ARIES Nainital, Uttarakhand, India - 1800 m a.s.l.

Balloon-borne measurements of water vapor, aerosol backscatter and ozone in Nainital (India) in August and November 2016

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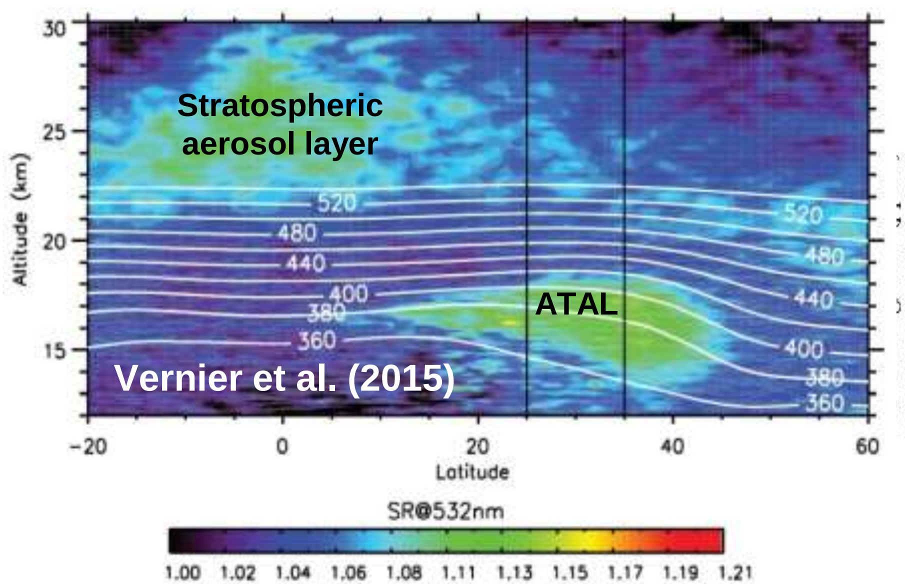
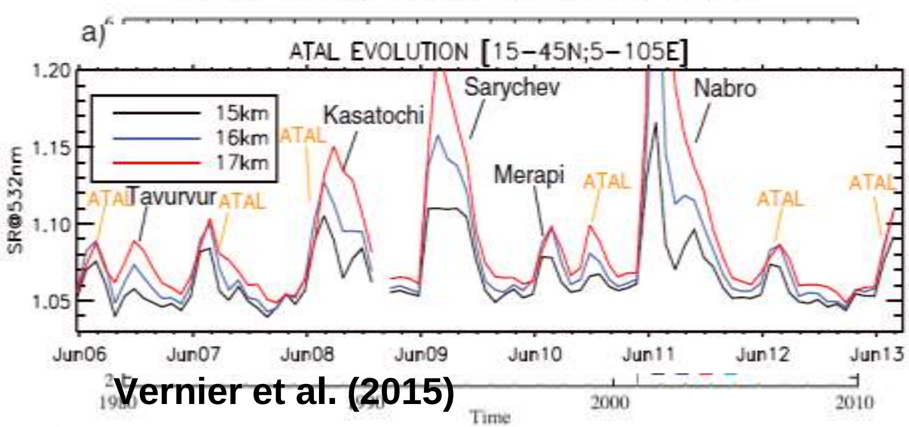
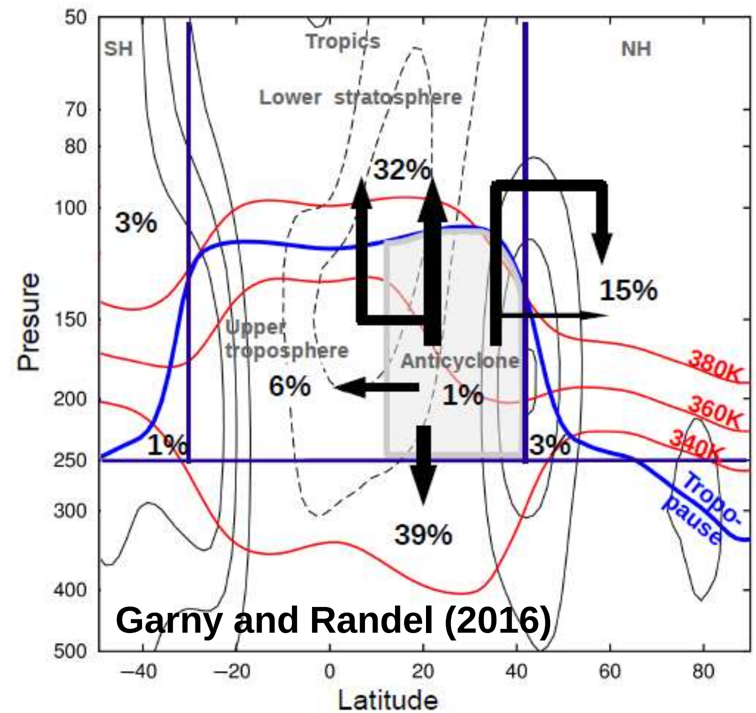
ACAM-3 Workshop, Jinan University, Guangzhou (China), 8 June 2017

The Asian summer monsoon UTLS anticyclone: a gateway to the global stratosphere?







Impact of Asian summer monsoon on stratospheric H2O trends?

And on stratospheric aerosols?

The StratoClim balloon campaign in Nainital (India)

Launching site: 29.35° N, 79.46° E, 1800 m a.s.l.

Southern slopes of Himalaya highly relevant region for H2O transport to the UTLS anticyclone (Fu et al., 2006; Fadnavis et al., 2013; Heath and Fuelberg, 2014)

Monsoon campaign

30 balloon soundings in August 2016 with payload:

- Pressure, temperature, winds (RS41)
- Ozone (ECC)
- Water vapor (CFH)
- Aerosol backscatter (COBALD)

Post-monsoon campaign

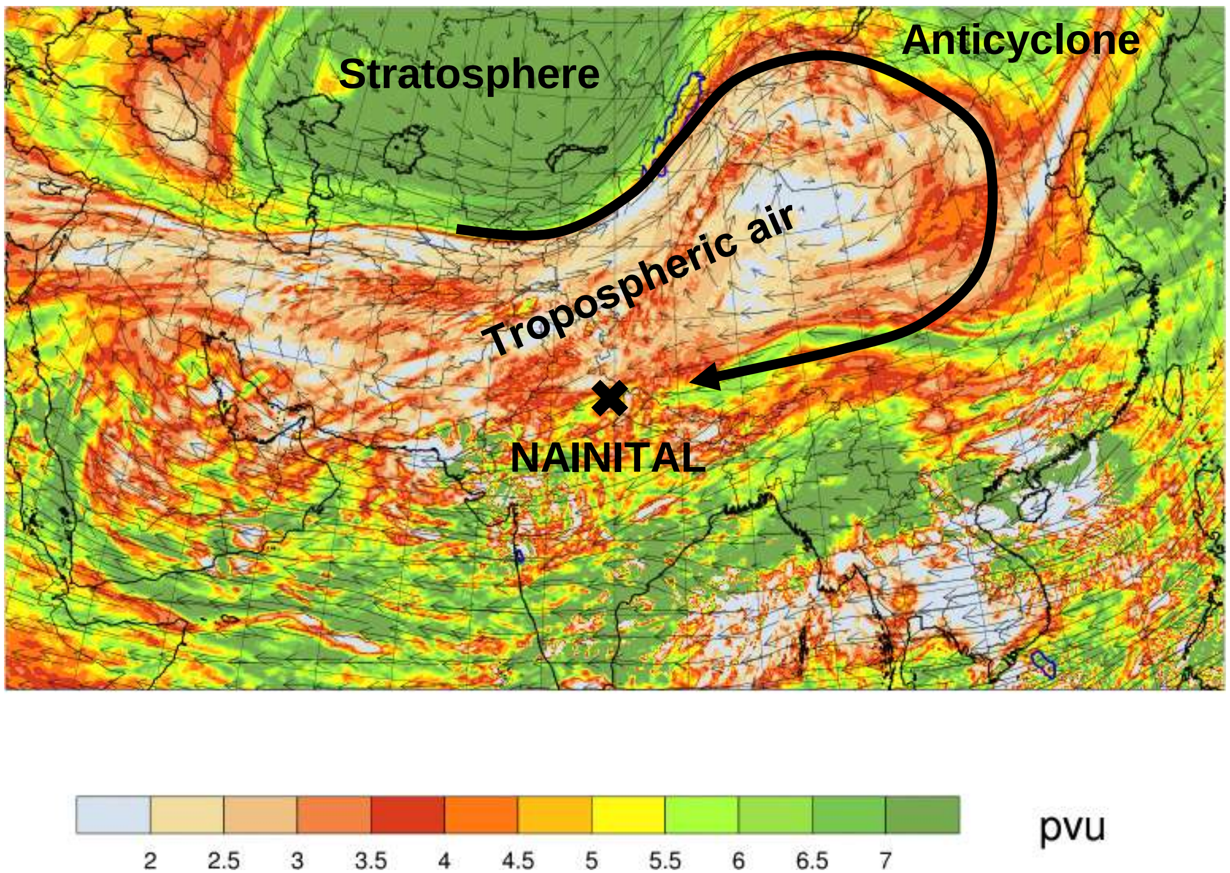
5 balloon soundings in November 2016, same payload.

The StratoClim balloon campaign in Nainital (India)

Launching site: 29.35° N, 79.46° E, 1800 m a.s.l.

