Impact of broken and inhomogeneous clouds on satellite r_e and cloud-phase retrieval

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- ✓Inhomogeneous clouds
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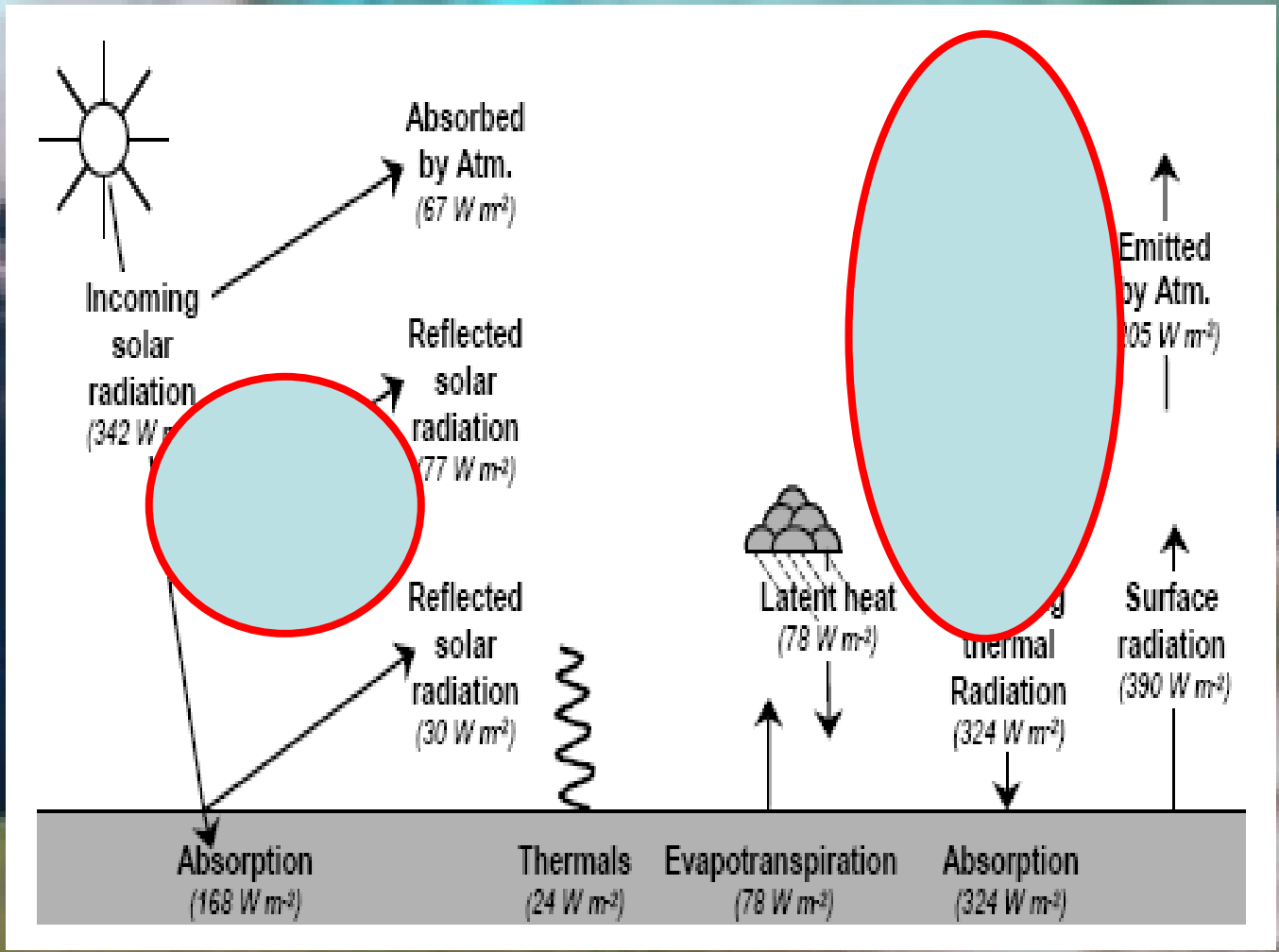
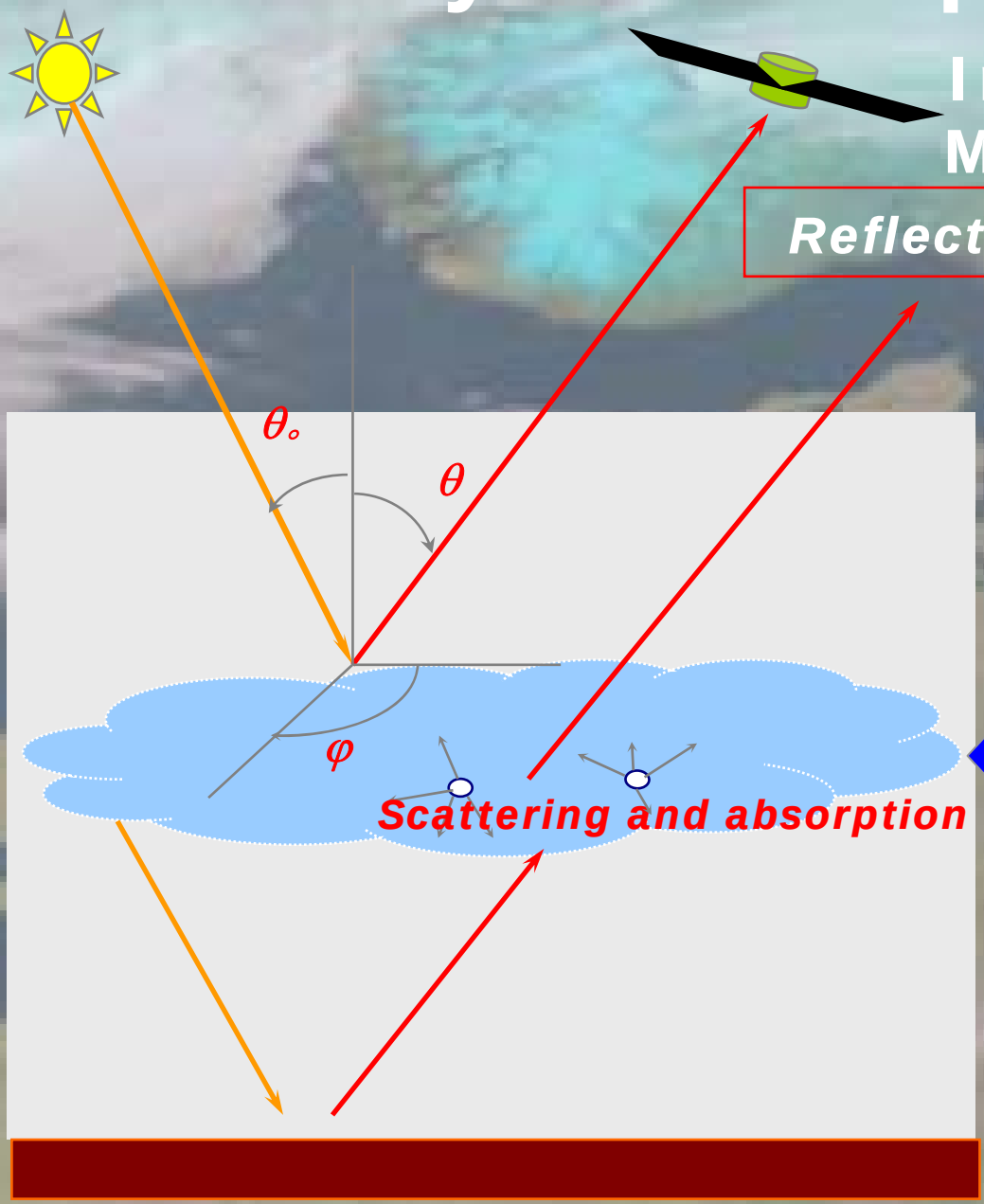
Clouds in the climate system



Climate Monitoring SAF

- ✓ **Main aim:** ***"to provide high-quality cloud property and radiation datasets to climate research community"***
- ✓ **2000-2004: Development Phase**
- ✓ **2004-2007: Initial Operations Phase (IOP), MSG satellites (SEVIRI, 3x3 km resolution, 1 km for HRV)**
- ✓ **2007-2012: Continued Development and Operations Phase (CDOP)**
- ✓ **2012-2018: CDOP II, MTG satellites (1-2 km resolution, ~500 m for HRV)**

