The Impact of the Summer Asian Monsoon on UTLS aerosols: Satellite Observations and Balloon Measurements

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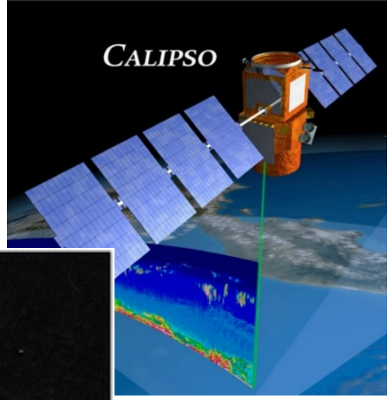
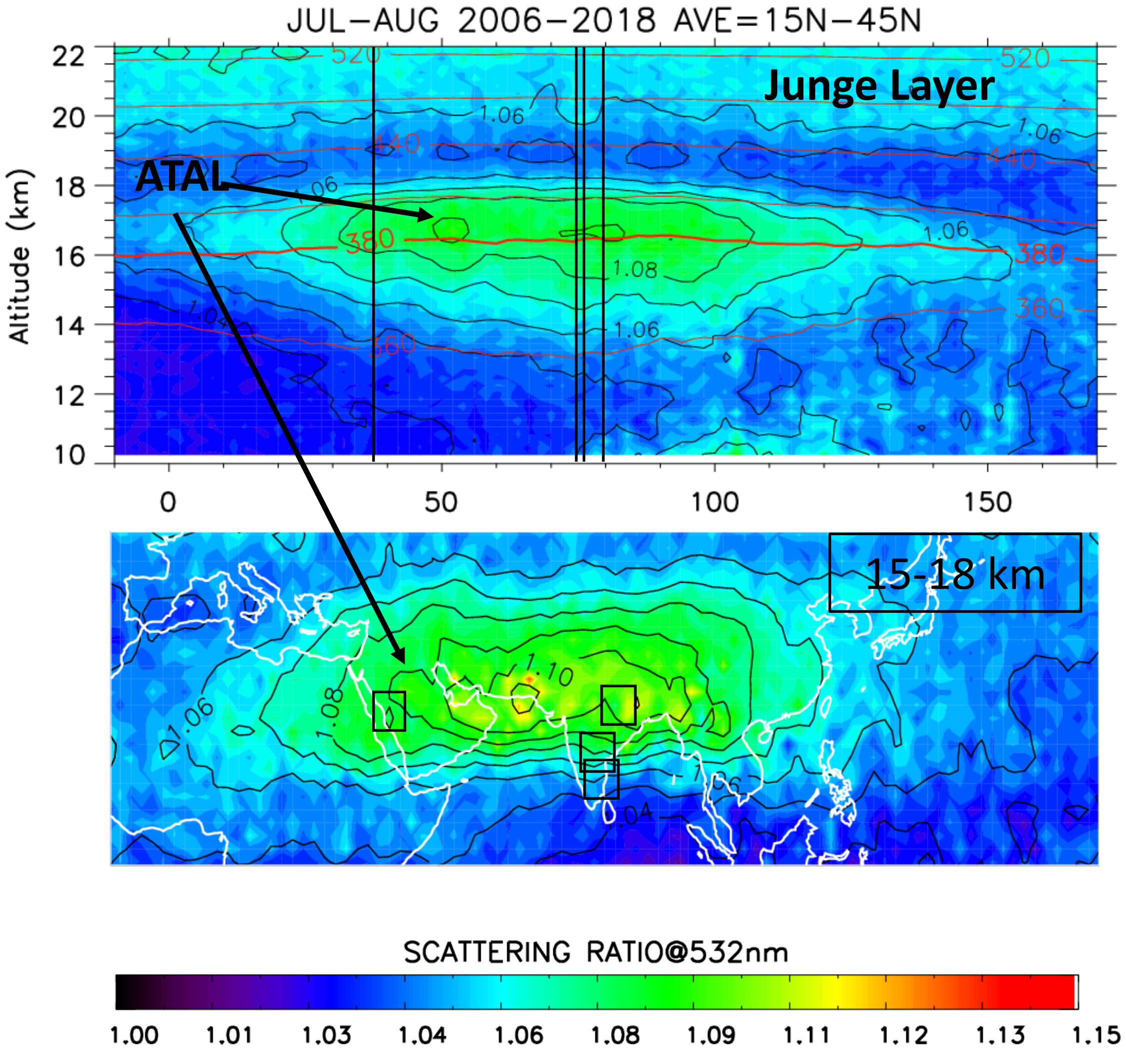
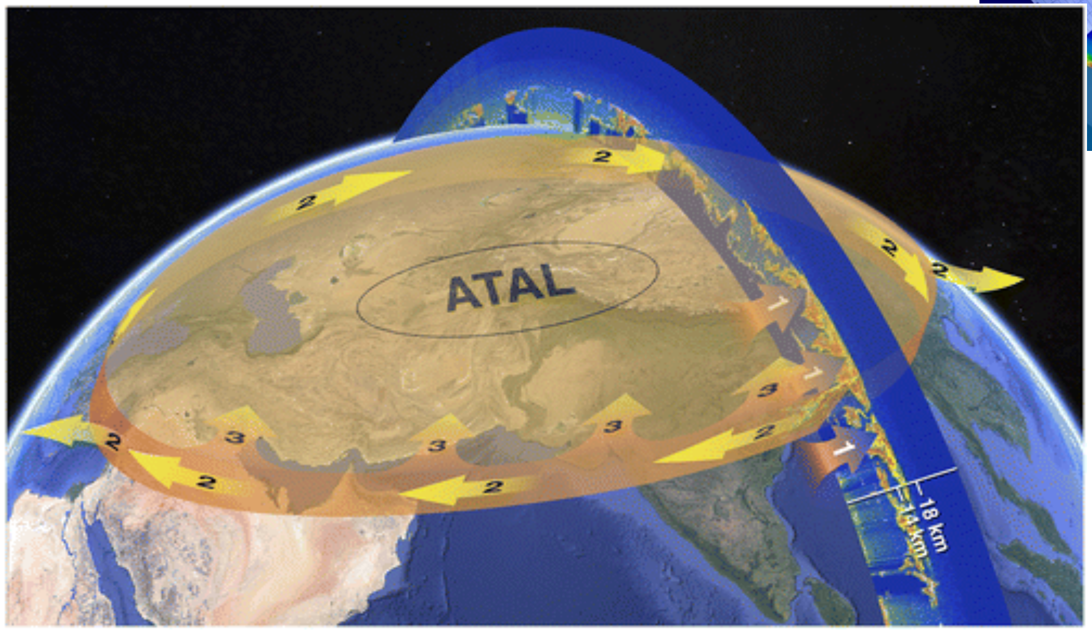
Summer Asian Monsoon influence on UTLS aerosols: The Asian Tropopause Aerosol Layer







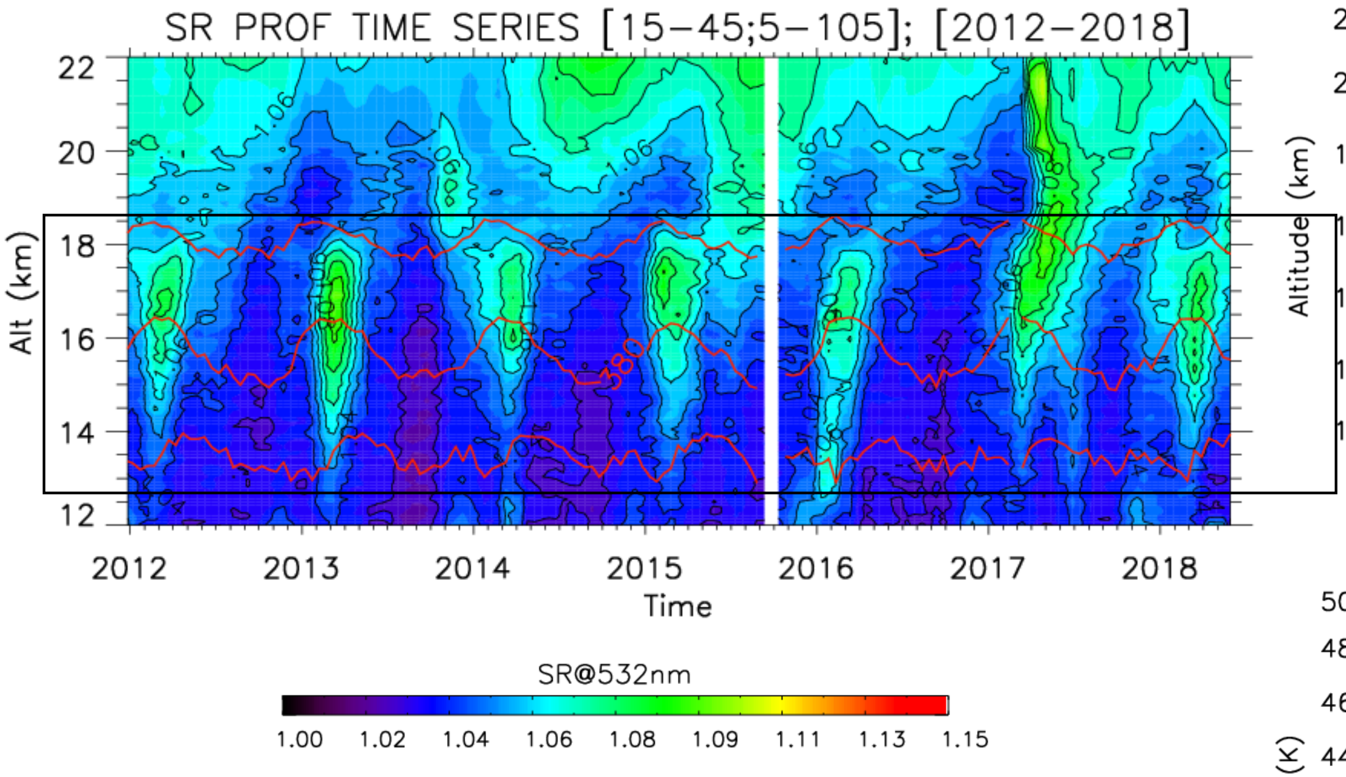
Scattering Ratio : SR
optically equivalent to an aerosol mixing ratio

<u>Transport pathways and the ATAL</u>:

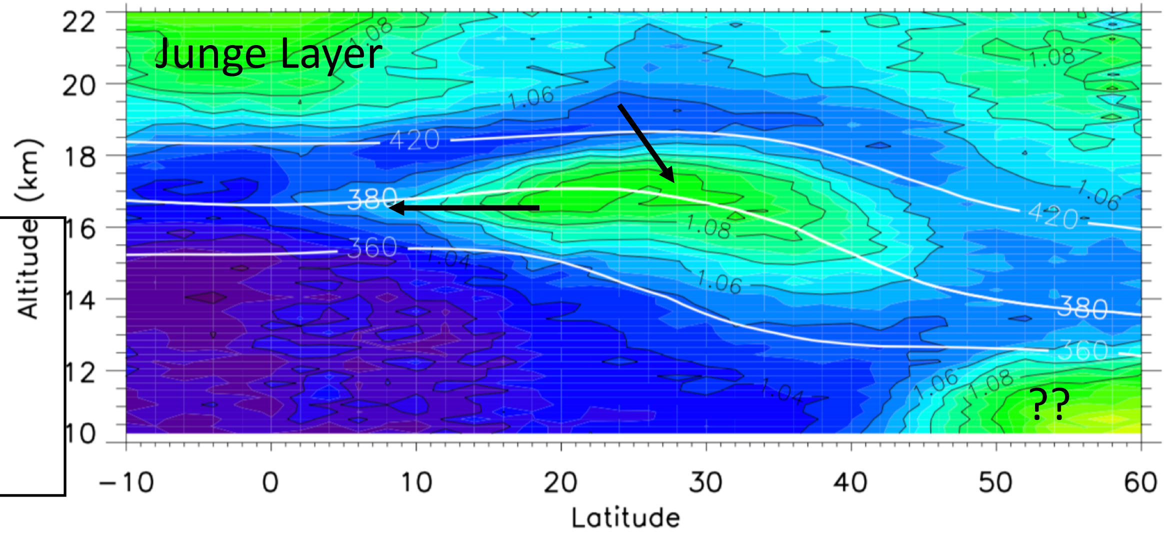
1. Deep convection from the ASM connects boundary layer pollution to the UTLS (Park et a., 2009, Randel et al., 2010)
2. The monsoonal outflow transport through tropical easterlies southern branch of the Asian anticyclone
3. Air in the tropical upper troposphere/southern edge of the Asian anticyclone can be uplifted into the lower stratosphere via diabatic ascent (Garny and Randel 2016)

