The Hazy Space Between Cloud and Aerosol

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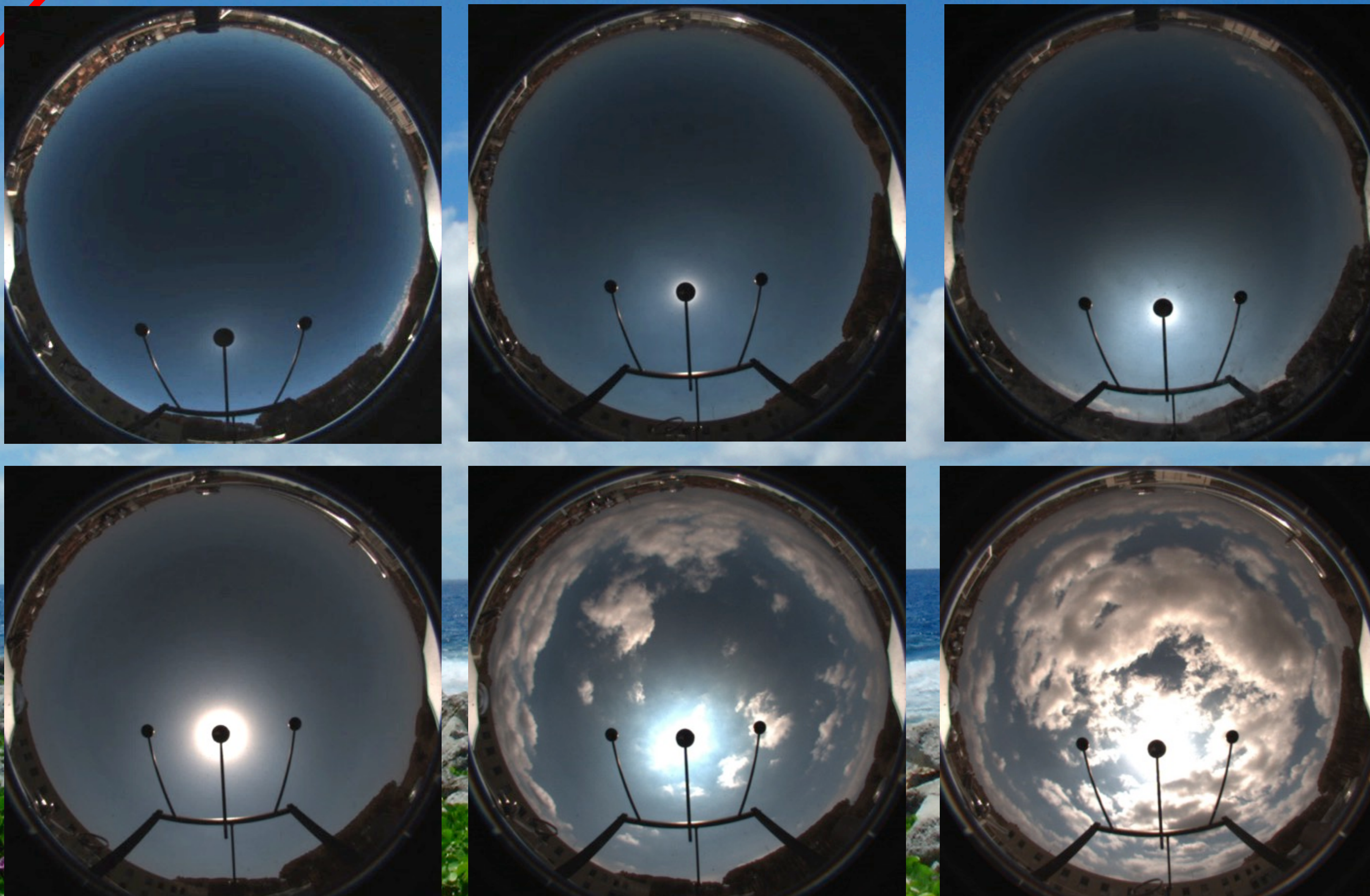
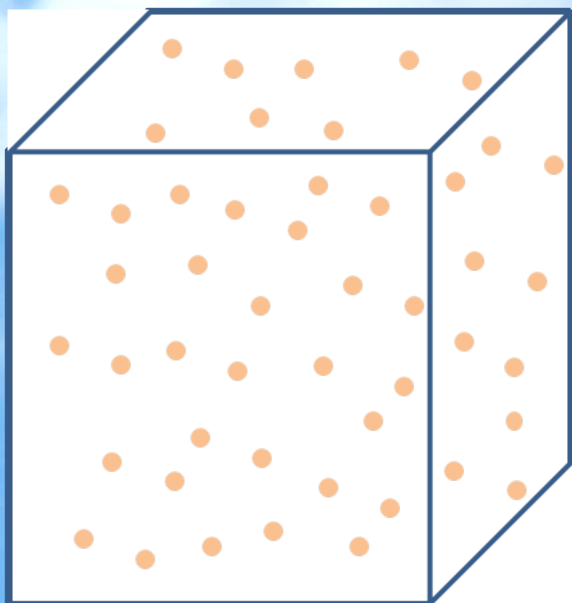
Paper in Review:

