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Dynamical response of the SH middle atmosphere to energetic particle precipitations in the latest reanalysis data

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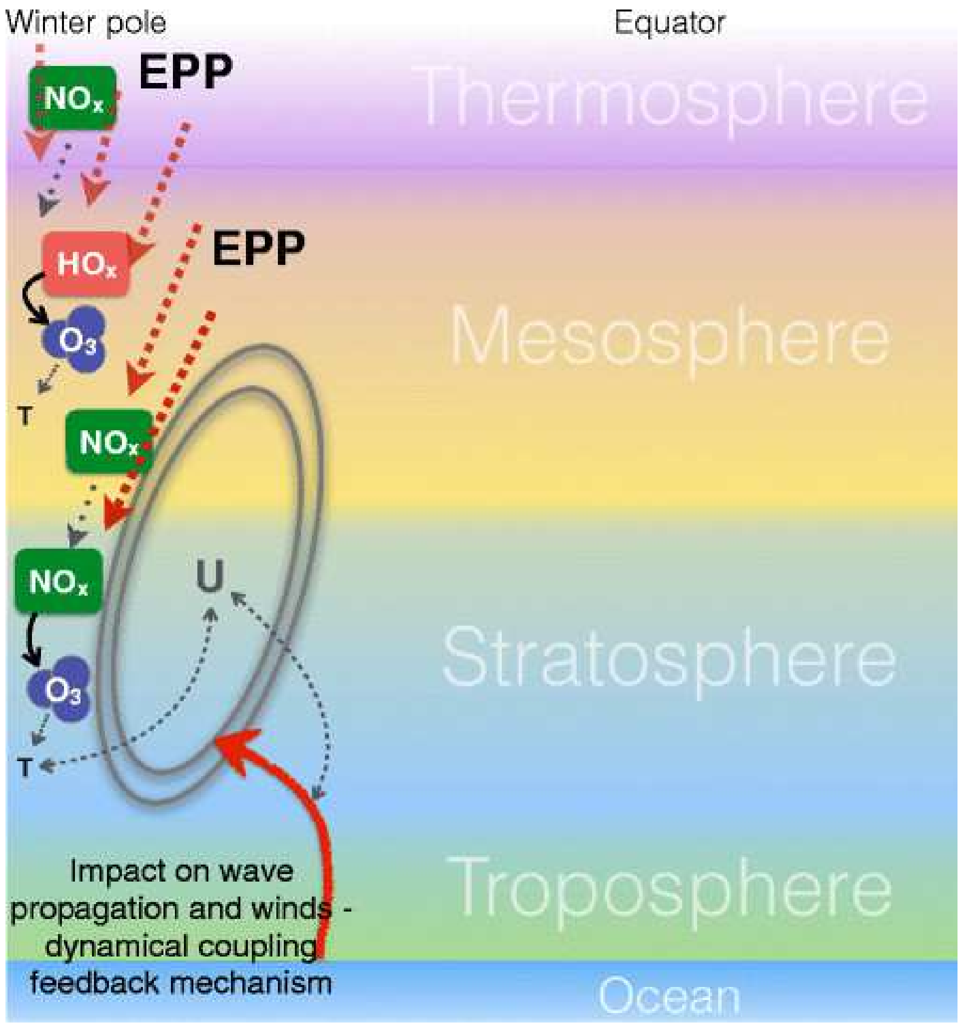
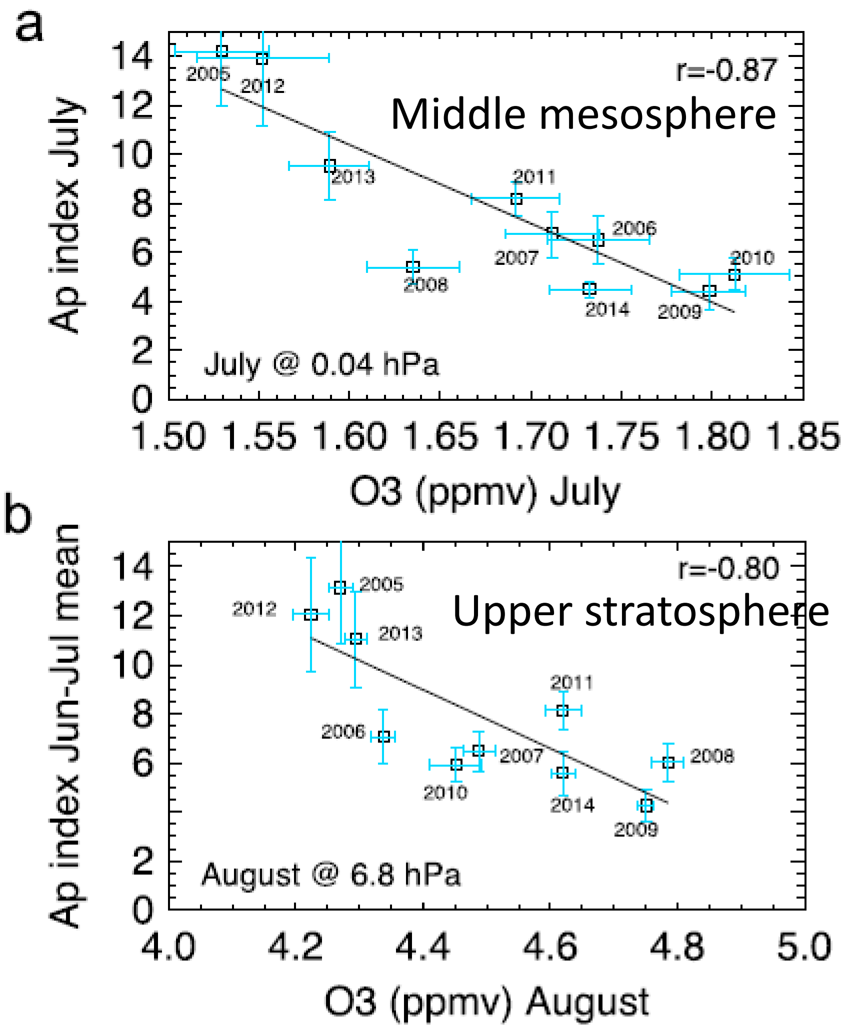
Energetic particle precipitation (EPP)

