Development of retrieval algorithm for the GPM DPR spectral latent heating algorithm in the midlatitudes

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Summary

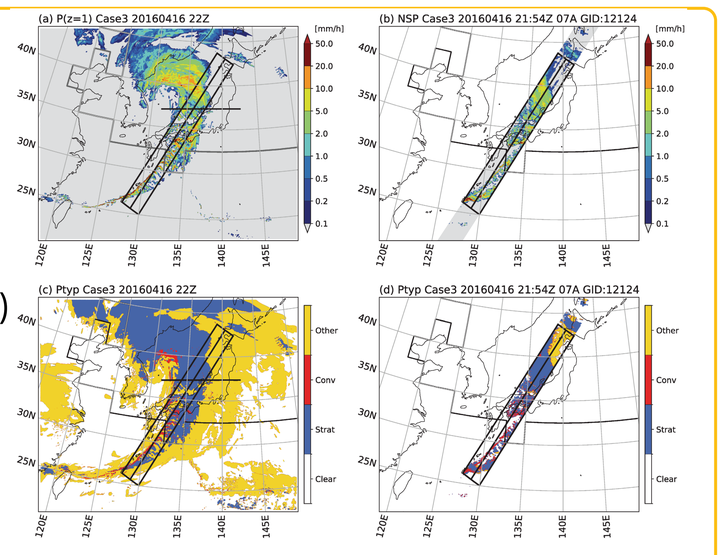
- A new algorithm for estimating the latent heating profile for precipitation in the extratropics was developed to extend the current spectral latent heating (SLH) algorithm that applies only to the tropics
- A Look-up table (LUT)-based estimation (please also visit companion poster by Yokoyama et al. (19-P42) for the LUTs construction)
- "Normalized relative height," incorporated for deep stratiform precipitation, successfully determine cloud base heights only from precipitation profile
- Three-dimensional heating estimates within 65°S–65°N are provided for the first time for the SLH product

1. Background

- Diabatic heating plays an essential role in global-scale circulation and energy and water budgets, therefore precise estimation is important
- The Spectral Latent Heating (SLH) algorithm (Shige+ 2004, 2007, 2008, 2009) has been developed for the tropics, data available as a GPM standard product
- Significant precipitation and heating are also present in the extratropics
- Here we introduce the SLH algorithm for the extratropics (Papers with detailed description are now under revision)

2. Data

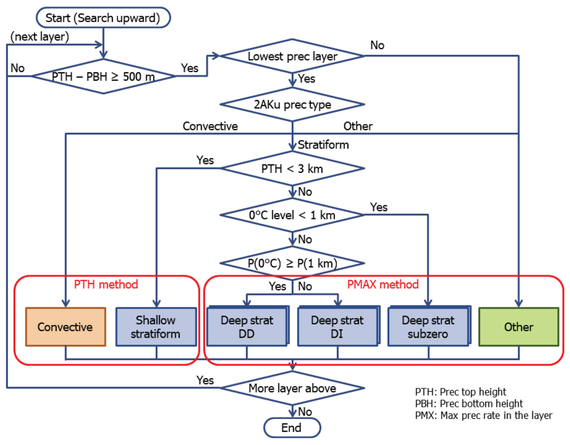
- Numerical simulations from the Local Forecast Model (LFM; JMA 2019) of the Japan Meteorological Agency (2 km, 58 levels 0–20.2 km)
  - Nine cases (8 over North Pacific, 1 over North Atlantic)
- Measurements from the dual-frequency precipitation radar (DPR) onboard the Global Precipitation Measurement (GPM) core satellite (2 km/125 m in horizontal/vertical, orbital, 65°S–65°N); 2AKu product
- A precipitation regime database originally developed by Takayabu et al. (2008) with updates



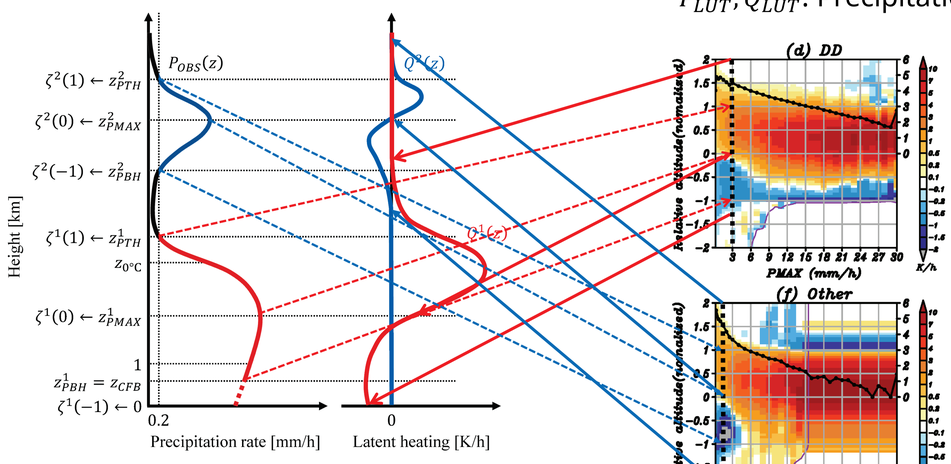
Case example: (a) LFM surface precipitation rate [mm/h], (b) near-surface precipitation rate [mm/h], (c) precipitation types determined from LFM precipitation, and (d) precipitation types determined from the GPM KuPR-measurements

