Enhanced transport and mixing of Arctic ozone during SSWs

Álvaro de la Cámara[1], M. Abalos[1], P. Hitchcock[2], N. Calvo[1], R. R. Garcia[3]

[1] Universidad Complutense de Madrid, Spain.
[2] Cornell University, NY, USA.
[3] NCAR, CO, USA.

https://www.atmos-chem-phys.net/18/16499/2018/

Atmos. Chem. Phys., 18, 16499–16513, 2018
https://doi.org/10.5194/acp-18-16499-2018

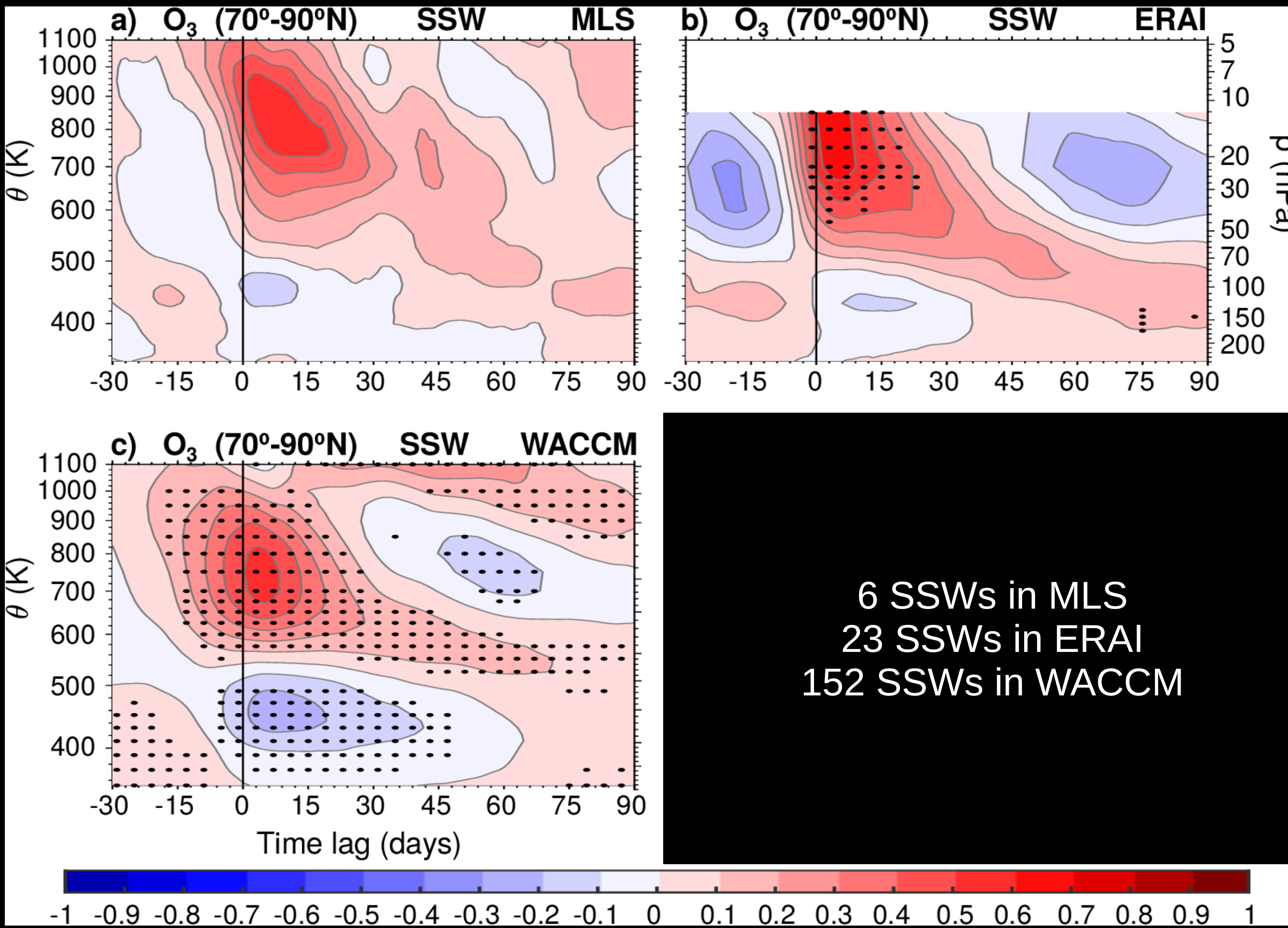
Atmospheric Chemistry and Physics
Open Access
EGU

