



Developing a Measurement System Uncertainty Framework for Earth Observing Satellites

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The CLARREO mission

- The Climate Absolute Radiance and Refractivity Observatory (CLARREO) is an Earth Observing Satellite mission to provide accurate measurements to substantially improve understanding of climate change.
- CLARREO will include a Reflected Solar (RS) Suite, an Infrared (IR) Suite, and a Global Navigation Satellite System–Radio Occultation (GNSS-RO).
- CLARREO is in the mission formulation phase (Pre-Phase A.)



CLARREO Uncertainty Framework

- ❖ The uncertainty framework is a pre-planning study for CLARREO.
- ❖ Iterative one-year process involves
 - Interviewing and collaborating with formulation manager, project scientist, mission scientist, IR instrument scientist, calibration manager, and research physical scientists.
 - Reviewing mission related materials.



CLARREO Uncertainty Framework

Mission Goals

MG-P Prove the ability to make global and zonal measurements with the accuracy, sampling and information content necessary to:

MG-P1 Detect annual and decadal climate change trends and

MG-P2 Test and improve global climate model predictions.

CLARREO Uncertainty Framework

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Science Objectives

SO-P Decadal climate change observations of *forcings*: Total and Spectral Solar Irradiance. (NOAA: TSIS).

SO-P Decadal climate change observations of *responses*:

SO-P1 Temperature and humidity profiles.

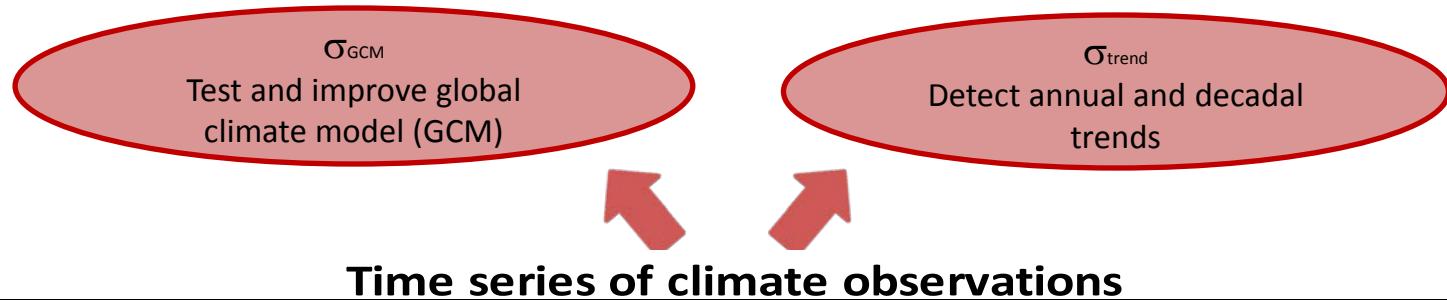
SO-P2 Cloud properties.

SO-P3 Top of atmosphere shortwave and longwave radiative fluxes.

SO-P Decadal climate change observations of *feedbacks*:

SO-P4 Cloud feedback, largest uncertainty

SO-P5 Water vapor and lapse rate feedback

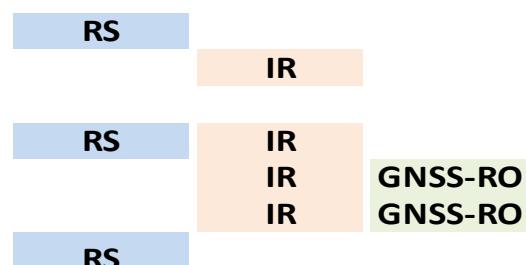


Forcings:

- Surface Albedo
- Greenhouse Gas

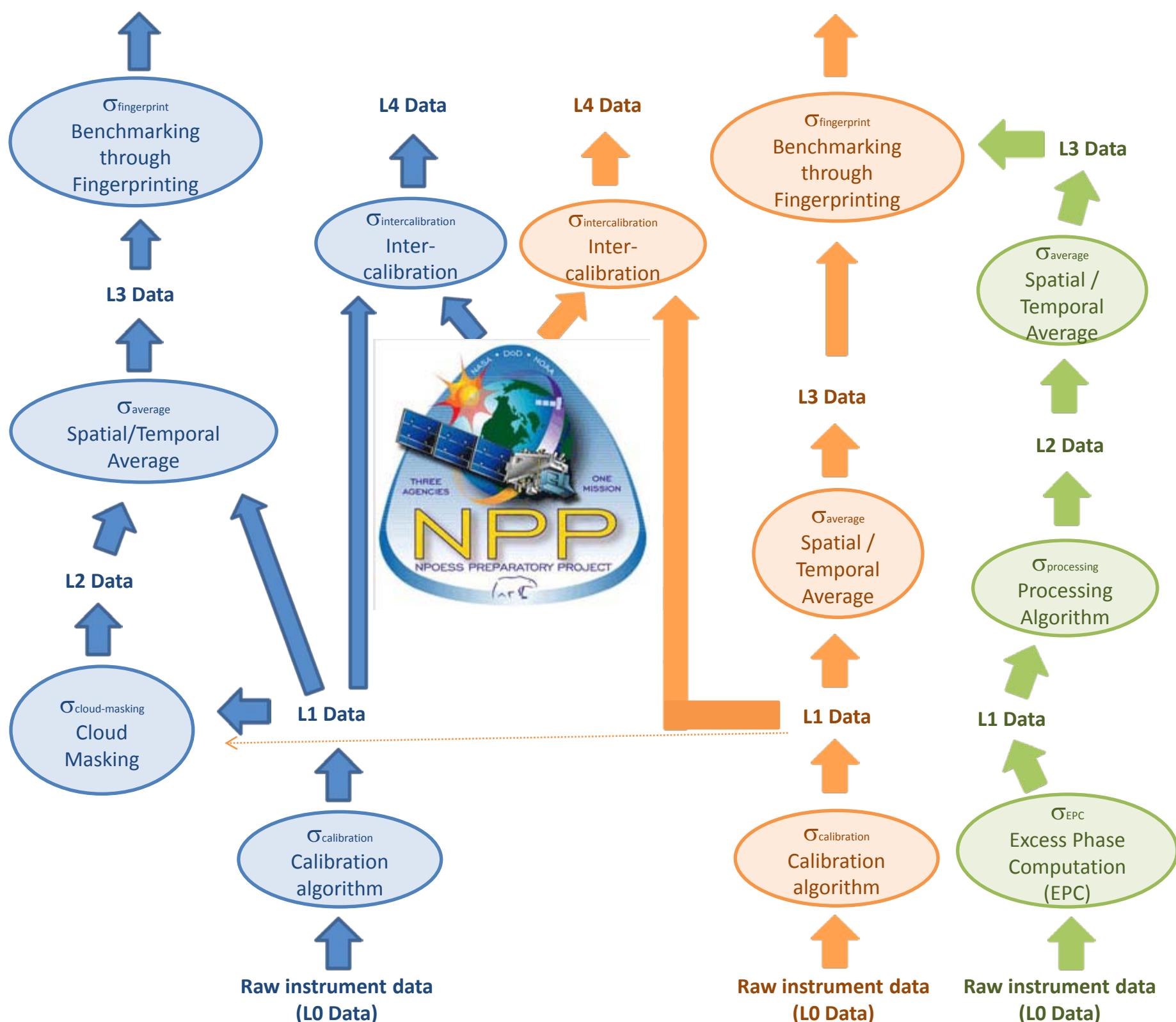
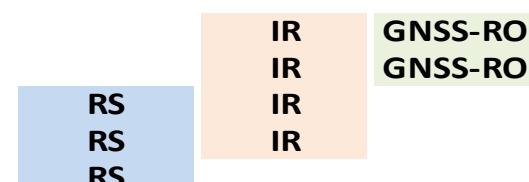
Feedbacks:

- Cloud
- Water Vapor
- Lapse Rate
- Snow/Ice Albedo



Responses:

- Temperature profiles
- Water Vapor profiles
- Cloud response
- Radiation response
- Snow/Ice Cover



CLARREO Uncertainty Framework

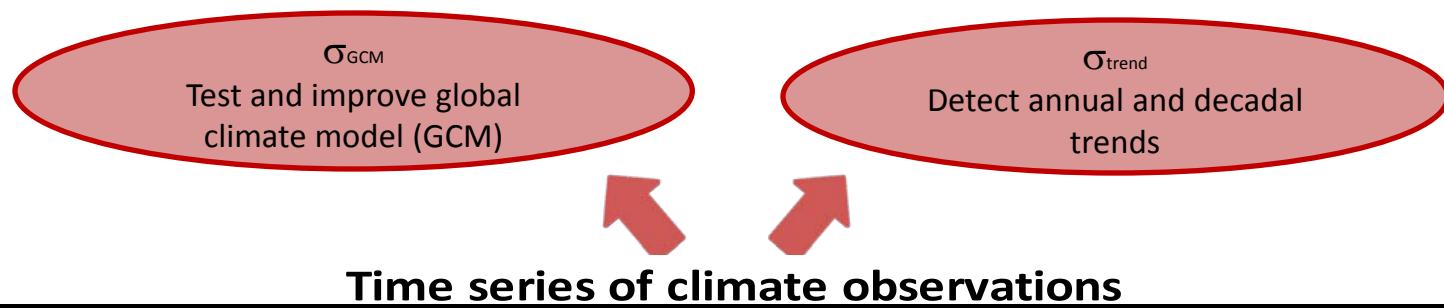
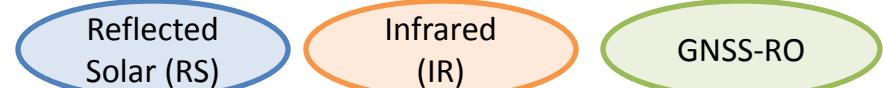
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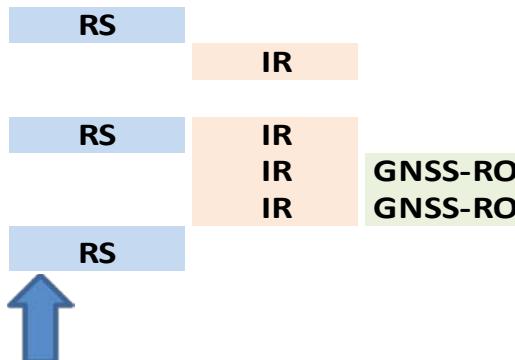
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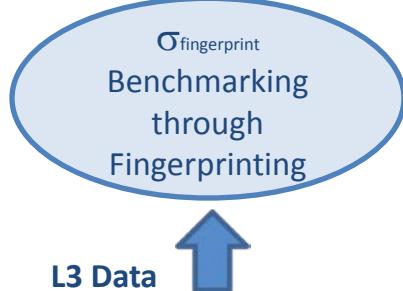
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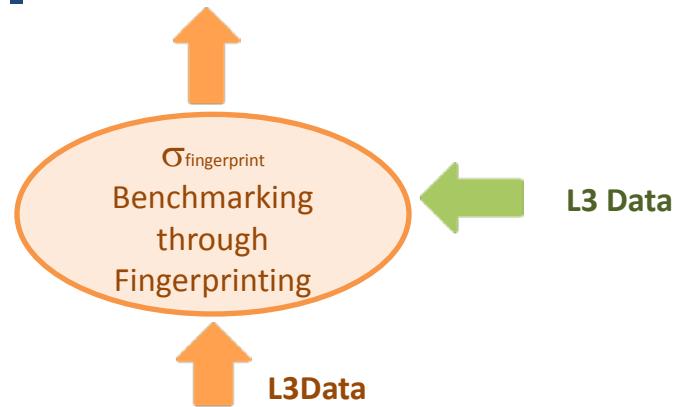
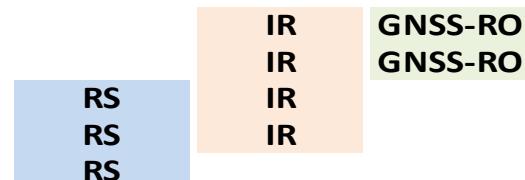
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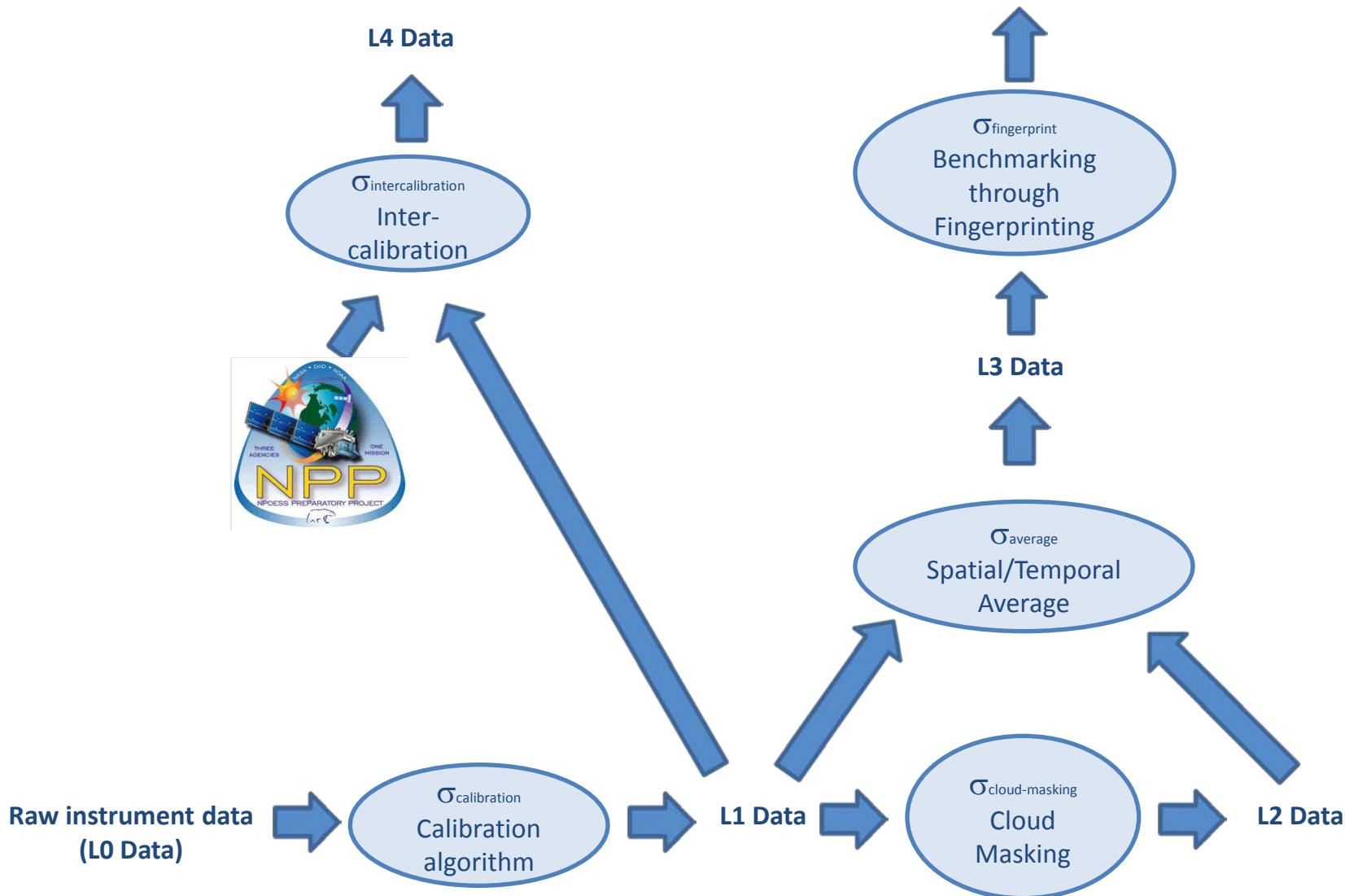


