How Airborne Measurements May Help to Evaluate Models?

Manfred Wendisch, Johannes Stapf, Jan Kretzschmar, Kevin Wolf

Leipziger Institut für Meteorologie, Universität Leipzig

Workshop on Radiation in the Next Generation of Weather Forecast Models

ECMWF, Reading, UK

23 May 2018

Poster Kevin Wolf et al.

http://ac3-tr.de/

ACLOUD/PASCAL

Wendisch et al. (2018), submitted to BAMS

http://halo-spp.de/

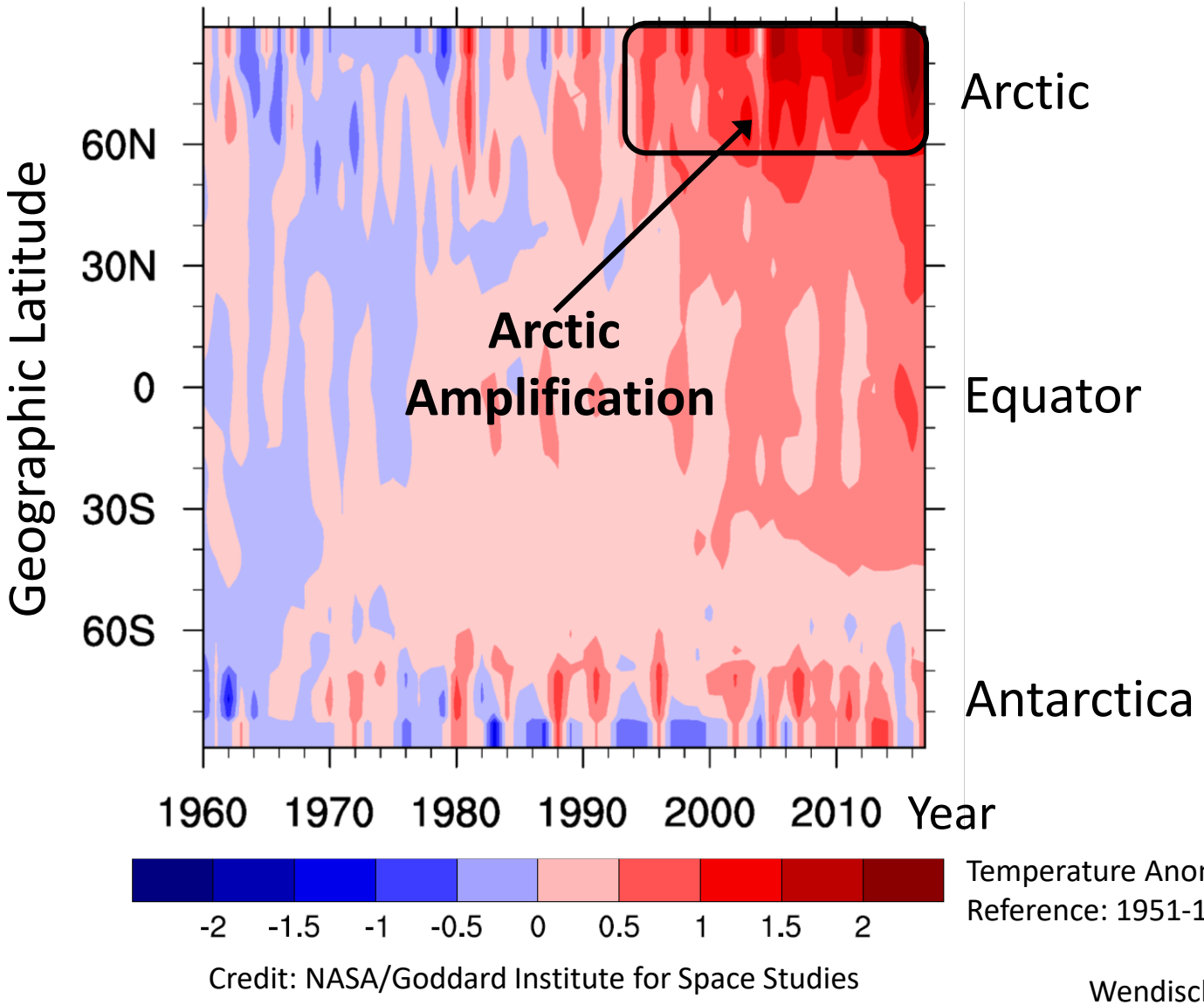
NAWDEX

Schäfler et al. (2018), accepted by BAMS

ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms (AC)^3

ACLOUD: Arctic CLoud Observations Using airborne measurements during polar Day
PASCAL: Physical feedbacks of Arctic boundary layer, Sea ice, Cloud and AerosoL

Arctic Near-Surface Air Temperature is on the Rise

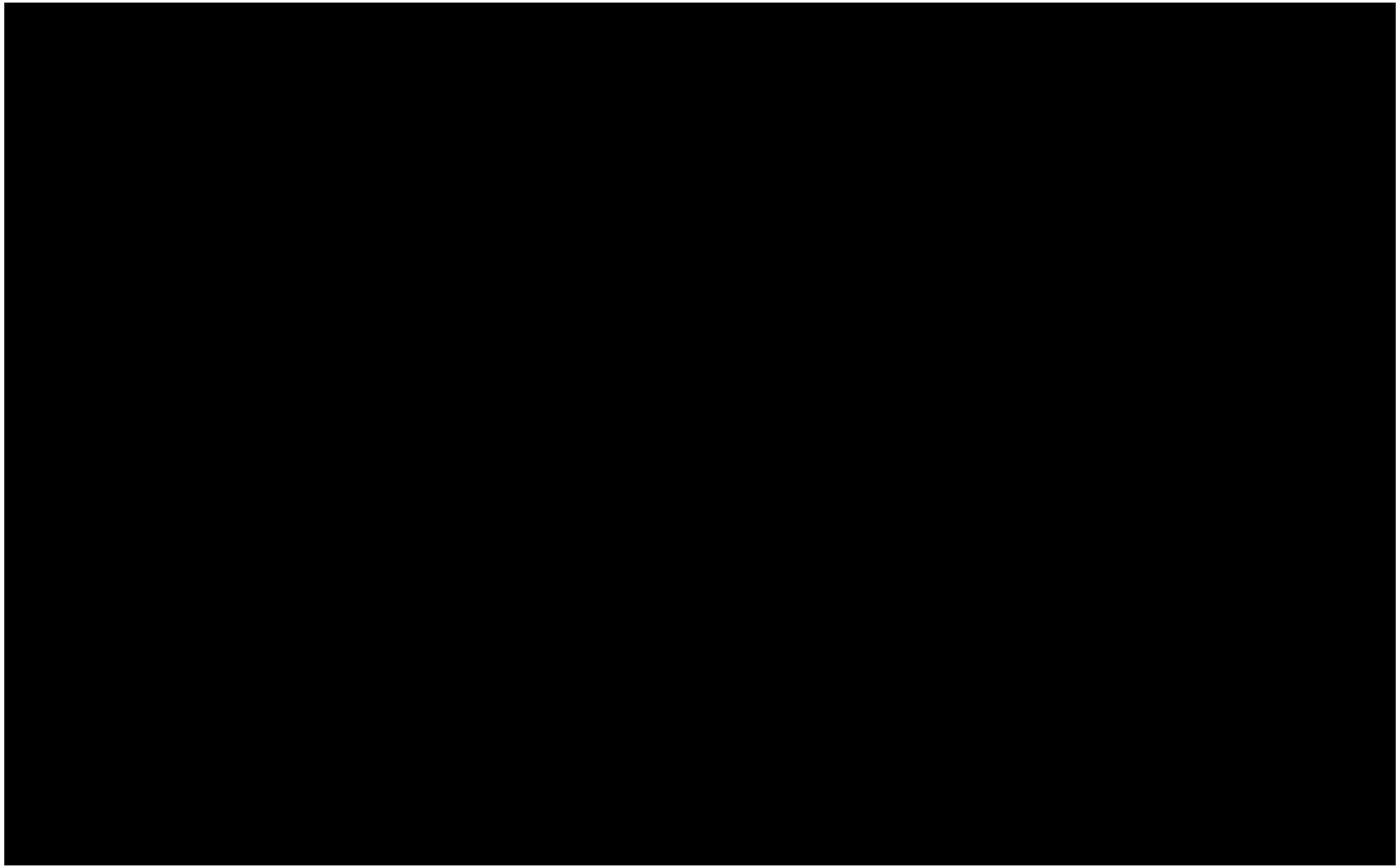


Credit: NASA/Goddard Institute for Space Studies

Wendisch et al. (2017)

Why should we care?

Polar jet stream at ca. 10 km height (Color ~ wind speed)



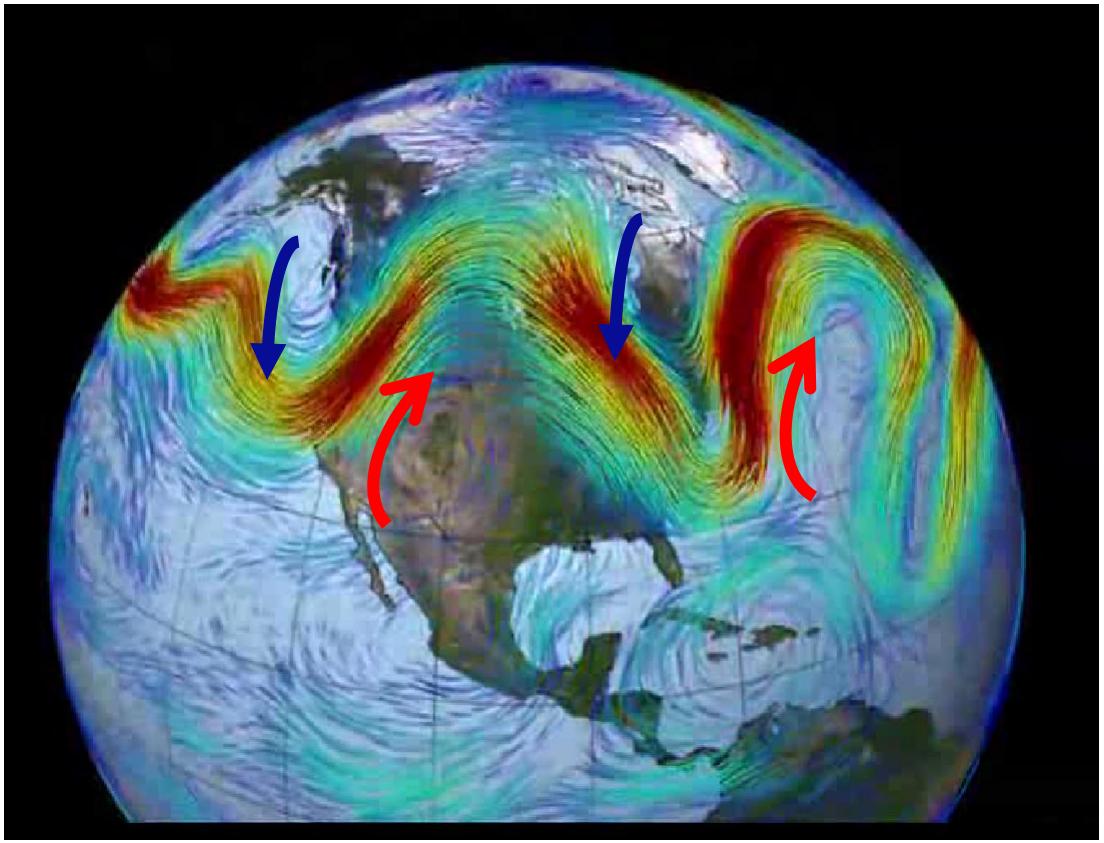
MERRA data, Jan. 2012, NASA

www.giss.nasa.gov/research/news/20120313/629341main_Earth_jet_stream.jpg

Increase of Meandring of Polar Jetstream

- Highly disputed
- Only one of several hypothesis

Polar jet stream at ≈10 km height



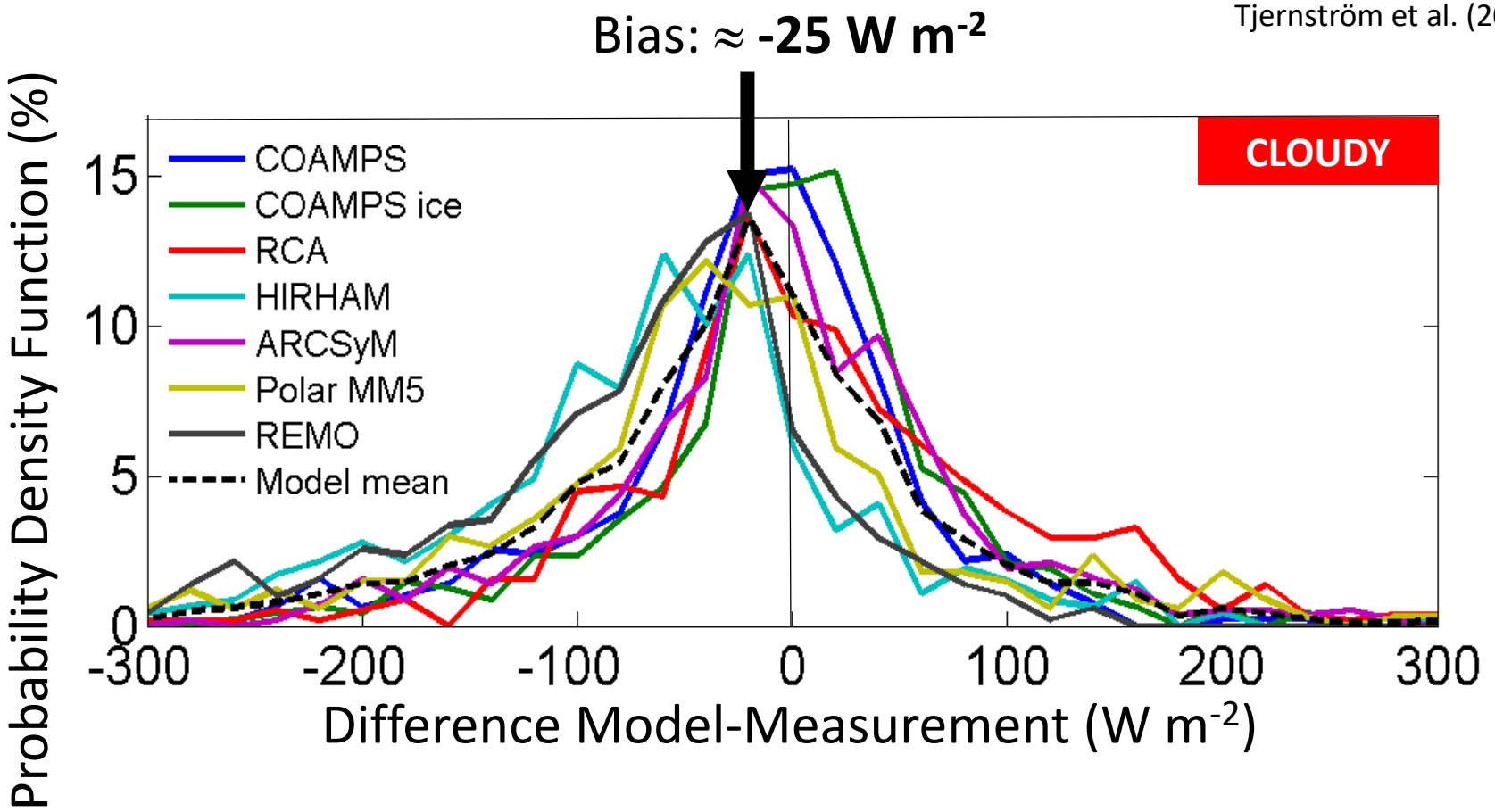
MERRA data, Jan. 2012, NASA

- Amplification of planetary wave amplitude?
- More blocking situations?
- Intensification of meridional transports?
- More extreme winters in mid-latitudes?