Response of Arctic ozone to sudden stratospheric warmings

Alvaro de la Cámara[1,2], Marta Abalos[1], Peter Hitchcock[3,a], Natalia Calvo[1], and Rolando R. Garcia[4]

[1]Dept. Física de la Tierra y Astrofísica, Universidad Complutense de Madrid (UCM), Madrid, Spain
[2]Instituto de Geociencias (IGEO), CSIC-UCM, Madrid, Spain
[3]Laboratoire de Météorologie Dynamique/IPSL, Ecole Polytechnique, Palaiseau, France
[4]National Center for Atmospheric Research, Boulder, CO, USA
[a]now at: Earth and Atmospheric Sciences Dept., Cornell University, Ithaca, NY, USA

Composite of Arctic ozone anomalies



(ppmv)

6 SSWs in MLS
23 SSWs in ERAI
152 SSWs in WACCM

The zonal-mean ozone continuity equation

$$\partial_t \bar{\mathrm{O}}_3 = \bar{S}^* - a^{-1}\bar{v}^*\partial_\phi \bar{\mathrm{O}}_3 - \bar{Q}^*\partial_\theta \bar{\mathrm{O}}_3 + \bar{\sigma_\theta}^{-1}\left[(a\cos\phi)^{-1}\partial_\phi(M_\phi\cos\phi) + \partial_\theta M_\theta\right]$$

Zonal-mean ozone tendency = **Chemical production minus loss** + **Mean advection** + ***Eddy transport***

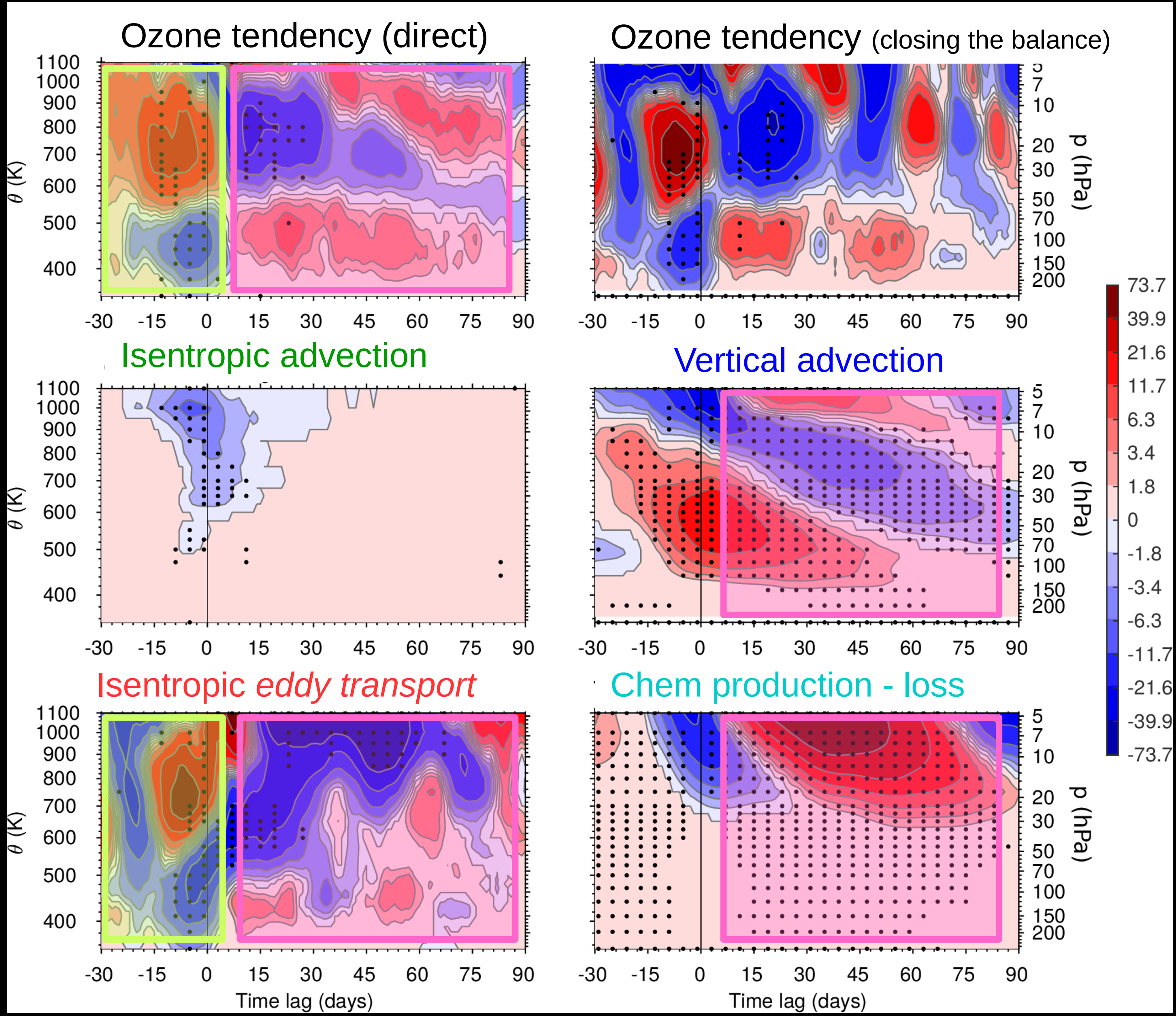
$$\boldsymbol{M} = (0, M_\phi, M_\theta) = (0, -\overline{(\sigma_\theta v)'\mathrm{O}_3'}, -\overline{(\sigma_\theta Q)'\mathrm{O}_3'})$$

