Cloud Property Retrievals using Ship-based Spectral Transmissivity Measurements

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1. Goals

- Ship-based measurements of spectral cloud transmissivity to retrieve cloud optical thickness and effective radius
- Apply improved and accelerate spectral retrieval algorithm
- Evaluate cloud radiative energy budget

2. Instrumentation

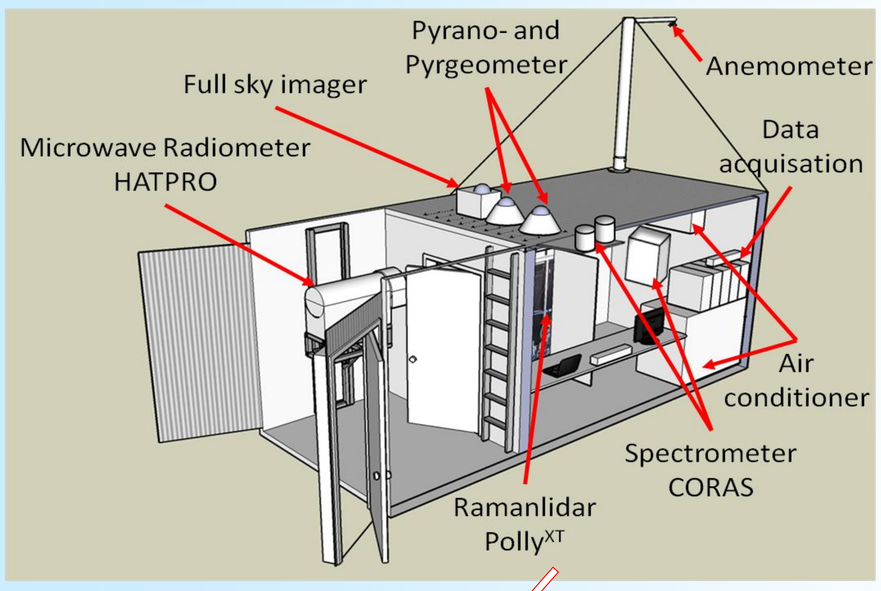


Fig. 1: *Sketch of the OCEANET-Container*

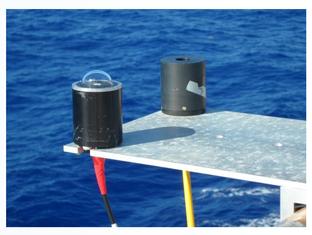


Fig. 3: *Optical inlets of CORAS*

Fig. 2: *Located Container on the Helicopter deck of RV Polarstern*

Tab. 1: *Overview of optical inlets from CORAS (COmpact RAdiation measurement System)*

	Measured Quantity	Spectral Range	Resolution
Ship – based	Downward Irradiance $F_\lambda^\downarrow$	290-2200 nm	2-3 (VIS)/15 (NIR) nm
	Downward Radiance $I_\lambda^\downarrow$	290-2200 nm	2-3 (VIS)/15 (NIR) nm

