Relationships between cloud thermodynamic structure and the properties of precipitation from cloud radar and disdrometer observations

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PrePEP 2025

20 March 2025

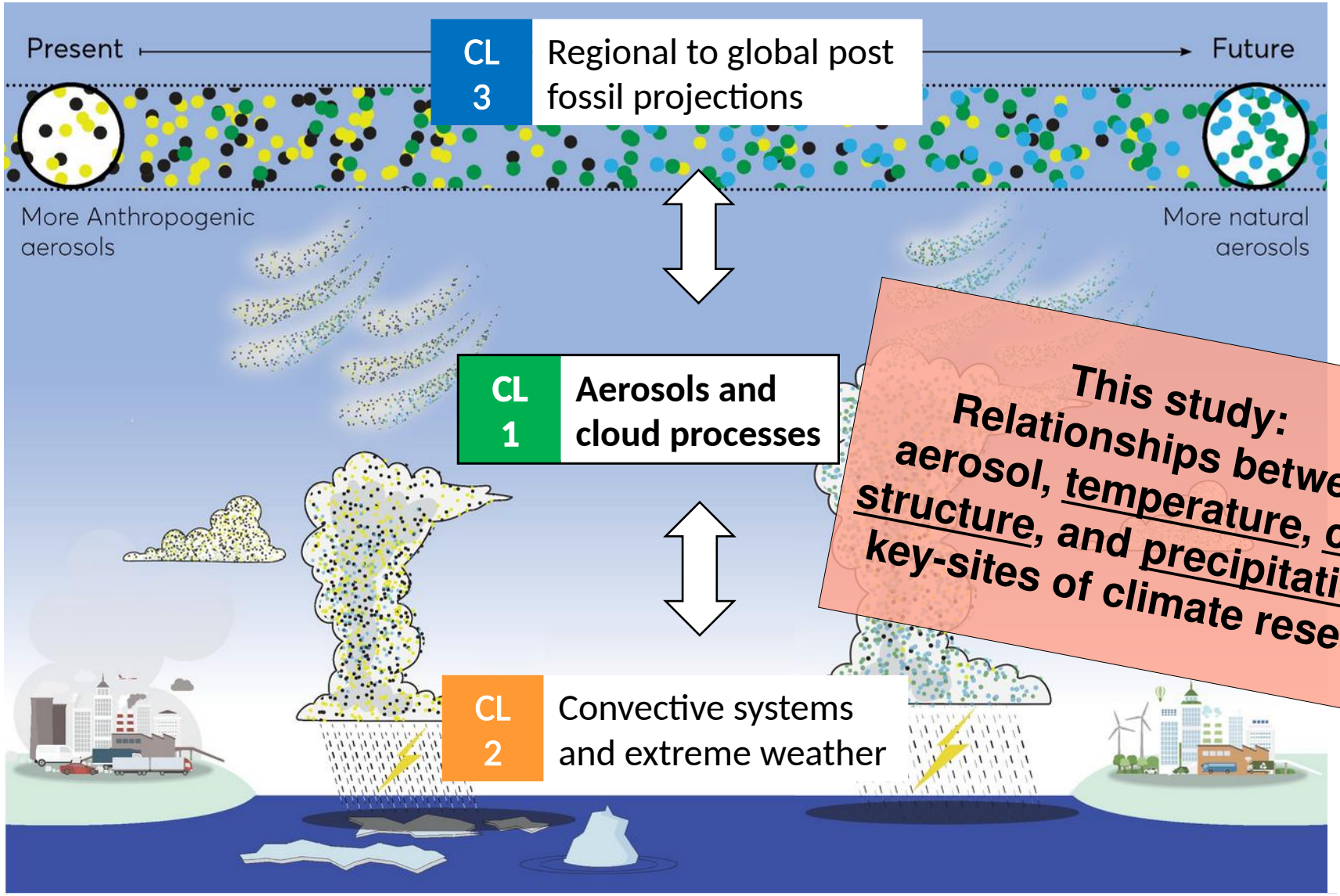
Leibniz Association

TROPOS
Leibniz Institute for Tropospheric Research

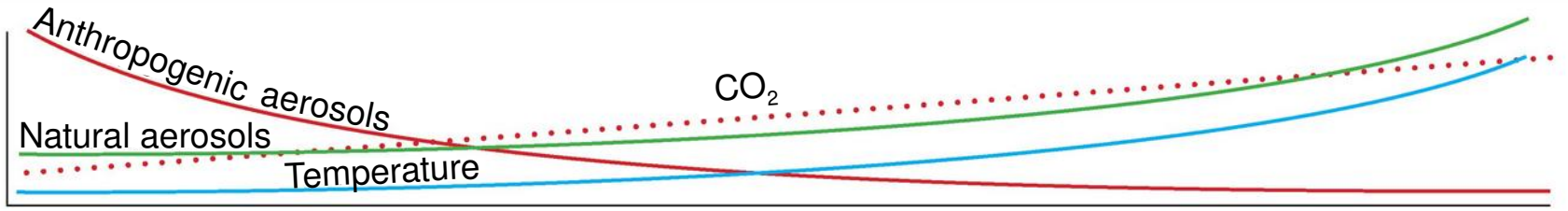
Clouds and climate transitioning to post-fossil aerosol regime

EU project

01/2024 – 12/2027



This study: Relationships between aerosol, temperature, cloud structure, and precipitation for key-sites of climate research



