CloudSat Based Assessment of ATMS Snowfall Observation Capabilities

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EGU General Assembly 2019

1. Introduction

Snowfall accounts from 30 to 90 percent of the global precipitation over mid- high-latitudes [1] and is the main input to the accumulation processes of glaciers. Thus, global monitoring of snowfall from space is key for improved understanding and prediction of ongoing climate changes.

2. State of Art

In the last year several studies have demonstrated the potentials of the exploitation of coincident space-borne active and passive microwave sensor datasets, which allow users to make comparison between the brightness temperature (Tbs) data obtained by microwave sensors and the cloud physical structure observed by active sensors.

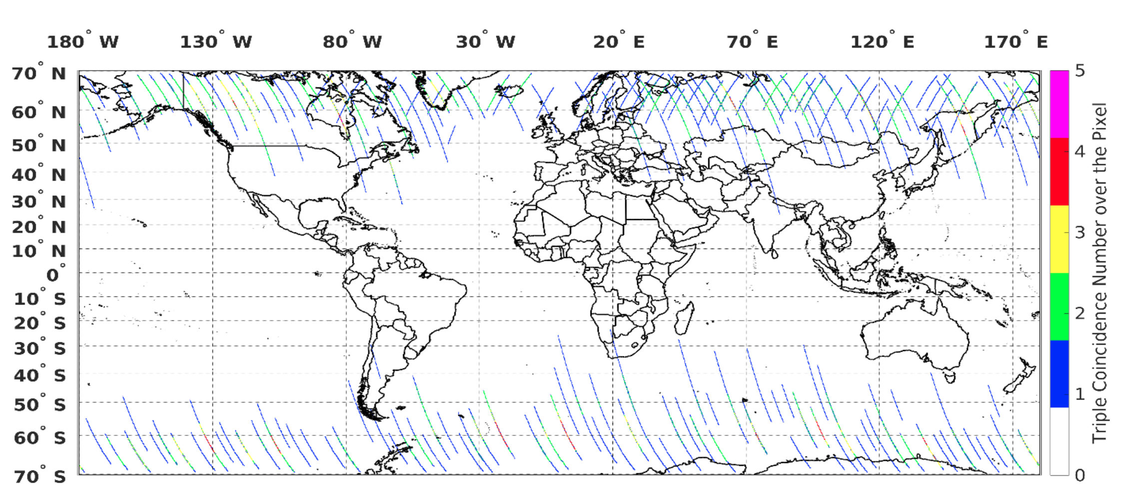
- it has been shown that CloudSat Cloud Profiling Radar (CPR) detects snow in a more effective way than GPM Dual-Frequency Precipitation Radar (DPR) [2]
- the sensitivity of GPM Microwave Imager (GMI) high frequency channels to snowfall in relation to environmental conditions has been demonstrated [3]
- the impact of the presence of a supercooled droplet layer has been highlighted [3]
- a new algorithm for snowfall detection and retrieval for GMI has been developed (SLALOM, Snow retrievaL Algorithm fOr gMi). This algorithm is tuned against coincident observation of the CPR [4]
- the influence of the background surface, and in particular of the snow cover type, on passive microwave signal in presence of snowfall has been analyzed [5]

4. Dataset

- **CloudSat-GPM Coincidence Dataset**: it consists of the intersections (coincidences) between the GPM core satellite and the 94-GHz CloudSat-CPR, within 15 min time differences, where also the coincidences within the NPP-ATMS radiometers are recorded. In this dataset, the set of ancillary ECMWF state variable data interpolated to each CloudSat CPR pixel has been added and the GMI, ATMS Tb data and the DPR products have been resampled over CPR data resolution using a Nearest Neighbor method. The CPR 2C-SNOW PROFILE (2CSP) product is used as reference in the study [6]
- **ICARE-DARDAR dataset**: a dataset created to retrieve cloud physical structure by combining the CloudSat RADAR and the CALIPSO LIDAR measurements, where the ice cloud properties and the presence of supercooled droplets are retrieved at CloudSat horizontal footprint resolution (1.4 km) [7]

The final dataset components are:

- 472 CS-ATMS-GMI coincidences within at least a snowfall pixel
- 546921 CloudSat observations
- 105735 2CSP snowfall events
- 24880 2CSP snowfall events bin where supercooled droplets on the cloud top are observed



