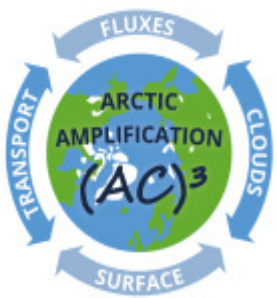
$\mathcal{A}$rcti$\mathcal{C}$ $\mathcal{A}$mplification: $\mathcal{C}$limate Relevant $\mathcal{A}$tmospheric and Surfa$\mathcal{C}$e Processes and Feedback Mechanisms $(\mathcal{AC})^3$

Retrieval of microphysical cloud parameters from IR-spectra, measured in summer 2017

P. Richter, M. Palm, C. Weinzierl, J. Notholt

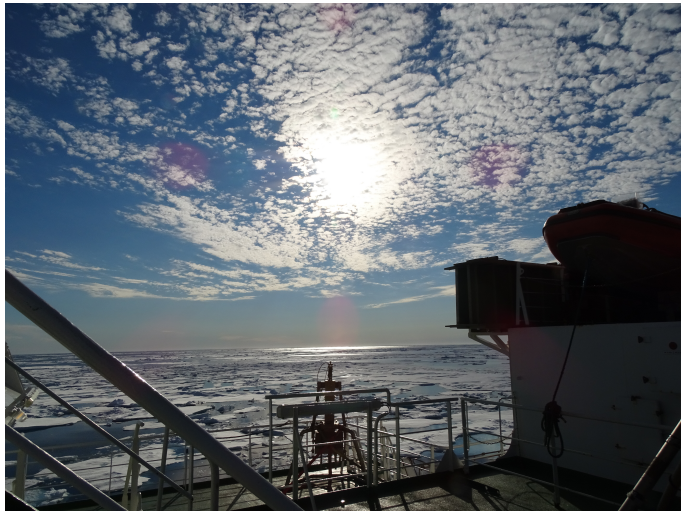


Project $(\mathcal{AC})^3$

- Arctic is warming faster than the rest of the earth
  - Project $(\mathcal{AC})^3$: Arctic Amplification: Climate Relevant Atmospheric and Surface Processes and Feedback Mechanisms
- In the arctic, about 80% of the clouds contain less than $100\,\mathrm{g\,m^{-2}}$ water (Shupe und Intrieri 2004) - In mid-latitudes only 50%! (Marchand et al. 2003)
- Up to $40\,\mathrm{g\,m^{-2}}$, change in longwave radiation flux (Turner et al. 2007)

Cloud observation and optical thin clouds

- Important quantites for the description of clouds are the water path, effective radius and optical depth
  - Water path: Water content (liquid, LWP; ice, IWP; total, TWP) integrated over the entire column
  - Effective radius: Weighted mean of droplet radii
  - Optical depth: Ability to absorb and emit radiation



Picture by P. Richter

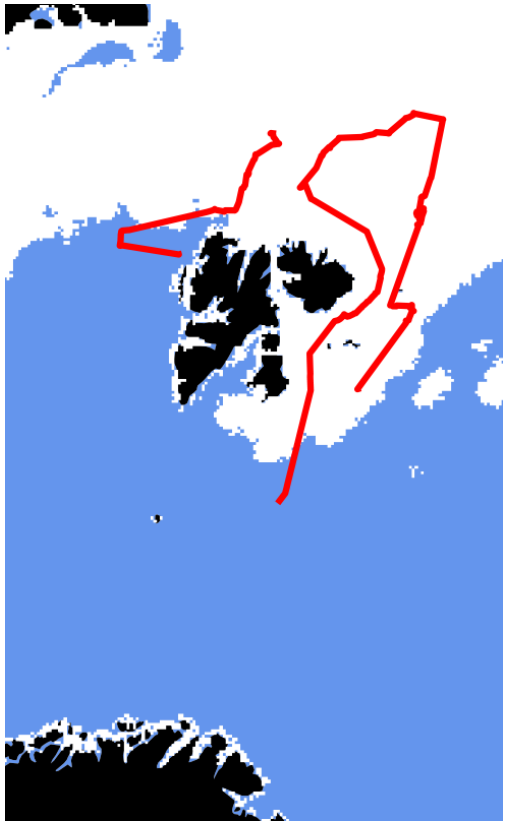
Microwave radiometer or FTIR spectrometer?

- Usual instrument for ground-bases cloud observation is the microwave radiometer (MWR)

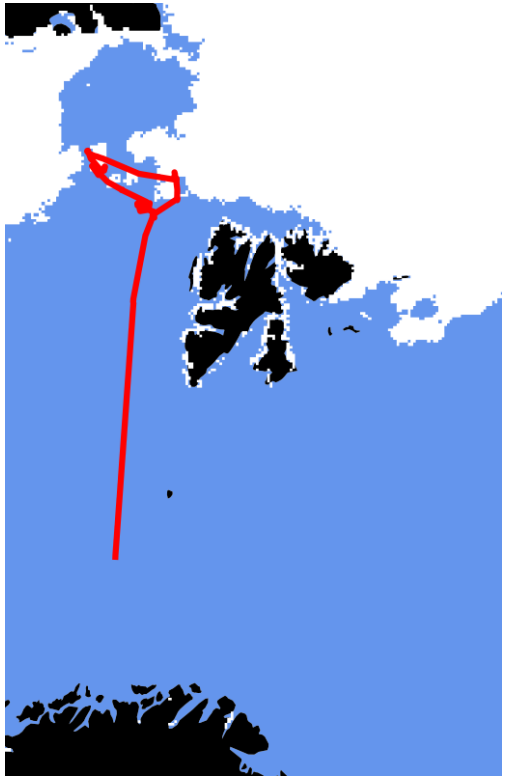
Microwave radiometer	FTIR spectrometer
High range of LWP	saturation above $40\,\mathrm{g\,m^{-2}}$
$20\,\mathrm{g\,m^{-2}} \leq \Delta LWP \leq 30\,\mathrm{g\,m^{-2}}$	$\Delta LWP \approx 5\,\mathrm{g\,m^{-2}}$ (thin clouds)
	IR active gases and aerosols