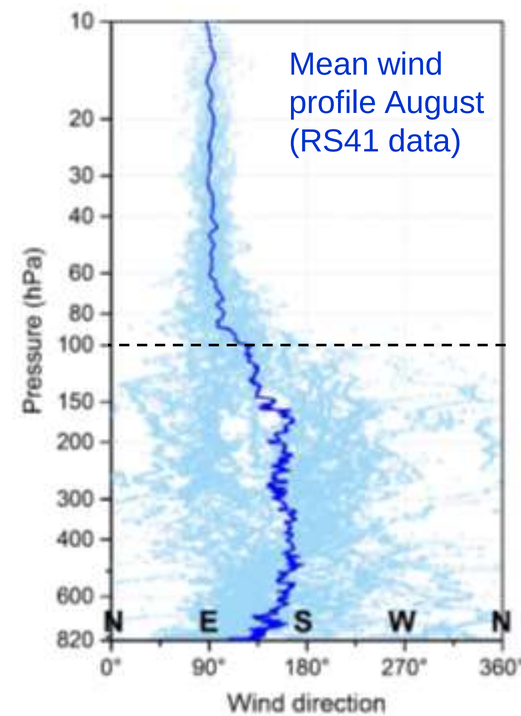
ECMWF analysis (0.125° res), 2 August 2016, 1200 UTC

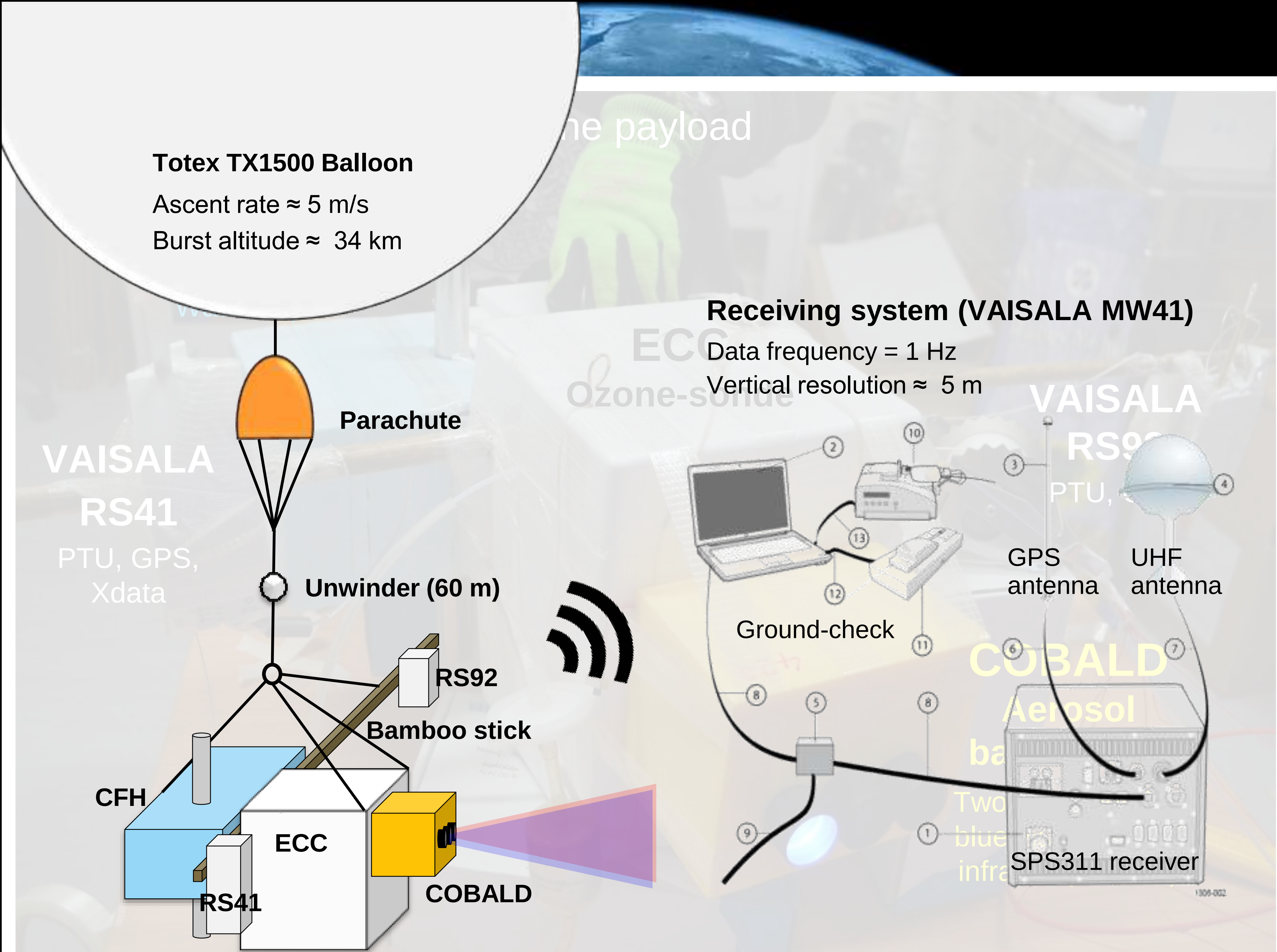
380 K ≈ 100 hPa



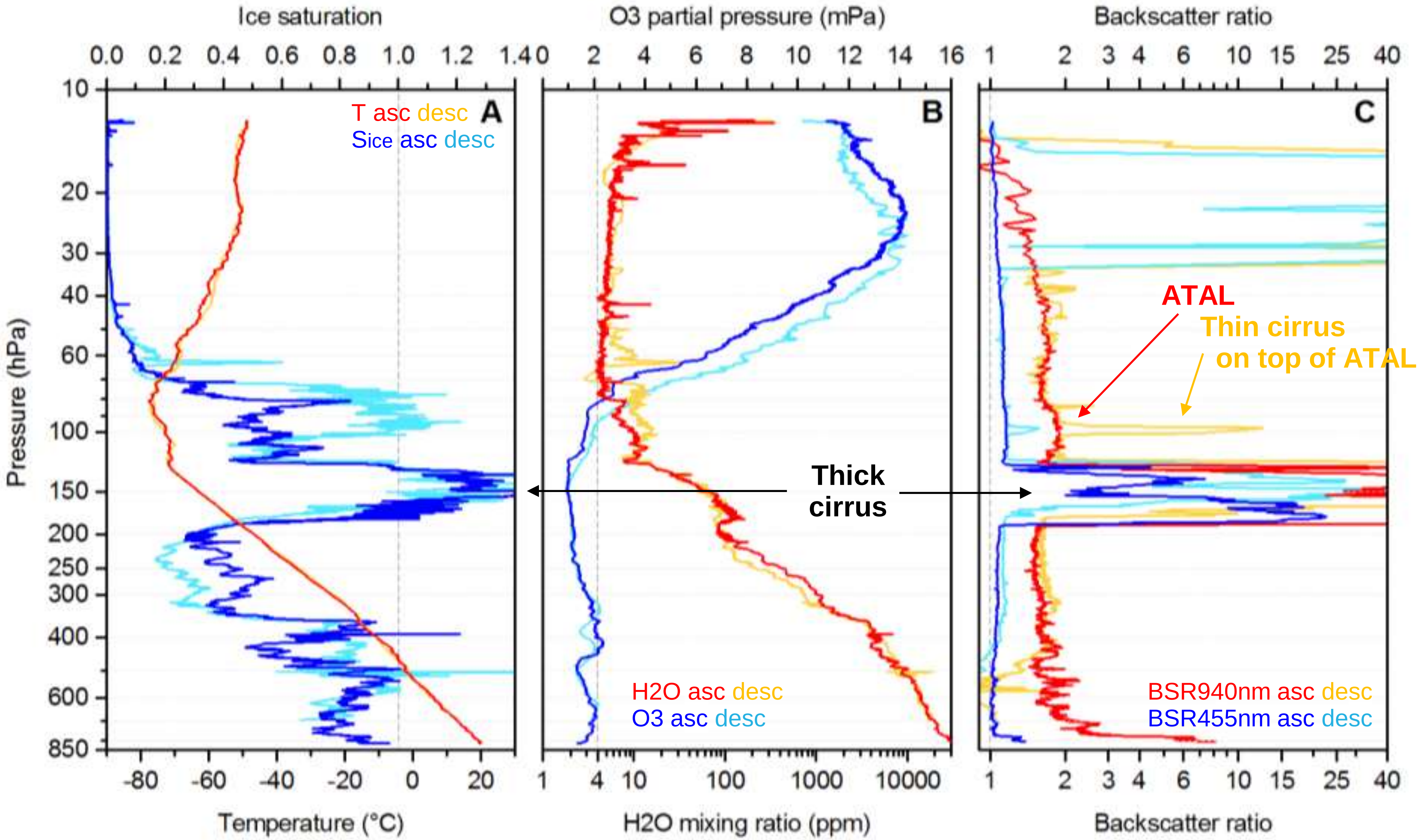
Nainital mainly on the **southern edge** of the ASMA circulation

