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Site Characterization for vicarious calibration of sensors

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Background

Goal of test sites for instrument characterization is to minimize the effect of the site itself

- True of all methods for vicarious approaches
  - Temporal effects
  - Directional
  - Spatial heterogeneity
  - Spectral
- Approaches to test site characterization have analogies in the laboratory
- Develop a set of basic protocols or best practices similar in philosophy to those agreed upon in the laboratory

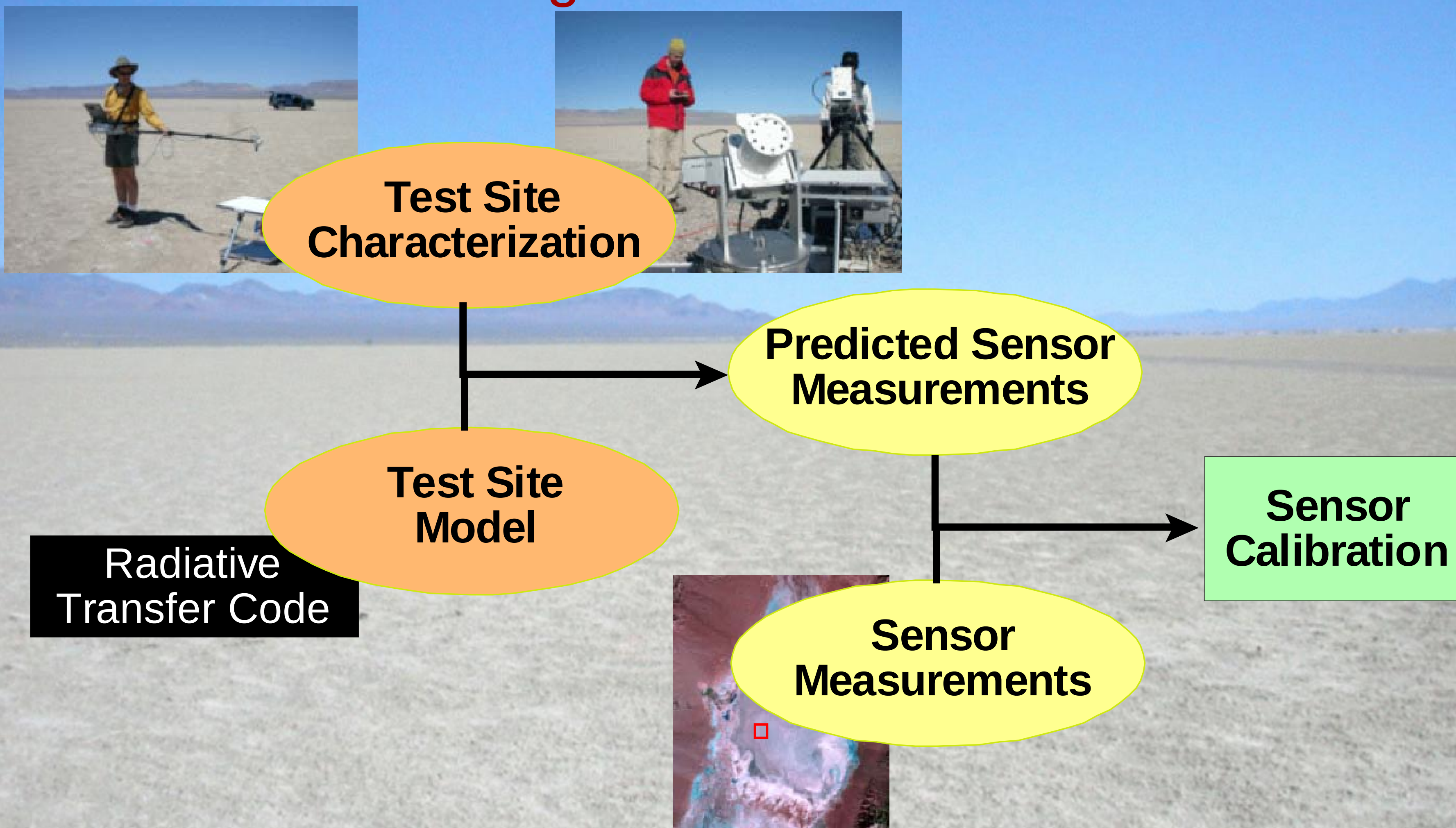
Background

Concentrate talk on ground-based measurement approaches in the solar reflective

- The term "site" is not limited to an area on the ground
  - Includes atmosphere/surface system
  - Not necessarily terrestrial
- Talk outline
  - Reflectance-based method
  - Site selection drivers
  - Measurement protocols
  - Application to general problem of site characterization

