HyspIRI derived water surface temperatures for aquatic studies

Glynn Hulley, Simon Hook, Nathan Healey, Todd Steissberg, Rebecca Trinh

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

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Outline

1. Thermal Infrared Physics
2. Temperature/Emissivity Retrieval Algorithms
3. Temperature Validation
4. Example imagery from HyspIRI airborne campaign

Theoretical Basis: Surface Temperature

Radiometric ('Brightness') Temperature

$$T_\lambda(\theta) = B_\lambda^{-1}\left(L_\lambda(\theta)\right)$$

Land Surface ('Skin') Temperature (LST)

$$T_s = B_\lambda^{-1}\left(\frac{L_\lambda(\theta) - \rho_\lambda L^{\downarrow}}{\varepsilon_\lambda}\right)$$

where :

B_λ = blackbody spectral radiance

λ = wavelength

T_s = Surface Temperature

$T_\lambda(\theta)$ = Surface Brightness Temperature

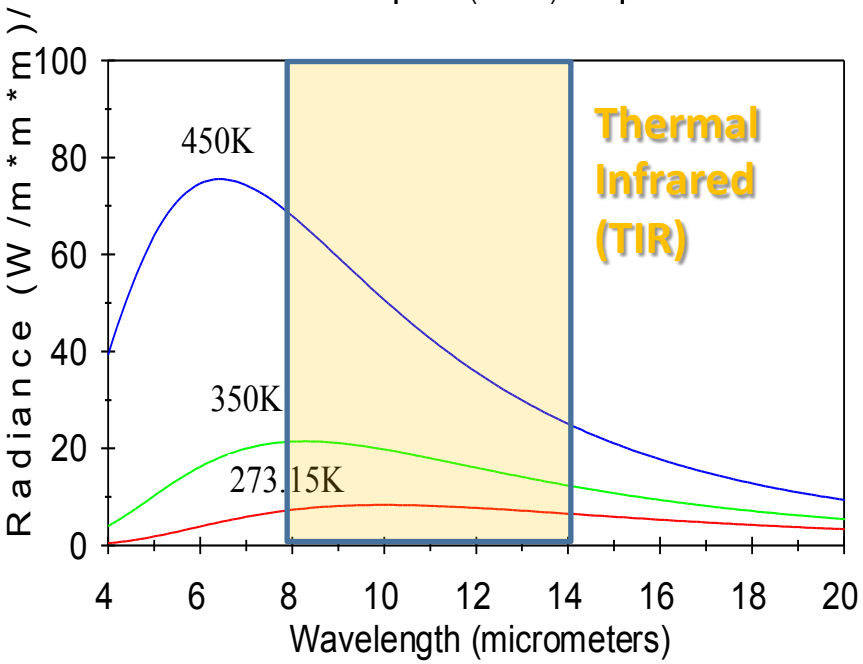
ρ_λ = Surface Reflection

$L^{\downarrow}$ = Downwelling Sky Irradiance

ε_λ = Emissivity

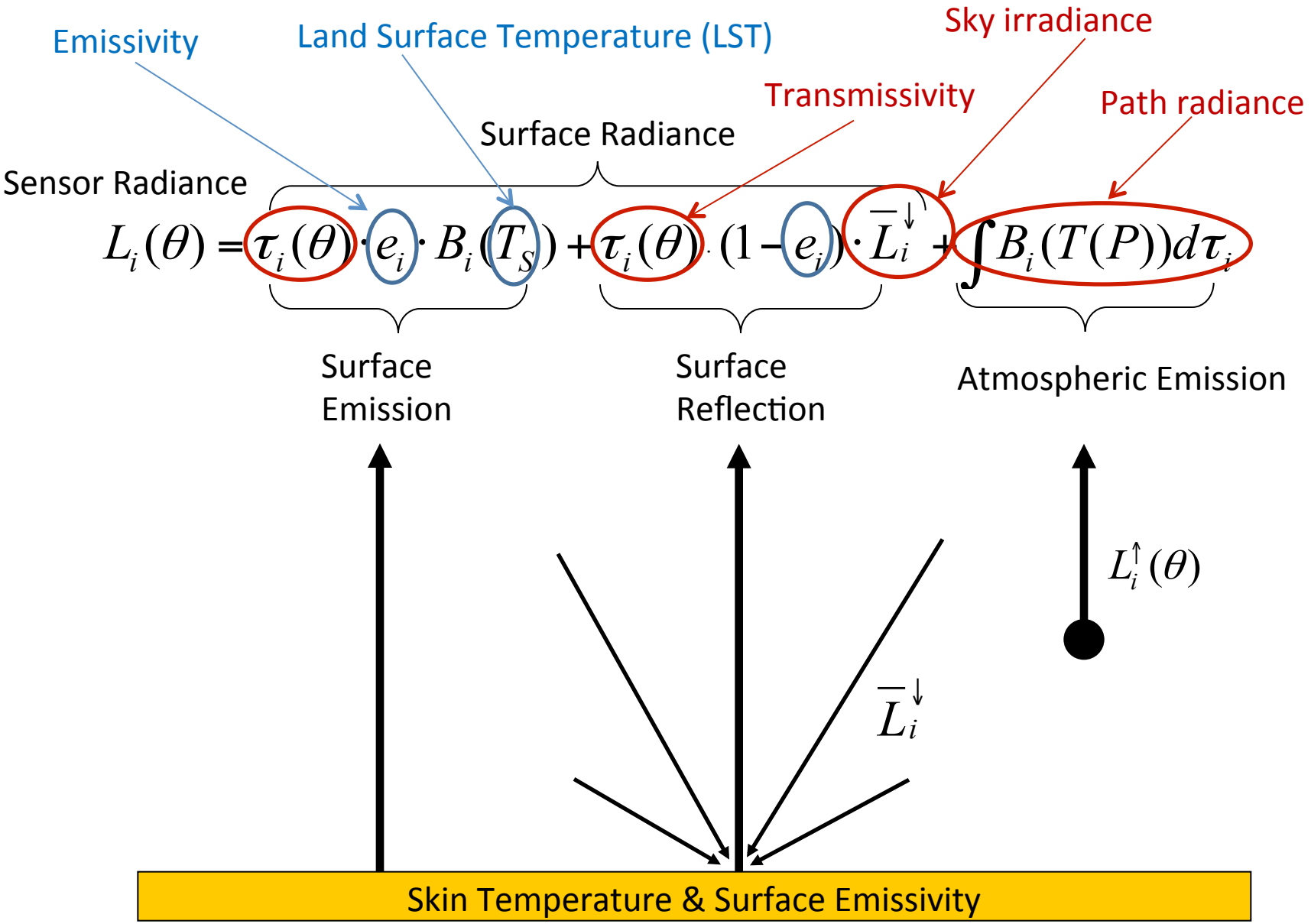
Planck Function

$$B_\lambda = \frac{c_1}{\lambda^5\left[\exp\left(\frac{c_2}{\lambda T_s}\right) - 1\right]}$$



