The 8th International Radio Occultation Working Group Meeting- IROWG-8 Hosted by NOAA / UCAR , April 7-9, 12 and 13, 2021, Virtual Meeting

Variations of Stratospheric Gravity Waves Derived from Temperature Observations of Multi-GNSS Radio Occultation Missions

Xiaohua Xu, Jialiang Hou, and Jia Luo
School of Geodesy and Geomatics, Wuhan University, China

Introduction

➢ Background:

① Studying the trends of GWs over the globe is challenging because of the limited temporal extension of the satellite observation data.

② Liu et al. (2017) for the first time studied the trends of GW activities over the globe during 2002 to 2015 based on the temperature data provided by SABER and the GW activities at the height 30-100 km are concerned about in their work.

③ Till now, the trends of the GW activities over the globe at the height lower than 30 km haven’t been investigated yet.

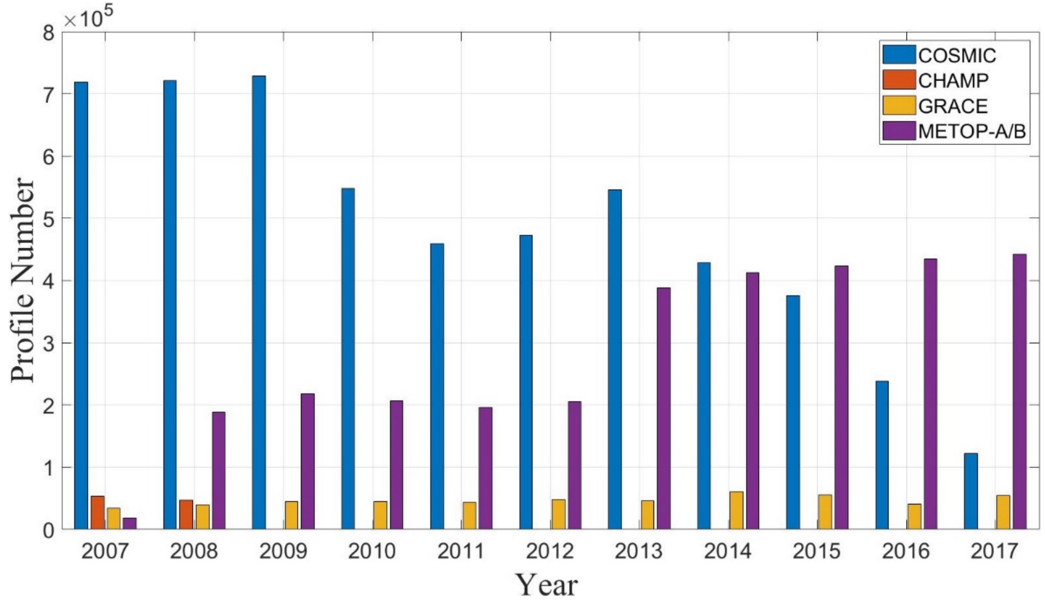
➢ Goal:

The present work is aimed to investigate the trends of the global GW activities at the altitude range of 20-35 km and their possible relationships with solar activity, ENSO and QBO, using GNSS RO data.

