TRANSREGIO TR 172
LEIPZIG | BREMEN | KÖLN

VERDI, RACEPAC and ACLOUD: Investigating Arctic clouds by airborne observations

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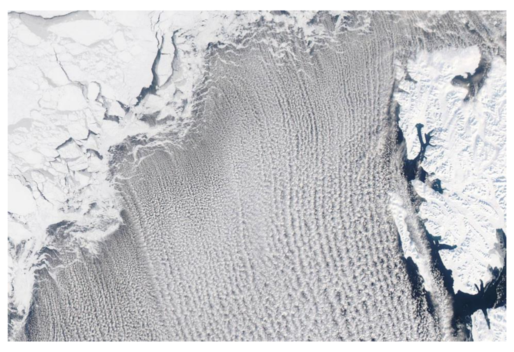
1. Introduction

Fig. 1: Photograph (top) and satellite image (bottom, MODIS) of Arctic mixed-phase clouds.



Relevance of Arctic boundary-layer clouds

- Arctic climate most sensitive to climate change
- Arctic clouds play a significant role in the Arctic energy budget
- Variety of formation processes
  - Convection above open water, mixing, radiative cooling
- Variety of microphysical and optical properties
  - Liquid, ice, mixed-phase, ice crystal shape

Why Arctic ?

- Arctic is an ideal test bed for cloud research
- Often no cirrus
- Different situations with open water, sea ice
- No restriction due to commercial air traffic
- Easy coordination of flight pattern

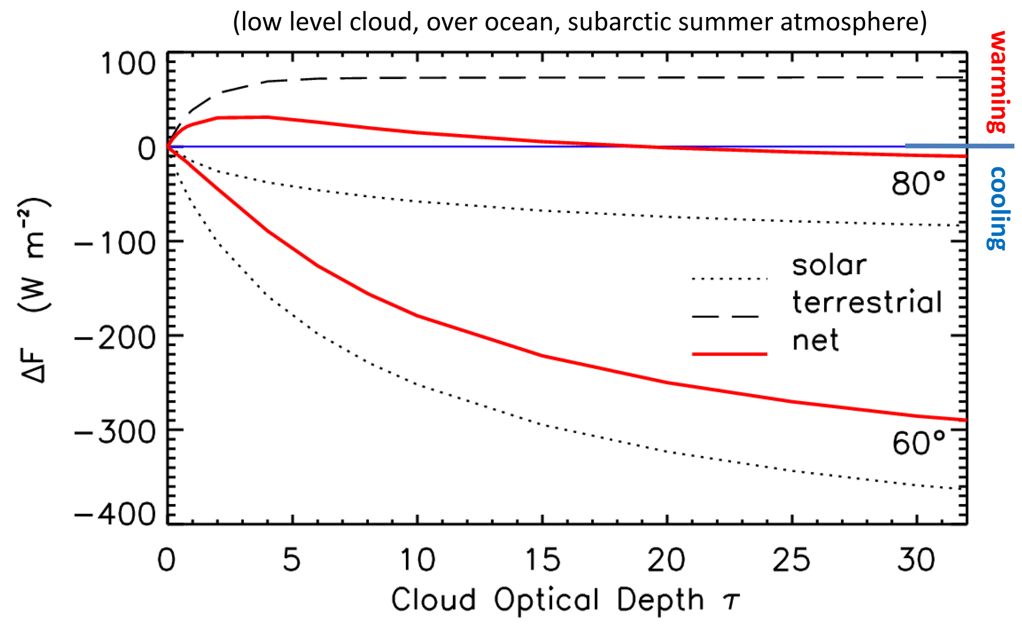


Fig. 2: Cloud radiative forcing at the surface of different optical depth τ and two solar zenith angles. Simulations are done for cloud above open ocean [1].

