Observations and modeling of areal surface albedo and surface types in the Arctic

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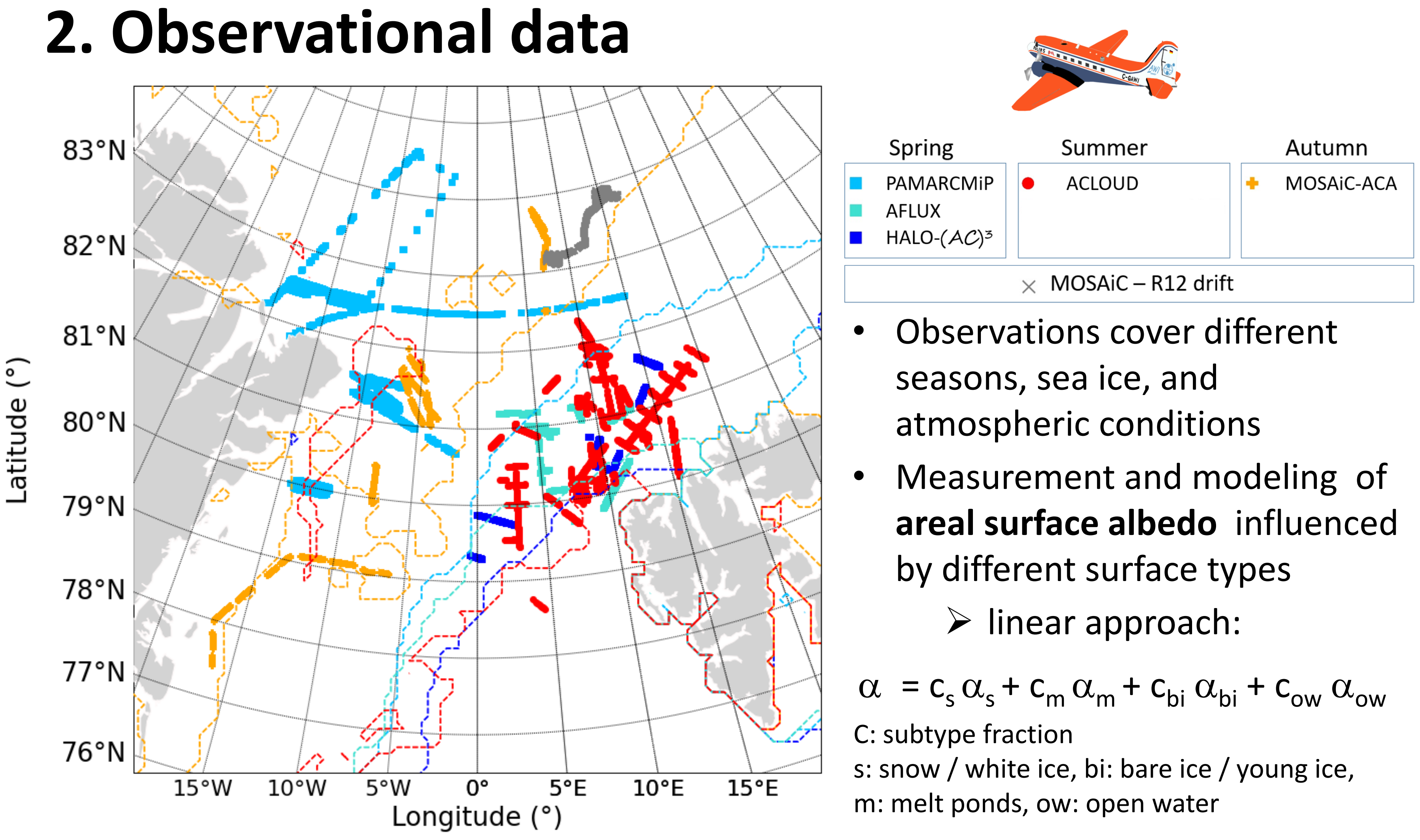
1. Introduction

- Models with **highest biases of snow/ice albedo feedback** have problematic representation of **sea ice albedo**
  - ➢ Need for a **validation** and **improvement** of snow/ice albedo schemes based on measurements
  - ➢ (AC)³ campaigns and MOSAiC as testbed of most recent adjustments[1,2]

2. Observational data



- Observations cover different seasons, sea ice, and atmospheric conditions
- Measurement and modeling of **areal surface albedo** influenced by different surface types
  - ➢ linear approach:

$$\alpha = c_s\,\alpha_s + c_m\,\alpha_m + c_{bi}\,\alpha_{bi} + c_{ow}\,\alpha_{ow}$$

C: subtype fraction
s: snow / white ice, bi: bare ice / young ice, m: melt ponds, ow: open water

Fig. 1: Selected flight sections to measure surface albedo of sea ice in low flight altitude (60 – 300 m) during the five (AC)³ campaigns (2017 – 2022). Drift track of radiation station R12 during MOSAiC in gray. Sea ice edges shown with dotted lines.

