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The October Effect in the Neutral Atmosphere Simulated by Different General Circulation Models

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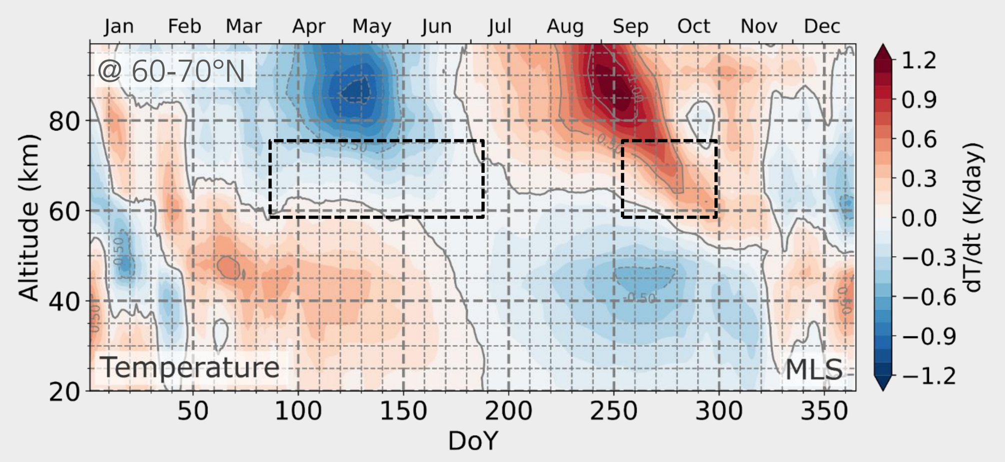
Introduction

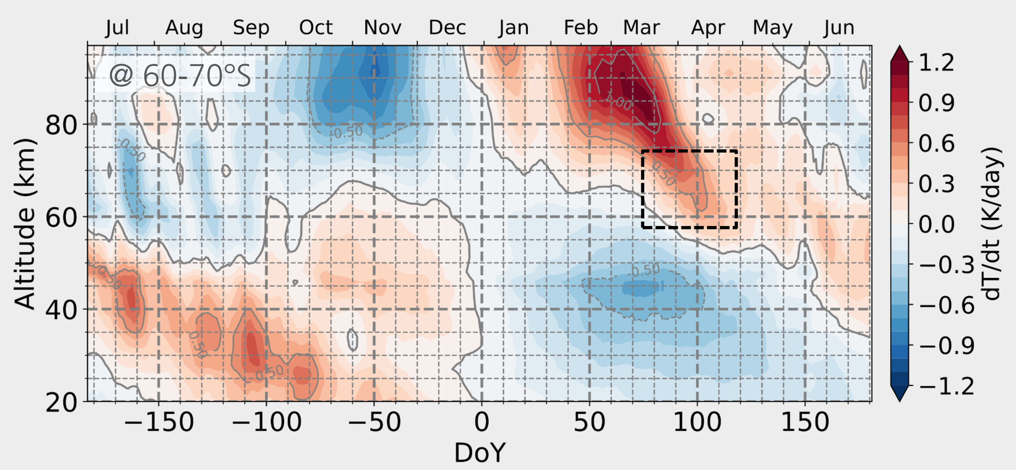
- The ionospheric **October Effect** is known as the rapid transition of the electron density from summer to winter conditions in the lower D-region in polar latitudes
- Such a rapid change, i.e. increase, is also observable in temperature in autumn in the lower mesosphere (see figure below; Wendt et al. 2024)



- There is a spring-fall asymmetry in the temperature tendency in the altitude range of 60 to 75km
- We call this phenomenon the **neutral October Effect**
- **Open questions:**
  1) What causes the neutral October Effect?
  2) To what extent do current global circulation models reproduce this effect?

Arctic vs. Antarctic

- Ionospheric October Effect is known from the Northern Hemisphere only due to the lag of observations in southern polar latitudes
- Neutral October Effect also occurs in the Southern Hemisphere autumn in March/April (see Figure below)

