

Composition and transport in the Asian summer monsoon anticyclone (ASMA): A case study based on in-situ observations during ESMVal and EMAC simulations

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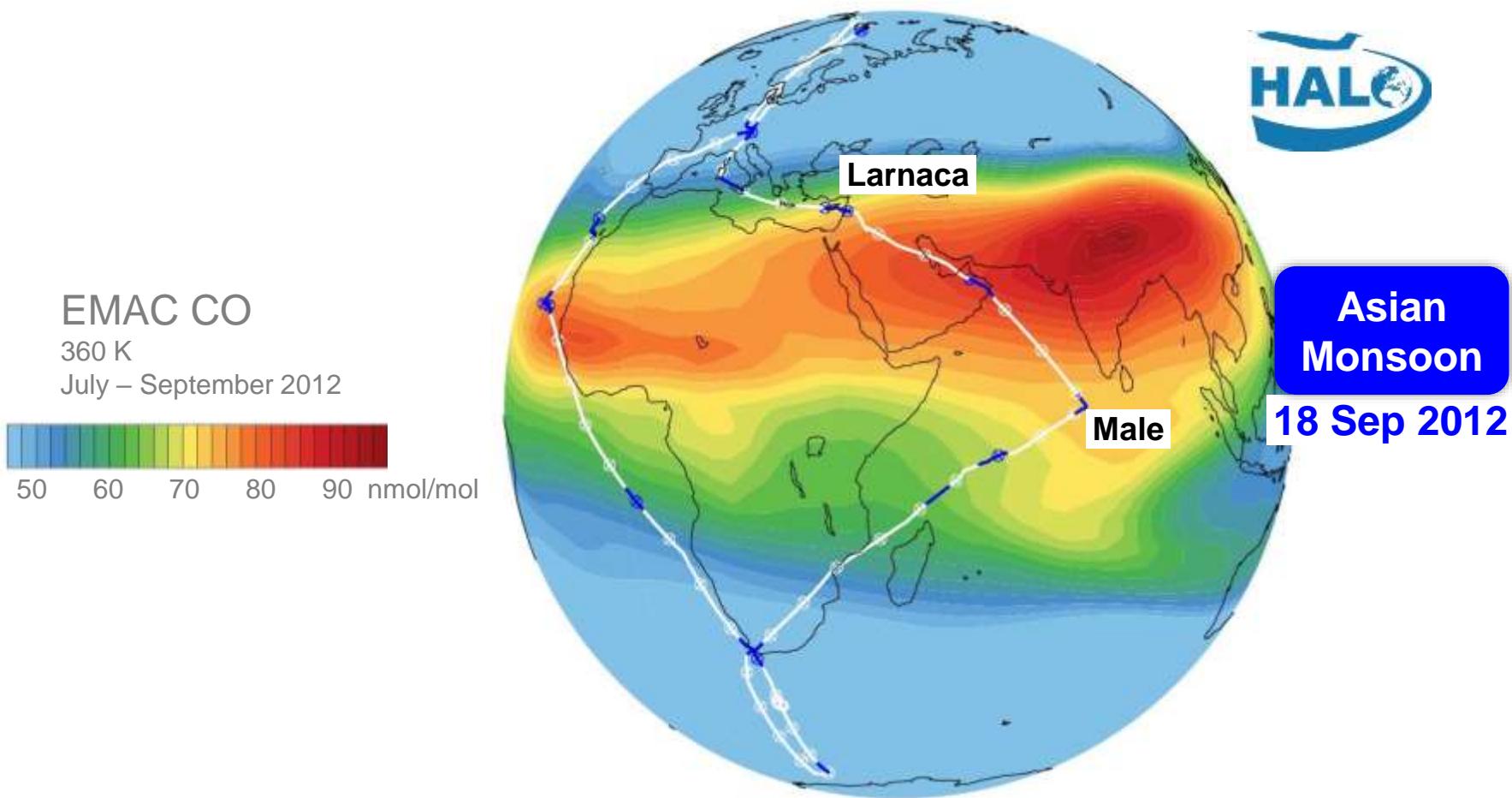
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Wissen für Morgen



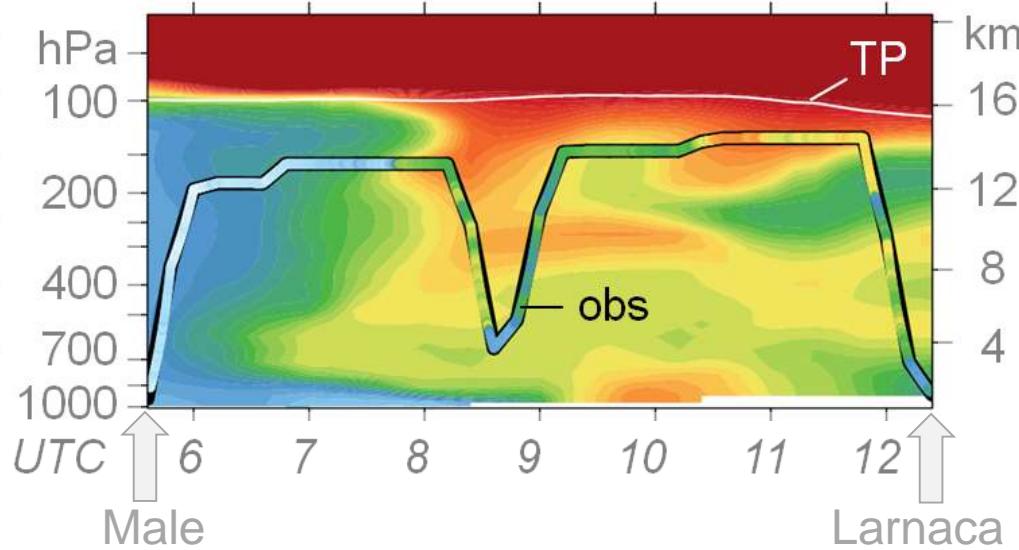
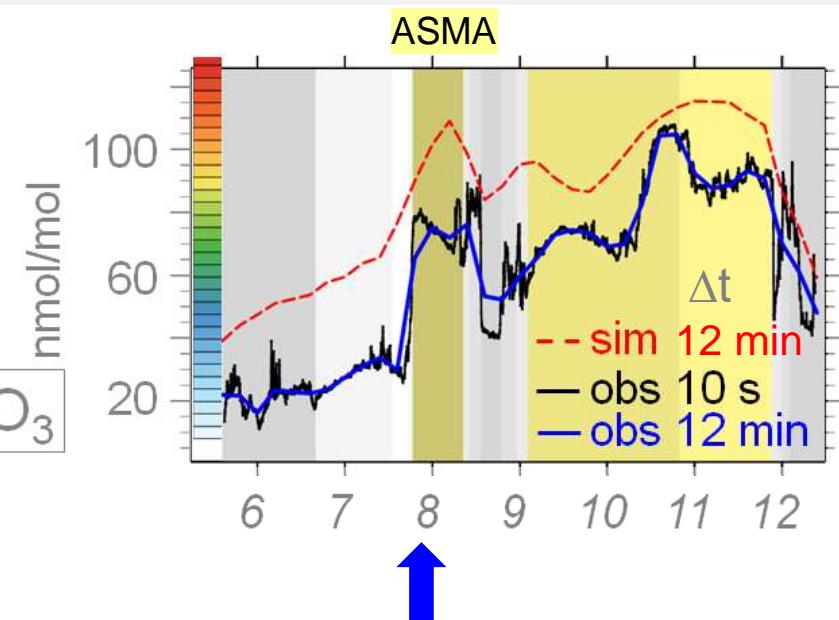
HALO ESMVal campaign



- Q1: What composition was encountered and can we explain the observations?
- Q2: What did we learn about processes in the ASMA in general?



Measurements & simulation: O_3



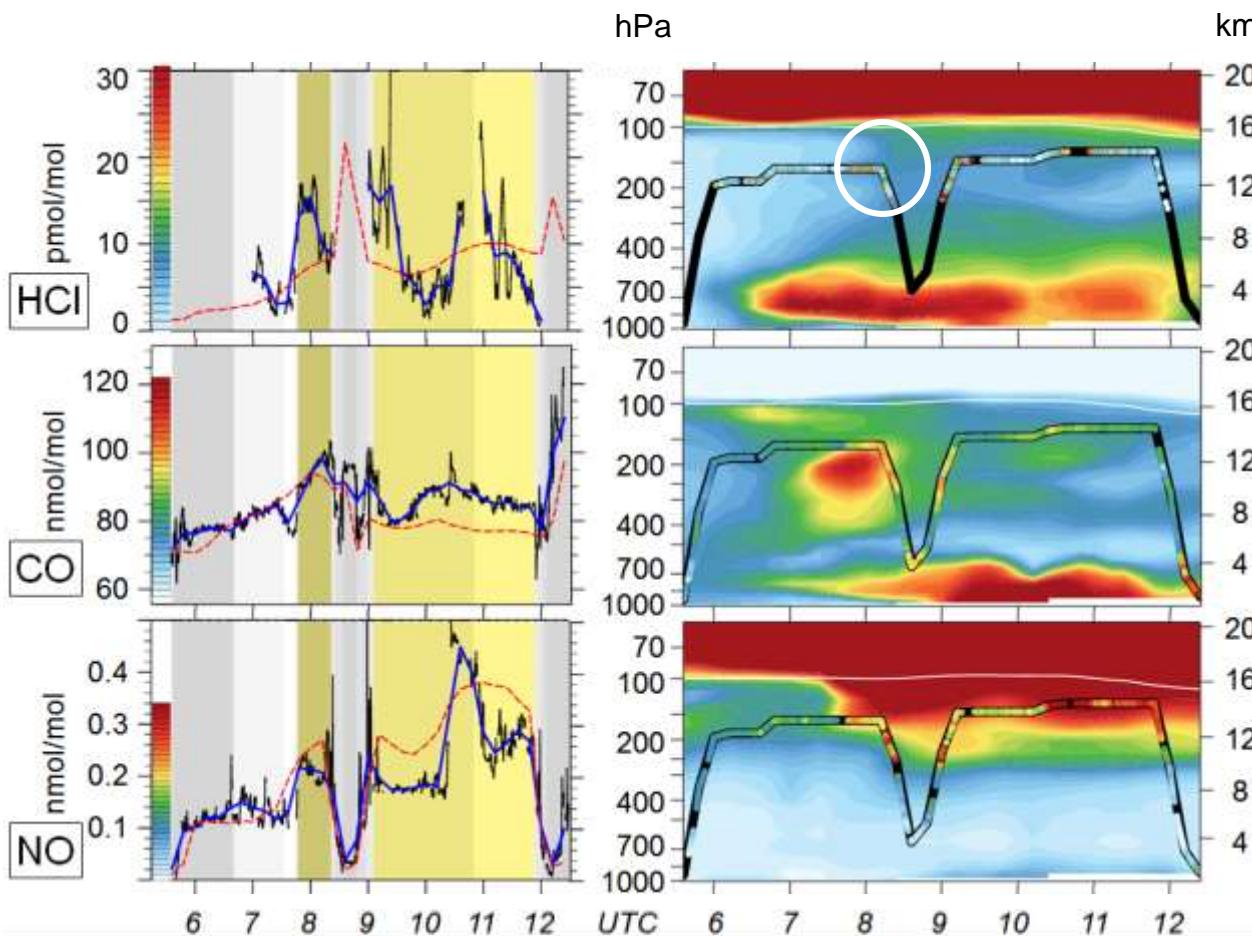
Increase contrasts presumption of decreased O_3 in the ASMA

EMAC simulation:

- global, specified dynamics (ESCiMo RC1SD-base-10a)
- $O_3 \sim 20$ nmol/mol too high
- Pattern reproduced



Measurements vs simulation: Other tracers



- @ instrument limit
- Spurious washing out or slightly misjudged gradient in sim
- Surprisingly good for monthly BB emissions

Parameterized lightning:

- Cannot expect exact match
- Magnitude ok

Measurements & simulation

Observations

HCl, CO, O₃, NO, NO_y enhanced in ASMA filament(s)

St Tr
tracer



Curious combination

Simulation

- Considering coarse resolution, approximations / parameterizations

Surprisingly well reproduces observations of HALO ESMVal,
at least large scale features