$\Rightarrow$ FTIR spectrometer applicable in observing thin clouds ($LWP \leq 40\,\mathrm{g\,m^{-2}}$)

Polarstern in summer 2017



Track of PASCAL/PS106



Track of FRAM/PS107

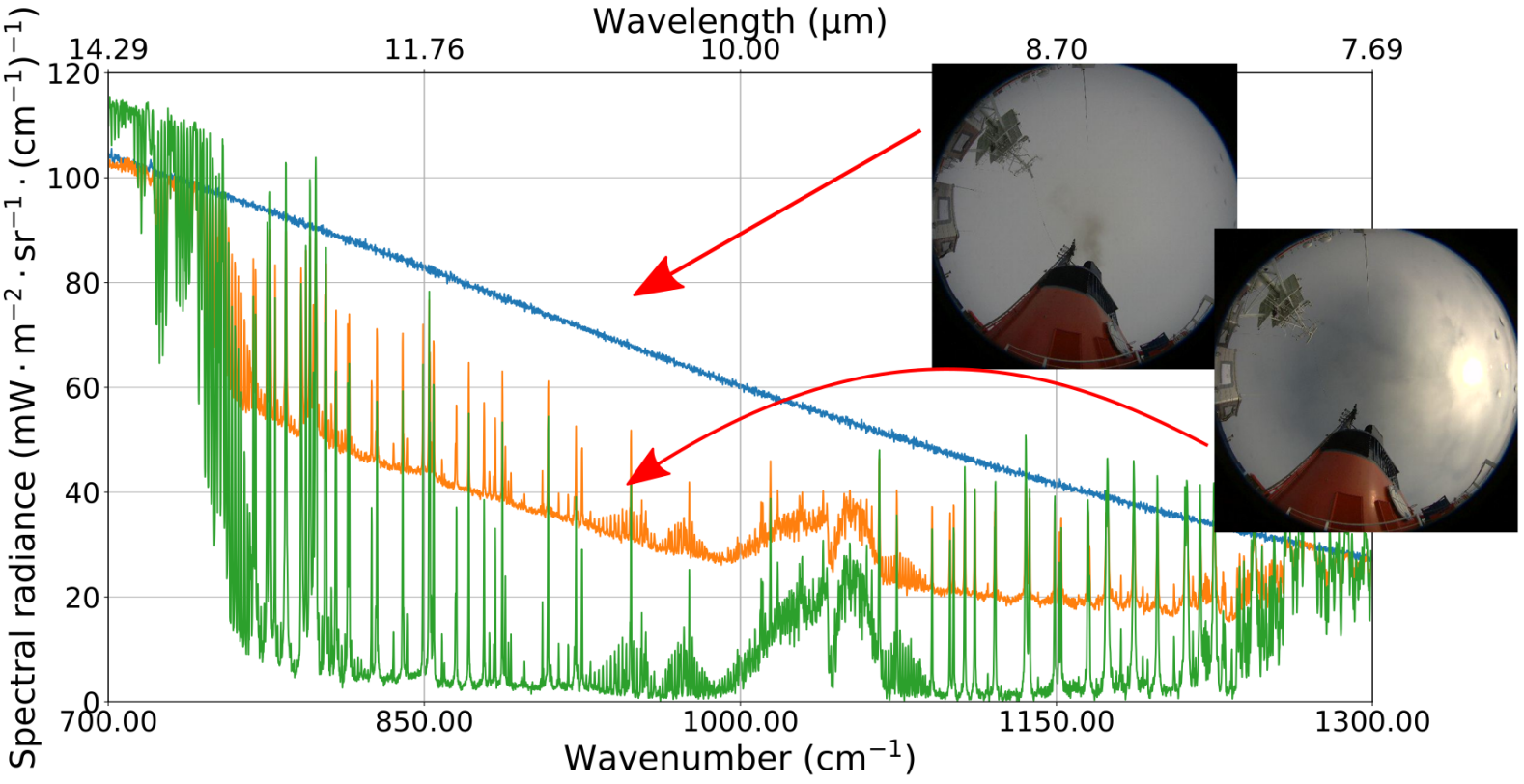
Sea ice data: Spreen, G., L. Kaleschke, and G.Heygster (2008), doi.org/10.1029/2005JC003384

Emission(EM)-FTIR

- Mobile *Fourier Transform Infrared Spektrometer Equinox 55*
- $\bar{\nu} = [700\,\mathrm{cm}^{-1}, 2000\,\mathrm{cm}^{-1}]$
- $\Delta\bar{\nu} = 0.3\,\mathrm{cm}^{-1}$
- Vaisala CL51 Ceilometer: Cloud base height
- Radiosondes: Profiles of temperature, pressure and humidity
- During PS106: Cloudnet (MWR, Lidar, cloud radar)

Pictures by P. Richter (upper) and M. Palm (lower)

