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Temporal variation of tropospheric ozone and springtime ozone depletion events at King Sejong Station, Antarctica

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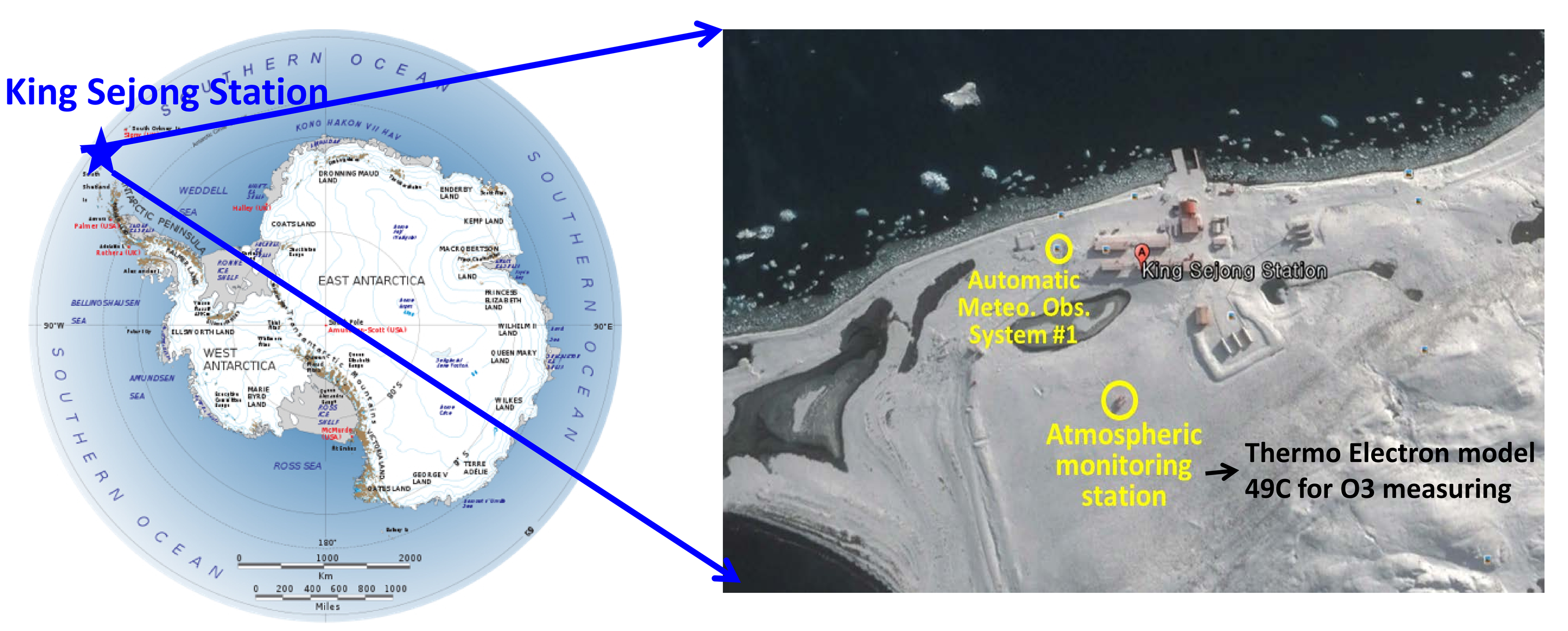
Introduction

Ozone is one of the key components of the atmosphere as a highly reactive oxidant (Thompson, 1992) and as a greenhouse gas (Houghton et al., 2001). Polar region where anthropogenic influences on ozone are very small is appropriate to observe the natural variation of ozone such as long-term trend and downward transport of stratospheric ozone. Also, a remarkable phenomenon that tropospheric ozone values drop unexpectedly from background levels to near zero level during the polar spring time for a few hours, or even several days, can be found in polar coastal regions (Simpson et al., 2007).

