The Accuracy of Retrieved Cloud Properties Impacted by Systematic Error

By Leandra Merola
Mentor – Odele Coddington
Why Study Clouds?

• They are pretty to look at!
• “Knowledge of cloud properties, including their spatial and temporal variability, is needed for understanding and quantifying the role of clouds in climate variability and for modeling clouds and their effects in climate and weather models.” (Vukicevic, et al. 2010)
Most importantly clouds effect our climate.
Irradiance – is the amount of radiation emitted from an object integrated over the hemisphere. It is measured in \( \text{W m}^{-2} \text{ nm}^{-1} \).

Albedo – a measure of the reflectivity of an object. (upwelling irradiance/downwelling irradiance.)
Inputs for Forward Model

- Cloud: Mie theory ($\omega$, $g$, $\tau$)
- $r_i$, $\tau_i$
- Absorbing Gases: $O_3$, $O_2$, $H_2O$
- atmospheric conditions $P$, $T$, $RH$
- Top of atmosphere irradiance
- surface spectral albedo
- Modeled albedo – Effective radii: $1\, \mu$m (solid lines), $30\, \mu$m (dashed lines)
- Optical thickness increases from blue to red

Tables of spectral irradiance for $r_i$, $\tau_i$ pairs

Graphs showing:
- Downwelling Irradiance

Graphs of Albedo vs. Wavelength (nm)
Retrieval Method

**Modeled Data**
- radiative transfer model
- tables of spectral irradiance

**Measured Data**
- SSFR (Solar Spectral Flux Radiometer)
- measured spectral irradiance

This method is known as inverse problem solving.

**Best fit** $r_i, \tau_i$

5 retrieval wavelengths
Bias – The Ultimate Enemy

- Overlying absorbing aerosols reduce albedo.
- These aerosols bias the cloud retrieval giving us inaccurate information about the cloud, which could be confused with the indirect aerosol effect.
- Aerosol 1st Indirect Effect – when aerosols physically change cloud microphysical properties and therefore change its albedo.
GENRA
(Generalized Nonlinear Retrieval Analysis)

• GENRA is a statistical program that lets us study cloud retrievals from many cloud types with and without systematic error *in an efficient way*.

• GENRA
  – Makes use of the pre-existing look up table.
  – Defines pdfs of measured and modeled albedo.
  – Aerosol impact is treated as a systematic error (shift) in the model pdf.
  – Solution pdf is the expected behavior in retrieved cloud properties.
Shannon Information Content

• A formal mathematical theory to quantify the information gained by making a measurement.
• Maximum information content is dependent on resolution of the look up table.
• It’s a scalar.
To Scale or Not to Scale?

- Scaling comes from the chi square statistic formula that determines the best fit, which is the minimum residual.
- Part one of the formula the absolute difference between measured and modeled albedo, weighted towards shorter wavelengths where there is more information about optical depth.
- The second is the absolute difference between scaled measured and modeled albedo, weighted towards higher wavelengths where there is more information about effective radii.

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GENRA Output for Case with No Systematic Error
True(\(\tau, r_e\)) = (40, 15 \text{ micron})
GENRA Output for Case with Systematic Error
True(\tau, re) = (40, 15 micron)
GENRA Output for Case with Systematic Error Using Different Retrieval Wavelengths
True(τ, re) = (40, 15 micron)

2-wavelength retrieval (e.g. satellite)

Optical Depth

Effective Radius

5-wavelength retrieval (e.g. SSFR)

Optical Depth

Effective Radius

24-wavelength retrieval (e.g. future retrievals)

Optical Depth

Effective Radius
Characterizing the Entire Look up Table

3000 \((\tau, r_e)\) pairs were characterized in 4 hours on the Cynewulf cluster using GENRA.
Future Research

• Look at other factors that may cause bias in cloud retrievals such as:
  – Absorbing aerosol mixed within a cloud
  – 3D cloud effects

• GENRA can be used for characterizing any retrieval statistic and to compare retrievals from different instruments.
Questions?