CLIMATE FEEDBACK MECHANISMS DETERMINED FROM FLUX TOWERS AND THE MODIS SENSOR IN A SEMI-ARID AREA IN SOUTHERN CALIFORNIA

A presentation for the Surface Heat Budgets and Climate meeting

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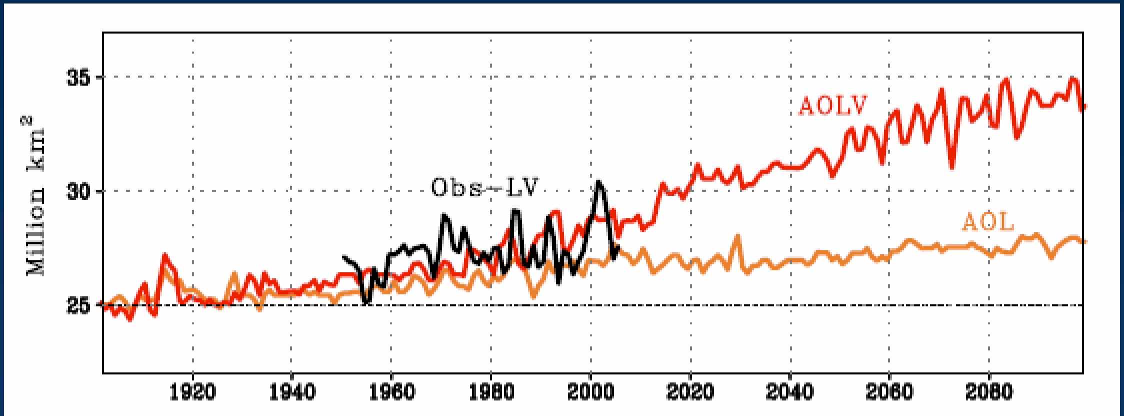
1. Introductions – phrasing the question(s)

- Satellite measurements have provided unprecedented imagery coverage of the planet. Questions remain on how well these measurements match ground measurements
- Having accurate and up to date maps of the global landcover and its climate feedback properties is important in running accurate GCM’s
- Understanding how climate feedback mechanism behave under climate stresses is very important in developing accurate models
- Areas that are sensitive to climate changes or stresses are of particular interest because of climate change

2. Introductions – feedbacks and semi-arid landcover

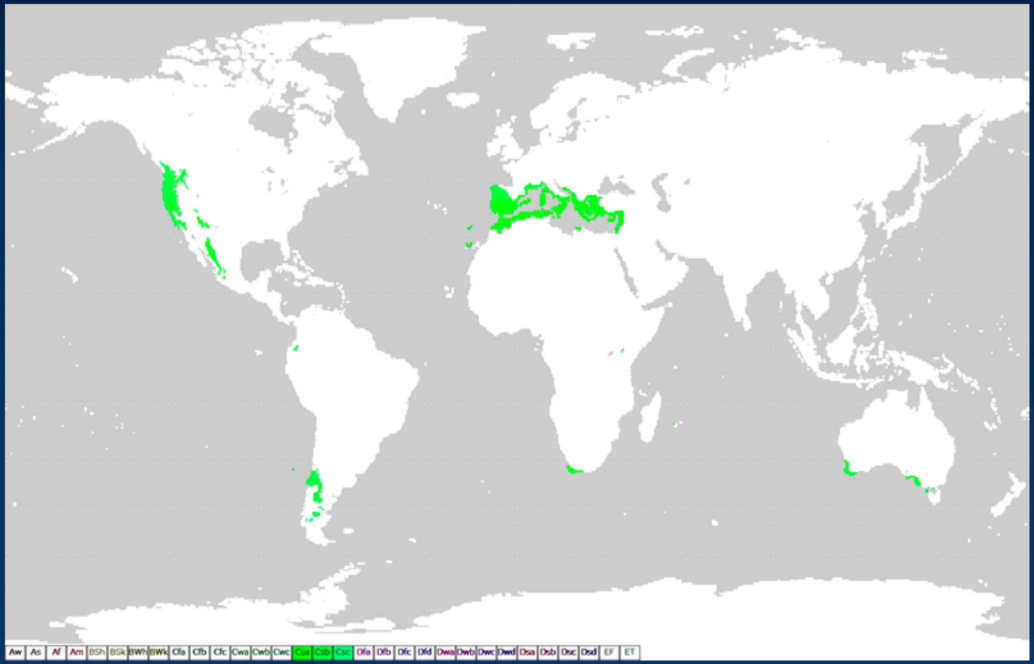
- It is predicted there will be increased occurrences of droughts, due in part from climate in the coming century. These droughts will have the largest impact on semi-arid areas
- How droughts will affect changes in land cover, and most importantly the amount of growing land, is still poorly understood
- General Circulation Model(GCM) Studies have shown that vegetation-albedo feedbacks, can reduce local precipitation and increase desertification



Zeng, N., and J. Yoon (2009), Expansion of the world's deserts due to vegetation-albedo feedback under global warming, Geophys. Res. Lett., 36, L17401, doi:10.1029/2009GL039699.

3. Introductions - Why Study?

- Having a deep understanding of how semi-arid regions change under climate stresses and more specifically how the feedback mechanism change is very important in predicting how these areas will behave under droughts and other climate change stresses