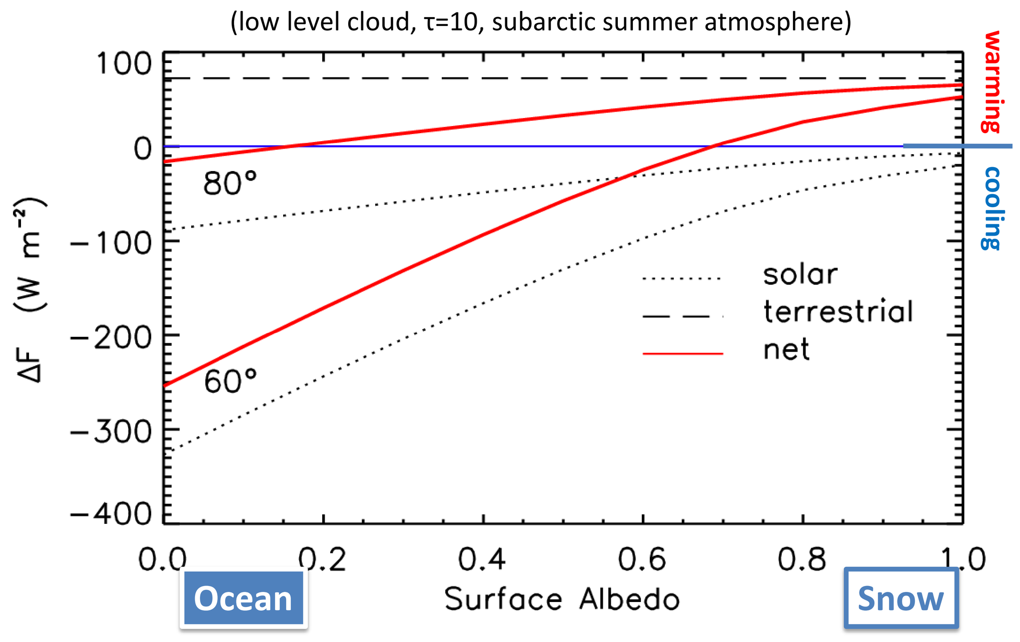


Fig. 3: Cloud radiative forcing at the surface in dependence of surface albedo. Simulations are for a cloud with optical depth of τ=10 and for two different solar zenith angles [1].

2. Airborne Field Campaigns

VERDI - Study of the Vertical Distribution of Ice in Arctic Clouds (2012)

- **Beaufort Sea** (Inuvik/NWT/Canada)
- 25 April – 17 May, 13 Flights, 49 Flight Hours, **1 Aircraft**
- Stable atmospheric conditions, colder temperatures, more sea ice

http://research.uni-leipzig.de/verdi

RACEPAC - Radiation–Aerosol–Cloud Experiment in the Arctic Circle (2014)

- **Beaufort Sea** (Inuvik/NWT/Canada)
- 28 April – 23 May, 16 Flights, 88 Flight Hours, **2 Aircraft**
- Frequent frontal activity, warmer temperatures, less sea ice

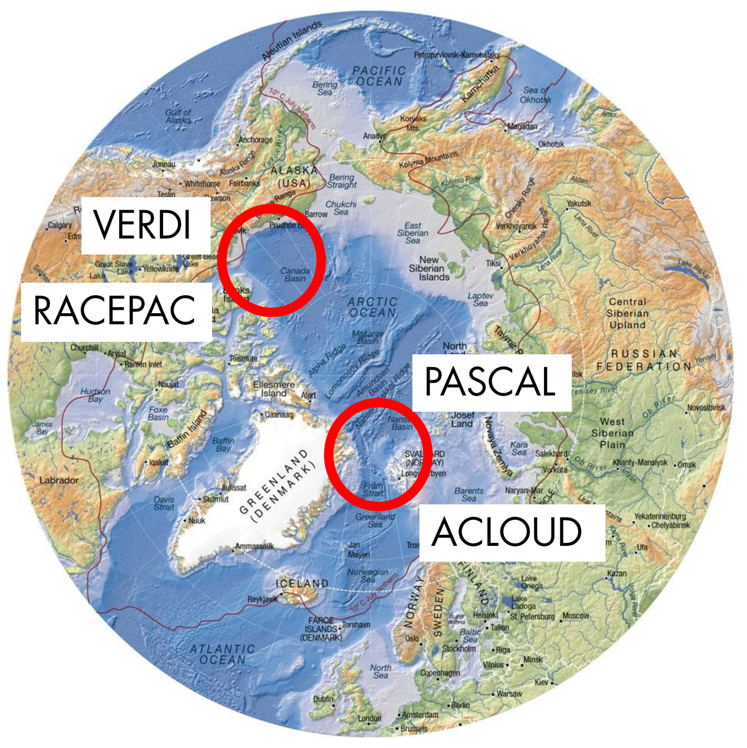
http://research.uni-leipzig.de/racepac

ACLOUD (planned for 2017)

