A probabilistic approach to determine the thermodynamic cloud phase using passive satellites

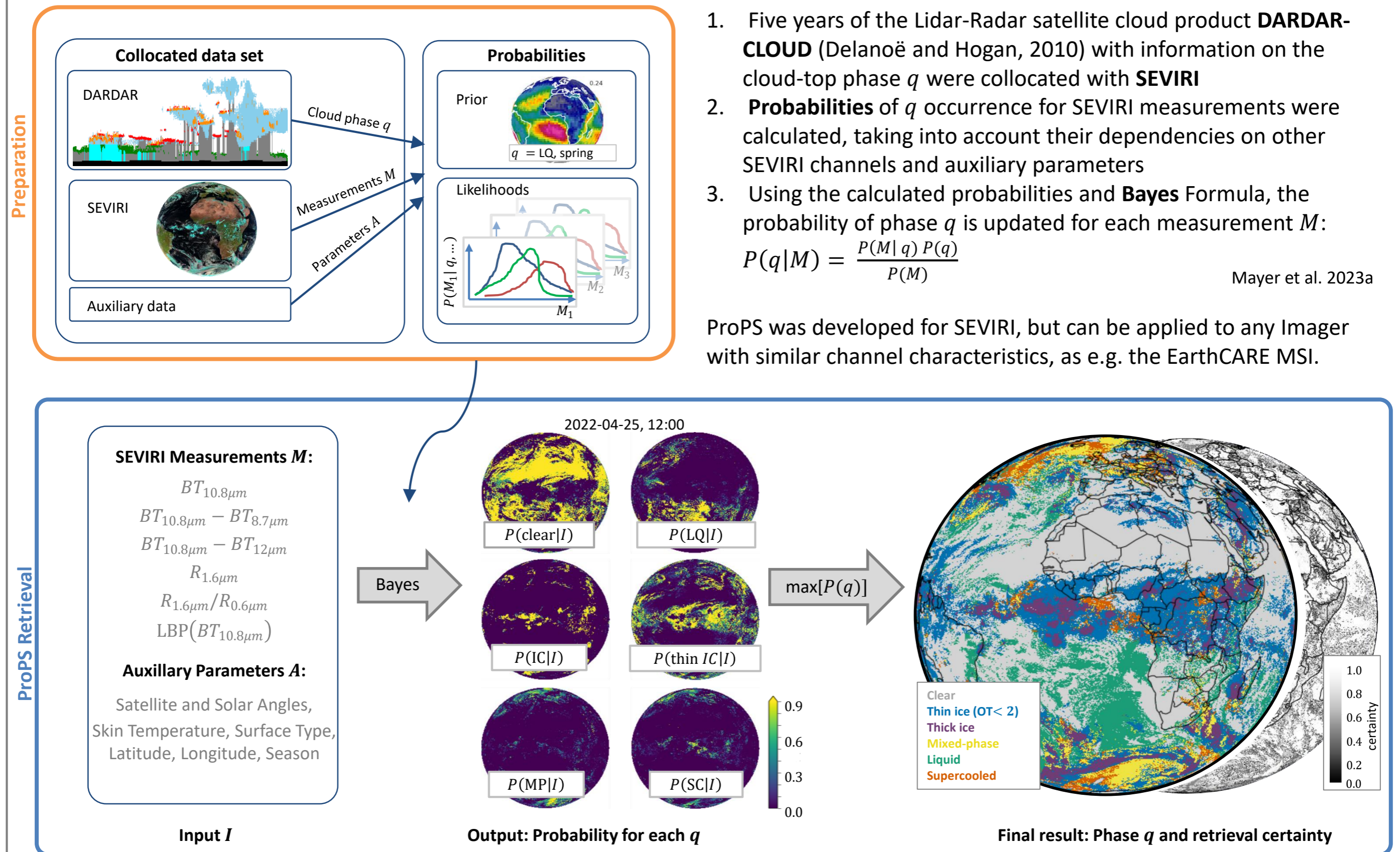Johanna Mayer[1] (johanna.mayer@dlr.de), Luca Bugliaro[1], Christiane Voigt[1,2], Bernhard Mayer[1,3]

[1]Institut für Physik der Atmosphäre, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen, Germany
[2]Institut für Physik der Atmosphäre, Johannes Gutenberg-Universität, Mainz, Germany
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Synergy of Active and Passive Instruments:
Transfer of the phase detection capabilities of DARDAR to the SEVIRI geostationary imager