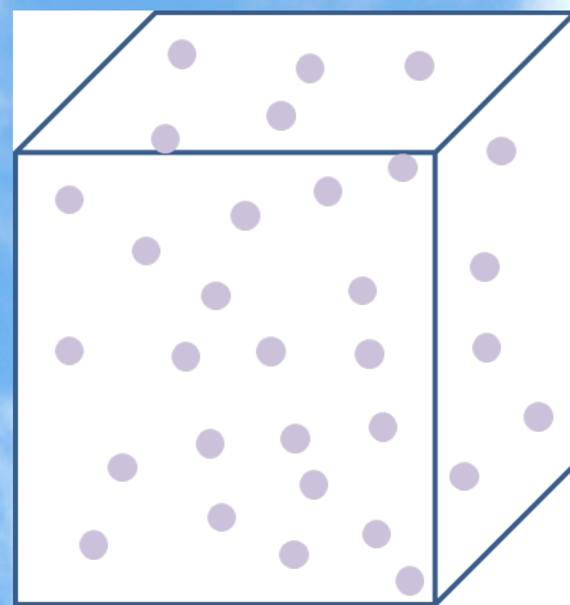
- **Josep Calbó, Charles N. Long, Josep-Abel González, John Augustine, Allison McComiskey (2017): *"The thin border between cloud and aerosol: sensitivity of several ground based observation techniques"*, Submitted Atmospheric Research, January 2017.**

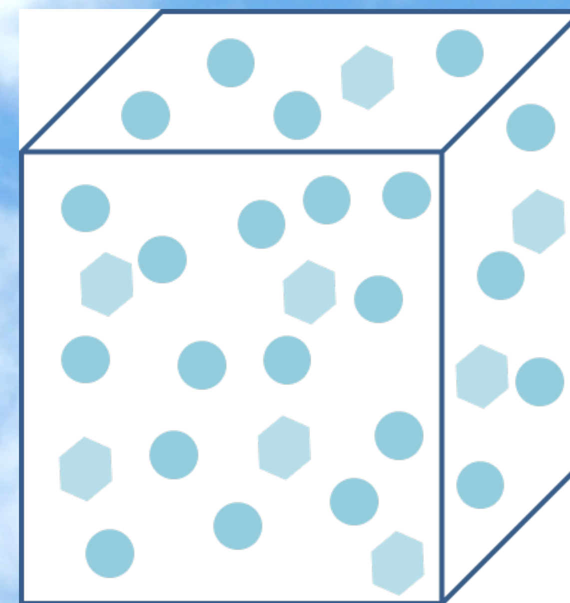
Some examples



Aerosol and cloud: suspensions of particles in the air







<u>Aerosol:</u>

< 1 μm
Diverse composition
Solid particles

<u>Transition, twilight, continuum (haze, hydrated aerosol, smog,...)</u>

Previous works by Koren, Charlson, Marshak, Chiu, Hirsch, Varnai, Feingold,...

<u>Cloud:</u>

> 5 μm
Mostly water
Liquid or solid

Goals and questions

Goal: to quantify the importance and frequency of situations where ambiguity between clouds and aerosol occur.

