Neural network-based cloud property retrievals from satellite multi-angle polarimetry

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NN polarimetric cloud retrieval scheme for POLDER-3

- Trained with synthetic measurements representing ocean and land scenes
- Retrieval performed using measurements at 14 viewing angles
- 4 separate NNs (separation by surface and retrieved cloud properties)

	COT NN	**Microphysics NN** ➢ **Eff. radius** ➢ **Eff. variance**
Ocean	• Reflectance (490, 670, 865, 1020 nm) • DoLP (490, 670, 865 nm)	• Polarized reflectance (490, 670, 865 nm)
Land	• Reflectance (490, 565, 670 nm) • DoLP (490, 670 nm)	• Polarized reflectance (490, 670, 865 nm)

Training set generation

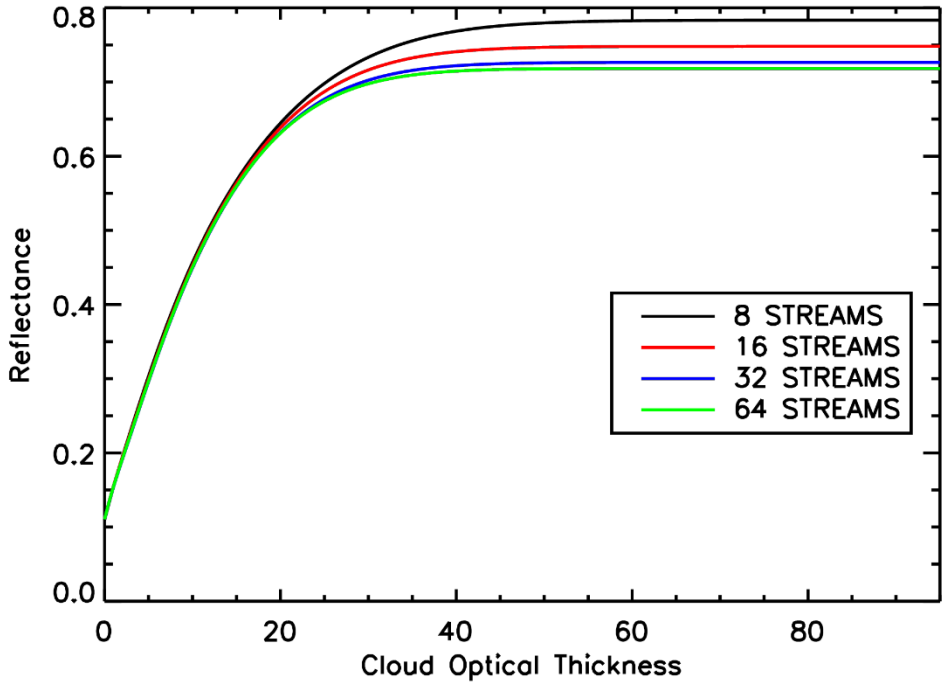
1) Realistic combinations of POLDER-3 viewing angles
   - 1 year of PARASOL data analysed
   - 25 orbits per month sampled
   - 5000 angle combinations extracted per orbit
   - Min. scattering angle: < 135°, max. scattering angle > 165° (for microphysics NN)
   - 1.5 X 10^6 combinations in total

2) Random combinations of cloud properties (uniform distribution)
   - COT between 0 and 40
   - Eff. radius between 3 and 25 µm
   - Eff. variance between 0.03 and 0.3
   - Cloud height between 2 and 20 km

3) Radiative transfer simulations
   - 16 streams forward model with MS correction of Nakajima and Tanaka (1988)

