Atmospheric Diabatic Heating Distributions Derived from a Combination of Satellite Sensor Data

Bill Olson, Tristan L’Ecuyer, Guojun Gu, Mircea Grecu, Xianan Jiang, and Michael Bosilovich

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transport

latent heating profile

GPM

NASA ENERGY AND WATER CYCLE STUDY
NEWS
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DJF distributions from Newell et al. (1969)
How is it done?

\[ Q_1 = \frac{L_v}{c_p}(\tilde{c} - \tilde{e}) + \frac{L_f}{c_p}(\tilde{f} - \tilde{m}) + \frac{L_s}{c_p}(\tilde{d} - \tilde{s}) + \bar{\pi} \left( \nabla' \cdot \nabla \theta' - \frac{1}{\bar{\rho}} \frac{\partial \bar{\rho} \bar{w}' \theta'}{\partial z} \right) + Q_R \]

**phase change or “latent heating”**

**eddy sensible heat flux convergence**

**radiative heating**

**Use satellite data:** latent and eddy sensible heating, \( Q_1-Q_R \), in precipitating convection from the TRAIN algorithm (Grecu and Olson 2006; Grecu et al. 2009), utilizing TRMM PR and TMI.

\( Q_1 - Q_R \) (precip)
How is it done?

\[ Q_1 = \frac{L_v}{c_p}(\bar{c} - \bar{e}) + \frac{L_f}{c_p}(\bar{f} - \bar{m}) + \frac{L_s}{c_p}(\bar{d} - \bar{s}) + \pi \left( -\nabla' \cdot \nabla'\theta' - \frac{1}{\rho}\frac{\partial \rho' w' \theta'}{dz} \right) + Q_R \]

- phase change or “latent heating”
- eddy sensible heat flux convergence
- radiative heating

Use satellite data: radiative heating, \( Q_R \), from the HERB algorithm (L’Ecuyer and Stephens, 2003/07), utilizing TRMM TMI, VIRS, and NCEP analyses.
How is it done?

\[ Q_1 = \frac{L_v}{c_p}(\bar{c} - \bar{e}) + \frac{L_f}{c_p}(\bar{f} - \bar{m}) + \frac{L_s}{c_p}(\bar{d} - \bar{s}) + \bar{\pi}\left[-\bar{V}' \cdot \bar{\nabla} \bar{\theta}' - \frac{1}{\bar{\rho}} \frac{\partial \bar{\rho} \bar{w}' \bar{\theta}'}{\partial z}\right] + Q_R \]

- *phase change or “latent heating”*
- *eddy sensible heat flux convergence*
- *radiative heating*

**Use satellite data:** latent and eddy sensible heating, \( Q_1 - Q_R \), in convective boundary layer from a simple energy balance model, given \( Q_R \) from HERB and environmental temperature from NCEP reanalysis.

\( Q_1 - Q_R \) (precip)  
\( Q_1 - Q_R \) (non-precip)
Satellite Estimates vs. Rawinsonde Analyses

SCSMEX NESA

Surface Rain Rates

TMI $Q - Q_s$ [K day$^{-1}$]

TMI/VIRS $Q_s$ [K day$^{-1}$]

Rawinsonde $Q_s$ [K day$^{-1}$]

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Surface Rain Rates

TMI $Q - Q_s$ [K day$^{-1}$]

TMI/VIRS $Q_s$ [K day$^{-1}$]

Rawinsonde $Q_s$ [K day$^{-1}$]

DATE

rawinsonde $Q_s$ from Johnson and Ciesielski (2002)  rawinsonde $Q_s$ from Katsumata et al. (2009), JAMSTEC
1998-2008 Mean Annual Cycle of Precip & Atmospheric Heating

TMI Surface Rain Rates

TMI Rain Rate Jan 9808

TMI Rain Rate Feb 9808

TMI Rain Rate Mar 9808

TMI Rain Rate Apr 9808

TMI Rain Rate May 9808

TMI Rain Rate Jun 9808

TMI Rain Rate Jul 9808

TMI Rain Rate Aug 9808

TMI Rain Rate Sep 9808

TMI Rain Rate Oct 9808

TMI Rain Rate Nov 9808

TMI Rain Rate Dec 9808

zonal-mean streamfunctions form Peixoto and Oort (1992)

from Olson, L’Ecuyer, Grecu (NEWS)
Applications to the Madden-Julian Oscillation

from A. J. Matthews
TMI/VIRS $Q_1$ Phase Anomalies due to Madden-Julian Oscillation

TMI/VIRS $Q_1{'}$ at 7 km

TMI/VIRS Equatorial Band $Q_1{'}$

Lin et al. (2004)
Eddy Available Potential Energy in the MJO

- Use 6 years of TRMM $Q_1$ data and AIRS $T$ data (2003–2008).

- Compute phase-average APE generation from diabatic heating (see Lau and Lau, 1992):

\[
\frac{\partial APE}{\partial t} \approx -\frac{c_p \gamma}{\bar{T}} \nabla_h T' \cdot \nabla_h \bar{T} + \frac{RT' \omega'}{p} + \frac{\gamma Q'_T \bar{T}}{\bar{T}} + \ldots
\]
MJO Eddy Available Potential Energy Generation

TMI/VIRS/AIRS

ECMWF during TOGA/COARE

from Yanai et al. (JAS, 2000)
Outlook

• $Q_1$ algorithm still maturing, but satellite estimates could offer a reasonable reference for evaluating reanalysis-based estimates of heating.

• New $Q_1$ validation data from CINDY/DYNAMO; use ARM & GPM ground validation for intermediate products.

• Adapt methods to ATRAIN (Aqua); improves sampling; other constraining observations available.

• Heating estimates available via ftp: Bill.Olson@nasa.gov