Basic approach with ground sites

All methods rely on “modeling” the expected signal at the sensor being calibrated



Radiative transfer code

Radiative transfer is dominant model in reflectance-based approach

- Multiple radiative transfer codes have seen use in ground-base methods with agreement within input uncertainties
- Differences in predictions from codes are caused by the way aerosol and reflectance inputs are included
  - Lambertian/non-lambertian capability
  - Aerosol phase functions and aerosol absorption
- Brighter surfaces, near-nadir views, clear atmospheres reduce the effects of the choice of radiative transfer

Surface properties

Spatial, spectral, temporal, directional (incident and view) properties

- Surface plays larger role in high reflectance case
- Common assumptions
  - Temporal invariance
  - Lambertian
  - Bi-directional

Atmospheric characterization

Spatial, spectral, temporal, directional (incident and view) properties

- Solar radiometry is common for many approaches
- Other common methods include
  - Climatology
  - Spatial invariance

Test site selection

Proper selection of test sites will determine accuracy of results from ground-truth approaches

- True for both geometric and radiometric calibration
- There are both natural and man-made scenes
- Most important factor is site accessibility by the imaging sensor
  - Frequency of scene collection
  - Typical view angles
- Other factors include
  - Temporal stability
  - Size
  - Location

Site examples – radiometric

Test site

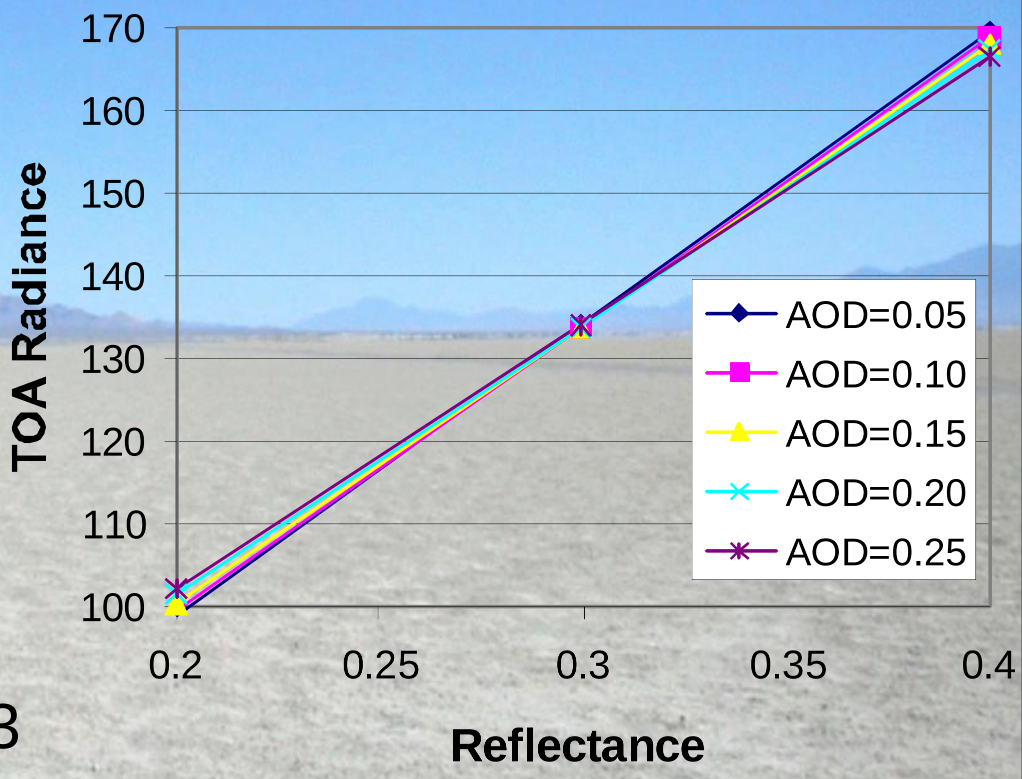
There is no perfect test site for radiometric calibration

