TEMPERATURE VARIATION CHARACTERISTICS IN THE MIDDLE ATMOSPHERE STUDIED WITH RAYLEIGH LIDAR AT HAIKOU (19.9°N, 110.3°E)

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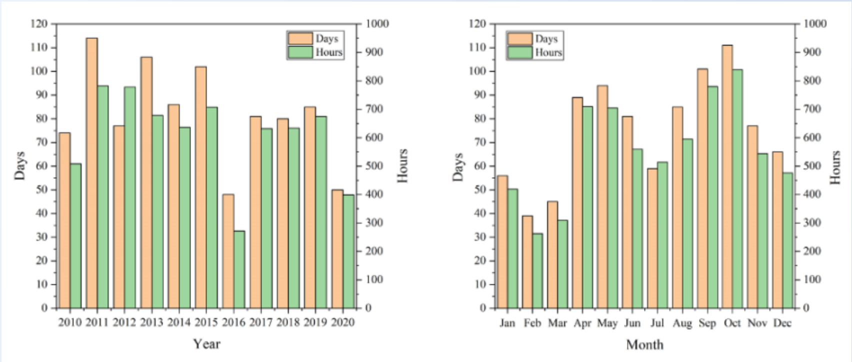
Abstract: Based on the long-term observations of Hainan lidar (19.9°N, 110.3°E) during 2010–2020, temperature variation characteristics in the middle atmosphere (32–64 km) are investigated by analyzing the Rayleigh back-scattering data. Statistical analysis results show that, at Haikou, the stratopause located in the altitude range of 42– 51 km, and the maximum of daily mean temperature was ~262 K. The temperature in the middle atmosphere varied periodically, and the maximum amplitude of annual, semiannual, and seasonal oscillations were 6.0 K, 3.8 K, and 1.7 K, respectively. The temperature variation in the stratosphere presented a prominent annual oscillation tendency, and semiannual and seasonal variation characteristics were not obvious. Temperature variations in the stratopause and the lower mesosphere were dominated by annual and semiannual oscillations, and seasonal oscillation tendency of temperature was very weak when it is compared to the other two oscillations. Analysis of interannual variation characteristics reveals that, during the time period of significant changes in solar activity, the stratopause temperature varied with the index of solar radiation flux F10.7. However, when the solar activity became calm, there was no correlation in the variation tendency between them. These observation results could be significant to the comprehensive understanding of global climate change.

Dataset & Methodology

1) Hainan lidar observations during 2010-2020.



Total : 5716.6 hours in 765 nights

2) Temperature in the middle atmosphere calculated with the method described by *Hauchecorne & Chanin*.

- Atmospheric density calculation:

$$\rho(z)=\frac{z^2\left(N(z)-N_B\right)}{z_0^2\left(N(z_0)-N_B\right)}\rho(z_0)$$

- Hypothesis: hydrostatic equilibrium & ideal gas:

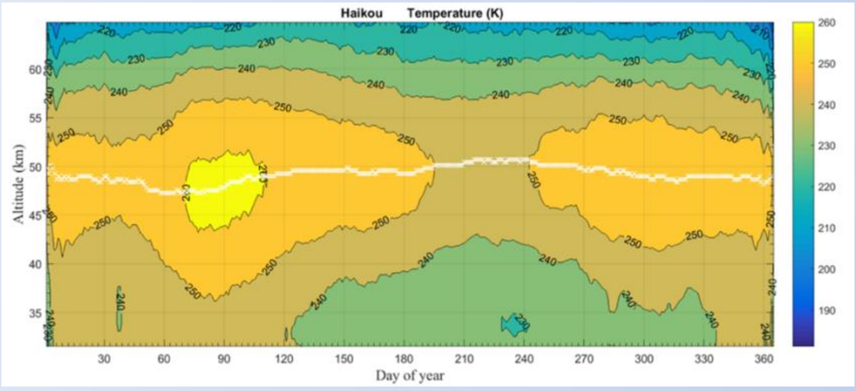
$$dP(z)=-\rho(z)g(z)dz \qquad P=nkT=\frac{\rho}{M}RT$$

- Atmospheric temperature estimation:

$$T(z)=\frac{\rho(z^*)}{\rho(z)}T(z^*)+\frac{M}{R}\int_z^{z^*}g(z')\frac{\rho(z')}{\rho(z^*)}dz'$$

Results & Discussions

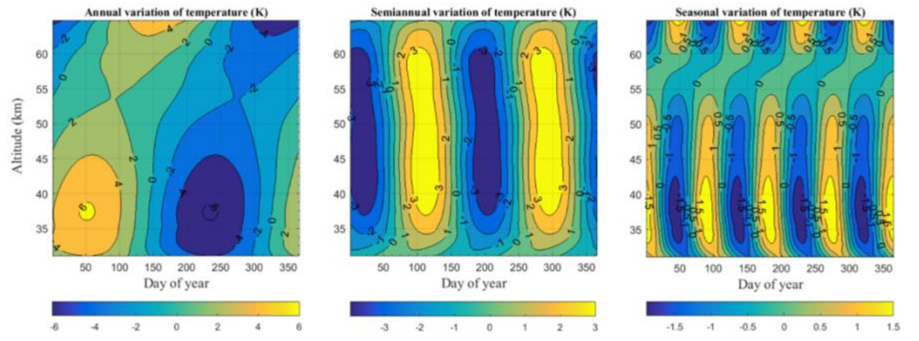
1) Date-dependent temperature structure of the middle atmosphere (32-64 km) over Haikou (19.9°N, 110.3°E)