in the Planck function shifts to shorter and shorter wavelengths

Thermal Infrared Radiative Transfer



Temperature/Emissivity retrieval algorithms

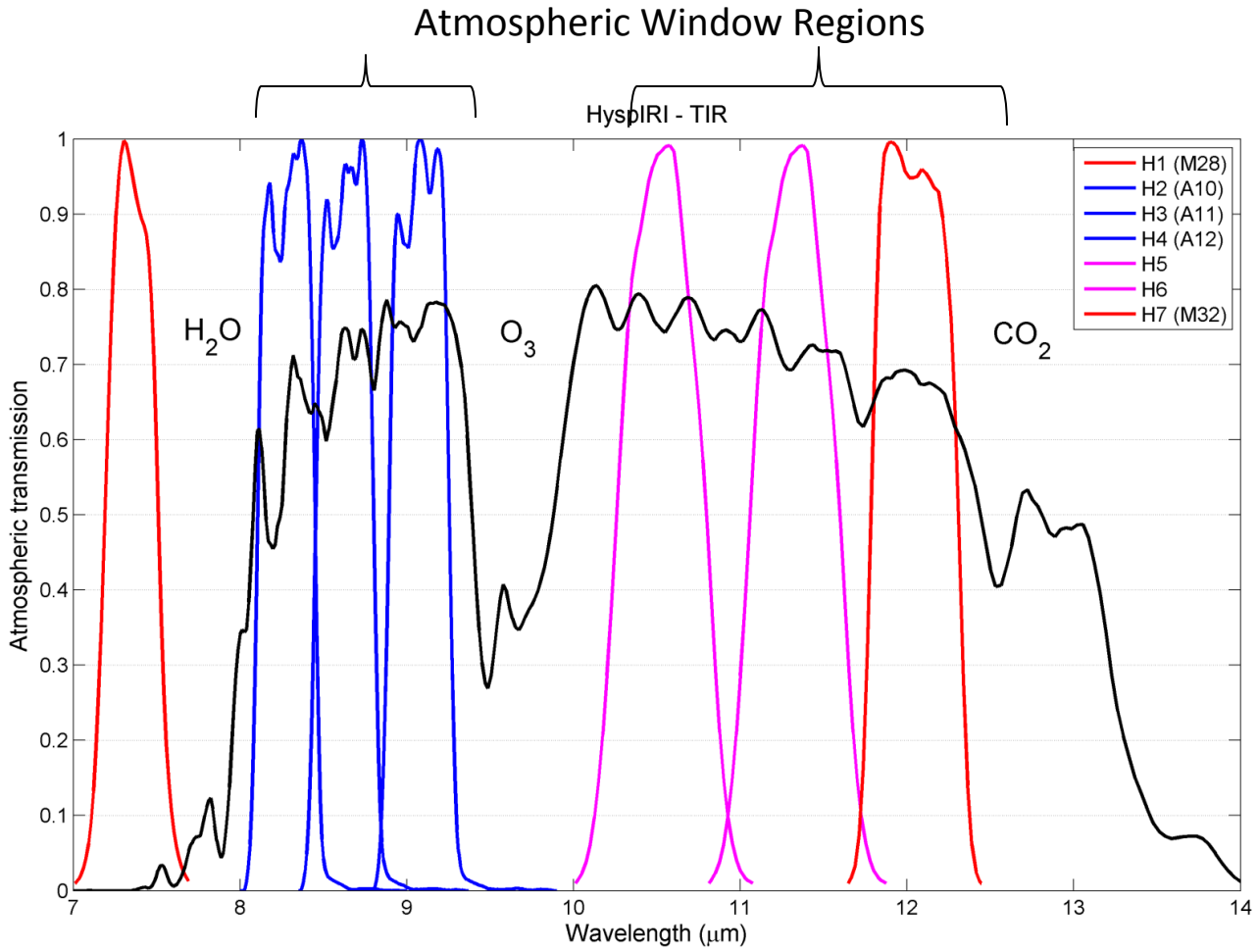
Under-determined problem:

N spectral measurements (N radiances) with N + 1 unknowns (N emissivity, 1 Temperature)

1. Split window approach $LST = a_0 + a_1 T_{11\mu m} + a_2 \left(T_{11\mu m} - T_{12\mu m}\right)$
   - Requires 2 bands, and prescribed spectral emissivity
   - Regression coefficients should represent all configurations (atmospheric water content, view angle, surface T_{air}, …)
   - Suffers large error when prescribed emissivity is incorrect (inconsistent)

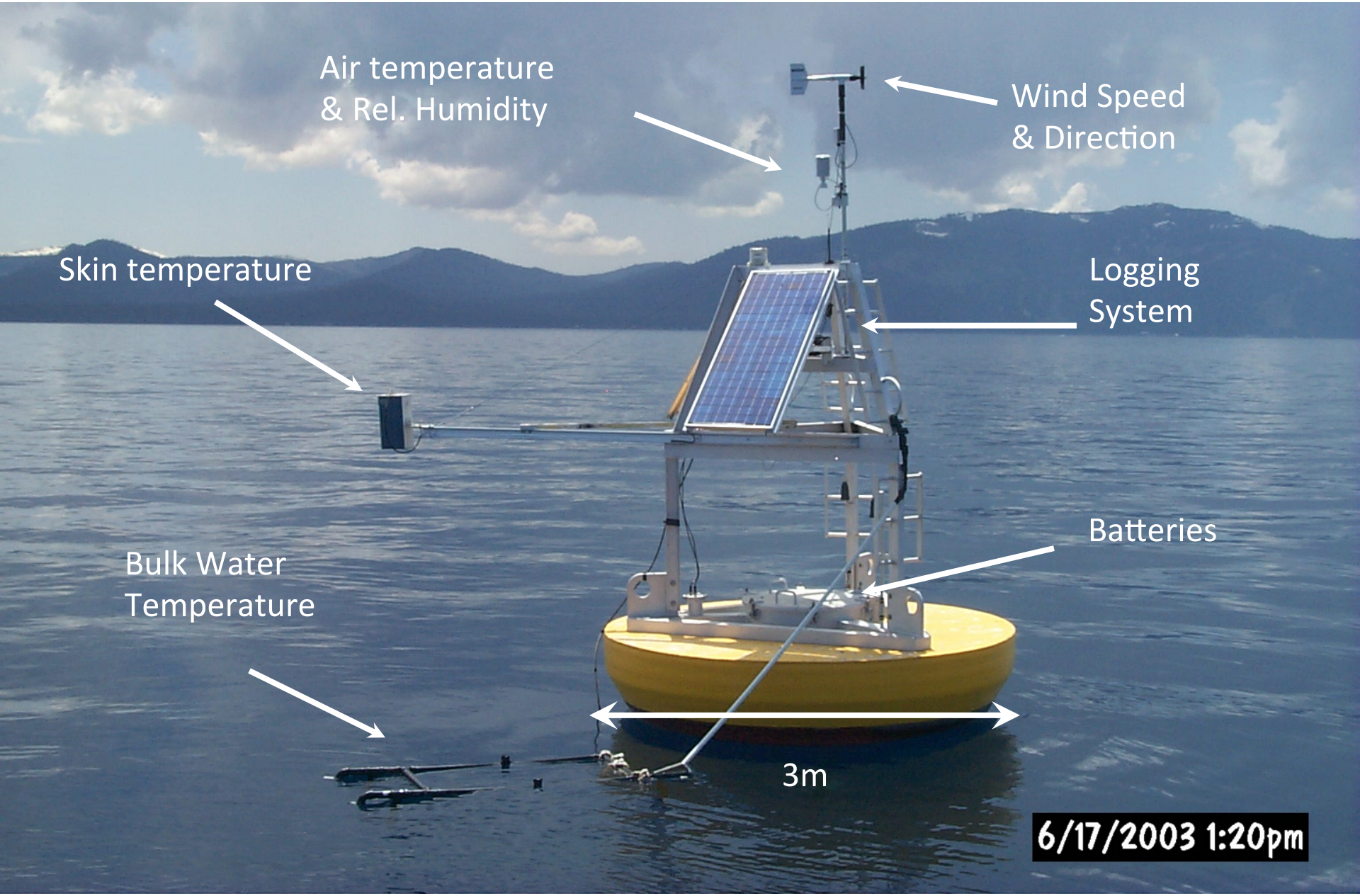
2. Temperature-Emissivity Separation Algorithm (TES) approach
   - Multispectral (minimum 3 bands)
   - MODTRAN atmospheric correction plus Emissivity model (Calibration Curve)
   - Current NASA standard approach ASTER, MODIS and VIIRS LST products
   - Standard algorithm for ECOSTRESS and HyspIRI (Also HyTES, MASTER)
   - Consistent accuracy across all land cover types