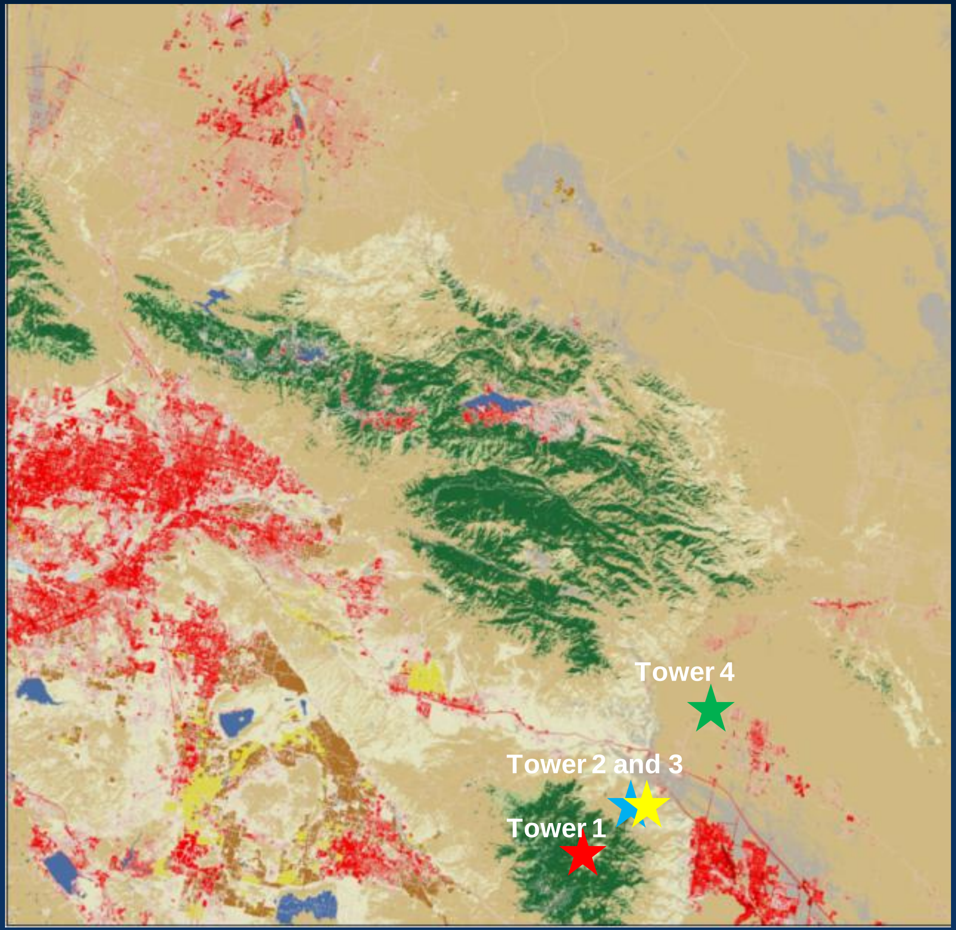


Global map of land areas classified as Csa, Csb or Csc, as defined by the Koeppen climate classification

4. Outline of talk

1. Examine each flux tower(FT) site, get a sense of the study areas
2. Build a sense of the quality of the data provided by the flux towers (FT) by examining measurements, looking for realistic results and values in the context of each FT and the time of the year
3. Discussion of results
4. Compare flux tower measurements of Albedo, NDVI and air temperature to MODIS measured quantities
5. Discussion of results
6. Examine Correlations between MODIS measured NDVI to precipitation. As well MODIS and FT measured Albedo to precipitation
7. Discussion of results
8. Conclusions

5. The Study Area



6. Tower Site - 1

- Located in Pine forest
- Elevation of 1770 m
- Tower height 27.1 m

7. Tower Site – 2 and 3

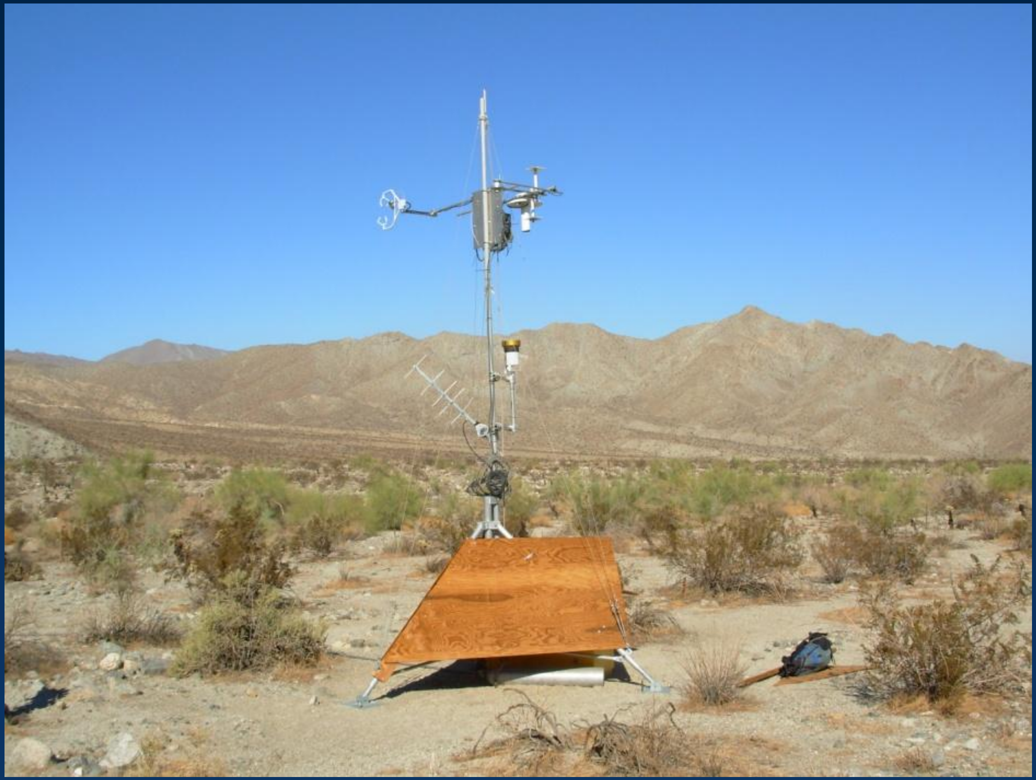
- Both located in Scrubland
- Elevation of 1280 m
- Tower 2 height 12.2 m, Tower 3 height 6.8 m
- Towers 2 and 3 are within 8 km to one another

