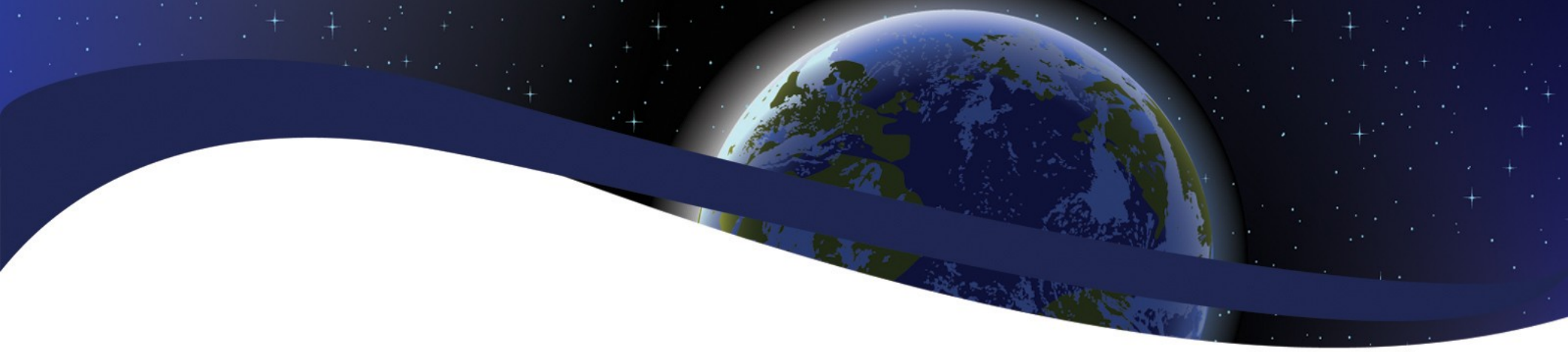

Uncertainty estimation in satellite remote sensing
Sources of error and ensemble techniques

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Thanks to Thomas Holzer-Popp and Greg McGarragh

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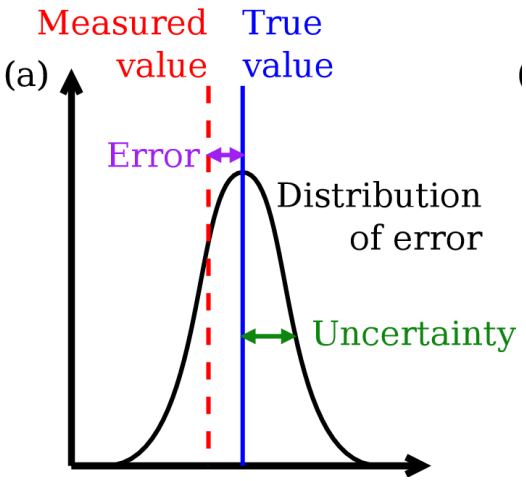
NATURAL ENVIRONMENT RESEARCH COUNCIL

Summary

- Uncertainty must represent the non-linear and circumstantial nature of errors often dominant in satellite products.
- As the distribution of these errors is not always well understood, data producers must engage in a dialogue with data users to work towards useful estimates.
  - This can include ensemble techniques, quality assurance, qualitative descriptions.
  - This is complimented, not replaced, by validation activities.

Classifying sources of error

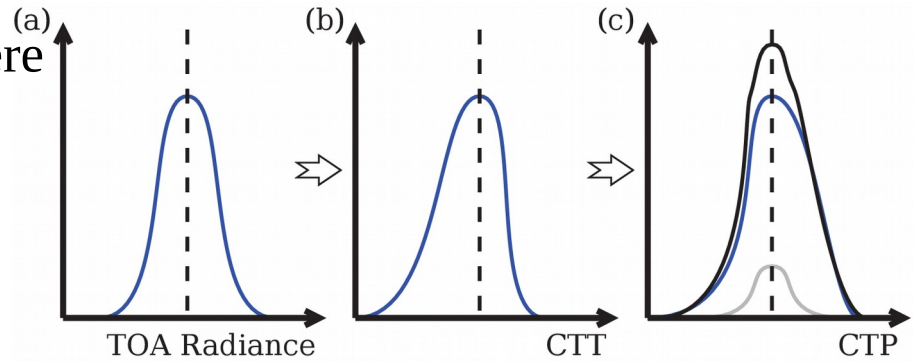
- Intrinsic sources of error
  - Measurement
    - Statistical variation in measurand or detector
    - e.g. dark current, radiometric calibration
  - Parameter
    - Uncertainty in auxiliary information used
    - e.g. spectroscopic data, meteorological profiles
  - Both also known as “parametric errors”



- Generally well-represented by traditional techniques for calculating uncertainty.