HyspIRI TIR Response Functions

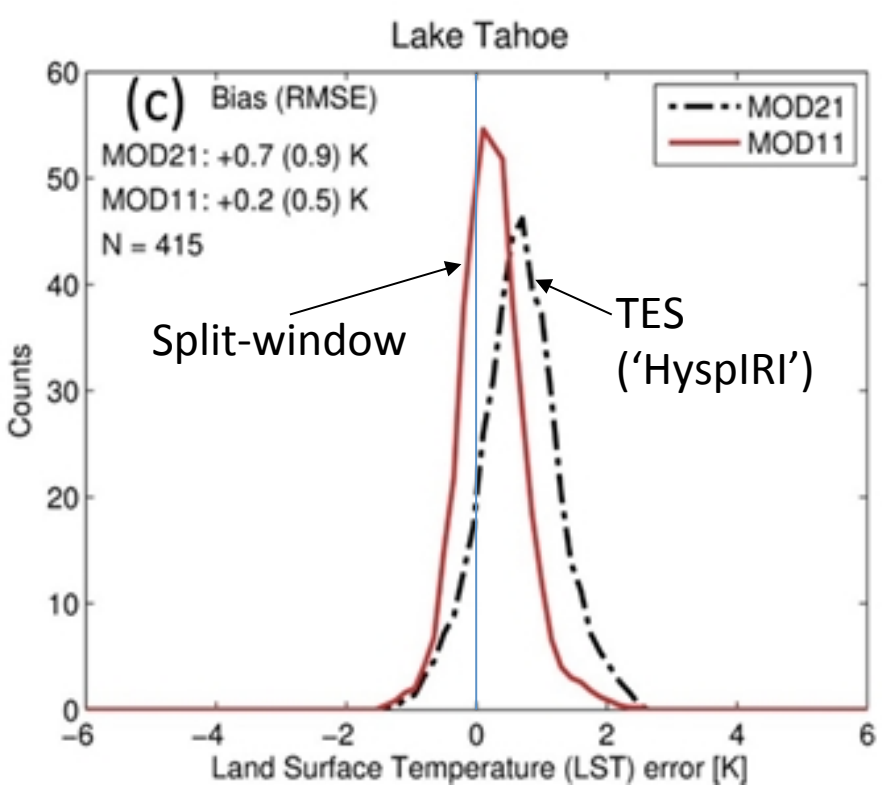


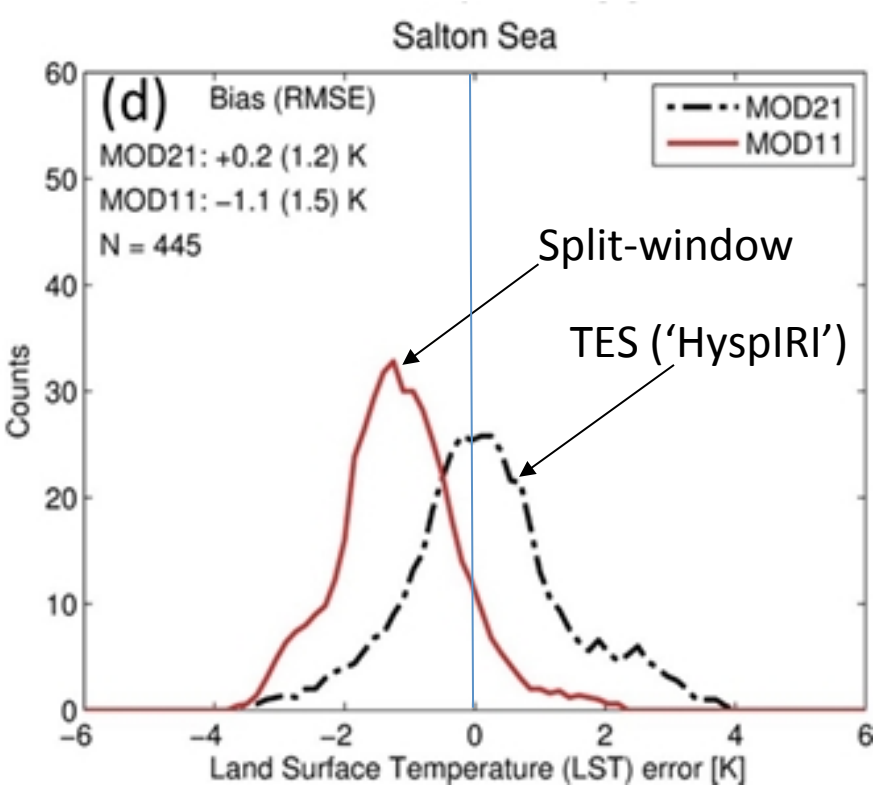
HyspIRI Level 2 Data = 6 emissivities, 1 surface temperature

Validation over water (Lake Tahoe)