Airborne Instrumentation

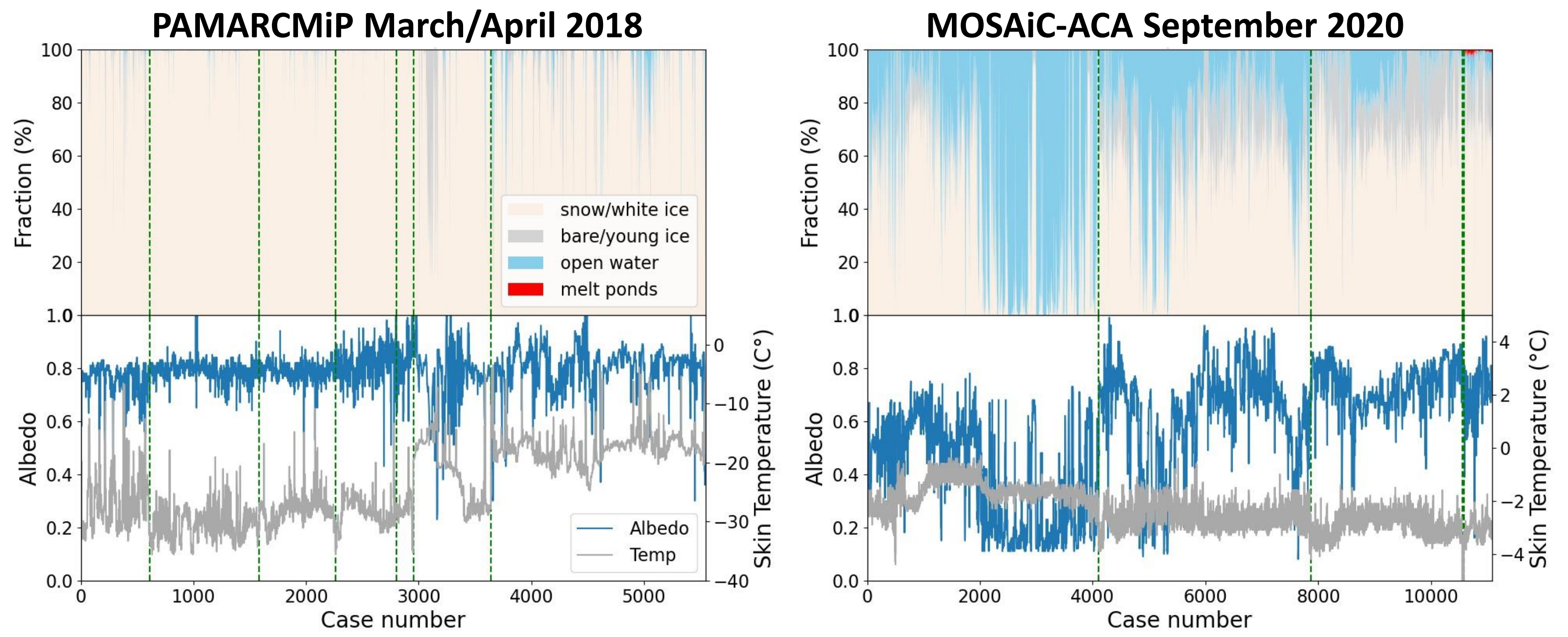
- Broadband and spectral **surface albedo**: CMP-22 pyranometer, SMART-Polar
- Surface **type** and **fraction**: RGB fisheye cameras (Canon, Nikon), wide-angle camera system Polar-MACS (DLR Berlin)
- Surface skin **temperature** (T_{surf}): KT19

Ground-based instrumentation during MOSAiC

- Spectral **surface albedo**: RAMSES-ACC-VIS radiometer

Satellite-based observation

- Multi-band **surface albedo**: Land Colour Instrument (OLCI) on Sentinel-3


PAMARCMiP March/April 2018

MOSAiC-ACA September 2020

Fig. 2: Time series of surface types, albedo and skin temperature for the spring campaign PAMARCMiP and the autumn campaign MOSAiC-ACA.