What drives the ozone changes during SSWs?

70ºN-90ºN *[ppbv / day]*

O3 tendency during the onset of SSWs is dominated by isentropic eddy transport.

In the aftermath of SSWs, reduced isentropic advection (↓wave activity) and vertical advection contribute to O3 recovery, with chemical tendency partially counteracting in upper levels.

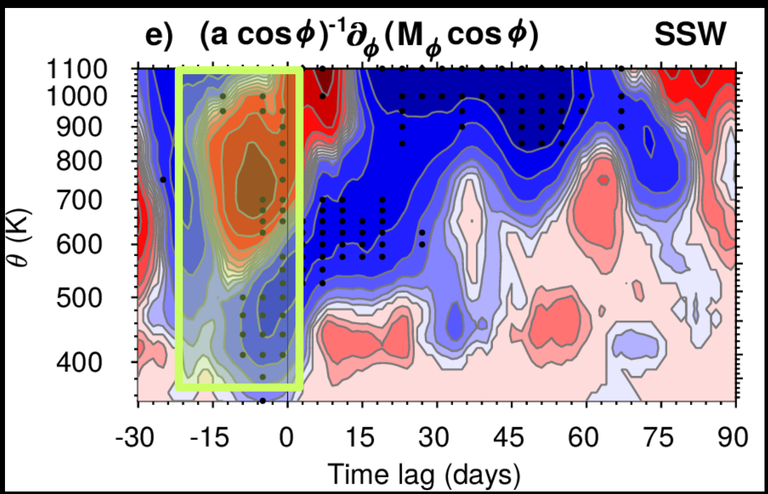


Irreversible mixing of ozone

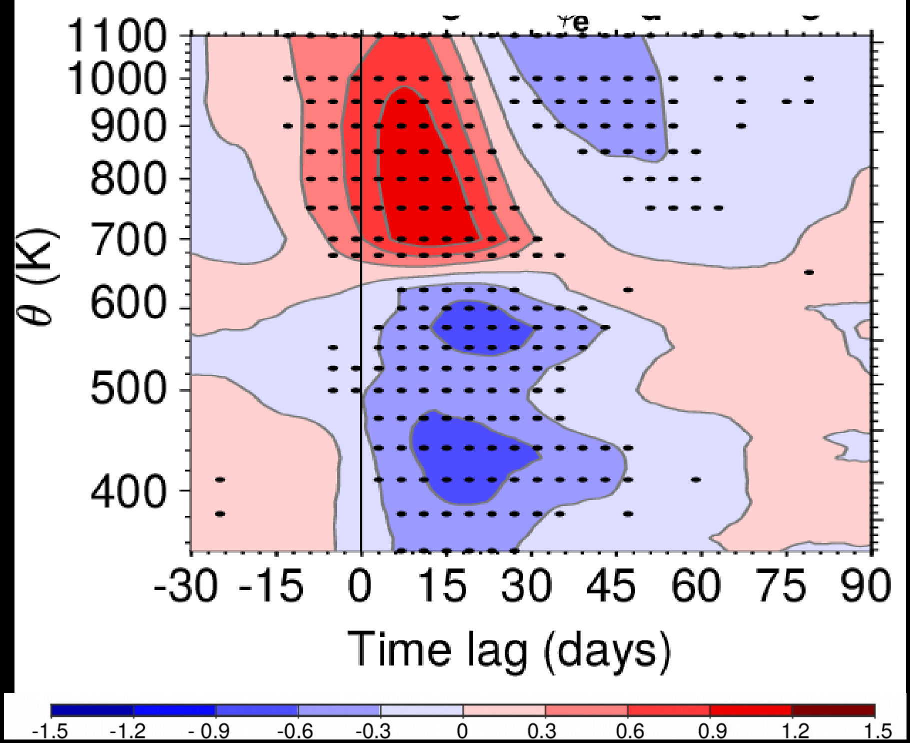
$$\partial_t O_{3,\phi_e} = \underline{-a^{-1}\partial_{\phi_e}\left(\kappa_{eff}(a\cdot\cos\phi_e)^{-1}\partial_{\phi_e}(\cos\phi_e\cdot O_{3,\phi_e})\right)} + \text{(diabatic and chemical terms)}$$

