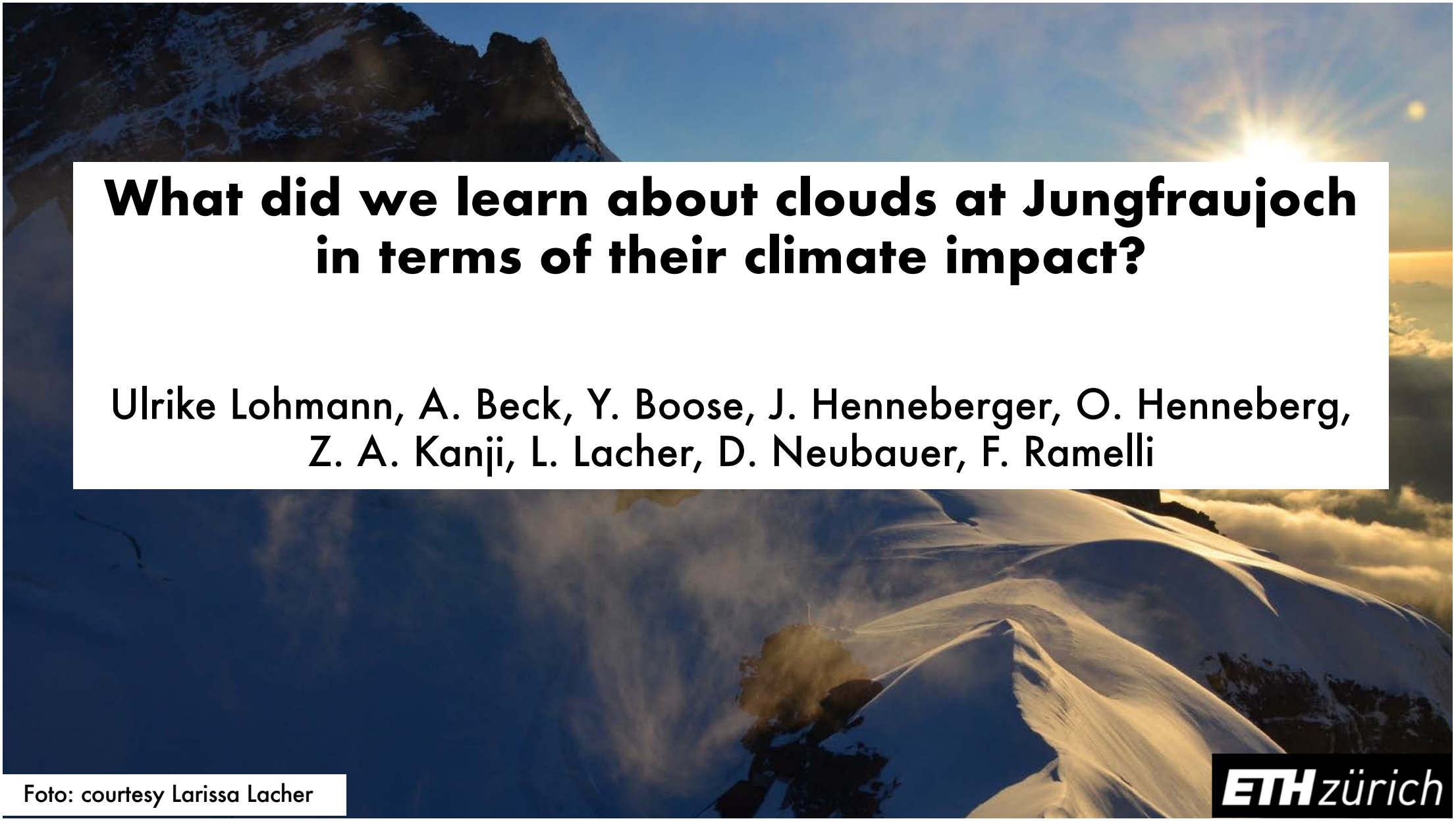


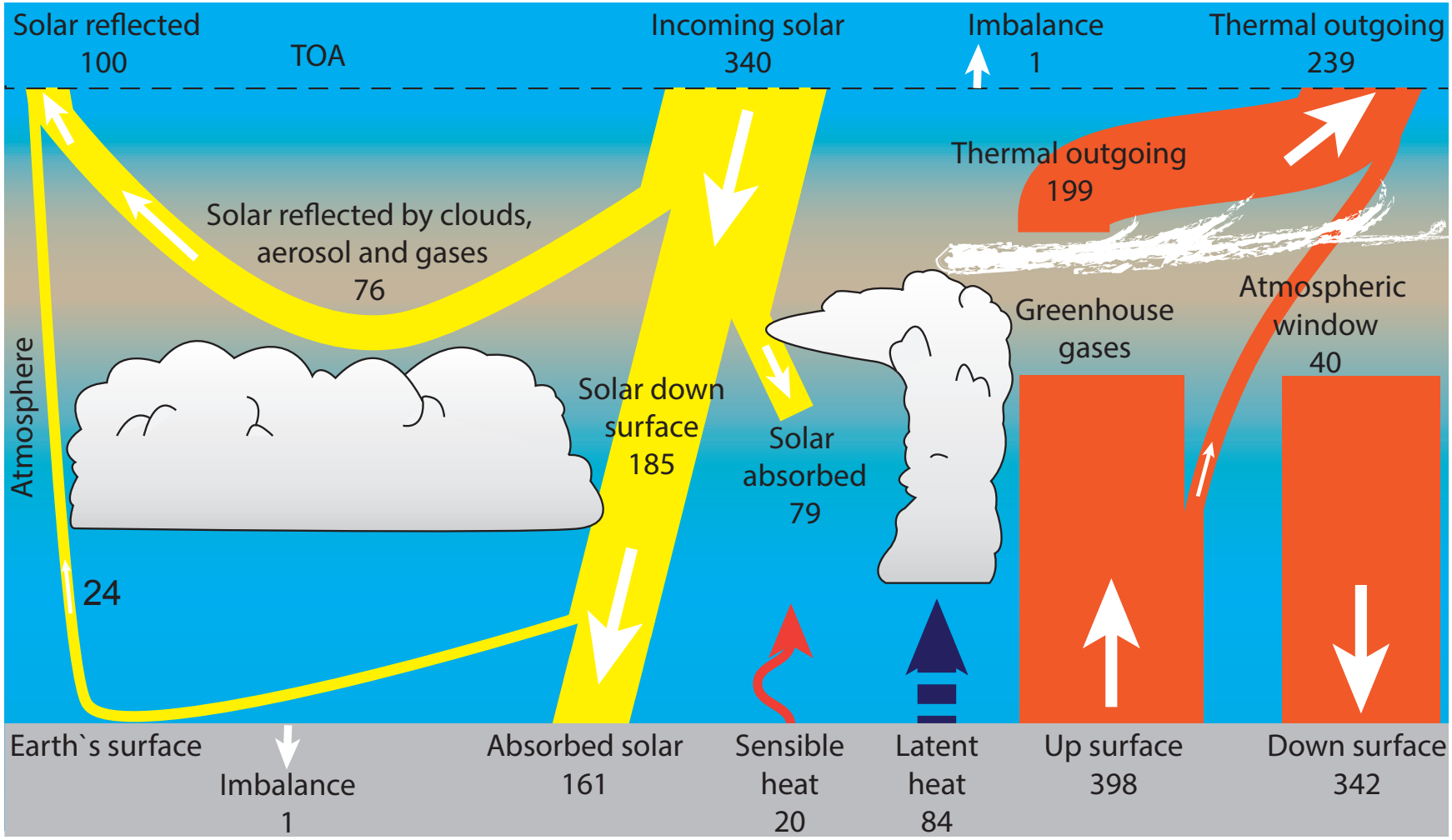
What did we learn about clouds at Jungfraujoch in terms of their climate impact?

Ulrike Lohmann, A. Beck, Y. Boose, J. Henneberger, O. Henneberg, Z. A. Kanji, L. Lacher, D. Neubauer, F. Ramelli

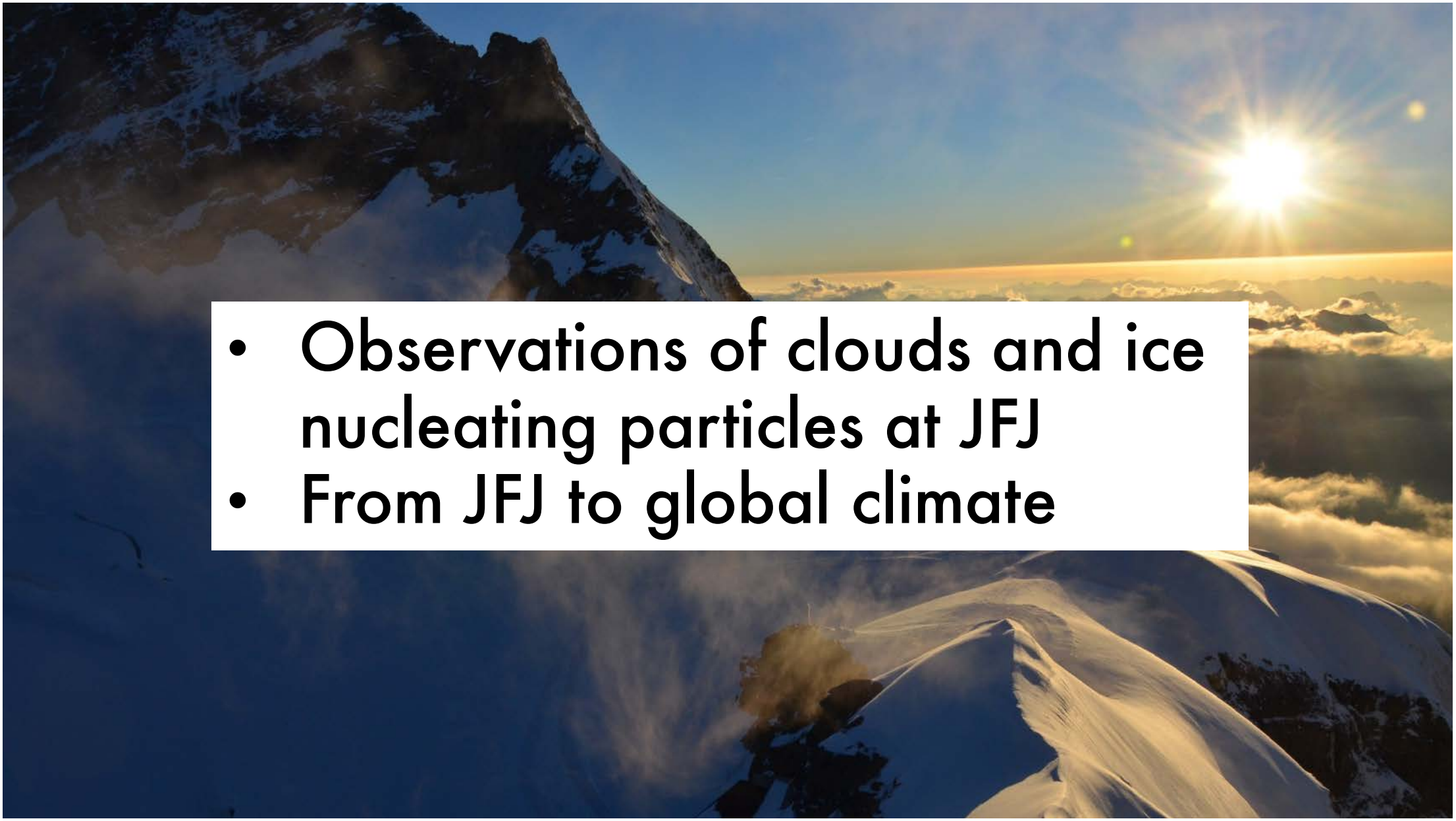
Foto: courtesy Larissa Lacher

ETH zürich

Global energy balance: prominence of clouds



Lohmann et al., 2016



- Observations of clouds and ice nucleating particles at JFJ
- From JFJ to global climate