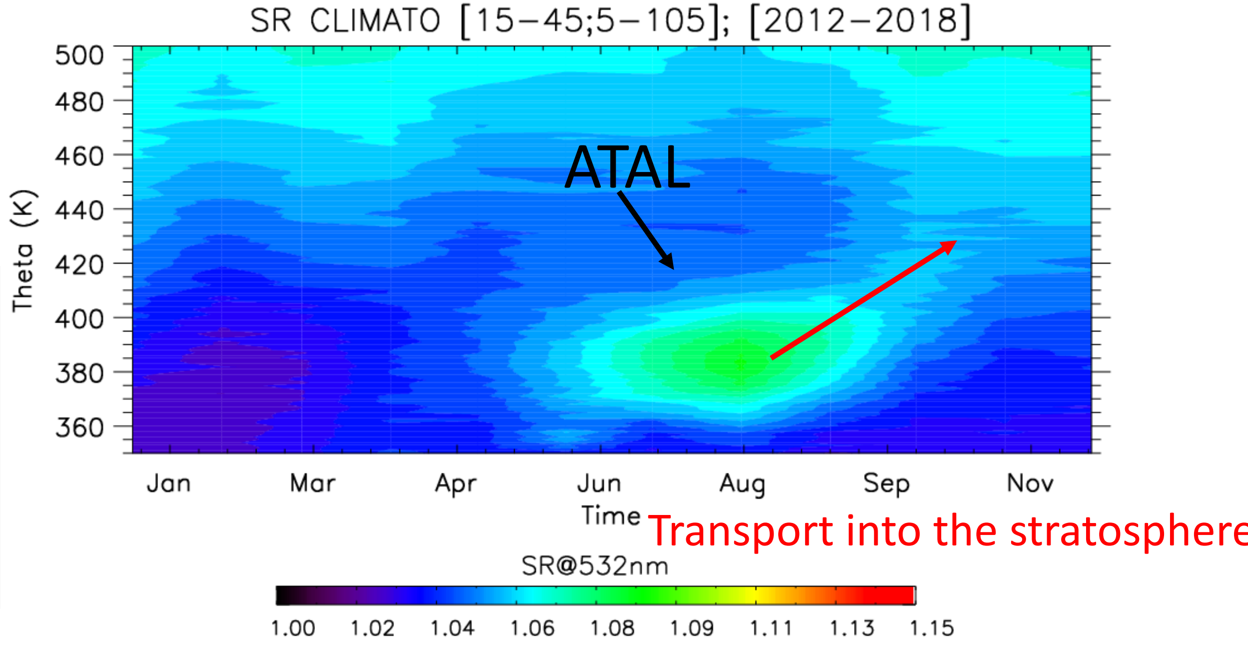
ATAL's transport into the Stratosphere

ATAL



JUL-AUG 2012-2018 (5-105E) Climatology

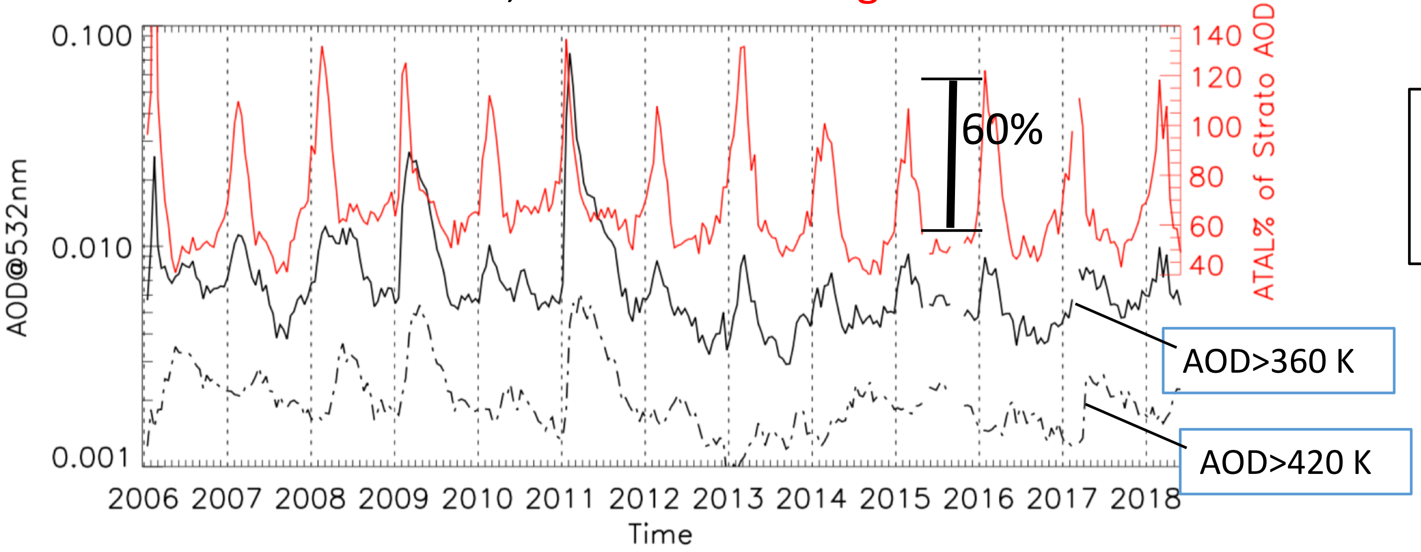




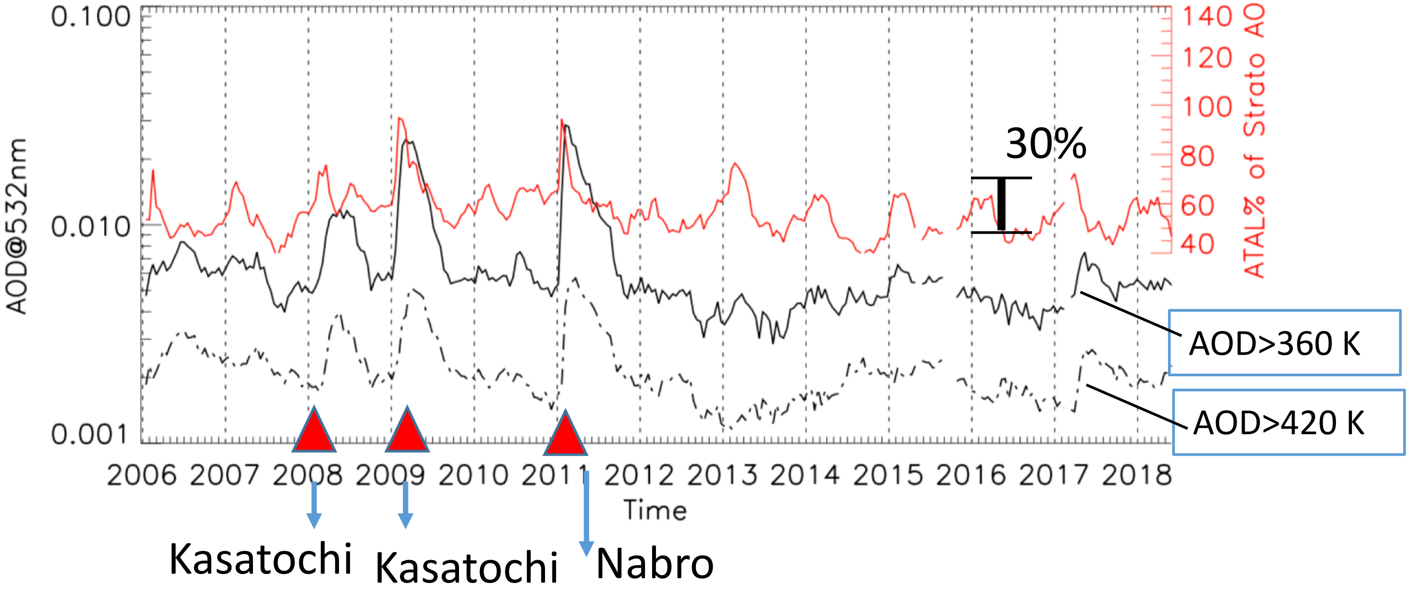
- ATAL's extends between 360 and 420 K (14-18 km)
- It follows isentropic surfaces broading from 10 to 40N
- Transport toward the tropics favors near 380 K
- Transport into the stratosphere is evident after September

Global Influence of the ATAL

15-45N; 5-105 E: "ATAL region"



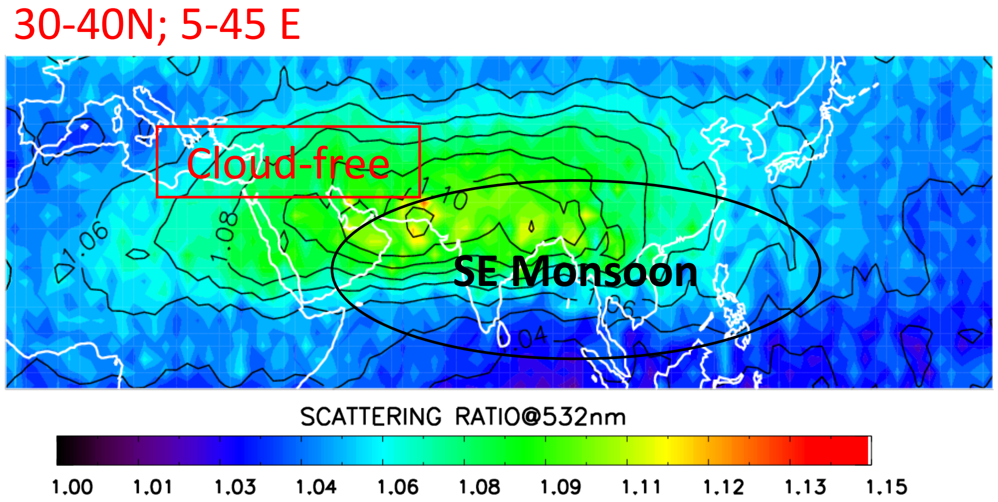
15-45N; 180W-180E: North Hemisphere Influence