Tower 2

Tower 3

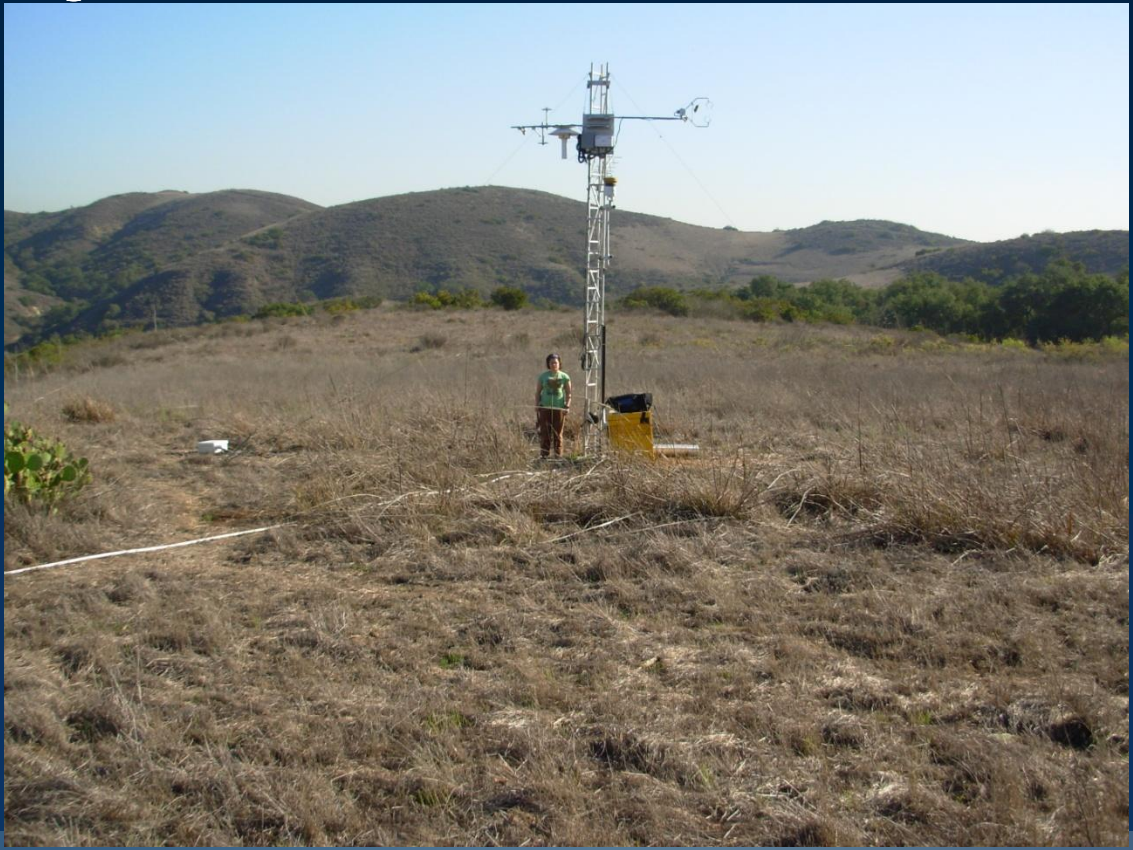
8. Tower Site - 4

- Located in Desert
- Elevation of 62 m
- Tower height 4.6 m



9. Tower Site - 5

- Located in Grassland
- Elevation of 451 m
- Tower height 5.8 m



Tower Site - 6

- Located in Coastal Sage
- Elevation of 320 m
- Tower height 5.8 m

11. Summary of Pertinent Measurements from Towers

- All Towers provide the following:
  - Wind speed and direction
  - Air temperature
  - Friction Velocity
  - Precipitation
  - Incoming Solar
  - Outgoing Solar
  - Net Radiation
  - Latent heat
  - Sensible heat
  - NDVI (only for 2009-2010)

12. Initial Characterization – Data Quality

- As an initial objective, the goal is to characterize the properties of each tower site through flux tower measurements
- To accomplish this we will examine several different quantities: surface roughness, Monin-Obukhov buoyancy parameter, albedo, surface heat budget
- For surface roughness and Monin-Obukhov buoyancy parameter we will examine it against wind speed
- For albedo and surface heat budget we will examine diurnal composites for both the summer and winter times

13. Surface Roughness

- We calculate the surface roughness using the friction velocity measurement, provided by the towers
- Using the following expression:

$$z_0 = \frac{z - d}{e^{\overline{M}\frac{k}{u_*}}}$$

- Where: M is the average wind speed, k is the von karman's constant, u_* is the friction velocity, z is the measurement height and d is the vegetation height

14. Monin-Obukhov Buoyancy Parameter

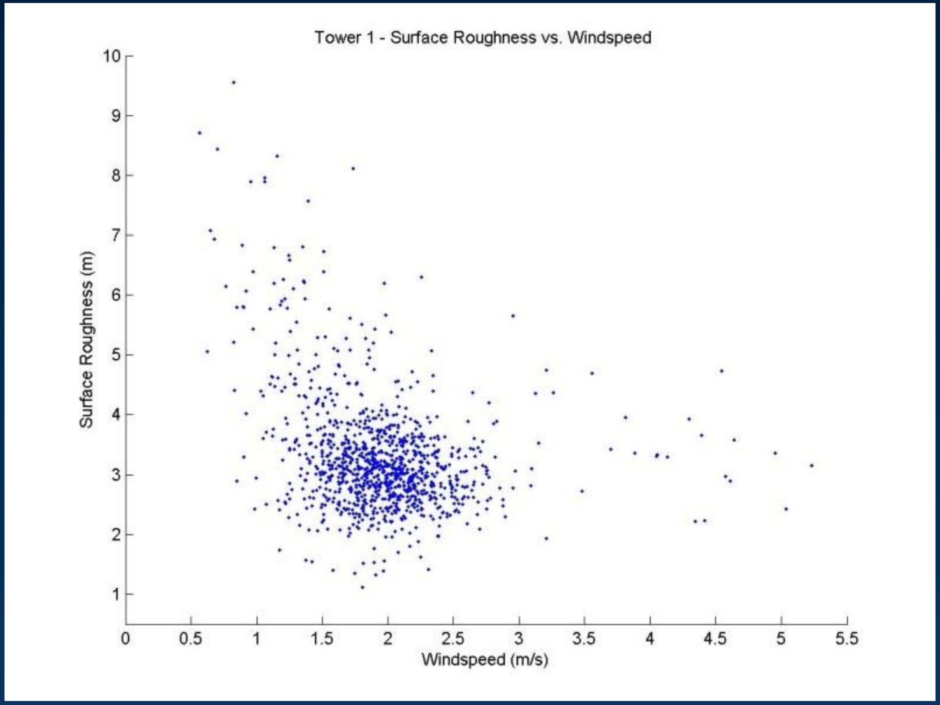
- We calculate the Monin-Obukhov buoyancy parameter using the friction velocity measurement, provided by the towers
- Using the following expression:

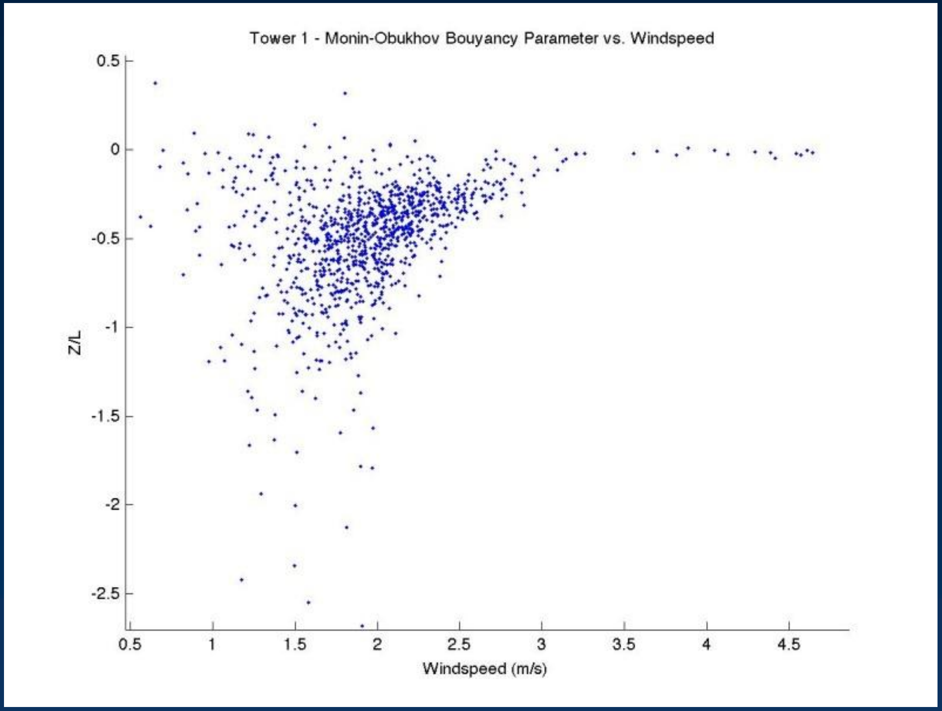
$$MO\_BP = -\frac{zkg(\overline{w'\theta_v'})}{u_*^{3}\overline{\theta}_v}$$

- Where: z is the measurement height, k is the von karman's constant, u_* is the friction velocity, θ is the average virtual potential temperature and w' θ' is the surface potential temperature flux determined from the sensible heat flux