Responses:

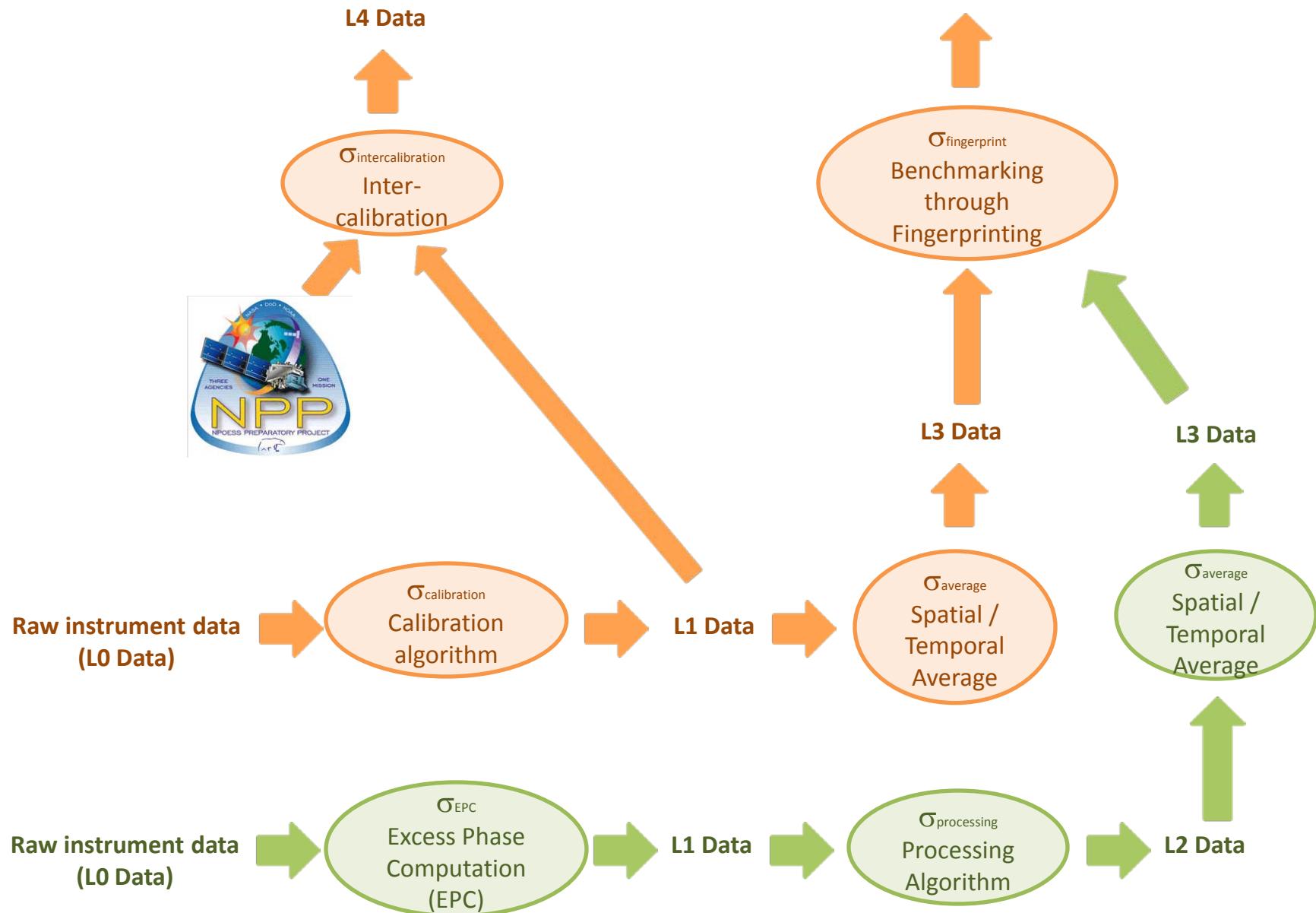
- Temperature profiles
- Water Vapor profiles
- Cloud response
- Radiation response
- Snow/Ice Cover



