Understanding balloon-borne frost point hygrometer measurements after contamination by mixed-phase clouds

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New Science

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StratoClim balloon campaigns

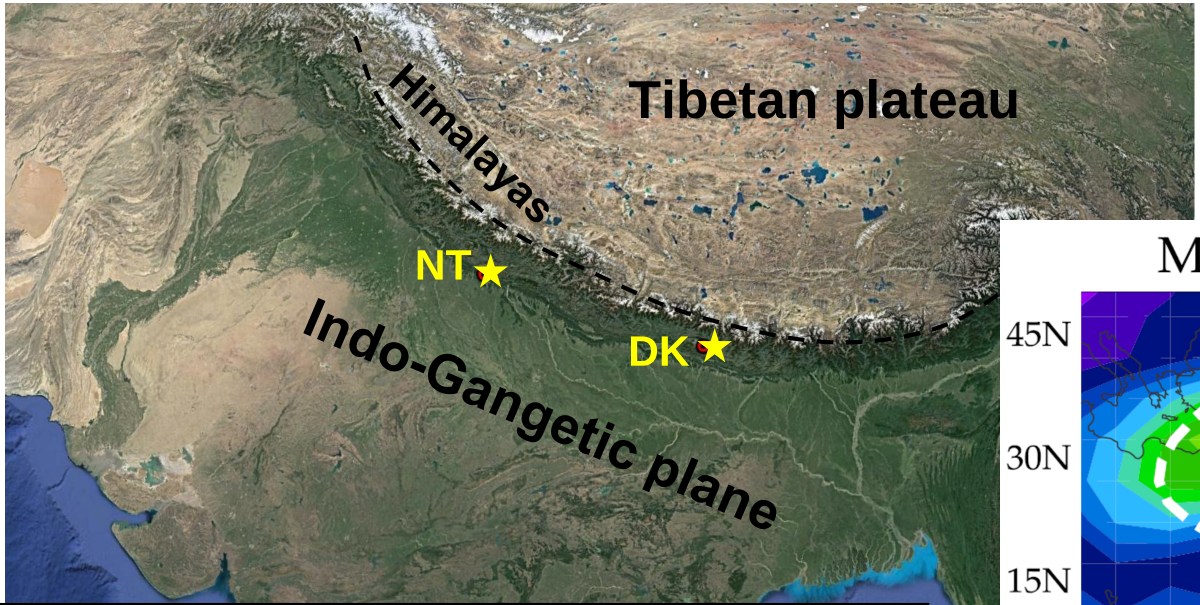
Southern slopes of the Himalayas

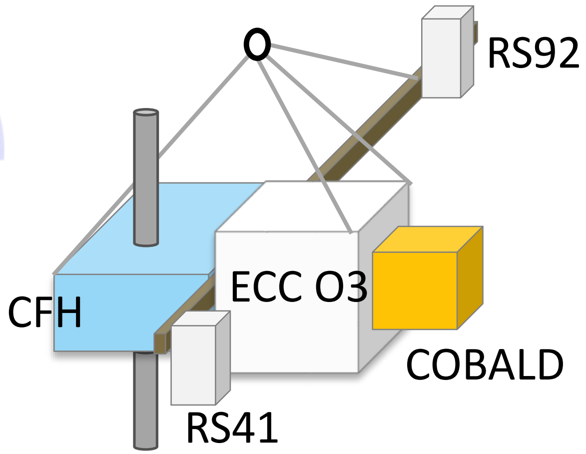
- **Nainital, India**

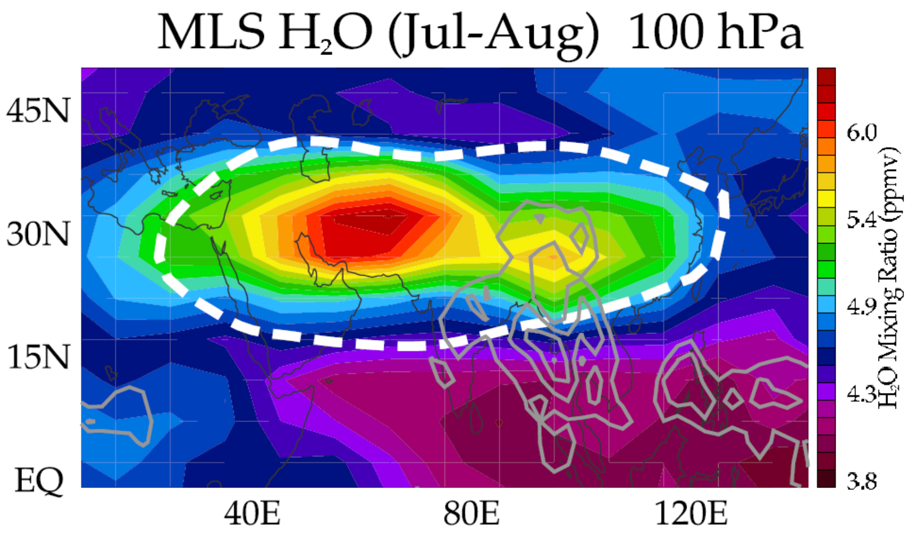
  (abbrev. **NT**)
  29.4° N, 79.5° E
  1820 m a.s.l.

- **Dhulikhel, Nepal**

  (abbrev. **DK**)
  27.6° N, 85.5° E
  1530 m a.s.l.