Classifying sources of error

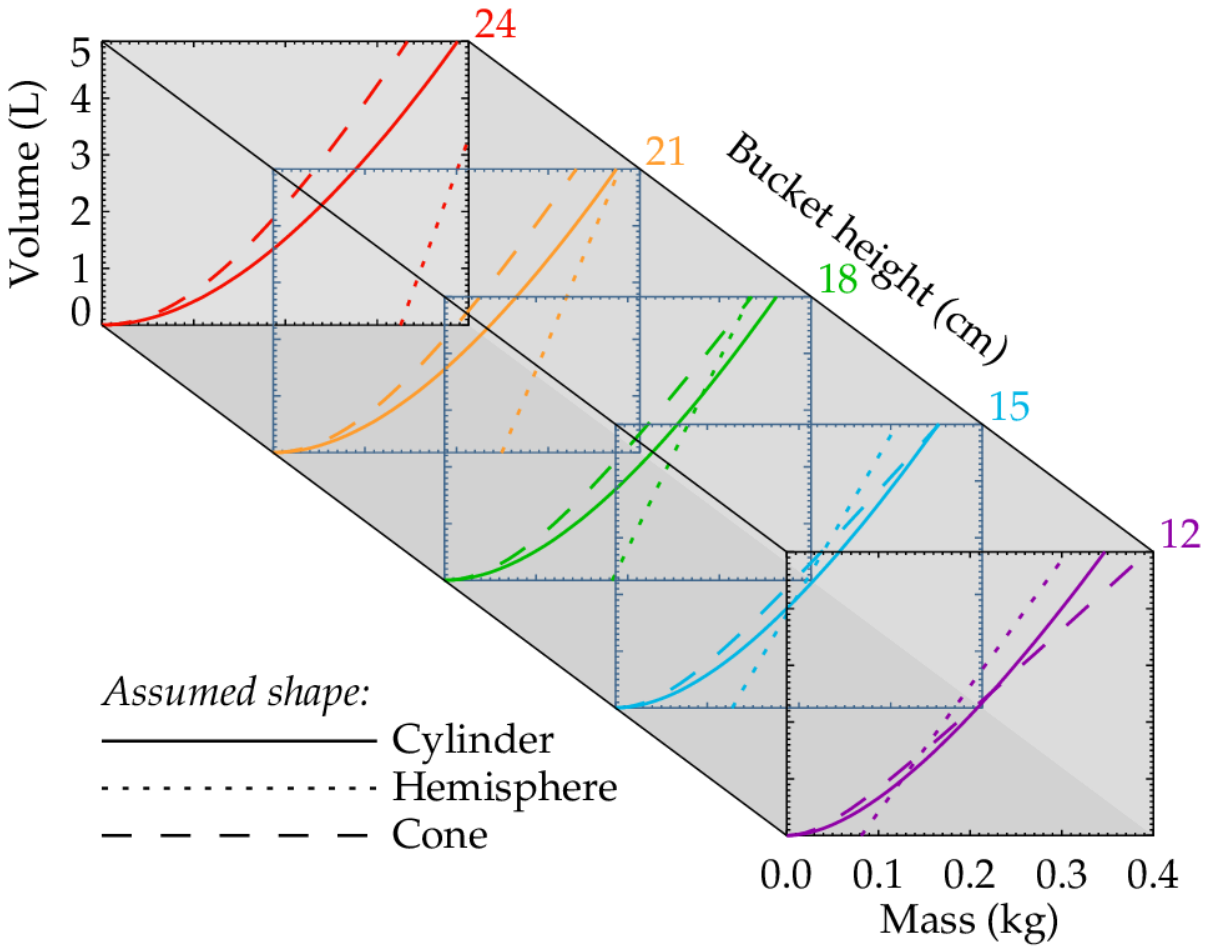
- Structural errors, resulting from choices made in the measurement and analysis systems
  - Resolution
    - Finite sampling of a constantly varying system
    - e.g. fair-weather bias, MODIS “bow-tie effect”
  - Approximation
    - Simplifications and approximations in calculations
    - e.g. using a LUT or plane-parallel atmosphere
  - System
    - Physically meaningful assumptions
    - e.g. choice of aerosol optical model



- Potentially non-linear and circumstantial.
  Thus, the source of error affects how it needs to be reported to users.