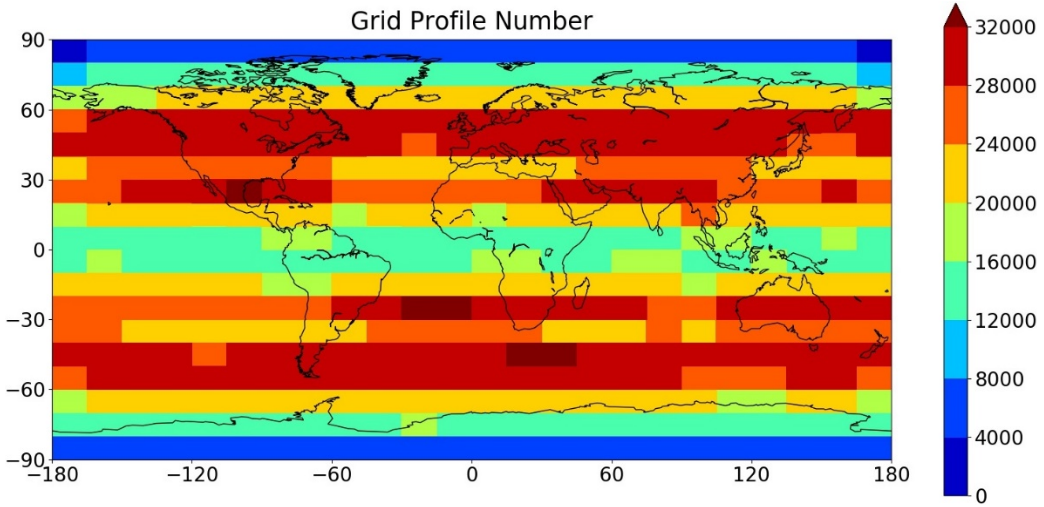
Reference: Liu, X., et al. (2017), Variations of global gravity waves derived from 14 years of SABER temperature observations, *J. Geophys. Res. Atmos.*, 122, 6231–6249, doi:10.1002/2017JD026604.

Data

- ➢RO data: Dry temperature profiles (atmPrf files) from 2007 to 2017 provided by UCAR COSMIC office
  1. COSMIC
  2. CHAMP
  3. GRACE
  4. METOP-A/B
- ➢F10.7, QBO and MEI indexes
  1. F10.7 index: www.spaceweather.gc.ca
  2. QBO index: www. geo.fu-berlin.de
  3. MEI index: www.esrl.noaa.gov
- ➢Monthly zonal wind during 2007-2017 provided by ERA-Interim data of ECWMF.



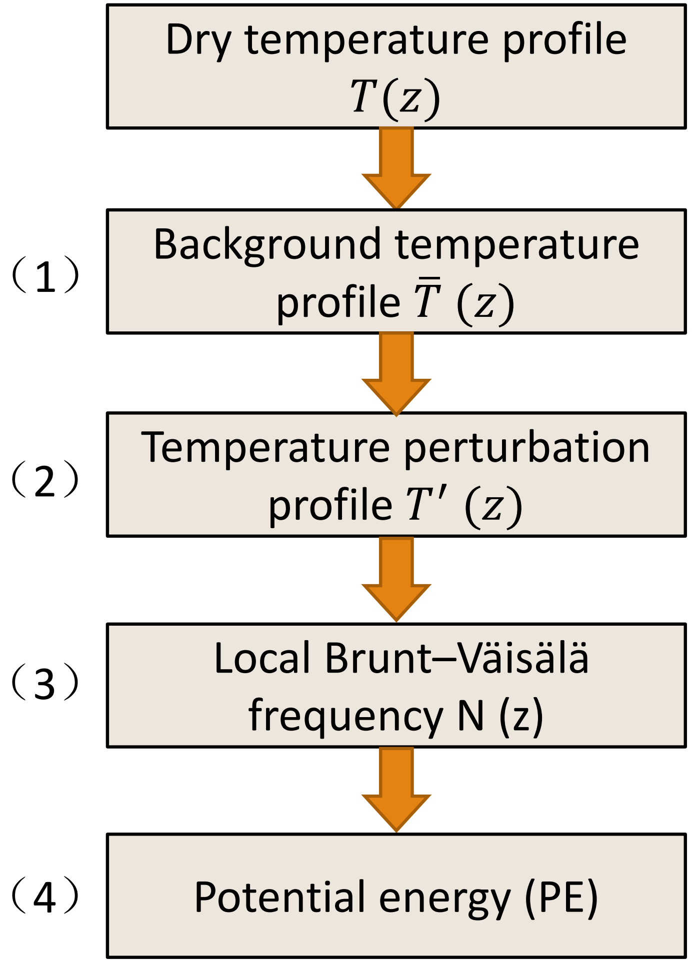
Yearly variation of the number of RO dry temperature profiles from multi- GNSS RO missions during 2007-2017