- Variation of areal surface albedo
  - ➢ Spring: depending rather on the effects of ice dynamics (open leads, surface roughness) than on surface temperature
  - ➢ Summer / Autumn: strong relation to surface skin temperature (determining melting and refreezing)

REFERENCES

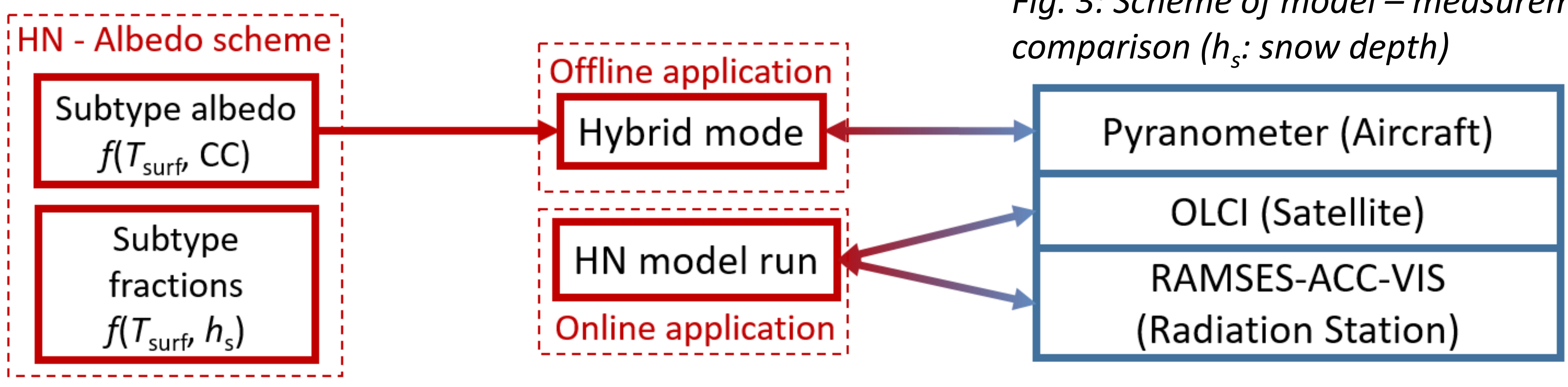
[1] Jäkel, E., Stapf, J., Wendisch, M., Nicolaus, M., Dorn, W., and Rinke, A.: Validation of the sea ice surface albedo scheme of the regional climate model HIRHAM–NAOSIM using aircraft measurements during the ACLOUD/PASCAL campaigns, The Cryosphere, 13, 1695–1708, https://doi.org/10.5194/tc-13-1695-2019, 2019.

[2] Foth, L., Dorn, W., Rinke, A., Jäkel, E., and Niehaus, H.: On the importance to consider the cloud dependence in parameterizing the albedo of snow on sea ice, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-634, 2023.

3. Model surface albedo scheme

- Surface albedo scheme **HIRHAM-NAOSIM** (HN, coupled atmosphere – ocean – sea ice model) was revised within (AC)³ based on early summer campaign data (ACLOUD 2017)
- **New scheme** includes cloud cover (CC) -dependent snow albedo range and adjusted threshold temperatures

Fig. 3: Scheme of model – measurement comparison (h_s: snow depth)