1. **How often do we observe situations where the suspension of particles may be classified as either cloud or aerosol depending on a subjective definition/threshold?**
   - **How much of the sky includes this phenomenon?**
2. **What are the radiative effects of these “transition zones”?**
3. **How similar (or different) are the radiative effects of an aerosol layer compared with a similarly optically thin haze/cloud?**

Methods

1. Observations
   – Sky cameras + image processing
   – Pyranometers + Radiative Flux Analysis
   – MFRSR + cloud “screening”
   – Change thresholds (strict and relaxed)
   – Girona, Spain + Table Mountain, CO
2. Radiative transfer computations
   – SBDART
   – LBLRTM → RRTM_SW
   – Explore conditions at the boundaries of aerosol and cloud descriptions

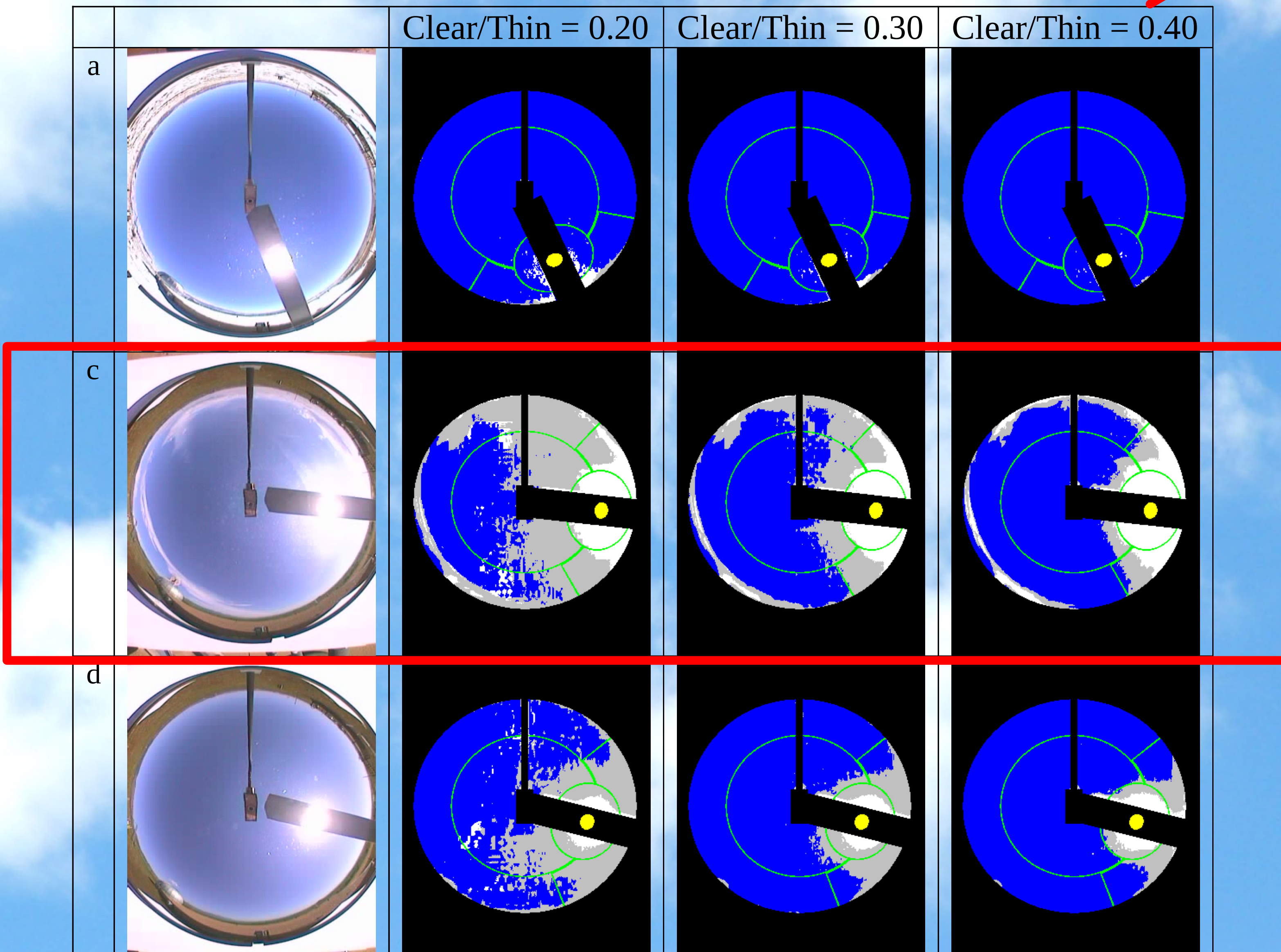
Transition zone: defined by comparing the screened points when applying "strict" or "relaxed" thresholds