Importance of orographic clouds

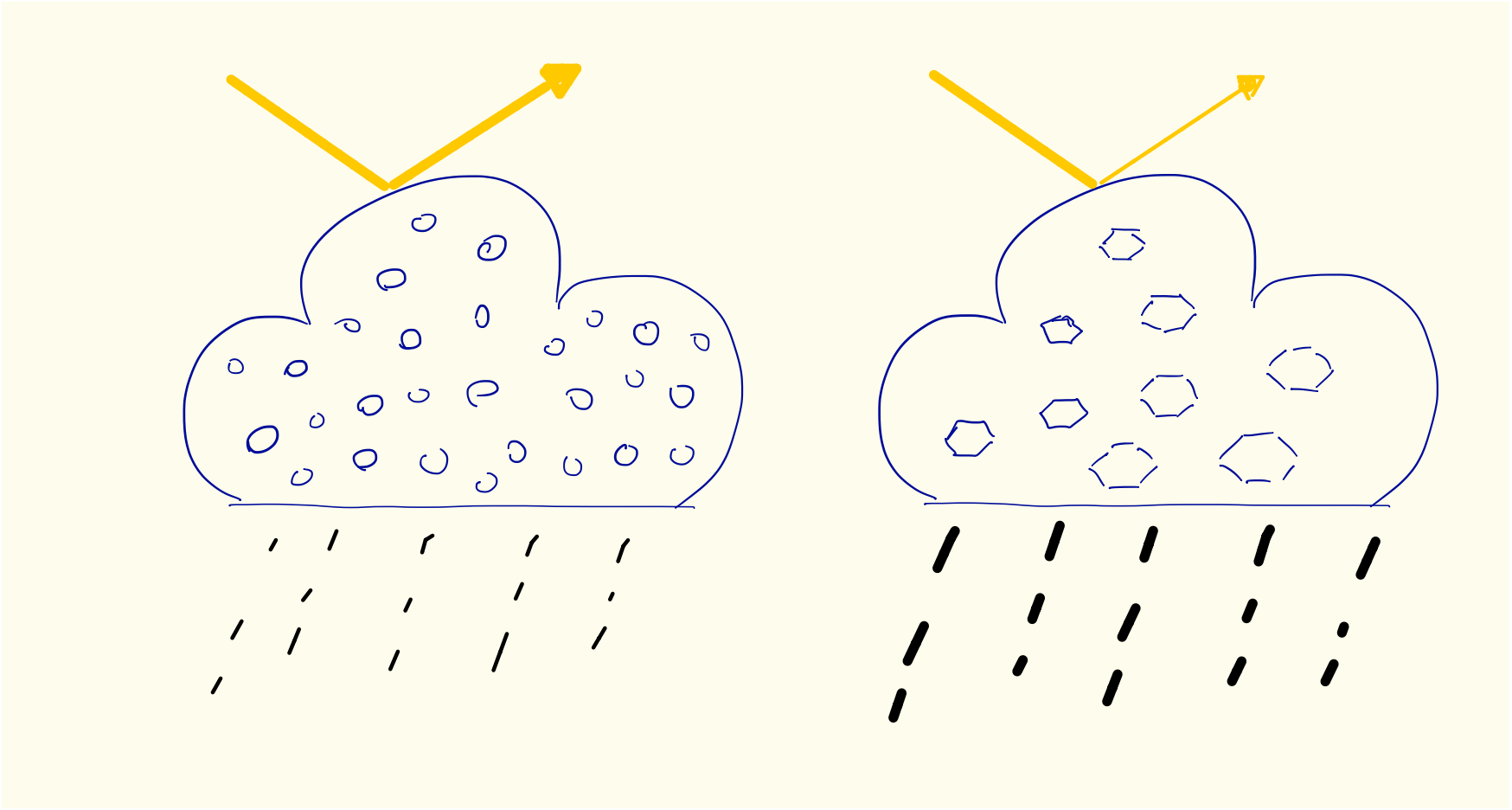
- Orographic precipitation is crucial for fresh water resources (Roe, 2005)
- Intense precipitation will increase in a warmer climate (Boucher et al., 2013)

Land slides/Flash floods

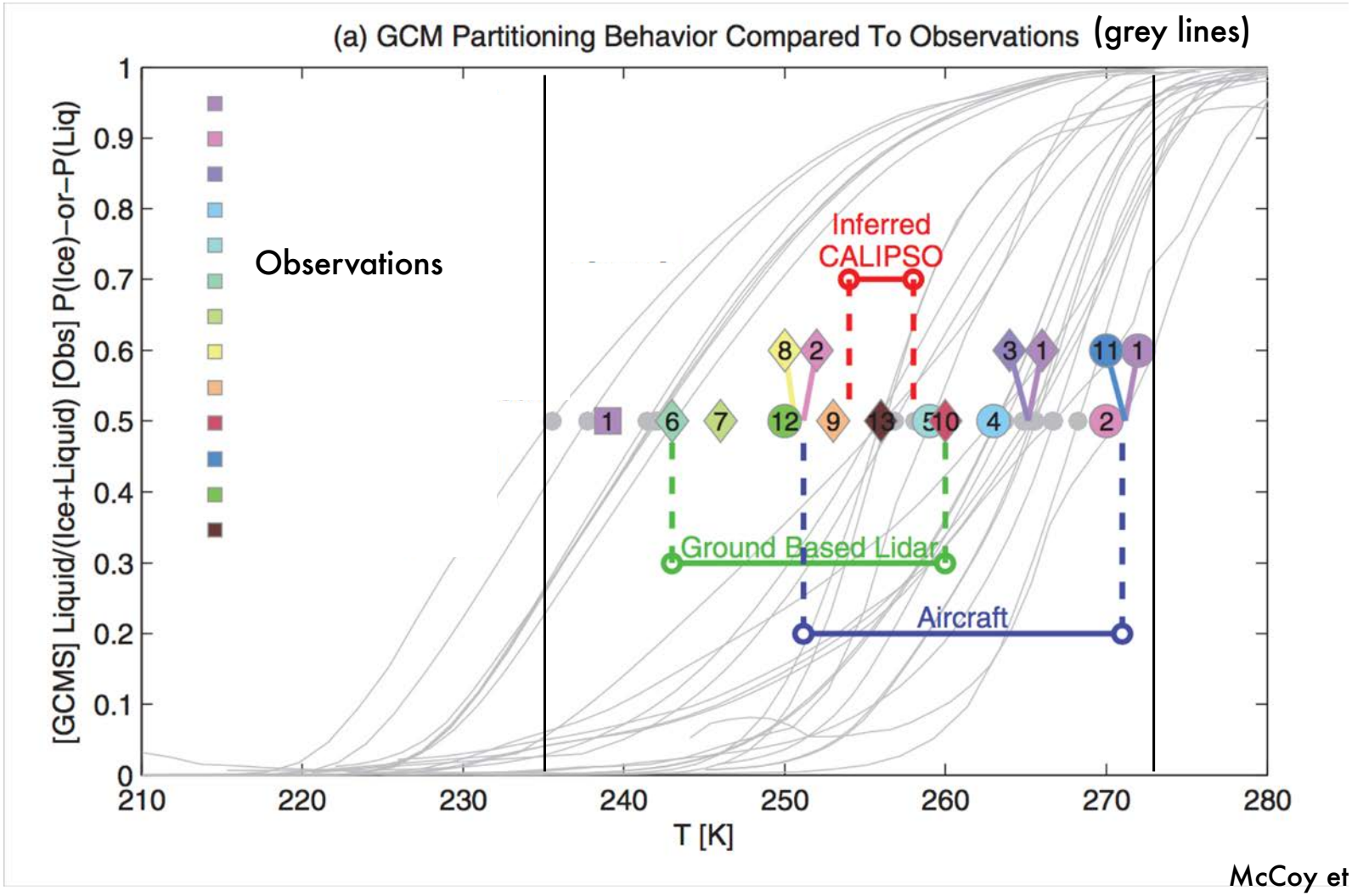
Avalanches

Foto: SLF

Differences between liquid and ice clouds

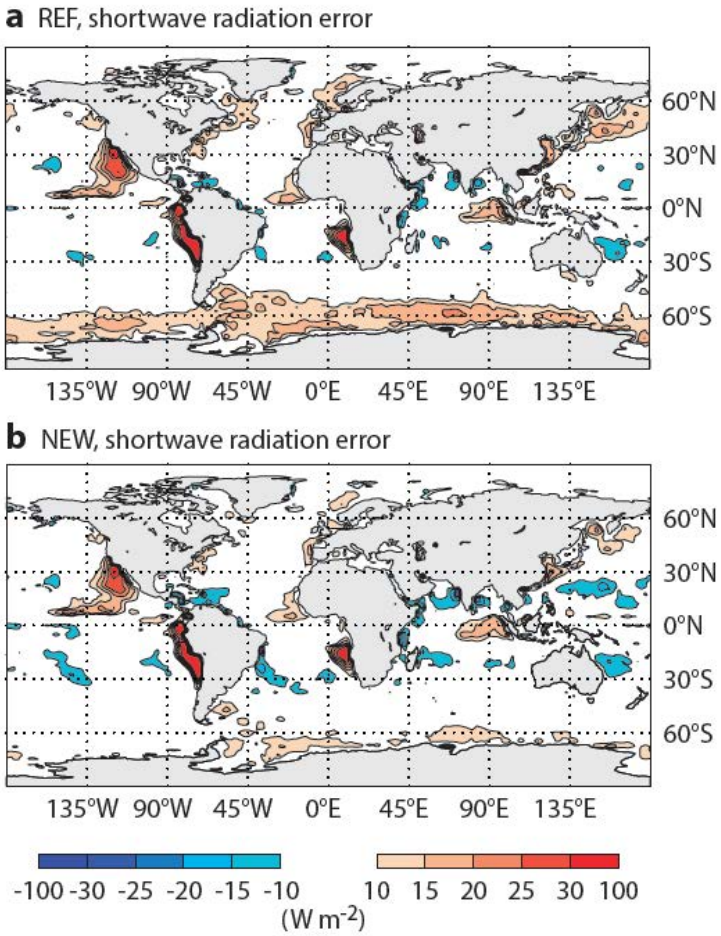


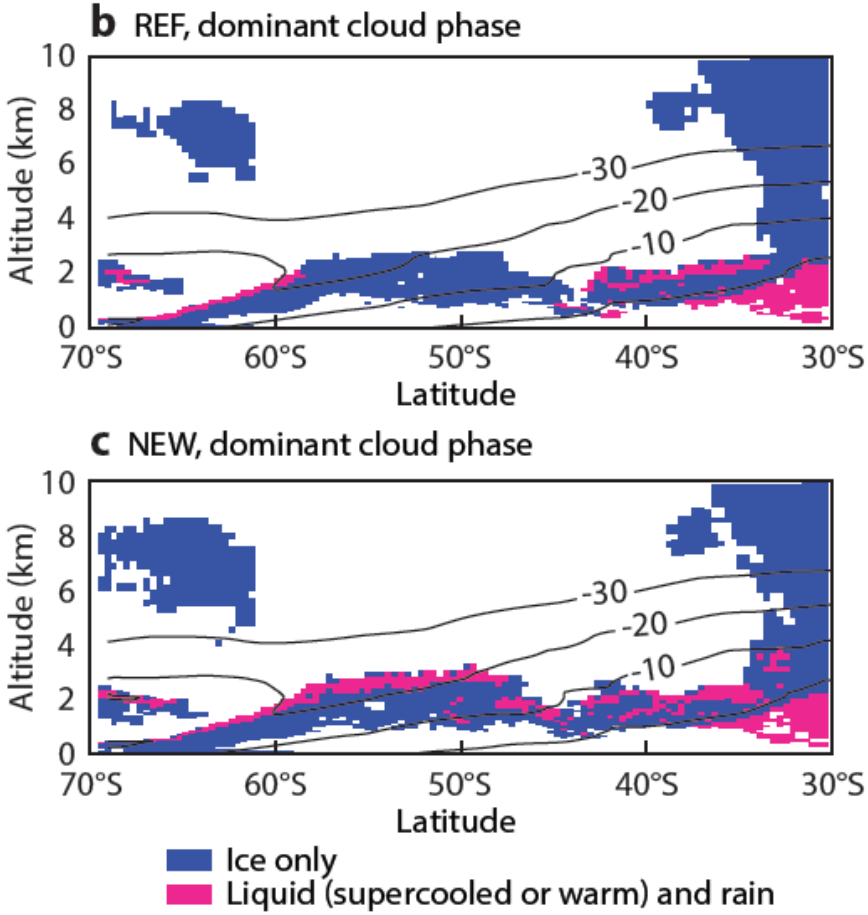
What do we know about mixed-phase clouds?



