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

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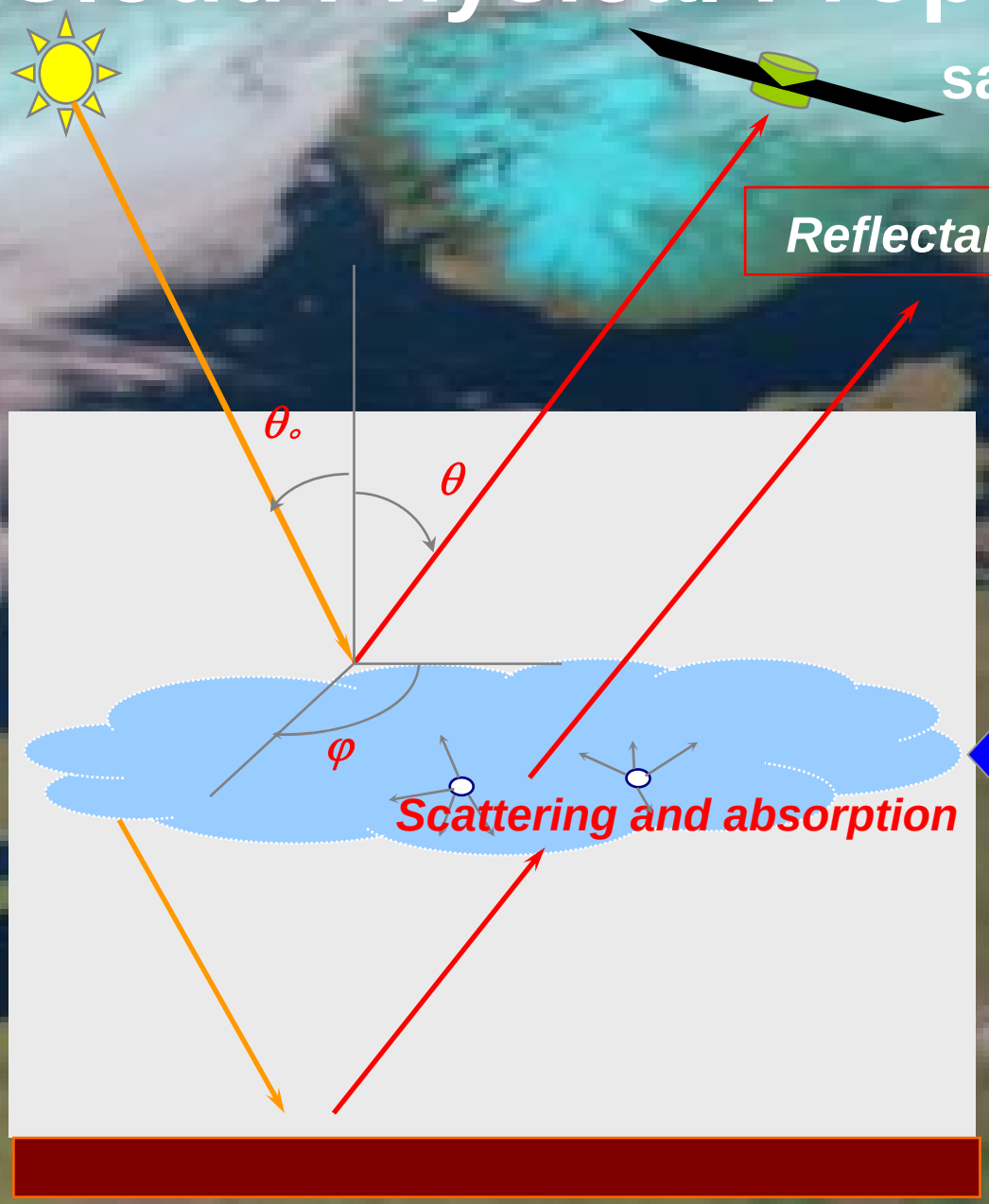
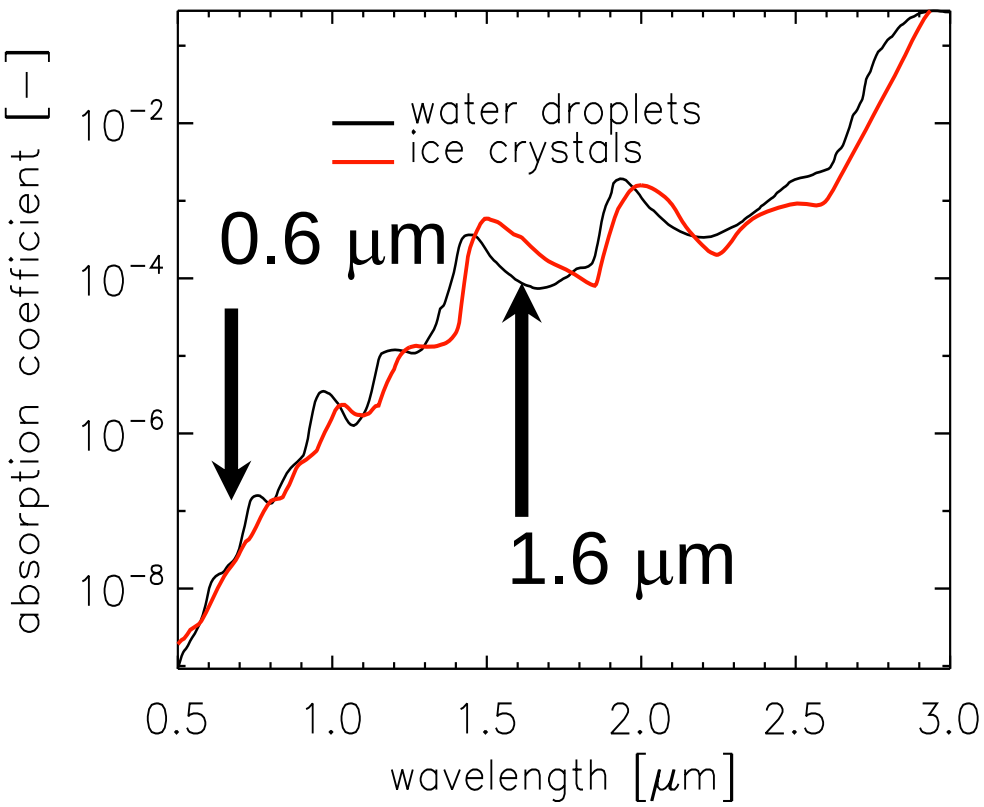
# Cloud Physical Property retrieval