In an effort to address the temporal variation and specific chemical reactions of tropospheric ozone over Antarctic circumpolar region, this study used ozone data measured for 6 years between 2009 and 2014 at the King Sejong station which is one of the sites located at the tip of the Antarctic peninsula, King George Island. Here we report for the first time the interannual, seasonal, and diurnal variation of tropospheric ozone at KSG. In addition, we investigate the characteristics of tropospheric ozone depletion events (ODEs) in circumpolar region at two aspects of the meteorological properties and the transport patterns of air mass during ODEs.

Data treatment & Method

1. Study area / data collection



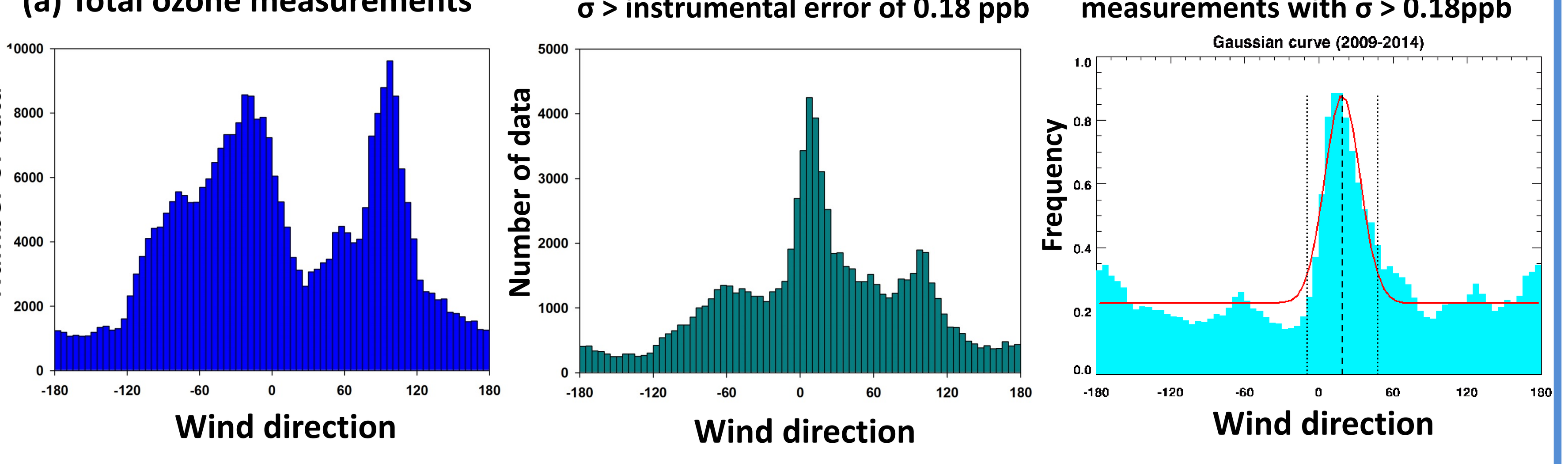
- Location of the Korean Antarctic base, King Sejong station (GAW ID: KSG, 62.22 °S, 58.78 °W) in King George Island, Antarctica, and location of the atmospheric observation laboratory, where ozone in the boundary layer was monitored (Thermo Electron model 49C), and of the automated meteorological observation system .
- Tropospheric ozone and meteorological data averaged at 10 minutes (2009-2014)

