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QOS2016-260

Four years measurements of the mesospheric nitric oxide (NO) and ozone with a ground-based millimeter-wave spectral radiometer at Syowa station, Antarctica

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1. Composition changes in polar mesosphere caused by energetic particle precipitation (EPP)

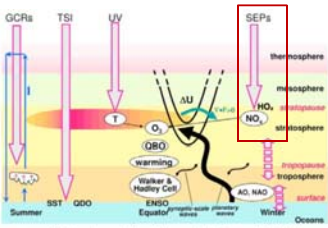


Fig.1) Mechanism of solar influence from Gray et al. 2010. (The figure is taken from SCOSTEP/VarSITI brochure 2013)

- Precipitation of SEPs (Solar Energetic Particles) into the middle atmosphere induces chemical composition changes;
  > N_2 and O_2 are dissociated and/or ionized, resulting production of N_2^+, N^+, O^+, O_2^+, ….
  >> leading to production of HO_x and NO_x
  >>> may induce the O_3 depletion.

- EPP occurs in an area depending on their origin.

Particle:	proton	relativistic electron	auroral electron
Origin:	Sun	radiation belt	plasma sheet
Energy:	>MeV	>10 keV	1-10 keV
Precipitation:	>75°	<70°	70- 75° (in M-lat.)

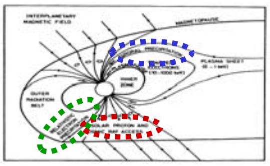


Fig.2) SEPs and their properties. (based on Turunen et al. 2009)

Scientific questions:
- What kind of SEPs is the most influence to the middle atmosphere composition?
- Do the composition changes affect to those in the lower altitude region? induce O_3 destruction?

↓
Continuous measurements of composition changes are desirable to investigate these influences. Especially, nitric compounds (NO_x) are important because they directly produce via ion chemistry by SEPs (e.g. Turunen et al. 2009; Andersson et al. 2014).

2. Millimeter-wave measurements of ozone and nitric oxide (NO) at Syowa station, Antarctica

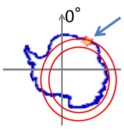


Fig.3) Millimeter-wave spectral radiometer at Syowa station.

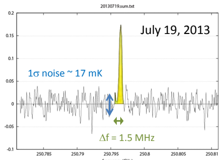


Fig.4) An example of the observed NO spectrum over Syowa.

Syowa station (69.00° S, 39.85° E, Mlat=66° S)

\# Hardware specification
Antenna: 12 cm parabolic mirror
Receiver: 4 K-cooled SIS mixer (Tsys ~ 300 K@250 GHz)
Spectrometer: Agilent Digital FFT (B~1 GHz, ΔB~70 kHz)

\# Measurements
Period: January 2012 ~
Number of measurements: 807 days (2012-2015)
Targets: NO: 250.796 GHz
O_3: 239.093 GHz (8 times/day)
Data Acquisition: every 10 min.
=> integrated every 3 hrs for NO
integrated every 0.5 hrs for O_3

\# Estimation of the NO column amount in the upper mesosphere approximately from 75 to 105 km (N_{NO})

$$N_{NO}(\mathrm{cm}^{-2}) = \text{Integrated Intensity (K MHz)} \times T(K) \times 3.9\times10^{13} ,$$

where we assume as T = 200 K (Isono et al. 2014a, b).
→ $N_{NO}(1\sigma) \sim 0.2 * 10^{15}$ cm^{-2}

3. Temporal variations of the column amount of NO in the upper mesosphere

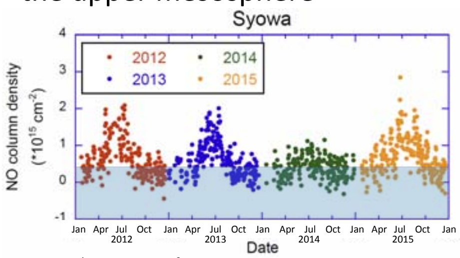
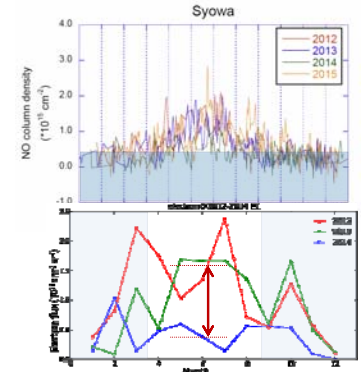


Fig.5) Time series of N_{NO} over Syowa station, Antarctica.

