A LAND SURFACE TEMPERATURE PRODUCT

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A Land Surface Temperature Product

Goals – Develop a methodology applicable to entire Archive (L4, L5 & L7) (L3?)

– Deliver methodology, software as appropriate and validation results/test sites to USGS for implementation.

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Approach – Focus initial efforts on north America to take advantage of available data

- NAALSED (N.A. Emissivity maps)
- NARR (N.A. Met data)

– Use North America to clarify how to do Globe

- Same approach with more interpolation of atmospheres & lower resolution emissivities
- Identify/develop better global reanalysis
- Build higher resolution global emissivity maps

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Implement Approach

Calibrate data base: Goddard, JPL, RIT

- L4, L5, L7 Updated trusted calibrations available – final error assessment ongoing

Atmospheric Compensation: RIT with JPL, USGS & Goddard

Emissivity values: JPL with RIT, USGS & Goddard

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Timeline: Year 1 Define Approach

- identify limitations
- identify filters
- perform sensitivity analysis
- identify QC issues

Implement & Test methodology

Year 2 Refine Algorithms and extend approach to Global database.

Evaluate initial products.

- compare to ASTER/MODIS
- compare to truth
- user evaluation

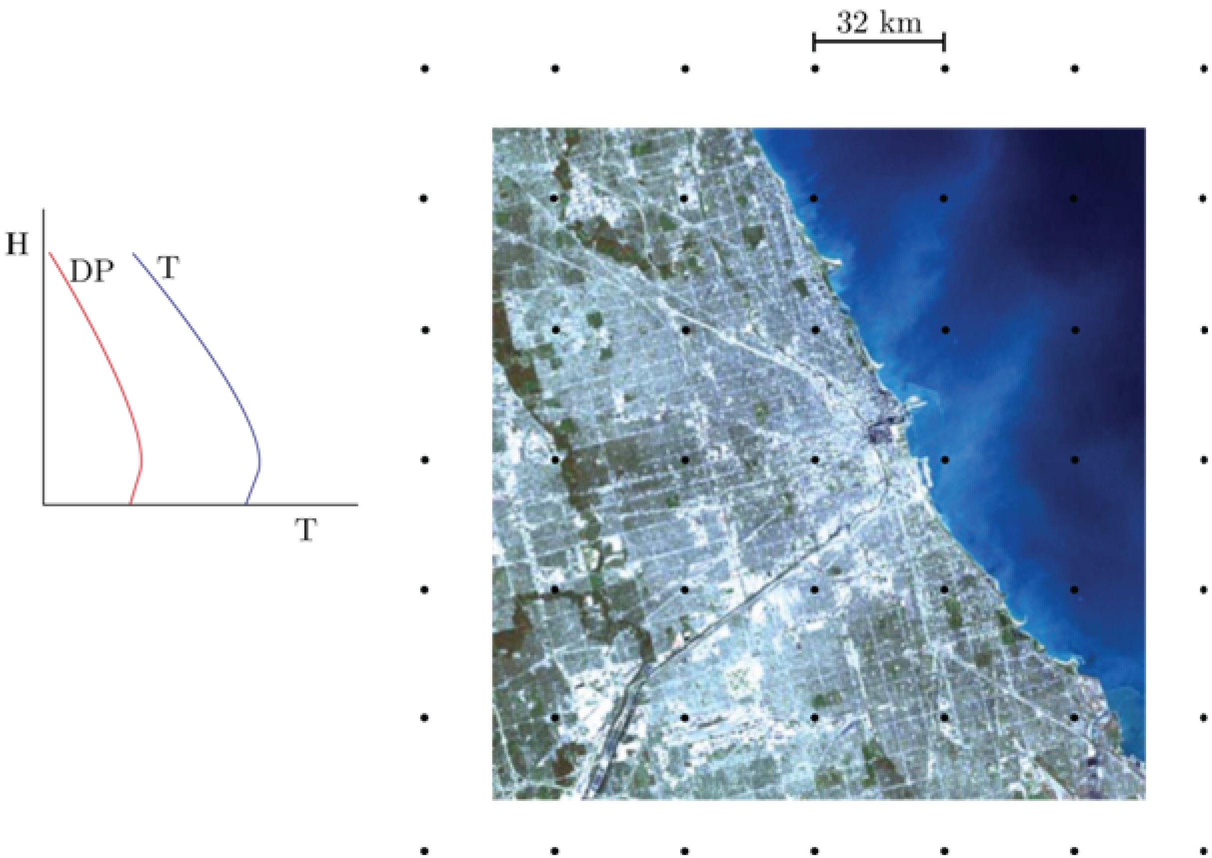
Year 3 Refine Global Algorithm based on Year 2 results

- validate at range of trusted sites
- deliver final tools to USGS

ATMOSPHERE

North America Regional Reanalysis (NARR) program

- 32 km. grid
- 3 hr temporal samples
- 29 atmospheric layers
- Spans entire Landsat time period