Spatial distribution of the number of RO dry temperature profiles from multi- GNSS RO missions during 2007-2017

Methods: GW PE calculation

Reference: Hindley, N. P. , et al. (2015), The southern stratospheric gravity wave hot spot: individual waves and their momentum fluxes measured by COSMIC GPS-RO. Atmospheric Chemistry and Physics 15 (3):3173-3217. doi:10.5194/acp-15-7797-2015



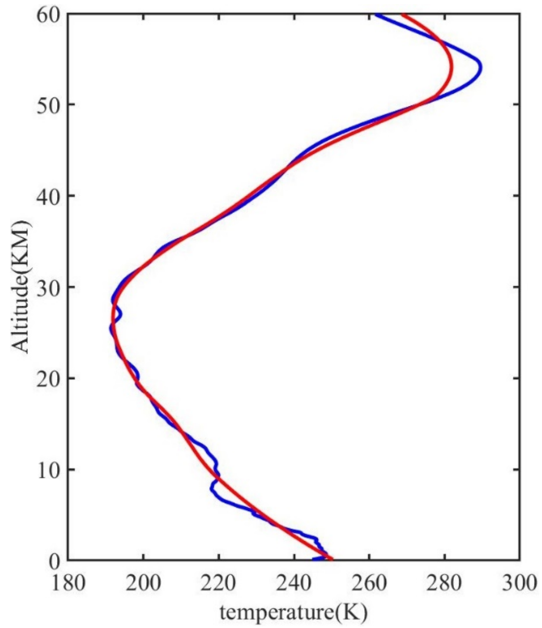
The flow chart to derive GW potential energy profile from a RO temperature profile

Step (1)

T(Blue)

Savitzky – Golay filter

$\bar{T}$ (Red)

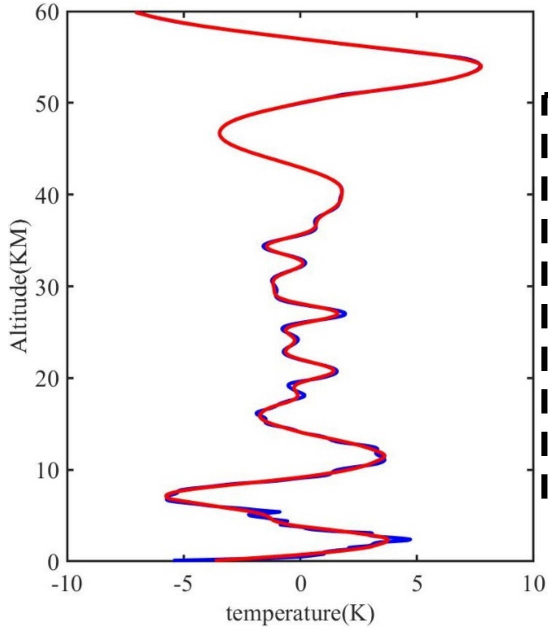


Step (2)

$T' = T - \bar{T}$ (Blue)

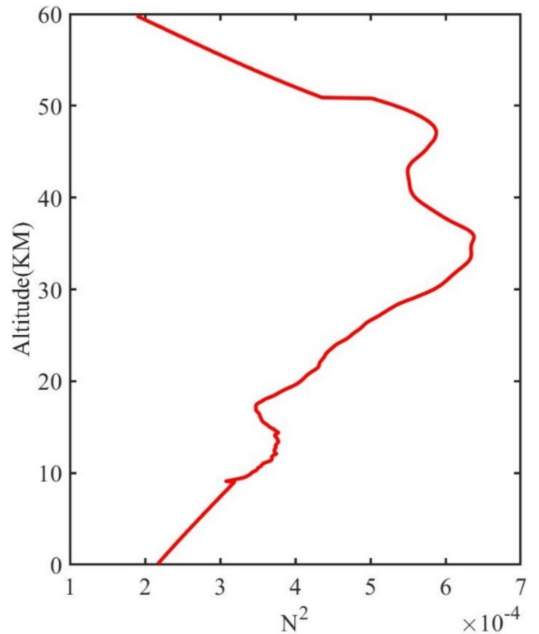
Savitzky – Golay filter

Final T'(Red)



