Stratosphere-Troposphere Transport of Ozone Associated with Atmospheric Rivers

By **Kirsten R. Hall**[1] , Huiqun Wang[1], Amir H. Souri[2,3], Xiong Liu[1], and Kelly Chance[1]

CENTER FOR **ASTROPHYSICS** HARVARD & SMITHSONIAN

Key Points

- This work reveals positive tropospheric O_3 anomalies within dry intrusions associated with ARs.
- Average excess ozone concentrations are 10-13 ppbv at 400 hPa, and are even greater for increasing intensity of ARs.
- STT of O_3 associated with ARs in the NE Pacific may account for 13 +/- 2% of the total Northern Hemisphere STT O_3 flux.

Introduction

- **Atmospheric Rivers (ARs)** are long streams of water vapor in the lower troposphere.
- While often associated with extratropical cyclones (EC), about 20% occur **not** in connection with an EC, and neither the intensity nor the precise location nor duration of the AR can be determined from the cyclone.
- ARs intensities are variable, and strong AR events can have catastrophic consequences upon landfall, such as causing flooding and mudslides.
- → A broad community of researchers endeavors to understand all aspects of ARs from inception to weather upon landfall, and most relevant here, to their connection to larger-scale dynamics.
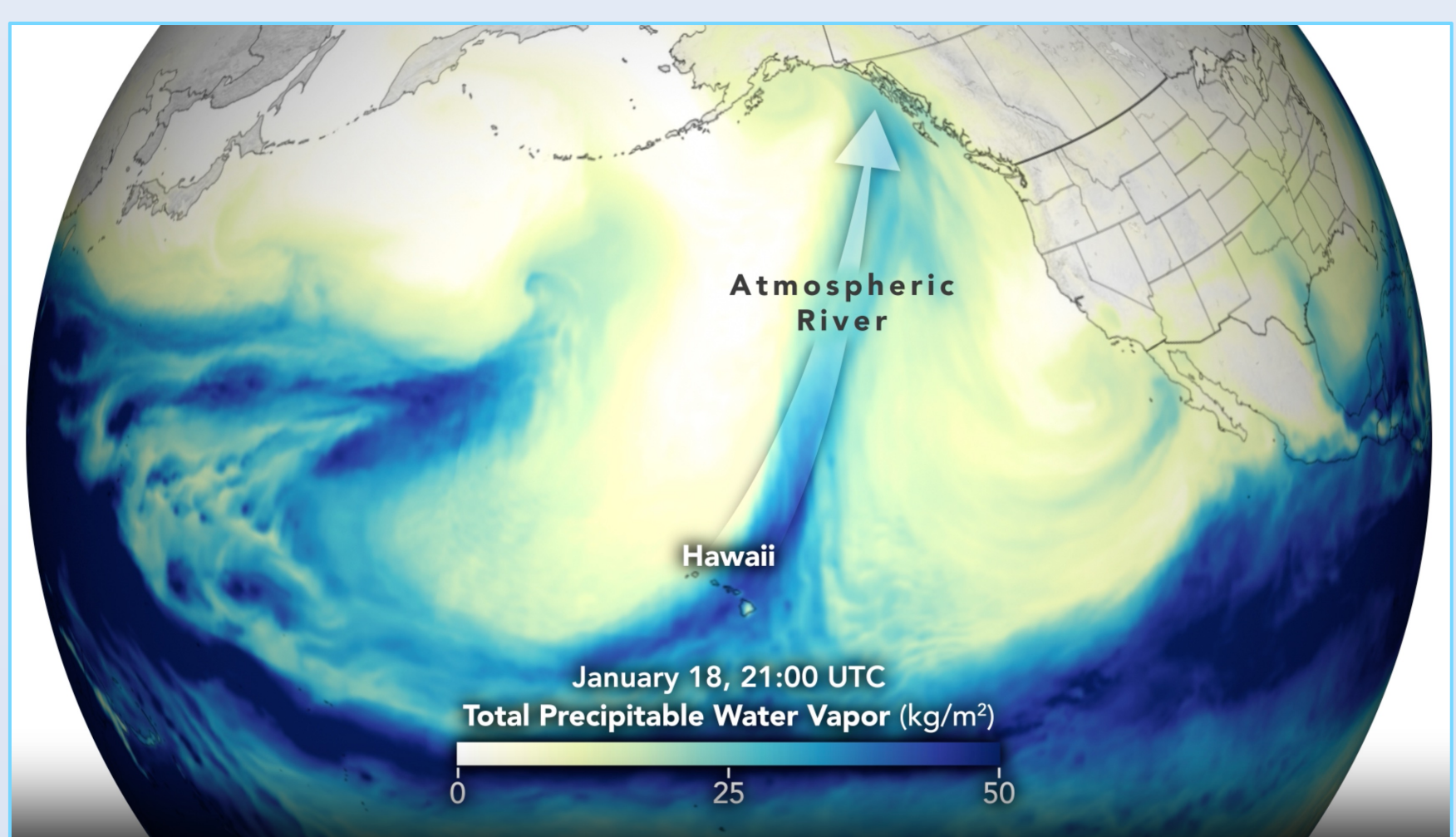