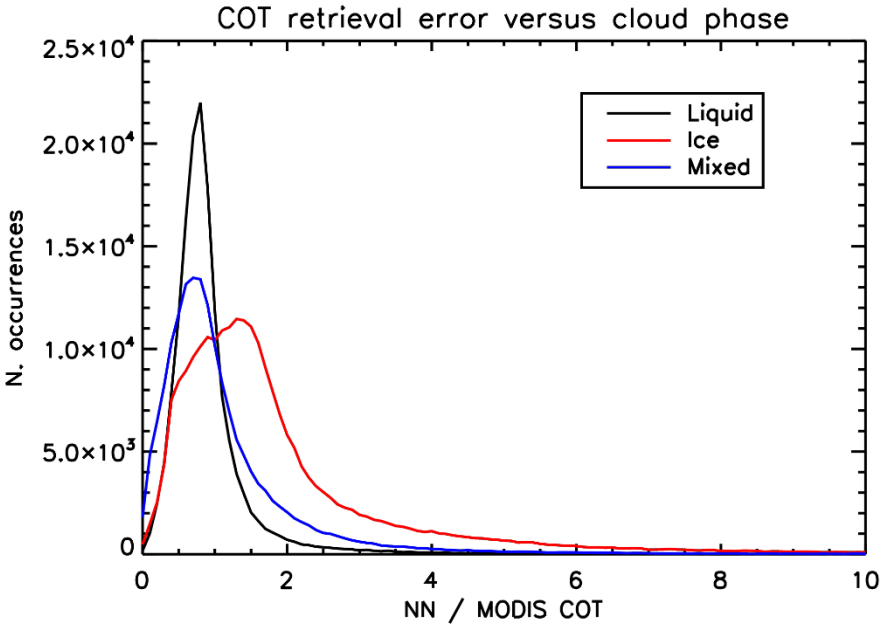
Simplifying assumptions

- Only liquid water clouds considered (modelling cirrus clouds yet to be done)
- Broken cloud cases not modelled in the training set (possible biases!)
- Aerosols above clouds not modelled (again, possible biases!)
- Accurate forward model simulations crucial for correct training
- 16 streams may be not accurate enough for large COTs



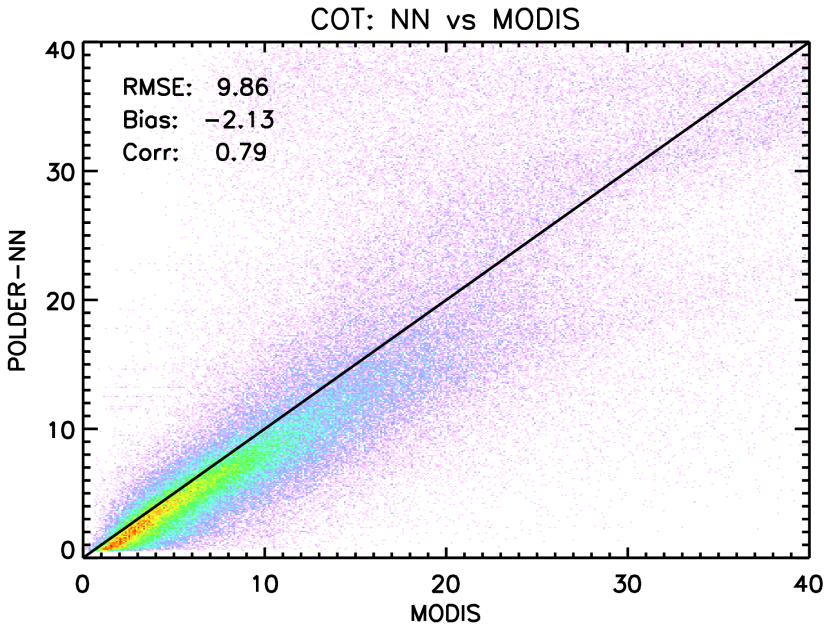
COT errors vs thermodynamic phase

- High bias in COT expected over ice clouds
- A simple theoretical model
  - TOA reflectance depends on asymmetry parameter
  - $R = \frac{\tau(1-g)}{2\mu_0+\tau(1-g)}$
  - Ice asym. parameter (MODIS C6) g_{ice}=0.75
  - Liquid water cloud has $g_{liq}\approx 0.85$
  - Expected bias: $\frac{\hat{\tau}_{liq}}{\tau_{ice}} = \frac{1-g_{ice}}{1-g_{liq}} \approx 1.66$



Global NN vs MODIS COT for 24 February 2006

- NN retrievals compared to MODIS L2 product over the entire globe
- Filtering criteria
  - MODIS cloud fraction larger than 0.95
  - Only liquid water clouds considered (based on CPI)
  - Ocean glint regions not considered
- NN retrieves systematically lower COT compared to MODIS. Bias around -2
- More scatter for COT>20
- Low bias: broken clouds?