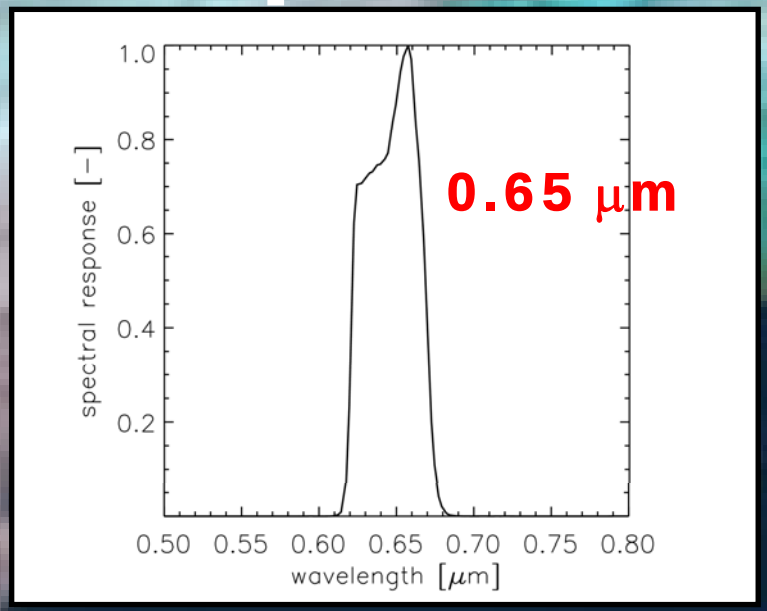
Cloud Physical Property retrieval

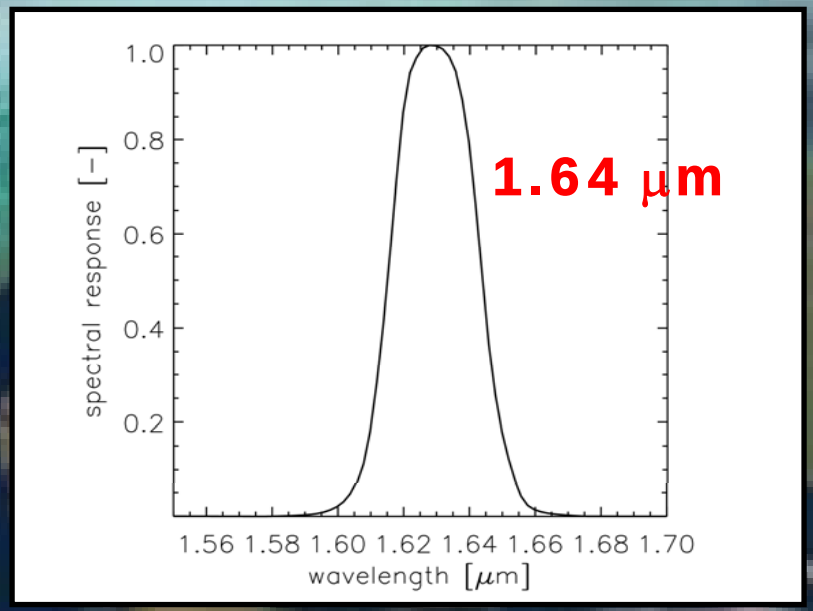


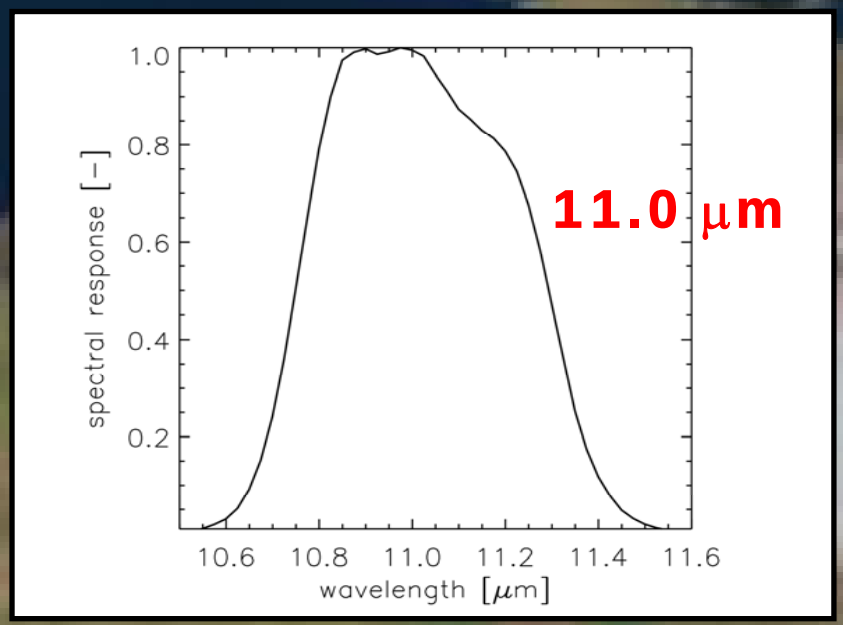
Cloud properties

- ✓Cloud phase
- ✓Optical thickness
- ✓Effective radius
- ✓Liquid water path

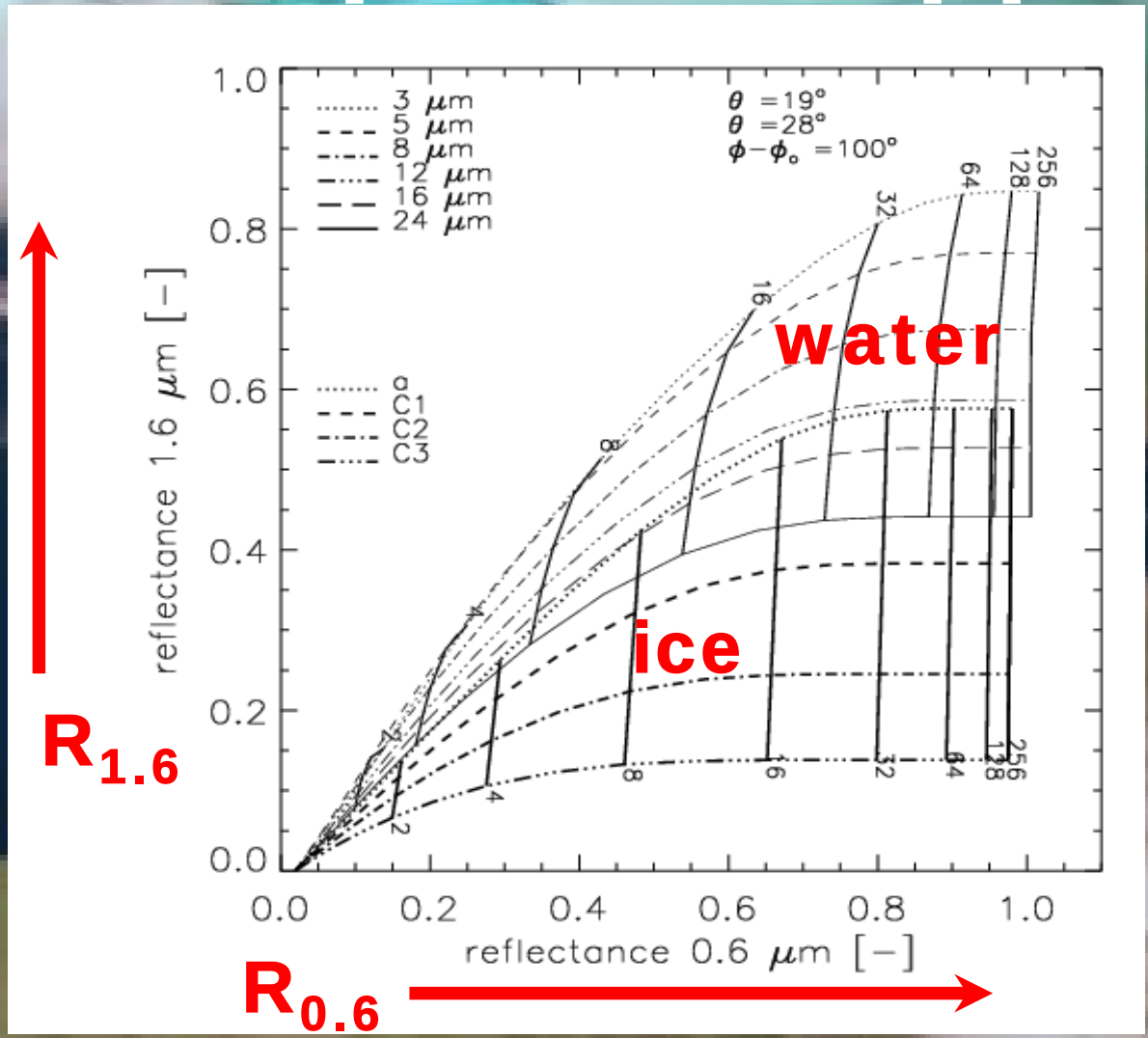
Spectral bands - MODIS







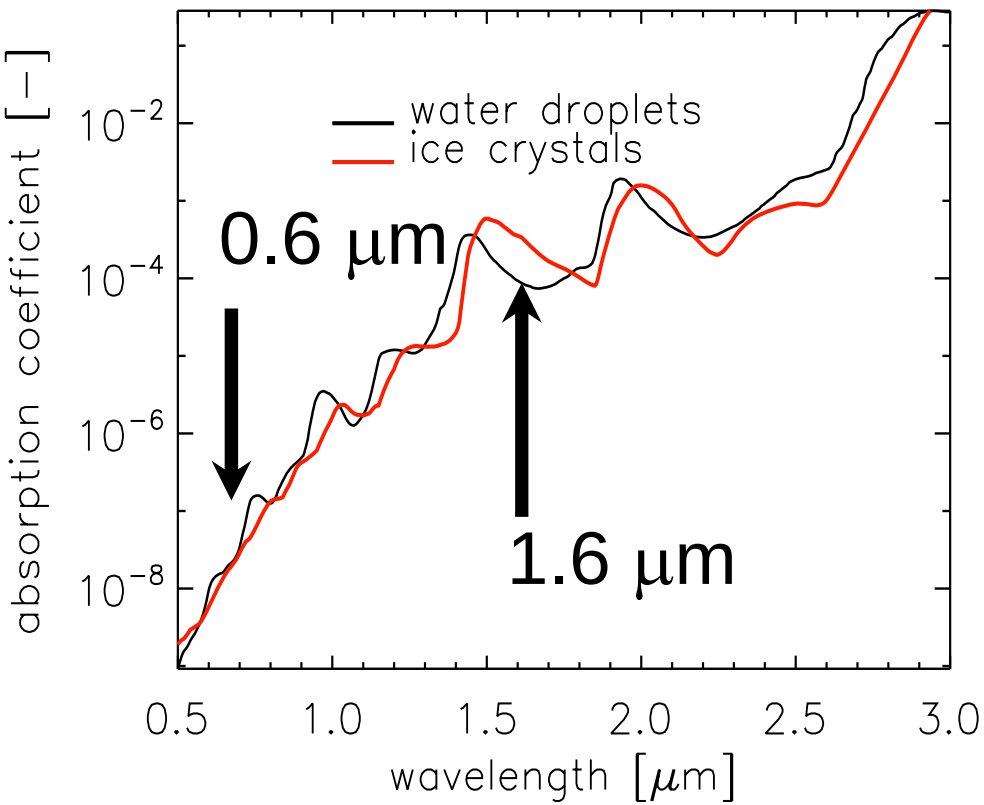
Lookup Table approach



$R_{1.6}$

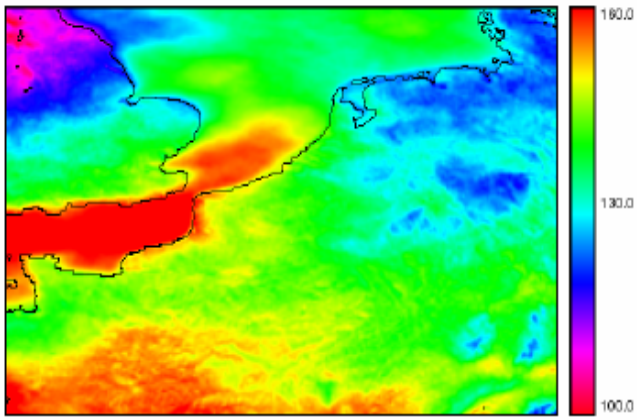
$R_{0.6}$

Retrieval principle - cloud phase

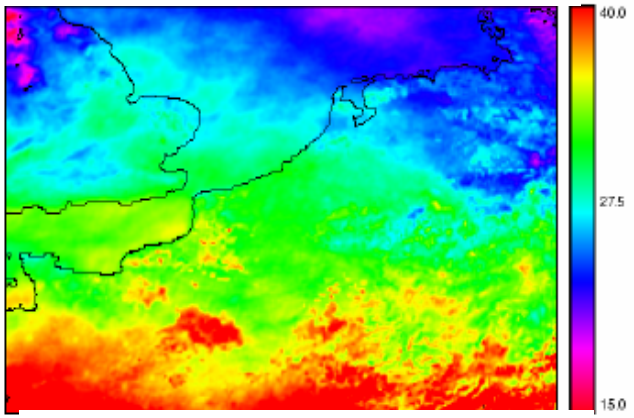


- ✓Ice crystals absorb radiation more effectively than water droplets at 1.6 μm
- ✓Cloud phase based on r_e retrieval
