ABSOLUTE RADIOMETRIC CALIBRATION USING PSEUDO INVARIANT CALIBRATION SITES (PICS)

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Outline

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Objective

- Pseudo Invariant Calibration Sites (PICS) have been used for many years to determine the stability of optical satellite sensors.
- However, the potential exists to use PICS for **absolute** calibration of optical satellite sensors. As a sensor views a calibration panel in the laboratory during pre-launch testing, in an analogous manner consider the sensor viewing PICS while on orbit.
- Specific goals:
  - Develop a comprehensive and accurate PICS absolute calibration model
    - **Empirical approach (<2014)**
      - Developing surface and atmospheric models based on satellite and meteorological observations. (Presented last year)
    - **First Principles approach (≥2014)**
      - Develop solar, surface and atmospheric models based on the inherent physics of the site. (Presented today)

PICS Abs Cal: Empirical Method

- An empirical method for absolute calibration of satellite sensors using a calibrated radiometer as reference (Terra MODIS).
- EO-1 Hyperion was used to derive the spectral content of the target.
- Terra MODIS data was used to derive the BRDF due to solar zenith angle.
- Hyperion data was used to derive BRDF due to viewing zenith angle.
- One major limitation of the approach is the use of a single sensor as the calibration standard.

PICS Abs Cal: First Principles Method

- The first principles model is not sensor dependent, hence the model can be used an independent method of calibrating a satellite sensor or can be used in conjunction with other calibration techniques.
- A first principles model approach consists of the Sun as a calibrated source, a full atmospheric model through meteorological observations, and a surface BRDF model.