Filters

- Clouds
- Bad data
- High humidity

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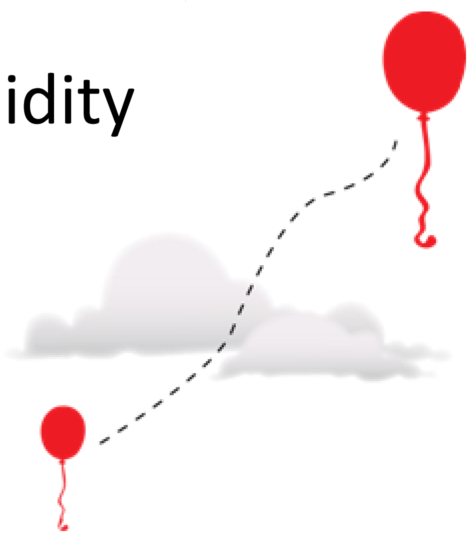
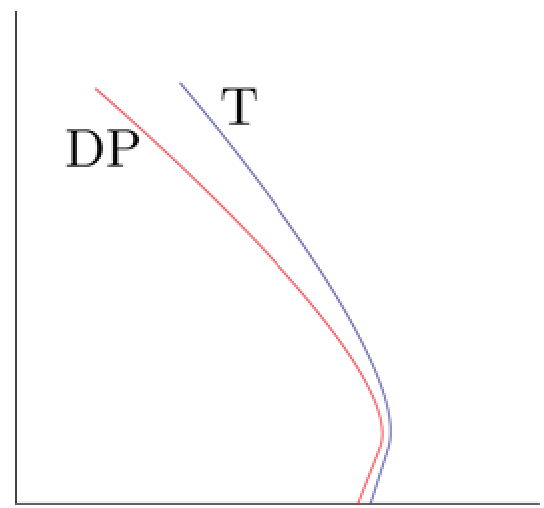
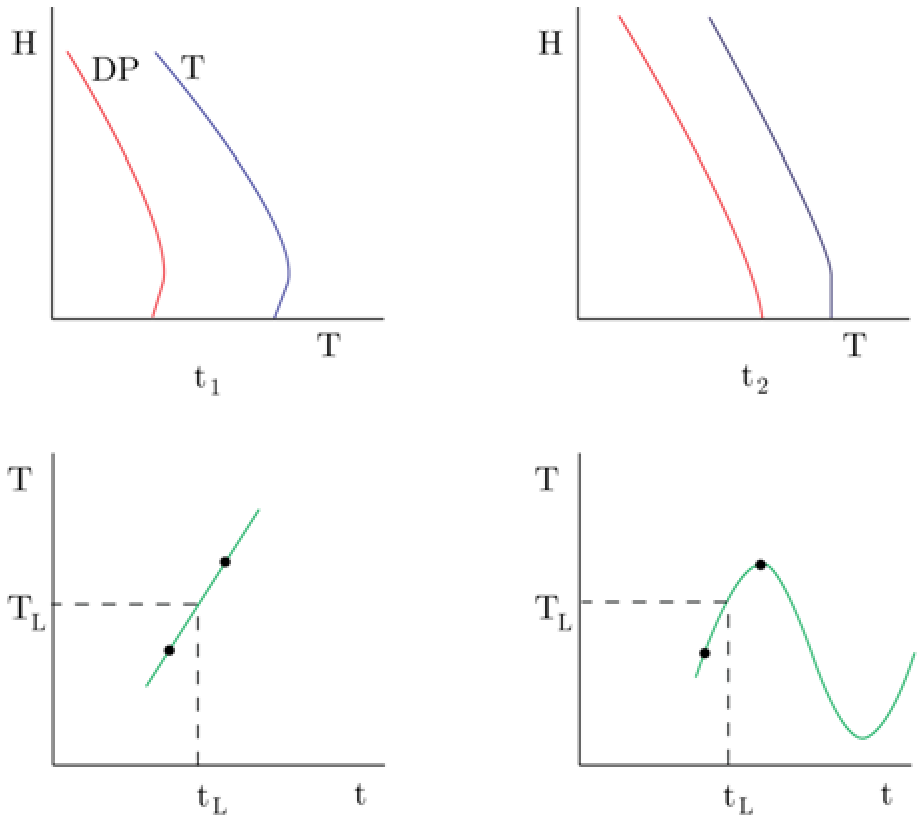
	25
	9999
	9999
2000	⋮
1000	
0	





- Interpolate in time
  - Linear
  - Diurnal

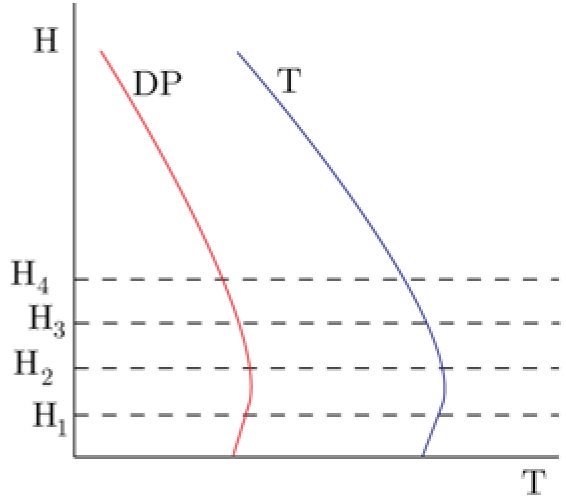


Profile samples at time 1 (t_1) and time 2 (t_2) for one sample location

Linear Interpolation for T at each altitude

Diurnal Interpolation for T at each altitude

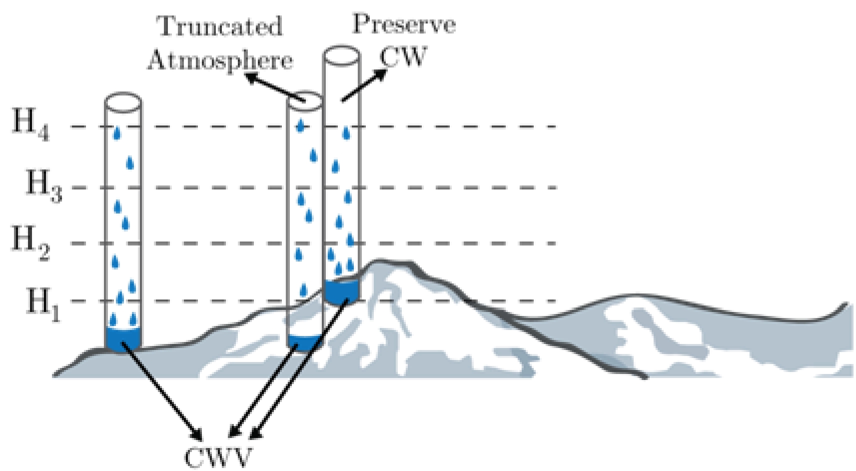
- Generate MODTRAN runs vs. Elevation(H) (H from USGS DEM)
  - Crop lower layers
  - Maintain CWV
  - Alternative logic?



Run Modtran for each altitude.

