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# High Precision and High Resolution Global Precipitation Map from Satellite Data

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## 1. Introduction

The high precision and high resolution global rain data are the most fundamental for the study of the global water cycle and water resources. The global rain rates with the uniform accuracy cannot be observed by any methods other than the satellite remote sensing. The five year research project, “The Global Satellite Mapping of Precipitation (GSMaP)” has been working since 2002 sponsored by Japan Science and Technology Agency(JST) [1]. The research project aims at developing microwave radiometer rain rate retrieval algorithms based on the reliable physical models of precipitations and producing high precision and high resolution global precipitation maps only from the satellite data. At present, several satellites with the microwave radiometers, such as TRMM, Aqua, DMSP-F13, F14, and F15 are in operation. GPM(Global Precipitation Measurement) satellite project is expected to be realized around 2013 with the core satellite loading dual frequency precipitation radars and the microwave radiometer, accompanied by about eight companion satellites which also mount microwave radiometers. Microwave radiometer data are expected to be the central data for producing the global maps of rain rates for the reason that they are used for the observation from satellite more frequently and have the wider observation swath width. The outlines and some recent results of the GSMaP project will be shown in the following chapters.

## 2. The Outlines of the GSMaP Project

The GSMaP project aims at developing a microwave radiometer algorithm compatible with the TRMM precipitation radar(PR) algorithm, and eventually producing global precipitation maps with temporally and spatially high resolution, for instance, produced on daily basis with grid spacing of 0.1 degs. of latitude by 0.1 degs. of longitude, by comprehensively analyzing satellite microwave radiometer data including IR data. Fig. 1 shows four pillars of research in order to attain the goals as follows; (1) routine observation of precipitation by the ground-based radars, (2) development of the physical models of precipitation, (3) development of the rain rate retrieval algorithms, and (4) creation of the global precipitation map.

TRMM PR database and also the ground-based radar database are used to produce precipitation physical models. The precipitation physical model is composed of rain type, rain vertical profile, rain drop size distribution(DSD), melting layer, snow and so on. The precipitation physical model is built onto the Radiation Transfer Model and the relations between surface rain rates and brightness temperatures are tabulated in the look-up table. The rain rates are estimated by verifying observed brightness temperatures and calculated brightness temperature, which are given by the look-up table. The rain rates giving the nearest brightness temperature values to the observed ones are considered to be the most appropriate estimation. The global precipitation map is produced by combining rain rates retrieved from several microwave radiometer brightness temperature data. The produced global precipitation map is compared with other global precipitation maps produced from TRMM PR algorithm and other TRMM TMI algorithm such as NASA’s GPROF algorithm, and also is compared with the ground-based gain gauge data.

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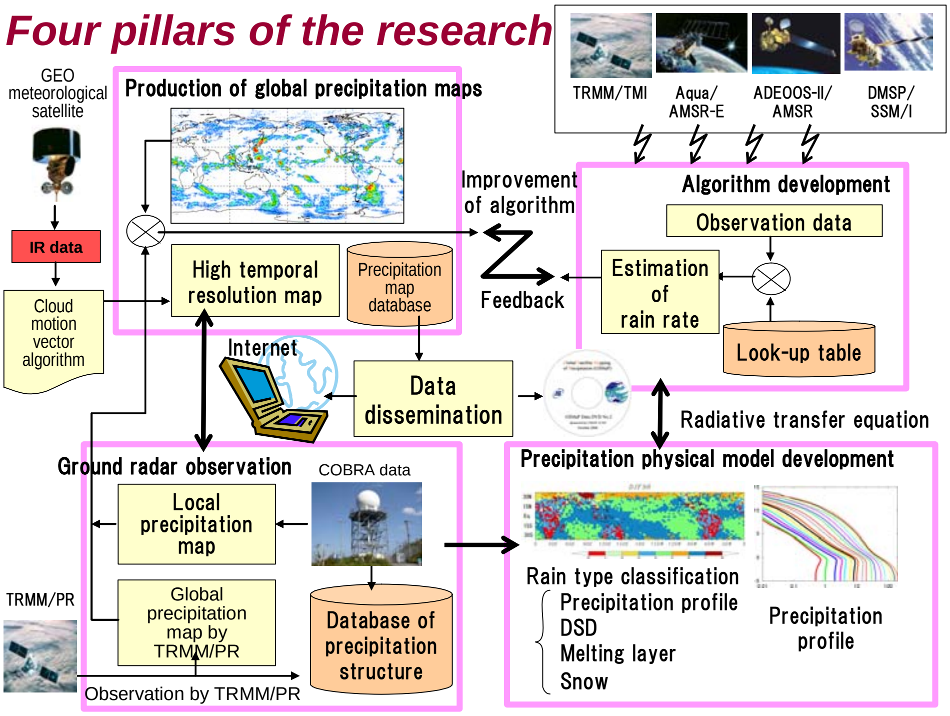


Figure 1. Outline of the GSMaP(Global Satellite Mapping of Precipitation) research project.

