Variation of ice crystal shape, size & asymmetry parameter in tropical deep convection retrieved from combined MODIS and POLDER measurements

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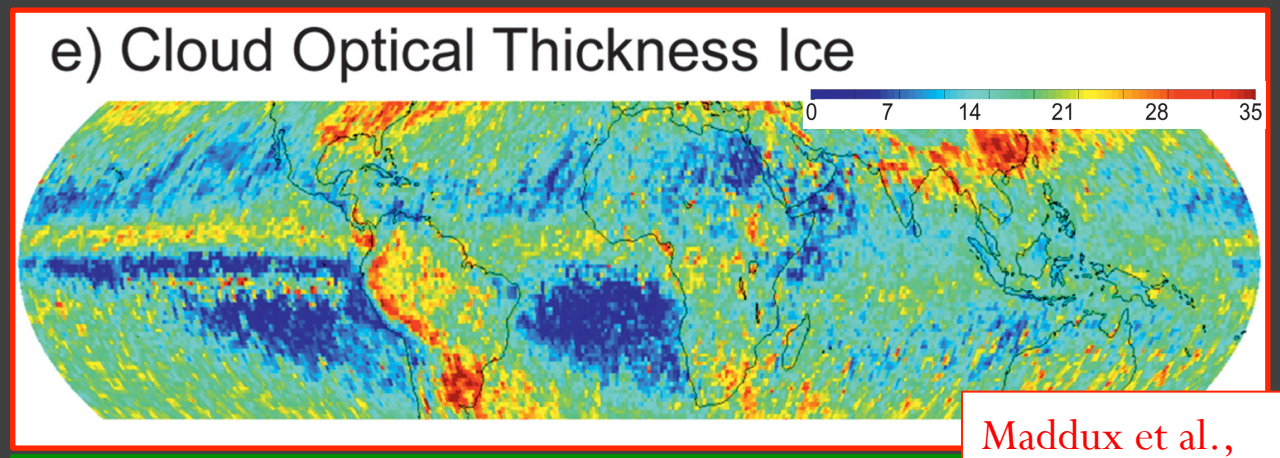
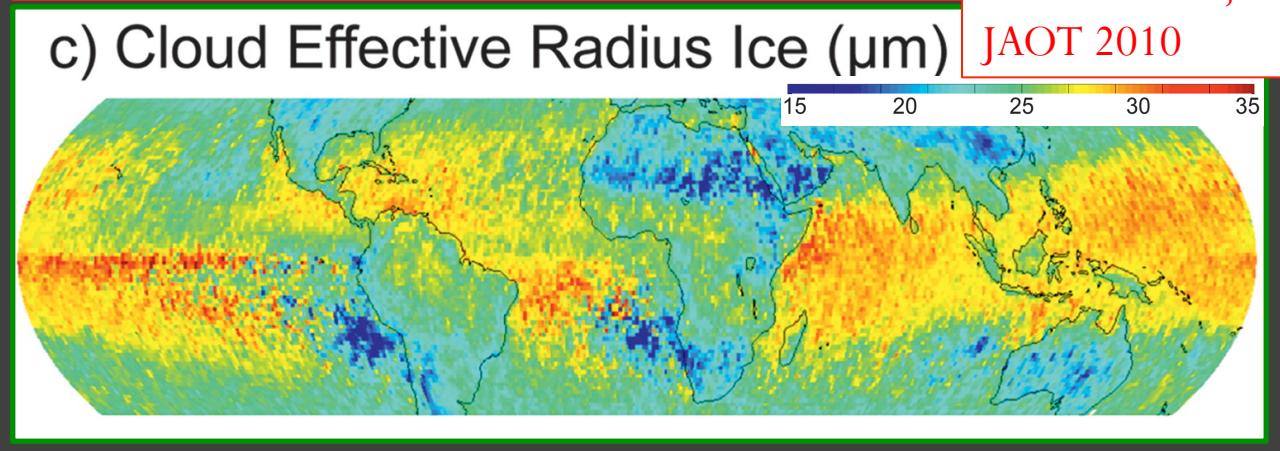
Current knowledge on global ice cloud properties



Maddux et al., JAOT 2010



Ice cloud asymmetry parameter:

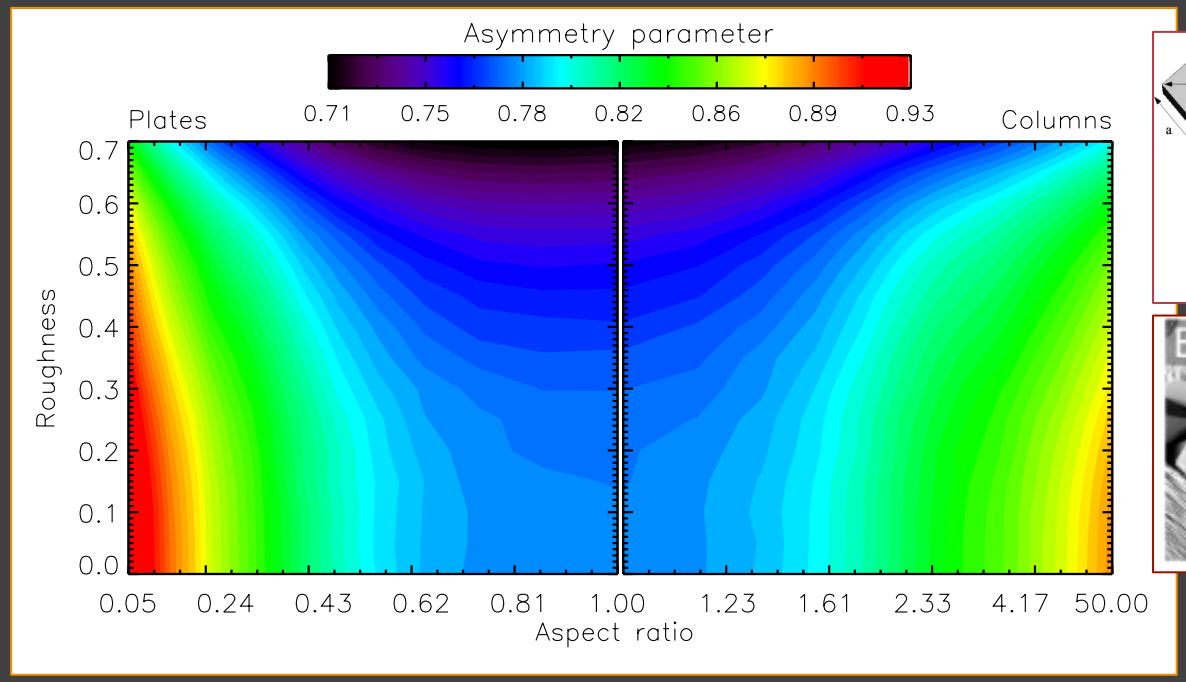
Models: 0.6-0.95

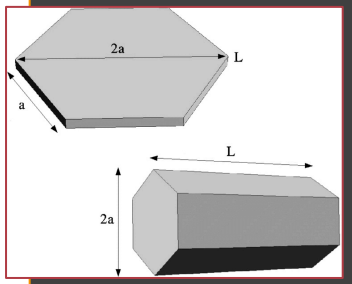
? In situ: ~0.75 ?

Required accuracy: 0.01-0.04 (Vogelmann & Ackerman, 1995)

Ice crystal asymmetry parameter

- Ice crystal asymmetry parameter mainly depends on
  - Shape (or shape of components)
  - Distortion/Microscopical Roughness/impurity
- Asymmetry parameter of aggregates similar to components





Information from Polarization

Polarization contains info about

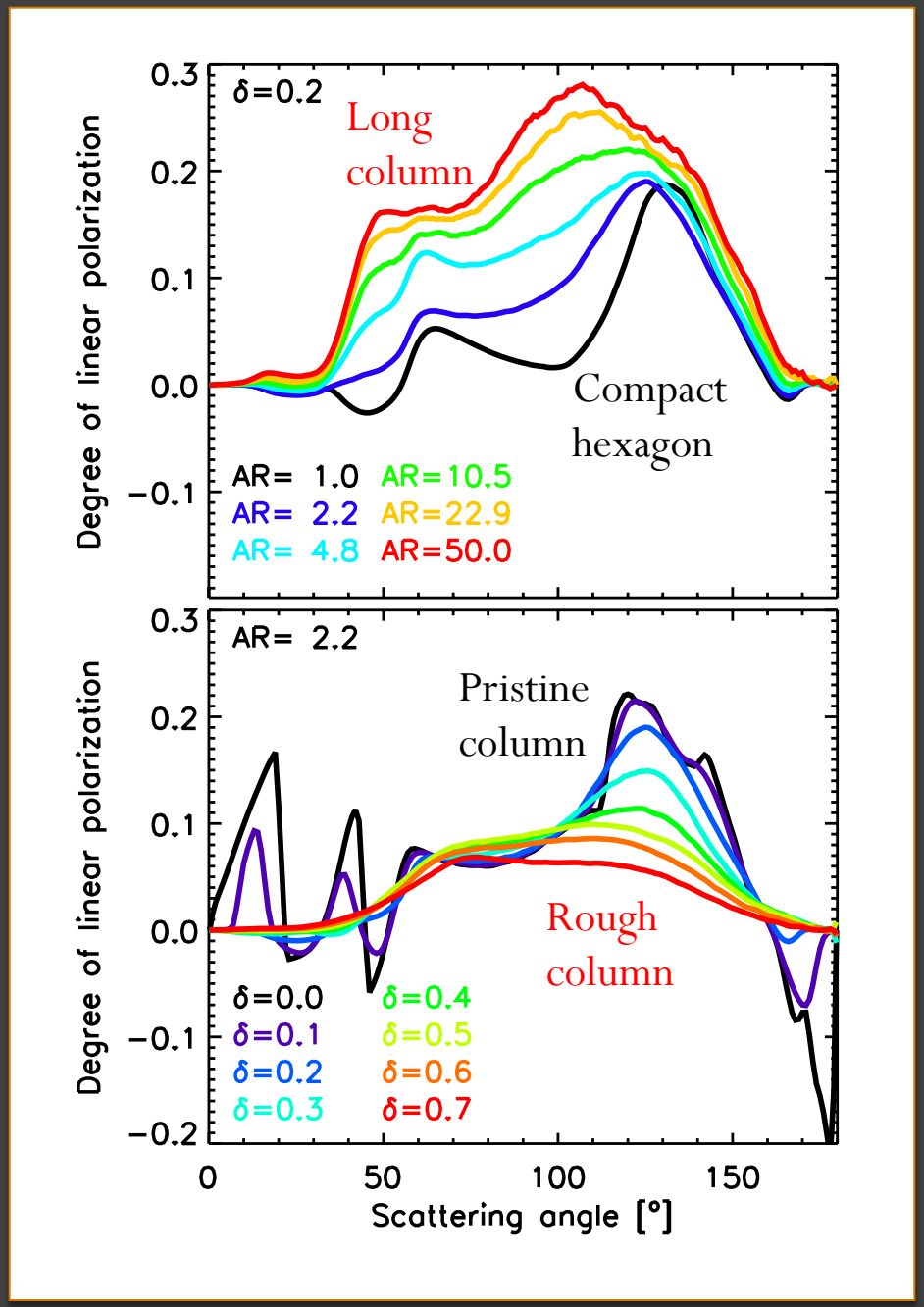
- Aspect ratio
- Roughness

Multi-directional polarized reflectance measurements

conserve

Single scattering features

Retrieve aspect ratio and roughness from polarization to estimate asymmetry parameter