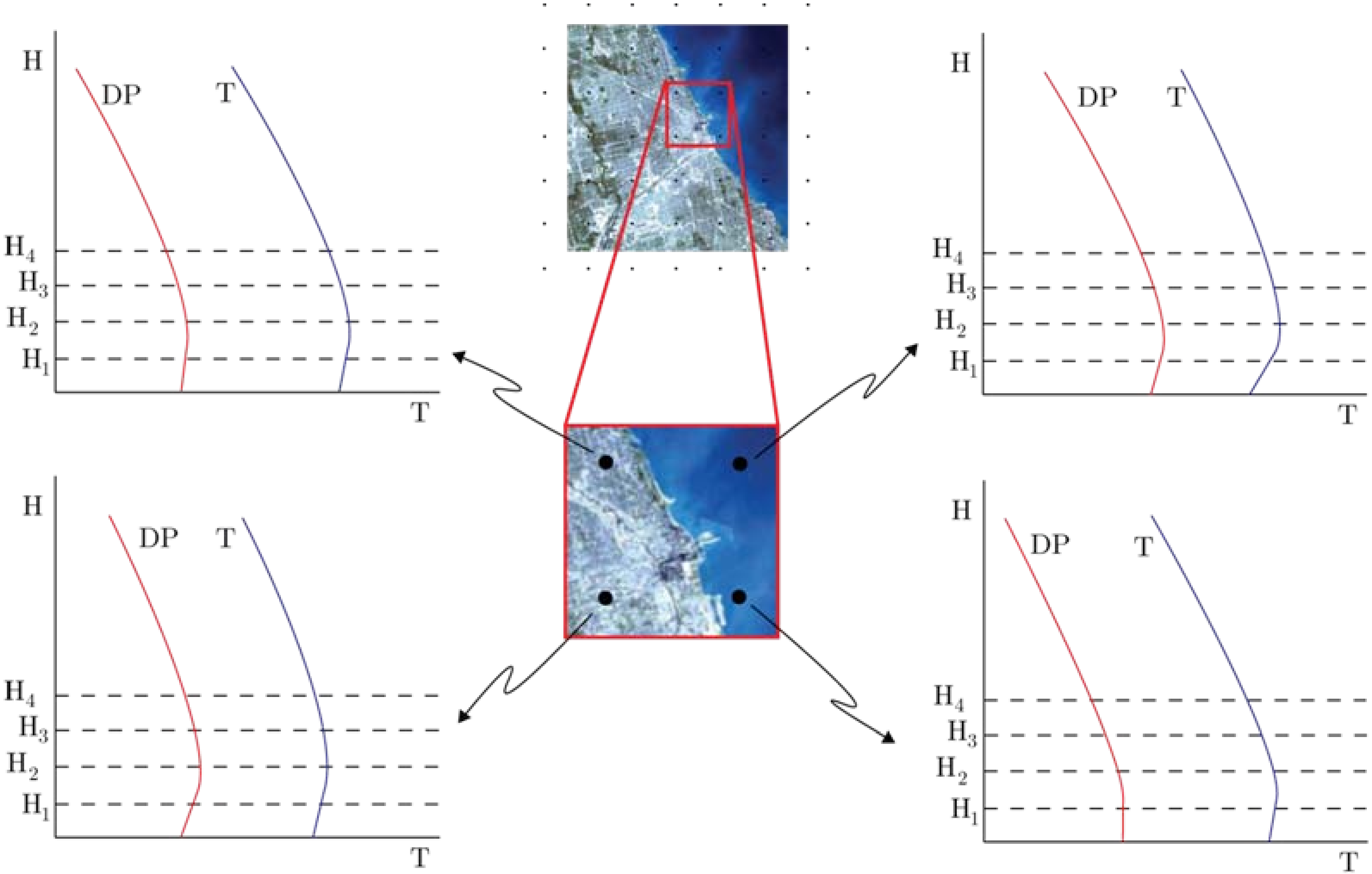
Output:

$$\tau(H),\ L_u(H),\ L_d(H)$$



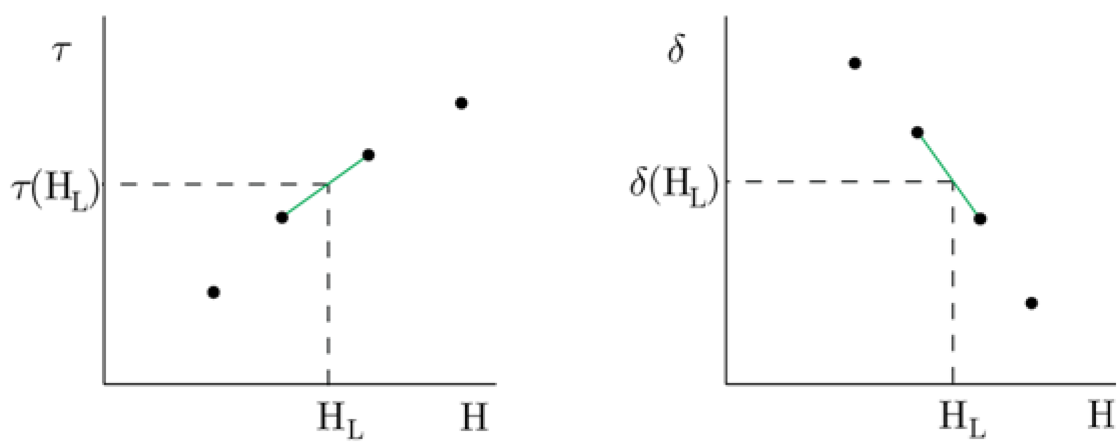
DIRS

For each node we can estimate the atmospheric parameters (τ, L_u, L_d) associated with altitudes H_i from Modtran



- Interpolate in parameter space (τ, L_u, L_d) on H for each profile site around the pixel of interest
  - Linear with H?
  - Linear in optical depth with H?

Interpolate to pixel height H_L

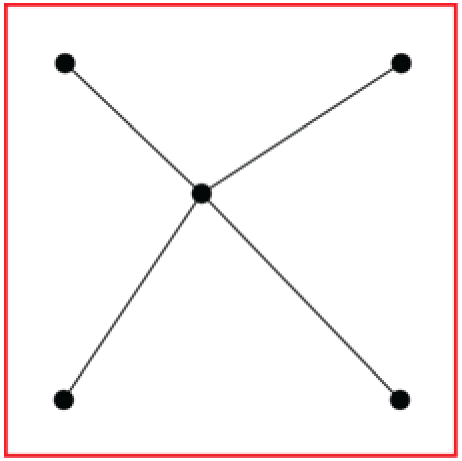


Linear with parameter

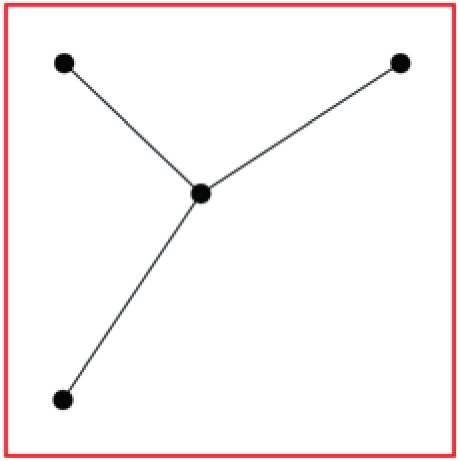
Linear with optical depth

Output: $\tau(H_L,t_L)$, $L_u(H_L,t_L)$, $L_d(H_L,t_L)$

- Interpolate spatially in parameter space for fixed time and elevation at Nodes (profile sites)
  - Nearest neighbor?
  - Inverse distance (3 node, 4 node)?
  - Inverse exponential?



4 node

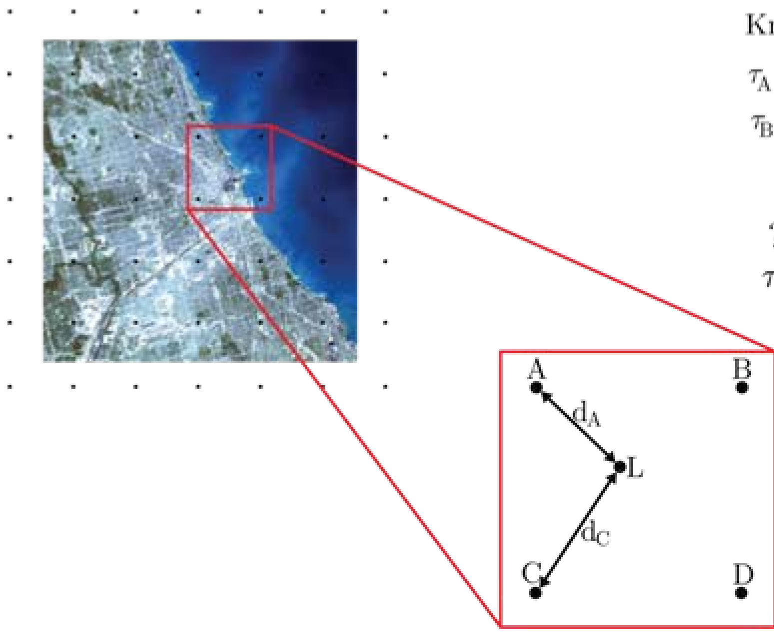


3 node

Output of Spatial Interpolation

$$L_{surf} = \frac{L_s - L_u}{\tau} = \varepsilon L_T + (1-\varepsilon) L_d$$

- Compute τ, L_u, L_d, $L_{surf} = (L_s - L_u)/\tau = \varepsilon L_T + (1-\varepsilon) L_d$



