COMPARISON BETWEEN TWO LATENT HEATING ALGORITHMS DEVELOPED FOR TRMM PR DATA

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1. Introduction

In Japan, two algorithms are used for estimating latent-heat profiles with TRMM PR products. One is the Precipitation Radar (Profiling) Heating (PRH) Algorithm, which was proposed by Satoh. The other is the Spectral Latent Heating (SLH) Algorithm, which was proposed by Takayabu and Shige. In this report we compare the results obtained using these two methods. Level-2 and level-3 data products retrieved using PRH and SLH algorithms were processed by the Earth Observation Research and application Center (EORC), the Japan Aerospace Exploration Agency (JAXA). The TRMM latent-heat algorithms are outlined in Section 2. The method used for comparing the two algorithms is described in Section 3. Section 4 presents the results of the comparison between the SLH and PRH products. A summary of the results is provided in Section 5. The two algorithms were evaluated at a meeting held by the Japanese TRMM PR algorithm representative. Figures produced by the EORC are included in the Appendix of this document. However, due to space limitations, we could not include all relevant figures. Representative figures are included to assist with the explanation of results.

2. Outline of latent-heat profiles

Table 1 presents the algorithms used for estimating latent-heat profiles from the TRMM data. Three algorithms were used on the PR data: PRH, SLH, and the Convective-Stratiform Heating (CSH) algorithm proposed by Tao et al (1993). CSH uses both PR and TMI data for latent-heat estimation, and the output is given as a monthly value. In contrast, PRH and SLH are based on PR data only, and can be used to estimate instantaneous latent heat profiles as well as monthly values.

Figure 1 depicts the conceptual model for squall lines, and typical latent heat profiles in convective and stratiform areas, as reported by Houze (1989). In convective areas, positive heating dominates all layers, while in stratiform areas, cooling dominates in the upper troposphere and warming dominates in the lower troposphere. As a result, total averaged latent heat profiles tend to have a top-heavy structure.

The characteristics of PRH and SLH algorithms are described by Satoh (2004) and Takayabu and Shige (2004). Both algorithms classify all convective rainfall in 2A23 and 2A25 products as “convective.” Stratiform rainfall in 2A23 and 2A25 products is classified by PRH as “stratiform.” However, stratiform rainfall is only classified as “stratiform” by SLH when the rain top height exceeds the melting level. When the rain-top height is lower than the melting level, it is classified as “shallow.” PRH classifies “other” rainfall types as “shallow,” if the rain bottom level reaches the land surface. SLH classifies “other” rainfall types as “convective” if the rain are classified as “shallow isolated” in the 2A23 product. If the rain bottom level does not reach the land surface, PRH classifies it as “anvil.” SLH cannot estimate the heating value for this rainfall type.

	Features	Applied data
GPROF (2A12)	- physical approach - random error by Bayesian method	**TMI only** - wide swath observations - less information on storm structure - depends on 85 GHz data over land
HH	- physical approach - ready to use (from 2A12, 2B31)	
CSH (LHUSA)	- based on diagnostic budget study - one single max heating level	**both TMI and PR** **(Only Level3)**
PRH	- independent of cloud model - w-profiles for the LH retrieval	**PR only** - Level2 (instantaneous vertical LH profiles - Level3 (monthly LH profiles)
SLH	- LH look-up table referring to PTH from CRM - RR at melting layer for referring in Anvil region	

3. Methods

PR 2A25 Version 5 input data were used for the analyses. Instantaneous latent heat products (Level 2) and monthly latent heat global maps (Level 3) were made in the same format and processed using PRH and SLH algorithms. The results obtained for each of the algorithms were then compared. Ten test cases were chosen for the comparison of Level-2 product data using 1) the vertical cross sections of the latent-heat profile along a satellite track (at nadir), 2) the averaged latent-heat profiles produced from the test cases, and 3) the difference between near-surface rain and rain estimated from latent-heat profile outputs.

For Level-3 products, we calculated 1) the global monthly average latent-heat profiles and 2) global maps of latent heat using three months of data collected before and after the termination of El Nino (February, May and June 1998). Monthly averaged latent-heat profiles were also calculated for 15 other locations.