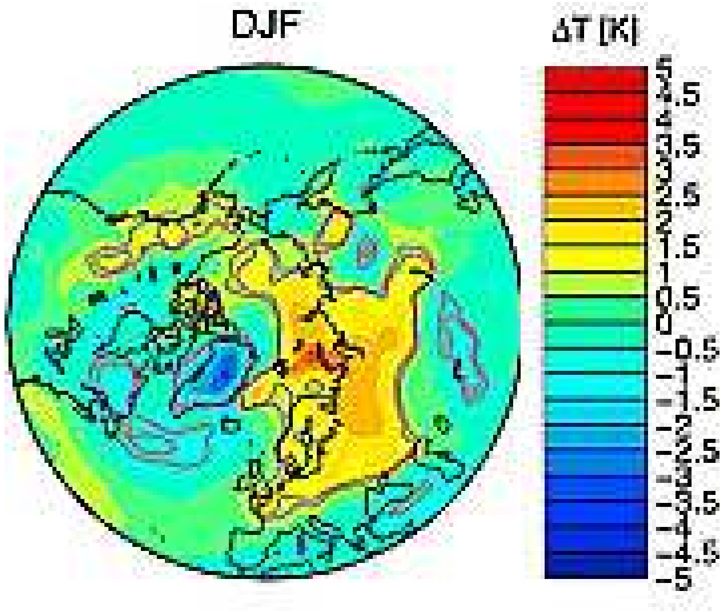


Seppälä et al. (2014)