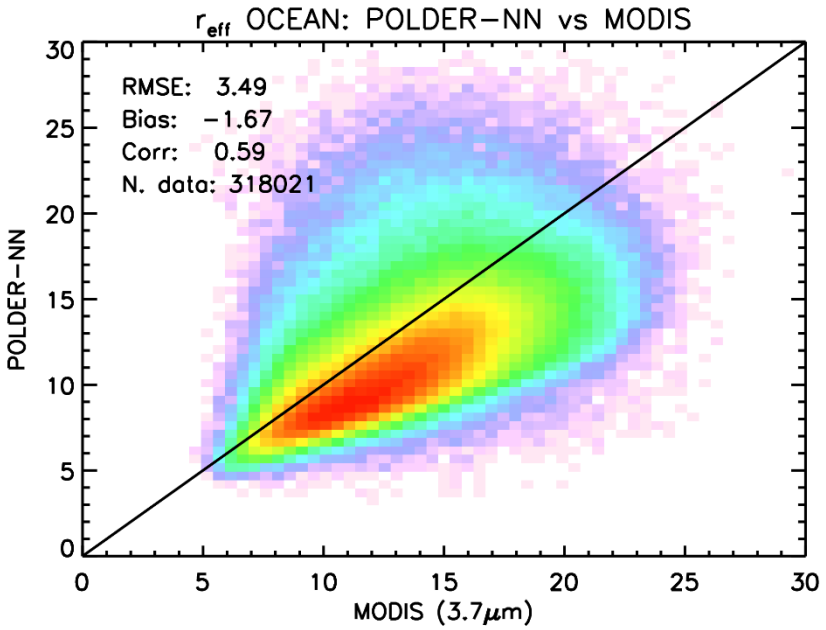


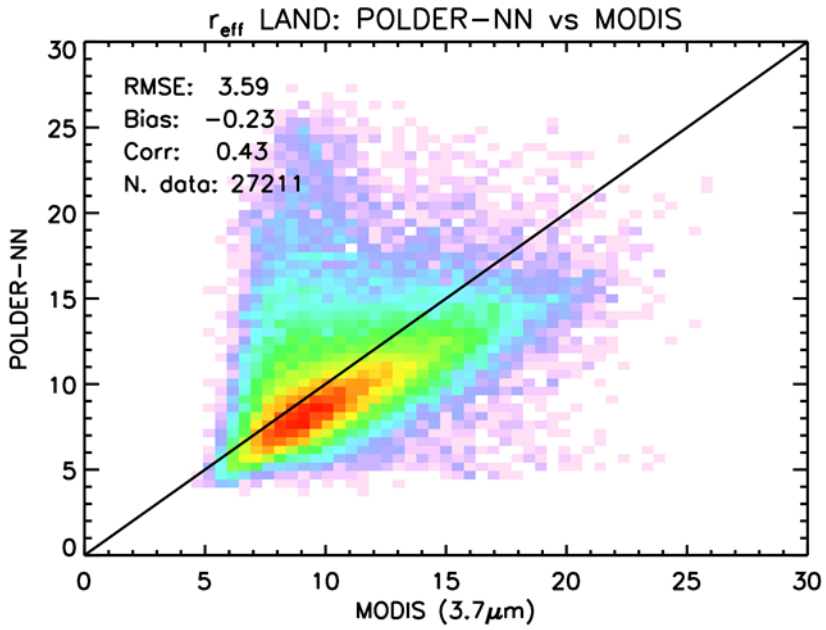
Comparisons for the full year 2006

- POLDER-3 L1B dataset for year 2006 processed
- Benchmark datasets
  - MODIS L2 product remapped on POLDER-3 grid (from LOA-ICARE)
  - MODIS gridded Collection 6 product
  - POLDER-3 existing cloud products (L2 COT, CDR eff. radius)
- Retrievals regridded on 1° grid for global comparison (comparison at native L1B pixel size too demanding)