## Cloud properties

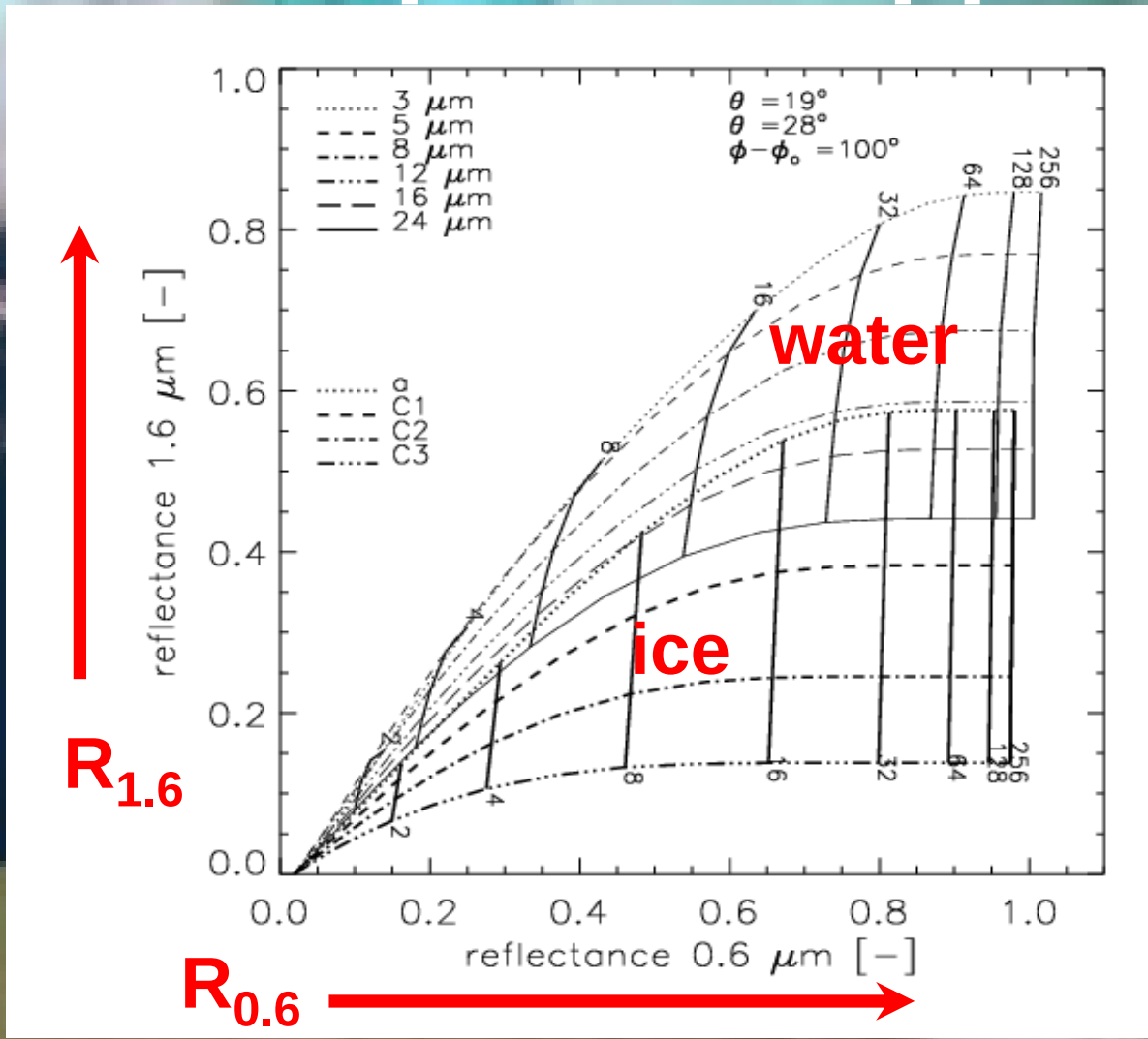
- ✓Cloud phase
- ✓Optical thickness
- ✓Effective radius
- ✓Liquid water path

# Retrieval principle - cloud phase



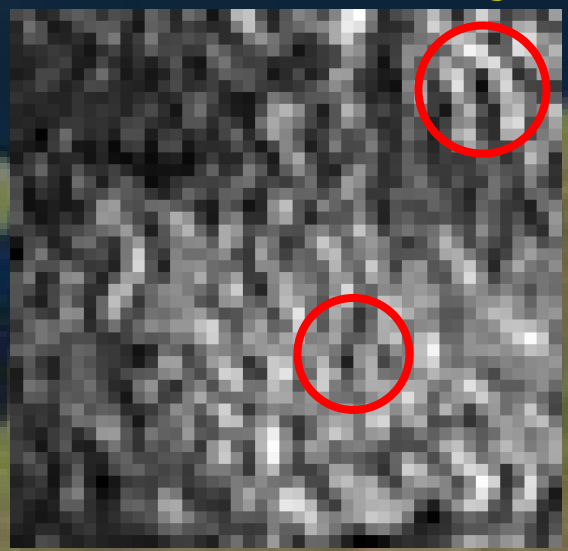

- ✓Ice crystals absorb radiation more effectively than water droplets at 1.6 μm
- ✓Cloud phase based on $r_e$ retrieval
- ✓Additional cloud-top temperature check if 'ice' is retrieved

# Lookup Table approach

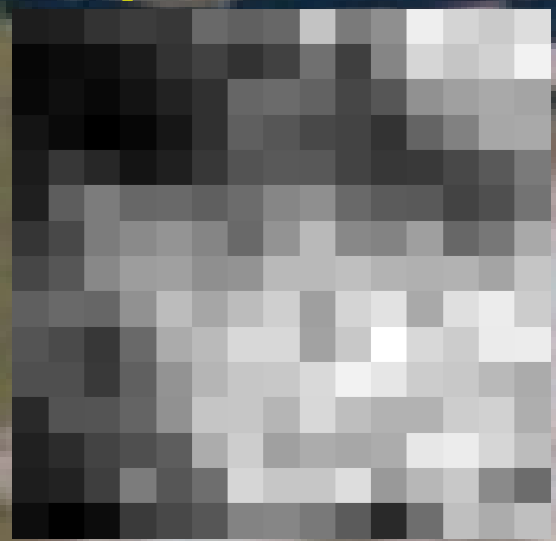


# The problem

- ✓ 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 is cloud-phase retrieval influenced by these (nonlinear) effects?*



SEVIRI HRV (1x1 km)