Mixing-induced O3 tendency

Eddy transport of ozone (polar cap)

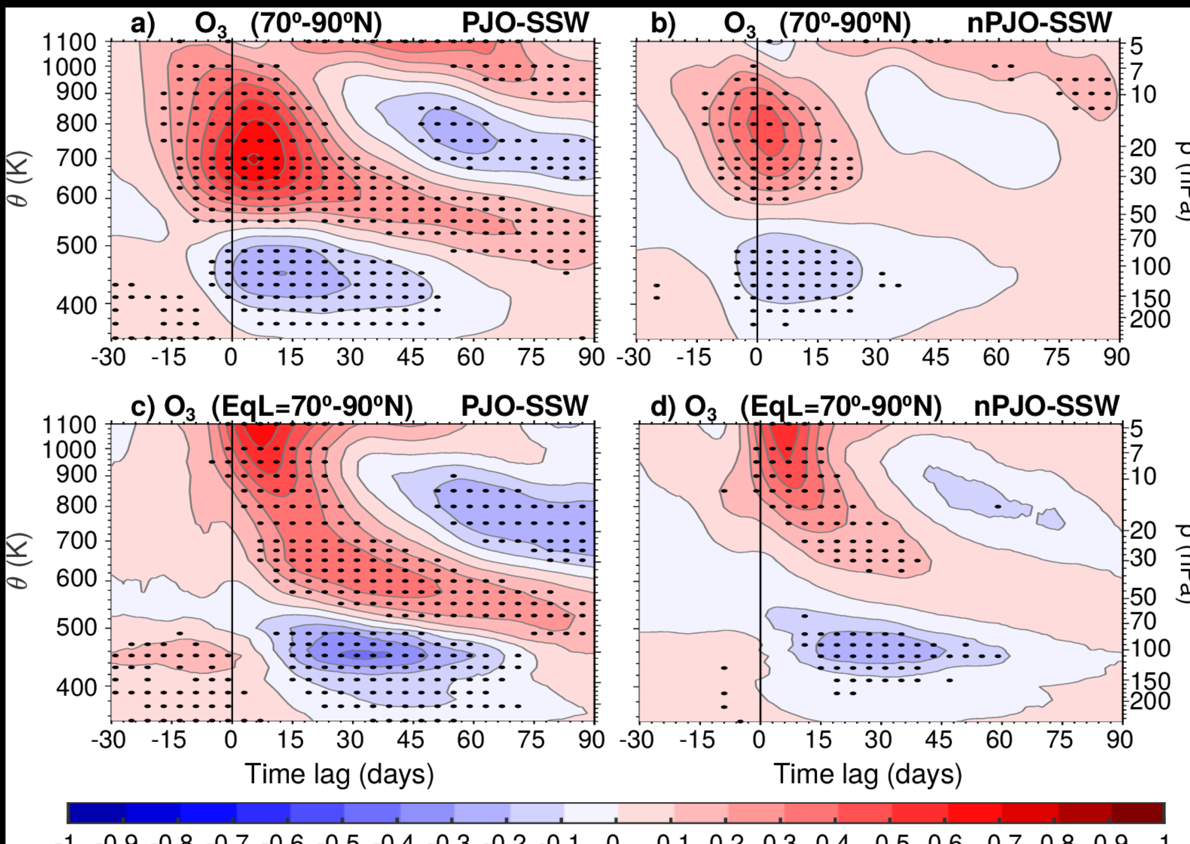


Mixing-induced ozone tendency
(eq latitude 70 -90N)



Although zonal-mean isentropic eddy transport is often referred to as mixing, the initial increase in isentropic *eddy* transport has a strong reversible component.