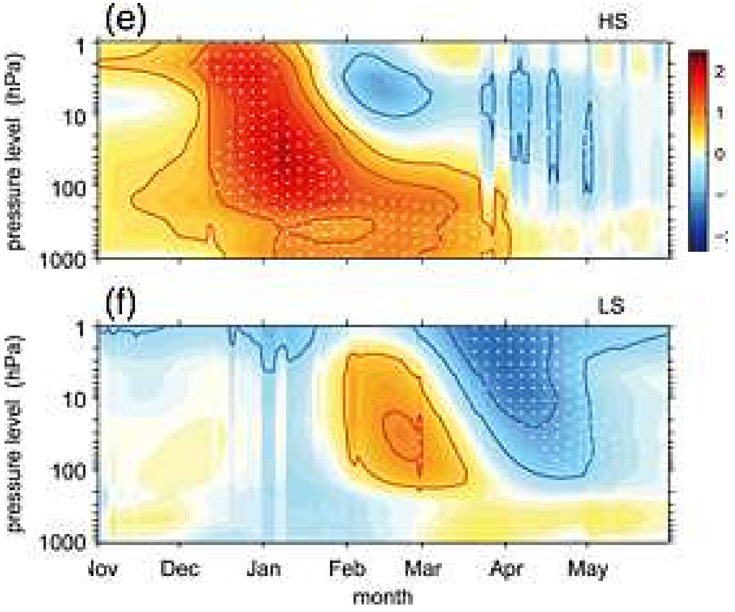


Damiani et al. (2016)

Effects of EPP on the atmosphere



Seppälä et al. (2009)



Lu et al. (2013)

Connections between EPP and the middle atmosphere and/or surface have been reported in several studies, but still controversial.

Purpose

Purposes of this study are

- to extract signals due to the EPP in the SH middle atmosphere
- to compare them between the latest reanalysis data
- to examine whether they are dynamically induced or not

using linear multiple regression and bootstrapping.

We focus on the SH, because

- dynamically inactive (i.e., small interannual variations)
- stronger polar vortex induces persistent downward transport of EPP-induced NOx.

Datasets used

Reanalysis	MERRA	JRA55	ERAI
Horizontal resolution	1.25°x1.25°		1.5°x1.5°
Vertical levels	42 levels from 1000 to 0.1 hPa (i.e., 0-64km)	37 levels from 1000 to 1 hPa (i.e., 0-48km)	
Period	1979 – 2015	1979 – 2015	1979 – 2015

F10.7 radio flux and Ap index data were taken from NOAA/NCEI.

Niño 3.4 index was taken from NCEP/CPC.

Aerosol optical depth was taken from NASA/GISS.

Linear multiple regression for each month

$$y_t = \sum_{i=1}^{n} \beta_i x_{i,t} + \varepsilon_{0,t}$$

y_t : observed variable at time t

β_i : ith regression coefficient

x : matrix comprised of n predictors for regression

$\varepsilon_{0,t}$: noise term

List of predictors

Linear trend with a break point at 1995 (as indices of GHGs and ozone depleting substances; Seidel et al., 2016),