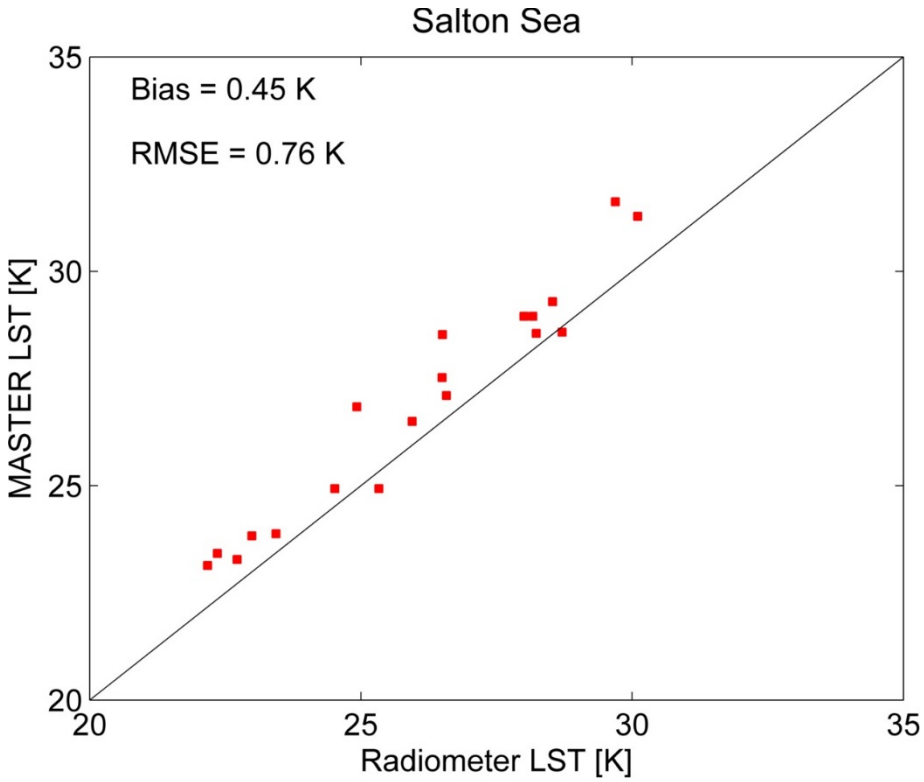


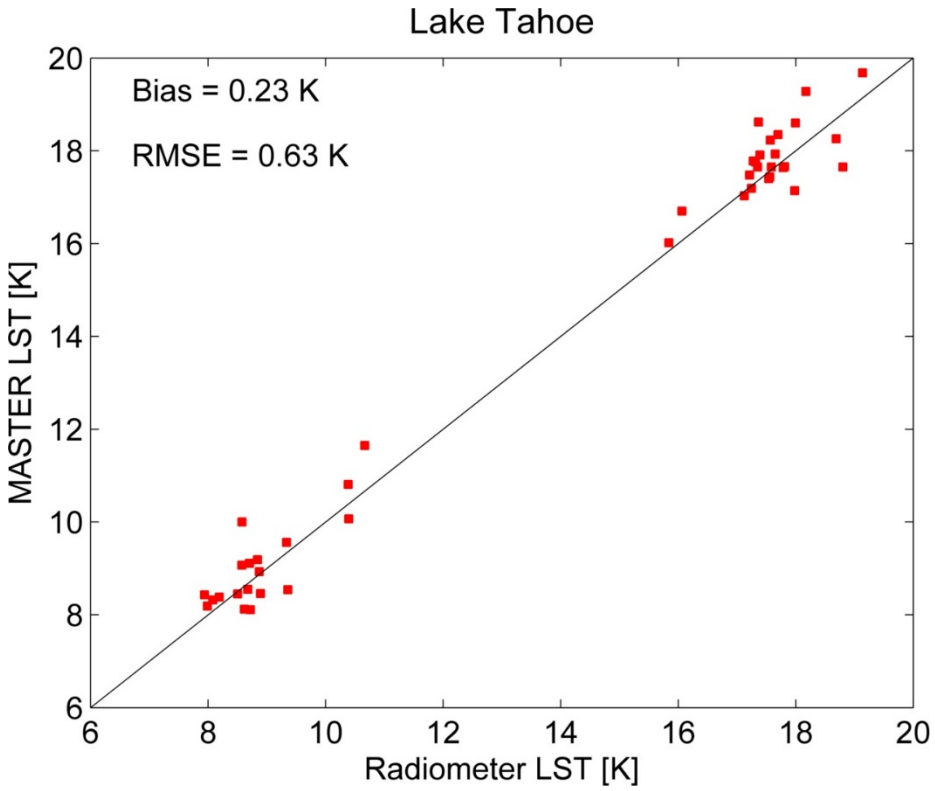
Temperature Validation at Tahoe/Salton Sea (MODIS)