Retrieval procedure

LUT of polarized reflectances for columns/plates

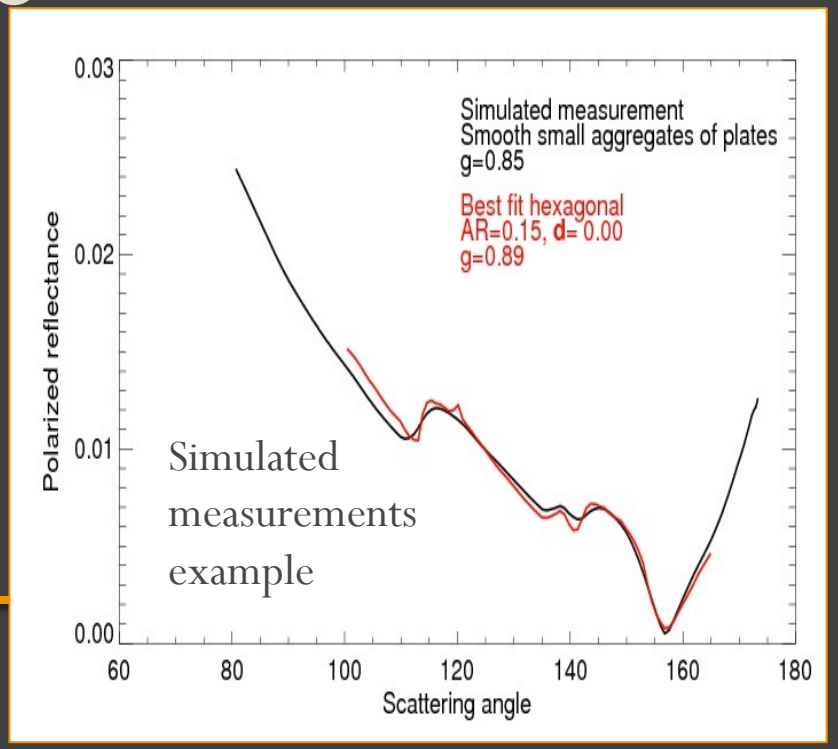
51 aspect ratios 0.02 – 50

15 roughness values (δ =0 – 0.7)

Find best fit to measured multi-directional polarized reflectances

At least scattering angles 120° – 150°

Asymmetry parameter of best-fit hexagon is retrieved value



Use retrieved asymmetry parameter for cloud optical thickness retrieval (later also effective radius)

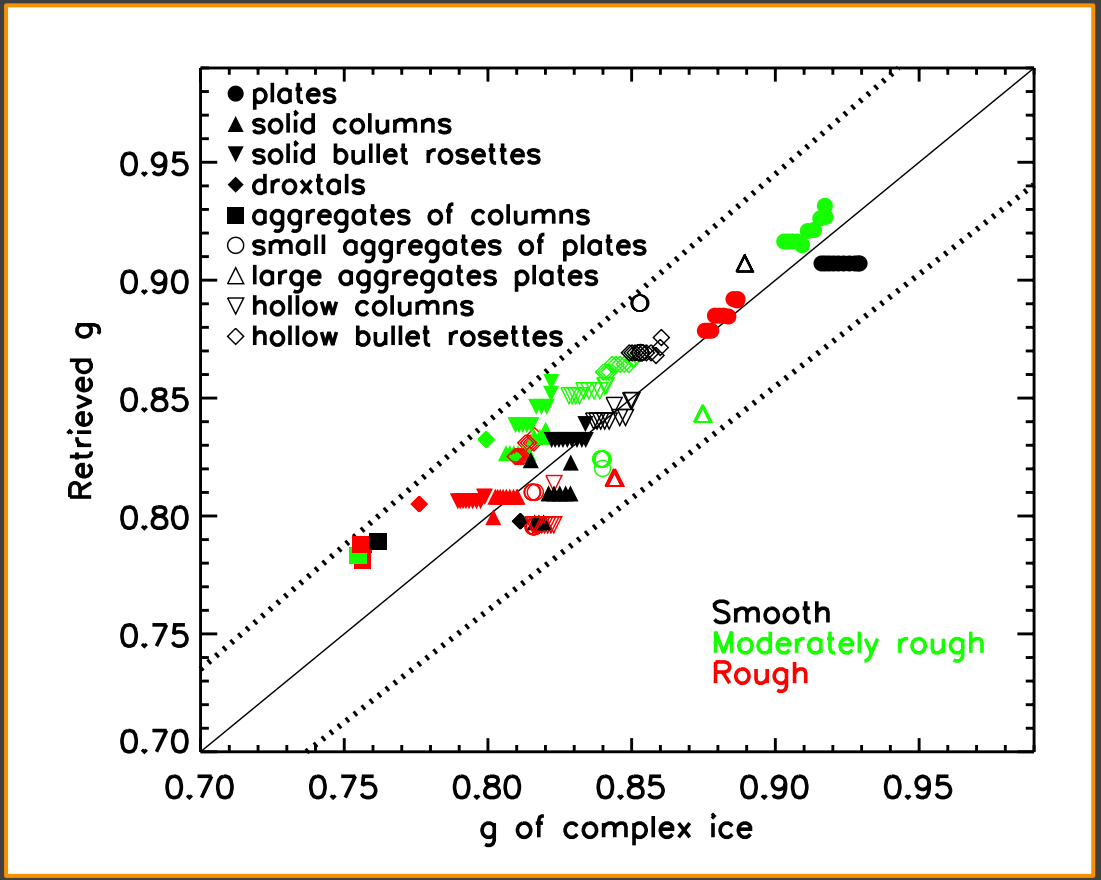
Simulated data test

Simulated data:

- Complex ice habits (Yang et al.)
- 3 roughness degrees
- 20 different size distributions

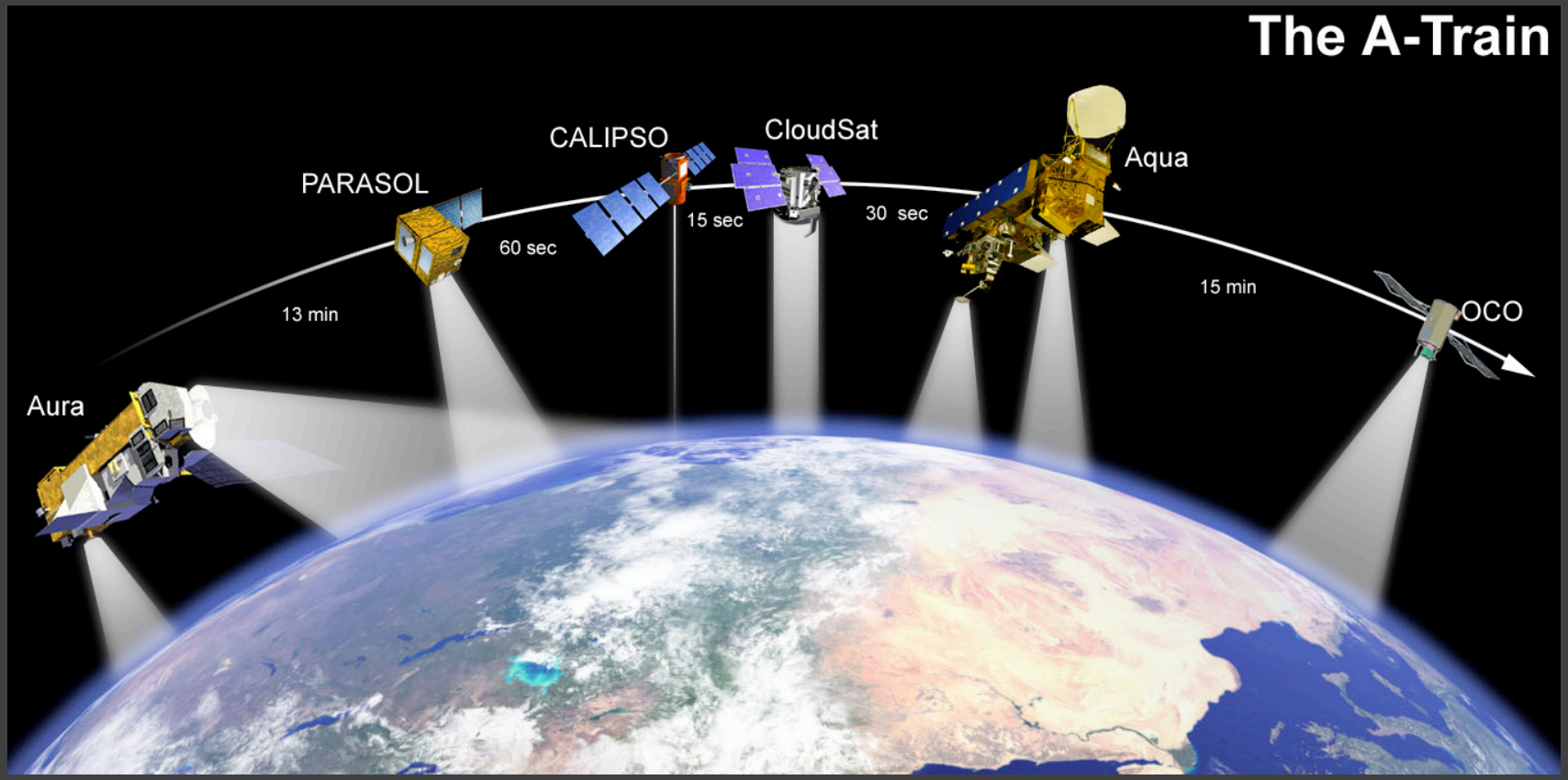
Retrieved asymmetry parameter

- Within 5% (0.04)
- Mean bias: 0.004
- Standard deviation: 0.02



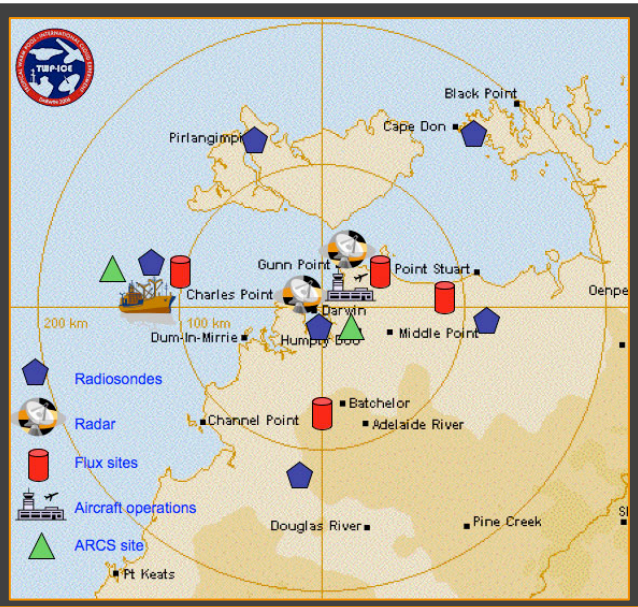
Van Diedenhoven et al.,
Atmos. Meas. Tech., 5, 2361–2374, 2012