	Date	Path #	Area	Type
1	19 May 1998	2719	SCSMEX	Clusters
2	24 May 1998	2807	SCSMEX	Scattering
3	31 May 1998	2915	SCSMEX	Scattering
4	3 Jun. 1998	2966	SCSMEX	Clusters/Scattering
5	16 May 1998	2681	Australia	Convective/Stratiform
6	10 May 1999	8329	Oklahoma	Squall line
7	22 Sep. 1999	10464	Hawaii	Shallow convection
8	3 Jun. 2000	14492	Japan	Baiu frontal rainfall
9	2 Aug. 2000	15432	W.Pacific	Typhoon (developing)
10	8 Aug. 2000	15526	Japan	Typhoon (decaying)

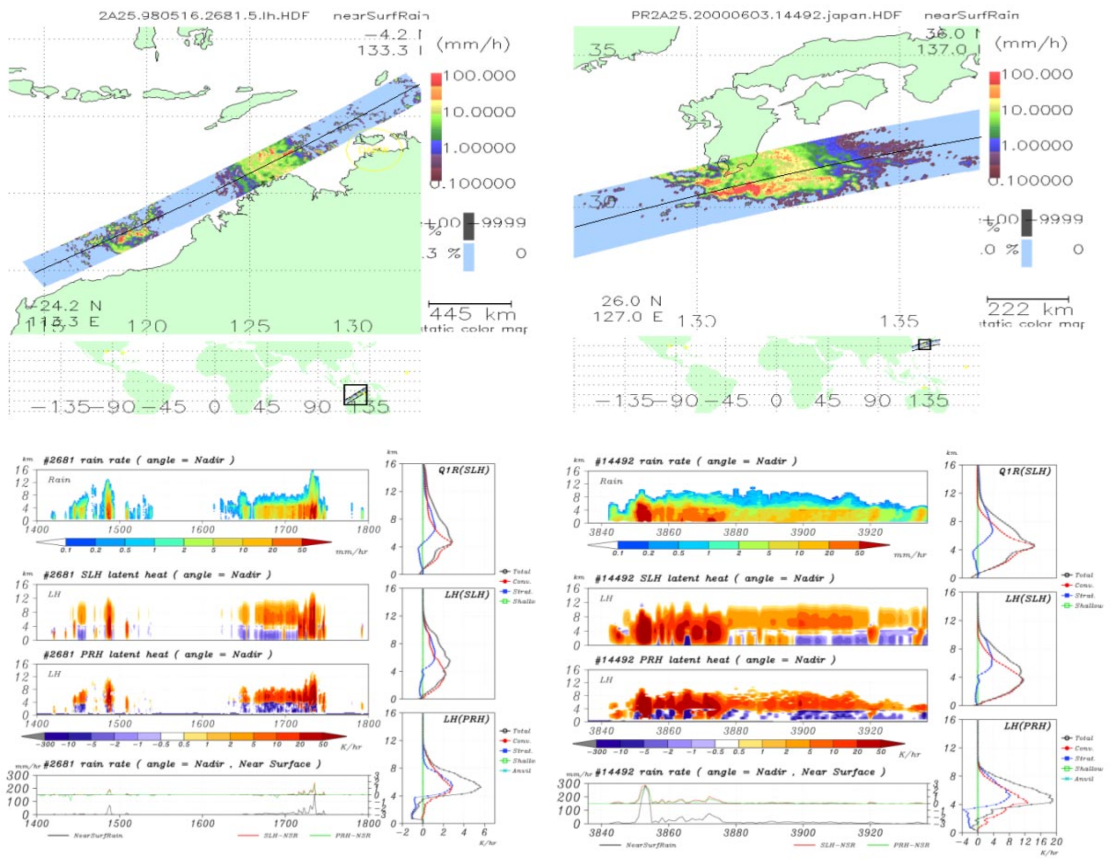
4. Results of Comparisons

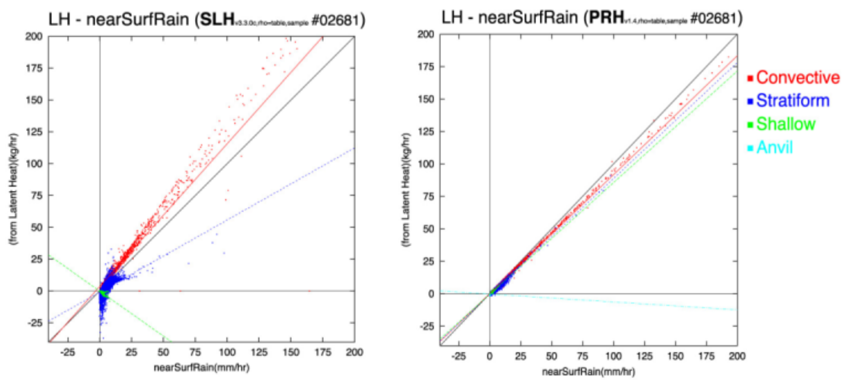
4.1 Level 2: Instantaneous latent-heat profiles

Table 2 shows the ten test cases used for the comparative analyses. The data for cases 1–4 were collected during the South China Sea Monsoon Experiment (SCSMEX) conducted in 1998. The other six cases were sourced from a range of other precipitation systems.