First principles approach

Solar Model

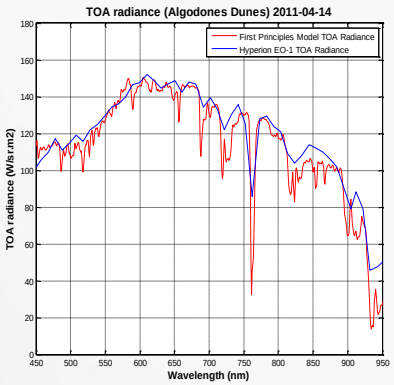
MODTRAN's NewKur solar model

Sensor data

Atmospheric Model

SDSU Atmospheric model was used for radiative transfer modeling

Validation

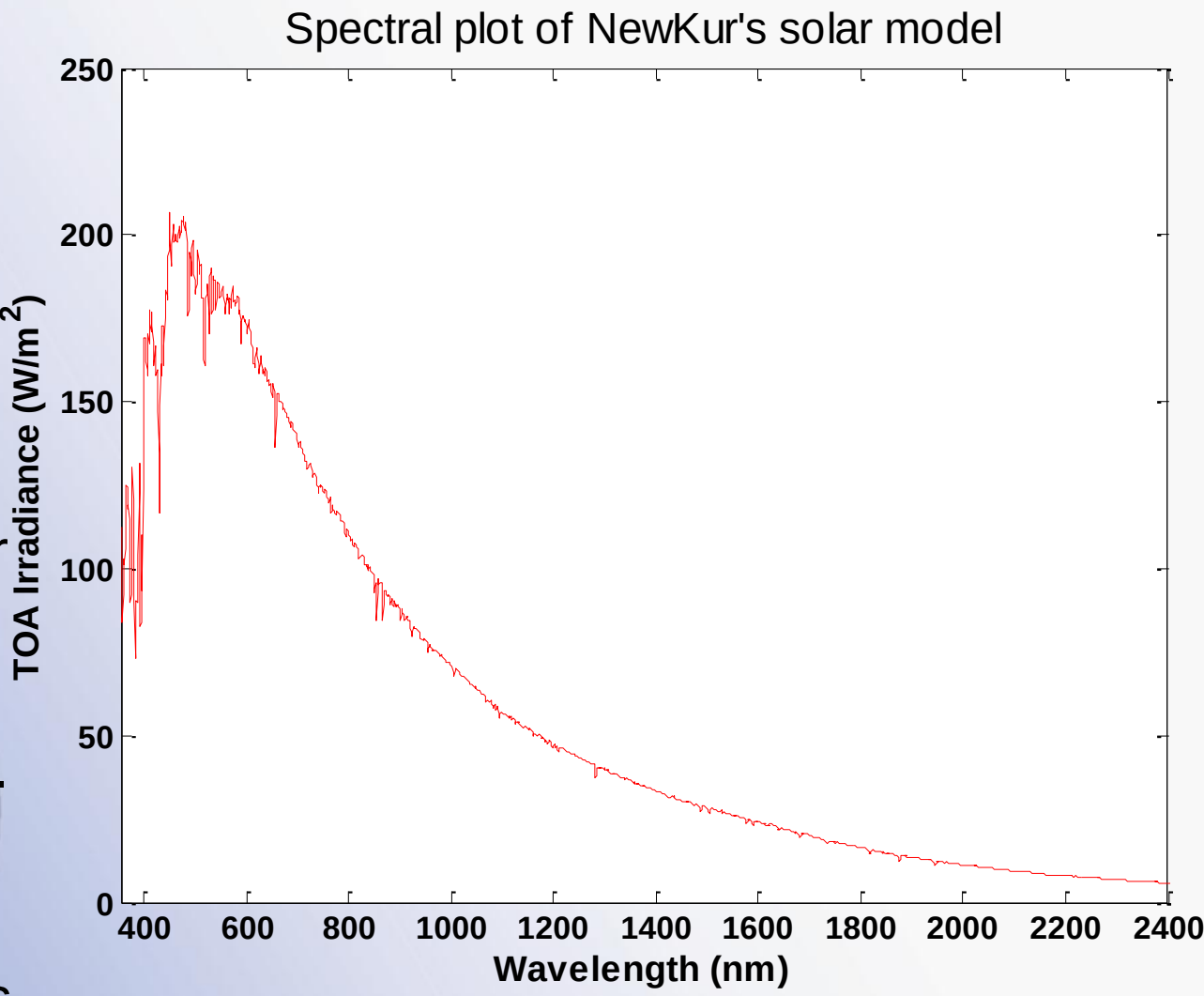


Surface Model

Surface spectra from Algodones Dunes

Solar Model

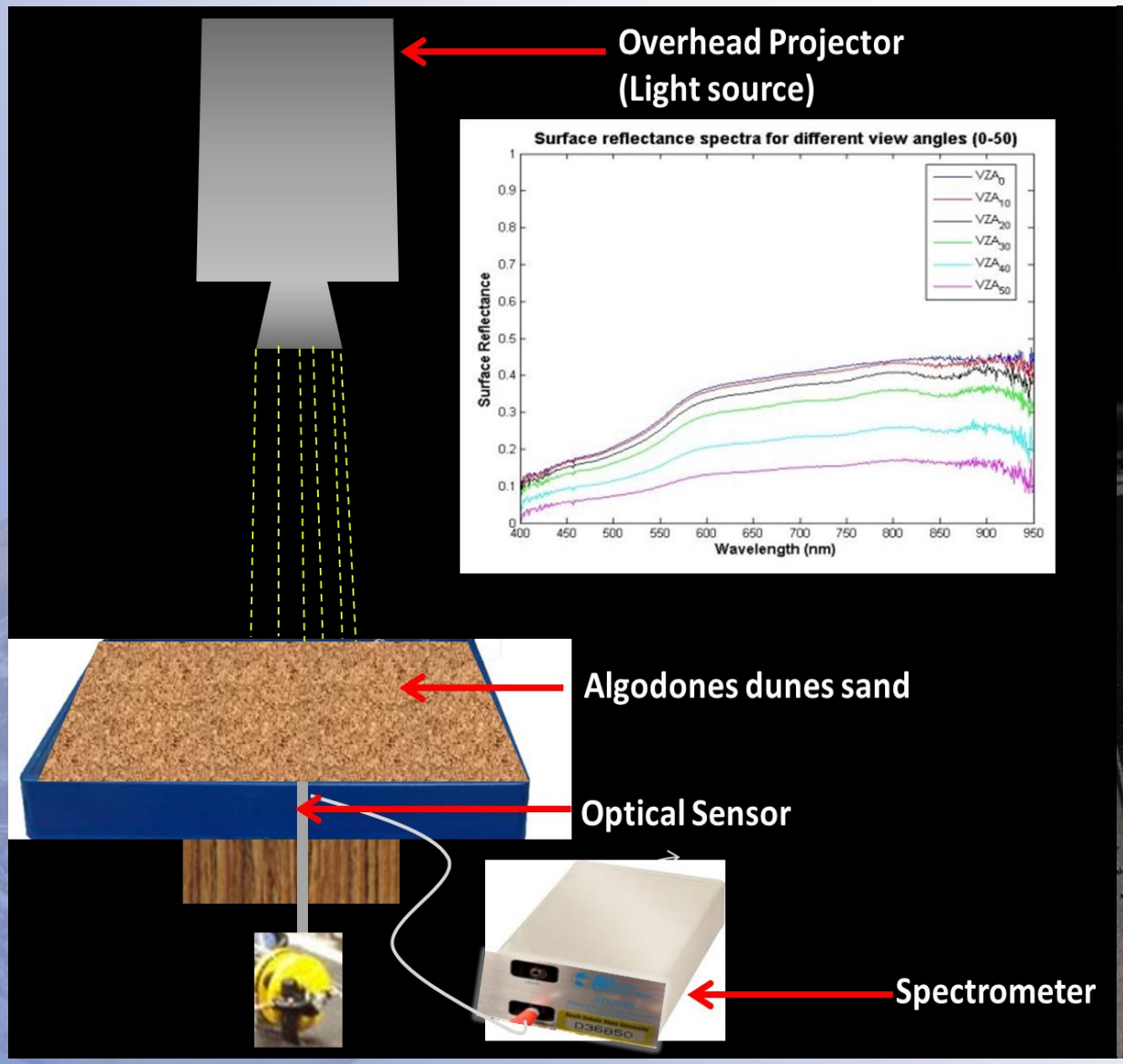
- Different solar irradiance models are:
  - Kurucz
  - ChKur
  - Thuillier 2002
  - WRC
  - ThKur
- Traditionally, ChKur Solar model has been used in Landsat calibration.
- The NewKur solar model is a default in Modtran and was used for initial work



