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NOAA PI PMM Annual Report:

A Physical Rainfall Rate Algorithm for All Surfaces: Applicability to All Microwave Sensors Including TRMM & GPM

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Project Objectives

Extend algorithm to TRMM and GPM sensors

The project will extend the development of an existing physically-based rainfall rate retrieval algorithm, applicable to all microwave passive sensors, to include the capability to process TRMM and GPM constellation sensors. This algorithm is valid over land and ocean. The design of the algorithm is based on the generic One-Dimensional Variational (1DVAR) approach where the solution starts from a first guess and converges to the final estimate based on a forward model and its Jacobian. The final solution found is guaranteed to at least fit the brightness temperatures measurements. The algorithm we build on is called the Microwave Integrated Retrieval System (MiRS). The MiRS algorithm uses a comprehensive approach to sensing geophysical parameters from space. It retrieves all parameters that have an impact on the measurements, simultaneously. It therefore retrieves soundings of temperature and moisture, along with surface emissivity, skin temperature and hydrometeors parameters, all at the same time, ensuring that the final solution is totally consistent with the measurements. This feature allows it for instance to account for emissivity variations when obtaining rain estimates which is critical for rain retrieval over land using low frequency channels. The MiRS algorithm has been applied successfully in the past, and its modular design allows for a timely and efficient extension to the TRMM and GPM sensors. MiRS has been running operationally for the AMSU and MHS sensors onboard NOAA-18, 19 and Metop-A as well as for SSMI/S onboard DMSP F16, running experimentally using AMSR-E data, and has been applied routinely to ATMS proxy data in preparation for the NPP launch in 2011. The rainfall rate algorithm over both ocean and land has been operational since 2008.

Validate algorithm and its products.

We will validate this expanded algorithm by using real data from TRMM and Megha-Tropiques (planned for 2010). We will leverage an internal validation testbed used for polar-orbiting satellites (NOAA-18, 19, Metop-A and DMSP-F16 SSMIS) as well as leverage NASA GPM ground validation (GV) activities – current and planned in the Science Implementation Plan SIP-. We will use the Canadian CloudSat/CALIPSO Validation Program, C^3VP and other field campaigns such as the planned Mid-Latitude Convective Clouds Experiment, MC^3E, which will be held at the DOE CART ARM facility in Oklahoma, in order to validate model microphysics parameterizations. We will use these analyses to interpret and validate MiRS rain and snow retrievals from various satellites including TRMM and GPM sensors during C^3VP and MC^3E, as well as polar-orbiting satellites with AMSU/MHS onboard.

Explore the combination of passive and active sensors:

In addition to providing a robust algorithm for TRMM and GPM sensors built on previous experience with existing polar satellites and validating it, we will also explore combining active and passive measurements within the 1DVAR context in order to optimize the solution by adding more physical constraints that will lead to a better rain and snow profiling. This will require extending the capability of the forward model to simulate backscattering coefficients and to have a Jacobian model associated with it.

Progress Report (August 1 – November 1):

The initial extension of MiRS to TRMM TMI is completed. TRMM TMI data has been ingested, matched to the appropriate footprint size, and corrected for any brightness temperature bias between simulations and observations. The MiRS retrieved parameters include atmospheric temperature and water vapor profiles, rainfall rate, cloud liquid water, ice water path, rain water path, total precipitable water, land surface temperature, surface emissivity spectrum. Figure 1 shows a comparison of rainfall rates from MiRS using TMI data to TRMM 2A12 data. These are preliminary results and we expect to make further refinements, so this comparison should not be considered final.

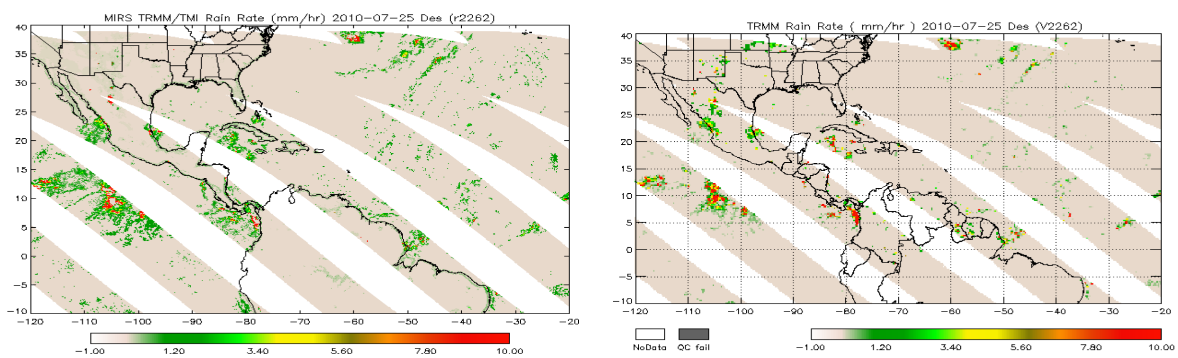

Figure 1. Example of retrieved rainfall rate from MiRS on TMI data at 10.65 GHz resolution (left) compared to TRMM 2A12 data at 85.5 GHz resolution (right) for 2010-07-25.