This subsection presents the results of the comparison using a vertical cross section of the latent-heat profiles collected along the orbit path (at nadir) and their averaged profiles by rainfall type for five cases.

Figure 1a depicts the horizontal rain map of PR 2A25 products at a site near Darwin, Australia. Figure 1b presents the vertical latent heat cross sectional profiles collected at nadir (along black line in Fig. 1a) and produced using the PRH and SLH algorithms. The two profiles exhibited qualitatively similar patterns. PRH had a lower cloud-top height in the latent-heat profile compared with the result obtained using the SLH algorithm. This was due to the fact that cloud-top height in the PRH algorithm is the same as in the PR profile, while in the SLH algorithm, cloud-top height is estimated using a cloud-resolving model. Heating values were estimated at all heights using the SLH algorithm. Cooling values were sometimes estimated at a lower level using the PRH algorithm. Averaged latent-heat profiles calculated using the SLH algorithm indicated that heating dominated the convective rainfall. The peak height was found to be at 3.5km. Heating (cooling) above (below) the melting layer dominated the stratiform rainfall. In contrast, the latent-heat profiles calculated using the PRH algorithm indicated heating of the whole layer and the peak height was found to be at 5km. For stratiform rainfall, the peak in heating above the melting layer was larger for PRH. The peak value obtained for average heating of all rainfall types was twice as large when calculated using the SLH algorithm.





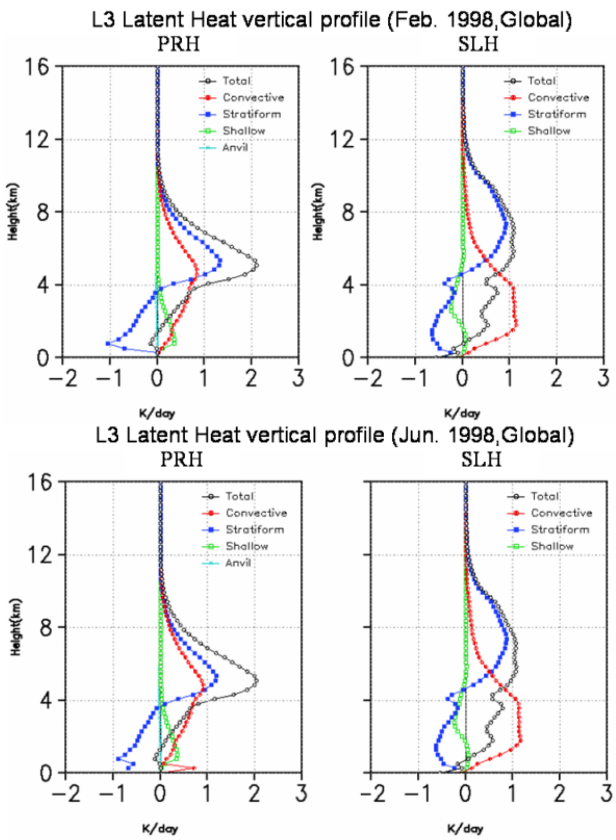
In the Baiu frontal case (Fig. 2), convective rainfall on the west side and stratiform rainfall on the east side developed along the nadir. The SLH algorithm estimated the heating caused by all convective rainfall. In contrast the PRH algorithm estimated cooling caused by some convective rainfall. Both algorithms estimated heating at all levels, and PRH estimated a lower value for heating in the lower levels, based on averaged latent heat profiles. Because the PRH algorithm estimated large cooling value below the melting layer in the stratiform rainfall. The estimated value estimated by SLH algorithm for total latent heat above the melting layer was much larger when calculated using the PRH algorithm.

The surface rain rate estimated by vertical integration of latent-heat profiles was compared with near-surface rain from the PR 2A25 product using scatter diagrams showing individual pixels (Fig. 3). The rain rate estimated by the PRH algorithm was also consistent with the near-surface rain. However, the rain rate estimated using the SLH algorithm was greater (less) than the measured value for near-surface rain on the convective (stratiform) rain. The advection of solid precipitation in the upper layers influenced estimations of the surface rain using the SLH algorithm.

4.2 Level 3: Monthly latent-heat distributions

This subsection presents the results obtained using monthly values for latent heat (Level-3 products). The products were characterized by 148 pixels from 37°S to 37°N latitude, and 720 pixels in longitude (0.5° x 0.5° grids) and 80 levels from 0km to 20 km in height (0.25 km).