Spectra of different clouds



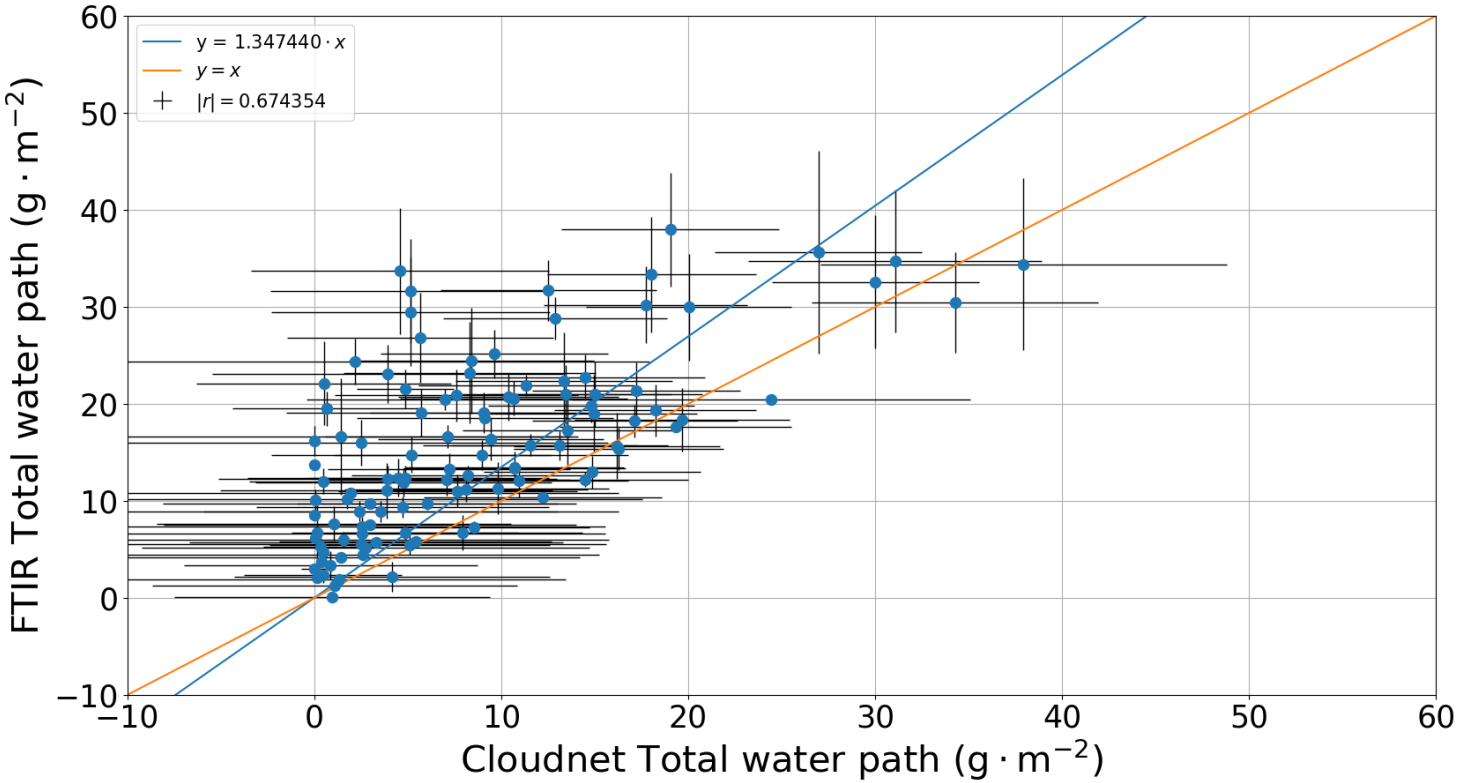
Spectra of clear sky, a cloud containing low amount of water and a cloud containing high amount of water.

Retrieval of cloud parameters

- Forward models: **LBLRTM** und **LBLDIS**
- Algorithm directly applied to the spectral radiances $\vec{I}$ (Collard et al. 1995, Rathke und Fischer 2000).
- Retrieval parameters are the optical depths τ and the effective radii r_{eff}. Ice particles are assumed to be solid hexagonal columns.
- Minimizing a costfunction using *non-linear least squares* fitting

$$\xi^2(\vec{x_n}) = \left[\vec{I} - F(\vec{x_n})\right]^T \mathbf{S_y}^{-1} \left[\vec{I} - F(\vec{x_n})\right] + [\vec{x_a} - \vec{x_n}]^T \mathbf{S_a}^{-1} [\vec{x_a} - \vec{x_n}]$$