The Surface

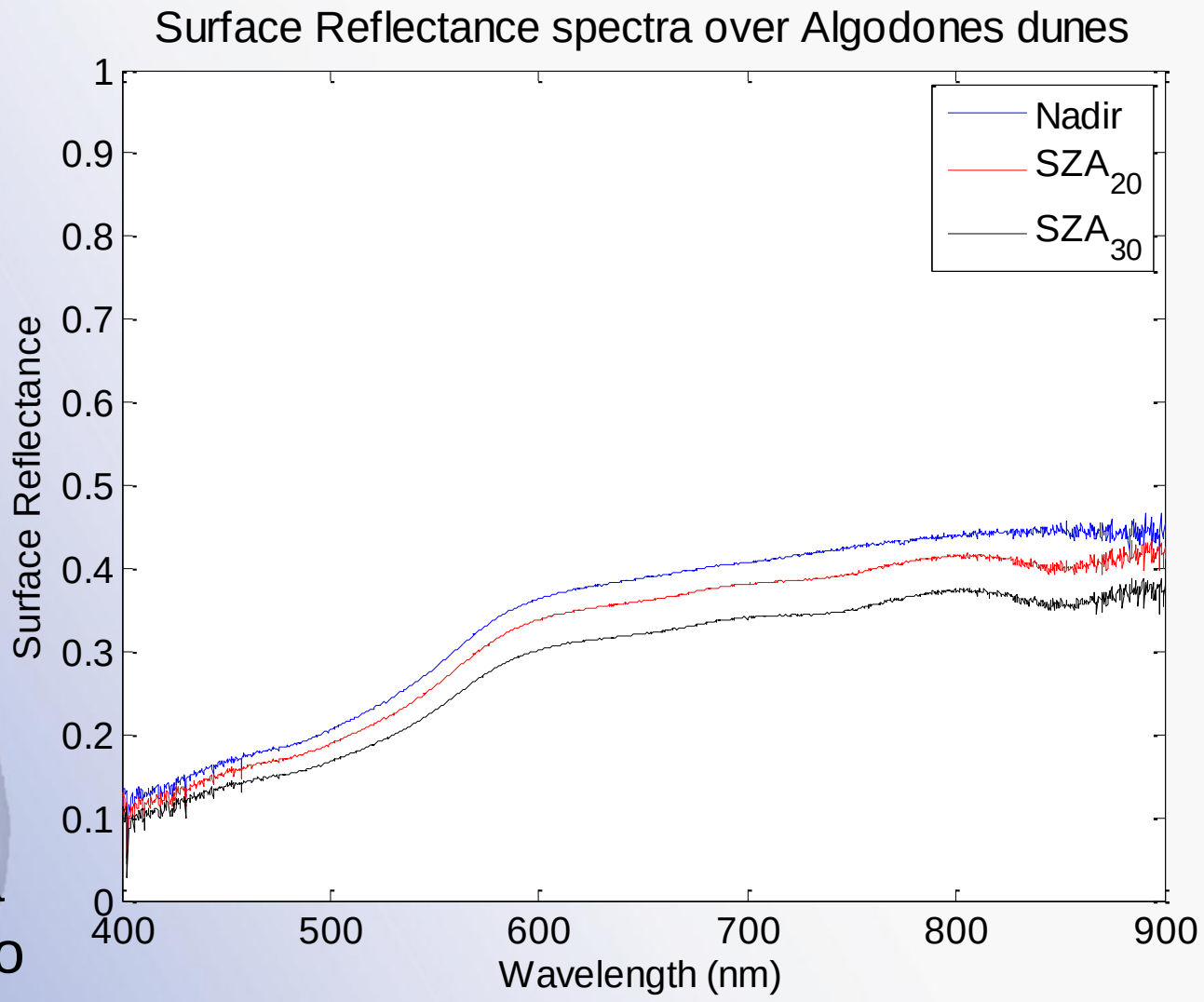
- Libya 4 is one of the primary PICS sites used for radiometric calibration and so was used for most of our observational data.
- Ground level surface reflectance measurement is a primary model constituent; however, obtaining direct measurement of the Libyan desert is not feasible.
- Thus, a continental U.S. site, **Algodones Dunes**, is used as an initial surrogate ground level reflectance site
- It is located in southeast CA and referenced to Path/Row 039/037 in WRS-2.