© https://projects.au.dk/cleancloud/cleancloud-project/work-packages

CleanCloud key sites

ACTRIS

Cloudnet

- CleanCloud: key regions with different dominating aerosol
- LACROS-like stations were operating in most of those key sites

→ longterm Cloudnet datasets available

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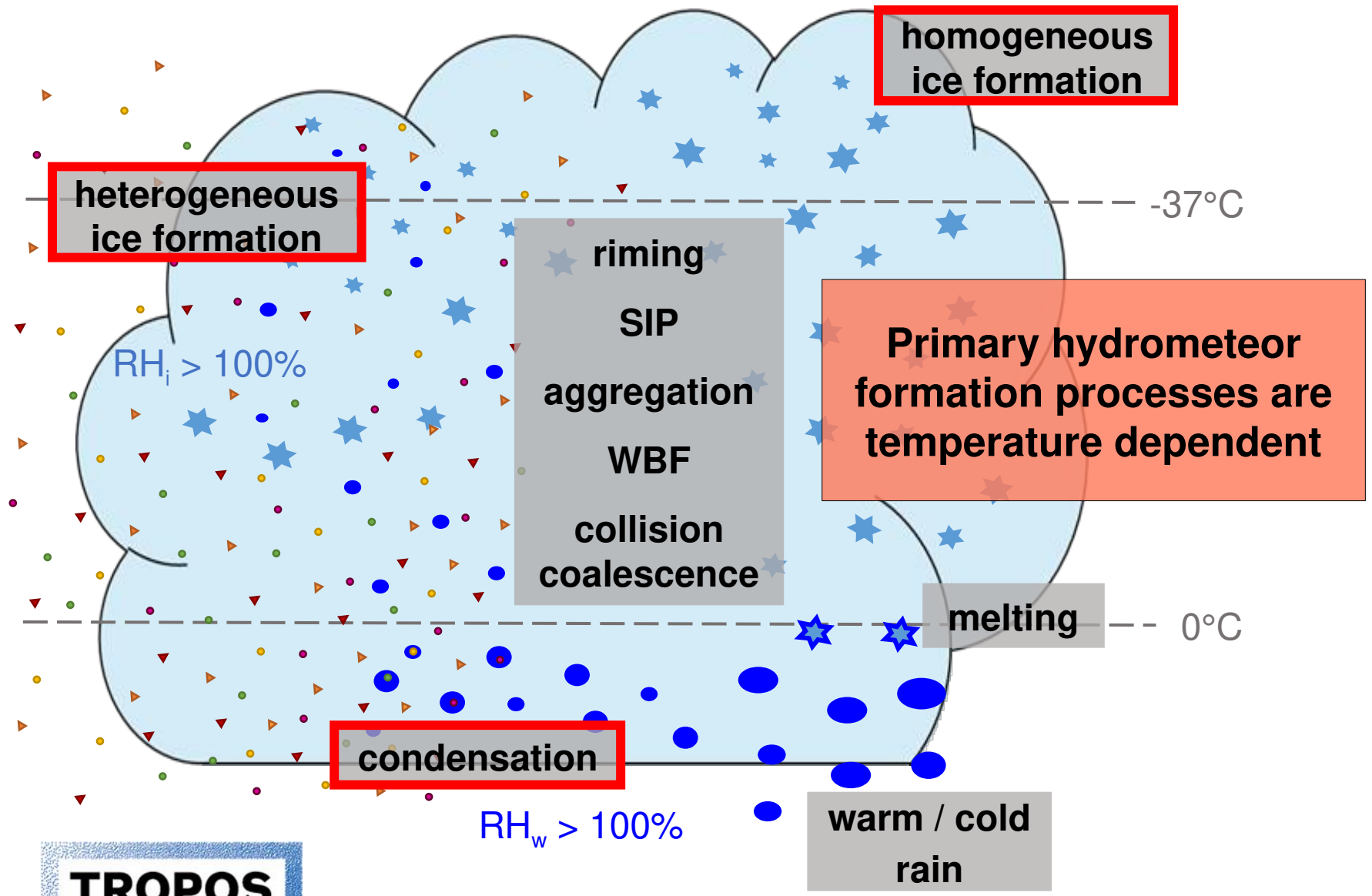
Precipitation formation



cloud-relevant aerosols

- **cloud condensation nuclei (CCN)**
- **ice nucleating particles (INP)**
- **liquid water**
- **ice particles**

SIP – secondary ice production

WBF – Wegener-Bergeron-Findeisen-process

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Definition of cloud-top temperature regimes

[1] de Boer et al. (2011, GRL)
[2] Ansmann et al. (2009, JGR)
[3] Westbrook and Illingworth (2011, GRL)
[4] Koop et al. (2004, ZPC)

Temperature	> 0°C	0 to -27°C	-27 to -37°C	< -37°C
warm rain				
liquid-dependent freezing[1,2] *				
deposition freezing[1,3]				
homogeneous freezing[4]				