Why should we care?

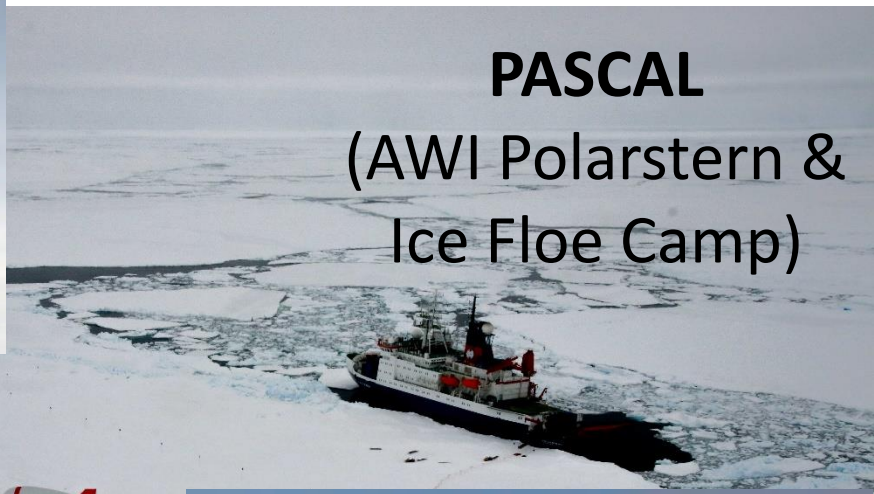
Downward solar RADIATIVE FLUXES at surface: 6 RCMs versus SHEBA observations

Tjernström et al. (2008)



Observations in May—June 2017

ACLOUD (AWI Aircraft P5 & P6, LYR)



PASCAL
(AWI Polarstern &
Ice Floe Camp)

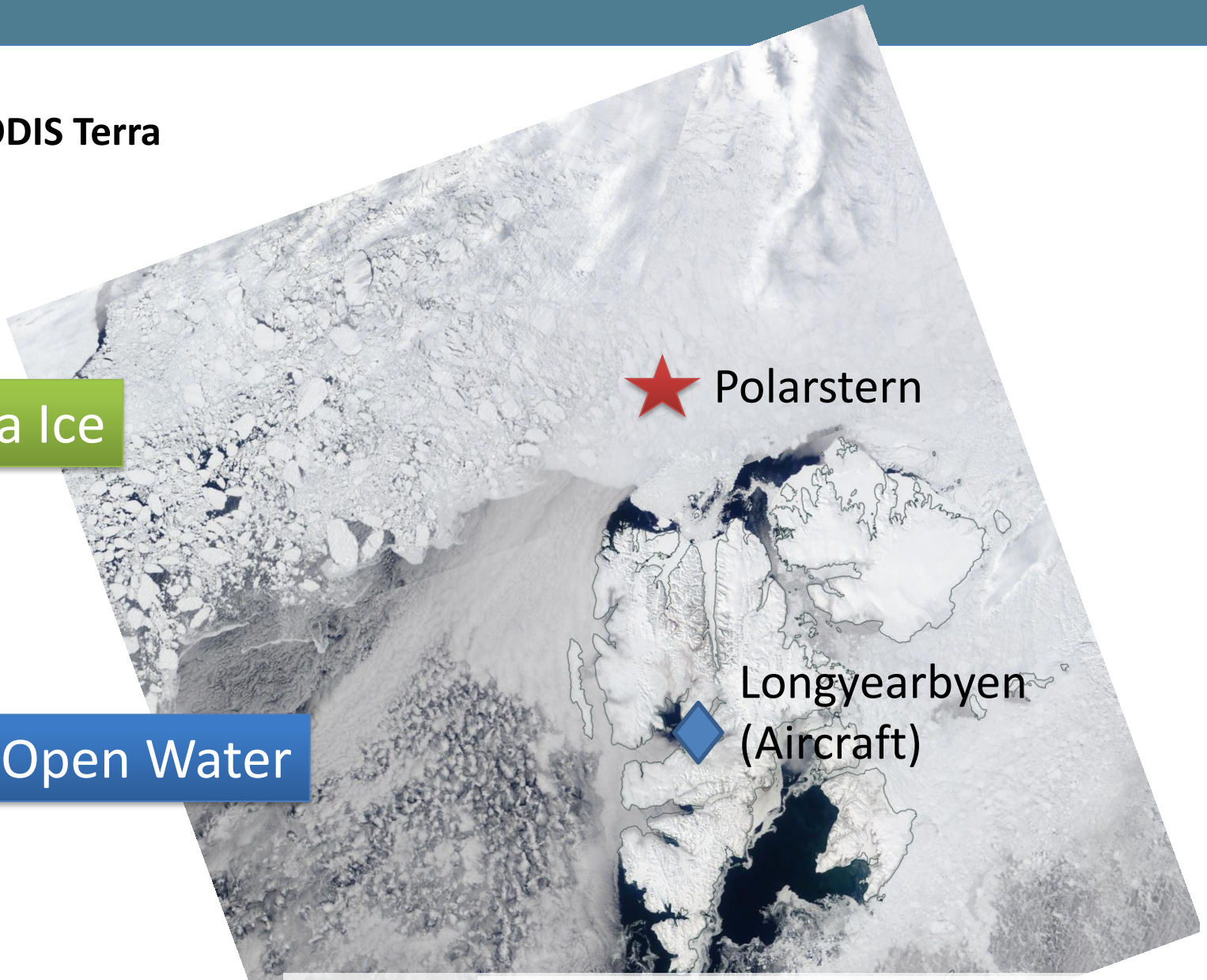
Tethered Balloon

Foto: Stephan Schön, Sächsische Zeitung

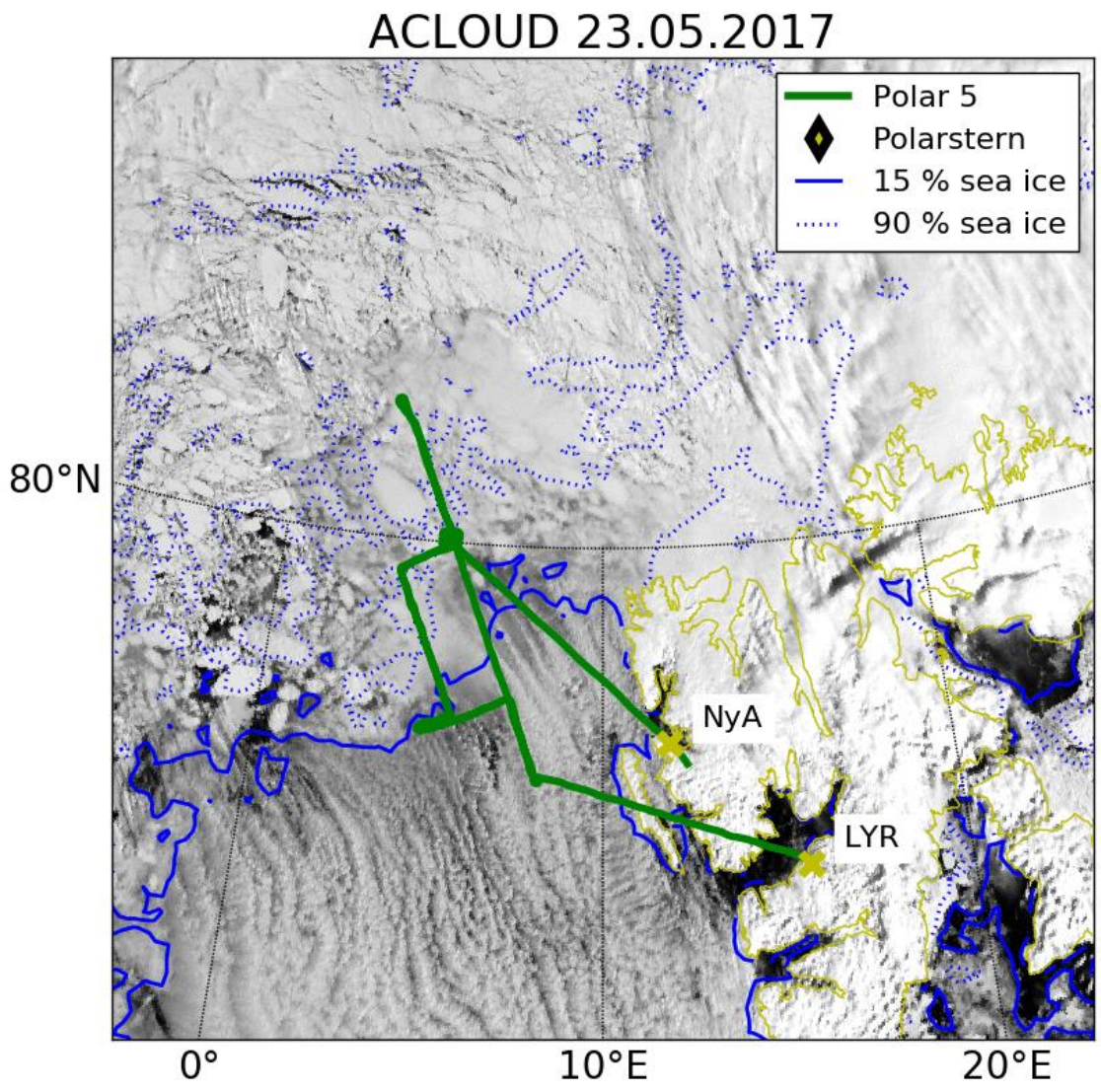
Ny Ålesund

Observations in May—June 2017

MODIS Terra



Observations in May—June 2017



Flight Statistics

19 Flights P5 (84 hours)
19 Flights P6 (81 Hours)
16 Flights P5/P6
13 Flights P5/P6/Ny Ålesund
10 Flights P5/P6/Polarstern
6 Flights P5/P6/Cloudsat/Calipso

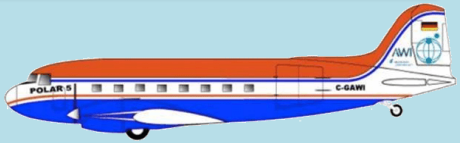
Mission Types

Mixed-Phase Clouds
Arctic Precipitation
Aerosol Particles & Trace Gases
Turbulent Fluxes
Radiation Budget
Surface Albedo
Satellite Validation

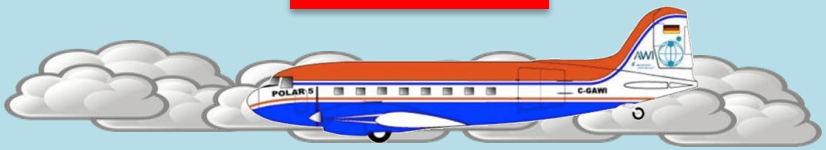
M. Mech (Uni Köln)