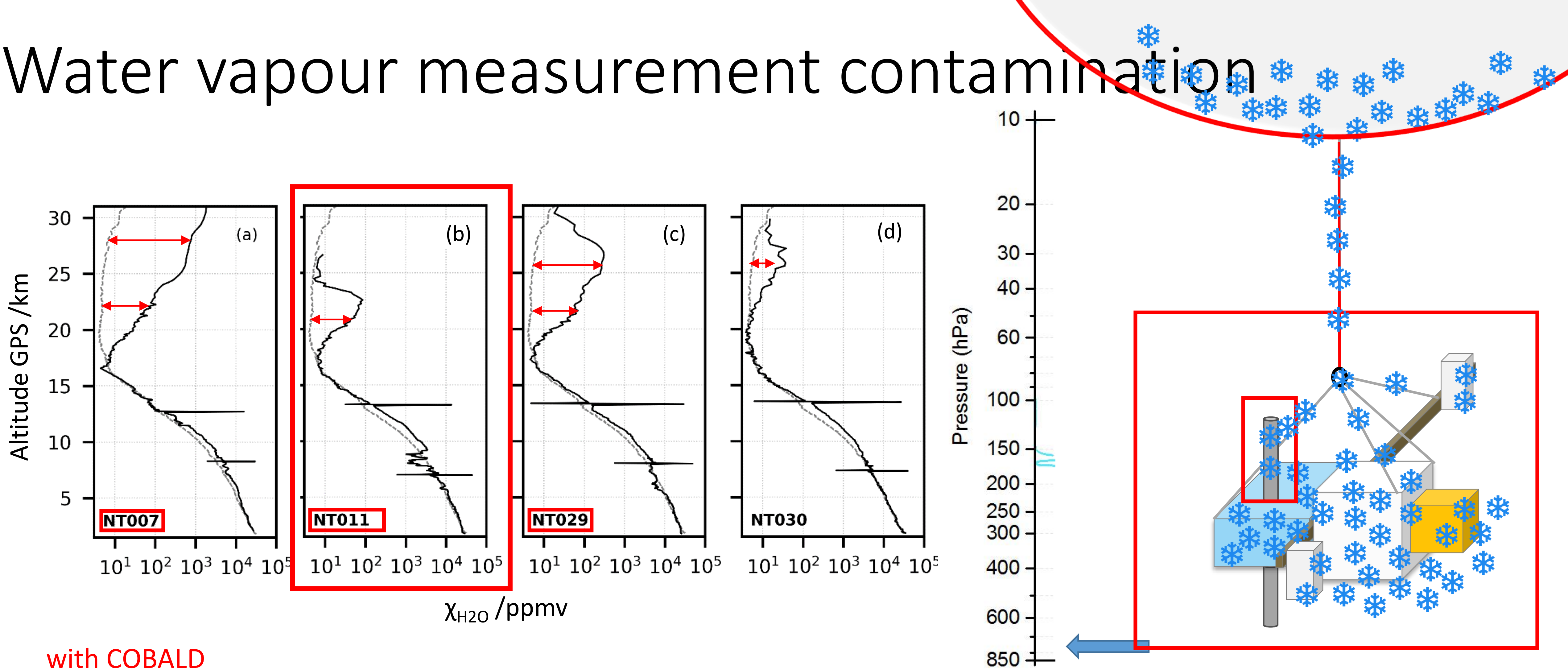
Park *et al.* (2007)

Station	*Campaign period*	*No. soundings*	*CFH*	*contaminated*
NT	2-31 August 2016	30	27	5
NT	5-8 November 2016	5	5	0
DK	30 July - 12 August 2017	28	11	4
Total		**63**	**43**	**9**

~ 20%

Adapted from Brunamonti et al., 2018

Water vapour measurement contamination



with COBALD

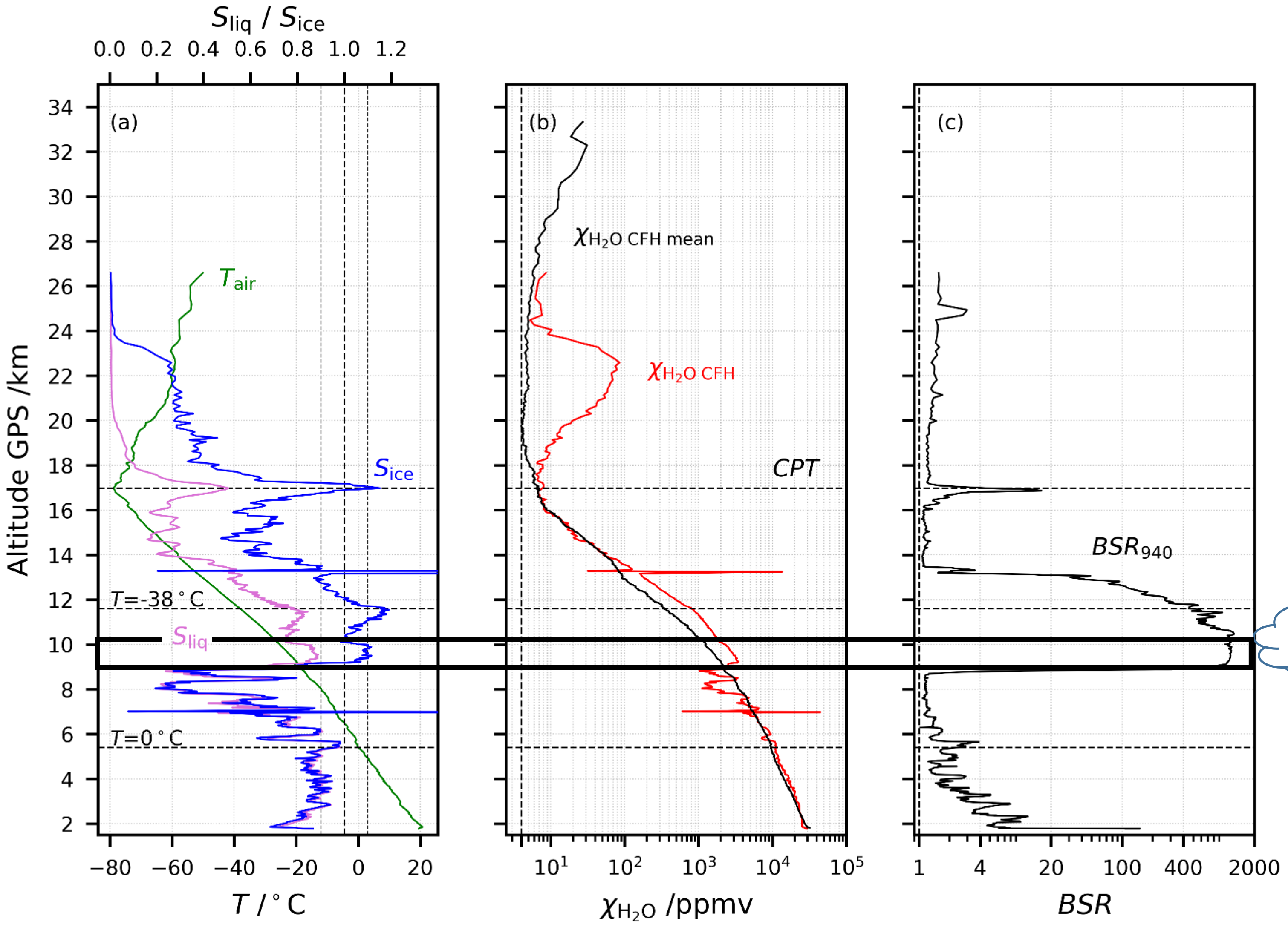
Payload goes through a mixed-phase cloud in the troposphere.