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3. Objectives

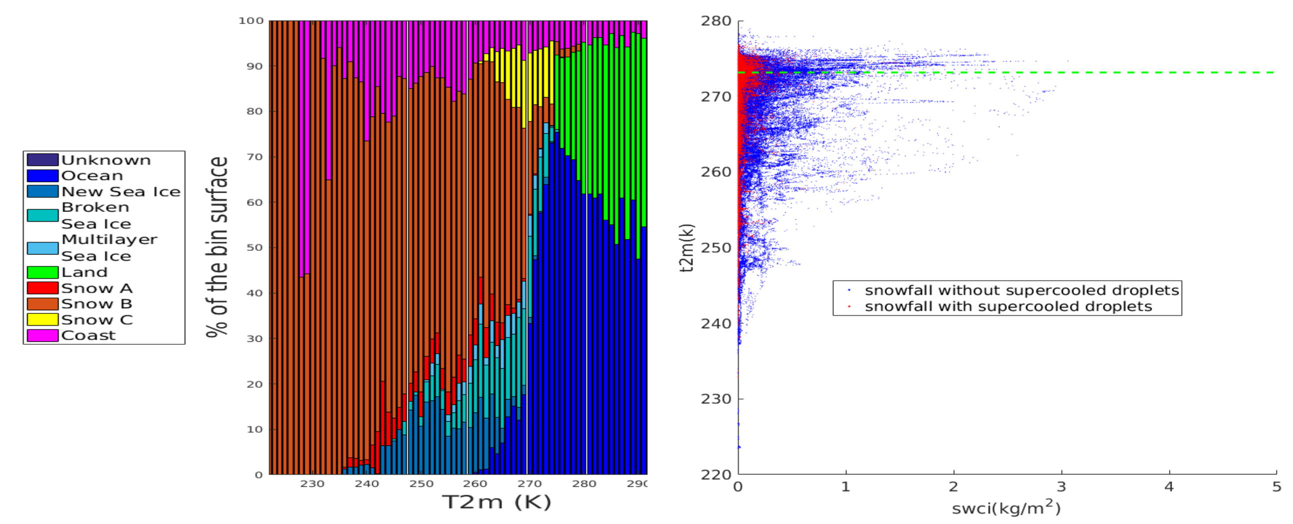
In this study **the snowfall observation capabilities of ATMS based on the use of coincident CloudSat CPR snowfall observation are analyzed**. The study focuses on ATMS because

- this radiometer is characterized by 5 channels in the water vapor absorption band, that are effective for the snowfall and light precipitation detection
- it is on board operational near polar orbit satellite (Suomi NPP and JPSS series), and so, differently from GPM-CO, it will provide long records of observations including the higher latitudes
- ATMS is very similar to the MicroWave Sounder (MWS) on board the next European MetoOp-SG operational satellites

Also **the different influence of the background surface is analyzed**. A surface classifier based on the GMI low frequency channels and ECMWF T2m data is used as ancillary information; therefore, the study has been based on a triple (CPR-ATMS-GMI) coincidence dataset.