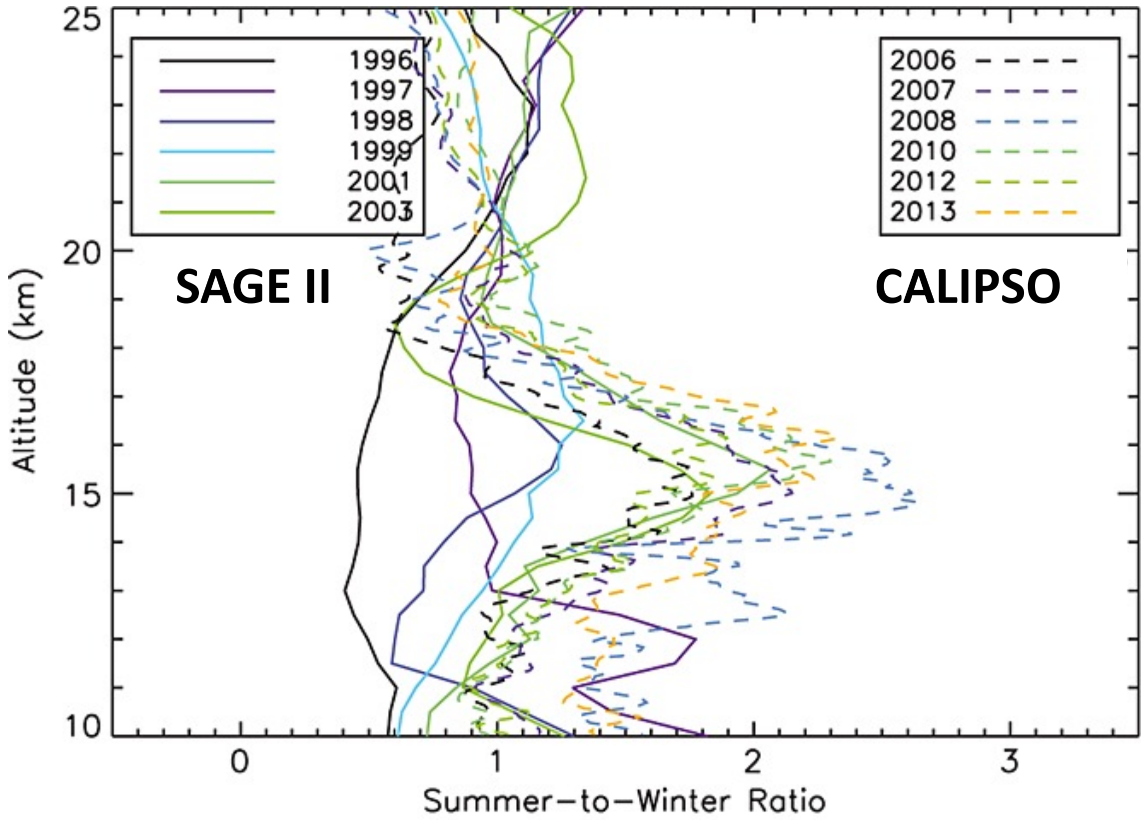


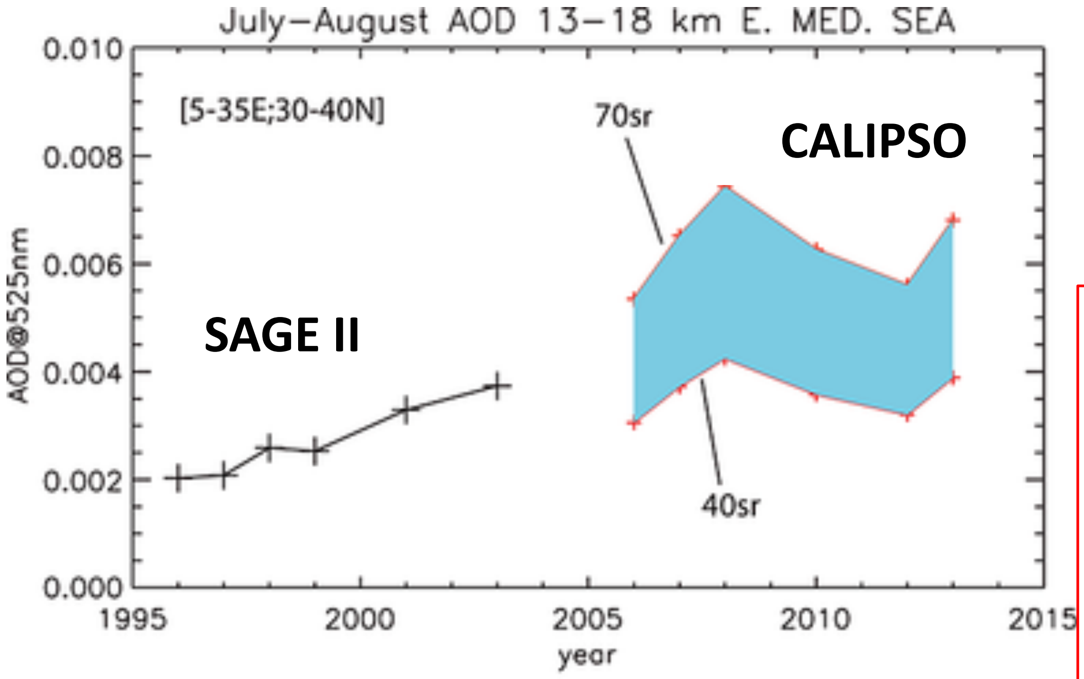
%ATAL of strato aod=100* $(AOD_{360}-AOD_{420})/AOD_{380}$

- "ATAL" AOD (360-420 K) 100-120 % of Stratospheric AOD (>380 K) in the Asian Monsoon Region
- 60% increase in summer compared to winter
- Up to 70% of total Stratospheric AOD of the NH in absence of volcanic eruptions.
- 20% more in summer compare to winter

ATAL’s trends since the late 90’s







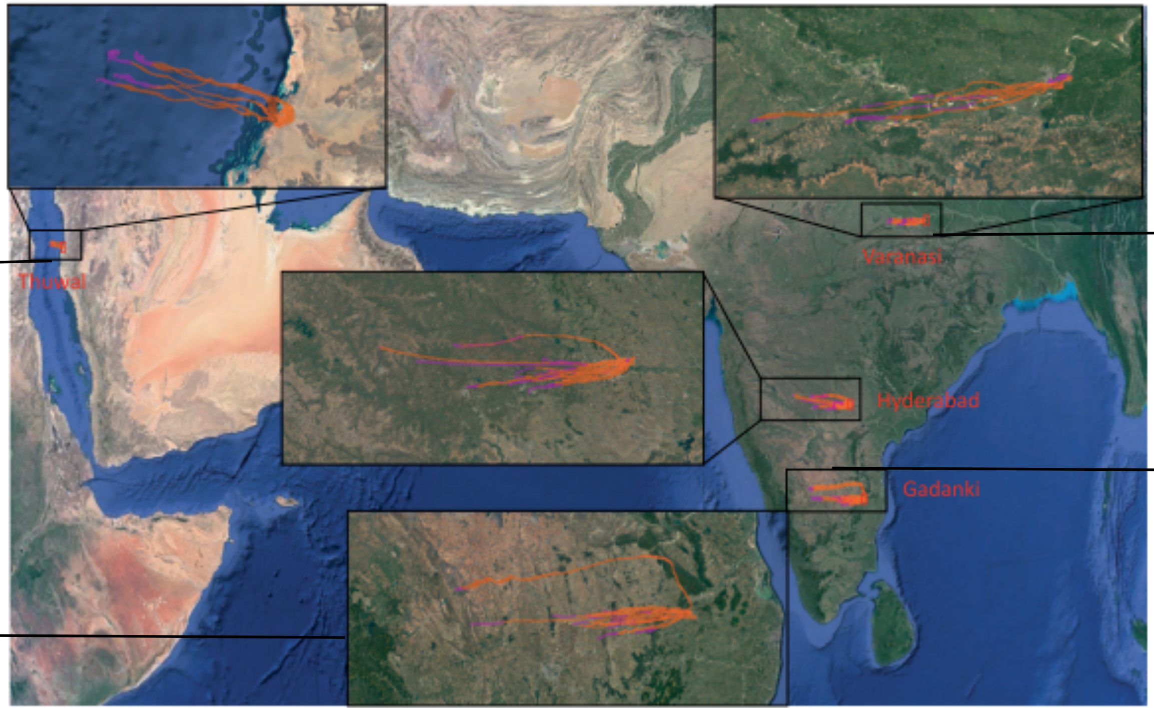
Vernier et al., 2015

- Selected region where cloud influence is minimal
- Trend analysis suggests increase AOD by factor 2-3
- RF between -0.09 to -0.11 W/m2 (assuming sulfate/organics) ; 1/3 of CO2 -RF forcing over same period
- Future work is to combine SAGE III/ISS

BATAL campaigns 2014-2018

King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia
Jul-Aug 2015-2016

Balloon Trajectories: Ascent/Descent (2015)



Vernier et al., 2018, BAMS

Banaras Hindu University (BHU), Varanasi, India
Jul-Aug 2015-2016

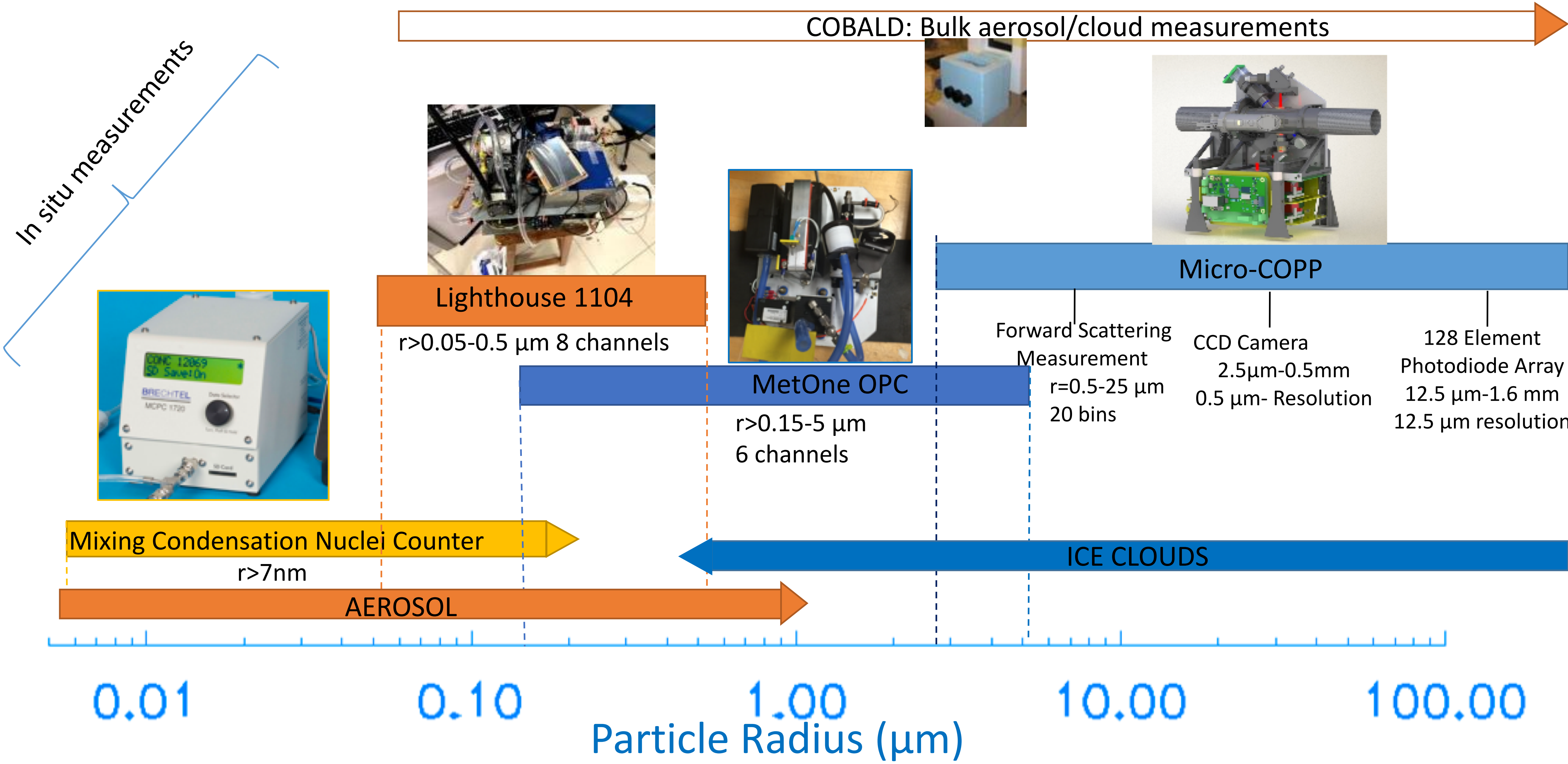
National Atmospheric Research Laboratory (NARL), Gadanki, India
Jul-Aug 2014-2015-2016-2017-2018

BATAL numbers

- 4-year project 2014-2018
- 4 Launch locations (3 India, 1 Saudi Arabia)
- 12 Institutes Involved
- 6 Countries
- ~ 90 Balloon Flights since 2014