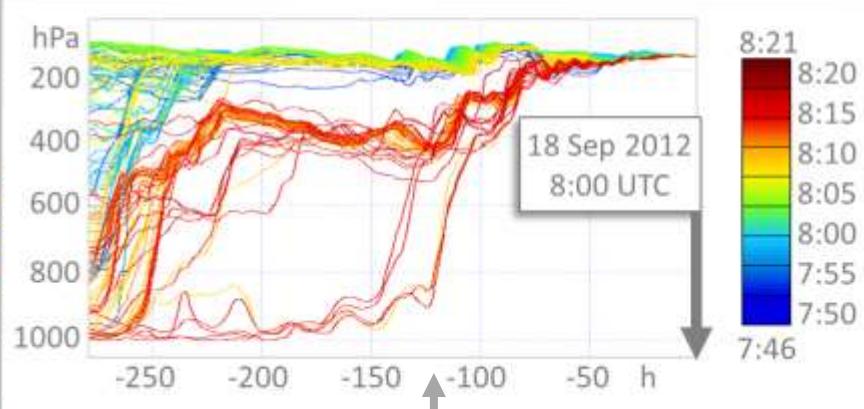
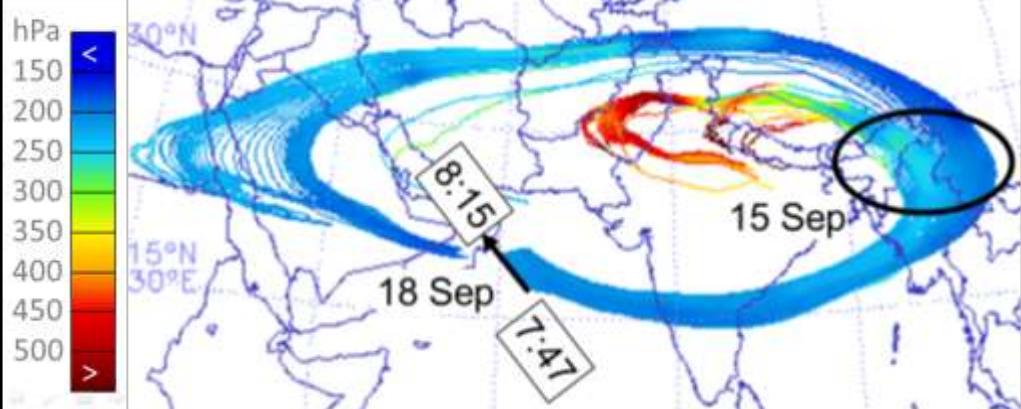
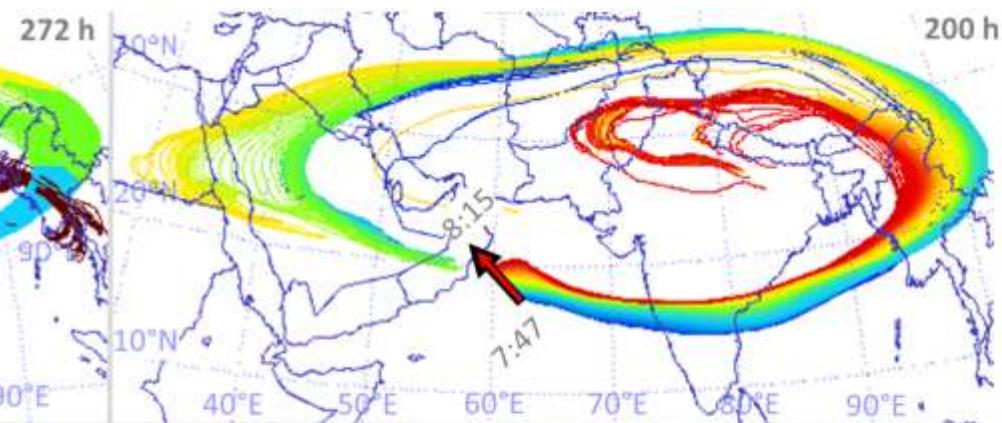
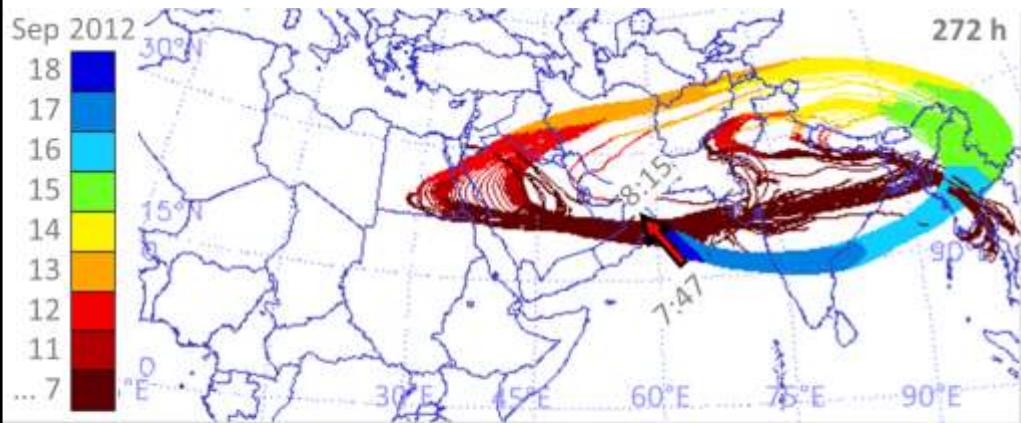
Ok to use simulation
for the interpretation
of the measurements

Back-trajectories

HYSPLIT

- ~10 days ASMA roundtrip
- ~3 days from eastern flank

- Almost parallel UT trajectories
→ Radial transport barrier

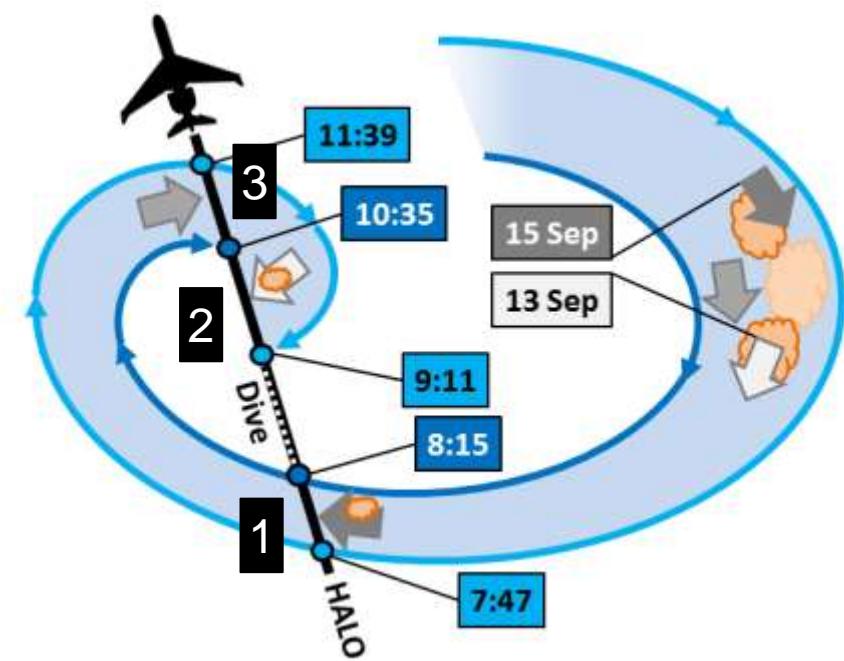
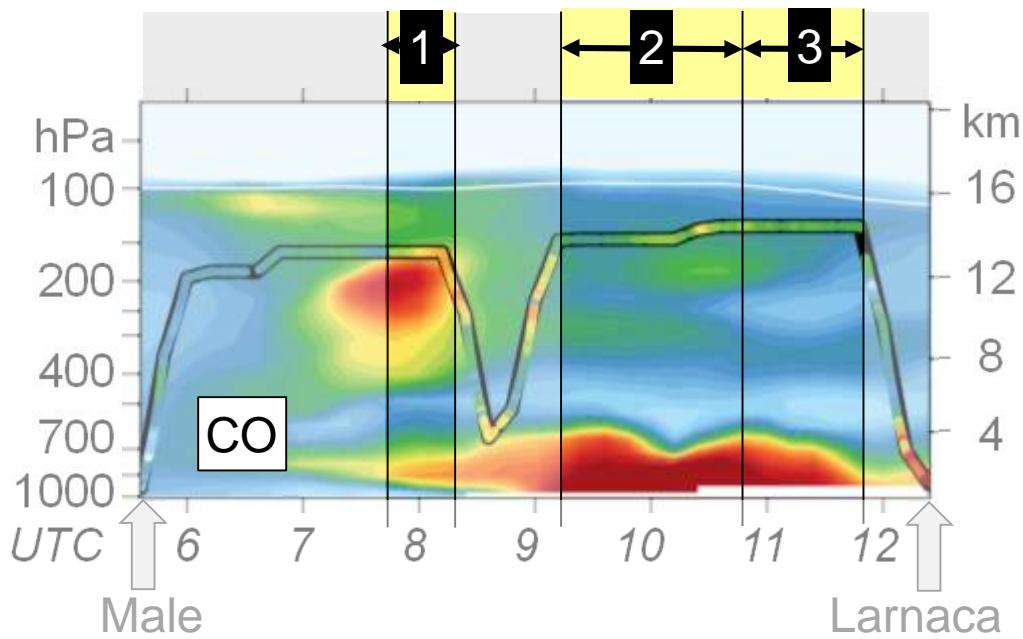


- UT + Lower Tropospheric air



Back-trajectories

Obs, EMAC, HYSPLIT



All 3 flight segments have seen a filament of similar genesis:

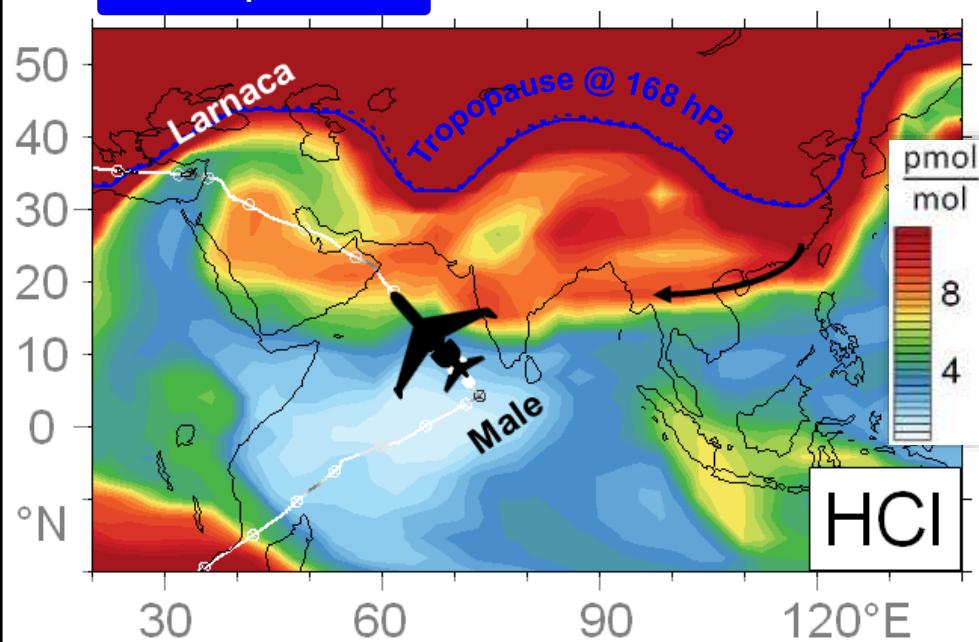
- At least one ASMA roundtrip in UT
- Entrainment by upwelling at eastern ASMA flank