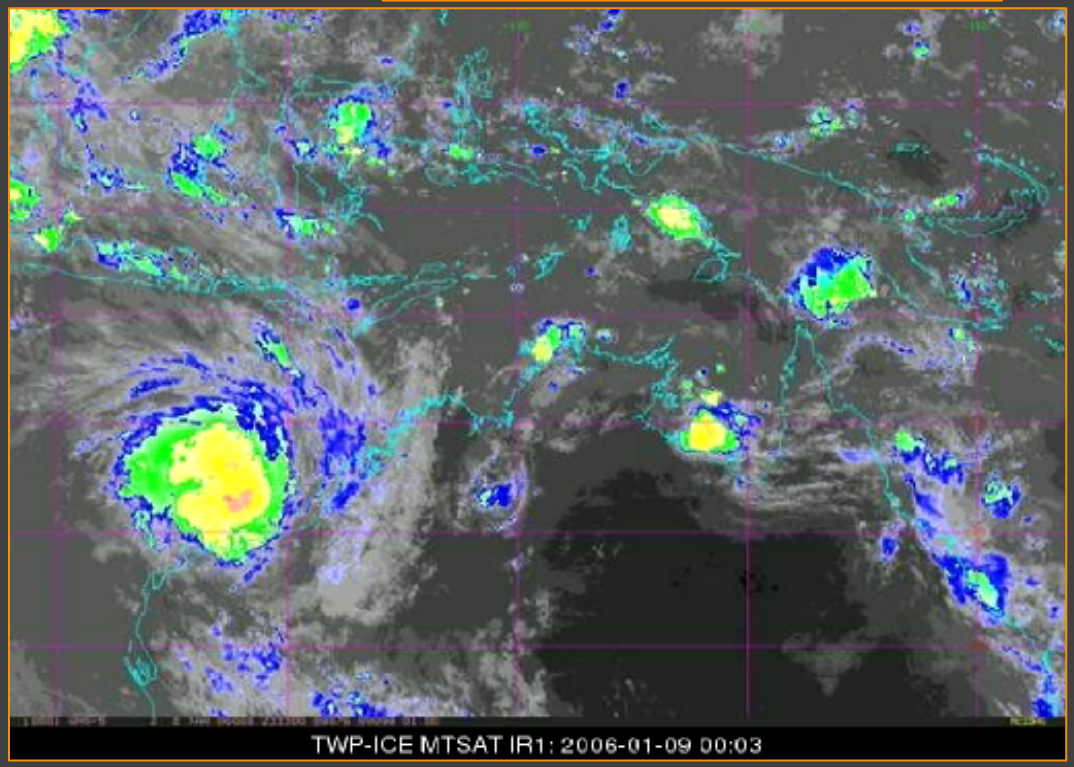
Application to POLDER/PARASOL and MODIS/Aqua



TWP-ICE campaign

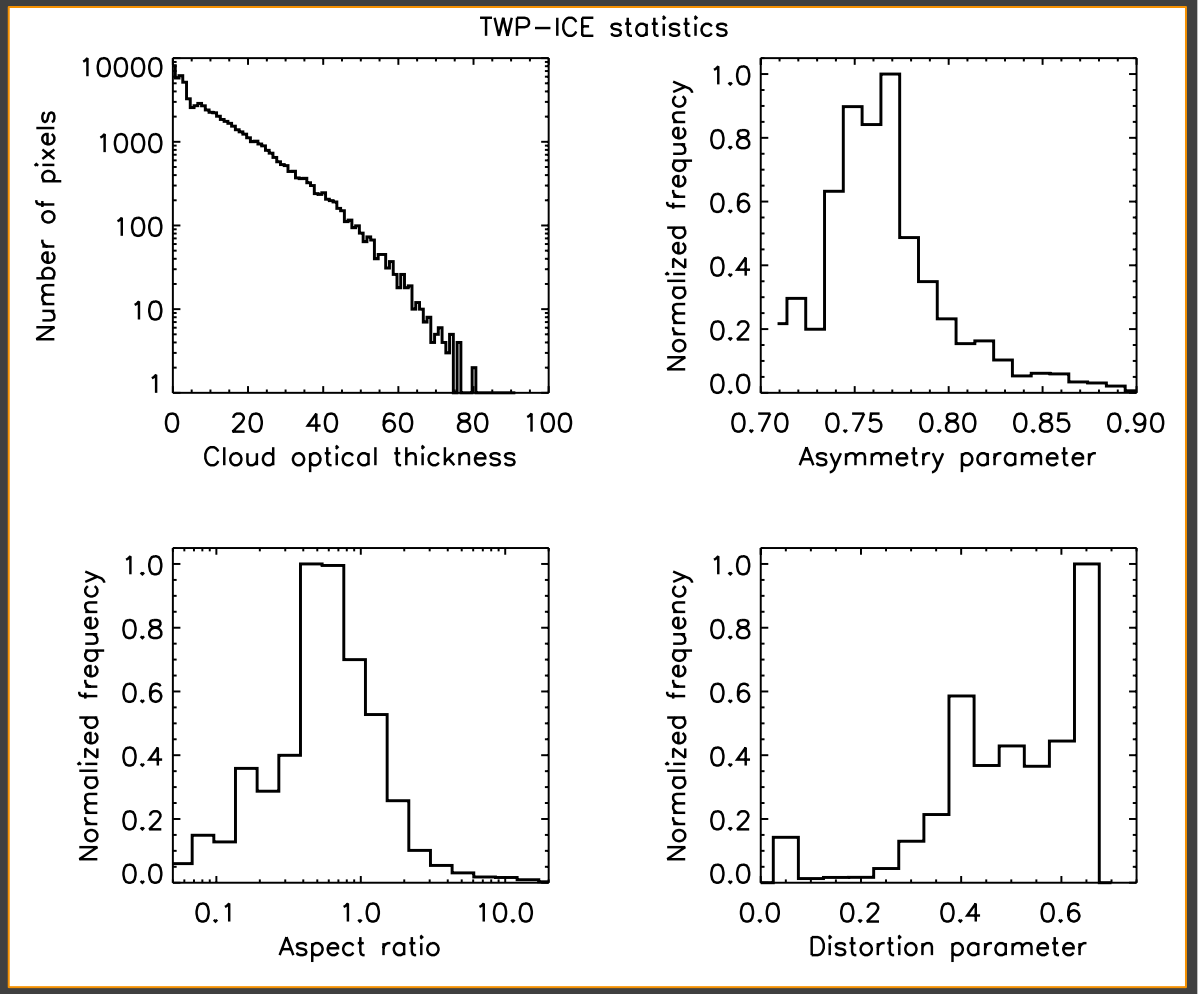
- ARM/NASA campaign in early 2006
- Sampling Asian monsoon in Northern Australia
- Here MODIS/POLDER data collected for extended period: 16 Jan.-20 Feb.





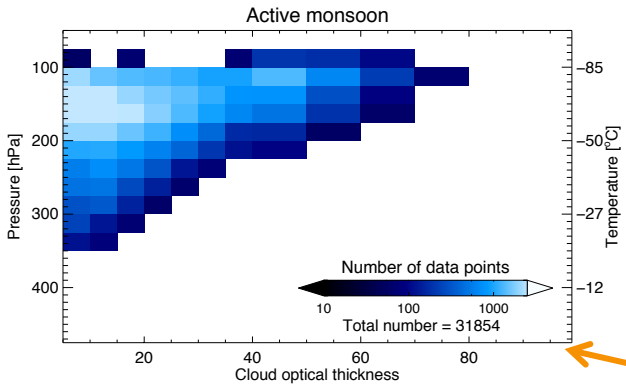
POLDER retrieval statistics COT>5

- ONLY retrievals for COT>5
- Asymmetry parameter
  - ~0.75-0.78
- Aspect ratio
  - ~0.4-0.7
  - Mostly plate-like
- Distortion
  - ~0.4-0.7 (rough-severely rough)