3. Retrieval algorithm: Overview

- 1-D latent heating profile (also for Q_{1R} and Q_2) is estimated from 1-D precipitation profile at each grid point
- Estimation steps (a bit quite complicated so plz also see Figs.1,2):
  1. Identify the precipitation layers within the input precipitation profile, as vertically contiguous bins with precipitation rates >= 0.2 mm/h
  2. Determine precipitation top and bottom heights (PTH and PBH) for each layer → Layers with PTH−PBH<500 m discarded
  3. Classify precipitation layers
     - For the lowest precipitation layer: Based on the "typePrecip" in the 2AKu product (stratiform/convective/"other"). Stratiform layer further classified into shallow (PTH < 3 km AGL) or deep (PTH >= 3 km AGL)
     - For the second and subsequent layer(s): All assigned to "other"
  4. (For deep stratiform layer) Classify in a more detail
     - At or above surface (clutter-free bottom), whether the height with the maximum precipitation is at or above the clutter-free bottom height
     - Subzero or not, based on the melting level (1 km AGL)
     - For non-subzero, downward decreasing (DD) or increasing (DI): Precipitation rate at 1 km is greater/less than that at the melting level
  5. (In total, there are nine precipitation layer types; Fig. 1)
  6. Select the method for heating profile
     - Convective or shallow stratiform: "PTH method"
     - Others: "PMX method"
  7. Sum up profiles of all layers to get the final heating profile at the target



Flow diagram for the classification of precipitation profiles developed in this study



Schematic figure for explaining the heating profile retrieval using the PMAX method

PTH/PMX methods

<PTH method>

- Almost same as used to estimate heating profiles for convective precipitation in the tropics (Shige et al. 2004)

<PMX method>

- Basic concept is the same as tropical algorithm
- Improvements were made to represent the diversity of extratropical precipitation, esp. the top and bottom heights of stratiform precipitation
- A "normalized relative height $\zeta(z)$" is introduced: For i-th layer,

$$\zeta^i(z) = \begin{cases} \frac{z - z^i_{PMAX}}{z^i_{PTH} - z^i_{PMAX}} & z \geq z^i_{PMAX} \\ \frac{z - z^i_{PMAX}}{z^i_{PMAX} - z^i_0} & z < z^i_{PMAX} \end{cases} \quad \text{(with some variants)}$$

z_{PMAX}: Height with maximum precipitation rate

z_{PTH}, z_0: Top and bottom heights of the layer

- $\zeta(z)$ are −1, 0, and 1 at PBH, the height w/ max prec rate, and PTH, respectively
- Heating profile for each precipitation layer is then estimated using $\zeta^i(z)$:

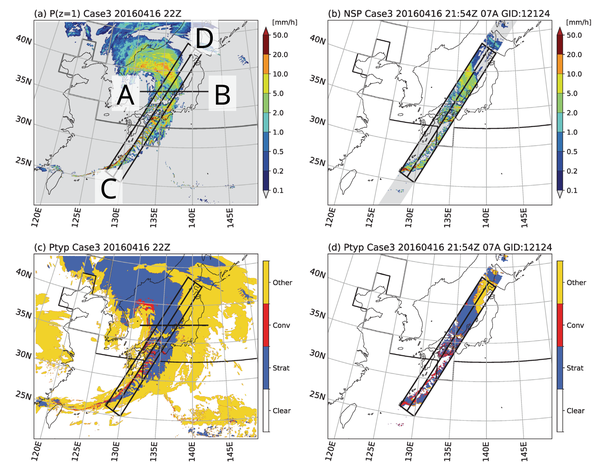
$$Q^i(z) = \begin{cases} \frac{P_{MEA}(z = z^i_{PMAX})}{P_{LUT}(\zeta^i = 0)} \cdot Q_{LUT}(\zeta^i(z)) & z \geq z^i_{PMAX} \\ \frac{P_{MEA}(z = z^i_{PMAX}) - P_{MEA}(z = z^i_{PBH})}{P_{LUT}(\zeta^i = 0) - P_{LUT}(\zeta^i = -1)} \cdot Q_{LUT}(\zeta^i(z)) & z < z^i_{PMAX} \end{cases}$$