- Large sites tend to vary temporally or are difficult to assess through in situ measurements
- Smaller sites can suffer from adjacency effects and sensor MTF problems
- High reflectance sites are sensitive to errors in reflectance and aerosol absorption
- Low reflectance sites are sensitive to aerosol properties
- Urban sites typically have large range of aerosol types
- Rural sites are difficult to access
- Best approach is to understand the difficulties with a given site that is well understood and readily accessible
  - Sensitivity analysis
  - Error analysis

Test site sensitivity study

Example shown here demonstrates how atmosphere and surface play a role

- Radiative transfer code output for a given sun angle and view angle
- Increasing the amount of aerosols increases scattering
- Increase in aerosols also decreases amount of surface- reflected energy
- At reflectance of about 0.3 these effects offset each other



Site reflectance

Two regimes are high reflectance and low reflectance surfaces

- High reflectance case
  - Atmospheric effects are minimized
  - Largest uncertainty is due to surface reflectance uncertainty
  - Largest atmospheric uncertainty is typically aerosol absorption
- Low reflectance case
  - Atmospheric uncertainties have much larger effect
  - Aerosol phase function and total column amount are largest source of uncertainty
- Adjacency effects are also a cause of uncertainty due to coupling between surface and atmosphere

Measurement protocols

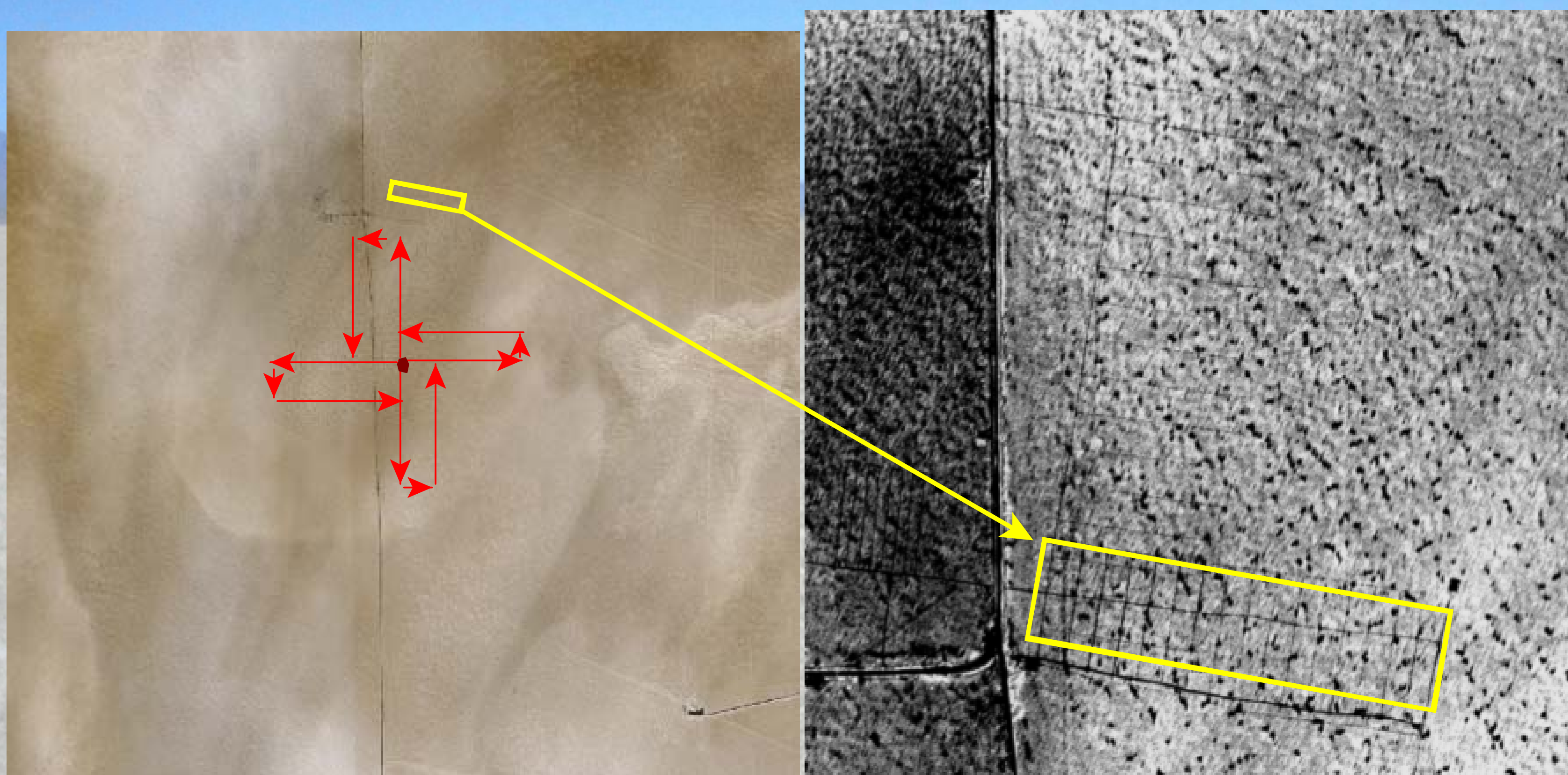
Sensitivity study results help select test site and also help determine measurement strategies