Sky Image Processing

- Technique uses the ratio of red over blue pixel color level
  - Blue sky is small ratio
  - For white, ratio approaches "1"
- A "baseline" across the typical cloud free images is used
- User adjusts clear/thin and thin/opaque limits which are percentages above the baseline
- This work adjusts the clear/thin limit

Results: Sky cameras

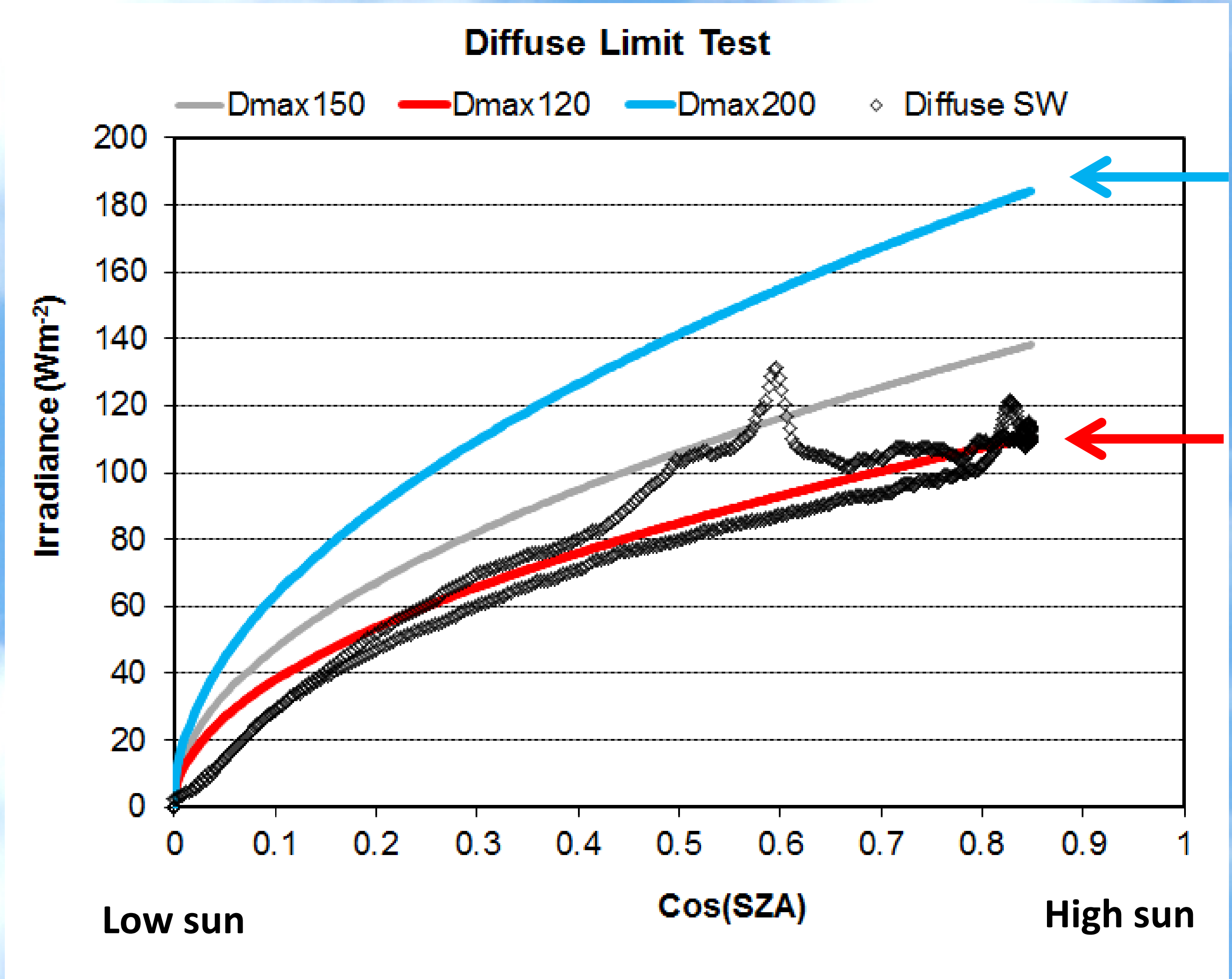
Smaller limit = more cloud **0.20** **0.30** **0.40**