Lab-Based Sand BRDF Measurements



Surface Reflectance Measurement

- Sand spectra gets brighter as wavelength increases
- Varying the illumination angle from nadir to 30°, changes the reflectance by ~20%
- The various reflectance spectra are used as input to the atmospheric model

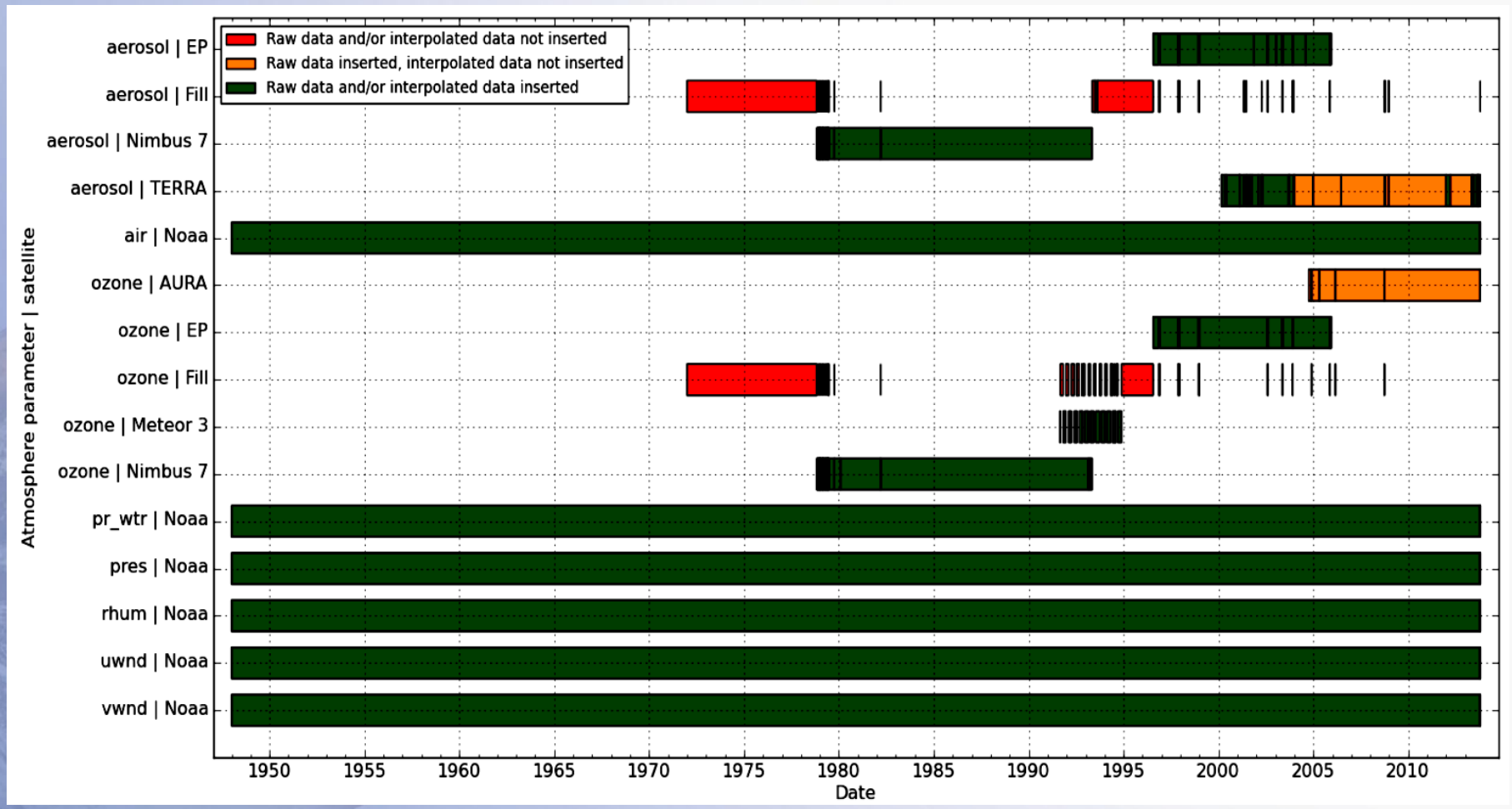


Atmospheric Model – SMACAA

- SDSU Modtran Atmospheric Correction Anywhere Anytime (SMACAA).
  - Collection of global atmospheric measurement from numerous sensors covering the time frame of 1972 to the present, data have been cross calibrated, and filtered to produce a continuous data set.
    - Measurements include: aerosol, water vapor, ozone, ground elevation, pressure, temperature, etc.
  - Database drives Modtran to produce a hyperspectral correction that can be used to correction any VNIR/SWIR sensor
  - Can transition ground-based spectral data to Top-Of-Atmosphere (TOA) predictions, or transition TOA measurements to ground level estimations.