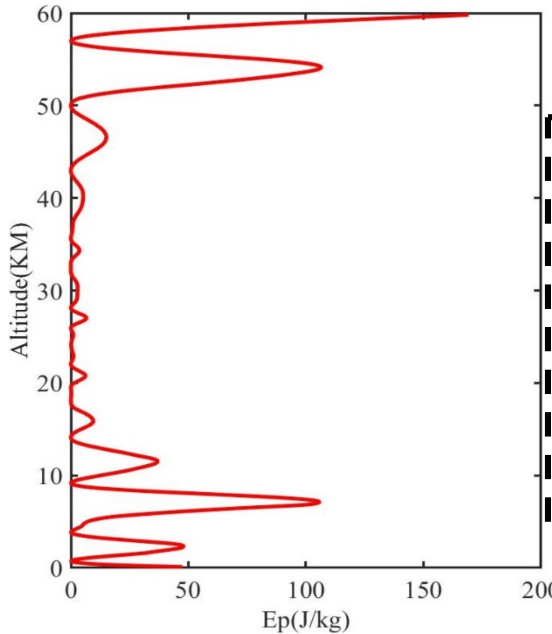
Step(3)

$$N^2 = \frac{g}{\bar{T}}\left(\frac{\partial \bar{T}}{\partial z} + \frac{g}{c_p}\right)$$



Step(4)

$$E_p = \frac{1}{2}\frac{g^2}{N^2}\left(\frac{T'}{\bar{T}}\right)^2$$



Methods: The derivation of GW RPE from PE

➢ For the globe and certain latitude band:

① The monthly mean GW PE profile is derived by averaging the PE profiles located in the specific geographic region in each month.

② The monthly relative GW PE (RPE) defined by Liu et al. (2017) is derived from the monthly PE profiles.

$$RPE(t_{i,j}) = \frac{PE(t_{i,j})}{< PE >}$$

With i=2007,2008,…,2017;j=1,2,…,12

Methods: Trend analyses of the GW RPE

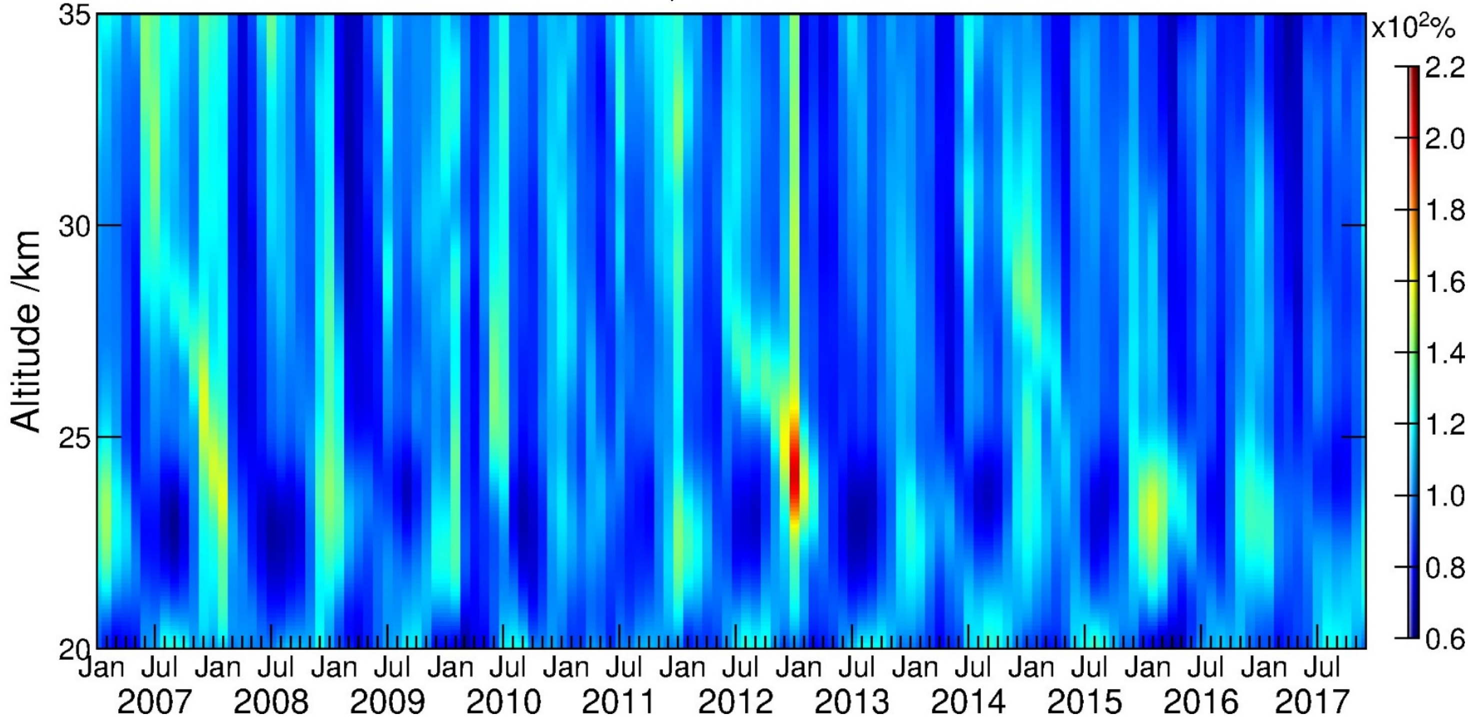
$$RPE(t_{i,j}) = \mu + \alpha t_{i,j} + \beta solar(t_{i,j}) + \gamma QBO(t_{i,j}) + \kappa ENSO(t_{i,j}) + Residual$$