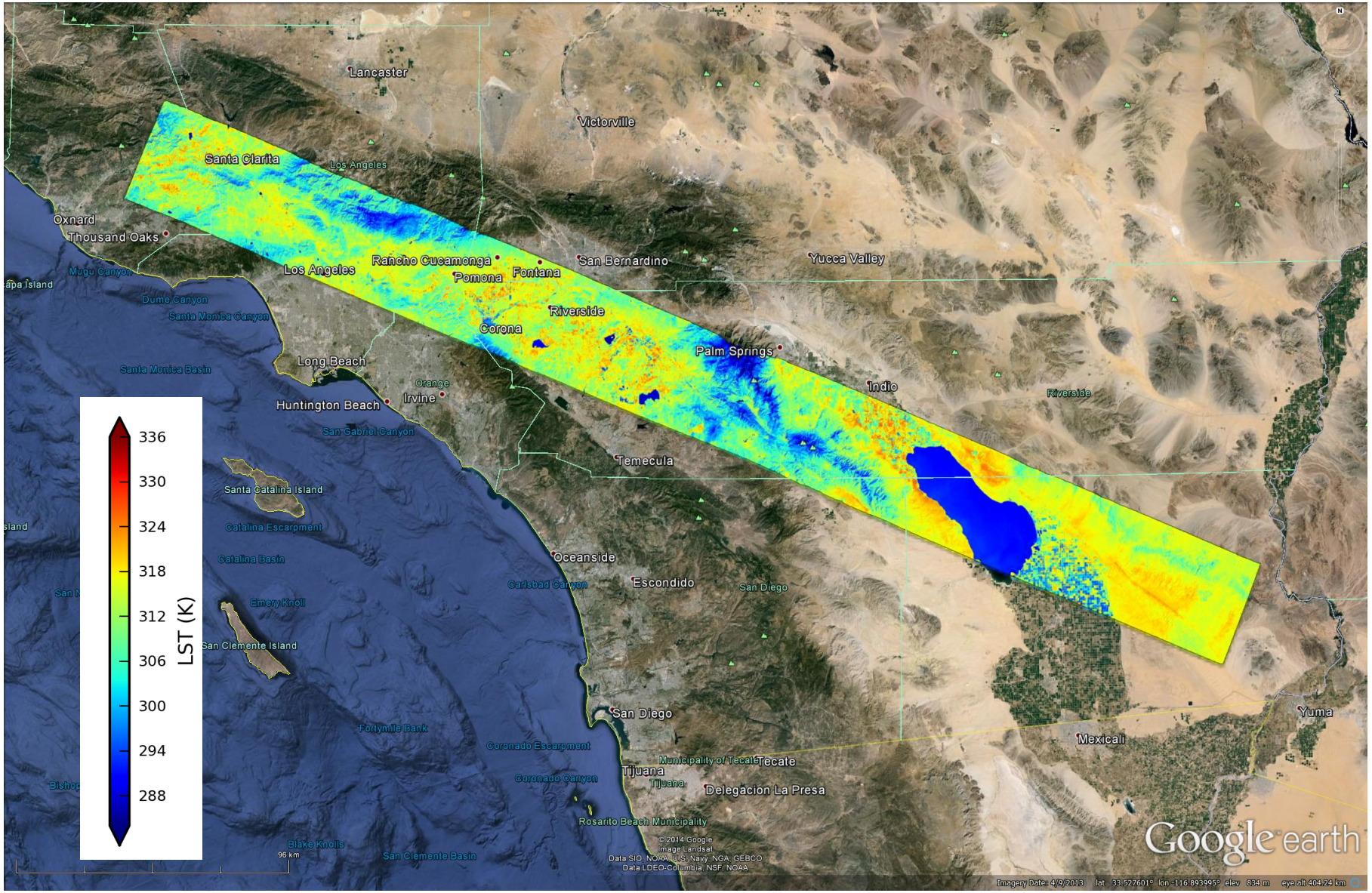


Temperature Validation (MASTER)