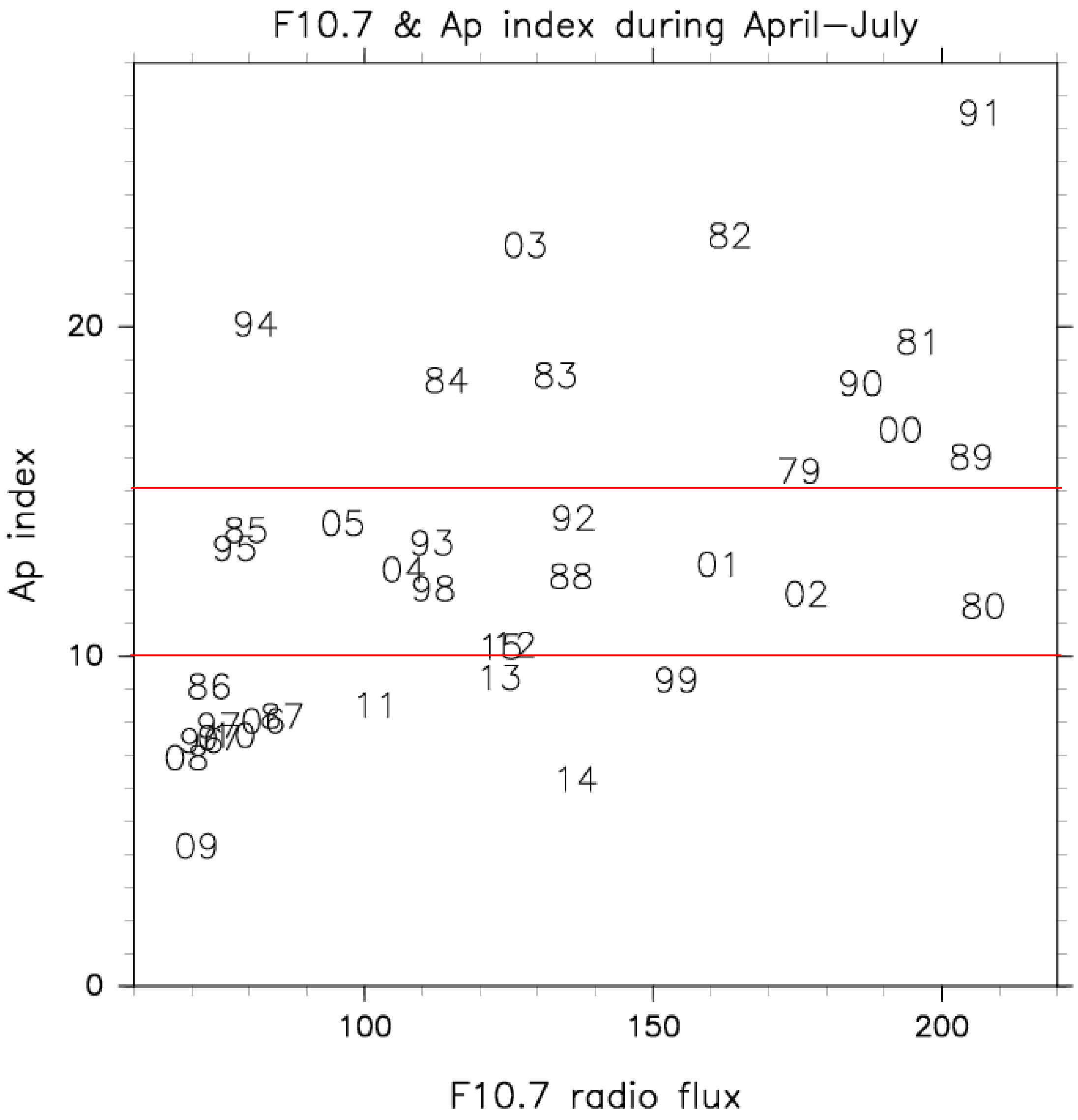
QBO(-A,B),

F10.7 (as an index of solar activity),

Niño3.4 (as an index of ENSO),

Aerosol optical depth (as an index of volcanic effect)