(i=2007,2008,…,2017;j=1,2,…,12)

- The trend of GW RPE for each month is derived directly from the time series of the monthly GW RPE.
- The overall trend of GW RPE and the responses of RPE to solar activity, QBO, and ENSO are derived from the deseasonalized monthly RPE using multiple linear regression method.
- The significances of the trends are tested with student *t* test with the confidence level of 90%.

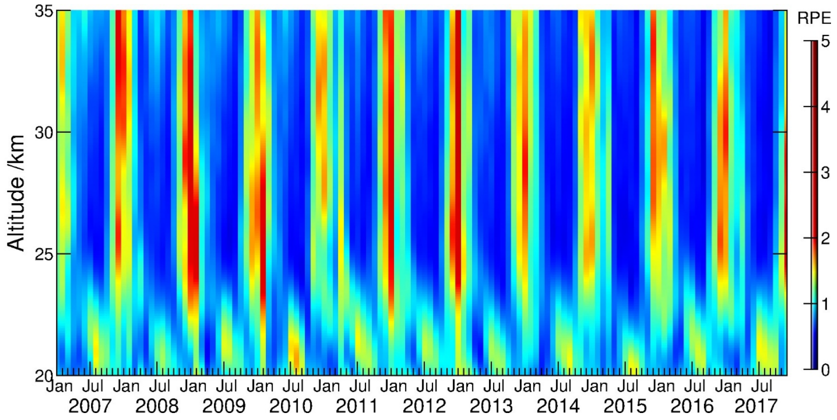
Results: The altitude-time variations of the GW RPE

