the workshop was devoted to brainstorming and coordinating analysis activities related to evaluating and improving satellite precipitation algorithms at high-latitudes. The general consensus is that the LPVEx datasets can impact both the *a priori* model databases and associated scattering tables that lie at the root of the CloudSat and GPM precipitation algorithms. Specific studies that could have an immediate and high impact include:

1. Characterizing the height and thickness of the melting layer as a function of rainfall intensity and background T and q profile.
2. Quantifying the extent to which mass is conserved through the melting layer and identifying the microphysical processes above, within, and beneath it.
3. Evaluating the extent to which the LPVEX domain and precipitation processes/characteristics (e.g., DSD profile) really differ from any other location for a similar type of precipitation event.
4. Examining how well these characteristics are reproduced by CRMs and in Bayesian databases.
5. Determining how much DSD or snow shape information is present in polarimetric C-band radar observations?
6. Assess scattering models by testing how well simulated brightness temperatures derived using the microphysics column reproduce those observed during satellite overpasses.
7. Using the forward and downward views of the WCR to evaluate attenuation models through the melting layer and rain column as a function of rainfall intensity.
8. Simulating Ka/Ku-band observations based on collocated W- and C-band reflectivity curtains and evaluating the quality of these simulations in instances where MRR K-band observations are available.
9. Using simulated Ka/Ku-band radar observations and collocated Parsivel/2DVD/Pluvio precipitation and DSD measurements to assess rainfall and snowfall detection thresholds for the DPR.
10. Similarly, use ground-based rainfall and DSD measurements in combination with satellite overpasses to quantify precipitation detection thresholds for the GMI.
11. Examine clear sky returns from ocean as a function of wind speed to test CloudSat PIA estimates.

**V Action Items**

1. All workshop presentations have been collected and will be uploaded to the LPVEx website.
2. A target date of mid-December was set for the release of all datasets to the science community. Announcements will be made by both GPM and CloudSat regarding the availability of these datasets at this time.
3. A tentative deadline for completing the development of the ‘microphysical column’ product was set to coincide with the International GPM GV workshop in June 2012.
4. Reflectivities from the Korpoo C-band radar need to be archived to accompany the Oct. 19, 2010 King Air sampling in the Gulf of Bothnia.
5. Vantaa radar data need to be processed separately and repackaged to create proper volume scan formats.
6. ZDR bias correction for Kerava radar. Magnitude is expected to be 0.3-04 dB.
7. Radar data set for other than the priority case dates requires conversion to UF.
8. HID dataset for Kumula and Kerava radars.
9. Subsets of all relevant satellite overpasses (CloudSat, NOAA, and DMSP) from Sept. 15, 2010 through the end of January 2011 need to be generated. ASCII format will be used and all data within a 5x5 degree box around the Kumpula radar will be stored.
10. Look into adding a saturation flag directly into the WCR data products.
11. Contributions will be sought for an article describing the LPVEx experiment and preliminary results that will be submitted to BAMS early next year. The end of the year is the initial target to circulate a draft of this manuscript – much of which will build off the initial results presented at this workshop.
12. All LPVEx participants are asked to think of tentative titles for one of two possible LPVEx special issues. Chandra is willing to put forward a special issue on instrumentation at JTech while Steve Nesbitt would be willing to do put forward a special LPVEx science issue in JAMC. Either or both options could be pursued provided there is sufficient interest (at least 10 tentative papers) and the deadline for submission of manuscripts would be December 2012.
13. Correction of Emasalo MRR data needs to be performed.