Enhanced CO

Enhanced HCl

EMAC

18 Sep 2012



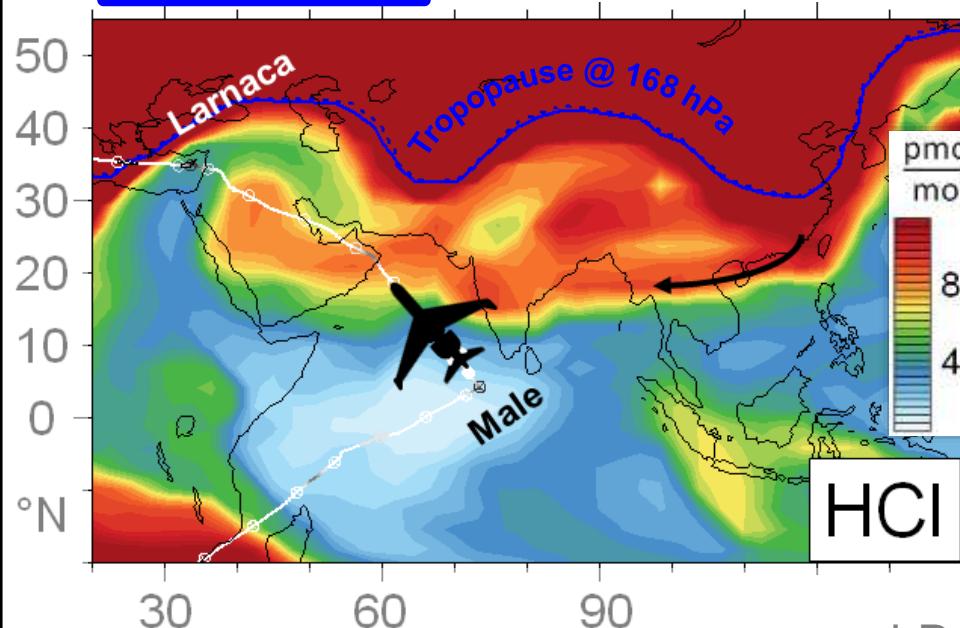
- HCl = tracer of stratospheric influence
- Filament originating in Tropopause Layer @ eastern ASMA flank



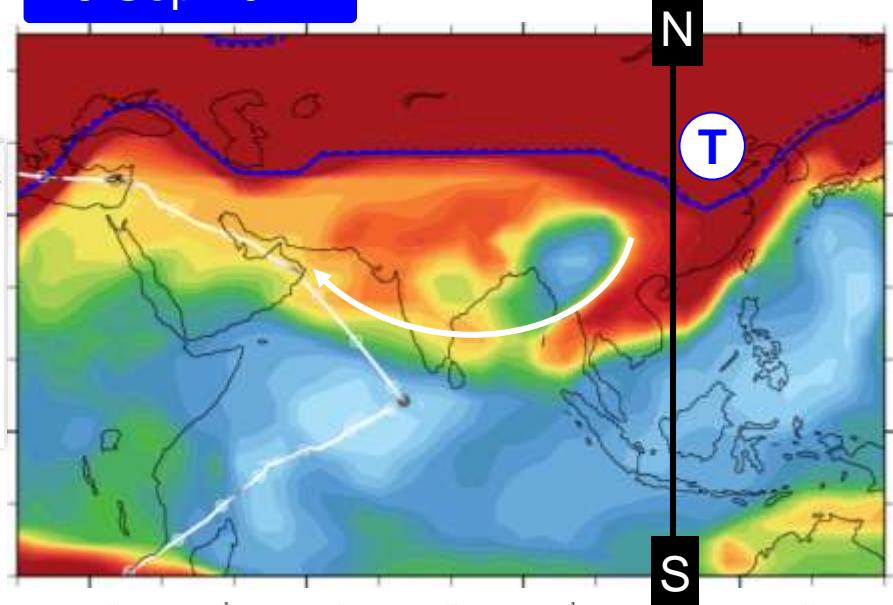
Tropopause layer entrainment

EMAC

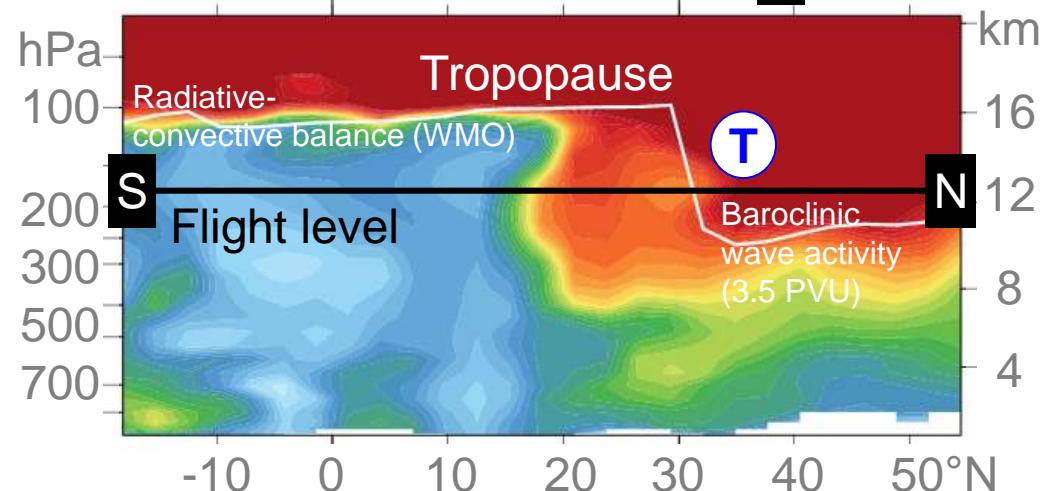
18 Sep 2012



15 Sep 2012



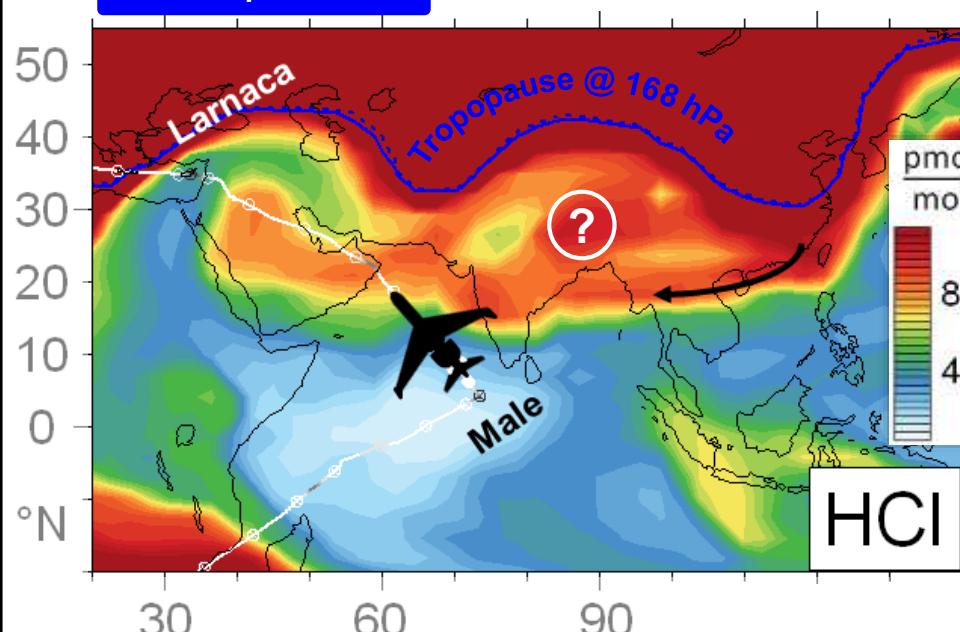
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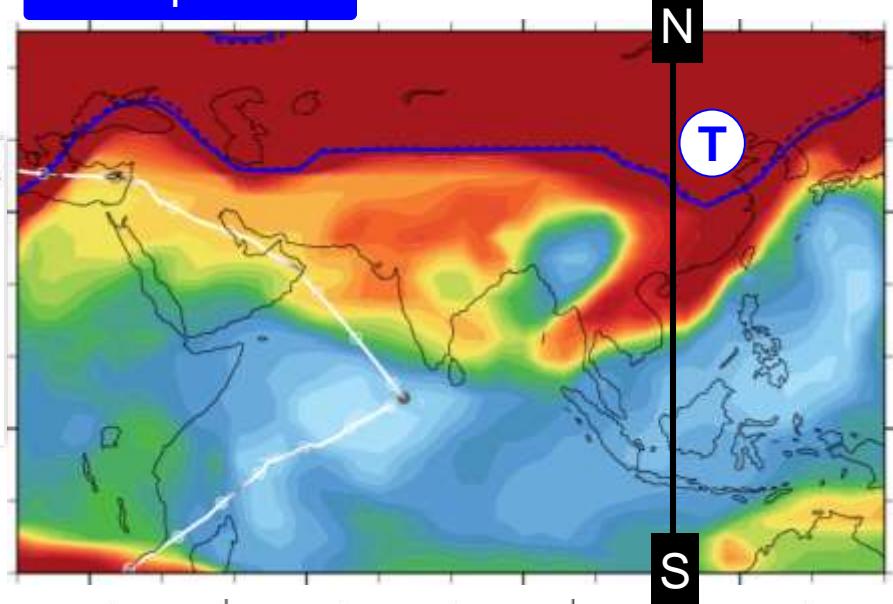
Tropopause layer entrainment