SMACAA Database

- 15 billions data points
- Used to create an input to the atmospheric model

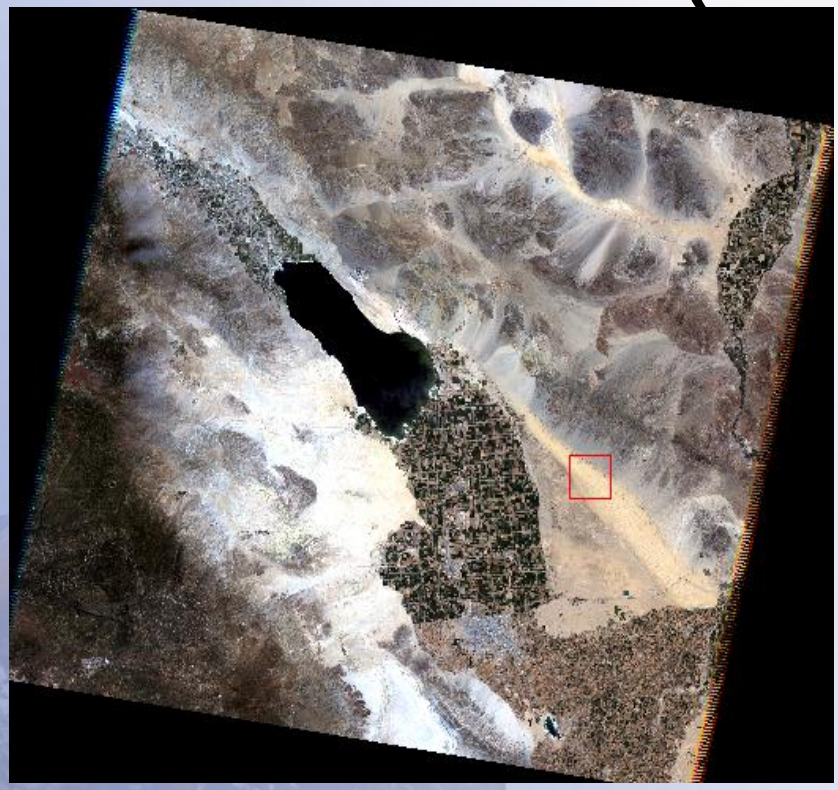


Preliminary Validation Results (Landsat 5 TM, Landsat 8 OLI and EO-1 Hyperion)

Validation Steps

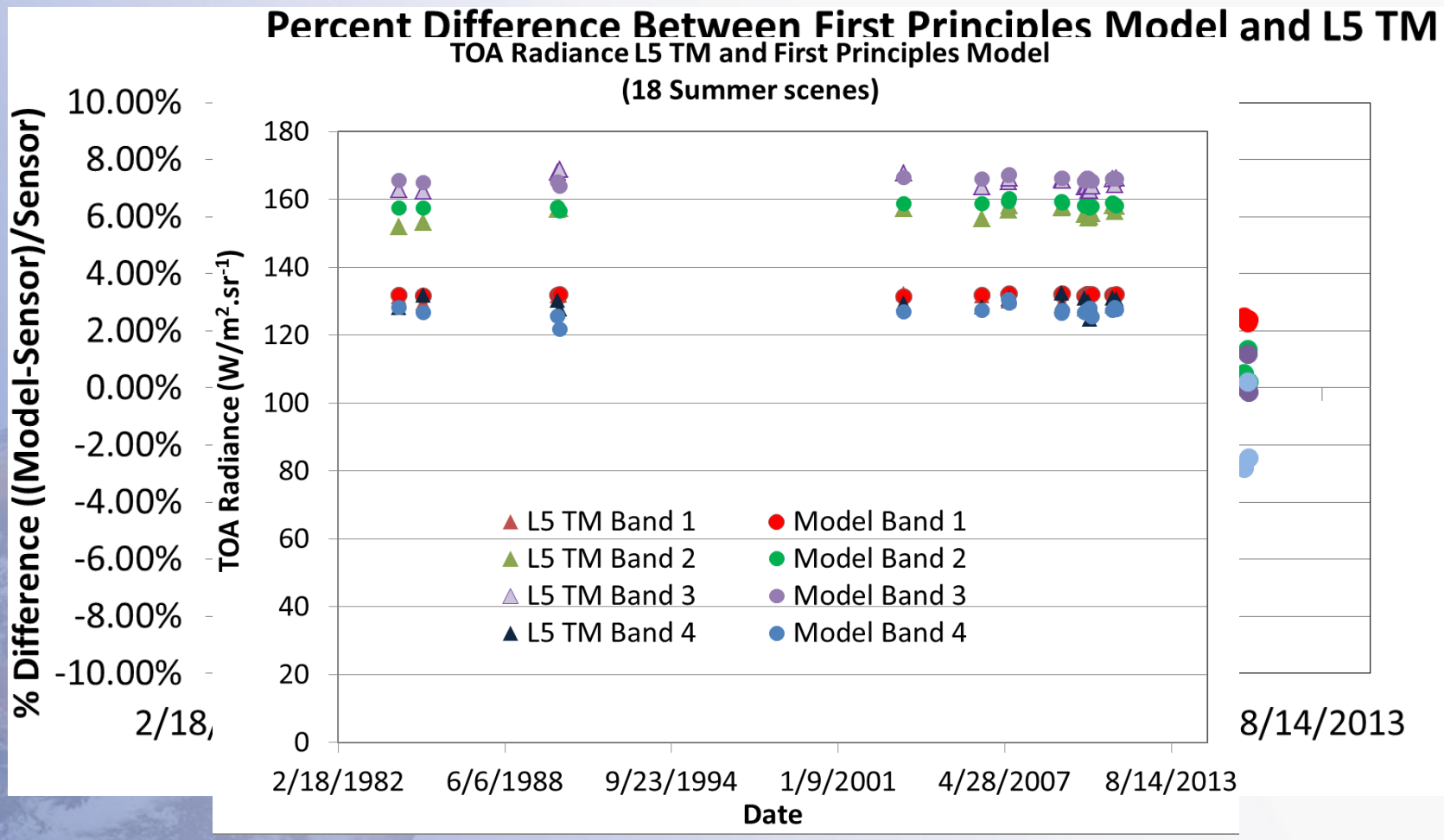
- Select a ROI (Region of Interest) from the site; apply appropriate surface BRDF data set.
- Retrieve information such as viewing and illumination geometry, date and time of image acquisition, etc., from the metadata files as an input to SMACAA.
- Using NewKur and MODTRAN, predict the at-sensor radiance based on geometry and date, and atmospheric parameters.
- Compare this prediction with the satellite measurements over the site
- Repeat process with multiple acquisition dates.
- Repeat process for multiple sensors.