Correlation FTIR/Cloudnet

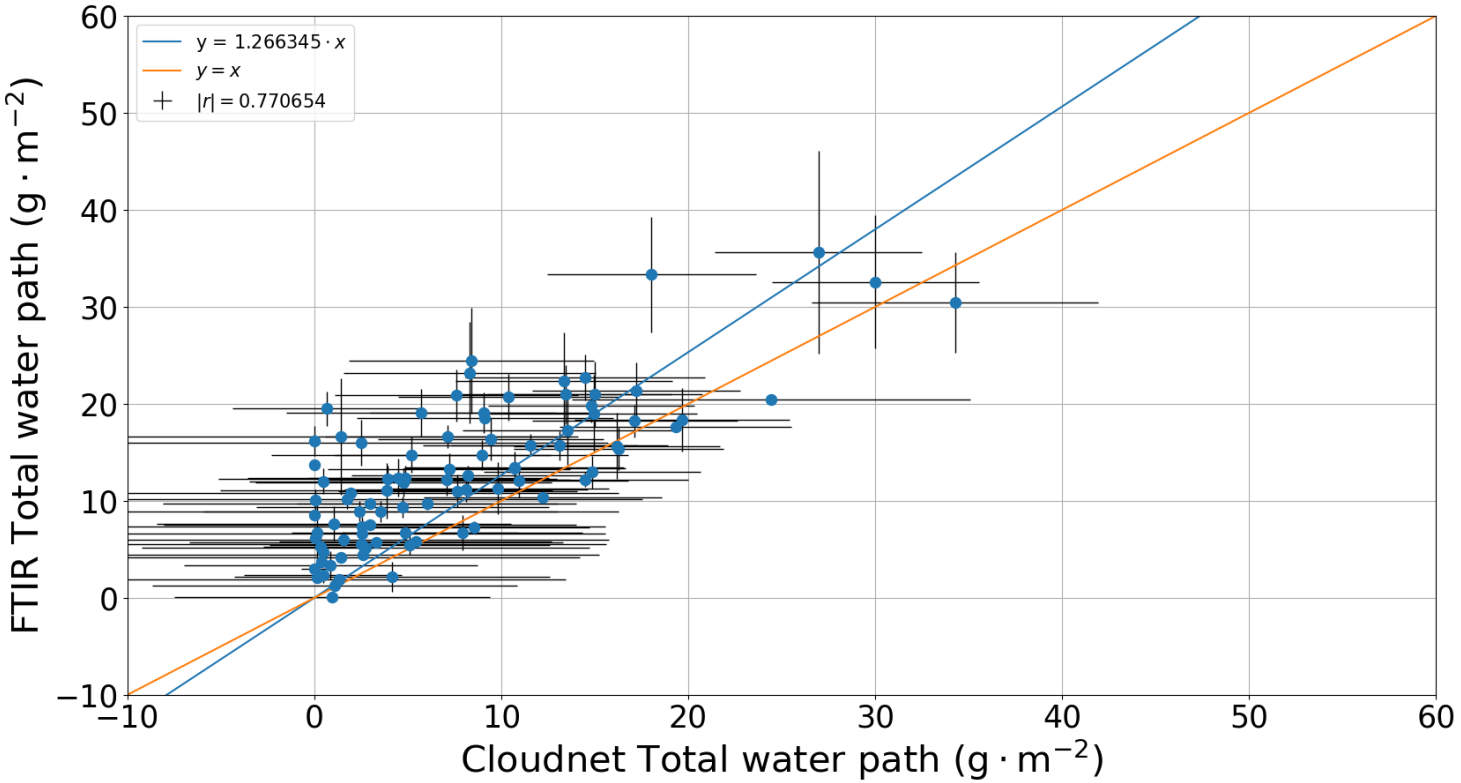


Correlation of TWP between FTIR and Cloudnet.

Cloudnet data: in preparation for upload to Pangaea
Griesche et al., 2019, in prep. for AC3 ACP/AMT special issue

FTIR data: submitted to Pangaea

Correlation FTIR/Cloudnet

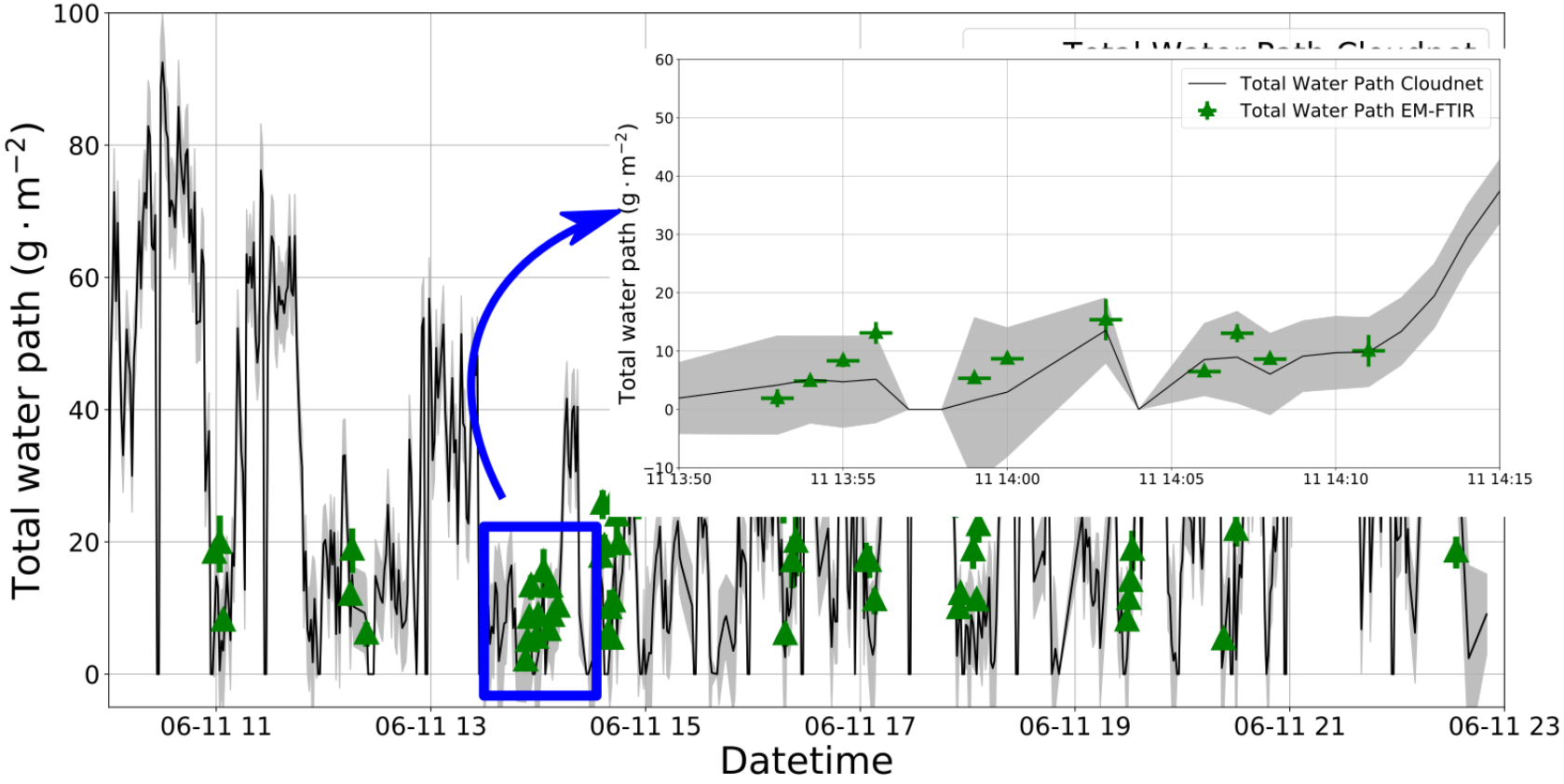


Filtered: $IWP \leq 15\,\mathrm{g\,m^{-2}}$

Cloudnet data: in preparation for upload to Pangaea
Griesche et al., 2019, in prep. for AC3 ACP/AMT special issue

