Influence of surface heterogeneity on cloud radiative forcing and retrieval of aerosol and clouds

C01

Manfred Wendisch, Georg Heygster,
Larysa Istomina, Evelyn Jäkel

TRANSREGIO TR 172 | LEIPZIG | BREMEN | KÖLN

UNIVERSITÄT LEIPZIG | Universität Bremen | University of Cologne | TROPOS | AWI

1 Summary

Arctic sea ice, snow and open water distribution **highly variable** in:

- Space and time
- Spectral and angular reflectivity

and are strongly related to the surface albedo effect

Special needs for measurements!

Aim: Quantify **heterogeneity effects** on

- Cloud radiative forcing
- Cloud and aerosol remote sensing

Hypothesis

The radiative warming (or cooling) due to Arctic clouds is sensitive to the heterogeneity of surface reflection properties (ice/snow and open water).

2 Research rationale

Surface properties – boundary condition for:

- **Directional surface reflectivity** → Remote sensing
- **Surface albedo** → energy budget, cloud radiative forcing, ice-albedo-feedback

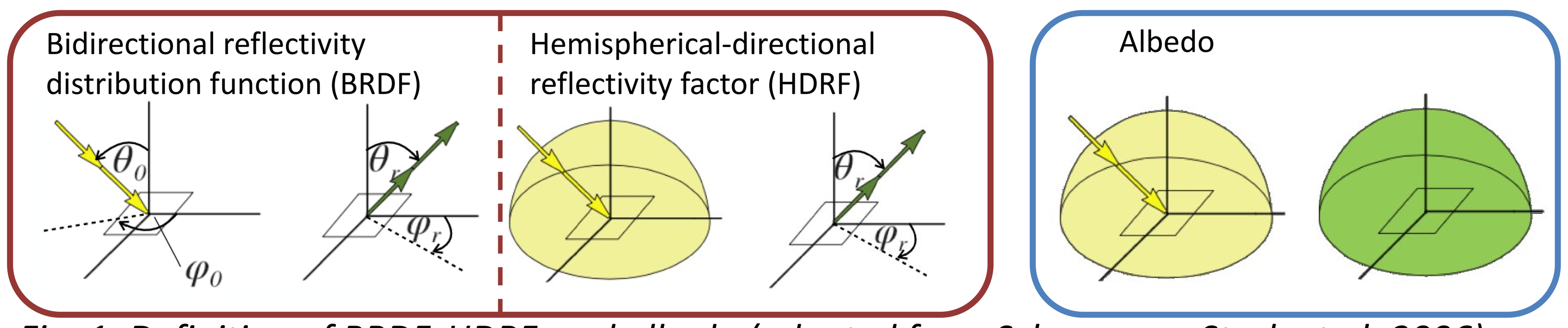

Fig. 1: Definition of BRDF, HDRF, and albedo (adapted from Schaepman-Strub et al.,2006)

Cloud radiative forcing (CRF) $\Delta F=(F^{\downarrow}-F^{\uparrow})_c-(F^{\downarrow}-F^{\uparrow})_{no}$

- Impact of clouds on the annual cycle of CRF is highly variable (Fig. 2)
- Shortwave (SW) radiation only relevant in Arctic summer