Know:

$\tau_A\ (H_L),\ L_{u_A}(H_L),\ L_{d_A}(H_L)$

$\tau_B\ (H_L),\ L_{u_B}(H_L),\ L_{d_B}(H_L)$

$\vdots$

?:

$\tau_L,\ L_{u_L},\ L_{d_L}$

Interpolate

Nearest neighbor → $\tau_L = \tau_A,\ L_{u_L} = L_{d_L}\ \cdots$

Linear in 1/d → $$\tau_L = \frac{\frac{\tau_A}{d_A} + \frac{\tau_B}{d_B} + \frac{\tau_C}{d_C} + \frac{\tau_D}{d_D}}{\sum_i \frac{1}{d_i}},\ \cdots$$

Linear in e^d → $$\tau_L = \frac{\tau_A e^{-d_A} + \tau_B e^{-d_B} + \tau_C e^{-d_C} + \tau_D e^{-d_D}}{\sum_i e^{-d_i}},\ \cdots$$

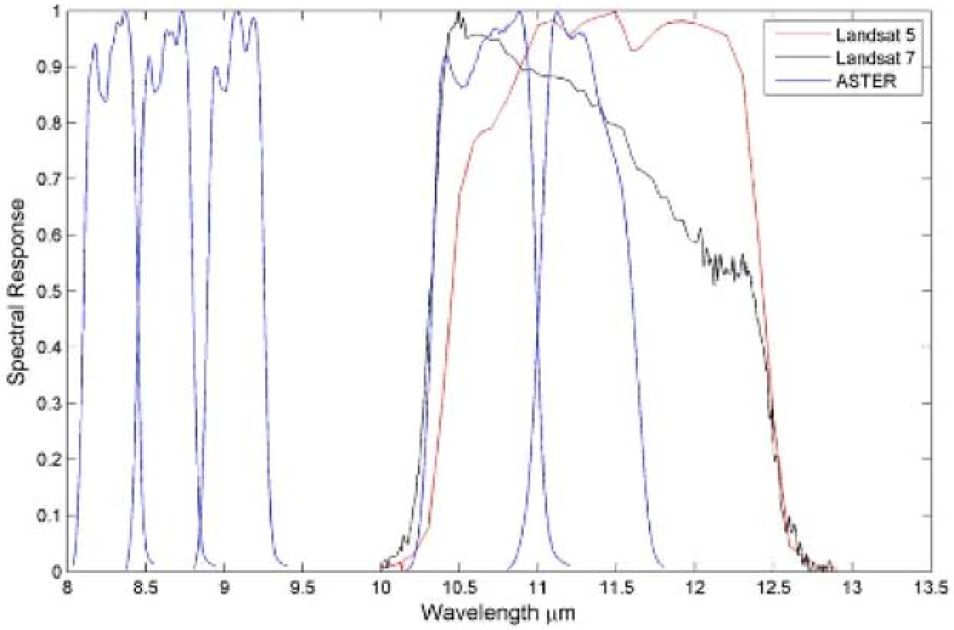
Output: $\tau(H_L, t_L, L),\ L_u(H_L, t_L, L),\ L_d(H_L, t_L, L)$

$$L = \begin{bmatrix} x \\ y \\ H_L \end{bmatrix}$$

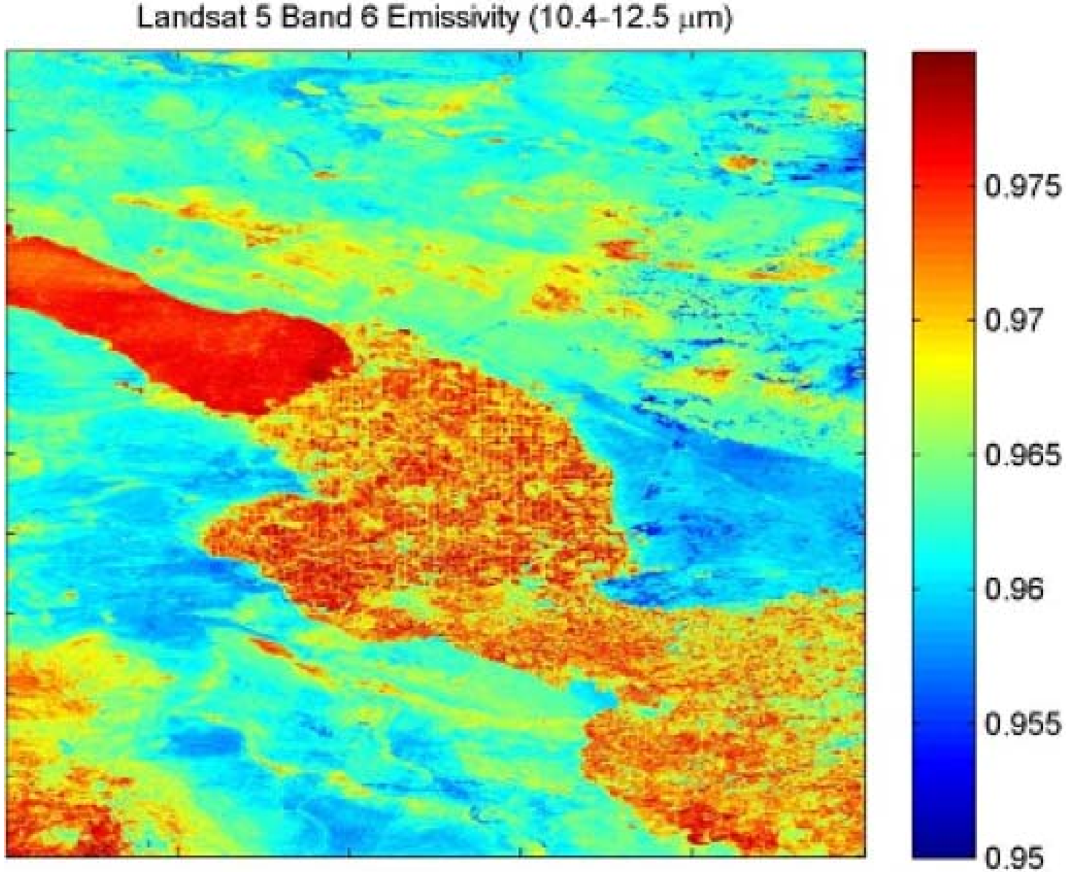
EMISSIVITY

- Extract Bare Earth Emissivity from the North American Aster Land Surface Emissivity Database (NAALSED)
  - Emissivities (ε_{13}, ε_{14}) and regression coefficients (JPL)