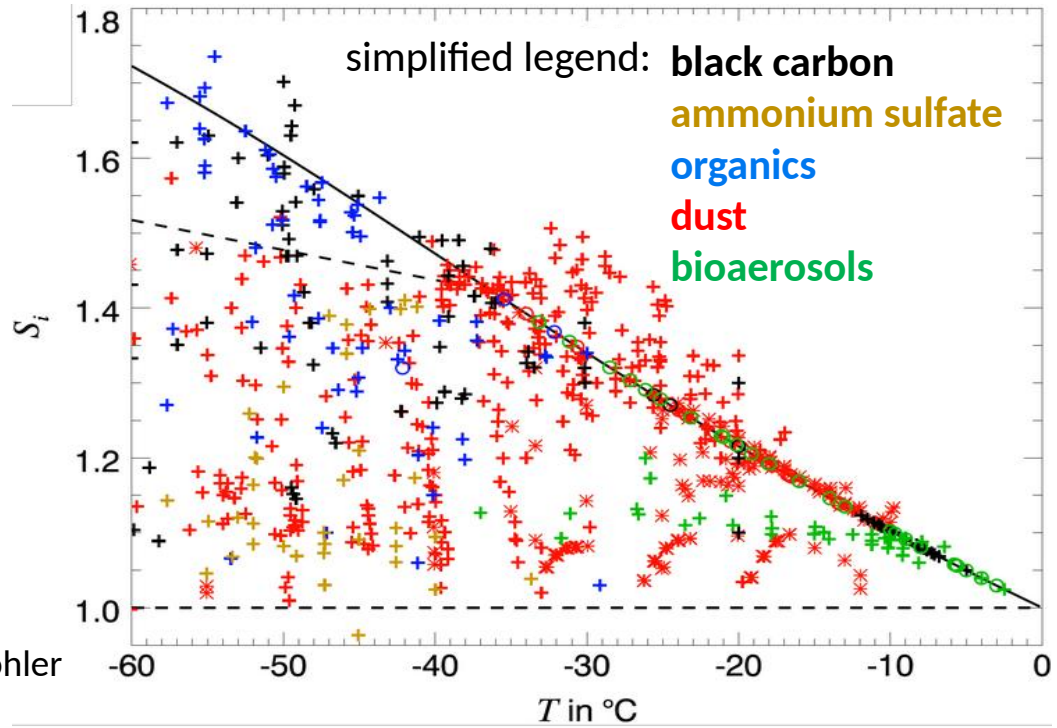
* liquid-dependent freezing includes immersion, condensation, and contact freezing

Freezing processes are temperature-dependent!

In which regions are which processes dominating?

How do models represent the precipitation patterns?

ice nucleation onset temperatures and saturation ratios from laboratory experiments



Hoose and Möhler (2012, ACP)

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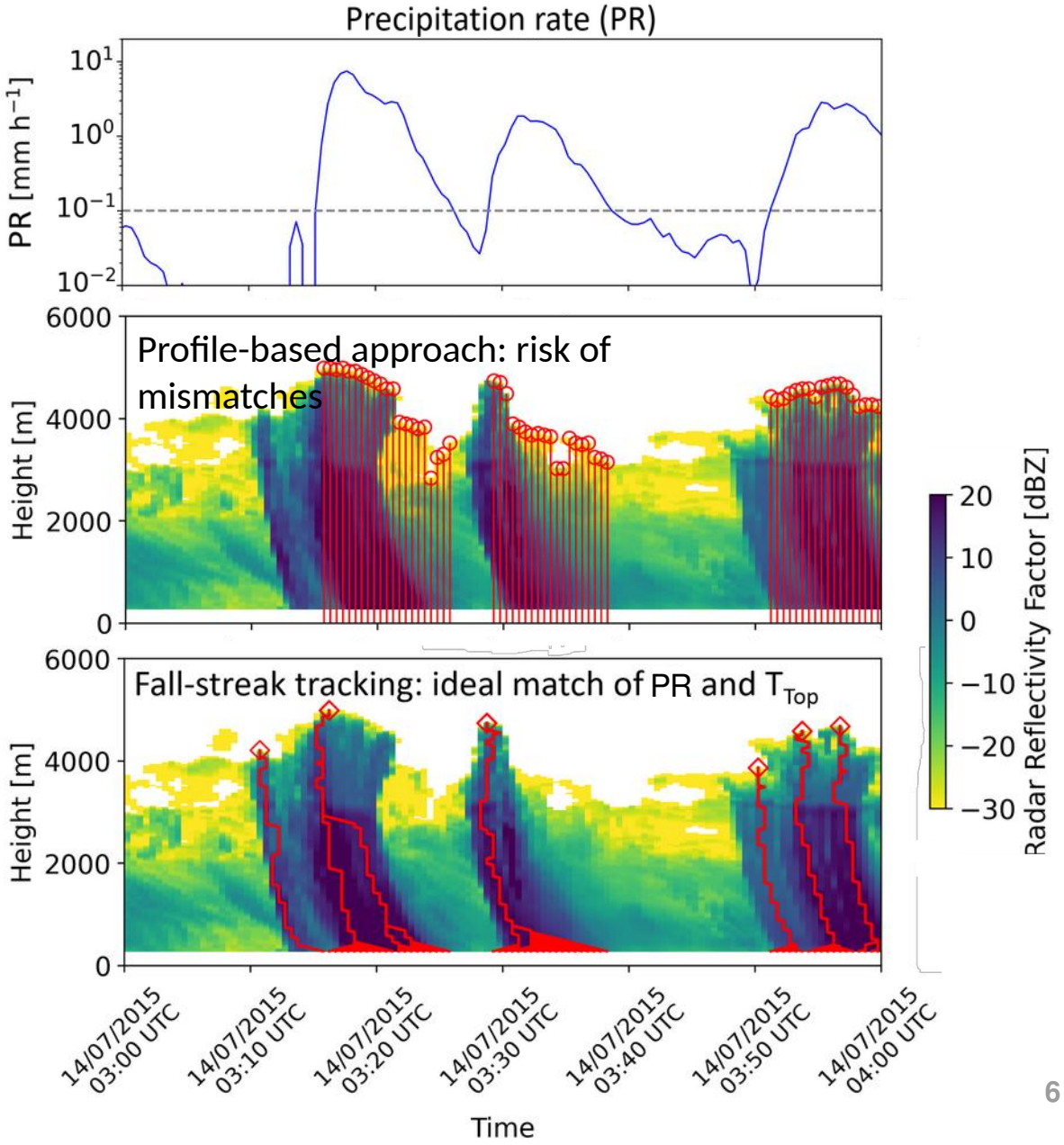
Cloud properties versus precipitation rate (CLOPPER)