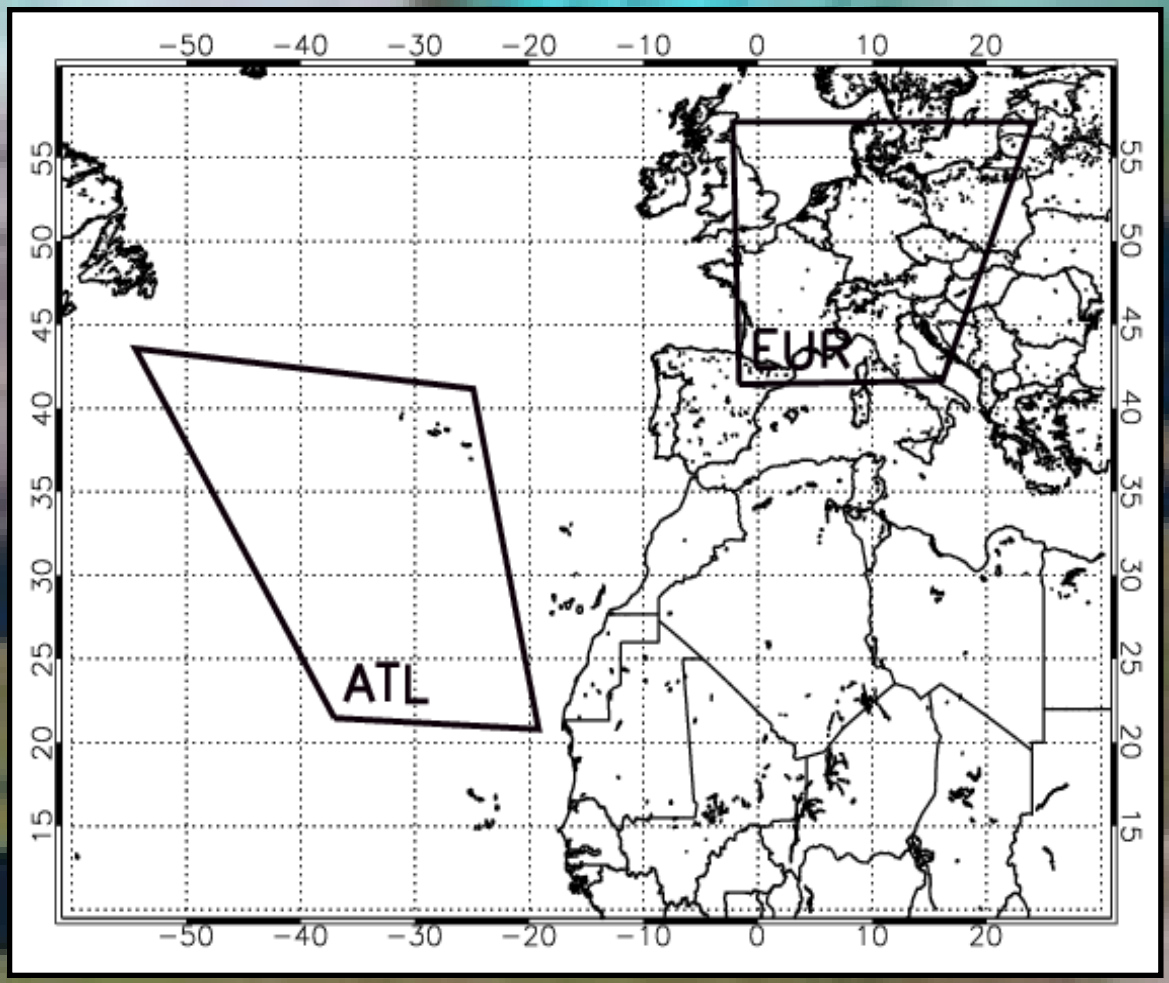


SEVIRI 0.6 μm channel (3x3 km)

# Approach and constraints

- ✓ Synthetic datasets and CPP retrievals on MODIS radiances to quantify effects
- ✓ Inhomogeneity effect only investigated for cloud fraction 1.0
- ✓ 3D cloud effects are not accounted for
- ✓ Only observations with $\theta, \theta_o < 50^o$ included
- ✓ Cloud fraction determined on MODIS Level-2 data