Preparation

Collocated data set — DARDAR, SEVIRI, Auxiliary data
Cloud phase q / Measurements M / Parameters A
Probabilities — Prior, q = LQ, spring — Likelihoods $P(M_1|q,...)$, M_1, M_2, M_3

1. Five years of the Lidar-Radar satellite cloud product **DARDAR-CLOUD** (Delanoë and Hogan, 2010) with information on the cloud-top phase q were collocated with **SEVIRI**
2. **Probabilities** of q occurrence for SEVIRI measurements were calculated, taking into account their dependencies on other SEVIRI channels and auxiliary parameters
3. Using the calculated probabilities and **Bayes** Formula, the probability of phase q is updated for each measurement M:

$$P(q|M) = \frac{P(M \mid q)\, P(q)}{P(M)}$$

Mayer et al. 2023a

ProPS was developed for SEVIRI, but can be applied to any Imager with similar channel characteristics, as e.g. the EarthCARE MSI.

ProPS Retrieval

SEVIRI Measurements M:

$BT_{10.8\mu m}$
$BT_{10.8\mu m} - BT_{8.7\mu m}$
$BT_{10.8\mu m} - BT_{12\mu m}$
$R_{1.6\mu m}$
$R_{1.6\mu m}/R_{0.6\mu m}$
$LBP(BT_{10.8\mu m})$

Auxillary Parameters A:

Satellite and Solar Angles, Skin Temperature, Surface Type, Latitude, Longitude, Season

Input I

Bayes

2022-04-25, 12:00

$P(\text{clear}|I)$ $P(LQ|I)$
$P(IC|I)$ $P(\text{thin } IC|I)$
$P(MP|I)$ $P(SC|I)$

Output: Probability for each q

max[$P(q)$]

Clear
Thin ice (OT< 2)
Thick ice
Mixed-phase
Liquid
Supercooled

certainty: 1.0, 0.8, 0.6, 0.4, 0.2, 0.0

Final result: Phase q and retrieval certainty

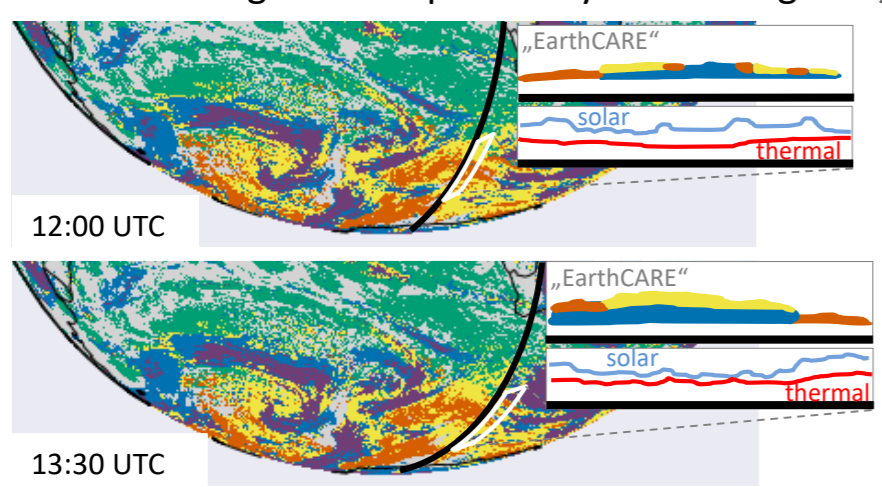„ProPS" = **Pro**babilistic cloud top **P**hase retrieval for **S**eviri

Publication: Mayer et al. 2023b submitted to AMT

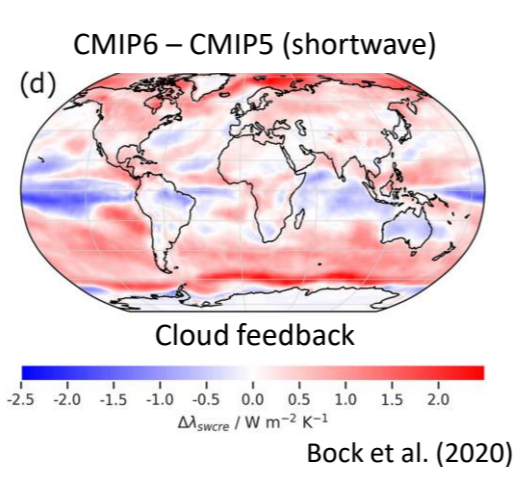## Ideas for synergies between EarthCARE and geostationary Imagers

Southern Ocean clouds

Differences between CMIP6 and CMIP5 in cloud feedback in high latitudes is largely due to different cloud phases between models (Bock et al., 2020).