- ✓Additional cloud-top temperature check if 'ice' is retrieved

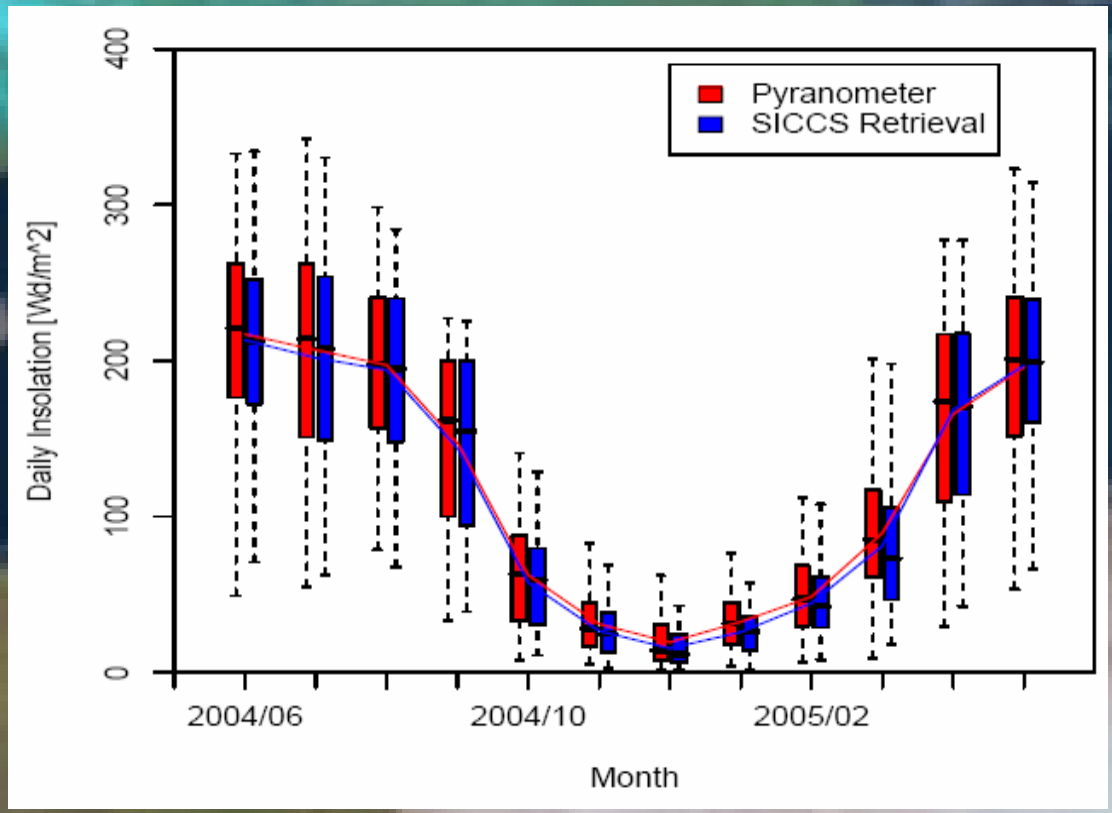
Solar irradiance from cloud optical thickness



Solar irradiance June – Sept. 2004



Solar irradiance Dec. 2004 – Mar. 2005



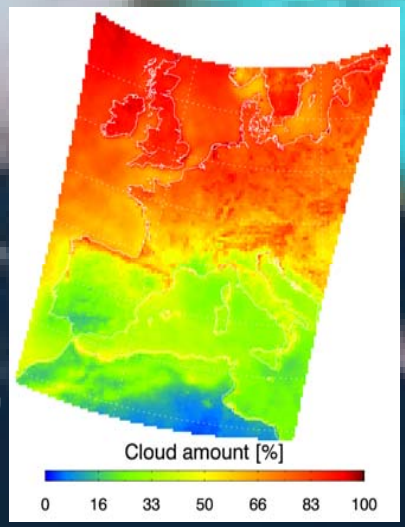
Annual cycle of solar irradiance from Jun. 2004 – May 2005, using CPP COT retrievals for cloudy conditions *(Deneke et al., Rem. Sens. Envir., 2008)*.

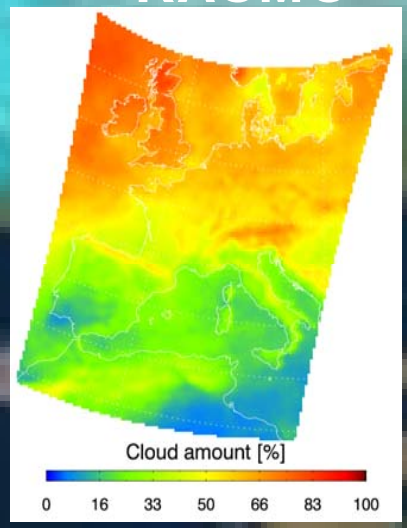
Climate model evaluation

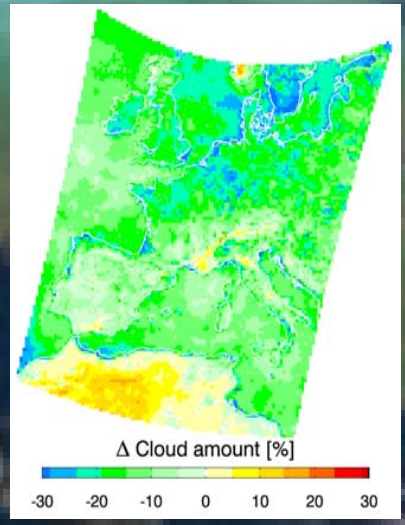
SEVIRI | RACMO | RACMO - SEVIRI

Cloud amount

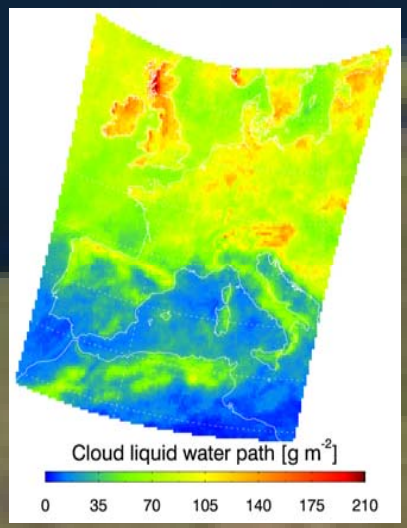
Roebeling and van Meijgaard, *J. Clim.*, 2009