- within Transregio TR 172: ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms *(AC)³*
- **Greenland Sea & Fram Strait** (Longyearbyen/Svalbard)
- 22 May – 28 June, 80 Flight Hours, **2 Aircraft**
- simultaneous ground and ship-based observations
  AWIPEV (Ny Ålesund + **PASCAL** (RV Polarstern, Ice Station)
- Observations above open ocean and sea ice

http://www.ac3-tr.de

Locations



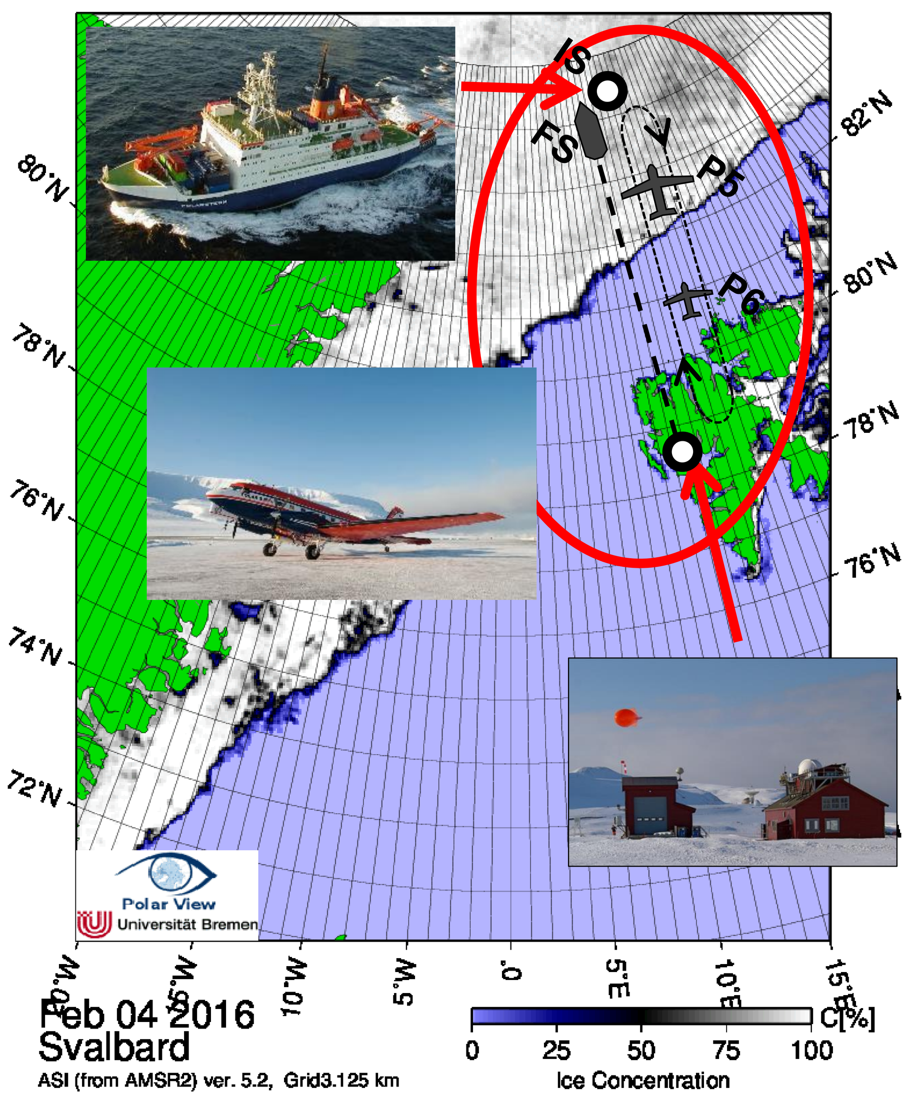


Fig. 4: Location of research campaigns and set up of airborne and ground-/ship-based observations planned for ACLOUD & PASCAL