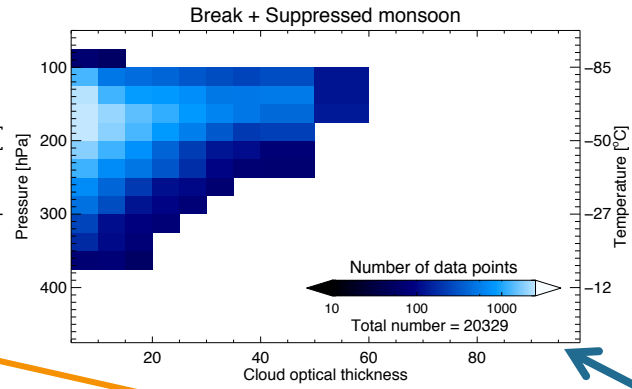


A more detailed look at statistics

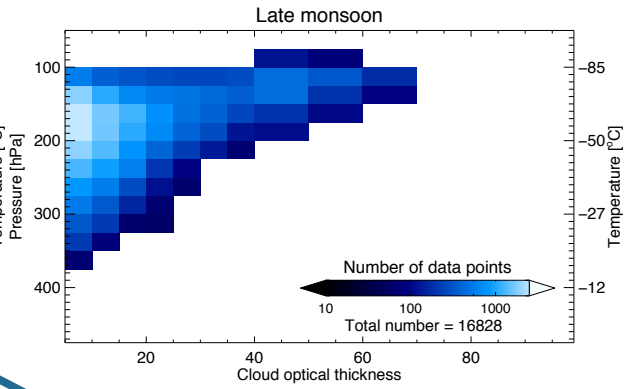
2006/01/16 – 2006/01/23

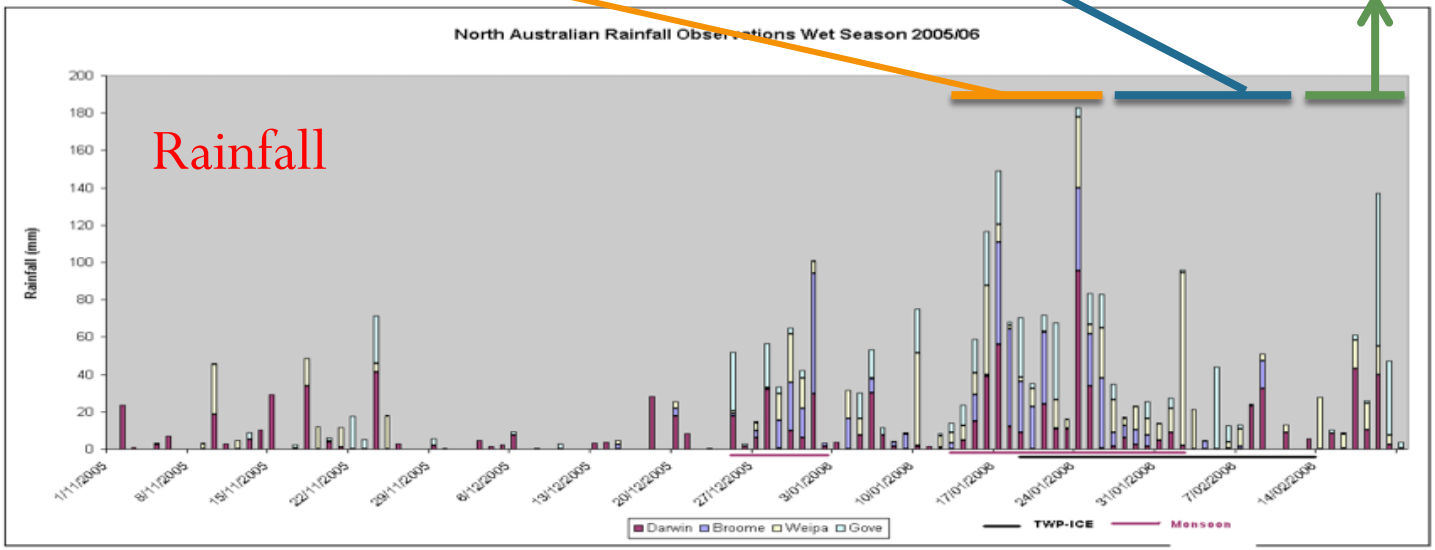


2006/01/25 – 2006/02/13



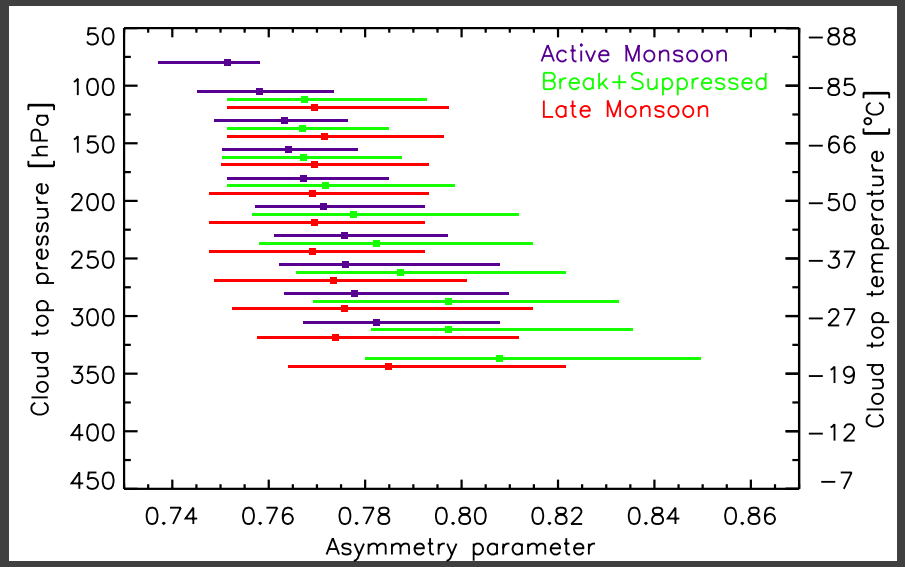
2006/02/14 – 2006/02/20

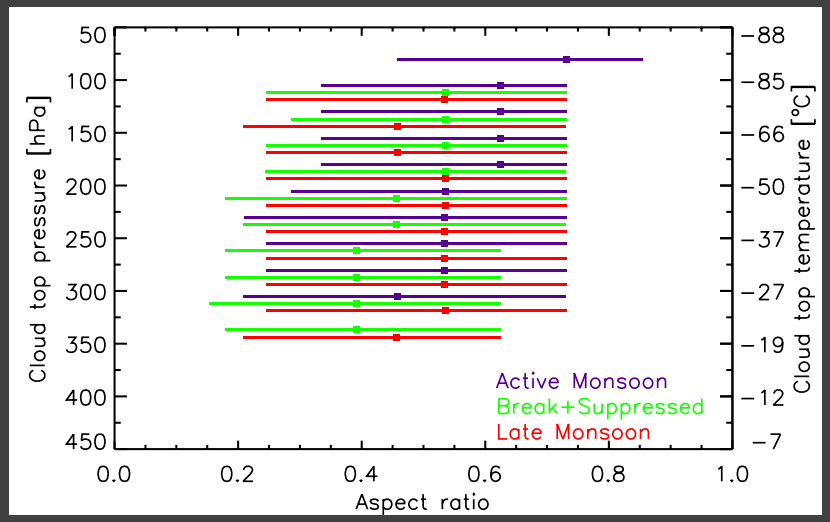


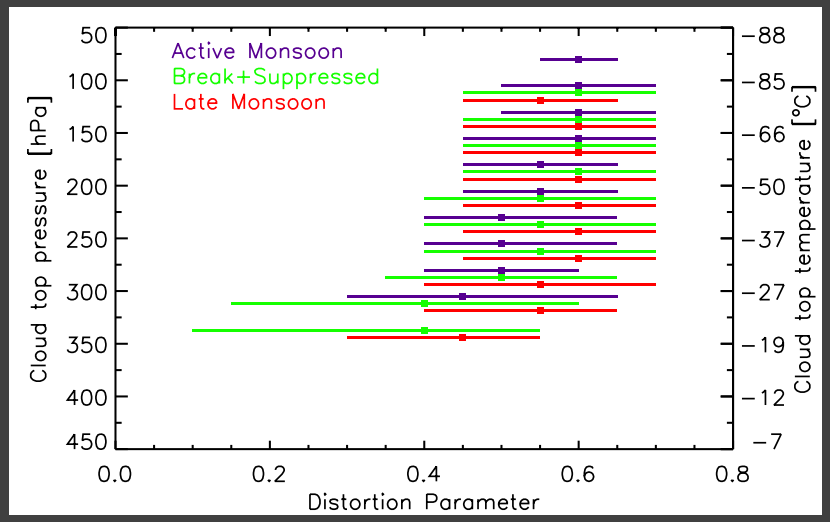


Vertical profiles

- Median values and IQR
- With increasing height
  - decreasing g
  - increasing aspect ratio
  - increasing distortion
- Profiles depend on atmospheric condition

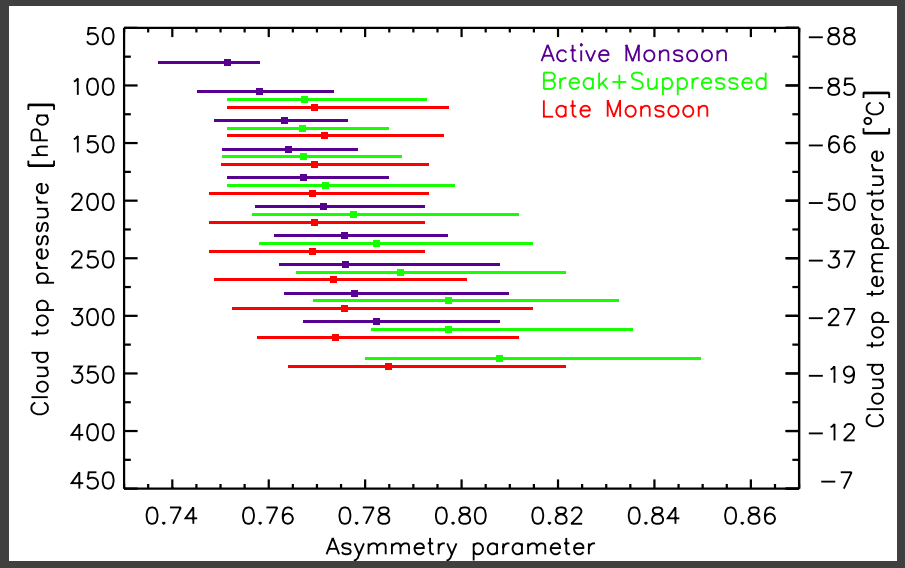




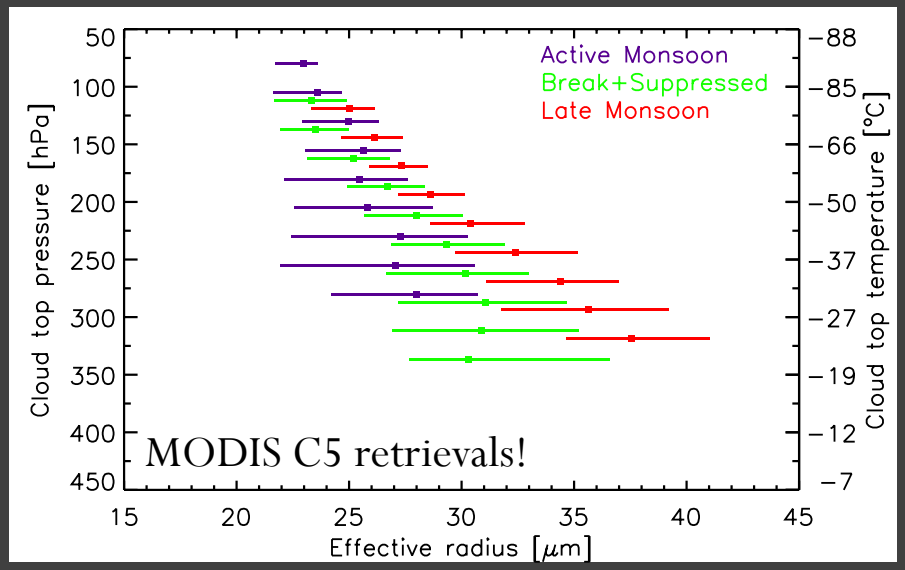


Vertical profiles g and R_{eff}

- With increasing height
  - decreasing g
  - decreasing R_{eff}
- Profiles depend on atmospheric condition