Classification by Ap index



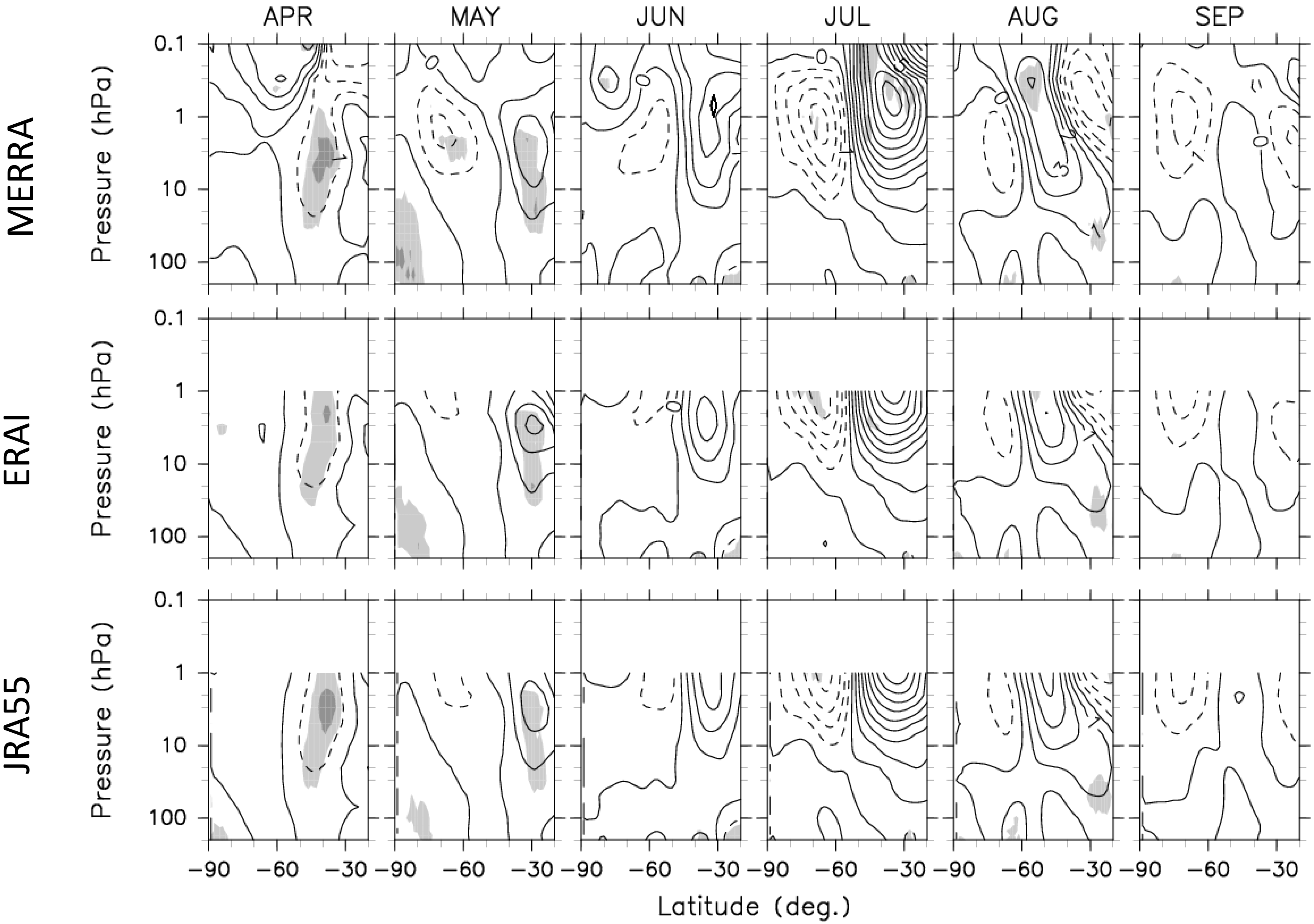
11 yrs for high Ap

13 yrs for medium Ap

13 yrs for low Ap

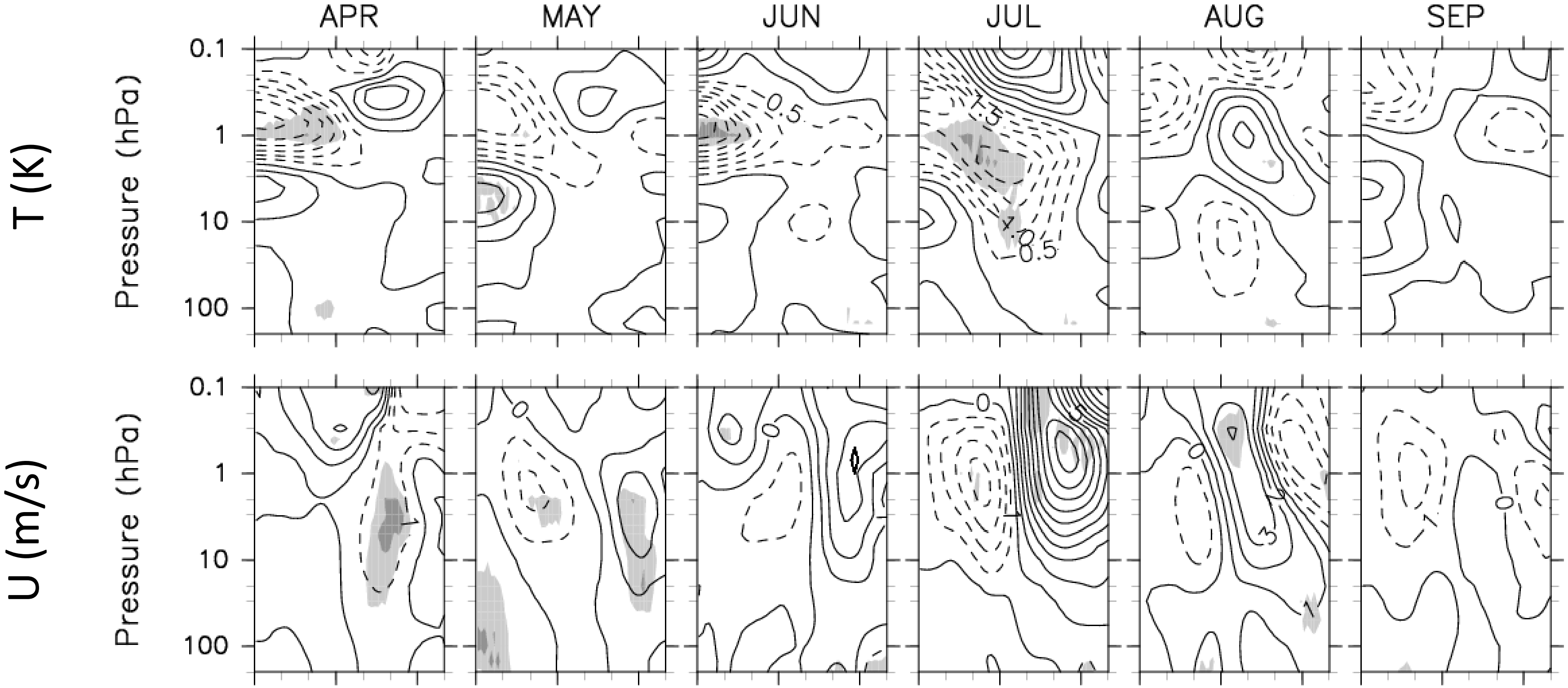