2. Data filtering

(a) Total ozone measurements

(b) Ozone measurements with σ > instrumental error of 0.18 ppb

(c) Frequency of ozone measurements with σ > 0.18ppb



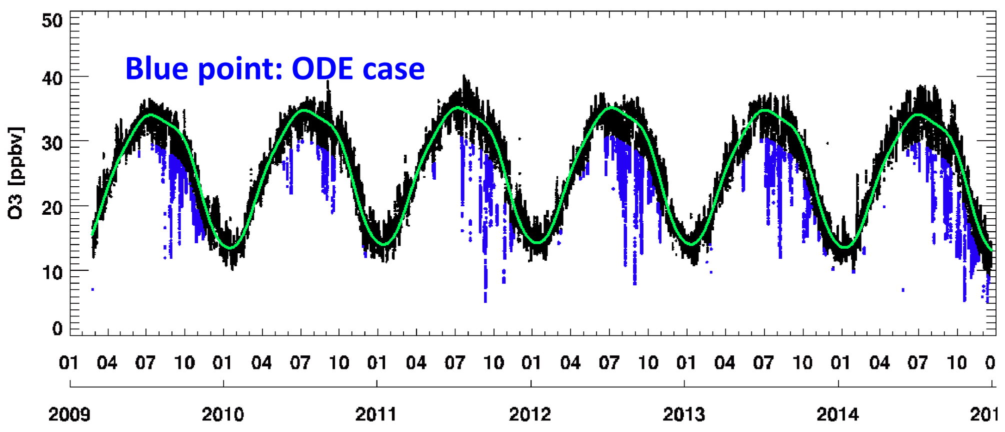
- On the basis of Gaussian fitting, ozone data were separated into "polluted" and "unpolluted" cases depending on the wind direction.
- Polluted case (0<WD<47.72 and 350.70<WD<360 degree): filtering of data with σ > 0.18 ppb
- Unpolluted case (47.72<WD<350.70 degree): filtering of data with σ > 0.25 ppb

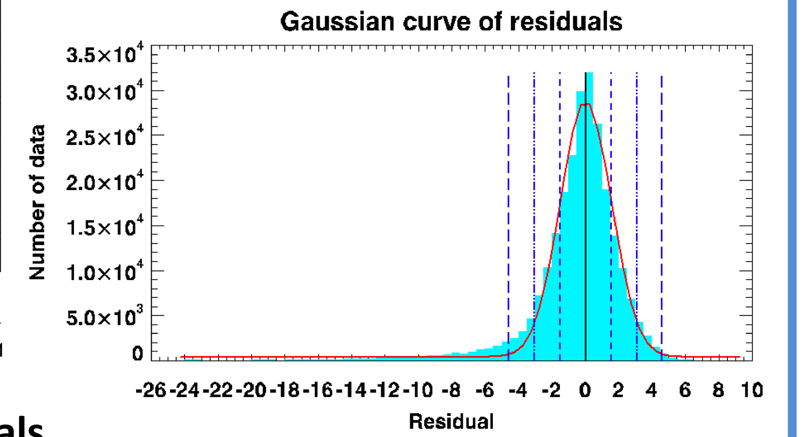
3. Baseline determination

$$f(t_i) = a_1 + a_2 t_i + a_3 t_i^2 + \sum_{j=1}^{4}\left[a_{(2j+2)}\sin(2\pi j t_i) + a_{(2j+3)}\cos(2\pi j t_i)\right]$$ (t_i : normalized time of observation i)

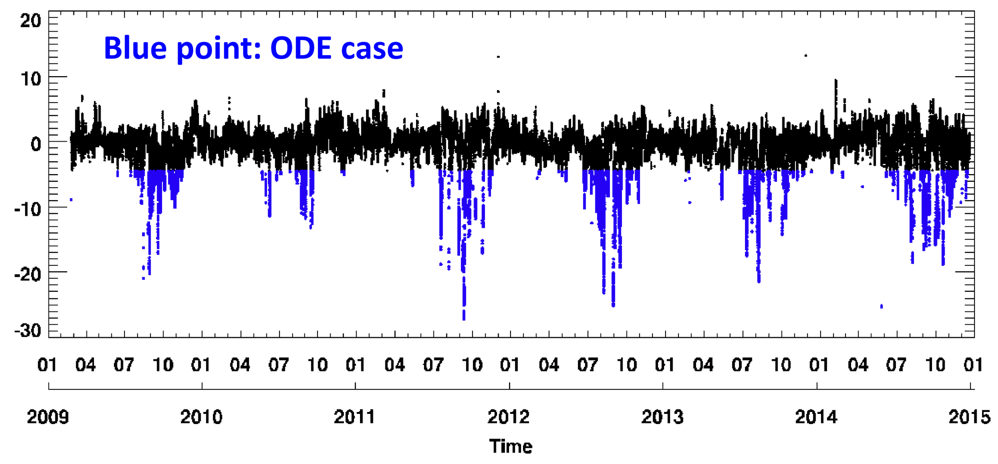
- The <u>polynomial</u> and the <u>sum of four harmonics</u> in Eq. represent the <u>trend</u> and the <u>average seasonal cycle</u>, respectively [Thoning et al., 1989].