$90°N - 90°S, 180°W - 180°E$

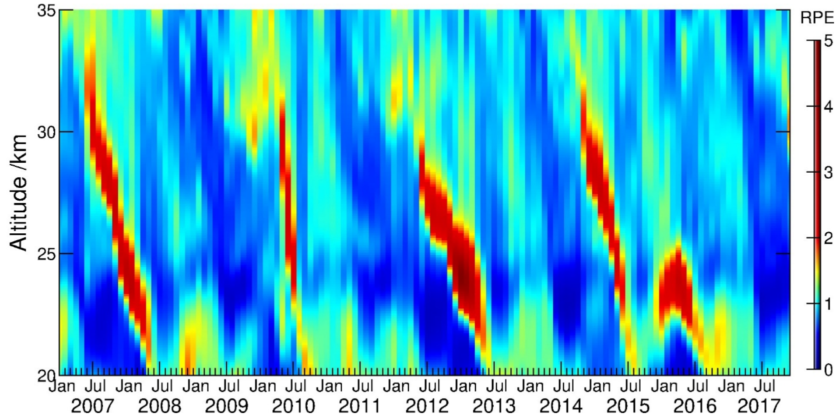


- ➢ Global GW RPE: Semiannual variations in 25-35 km, annual variations in 20-25 km
- ➢ At middle and high latitude bands, peaks of RPE are generally got during the hemispheric winter seasons at 25-35 km.
- ➢ In the low latitude bands, the impact of QBO can be figured out in the time variation of RPE.