Comparison btw reanalyses

U anomaly (m/s) btw high and low Ap



EPP signals in MERRA

Difference btw high and low Ap

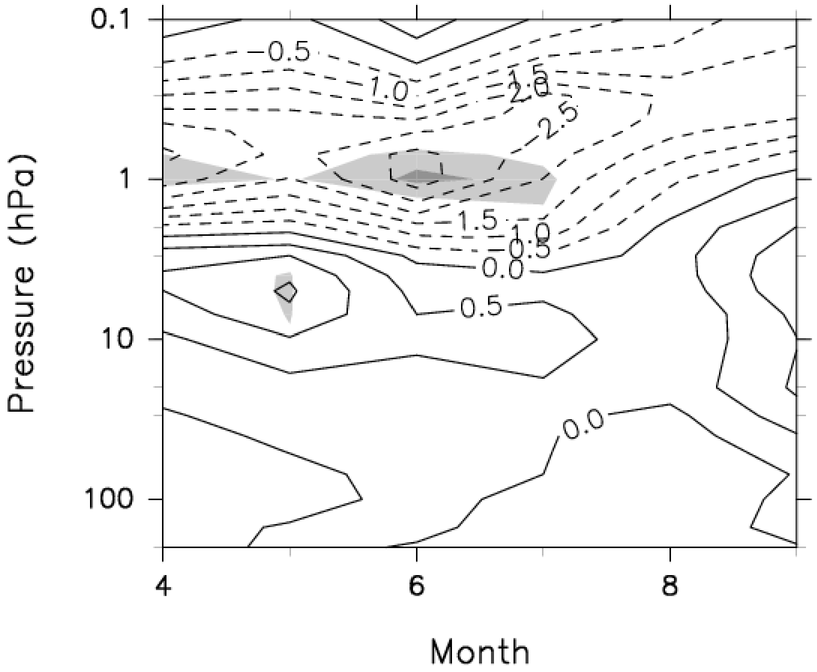