Image credit: NASA Earth Observatory. Screenshot from an animation generated by the Goddard Earth Observing System Data Assimilation System (GEOS DAS).

What is the connection between ARs and Tropospheric O_3?

- Understanding the total stratospheric contribution to tropospheric O_3 is a significant area of research.
- Disentangling the contributions to tropospheric O_3 by STT from the production of O_3 due to precursor emissions is vital for understanding air pollution and future warming due to greenhouse gases.
- In addition to the planetary-scale continuous downward flow of air masses, in the extratropics, STE also occurs as an episodic phenomenon in association with synoptic-scale processes that perturb the tropopause.
- Similarly to how STT of O_3 has been quantified in connection with ECs, in this study we uncover the relationship between ARs and associated anomalies in tropospheric O_3 as a consequence of STT.

Affiliations:
[1]Center for Astrophysics | Harvard & Smithsonian
[2]NASA Goddard Spaceflight Center
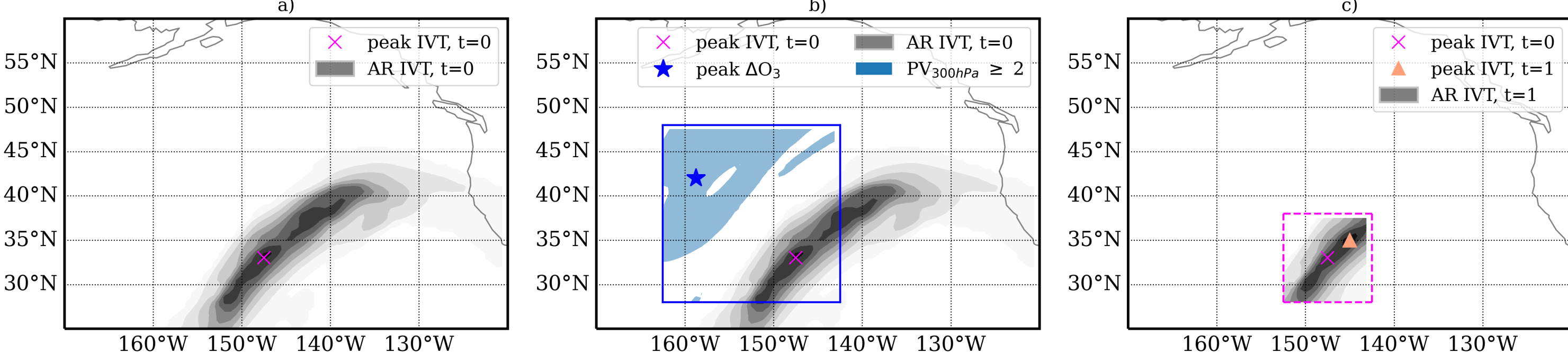[3]Morgan State University

SCHMIDT SCIENCE FELLOWS

KRH email: kirsten.hall@cfa.harvard.edu

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Method

1. Track ARs using ARTMIP AR catalogs and the integrated vapor transport (IVT) computed from MERRA-2 data, as well as their associated O_3 anomalies in the NE Pacific


Left, step one: identify the AR (gray shading) and its peak IVT (magenta x). Middle, step two: Identify potential tropopause lowering (blue shading), then find the peak value of anomalous O_3 (blue star) at 200 and 400 hPa. Right, step 3: within a 10 degree latitude by 10 degree longitude box (magenta dashed box) centered on the peak IVT at t=0 (magenta x), identify the peak IVT for the AR at the next time step, t=1 (peach triangle). The algorithm repeats steps two and three until the AR dissipates or a new AR enters the smaller search box.