3. Examples

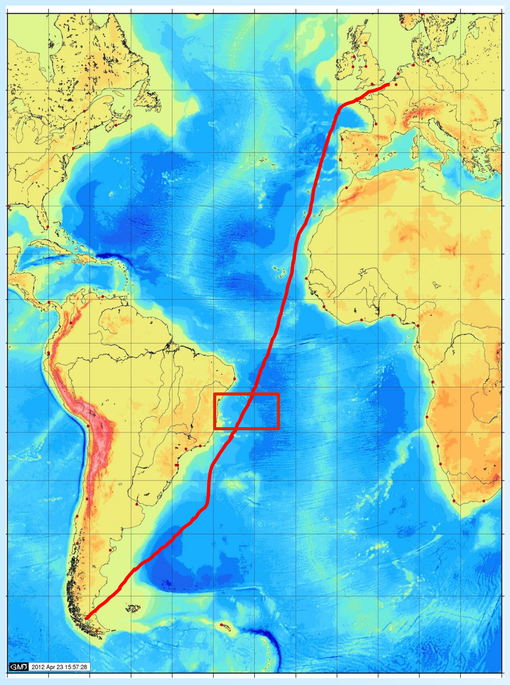


Fig. 7: *Cruise track from ANT-XXVIII/5*

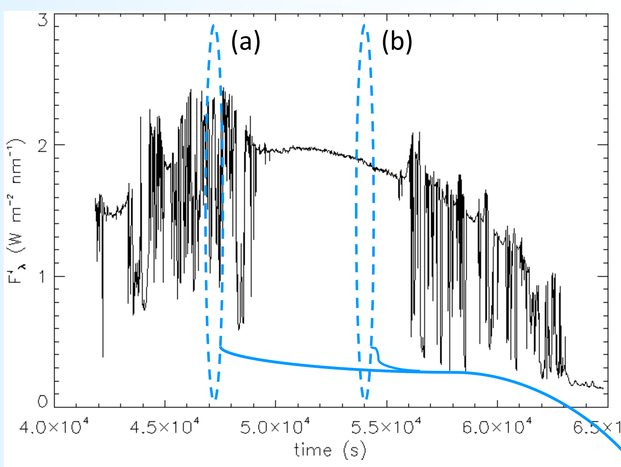
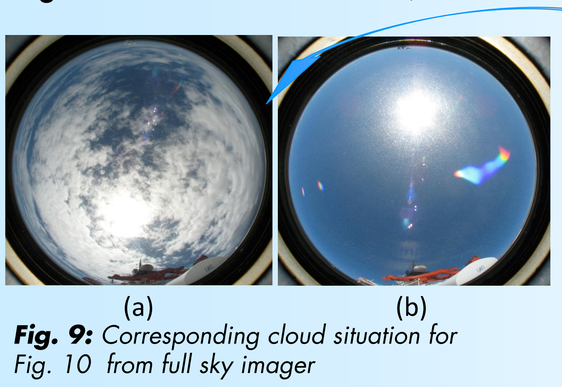


Fig. 8: *Time series of measured spectral downward irradiance at 532 nm from 11:30-18:00 UTC on 24th April, 2012 aboard RV Polarstern*



(a) (b)

Fig. 9: *Corresponding cloud situation for Fig. 10 from full sky imager*

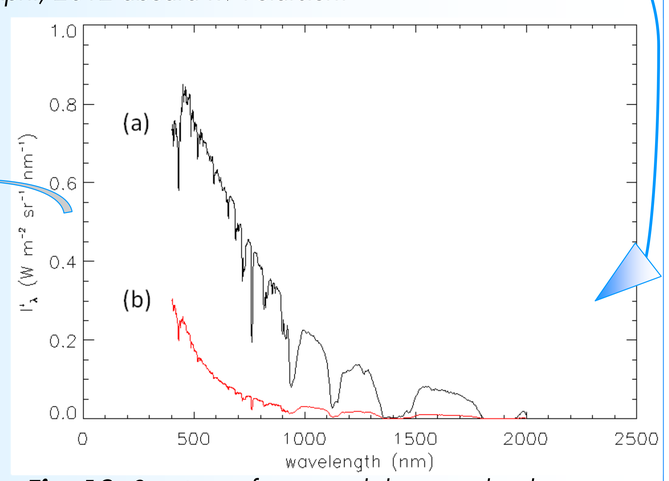


Fig. 10: *Spectrum of measured downward radiance from (a)13:10-13:15 UTC and (b) 15:00-15:05 UTC on 24th April, 2012 aboard RV Polarstern*

4. Methodology

Plane-parallel (PP) Radiative Transfer Model [1]
Model $I_{\lambda,\mathrm{mod}}^\downarrow(z_0)$ and $F_{\lambda,\mathrm{mod}}^\downarrow(z_0)$ at sea level z_0 (using optical and microphysical observations)

ship-based observations
Observation of $I_{\lambda,\mathrm{obs}}^\downarrow(z_0)$ and $F_{\lambda,\mathrm{obs}}^\downarrow(z_0)$ at sea level z_0 from CORAS