## 3. Microwave Radiometer Algorithms by the GSMaP

The GSMaP microwave radiometer algorithm calculates brightness temperatures of several microwave channels by using radiative transfer model and tries to find the optimum surface rain rate which gives calculated bright temperatures which best fit with the observed brightness temperatures by the weighted least square methods. Fig. 2 shows the float chart of the current GSMaP algorithm [2]. The left panel of Fig. 2 describes the process of making the look-up tables which gives relationship between surface rain rates and brightness temperatures. The right panel of Fig. 2 shows the process of the retrievals from the brightness temperatures of microwave radiometers.

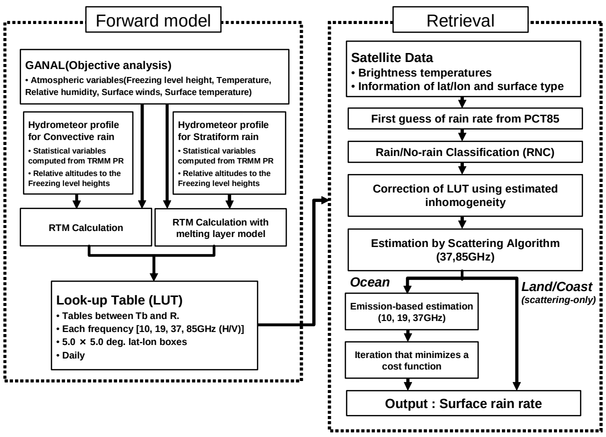


Figure 2: The float chart of the current GSMaP microwave radiometer algorithm

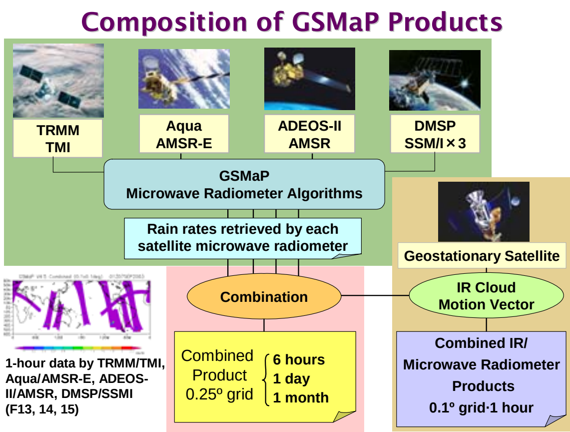


Figure 3: The composition of the GSMaP products

# 4. Global Precipitation Map Products by the GSMaP

Fig. 3 shows the composition of the GSMaP products. In the GSMaP project, surface rain rates have been retrieved by the microwave radiometer algorithm from brightness temperature data of TRMM TMI for eight years(1998 to 2005), the Aqua AMSR-E for three years(2003 to 2005) , ADEOS-II AMSR for seven months(April to October 2003), and DMSP F13, F14, F15 SSM/I for three years(2003 to 2005). The products of the TMI-only retrievals is referred to as GSMaP_TMI. The product combined with these six microwave radiometer-derived rain rate estimates is referred to as the GSMaP_MWR. The spatial resolution of these microwave products is 0.25 degs by 0.25 degs, and typical temporal resolution is six hours. The GSMaP project is also developing algorithms which combine microwave radiometer data with GEO infrared(IR) radiometer data. High temporal interpolation(1 hour) of the GSMaP_MWR is obtained by the morphing technique using IR cloud moving vector and Kalman filter technique. These products are referred to as GSMaP_MV or GSMaP_MVK [3]. The spatial resolution of these microwave-IR combined products is 0.1 degs by 0.1 degs

Fig. 4 is an example of the global precipitation map(monthly accumulated rain rate) which is produced by retrieving TRMM TMI brightness temperature data for eight years(1998 to 2005). The upper panel is for boreal summer(JJA) and lower panel is for boreal winter(DJF). Fig. 5 shows the comparisons of the seasonal variation of zonal mean of monthly rain rates from 1998 to 2005 by TRMM PR(red), TMI/GPROF(green), and TMI/GSMaP(blue) algorithms. a) shows ocean zonal mean in DJF, b) shows ocean zonal mean in JJA, c) shows land zonal mean in DJF, and d) shows land zonal mean in JJA., respectively. Over the ocean, PR, GPROF and GSMaP give almost the same results. However, over the land, GPROF gives larger rain rates than PR and GSMaP. It seems that PR underestimates and GPROF overestimates the rain rates over the land.