Tata Institute for Fundamental Research Balloon facility (TiFR)
Jul-Aug 2015-2017-2018

Payloads to cover aerosol and cloud size spectrum

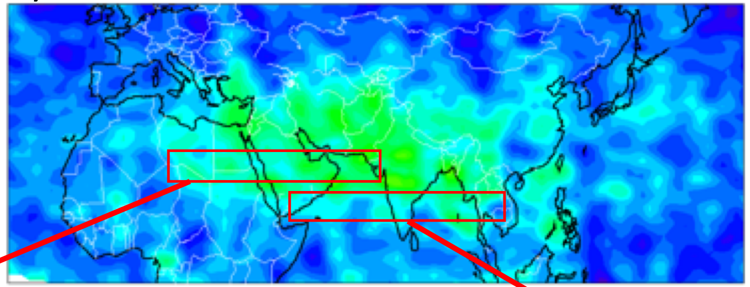


Balloon launch from the TiFR, Hyderabad

CALIPSO Validation with COBALD

- COBALD backscatter sonde (ETH)
- Two wavelengths (455nm/970nm)
- In situ backscatter

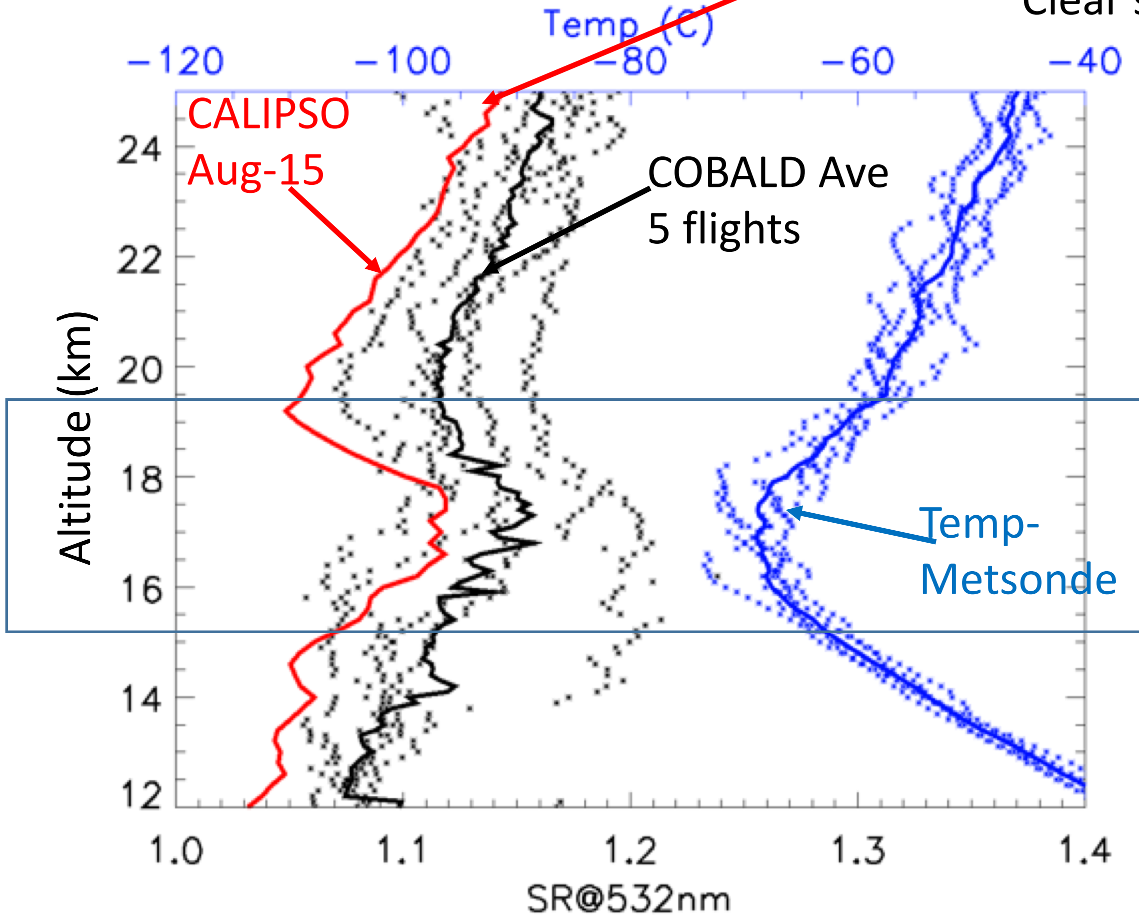
CALIPSO-JUL-AUG-15 16-18 km

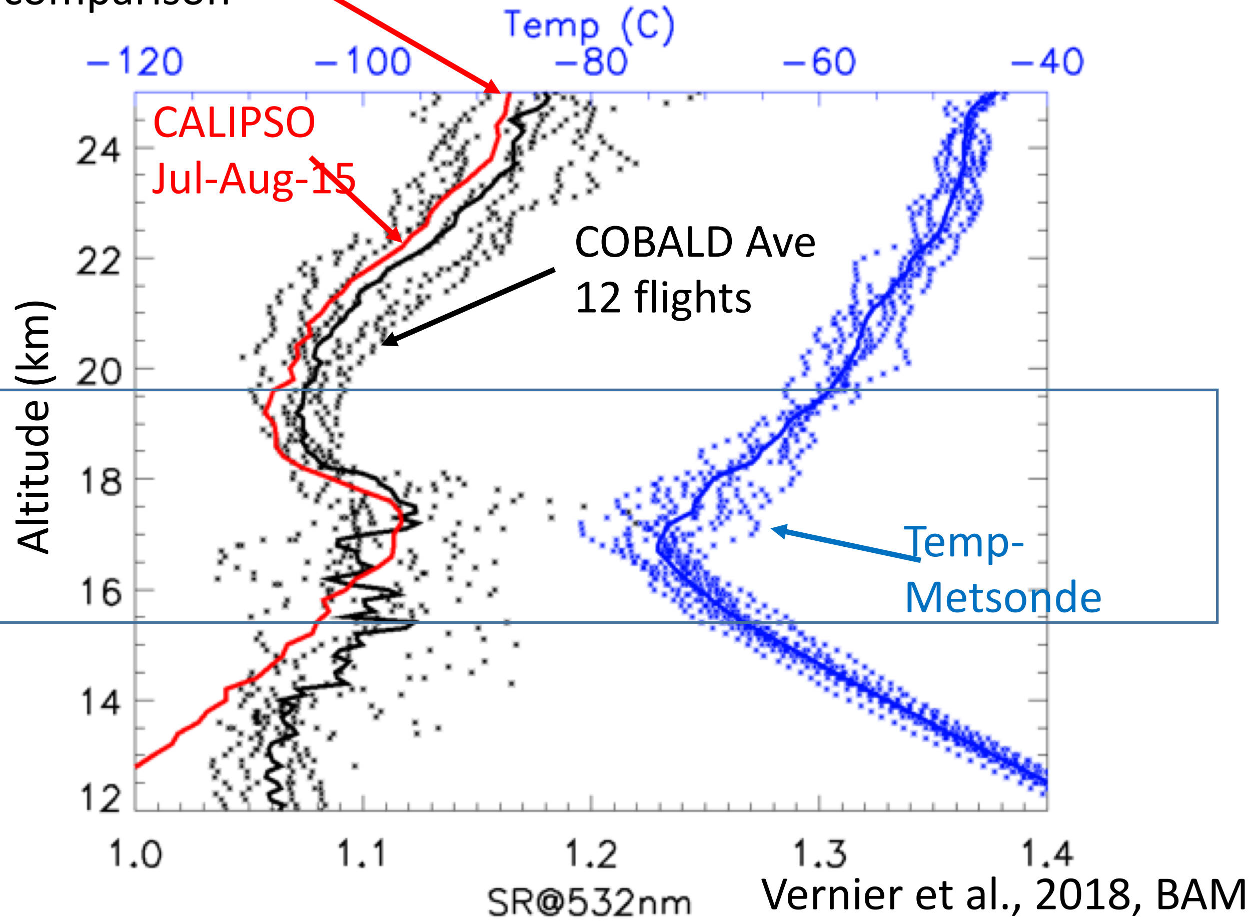


Thuwal
5Aug-12Aug 2015

Gadanki-Hyderabad
17jul-13Aug 2015

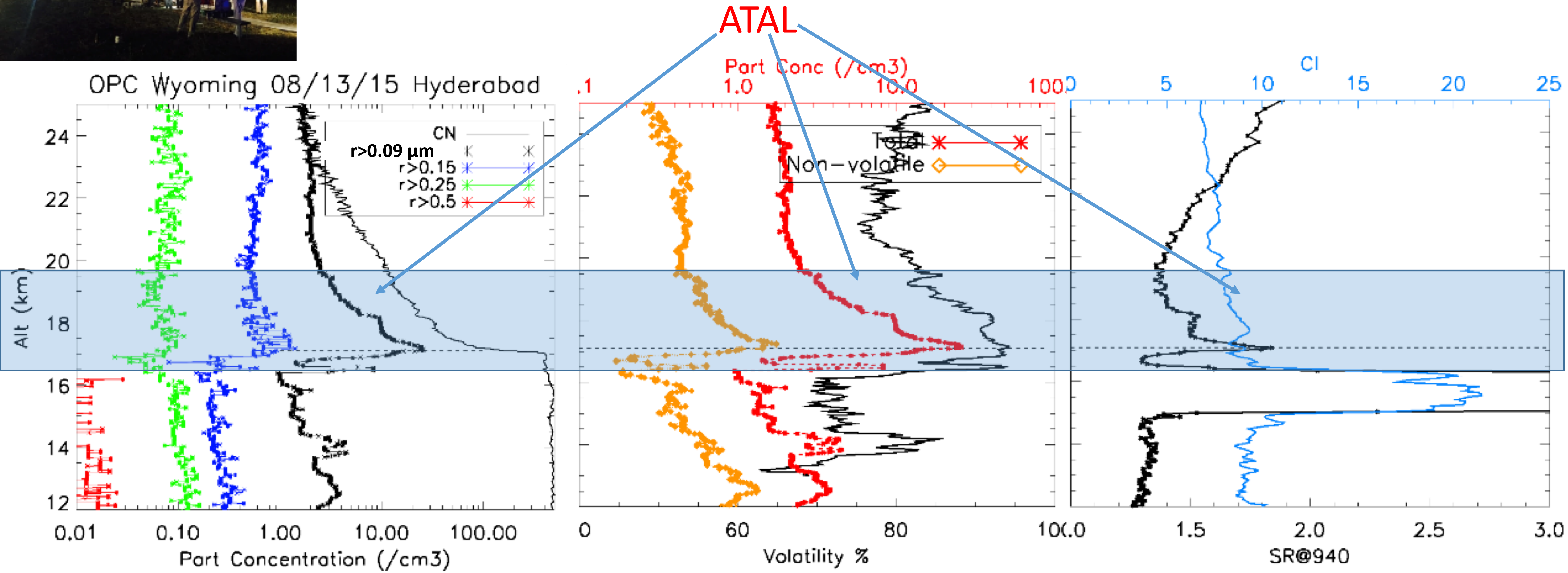
Clear sky comparison





Vernier et al., 2018, BAMS

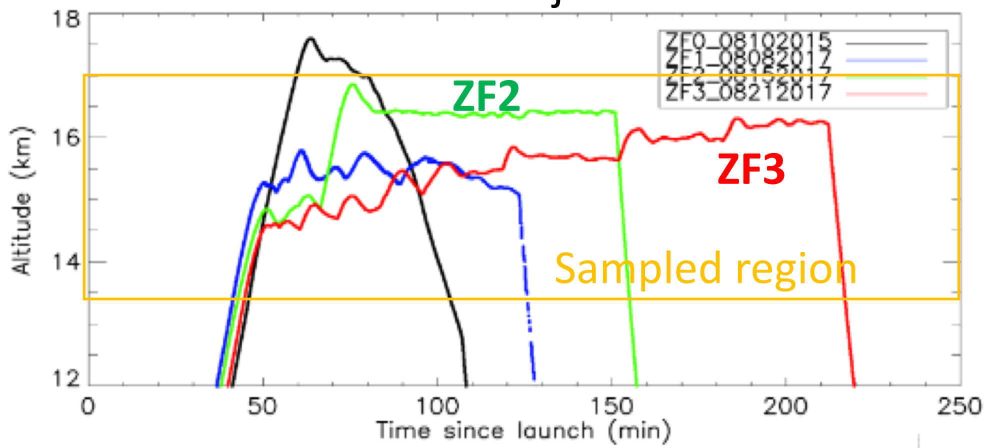
Size distribution and volatility measurements obtained within the ATAL