Supercooled water freezes on the surfaces, specially inside the intake tube;

which later sublimates in the dryer warmer stratosphere.

Intake tube vs balloon contamination

NT011 flight



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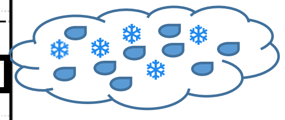
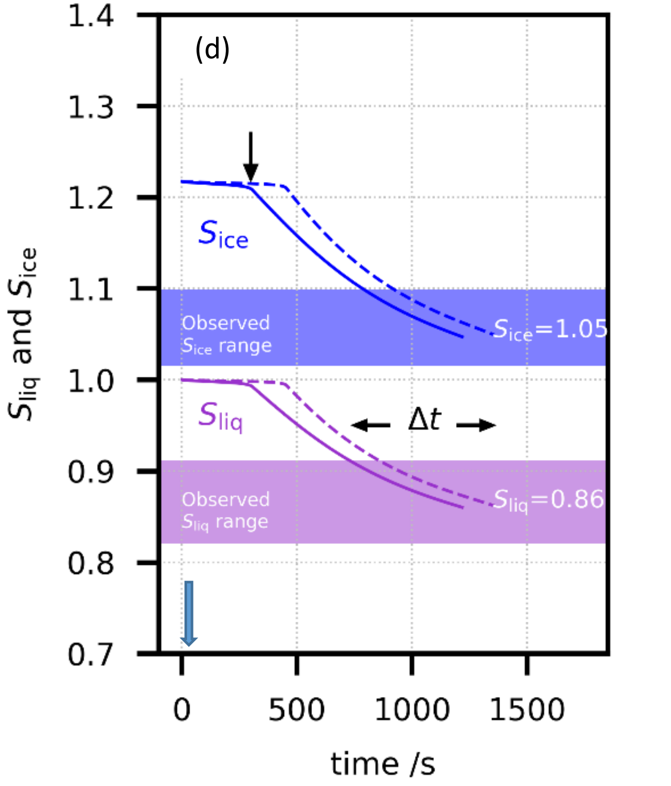