Observations in May—June 2017

P5 = Remote Sensing

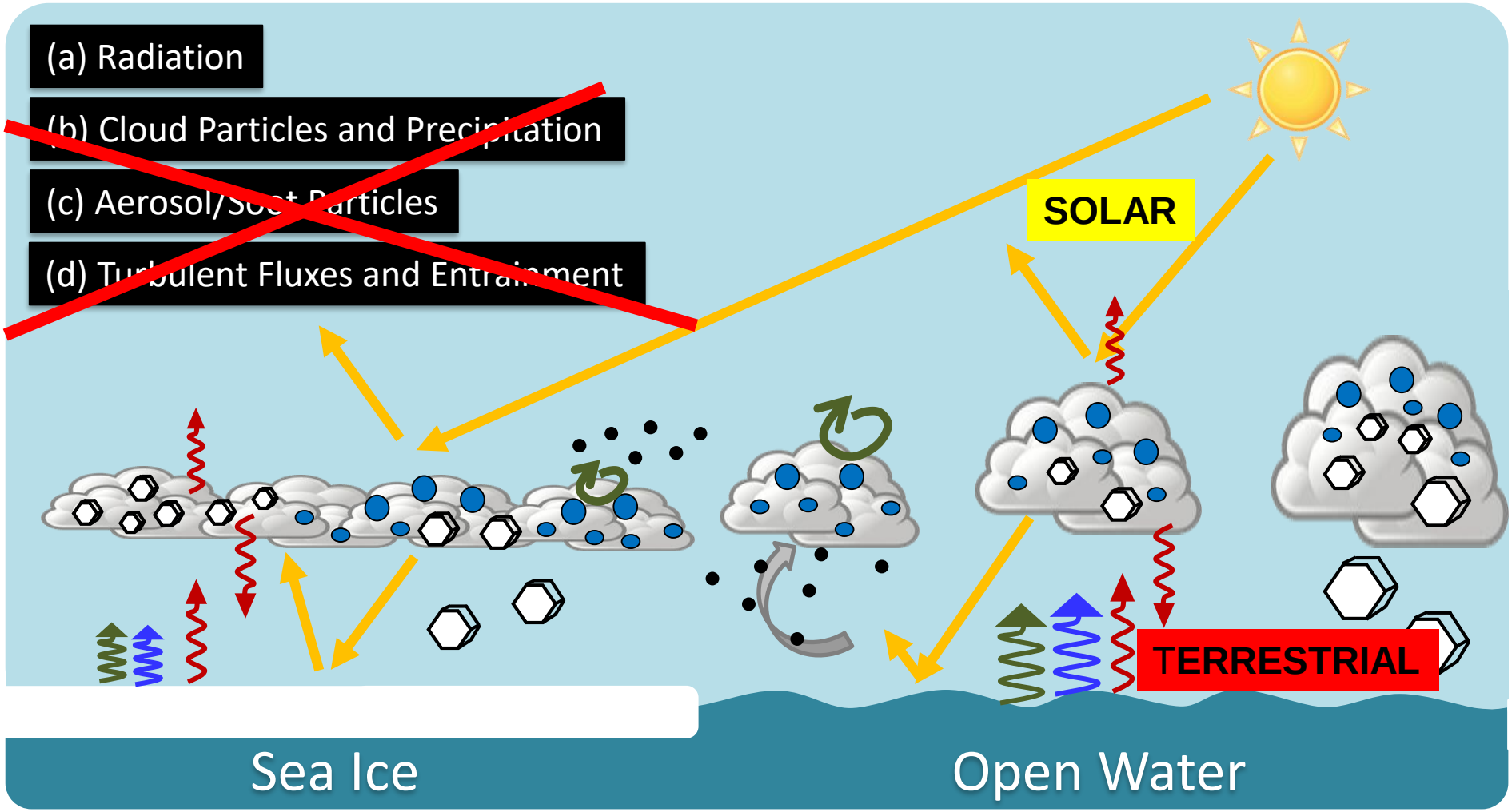


P6 = In Situ



Polarstern + Balloon+ Ice Floe Camp & Ny Ålesund = Remote Sensing + In Situ

Observations in May—June 2017



Observations in May—June 2017

- Surface Albedo and Brightness Temperature

  $F^{\uparrow}$ / $F^{\downarrow}$

- Net Irradiance

  $F_{net} = F^{\downarrow} - F^{\uparrow}$

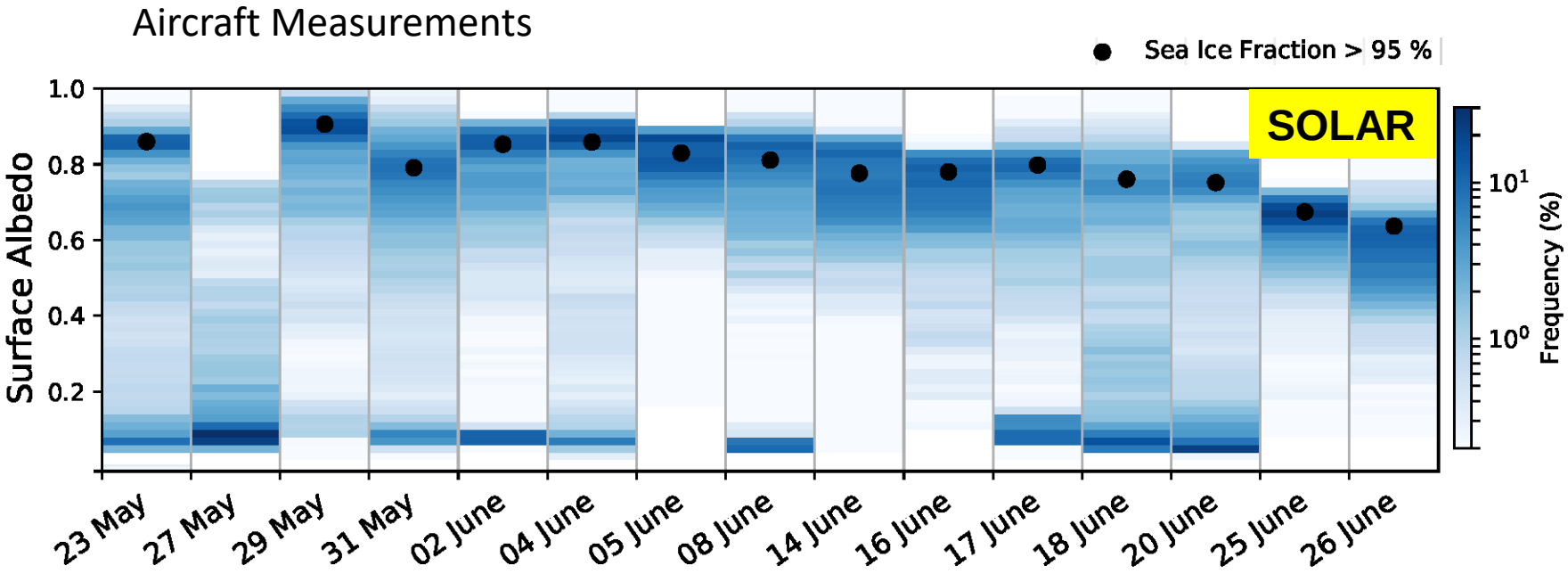
- Heating Rates

  dF_{net} / dz

- Cloud Radiative Forcing

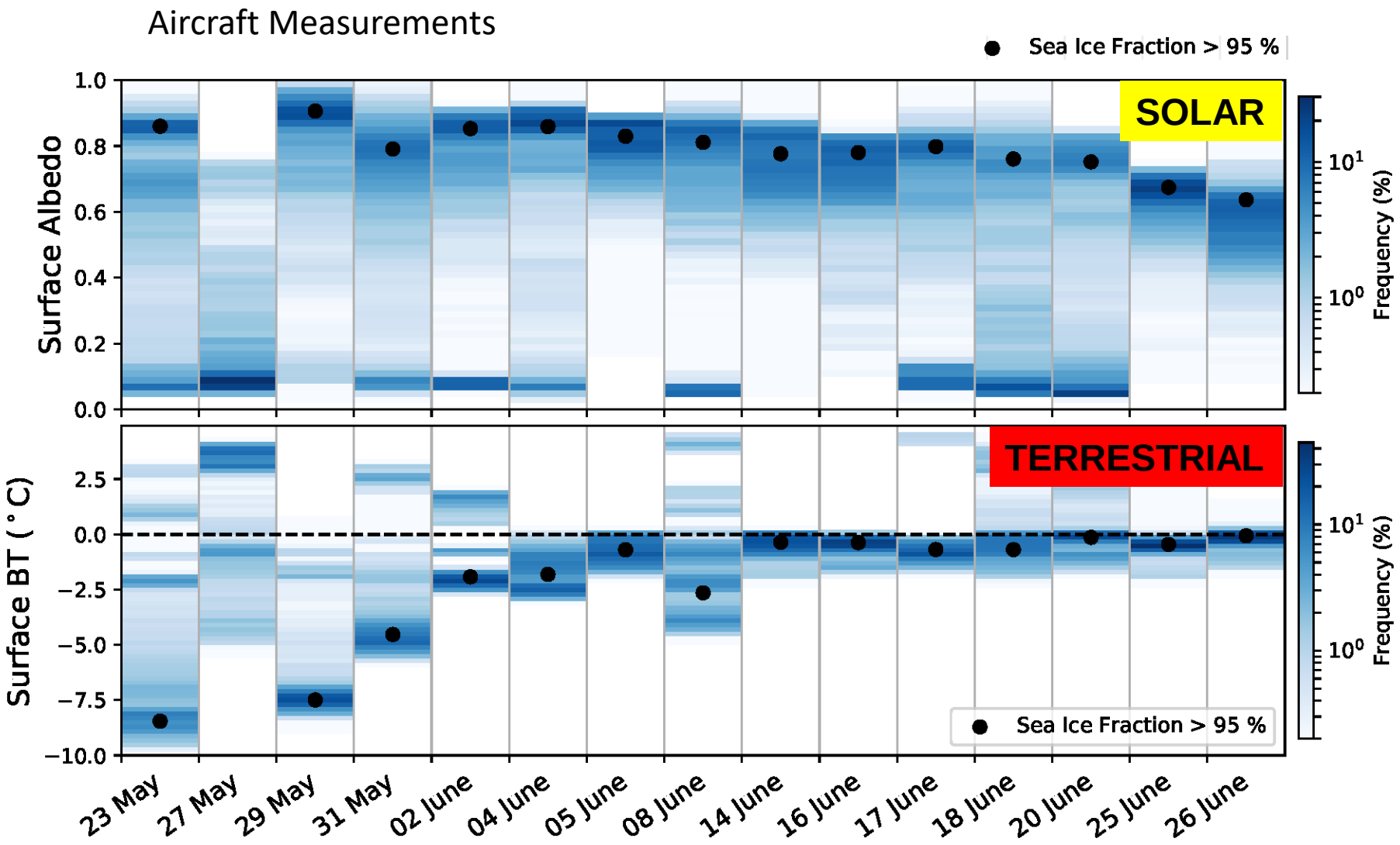
  $F_{net,cloud} - F_{net,cloud\text{-}free}$

Surface Albedo and Brightness Temperature



J. Stapf (Uni Leipzig)

Surface Albedo and Brightness Temperature



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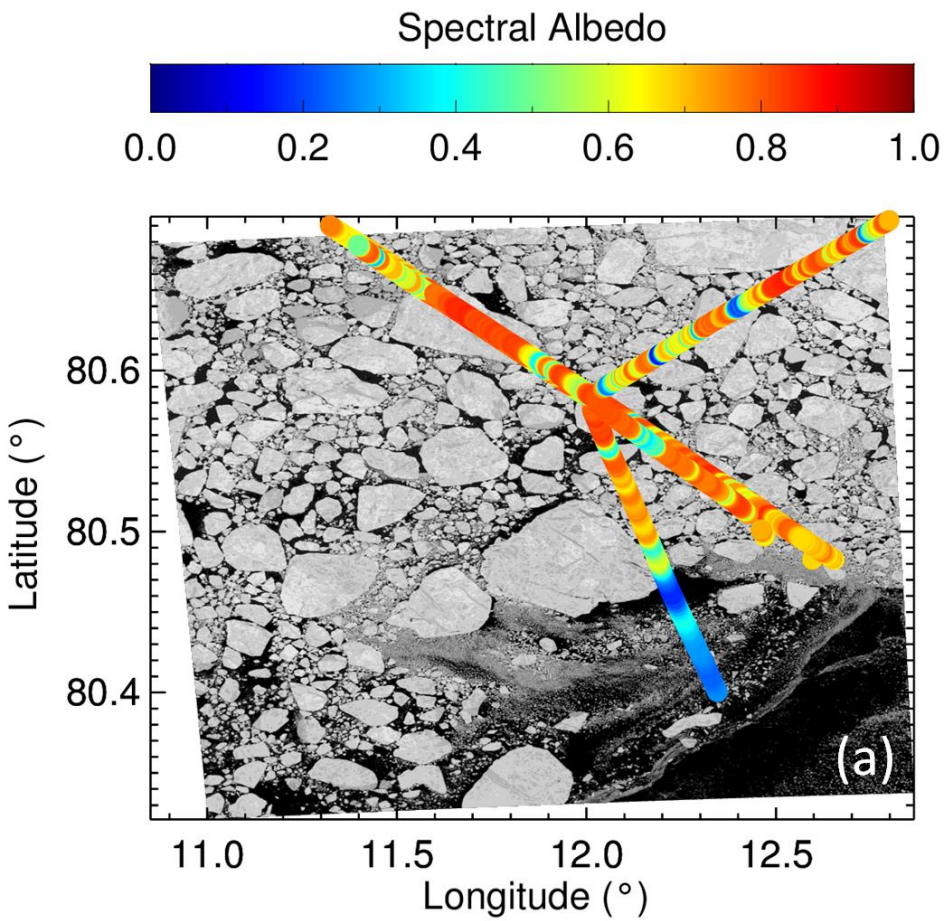
Surface Albedo and Brightness Temperature

SOLAR

Aircraft Measurements

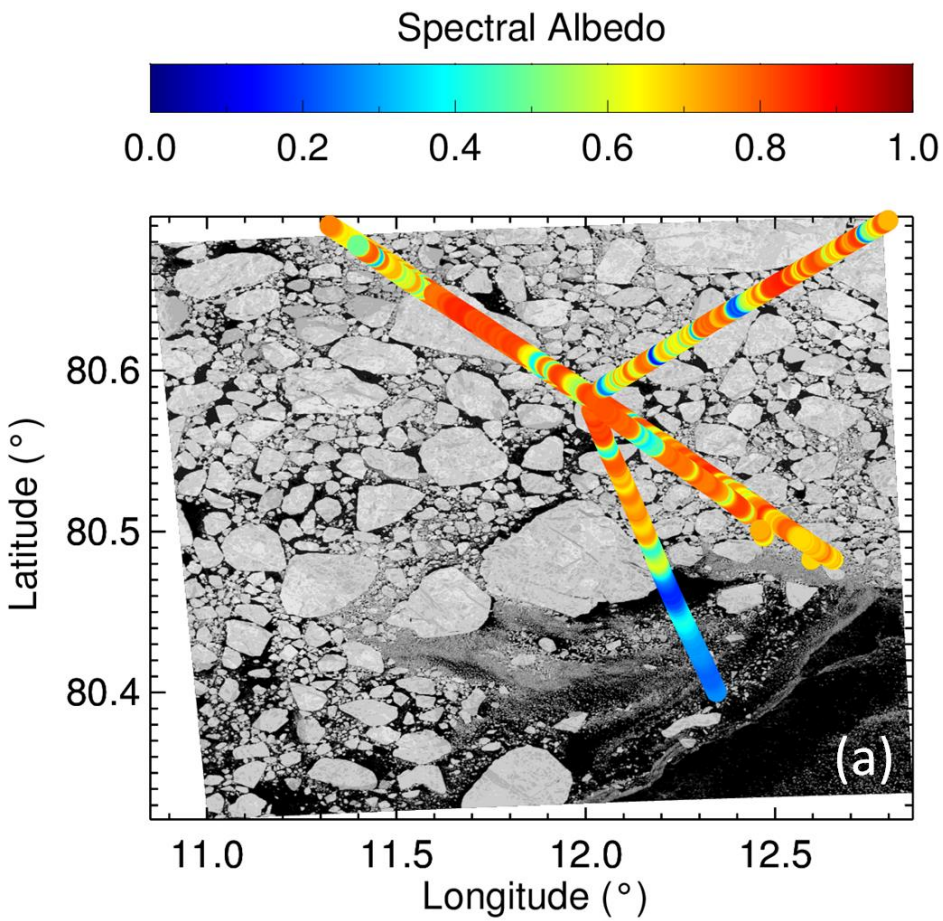


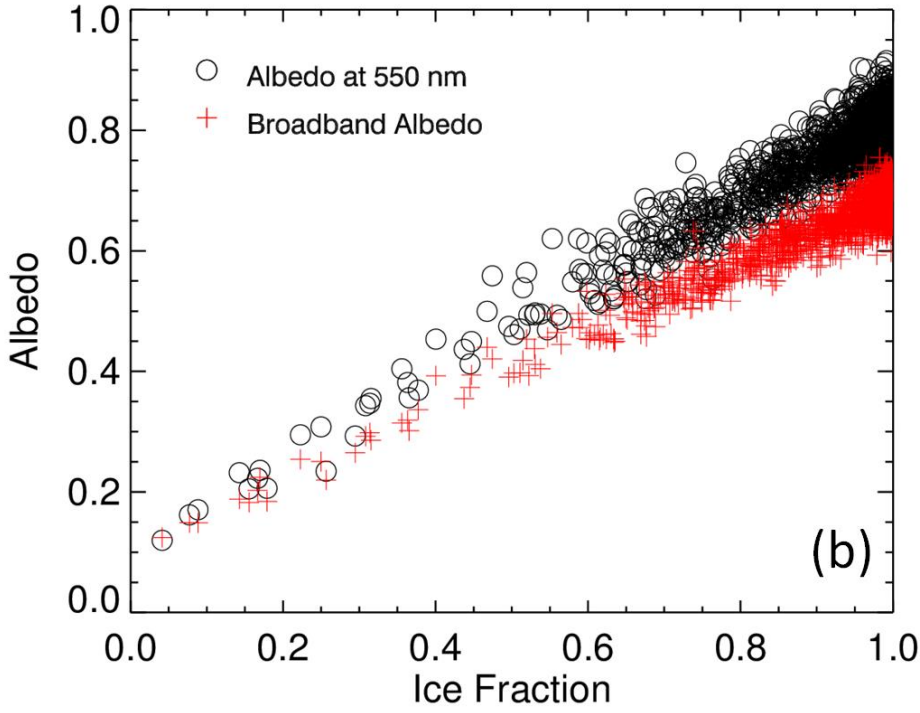
E. Jäkel (Uni Leipzig)