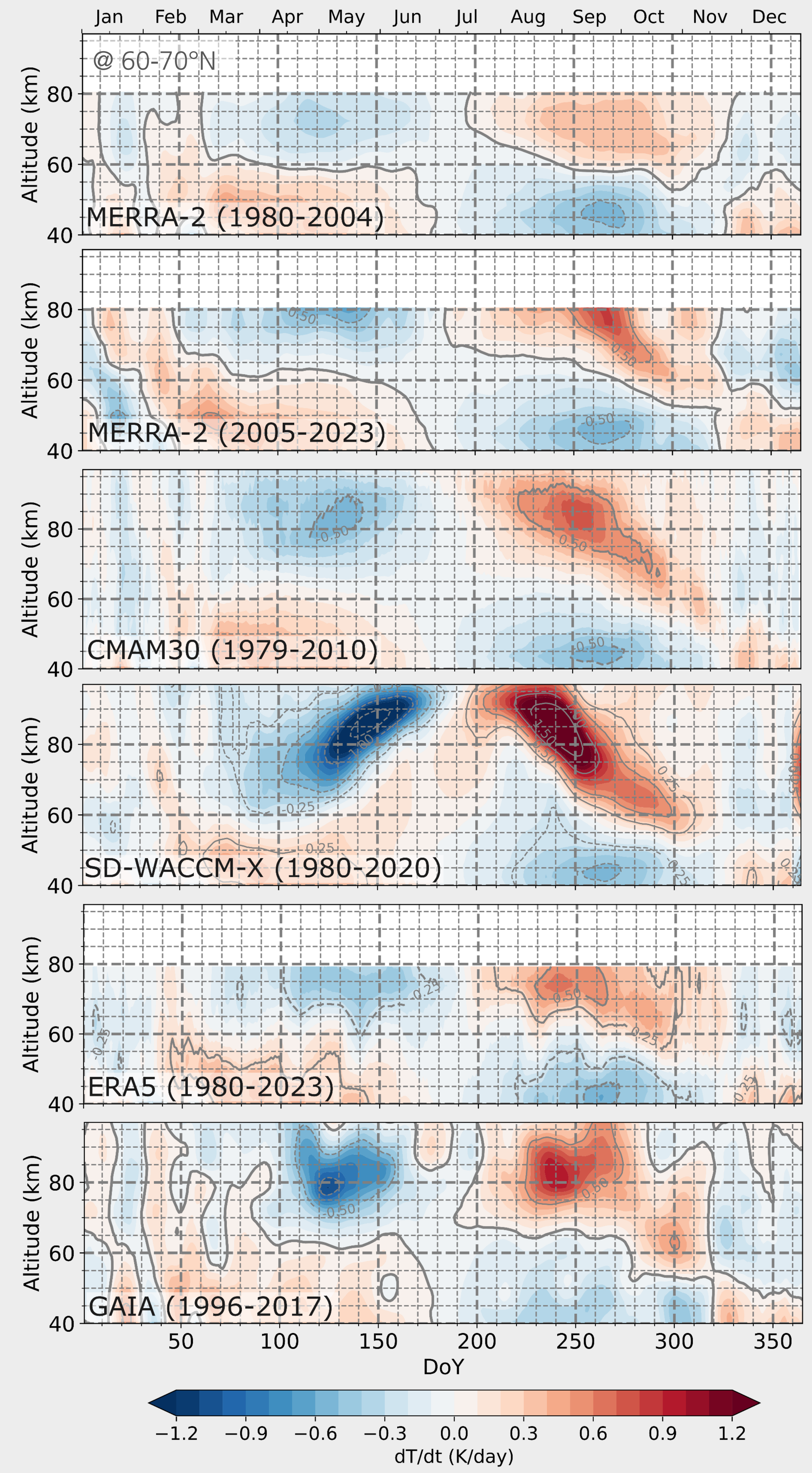


- in spring and autumn the residual mean meridional circulation, i.e. circulation from summer to winter pole, changes its direction (northward <-> southward)

Hypothesis:

The onset of the residual mean circulation from the summer to winter pole causes downwelling and therefore adiabatic warming in the lower mesosphere.

Neutral October Effect in GCMs



- No asymmetric warming in the lower mesosphere in autumn
- No neutral October Effect in MERRA-2 before 2005

- Asymmetric warming in lower mesosphere in fall
- Neutral October Effect in MERRA-2 after 2004 possibly due to the assimilation of MLS data in the mesosphere

- Asymmetric warming in lower mesosphere in fall
- Neutral October Effect in CMAM30

- Too strong and symmetric warming in late summer and autumn
- No neutral October Effect in SD-WACCM-X

- Weak asymmetric warming in the lower mesosphere in autumn
- Weak neutral October Effect in ERA5

- Late and weak asymmetric warming in the lower mesosphere in autumn
- Weak neutral October Effect in GAIA

⇒ Commonly used GCMs have problems reproducing the neutral October Effect in the lower mesosphere in autumn in polar latitudes

⇒ Data assimilation can help to overcome this issue

Open Questions:
1) What causes the neutral October Effect?
2) What causes the differences in the commonly used GCMs?

References:

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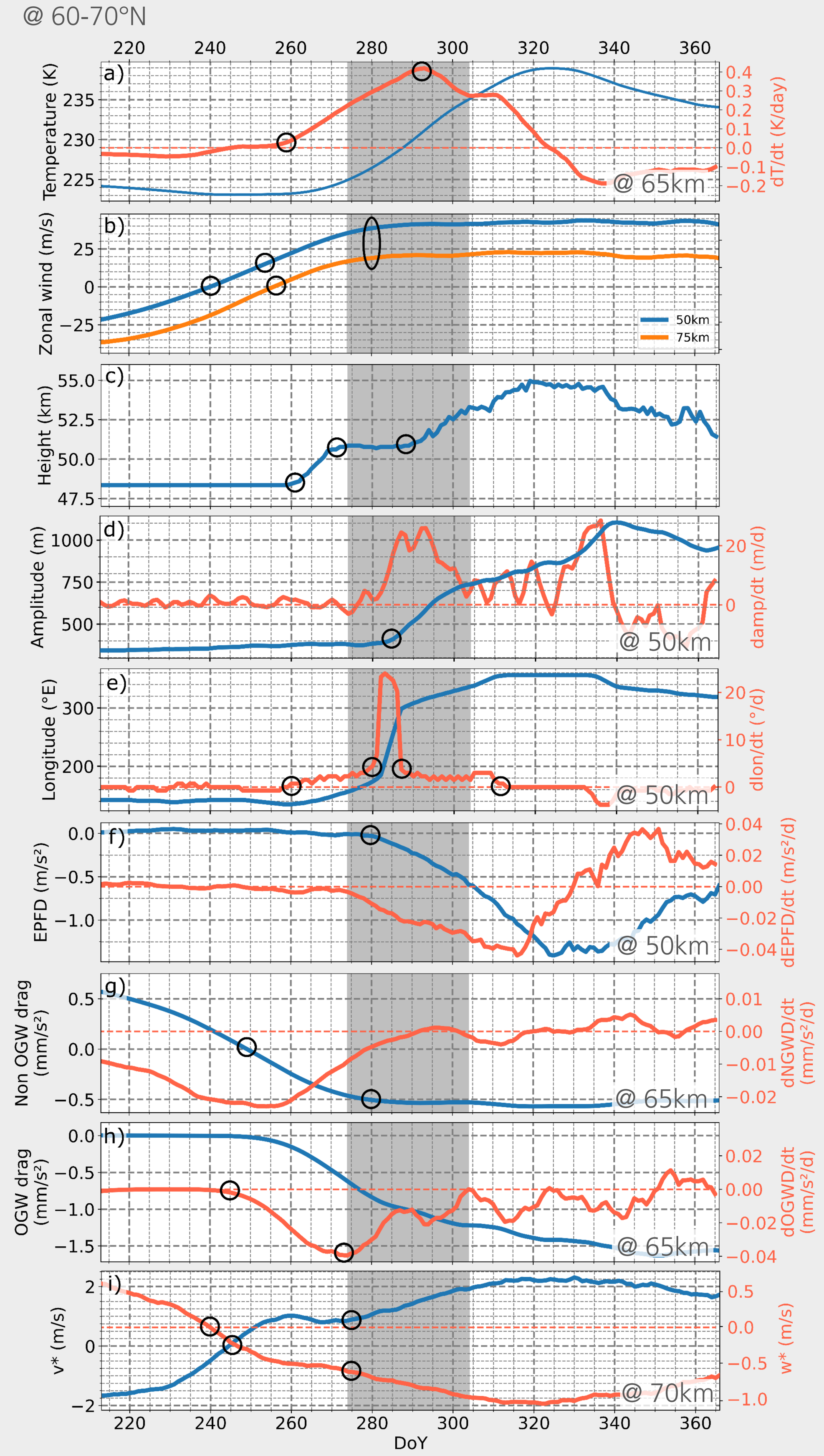
Data Analysis using CMAM30



DoY 240:
- $\bar{u}$ @ 50km > 0 m/s (b)
- w* < 0 (i)

DoY 245:
- orographic GWD < 0 (h)
- v* > 0 (i)

DoY 253:
- $\bar{u}$ @ 50km > 15 m/s (b)

DoY 257:
- $\bar{u}$ > 0 m/s in whole middle atmosphere (latest @ 75km; b)

DoY 260:
- Start of phase change of SPW (e)
- Start of temperature increase (a)
- Start of stratopause height jump (c)

DoY 270:
- First level of Stratopause height is reached (c)

DoY 280:
- Zonal winds reach winter level (b)
- Start of a significant increase in SPW amplitude (d)
- Non-orographic GWD reaches winter level (g)
- EPFD gets negative (f)
- SPW phase jump (e)

DoY 287:
- SPW phase jump ends (e)
- Start of further stratopause height increase to winter level (c)

DoY > 300:
- SPW phase reaches winter level (e)
- Temperature reaches winter level (a)

- In autumn the wind reversal from summer easterlies to winter westerlies occurs not simultaneously at all altitudes -> about 15 days later at 75km than at 50km
- When the absolute orographic GWD begins to increase, the temperature starts to increase strongly and the stratopause makes a jump
- Orographic GWD is responsible for the jump in stratopause height -> winter stratopause is maintained by GW-driven diabatic descent (France, JGR, 2012)
- When the zonal wind is westerly at all altitudes, the SPW phase slowly begins to shift
- SPW phase jumps when the zonal wind reaches winter level
- Peak of temperature change when SPW activity starts to increase (amplitude and EP-flux)

1) Orographic GWD and PW drag play a key role in the mechanism of the neutral October Effect.

Orographic GWD Schemes:
- MERRA-2: McFarlane (1987)
- CMAM30: Scinocca and McFarlane (2000)
- WACCM-X: McFarlane (1987)
- ERA5: Lott and Miller (1996)
- GAIA: McFarlane (1987)

2) The differences in the neutral October Effect of the various GCMs may be due to the different orographic GWD schemes.

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