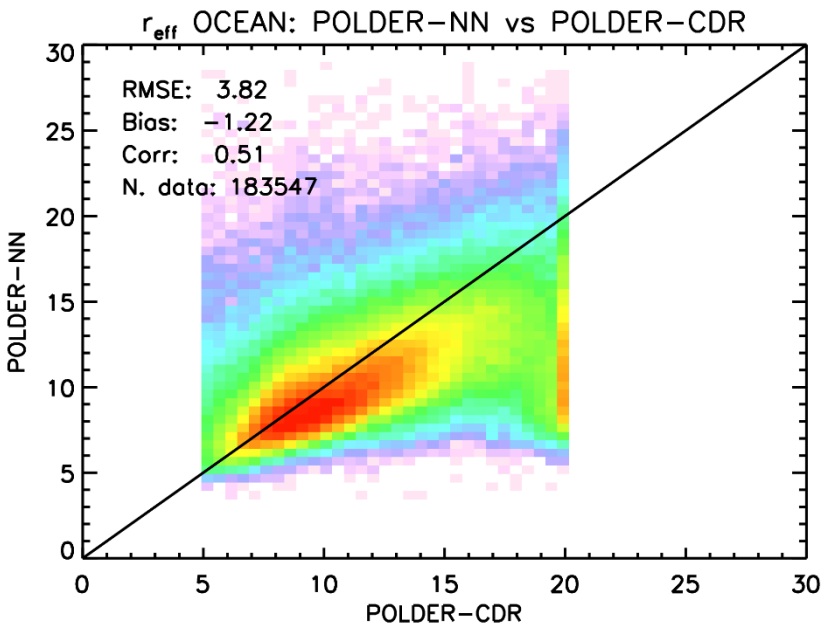
Eff. Radius: NN vs MODIS

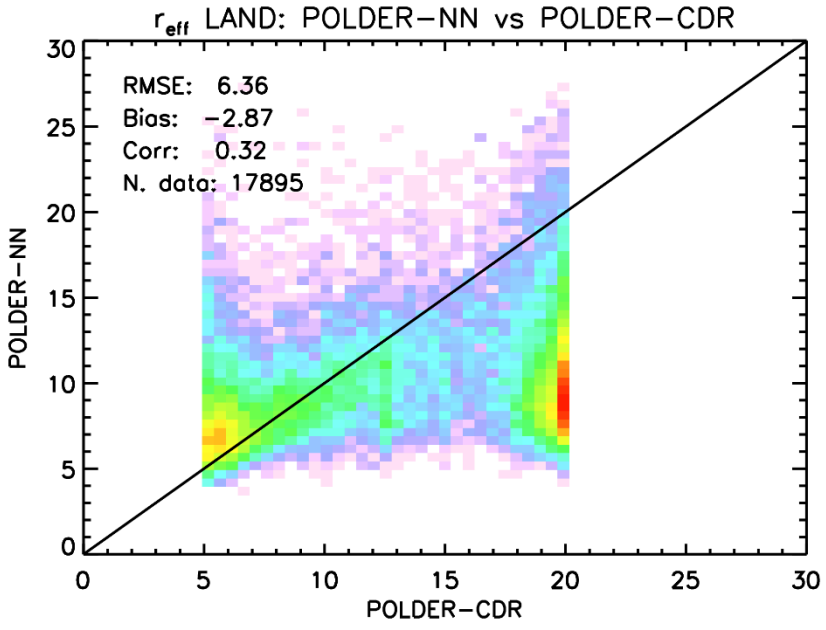
- Additional filtering criteria
  - Min. scattering angle: < 135°
  - Max. scattering angle > 165°
  - (MODIS cloud top pressure > 600 hPa)
- MODIS 3.7 μm product sensitive to upper cloud layers (more similar to polarimetry)
- NN biased low ~1-2 μm against MODIS (in line with existing literature)