→ UTLS easterly flow

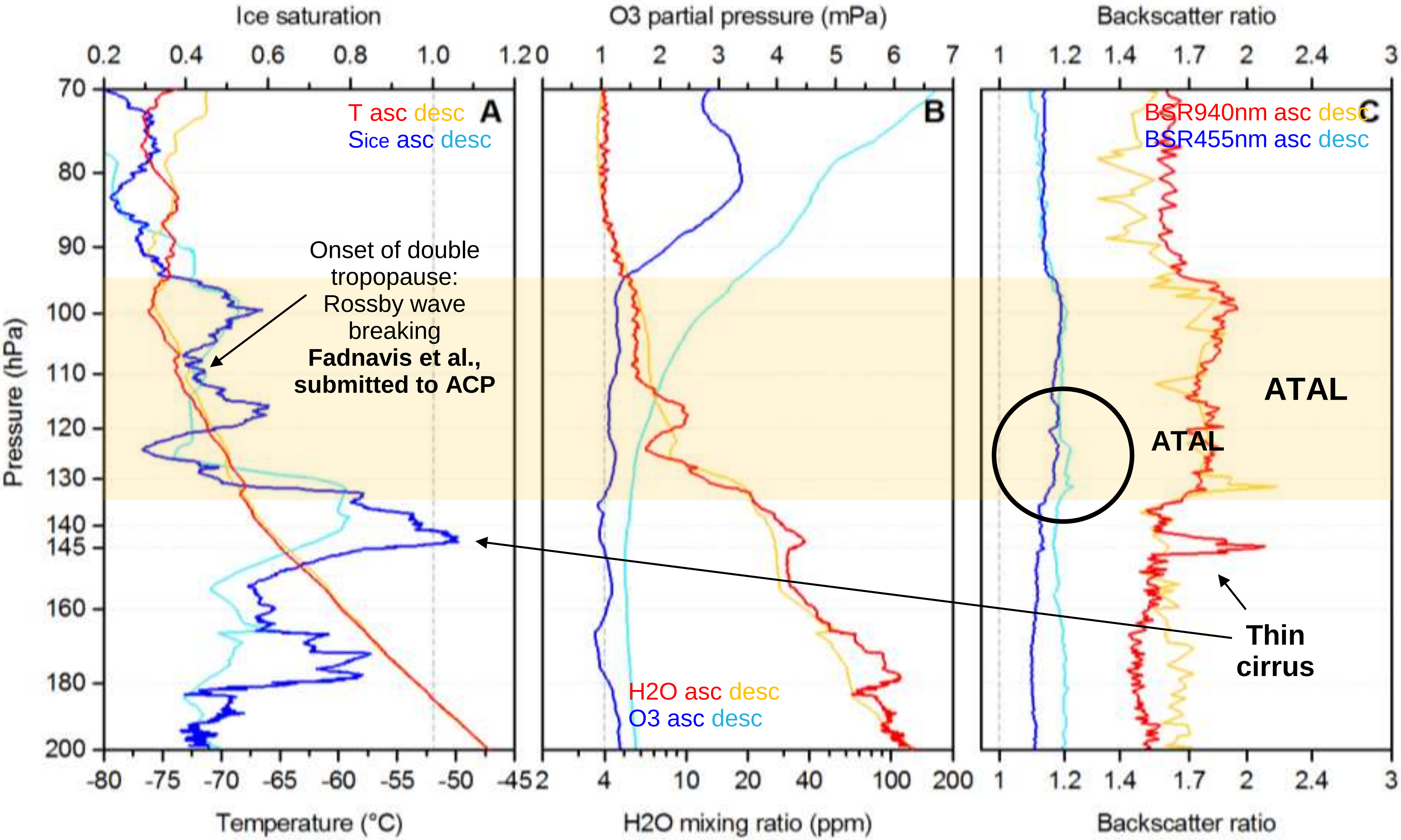



Totex TX1500 Balloon
Ascent rate ≈ 5 m/s
Burst altitude ≈ 34 km
Parachute
Unwinder (60 m)
RS92
Bamboo stick
CFH
ECC
RS41
COBALD
VAISALA
RS41
PTU, GPS,
Xdata
Receiving system (VAISALA MW41)
Data frequency = 1 Hz
Vertical resolution ≈ 5 m
GPS
antenna
UHF
antenna
Ground-check
SPS311 receiver

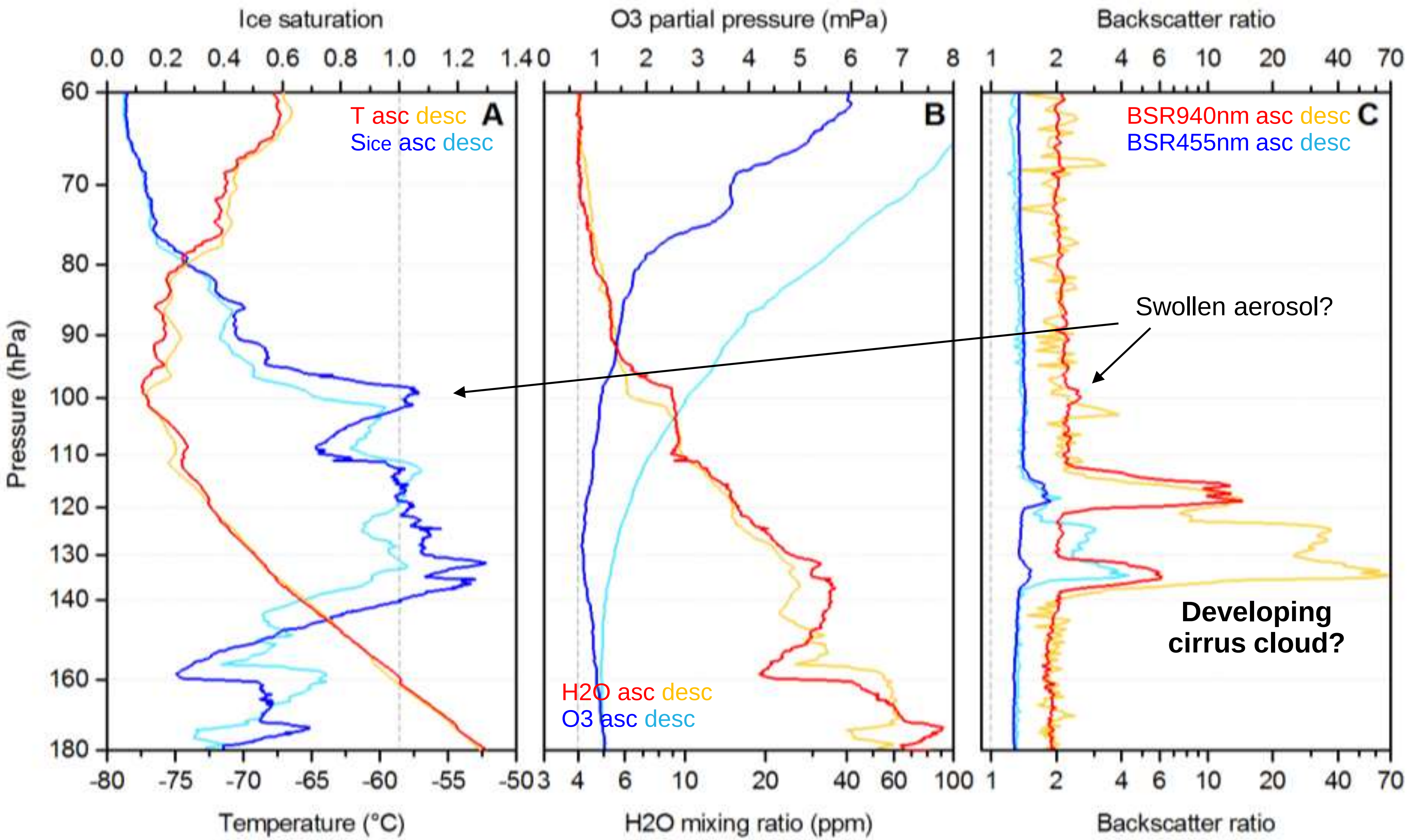
Sounding NT002 - Launched 3 August 2016, 1520 UTC



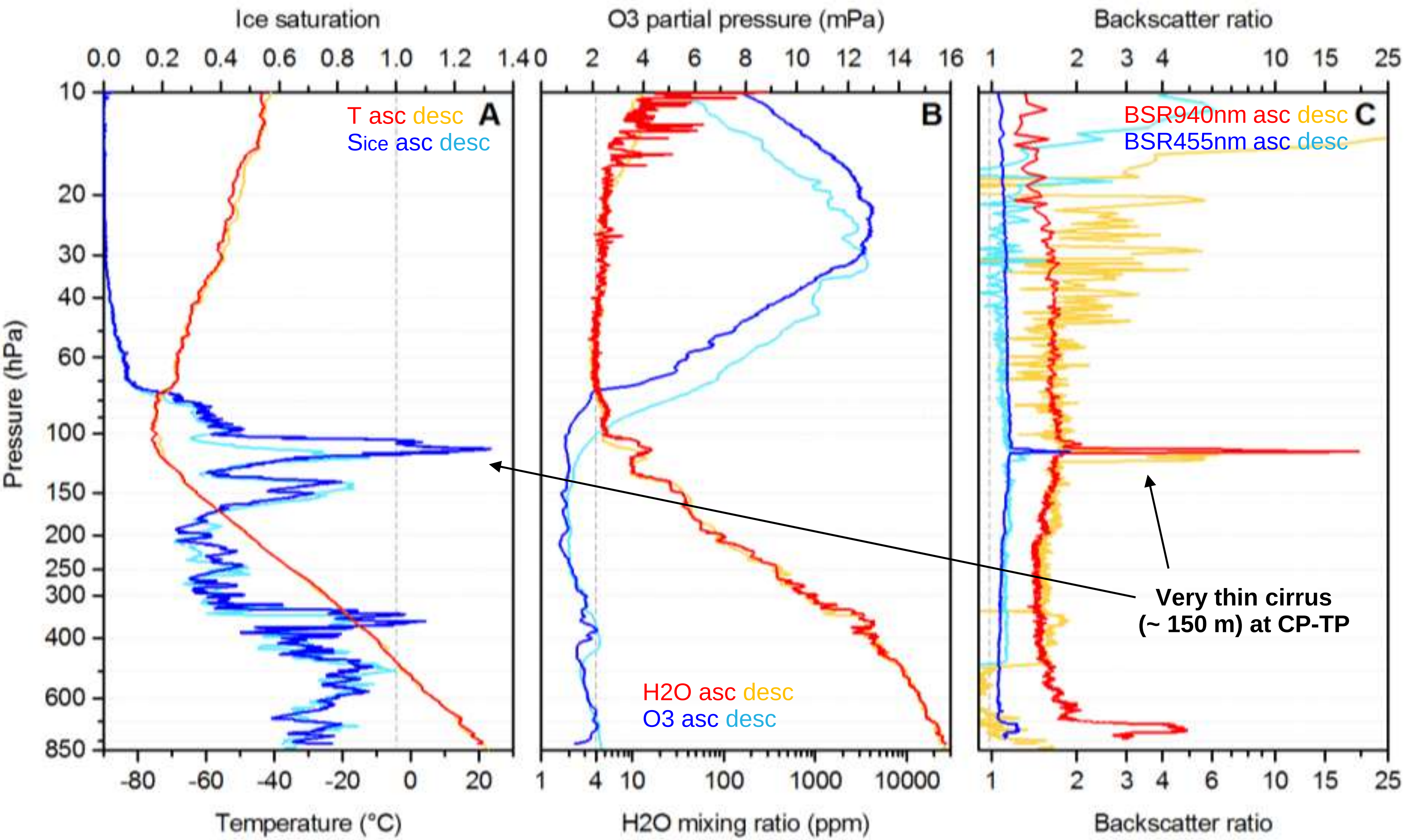
Sounding NT004 - Launched 6 August 2016, 1757 UTC