HN - Albedo scheme

Subtype albedo $f(T_{surf}, CC)$

Subtype fractions $f(T_{surf}, h_s)$

Offline application

Hybrid mode

HN model run

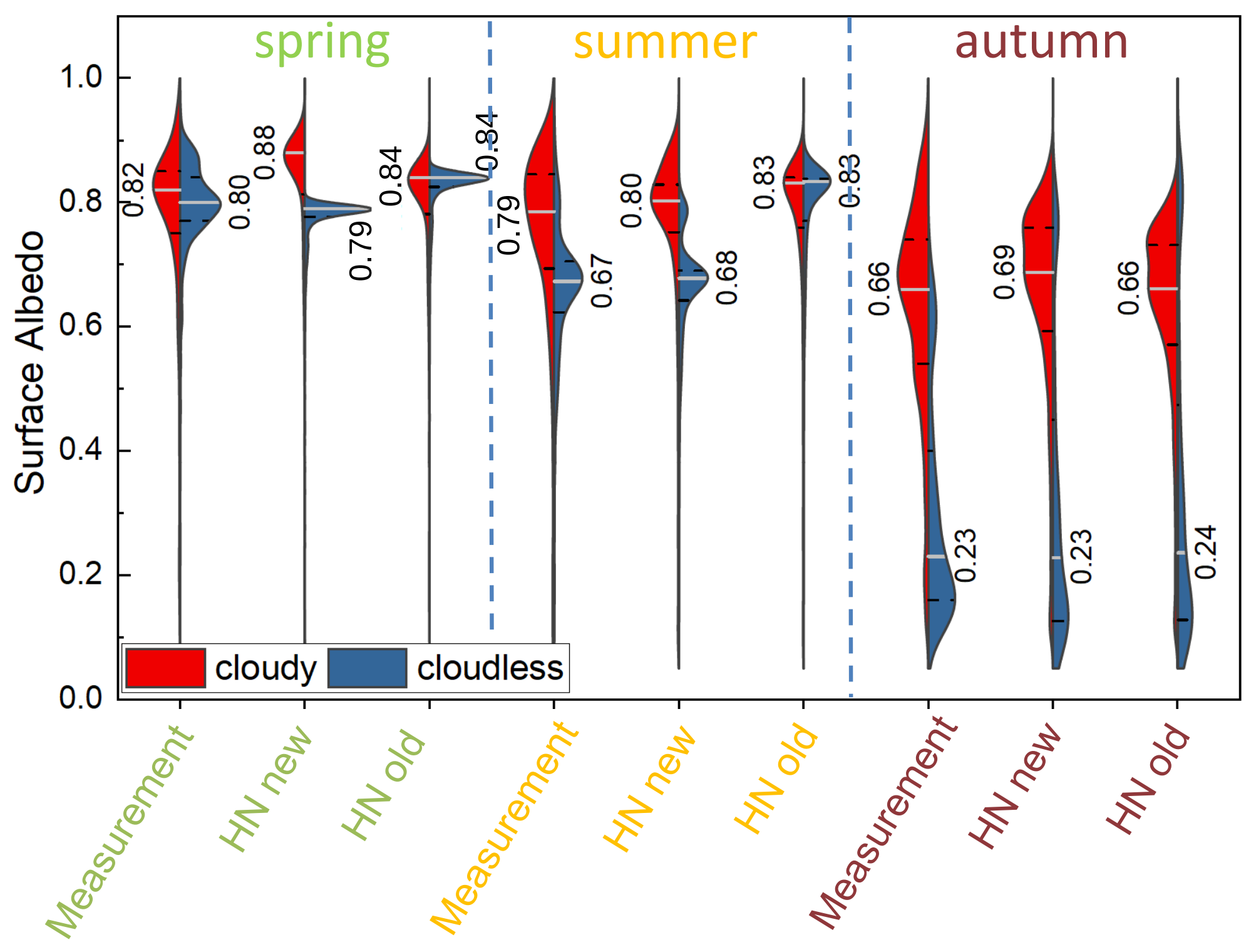
Online application

Pyranometer (Aircraft)

OLCI (Satellite)

RAMSES-ACC-VIS (Radiation Station)