Surface Albedo and Brightness Temperature

SOLAR

Aircraft Measurements





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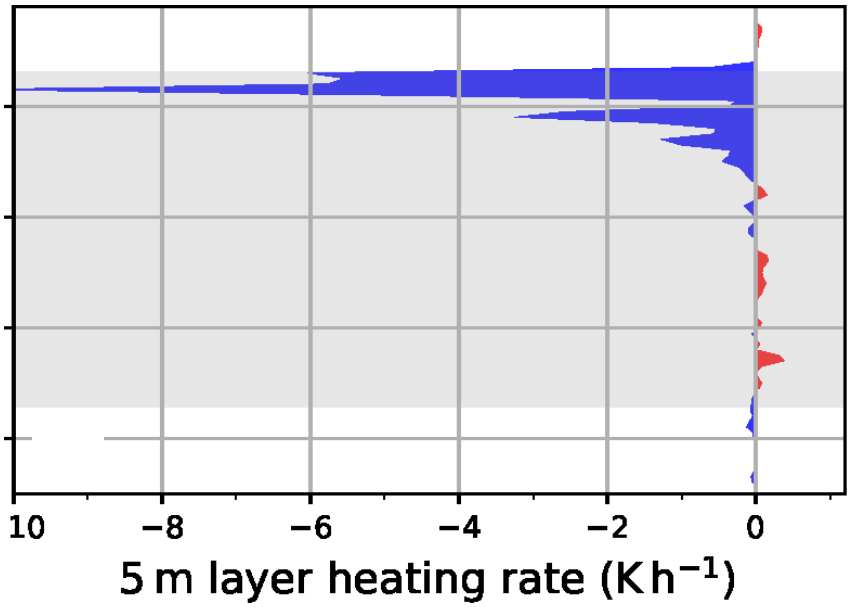
Heating Rates → dF_{net} / dz

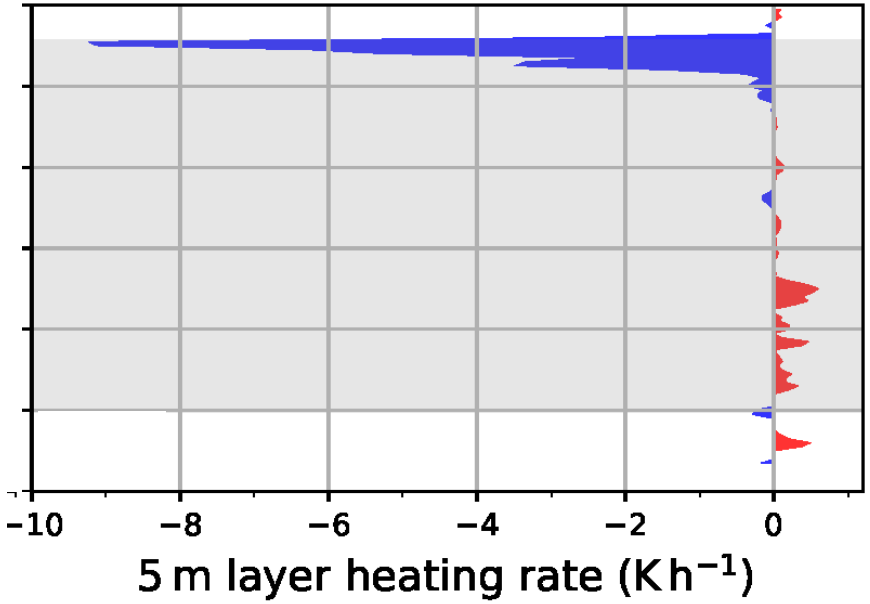
TERRESTRIAL

Aircraft Measurements

Over SEA ICE



Over OPEN OCEAN

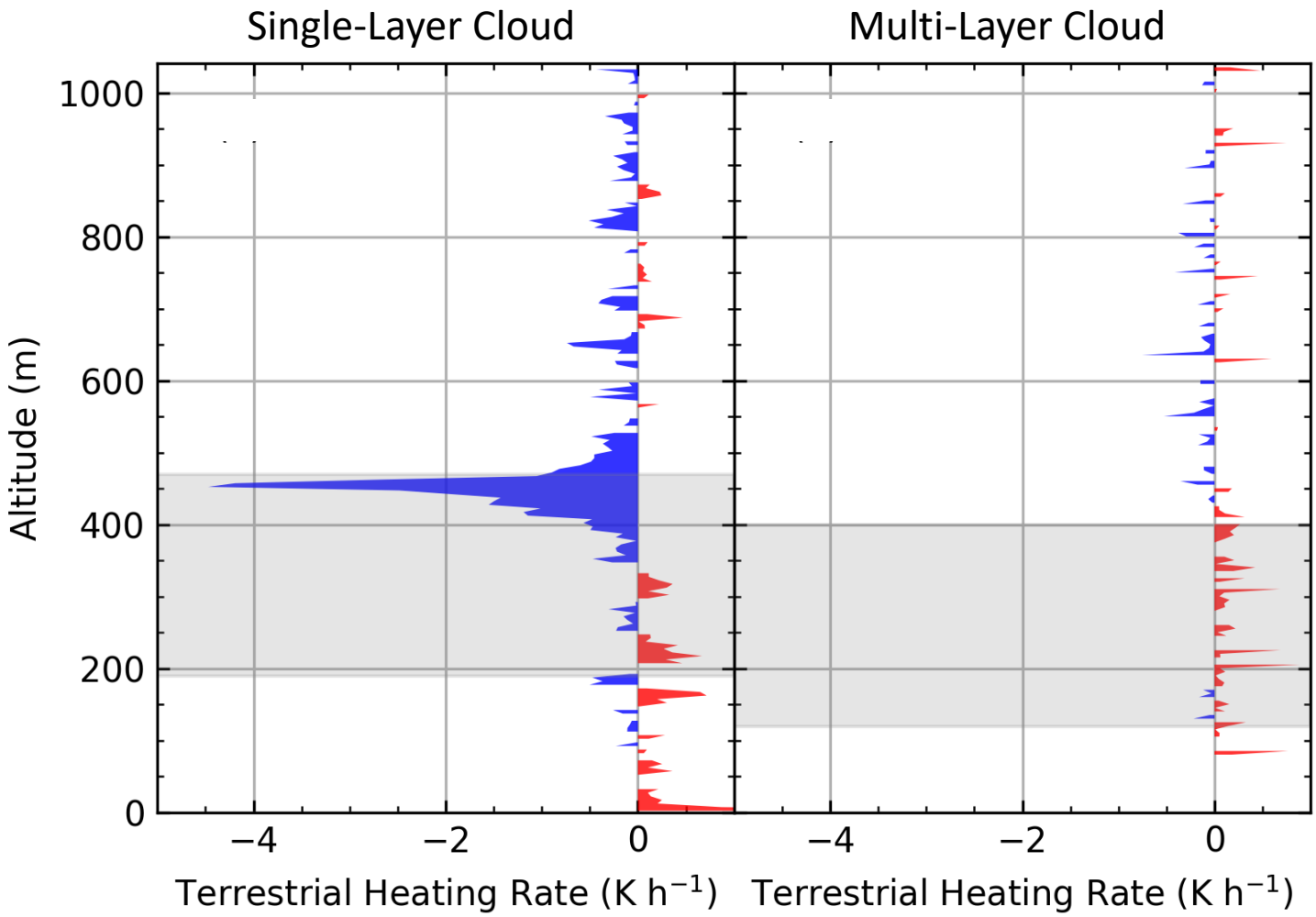


J. Stapf (Uni Leipzig)

Heating Rates → dF_{net} / dz

TERRESTRIAL

Balloon Measurements

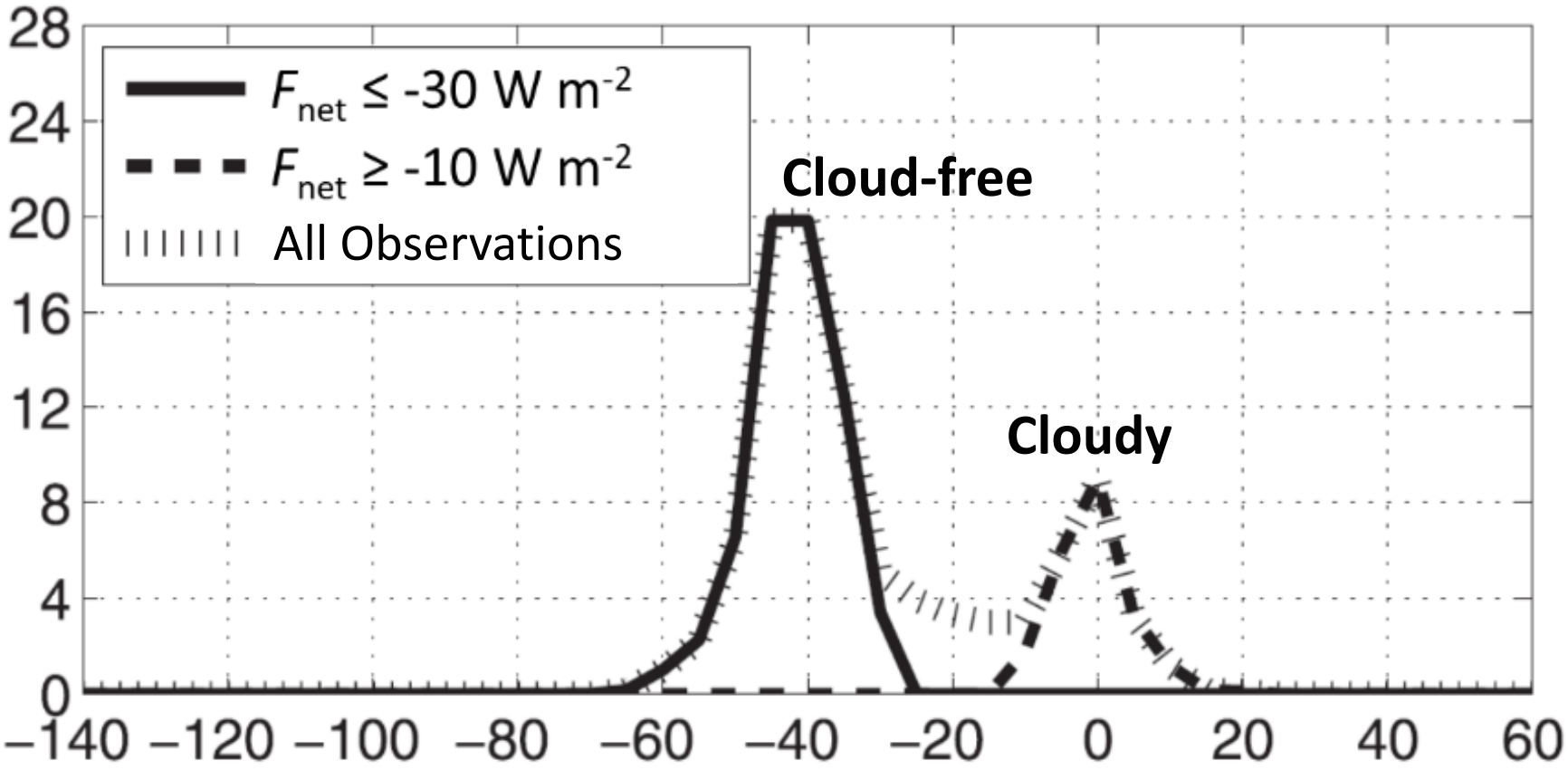


M. Gottschalk (Uni Leipzig)

Net Irradiance → $F_{net} = F^{\downarrow} - F^{\uparrow}$

TERRESTRIAL

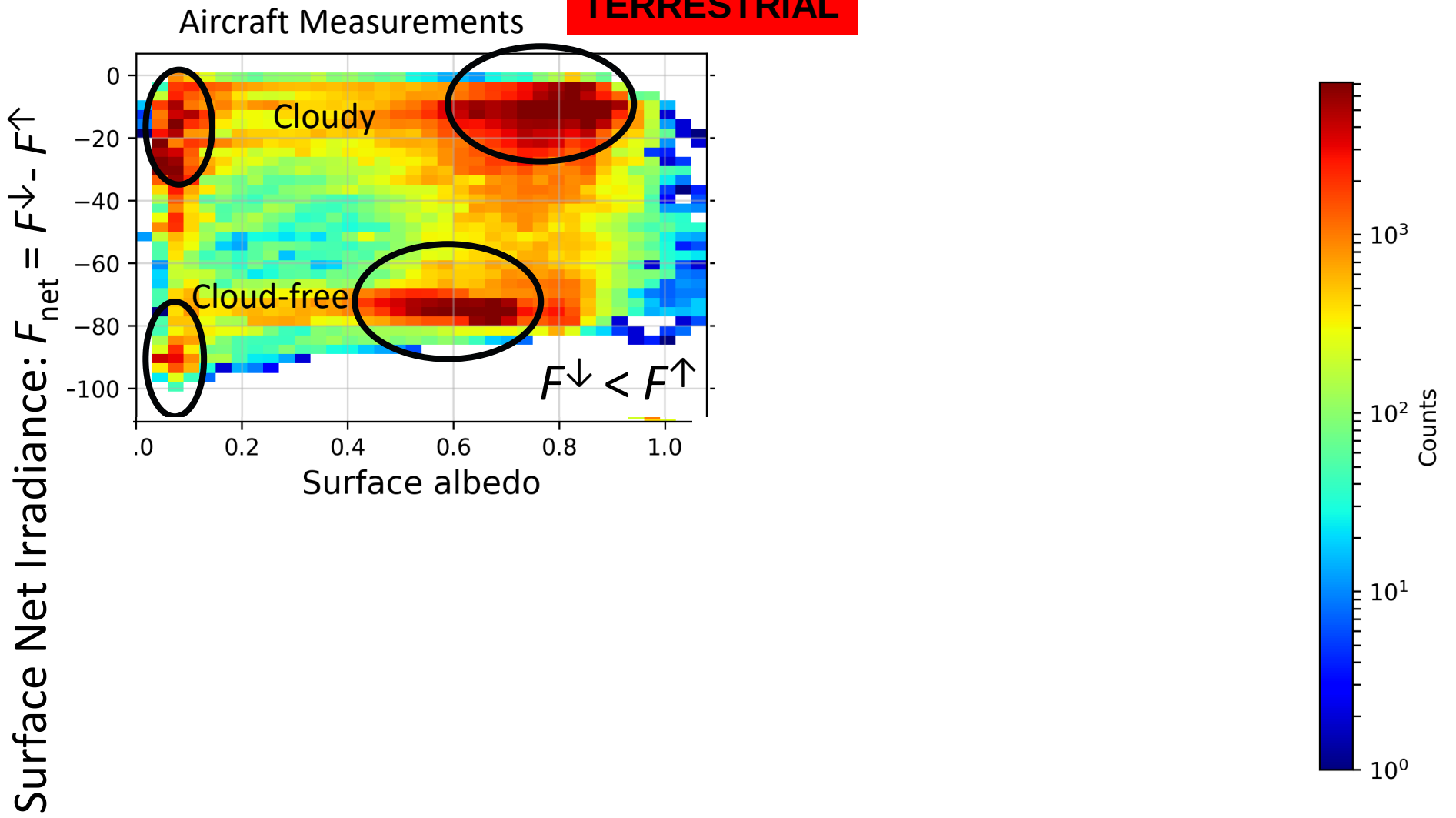
Surface Measurements



Stramler et al. (2012)