CLARREO Uncertainty Framework - RS



CLARREO Uncertainty Framework – IR and GNSS-RO



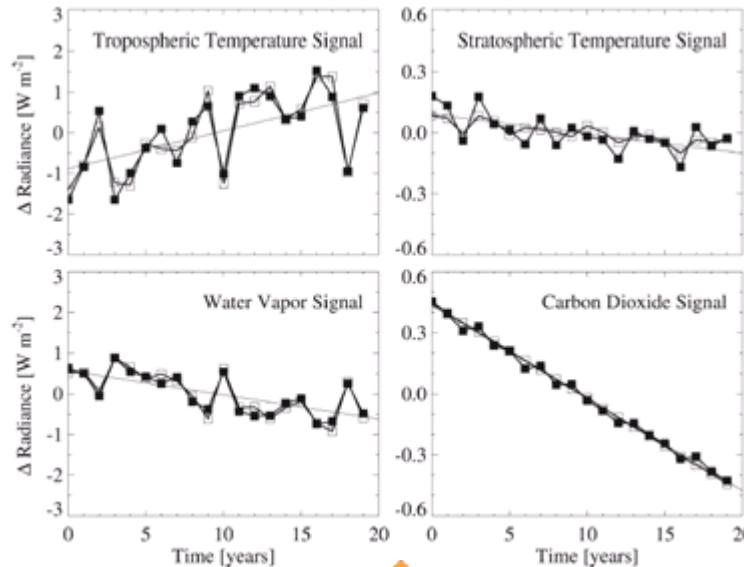
σ_{GCM}

Test and improve global
climate model (GCM)