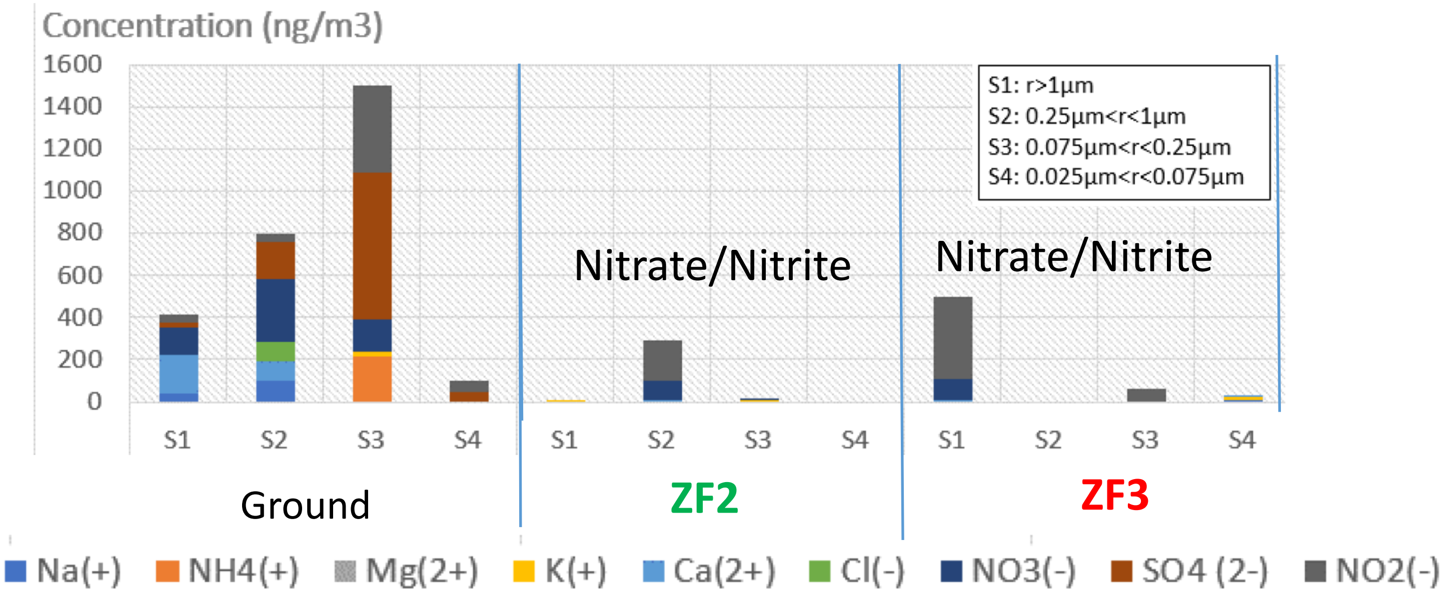


- ➢ Maximum SR coincides with peak in OPC number concentration for r > 0.09 µm at the cold point tropopause
- ➢ Heated (180°C) and unheated inlets on OPC instruments indicate >90% small, volatile particles
- ➢ Microphysical modelling tests with M7. ~17 km Nucleation/Growth of aerosols within 1.5 days.

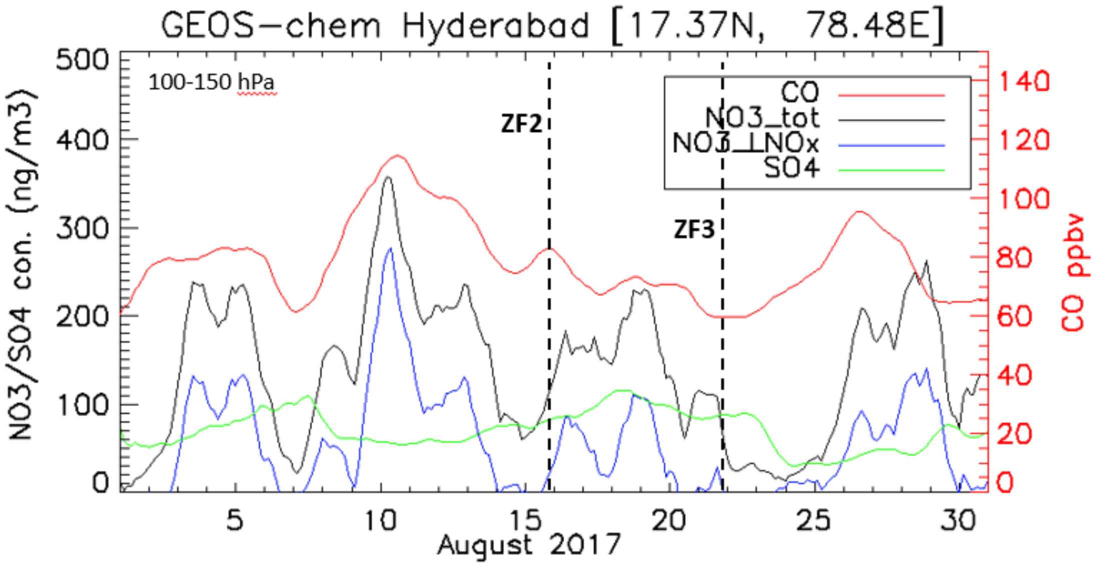
Ionic composition of the ATAL

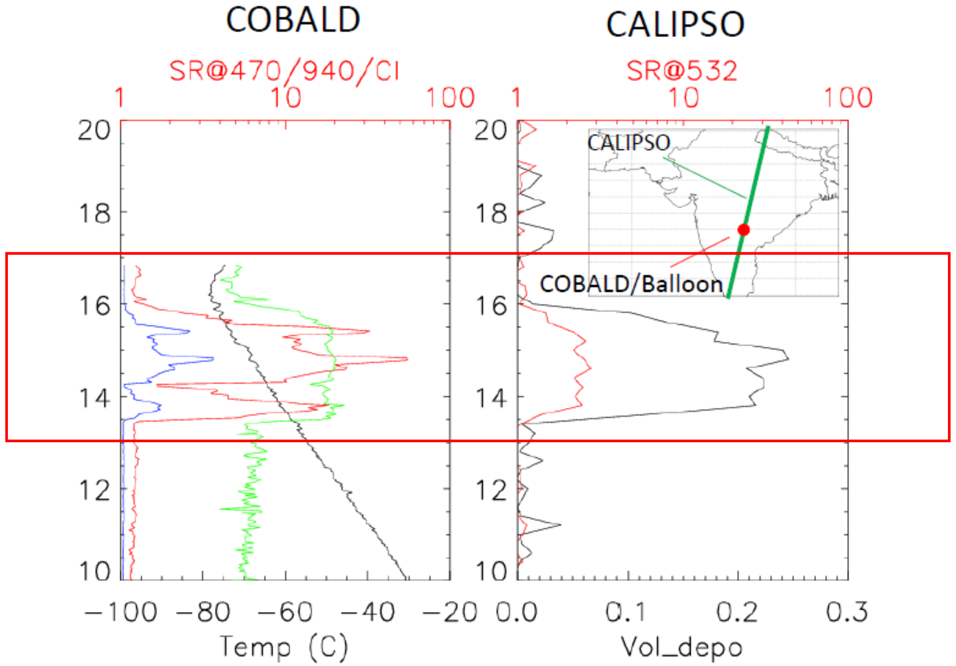
Balloon trajectories



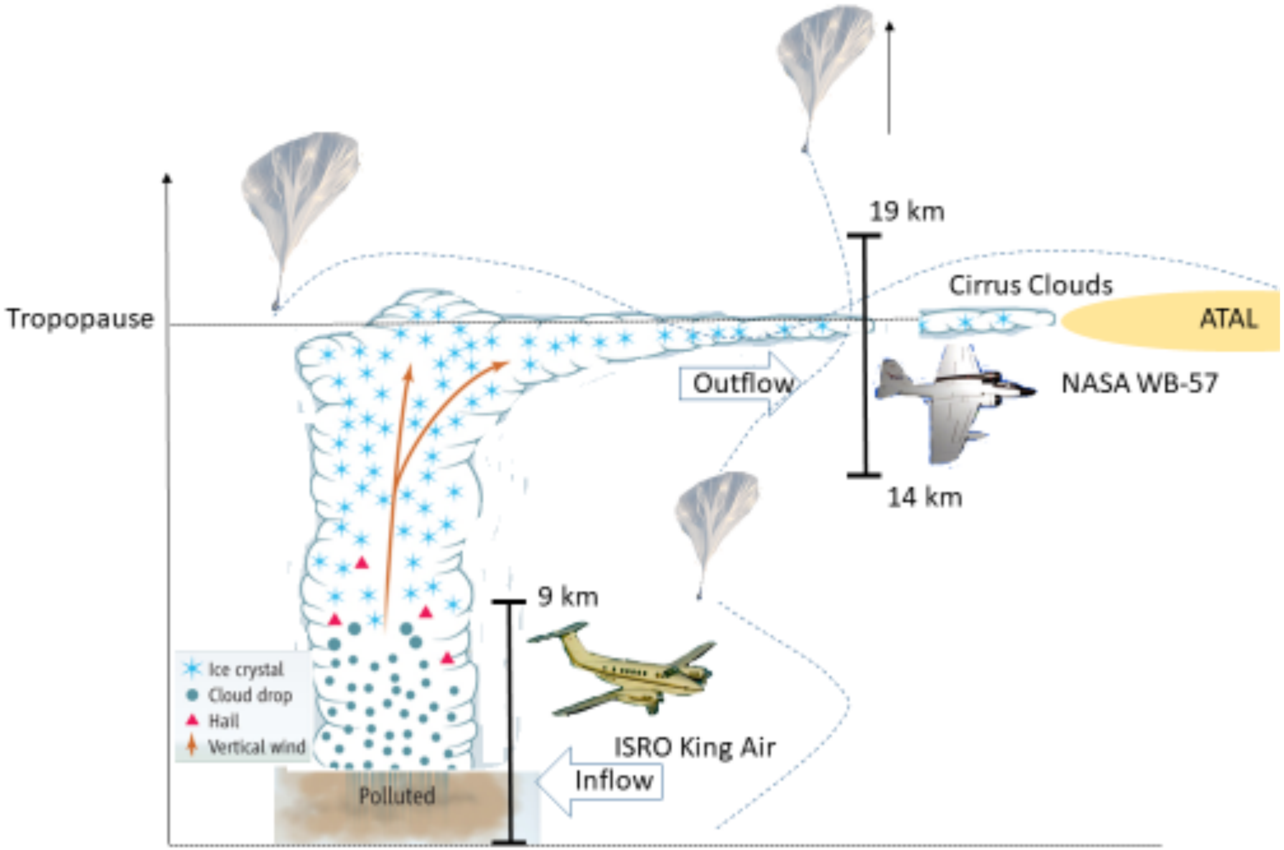


Lightning versus Anthropogenic Contribution/GOES-Chem





Future of BATAL....2021 and beyond ?



- Since 2017 BATAL project is under the umbrella agreement between ISRO and NASA
- Future campaigns involving aircraft measurements under discussion
- Connecting boundary layer measurements and the UTLS with balloon and aircraft measurements in a key location in Asia.