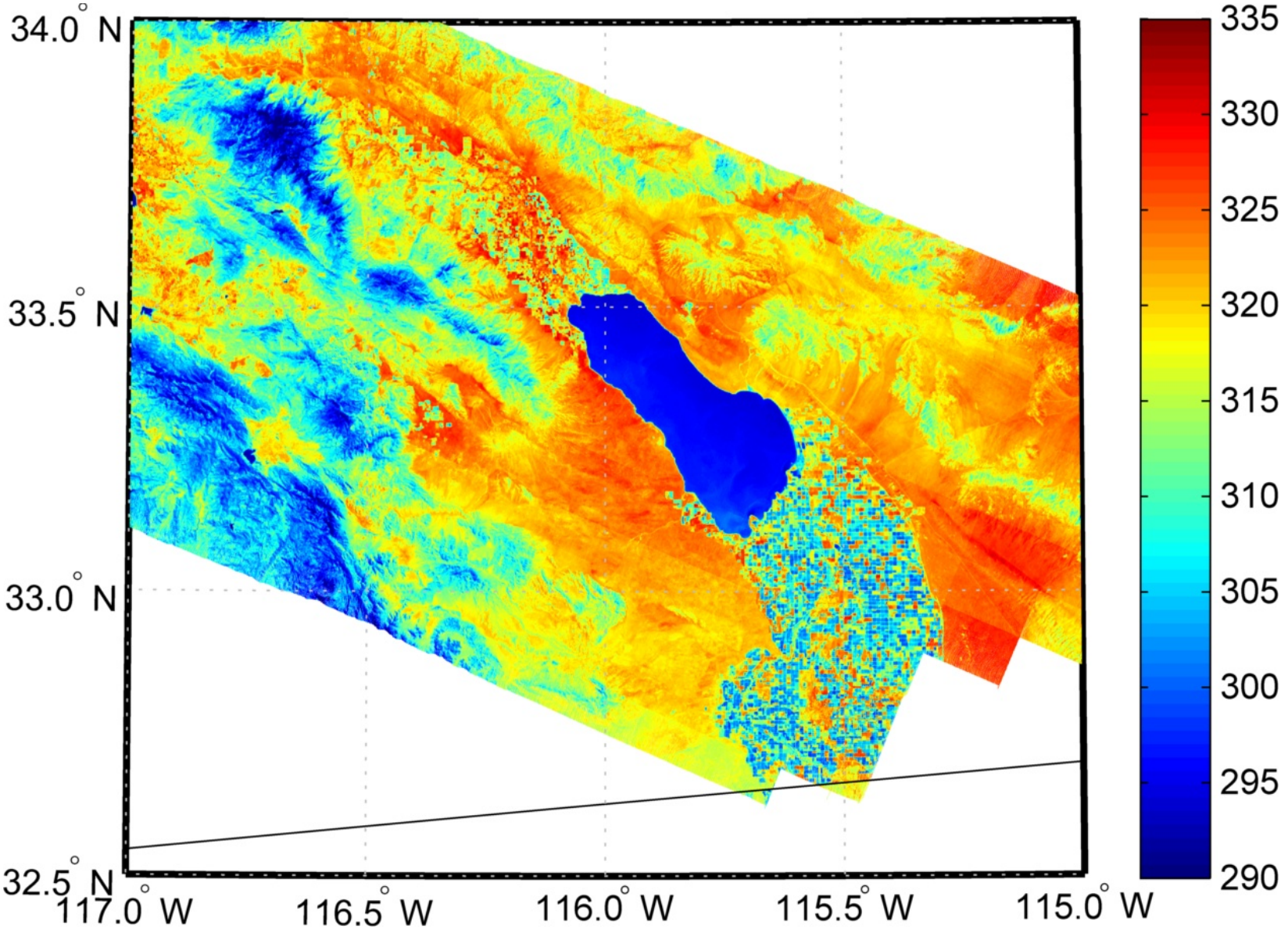




MASTER Temperature Image over Southern California

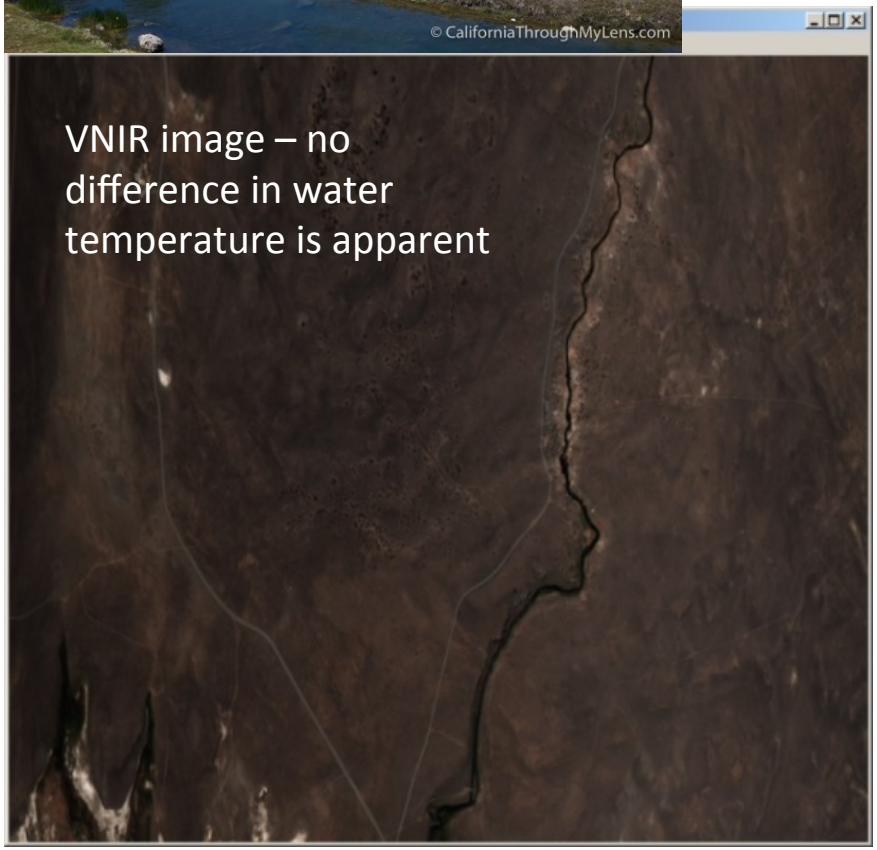


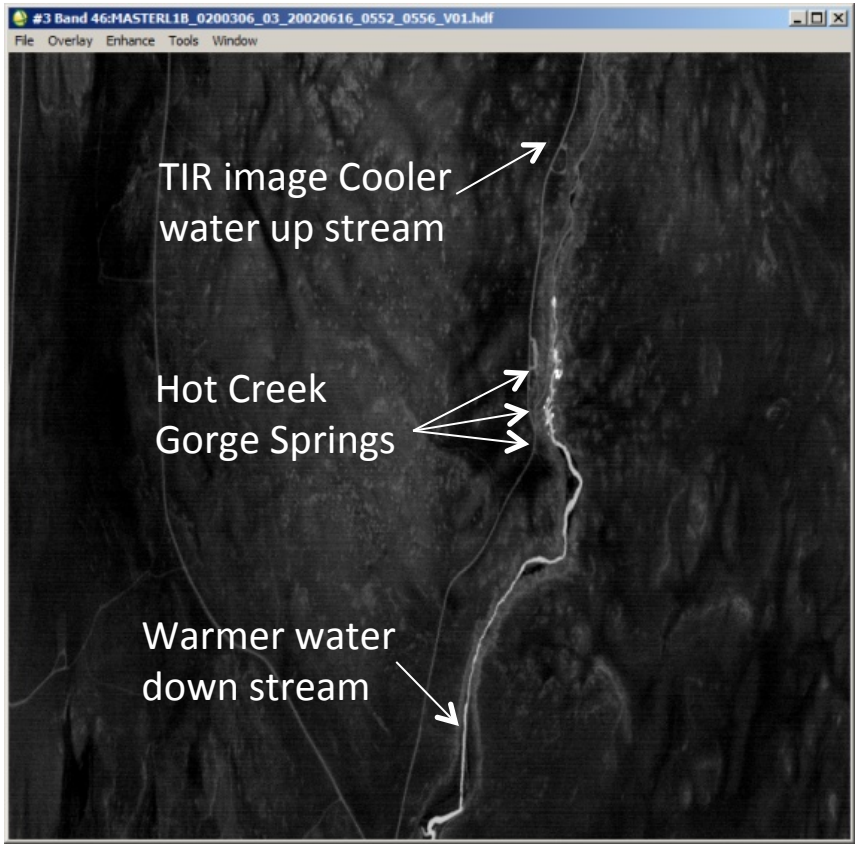
MASTER LST Mosaic at ~60 m (HyspIRI)



Temperatures of inland water bodies

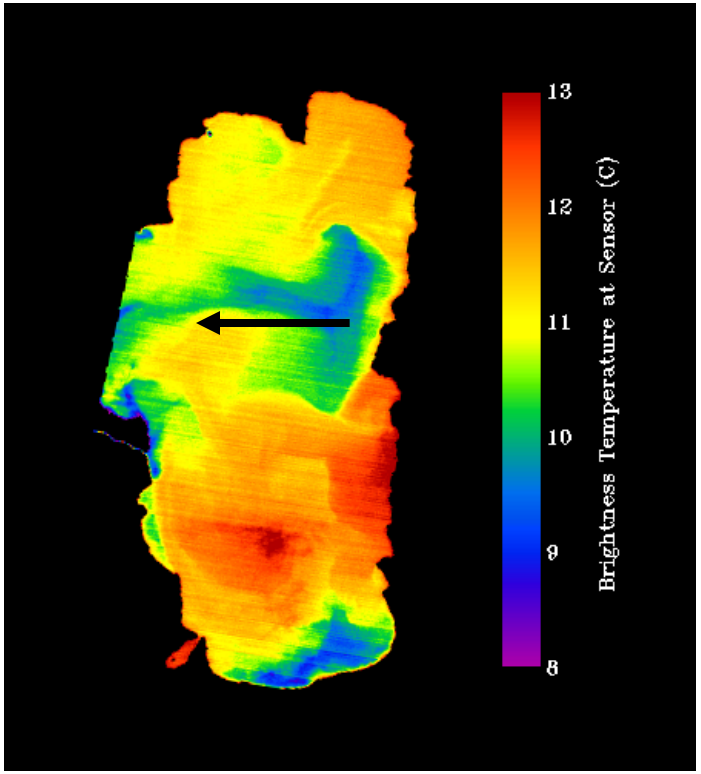
MASTER temperatures of Hot Springs in CA