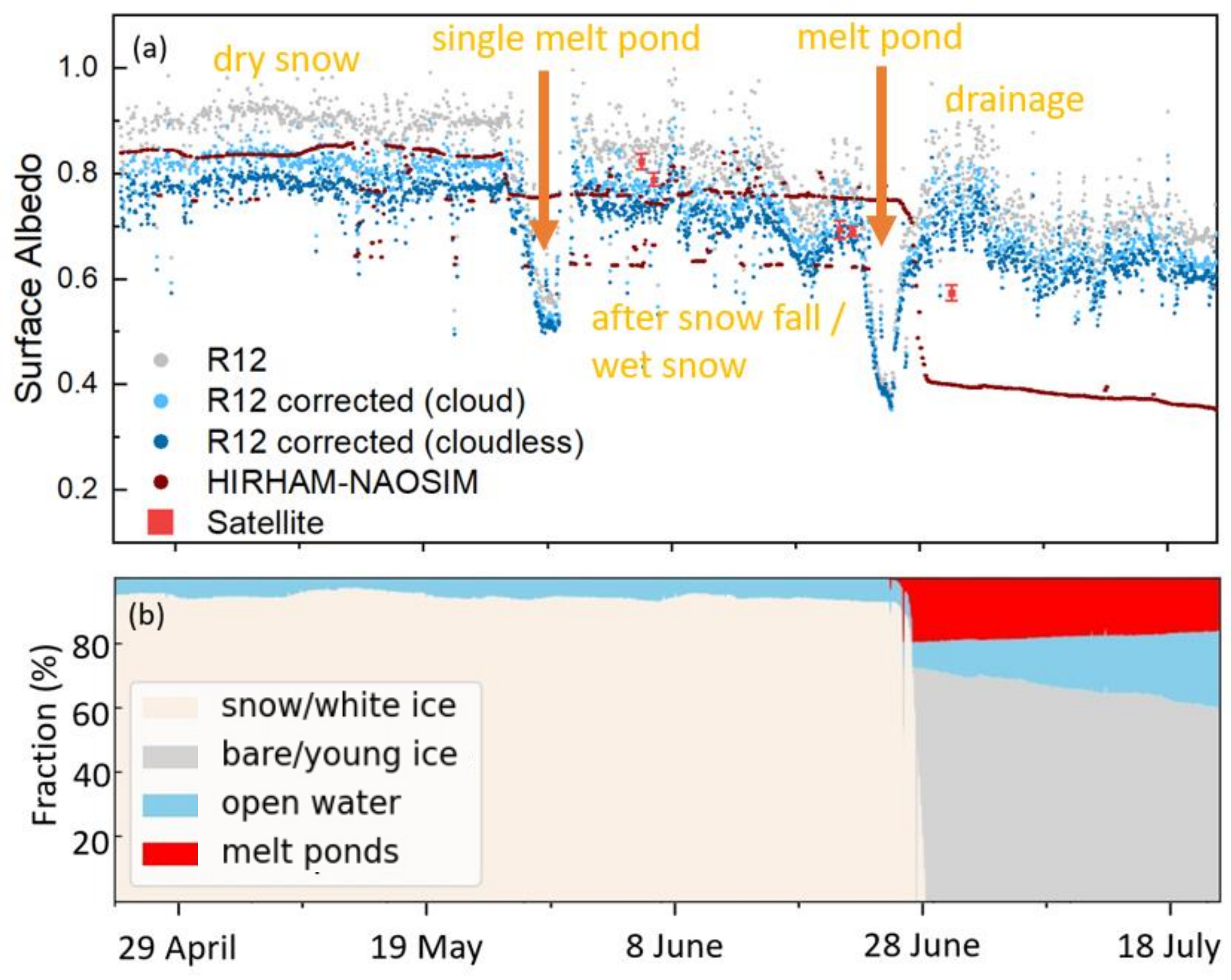
4. Application of surface albedo scheme



Hybrid mode application

- Seasonal and cloud dependent agreement
- Major improvement for summer
- Weakening for spring (cloudy cases)

Fig. 4: Distribution of measured and modeled (hybrid mode) surface albedo for the spring, summer and autumn campaigns



HN model run

- Satellite product: area-averaged (model grid size) indicate representativeness of ground-station data
- Transition to wet snow and onset of major melt pond development well covered by the model
- Bias in July: melt pond fraction (satellite) similar to modeled fraction, but brighter (observed) scattering layer than darker (modeled) bare ice contribution

Fig. 5: MOSAiC time series of broadband surface albedo (original and corrected) derived from radiometer measurements and HN modeling. (b) Temporal evolution of surface type fractions calculated by HN.

Implications on net irradiance (F_{net})

- Calculation of $F_{net} = F^{\downarrow} - F^{\uparrow}$ for parameterized (new) and measured albedo (hybrid mode cases) using radiative transfer simulations
- Cloud optical depth (COD) estimated from transmitted radiation
- Overestimation of cloud enhancement effect on α_{para} → negative bias (median: -6.4 W m^{-2}) for optical thin clouds (COD < 5)