Calculate spectral transmissivity at sea level

$$T_{\lambda,\mathrm{mod}} = \frac{\pi I_{\lambda,\mathrm{mod}}^\downarrow(z_0)}{\mu_0 F_\lambda^\downarrow(z_{\mathrm{TOA}})} \qquad T_{\lambda,\mathrm{obs}} = \frac{\pi I_{\lambda,\mathrm{obs}}^\downarrow(z_0)}{\mu_0 F_\lambda^\downarrow(z_{\mathrm{TOA}})}$$

Cloud property retrieval[2] using spectral transmissivity
Spectral cloud retrieval with modeled transmissivity $T_{\lambda,\mathrm{mod}}$ and observed transmissivity $T_{\lambda,obs}$ to retrieve optical thickness τ and effective radius r_{eff}

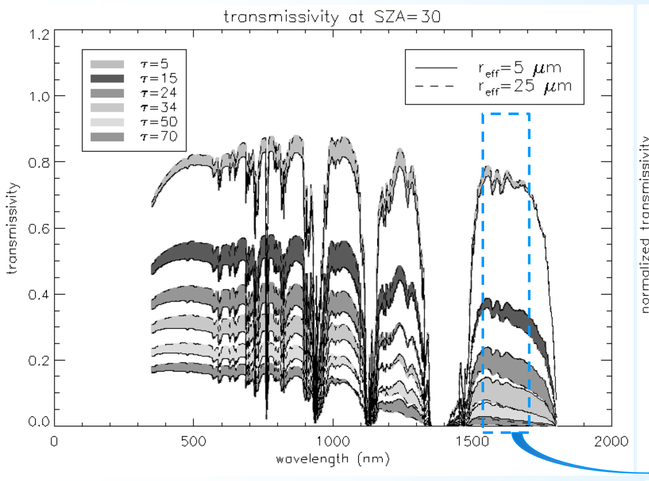


Fig. 4: *Modeled spectral transmissivity (PP-RTM) for a liquid water cloud at SZA=30° in dependence on optical thickness and effective radius*

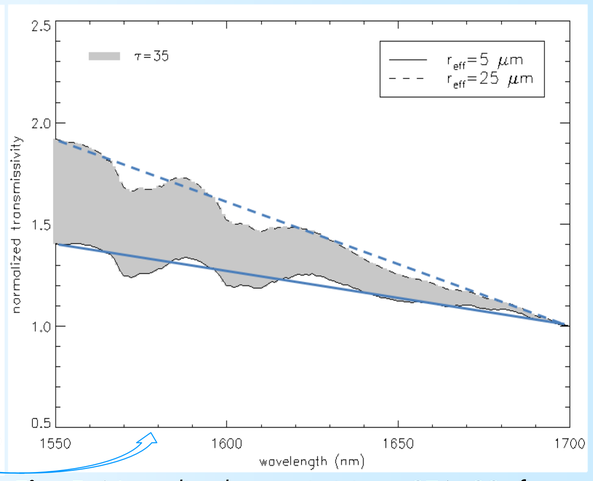


Fig. 5: *Normalized transmissivity at SZA=30° for optical thickness of 35 and effective radius of 5 µm (solid line) and 25 µm (dashed line)*