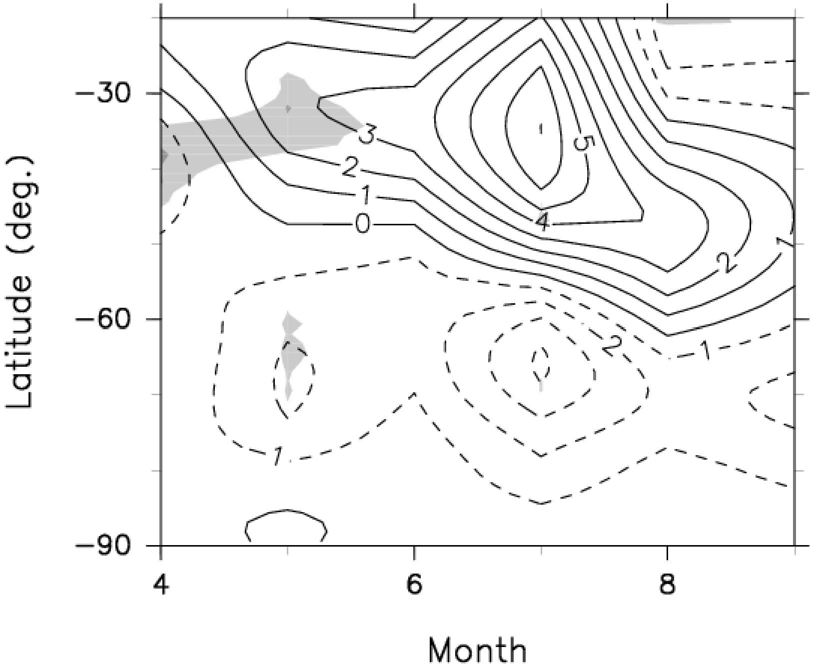
Dark and light shades represent 99% and 95% confidence levels by bootstrapping, respectively.

Persistent positive (negative) T anomalies in polar LM (US)