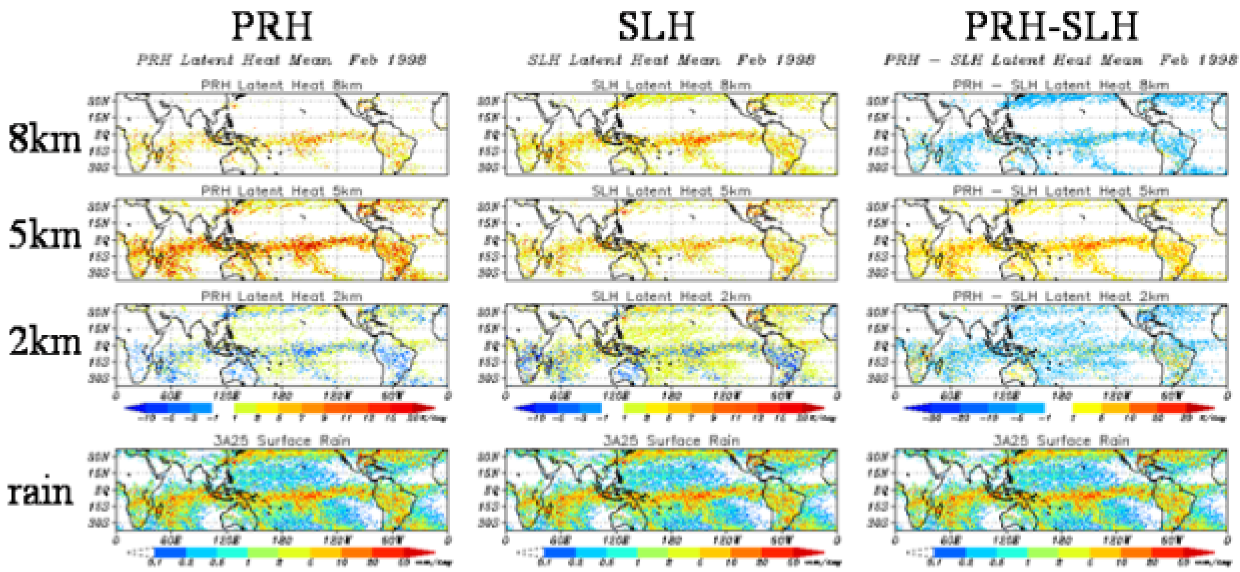
Monthly global latent heat and rainfall maps differed before and after the termination of the El Nino event. However, differences in the global averaged latent-heat profiles were quite small (Fig. 4). The patterns of heat distribution estimated using PRH and SLH algorithms were similar, although heating values obtained using the PRH algorithm were larger at 5km and smaller at 2km and 8km than those estimated using the SLH algorithm (Fig. 5). In the winter areas of northern mid-latitudes, heating values were estimated at 8km using the SLH algorithm. No values could be estimated using PRH at the winter sites (Fig. 5). The peaks of the total latent-heat profile estimated using PRH and SLH were



5 and 7km respectively (Fig. 5). Heating and cooling profiles for 'shallow rain' were estimated independently using both PRH and SLH, because the definitions of shallow rain differ between the two algorithms. The resulting global latent-heat patterns were consistent with those reported by Tao et al. (2001).

5. Summary

In this study, we compared the results obtained using two latent-heat algorithms: the Precipitation Radar (Profiling) Heating (PRH) Algorithm and the Spectral Latent Heating (SLH) Algorithm. Instantaneous (Level 2) and monthly (Level 3) latent-heat products were measured using the algorithms for the PR 2A25 products and compared. For Level-2 products, the main differences between the results obtained using PRH and SLH algorithms are described below:



1) The peak height for maximum heating obtained using the PRH algorithm was higher (lower) than that obtained using the SLH algorithm for convective (stratiform) rainfall. The magnitude of convective heating was larger using the PRH algorithm.

2) Using pixel-by-pixel data, surface rain estimated by integrating the latent-heat profiles (P_o) was found to be similar to the PR near-surface rain (P_s) for PRH algorithms. P_o was found to be larger (smaller) than P_s for convective (stratiform) rains for SLH algorithm.

For Level-3 products, the differences between PRH and SLH algorithms are summarized below:

1) The profiles obtained using the PRH algorithm had a lower latent heat top height than those obtained using the SLH algorithm.

2) The PRH algorithm predicted that the peak height (5km) of heating does not depend on rain types. The profiles obtained using the SLH algorithm were found to have higher heating peaks for stratiform rain and lower heating peaks for convective rain.

3) Higher peak heating values were obtained using the PRH algorithm.

4) From shallow rain the PRH algorithm estimates heating value and the SLH algorithm estimates cooling value.

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