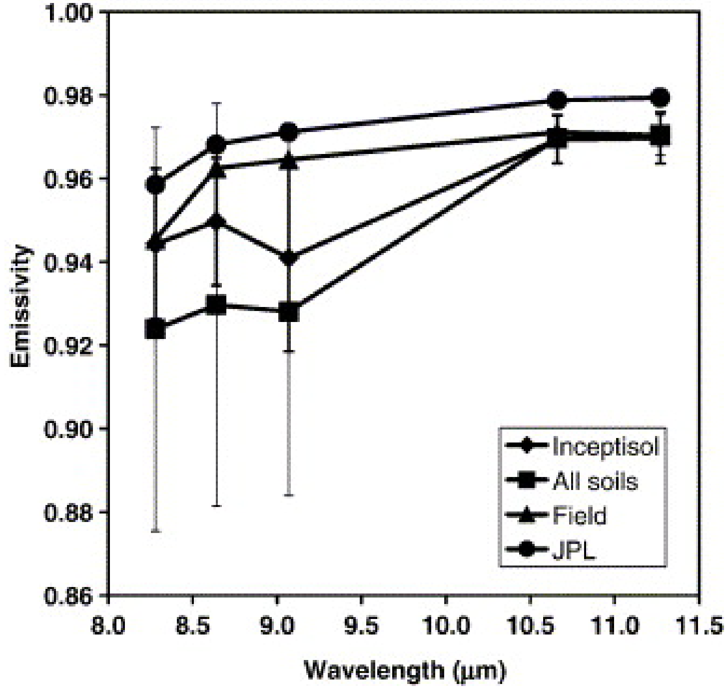
$$\varepsilon_{landsat} = C_{13}\,\varepsilon_{13} + C_{14}\,\varepsilon_{14} + C$$



LANDSAT 5 derived emissivity from NAALSED bands 13 & 14 over the Salton Sea and Imperial Valley, CA.(JPL)



Correct Emissivity for High NDVI conditions
Note: an error in emissivity of 0.01 corresponds to 0.7K error in temperature in these bands.



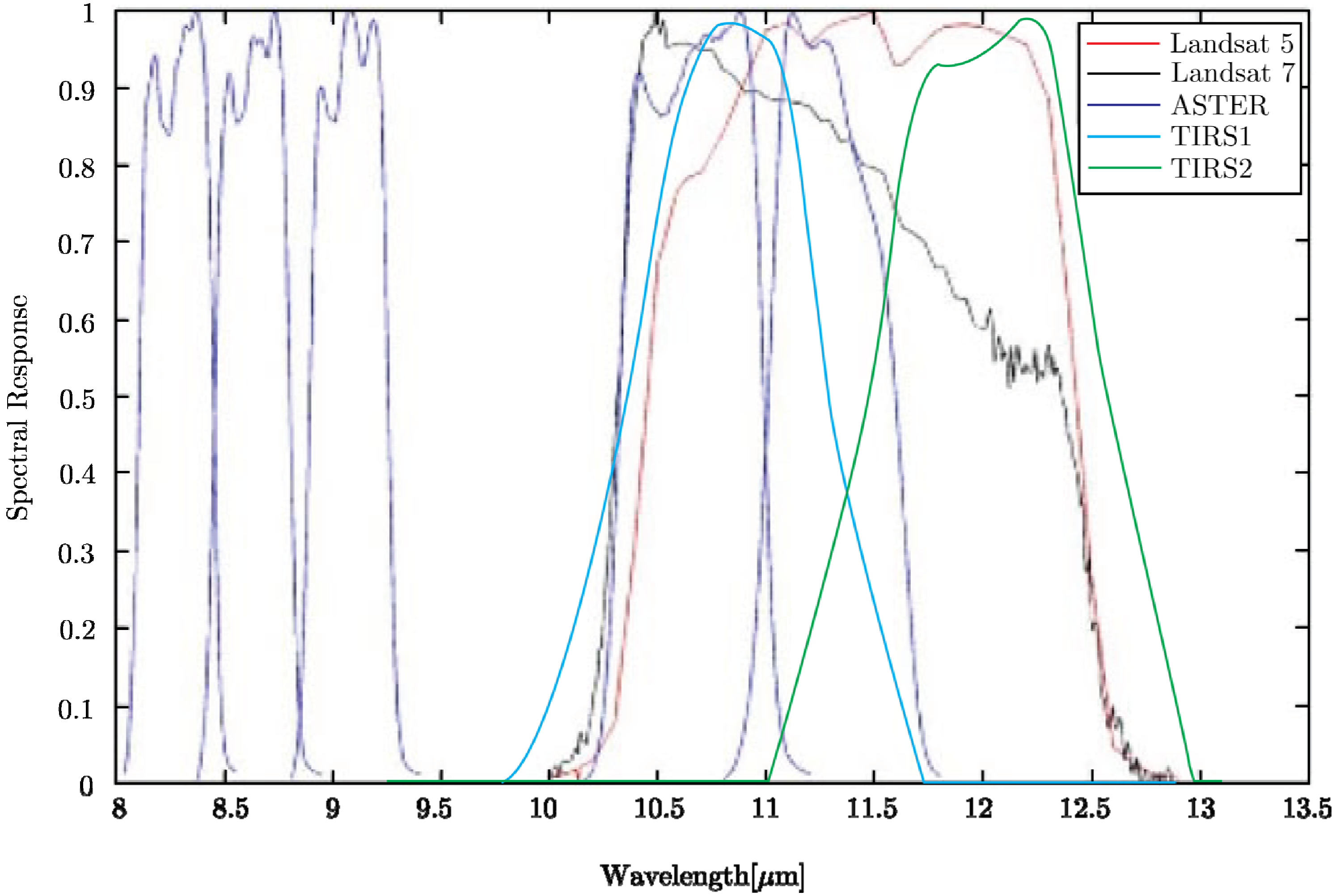
$$\varepsilon_{13} = 0.968 + 0.022\ P_V$$

$$\varepsilon_{14} = 0.970 + 0.020\ P_V$$

$$P_V = \left(\frac{\mathrm{NDVI}-\mathrm{NDVI_s}}{\mathrm{NDVI_v}-\mathrm{NDVI_s}}\right)^2$$

Fig. 3. Average emissivity spectra for different soil samples included in the ASTER spectral library (http://speclib.jpl.nasa.gov). 'Inceptisol' refers to the mean value for all the soil samples included in the ASTER library and classified as Inceptisol (7 samples). These values have been chosen a soil emissivities in the NDVI method. 'All soils' refers to the mean value for all the soil samples included in the ASTERlib (49 samples). Error bars refer to the standard deviation of the mean values. The emissivity spectrum obtained from field measurements (Field) and the one measured in the JPL are also given for comparison.[Munoz et al. (2006) RSofE V.103,#4, pp. 474-487].