$S_{liq} < 1$

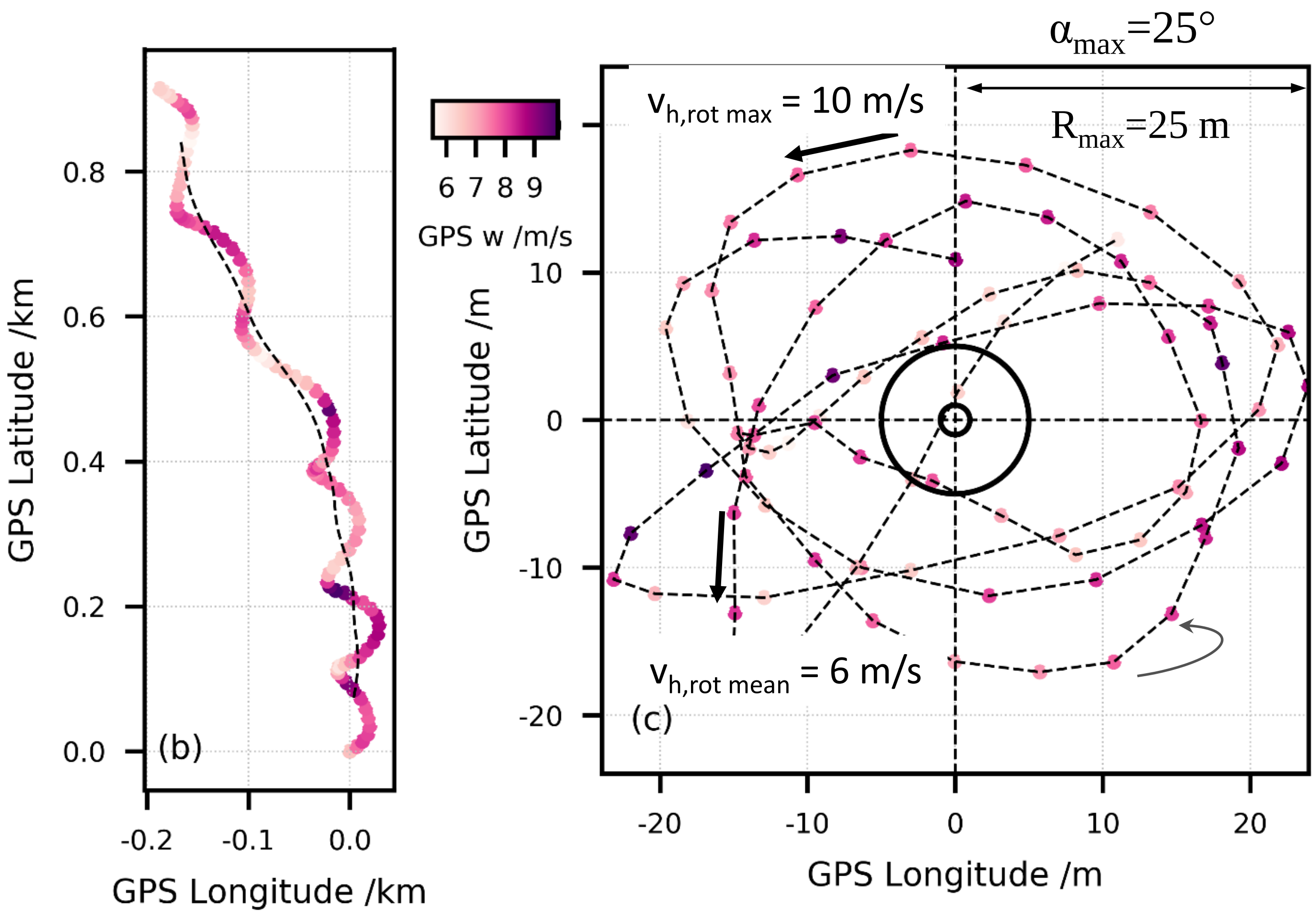
Glaciation simulation results

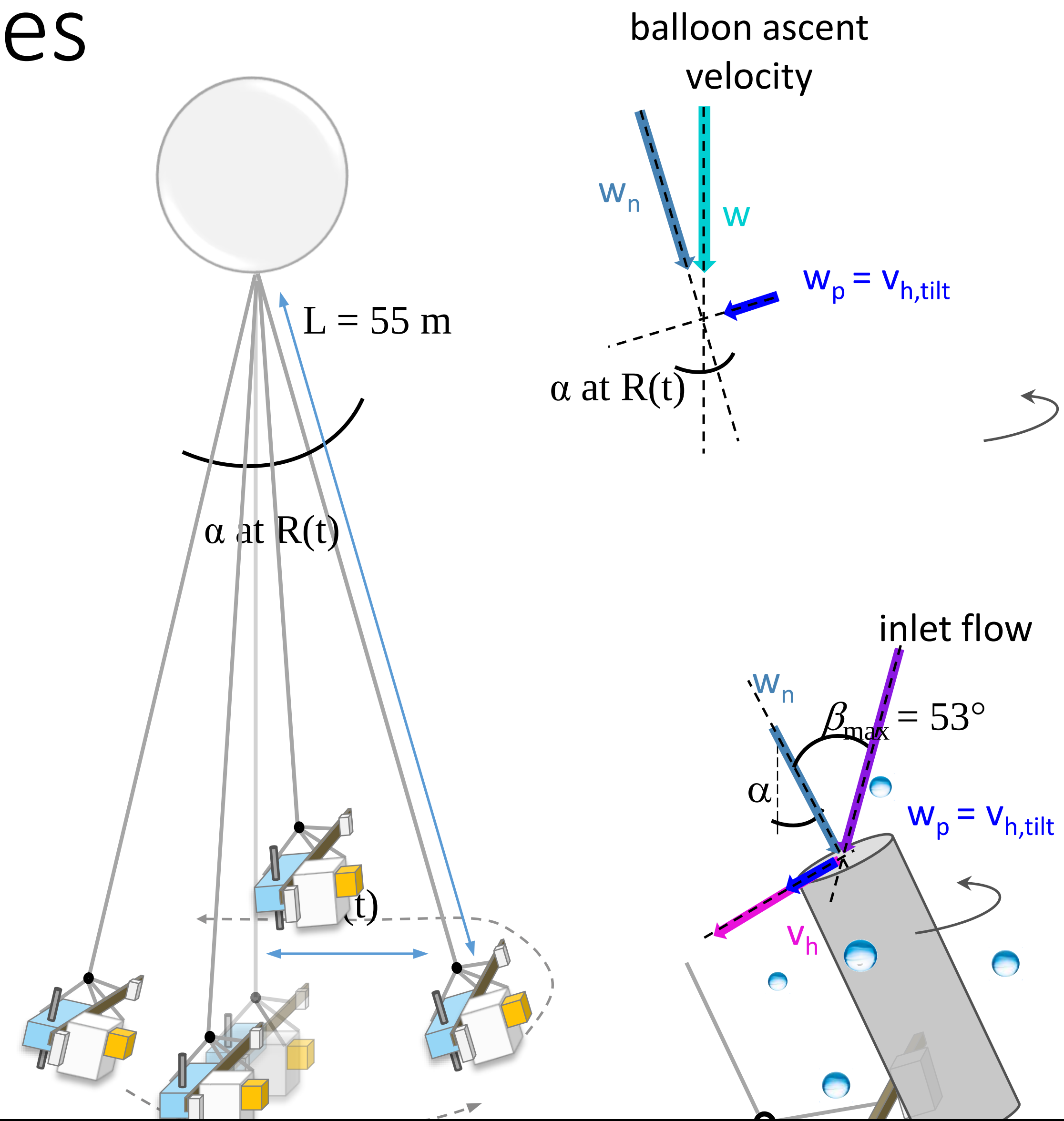


no secondary ice formation

After the small liquid droplet evaporate, the big droplets can survive at the observed water subsaturation.