15. Surface Roughness - Monin-Obukhov Buoyancy Parameter – Tower 1

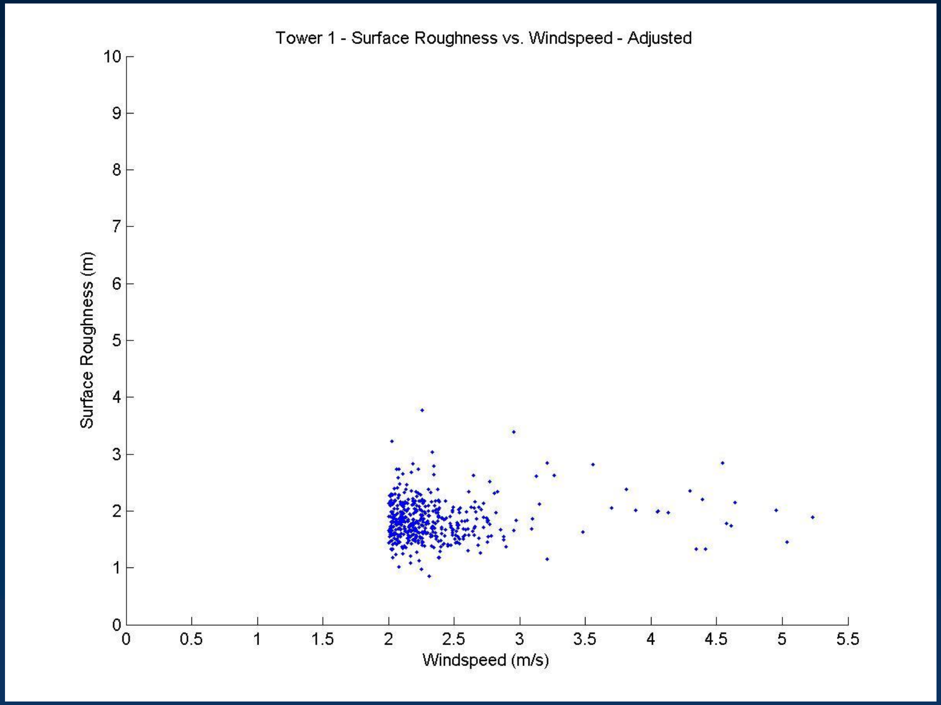
- d = 18.97

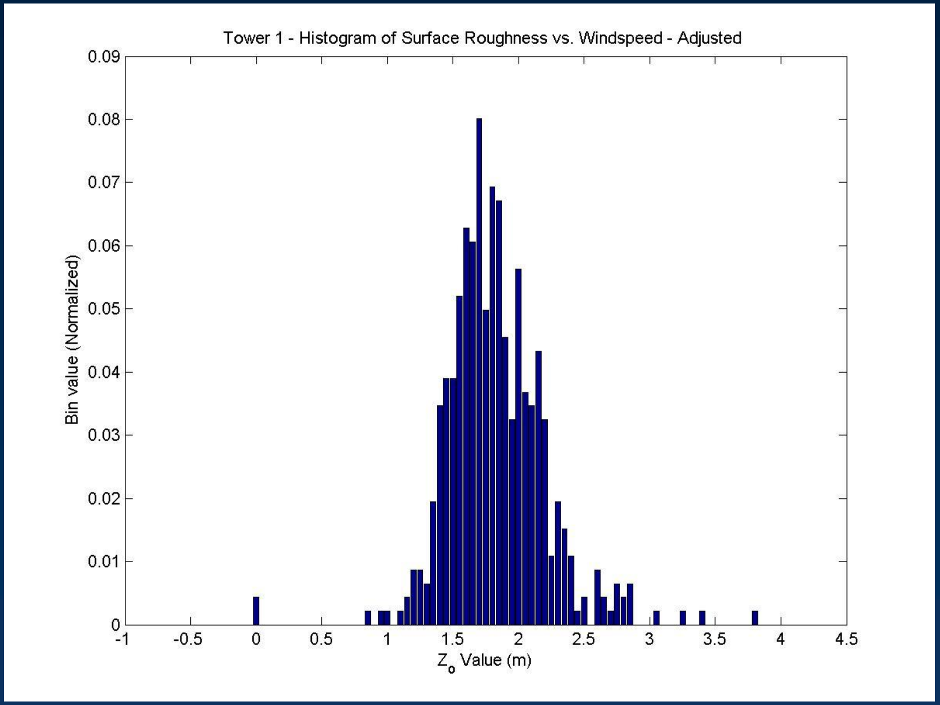




16. Adjusted Surface Roughness Using Results from Monin-Obukhov Buoyancy Parameter – Tower 1

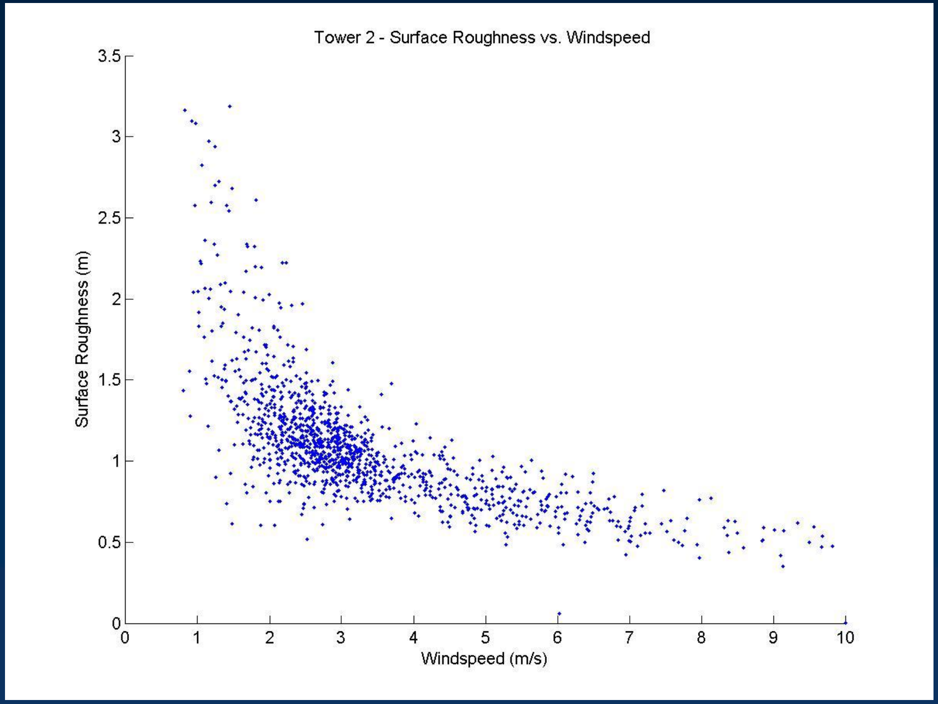
- d = 18.97