(a) Time series of ozone data and fitted line





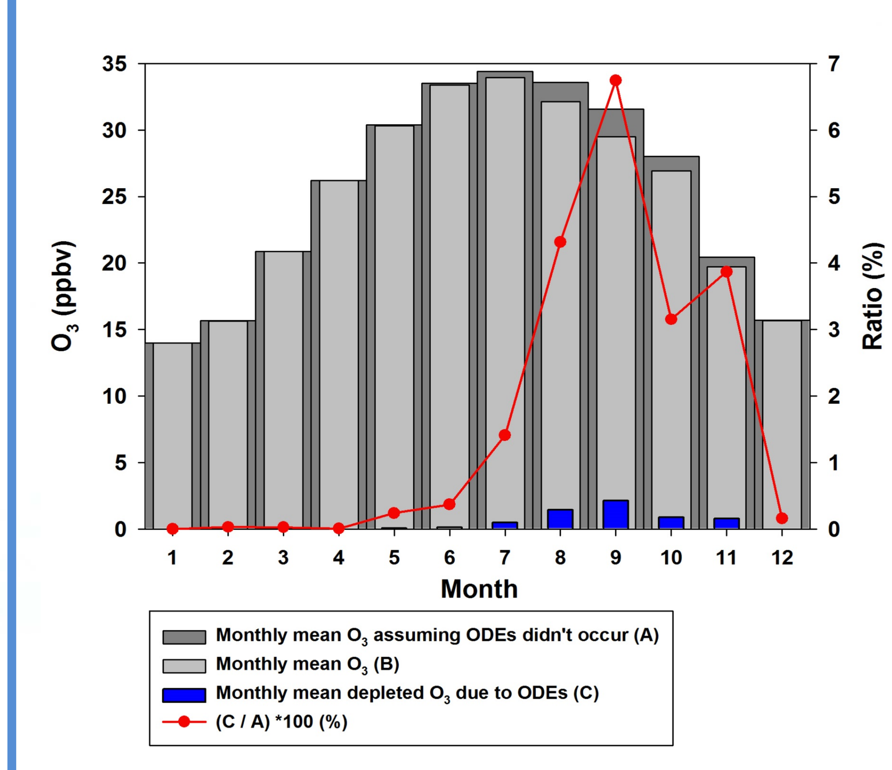
(b) Time series of detrended and deseasoned residuals