McCoy et al., JAMES, 2016

Do mixed-phase clouds matter?

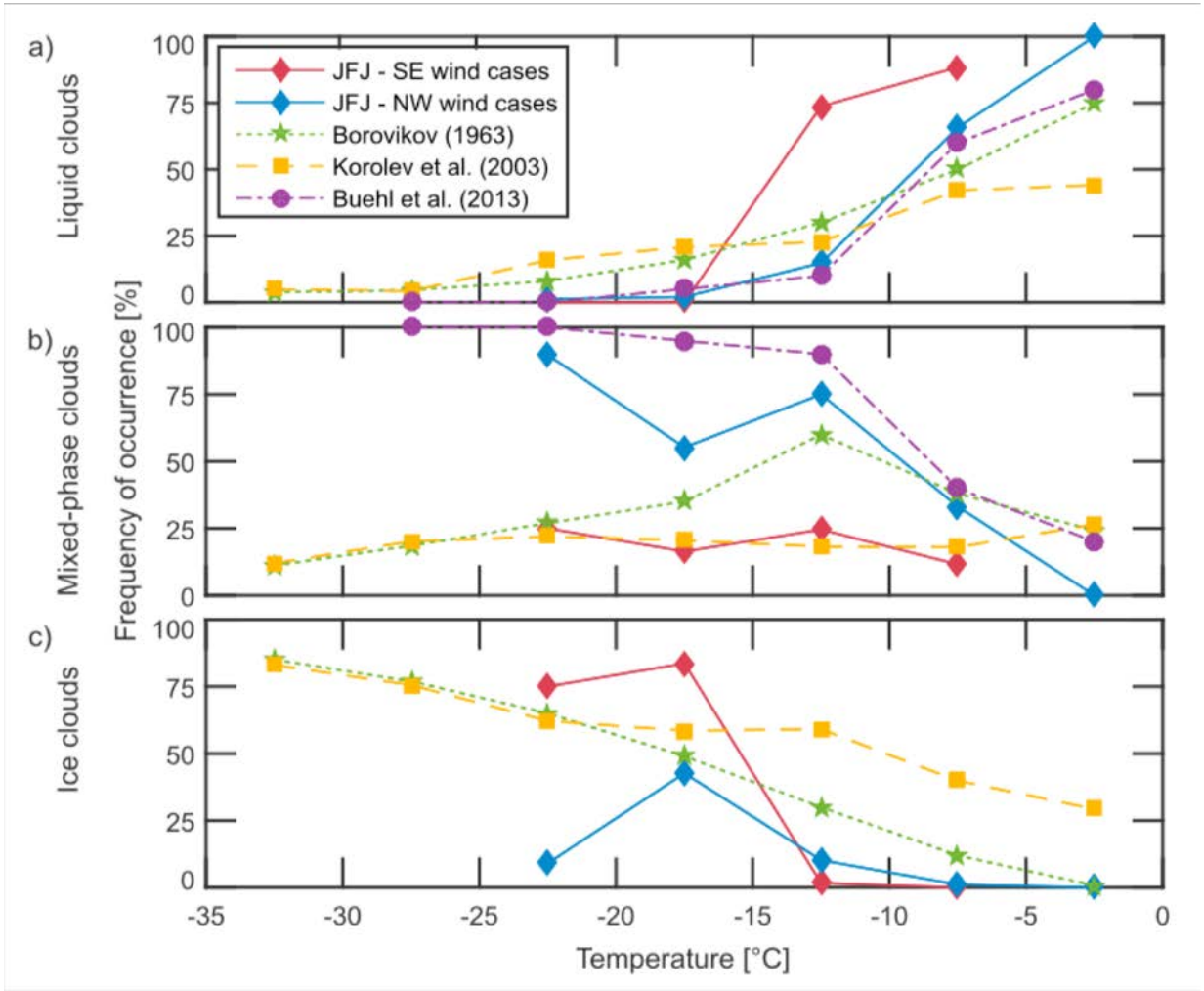




REF: control simulation, NEW: detrainment from convective clouds is liquid if the cloud top is below 600 hPa → Implications for climate change?

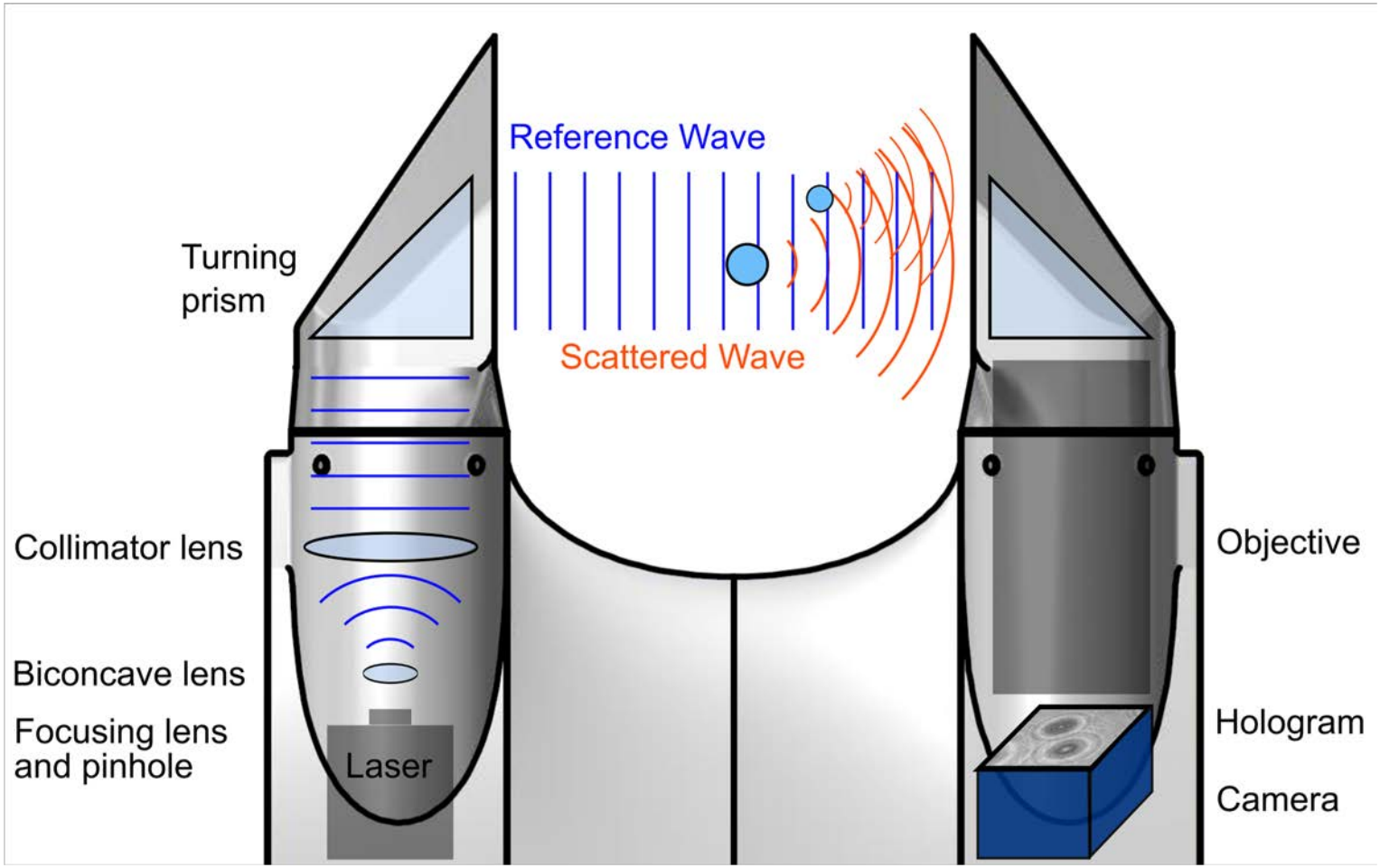
Forbes et al., 2016

Can observations from JFJ help?