EMAC

18 Sep 2012



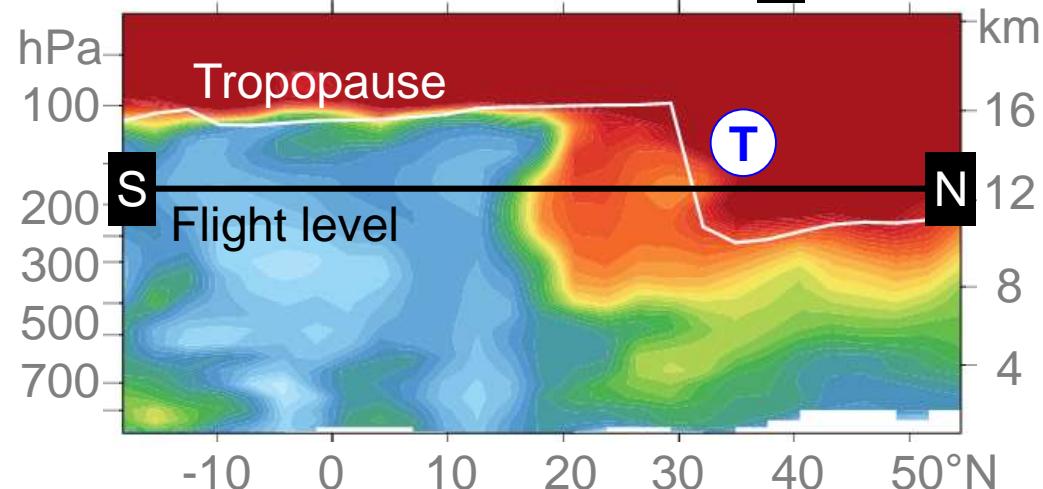
15 Sep 2012



Enhanced HCl in fringe

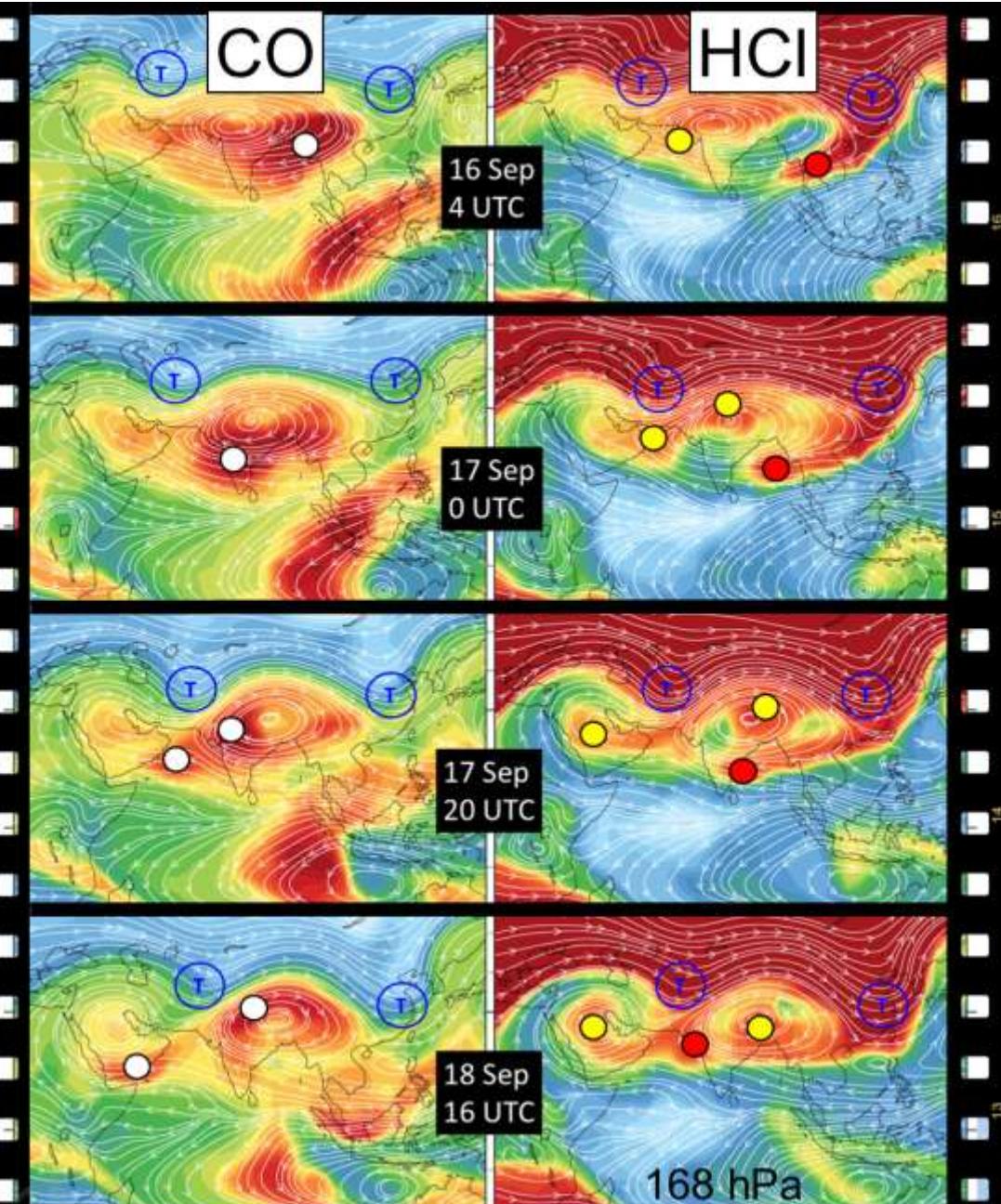


Enhanced HCl in center

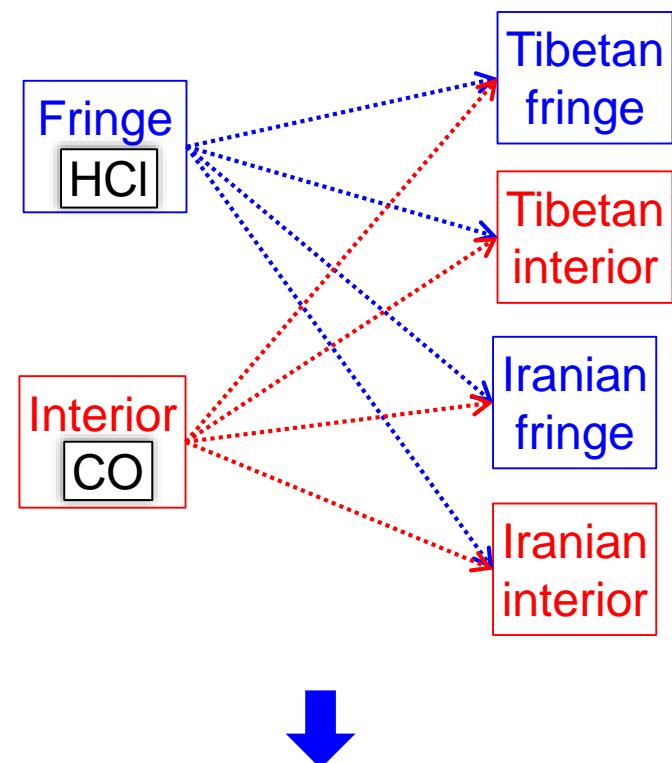


Dynamics: Splitting and stirring

EMAC

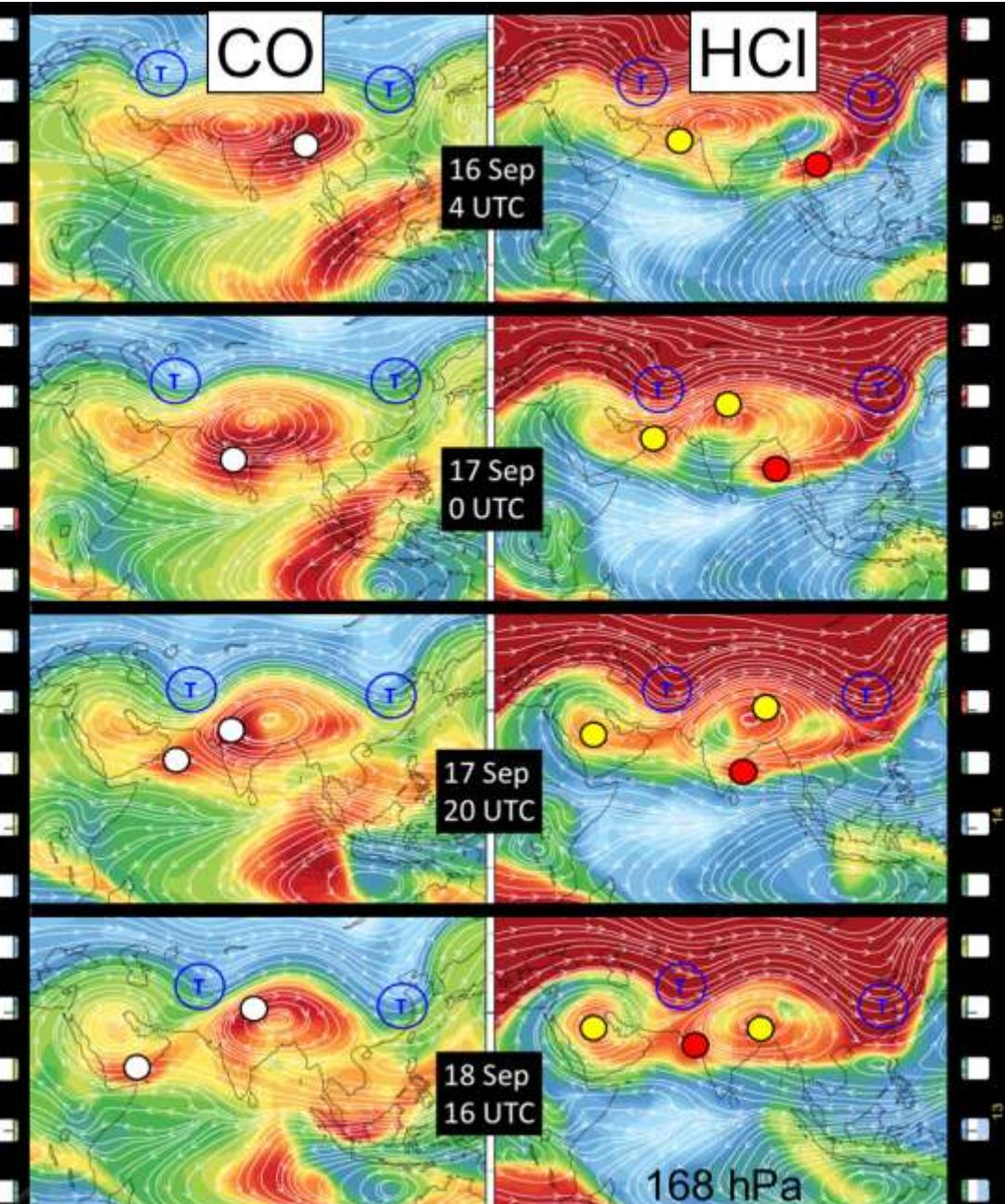


ASMA splits

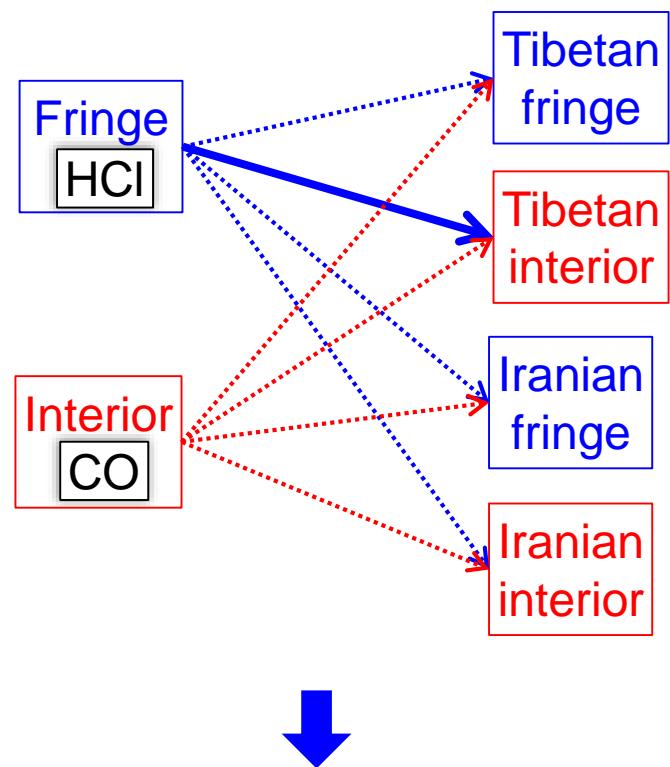
Stirring accross former
transport barriers