Radiative Flux Analysis (RadFlux)

- **Detection of clear skies uses a limit on the amount of diffuse shortwave irradiance allowed**
- **$D_{lim} = D_{max} \text{ X } Cos(SZA)^{0.5}$**
  - **Set "D_{max}" as the limit**
- **A larger limit allows more "haze" to be classified as "clear sky"**
- **The all-sky minus clear-sky diffuse difference is used to infer fractional sky cover (fsc)**
  - **Thus the clear-sky diffuse magnitude affects retrieved fsc magnitude**

Diffuse Magnitude Test

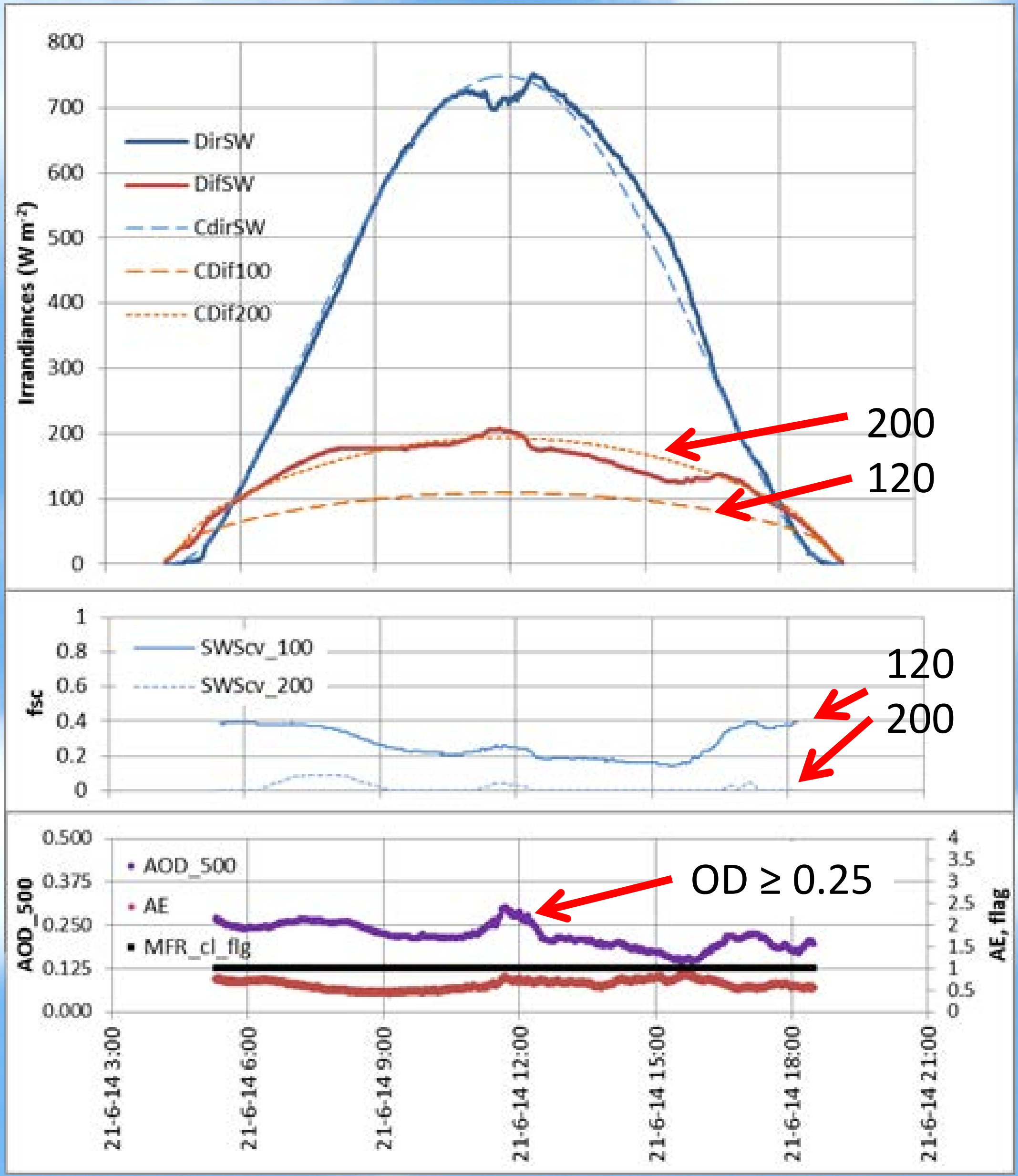


D_{max} 200 allows all to be called "clear"

D_{max} 120 allows only pristine morning and late afternoon to be called "clear"

Long CN and TP Ackerman. 2000. "Identification of Clear Skies from Broadband Pyranometer Measurements and Calculation of Downwelling Shortwave Cloud Effects." Journal of Geophysical Research 105(D12): 15609-15626.