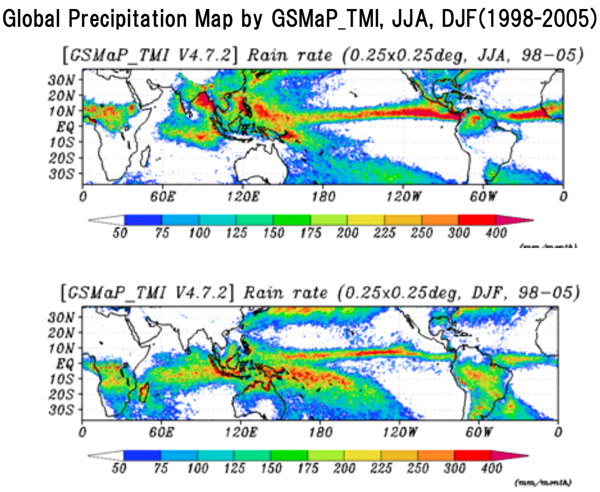


Figure 4: An example of the global precipitation map

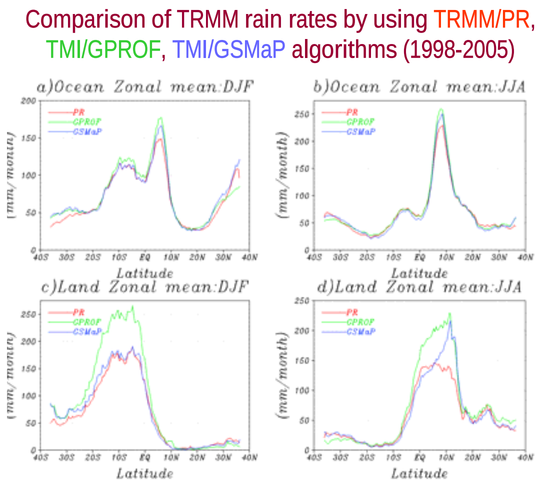


Figure 5: Comparisons of the zonal mean of monthly rain rates from 1998 to 2005 by TRMM PR(red), TMI/GPROF(green), and TMI/GSMaP(blue) algorithms.

Fig. 6 shows a flow to produce precipitation maps with high temporal resolution of 1hr and high spatial resolution of 0.1 degs. by 0.1degs. by the combination of microwave radiometer rain rates and IR cloud motion vector. By comparing the present IR cloud image with the IR cloud image of one hour before, we can estimate the cloud motion vector. This cloud motion vector is applied to the GSMaP of one hour before to produce the predicted present GSMaP. Then the Kalman filter estimation method is applied to the predicted present map. Simultaneously, the newly retrieved rain rates by microwave radiometer for the past one hour are added to the output of Kalman filter estimation to produce the present GSMaP. Fig. 7 shows an example of the combined global precipitation map(GSMaP_MVK) by the microwave radiometer retrieved rain rates (GAMaP_MWR) and the IR cloud motion vector with Kalman filter. The temporal resolution is one hour and the spatial resolution is 0.1 degs. by 0.1 degs. It is an example around Japan at 17:00 on September 9, 2003.

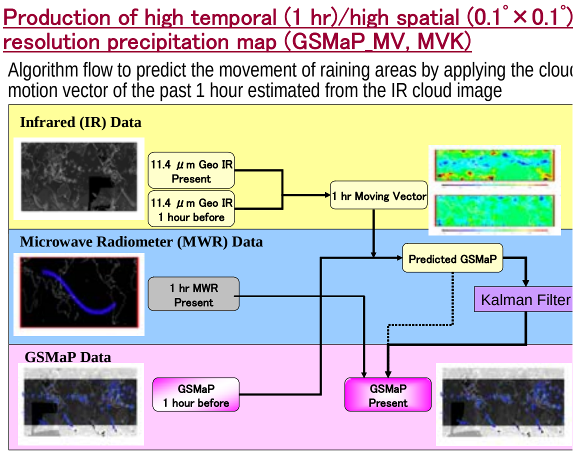


Figure 6: A flow of microwave and IR radiometer combined algorithm for the high temporal and spatial resolution precipitation map

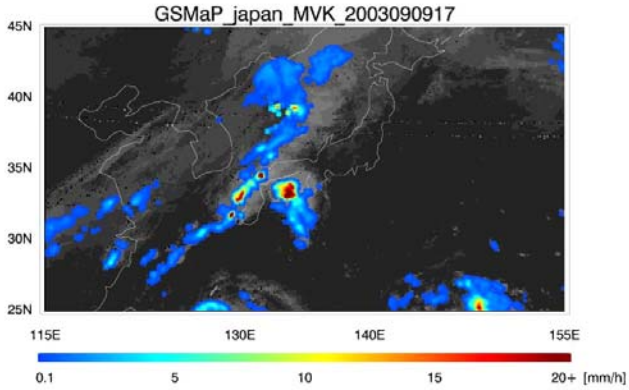


Figure 7: An example of the combined global precipitation map(GSMaP_MVK)

## 5. Summary

GSMaP precipitation products are distributed to the user's community in the form of DVD-R and via the Internet. GSMaP project participates in the international projects IPWG/PEHRPP(International Precipitation Working Group/Program to Evaluate High Resolution Precipitation Products) and evaluate precipitation maps around Japan produced by several foreign research institutes by using radar-AMeDAS composite map . GSMaP project also offers developed algorithms for the application of flood prediction and warning system(GFAS-II), which Public Works Research Institute and JAXA are now preparing, especially for the floods of Asian countries.

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## References

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