L5 TM scene over Algodones Dunes (05/26/2011)



- Located in the southeastern portion of the U.S. state of California, near the border with Arizona and the Mexican state of Baja California.
- Human-made structures in the area are the All-American Canal that cuts across the southern portion from west to east and the Coachella Canal on the western edge.
- Salton sea is located northwest of the dunes.

First Principles Model and L5 TM TOA Radiance



For Bands 2 and 3, the model predicts very close to the measured values for all the scenes and this can be related to the surface measurements in this range having a smooth linear trend.

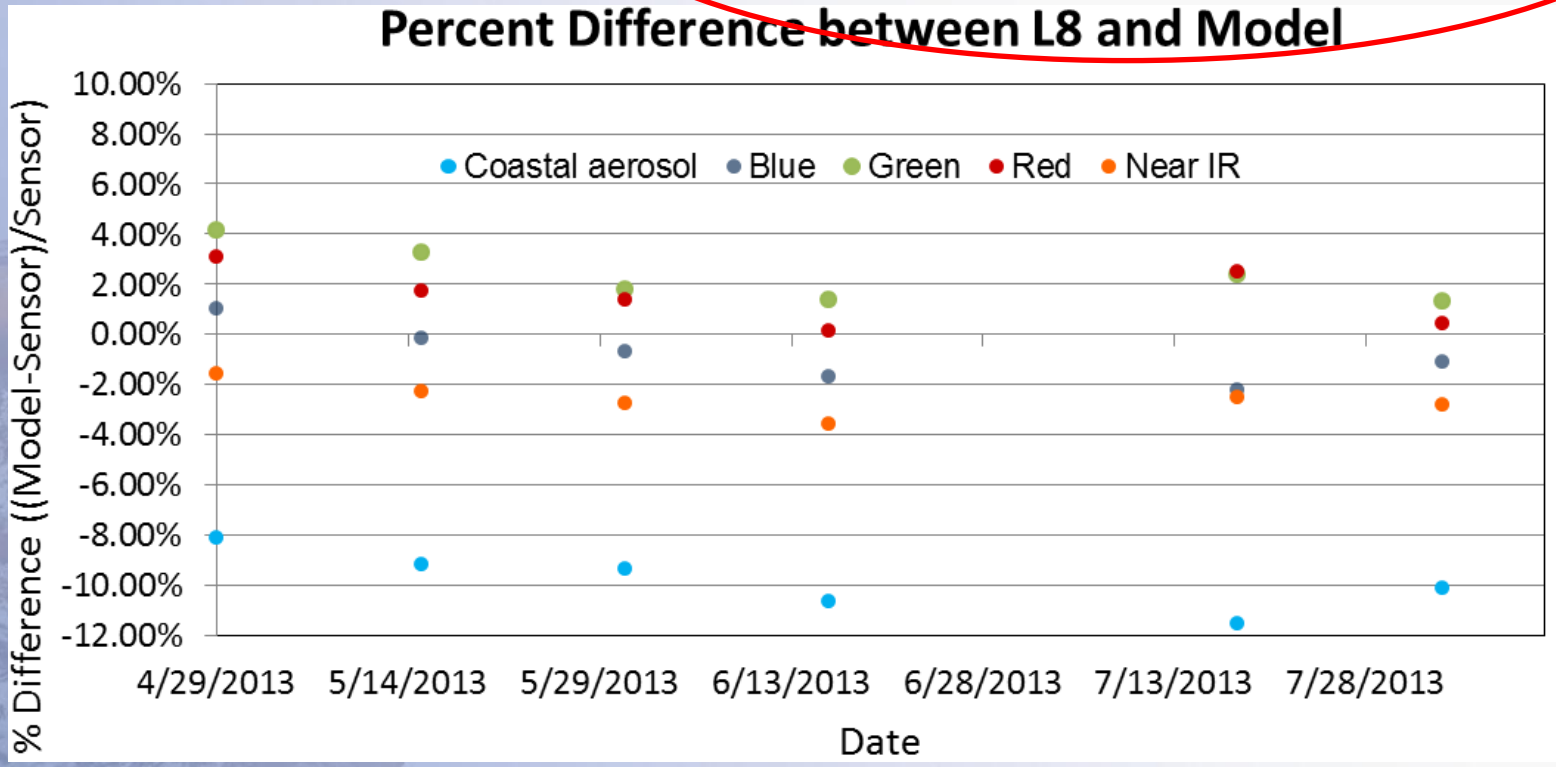
Summary of Model Validation Using L5 TM (18 scenes)

	Blue	Green	Red	NIR
RMSE	2.11%	1.81%	1.40%	2.59%
STD	1.26%	1.07%	1.31%	1.88%

- RMSE explains the systematic error in the data and STD explains the random variation.
- Bands 1 and 4 have higher systematic error(~2.5%) as compared to Bands 2 and 3(~1.5%).
- Absolute calibration of Landsat 5 TM uncertainty is in the 3-5% range.