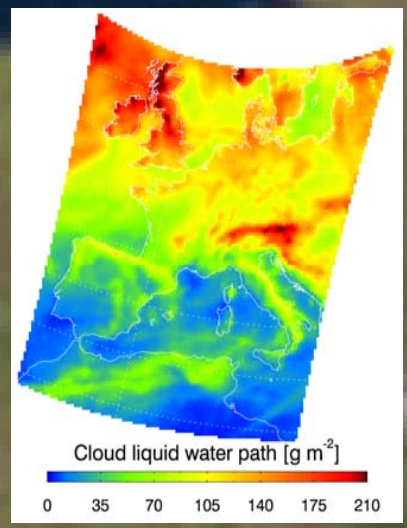


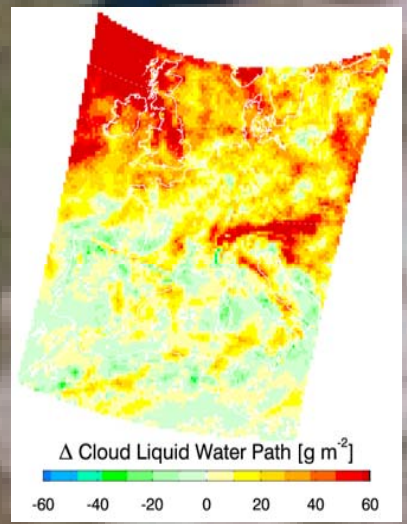




LWP

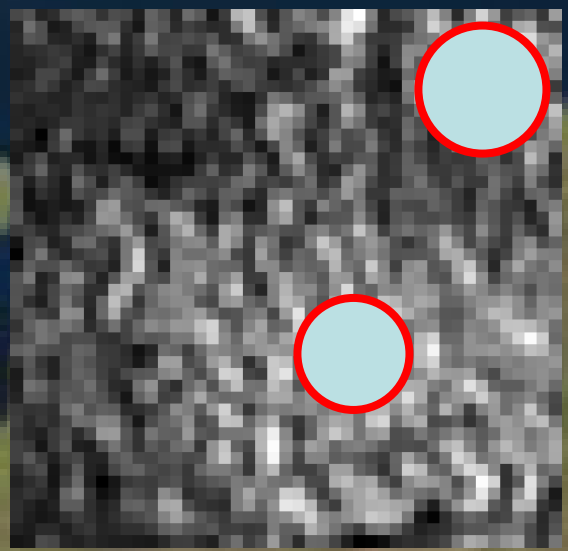




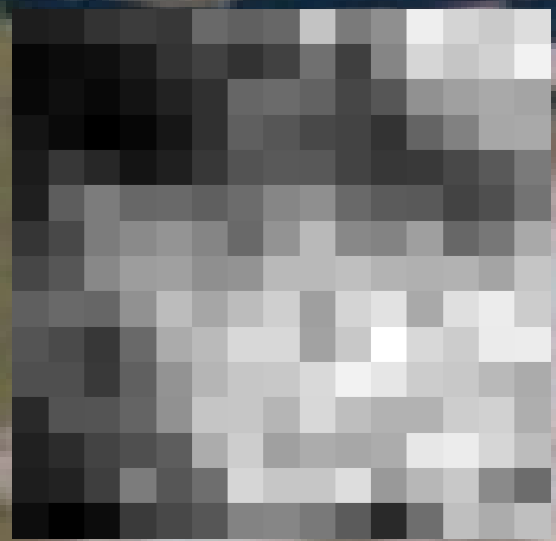


Research question

- ✓ SEVIRI resolution coarse compared to e.g. MODIS or AVHRR (3x3 vs 1x1 km)
- ✓ Broken cloudiness and inhomogeneity is not always detected by SEVIRI
- ✓ *To what extent are r_e and cloud-phase retrieval influenced by these (nonlinear) effects?*



SEVIRI HRV (1x1 km)

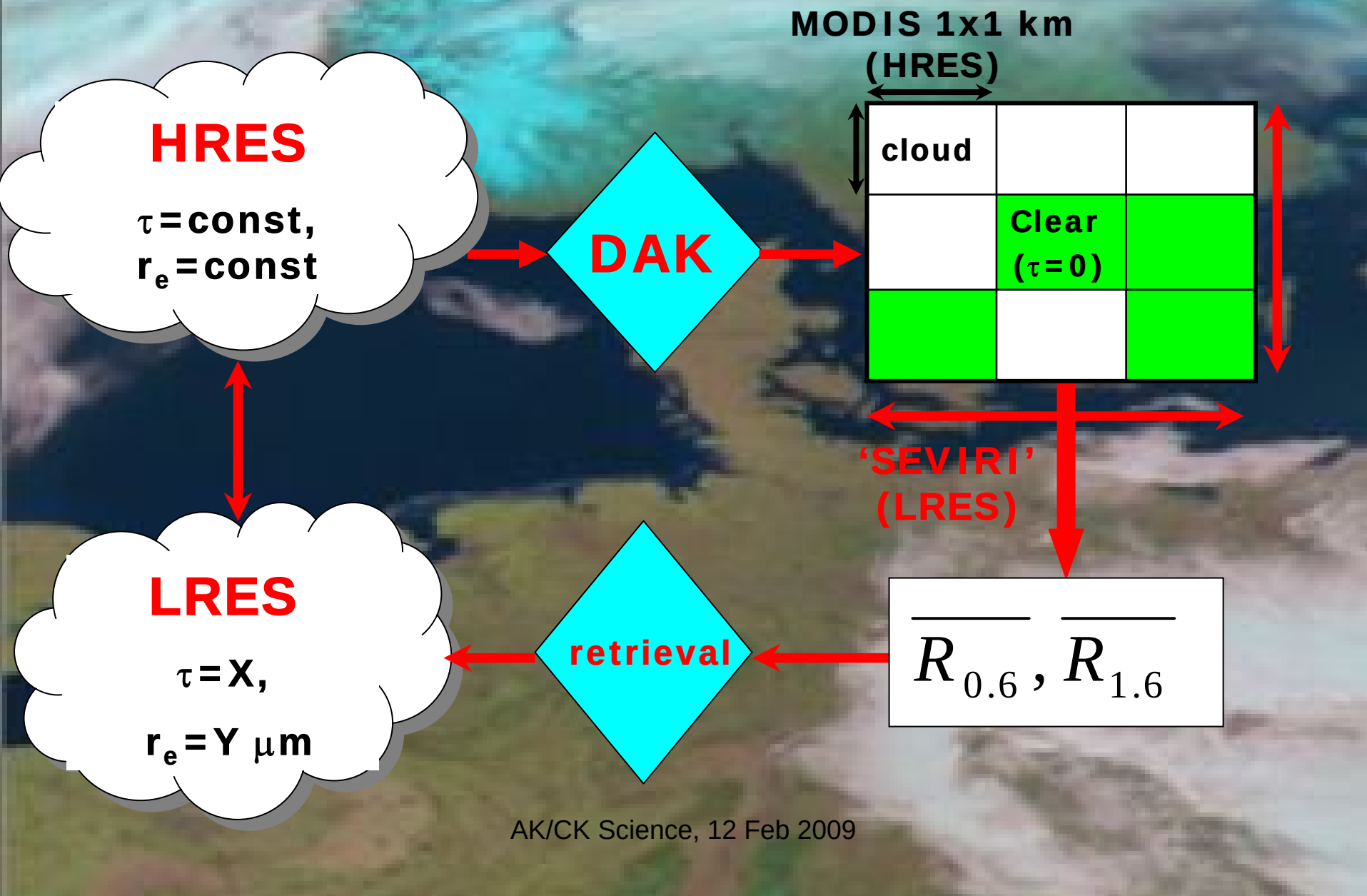


SEVIRI 0.6 μm channel (3x3 km)

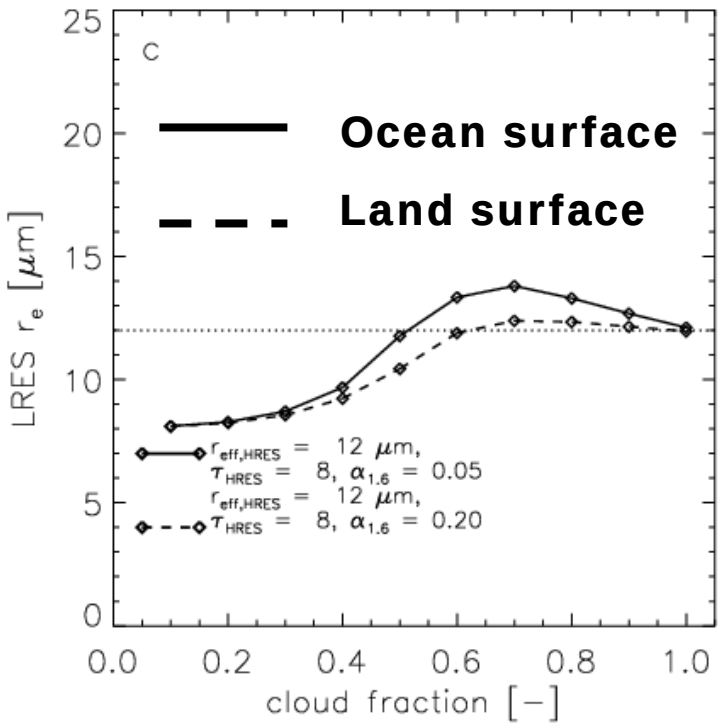
Approach and constraints

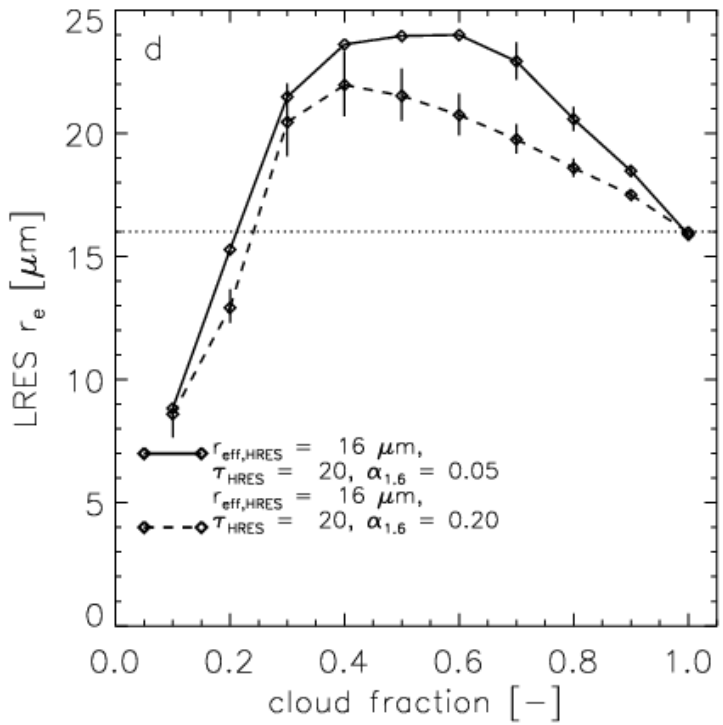
- ✓ Synthetic datasets and CPP retrievals from MODIS radiances to quantify effects
- ✓ Inhomogeneity effect only investigated for cloud fraction 1.0
- ✓ 3D cloud effects are not accounted for
- ✓ Only retrievals with $\theta, \theta_o < 60^o$ included
- ✓ Cloud mask and cloud fraction from MODIS Level-2