- Equipment technology may force a specific collection protocol
- Sensor being calibrated forces certain protocols
- First goal in collections is to do the same things in the same way as much as possible
  - Focus on precision and establish accuracy later
  - Improved accuracy can only be shown after improved precision
- Note that sensitivity studies must be followed by closure studies to understand absolute accuracy errors

Sensor-driven protocol

Two ranges of resolution leads to two approaches for surface reflectance characterization

- Different sampling strategies
- Different areas measured



Equipment drives protocol

Size of portable spectrometer and field reflectance standards determines sampling strategy

- Larger-sized panels chosen to limit out-field response effects from spectrometer
  - Heavier
  - Necessity to level panels makes stands even heavier
- Sampling of reference must be frequent enough to offset temporal changes
  - Atmosphere
  - Spectrometer
  - Panel BRF

Diffuse-light correction example

Sensitivity studies indicate that diffuse-light on reflectance standards can be important

- At short wavelengths or high aerosol conditions
- Impact on real data not as large as models indicate
- Logistics of making measurements properly means this effect is ignored currently

Ancillary information

Instrumentation not the only thing

- Notes related to the collection are critical
  - Descriptions of instrumental issues
  - Weather conditions
  - Logging of key parameters such as pressure
- Help in processing
  - Points to reasons why results may be anomalous
  - Location of data
- Help in planning and undertaking future campaigns
  - Timing
  - Instrument limitations

Note taking

Most important person on campaign is the note taker

- Ensure reference panel is level and in appropriate location
- Helps spectrometer user to go to the right place
  - Especially important in hot weather
  - Watches health of person
- Notes anomalous data
- Writes down missing data
- Watches weather conditions for changes in sky irradiance
- Reminds operator to check health of instrument