Dynamics: Splitting and stirring

EMAC

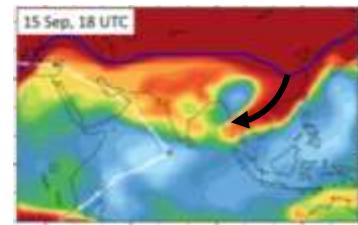


ASMA splits



HALO ESMVal = exceptional? TL entrainment

EMAC



2012

HALO ESMVal

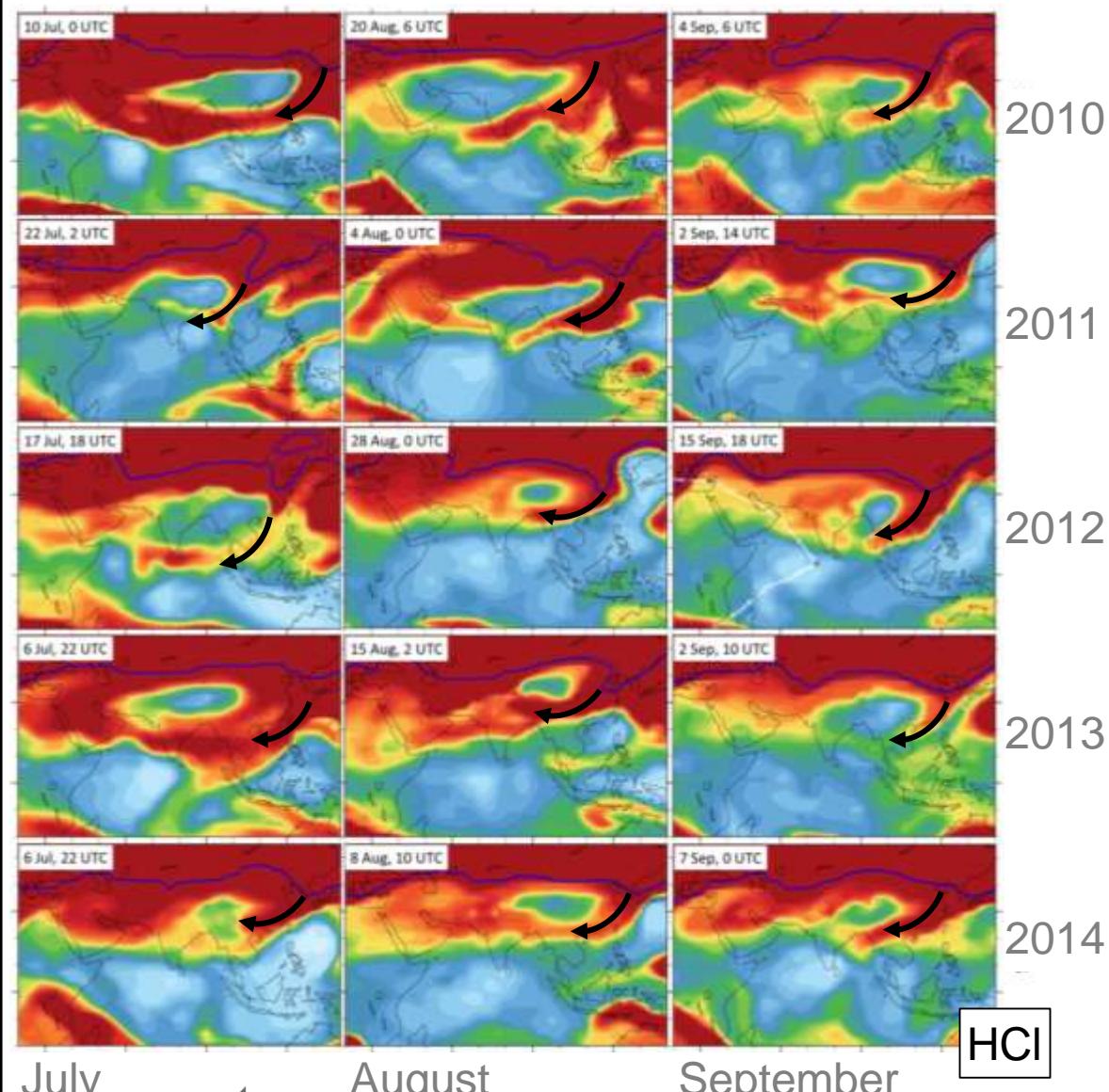
September

HCI



Gottschaldt et al.:
Composition and transport ... ASMA ... ESMVal

HALO ESMVal = exceptional? TL entrainment



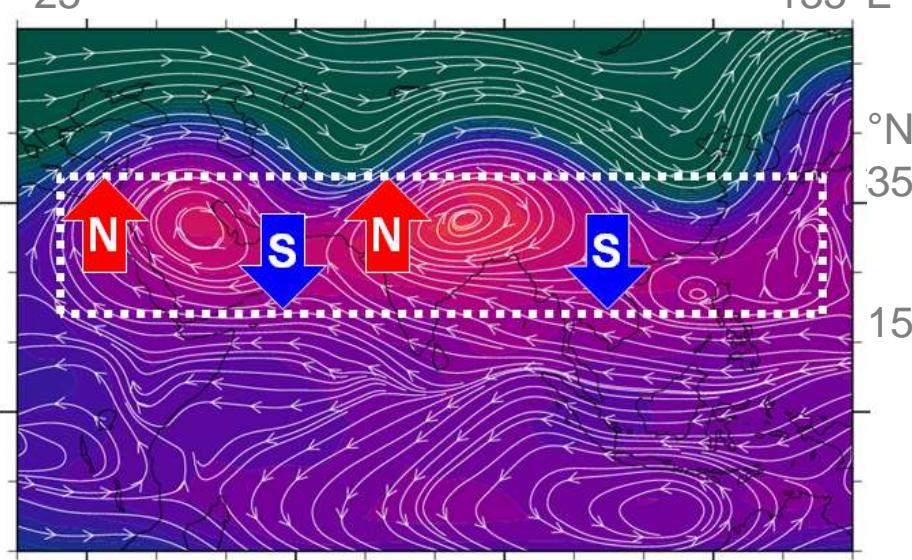
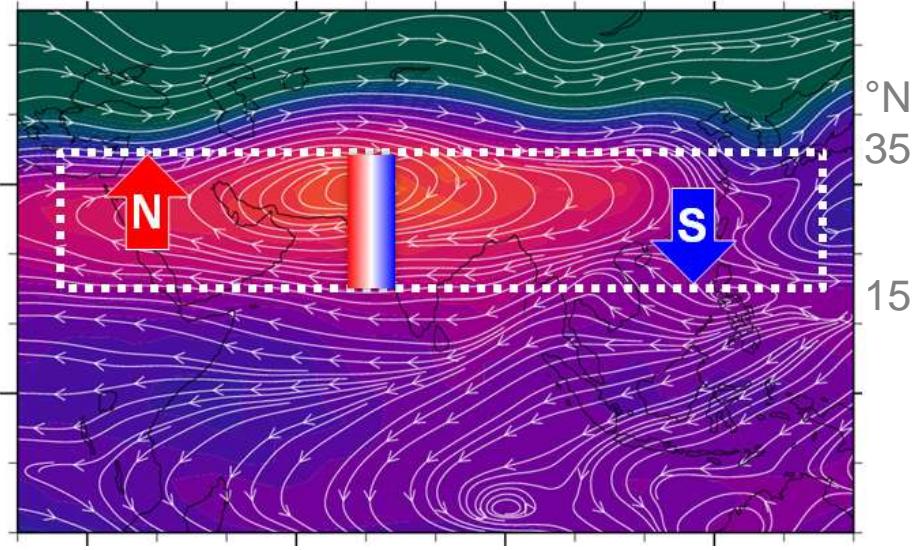
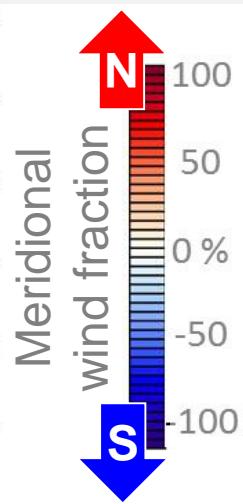
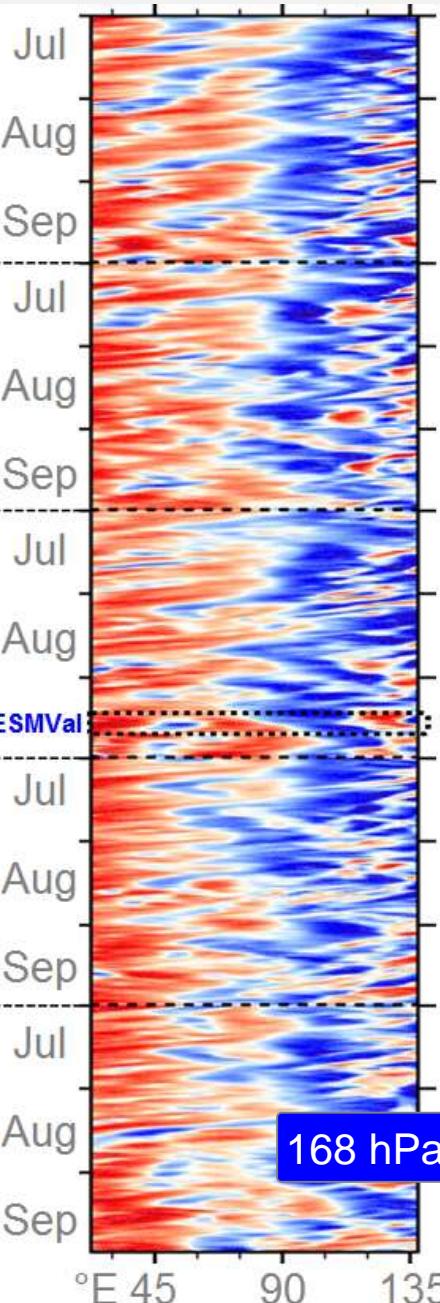
Entrainment of
stratospheric tracer
at eastern ASMA flank
not a rare event



HALO ESMVal = exceptional? Splitting

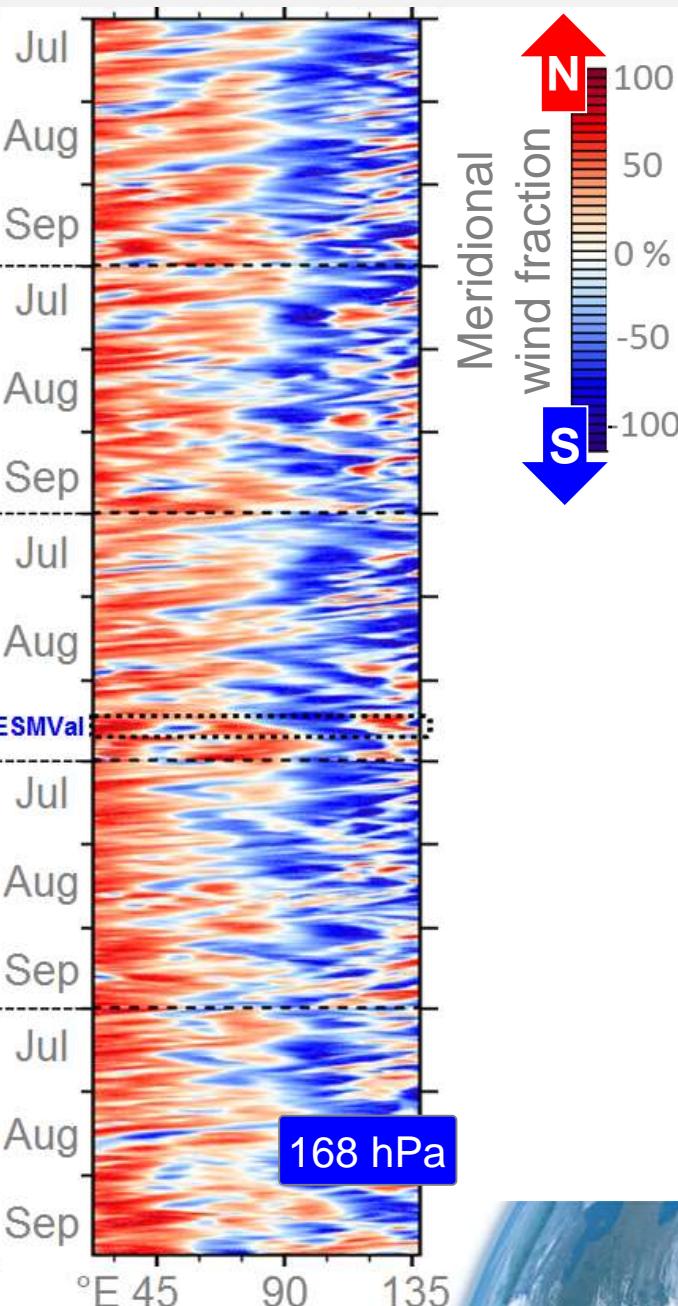
EMAC

2010



HALO ESMVal = exceptional? Splitting

2010

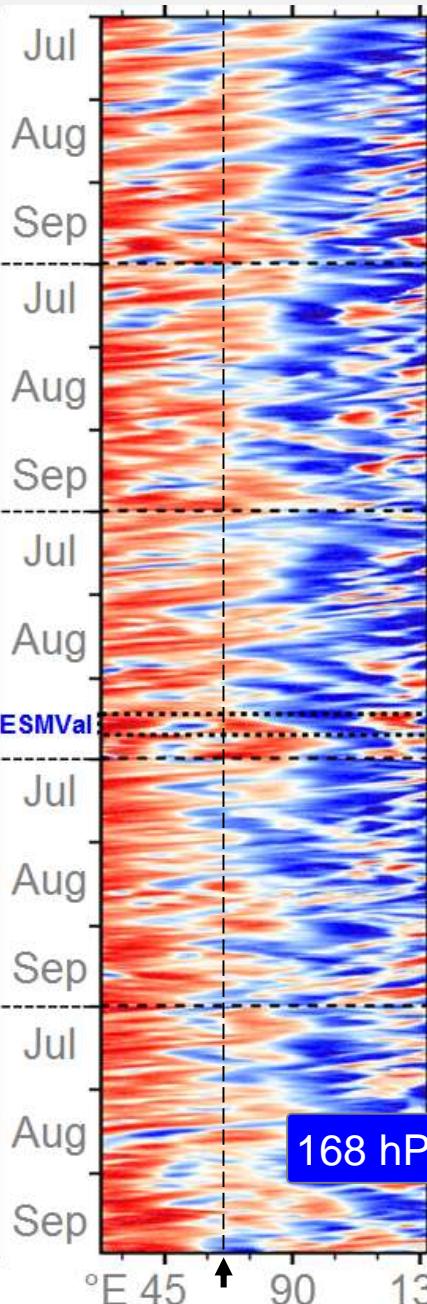


Dynamical instabilities ubiquitous
(e.g. ASMA splitting)