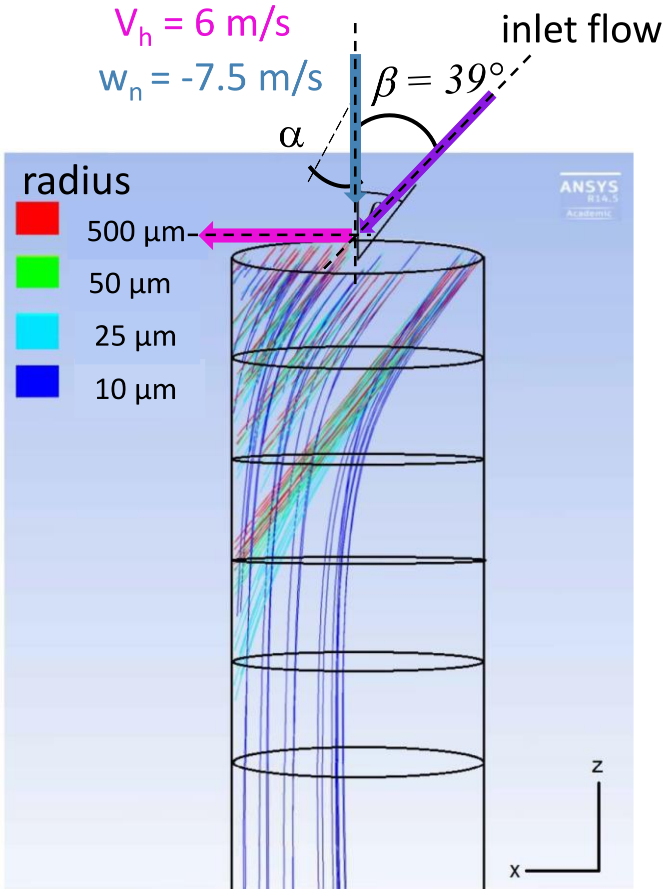
Payload oscillation, collision angles



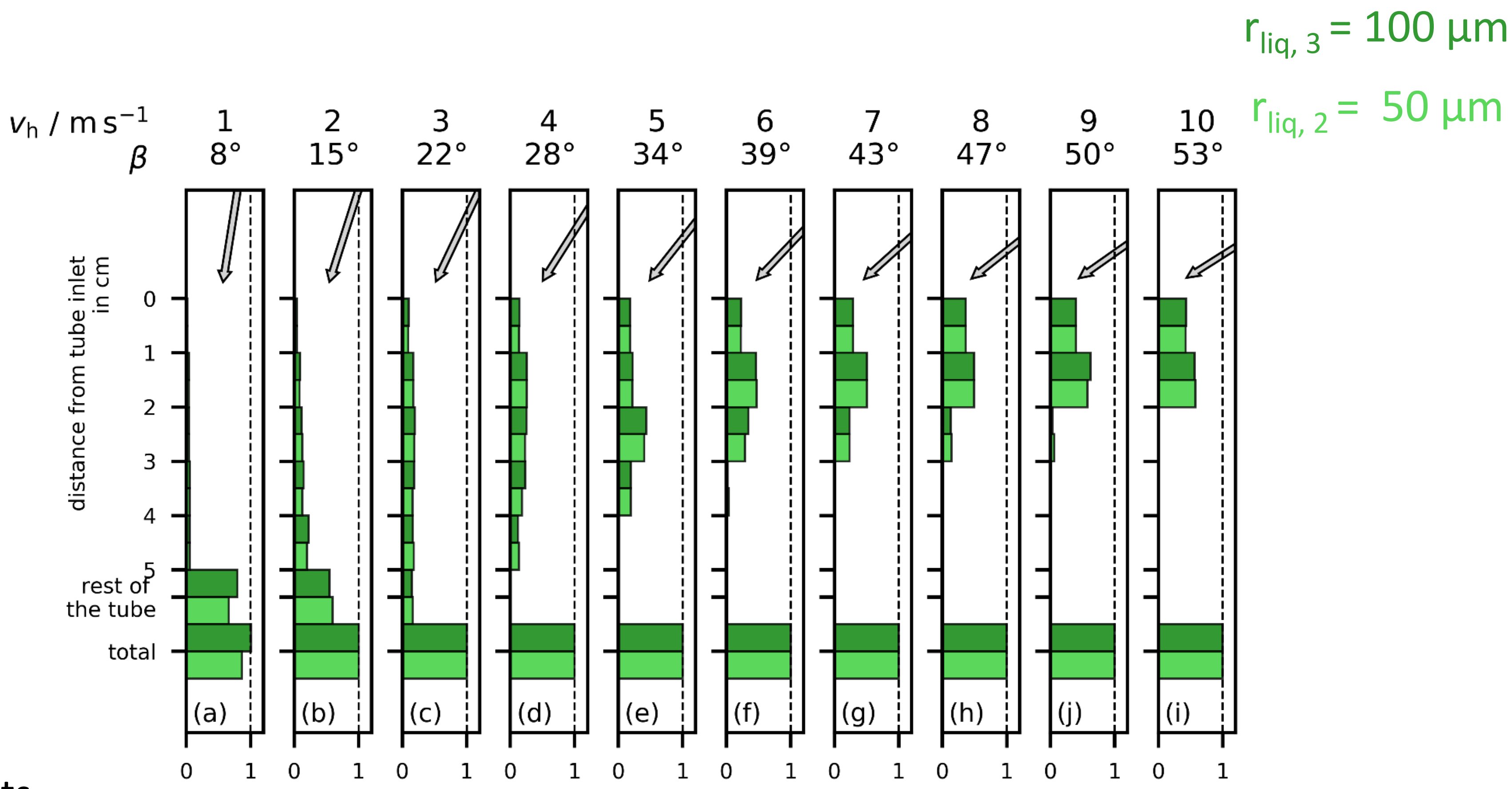


Payload pendulum motion creates collision trajectories for the supercooled droplets inside the intake tube.