FTIR data: submitted to Pangaea

Timeseries 11th June 2017

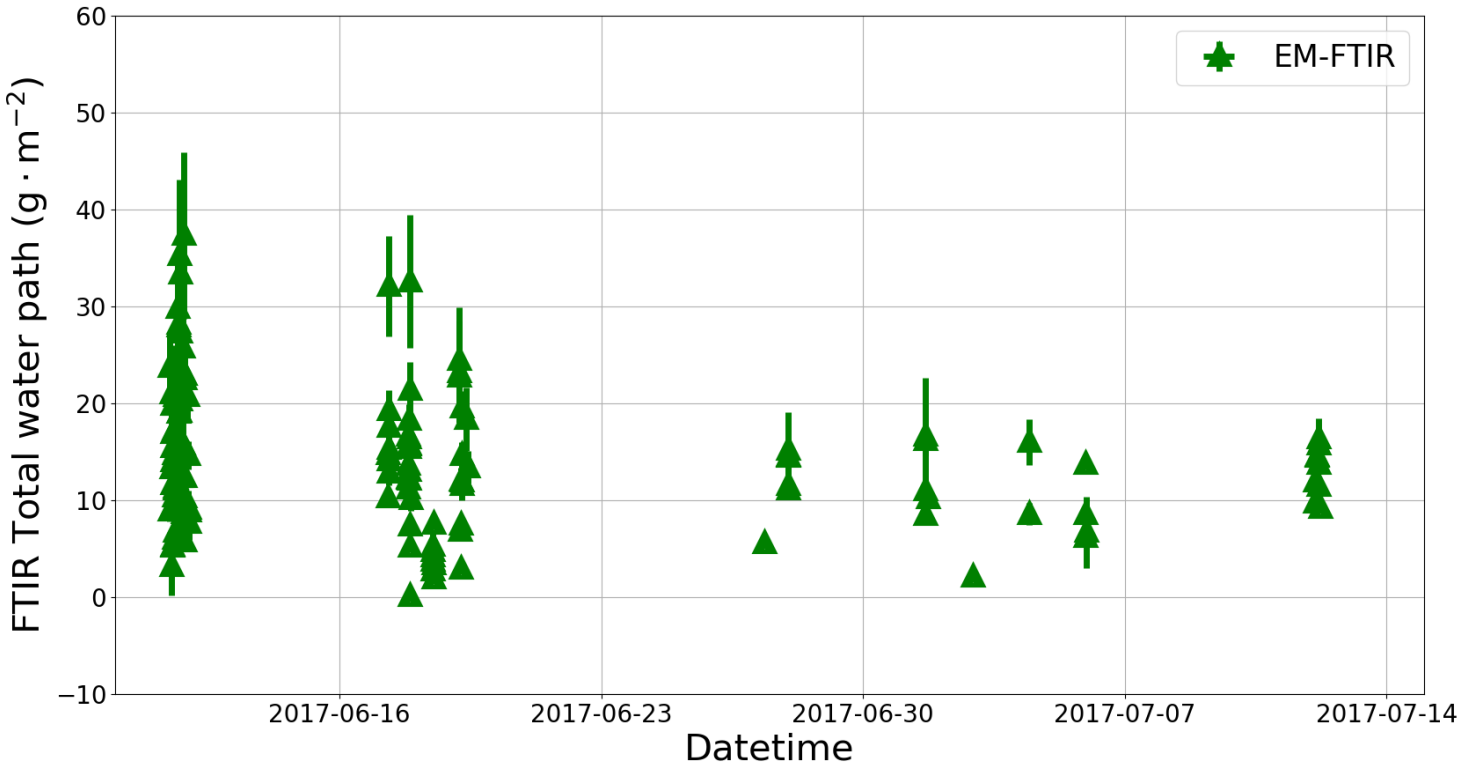


TWP on the 11th June 2017.

Cloudnet data: in preparation for upload to Pangaea
Griesche et al., 2019, in prep. for AC3 ACP/AMT special issue