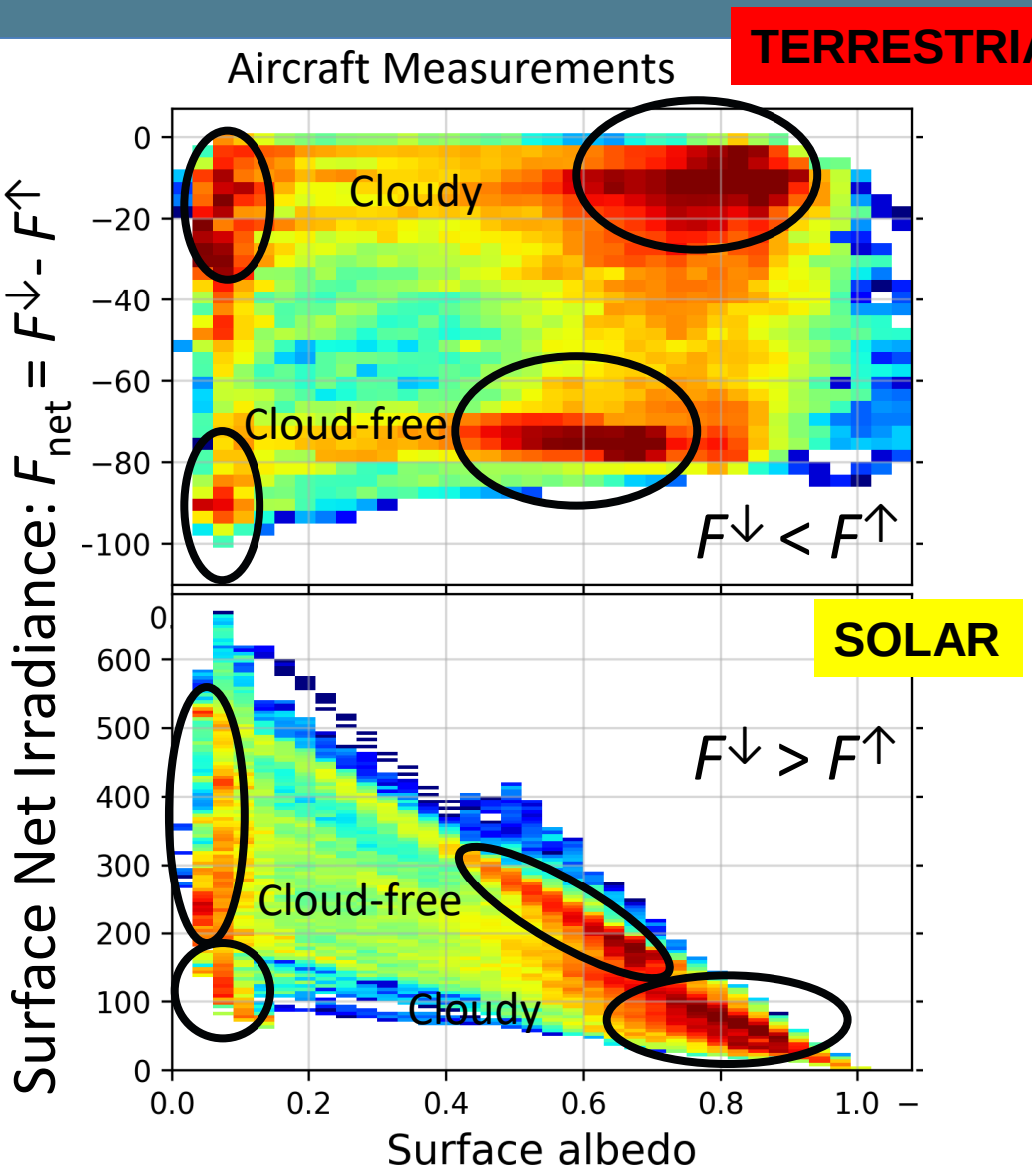
Net Irradiance → $F_{net} = F^{\downarrow} - F^{\uparrow}$

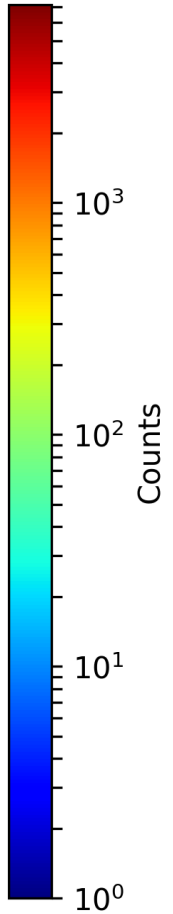
TERRESTRIAL



J. Stapf (Uni Leipzig)

Net Irradiance → $F_{net} = F^{\downarrow} - F^{\uparrow}$





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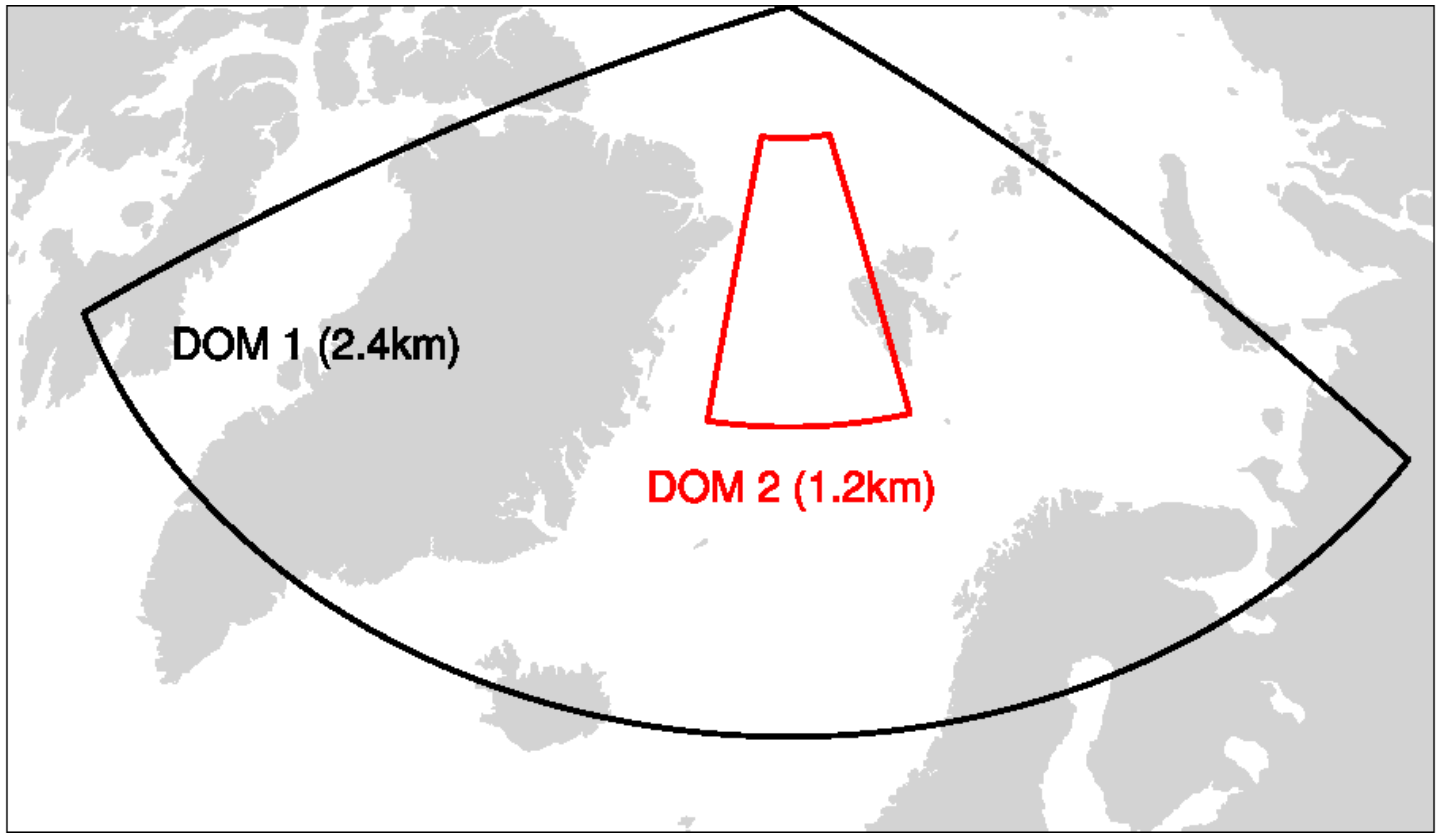
ICON (ICOsahedral Non-hydrostatic)—NWP model, DWD

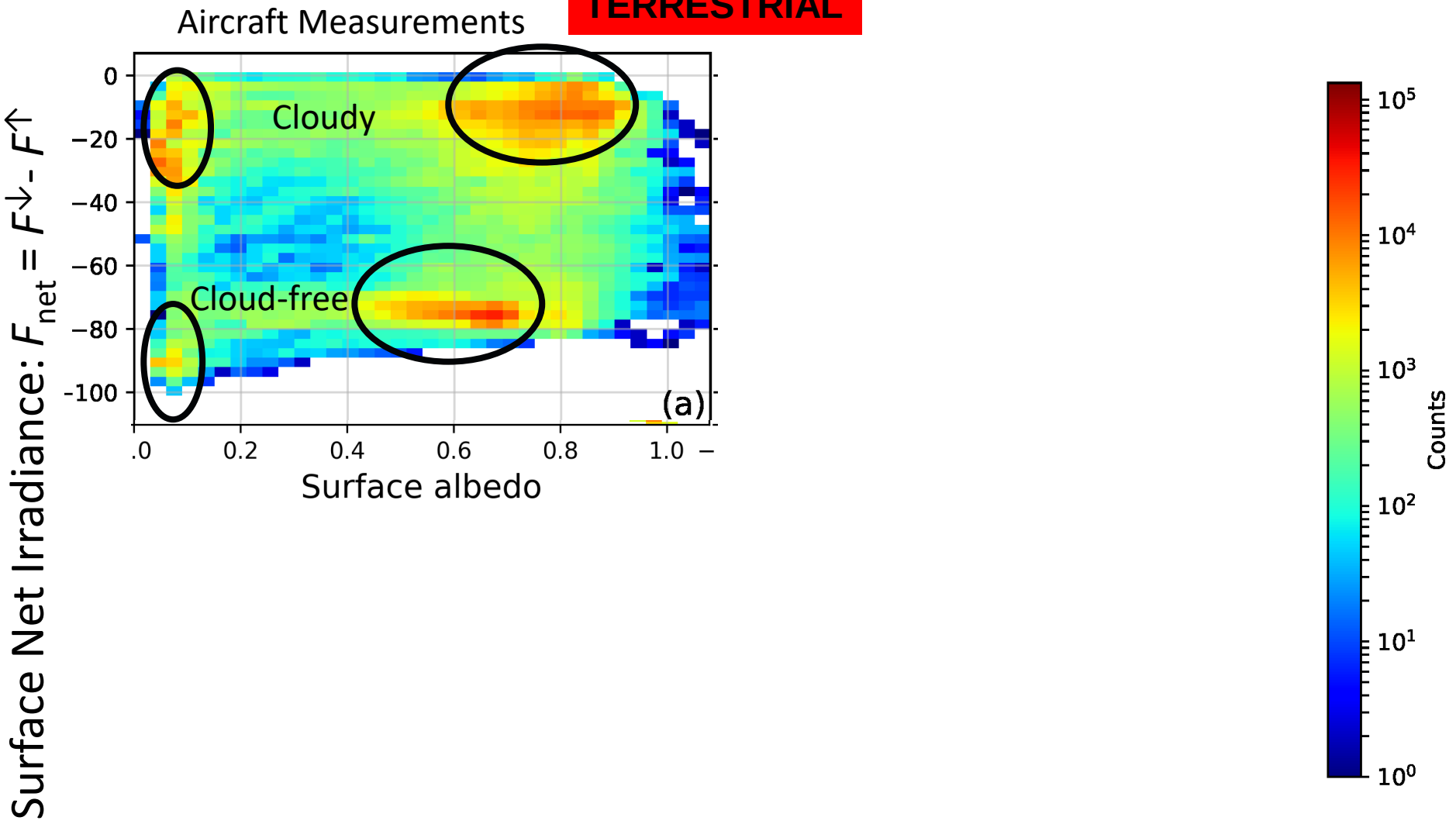


- ICON runs (2.4 km, nest with 1.2 km, 75 vertical layers each)
- Intital and boundary condition from IFS (reinitialized every day)
- Sampled model output (temporal and spatial) along flight track

