Atmospheric temperature tides in the tropical upper troposphere and lower stratosphere

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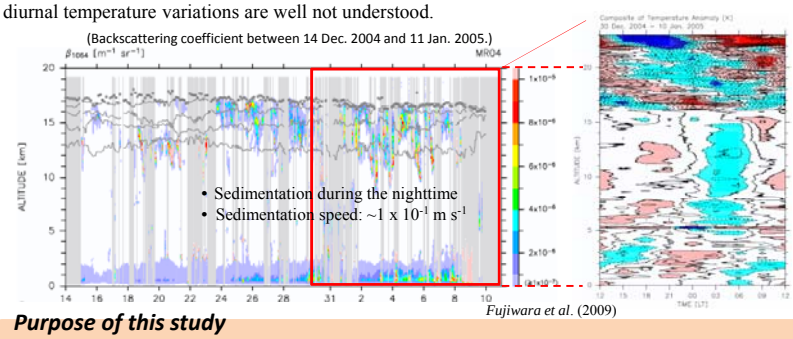
1. Introduction

- Recent studies reported **diurnal variations in cirrus cloud in the TTL** that may impact on the dehydration process (*Fujiwara et al.* 2009; *Sassen et al.*, 2009) . ["Nighttime > Daytime" (*Sassen et al.*, 2009)]
- **Diurnal temperature variations** may impact on the cirrus cloud formation and maintenance (Fujiwara et al., 2009).
- Although some in-situ observations were made in the tropics (e.g., *Alexander and Tsuda*, 2008), global structure of diurnal temperature variations are well not understood.



Fujiwara et al. (2009)

Purpose of this study

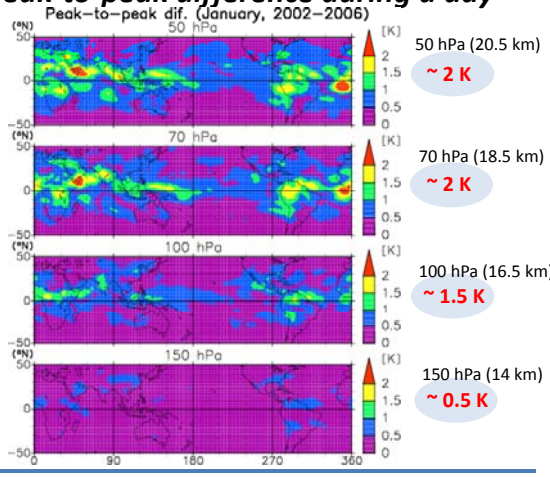
to reveal the global pattern of diurnal temperature variations and its seasonal dependence in the TTL.

2. Data description

- **MERRA**: Modern-era retrospective analysis for research and applications
  - Analysis period: **2002-2006**
  - Horizontal resolutions: **1.25° x 1.25°**
  - Vertical layers: **42** layers
  - Time resolution: **3-hourly**

Validation of MERRA
- Temperature at 100 hPa (mean/equatorial waves): *Fujiwara et al.* (2012)
- The stratospheric temperature (mean/tides): *Sakazaki et al.* (2012a)

3. Peak-to-peak difference during a day



50 hPa (20.5 km) ~ 2 K

70 hPa (18.5 km) ~ 2 K

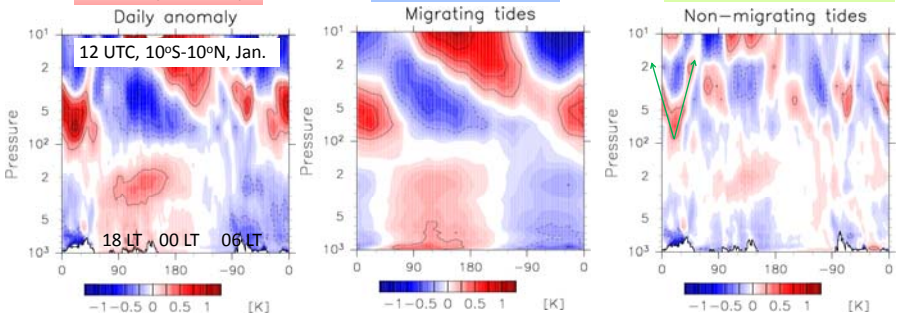
100 hPa (16.5 km) ~ 1.5 K

150 hPa (14 km) ~ 0.5 K

4. Migrating tides & Non-migrating tides

- Daily anomaly is decomposed into migrating and non-migrating component.

