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Editorial: Observations and Simulations of Layering Phenomena in the Middle/upper Atmosphere and Ionosphere

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Editorial: Observations and simulations of layering phenomena in the middle/upper atmosphere and ionosphere

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Editorial on the Research Topic
Observations and simulations of layering phenomena in the middle/upper atmosphere and ionosphere

Introduction

The middle/upper atmosphere and ionosphere are the transition between neutral and ionized components of the Earth's atmosphere, including stratosphere, mesosphere, thermosphere, ionospheric E region and ionospheric F region (Laštovička et al., 2006; Xu, et al., 2007; Smith, 2012). The atmospheric thermal structure and composition are significantly affected by dynamical processes through coupling. The layering phenomena such as mesospheric metal layers, sporadic E layers, and noctilucent clouds are important tracers to study mechanisms of the vertical coupling from the lower to the upper atmosphere (Dou et al., 2010; Plane, 2012; Xue et al., 2013).

Although extensive research employing satellite data and global models have been conducted on the middle/upper atmosphere and ionosphere in recent years (Froidevaux, et al., 2006; Gettelman et al., 2019; Yu et al., 2019; Cai et al., 2020; Cai et al., 2021; Wu et al., 2021; Yu et al., 2021; Cai et al., 2022; Emmons et al., 2022; Yu et al., 2022), it is still a challenge to forecast changes in ionospheric irregularities and dynamic processes in the Earth's upper atmosphere (Tian et al., 2022; Tian et al., 2023). The objectives of this Research Topic are the new results of "*Observations and simulations of layering phenomena in the middle/upper atmosphere and ionosphere*" that can advance our knowledge of atmospheric dynamics, chemistry as well as vertical coupling of atmospheric layers. It comprises five research articles contributed by 39 authors with more than 7,500 views to date. The research objects of the papers involve ionospheric irregularities, mesospheric metal layers, atmospheric winds, and polar mesospheric clouds.

Equatorial plasma bubbles (EPBs) are large-scale ionospheric plasma depletions at the magnetic equator. EPBs can cause the degradation of radio signal, and thus significantly impact the measurement accuracy of global navigation satellite systems. Carmo et al. analyzed the EPB features over the Brazilian sector using total electron content index under different solar and magnetic activity conditions. The latitudinal extension and zonal drift velocity of EPBs are higher during the solar maximum than those in the solar minimum. The EPBs presented longer durations in winter, attributed to the electric field direction associated with either prompt penetration electric fields or disturbance dynamo electric fields.

The sporadic E layer is one of the typical ionospheric layering phenomena between 90 and 130 km. Unlike the more predictable F1 and F2 layers of the ionosphere, the sporadic E exhibits irregularities in its occurrence and intensity. Radio occultation observations from satellites have been shown considerable promise for monitoring sporadic E layers. Knisely and Emmons investigated the power spectra of sporadic-E layers during Kelvin-Helmholtz billow formation. By the two-fluid simulations of K-H billows within a sporadic-E layer over time, it is found that the intense sporadic-E layers transform into wider, more turbulent layers. The large variations in amplitude profiles over 5 min during billow formation can result in large variation of amplitude (S4) and phase ($\sigma\phi$) scintillations. The rapid change in the ionospheric scintillation over a short period of time can introduce uncertainty in the characteristics of Es layers, thereby leading to the uncertainty of simultaneous observations of GNSS RO for the Es layers. Therefore, a comparison of GNSS RO measurements with high time-resolution measurements using such as the incoherent scatter radars would provide crucial validation of global measurements of Es layers for the predicting models.

The polar mesospheric clouds (PMCs) are mainly composed of small water ice crystals in the mesopause region at high latitudes during summer times. Qiu et al. studied the impact of activity and variability of solar radiation on the PMCs from observations of the Solar Occultation For Ice Experiment onboard the Aeronomy of Ice in the Mesosphere satellite and Microwave Limb Sounder onboard the Aura satellite. The solar 27-day modulation affects PMCs.

The mesospheric meteoric metal layers occur at 70–120 km altitude in the mesosphere and lower thermosphere (MLT) as a result of meteoric ablation. The sporadic sodium layers (SSLs) refer to the sodium layer whose number density increases rapidly to be more than double the background value. Qiu et al. analyzed the sodium density data observed from a narrow band lidar at the Andes Lidar Observatory. The oscillation characteristics of SSLs are proposed to be strongly related to wave fluctuations.

These are oscillations in global atmospheric parameters such as neutral density, temperature, and wind in the MLT region. The MLT region is the temperature minimum that delineates the middle atmosphere from the thermosphere, stands as the coldest region within the Earth's atmosphere. The sudden stratospheric warming (SSW) is a large-scale meteorological event that occurs in the winter polar stratosphere and impacts the global atmosphere. It is typical evidence for dynamical coupling phenomena from the lower atmosphere to the upper atmosphere. Zhou et al. investigated the response of neutral density from four meteor radars to a major stratospheric warming. The four meteor radars include Beijing (40.3°N, 116.2°E), Mohe (53.5°N, 122.3°E), Tromsø (69.6°N, 19.2°E), and Svalbard (78.3°N, 16°E) meteor radars at mid-to-high latitudes in the Northern Hemisphere. The neutral density over Svalbard and Tromsø at high latitudes increased at the beginning of SSWs and decreased after the zonal mean stratospheric temperature reached the maximum, while the neutral density over Mohe at midlatitudes exhibits precisely the opposite trend. The temperature cooling in the MLT region was found throughout SSWs, with more days' lag to the higher latitudes. It has been proven that the SSW effect can extend beyond the stratosphere and modulates the mesosphere and thermosphere.

Conclusion

In summary, the articles in the Research Topic "*Observations and Simulations of Layering Phenomena in the Middle/Upper Atmosphere and Ionosphere*" report various prominent layers and their coupling behaviors in the MLT region. This will further advance our knowledge on chemical and dynamics in the upper atmosphere and ionosphere. A future challenge is to predict the changes in Earth's upper atmospheric conditions by comprehending the physical mechanisms governing the coupling between the various layers of the Earth's atmosphere as one whole system. In the face of growing demand for accurate prediction of the upper atmosphere and ionosphere environments, it is crucial to understand both the long-term changes and short-term dynamical coupling processes through trace species in the region. Therefore, we can gain an understanding of how the upper atmospheric layers behave and its fundamental atmospheric interaction processes.

Author contributions

BY: Writing–original draft, Writing–review and editing. XC: Writing–review and editing. DE: Writing–review and editing. CW: Writing–review and editing. JW: Writing–review and editing.

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Conflict of interest

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