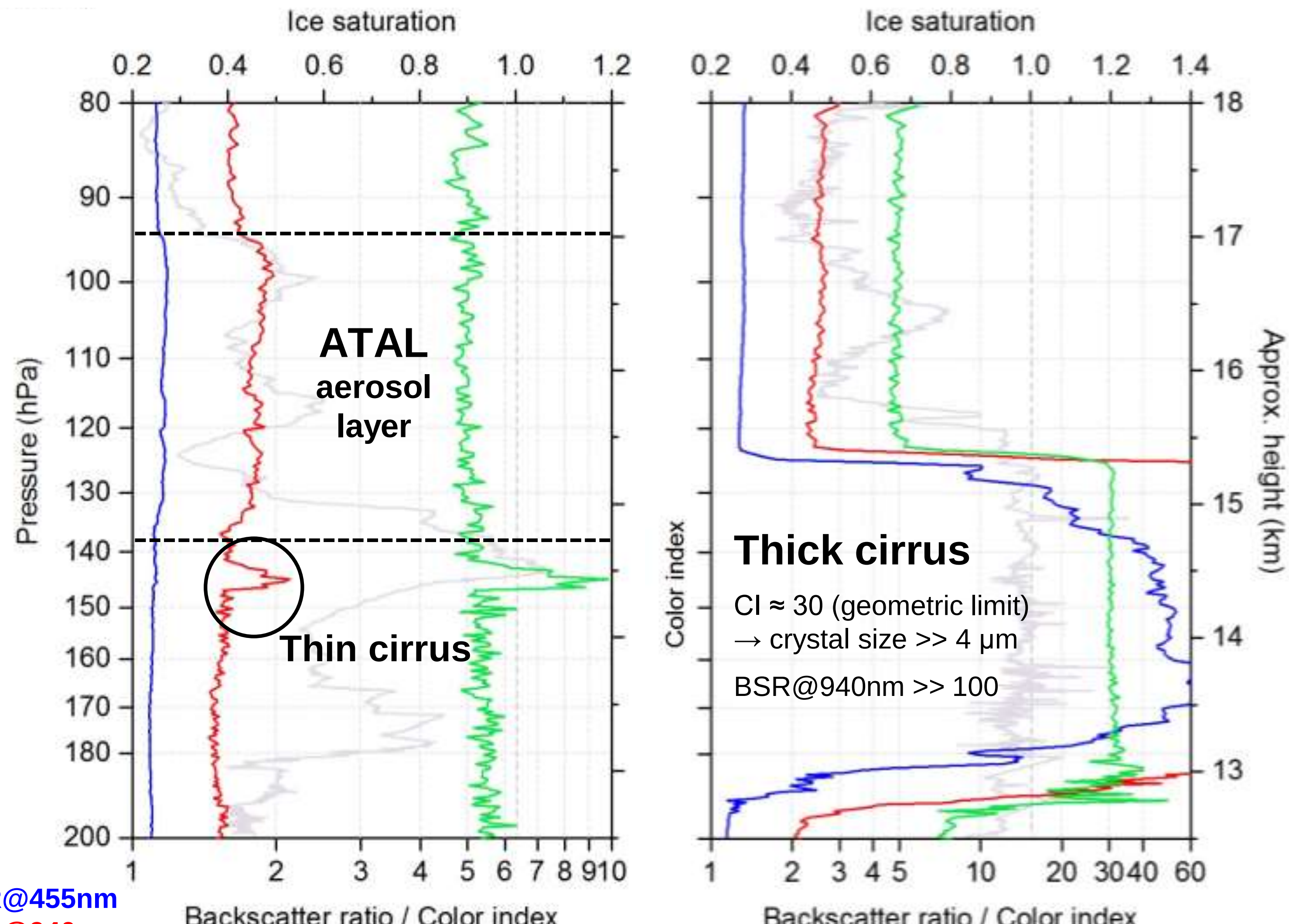
Sounding NT015 - Launched 17 August 2016, 1530 UTC



Sounding NT017 - Launched 18 August 2016, 1604 UTC



UTLS clouds vs aerosols: COBALD interpretation

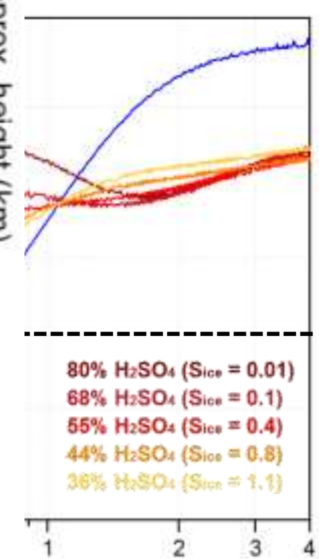


55nm -1)

ıistribution,

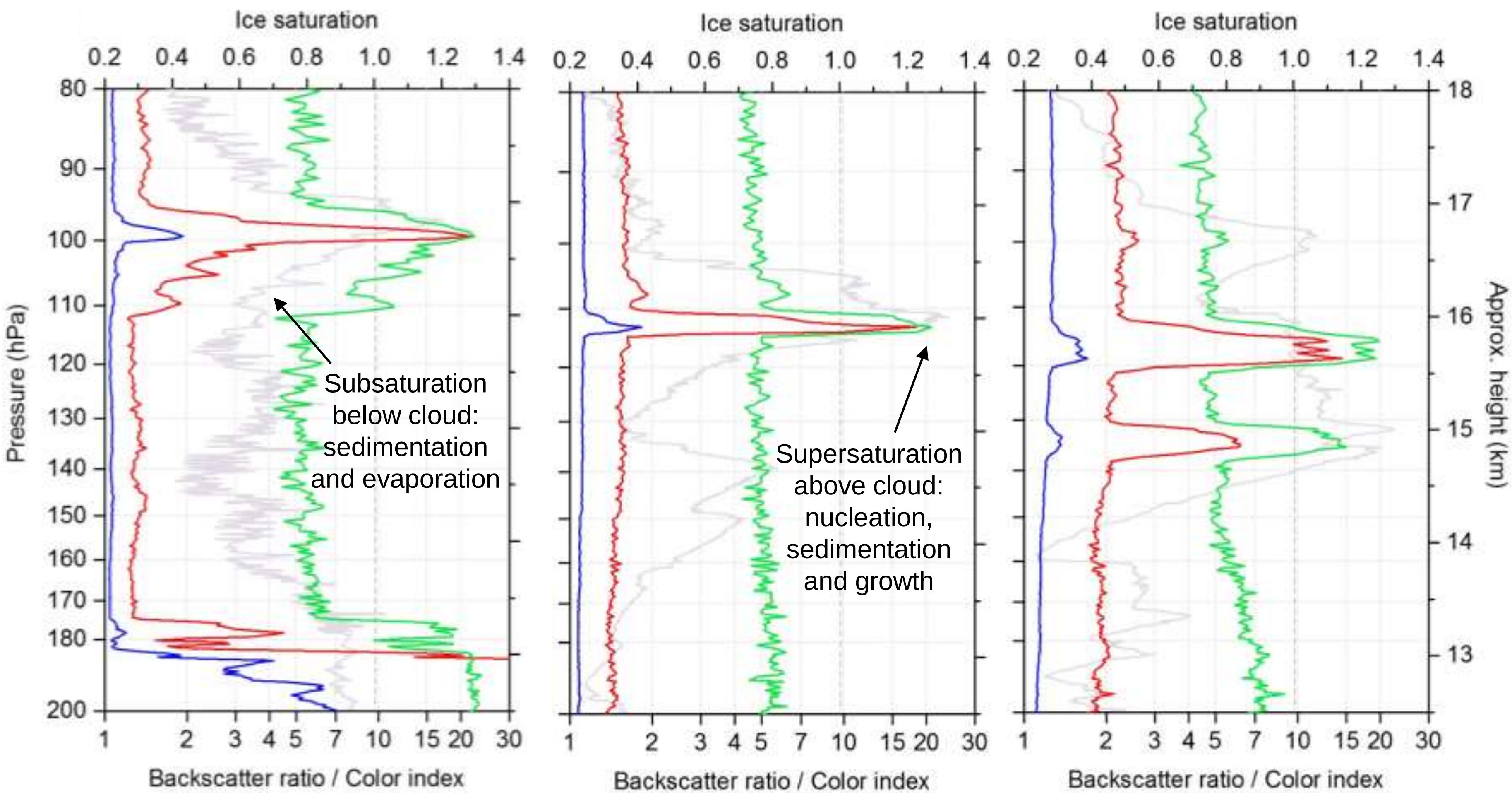
ıber density

particle size



BSR@455nm
BSR@940nm
Color index
Ice saturation (CFH)

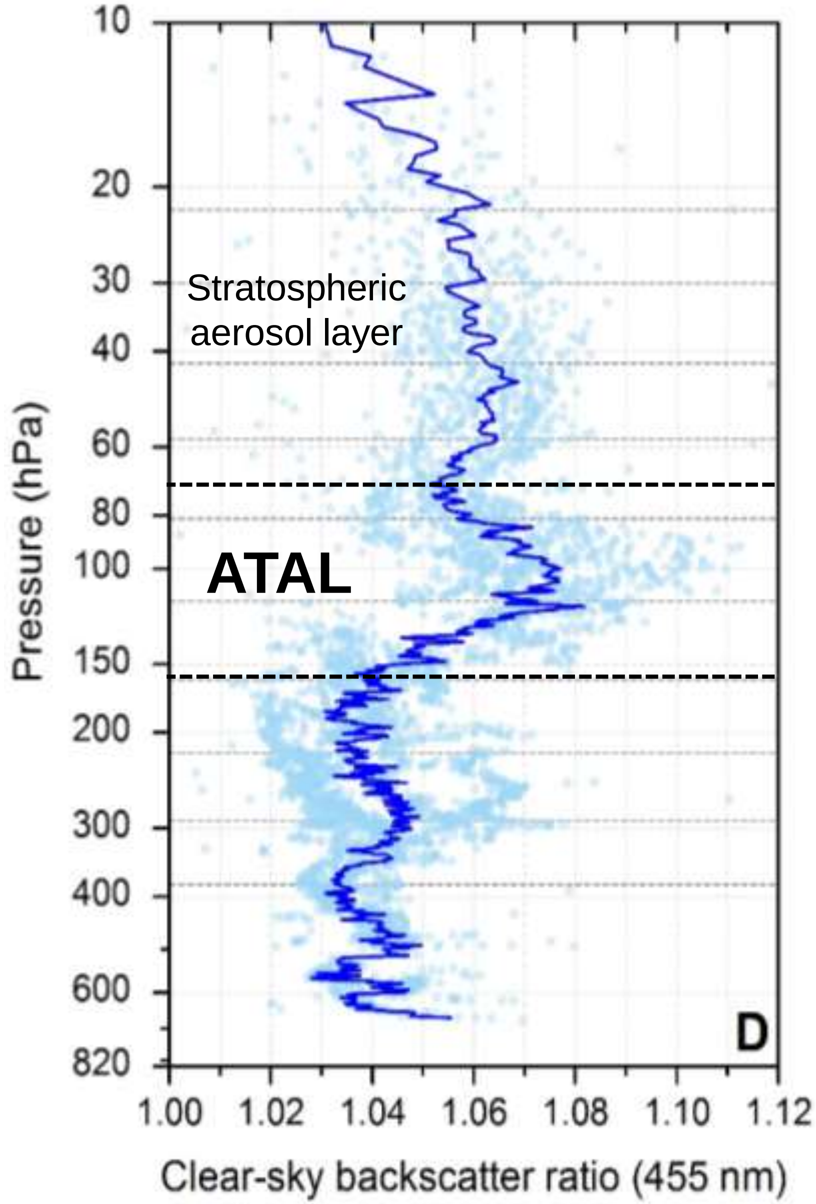
High-altitude, optically-thin cirrus clouds observed in 7/16 COBALD soundings in August 2016



BSR@455nm
BSR@940nm
Color index
Ice saturation (CFH)

Low BSR → Low number density → Heterogeneous nucleation?

