

1 ☐ Satellite sensor radiometric calibration

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3 ☐ Background

- Working Group on Calibration & Validation (WGCV) – International Committee on Earth Observation Satellites (CEOS)
- *Remote sensing calibration* – process of quantitatively defining the system response to known controlled signal inputs

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5 ☐ Fundamental aspects to be calibrated

- Sensor system's response to EMR as a function of:
 - Wavelength and/or spectral band (spectral response)
 - Intensity of input signals (radiometric response)
 - Different locations across the IFOV and/or the overall scene (spatial response, uniformity)
 - Different integration times & lens or aperture settings
 - Unwanted signals – stray light & leakage – from other spectral bands

6 ☐ Why is this important?

- Estimating land surface bio/geophysical variables accurately from RS data relies largely on quality of the data
- Depends on accuracy of radiometric calibration

7 ☐ Terminology

- Radiometric calibration
 - Process that converts recorded sensor voltages or digitized counts to an absolute scale of radiance – independent of image forming characteristics of the sensor
 - Relative or absolute calibration

8 ☐ Terminology

- Absolute calibration
 - Linear sensor: performed by ratioing the digital numbers from the sensor with the value of an accurately known, uniform radiance field at its entrance
- Relative calibration
 - Normalizing the outputs of the detectors to a given, often average, output from all detectors in the band

9 ☐ Preflight calibration

- Calibration may change in space – response to variations in the environment surrounding the sensor in a spaceborne environment
 - Outgassing
 - Bombardment by energetic particles from space
 - Variation in the filter transmittance & spectral response
 - Slow deterioration of the electronic system

10 ☐ In-flight absolute calibration

- Performed on a routine basis for thermal IR bands – allows for precise temperature information

- Solar channels for imaging – don't have onboard calibration capabilities because of limitations in satellite power, weight & space
- 11 ☐ **Post-launch calibration data**
 - Need to obtain from vicarious calibration techniques
 - Vicarious calibration – techniques that make use of natural or artificial sites on the surface of the Earth for post-launch calibration of sensors
- 12 ☐ **Approach to sensor calibration**
 - Formulate a sensor calibration model
 - Simplest form:
 - $Y = A L$
 - where Y represents the DN values, A is the matrix of absolute calibration coefficients, L is radiance
 - To determine matrix A:
 - Accurate preflight measurements, then monitored on orbit by onboard calibration devices (secondary or tertiary standard light sources – lamps or the Sun)
 - Vicarious methods – images of specific well-known ground targets or the Moon
- 13 ☐ **Post-launch calibration methods**
 - Radiance-based calibration method
 - Fly an aircraft with a calibrated radiometer
 - Measure the spectral radiance of the target observed by the satellite in the same illumination & observing directions – simultaneous measurements
 - Reflectance-based calibration method
 - Accurate measurement of spectral reflectance of the ground target
 - Measurement of spectral extinction depths & other meteorological variables
 - See Figure 5.1
- 14 ☐ **Post-launch calibration methods**
 - These calibration methods - most direct – relatively expensive & complex
 - Can't calibrate historical data
- 15 ☐ **Post-launch calibration methods**
 - Another technique: compare observed radiance with radiative transfer calculations using physical characteristics of atmosphere & surface targets – see Chapter 2
 - Surface targets: ocean, desert, cloud, snow, dry lake, ice sheet, Moon
- 16 ☐ **Ocean calibration**
 - Relies on molecular scattering in the atmosphere over the ocean
 - Conditions: cloudless air mass, small amount of haze far away from the ocean glint – major contribution (70-80%) to upward radiance over deep oceans in the visible part of the spectrum is from molecular scattering in the atmosphere
 - Viewing conditions: deep oceans to get clear water, large viewing & solar zenith angles to increase the photon travel path length, viewing the western direction to avoid specular reflection
- 17 ☐ **Ocean calibration**
 - Glint radiance – 87% is due to specular reflectance
 - Depends on wind speed & wave structure
 - Independent of wavelength – determine relative calibration of near IR bands to visible bands
 - Good conditions – 2-5 m/sec wind speed
- 18 ☐ **Desert calibration**
 - Advantages

- Stable spectral response over time
- With their high reflectance, atmospheric effect on upward radiance is minimal
- Spatially uniform
- Typical desert sites
 - Libyan desert for AVHRR
 - North Africa desert for SPOT
 - Egyptian desert for int'l sensor intercalibration
 - White Sands Missile Range for high resolution imagery, used since the 1980s

19 ☐ Clouds

- Very-high-altitude (10-km) bright clouds used for good validation targets
 - Visible & near IR spectral
 - High spectrally consistent reflectance
- With clouds high, don't need to correct for aerosol scattering & water vapor absorption (these are distributed near the surface)
- Consider only Rayleigh scattering & ozone absorption

20 ☐ Other calibration sites

- Dry lakes & other large homogenous areas – Railroad Valley Playa (clay), Rogers Dry Lake (Edwards AFB)
- Permanent ice sheets – Greenland & Antarctica
- Cloud shadows over water – calibrate high-resolution sensors

21 ☐ Other calibration sites

- Moon – stability of reflectance is extremely high
 - Check in-flight stability of a solar diffuser
 - Provide a direct calibration of the sensor
- Flagstaff, AZ – making long-term radiometric measurements of the Moon
 - EOS calibration – radiometric stability of the lunar surface to give long-term, on-orbit calibration & cross-calibration of EOS and non-EOS sensors flown on similar & different platforms
- See Table 5.1

22 ☐ Linear radiometric response

- Each spectral band has its own response function
- Band characteristics monitored using onboard calibration lamps (temperatures references for thermal band)
- Absolute spectral radiance output of calibration sources known from prelaunch calibration – assume stable over life of sensor

23 ☐ Figure 7.4

- Linear fit to the calibration data – radiance & DN values related by:
 - $DN = GL + B$
 - DN = digital number value recorded
 - G = slope of response function (channel gain)
 - L = spectral radiance measures (spectral bandwidth of channel)
 - B = intercept of response function (channel offset)
- Slope & intercept – *gain* & *offset* of the response function

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25 ☐ Figure 7.4

- LMIN – spectral radiance corresponding to a DN response of 0

- LMAX – minimum radiance required to generate the maximum DN (255)
 - LMAX – radiance at which the channel saturates
- Range from LMIN to LMAX is the dynamic range of the channel

26 ☐

27 ☐ Figure 7.5

- Inverse of the radiometric response
- Interchanged the axes from Fig. 7.4
- $L = (LMAX - LMIN / 255) DN + LMIN$
- Can convert any DN in a particular band to absolute units of spectral radiance in the band, if LMIN & LMAX are known from sensor calibration
- LMIN & LMAX values – $mW\ cm^{-2}\ sr^{-1}\ \mu m^{-1}$
- To estimate total within-band radiance, multiply by width of spectral band

28 ☐ Calibration coefficients

- Landsat TM
- NOAA AVHRR
- See Section 5.3 for details