(a) Daily anomaly = (b) Migrating tides + (c) Non-migrating tides



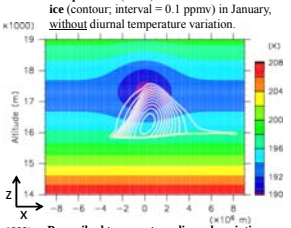
- **Migrating tides**, particularly the **diurnal** migrating tide, is dominant (The peak-to-peak difference is **~1 K** in the TTL).
- **Non-migrating tides** are excited over the continent by latent heat release, with the peak-to-peak difference of **~0.5 K** in the TTL.

5. Impact of temperature tide on the dehydration

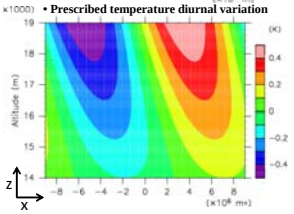
- Preliminary results with the model by Holton and Gettelman (2001) -

- **Dehydration** is assessed using a simple 2D model, with and without the **diurnal migrating temperature tide**.

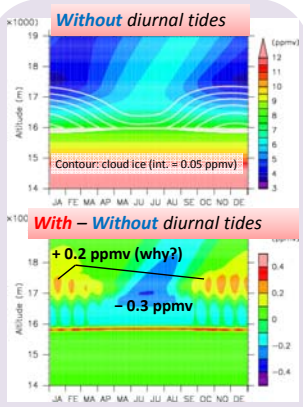
- **Temperature** (color) and calculated **cloud ice** (contour; interval = 0.1 ppmv) in January, without diurnal temperature variation.



- **Prescribed temperature diurnal variation**



"Tape Recorder" in water vapor



Tidal effects depend on season?

Model description

- 2D (x, z) model by *Holton and Gettelman* (2001) is used.
- L_x = 18000 km, L_z = 5 km (between 14 and19 km)
- Δx = 3.6 km, Δz = 20 m, Δt = 1 hr
- Temperature (T) and zonal wind (u): prescribed

$$T(x,z,t) = T_0(z) - 4\exp\left[-\left(\frac{z-z_{trop}}{d}\right)^2\right]\exp\left[-\left(\frac{x}{L}\right)^2\right]\frac{1+\cos(\pi t_{day}/180)}{2} + T_{Diurnal}(x,z,t)$$

← annual mean + seasonal/diurnal variations

Seasonal variation is localized at x = 0.

$u = -10$

- Vertical wind (w): parameterized

$$w(x,z,t) = w_0 - (4\times10^2)q_0\exp\left[-\left(\frac{x}{L}\right)^2\right] - w_{fall}$$

w_0 = 0.03 mm s^{-1} w_{fall} = 4 mm s^{-1}

- **Water vapor (q_v) and cloud ice (q_i)**: predicted

$$\frac{Dq_v}{Dt} = -\alpha(q_v - \bar{q}) + K\frac{\partial^2 q_v}{\partial z^2} + E - C$$

$$\frac{Dq_i}{Dt} = -\alpha q_i + K\frac{\partial^2 q_i}{\partial z^2} - E + C$$

E (evaporation) = q_i/τ_E (τ_E = 1 day)
C (condensation) = $(q_v - q_s)/\Delta t$

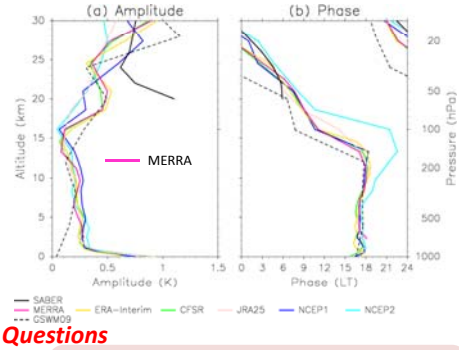
- Water vapor pressure of ice (p_{ice})

$p_{ice} = \exp(9.550426 - 5723.265/T + 3.53068\ln(T) - 0.00728332T)$
(Eq. (7) of *Murphy and Koop*, 2005)

To do in the future
- Diurnal variations in w should be included.
- What if non-migrating tides are included?
- Some sensitivity tests need to be done.