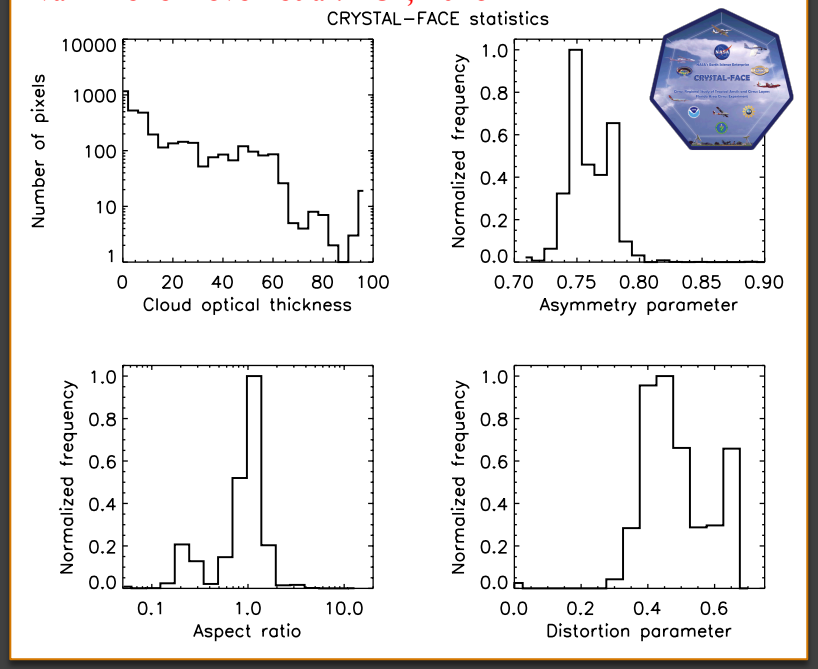
- C5 R_{eff} biased by 1-5 micron due to high g assumed!
- Part of R_{eff} profile could explained by g profile

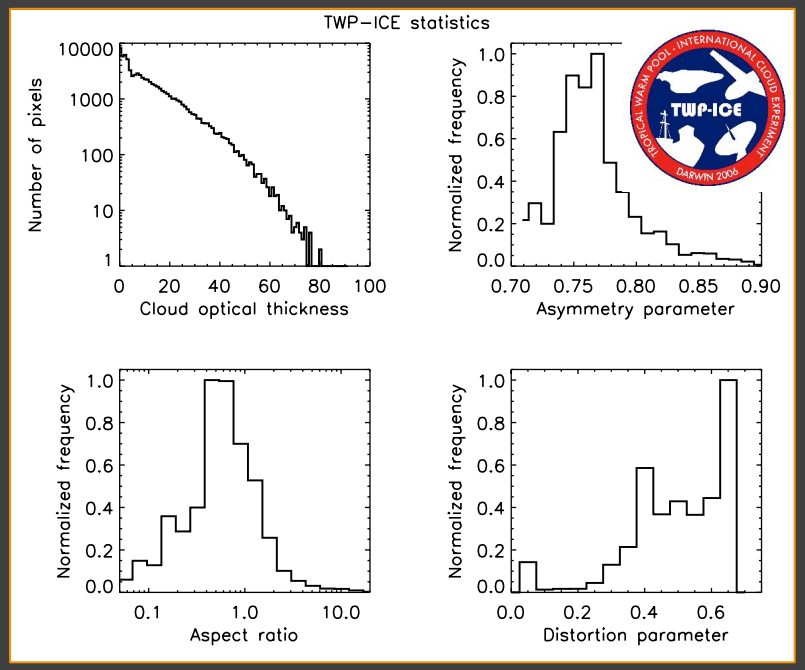


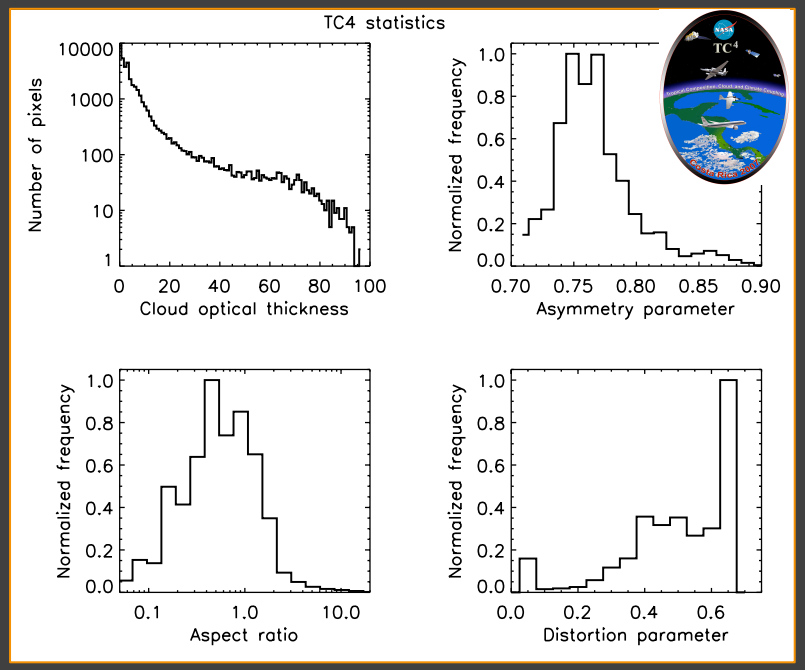
TWP-ICE, TC4 & CRYSTAL-FACE

- Deep convection (COT>5)
  - g~0.75-0.79
  - Aspect ratios ~0.2-1.2
  - Distortion ~0.4-0.7

From 4 case studies using airborne RSP!
Van Diedenhoven et al. ACP, 2013







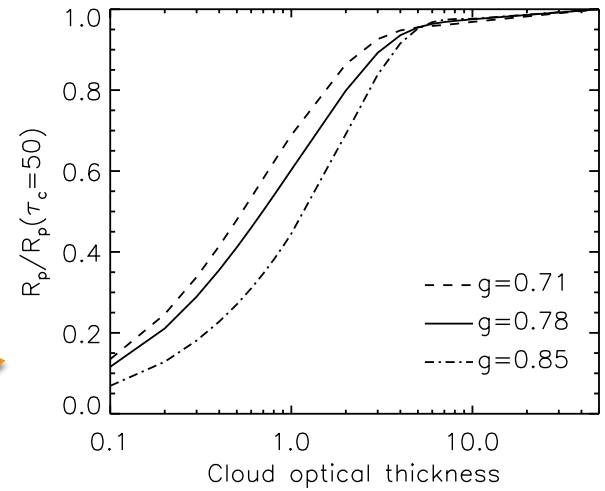
Future work

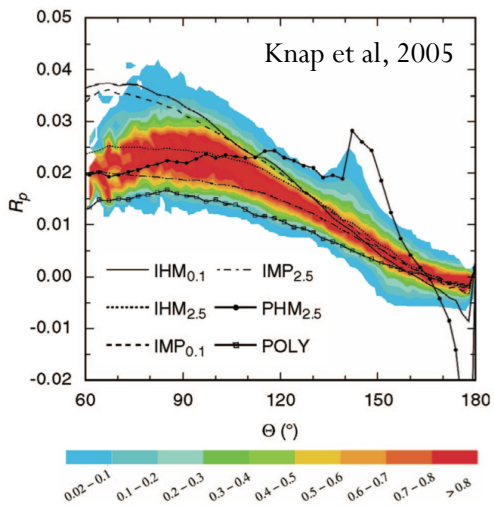
- POLDER retrievals for unsaturated polarized reflection (COT<5)
  - Proper surface
  - Rayleigh
- Effective radius retrievals based on retrieved asymmetry parameters
- Speed up algorithm
- Global MODIS/POLDER retrievals
- Validation studies using new processing techniques for in situ CPI images (Greg McFarquhar)

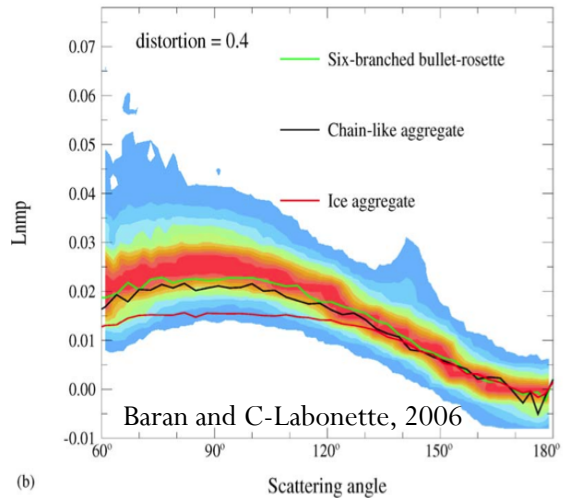
Caution! Thick cloud bias?

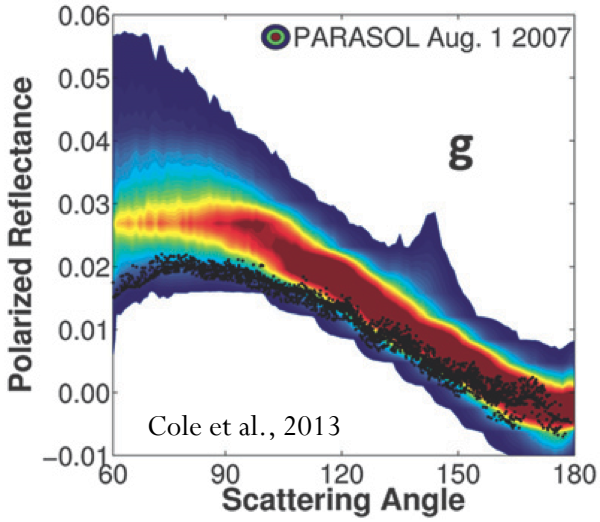
- Previous global POLDER analysis
  - show narrow range of polarized reflectance
  - assume saturation of polarized reflectance
- But Rp only saturates at COT~5
- Where are all the cloud COT<5 ??