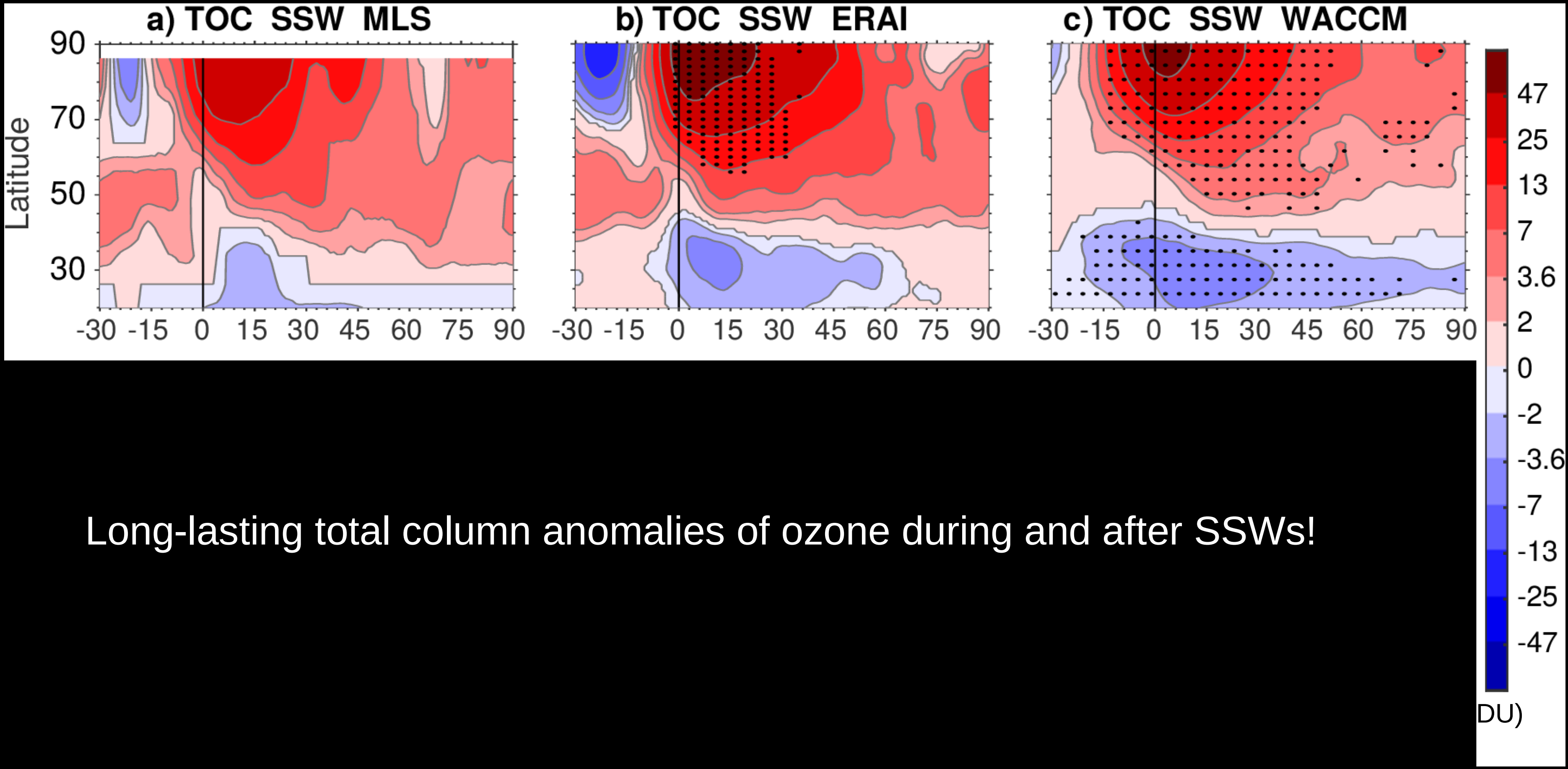
Arctic ozone and PJO sudden warmings



- Ozone anomalies during PJO-SSWs (left column) persist much longer after SSWs than nonPJO-SSW(right column)
- Anomalies appear later in equivalent latitude (EqL) than in geographical, which confirms that the initial increase in Arctic ozone over the pole has a strong reversible component (→ the vortex changing shape and position right before SSWs)

