GSMaP_MWR algorithm

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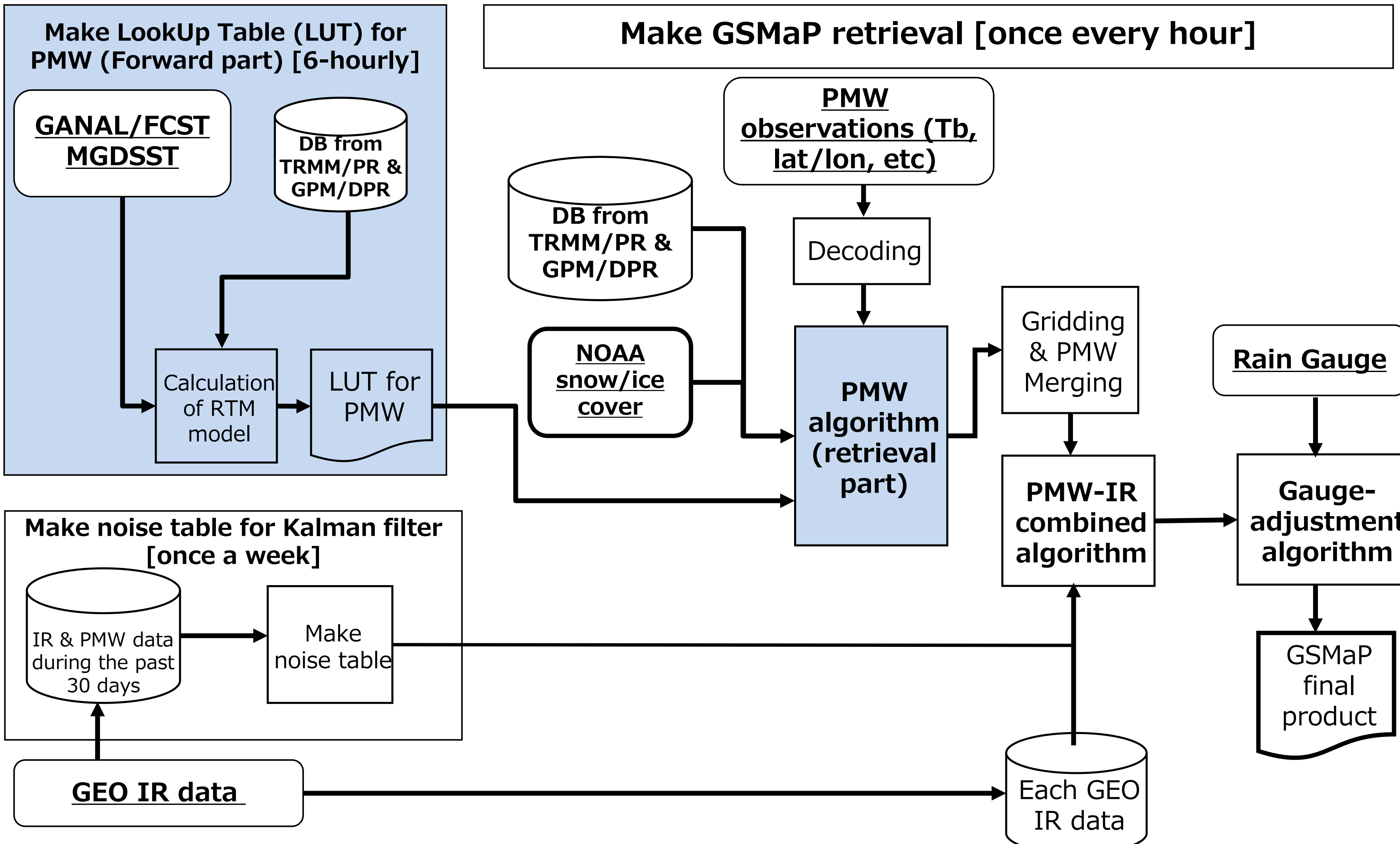
GSMaP_MWR algorithm in the flowchart of the GSMaP product



Ancillary data

- JMA global analysis (GANAL) and forecast (FCST) data set
  - 6-hourly data with 0.5 degree grid box, are used as ancillary data of atmospheric conditions to calculate look-up tables (LUTs).
    - GANAL data are used to process standard products, and FCST data are used to process near-real-time products.
    - In the reanalysis product, the JRA-55 data (6-hourly, TL319L60 model grid) are used instead of operational data.
- The JMA merged satellite and in situ data global daily SST data (MGDSST) (0.25 degree grid box)
  - are used as ancillary data of SST for calculating LUTs.
- Sea Ice and Surface snow
  - Climatological sea ice values from the JAXA Advanced Microwave Scanning Radiometer for EOS (AMSR-E) product were used for screening sea ices in V6, while ancillary data for surface snow were not used.
  - In the V7, the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) multi-sensor snow/ice cover maps were used as ancillary data to detect the sea ice and the surface snow.

Outline of the PMW algorithm

- The PMW algorithm retrieves global precipitation rates from brightness temperatures (Tbs) of the PMW sensor.
- The PMW algorithm has been improved based upon the Microwave Imager (MWI) algorithm of Aonashi et al. (2009).
  - The basic idea of the PMW algorithm is to find precipitation rates that give radiative transfer model (RTM)-calculated Tbs that best fit with the observed Tbs.
  - The MWI algorithm employs polarization corrected temperatures (PCTs) at higher frequencies (37 and 85 GHz for the TMI) over land and coast, and Tbs with vertical polarization at lower frequencies (10, 19, and 37 GHz for the TMI) in addition to the higher frequency PCTs over ocean.
  - Several modifications due to sensor specifications are highlighted later.