Meteorological and sea ice situation

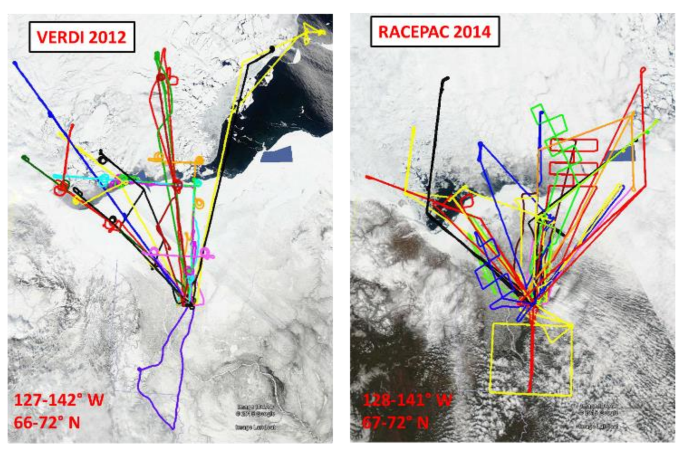


Fig. 5: Flight tracks of VERDI and RACEPAC.

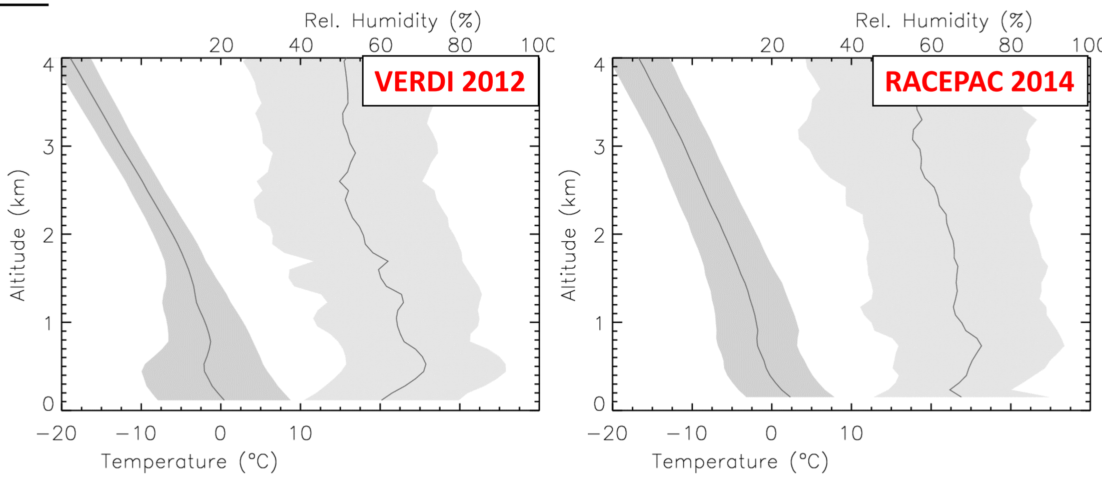
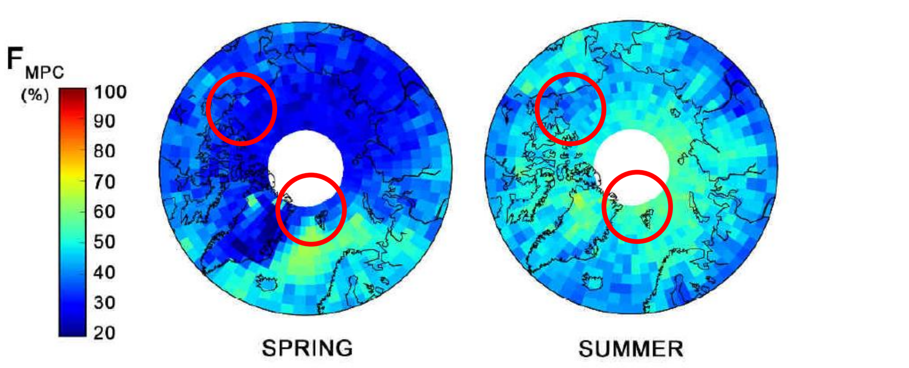


Fig. 6: Mean radio soundings for the period 25 April–24 May during VERDI (left) and RACEPAC (right).