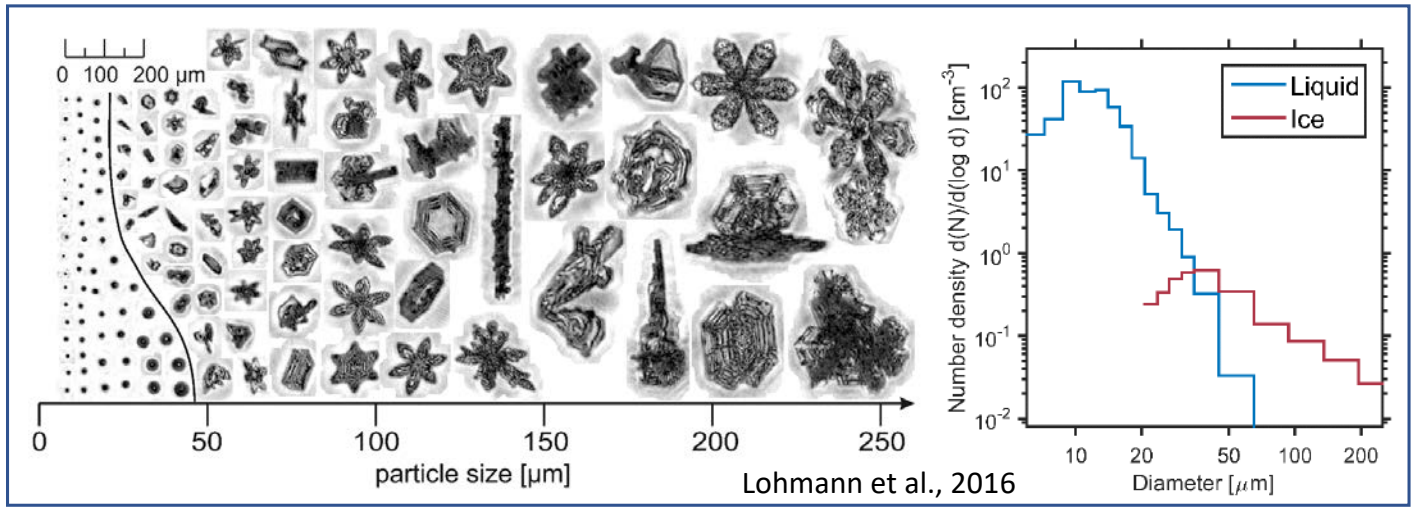
Lohmann et al., 2016

Working principle of HOLIMO



Ramelli et al., 2019

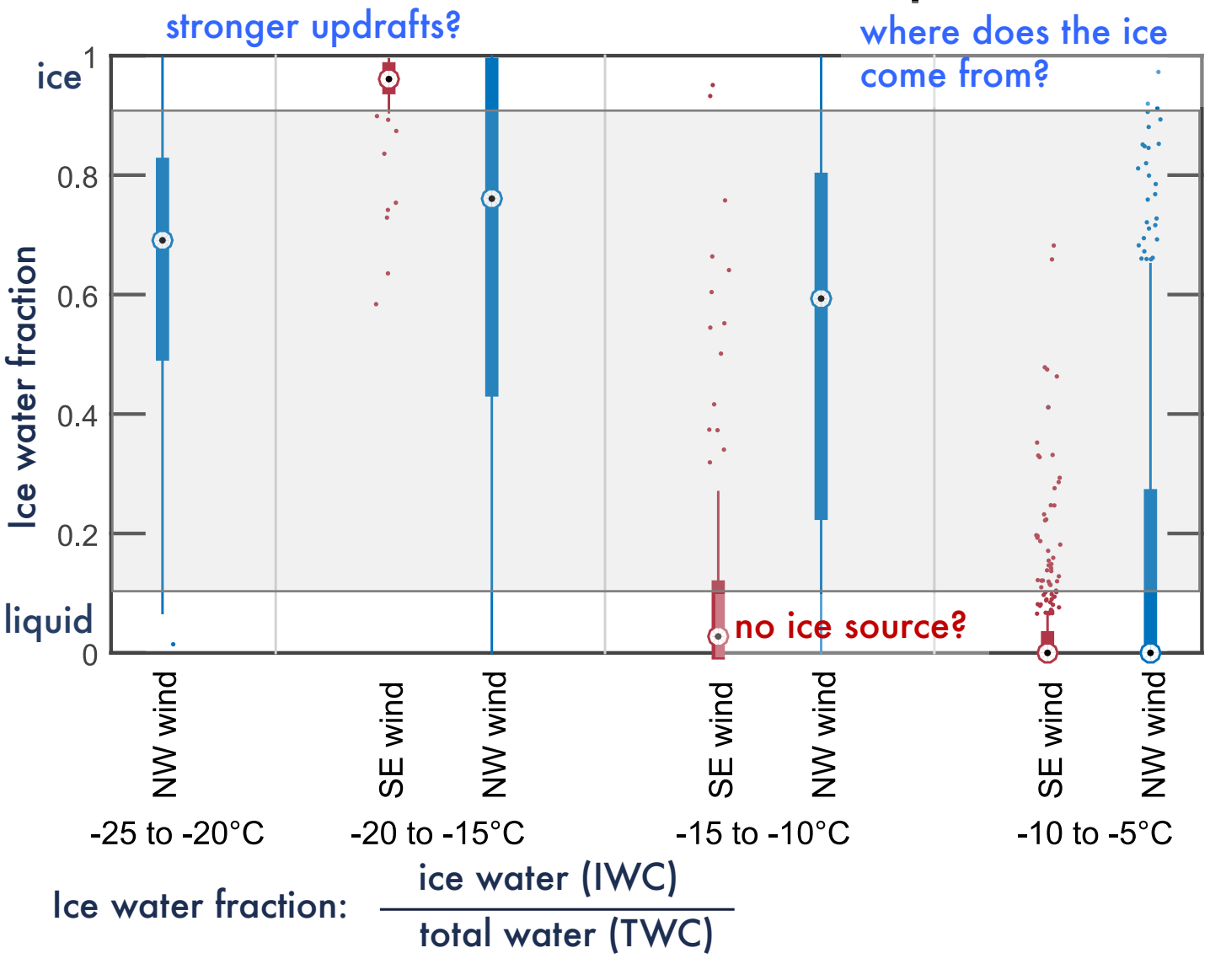
Observations with HOLIMO



Lohmann et al., 2016

Henneberger et al., AMT, 2013

Observation of mixed-phase clouds



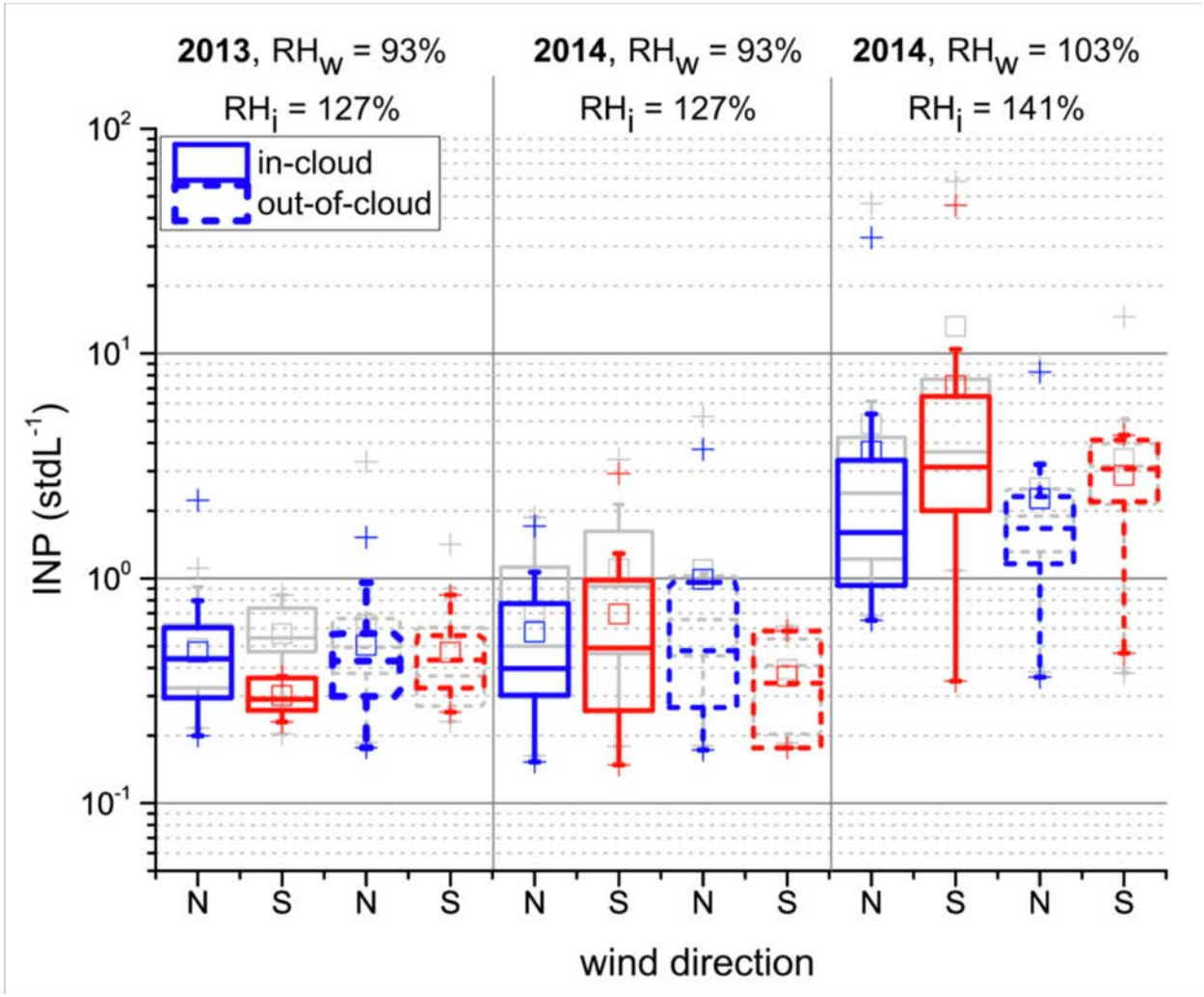
Ice water fraction: $\frac{\text{ice water (IWC)}}{\text{total water (TWC)}}$

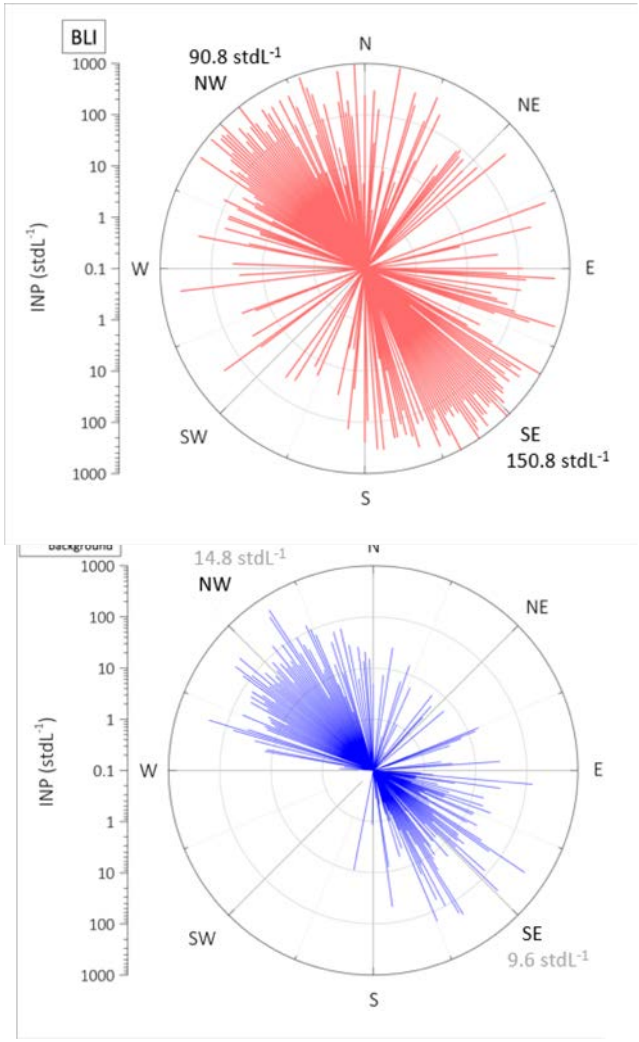
North-West (NW)

Jungfraujoch (JFJ)

South-East (SE)