The idea of CLOPPER:

- idea: different temperature regimes can be assigned to certain hydrometeor formation processes
- combination of disdrometer, cloud radar, and ECMWF IFS model is used (combined in CLOUDNET categorize files)
- fallstreak algorithm is applied



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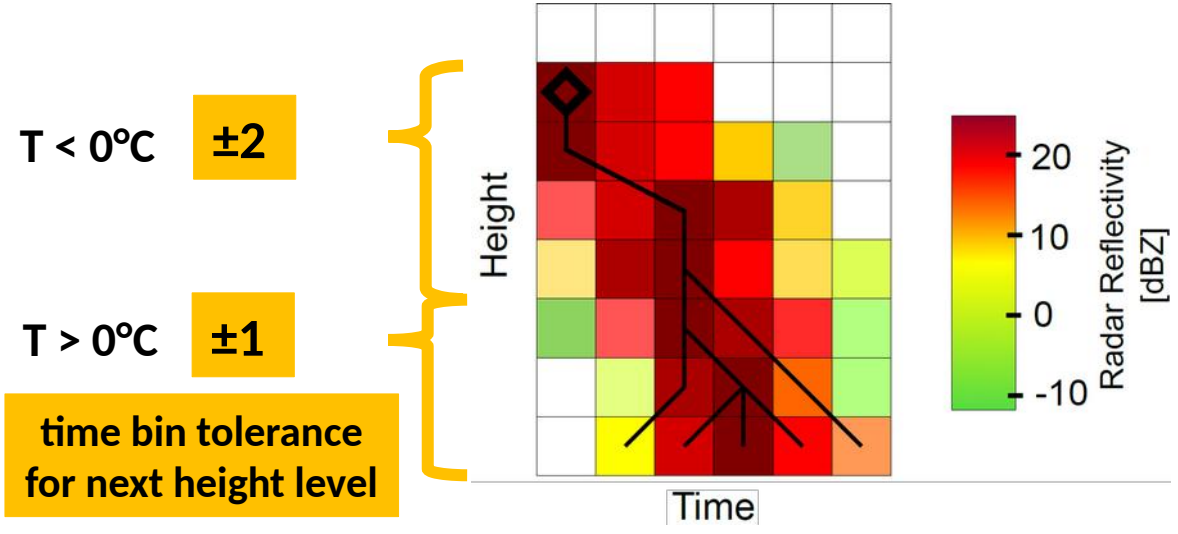
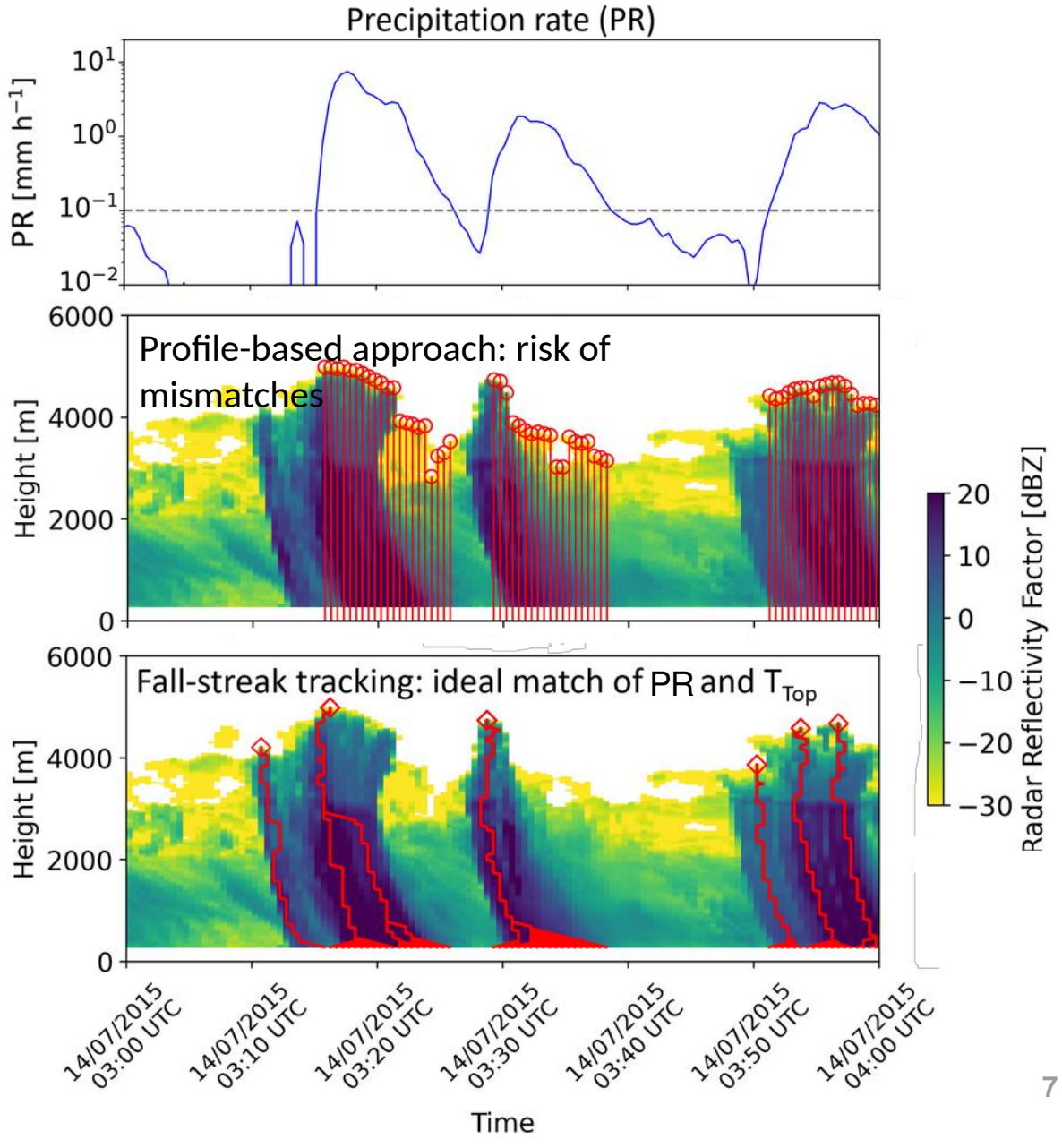
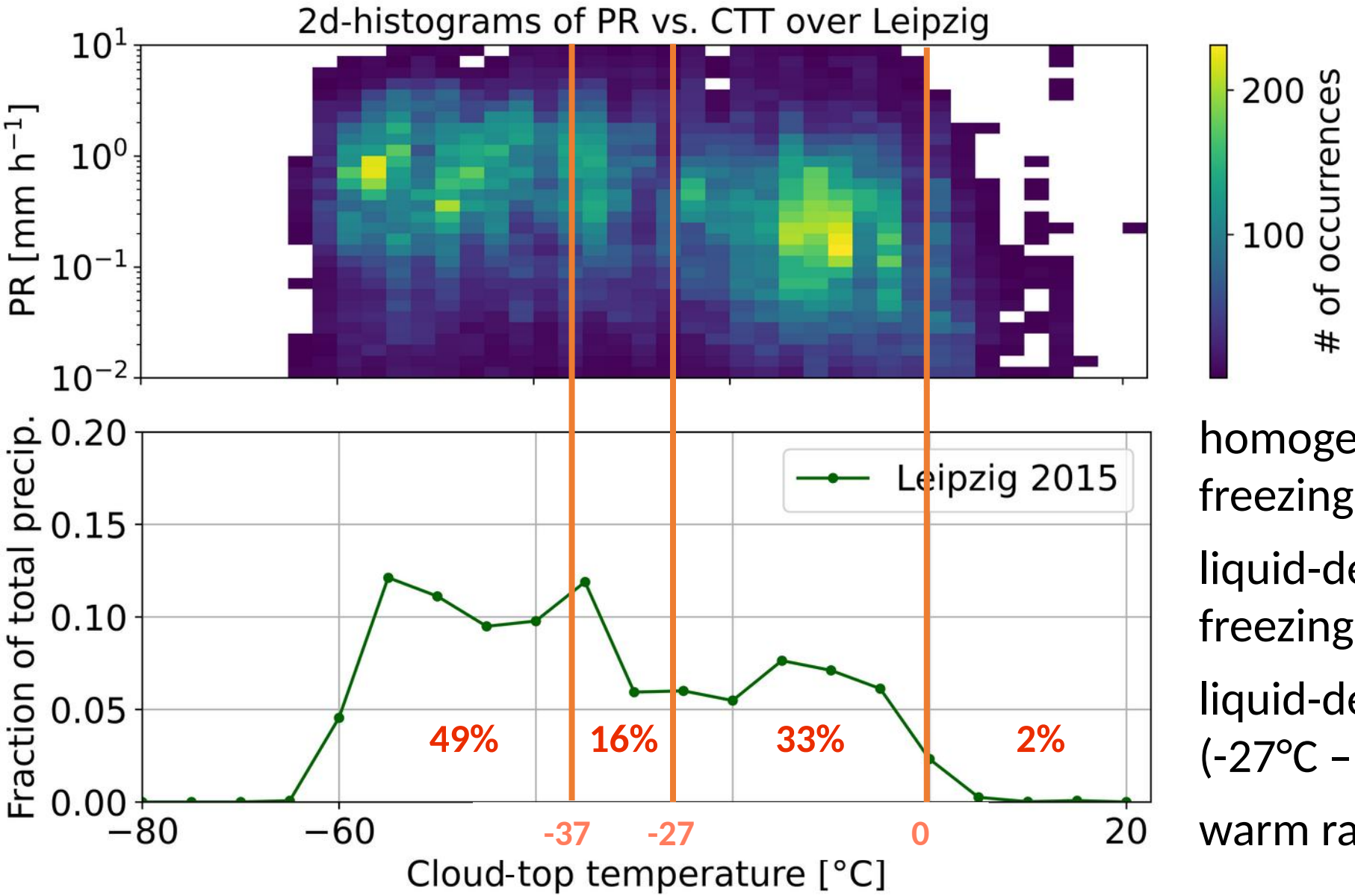
schematic fallstreak reconstruction