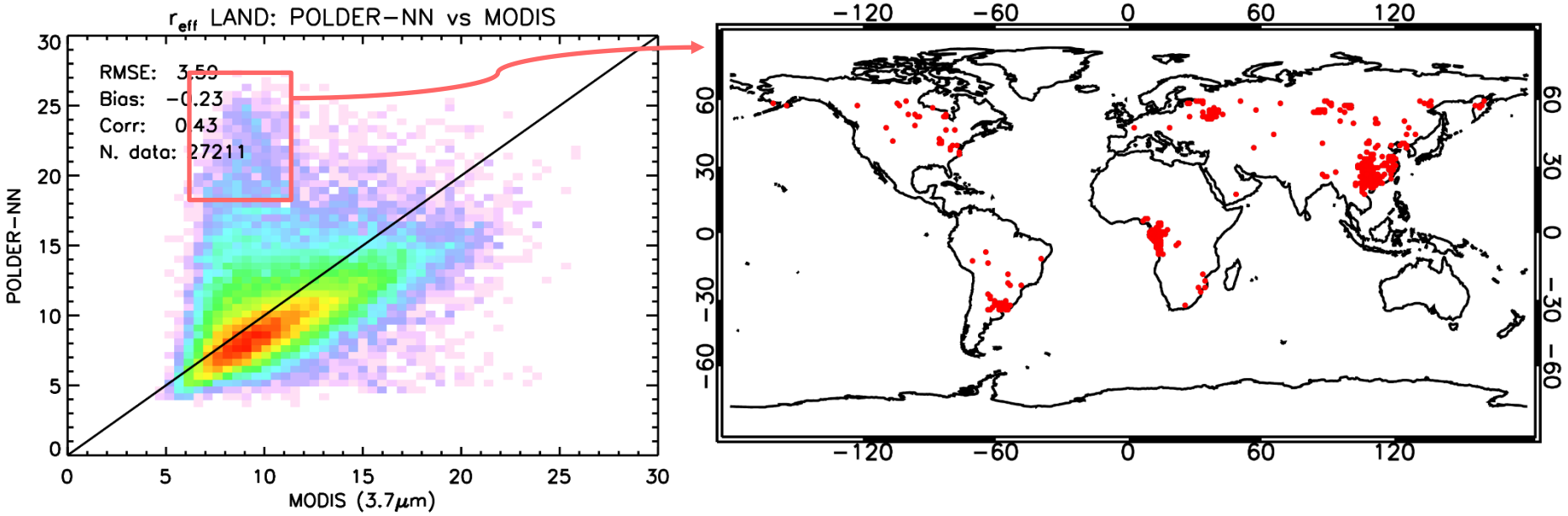
Eff. Radius: NN vs POLDER CDR



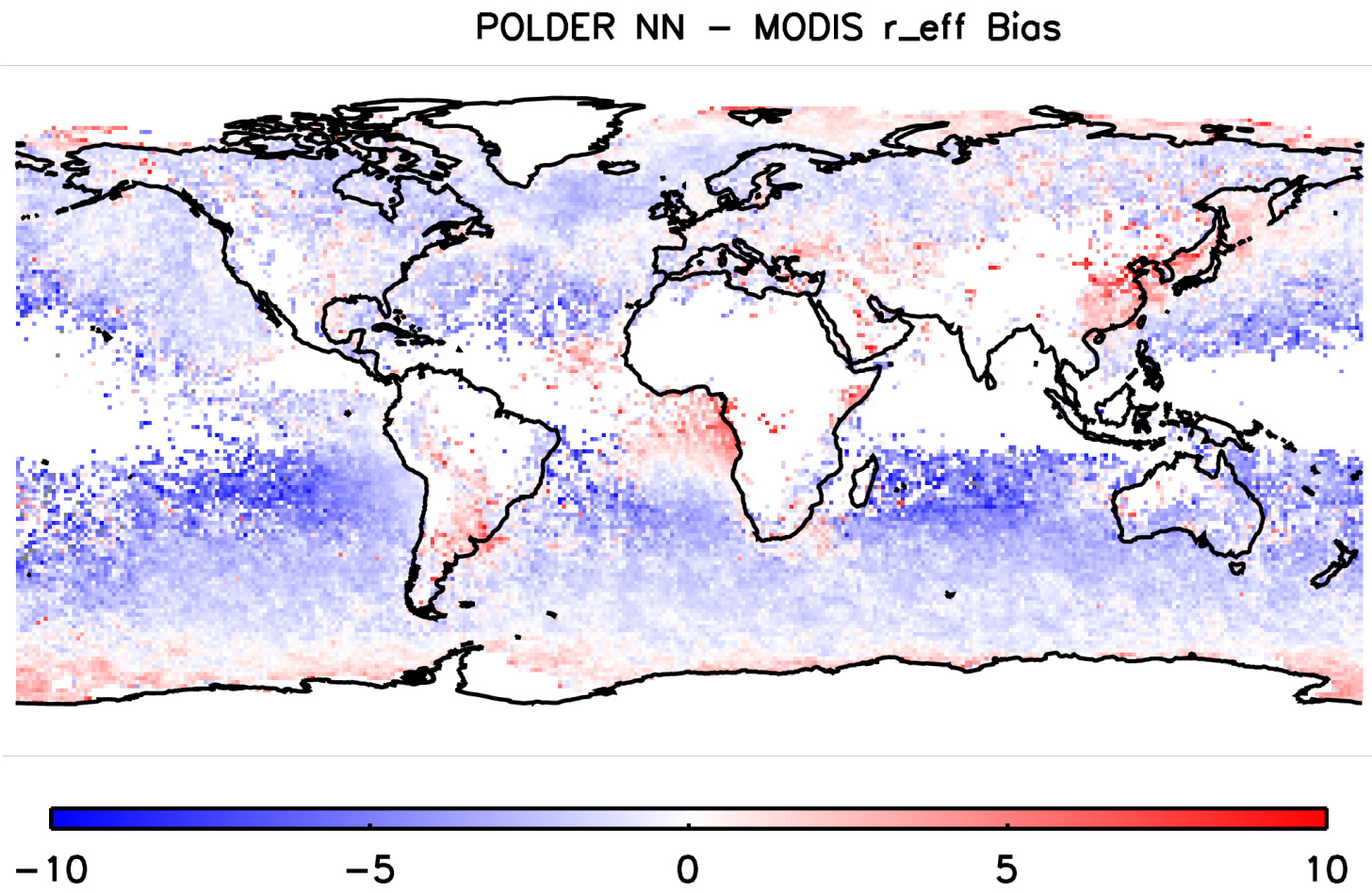


Patterns in eff. radius differences over land

- In some cases NN sees much larger droplets than MODIS over land
- Where does this happen?
- Causes: particular cloud types? Aerosols above clouds?