Methodology in the PMW algorithm (1)

- The PMW algorithm consists of a forward calculation part and a retrieval part.
- The forward calculation part
  - LUTs are calculated for homogeneous precipitation by incorporating atmospheric and surface variables of the GANAL or FCST data and precipitation physical models based on spaceborne precipitation radar observations into the RTM program of Liu (1998).
  - The precipitation physical models have been developed by previous works (Takayabu 2008; Takahashi and Awaka 2005; Kozu et al. 2009; Yamaji et al. 2017).
    - In construction of the model, the TRMM/PR data were used in V6 algorithm, and both the TRMM/PR and GPM/DPR data were used in the V7 algorithm.
  - The land surface emissivity was used from the TRMM observations (Furuzawa et al. 2012).
  - LUTs for inhomogeneous precipitation are derived from the above LUTs using the approximations of Aonashi and Liu (2000) and Kubota et al. (2009a).

Methodology in the PMW algorithm (2)

- The retrieval part of the PMW algorithm
  - a detection of rainfall, a retrieval using scattering signals, and an over-ocean retrieval using emission signals.
  - Detection scheme
    - Seto et al. (2005, 2008, 2016) for over-land
    - Mega and Shige (2016) for over-coast
    - Kida et al. (2009, 2010a) and Aonashi et al. (2016) for over-ocean
  - Dual-frequency PCTs (at 37 and 85 GHz for TMI) are employed in retrievals using scattering signals.
    - An adjustment method is introduced using indices of frozen precipitation depth and surface temperature.
  - In the over-ocean retrieval using emission signals, a rainfall rate is derived by minimizing a cost function for lower frequency, vertically polarized Tbs (10, 19, and 37 GHz for the TMI), with the scattering retrievals as the first guess.

Orographic/non-orographic rainfall classification scheme

- Over coastal mountain ranges, heavy rainfall can be caused by shallow orographic rainfall, which is inconsistent with the assumption in the PMW algorithm that heavy rainfall results from deep clouds with significant ice.
  - For example, severe underestimations of the GSMaP rainfall estimates in old versions were found over orographic rainfall areas in Japan (Kubota et al. 2009b).
- Therefore, orographic/non-orographic rainfall classification scheme was developed (Shige et al. 2013; Taniguchi et al. 2013) and installed in the PMW algorithm.
  - LUTs for orographic rainfall are calculated according to Shige et al. (2014).
  - In addition, detection schemes have been developed for orographic rainfall areas where the LUTs for orographic rainfall are applied.
    - The scheme and modified one were installed in V6 (Yamamoto and Shige 2015) for the TMI and V7 (Yamamoto et al. 2017) for all sensors, respectively.

Modifications due to sensor specifications

- While the basic structure described above is common in the PMW algorithms, several modifications have been applied because of sensor specifications.
  - Shige et al. (2009) developed an Microwave Sounder (MWS) algorithm which combines an emission-based estimate from Tb data at 23 GHz and a scattering-based estimate from Tb data at 89 GHz over ocean, depending on a scattering index computed from Tb at both 89 and 150 GHz.
  - In addition, the MWS algorithm adopts a rain/no-rain classification method over land using 150 GHz and 183 GHz channels, as described in Kida et al. (2017).
- The over-ocean algorithms for the SSMIS and the SSM/I calculate estimates from normalized polarization differences (Petty 1994) at 19 GHz, and combine them with emission-based estimates from Tb at 19 GHz vertical polarization and scattering-based estimates from the PCTs at 89 GHz (Hashizume et al. 2006; Kubota et al. 2011).

Snowfall estimation method

- Recently, a snowfall estimation was implemented in the V7 algorithm (Kubota et al. 2018).
  - In the V6 or earlier versions, there was no snowfall estimation in the GSMaP products.
- The snowfall estimation method can be divided into a method of classifying precipitation phase (rain/ snow) and if determined to be snow, a method of estimating snowfall intensity.
  - Here, the rain/snow classification method is based upon the method of Sims and Liu (2015), with inputs of the GANAL/FCST data.
    - Based on the results of past ground observations, the method determines the precipitation phase, if rain or snow.
  - The snowfall intensity estimation method was developed using the CloudSat-GPM coincidence dataset, based upon the method of Liu and Seo (2013).
    - This statistical method which uses radar observations to train the PMW data uses information contained in the first three principal components that resulted from an empirical orthogonal function.
- In the V7, the snowfall estimation method was installed in the GMI and the SSMIS.

Evolutions in GSMaP_MWR algorithms from V6 to V7

Item	V6	V7
Utilization of spaceborne radar data in precipitation physical models	TRMM/PR	TRMM/PR and GPM/DPR
Ancillary data for sea ice	JAXA AMSR-E (climatological)	NESDIS
Ancillary data for surface snow	None	NESDIS
Detection over the land for MWI/SSMIS/GMI	Seto et al. (2008)	Seto et al. (2016)
Detection over the ocean for MWI/SSMIS/GMI	Kida et al. (2009, 2010a)	Kida et al. (2009, 2010a), Aonashi et al. (2016)
Orographic/non-orographic rainfall classification scheme	Yamamoto and Shige (2015) for the TMI	Yamamoto et al. (2017) for all sensors
Snowfall estimation method	Not implemented	Implemented in GMI/SSMIS

Reference

- Recently, we submitted the following paper to the Springer Book on Satellite Precipitation.
  - T. Kubota, K. Aonashi, and co-authors, Global Satellite Mapping of Precipitation (GSMaP) products in the GPM era, *Satellite precipitation measurement*, Springer, *submitted*.
- This ppt file is a subset of the paper.