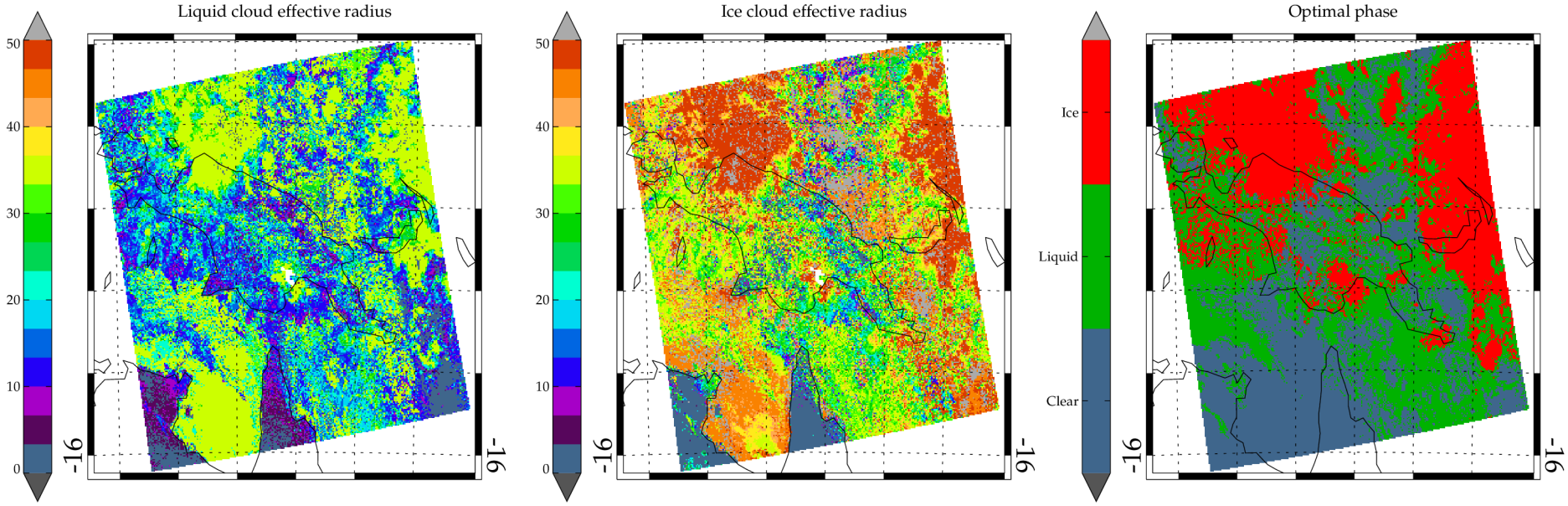
Ensemble Techniques

- Consider estimating the volume of a bucket, knowing only its mass.
- Shape is assumed but different assumptions produce different errors.
- The magnitude of error due to that assumption depends on the underlying state and other parameters of the retrieval.



Ensemble techniques

- Ensemble techniques can better communicate uncertainties resulting from such errors.
  - A “multi-model” ensemble of analyses with differing assumptions and approximations.
  - A “multi-run” ensemble of analyses with different constraints.



Questions and comments?

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Known and unknown unknowns: ~~the application of ensemble techniques to~~ uncertainty estimation in satellite remote sensing ~~data~~

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Communicating with users

- Important to clarify the difference between what is measured and what the user wants to know.
  - For example, satellites only sample one time of day but users may need observations at other times.
    - For SST, in situ observations indicate the diurnal cycle is somewhat predictable so empirical corrections may be useful.
    - For cloud, data indicates the diurnal cycle is highly circumstantial so a single observation is not representative of an entire day.
- A quantity can be adjusted to meet a user's needs but
  - The transformation will introduce additional uncertainty and
  - The new quantity may not meet other user's needs.
- We prefer to report only the measured value and provide secondary support (i.e. communication) to produce transformations as needed.