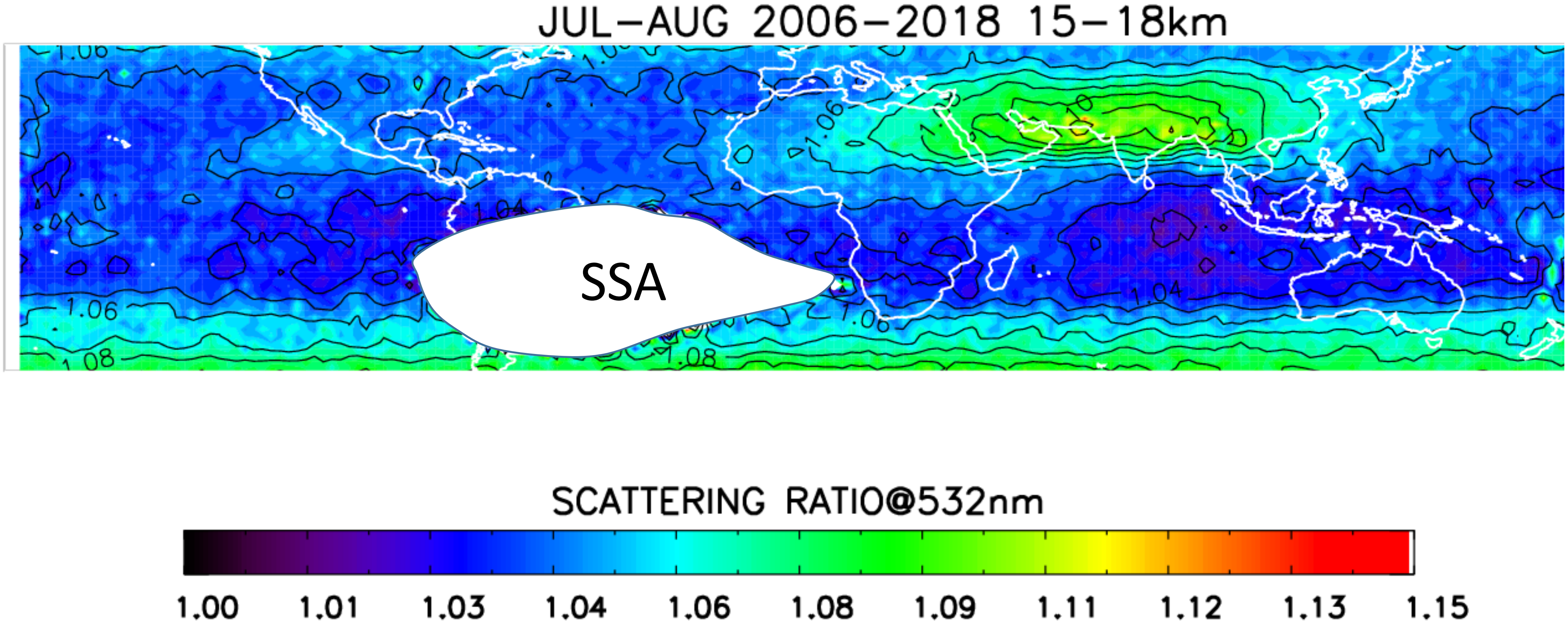
Conclusions

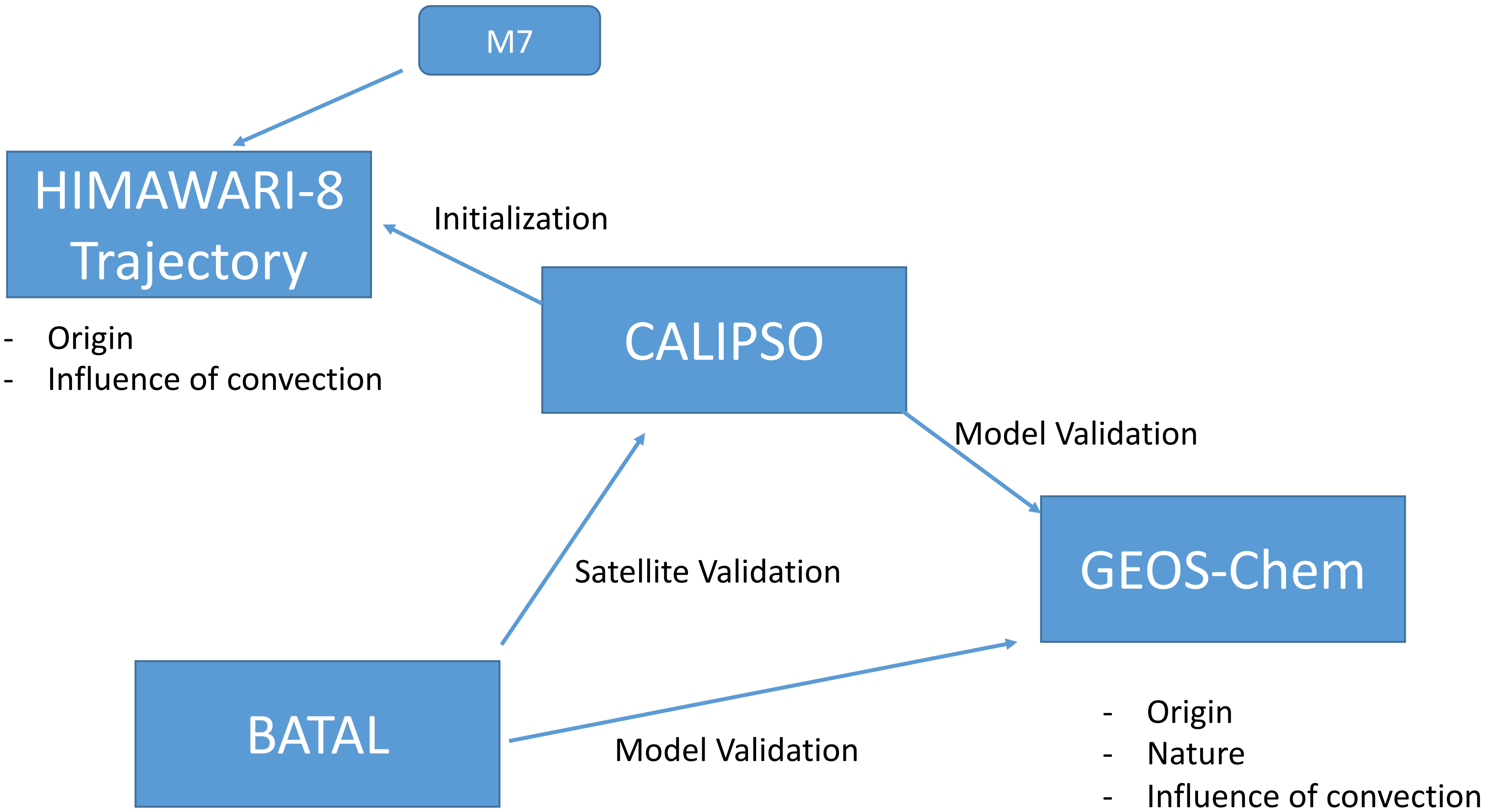
- Summer Asian Monsoon is a significant source of UTLS aerosols in absence of volcanoes: the ATAL
- ATAL's AOD represents ~ 30% of the total SAOD in the NH
- Optical, Physical and Chemical properties of the ATAL have been investigated since 2014 during the BATAL campaigns
- ATAL composed of volatile aerosols that could be consistent with new particle formation with large contribution of nitrate
- BATAL 202X: combined Balloon/Aircraft campaign between NASA/ISRO under discussion