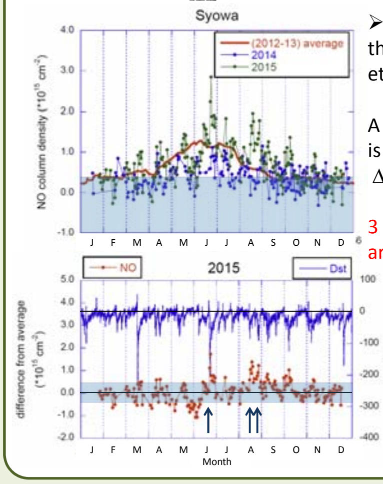
- N_{NO} clearly shows a seasonal variation except for 2014.
  N_{NO} ~ 2.0 × 10^{15} cm^{-2} in winter
  ~ 0.6 × 10^{15} cm^{-2} in others
  ↓
  Photo-chemical processes are dominant in the mesospheric NO chemistry.



- In 2014 winter, there is not significant enhancement of N_{NO}.

Monthly accumulated number of precipitating energetic electron (N_{EE}) with an energy of >30 keV observed with the POSE/MEPED 0 deg. telescope in 2014 winter is by 1/5 less than those in 2012 and 2013.
↓
N_{EE} is a key parameter of the winter enhancement of N_{NO}.

Fig.6) Seasonal variations of N_{NO} (upper) and N_{EE} (lower).



- Short-term N_{NO} enhancements, suggesting the relation with events of SEPs (e.g. Isono et al. 2014a), appear in Fig.5.
  ↓
  A significant N_{NO} enhancement (anomaly > 3σ) is defined in 2014-2015 dataset as below,
  Δ N_{NO} = N_{NO} - N_{NO}(30 days ave. in 2012-2013)

3 events in 2015 is found (arrows in Fig.7), but are not correlated with the geomagnetic disturbance index (D_{st}).
↓
The quantity of precipitating particles is much important to the N_{NO} enhancement

Fig.7) Seasonal variations of N_{NO} (upper) and time series of D_{st} (blue) and N_{NO} anomaly (red) in 2015 (lower).

4. Summary and next steps

- The observed N_{NO} shows a seasonal variation with a winter maxima except for in 2014. In case of 2014, N_{EE} with an energy of > 30 keV is by 1/5 less than those in 2012 and 2013, suggesting it is a key parameter of the seasonal variation of N_{NO}.

- Short-term N_{NO} enhancements are derived from the 2014-2015 dataset, however, no significant correlation with D_{st} is found, implying the quantity of precipitating particles is important to the N_{NO} enhancement rather than geomagnetic environmental indices.

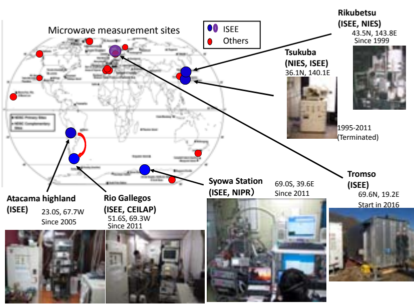


Fig.8) The ISEE millimeter-wave spectral radiometers.

- Extension of the millimeter-wave measurement sites to the Arctic region
  Remaining questions;
  >Does N_{NO} enhancement appear in Arctic and Antarctic regions at an EPP event?
  >Do the seasonal and long-term variations of N_{NO} show a similar pattern?
  ↓
  A new spectral radiometer is installed in Tromso, Norway, and will start simultaneous measurements in both the polar regions.

References
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