 σ_{trend}

Detect annual and decadal
trends

Time series of climate observations

 $\sigma_{\text{fingerprint}}$

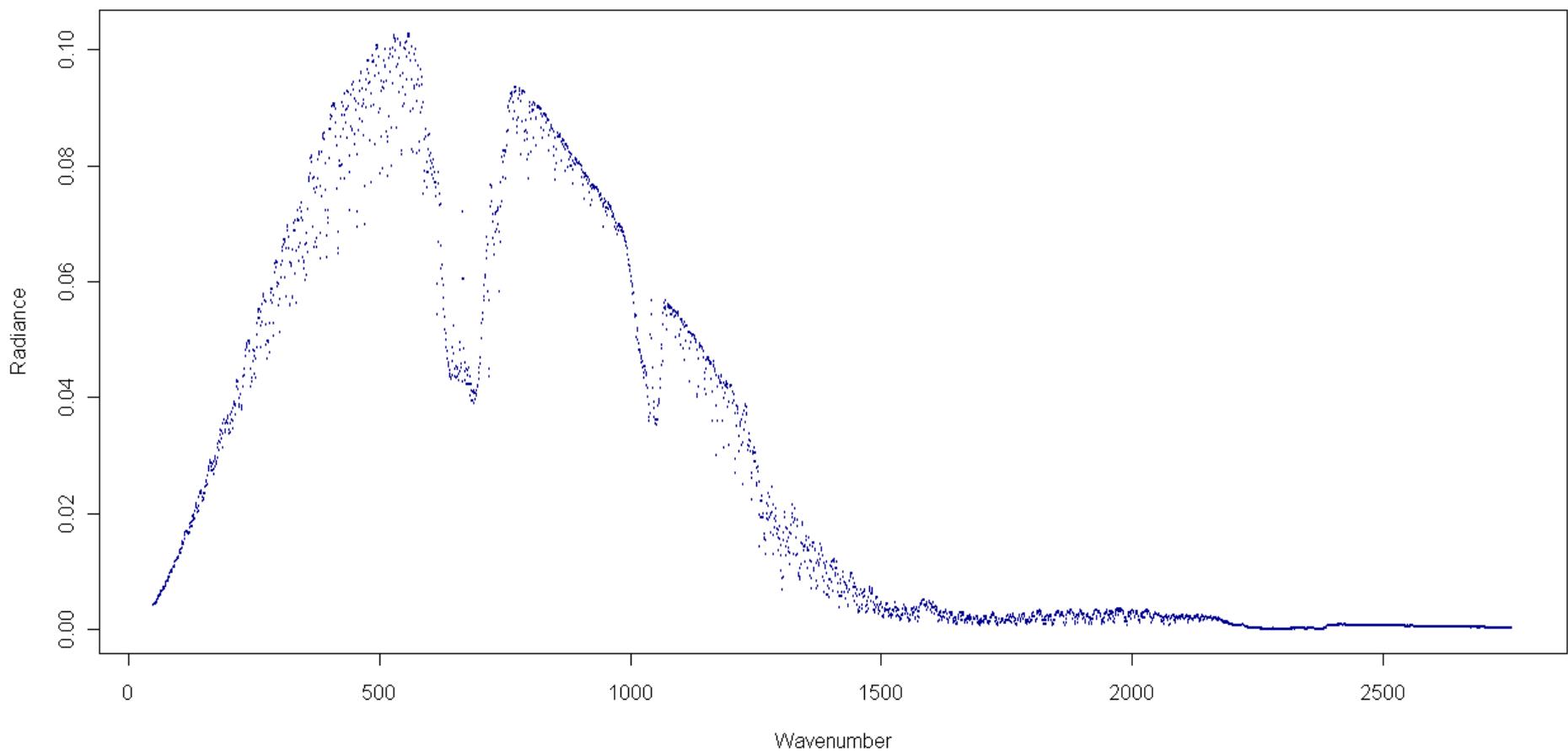
Benchmarking
through
Fingerprinting



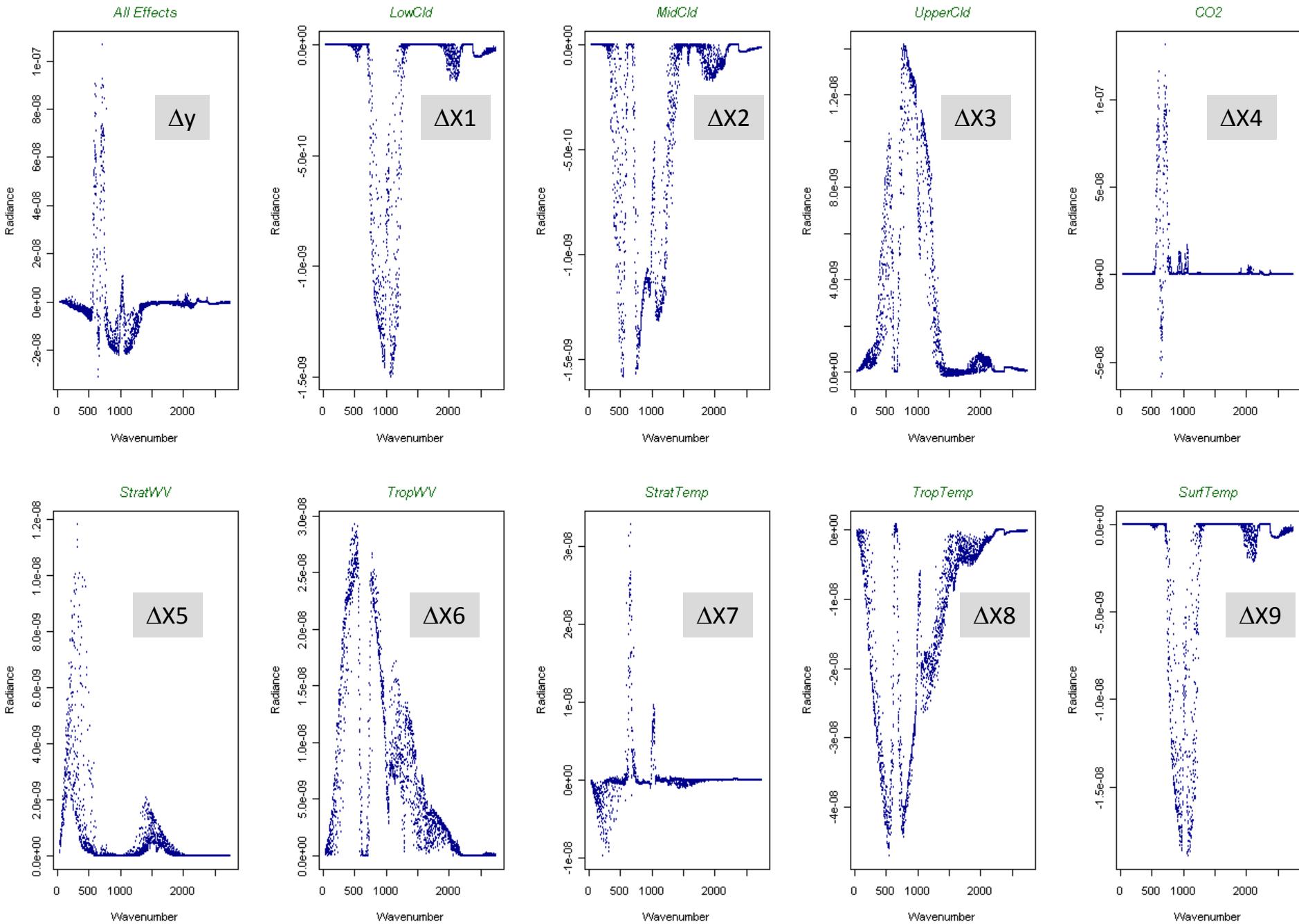
L3 Data



Calibrated Measurement (L3 data)