Tibetan and Iranian anticyclones

2010



- Tibetan part dominates UT
- Iranian part dominates mid troposphere

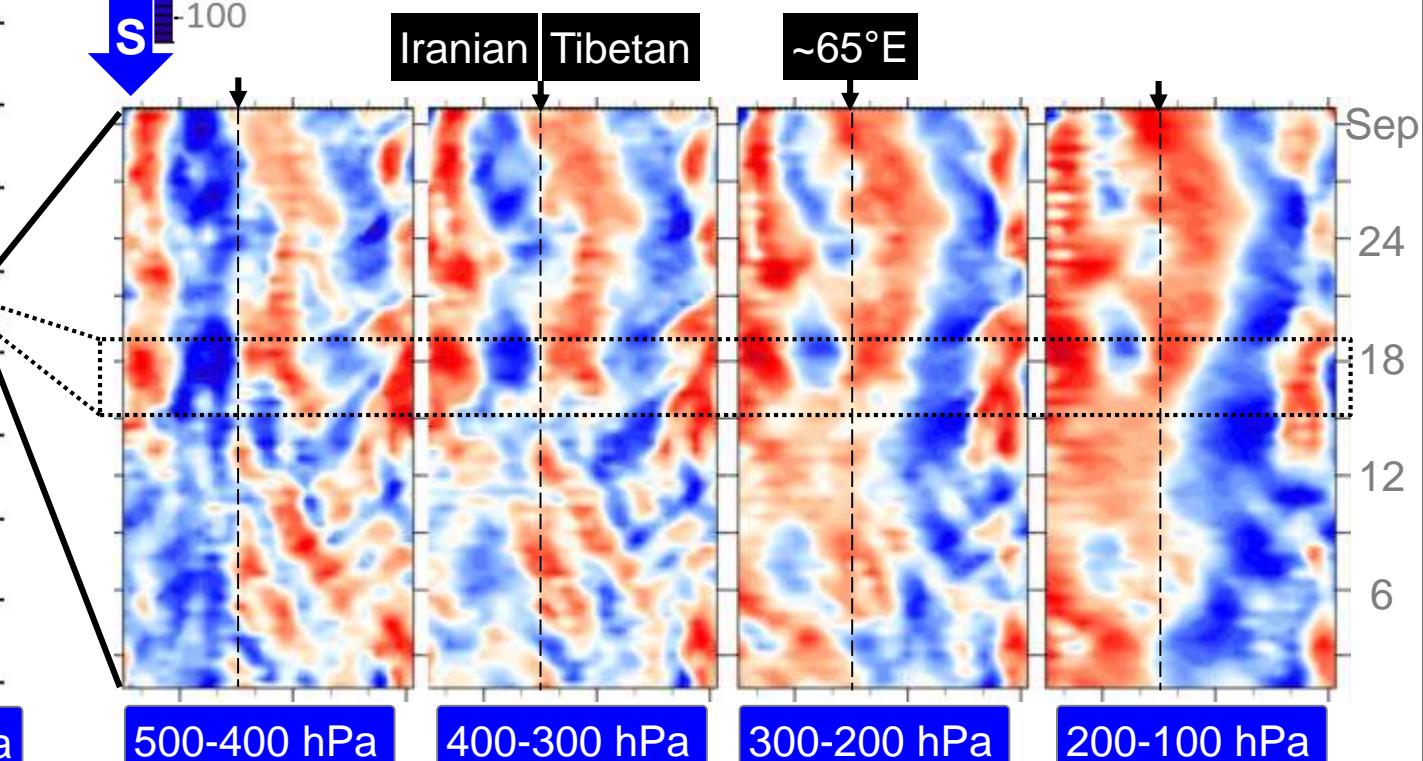
2011

2012

ESMVal

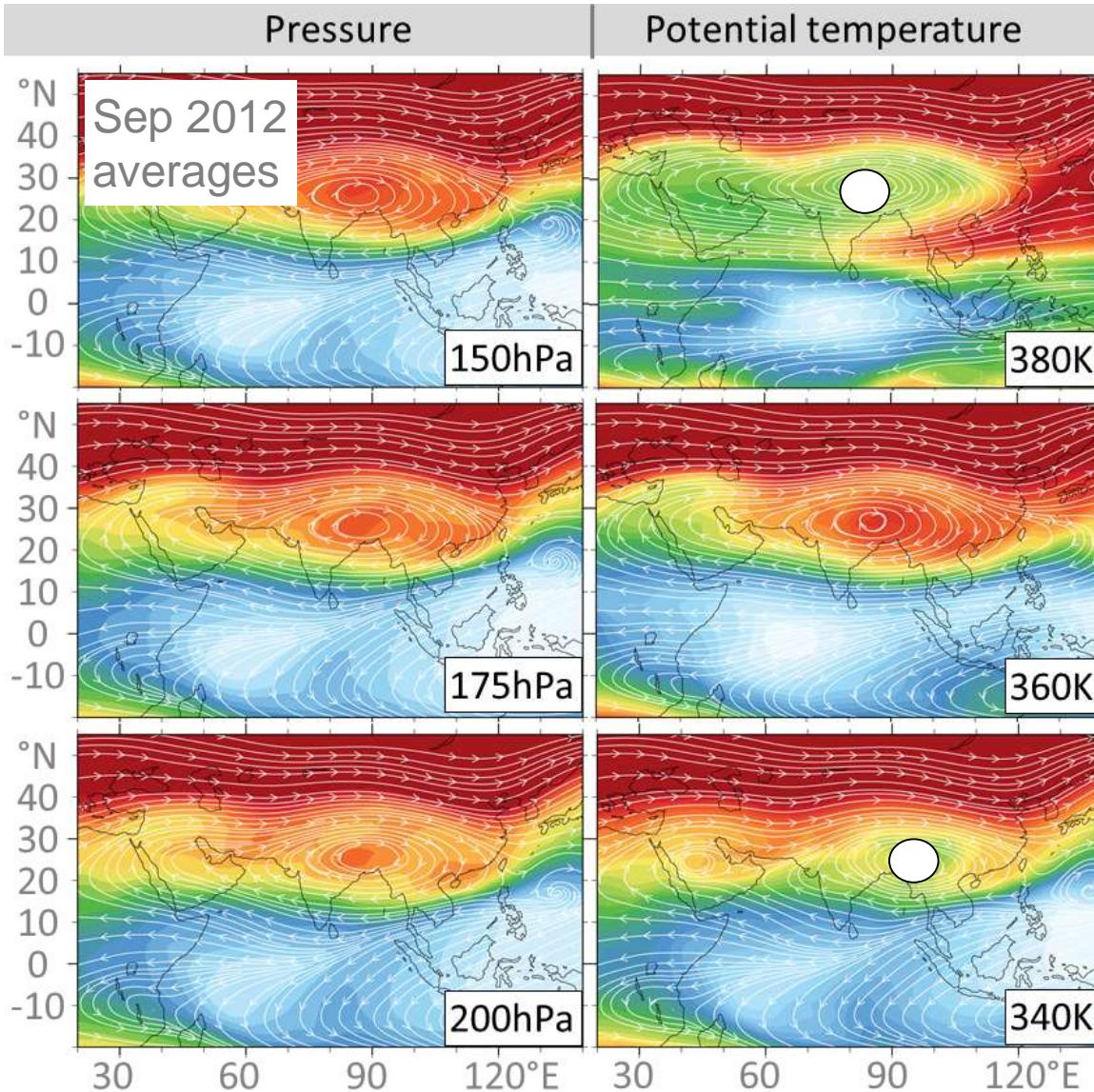
2013

2014



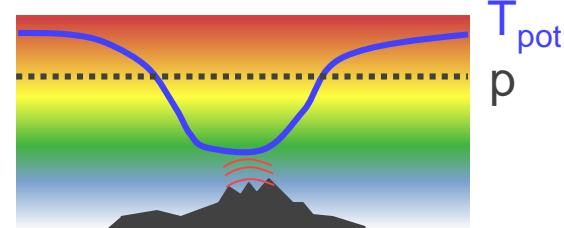
Decreased O₃ in the ASMA?

EMAC



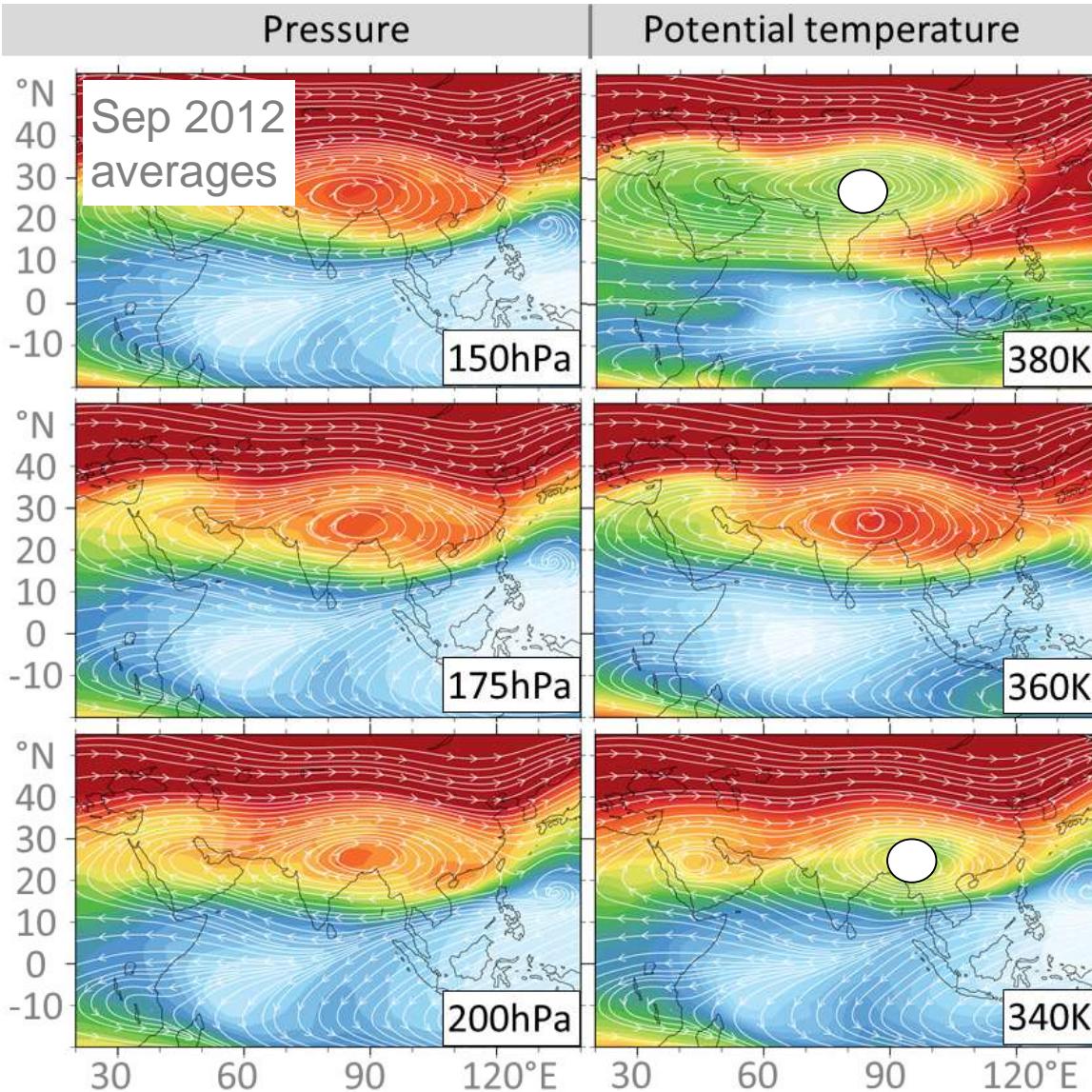
O₃ minimum ...

- rather in isentropic than in p-coordinates



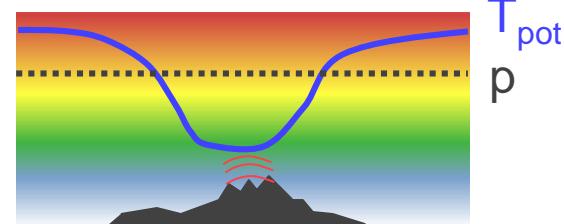
Decreased O₃ in the ASMA?

EMAC



O₃ minimum ...