- Meteorology, cloud and sea ice conditions are strongly linked
- ACLOUD observations in transition season from high to low fraction of mixed-phase clouds



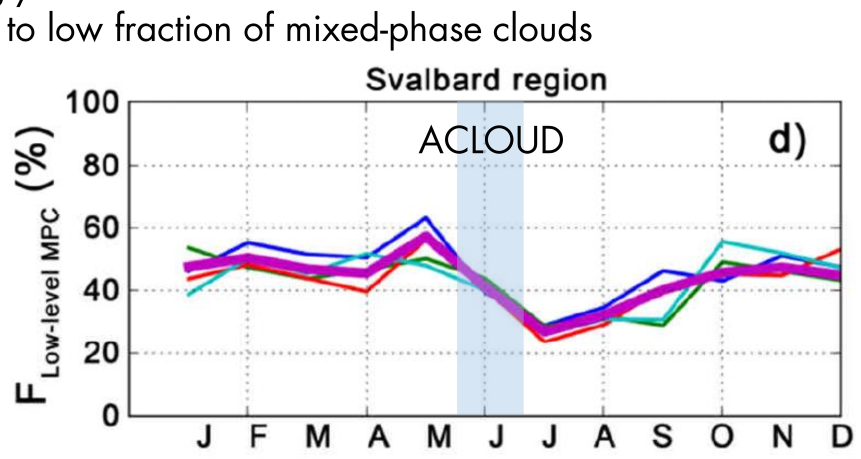


Fig. 7: Spatial distribution (left) and seasonal cycle (right, Svalbard region only) of mixed-phase cloud fraction [2].

3. Observation Strategy

Instrumentation

Tab. 1: Instrumentation of Polar 5 and 6 during VERDI, RACEPAC and ACLOUD.

	VERDI	RACEPAC		ACLOUD	
	P5	P5	P6	P5	P6
Standard Meteorology (wind vector, p, T, rH)	X	X	X	X	X
Drop Sondes (wind vector, p, T, rH)	X	X		X	
Turbulence – Nose Boom				X	X
Cloud Microphysics I (NICE-CAPS, CAS-DPOL)	X		X		
Cloud Microphysics II (SID-3, CCP, PIP, PHIPS-HALO)	X		X		X
Cloud Microphysics III (Polar Nephelometer, HALO-HOLO)			X		
Aerosol Mass Spectrometer (ALABAMA, CToF-AMS)	X		X		X
Aerosol Sensors (OPC, CPC, UHSAS, SP2)			X		X
Trace Gas CO/CO_2			X		X
Counterflow Virtual Impactor (aerosol inlet)			X		X
SMART Albedometer (spectral albedo and reflectivity)	X	X		X	
AISA-Eagle (spectral imaging)	X	X		X	
AISA-Hawk (spectral imaging)				X	
Digital Camera (180° Fisheye)	X	X		X	
Airborne Mobile Lidar (AMALi)	X	X		X	
Sun Photometer	X	X		X	
MIRAC (Radar + MW Radiometer)				X	