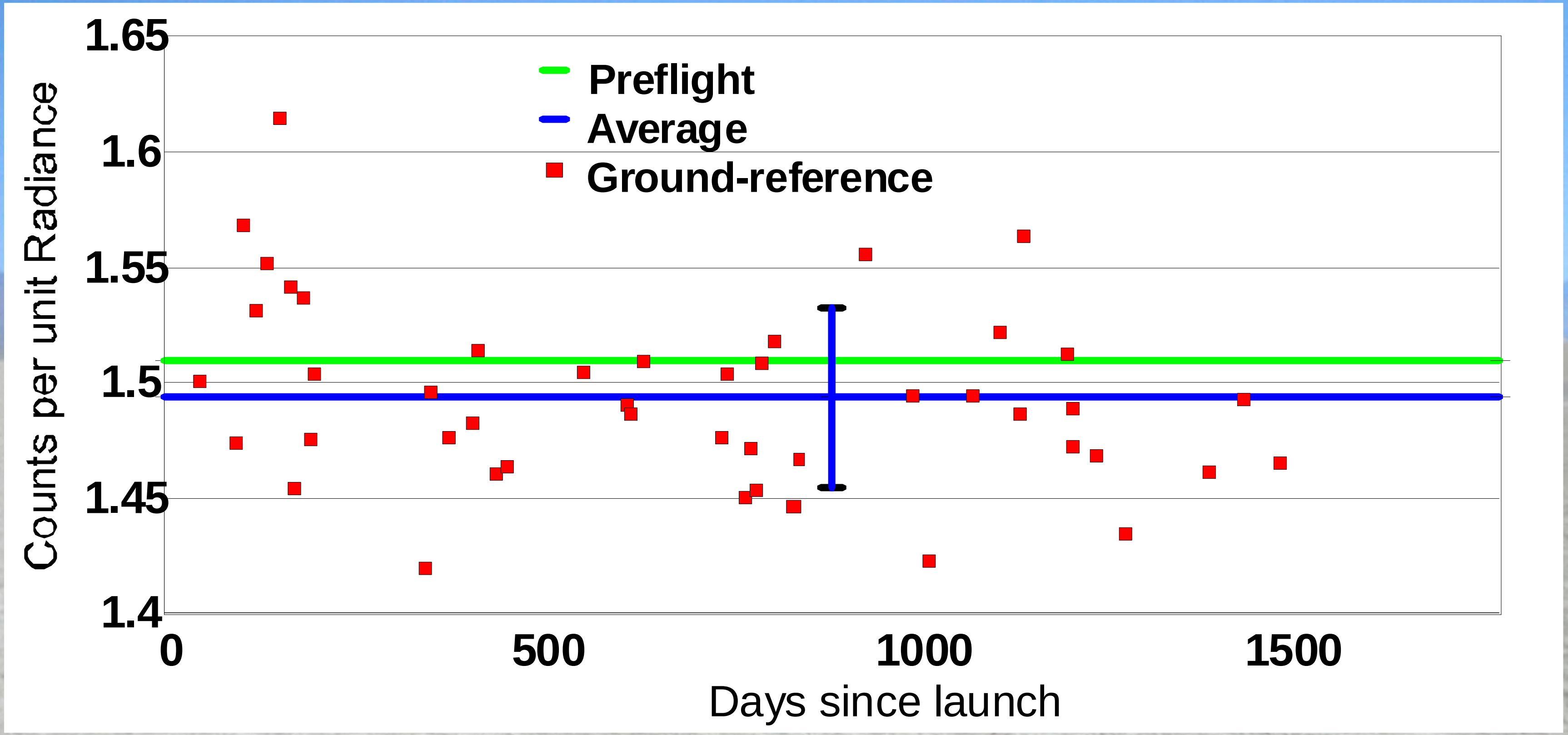
Traceability protocol

Traceability to an SI standard is key to comparisons between sensors and methods

- Reflectance results are traceable via pressed PTFE reflectance standard or primary standards of reflectance
- Radiance-based measurements are traceable to standards of spectral irradiance
- Solar irradiance models that are used have traceability to standards of spectral irradiance
- Error budgets can be developed based on the traceability
  - Also evaluated using sensitivity studies
  - Finally evaluated compared to measured data

Errors, accuracy, precision

Sample results from University of Arizona group for band 3 of Landsat-7 ETM+



Outlier data sets

There are a variety of effects that lead to larger uncertainties in predicted, at-sensor radiance

- Changes in surface conditions
- Personnel-related Issues
- Equipment
- Atmospheric effects

Site characterization protocols

Successful site characterization will be derived from well-understood protocols

- Consistent measurement practices
- Instruments
- Modeling
- Protocols for site characterization should concentrate on four key areas
  - Should be reasonably accessible to all groups
  - Recommendations for data dissemination
  - Defensible error budgets with associated sensitivity and closure studies are imperative
  - Traceability

Space-based and aircraft-based

Next step in the site characterization is by airborne and spaceborne sensors

- Current site characterization is limited by the sensors on orbit being calibrated
  - Reached a point where some of the variability seen is caused by the on-orbit sensor
  - Lunar calibrations are a good example of this
- Future missions should help with this
  - TRUTHS
  - CLARREO
  - Airborne hyperspectral systems
- Places even greater emphasis on transferring laboratory calibration to the field

Site characterization issues

A single, specific approach for characterization not feasible due to differences in vicarious methods

- Low reflectance site requires different characterization than high reflectance, for example
- Broader view of problem is necessary
  - Emphasis on traceability
  - Well-understood assumptions in modeling process
- One goal should be to develop all sites for both relative and absolute calibration
  - Absolute calibration can refer to reflectance
  - Should force a better understanding of the test sites
  - Improve understanding of the calibration methods
  - Better comparability between methods
- Lead to better use of combinations of methods for overall sensor calibration

Summary

High quality sensors and international efforts have improved vicarious methods

- Multiple groups calibrating the same sensors in independent fashions
  - Similar vicarious approaches
  - Different vicarious approaches
- IVOS and WGCV activities as well as those of other organizations (GSICS) are building on results of the past decade
  - Tuz Golu intercomparisons
  - Laboratory round robins
  - QA4EO
- Need for demonstrated traceability is now well accepted – now need to implement it