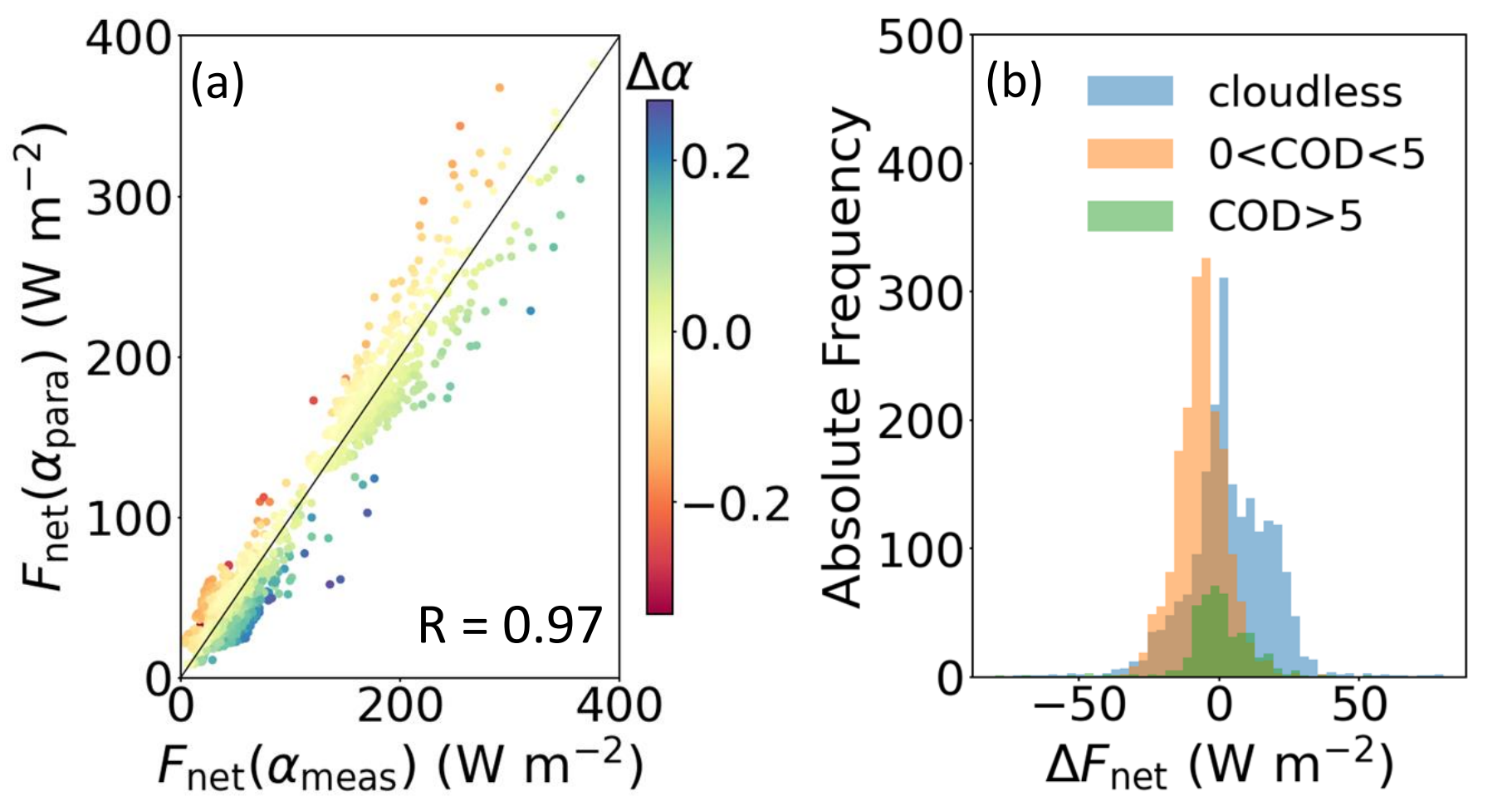


Fig. 6: (a) Scatterplot of F_{net} based on measured and parameterized surface albedo (flights in all seasons), albedo bias is color-coded. (b) Frequency distribution of $\Delta F_{net}=F_{net,para} - F_{net,meas}$ separated into three cloud classes.

5. Conclusions & Outlook

General:

- Model improvement for cloudless cases applying new parametrization
- Seasonal evolution of surface albedo is well reproduced by the model

Spring:

- Overestimation of parametrized surface albedo below optically thin clouds
  - ➢ New functional dependence on liquid and ice water path

Summer / Autumn:

- Model agreement driven by accuracy of subtype fractions rather than by the subtype albedo parametrization
  - ➢ New parametrization of subtype fraction

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