Results: RadFlux, D_{max} = 120 & 200 Wm^{-2}



MFRSR Retrievals

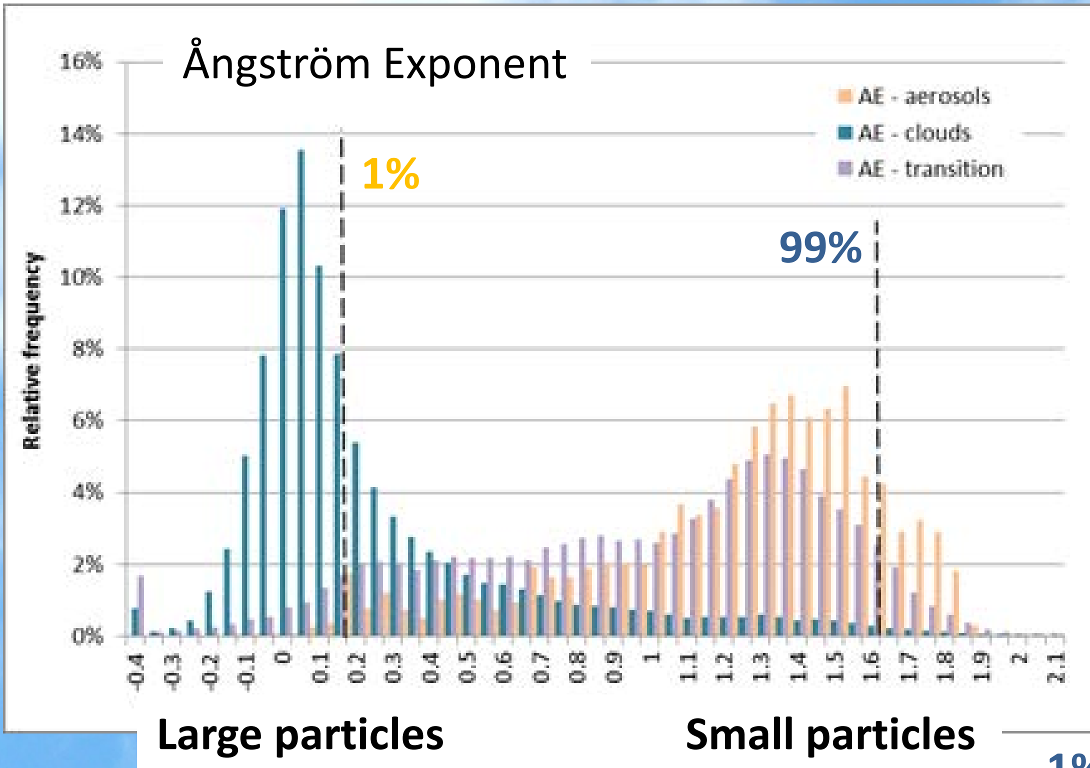
- MFRSR measures irradiance in 7 narrow visible and near IR spectral wavelength bands
- Each channel direct irradiance is processed relative to corresponding TOA values to infer aerosol optical depth (after accounting for molecular scattering and trace gas absorption)
- Screening for “cloud contamination” uses the OD variability through time
  - Allow smaller variability = “strict” screening
- The Ångström relationship uses the relative differences of optical depth across the wavelengths
  - Smaller Ångström Exponent is associated with larger particles