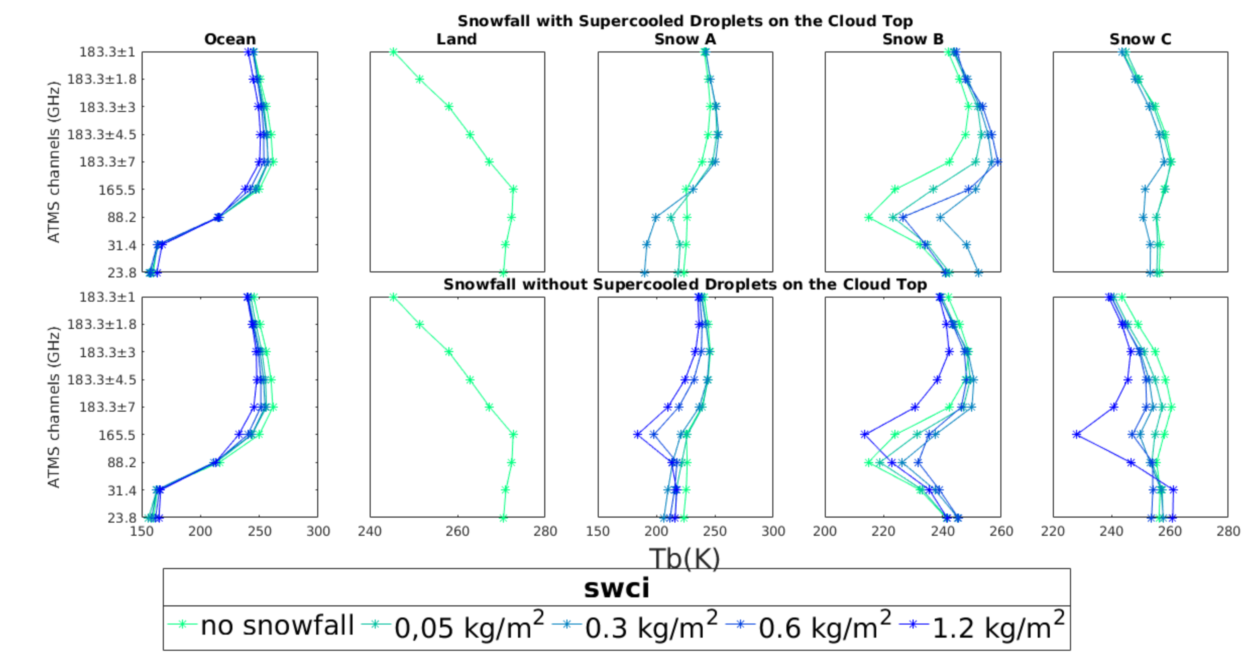
5. Climatology

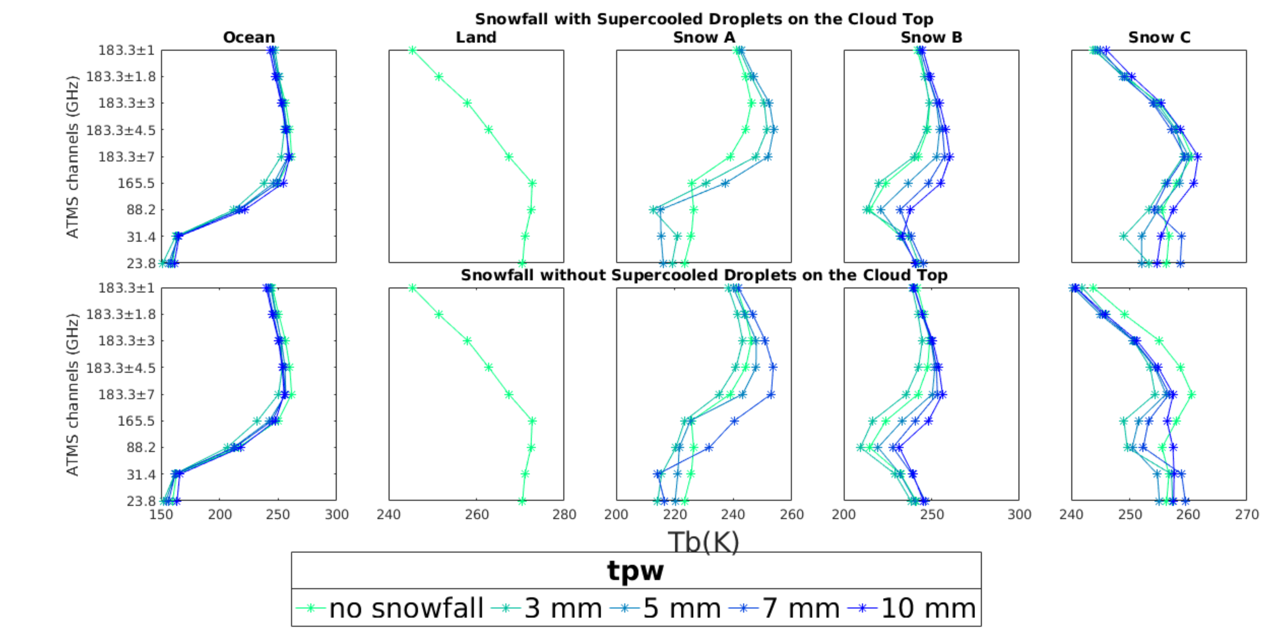
The CNR-ISAC GMI surface classifier identifies 9 surface type classes: ocean, new sea ice, broken sea ice, multilayer sea ice, land snow A, snow B snow C and coast



From the graph on the left side it is possible to hypotize that Snow C represents wet snow while snow A and snow B represent dry snow, because Snow C is linked to warmer situations.
By the graph on the right side it is possible to observe that the presence of supercooled droplets on the cloud top layers characterizes light snowfall events.
No significative dependence of supercooled water occurence and of snowfall intensity on the total precipitable water (tpw) is observed (not shown).