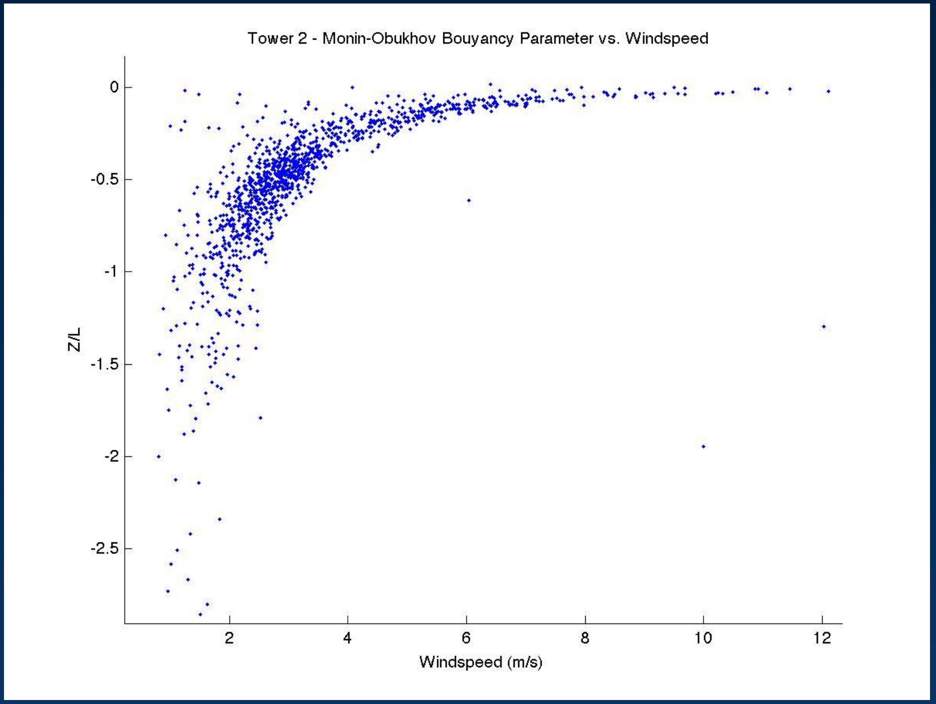




17. Surface Roughness - Monin-Obukhov Buoyancy Parameter – Tower 2

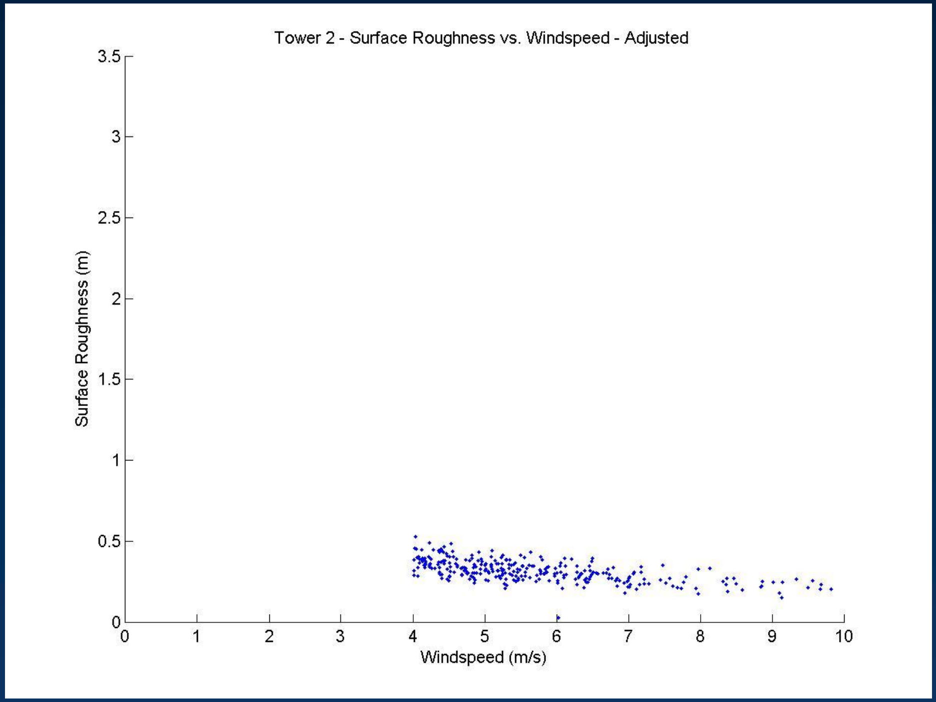
- d = 3.66

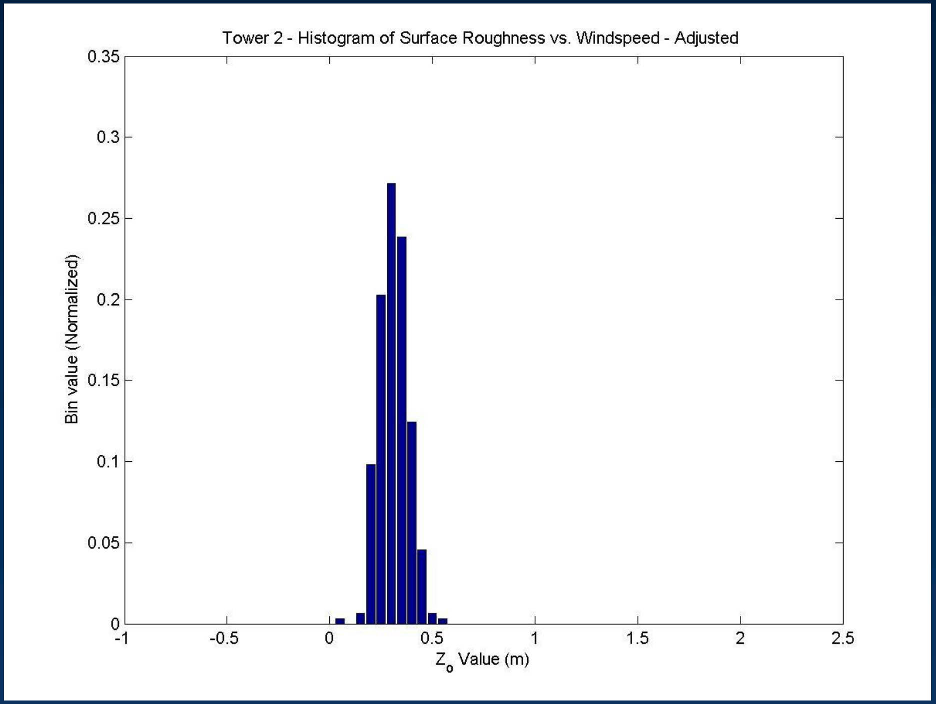




18. Adjusted Surface Roughness Using Results from Monin-Obukhov Buoyancy Parameter – Tower 2

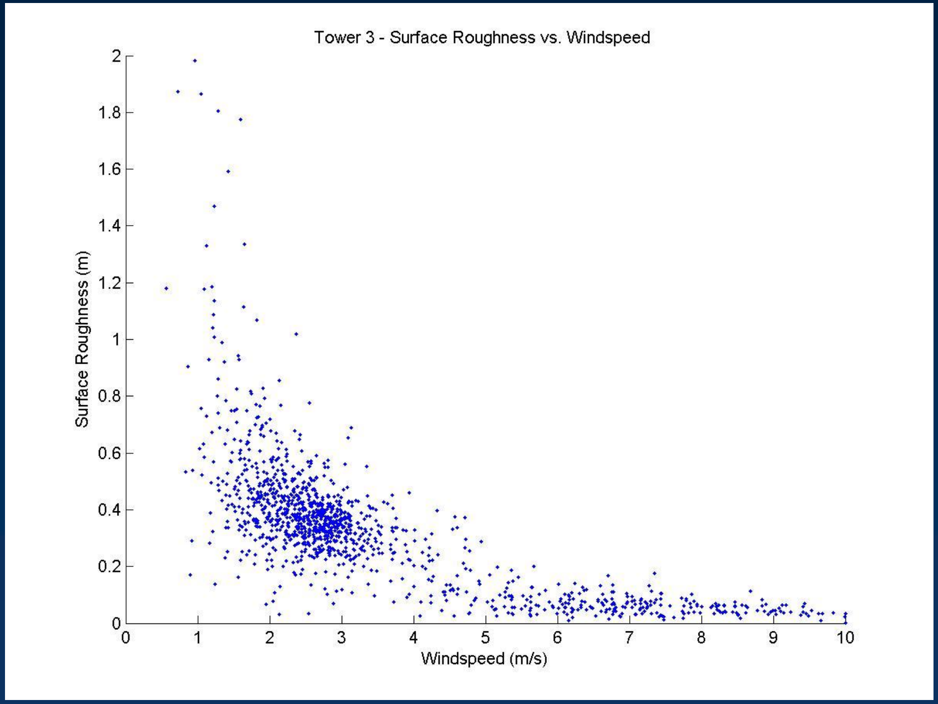
- d = 3.66