# Areas of investigation




- ✓Retrievals for May and Aug 2007
- ✓MODIS white sky albedo maps included in retrieval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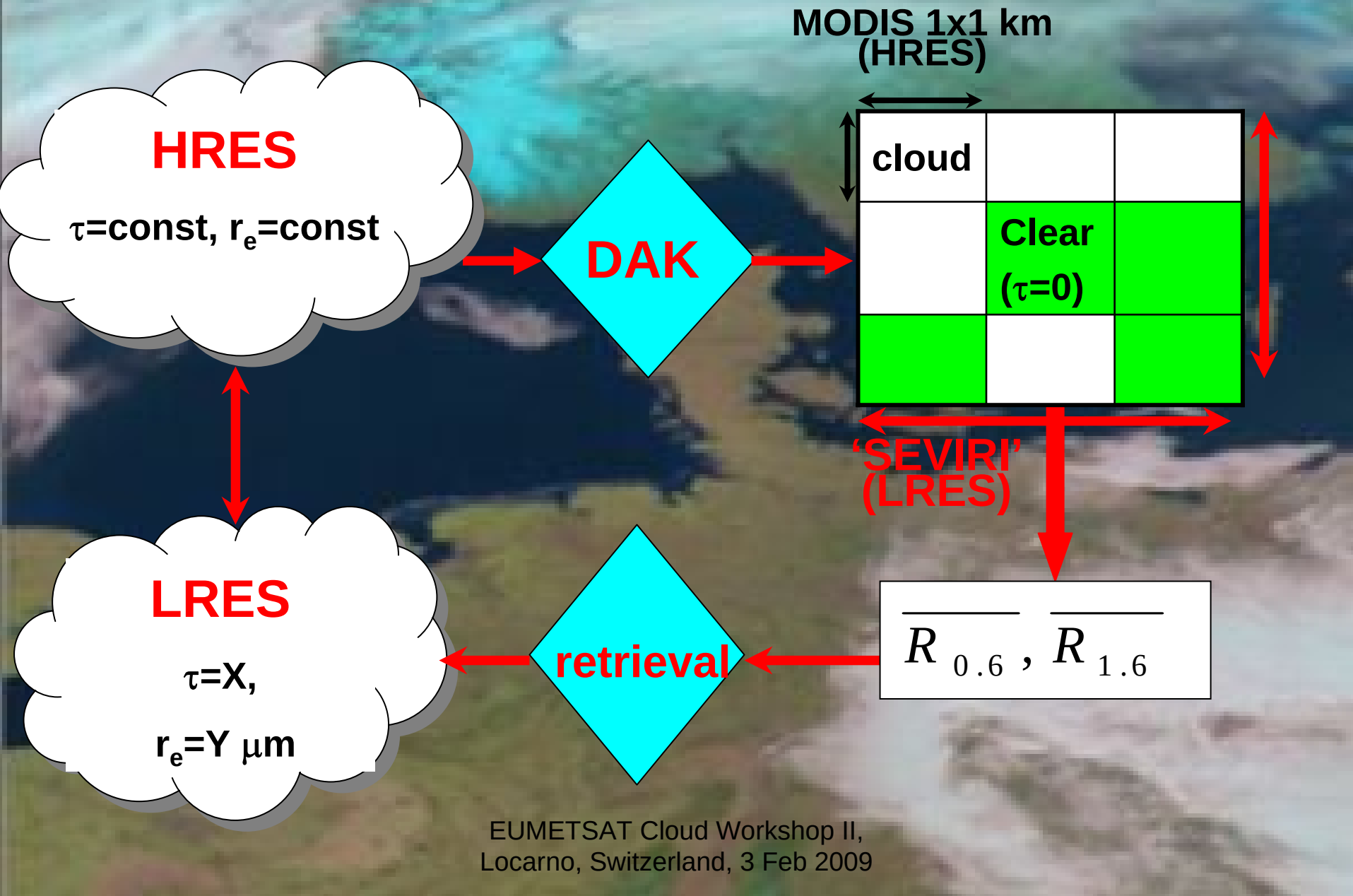
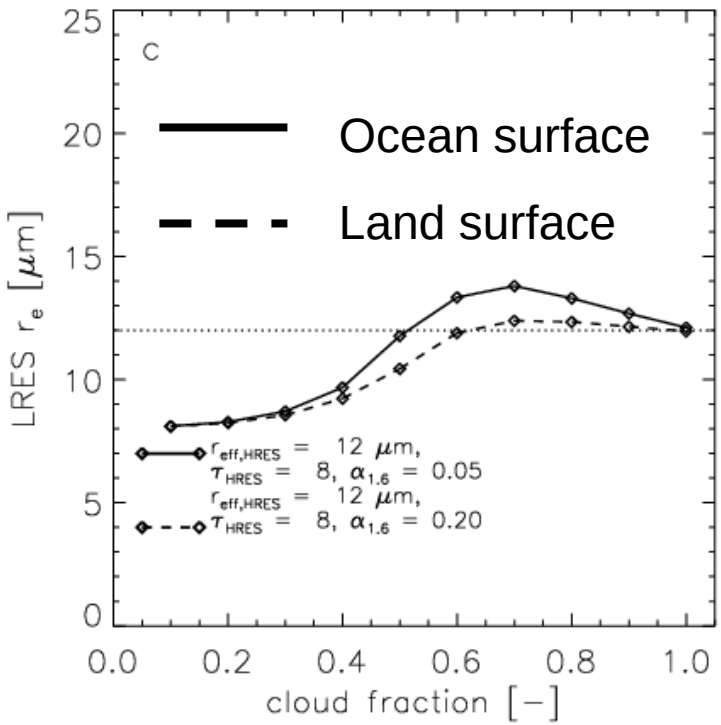
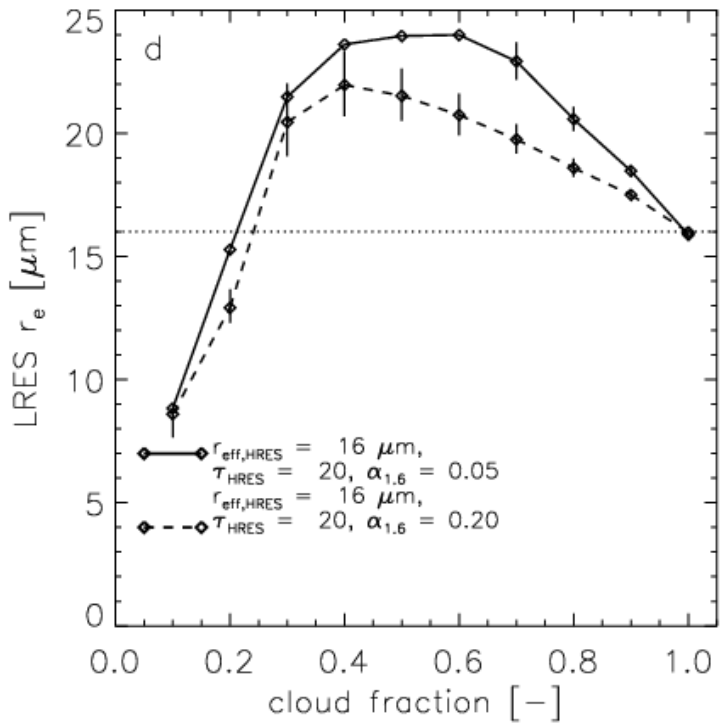
# Synthetic datasets – broken clouds