6. Global Analysis





The dataset has been split into 3 subsets:

- no snowfall observation
- snowfall observation without supercooled droplets on the cloud top
- snowfall observation with supercooled droplets on the cloud top

The subsets have been divided into different bins depending on the integrated snow water content (swci) or the tpw. It is possible to observe that:

- as described in [5] over land, ocean and wet snow (snow C) the snowfall presence causes a scattering effect on the microwave signal
- over dry snow (Snow A and Snow B) Tbs increase in presence of snowfall; only in presence of intense events the scattering effect is visible
- over snow covered background, the thermal emission of supercooled droplets on the cloud top causes an increase of the Tbs; over wet snow, it is very difficult to distinguish snowfall situation from clear sky using only Tbs

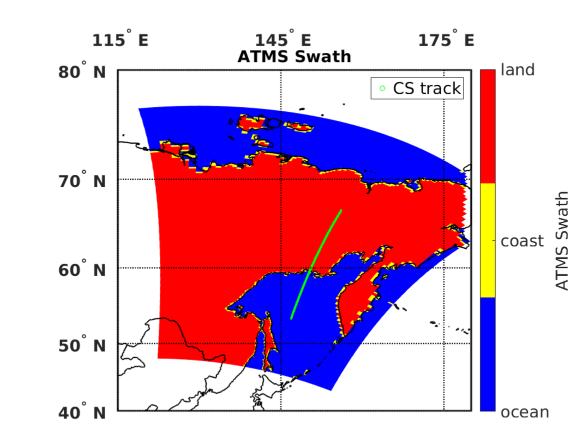
From the graph on the right side it is possible to observe that

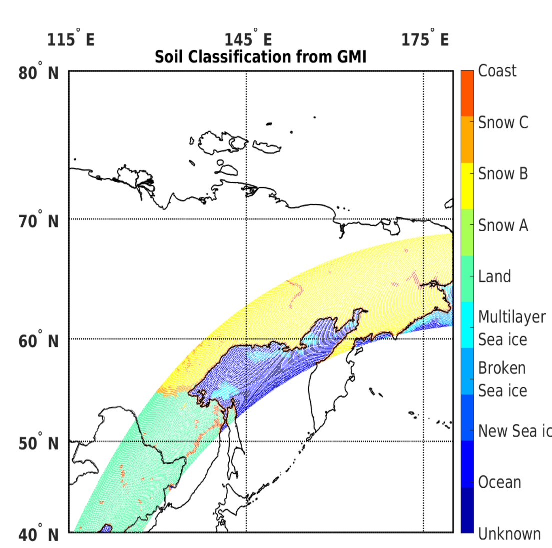
- over snow A in presence of supercooled droplets on the top there is a thermal emission effect in all cases, while in absence of supercooled water a scattering effect is observed in very dry conditions
- over snow B there is a clear thermal emission effect, apart from very dry conditions without supercooled droplets
- over wet snow (snow C) the scattering effect is visible without supercooled droplets; on the other hand, the supercooled droplets presence makes it very difficult to detect snowfall events, especially in moist conditions
- The different behavior of the two dry snow classes is linked to the environmental conditions: in fact it has been observed that Snow A surface type is detected for very low tpw and it is associated to light snowfall events (not shown)

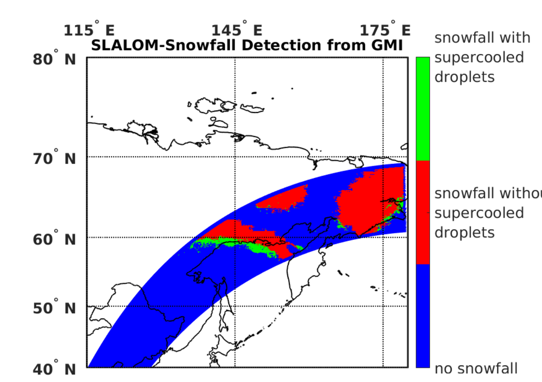
These results are very promising towards the development of a snowfall global product for the MWS onboard the next EPS-SG mission. It will be necessary to exploit all available channels for proper characterization of the background surface at the time of the satellite overpass.