Synthetic datasets – broken clouds



Results r_e broken clouds





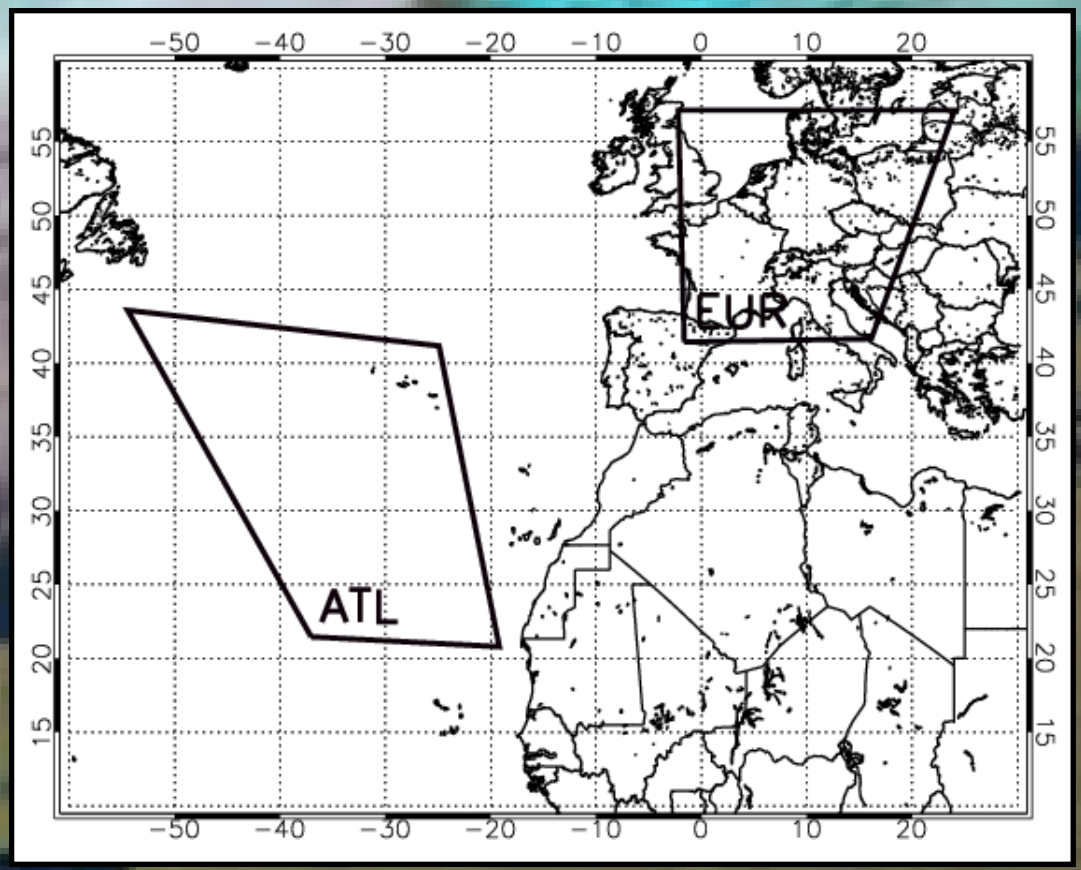
Thin HRES clouds

(τ_{HRES}=8, $r_{e,HRES}$=12 μm)

Thick HRES clouds

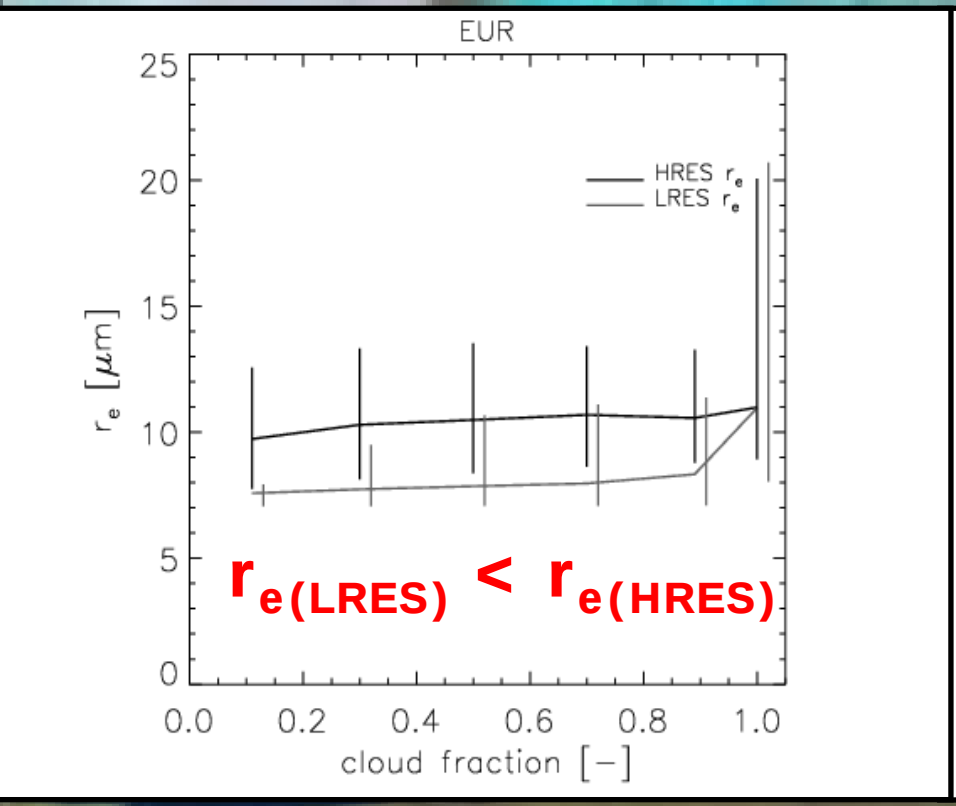
(τ_{HRES}=20, $r_{e,HRES}$=12 μm)

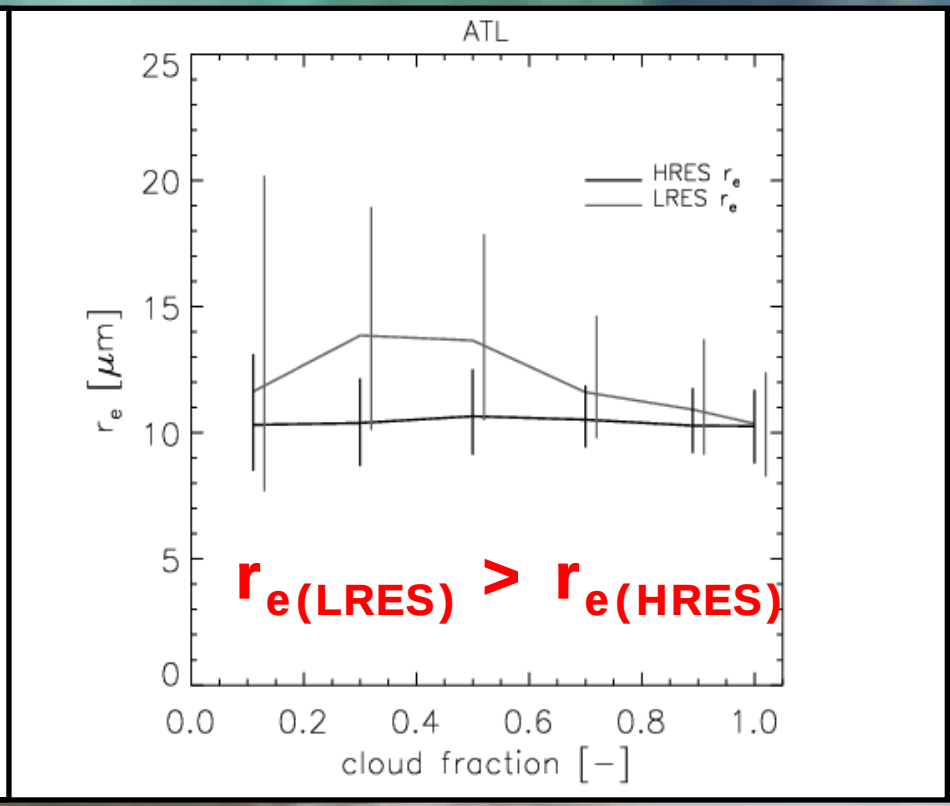
Areas of investigation



- ✓Retrievals for May and Aug 2007
- ✓ *MODIS-Terra* and *MODIS-Aqua* Level-1 data combined
- ✓HRES and LRES retrievals