2. Assess the AR IVT – anomalous O_3 relationship for case studies
3. Track tropopause lowering/folding using MERRA-2 potential vorticity via a vertical cross section across peak IVT and maximum anomalous O_3 at 400 hPa
4. Generate AR-centric composites for the years 2004-2014
5. Assess the AR IVT – anomalous O_3 relationship for composites, including an estimation of total O_3 flux into the troposphere

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Anomalous O_3 with AR IVT contours in 3-hour time steps from MERRA-2.
→ O_3 filament traces the AR
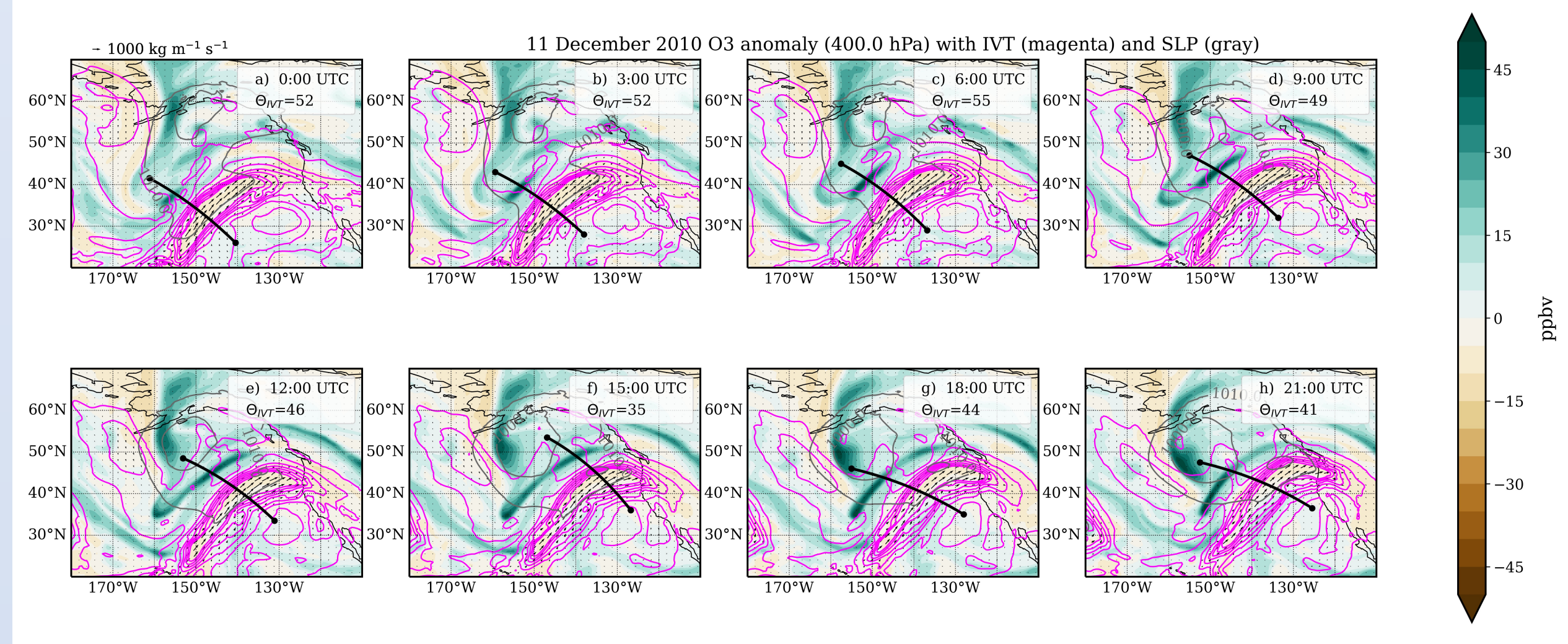