# Results broken clouds - $r_e$ simulations



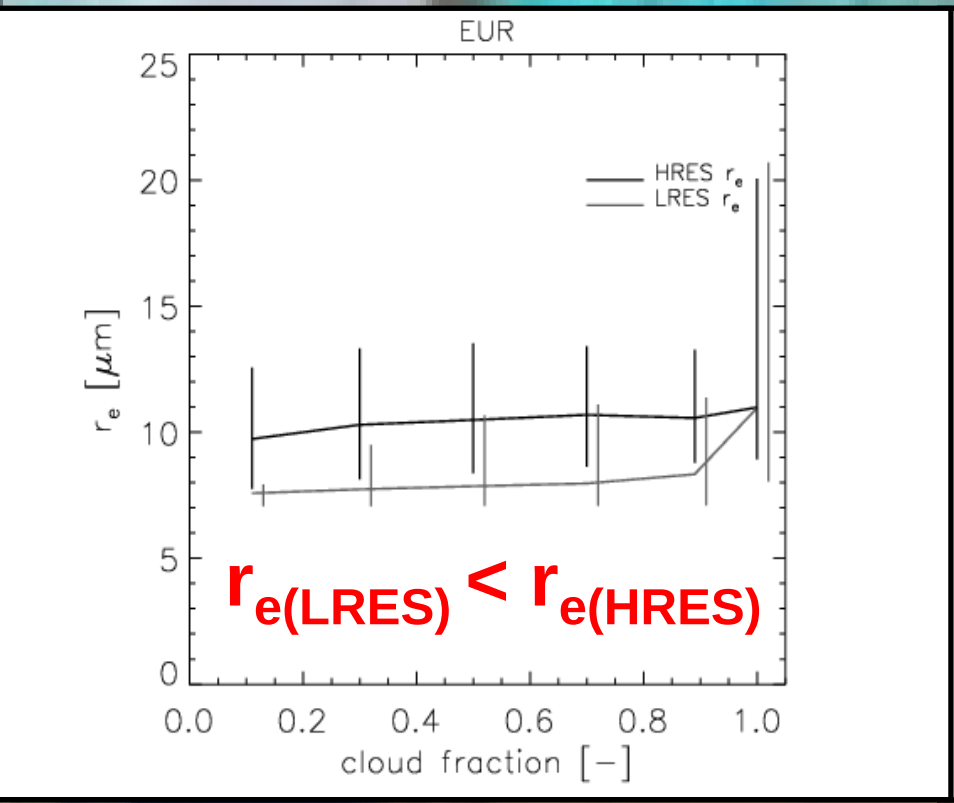

## Thin clouds

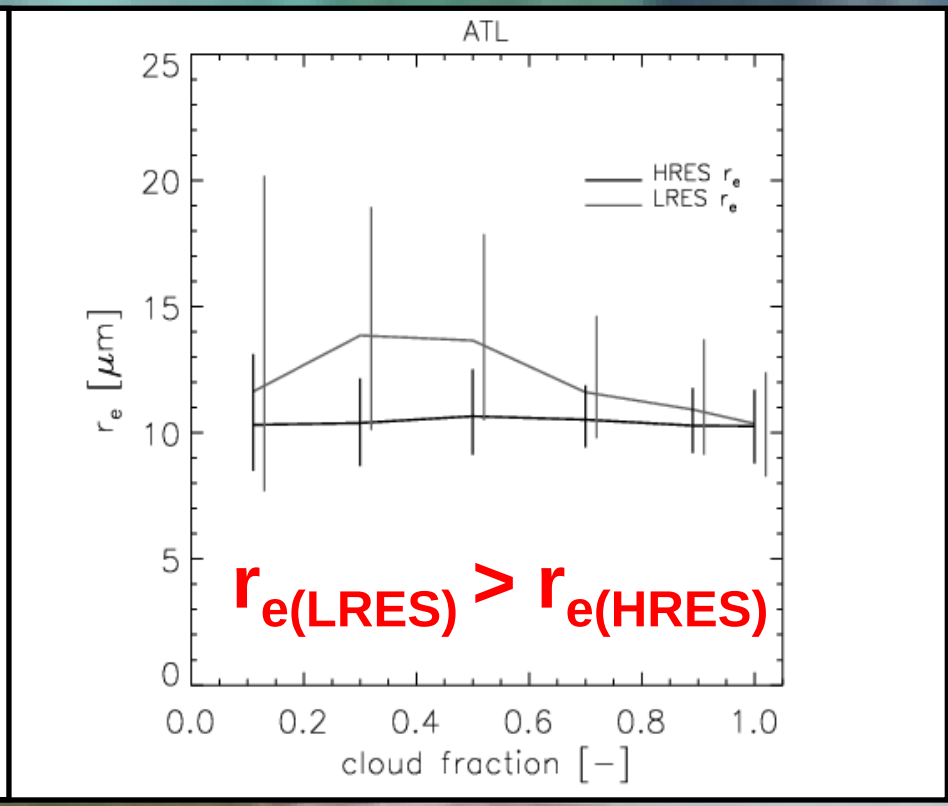
($\tau_{HRES}$=8, $r_{e,HRES}$=12 $\mu$m)

## Thick clouds

($\tau_{HRES}$=20, $r_{e,HRES}$=12 $\mu$m)