J. Stapf, J. Kretschmar (Uni Leipzig)

Net Irradiance → $F_{net} = F^{\downarrow} - F^{\uparrow}$

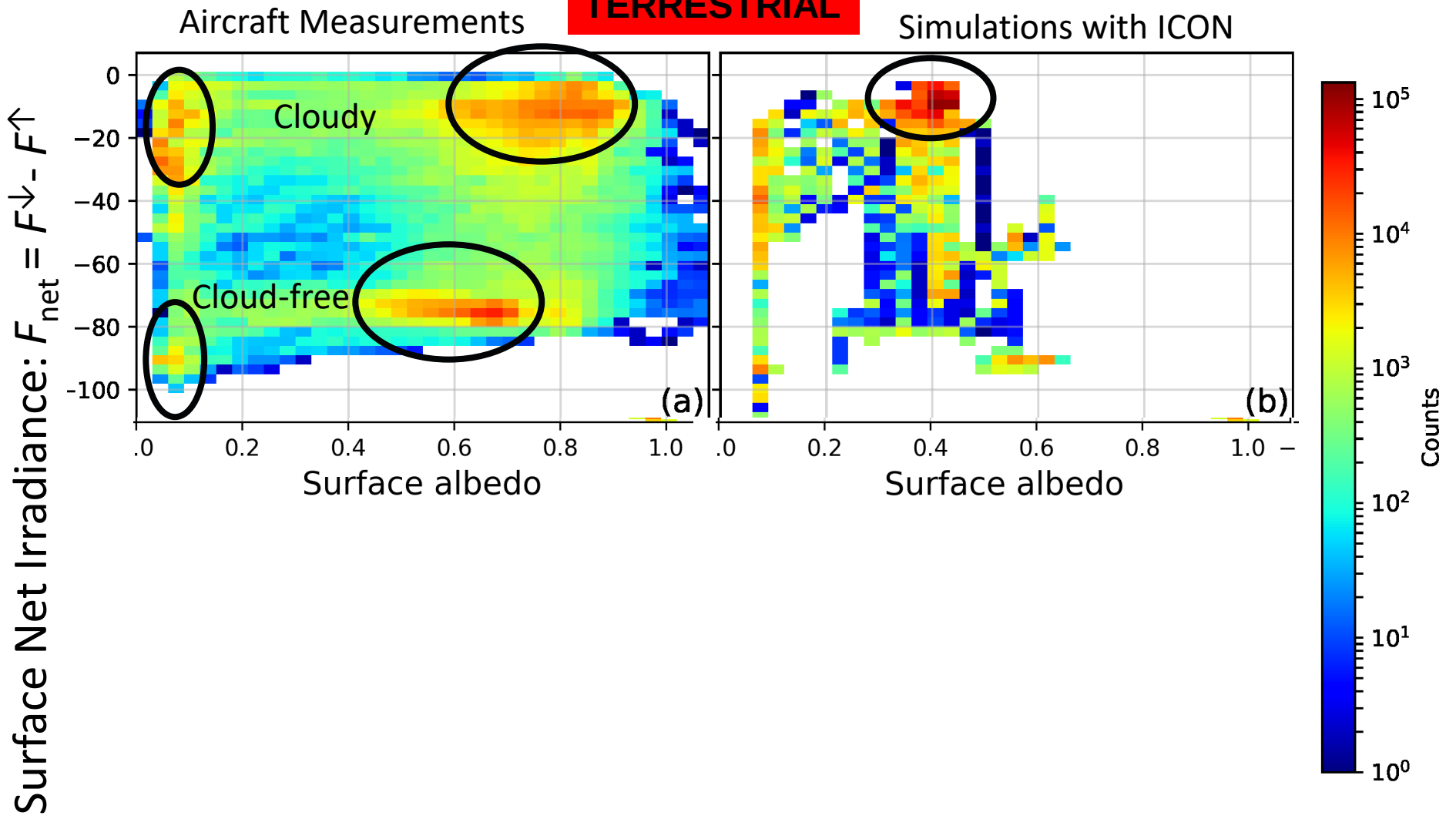
TERRESTRIAL



J. Stapf, J. Kretschmar (Uni Leipzig)

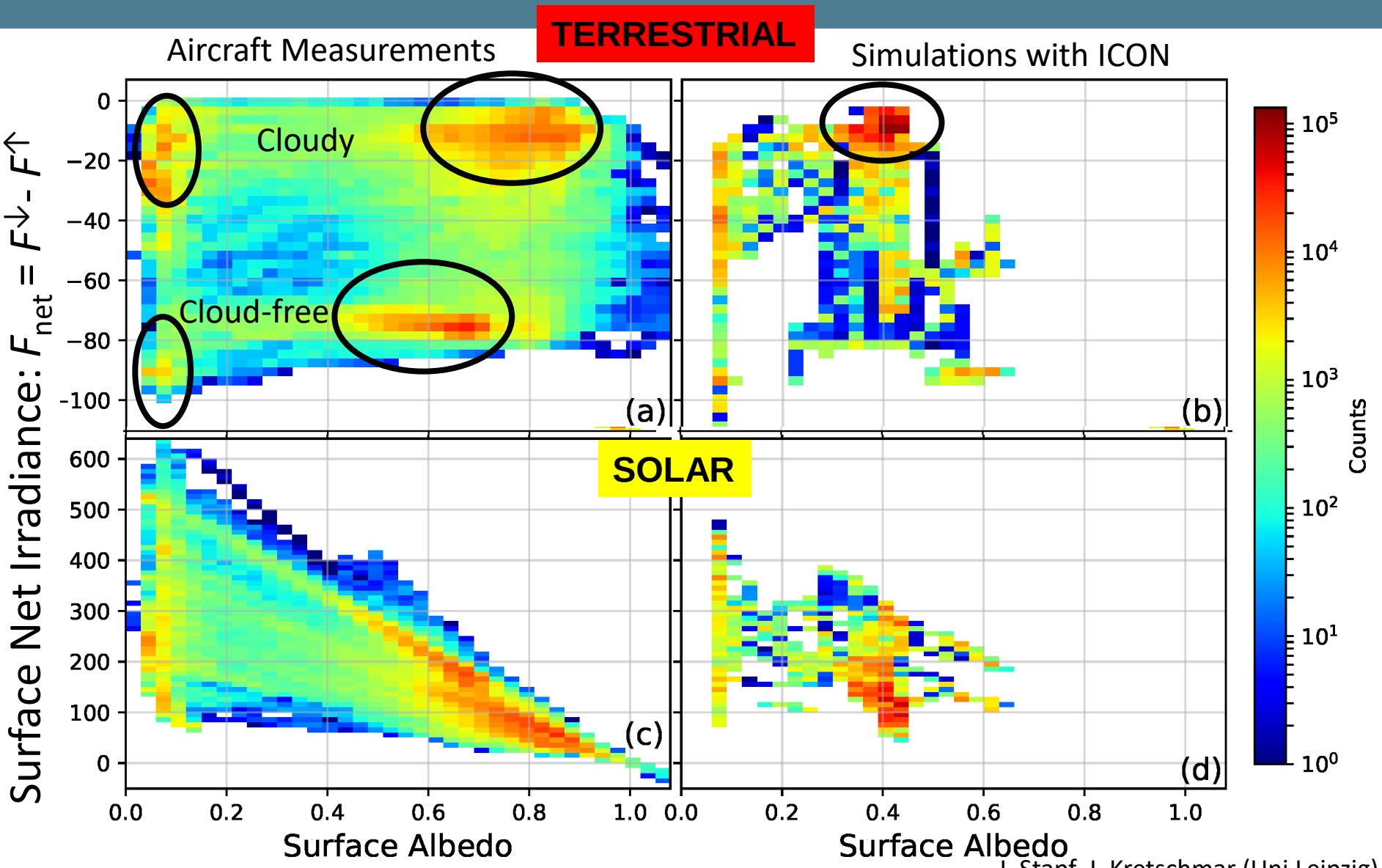
Net Irradiance → $F_{net} = F^{\downarrow} - F^{\uparrow}$

TERRESTRIAL



J. Stapf, J. Kretschmar (Uni Leipzig)

Net Irradiance → $F_{net} = F^{\downarrow} - F^{\uparrow}$



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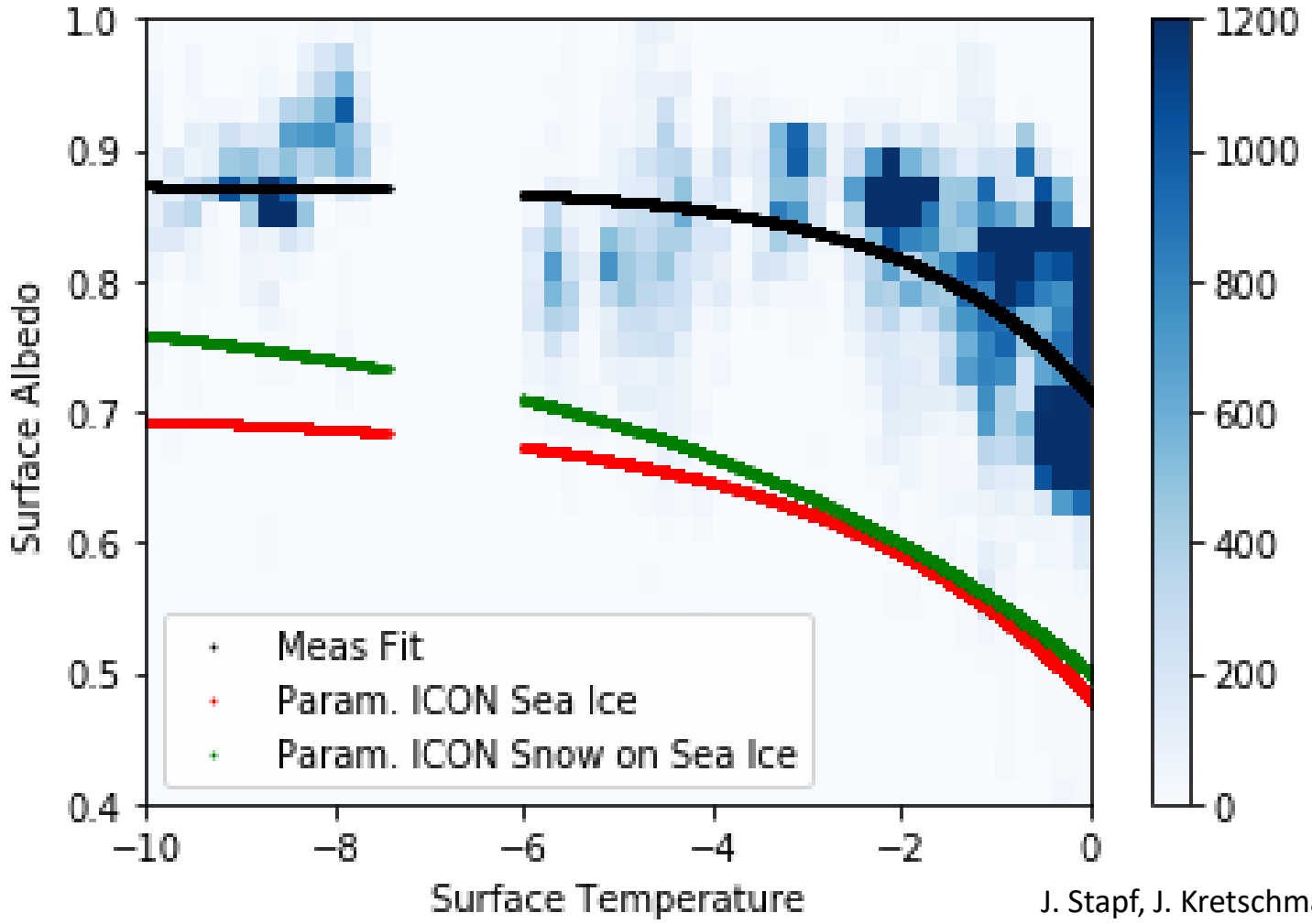
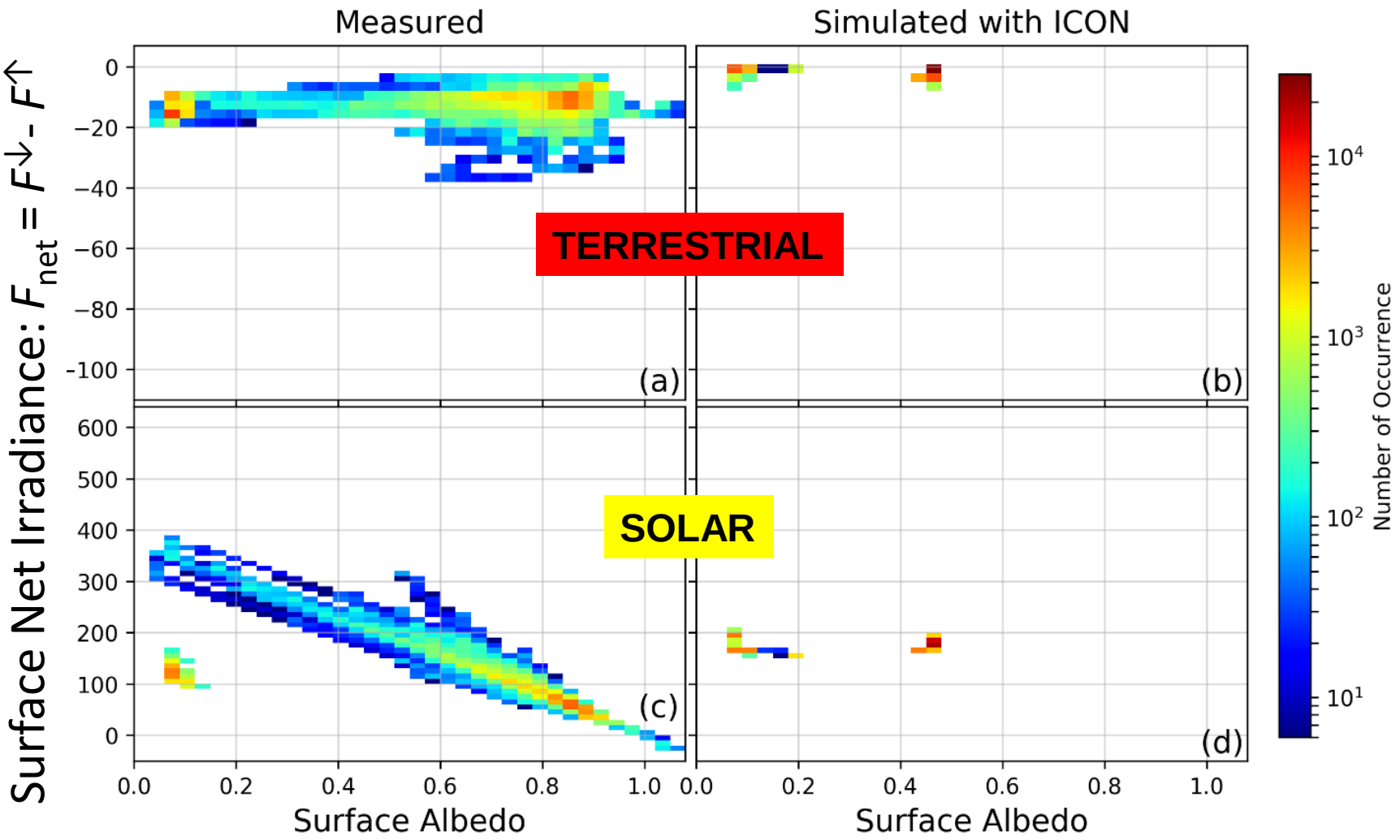
Net Irradiance → $F_{net} = F^{\downarrow} - F^{\uparrow}$

In the applied ICON-NWP version, the surface albedo is solely a function of surface temperature over sea ice



J. Stapf, J. Kretschmar (Uni Leipzig)

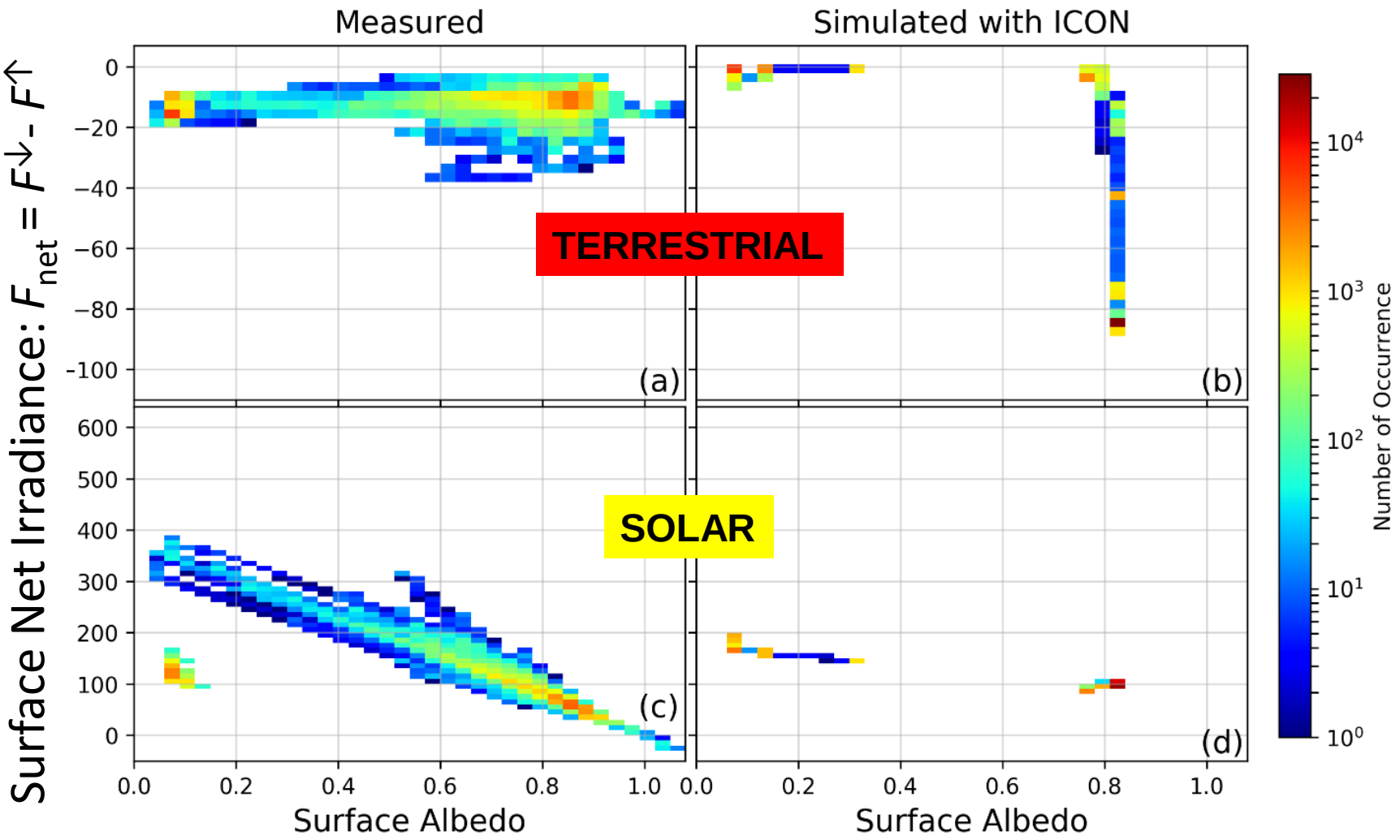
Net Irradiance → $F_{net} = F^{\downarrow} - F^{\uparrow}$