P. Richter et al., 2019, in prep.

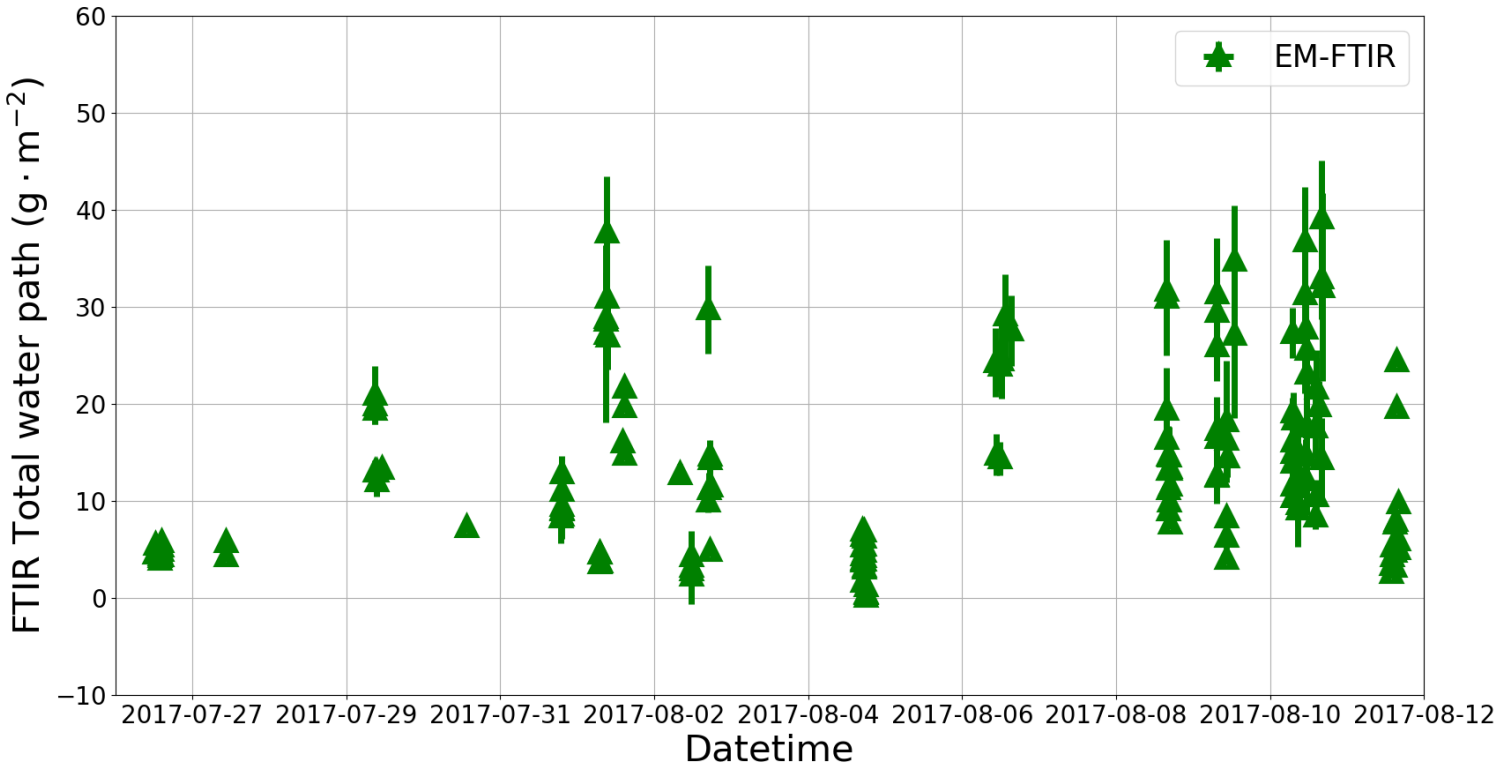
Timeseries PASCAL/PS106



Timeseries of the total water path for the PASCAL/PS106.

P. Richter et al., 2019, in prep.

Timeseries FRAM/PS107



Timeseries of the total water path for the FRAM/PS107.

P. Richter et al., 2019, in prep.

Summary and next steps

- Retrieval for microphysical cloud parameters implemented.
- TWP retrieved for spectra measured during PASCAL/PS106 and FRAM/PS107.
- Agreement between FTIR and Cloudnet.

- EM-FTIR instrument will be set up at Ny-Ålesund.
- How does the cloud parameters have changed in comparison to 1997 (SHEBA campaign)?

Acknowledgements

The participation on the expedition has been supported from the Transregional Collaborative Research Center (TR) 172.

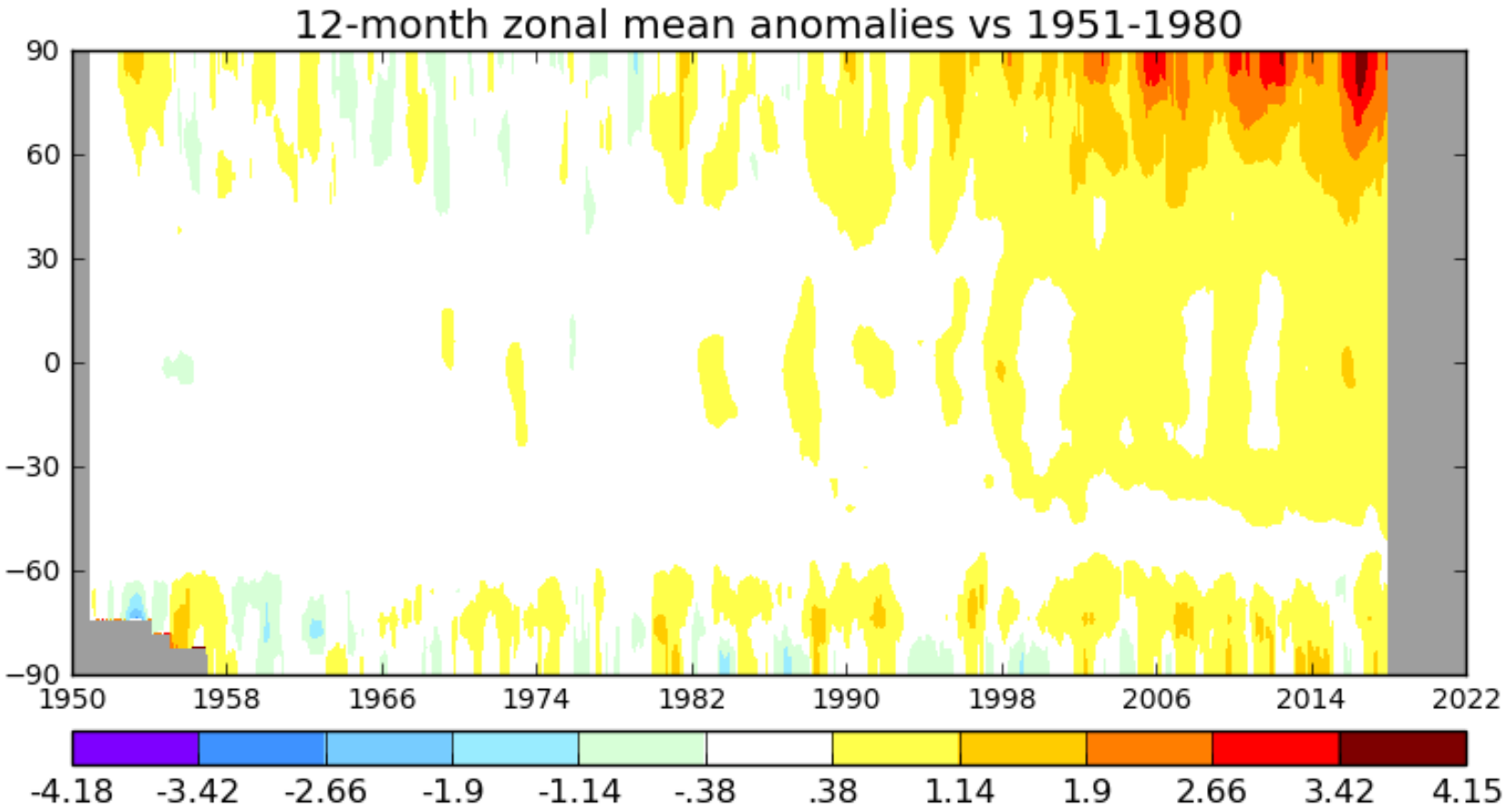
ArctiC Amplification:
Climate Relevant Atmospheric and SurfaCe Processes and Feedback Mechanisms (AC)³

We acknowledge the AWI Bremerhaven, the technical and scientific staff on the research vessel Polarstern and the AWI Bremerhaven for support during the cruises PS106 and PS107.