Anomalous O_3 with PV contours (white) and VT contours (pink) taken from the vertical cross section over the black line in the above panels.
→ Excess O_3 follows the PV intrusion
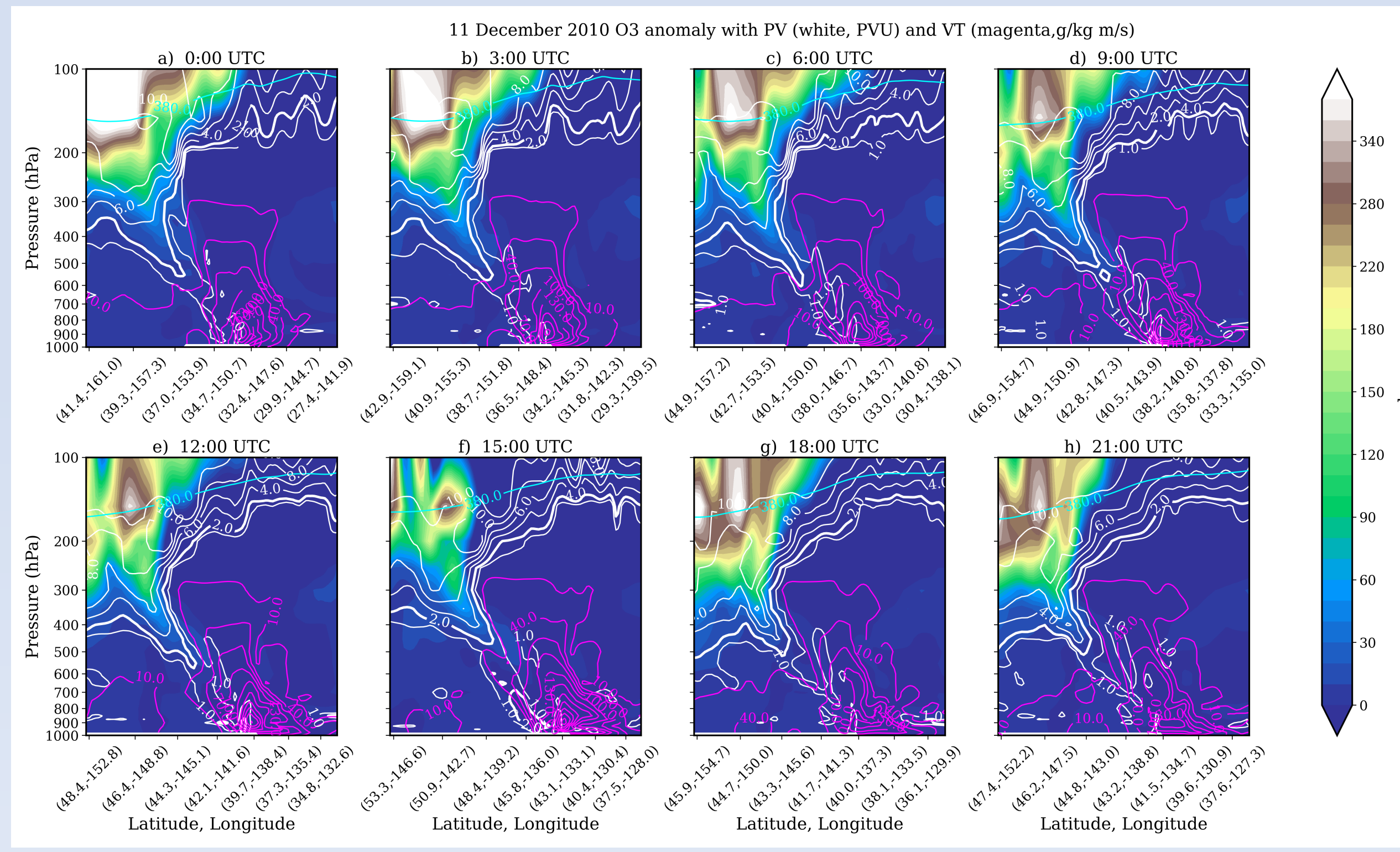
Composite Results

ARs placed in 7 bins of direction of travel θ_{IVT} (3 shown, rows), and 4 bins of peak IVT; We compare the 1st (lowest, left) and 4th (highest, right) quartiles of peak IVT bins
→For each, top left: 200 hPa, top right: 300 hPa, bottom left: 400 hPa, bottom right: vertical cross section over white dashed line in the other panels