Summary of Model Validation Using Landsat 8 OLI (6 scenes)

	Coastal Aerosol	Blue	Green	Red	NIR
RMSE	9.91%	1.33%	2.59%	1.86%	2.67%
STD	1.20%	1.14%	1.12%	1.15%	0.66%



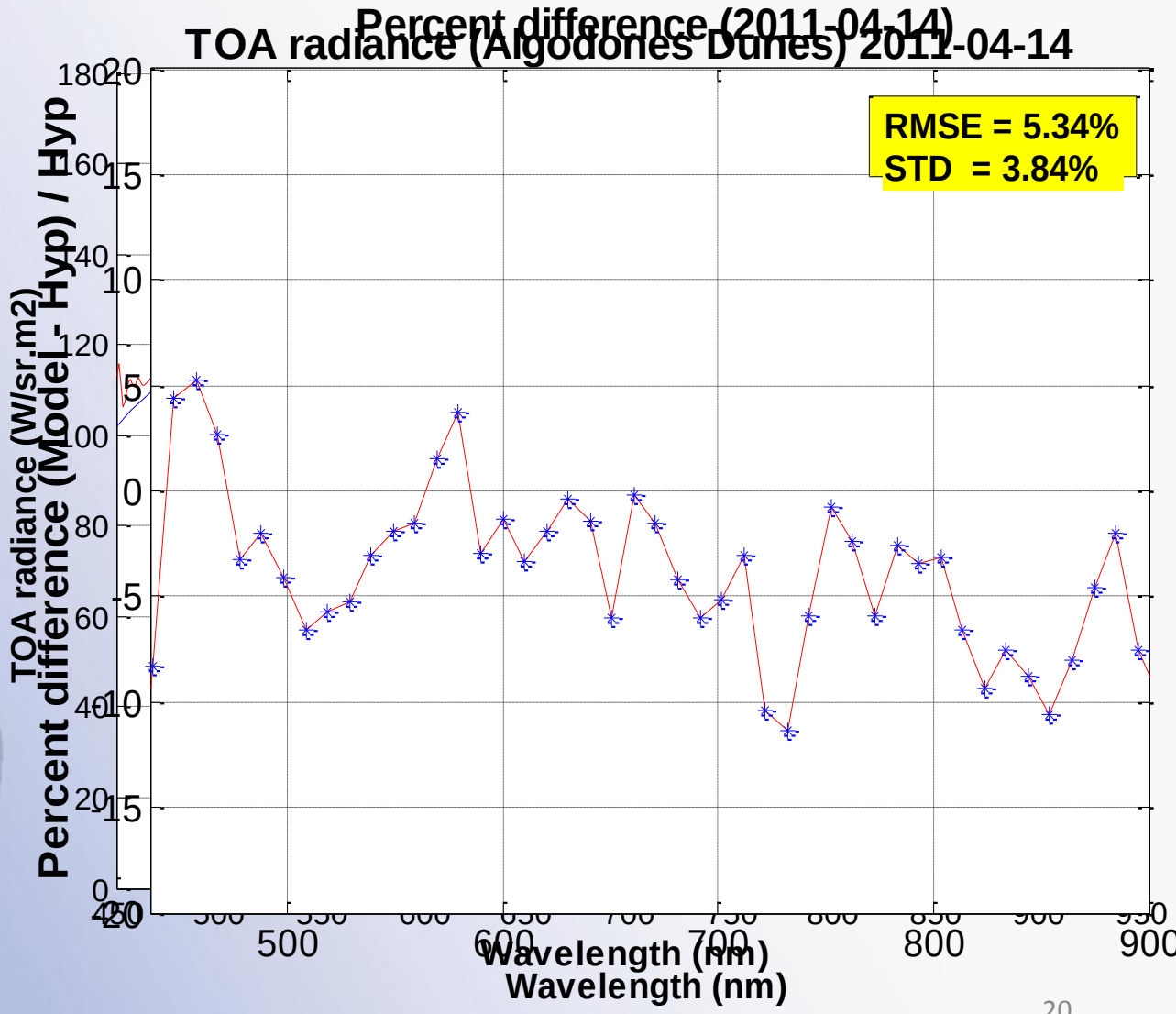
Coastal Aerosol band has very high systematic error which can be related to the surface reflectance measurement at lower wavelength.