Spectral Response Functions
TIRS and the Future



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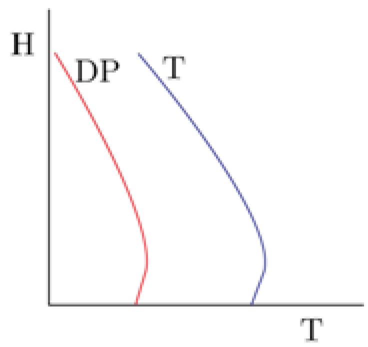
Validation

- Use calibration sites – Atm. Compensation
  - Salton Sea (below sea level and hot)
  - East & West Coast (sea level – wide range of atmosphere)
  - Great Lakes (≈ 0.2 km)
  - Lake Tahoe (≈ 1.4 km)
  - Covers all dates, all instruments
  - Only tests atmospheric compensation since all targets are water
- Cross calibrate with other instruments
  - ASTER-MODIS
    - » Need to account for time difference and any errors in alternate emissivity retrieval
  - Field sites?
    - » Historical?
    - » New???

Questions? Help!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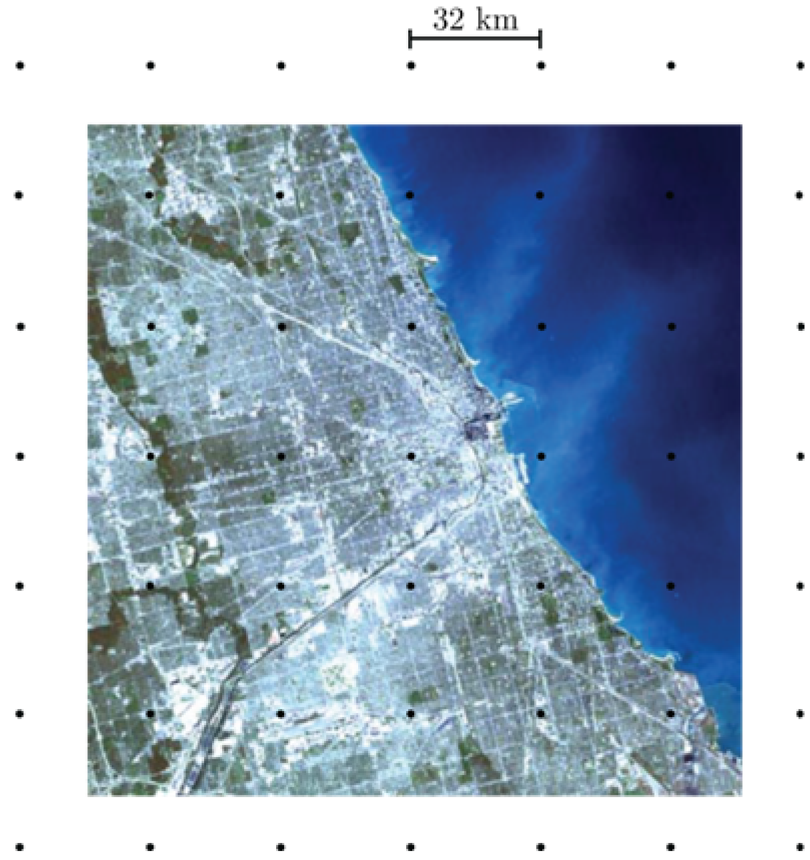
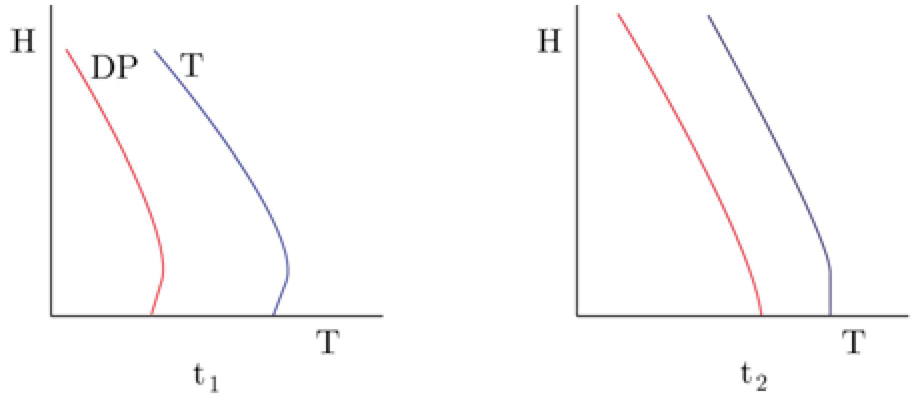
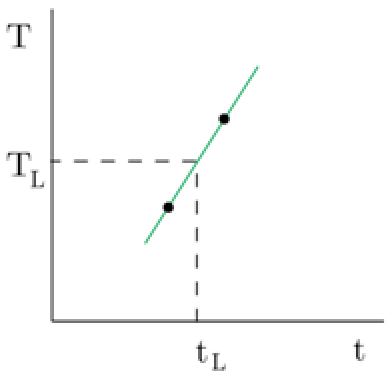
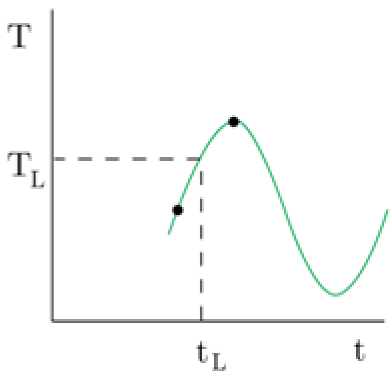

32 km



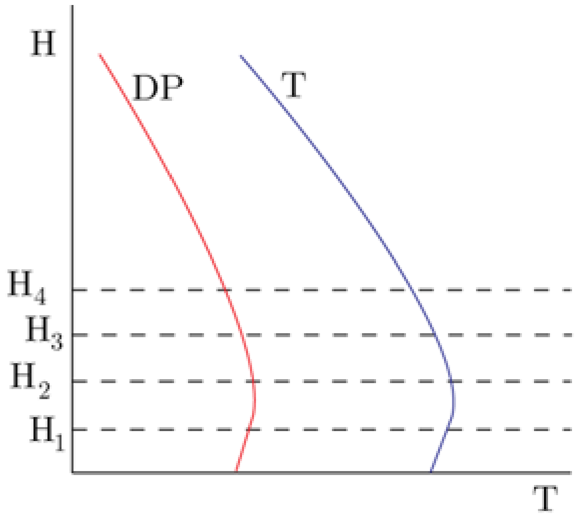
Profile samples at time 1 (t_1) and time 2 (t_2) for one sample location