6. Diurnal migrating tide *(Sakazaki et al., 2012a, 2012b)*

Reanalyses *(January, 10°S-10°N)*



Questions

What causes this vertical structure?
(1) amplitude maximum at ~20 km.
(2) constant phase within the troposphere.

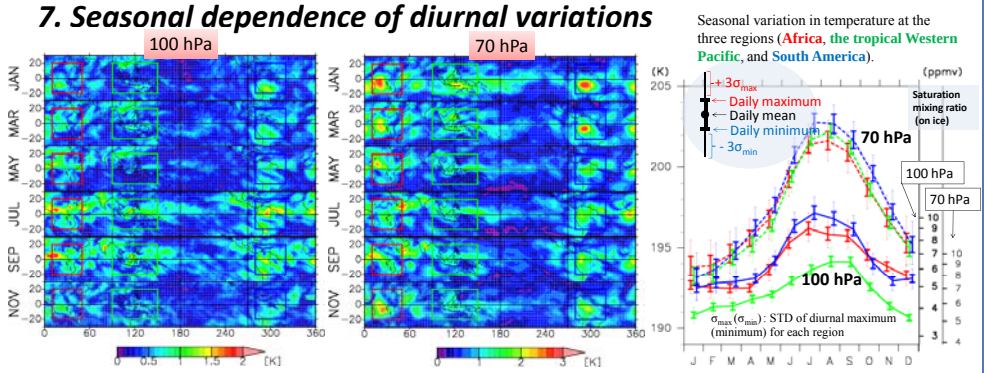
(1): The N^2 maxima at 20 km (e.g., *Grise* et al., 2010) amplify the adiabatic process.

(2): The diabatic heating has a constant phase (~50%), and the adiabatic process (~50 %) also has a constant phase within the troposphere. The constant phase of adiabatic process (i.e., w) is due to small N^2 value in the troposphere (vertical wavelength of the first propagating Hough mode is ~50 km in the troposphere).

$$\frac{\partial T_n}{\partial t} + \frac{HN^2}{R}w_n = \frac{Q_n}{c_p}$$

adiabatic process — diabatic heating (maximizes at 1200 LT)

7. Seasonal dependence of diurnal variations



Seasonal variation in temperature at the three regions (**Africa**, **the tropical Western Pacific**, and **South America**).

8. Conclusions

- The peak-to-peak difference within the TTL reaches 1-2 K, which might impact the dehydration by +/− 0.3 ppmv.
- The diurnal temperature variations are mainly caused by diurnal migrating tides, as well as non-migrating tides enhanced over the continent.
- Diurnal amplitude is large (small) in the Northern Hemisphere winter (summer) at 100 hPa (70 hPa).

References

- Alexander and Tsuda (2008), J.G.R., doi:10.1029/2007JD008717.
- Fujiwara et al. (2009), J.G.R., doi:10.1029/2008JD011040.
- Fujiwara et al. (2012), J.G.R., doi: 10.1029/2011JD016808.
- Grise et al. (2010), J. Clim., 23, 2275-2292.
- Holton and Gettelman (2001), G.R.L., 28, 2799-2802.
- Murphy and Koop (2005), Q.J.R.M.S., 131, 1539-1565.
- Sakazaki et al. (2012a), J.G.R., doi:10.1029/2011JD019117.
- Sakazaki et al. (2012b), submitted to JGR
- Sassen et al. (2009), J.G.R., doi:10.1029/2009JD011916.

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