# MODIS-observed *median* $r_e$

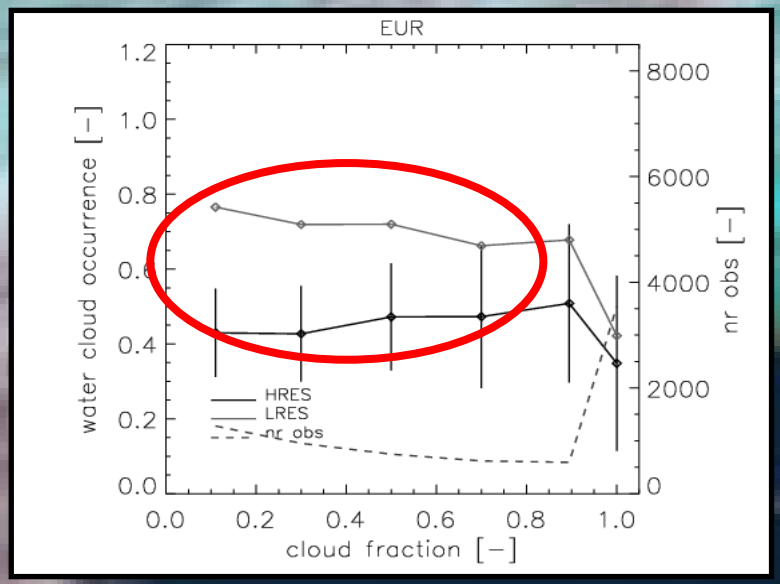


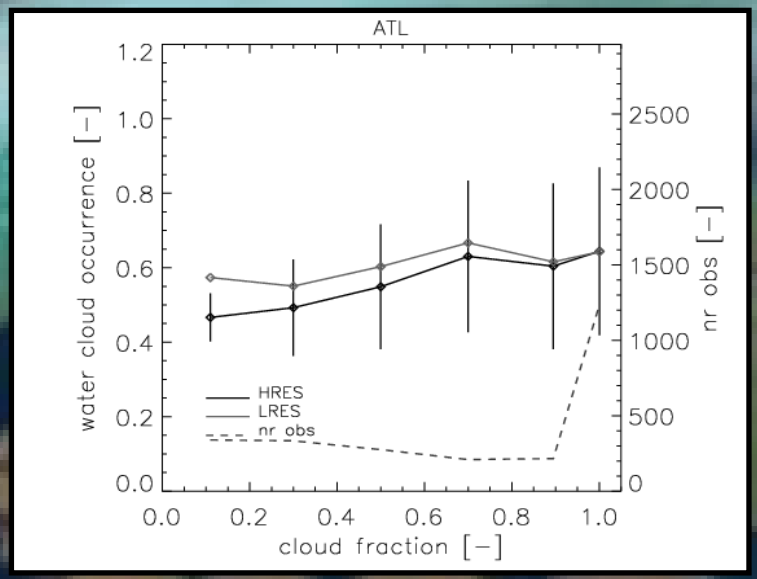




**Central Europe**

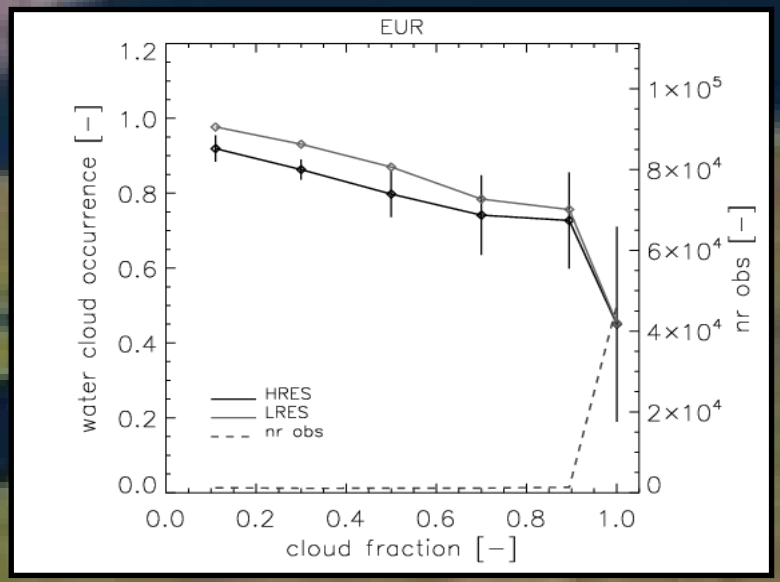
**Atlantic Ocean**

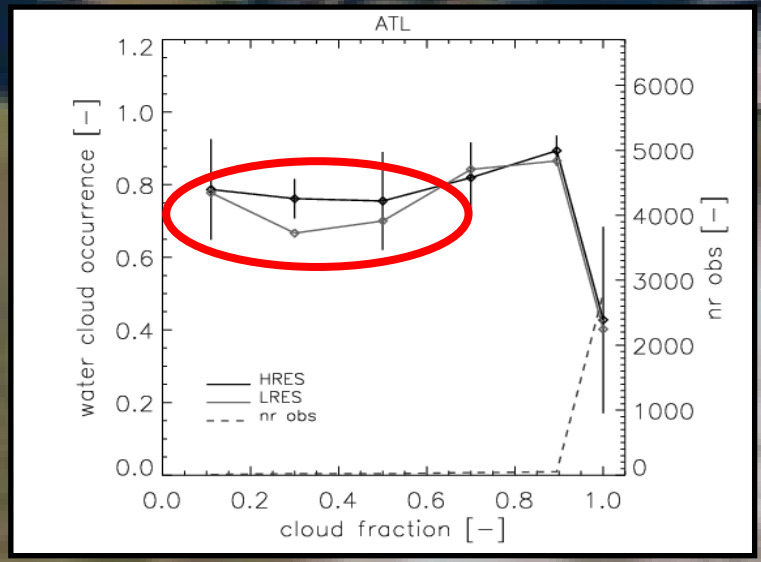
# CPP on MODIS water cloud fraction




$\tau_{HRES}<4$




$\tau_{HRES}>4$

**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 reflectances
- ✓ CPP on MODIS retrievals $r_e$:
  - ✓ $r_e$(LRES) < $r_e$(HRES) over land (≈2 μm)
  - ✓ $r_e$(LRES) > $r_e$(HRES) over ocean surface (≈3 μm)
- ✓ CPP on MODIS retrievals water cloud fraction:
  - ✓ 10-30% more water at LRES for thin clouds over Europe
  - ✓ Up to 10% less water at LRES for thick clouds over Atlantic Ocean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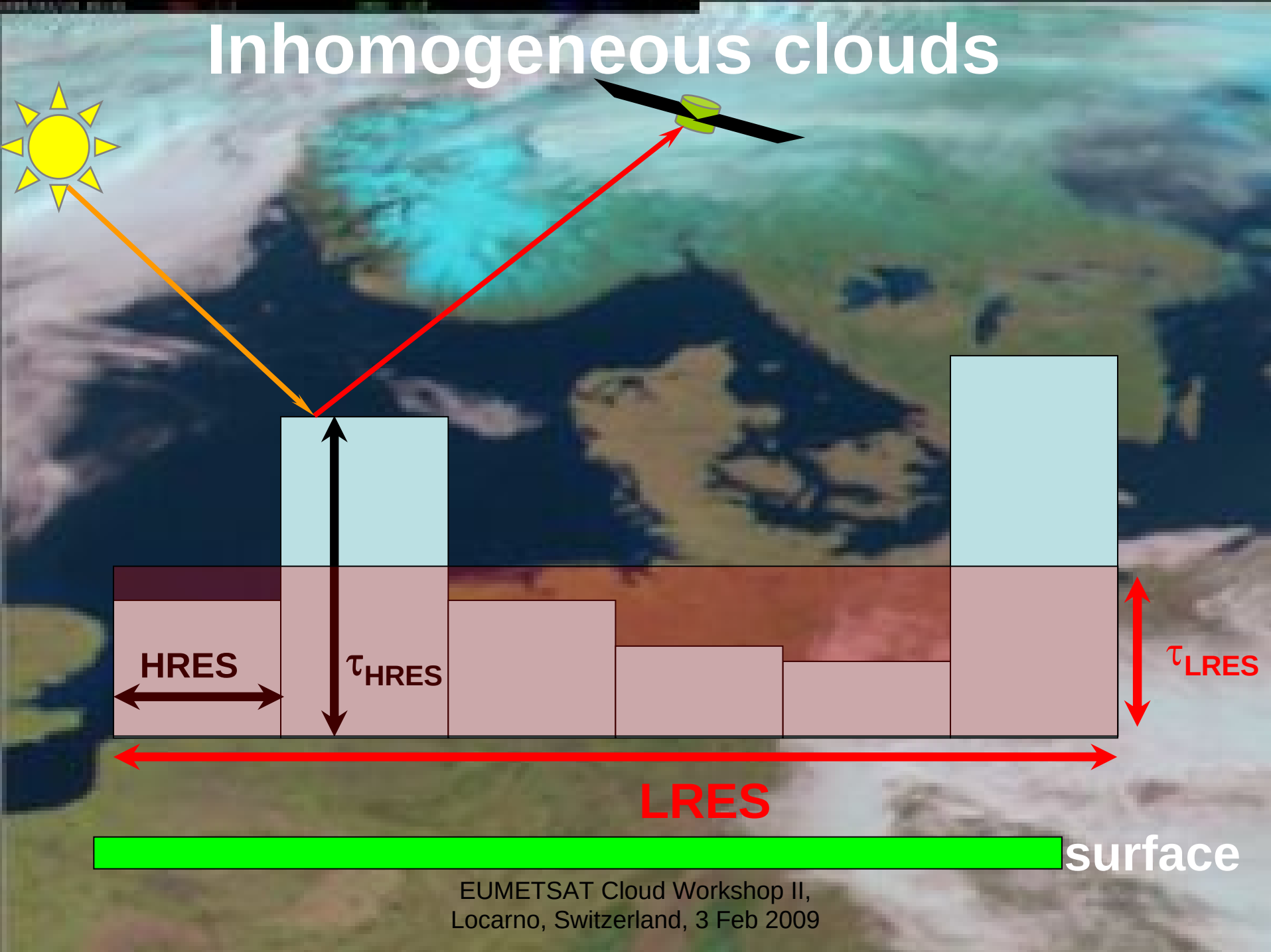
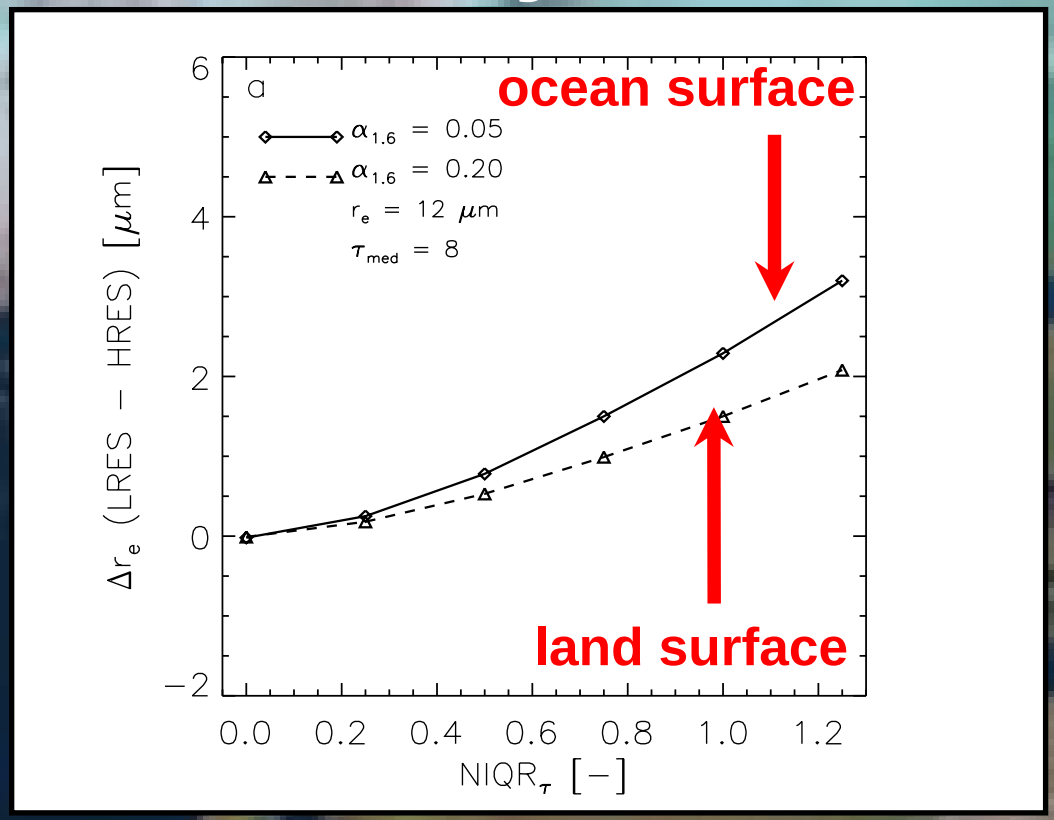
# Inhomogeneous clouds