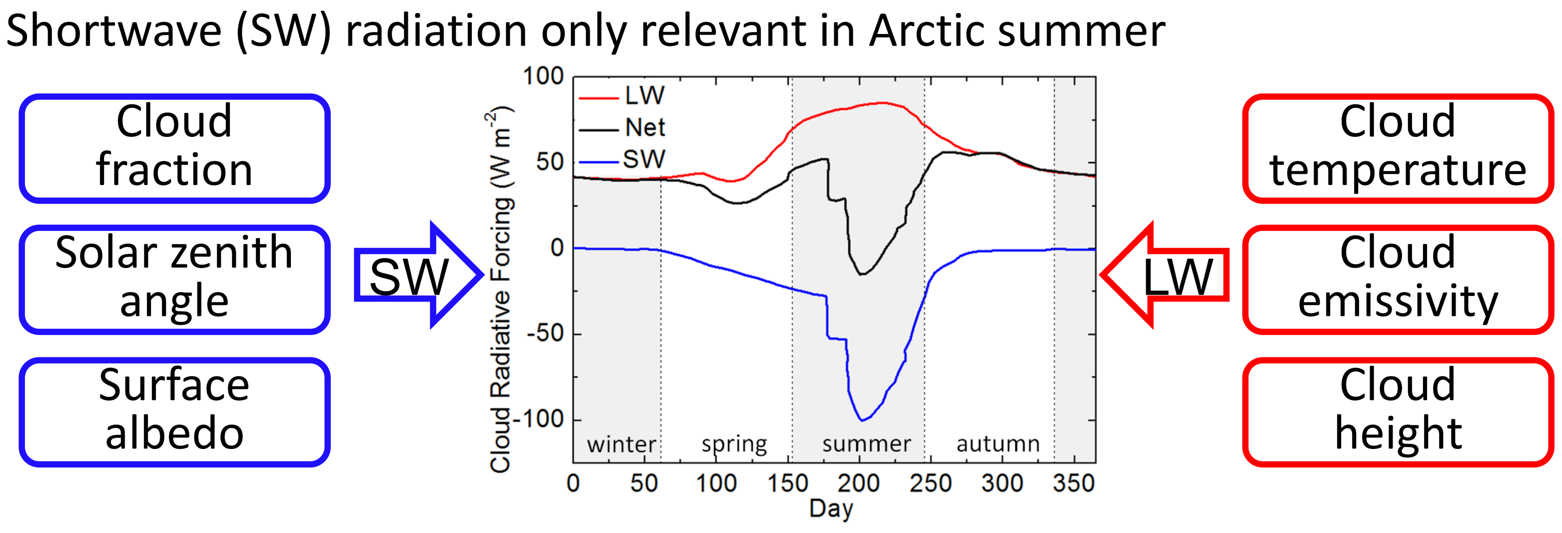

Fig. 2: Annual cycle of CRF at surface for longwave (LW), shortwave (SW), and net radiation (adopted from Curry and Ebert, 1992)

3D radiative effects

- Clear effect of horizontal photon transport below cloud as a function of surface heterogeneity (Fig. 3a)
- Cloud retrieval uncertainty over open water depeding on distance to ice edges (Fig. 3b)

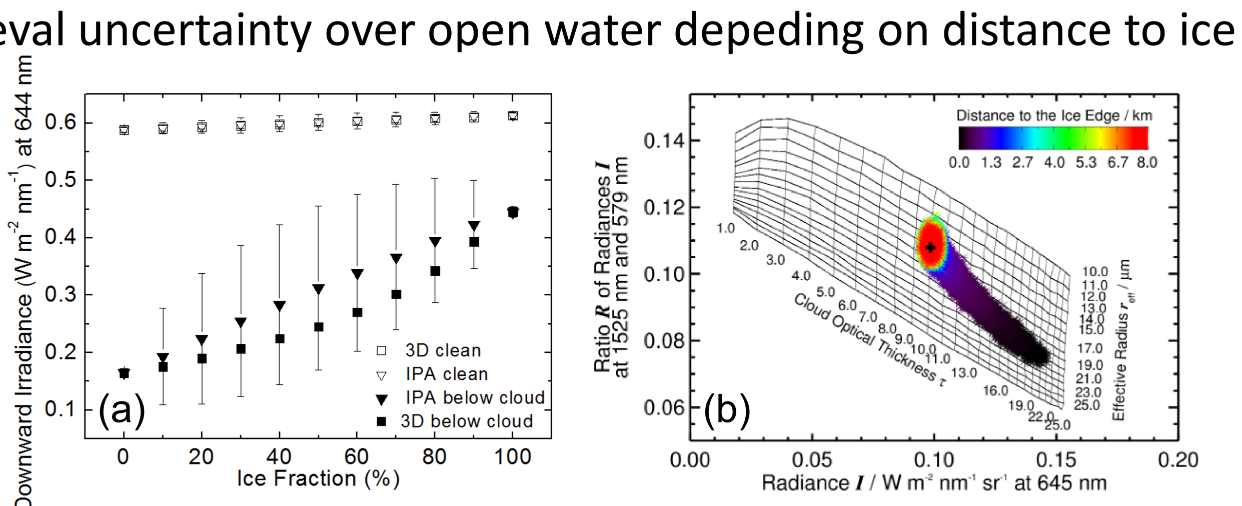

Fig. 3: (a) Surface mean downward irradiance as a function of surface ice fraction for 3D and IPA simulations. (b) Retrieval grid of cloud properties over open water. The radiance of the 3D simulation are colour-coded with repect to distance to the ice-floe edge (Schäfer et al., 2015)

3 Research plan

Aims

- Characterization of heterogeneity (WP1)
- Instrumental and sky conditions effects on surface albedo/BRDF – products (WP2)
- Quantification of 3D radiative effects to assess retrieval accuracy (WP3)