Future work: microphysical box modeling simulations



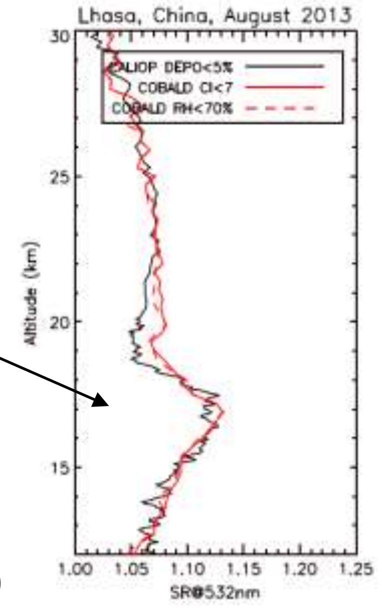
COBALD clear-sky aerosol backscatter (455 nm)

All COBALD data from August 2016 (16 soundings) and mean profile **after subtracting in-cloud data**

Cloud-filtering threshold:

- BSR@940nm < 2.5
- Color index < 7
- Ice saturation < 0.7

similar to Vernier et al. (2015)



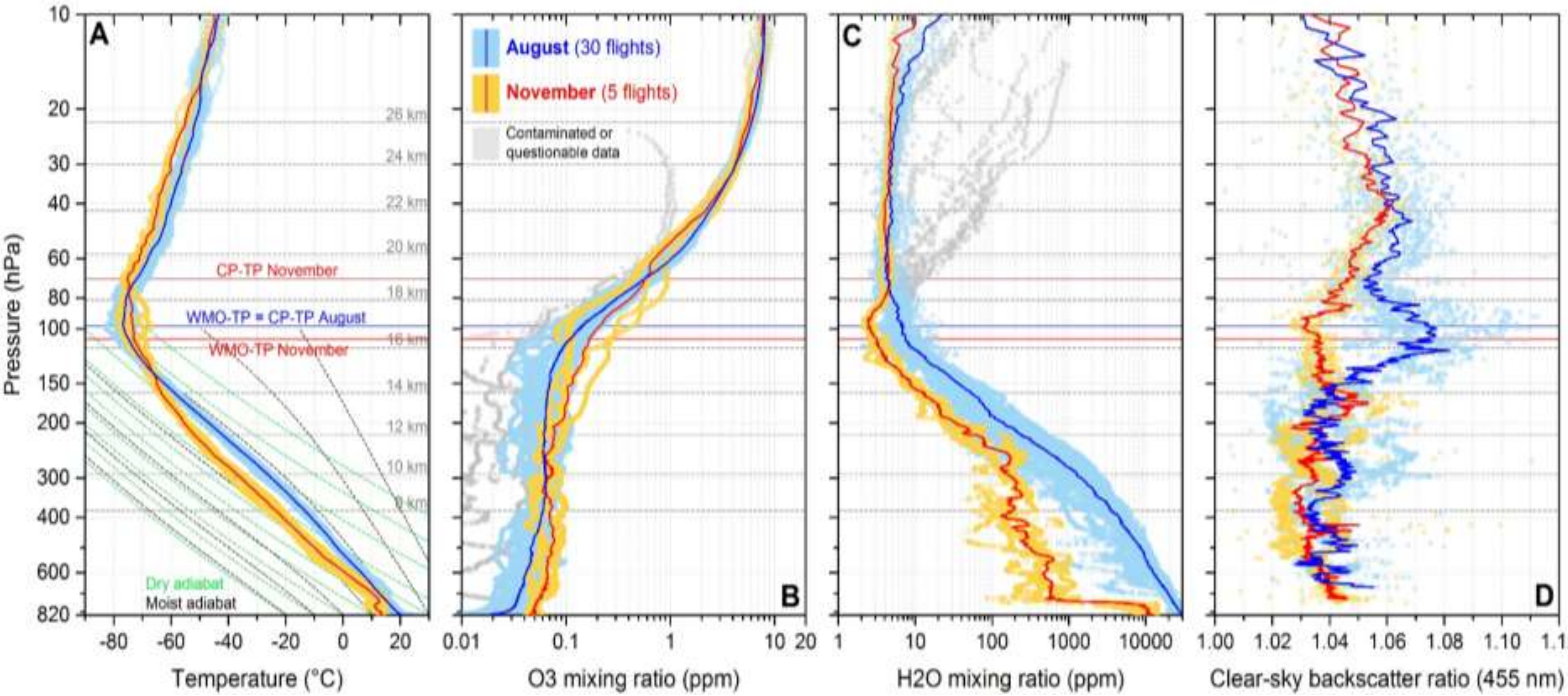
Further refinement planned:

- RHw < 95% for T > 0 °C

(to show boundary layer aerosols)

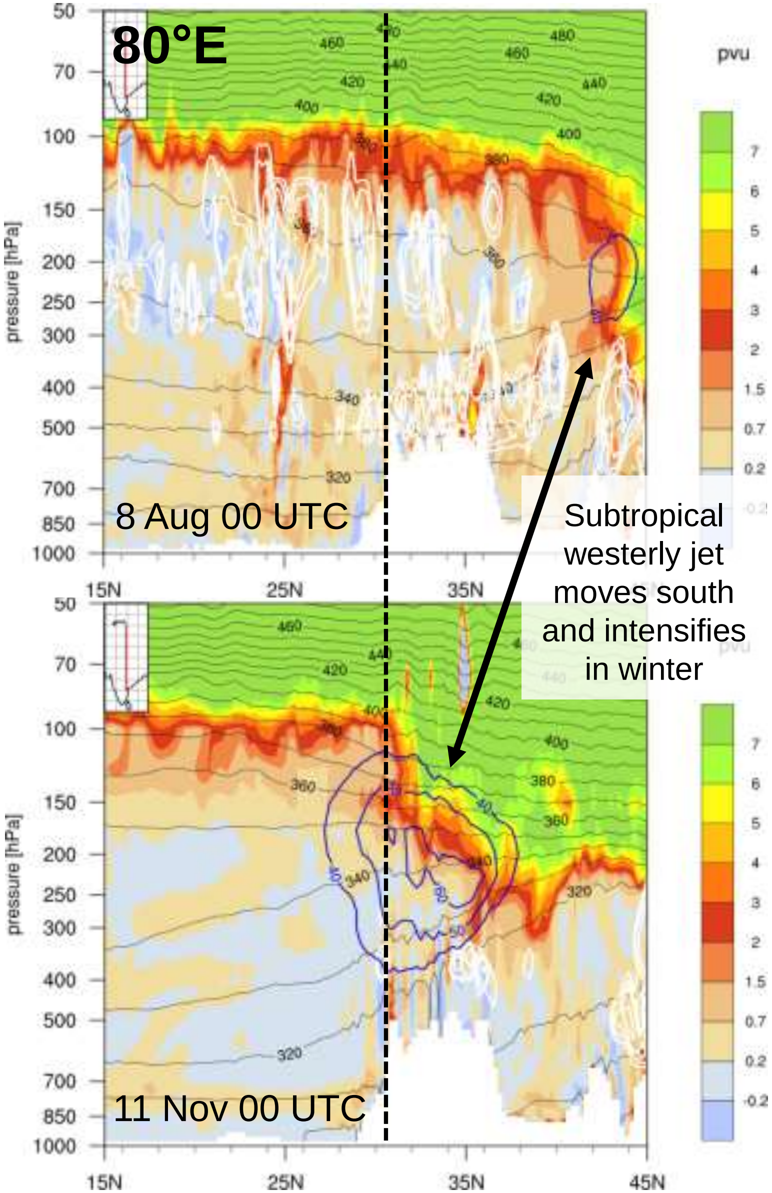
Campaign overview: mean profiles T, O3, H2O, aerosol BSR

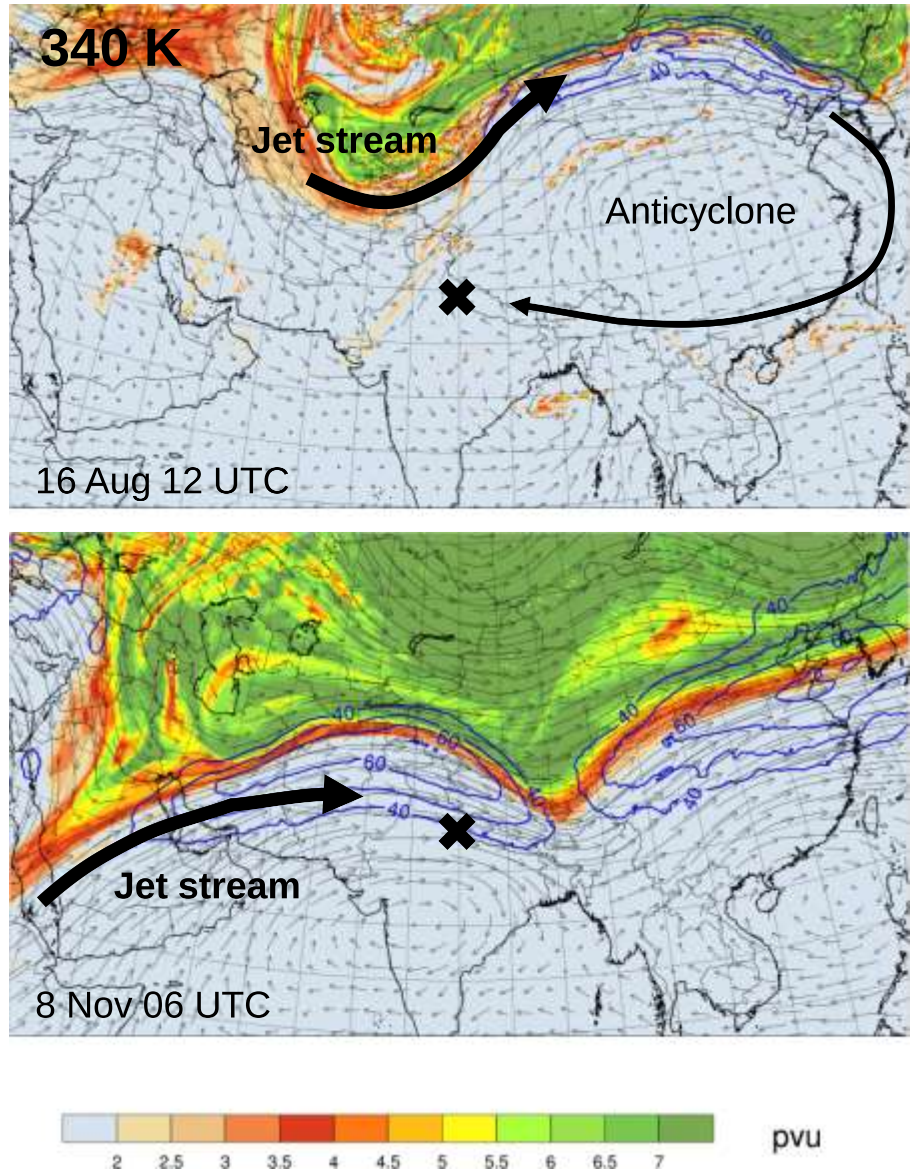
August (30 soundings) vs November (5 soundings)