Results: MFRSR

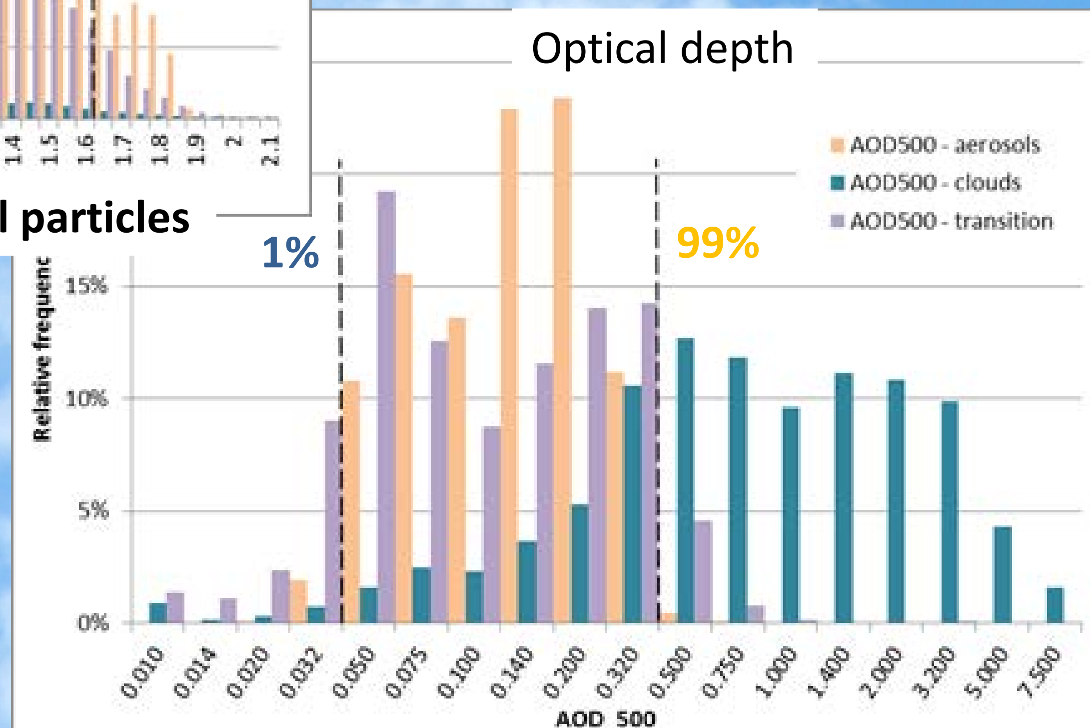
Aerosols

Clouds

Transition



Aerosols tend to have smaller optical depths (0.03-0.4), clouds have larger (0.15-7.5), transition more similar to aerosols