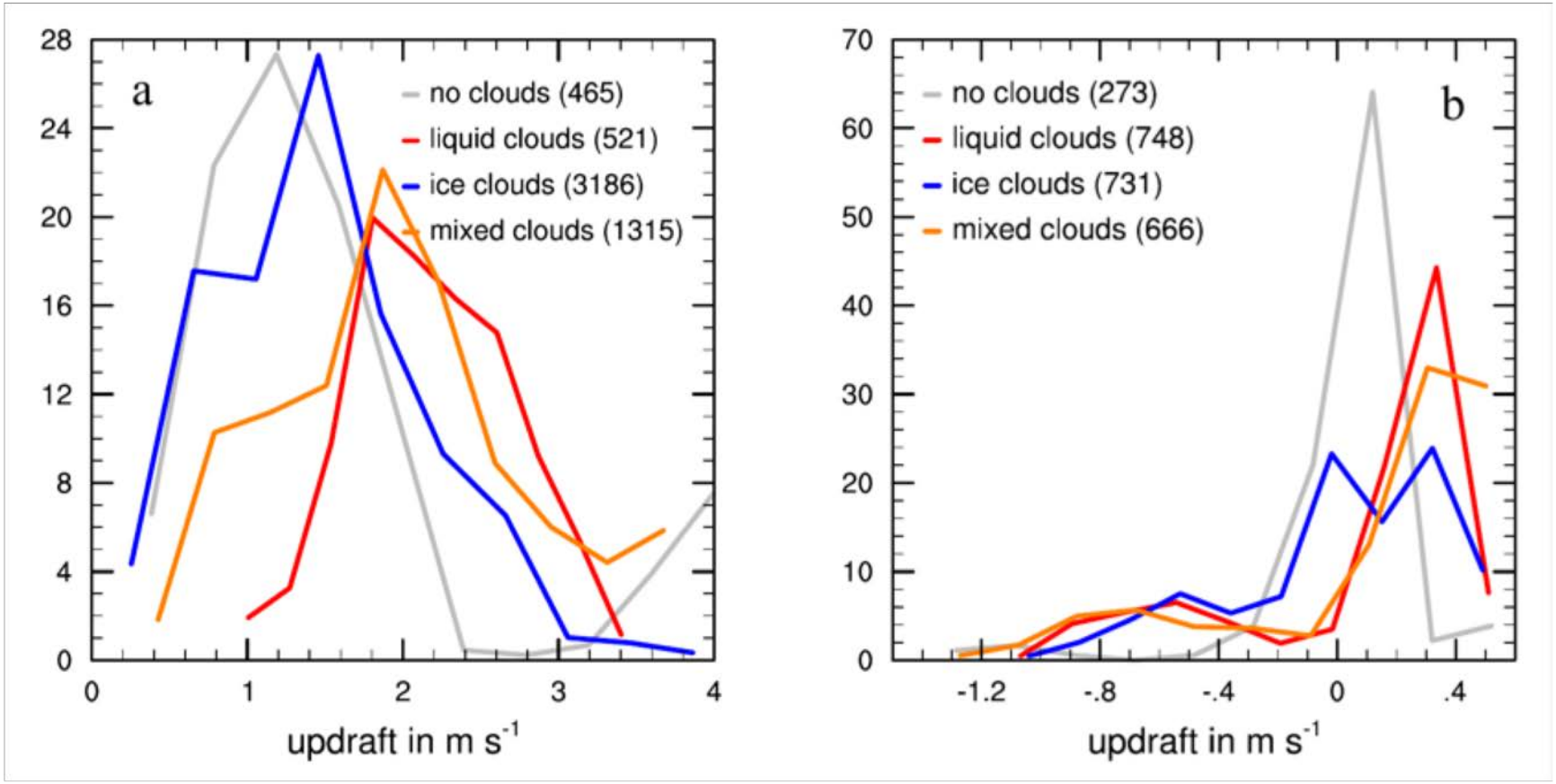
Are there differences in INPs depending on wind direction?





Boose et al., JAS, 2016; Lacher et al., 2018

Differences in updraft velocity – inferred from model results

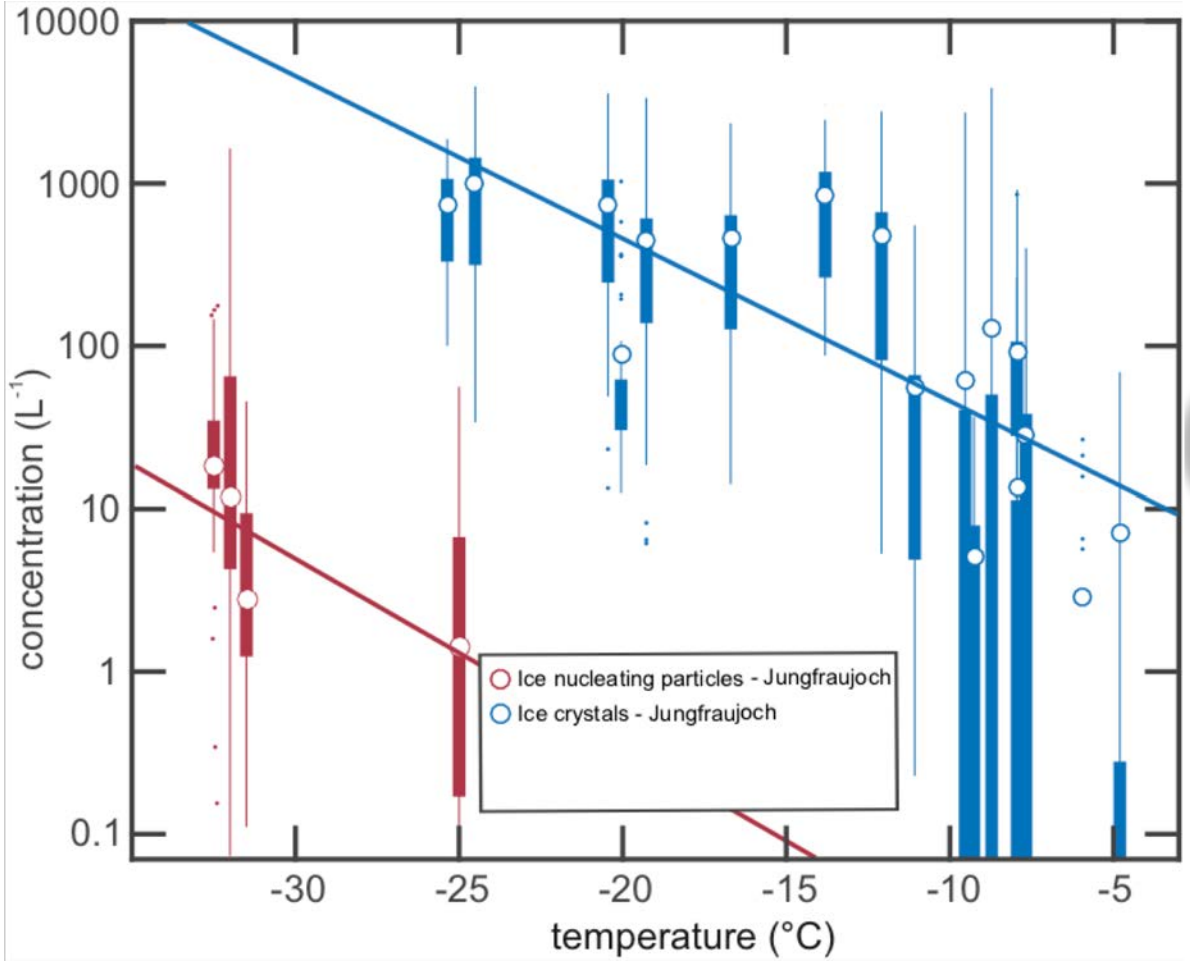


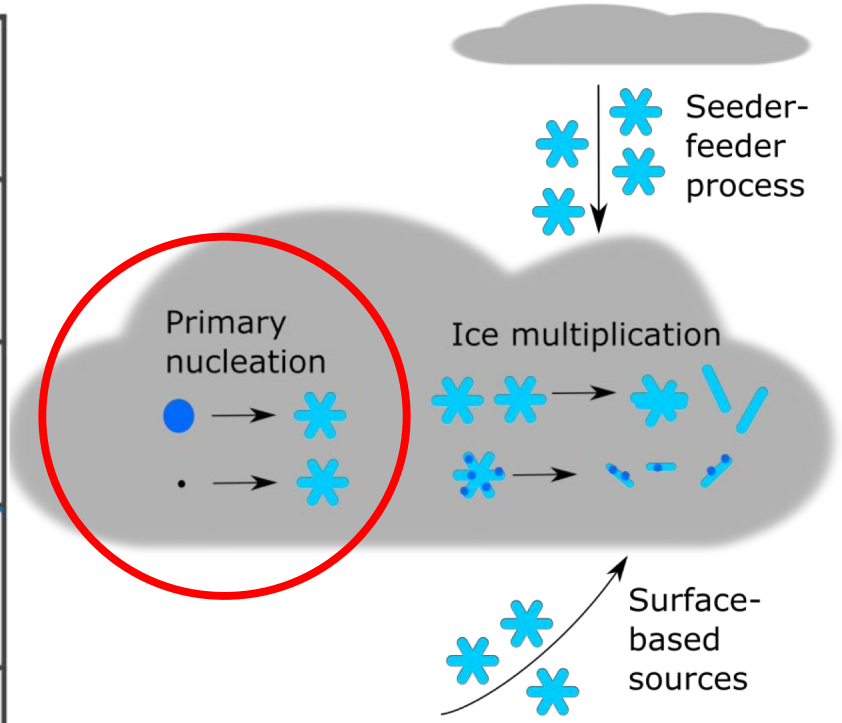
NW wind cases

SE wind cases

Lohmann et al., GRL, 2016

Origin of ice crystals?



