First climatology of temperature structure from 0 to 110 km during 2011-2014 and mechanism study of winter temperature tides of fast amplitude growth above 100 km at McMurdo (77.8S, 166.7E), Antarctica

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Abstract
Over 5000 hours of lidar data have been collected after the installation of an Fe Boltzmann lidar system at McMurdo (77.8S, 166.7E), Antarctica since late 2010. We established the first temperature climatology based on lidar and radiosonde observations from 2011 to 2014 between 0 and 110 km. We compare the seasonal variation of temperature climatology with other Antarctic stations. Also, McMurdo lidar demonstrates the capability to derive winter temperature from 110 to 120 km, where almost no instrument can provide reliable range-resolved measurements. Observations of winter tides are rare in the MTL altitude of Antarctic region, especially for temperature tides. McMurdo lidar provides measurements of winter temperature tides from 30 to 110 km and find that the tidal amplitude grow super-exponentially above 100 km, exceeding that of the lower atmosphere, and increase in strength with the Kp magnetic-activity index. The CTIPE model is utilized to investigate possible sources that lead to the fast amplitude growth of tides. Simulations of the CTIPE model reproduce the lidar observations and exhibit concentric ring structures of diurnal amplitudes encircling the south geomagnetic pole and overlapping the auroral zone, indicating to the magnetospheric source origin. The adiabatic cooling/heating associated with Hall drag is shown to be the dominant source of this feature.

2.1. Lidar Observations of Winter Temperature Tides and Comparison with CTIPE Model

Lidar Tidal Amplitudes and Phases

- Amplitudes of 24-hr tide are ~1–3 K below 100 km. From 100 km to 110 km, they quickly increase from 3 to >5 K.
- For all Kp indices, tidal amplitude grows across freely propagating waves. Larger Kp index corresponds to larger amplitude of the diurnal tide. It indicates a link between geomagnetic activity and diurnal tides.

CTIPE diurnal tides in June of 2011 under different Kp

- CTIPE diurnal tidal amplitudes show similar trend as observed by lidar except for 100 km and the phase differences are within 3–5 hours.
- The good agreement between CTIPE and lidar results enable to analyze the model results to determine the tidal waves behavior behind the observed fast growth of the diurnal tide.
- At McMurdo, the CTIPE tidal amplitude have maximum at Kp ≥7 (~116 Kp) of ~22.7 K.

Two Questions are Raised from the Lidar Observations:
1. What are the mechanisms responsible for the fast grow of tides in the lower thermosphere?
2. How does geomagnetic activity affect the tides in the lower thermosphere?

2.2. Mechanism Study of Fast Growth of Winter Temperature Tides by CTIPE

Real-time Model Run

- Kp ≤1
- Kp ≥2

Hall Ion Drag Off Model Run

- Kp 0
- Kp 2

Houre (Episode)

- Kp 1
- Kp 2
- Kp 2

Joule Heating

- Joule heating alone tend to cancel the Joule heating effects.
- The test results also indicates that it is the adiabatic effects of the Hall ion drag that dominate the diurnal tidal forcing, while Joule heating has less contribution.

Sources of Adiabatic Heating/Cooling

- Both ion drag and Joule heating can induce adiabatic heating/cooling by inducing vertical winds.

Horizontal Wind Pattern Changes

- The horizontal winds in the case of the Hall drag on run are smaller than real case run. And the wind vector differences between the two runs show divergence and convergent patterns.

Conclusions and Outlook

- We established the first temperature climatology at McMurdo from 2011-2014 using over 4000 hours of lidar observations. This temperature climatology will serve as the baseline for measurements decades from now on to compare with to assess/monitor climate changes.
- The temperature structures are well comparing with the SABER and MLS satellite measurements, and the McMurdo lidar demonstrates the capability to obtain T above 110 km.
- The winter temperature tides simulated by the CTIPE model are consistent with the 4 years of lidar observations at McMurdo, including the fast growth features are reproduced.
- From mechanistic studies using CTIPE, the Hall ion drag induced adiabatic effects, varying with magnetic local time, are the dominant source for the observed winter tidal amplitudes.
- A possible future study would be to quantify the relative importance of the different sources of vertical motion, by turning off one or more of the different drivers in the model (such as Joule heating, particle heating, ion drag, etc), and investigate their effects under different Kp levels.