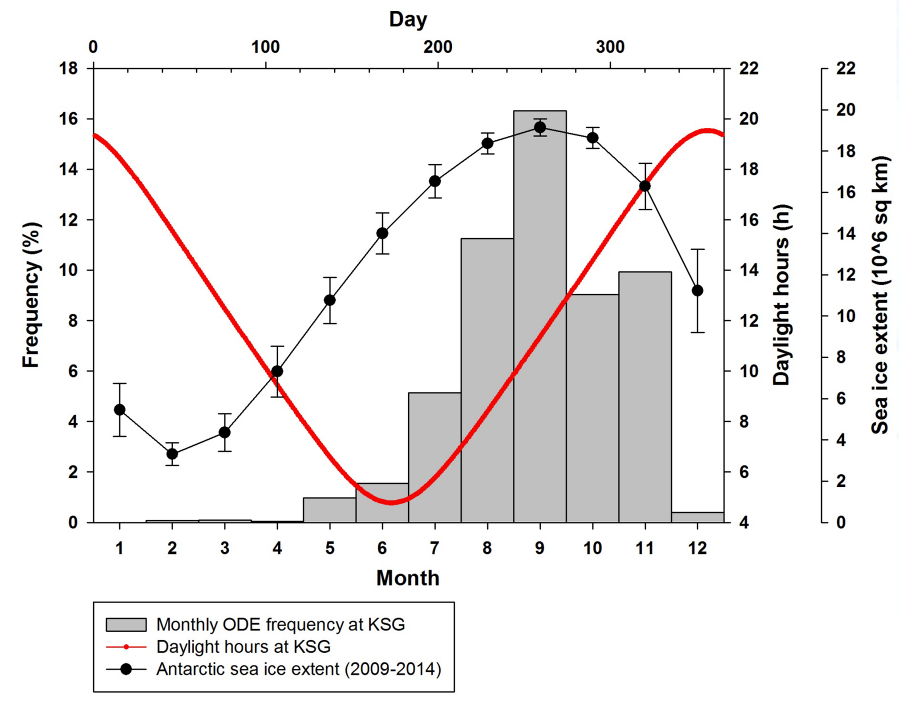


In this study, ozone depletion event (ODE) is defined as detrended and deseasoned residual is lower than -3σ range of distribution (Residual < -4.56 ppb) for quantitative analysis.

Results & Discussion

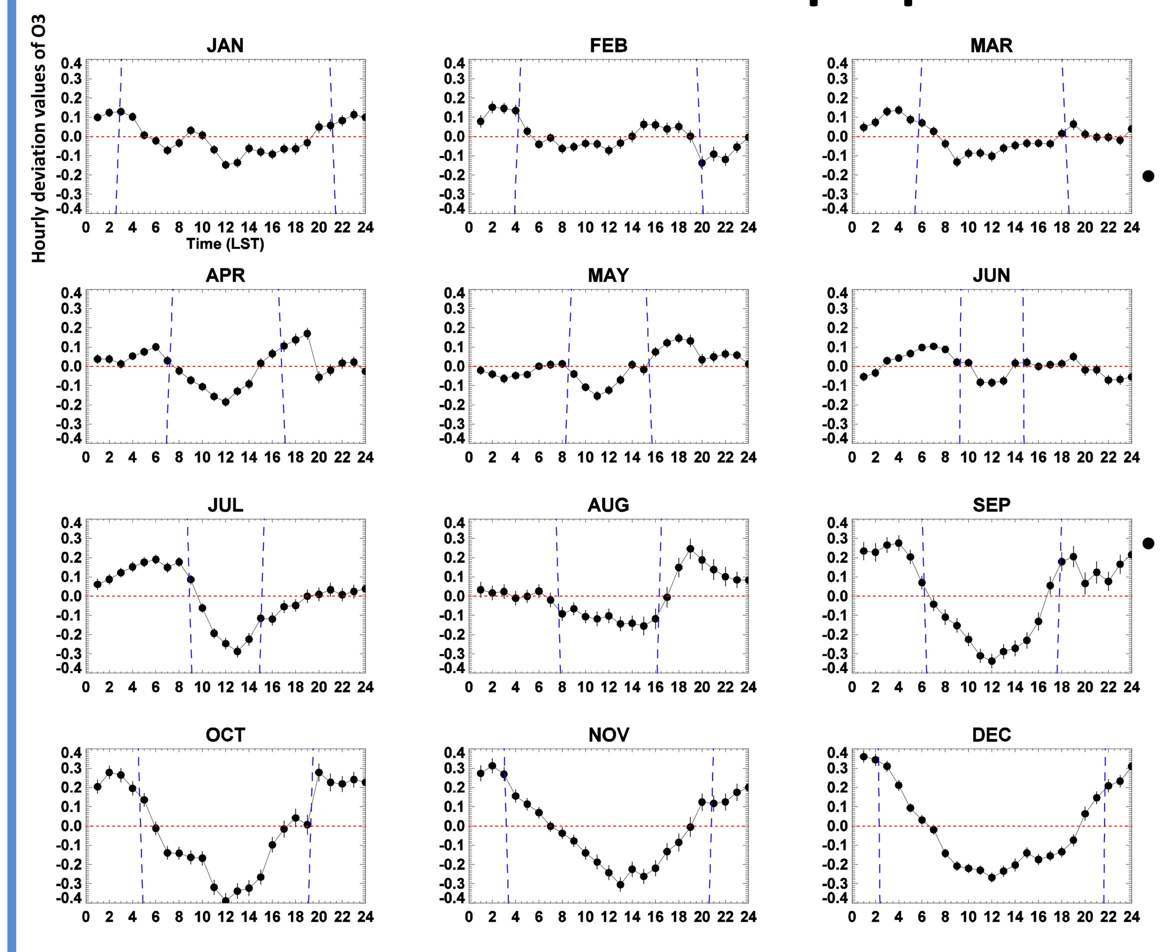
4.1. Seasonal variation of tropospheric ozone at KSG