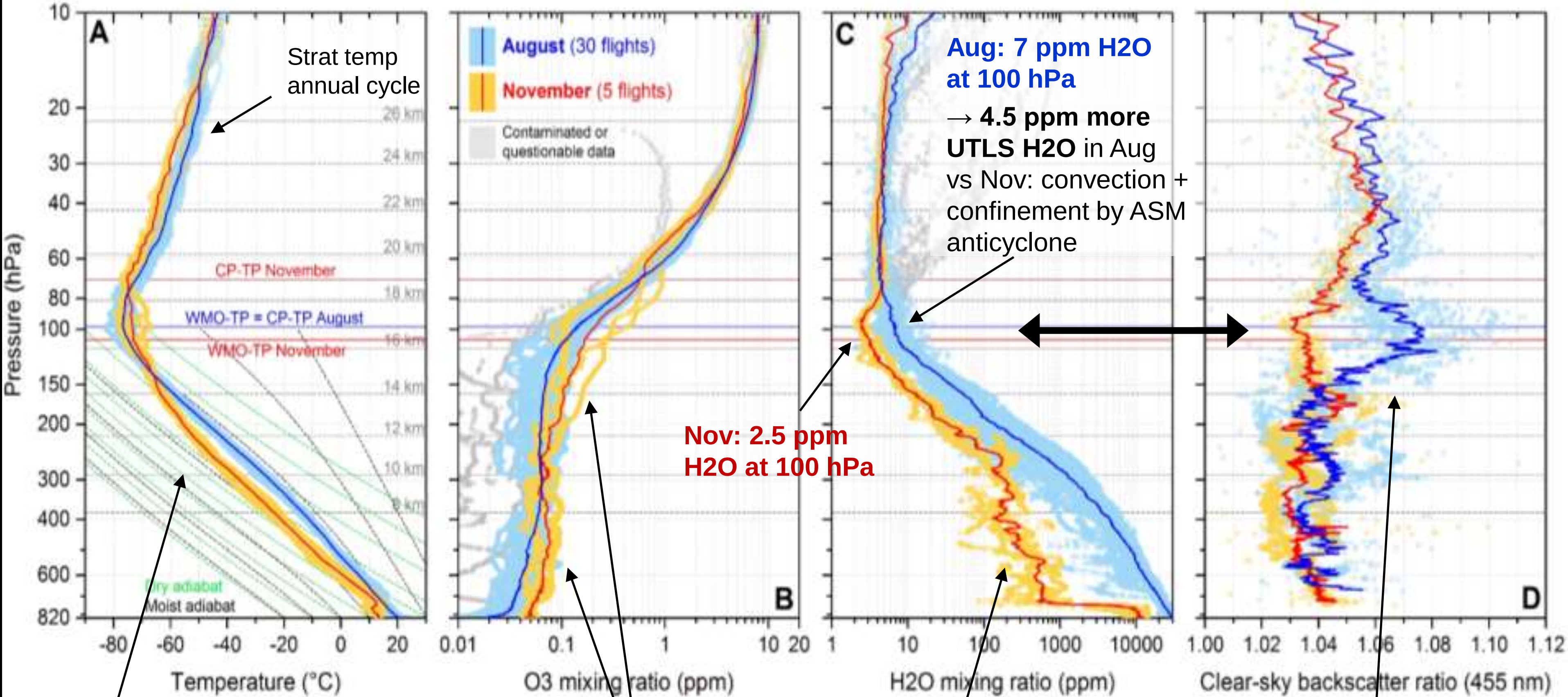
(**A**) Temperature from RS41, (**B**) ozone mixing ratio from ECC, (**C**) water vapor mixing ratio from CFH, (**D**) clear-sky aerosol backscatter ratio (BSR) at 455 nm from COBALD (cloud filtering treshold: color index < 7, BSR 940 nm < 2.5, ice saturation < 0.7). Horizontal lines: mean cold-point tropopause (CP-TP) and WMO tropopause (WMO-TP: lapse rate < 2 °C/km for at least 2 km).

August vs November: meteorological situation (ECMWF analysis data)





Nainital campaign overview: August vs November 2016



August: moist troposphere, sharp cold-point tropopause «tropical»

November: dry troposphere, jet stream, smooth transition between trop-strat «mid-latitude»

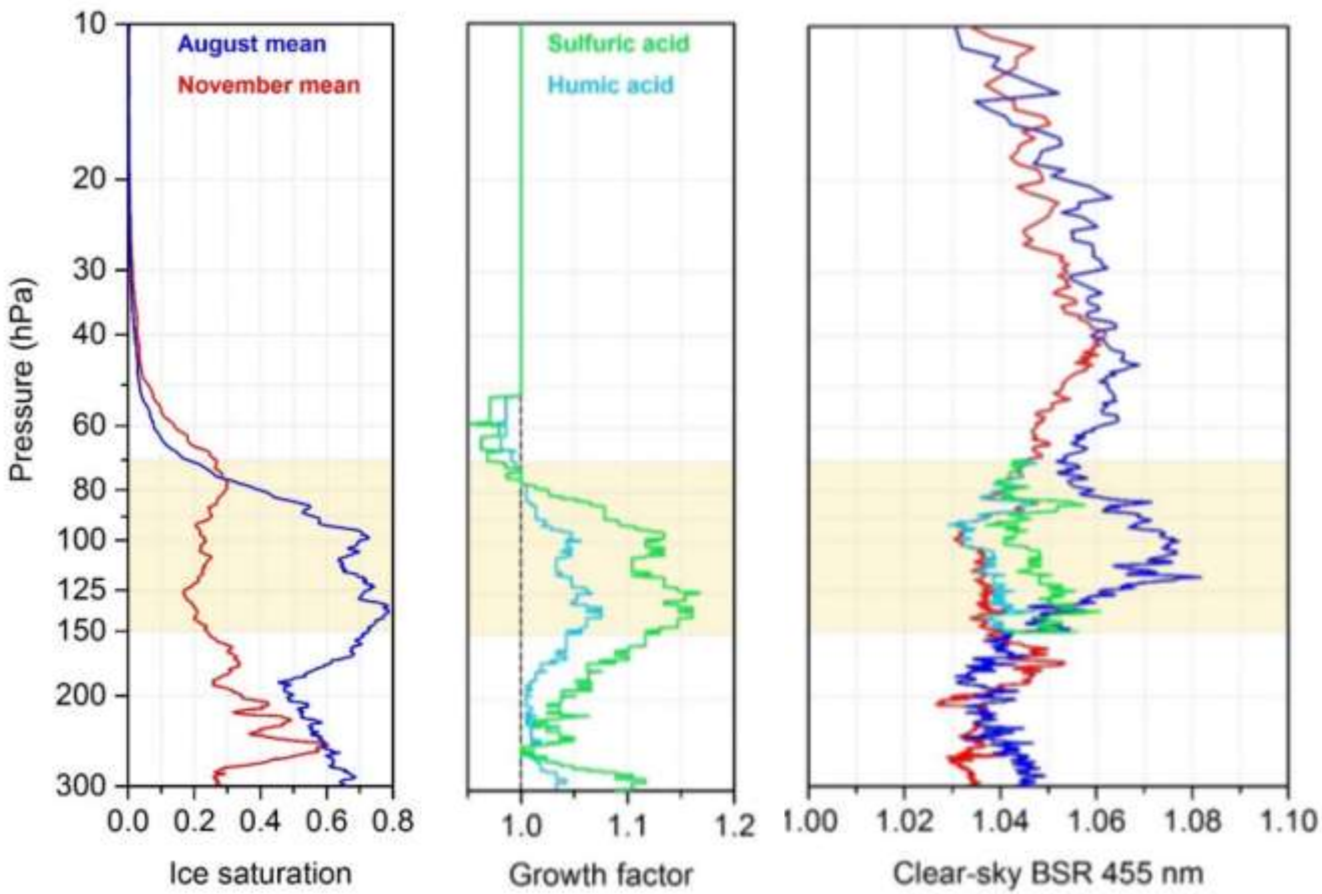
More tropospheric O3 in Nov vs Aug: enhanced NOx washout during monsoon season?

95% less water vapor in the lower troposphere in November vs August: dry vs monsoon season

ATAL aerosol BSR increased by 100% in Aug vs Nov:
secondary aerosol formation?
growth of background aerosol?
transport from boundary layer?

ATAL optical modeling [work in progress]

Assume pre-existing aerosol population (N=100 cm^{-3}) and simulate the change in size due to higher humidity in August vs November (**diffusional growth model**). Then calculate the resulting change in aerosol BSR (**Mie-theory model**).