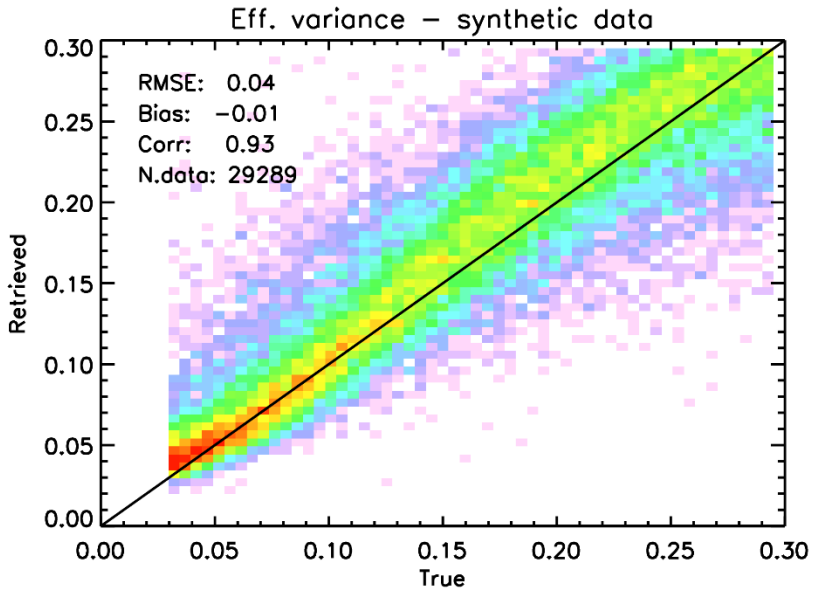


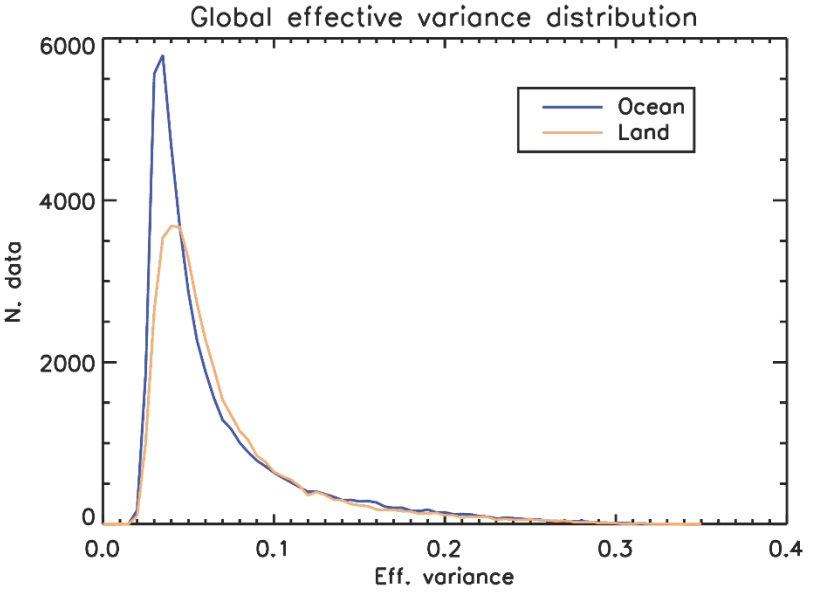
Eff. Radius bias map



A few words on effective variance retrieval

- Our algorithm also retrieves effective variance
- Only "plausibility checks" possible
  - How does it work on synthetic data?
  - For real clouds, v_{eff} often less than 0.15. What do retrievals look like?
- NN trained on broad v_{eff} range (0-0.35) = "loose prior"
  - Synth retrievals work quite well
  - v_{eff} over ocean in line with recent literature (Benas et al., AMT 2019)
  - v_{eff} over land probably too small: sensitivity issues?





Conclusions

Main results

- Neural network scheme for cloud retrievals from POLDER-3 developed
- Retrieved COTs are biased low with respect to MODIS (broken clouds?)
- Eff. radii agree well with MODIS over ocean and land. Low bias in line with literature
- Eff. variances appear realistic over ocean, more investigations needed over land

Perspectives

- Including ice clouds in the training set may improve COT estimates
- Extension to 3MI straightforward. New polarized channels may further improve results (Polarization at 410 nm for cloud height? SWIR channels for eff. radius, cirrus?)

Further info

- Paper published on AMT – doi: 10.5194/amt-12-1697-2019