- Seasonal variation with the range of 14.0-33.9 ppb, where the high values were in winter and the low values in summer (July: 33.9 ppb, January: 14.0 ppb).
- Monthly mean depleted ozone concentration of 2.1 ppb in September is the largest value, followed by 1.4 and 0.9 ppb in August and October, respectively.
- ODEs were mainly found in spring season from August to November with the monthly frequency of 8.2~16.7 %.
- The main cause of frequent springtime depletion events of ozone is a satisfaction of both the solar radiation for photochemical reactions and sea ice expansion for supply of reactive halogen.

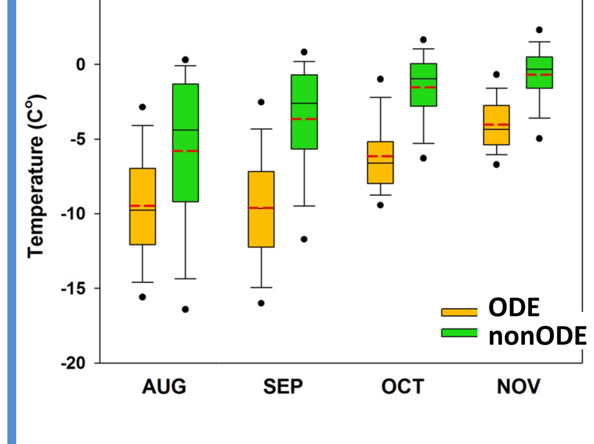
4.2. Diurnal variation of tropospheric ozone at KSG