Improvements have been made also to science components of the algorithm. The covariance matrix in MiRS is composed of atmospheric, hydrometeors, and surface components to account for (and benefit from) natural correlations that exist between these parameters. Improvements to the covariances constrain the physical retrievals. As a way to improve on the MiRS performance in rainy conditions, an effort has been undertaken to generate multi-class covariances, in order to account for flow dependent constraints. The covariance matrix associated with precipitation and rainfall retrievals based on relationships between rain and other hydrometeors have been stratified by season and latitude. Figure 2 shows that mid-latitude profiles of ice and rain are quite different than tropical profiles.

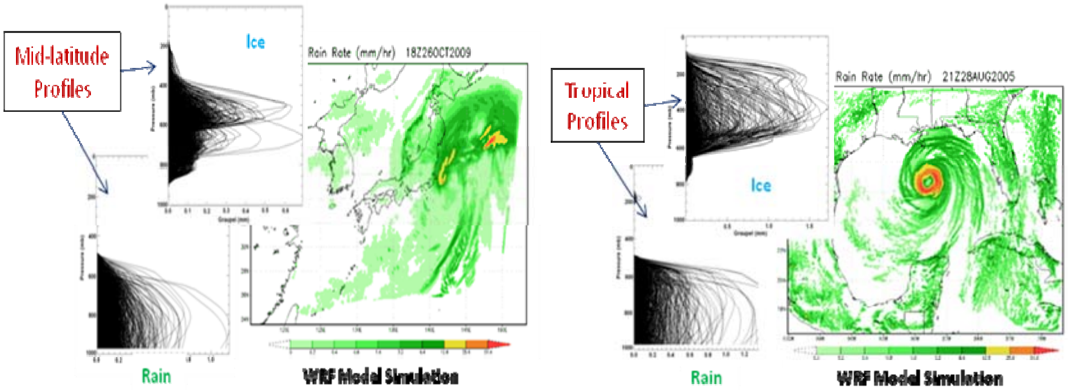

Figure 2. Example of WRF model simulations of rainfall rates, ice and rain profiles in the mid-latitudes on 2009-10-26 (left) and in the tropics on 2005-08-28.

<u>Plans for the upcoming year:</u>

- Generate GMI proxy data
- Extend MiRS to GMI and Megha-Tropiques
- Comparisons of MiRS TMI-based hydrometeors to TRMM
- Assess improvements from stratified rain-hydrometeor relationships
- Daily processing and validation of MiRS TMI, GPM, and Megha-Tropiques
- Investigate the use of active sensors to improve hydrometeor profile retrievals

<u>Publications and Presentations:</u>

S.-A. Boukabara and K. Garrett, "A Physically-Based Rainfall Rate Algorithm for the Global Precipitation Mission." 5th IPWG Workshop,Oct. 12, 2010, Hamburg, Germany.

<u>Budget Summary</u>

The project has just begun and is on budget. A contractor scientist has been hired and began work September 7, 2010.

<u>Reviewer Comments</u>

0. MiRS is the state of the art in passive microwave retrievals and will continue to do so through the NPP and JPSS era. There are a number of products besides precipitation that would be of considerable interest to NOAA users, including the vertical profiles of temperature, moisture and hydrometeors. This is a great new addition to the NOAA PMM team.

We intend to make available all by-products of MiRS; including vertical profiles, but the focus will be on rainfall rates over all surfaces.

1. It would be great if in the future the developers can provide a thorough examination of the products compared to other similar products and radar observations. In particular, we are interested in a) how well

the algorithm performs over mid-latitudes during cold season; and b) how well the PDF of precipitation is reproduced.