2 June 2017

J. Stapf, J. Kretschmar (Uni Leipzig)

Net Irradiance → $F_{net} = F^{\downarrow} - F^{\uparrow}$



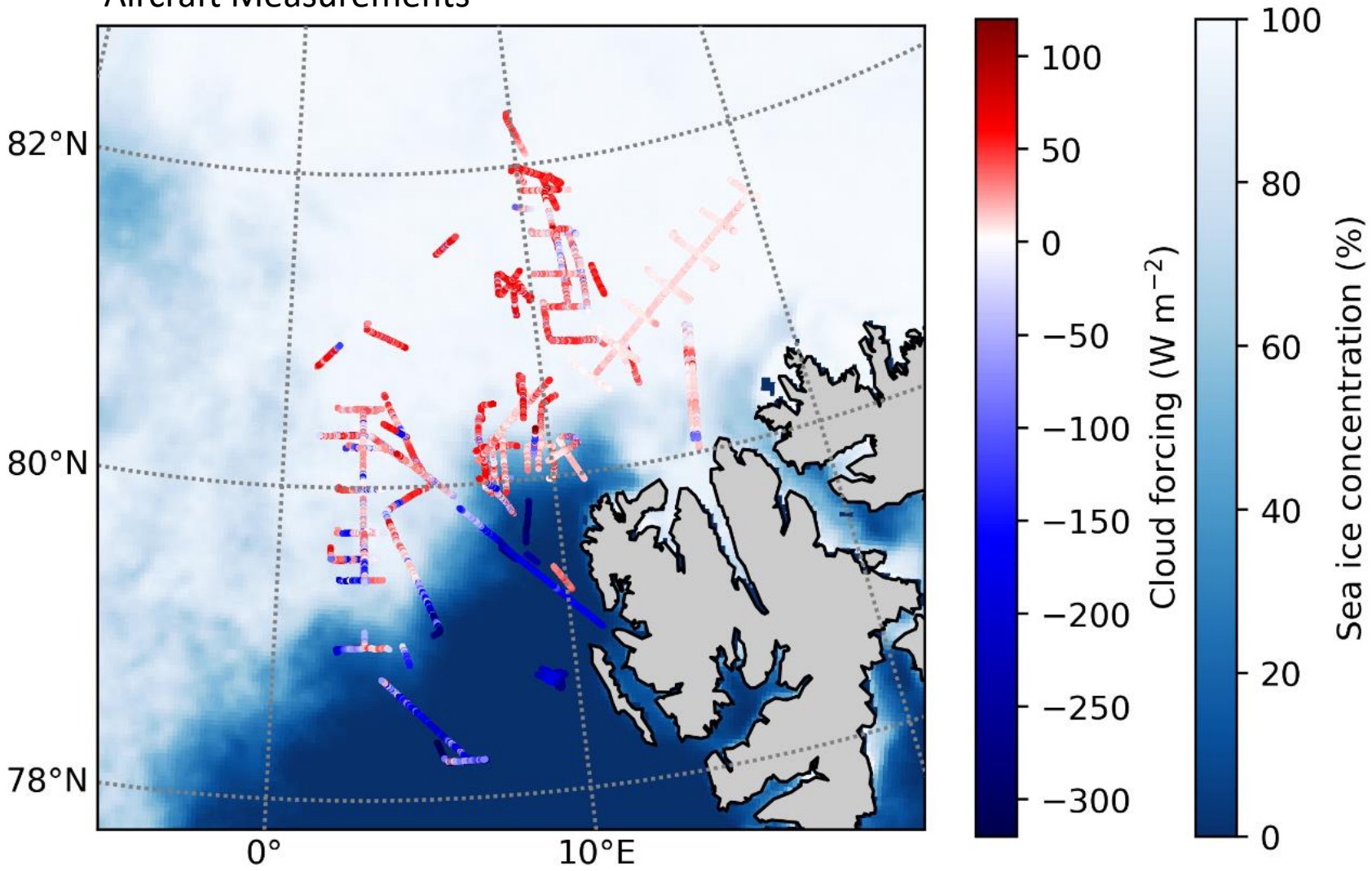
2 June 2017

J. Stapf, J. Kretschmar (Uni Leipzig)

Cloud Radiative Forcing → $F_{net,cloud} - F_{net,cloud\text{-}free}$

SOLAR + TERRESTRIAL

Aircraft Measurements



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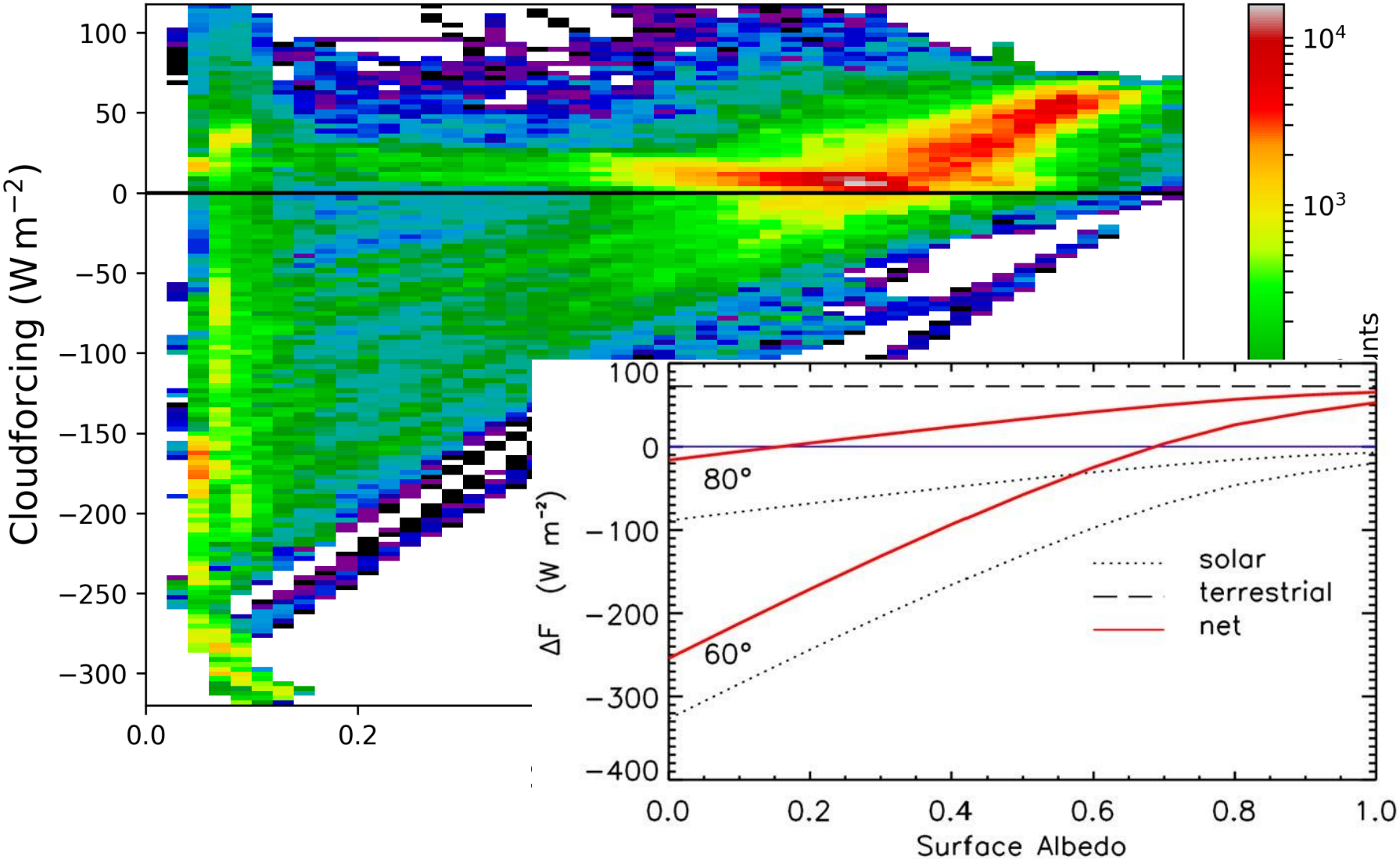
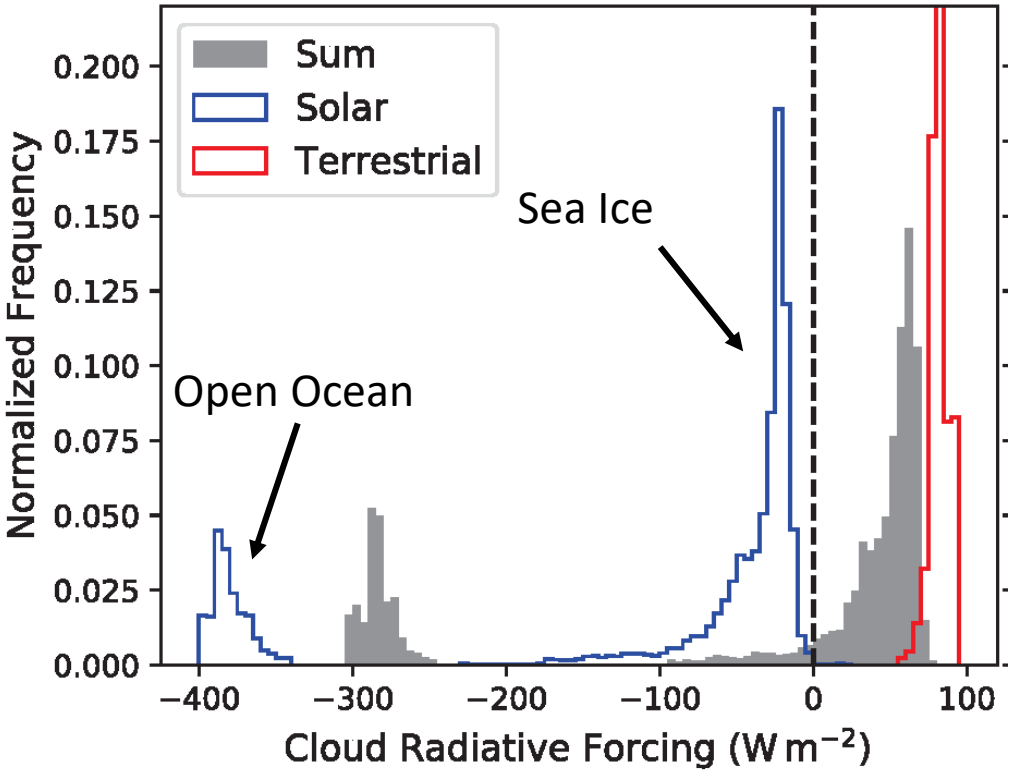


Cloud Radiative Forcing → $F_{net,cloud} - F_{net,cloud\text{-}free}$

Aircraft Measurements

2 June: Thick Clouds over Open Ocean/Sea Ice



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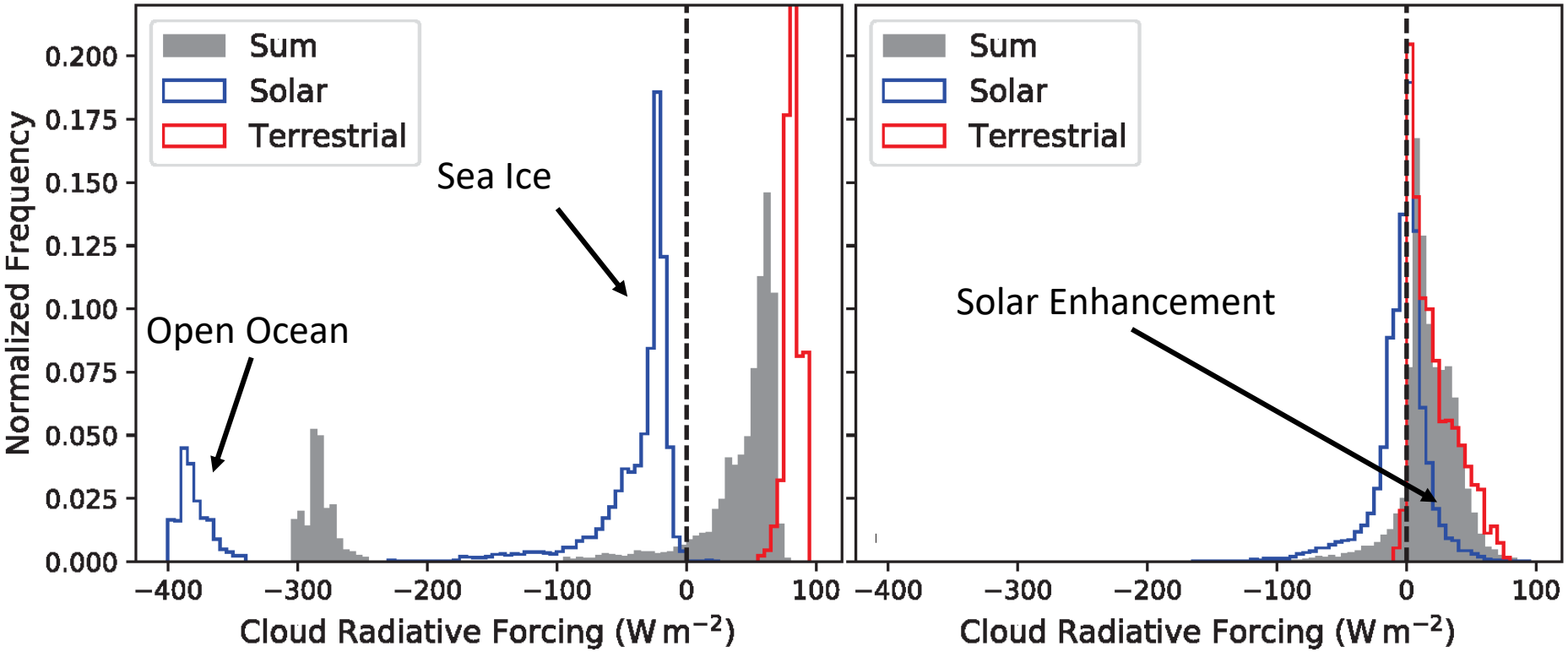
Cloud Radiative Forcing → $F_{net,cloud} - F_{net,cloud\text{-}free}$

Aircraft Measurements

2 June: Thick Clouds over Open Water/Sea Ice

31 May: Thin, Broken Cloud over Sea Ice



J. Stapf (Uni Leipzig)

Questions

- How to compare?
- What to compare?
- Where to compare?
- Parameterizations?