7. Case Studies

Eastern Siberia-2014/04/30

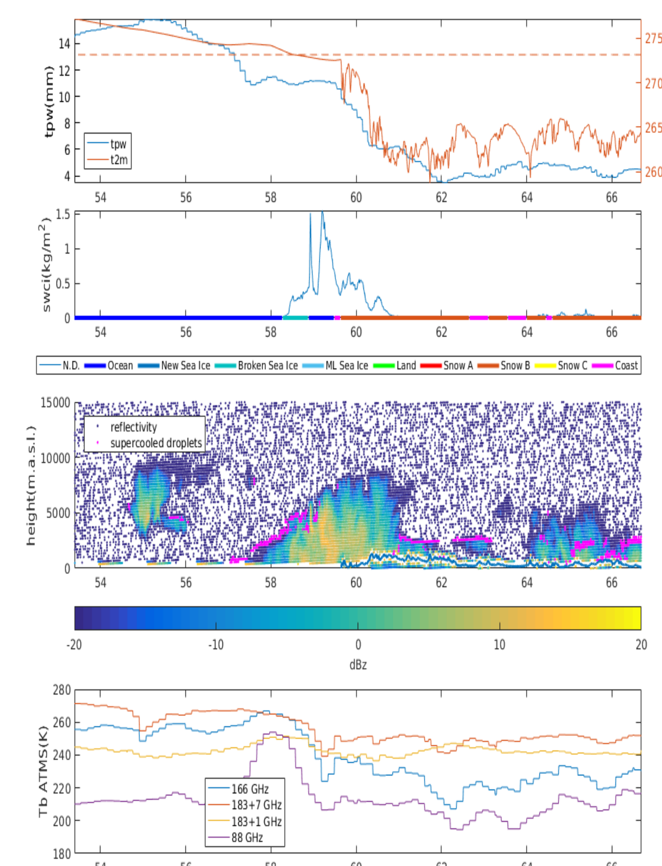




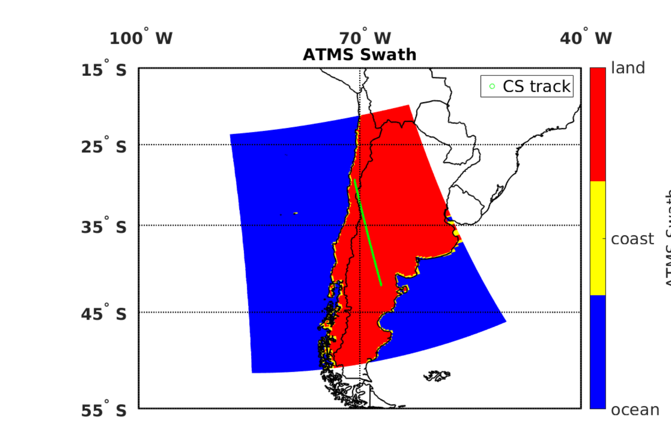


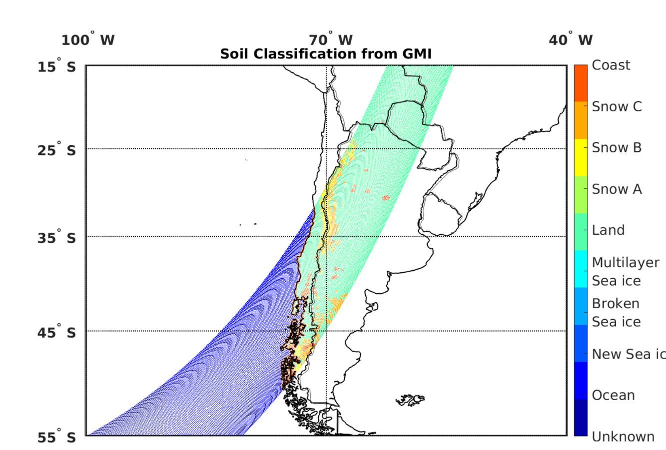
The event is characterized by an intense snowfall between the ocean and the coast and by a lighter snowfall event over the internal regions. Both DARDAR data and SLALOM detection product show the presence of supercooled droplets on the cloud top in the southern part of the event and the GMI surface classifier identifies a dry snow cover (snow B) on the continental part
It is possible to observe that:

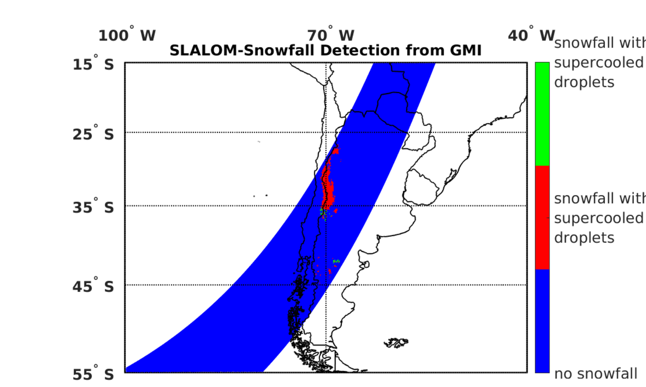
- thermal emission by supercooled droplets is visible, especially at 88 GHz and 183±1 GHz channels
- the scattering effect is visible only for intense snowfall without supercooled droplets on the cloud top
- for weaker snowfall, the cloud appears "warmer" than the dry snow background



Andes-2016/06/03

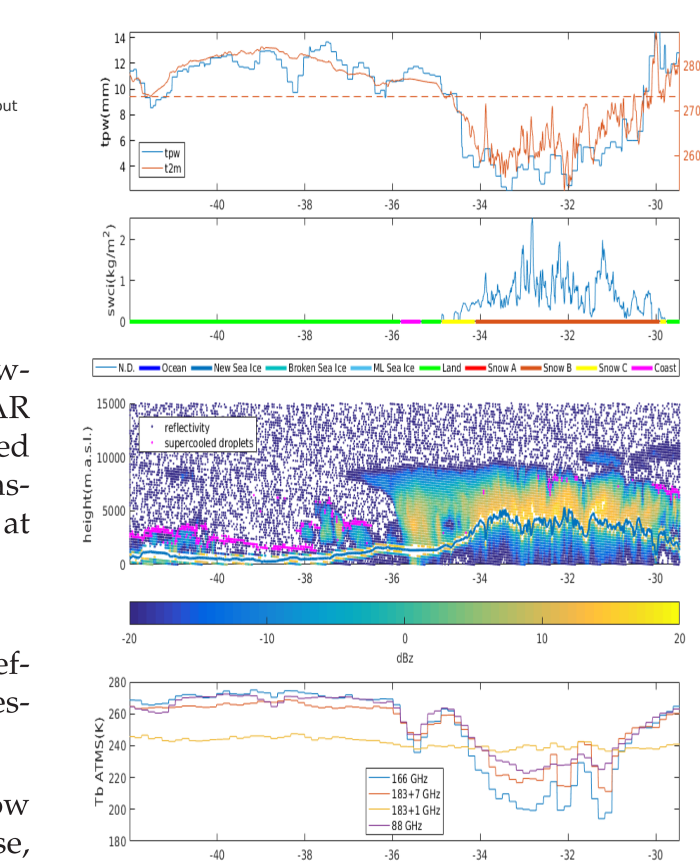






This event is characterized by a very intense snowfall over the mountains. Neither the DARDAR or the SLALOM products detect the supercooled droplets on the cloud top. The GMI surface classifier identifies dry snow (snow B) background at the higher altitudes.
It is possible to observe that:

- the snowfall has a very intense scattering effect on the MW signal, in spite of the presence of dry snow background
- Tbs over the lower altitudes (without snow cover) are warmer than in the Siberia case, because of the thermal emission by the water vapor (moister condition) and because of the surface emissivity



Aknowledgements

This research was supported by the EUMETSAT "Satellite Application Facility on Support to Operational Hydrology and Water Management" (H-SAF)) CDOP-3. The PMM Research Program and EUMETSAT are warmly acknowledged for supporting H SAF and GPM collaboration