Polarized reflectance at scattering angle 120° for specified COT vs saturated value







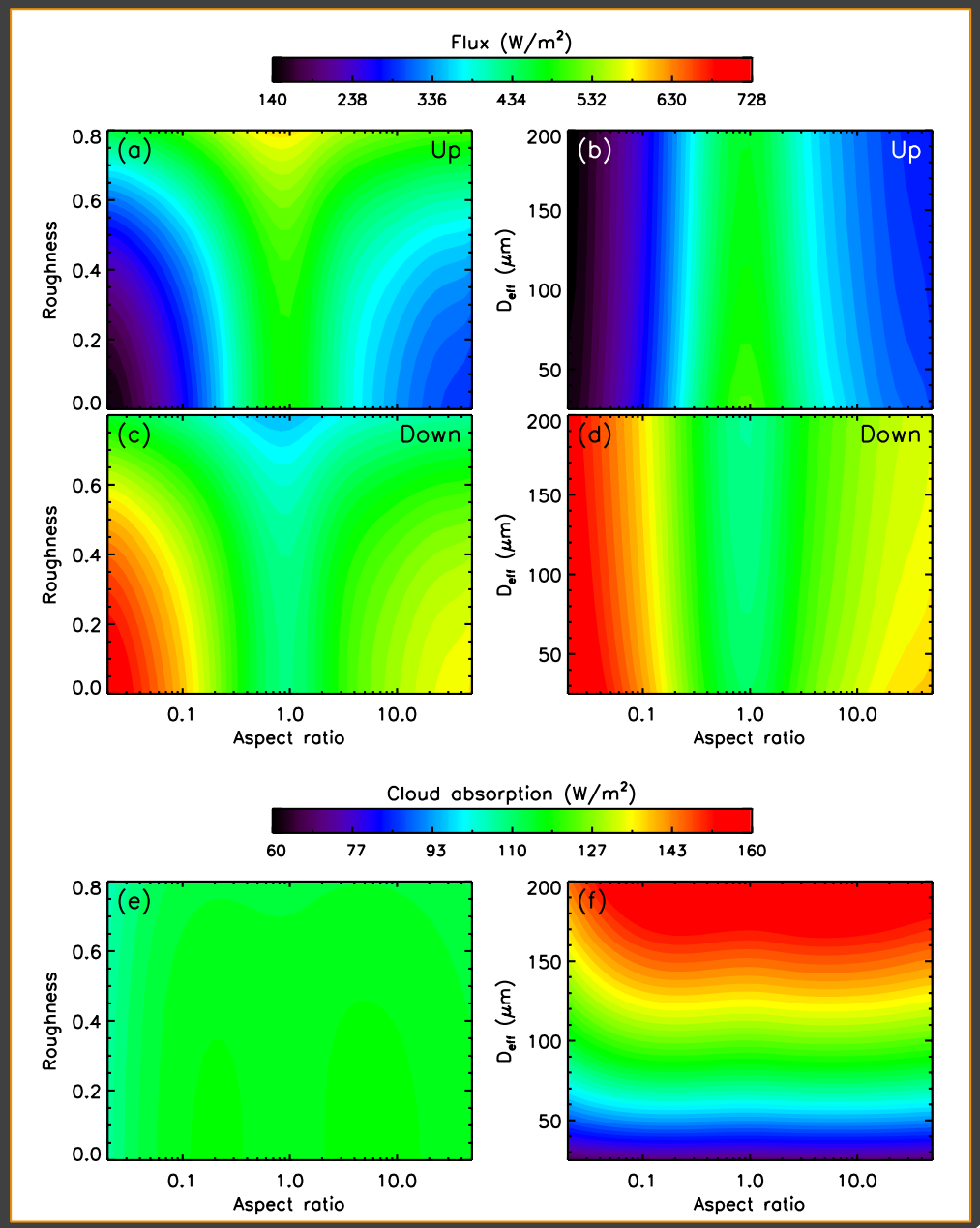



DANGER
EJECTION
SEAT
DRYDEN
FLIGHT RESEARCH CENTER

Backup slides

Shortwave flux

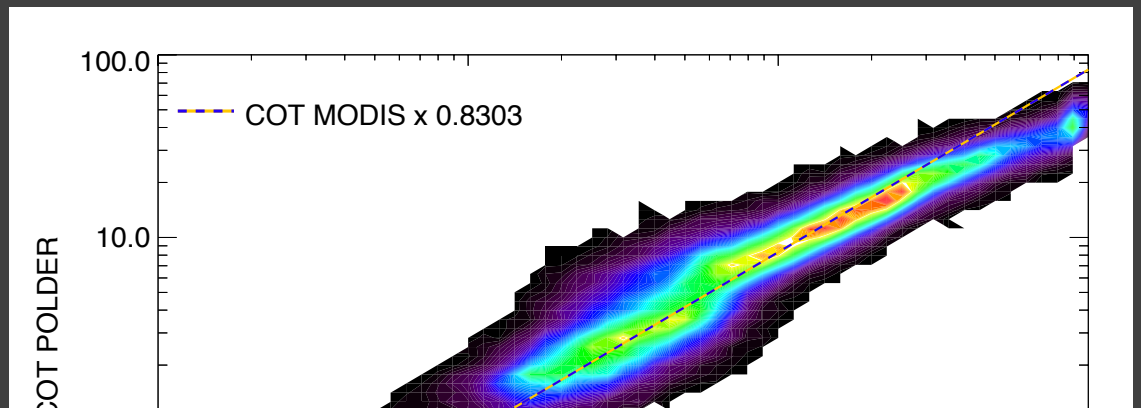
- Cloud optical thickness =4
- Cloud between 10-11 km
- SZA=60 degrees

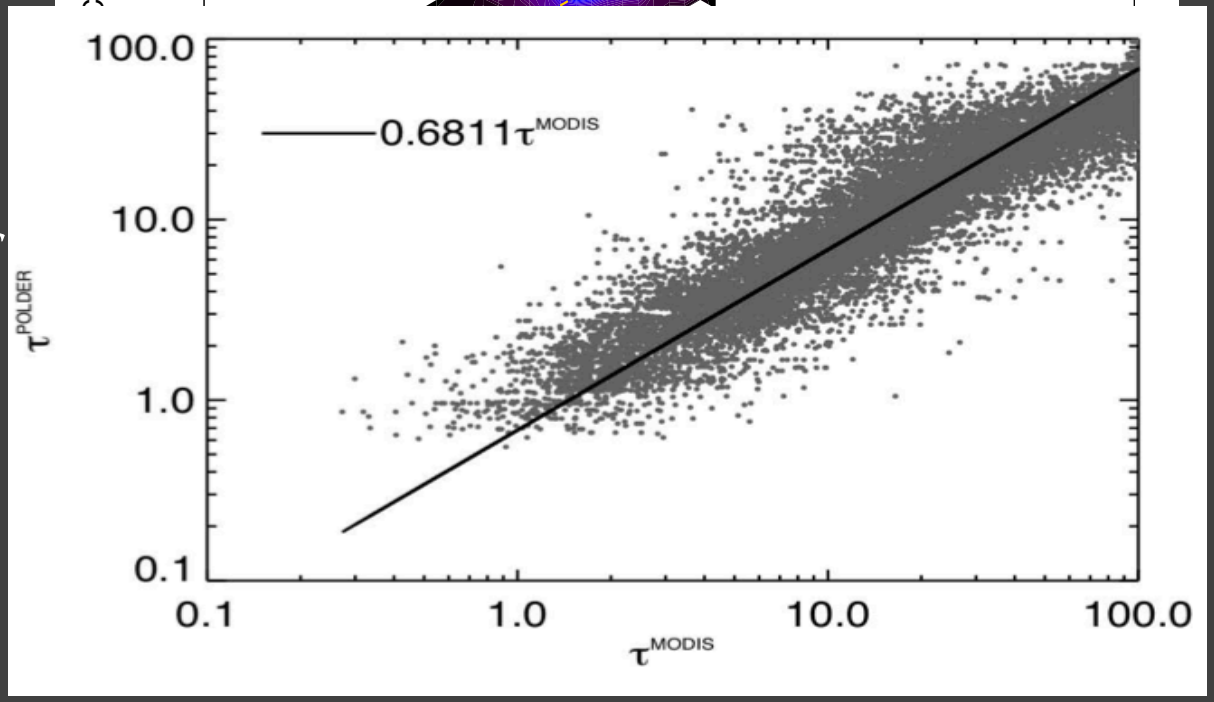


From "An accurate and flexible parameterization for shortwave optical properties of ice crystals", van Diedenhoven et al., in preparation

POLDER vs MODIS C5 optical thickness

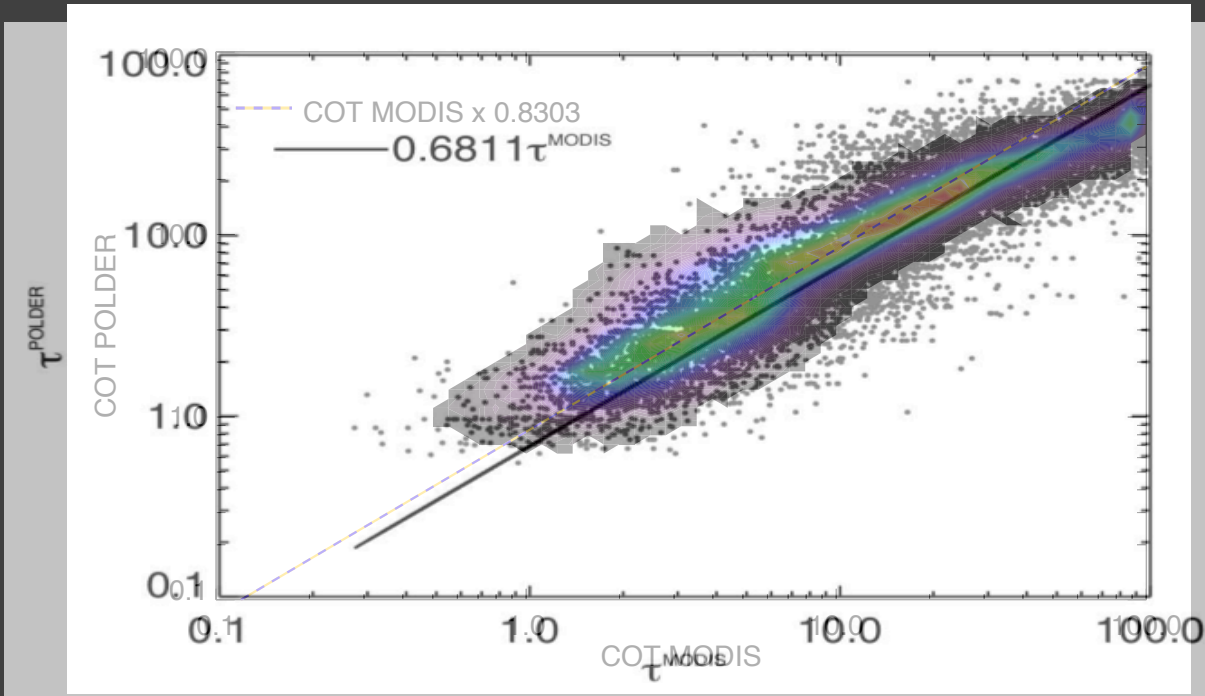
- MODIS C5 biased high by ~0.83
  - Makes sense: (1-0.77)/ (1-0.82)= 0.78
- Thick clouds have stronger bias!
- Similar to results of Zhang et al. 2009