NASA-funded project through UARP/ACMAP programs

Extra

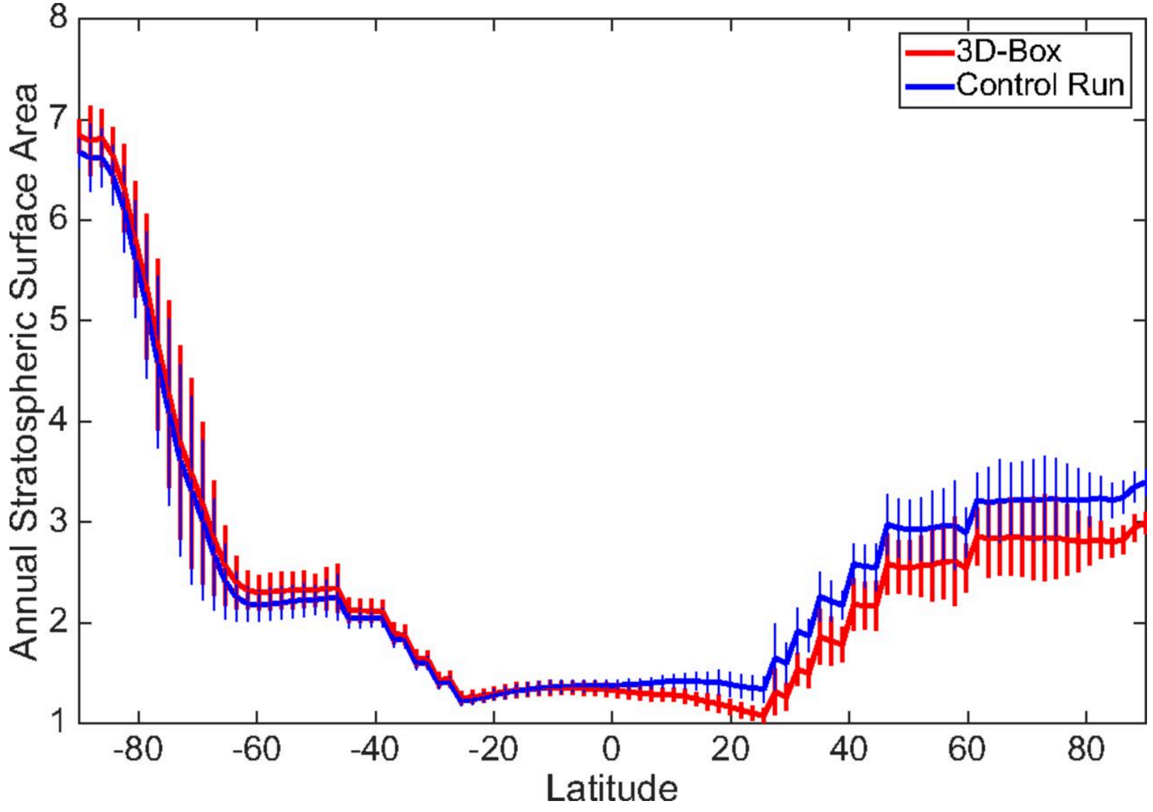
Global Impact of the ATAL

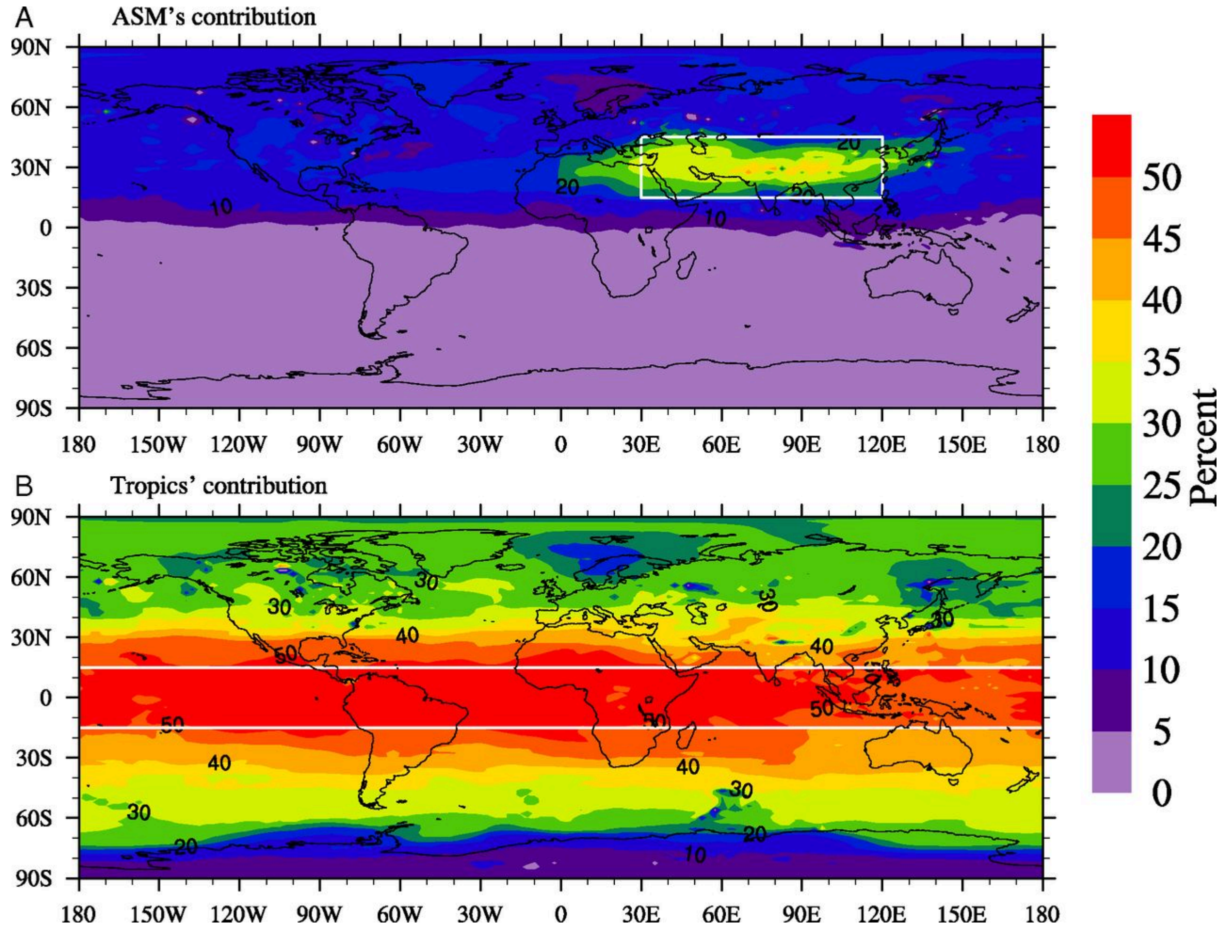




M7
HIMAWARI-8 Trajectory
- Origin
- Influence of convection
Initialization
CALIPSO
Model Validation
Satellite Validation
GEOS-Chem
BATAL
Model Validation
- Origin
- Nature
- Influence of convection

Impacts of the ATAL on stratospheric aerosol surface area density





Yu et al., 2018, PNAS

The impact of the Summer Asian Monsoon on stratospheric aerosols

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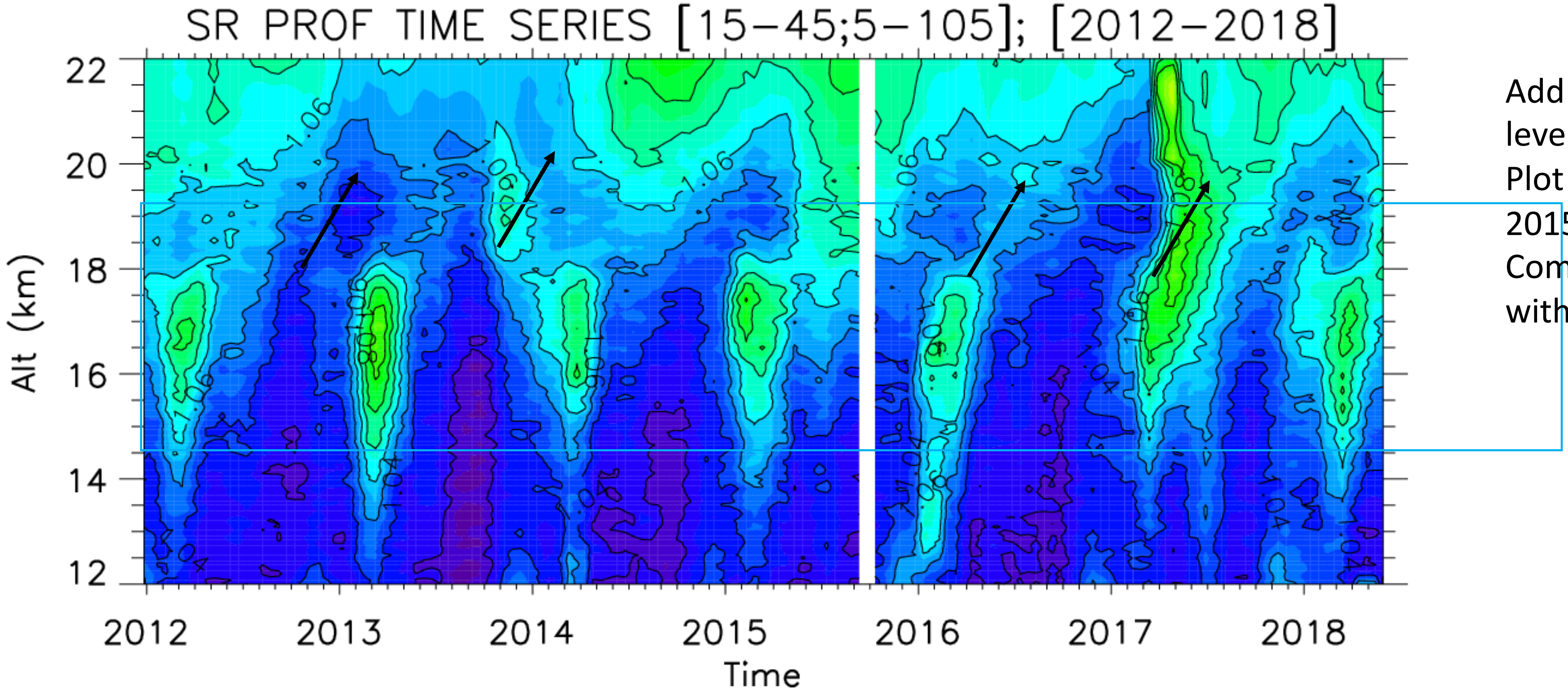
(5) Physical Research Laboratory, Ahmedabad, India.
(6) LCP2E, Université d'Orléans, France.
(7) TIFR Balloon Facility, Hyderabad, India.
(8) Virginia Institute of Marine Science, USA .

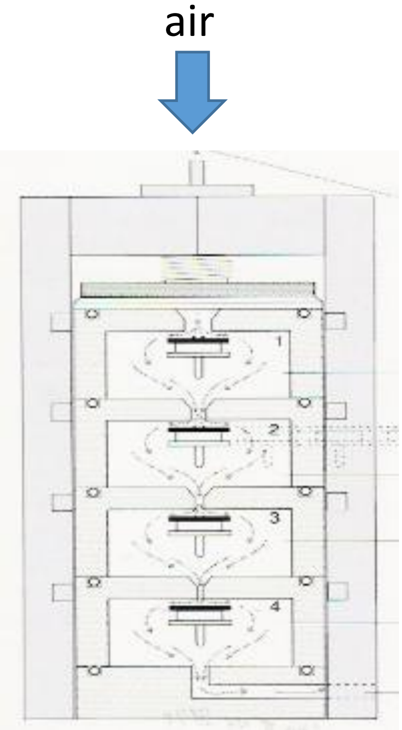
EGU, General Assembly 7-12 April 2019, Vienna

Ascension of the ATAL into the Stratosphere



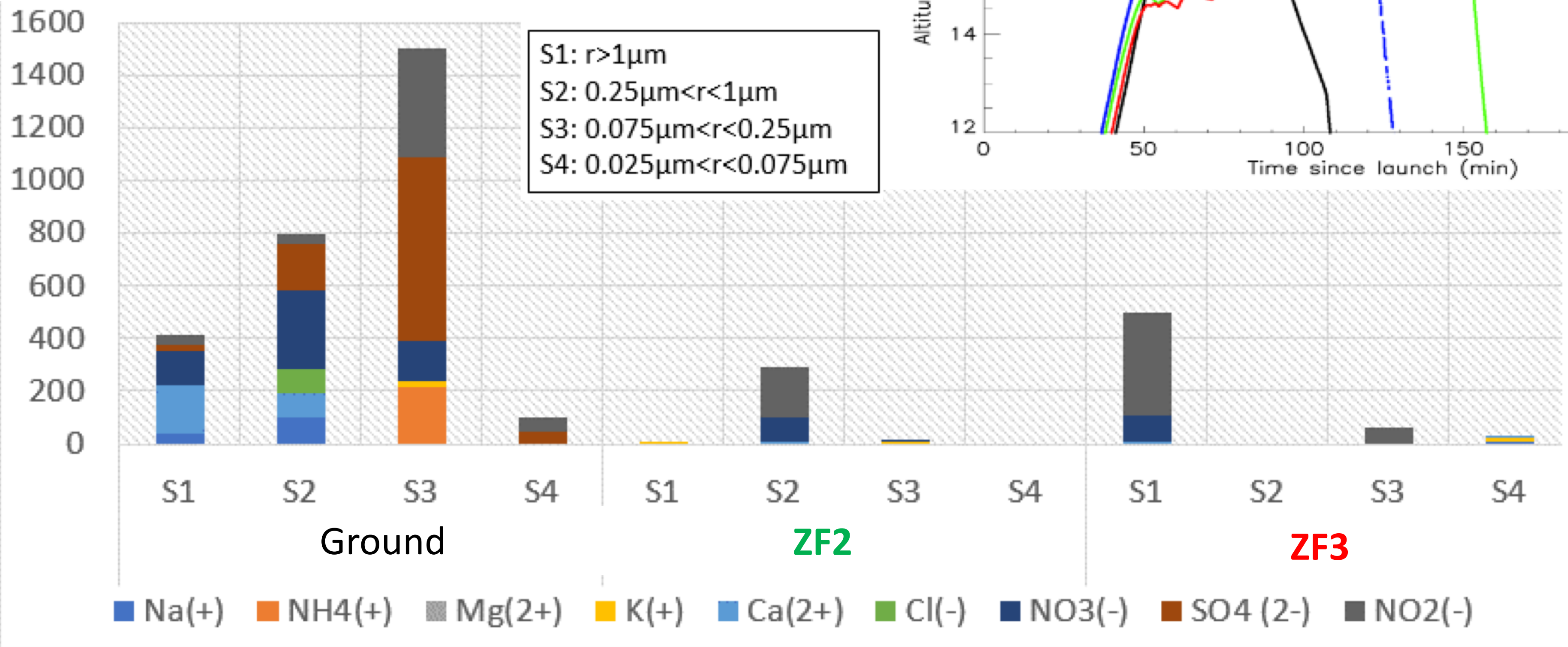
Add 380 K levels…
Plot Average 2015
Comparison with

Ionic composition of the ATAL

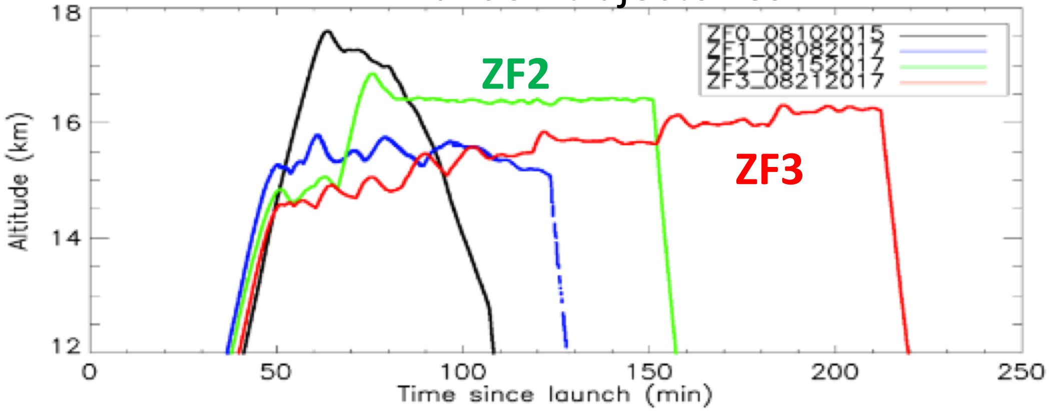


Aerosol impactor

Ion concentration (ng/m3)