# Experimental setup

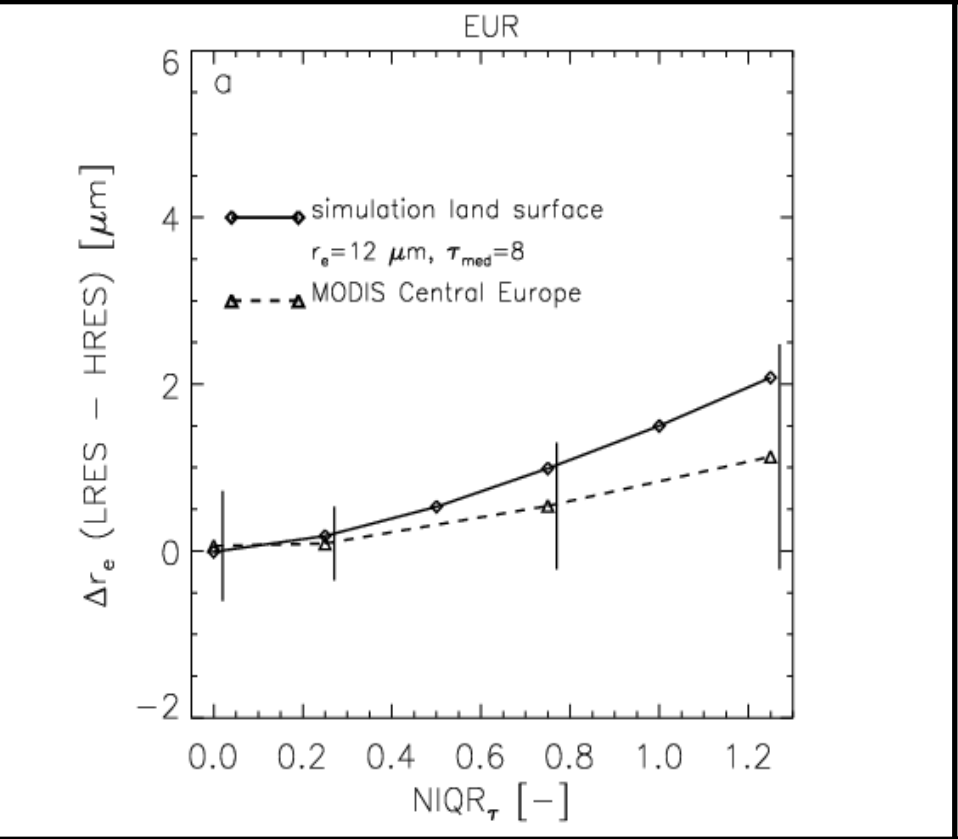
- ✓ Synthetic datasets, 20 high-resolution pixels with overcast water clouds
- ✓ $\tau_{med}$=8, $r_e$=12 μm (thin clouds); $\tau_{med}$=15, $r_e$=16 μm (thick clouds)
- ✓ Variation in $\tau$ is constrained through IQR
- ✓ Obtain $R_{0.6}$ and $R_{1.6}$ for all pixels
- ✓ Average $R_{0.6}$ and $R_{1.6}$
- ✓ Low-resolution $\tau$ and $r_e$ are retrieved