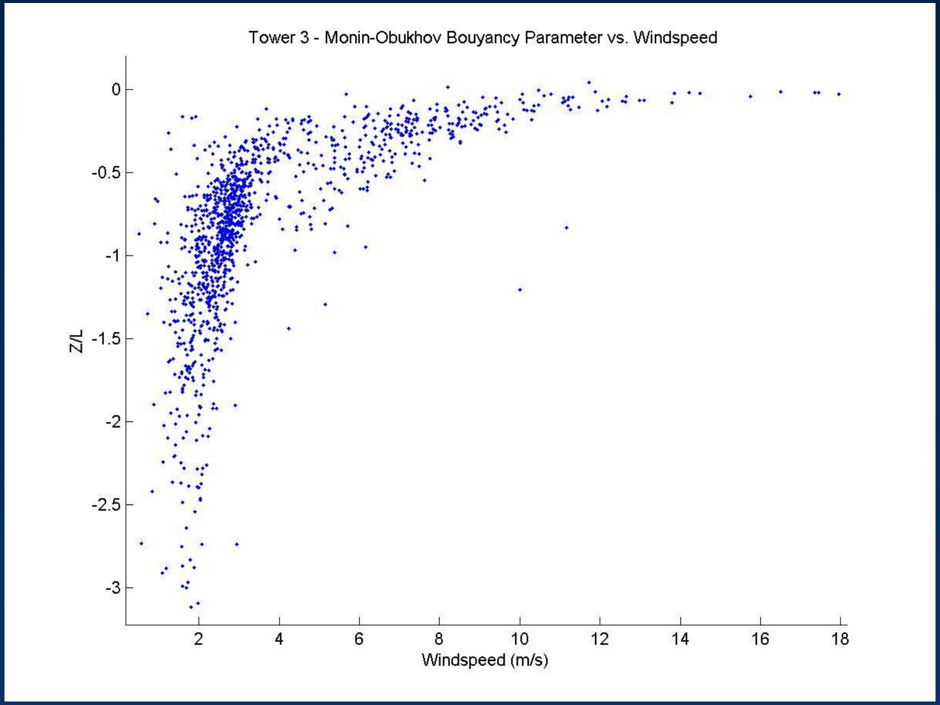




19. Surface Roughness - Monin-Obukhov Buoyancy Parameter – Tower 3

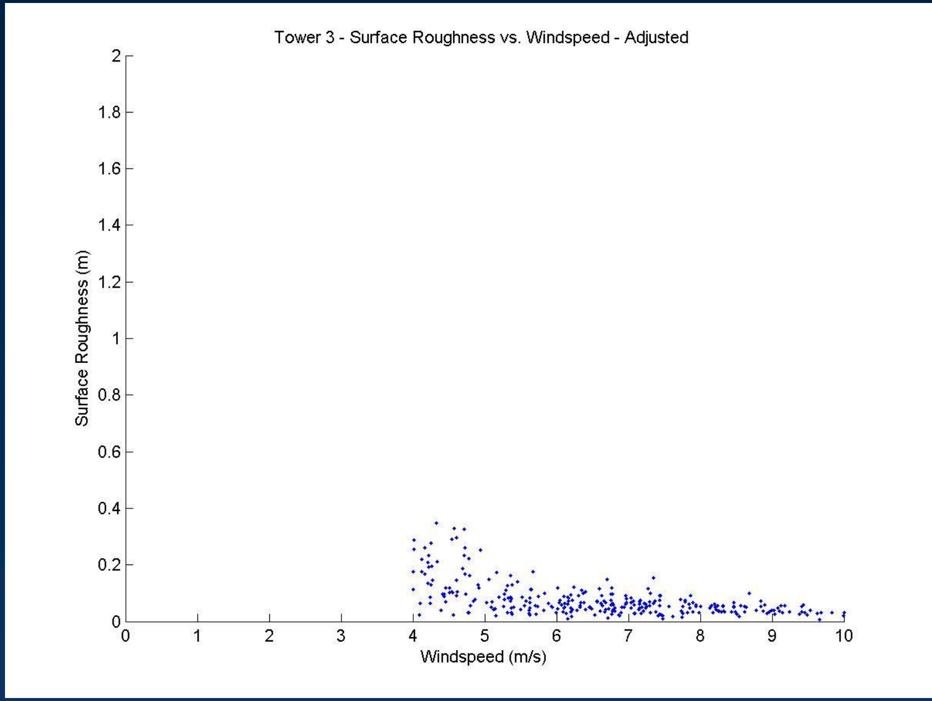
- d = 2.04

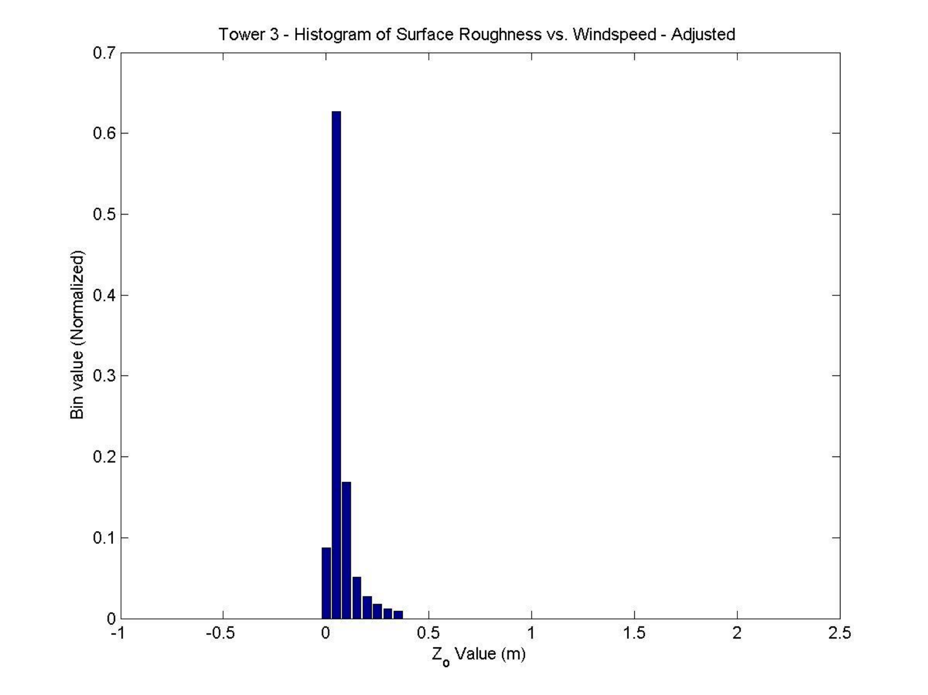




20. Adjusted Surface Roughness Using Results from Monin-Obukhov Buoyancy Parameter – Tower 3

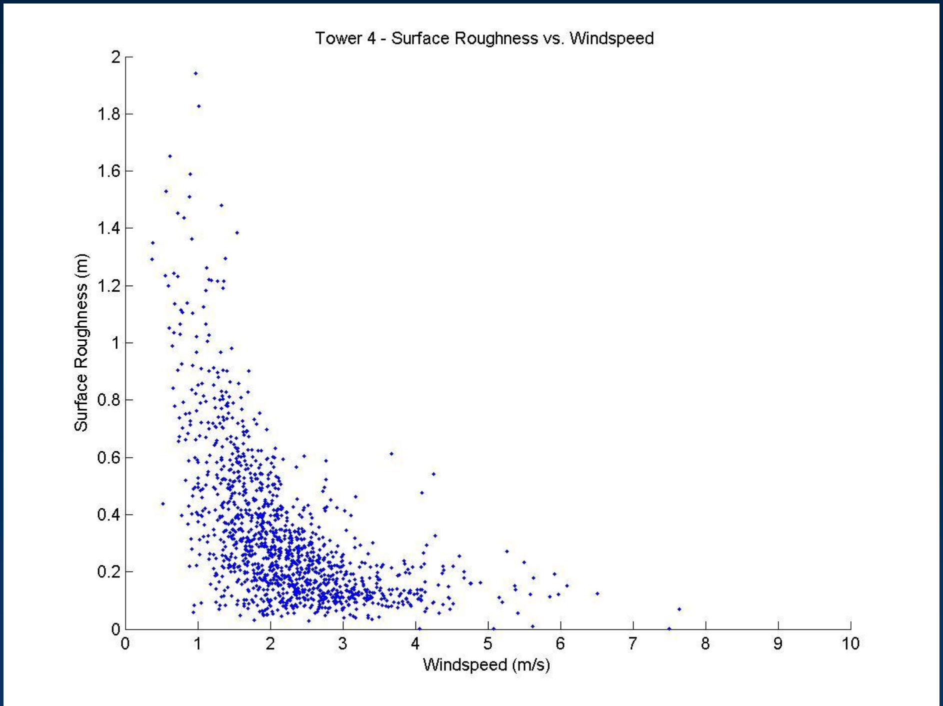