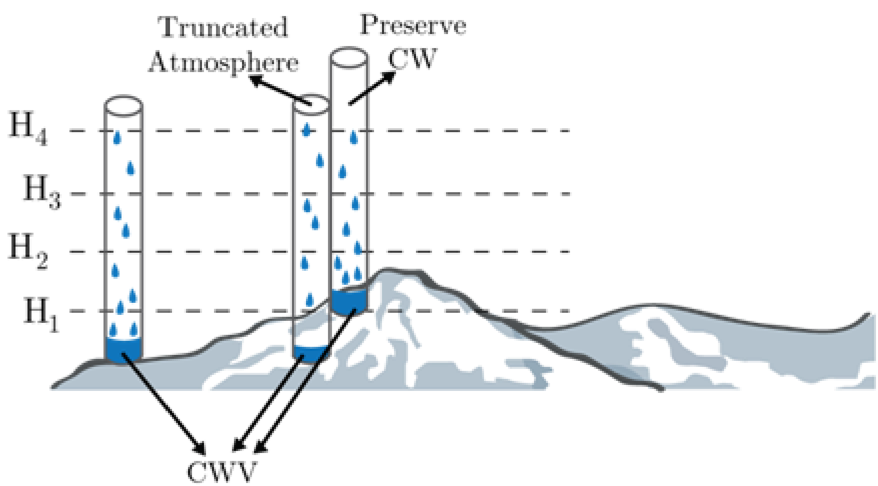


Linear Interpolation for T at each altitude



Diurnal Interpolation for T at each altitude



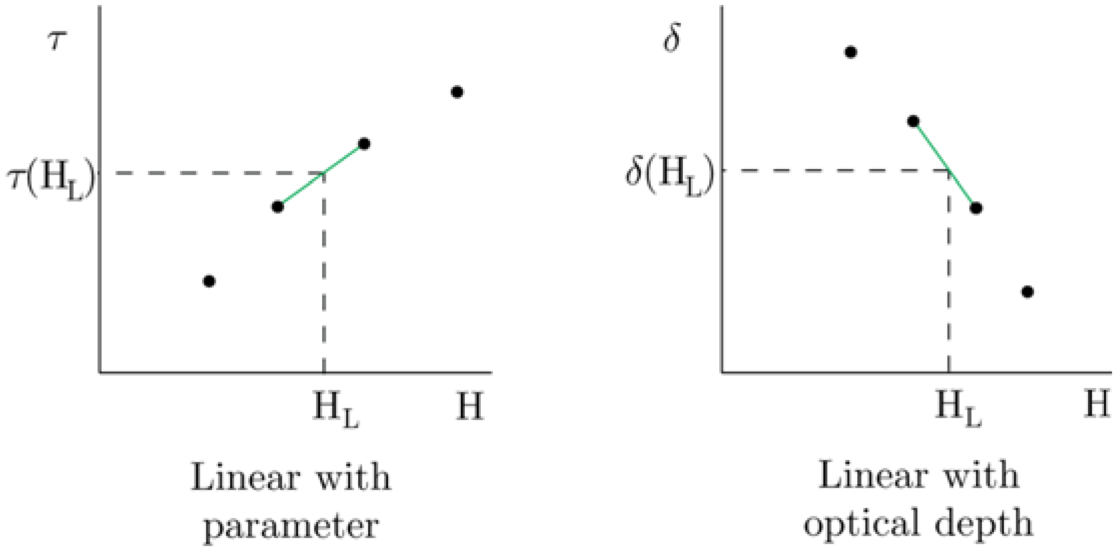


Run Modtran for each altitude.

Output:

$$\tau(H),\ L_u(H),\ L_d(H)$$

Interpolate to pixel height H_L



Output: $\tau(H_L, t_L)$, $L_u(H_L, t_L)$, $L_d(H_L, t_L)$

Know:

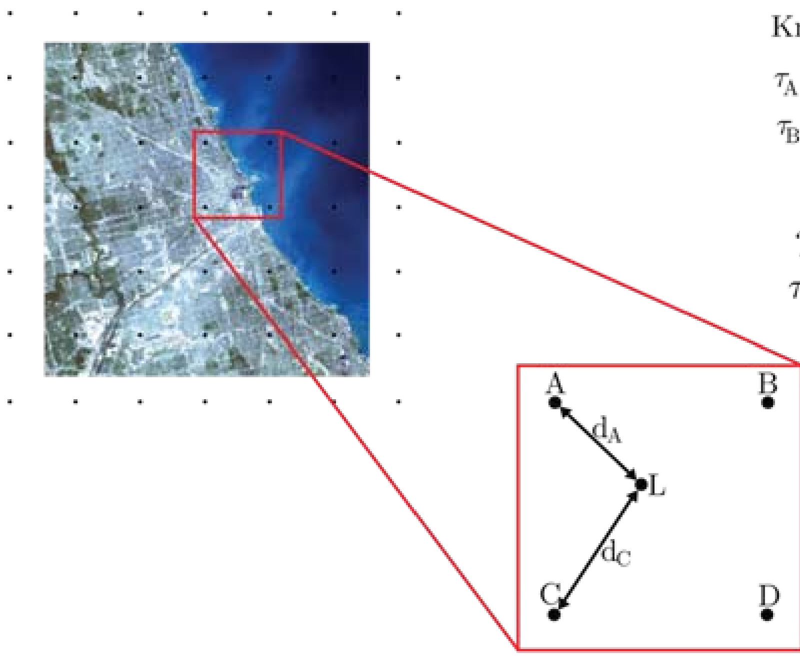
$\tau_A\,(H_L),\ L_{u_A}(H_L),\ L_{d_A}(H_L)$

$\tau_B\,(H_L),\ L_{u_B}(H_L),\ L_{d_B}(H_L)$

$\vdots$

?:

$\tau_L,\ L_{u_L},\ L_{d_L}$



Interpolate

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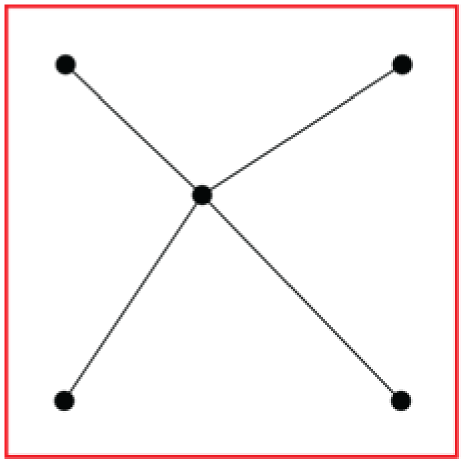
Linear in 1/d → $$\tau_L = \frac{\dfrac{\tau_A}{d_A} + \dfrac{\tau_B}{d_B} + \dfrac{\tau_C}{d_C} + \dfrac{\tau_D}{d_D}}{\sum_i \dfrac{1}{d_i}},\ \ldots$$