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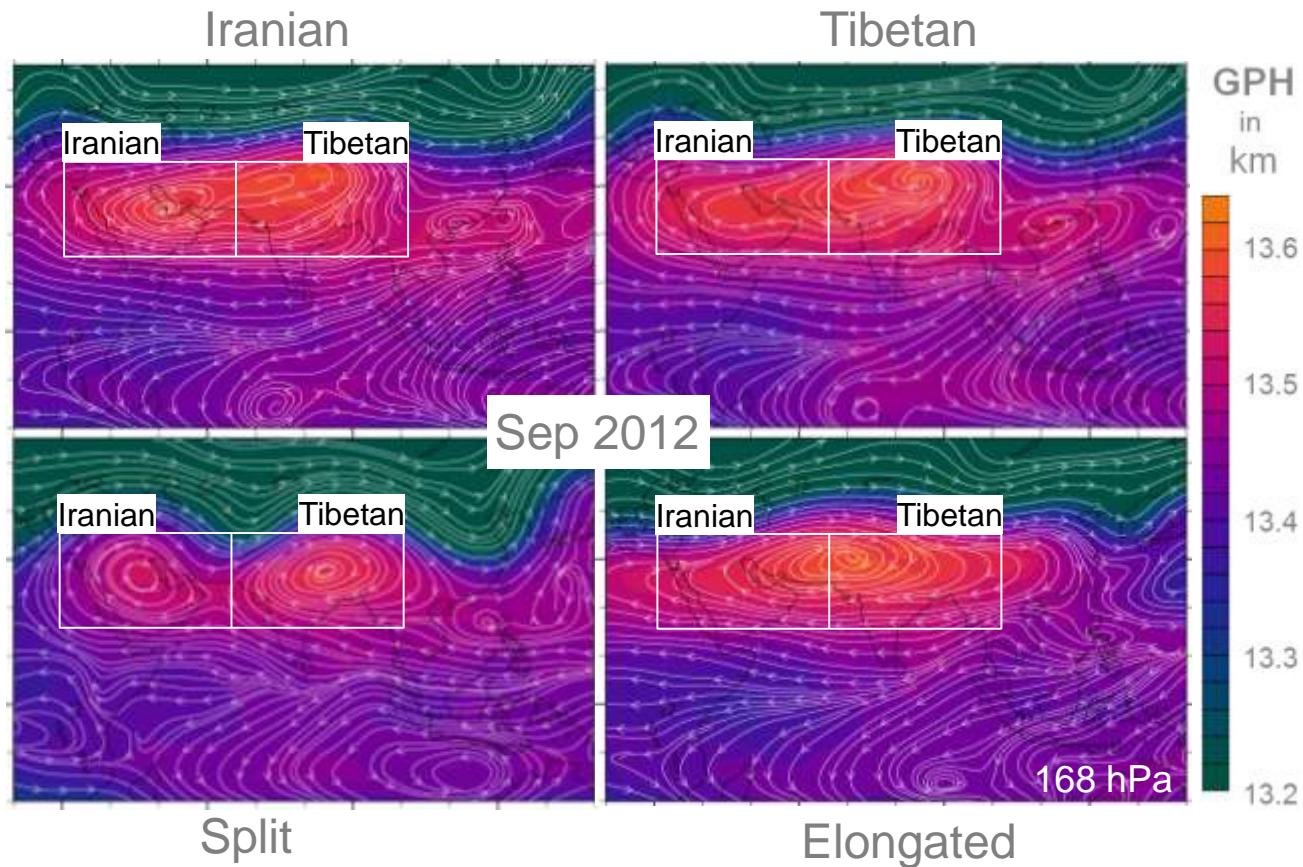
Local O₃ maximum
at ~ flight level

!?

Seasonal evolution

EMAC

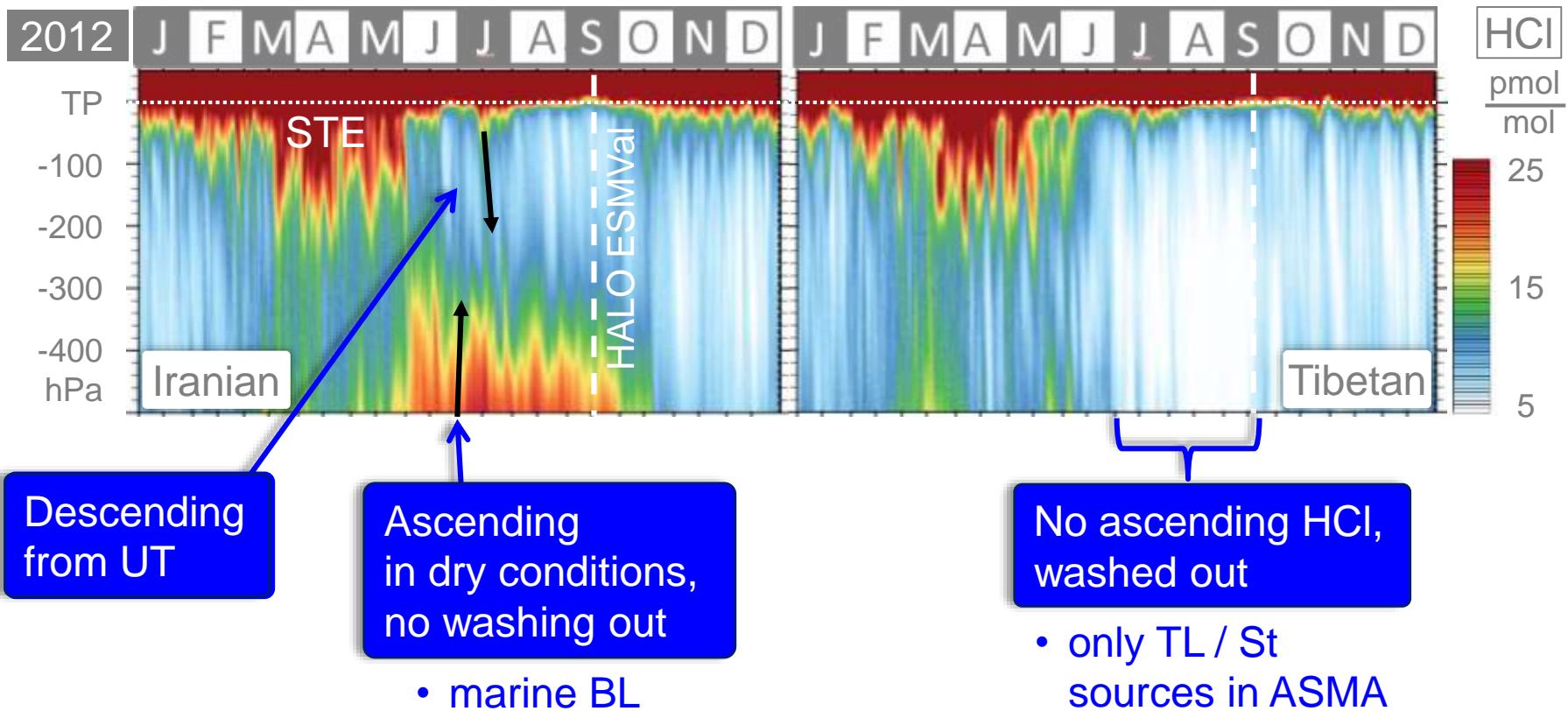
Dynamical modes
(Pan et al., 2016)



- Evolution of laterally averaged profiles throughout a year
- Separately for eastern & western ASMA parts

Seasonal evolution: HCl

EMAC

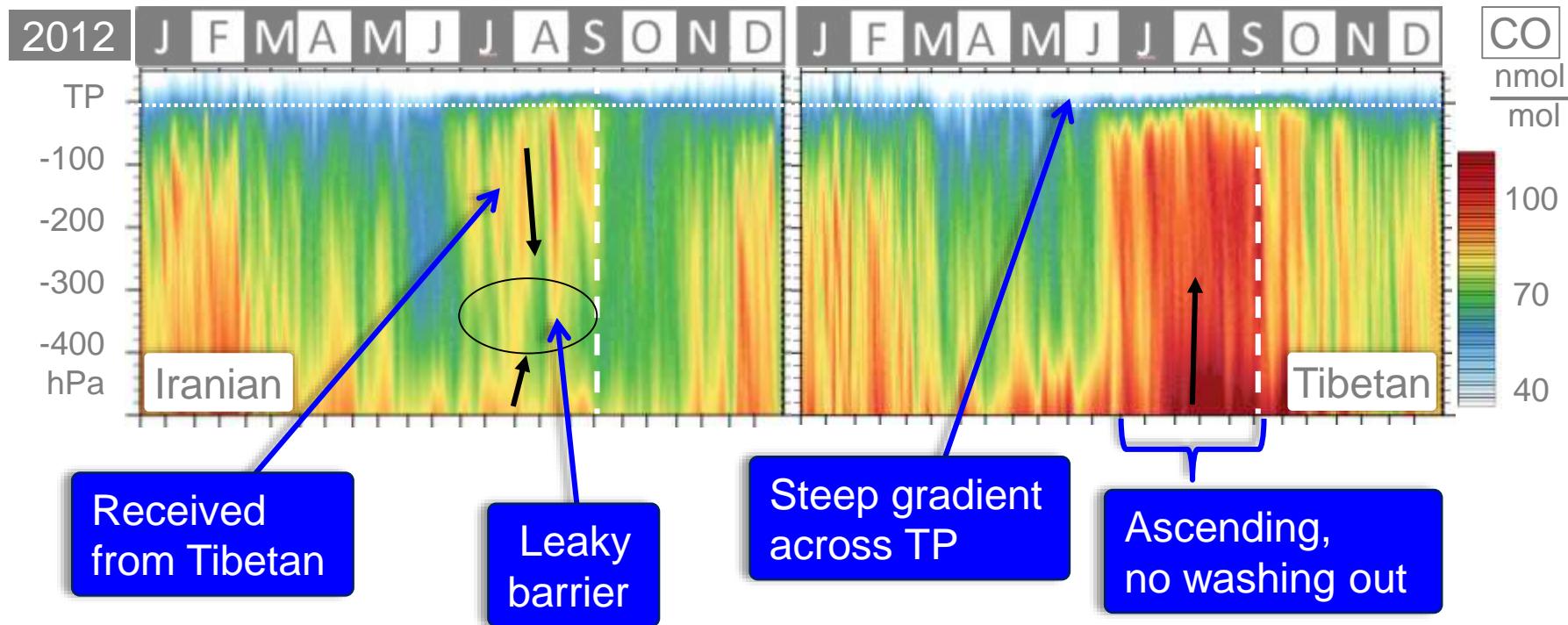


HCl in the UT ASMA is a tracer of TL or St inmixing

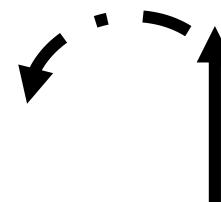


Seasonal evolution: CO

EMAC

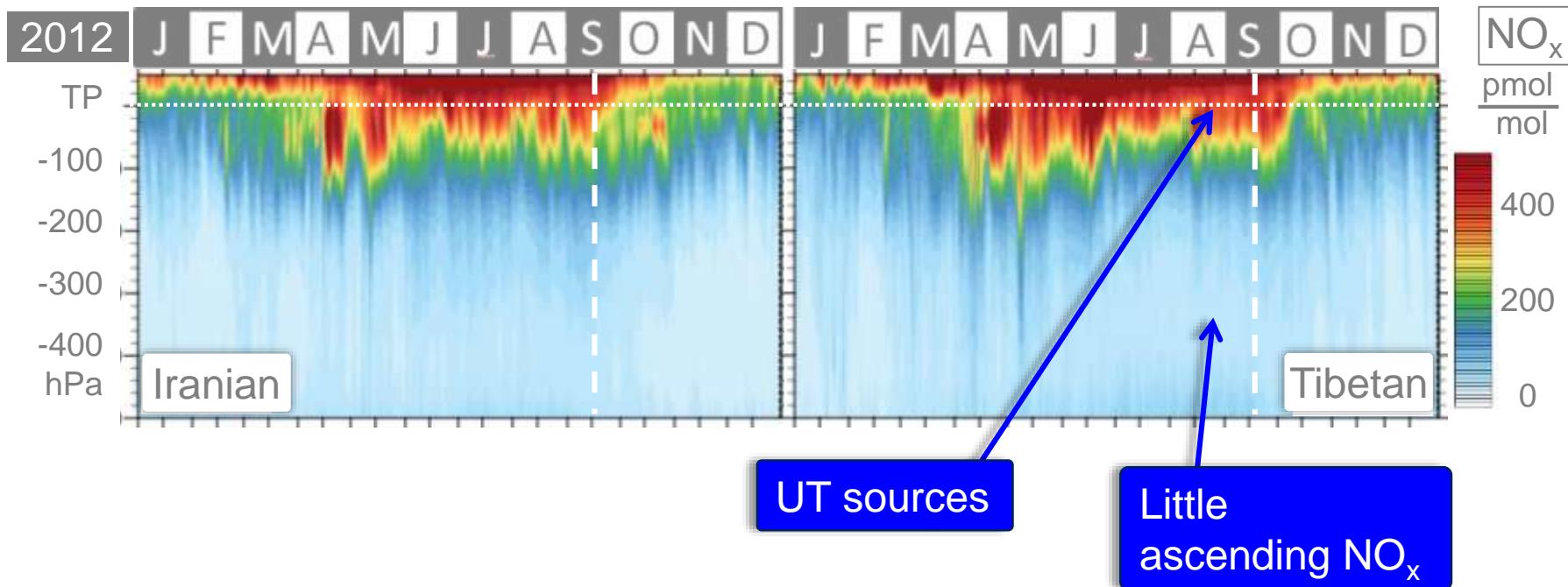


- CO in the UT ASMA is a tracer of BL air, incl. other O_3 precursors
- Uplift in Tibetan part,
episodic UT transport to Iranian part,
descent to mid Troposphere