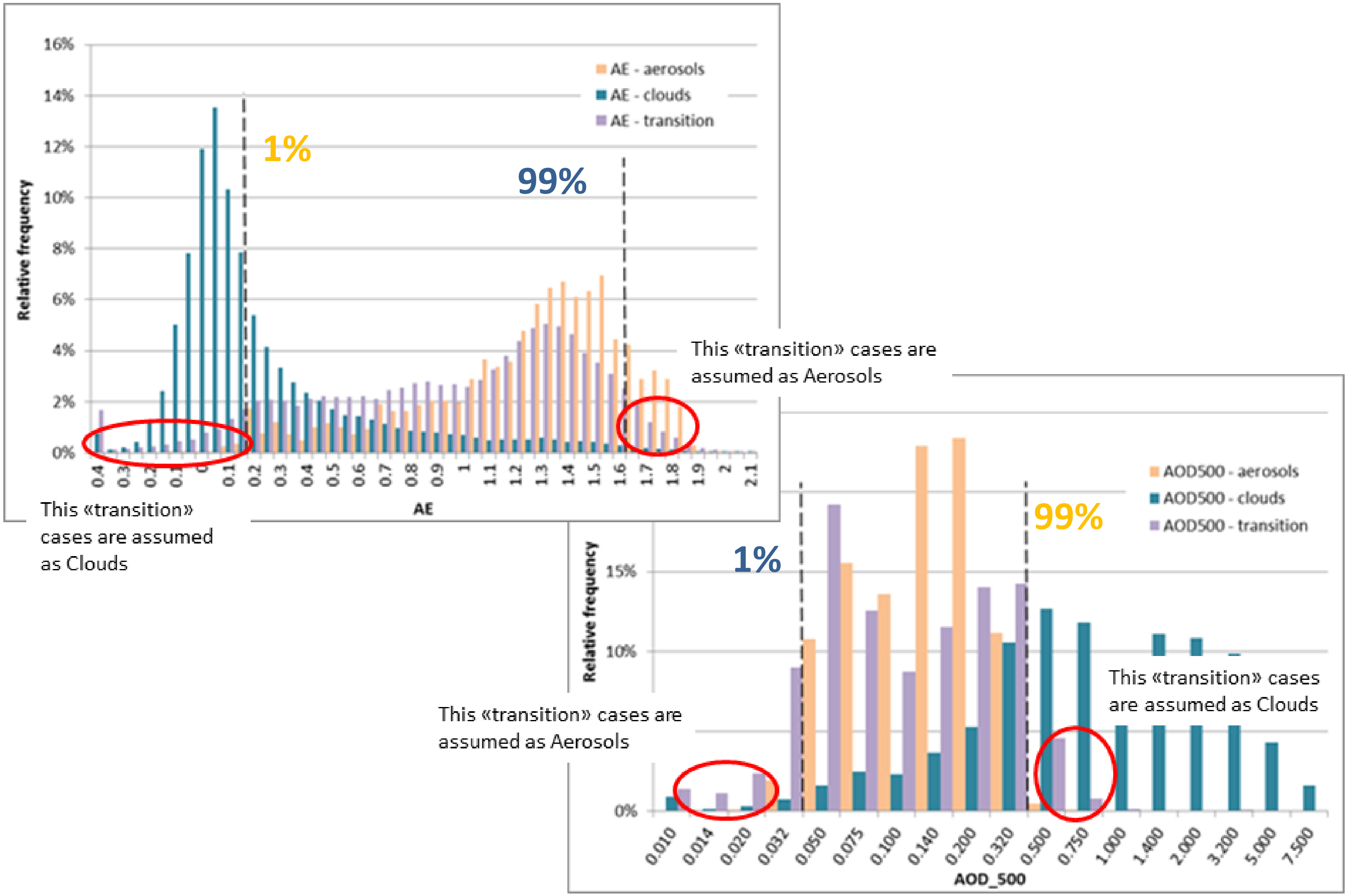
Aerosols tend to have smaller particles, clouds have larger particles, transition shares aspects of both but slanted toward smaller particles

Strict vs Relaxed Results Summary

	GIR	TMT	
Sky Cameras			
	13%	15%	Images with difference in fsc > 0.1 (thin clouds / aerosol) [20% for non-overcast cases]
Flux Analysis			
	4.9%	7.3%	Difference in the number of daylight minutes detected as clear
	14%	16.5%	Minutes with difference in fsc > 0.1 (thin clouds / aerosol)
MFRSR			
	19%	28%	Records considered cloud or aerosol depending on the “strictness” of the screening.
	14%	11%	Same as above but “cutting tails.”

“Cutting tails”

Results. MFRSR



Strict vs Relaxed Results Summary

	GIR	TMT	
Sky Cameras			
	13%	15%	Images with difference in fsc > 10% (thin clouds / aerosol) [20% for non-overcast cases]
Flux Analysis			
	4.9%	7.3%	Difference in the number of daylight minutes detected as clear
	14%	16.5%	Minutes with difference in fsc > 10% (thin clouds / aerosol) [>20% for non-overcast cases]
MFRSR			
	19%	28%	Records considered cloud or aerosol depending on the "strictness" of the screening.
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Thanks for listening… chuck.long@noaa.gov

EXTRA

Results: MFRSR Screening