MODIS-observed r_e





Central Europe **Atlantic Ocean**

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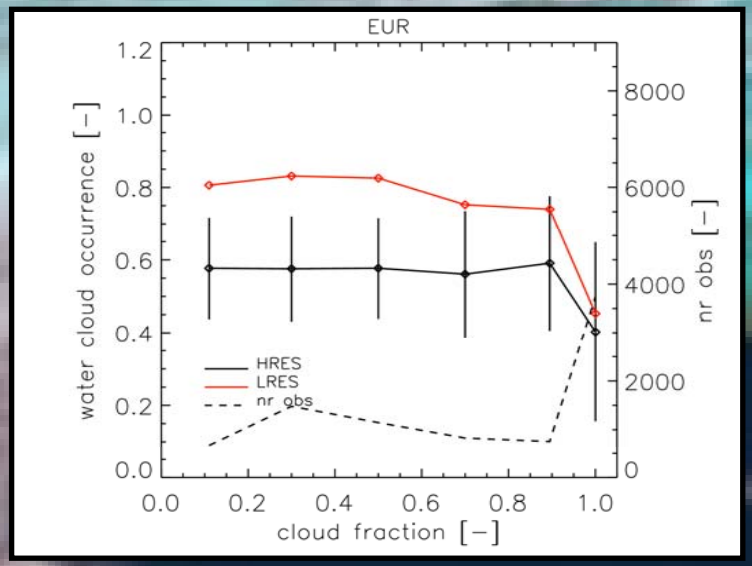
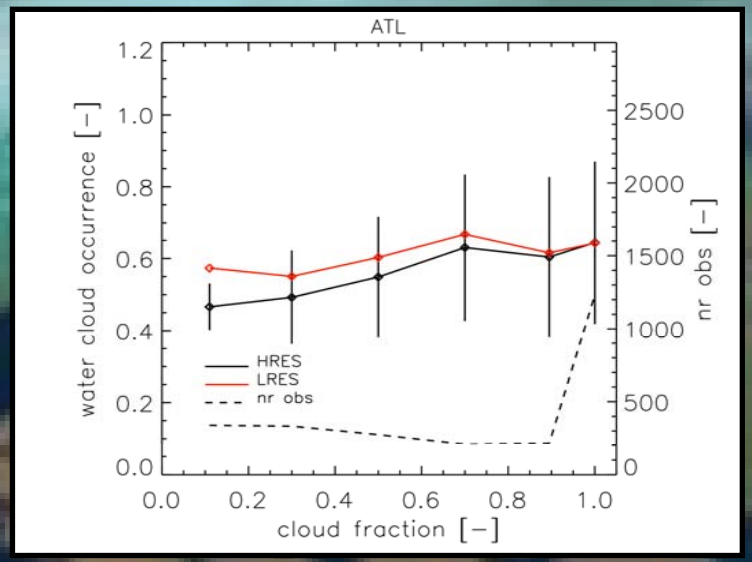
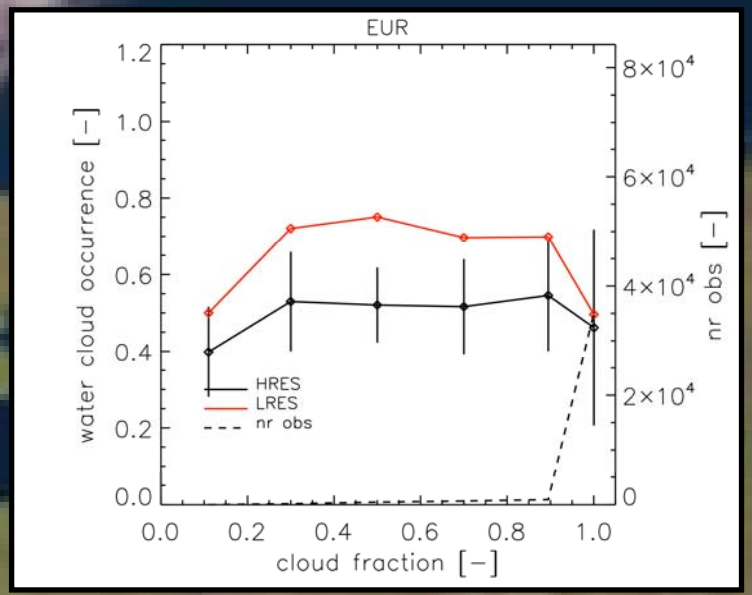
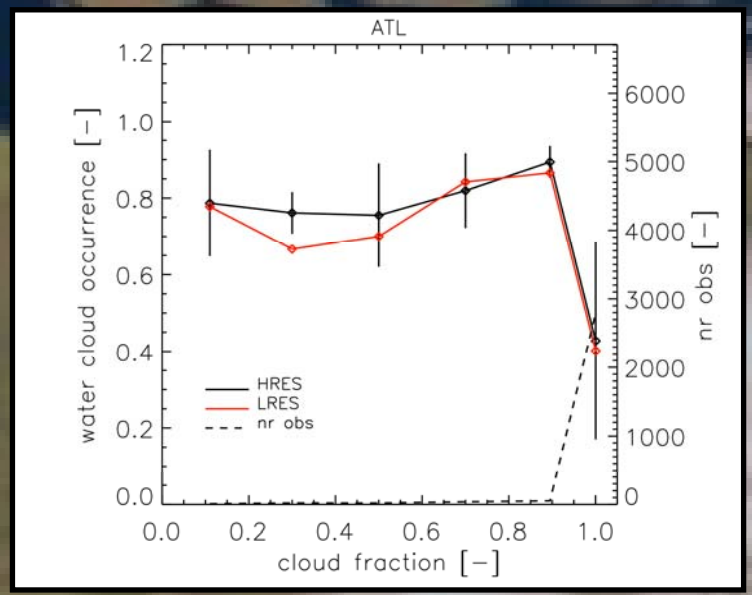
CPP on MODIS water cloud fraction





$\tau_{HRES} < 4$





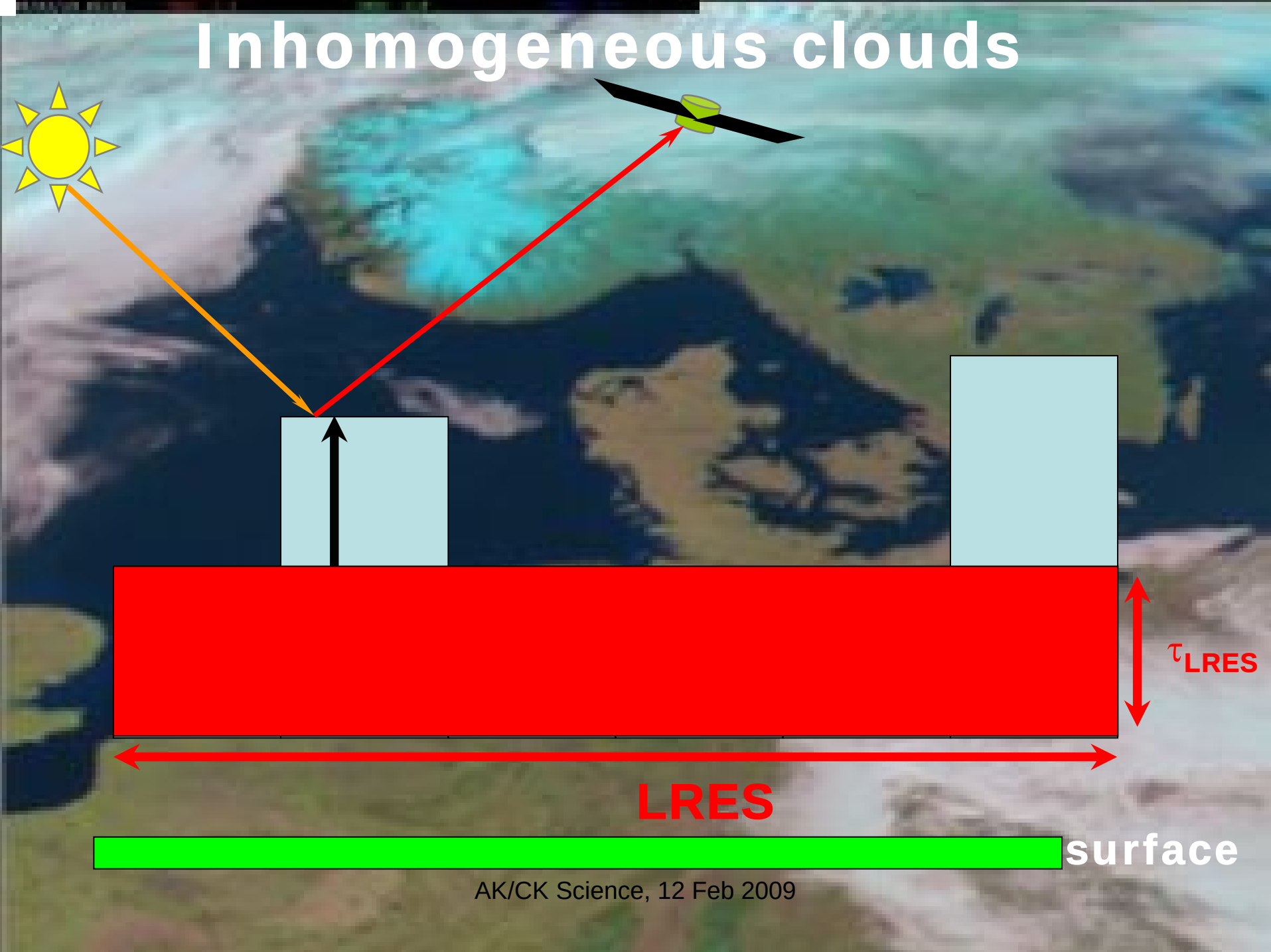
$\tau_{HRES} > 4$

Central Europe **Atlantic Ocean**

Summary broken clouds

- ✓ Largest effect on r_e and cloud-phase expected for thick broken clouds over dark surfaces
- ✓ Effects due to clear-sky contribution on LRES reflectance
- ✓ CPP r_e retrievals from MODIS radiances:
  - ✓ r_e(LRES) < r_e(HRES) over land (≈2 μm)
  - ✓ r_e(LRES) > r_e(HRES) over ocean (≈3 μm)
- ✓ CPP on MODIS retrievals water cloud fraction:
  - ✓ 10-25% more water at LRES for thin and thick clouds over Europe
  - ✓ Up to 10% less water at LRES for thick clouds over Atlantic Ocean