A synergy of EarthCARE and geostationary imagers like SEVIRI will improve our understanding of cloud phases by connecting:


CMIP6 − CMIP5 (shortwave)
(d)
Cloud feedback
-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0
$\Delta\lambda_{swcre}$ / W m^{-2} K^{-1}
Bock et al. (2020)
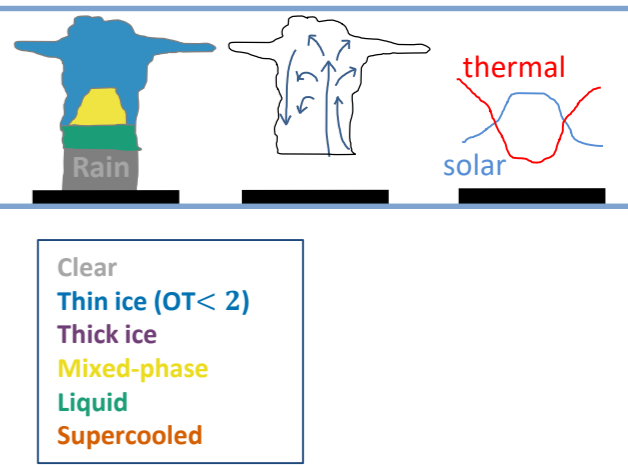
„EarthCARE" — solar — thermal
12:00 UTC
13:30 UTC

- Vertical cloud profiles at different times
- Short-wave and long-wave fluxes
- Horizontal variability
- Temporal development

Example for clouds with different phases over the Southern Ocean on the 2023-04-24

Convective clouds

A synergy of EarthCARE and geostationary imagers like SEVIRI will provide and connect:
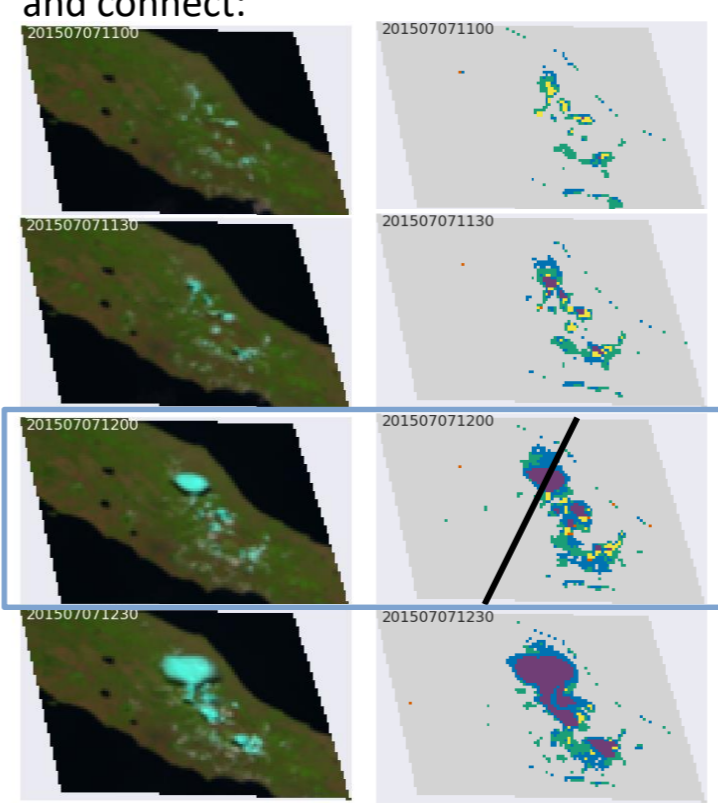
- Vertical cloud profiles
- Vertical velocity
- Precipitation
- Short-wave and long-wave fluxes
- Temporal development
- Horizontal extent

201507071100
201507071130
201507071200
201507071230

Rain — thermal — solar

Clear
Thin ice (OT< 2)
Thick ice
Mixed-phase
Liquid
Supercooled

Convective cells near Rome. Left: RGB; right: Cloud top phase