Peak IVT $\leq$ 659 kg/m/s   Peak IVT $\geq$ 1063 kg/m/s
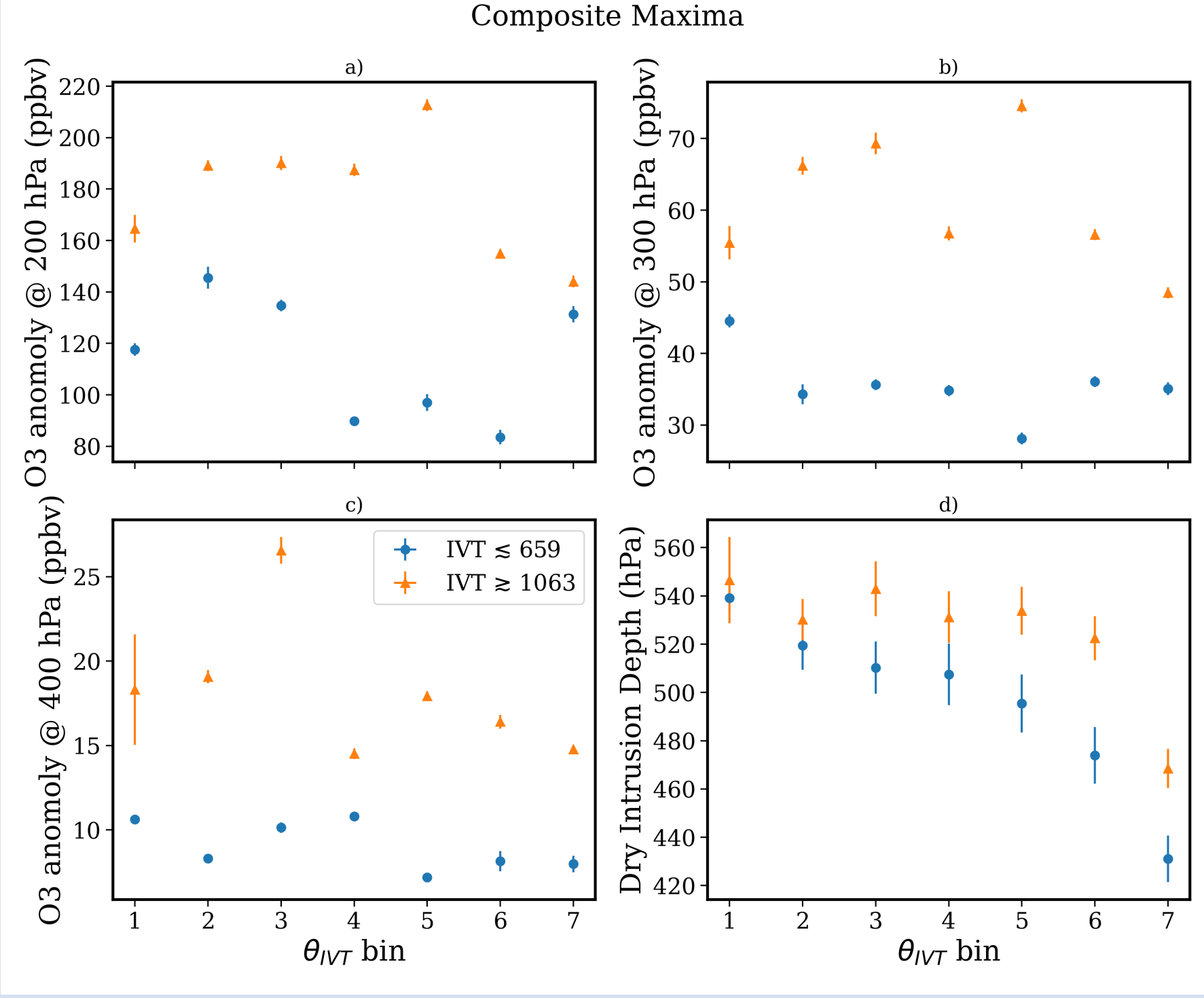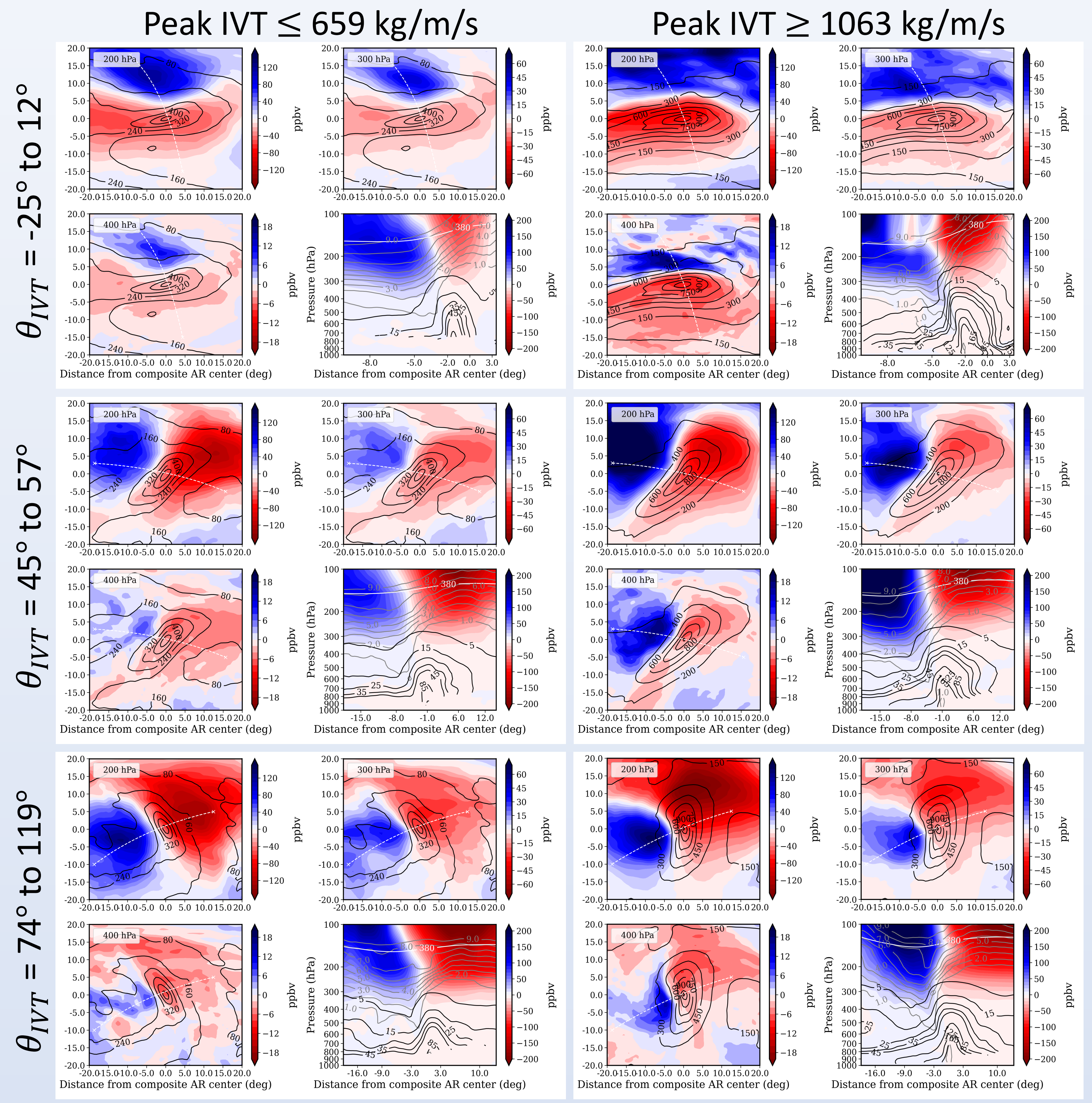
→ Composite maxima of anomalous O_3 at 200 (top left), 300 (top right) and 400 (bottom left) hPa for the 1st (lowest, blue) and 4th (highest, orange) quartiles of peak IVT in bins of AR direction of travel.
→ Bottom right: average depth of the dry intrusions for each AR time step

→ Composite maxima of O_3 flux into the troposphere (left) and mean area averaged O_3 flux (right)