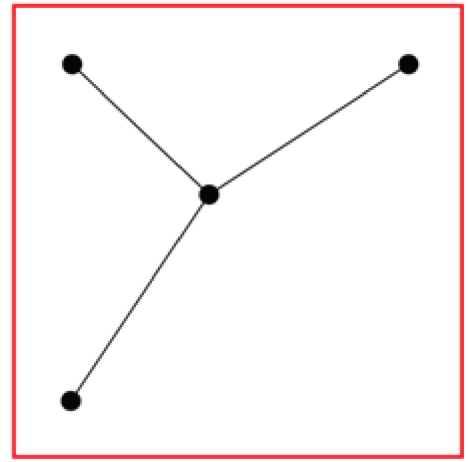
Linear in e^d → $$\tau_L = \frac{\tau_A e^{-d_A} + \tau_B e^{-d_B} + \tau_C e^{-d_C} + \tau_D e^{-d_D}}{\sum_i e^{-d_i}},\ \ldots$$

Output: $\tau(H_L,\ t_L,\ L),\ L_u(H_L,\ t_L,\ L),\ L_d(H_L,\ t_L,\ L)$

$$L = \begin{bmatrix} x \\ y \\ H_L \end{bmatrix}$$



4 node



3 node

Output of Spatial Interpolation

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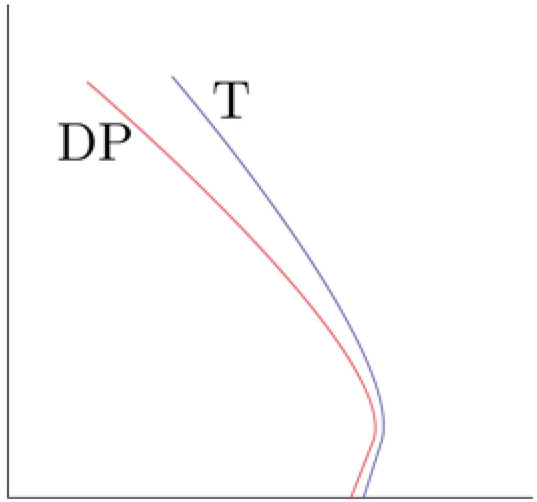

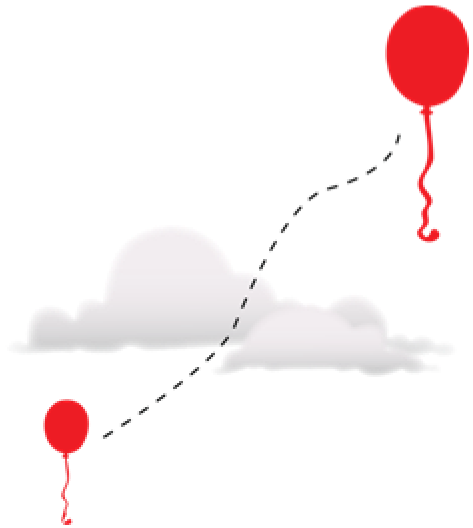

H	T
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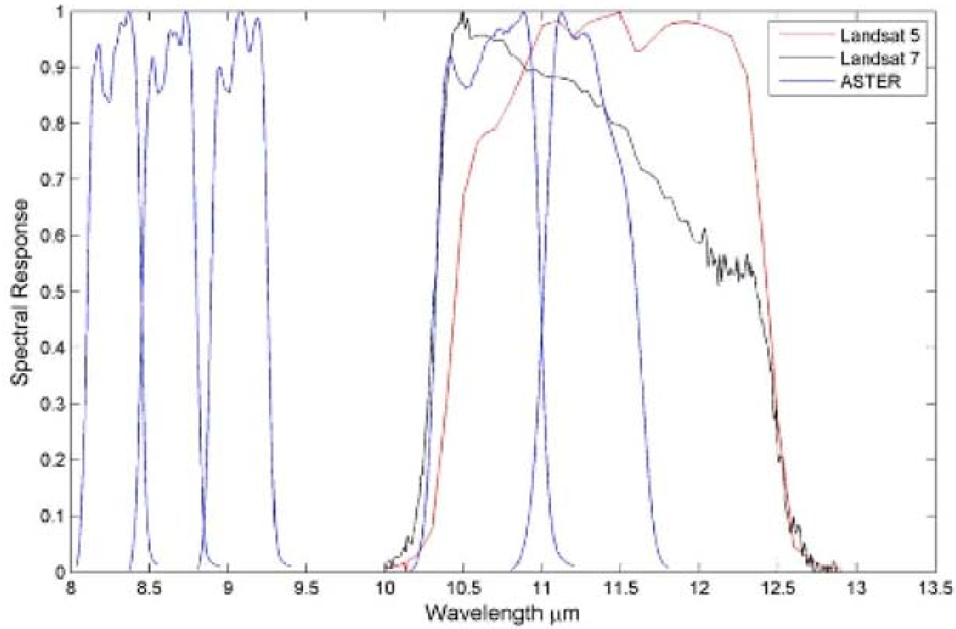
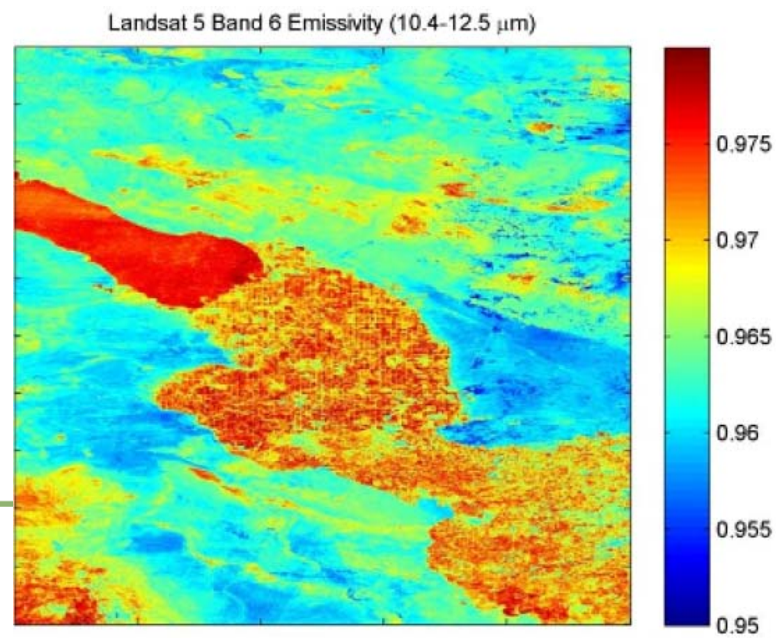

Landsat 5
Landsat 7
ASTER
Spectral Response
Wavelength µm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
8
8.5
9
9.5
10
10.5
11
11.5
12
12.5
13
13.5


Landsat 5 Band 6 Emissivity (10.4-12.5 µm)
0.975
0.97
0.965
0.96
0.955
0.95