MOSAiC

The **M**ultidisciplinary drifting **O**bservatory for the **S**tudy of **A**rcti**c** **C**limate

www.mosaic-expedition.org

Central Observatory
Comprehensive
Detailed — <5 km
Interdisciplinary
LES/process scale

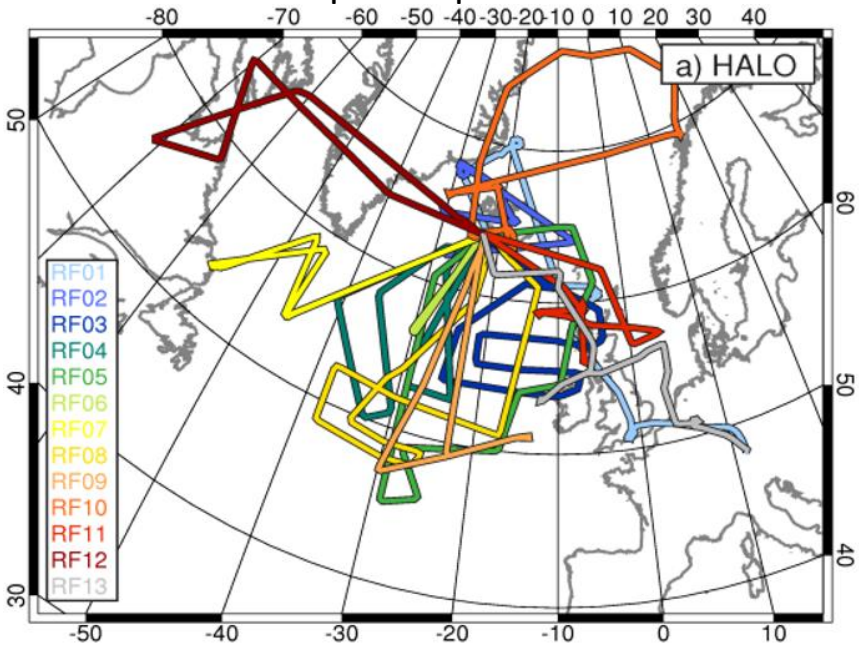
Distributed Network
Heterogeneity
Variability — 50 km
Context
Grid-box scale

Large-scale Linkages
Teleconnections — ~1000 km
Coordinated Activities
Synoptic & Pan-Arctic scale

Thank you for your attention!

High Altitude and Long Range Research Aircraft—HALO

- **NAWDEX: N**orth **A**tlantic **W**aveguide and **D**ownstream Impact **Ex**periment



- Keflavik, Iceland, 14 September – 25 October 2016, ~ 100 h duration

Remote Sensing Instrumentation on HALO

BAHAMAS
in-situ basic meteorology

WALES
- Differential Absorption and High Spectral Resolution Lidar

HAMP
- Microwave radiometer
- Cloud radar

SMART
- passive cloud spectrometer

specMACS
- Imaging cloud spectrometer

Dropsonde

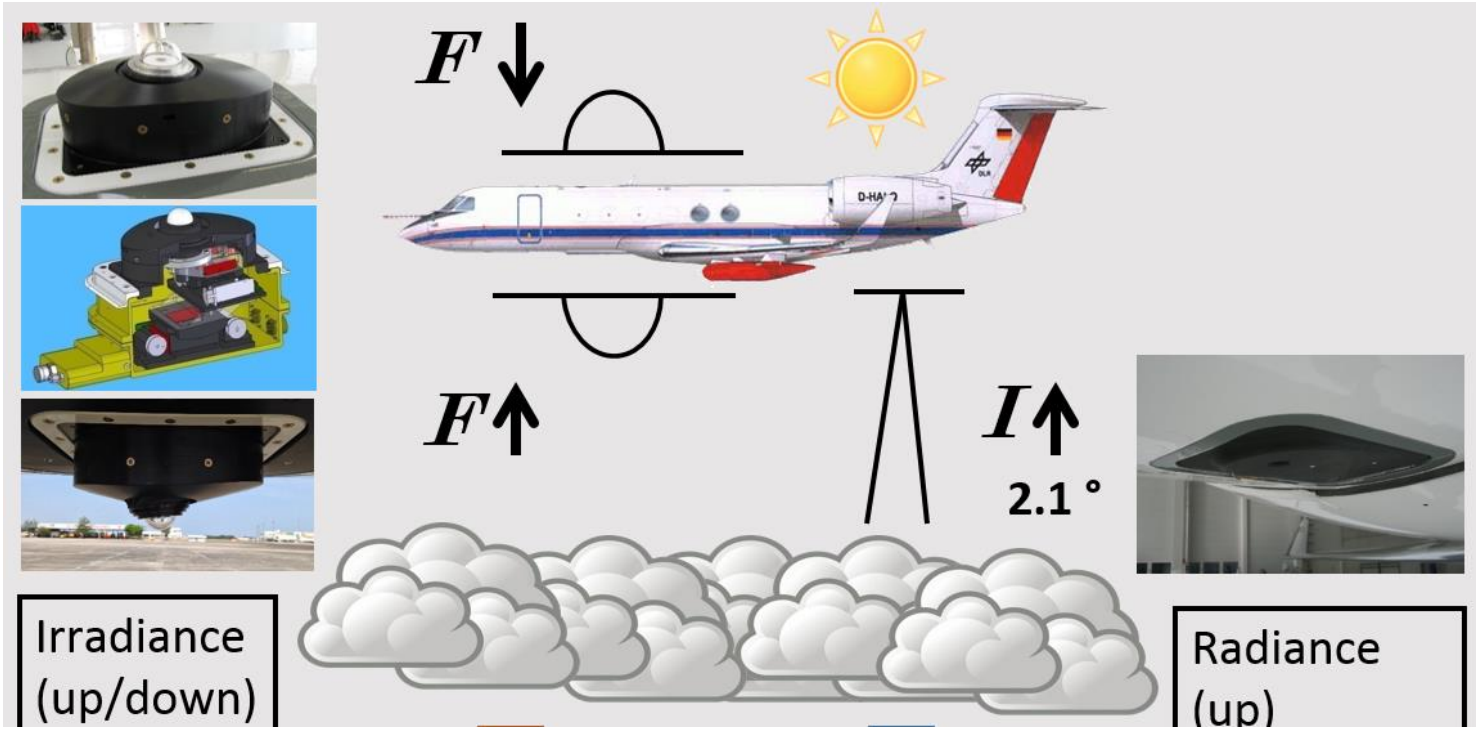
Spectral (Solar) Radiation Measurements

SMART

- passive cloud spectrometer

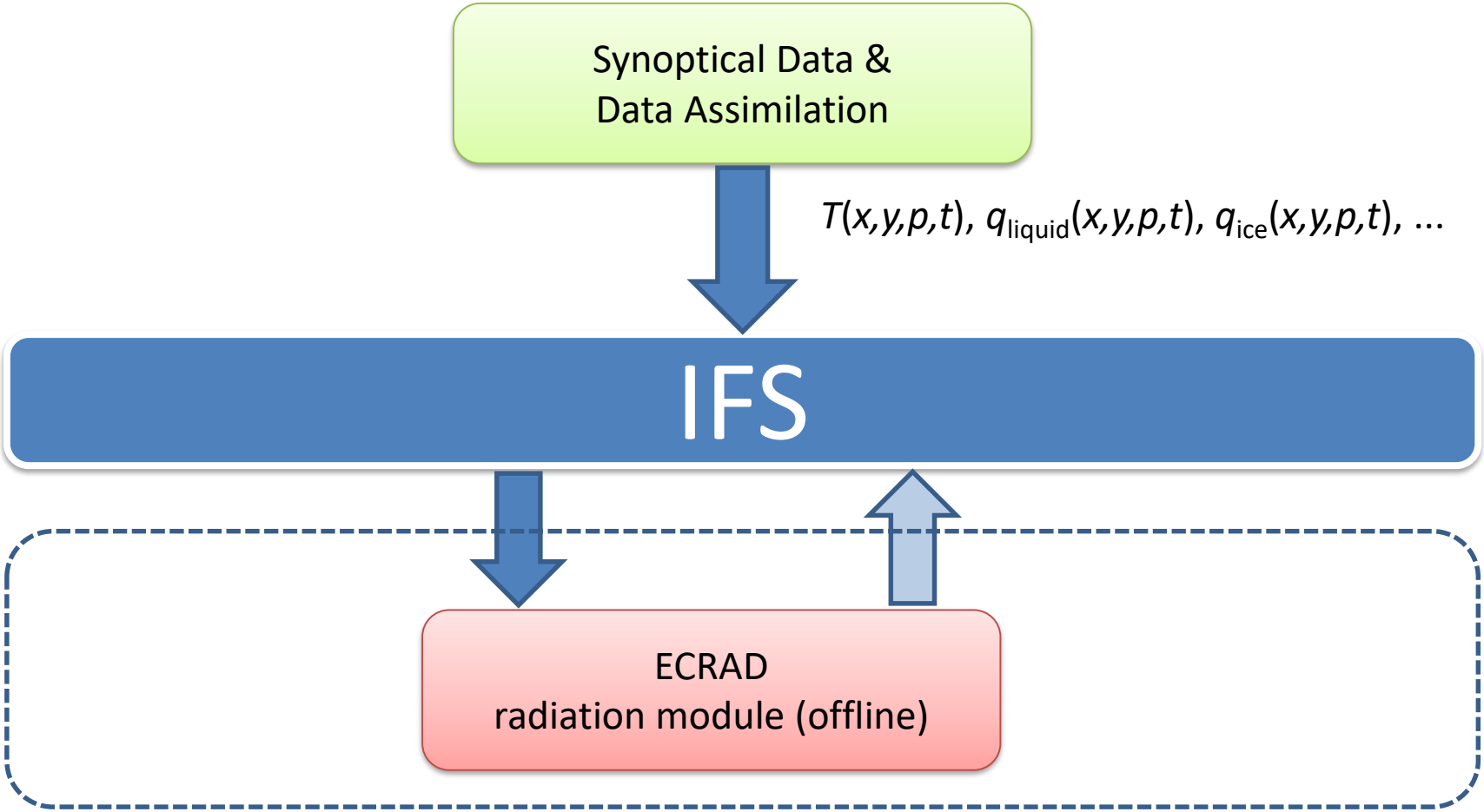
Spectral (Solar) Radiation Instruments

Spectral **M**odular **A**irborne **R**adiation measurement sys**T**em (SMART)

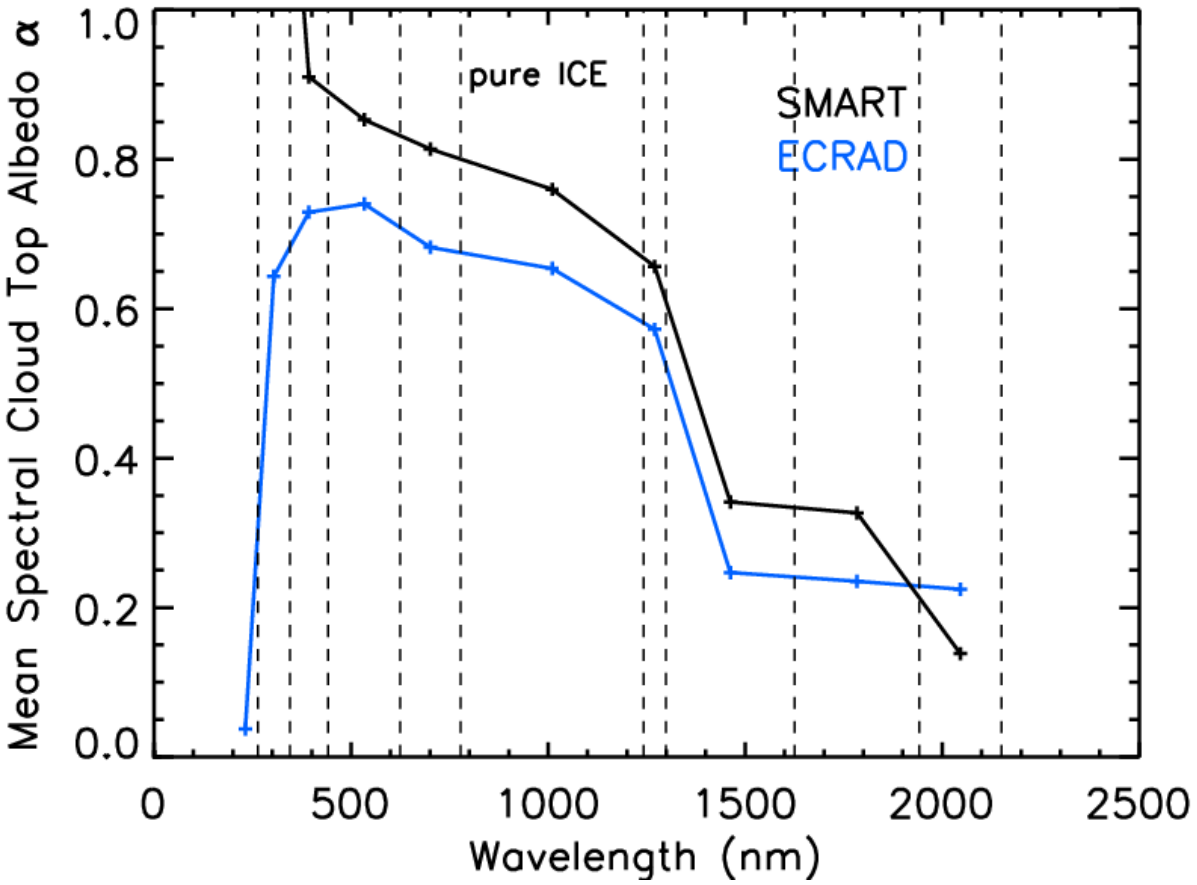


- Zeiss grating spectrometers
- Temporal resolution: 2 – 5 Hz
- Spatial resolution: 2° FOV 120m x 110 m (@ 220 m s^{-1} and at 10,000 m)
- Wavelength range: 300 – 2200 nm
- Spectral resolution: 2 – 16 nm FWHM

Model Setup


Synoptical Data &
Data Assimilation
$T(x,y,p,t)$, $q_{liquid}(x,y,p,t)$, $q_{ice}(x,y,p,t)$, ...
IFS
ECRAD
radiation module (offline)

Mean Spectral Cloud Top Albedo



Spectral (Solar) Cloud Radiative Forcing