Seasonal evolution: NO_x

EMAC



- Mostly lightning NO_x in UT ASMA (Sensitivity simulations)
- NO_x in simulation supported by ~ matching in-situ obs

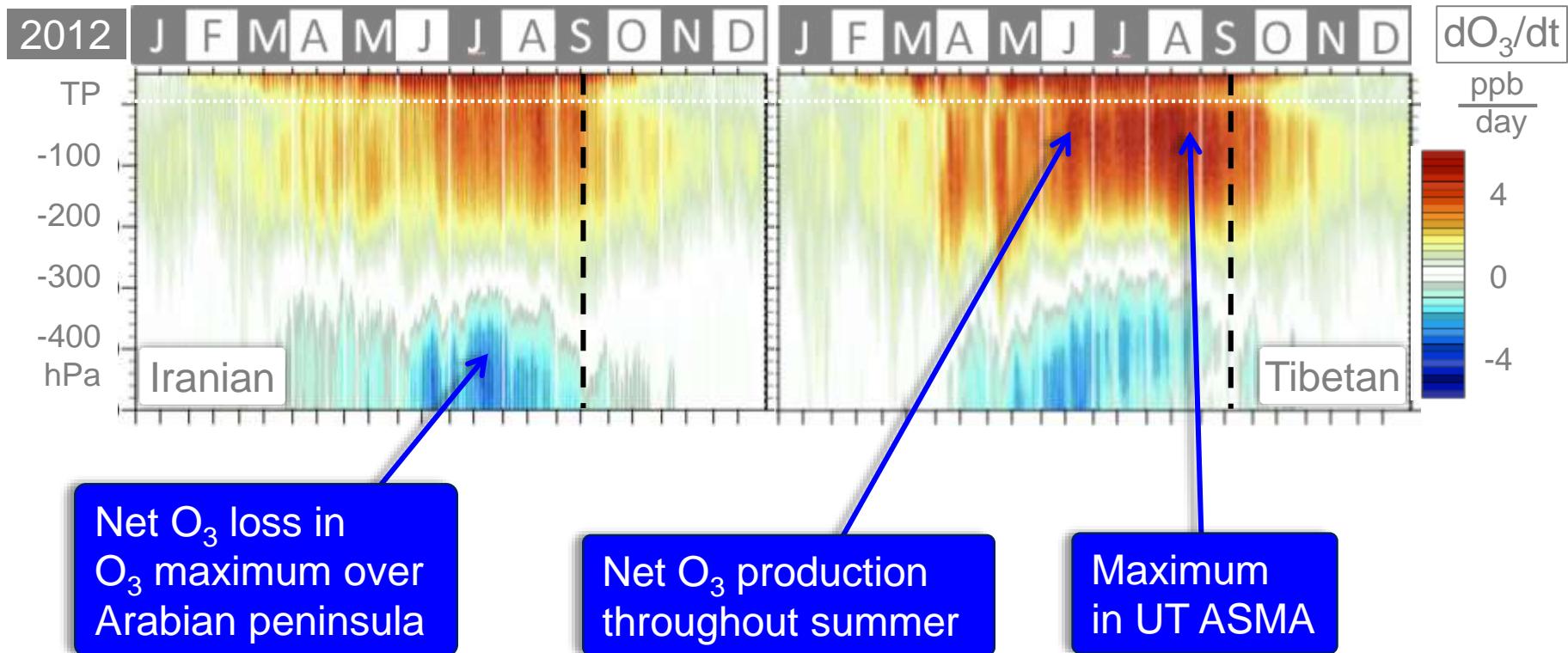


Enhanced NO, NO_y



Seasonal evolution: Net O₃ production

EMAC

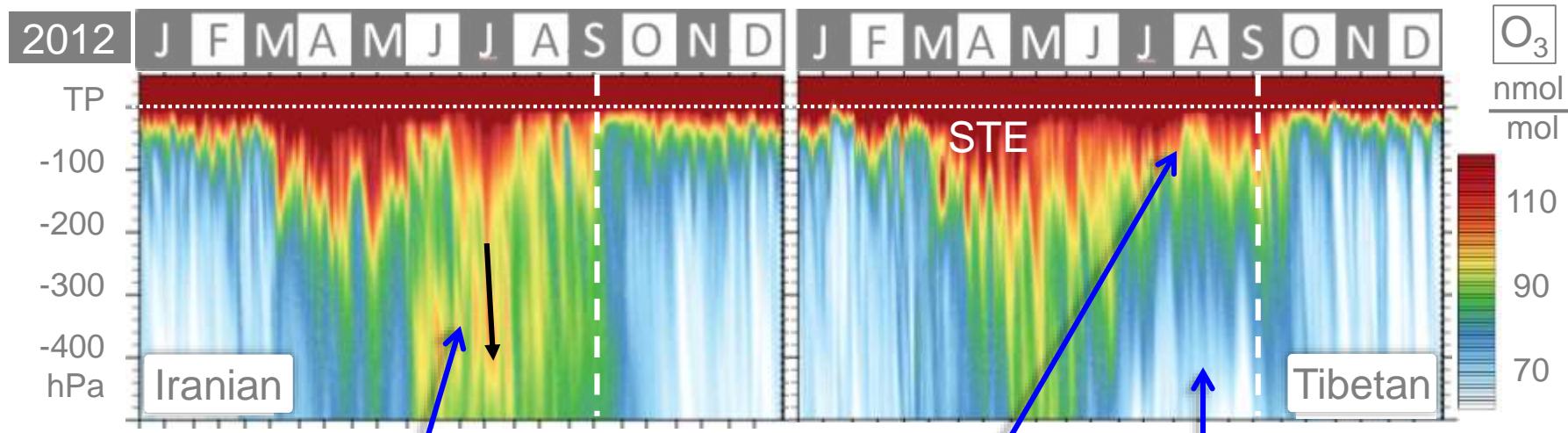


- Maximum photochemical O₃ production where (lightning) NO_x meets other precursors (~CO)



Seasonal evolution: O_3

EMAC



Mid tropospheric
O₃ maximum

- Enhanced by transport
- Preferential export of fringe air
- ASMA outflow O₃-rich

ASMA not
O₃-poor

- TL entrainment + in-situ production

Ascending
O₃-poor air



Publications

Atmospheric Chemistry and Physics An interactive open-access journal of the European Geosciences Union

Trace gas composition in the Asian summer monsoon anticyclone: A case study based on aircraft observations and model simulations

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Interplay of dynamics and composition in the Asian summer monsoon anticyclone

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submitted

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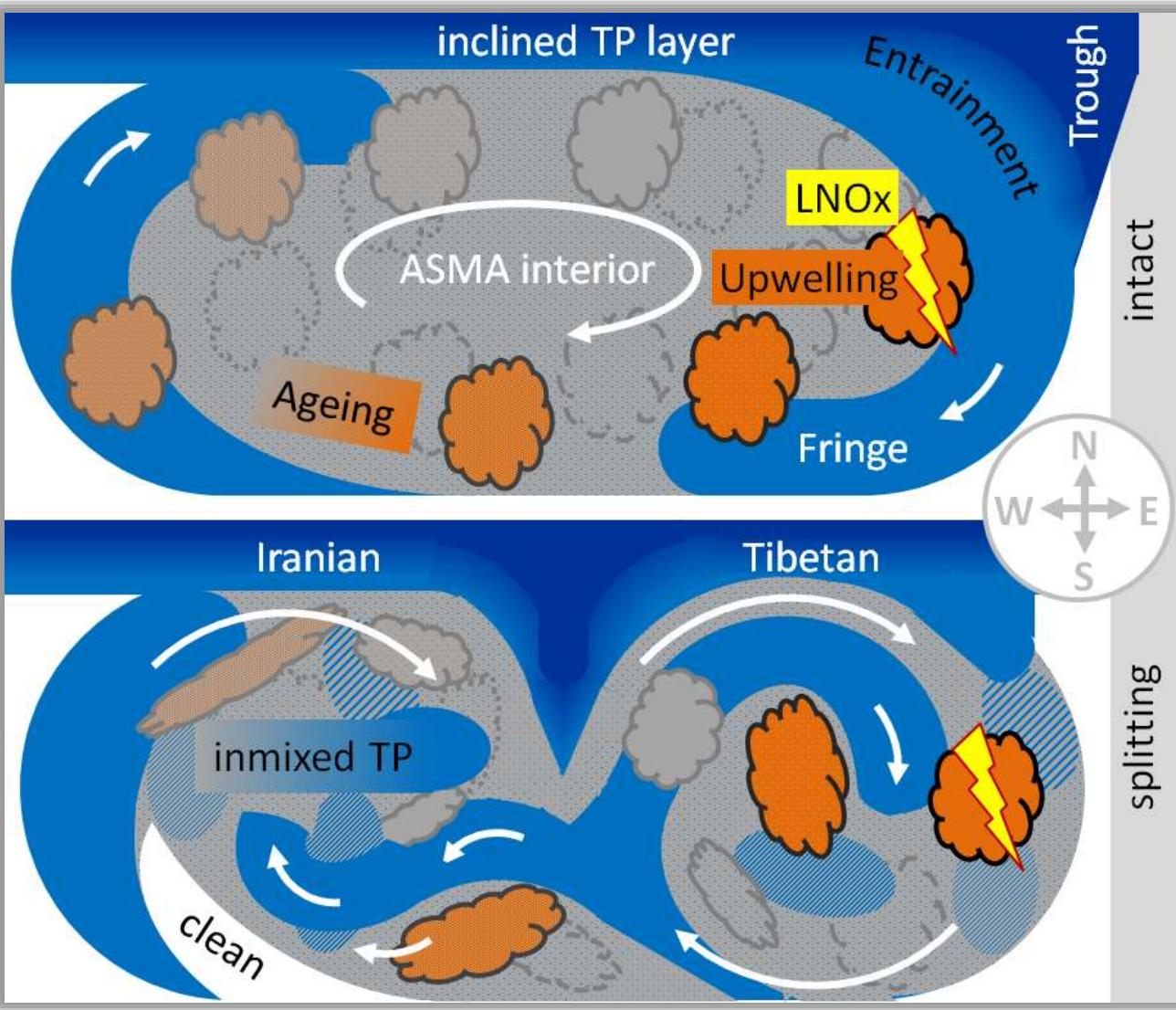
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Gottschaldt et al.:
Composition and transport ... ASMA ... ESMVal

Summary



Enhanced
HCl, CO, NO, NO_y, O₃

- TL entrainment
- Upwellings / convection
- Lightning NO_x
- Net O₃ production

Variability due to

- On-off nature of convection
- Dynamical instabilities

ASMA processes important beyond HALO ESMVal