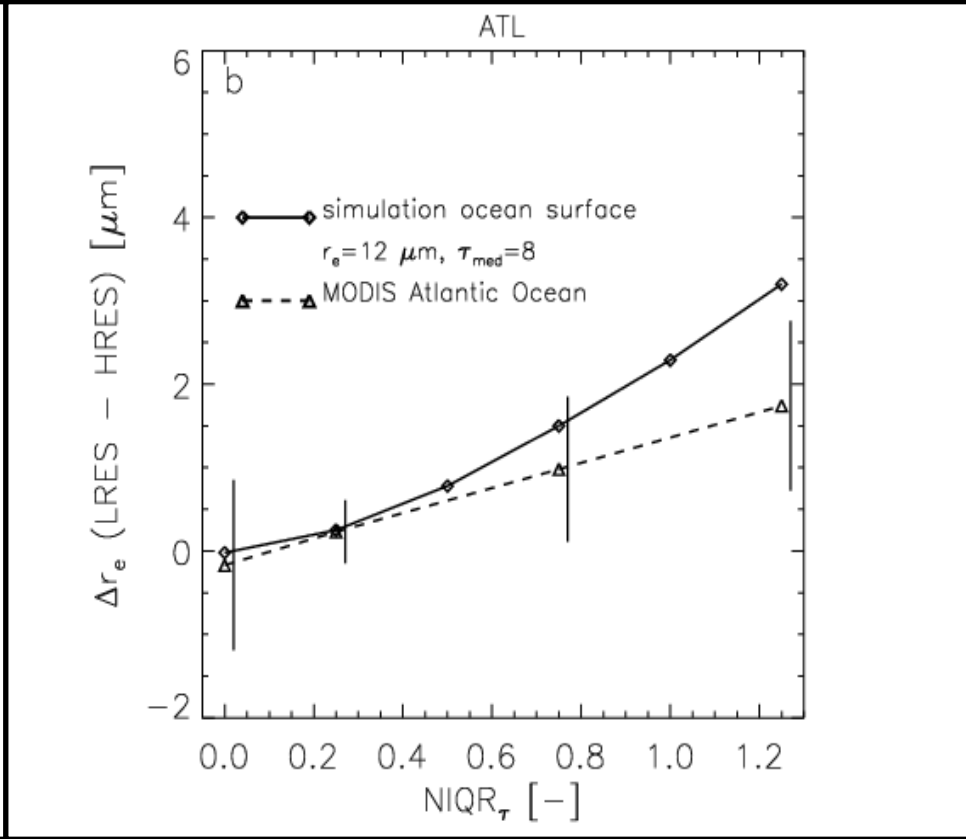
# Results – synthetic dataset




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

# CPP on MODIS-derived $\Delta r_e$ water clouds




**Central Europe** **Atlantic Ocean**

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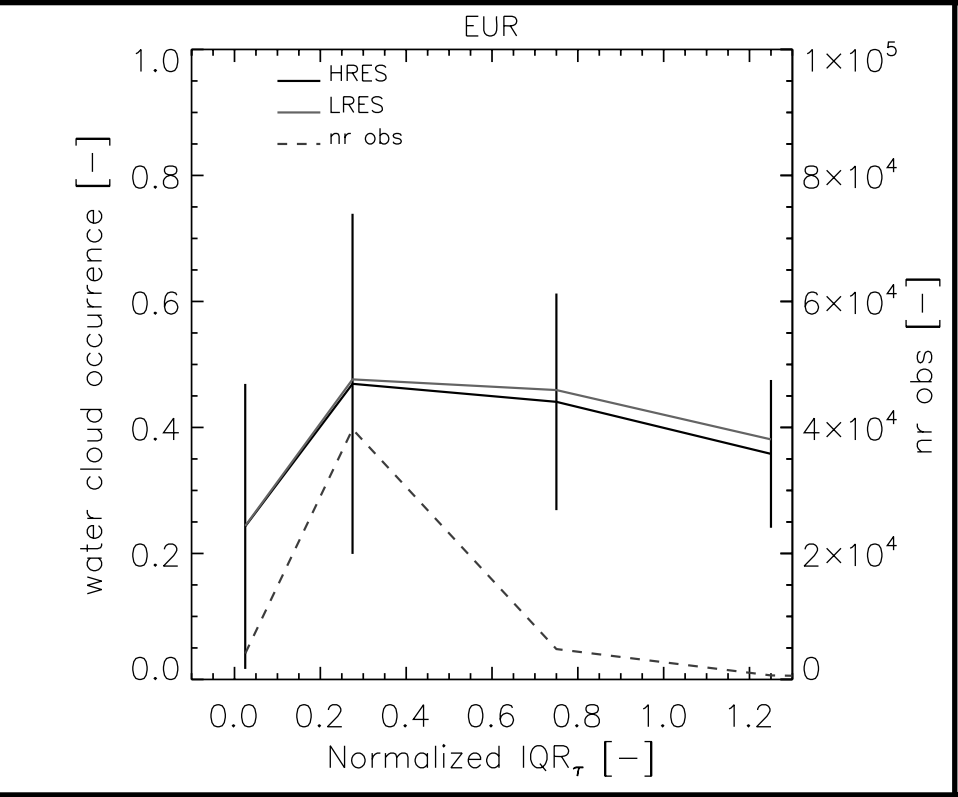
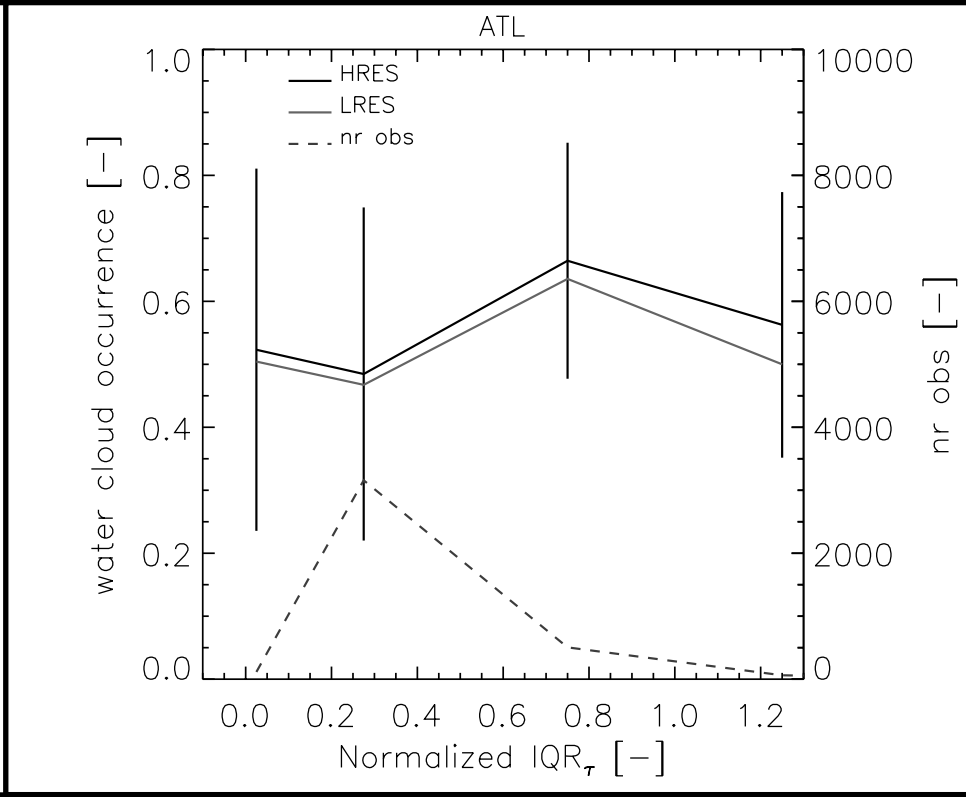
# CPP on MODIS water cloud fraction




## Central Europe

## Atlantic Ocean

# Conclusions

- ✓ Simulations show effect on $r_e$ retrieval for broken and inhomogeneous clouds
- ✓ Effects most prominent over dark surfaces
- ✓ CPP on MODIS retrievals in accordance with simulations for $r_e$
- ✓ Broken cloud effect larger than inhomogeneity effect for cloud phase
- ✓ Use SEVIRI HRV channel to correct retrievals for both effects?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# 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
- ✓ $\tau$=8, $r_e$=12 µm (thin water clouds); $\tau$=20, $r_e$=16 µm (thick water clouds)
- ✓ $\tau$=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 $\tau$ and $r_e$ are retrieved

# Clouds in the climate system