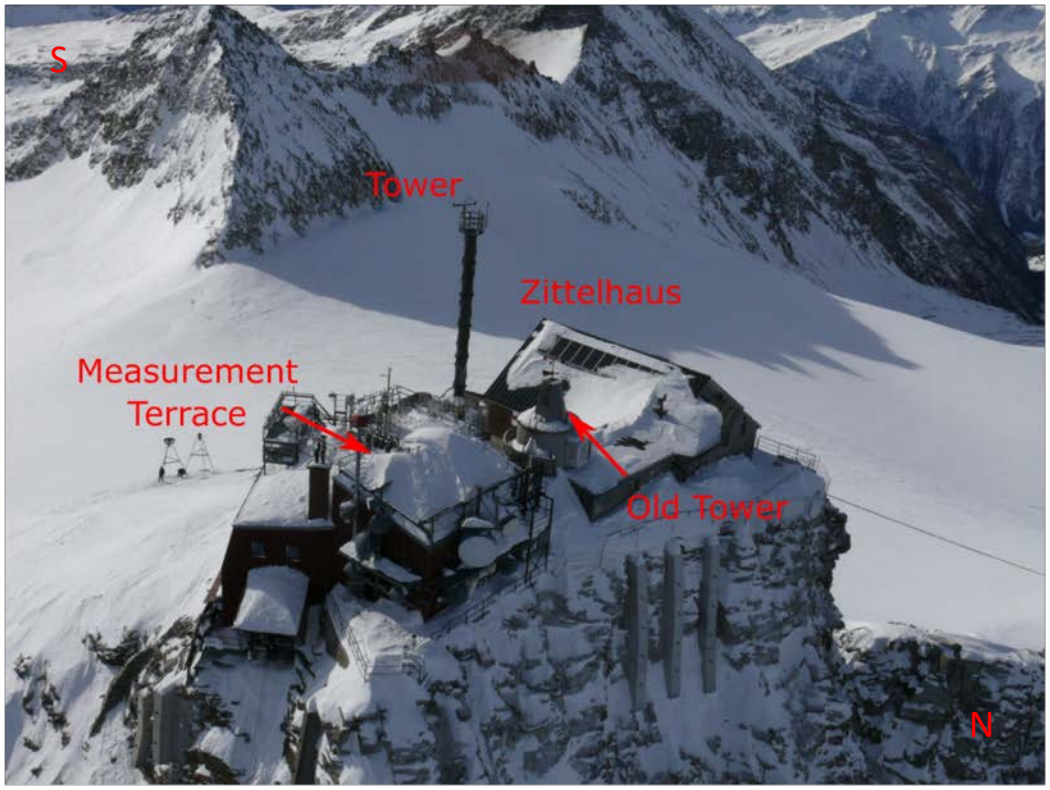


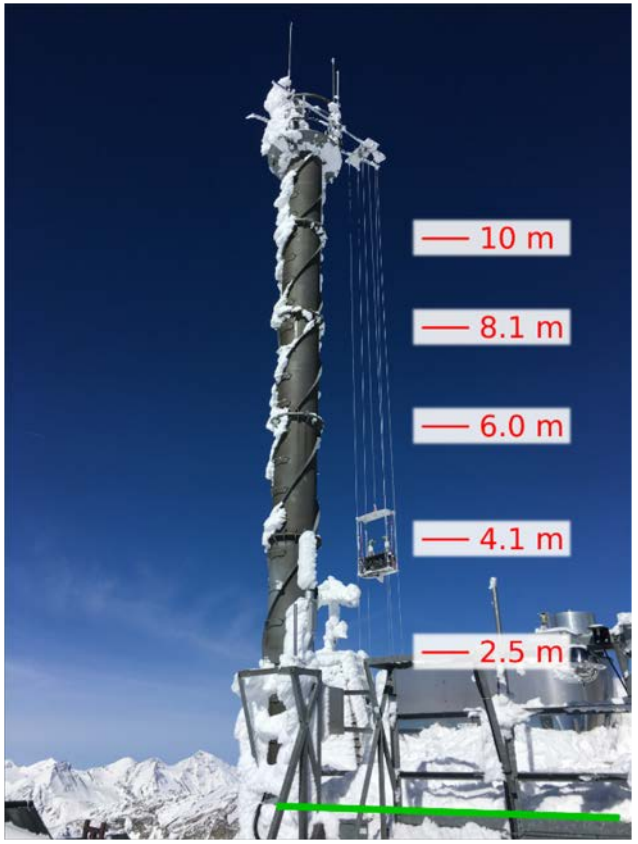
Beck et al., ACP, 2018

Sources of ice crystals in orographic clouds

Courtesy: Alex Beck

Setup to observe blowing snow at Sonnblick Observatory



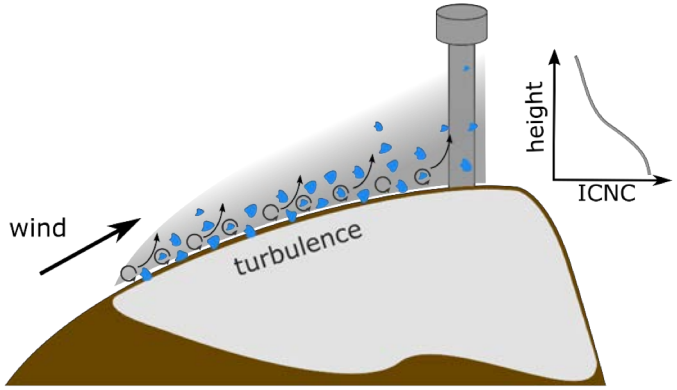


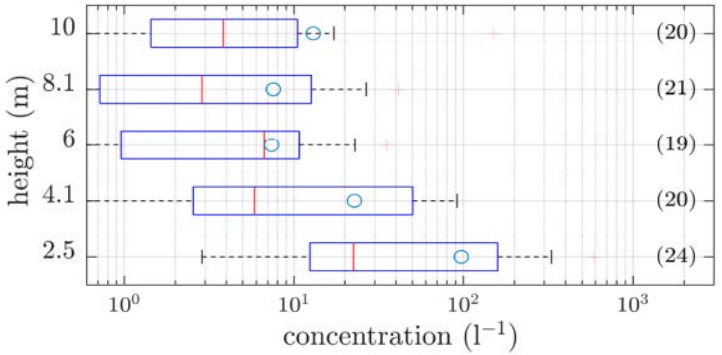
Courtesy: Alex Beck

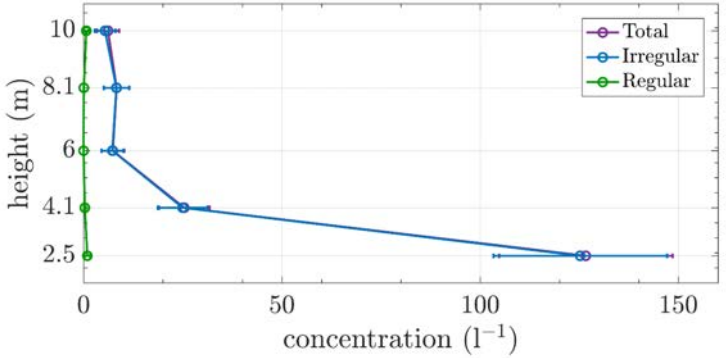
Detection of surface processes (no cloud)

Surface-based processes should cause:

- Mainly irregular crystals
- Decrease of the ice crystal number concentration with height







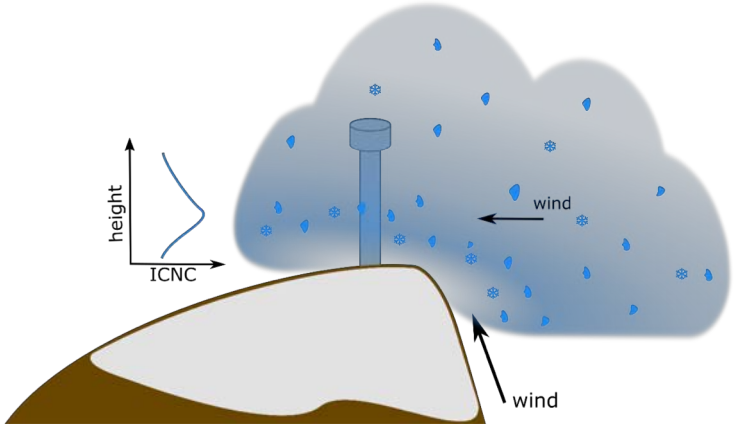
→ Strong influence from surface processes

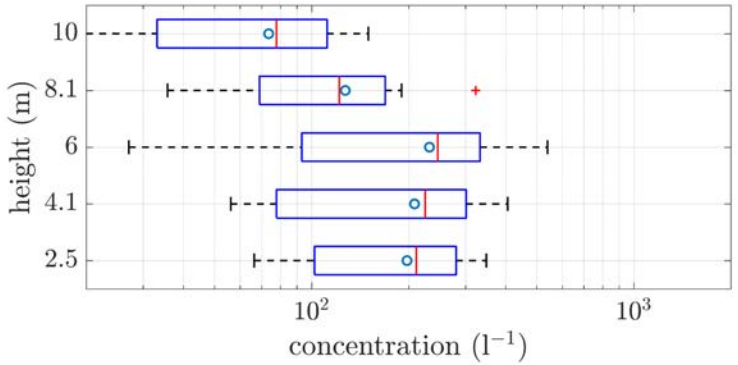
Beck et al., ACP, 2018

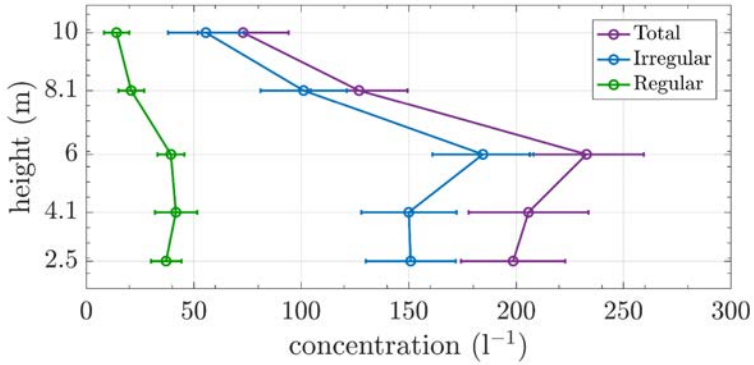
Impact of near-surface processes (in-cloud)

Surface-based processes should cause:

- mainly irregular ice crystals
- decrease of the ice crystal number concentration with height



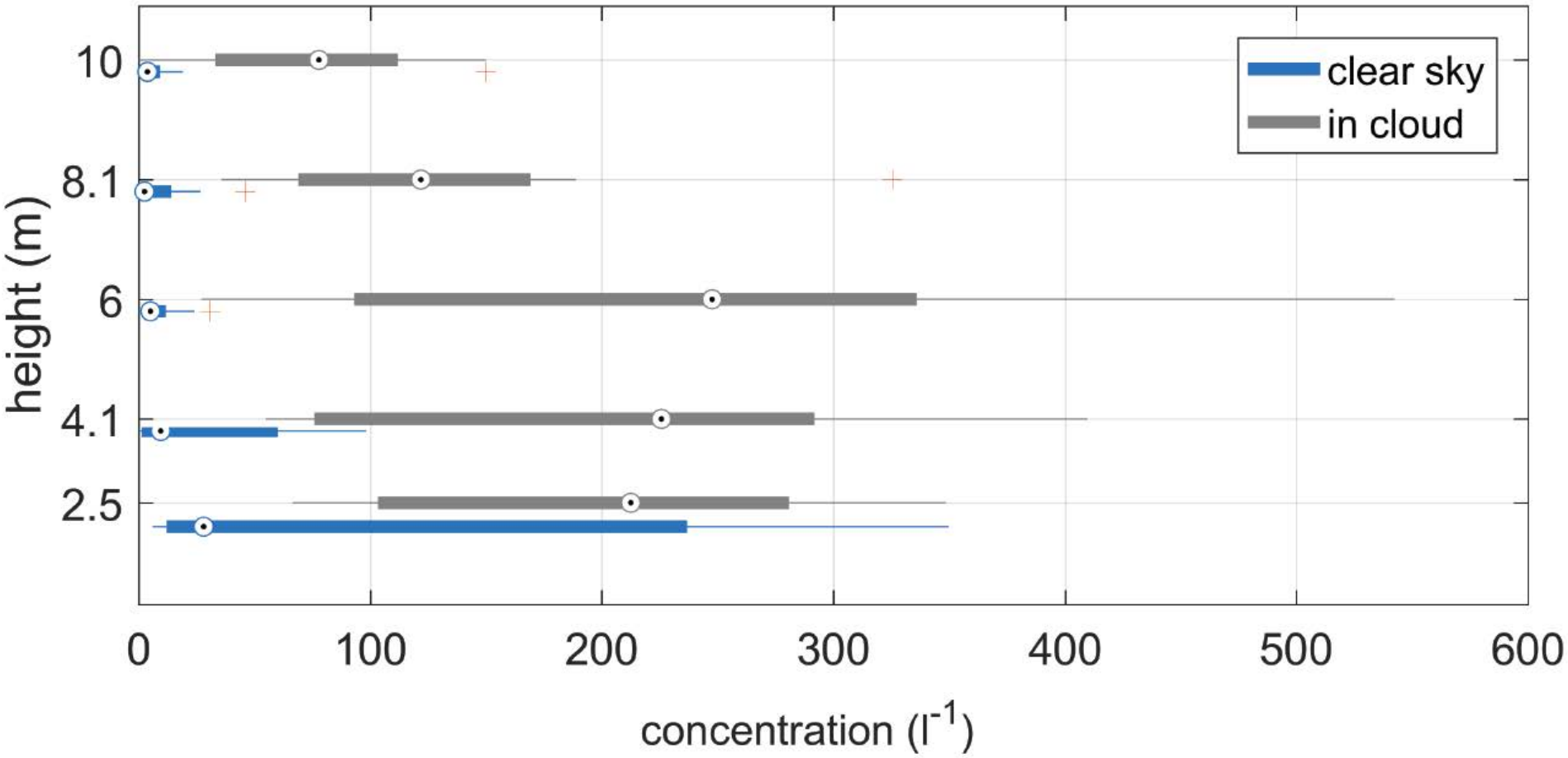




→ Similar height dependence for different IC habits
→ Not only surface-based processes