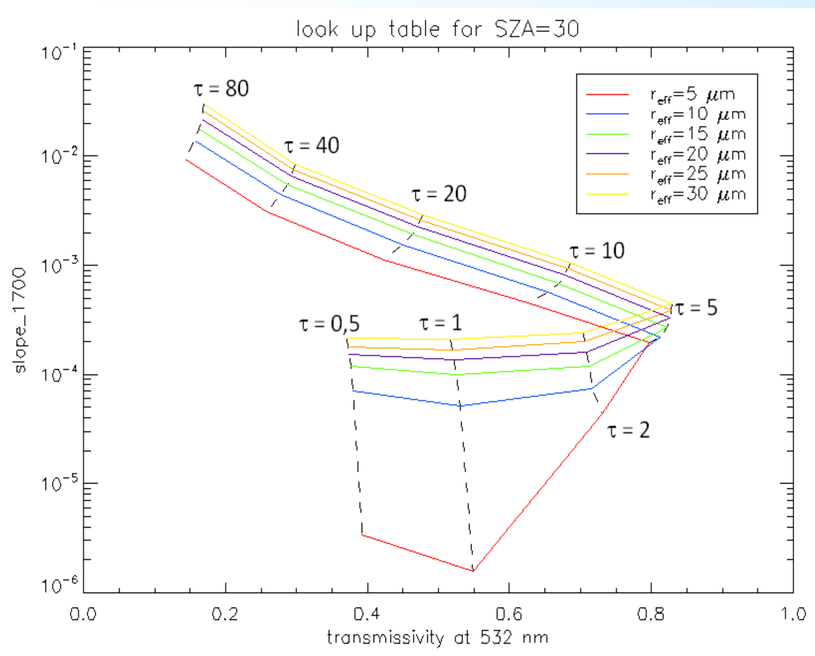
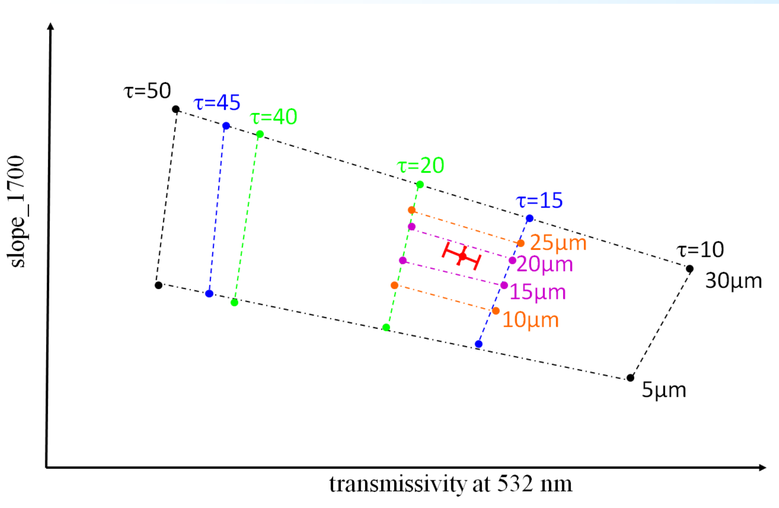


Fig. 6: *Look up table for spectral cloud retrieval using modeled transmissivity (PP-RTM) and spectral slope fit through normalized transmissivity at SZA=30°*

- Information on optical thickness and effective radius
- Normalization removes effect of spectrally correlated errors [2]
- Less sensitivity to effective radius for optical thickness lower then 5

5. Outlook



iteration step τ_1 , r_{eff}=const.
iteration step τ_2 , r_{eff}=const.
iteration step τ_3 , r_{eff}=const.
…

iteration step $r_{\mathrm{eff}\,1}$, τ =const.
iteration step $r_{\mathrm{eff}\,2}$, τ =const.
iteration step $r_{\mathrm{eff}\,3}$, τ =const.
…

Fig. 11*: Sketch of zooming retrieval technique; red cross marks the observation*

- Zooming retrieval technique for optical thickness larger then 5
- Classify differences in retrieved cloud parameters by cloud fraction and cloud vertical inhomogeneities from full sky imager, lidar and microwave radiometer
- Retrieve cloud optical thickness and effective radius using 3D Monte-Carlo RTM to quantify 3D cloud effects on modeled spectral transmissivity for different cloud types

References: [1] Mayer, B. and Kylling, A.: Technical note: The libRadtran software package for radiative transfer calculations - description and examples of use, Atmos. Chem. Phys., 5, 1855–1877, 2005, http://www.atmos-chem-phys.net/5/1855/2005/.
[2] McBride, P.J. et al.: A spectral method for retrieving cloud optical thickness and effective radius from surface-based transmittance measurements, Atmos. Chem. Phys., 11, 7235-7252, 2011

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