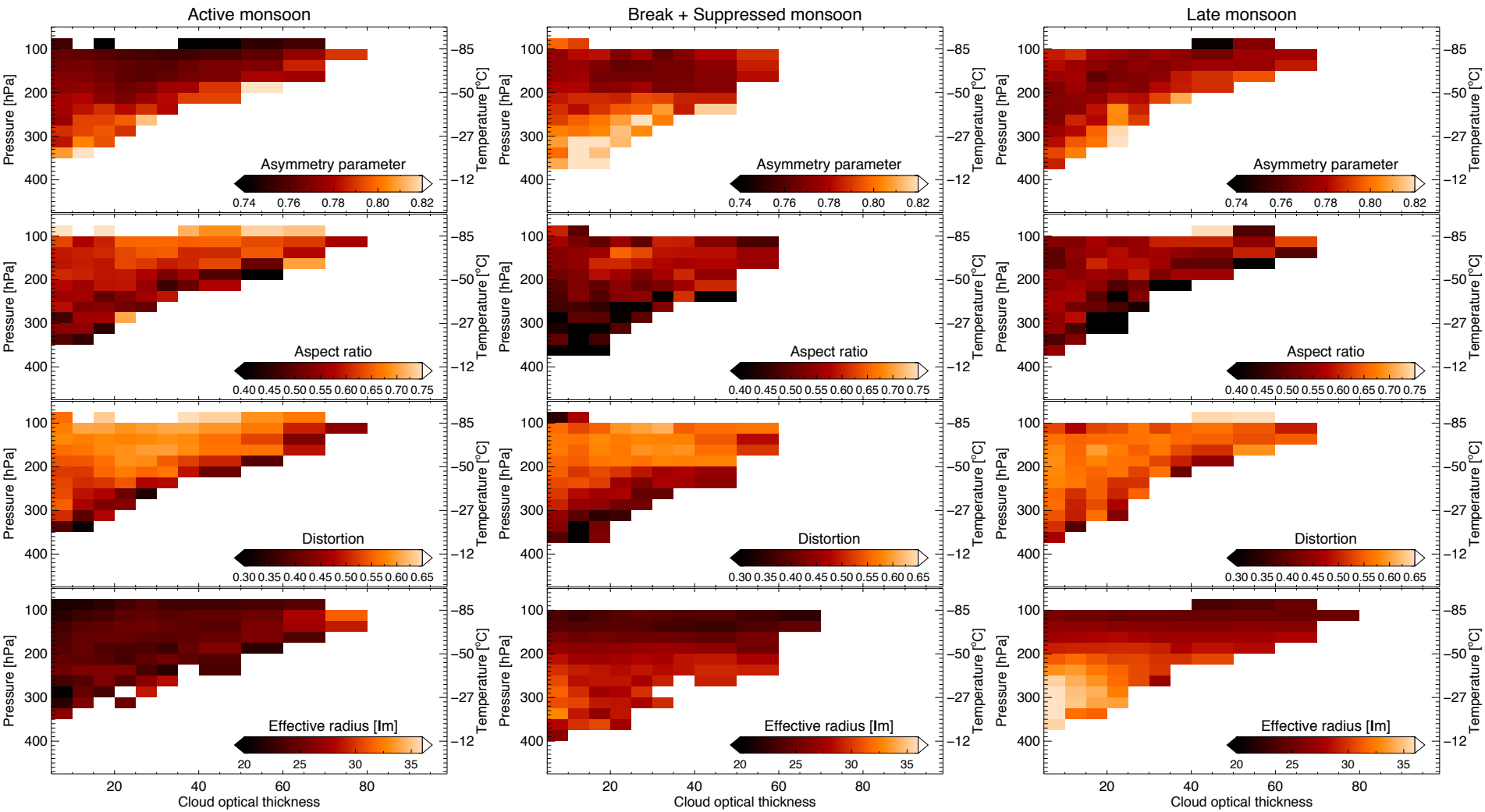


POLDER vs MODIS optical thickness

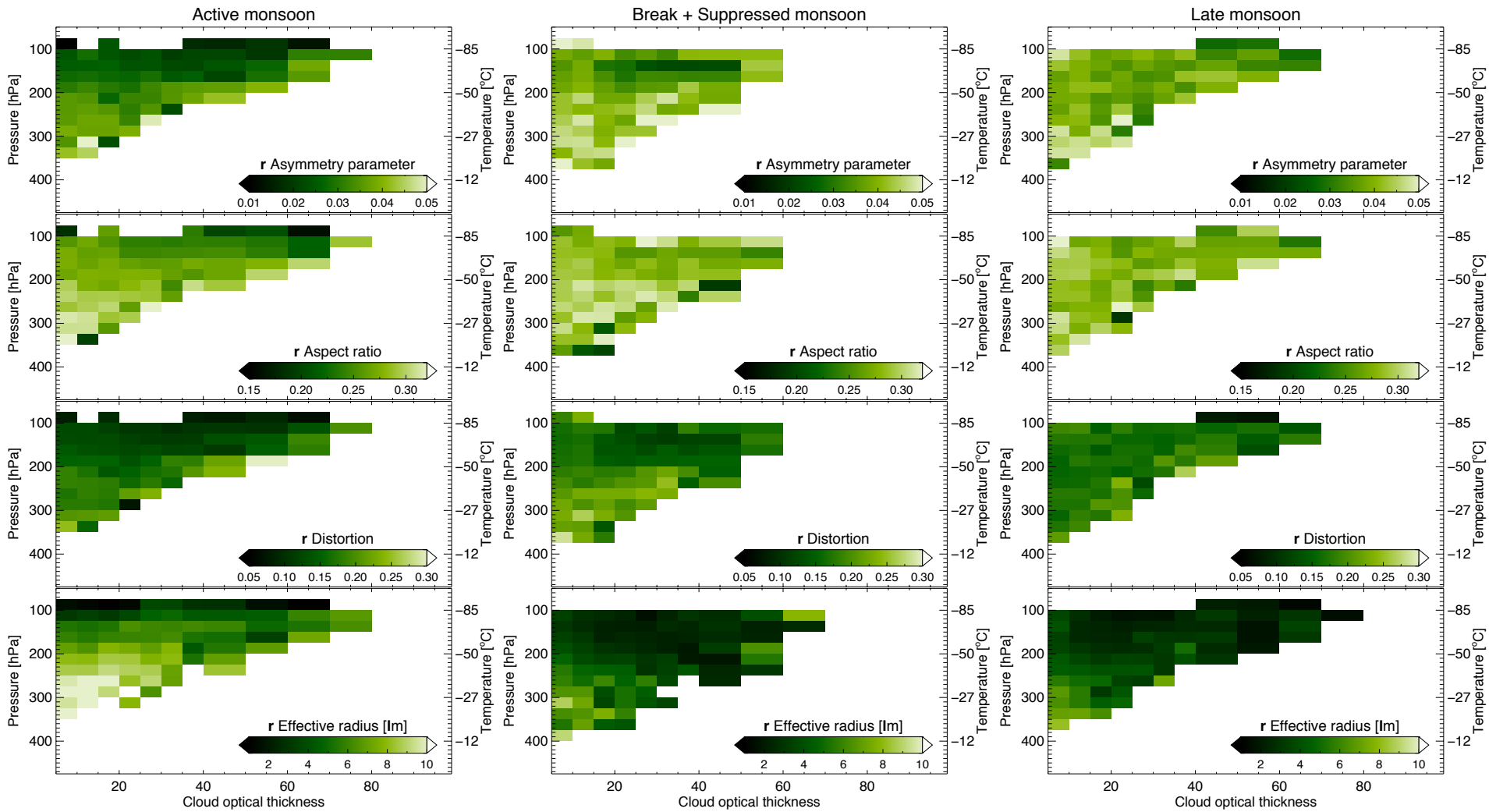
- Zhang et al. 2009 compares POLDER level-2 product to MODIS C5
- Level-2 uses g=0.74
  - (1-0.74)/(1-0.82)= 0.69