- The daily average temperature of the middle atmosphere varied periodically with the seasons, and the highest temperature (262 K) occurred @ 43–52 km in the spring.
- The stratopause (white crosses) location: 42-51 km.

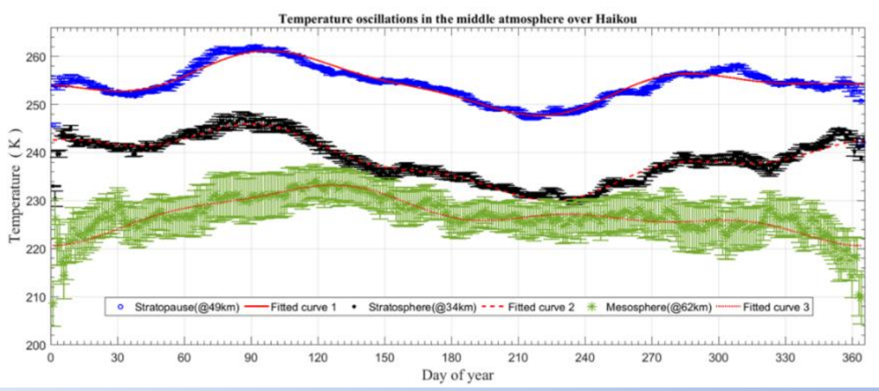
2) Annual, semiannual and seasonal variations of temperature in the middle atmosphere

$$\hat{x}(d)=A_0+A_1\cos\left[\frac{2\pi}{365}(d-d_1)\right]+A_2\cos\left[\frac{4\pi}{365}(d-d_2)\right]+A_3\cos\left[\frac{8\pi}{365}(d-d_3)\right]$$



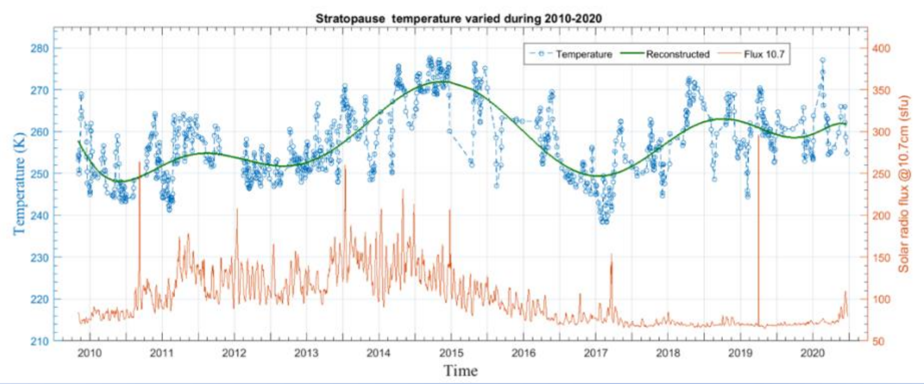
- Amplitude of annual variation: first decreased and then increased with height.
- Semiannual variation characteristic was obvious at all heights.
- Seasonal variation characteristics was obvious in the stratosphere (34-52 km) and the lower mesosphere (>60 km), but the seasonal variation amplitudes of temperature at altitudes 54-60 km were approximately 0.

3）Temperature oscillations @34 km, @49 km, and @62 km



- The temperature variation presented a prominent annual oscillation tendency in the stratosphere (@34 km).
- The temperature variations in the stratopause and lower mesosphere were mainly dominated by annual and semiannual variations.
- The seasonal variation tendency was not obvious in the middle

4）Interannual variation of stratopause temperature



- During the time period of significant changes in solar activity, the stratopause temperature varied with solar flux F10.7.
- However, when the solar activity became calm, there was no correlation in the variation tendency between them.

Conclusions

- **1)** For the first time, date-dependent temperature structure of the middle atmosphere (32-64 km) obtained with Hainan lidar (19.9°N, 110.3°E) in China.
- **2)** The daily mean temperature in the middle atmosphere over Haikou varied periodically, with a maximum temperature of 262 K.
- **3)** The temperature variation presented a prominent annual oscillation tendency in the stratosphere, the temperature variations in the stratopause and lower mesosphere were mainly dominated by annual and semiannual variations, and the seasonal variation tendency were not obvious.
- **4)** For the interannual variation of stratopause temperature, it had a good response to the significant change of solar activity. However, there was no correlation in the variation tendency between them, while the solar activity was calm.