Formation of icy layer at top of intake tube

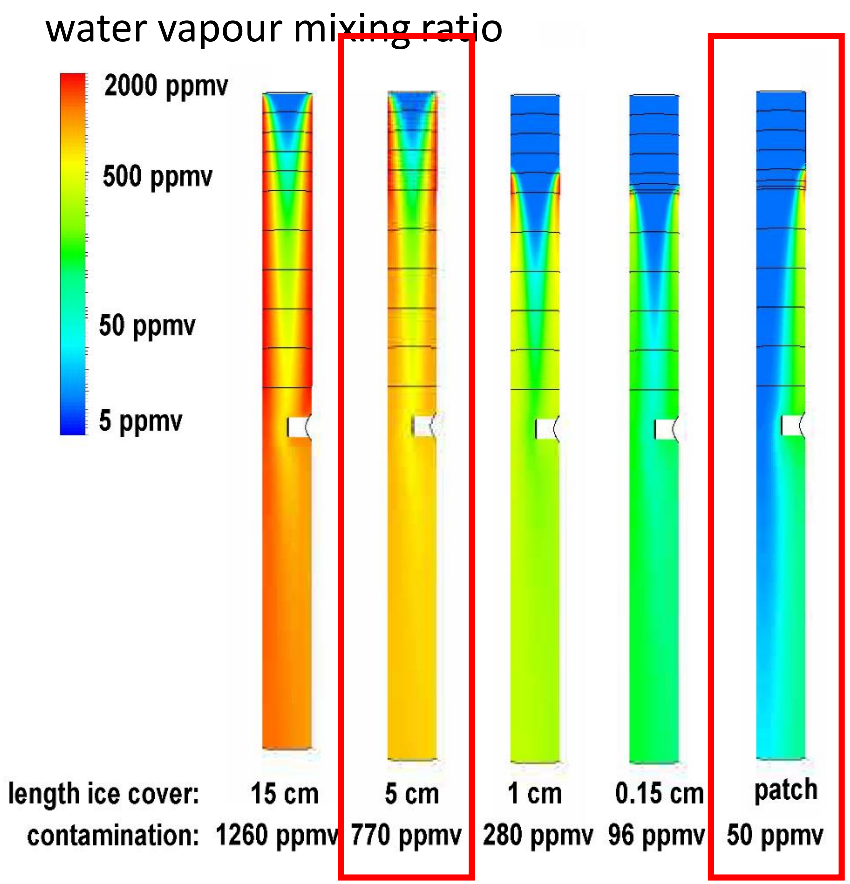


Computational fluid dynamics results



Due to high frequency of big inlet angles the supercooled droplets accumulate at the top of the intake tube.

Contamination in the stratosphere



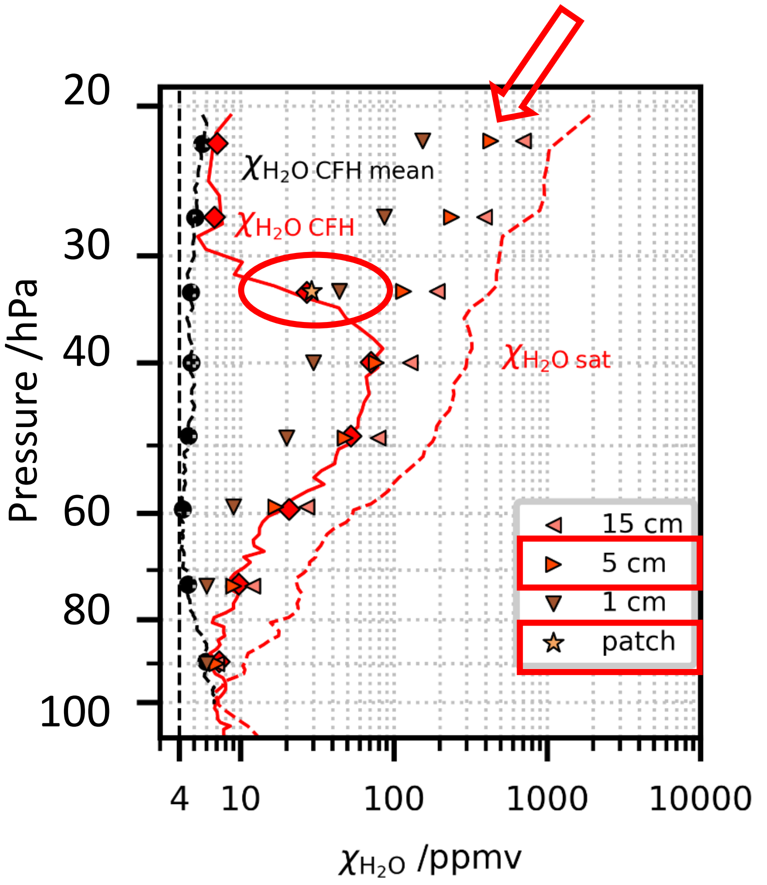
Computational fluid dynamics results for p= 15 hPa, T= -51.4 °C