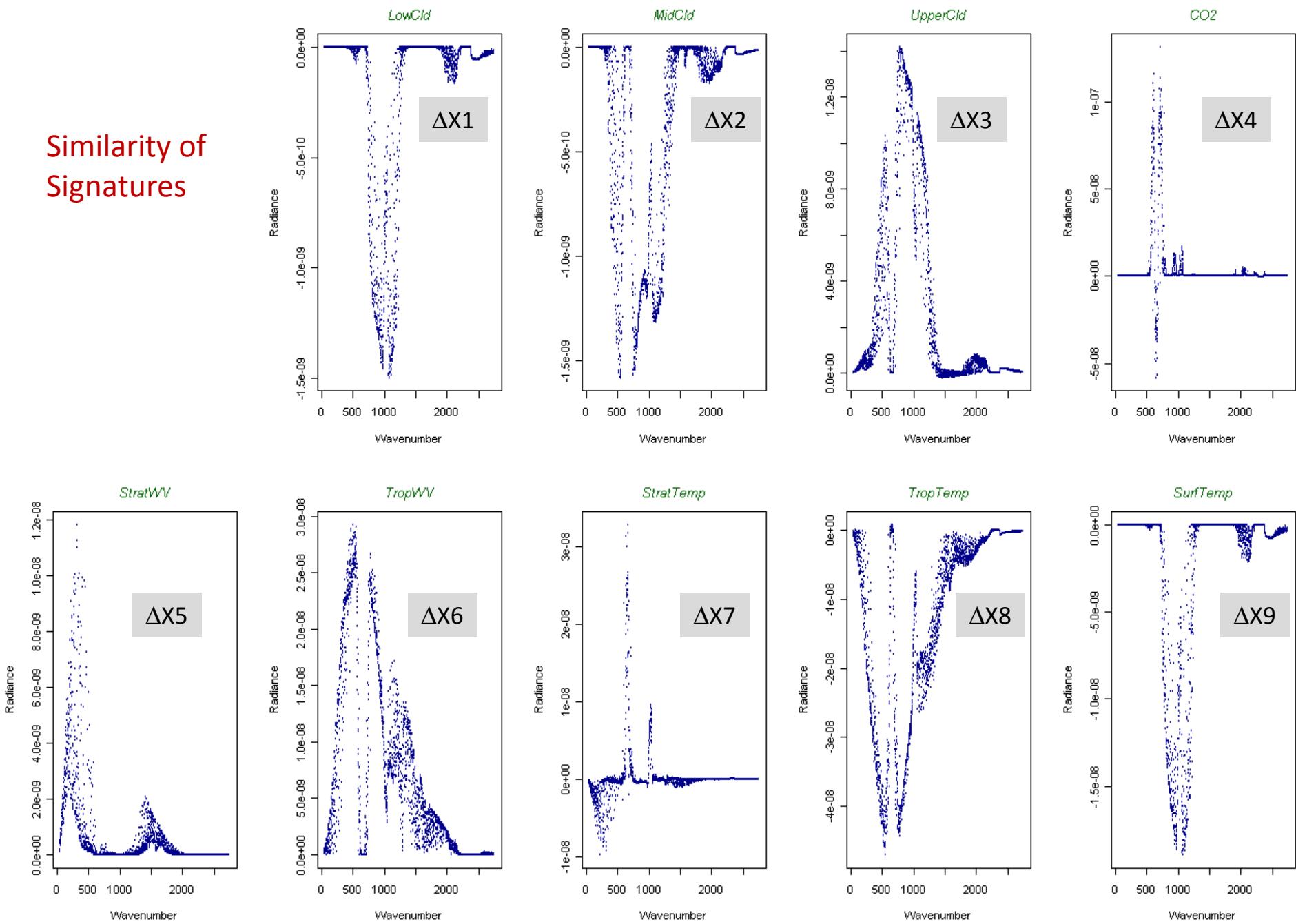


Signal Signatures – Spectral Correlation

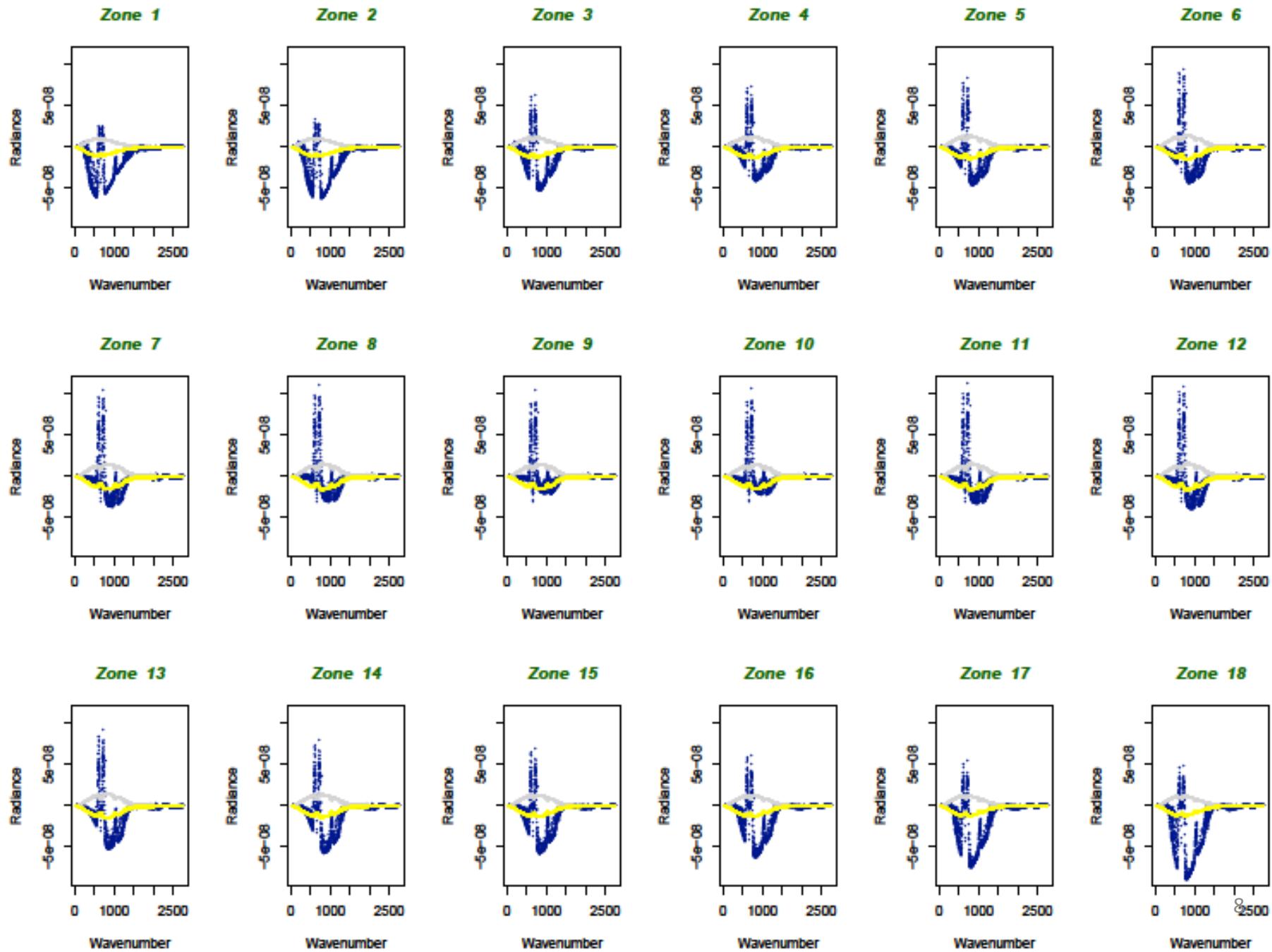


Signal Signatures – Multi-Collinearity