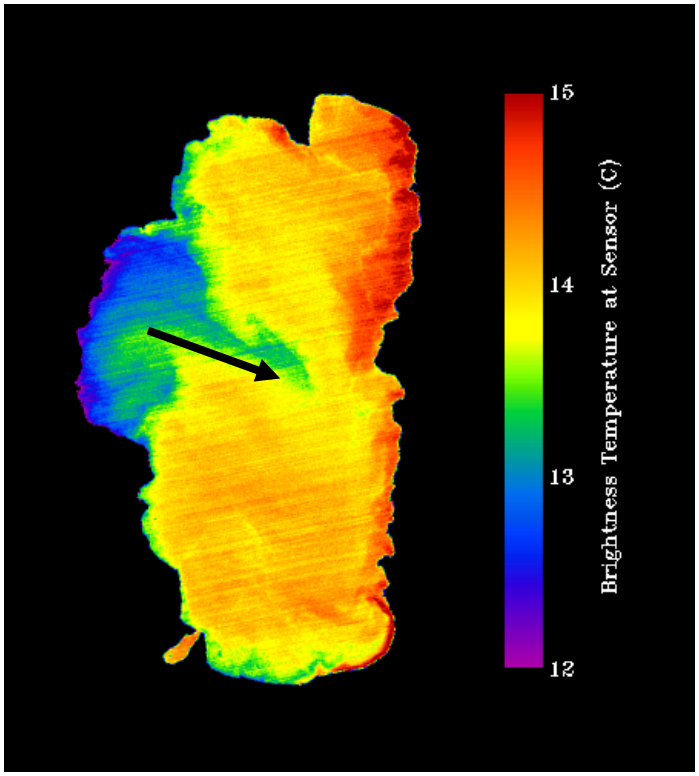




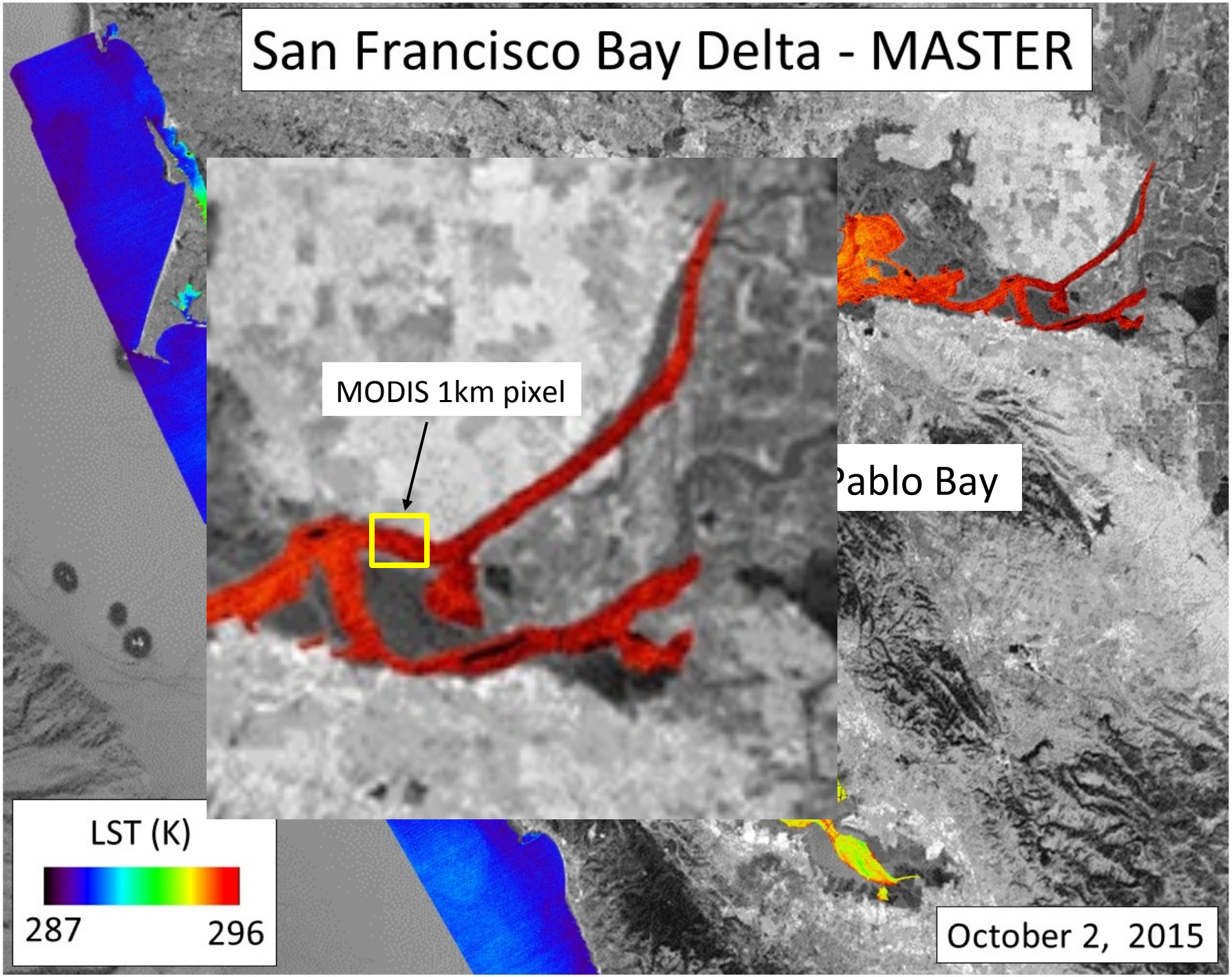
Temperatures of lacustrine systems

MASTER temperature of upwellings in Lake Tahoe, CA

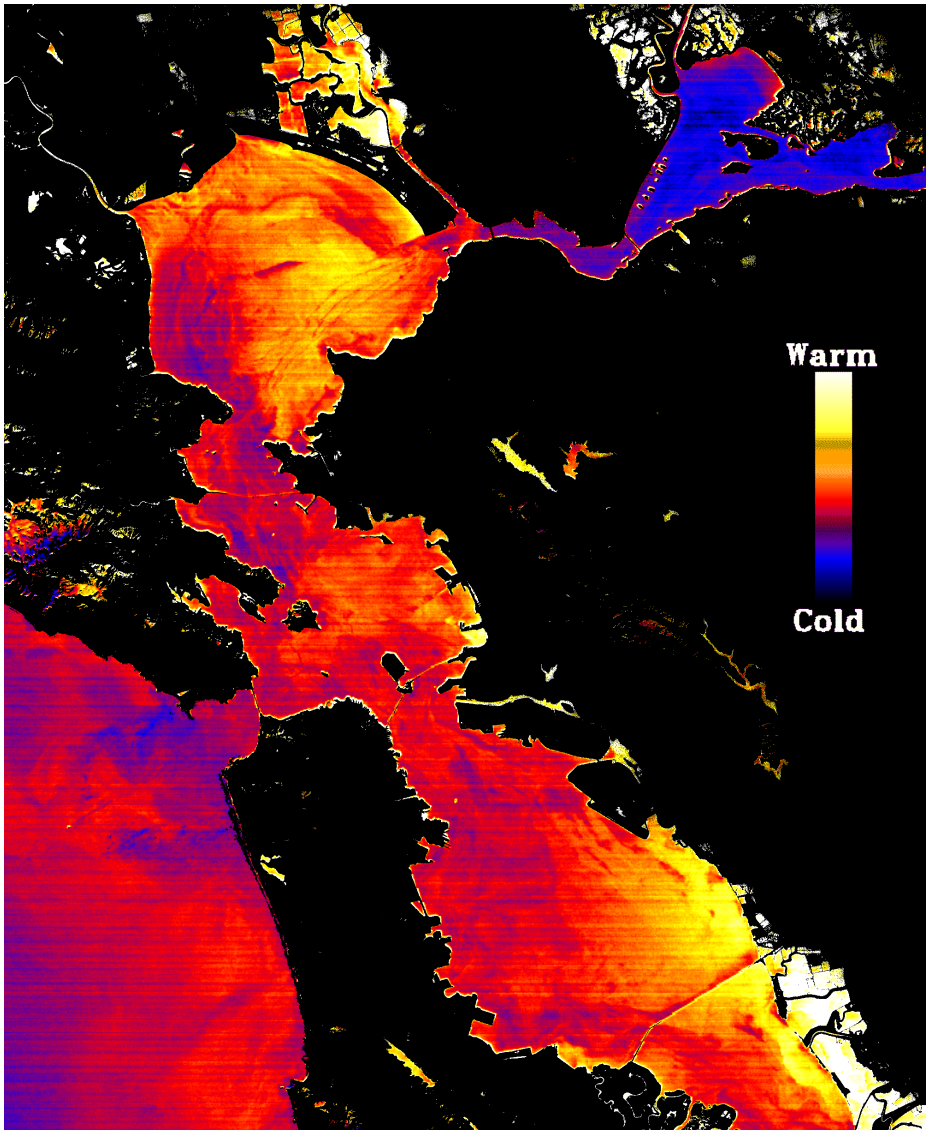




- Wind induced
- Denser water at depth (10-30m) at upwind lake boundary
- Ecosystem functioning - facilitate phytoplankton growth
- Satellite/airborne imagery can tell us about frequency, distribution, water quality


San Francisco Bay Delta - MASTER
MODIS 1km pixel
Pablo Bay
LST (K)
287
296
October 2, 2015

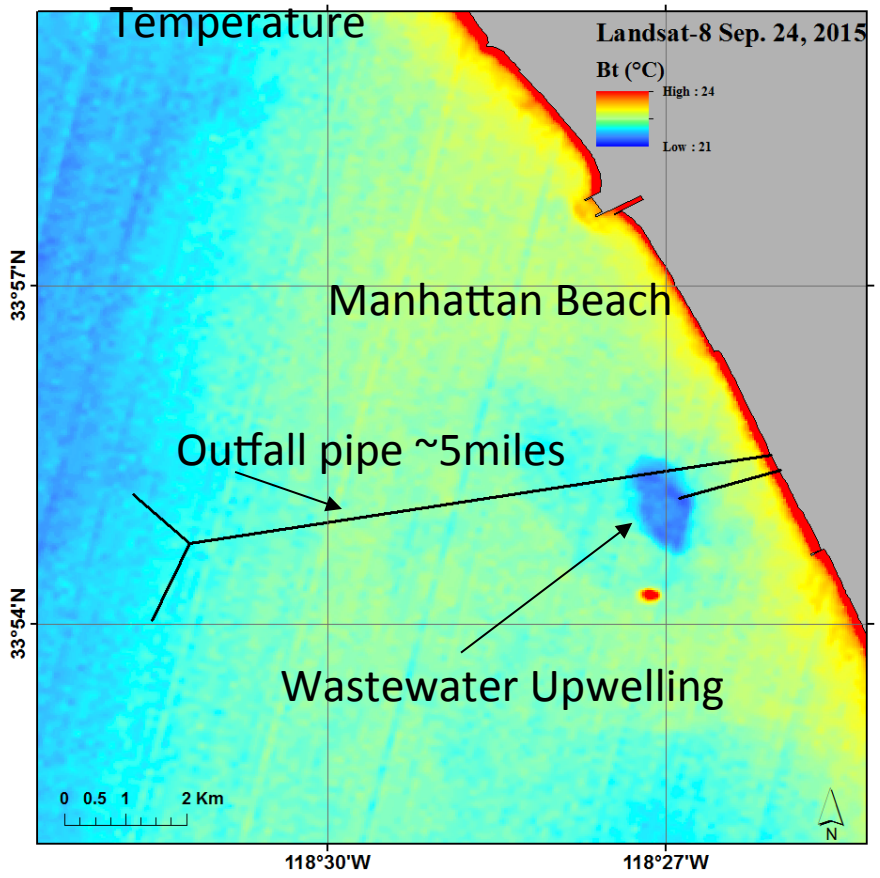
ASTER Image of San Francisco – March 2000



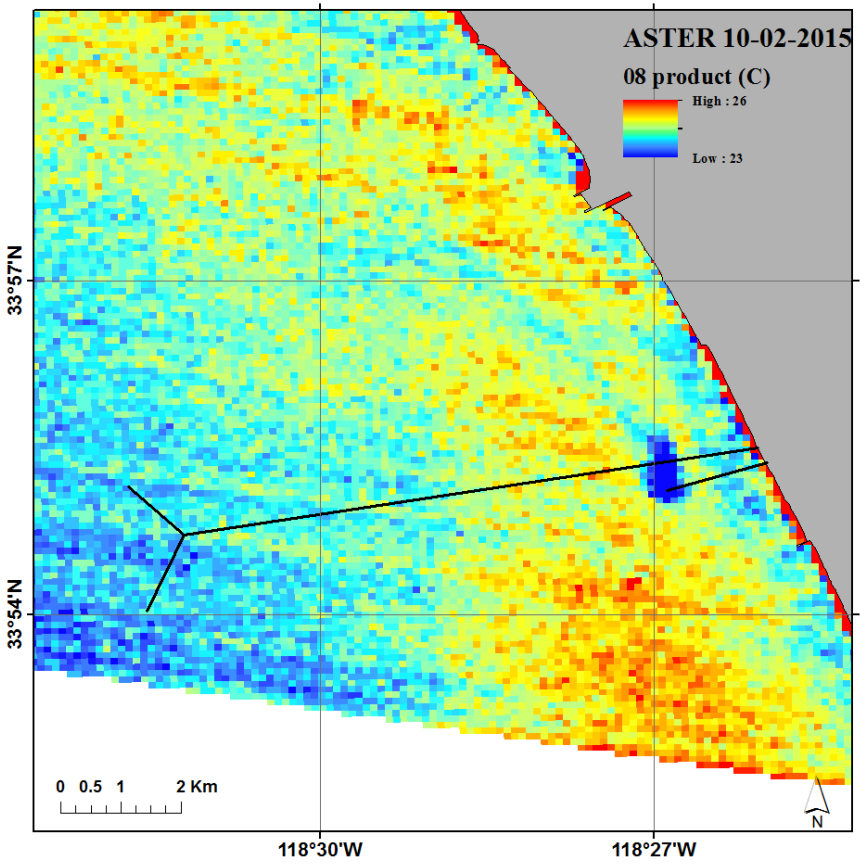
Note how the water from snowmelt is much cooler coming in from San Pablo Bay

Temperature Anomaly Detection
- Hyperion wastewater treatment facility

Landsat 8 Brightness Temperature



ASTER 08 Surface Temperature



**Small-scale anomalies only observable with HyspIRI-like measurements

Summary

- HyspIRI TES algorithm will retrieve land/water surface temperature at 60m spatial resolution with a 5-day repeat

- Validation of TES algorithm with other instruments has shown accuracies of ~1K over all surface types

- Useful for monitoring temperatures in deltas, coastal and inland water bodies, e.g. seasonal changes, upwellings in lacustrine systems, anomaly detection, and environmental disasters