Beck et al., ACP, 2018

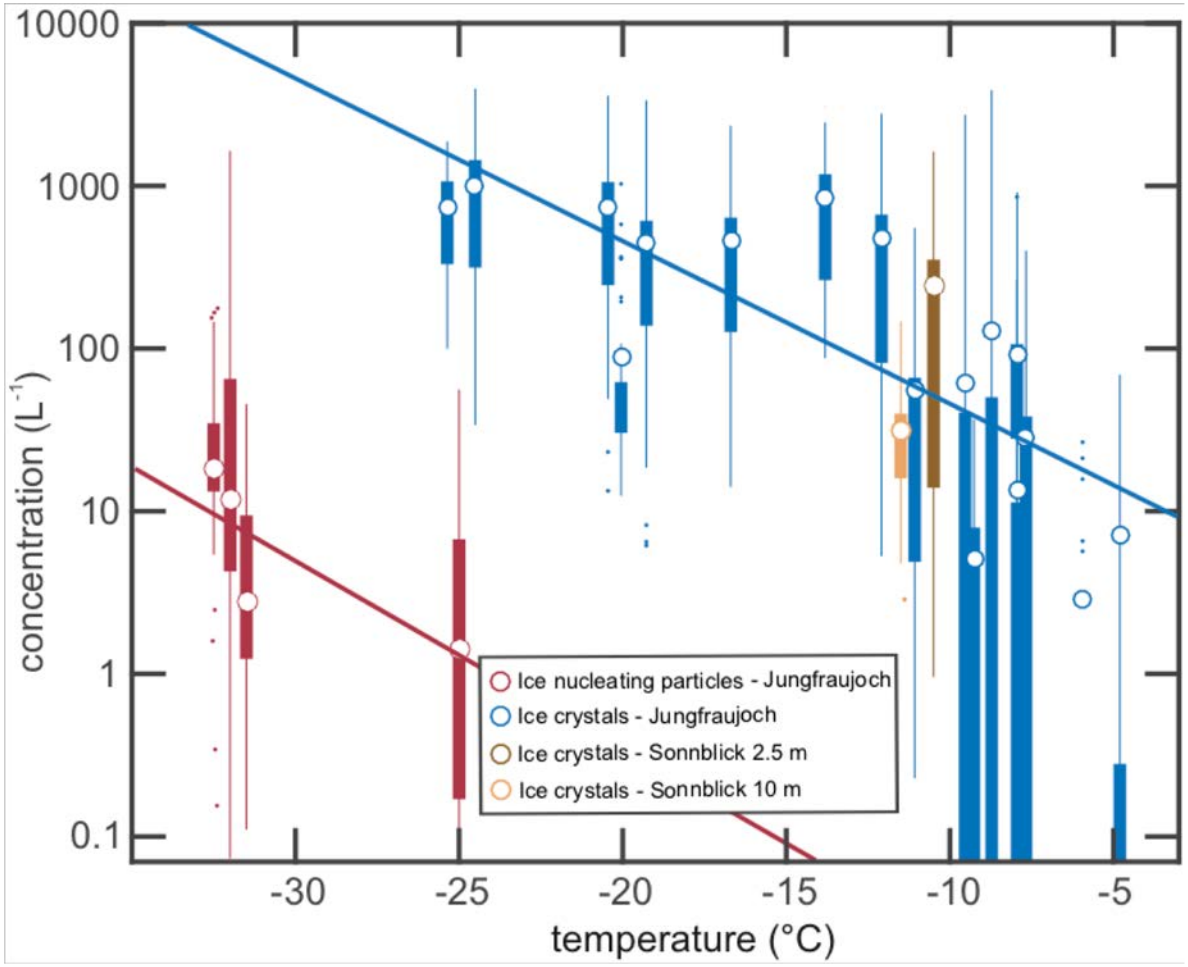
Mountain-top observations influenced by surface processes

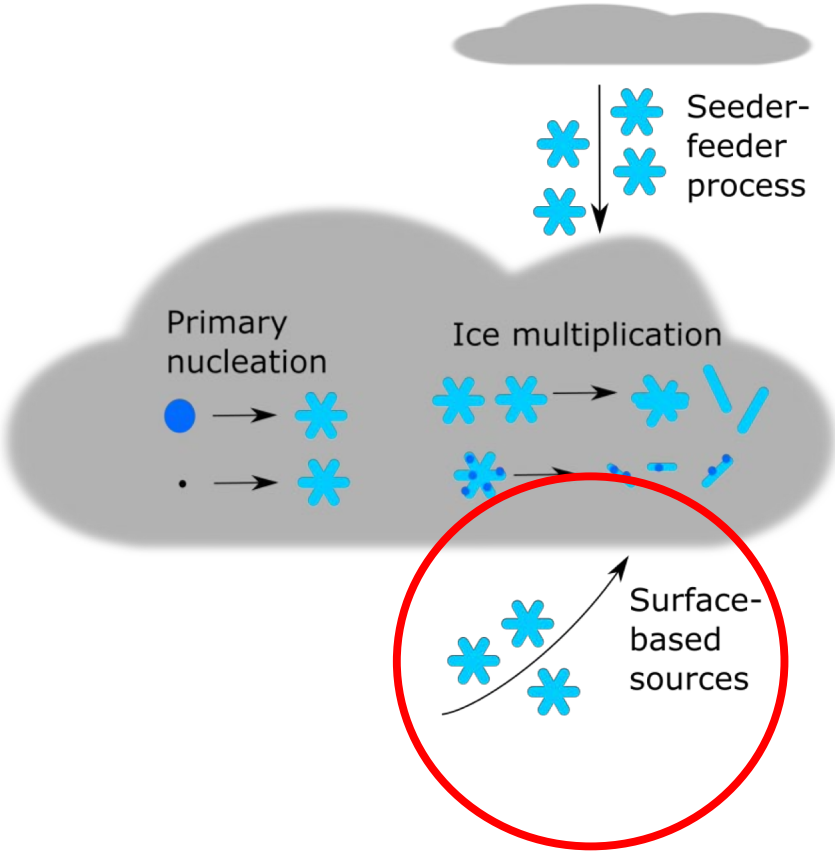


Measurements at Sonnblick observatory (SBO), Austria

Beck et al., ACP, 2018

Origin of ice crystals?