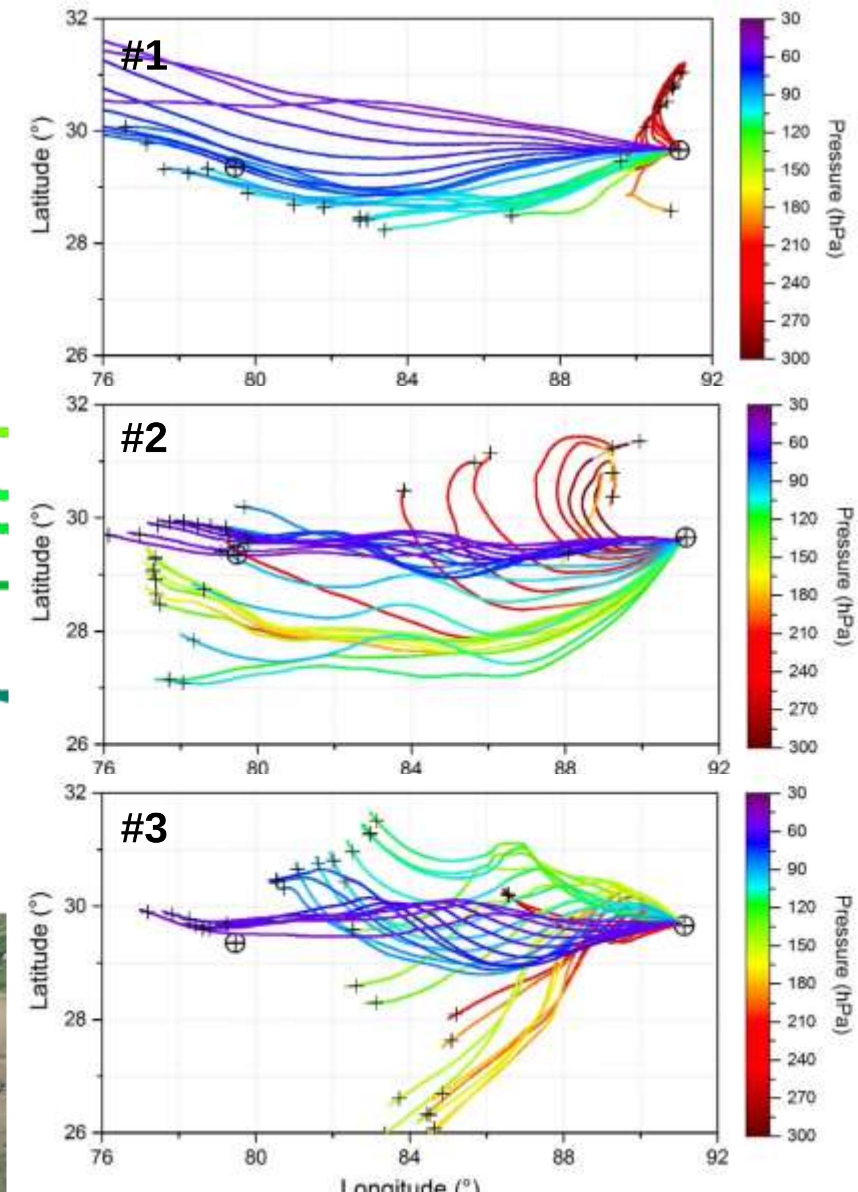


Change in size due to diffusional growth is **not sufficient** to reproduce the BSR difference observed in Aug vs Nov (independent of number density assumed).

This implies that either secondary aerosol formation or transport of particulate matter by convection is involved in ATAL formation.

Sulfuric acid: growth factor from diffusional growth model
Humic acid: growth factor parameterization from Badger et al. (2006)

Lagrangian match measurements: Lhasa-Nainital



…sa, SWOP campaign)
…n track based on ECMWF forecast
(Nainital) for best match with trajectories

LAGRANTO trajectories along ECMWF analysis (6-hourly) + forecast (1-hourly) data, resolution 0.125°

34 km
26 km
10 km

Match #1
Lhasa LH104 – 2 Aug 1532 UTC
Nainital NT002 – 3 Aug 1520 UTC

Match #2
Lhasa LH109 – 10 Aug 1928 UTC
Nainital NT007 – 11 Aug 1857 UTC

Match #3
Lhasa LH113 – 18 Aug 1732 UTC
Nainital NT018 – 19 Aug 1728 UTC

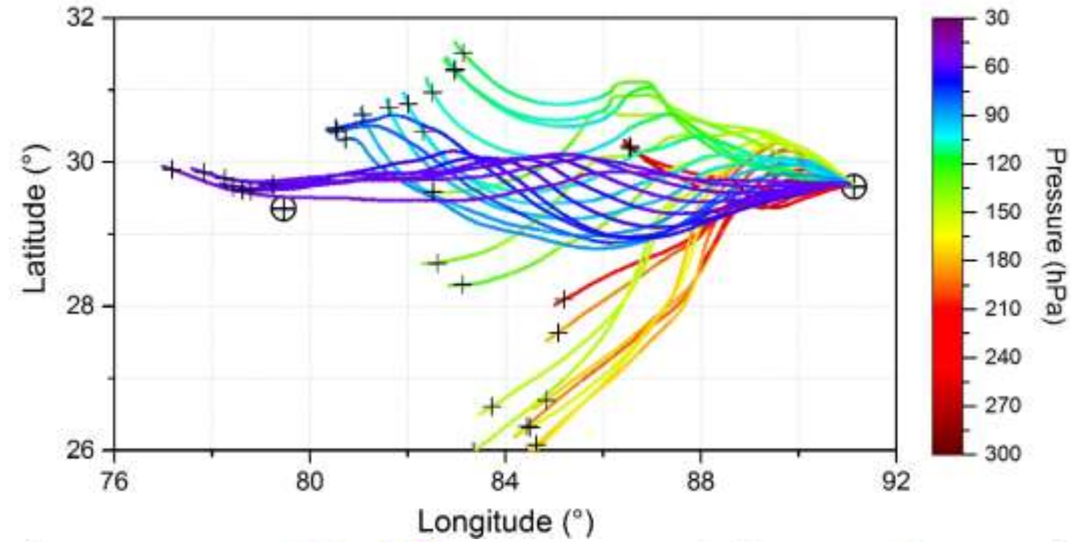
Time = 0

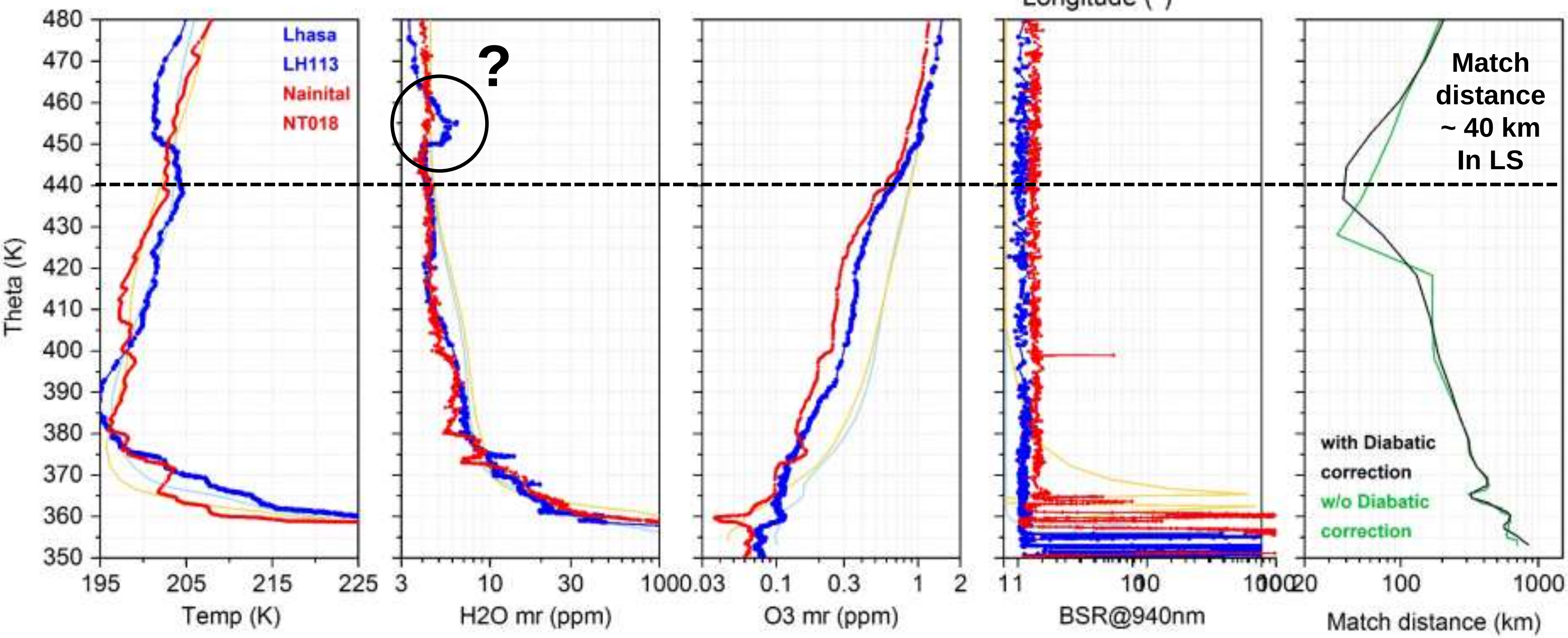
google.com/maps

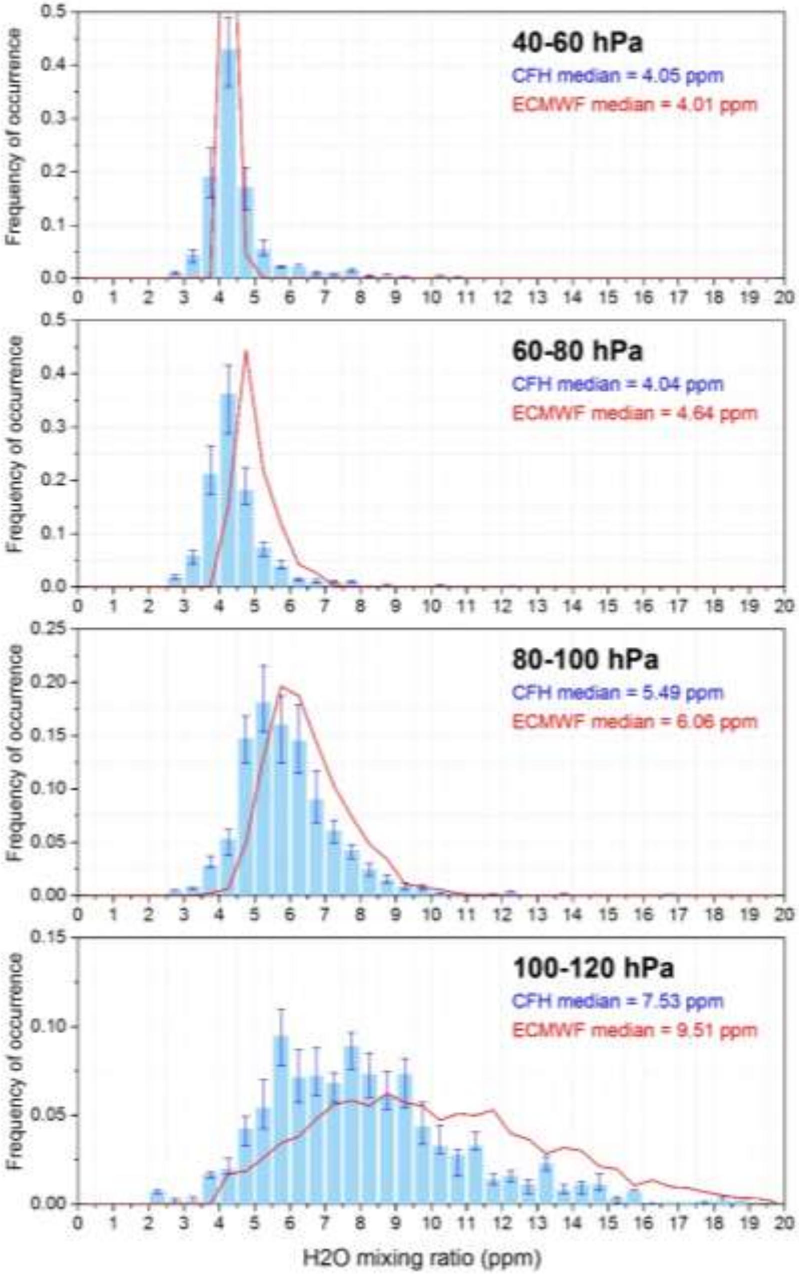
Lhasa LH113 – 18 Aug 1732 UTC
Nainital NT018 – 19 Aug 1728 UTC