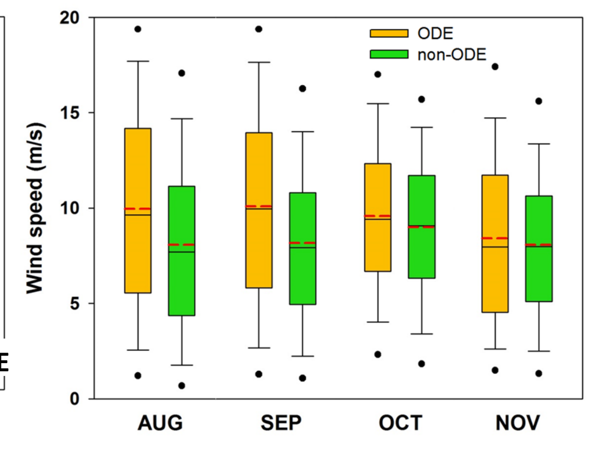


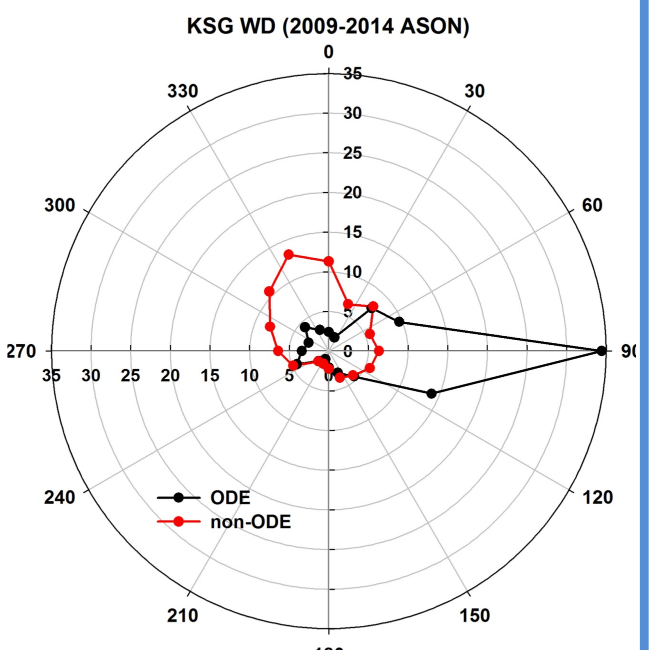
- Diurnal amplitude is large in austral summer (daylight hours > 20 hours, strong solar radiation), whereas that are small in austral winter (daylight hours<4 hours, week solar radiation)
- Through the noticeable drop of ozone during the daytime, we can identify the most dominant factor in diurnal variation of tropospheric ozone at KSG is the solar radiation.

4.3. Characteristics of ODEs at KSG

- Meteorological properties during ODEs





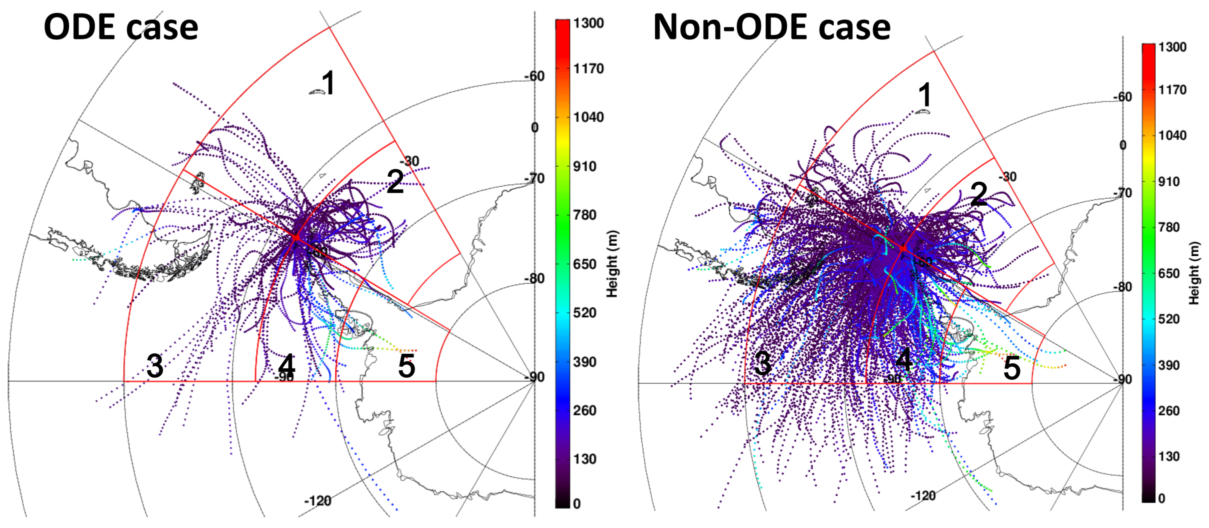


- ODEs at KSG was significantly related with specific meteorological conditions of lower temperature and easterly wind with higher wind speeds.

- Transport patterns of air mass during ODEs

ODE case

Non-ODE case



- HYSPLIT with the NCAR/NCEP global reanalysis archives
- Arrival altitude : 100m
- Two-day back trajectories
- ASON (austral springtime)

	Frequency of occurrence (%)		Frequency of ODEs
Sector	ODE	Non-ODE	in each sector (%)
Sec 1	18.8	9.2	19.6
Sec 2	38.8	11.7	28.2
Sec 3	17.0	49.3	3.9
Sec 4	23.9	28.5	9.1
Sec 5	1.5	1.3	11.6

- Ozone-poor air masses or air masses with enhanced bromine radicals which derive ODEs were frequently advected from the Weddell Sea sea ice zone (sector 2) to KSG in spring times.