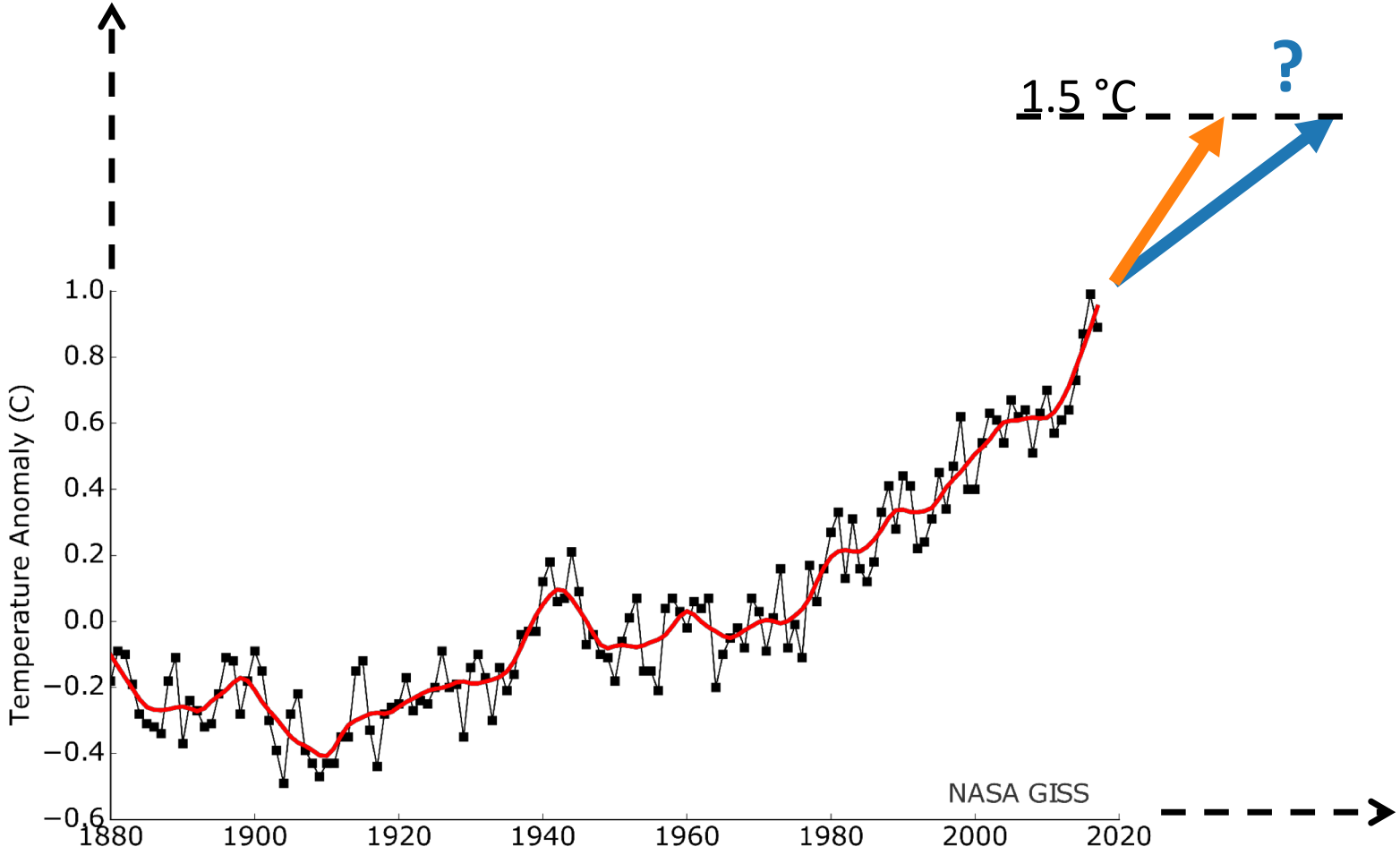




Beck et al., ACP, 2018

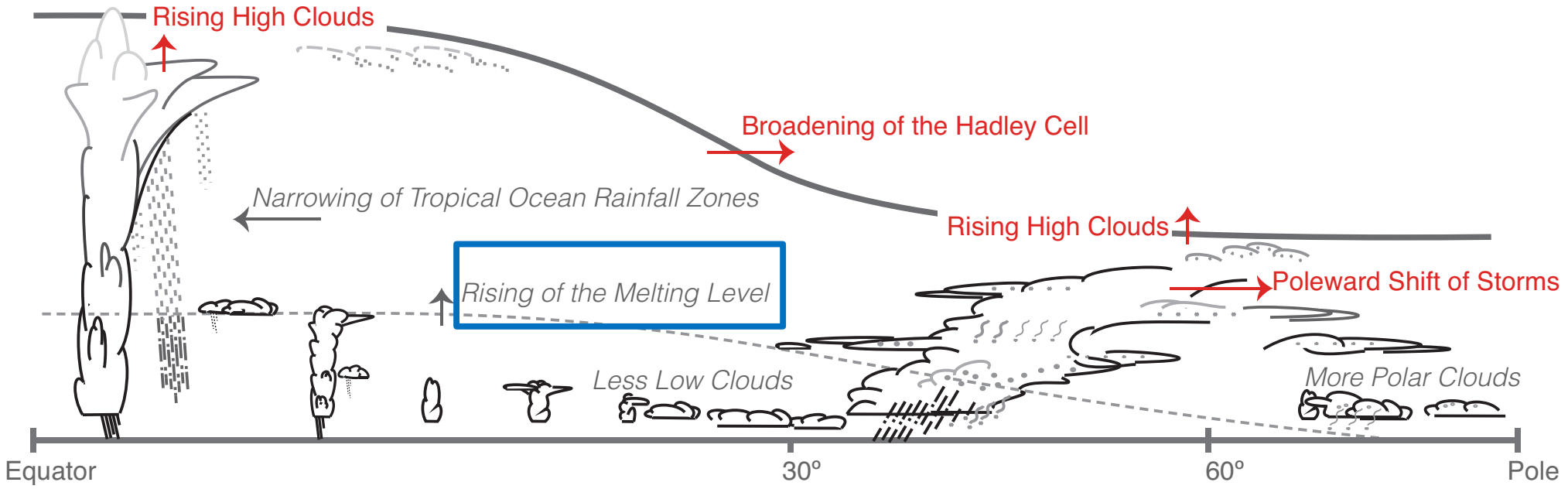

From JFJ to global climate

Global climate change



Courtesy: Remo Dietlicher

Response of clouds to CO_2 doubling

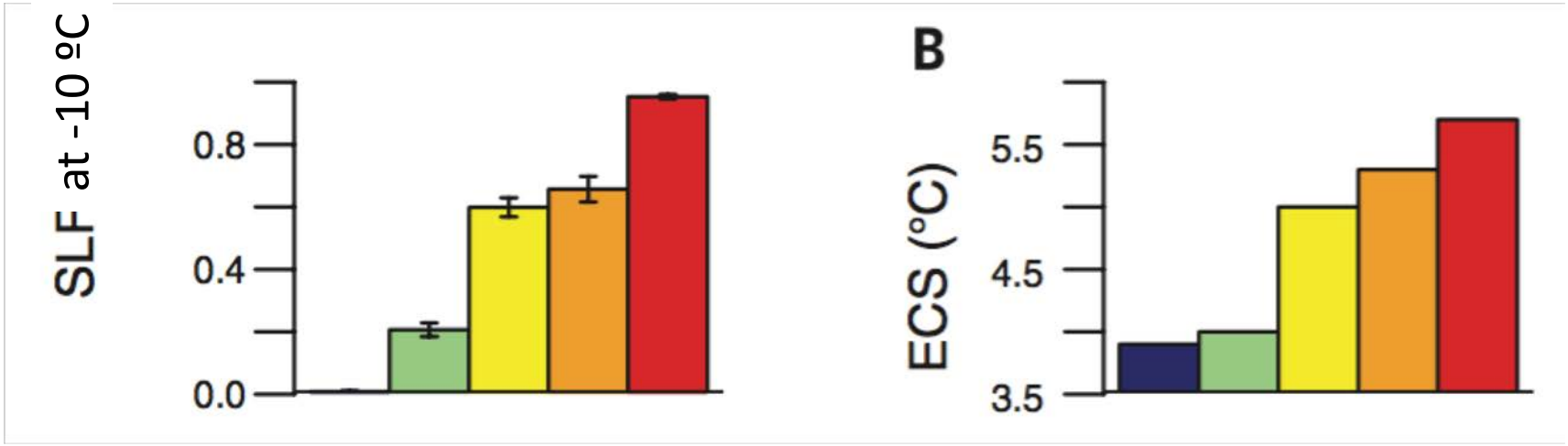


→ The net radiative feedback due to all cloud types is *likely* positive

→ Rising of the melting level causes more liquid instead of ice clouds → more reflection of shortwave radiation → negative cloud feedback

IPCC, 2013, Fig. 7.11

Sensitivity of the equilibrium climate sensitivity (ECS) to the present-day supercooled liquid cloud fraction (SLF)



→ The higher SLF (liquid water/(liquid+ice water)) in the current climate, the smaller the negative cloud phase feedback → larger ECS

Similar results in other models?

Tan et al., Science, 2016

Sensitivity simulations with ECHAM6-HAM2

Simulation	Description
REF	Release version ECHAM6.3-HAM2.3 (Tegen et al., 2019; Neubauer et al., 2019)
ALL_ICE	no supercooled liquid water at T < 0 °C
ALL_LIQ	only supercooled liquid water at T > -35 °C

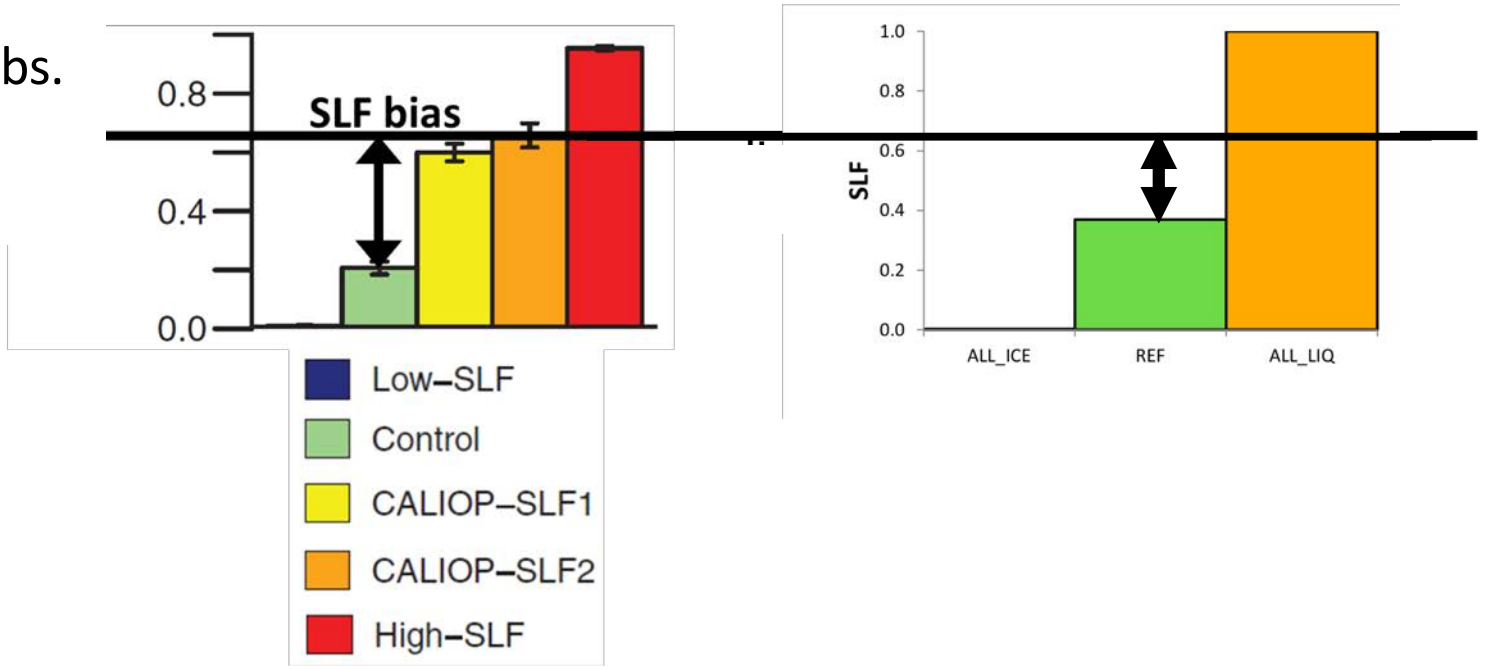
Lohmann and Neubauer, ACP, 2018

Present-day supercooled liquid fraction at -10°C

CESM

ECHAM6-HAM2

Obs.



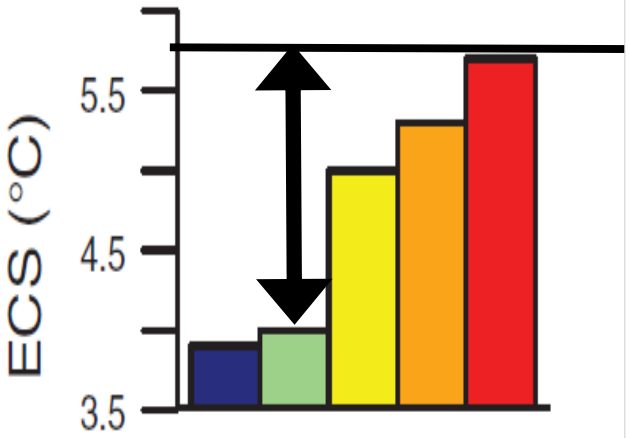
ECHAM also underestimates SLF, but less than CESM

→ do we also underestimate ECS? And if so, by how much?

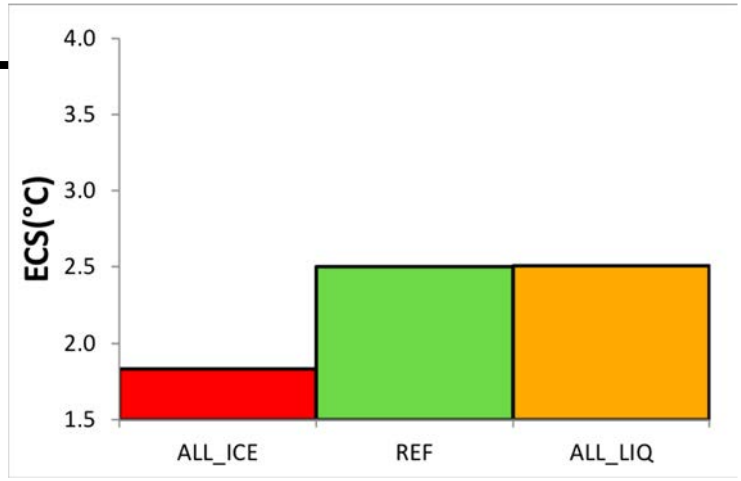
CESM Figure from Tan et al. (2016)

Equilibrium climate sensitivity (ECS)

CESM



ECHAM6-HAM2



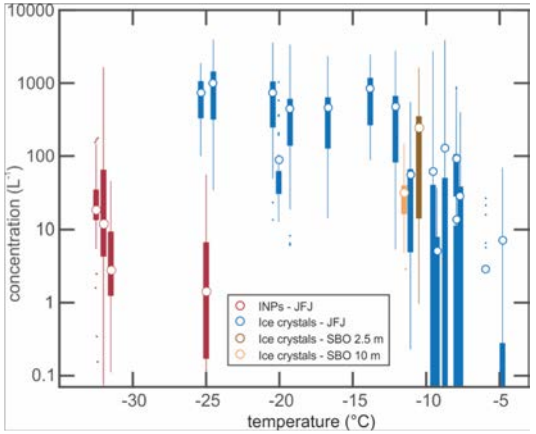
Low–SLF
Control
CALIOP–SLF1
CALIOP–SLF2
High–SLF

No ECS increase between simulation REF and ALL_LIQ in ECHAM6-HAM2 despite the overall higher cloud feedback → why not?

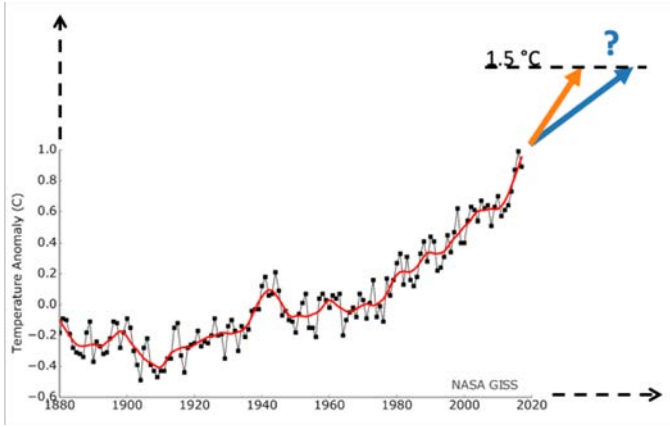
CESM Figure from Tan et al. (2016)

Take-home messages

- Can we predict ice crystal number concentrations from INP concentrations? no
  - Must consider other sources of ice
    - Secondary ice production
    - Surface sources (from below)
    - Feeding crystals (from above)
  - Must continue measurements of INPs at JFJ for a better characterization of primary ice



- The impact of mixed-phase clouds on climate remains an open question.
  - Further in-situ measurements of cloud properties, such as taken at the JFJ, are needed to validate our climate models




Thanks a lot for your attention