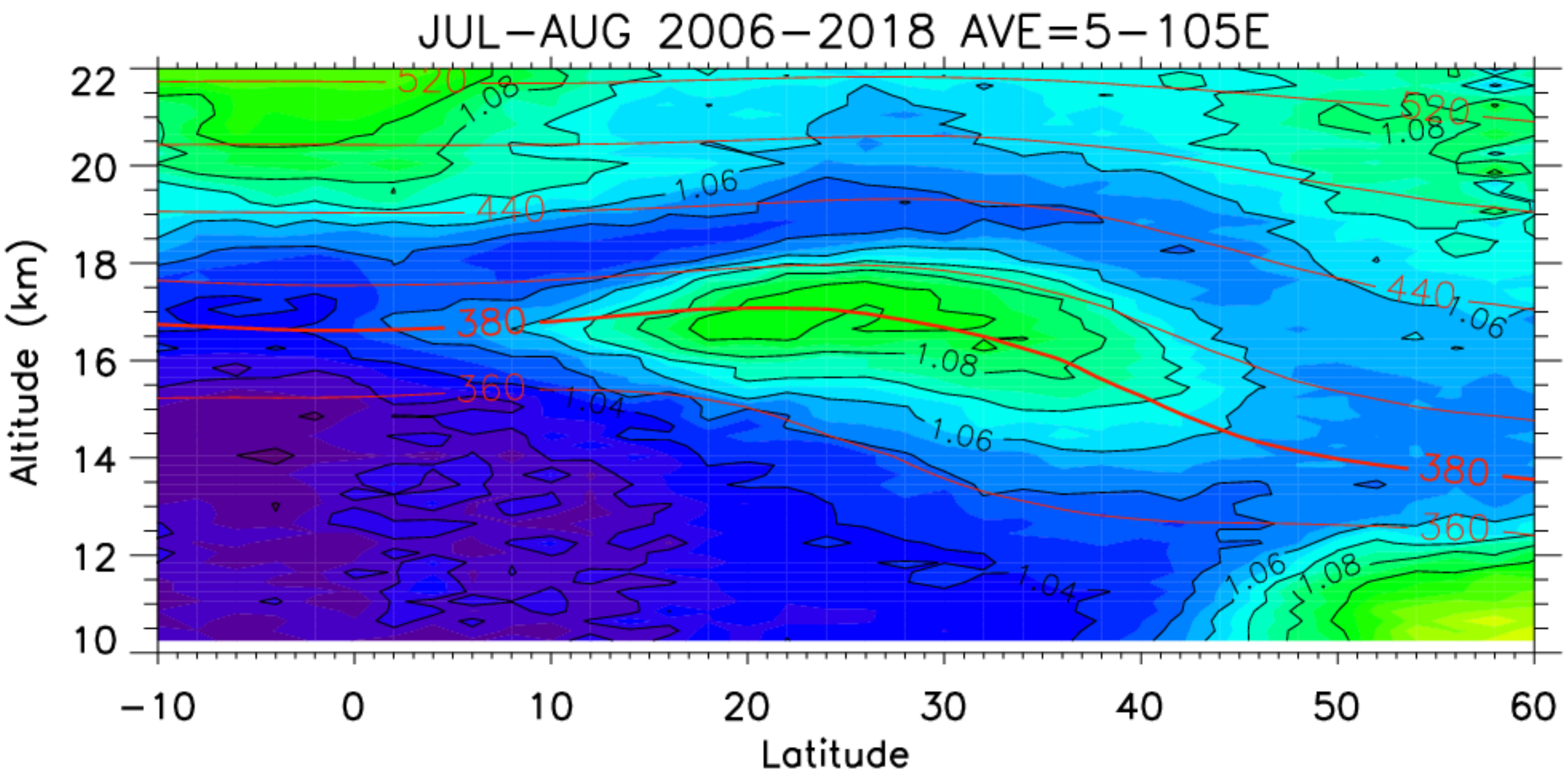


Balloon trajectories



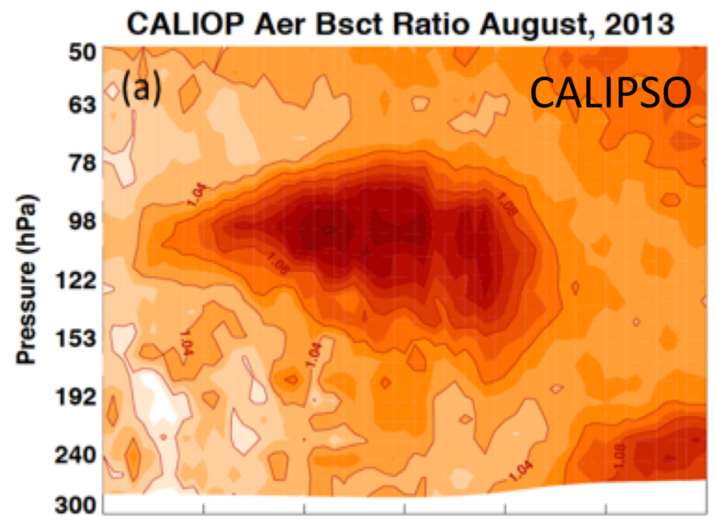
- Aerosols collected using balloon-borne impactors near the tropopause were analyzed through Ion Chromatography
- Two balloon experiments in 2017 (ZF2/ZF3) reveals the dominant presence of nitrate/nitrite containing particles with sulfate concentration less than 10 ng/m3 consistent with GEOS-Chem simulations.

POSTER

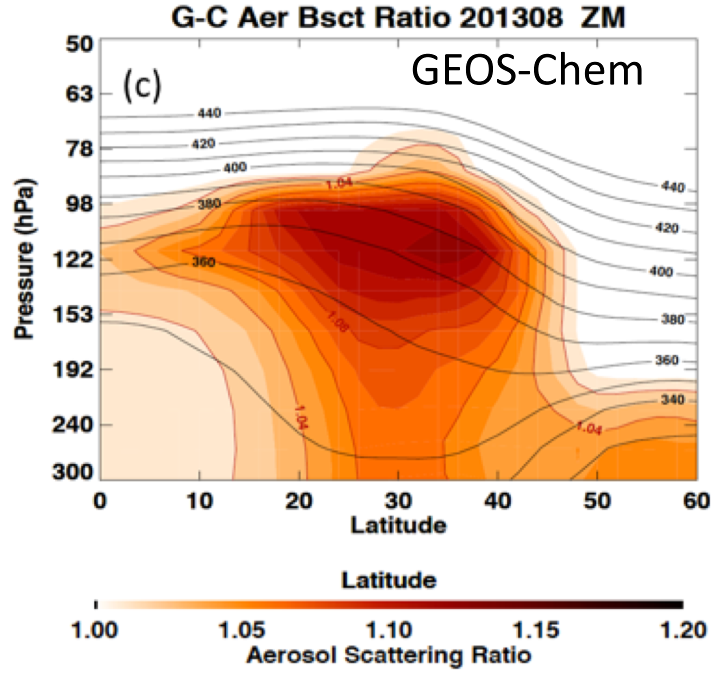


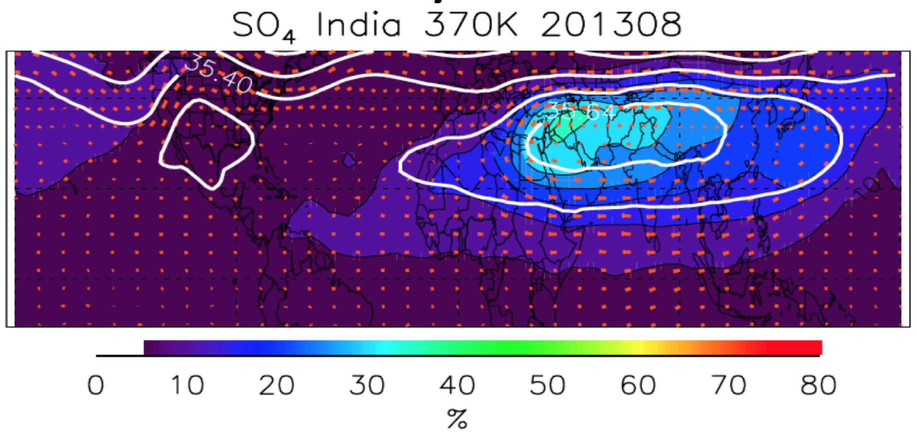
JUL−AUG 2006−2018 AVE=5−105E
Altitude (km)
Latitude
520
440
380
360
1.08
1.06
1.04

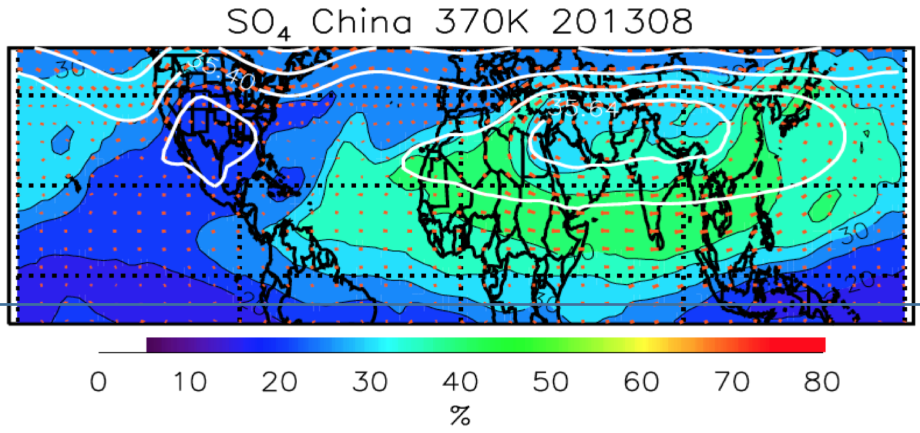
Origin of the ATAL: GEOS-Chem Model Analysis

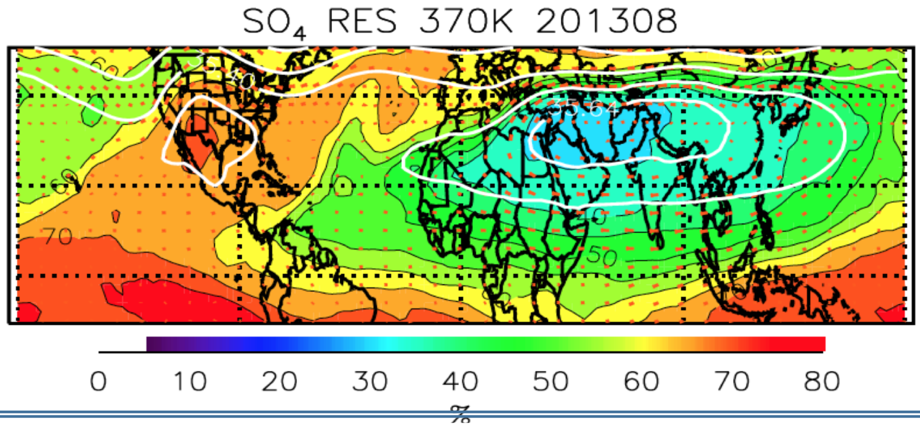


- GEOS-Chem (CTM), Aug. 2013
- Aerosols: SO4, NIT, NH4, BC, OC, Sea Salt, Dust
- Treatment of SO_2 scavenging in convective updrafts improved using Henry's law (Fairlie et al., 2019, in prep.)
- Shape and magnitude of ATAL agree well with CALIPSO









<u>Source attribution study</u>

- Neely et al. (2013) concluded that anthrop. emissions in India+China contribute only ~30% of sulfate aerosol in ATAL
- Our GEOS-Chem analysis shows that Indian+China emissions contribute ~60 % of sulfate