P_{MEA}: Measured precipitation rate

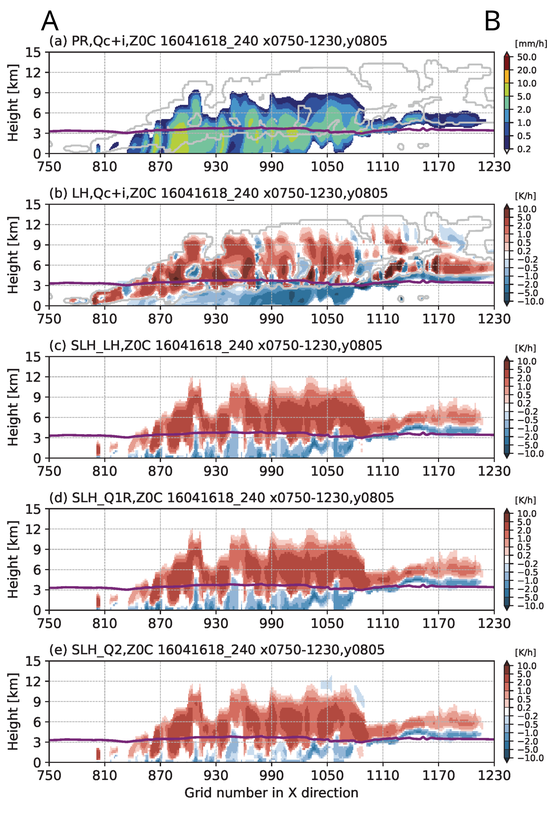
P_{LUT}, Q_{LUT}: Precipitation and heating rates in the look-up table

4. Consistency check

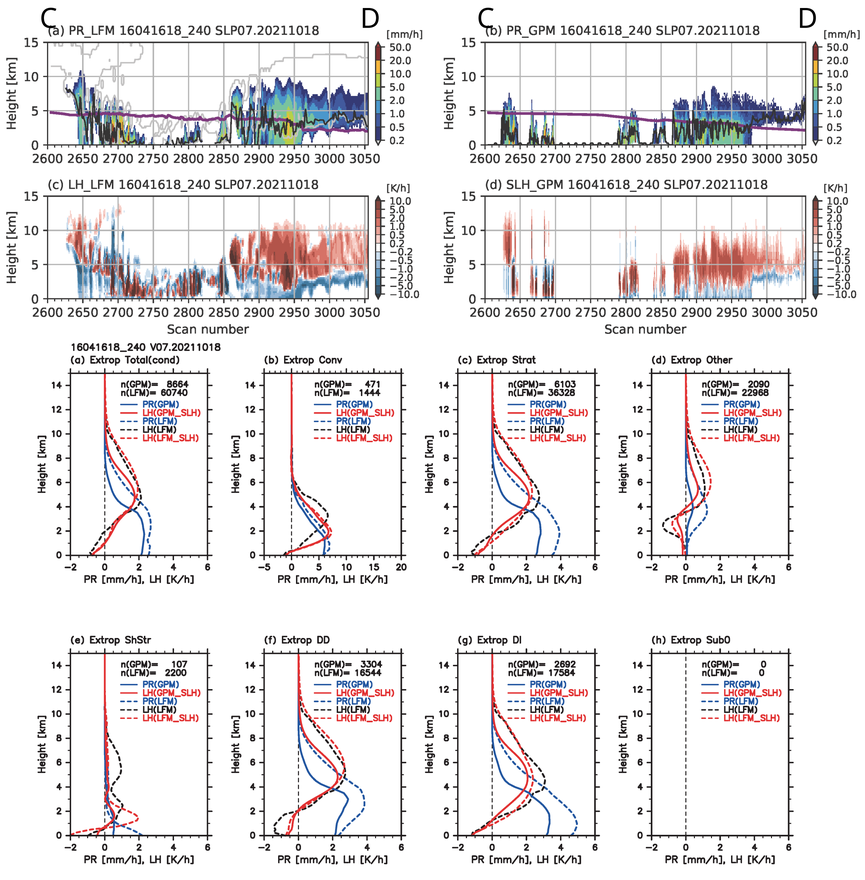
Snapshots of LFM and prec/prec type



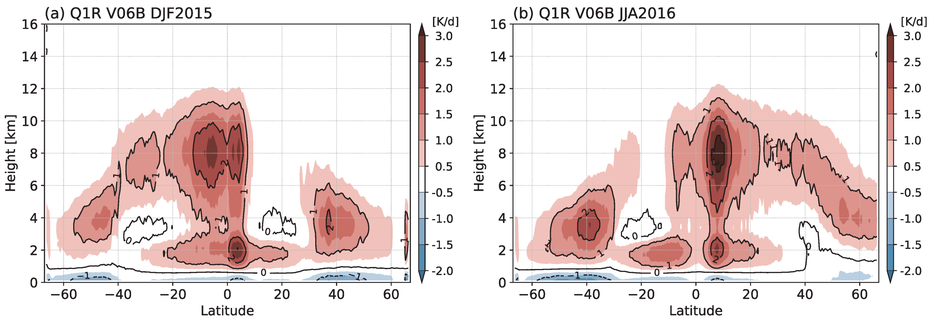
LFM-simulated prec and heating vs. SLH estimates using LFM prec



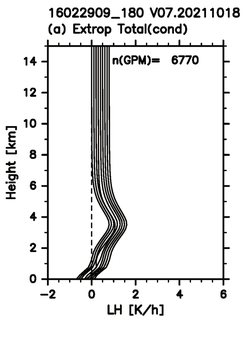
LFM-simulated prec and heating vs. SLH estimates using GPM prec



Meridional cross sections of SLH estimates using GPM prec



Cross-validation analysis



RMSEs with different horizontal averaging scales