We will validate this expanded algorithm by using real data from TRMM and Megha-Tropiques (planned for 2010). We will leverage an internal validation testbed used for polar-orbiting satellites (NOAA-18,19, Metop-A and DMSP-F16 SSMIS) as well as leverage NASA GPM ground validation (GV) activities – current and planned in the Science Implementation Plan SIP. The testbed MiRS comparisons are made on a daily basis globally and over continental United States. The results are available online for authorized users. For example, daily comparisons between MiRS retrievals and the Climate Prediction Center (CPC) rainfall analysis include displays of its spatial distribution, scatterplots, histograms, and time series. For ground validation, we will use the Canadian CloudSat/CALIPSO Validation Program, C^3VP and other field campaigns such as the planned Mid-Latitude Convective Clouds Experiment, MC^3E, which will be held at the DOE CART ARM facility in Oklahoma, in order to validate model microphysics parameterizations. We will use these analyses to interpret and validate MiRS rain and snow retrievals from various satellites including TRMM and GPM sensors during C^3VP and MC^3E, as well as polar-orbiting satellites with AMSU/MHS onboard. With the added goal of precipitation retrievals from the tropics to increased global coverage, assessment in the cold season over higher latitudes will be especially important.

2. Clarify what you mean by "extension to active radars"?

Passive sensors such as the TMI and GMI have a limited ability to determine the profiles of hydrometeors. By combining the passive sensor data with active sensors we hope within the 1DVAR context to optimize the solution by adding more physical constraints that will lead to a better rain and snow profiling. This will require extending the capability of the forward model to simulate backscattering coefficients and to have a Jacobian model associated with it. It will also necessitate having an estimate of the uncertainty of the active measurements and adjusting the covariance matrix to account for the active sensors.

3. Could you provide more information on the full product suite, including resolution and accuracy?

The MiRS retrieved parameters depend on the specific sensor but generally include atmospheric temperature and water vapor profiles, rainfall rate, cloud liquid water, ice water and rain water integrated amounts, total precipitable water, land surface temperature, and surface emissivity spectrum. From the emissivity vector the MiRS determines surface parameters such as snow water equivalent, sea-ice concentration, snow cover, and wind speed. The spatial resolution varies depending on sensor; the TRMM TMI footprint size for the widely used 85 GHz channels is roughly 5 kilometers. The MiRS products for POES and Metop currently have the option to be retrieved at AMSU-A resolution or MHS resolution, 45 km and 15 km at nadir, respectively. For MIRS GPM GMI products, the resolution will be at 183 GHz resolution, or roughly 4.4 km. The operational implementation and choice of resolution would depend on the available resources.

4. Should identify resources to fully operationalize products at full spatial/temporal resolution. Weather forecasters want it!

Multiple considerations should be taken into account for operationalizing satellite products in general, and MiRS products for the GPM era specifically. These operational products will demand latency requirements, or timely delivery to the user community (e.g. forecasters). Components of the processing system which will impact data/product latency are: raw satellite data transfer frequency and rate, level 1 algorithm processing (generation of TDRs, SDRs), science algorithm processing (generation of EDRs from MiRS), post processing and tailoring of EDRs into usable products, and dissemination.

Machine	CPU Core Speed	Number of CPUs	"Effective" Core Speed	Time:1 Granule (7950 FOVs)
Single CPU	3.16 GHz	1	3.16 GHz	10.3 min
Multi-CPU 1	3.16 GHz	8	25.3 GHz	1.3 min
Multi-CPU 2	3.16 GHz	24	64.1 GHz	25.8 sec

Table 1. Processing times for MiRS given orbital or daily data as a function of available CPU cores. The values are based on assumptions for demonstration of processing times only, and do not reflect actual data characteristics of GMI. Processing times can easily be computed when real data characteristics are known for full resolution GMI.

Resources will also be required for storage of MiRS GPM outputs. Currently, for 1 day of low resolution MiRS NOAA-18 outputs, about 1.5 GB of storage is needed. When scaled up to the number of high resolution MiRS GMI profiles, about 56 GB of storage will be required per day of data. Effort is underway to approach OSD/OSDPD in order to potentially run MiRS operationally for TRMM/TMI and Megha-Tropiques (M-T) at the highest resolution possible.

5. Discussions with PIs would be beneficial to understand how this fits into the big picture: esp. on the NOAA side but also with the NASA science team.

We intend to attend all PMM science meetings, passive algorithm sub-group meetings, and land surface characterization working group meetings, as well as interact on a regular basis with all relevant PIs and project managers. In addition we intend to interact with the IPWG community.

6. Synergy with other projects would be greatly beneficial, in particular, Ferraro, Weng, Williams and Xie.

Synergy and leveraging from fellow investigators' work are an important component of our project. Regular meetings and collaborations are ongoing.