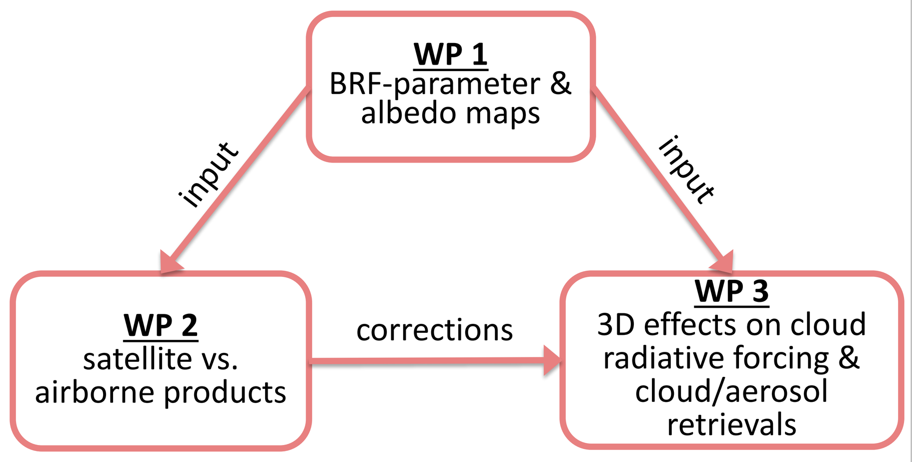

Fig. 4: Link between workpackages

Tools

- Airborne (high spatial and spectral resolution) measurements of albedo (SMART spectrometer) and HDRF (imaging spectrometer Eagle/Hawk + Fish-eye camera)
- Satellite (continuous observations) retrievals of albedo/BRDF (MODIS, MERIS)
- 3D radiative transfer simulations (Monte Carlo model MCARATS) vs. 1D simulations

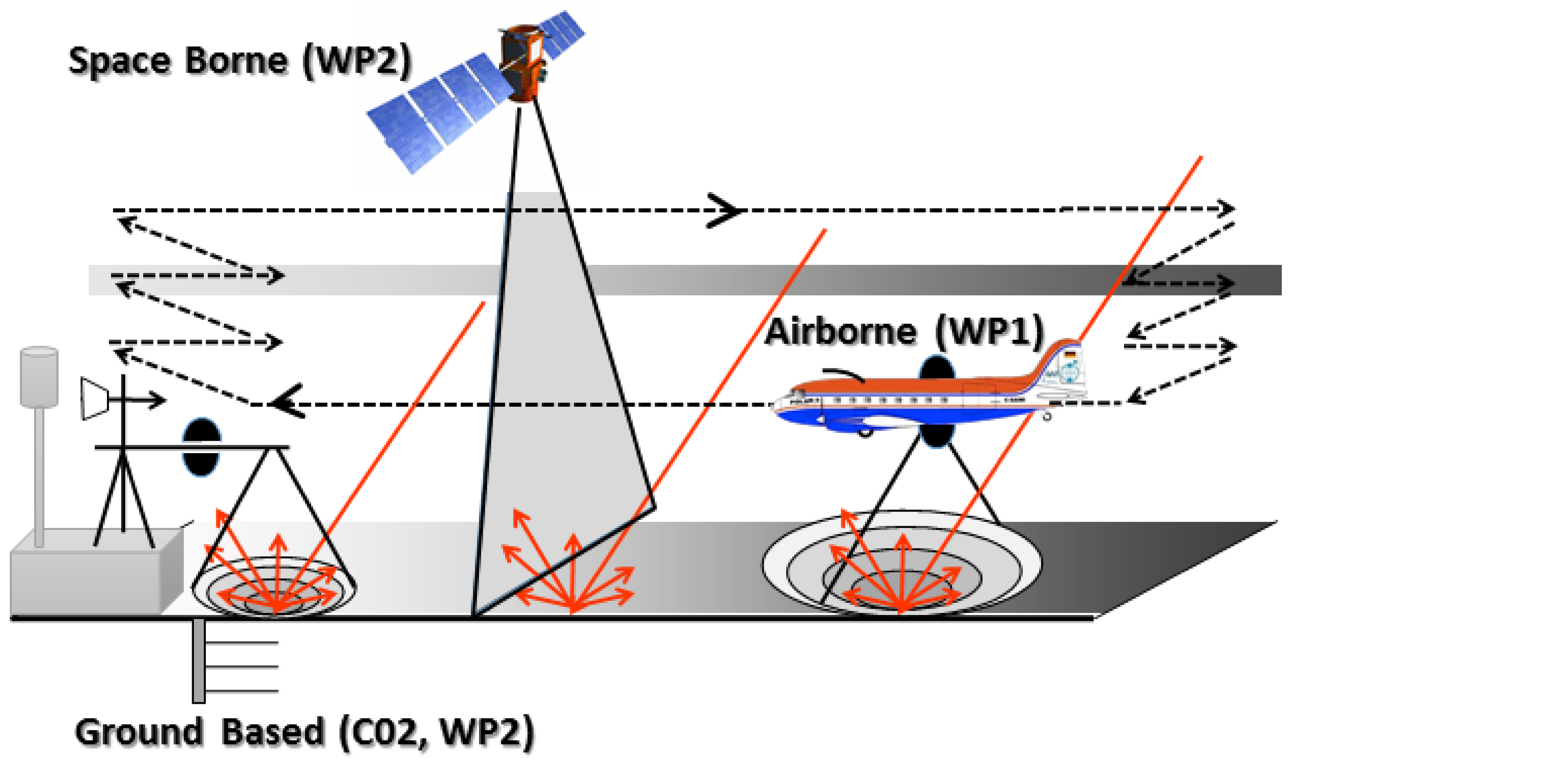

Fig. 5: Surface observations combining airborne (WP1), spaceborne (WP2), and ground-based (C02, WP2) measurements.