$$\int H_2O = 4.35\ \mathrm{mg}$$

Cloud thickness 750 m

Collision efficiency 100%

Cloud LWC 0.011 g m^{-3}

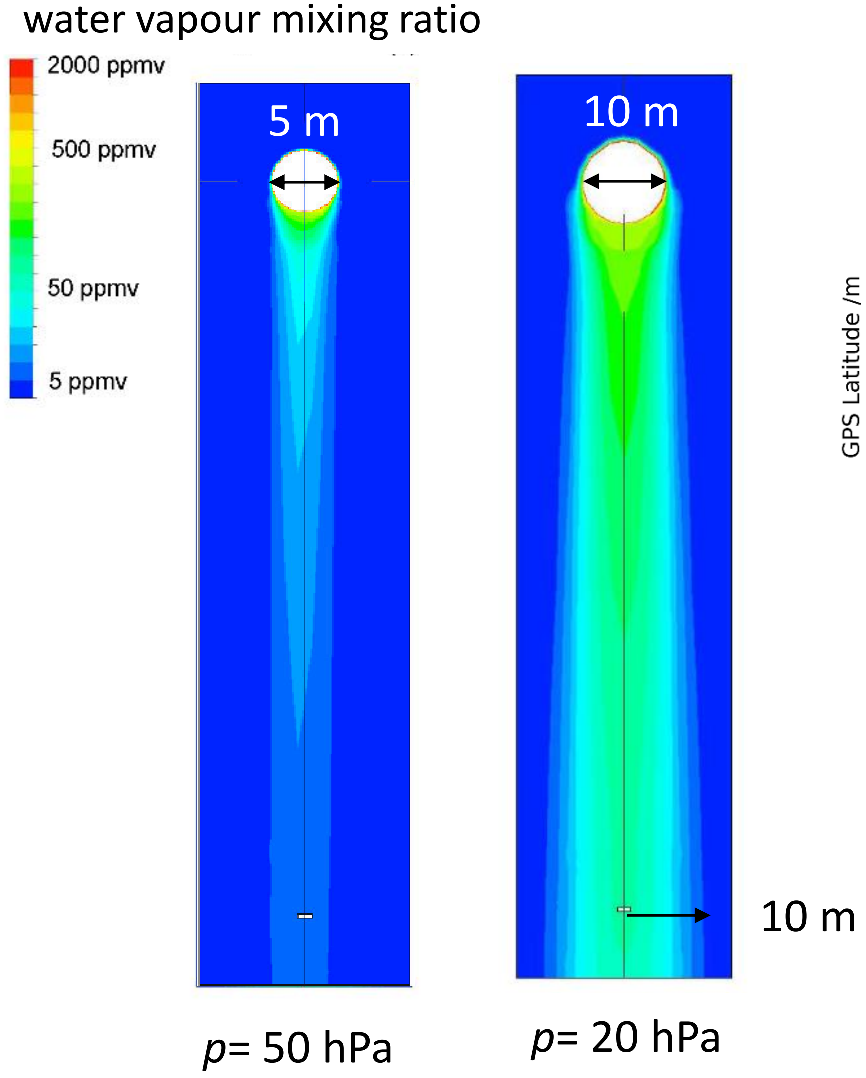


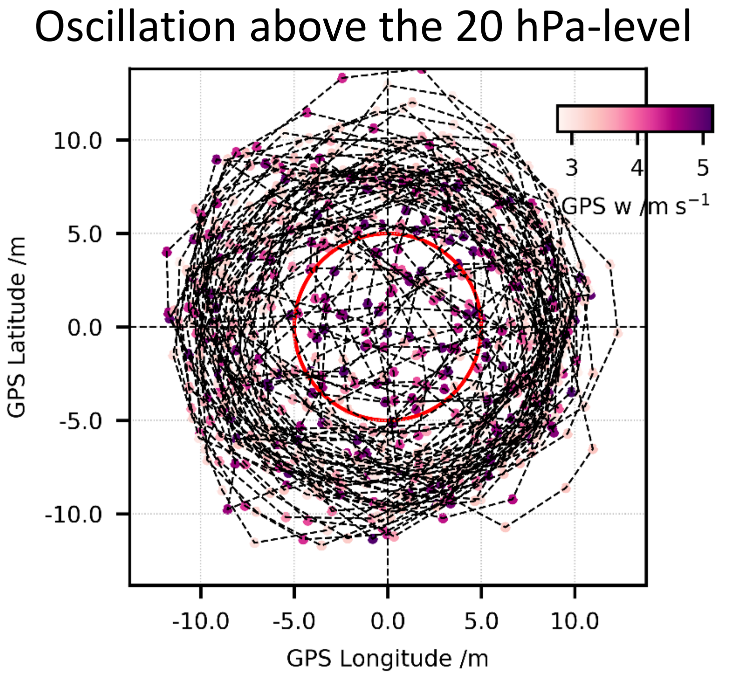
Stratospheric part of flight NT011

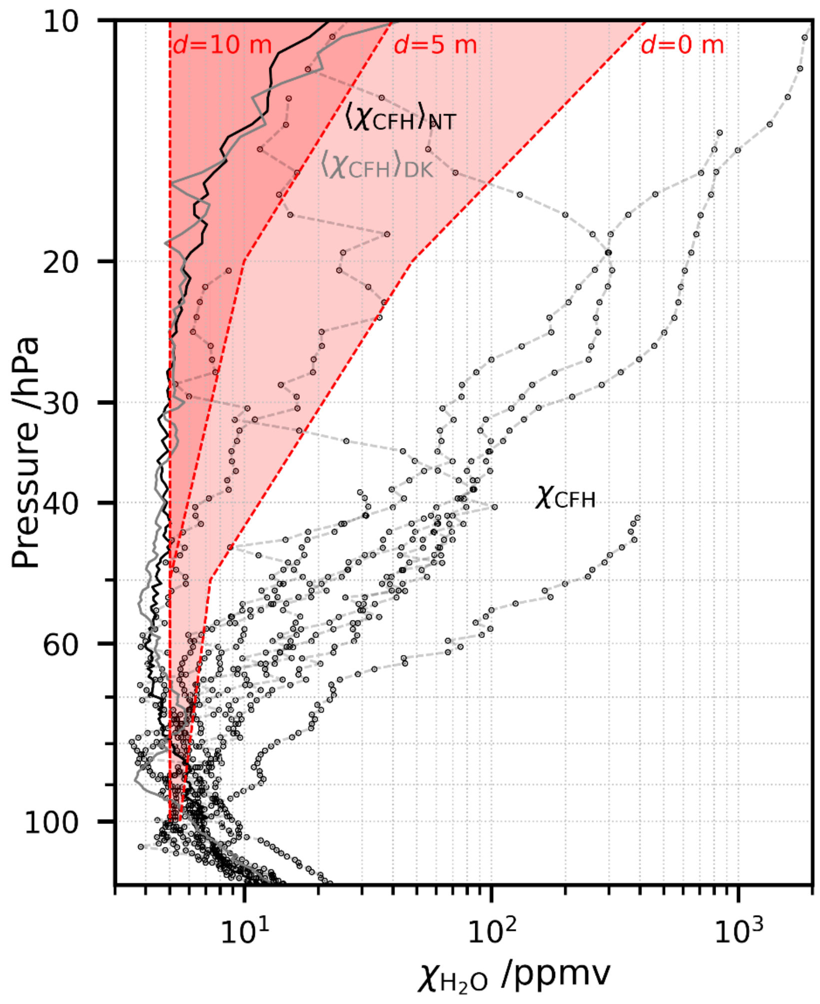
The sublimation simulations confirm the likelihood that the top 5 cm of the intake tube is covered in ice.

Thin mixed-phase clouds can cause the type of contamination observed during the StratoClim balloon campaigns.

Balloon contamination

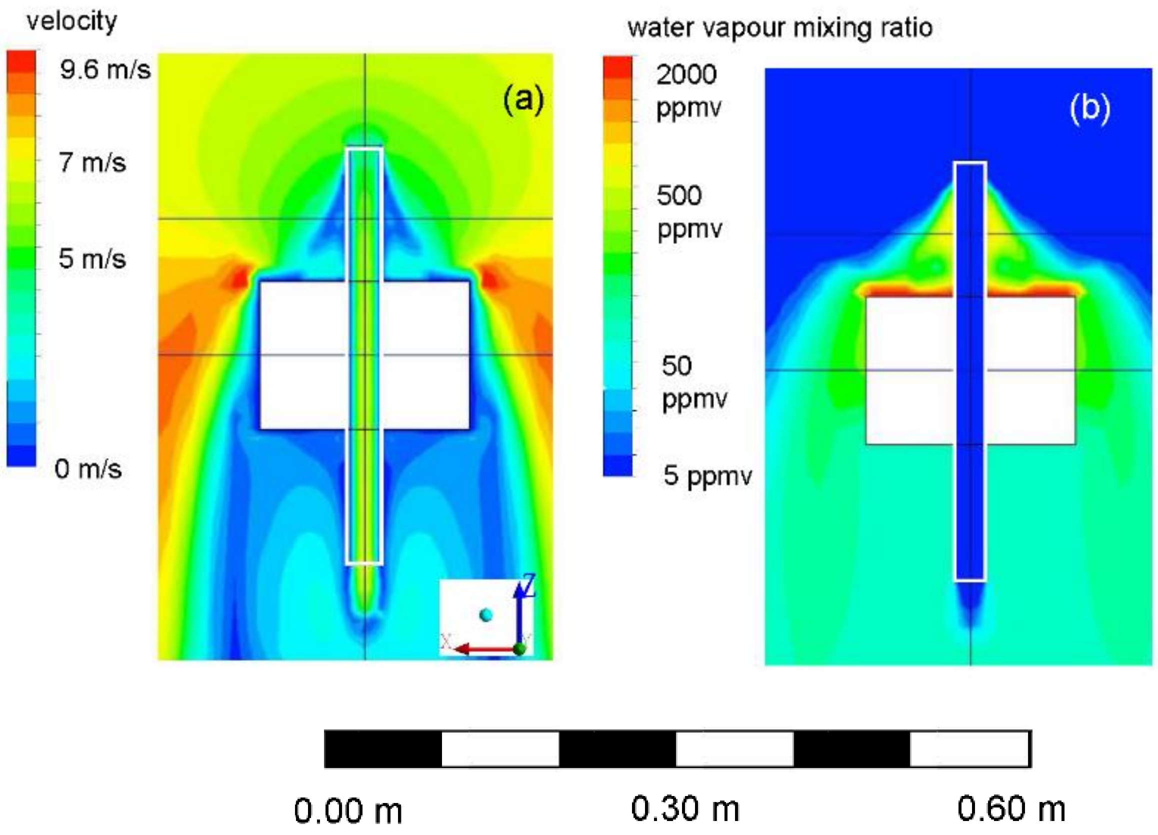






Balloon contamination is only significant above 20-hPa level, observed in average in all flights.

Package contamination



Package contamination is not significant.

Summary

- Investigated three potential source of contamination
  - Inlet tubes
  - Balloon
  - Package

- Using Computational Fluid Dynamic (CFD) tools

- Concluded most likely source is impact of big supercooled droplets inside inlet tube
  - and subsequent sublimation in the stratosphere

- Developed a new method to study pendulum oscillation of instruments pulled by a balloon

Thanks you. Questions?