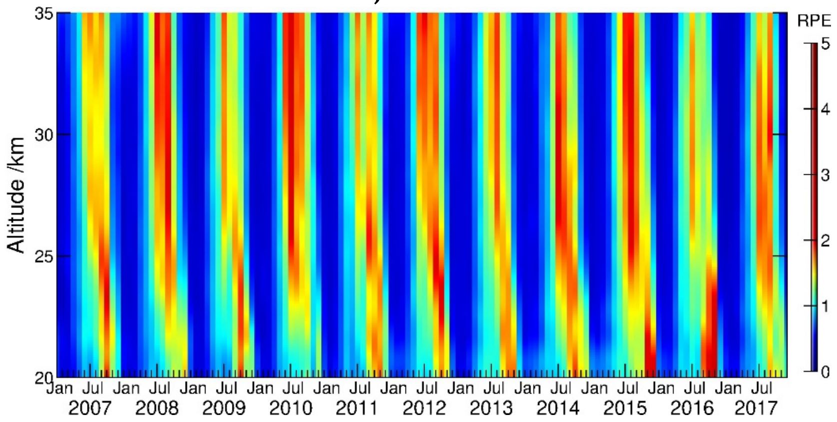
$30°N - 50°N, 180°W - 180°E$



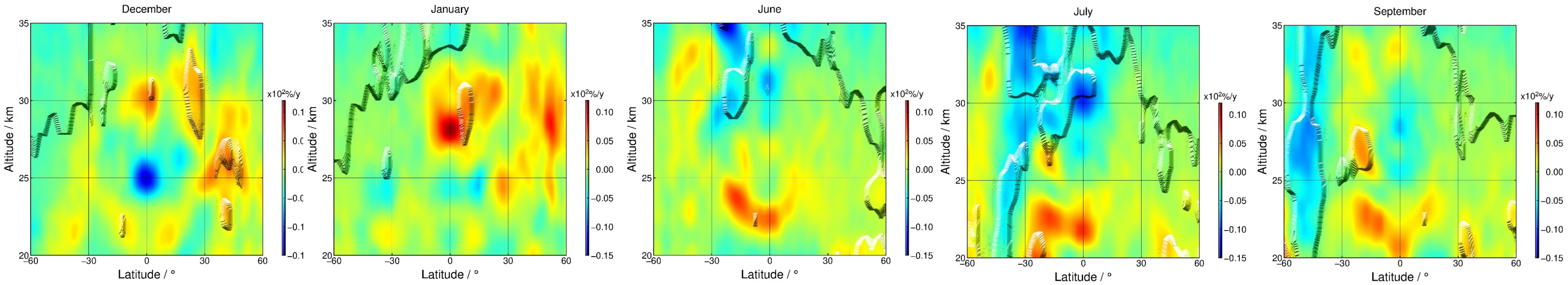
$10°S - 10°N, 180°W - 180°E$



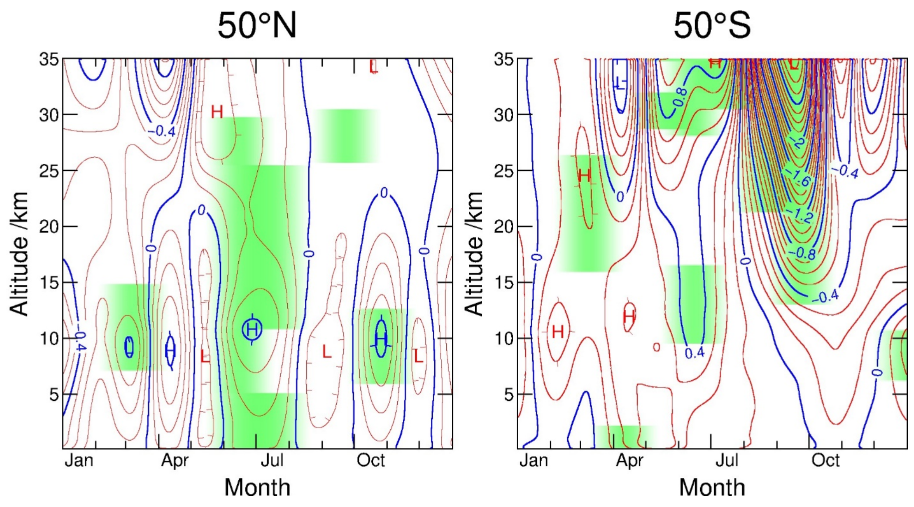
$50°S - 70°S, 180°W - 180°E$



Results: The trends of GW RPE for representative months

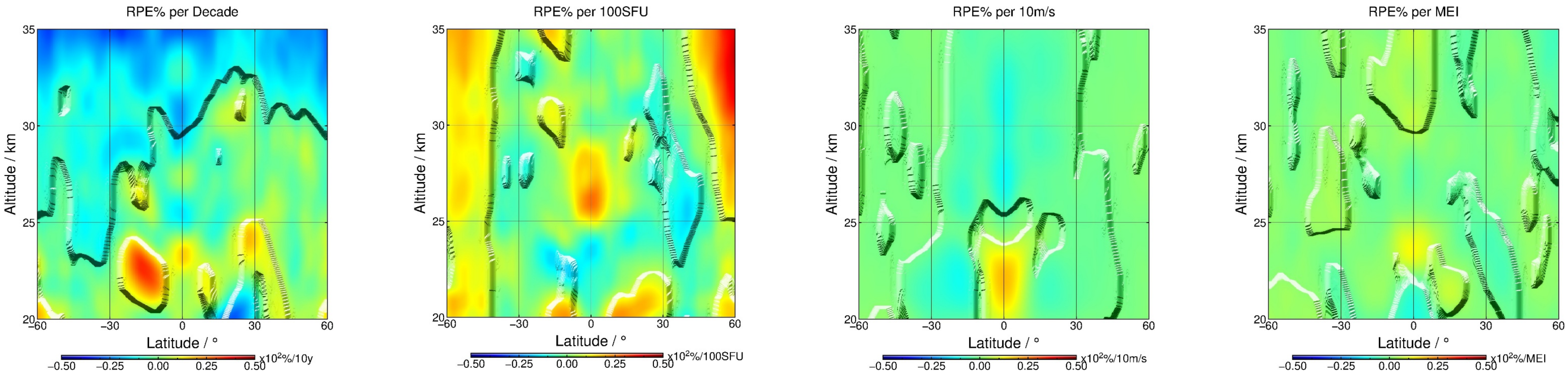


Latitude-height sections of the trends of GW RPE during representative months

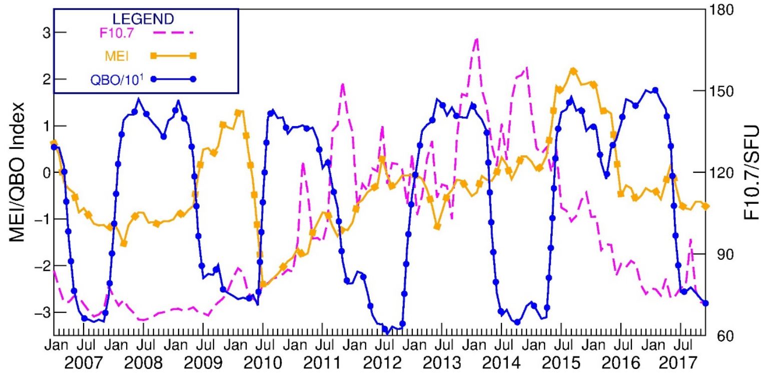


Month-height sections of the trend of zonal wind at 50° N/S derived from ERA-Interim zonal-mean zonal wind data