Open issues

- Quantification of surface heterogeneity
- Effects on CRF
- Strategy to compare satellite, airborne and in situ albedo/BRDF
- Significance for aerosol/cloud retrievals

4 Role within (AC)³ & perspectives

Collaboration within (AC)³

- Deliver measures of heterogeneity, surface albedo
- Estimate of CRF over highly variable Arctic surface (contrast between ice/snow/open water/melt ponds)
- Sensitivity of the existing aerosol/cloud retrievals on surface heterogeneity
- Recommendations on how to compare satellite, airborne and in situ measurements made over challenging surfaces in the Arctic

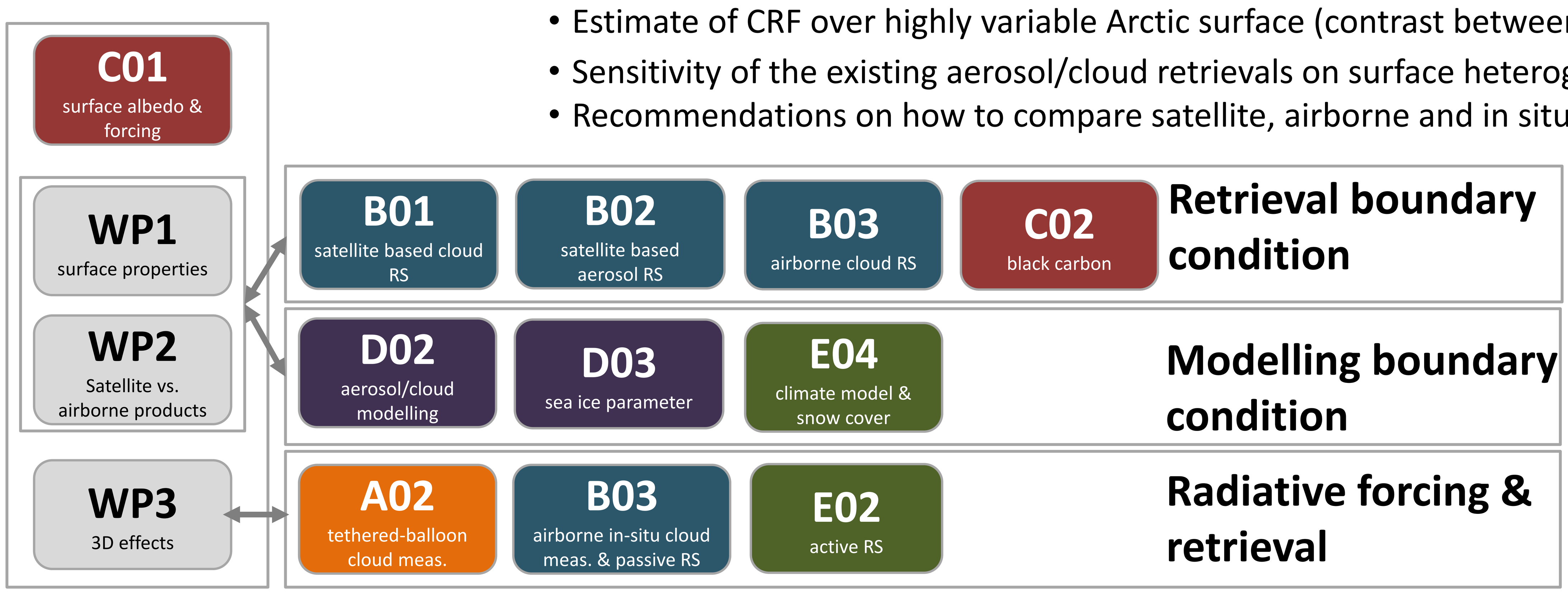

Fig. 6: Links between C01 and other projects. RS stands for remote sensing.

Perspectives

Observations:

- Extension to other seasons and Arctic regions (PAMARCMiP, MOSAiC)
- Extension of spectral range (thermal camera)

Retrievals:

- Improvement of cloud & aerosol retrieval methods based on outcome of first phase (quantification of 3D effects)

printed at Universitätsrechenzentrum Leipzig