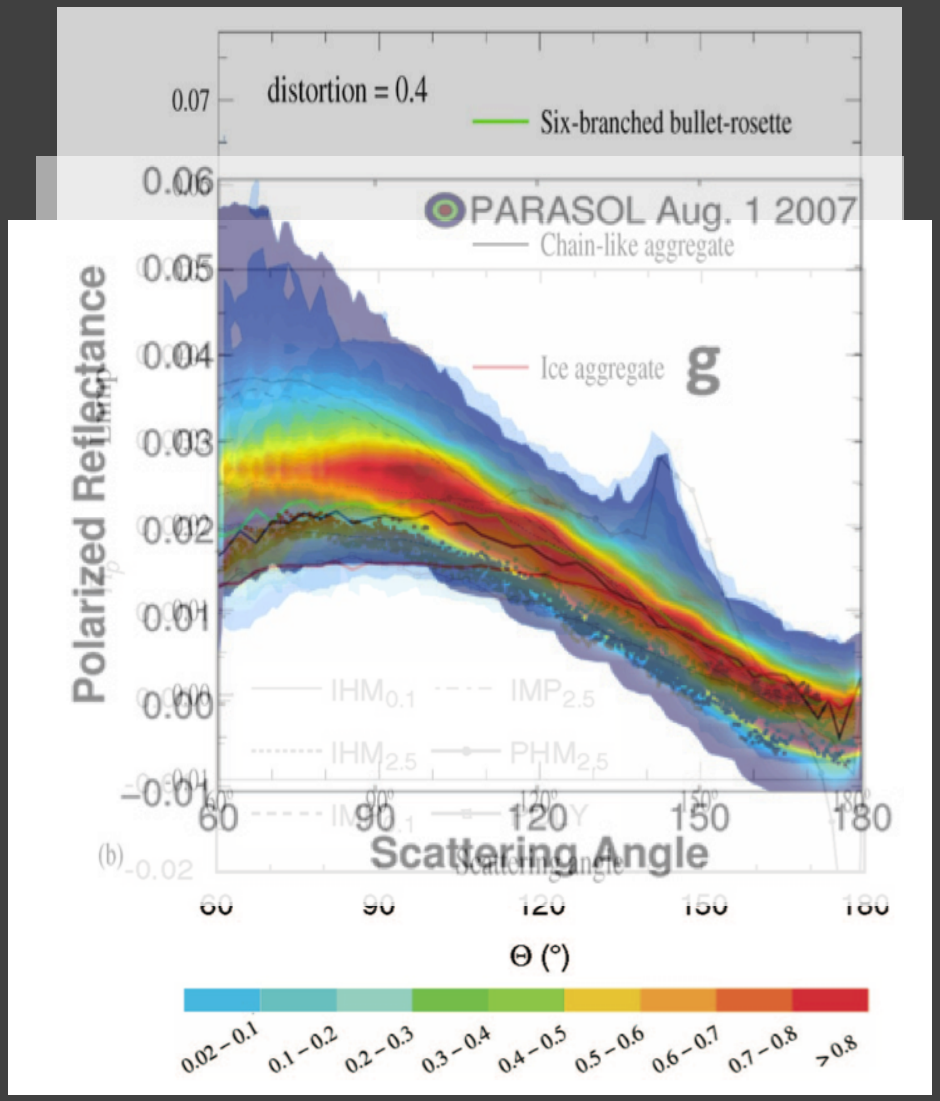


Retrievals mean



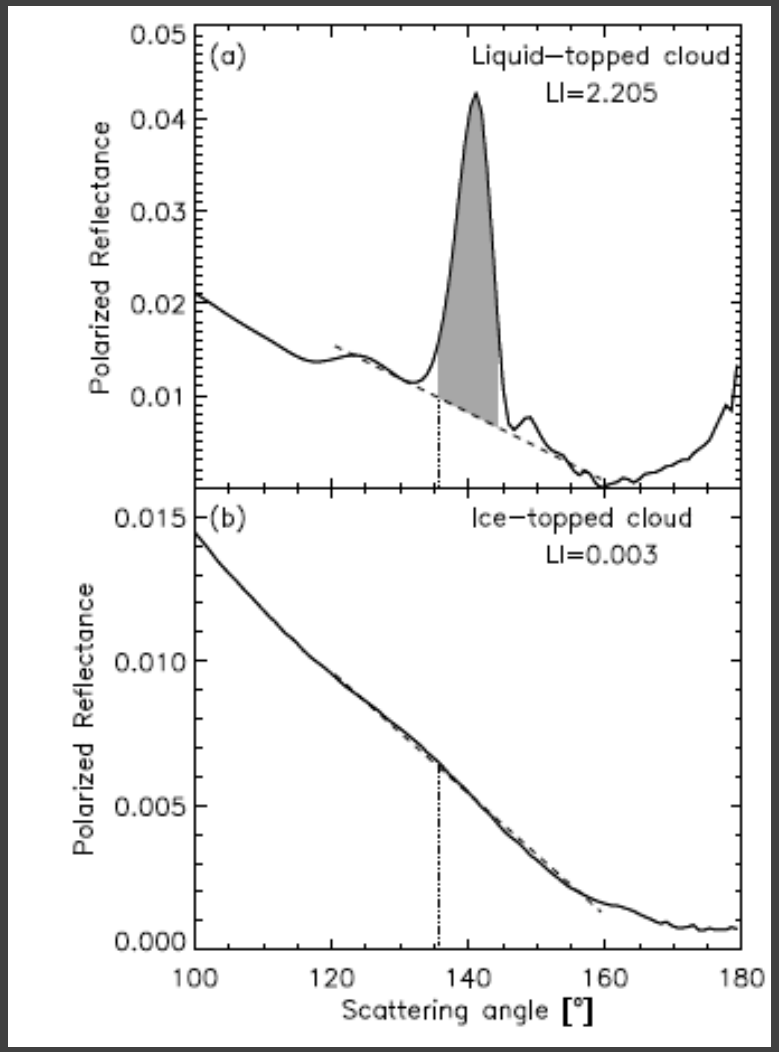
Retrievals standard deviation




distortion = 0.4
Six-branched bullet-rosette
PARASOL Aug. 1 2007
Chain-like aggregate
Ice aggregate
g
Polarized Reflectance
Scattering Angle
Θ (°)
0.02 – 0.1
0.1 – 0.2
0.2 – 0.3
0.3 – 0.4
0.4 – 0.5
0.5 – 0.6
0.6 – 0.7
0.7 – 0.8
> 0.8

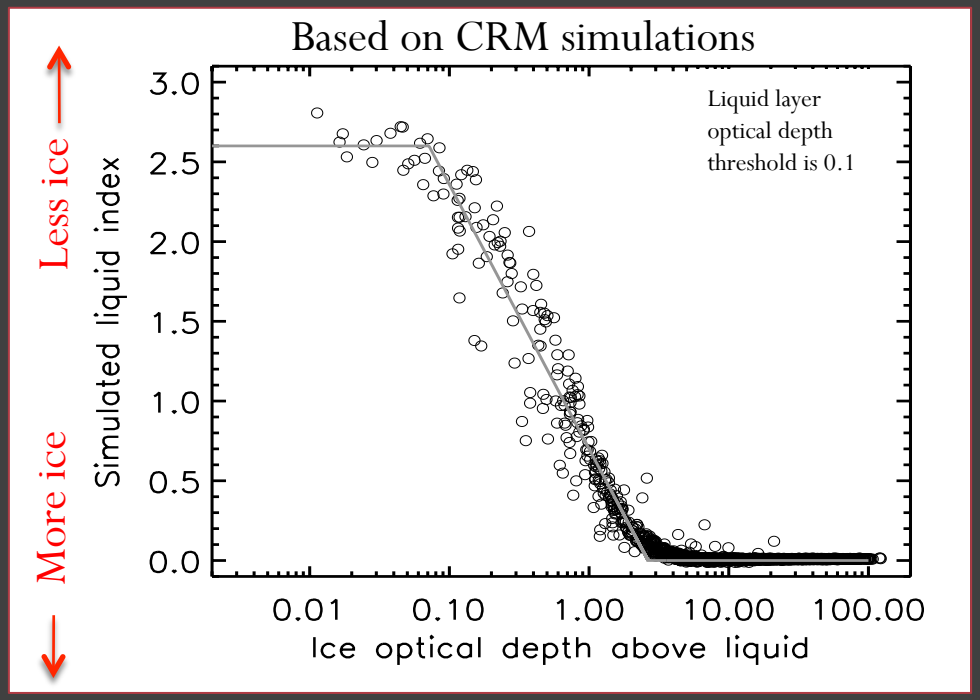
POLDER Liquid index

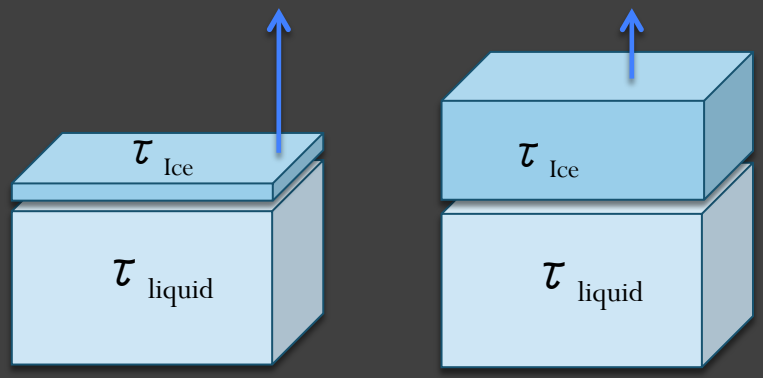
- Fit straight line through 120º-160º measurements
- Ice index = Mean(|fit-measurement|)
- Straight-forward to simulate from model



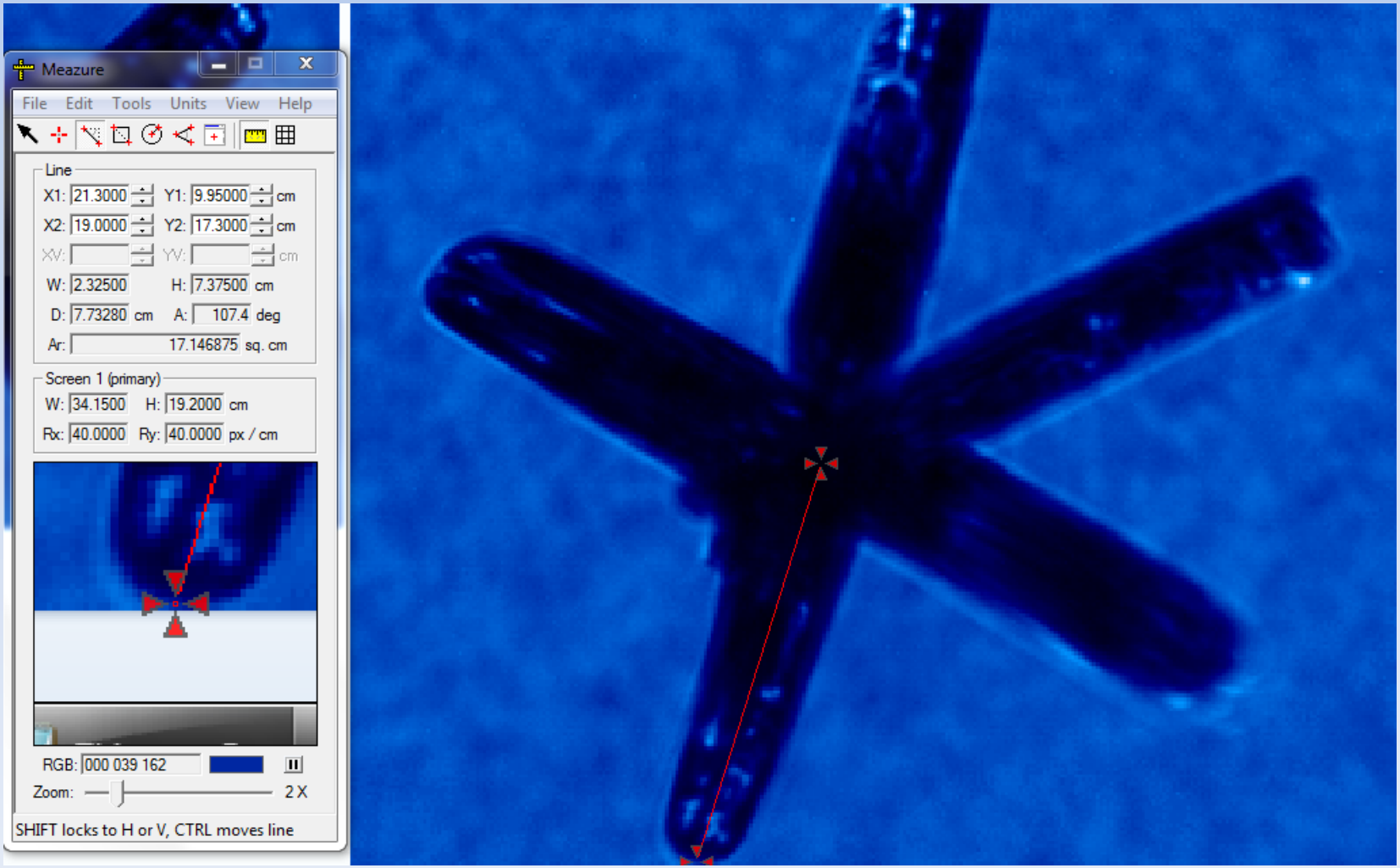
Physical interpretation of liquid index

- Liquid index
  - Indicates to what degree liquid is *obscured* by ice above
  - ~2-3 for pure water clouds
  - ~0 for pure ice clouds or ice *topped* clouds





Determining Aspect Ratios from CPI (McFarquhar et al.)



Determining Aspect Ratios from CPI (McFarquhar et al.)