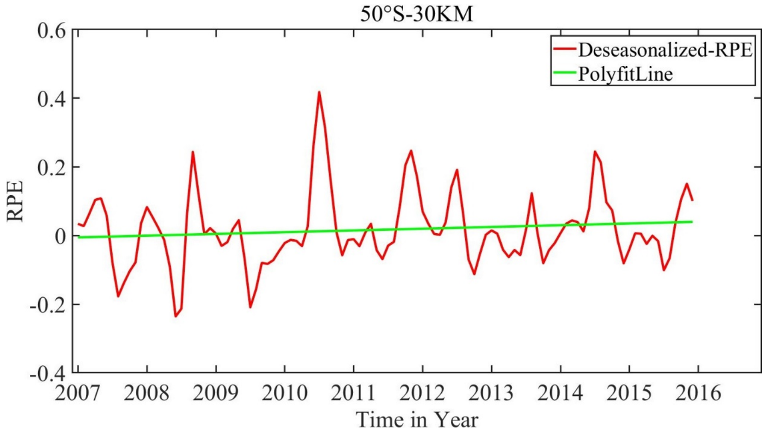
Results: The trends of GW RPE during the 11years and the response of RPE to solar activity, QBO, and ENSO



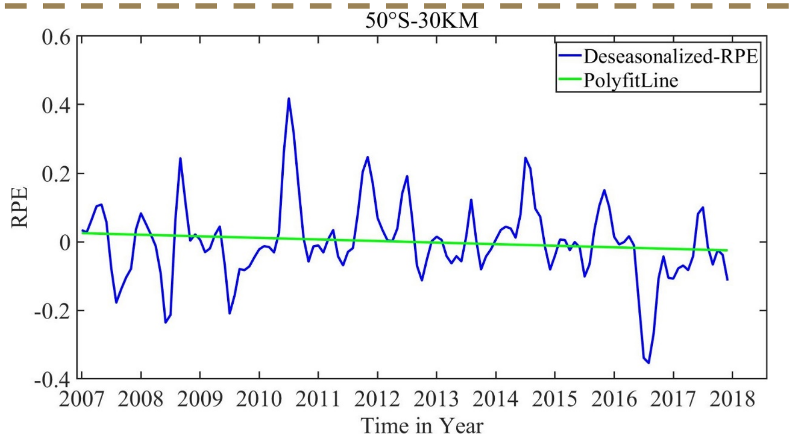
The trends of the deseasonalized GW RPE during the 11years and the response of RPE to solar activity, QBO, and ENSO



The time variation of F10.7 index, MEI index and QBO index during 2007-2017



(a)Trend of deseasonalized RPE from Jan 2007 to Dec 2015



(b) Trend of deseasonalized RPE from Jan 2007 to Dec 2017

Summary

① At latitudes of 40° -60° N/S, positive trends occur in both GW RPE and zonal winds during local winter months, and at around 50° S , significant negative trends occur in both GW RPE and zonal winds during September.

② At the height range of 25-35 km, significant negative response of GW RPE to QBO occurs at 30° S-30° N, and at the height range of 30-35 km, significant positive response of RPE to ENSO occurs at 15° S-15° N, which are both consistent with Liu et al. (2017).

③ Significant negative trends of deseasonalized GW RPE occur at the height range of 30-35km during 2007-2017,which is different from the positive trend during 2002-2015 derived by Liu et al. (2017) using SABER data. The difference between ours and Liu et al.'s results might be attributed to the impact of the decreasing of the solar activity after the year of 2015, which needs to be further investigated.