Statistics for Leipzig 2015



Leipzig 01/2015 – 12/2015

homogeneous &| deposition freezing (< -37°C): 49%

liquid-dep. &| deposition freezing (-37°C – -27°C): 16%

liquid-dep. &| warm rain (-27°C – 0°C): 33%

warm rain (> 0°C): 2%

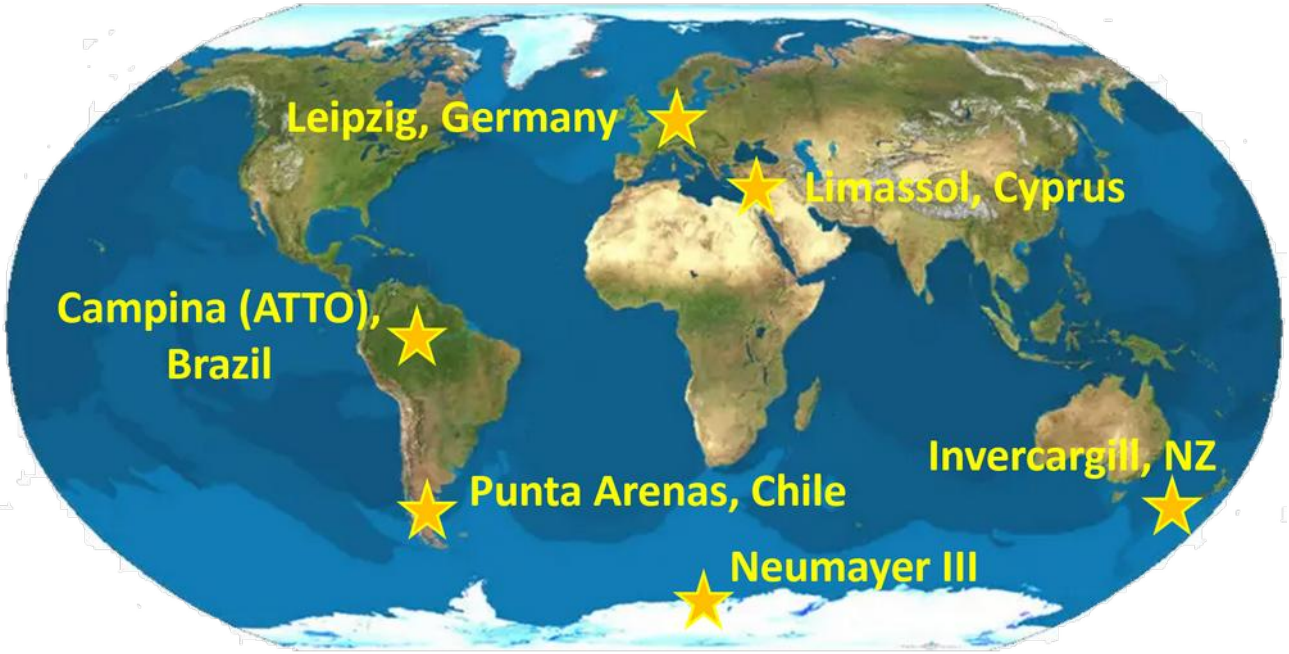
Summary

CLOPPER: assignment of precipitation formation processes to temperature regimes

Temperature	**0°C** warm rain	**0 to -27°C** liquid-dep. &| warm rain	**-27 to -37°C** liquid-dep. &| depos. freezing	**< -37°C** hom. &| depos. freezing
Leipzig	2%	33%	16%	49%

Outlook

- CLOPPER will be applied to different stations
- CLOPPER can be extended
  - in-cloud vertical velocity
  - ambient aerosol properties
  - evolution of hydrometeor and habits
- combined cloud tracking studies
  - analyse the impact of the air mass origin on detected clouds



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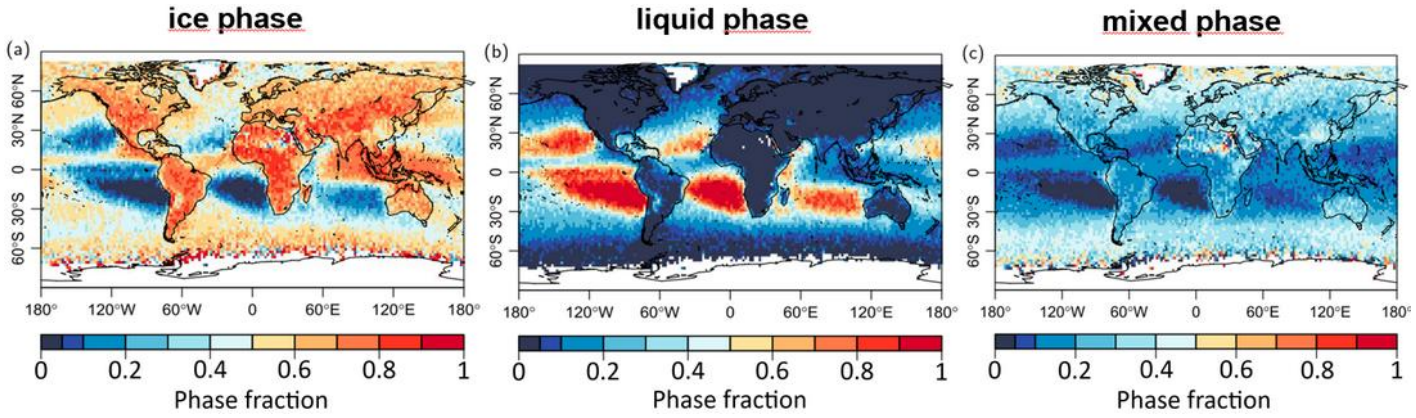
Observation of cloud and precipitation processes