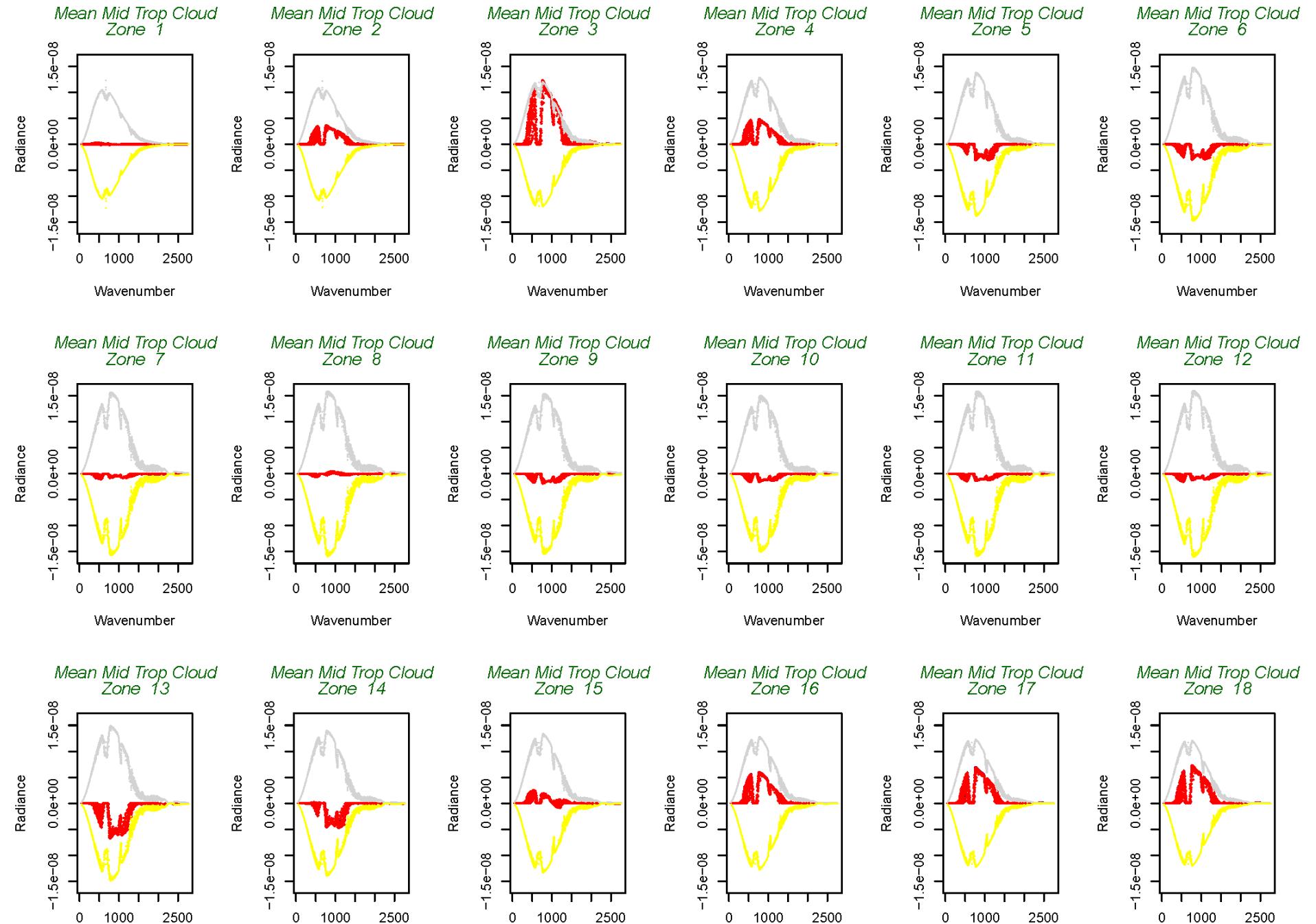
Similarity of
Signatures



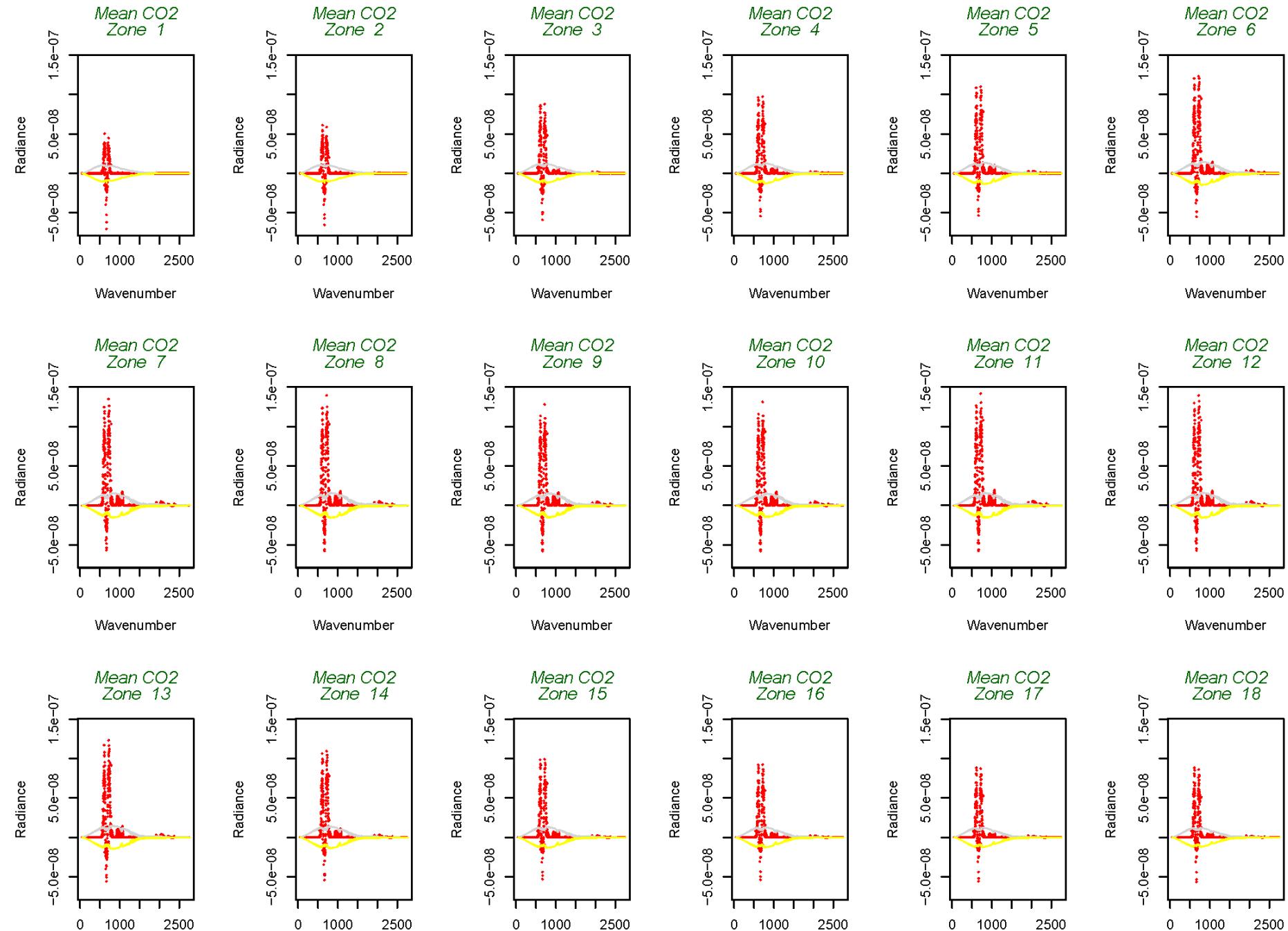
Measurement Radiance Difference (Δy) – Spatial Variation