Poleward propagating U anomalies around the stratopause

Time evolution of EPP signals

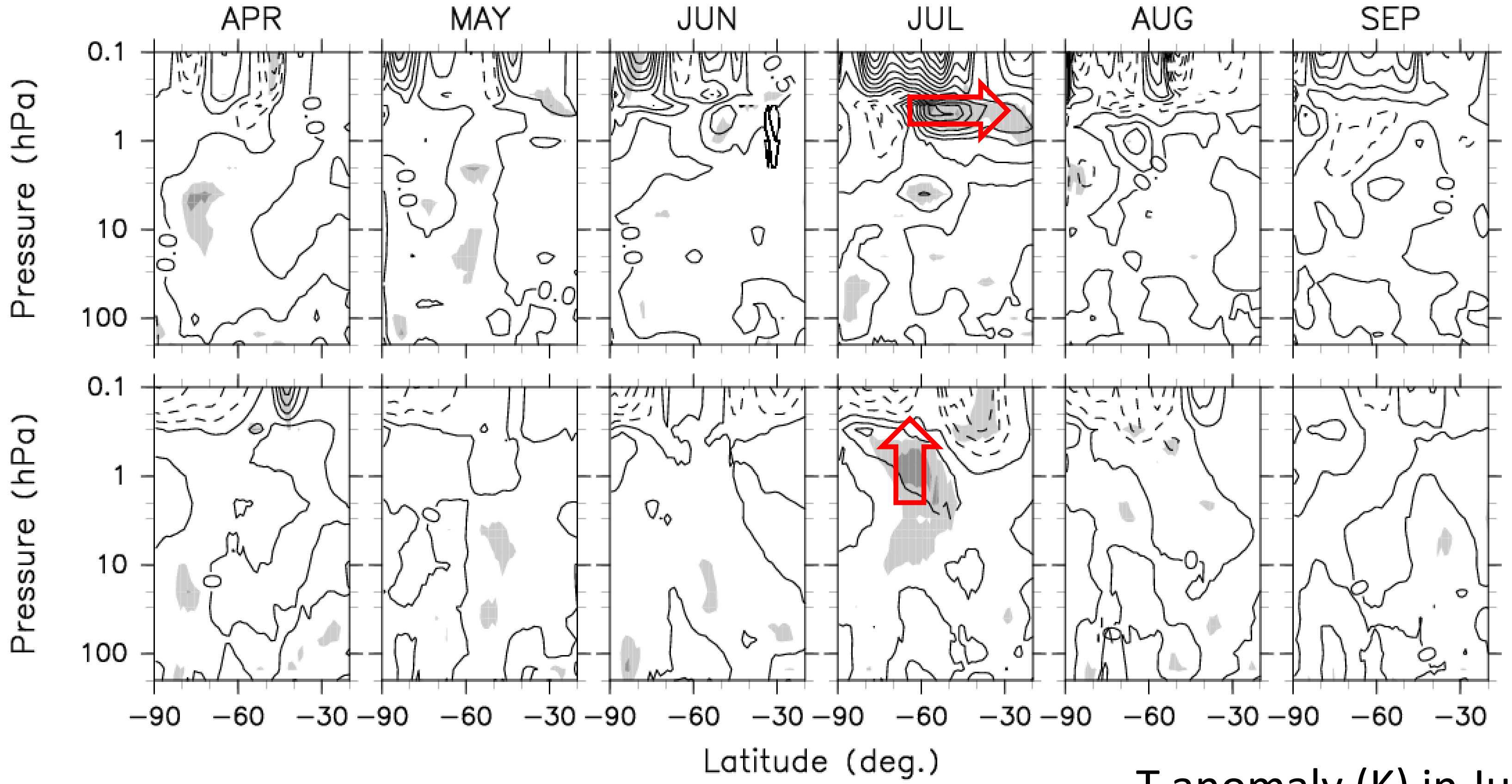

T anomaly (K) at 80S


U anomaly (m/s) at 2hPa

Persistent positive (negative) T anomalies in polar LM (US)

Poleward propagating U anomalies around the stratopause

TEM analysis



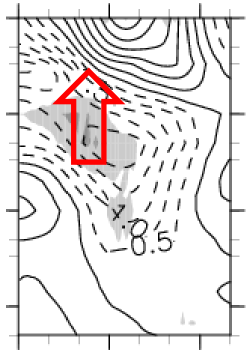
$\boldsymbol{\nabla} \cdot \mathrm{F}$

(m/s/day)

$\overline{W^*}$

(mm/s)

T anomaly (K) in July



Statistically significant signal is seen in July.

$\boldsymbol{\nabla} \cdot \boldsymbol{F}$ and $\overline{W^*}$ are dynamically consistent with each other.

Summary

The latest reanalysis data showed similar EPP signals.

- Persistent positive (negative) T anomalies in polar LM (US)
- Poleward propagating U anomalies around the stratopause (→no downward propagation unlike the previous studies)
- Statistical significance is not high (→too short?)

The obtained EPP signals are explained by a dynamical process in July . In the other months, they may be explained by shortwave and longwave radiation change due to ozone loss in the polar US/LM (cf. Langematz et al., 2003).