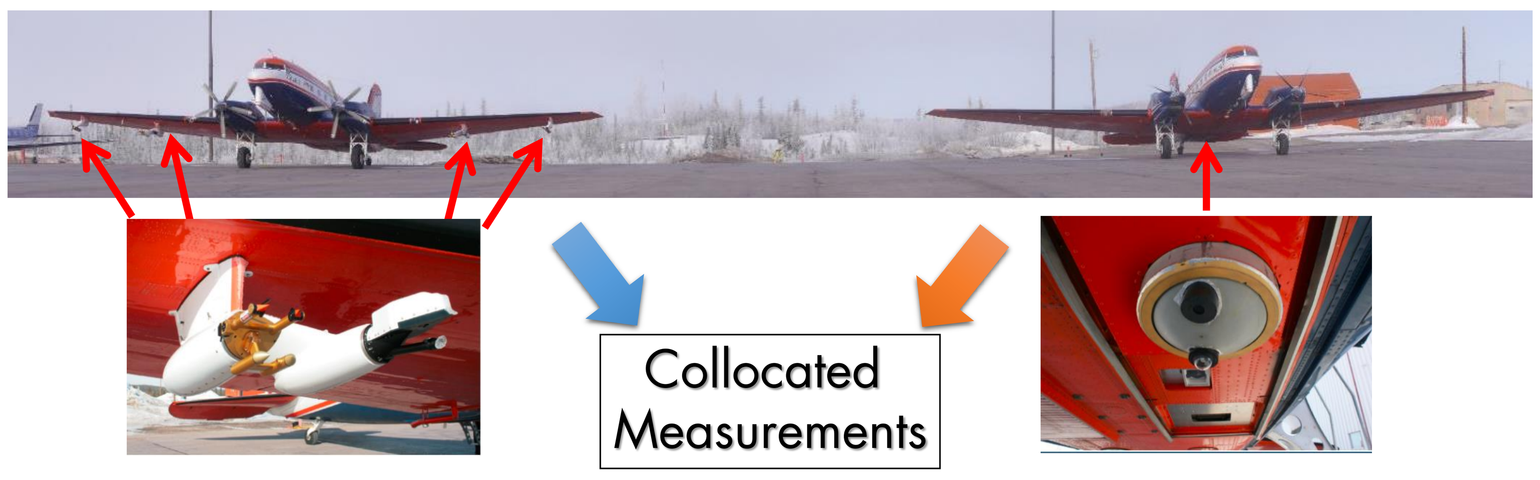
- **Polar 5 and 6** (Basler BT 67) operated and funded by Alfred-Wegener Institute for Polar and Marine Research
- Payload in situ and remote sensing separated
  → **collocated measurements**
- **New** instrumentation **ACLOUD**
  - **Nose Boom** → Turbulent fluxes
  - Counter flow virtual impactor **CVI**
    → Cloud particle residue
  - NIR imaging spectrometer **AISA-Hawk**
    → Remote sensing of cloud phase
  - Radar and MW Radiometer **MiRAC**
    → Vertical profiling of clouds

Polar 6 = In Situ

- Cloud and Aerosol particle sampling
- Trace gas CO/CO2
- Turbulent fluxes

Polar 5 = Remote Sensing

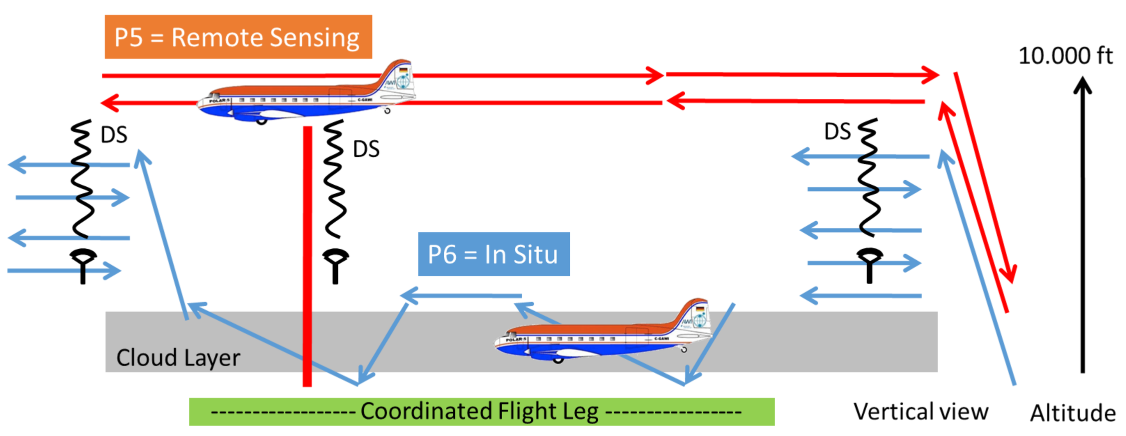
- Cloud radiative properties
- Horizontal and vertical variability
- Turbulent fluxes



Flight pattern & Collocation

Airborne – Airborne & Airborne – Satellite & Airborne – Ground-/Ship-Based

- Cloud and atmosphere sampling combined by remote sensing (500 ft to 10.000 ft)
- **RACEPAC** and **ACLOUD:** collocated measurements with **<200 m** horizontal displacement (<5min in time, for safety reasons)
- Coordination of A-Train overpasses
- Adjustment to wind direction for turbulence measurements