Hyperion EO-1

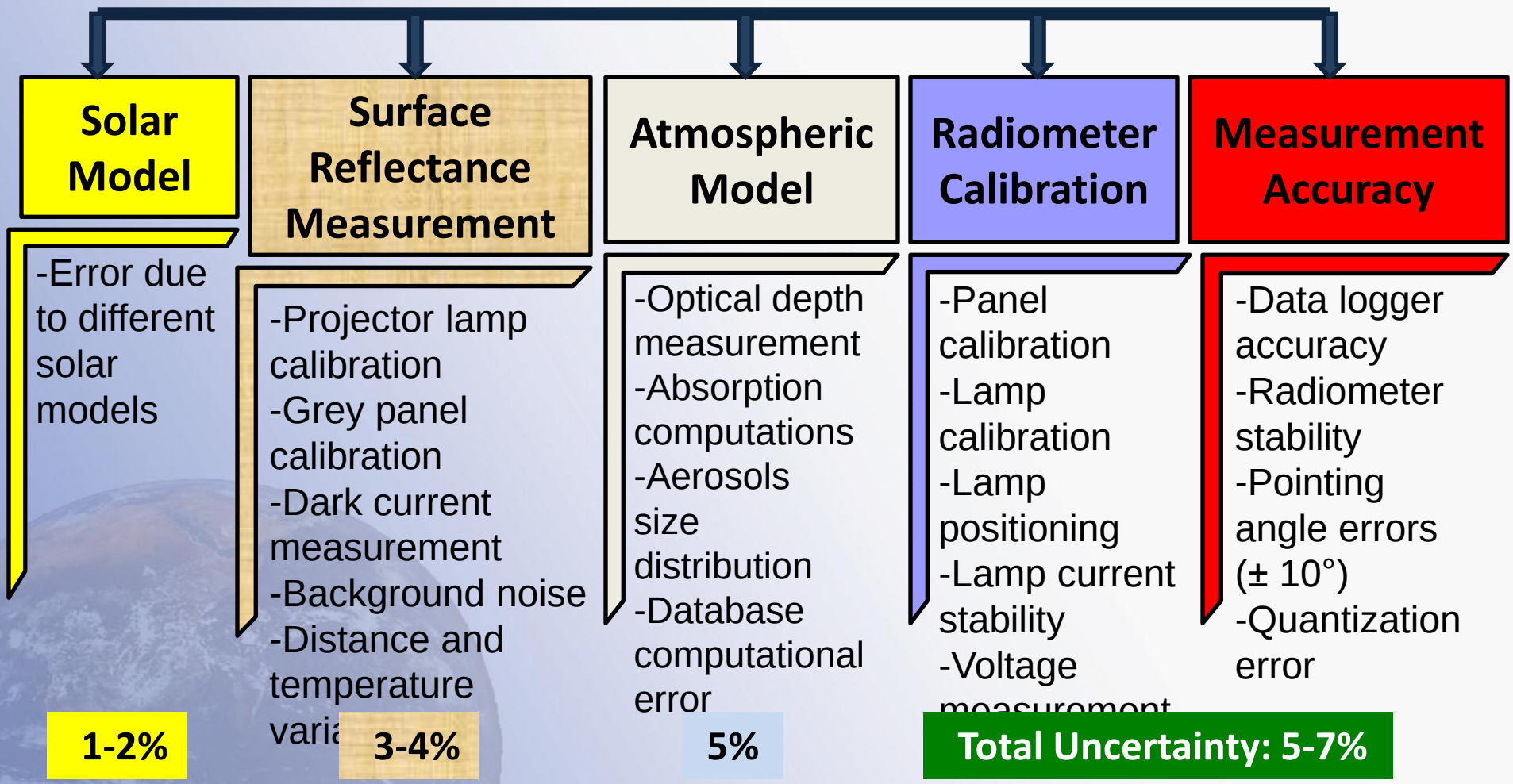
- Hyperion EO-1 image over Algodones dunes at center latitude 33.995 N and longitude 115.134 W.
- Hyperion provides a high resolution hyperspectral imager capable of resolving 220 spectral bands (from 0.4 to 2.5 μm) with a 30-meter resolution.
- The instrument can image a 7.5 km by 100 km land area per image, and provide detailed spectral mapping across all 220 channels with high radiometric accuracy.

Comparison of First Principles Model and Hyperion TOA Radiance

- The model(red curve) sampled at every 1nm allows to observe the various spectral features clearly as compared to Hyperion(blue curve) with spectral resolution of 10nm.
- Hyperion calibration coefficients are all based on pre- launch
- Some evidence that calibration drift may have occurred.



Error Sources



Thus, the 1st Principles model seems to be performing well within estimated uncertainties.

Summary and Next Steps

- ✓ A first principles model approach was used with the Sun as a calibrated source, a full atmospheric model through meteorological observations and a surface BRDF spectra.
- ✓ Validation of the first principles model was extended to nadir sensors (L5 TM and L8 OLI), nadir collects for Hyperion and the results were encouraging.
- ➢ Develop a surface model using reflectance measurements from Algodones dunes sand.
- ➢ Optimize solar and atmospheric models.
- ➢ Develop an error budget.
- ➢ Transfer the surface model to PICS sites in Africa.

Thank You!