The computations were perfomed on the HPC cluster Aether at the University of Bremen, financed by DFG in the scope of the Excellence Initiative.

Deutsche Forschungsgemeinschaft

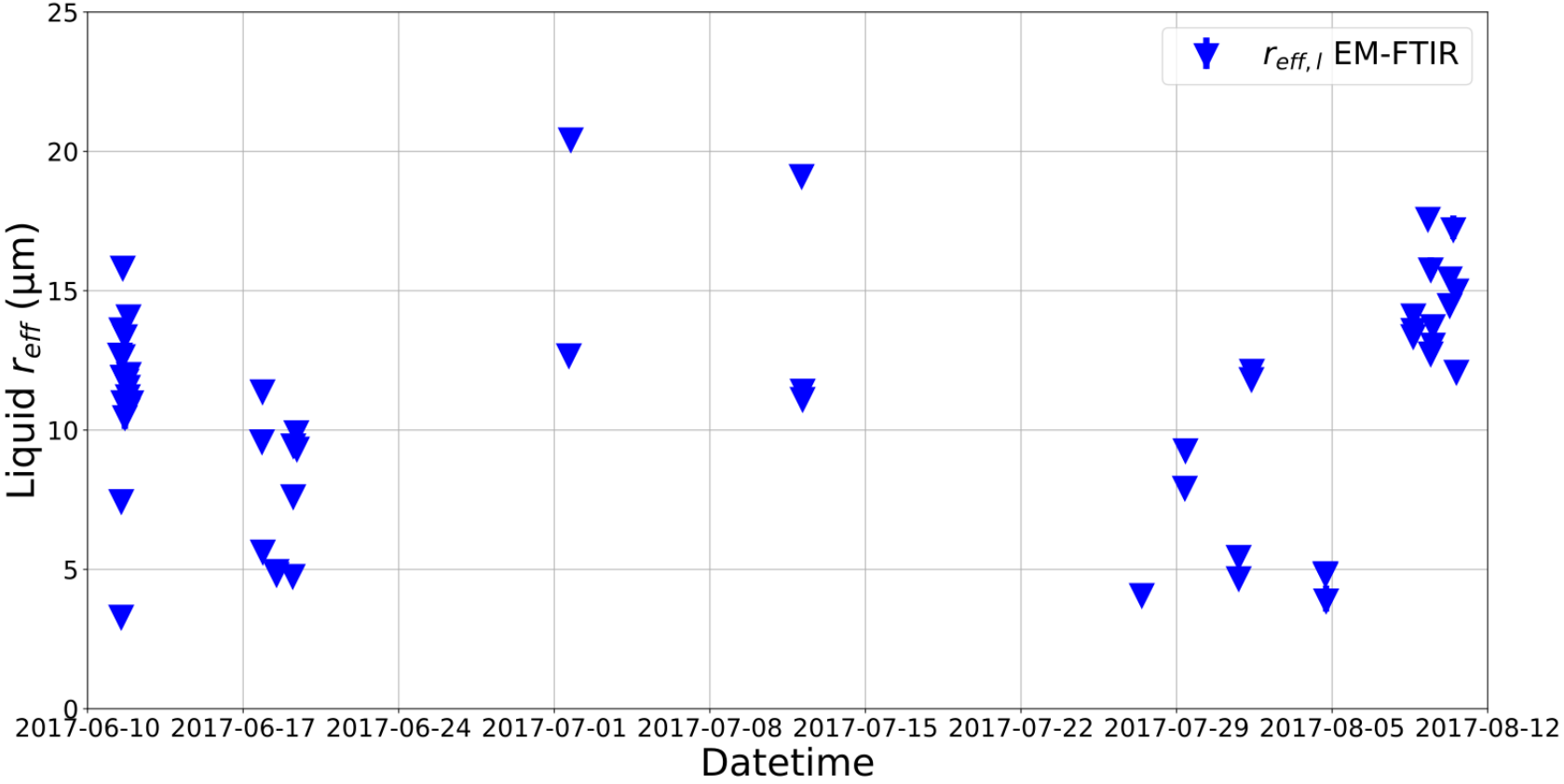
Projekt $(\mathcal{AC})^3$



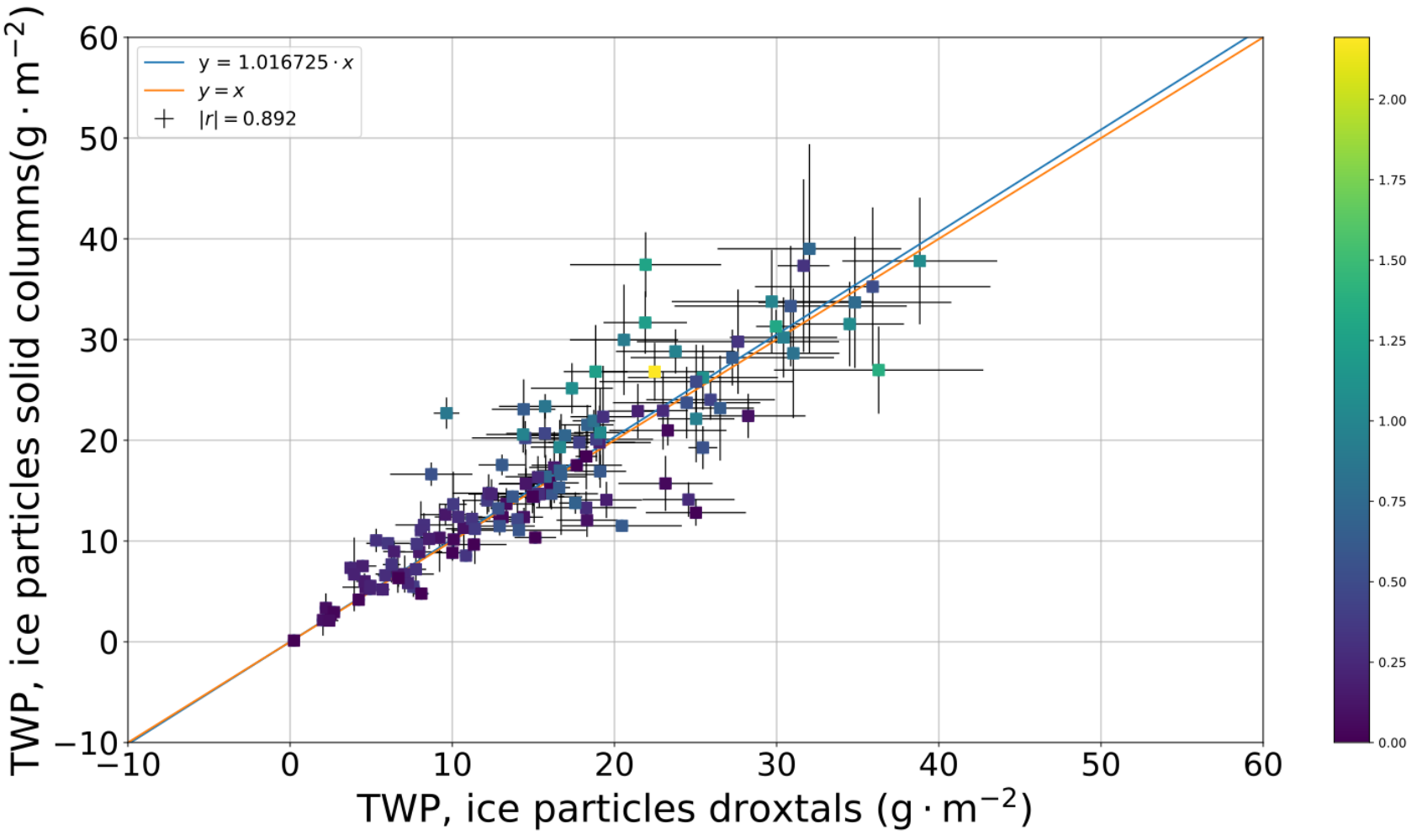
Breitengradverteilung der Temperaturanomalie, bezogen auf den Zeitraum 1951 bis 1980 GISTEMP Team, 2018 abgerufen am 2018-09-07