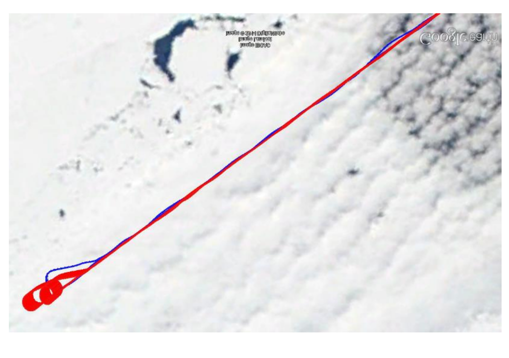
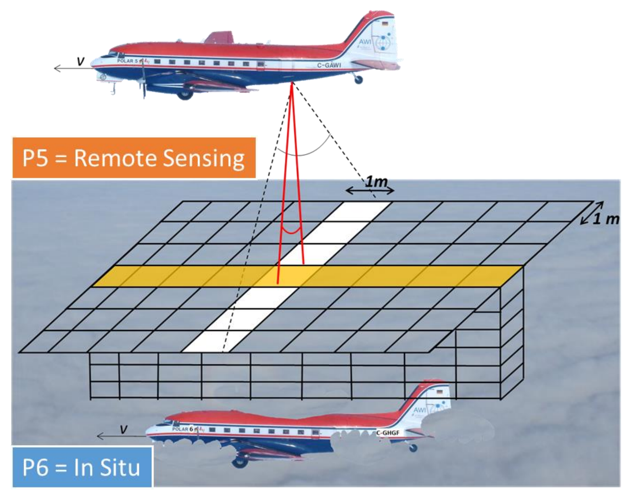
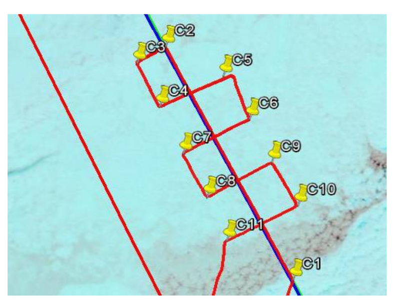


Fig. 8: Flight strategy for collocated measurements during RACEPAC. (left) Flight track of P5 and P6 on a MODIS image (right).





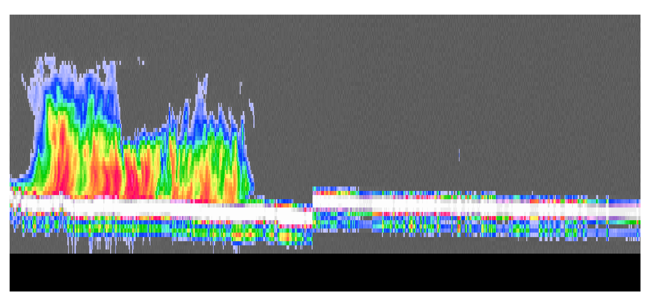


Fig. 9: Horizontally and vertically resolved remote sensing by combining spectral imaging and active radar/lidar observations (left). Flight track coordinated with A-Train overpass and CloudSat profile on 20. May 2014 (right).

4. Outlook

- AFLUX 2019: Station Nord, Spring season, one polar aircraft only → more sea ice
- Beyond first phase of (AC)³
  - MOSAiC campaign 2019/2020
  - HALO mission proposed for spring 2020
- ACP/AMT Special Issue http://www.atmos-chem-phys.net/special_issue362.html

[1] Wendisch, M., Yang, P., and Ehrlich, A., eds.: Amplified climate changes in the Arctic: Role of clouds and atmospheric radiation, vol. 132 (3), 1-34, Sitzungsberichte der Sächsischen Akademie der Wissenschaften zu Leipzig. Mathematisch-Naturwissenschaftliche Klasse, S. Hirzel Verlag, Stuttgart/Leipzig, 2013
[2] Mioche, G., Jourdan, O., Ceccaldi, M., and Delanoë, J.: Variablity of mixed-phase clouds in the Arctic with a focus on the Svalbard region: a study based on spaceborne active remote sensing, Atmos. Chem. Phys., 15, 2445-2461, 2015
[3] http://www.atmos-chem-phys.net/special_issue362.html

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