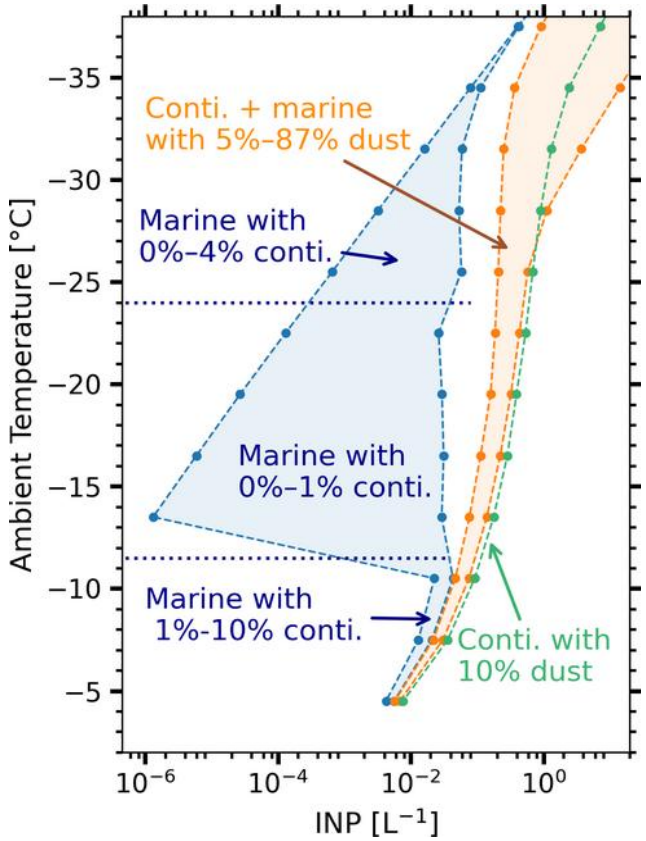


satellite-based observation of cloud phase during rain events[5]

Heymsfield et al. (2020): global cloud phase fractions during precipitation events

→ combined satellite and modelling data

→ 57% cold rain; 15% combination of cold and warm rain; 23% warm rain; 5% precipitating ice[6]