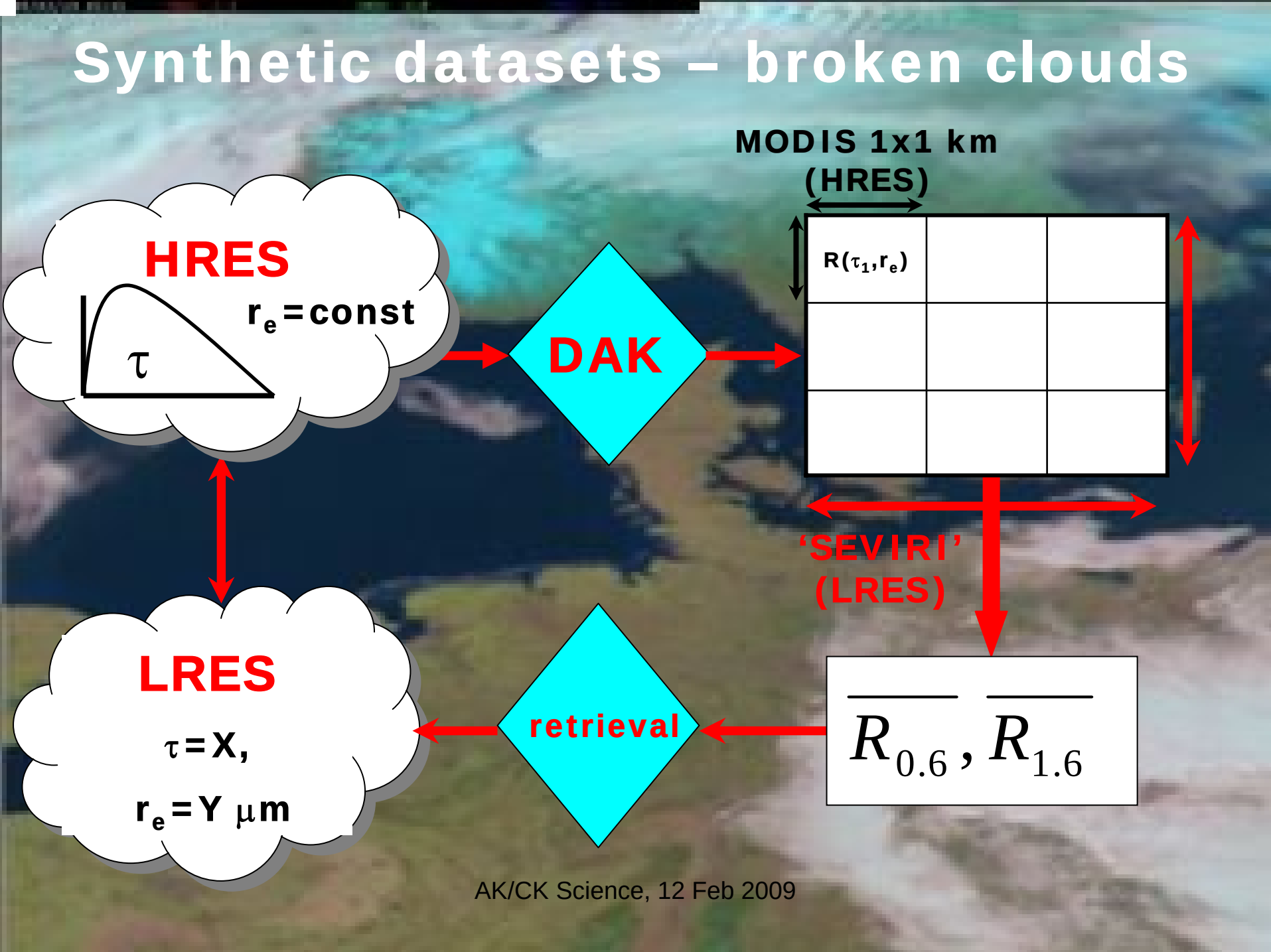
Inhomogeneous clouds



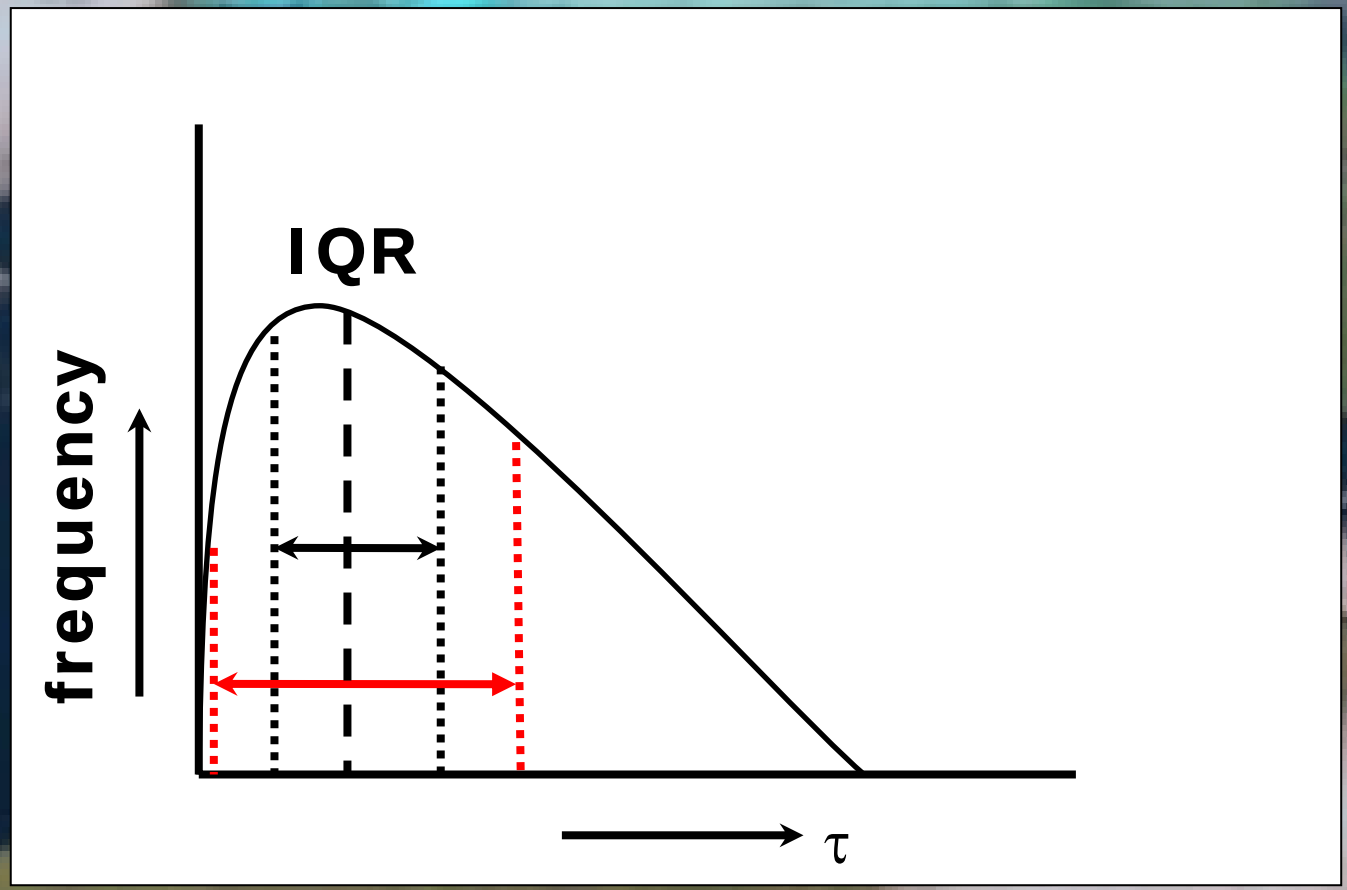
Experimental setup

- ✓ Synthetic datasets, high-resolution pixels with overcast water clouds
- ✓ $\tau_{med}=8$, $r_e=12$ μm (thin clouds); $\tau_{med}=15$, $r_e=16$ μm (thick clouds)
- ✓ Variation in τ is constrained through IQR
- ✓ Obtain $R_{0.6}$ and $R_{1.6}$ for all pixels
- ✓ Average $R_{0.6}$ and $R_{1.6}$
- ✓ Low-resolution τ and r_e are retrieved

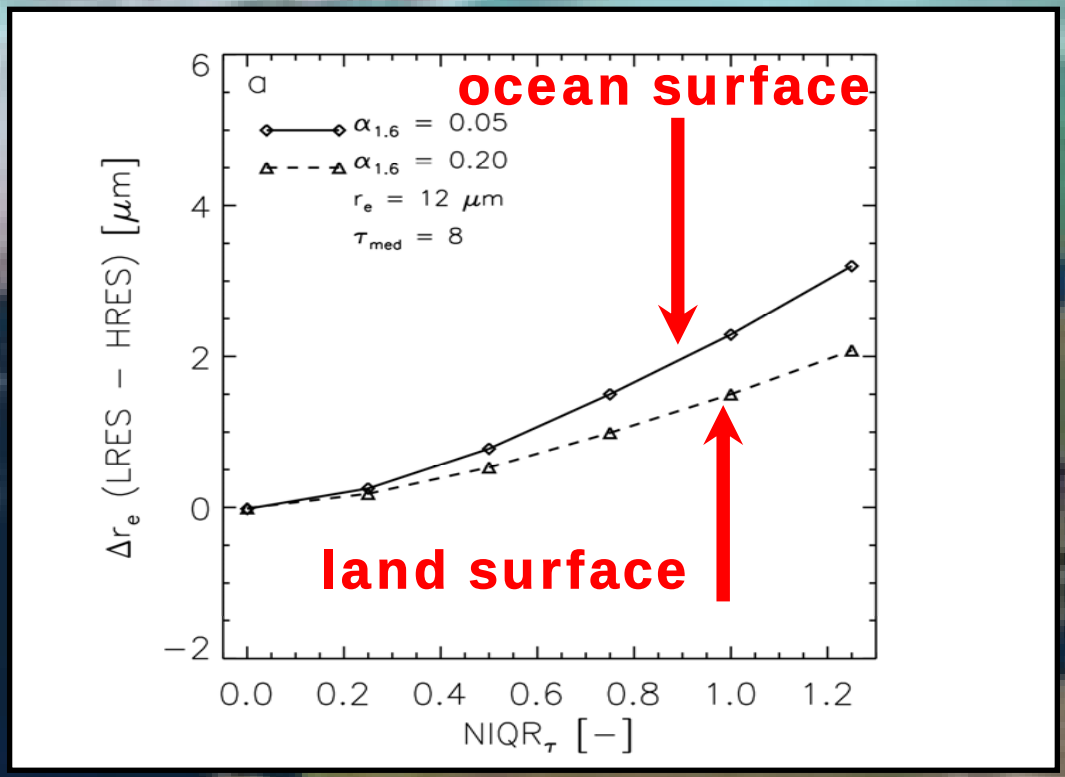
Synthetic datasets – broken clouds



Variability in τ



Results – synthetic dataset



- ✓ **Droplets appear larger at low resolution for inhomogeneous clouds**
- ✓ **Strongest effect over dark surface**
- ✓ **Might lead to erroneous low-resolution cloud-phase retrieval**