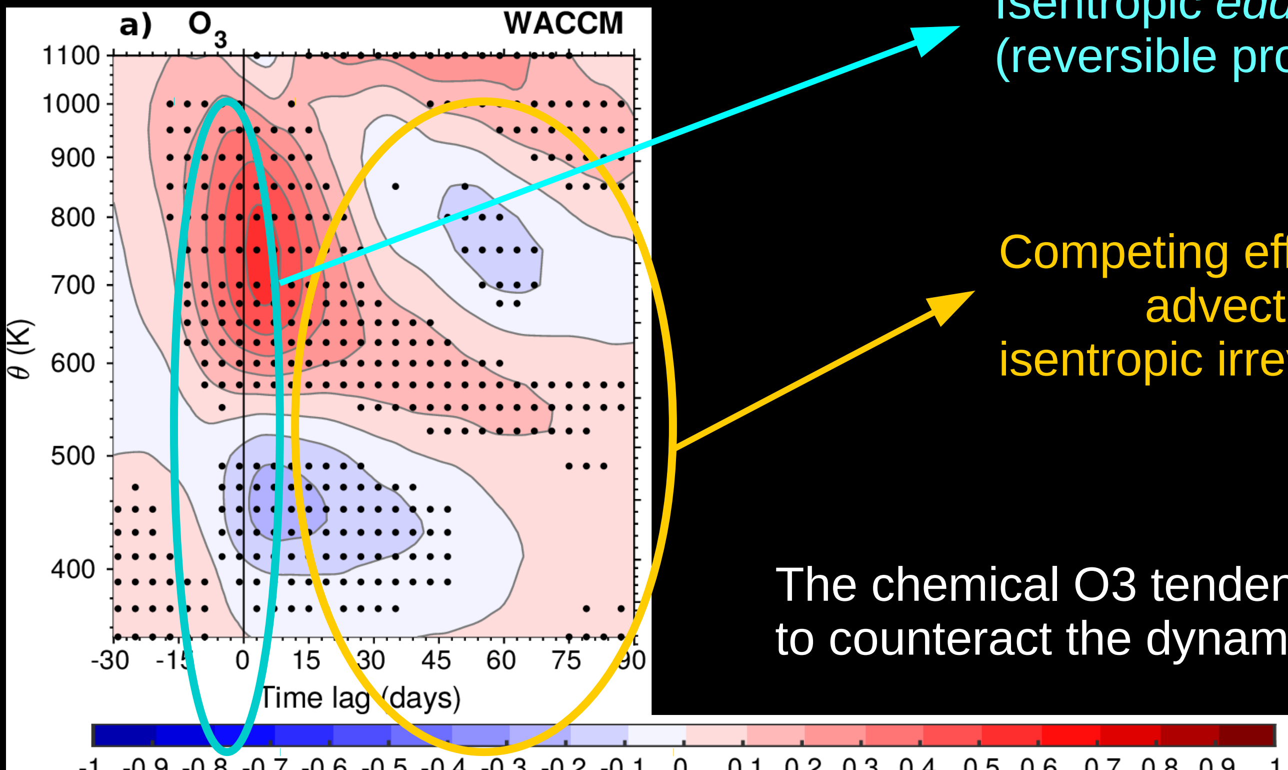
PJO (polar night-jet oscillation) sudden warmings are deep SSWs whose temperature and wind anomalies reach the lower stratosphere, where they persist longer than non-PJO SSWs (Hitchcock et al 3013).

Total ozone column anomalies



Long-lasting total column anomalies of ozone during and after SSWs!

Conclusions



Isentropic *eddy* transport of O3 (reversible process)

Competing effects of vertical advection and isentropic irreversible mixing

The chemical O3 tendencies simulated in WACCM tend to counteract the dynamically induced changes of ozone

SSW that occur during PJO events (sufficiently deep SSWs) have a stronger and more persistent response of ozone (details in the paper).

REFERENCES:

- de la Cámara, Abalos, Hitchcock (2018 *JGR*) Changes in stratospheric transport and mixing during SSWs
- de la Cámara, Abalos, Hitchcock, Calvo, Garcia (2018 *ACP*): Response of Arctic ozone to SSWs