$(\mathcal{AC})^3$: Arctic Amplification: Climate Relevant Atmospheric and Surface Processes and Feedback Mechanisms

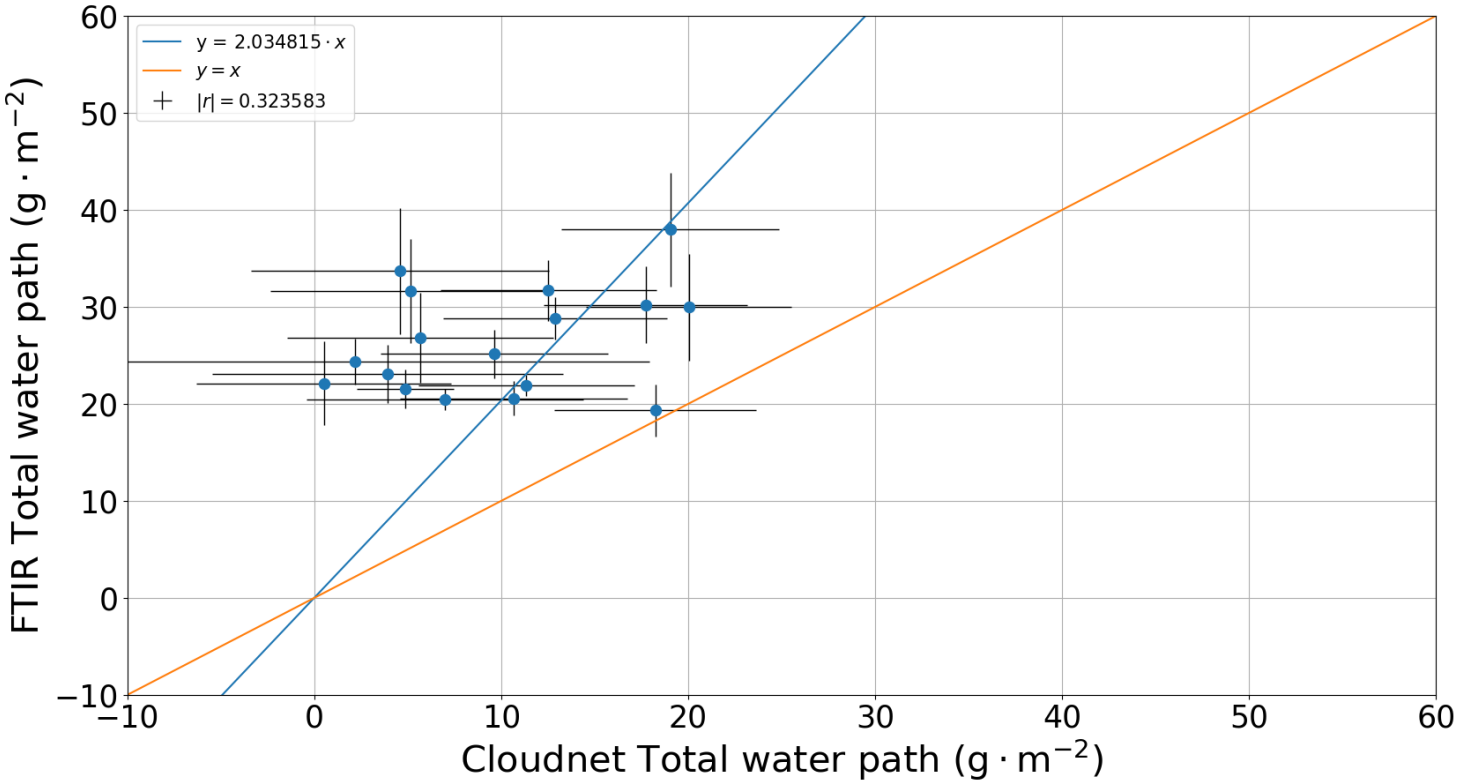
Effective droplet radii in liquid-only clouds



Different ice shapes: Droxtals



Correlation FTIR/Cloudnet



Filtered: $IWP \geq 15\,\mathrm{g\,m^{-2}}$

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