$\Delta X2$ – Spatial Variation



$\Delta X4$ – Spatial Variation





Fingerprint Challenges

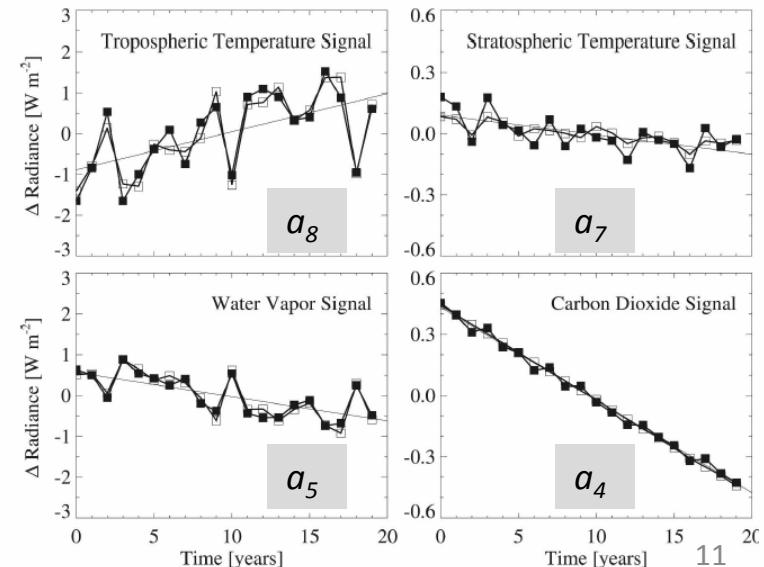
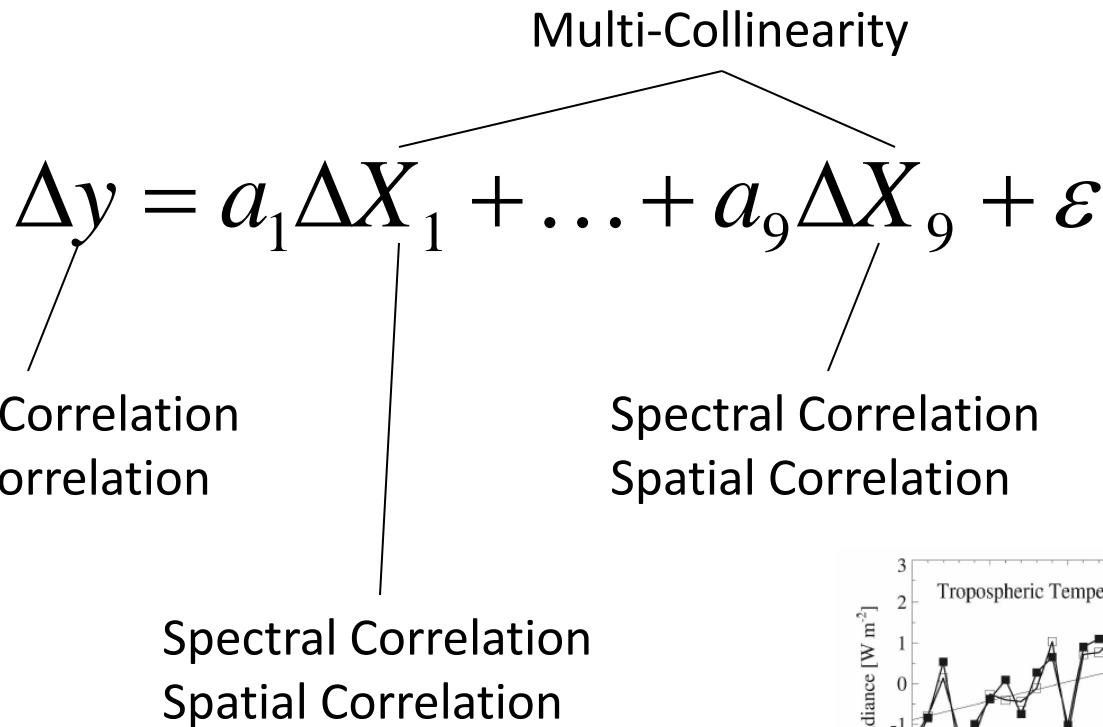


Figure 1 Time series samples obtained from fingerprinting analysis.



Conclusion

In developing a measurement system for Earth Observing Satellites to meet the accuracy level set by the mission to fulfill the goals, we need to

- Understand the end-to-end process from raw measurement to final science data.
- Evaluate the uncertainty budget for all steps of the end-to-end process.
- Determine the critical uncertainty driver(s) that could potentially affect the accuracy requirement.
- Allocate resources accordingly to these drivers.