Trajectories: LAGRANTO based on ECMWF analysis (6-hourly) + forecast (1-hourly), resolution 0.125°

Diabatic correction: vertical motion calculated with Fu and Liou [1993] model for heating rates by cirrus clouds



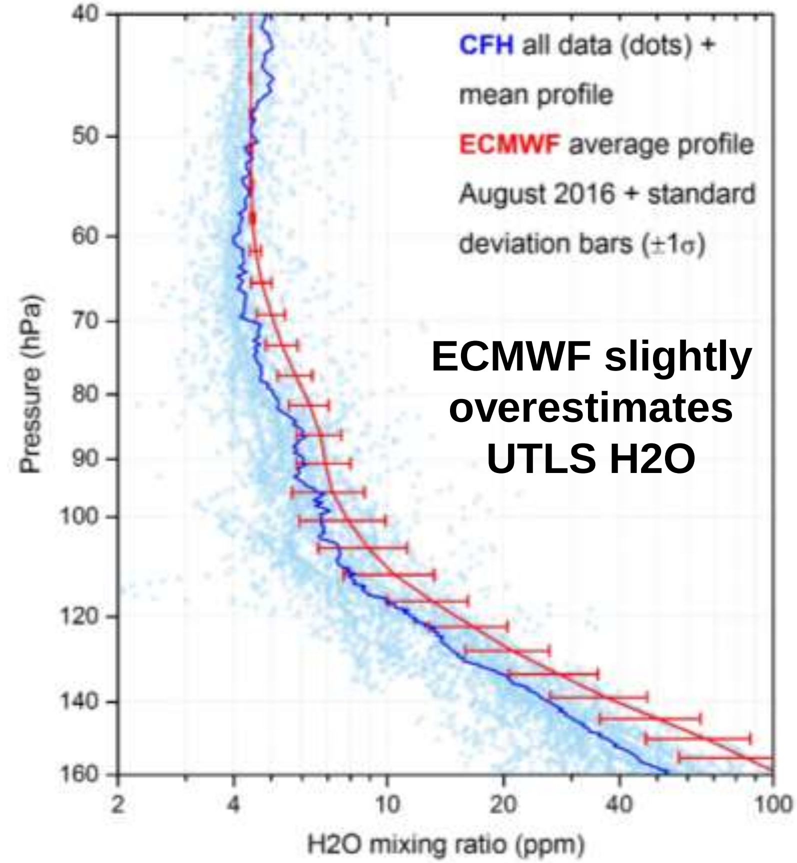




UTLS H2O: CFH vs ECMWF

CFH: all data from 29 soundings (2-31 August 2016)

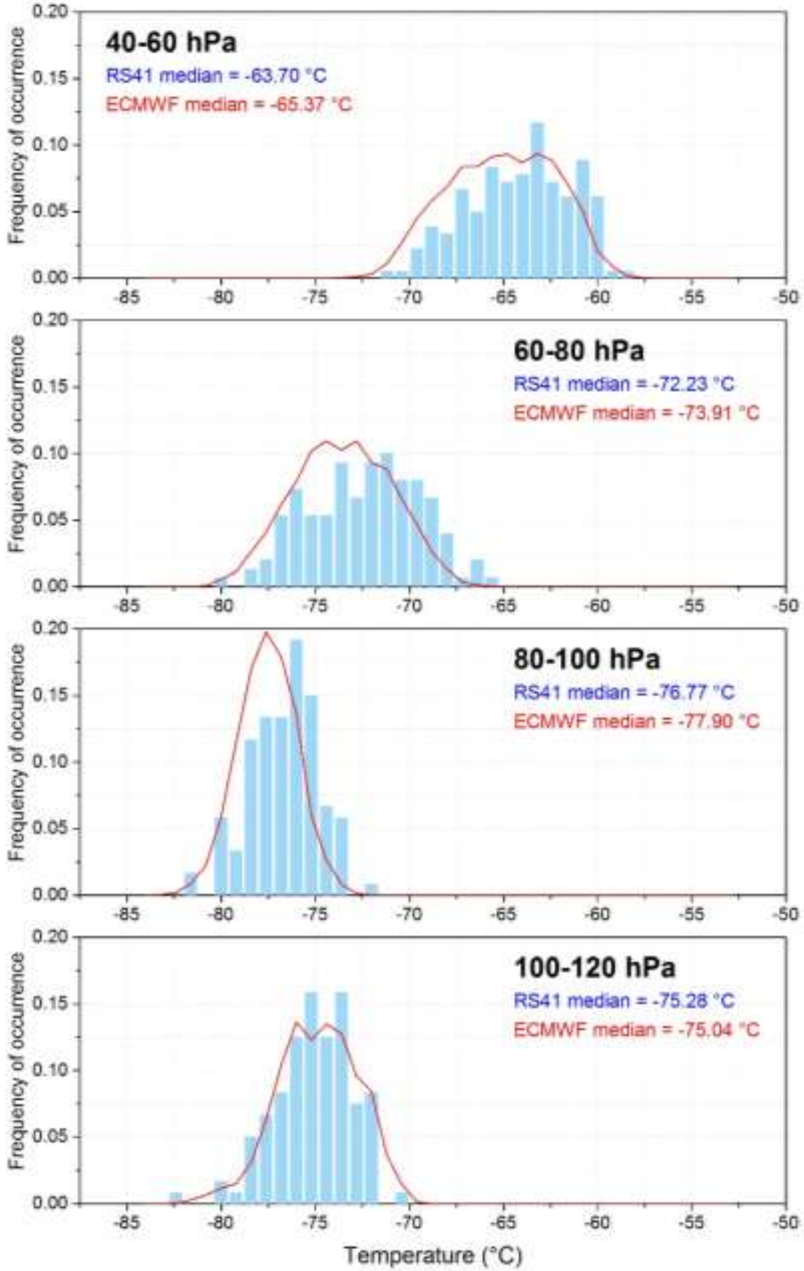
ECMWF: analysis (6-hourly) + forecast (1-hourly) data, 0.125° resolution, August 2016 (entire month)

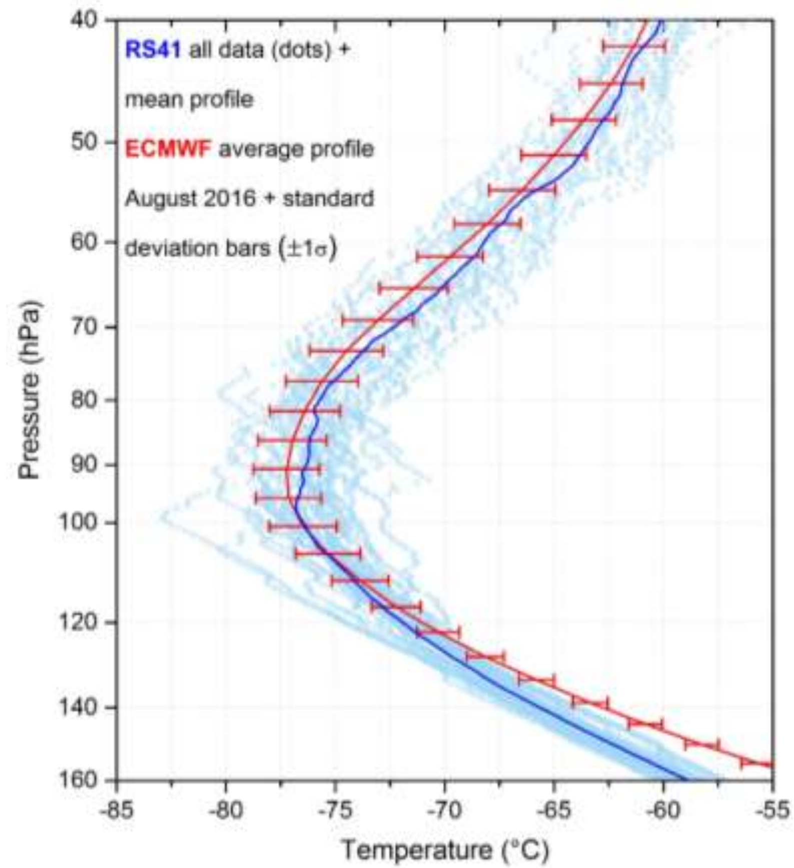


UTLS Temp: RS41 vs ECMWF

RS41: all data from 29 soundings (2-31 August 2016)

ECMWF: analysis (6-hourly) + forecast (1-hourly) data, 0.125° resolution, August 2016 (entire month)





In summary

- 30 balloon-borne profiles of T, H2O, O3 and aerosol BSR measured in Nainital, India (southern slopes of Himalaya) in August 2016 + 5 in November 2016
- Many high-resolution observations of optically-thin cirrus clouds inside the ASMA
  Future work: microphysical simulations to estimate ice number density
- In-situ observations of Asian tropopause aerosol layer (ATAL)
- High quality H2O measurements up to the middle stratosphere: 4.5 ppm more H2O at the UTLS in August vs. November
- Statistical comparison of UTLS H2O and T with ECMWF analysis
- 3 match measurements with SWOP campaign in Lhasa, China
- **New campaign in July-August 2017, coordinated with Geophysica-M55**

StratoClim