Leipzig, Germany

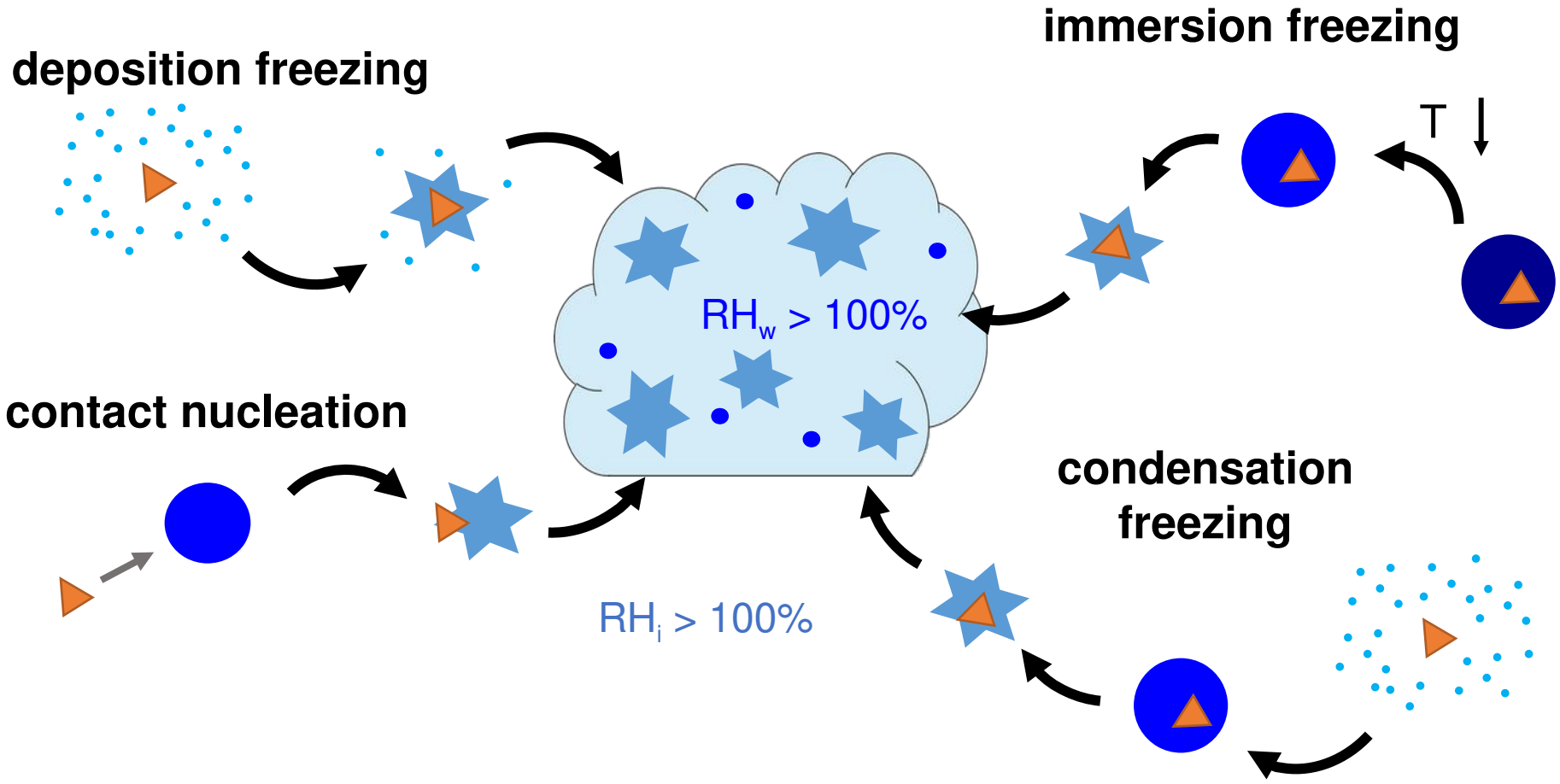
Limassol, Cyprus

Punta Arenas, Chile

hemispheric contrast studies: average INP concentrations for different stations derived by ground-based lidar measurements[7]

[5] Mülmenstädt et al. (2015, GRL)
[6] Heymsfield et al. (2020, JAS)
[7] Radenz et al. (2021, ACP)

heterogeneous (primary) ice formation processes



ice nucleating particle (INP)

liquid water

ice particle

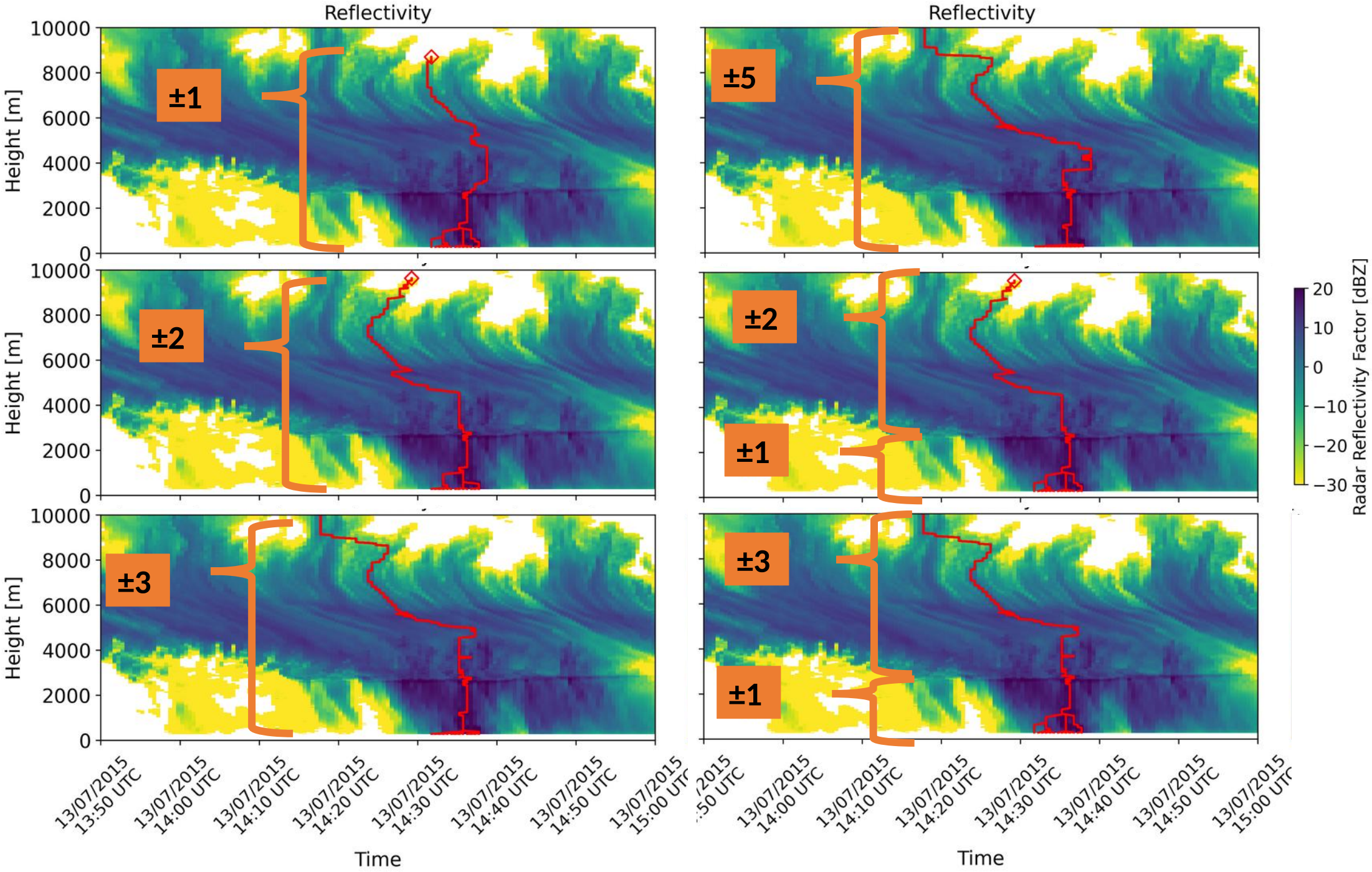
water vapour

contact nucleation
+ condensation freezing
+ immersion freezing

→ **liquid-dependent freezing processes**

13 Jul 2015
13:50 – 15:00

time bin tolerance for next height level



Statistics over Leipzig – V1 vs. V2

Version 1 ±1 { all T

Version 2 ±3 { T < 0°C ; ±1 { T > 0°C