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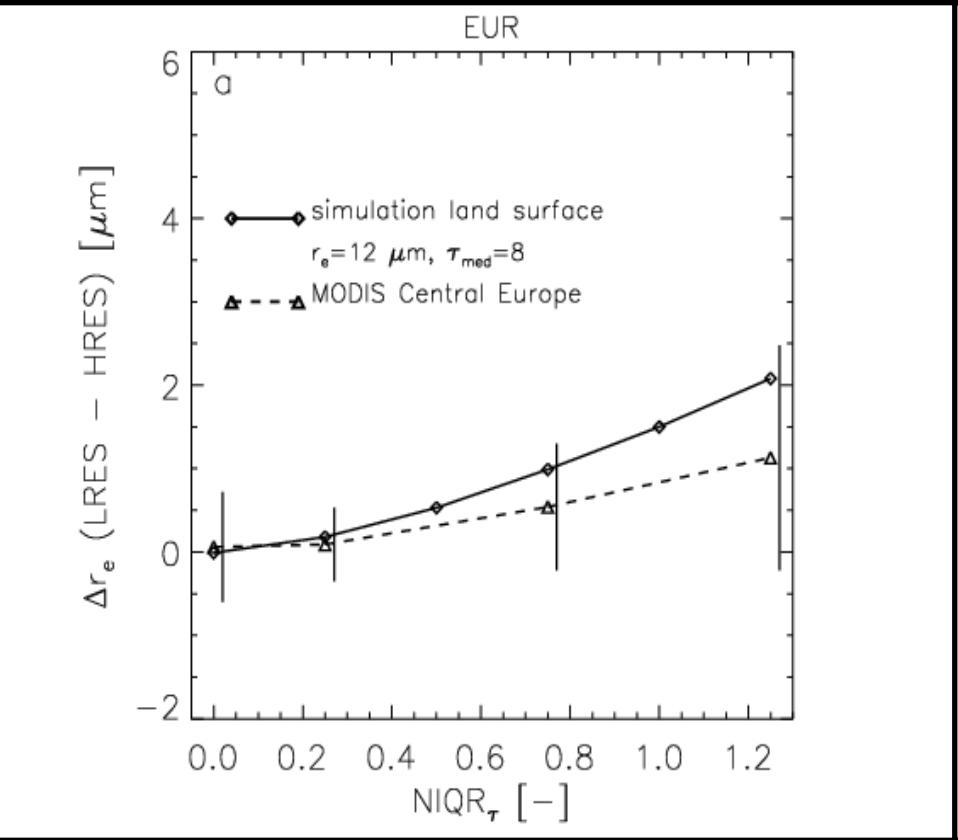
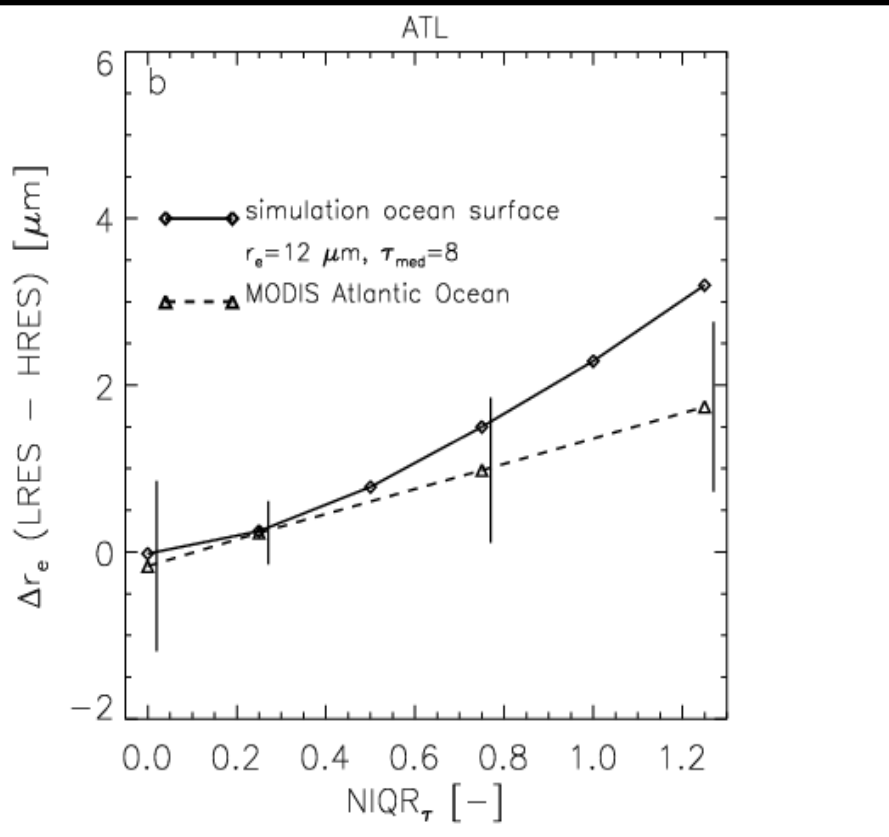
CPP on MODIS-derived Δr_e water clouds





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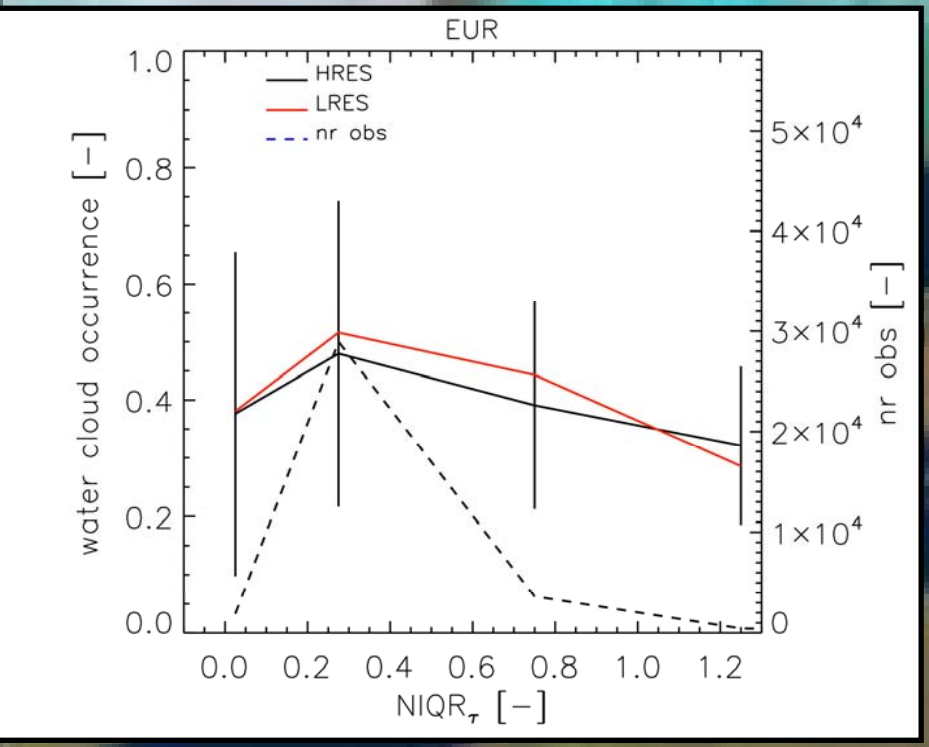
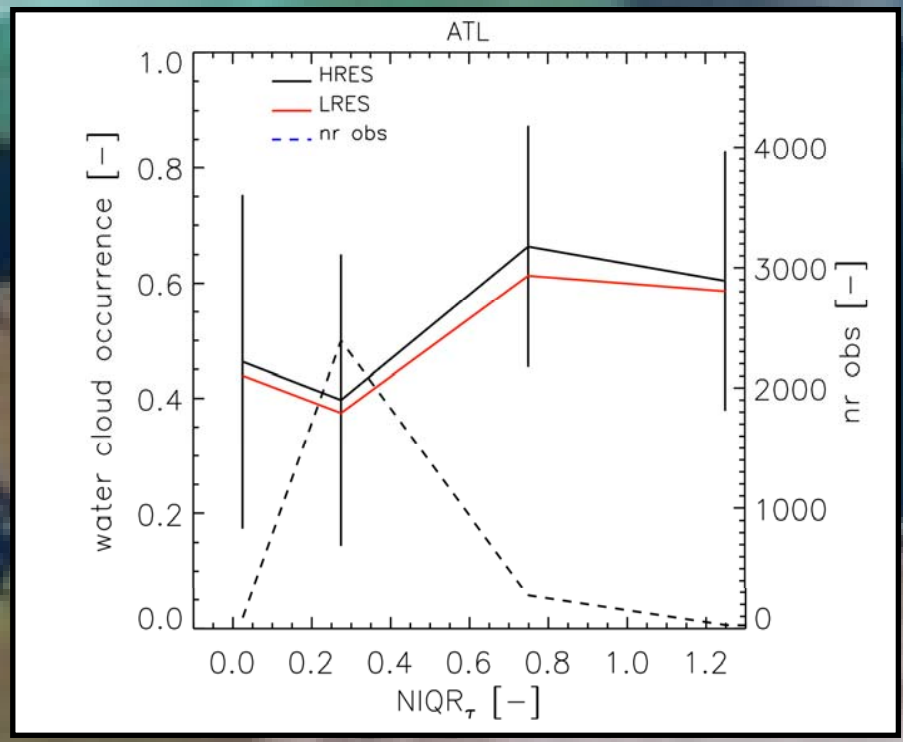
CPP on MODIS water cloud occurrence





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Conclusions

- ✓ Simulations show effect on r_e retrieval for broken and inhomogeneous clouds
- ✓ CPP on MODIS retrievals in accordance with simulations for r_e
- ✓ Broken cloud effect larger than inhomogeneity effect for cloud phase
- ✓ HRV channel to correct retrievals for both effects?


Thank you!

Papers

- ✓ Wolters, E.L.A., R.A. Roebeling, and A.J. Feijt, Evaluation of cloud-phase retrieval methods for SEVIRI on Meteosat-8 using ground-based cloud radar and lidar data, *J. Appl. Meteor. Clim.,* **47**, 1723-1738, 2008
- ✓ Wolters, E.L.A., H.M. Deneke, B.J.J.M. van den Hurk, J.F. Meirink, and R.A. Roebeling, Quantification of broken and inhomogeneous cloud impact on satellite cloud-phase retrieval, *to be submitted to J. Geophys. Res.*
- ✓ H.M. Deneke, R.A. Roebeling, E.L.A. Wolters, A.J. Feijt, and C. Simmer, On the sensitivity of satellite-derived cloud properties to sensor resolution and broken clouds, *in preparation.*

Experimental setup

- ✓ Synthetic datasets, 20 high-resolution pixels within a super pixel
- ✓ τ=8, r_e=12 μm (thin water clouds); τ=20, r_e=16 μm (thick water clouds)
- ✓ τ=0 is imposed dependent on cloud free fraction
- ✓ Obtain $R_{0.6}$ and $R_{1.6}$ for all pixels
- ✓ Average $R_{0.6}$ and $R_{1.6}$
- ✓ Low-resolution τ and r_e are retrieved