- d = 2.04

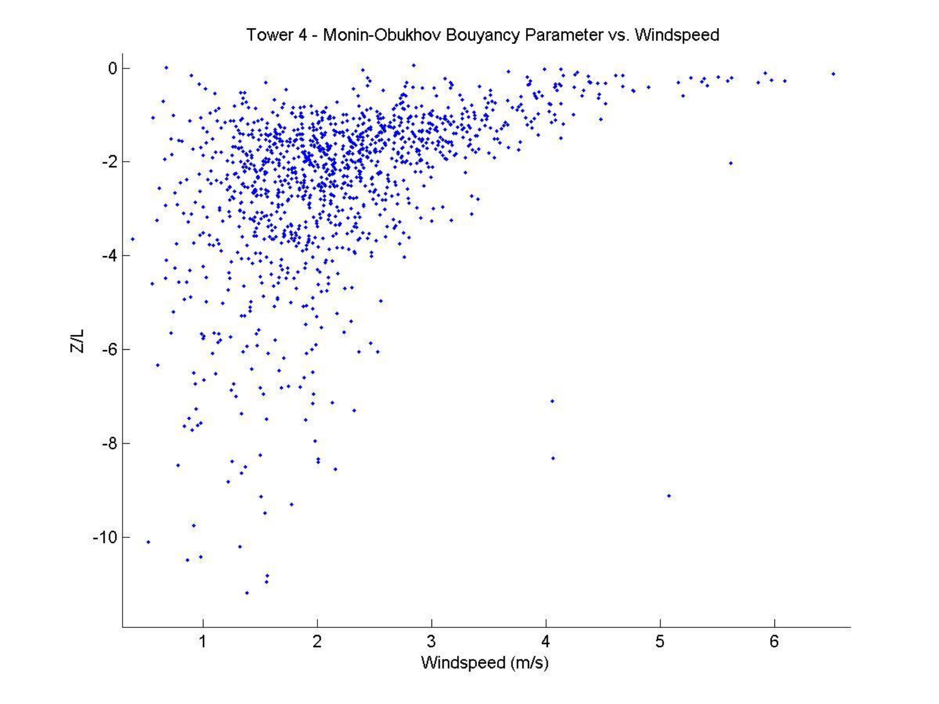




Surface Roughness - Monin-Obukhov Buoyancy Parameter – Tower 4

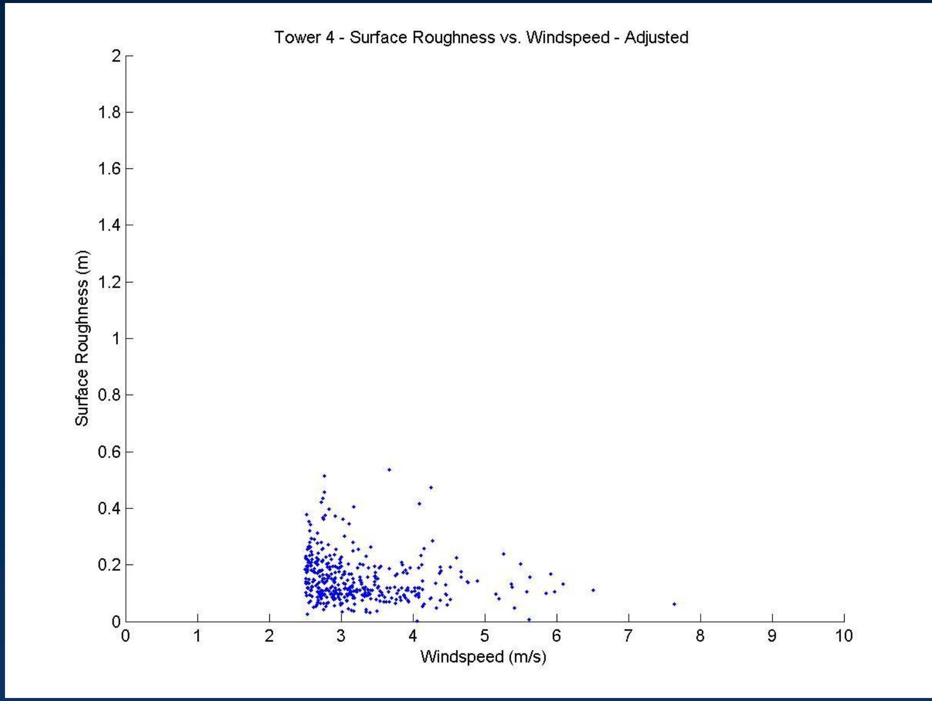
- d =0.92

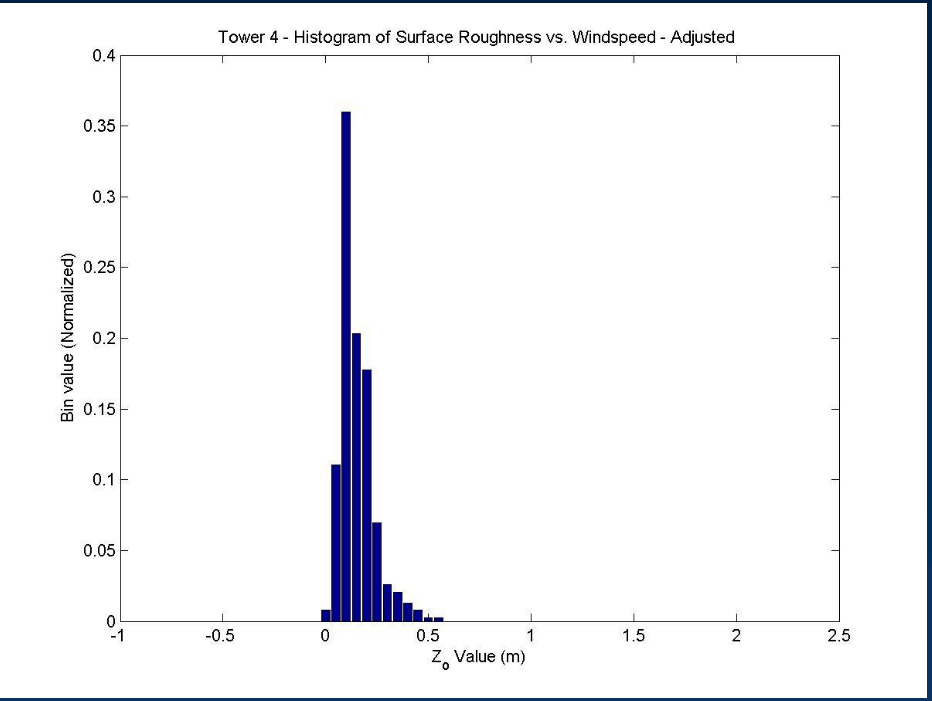




22. Adjusted Surface Roughness Using Results from Monin-Obukhov Buoyancy Parameter – Tower 4

- d = 0.92



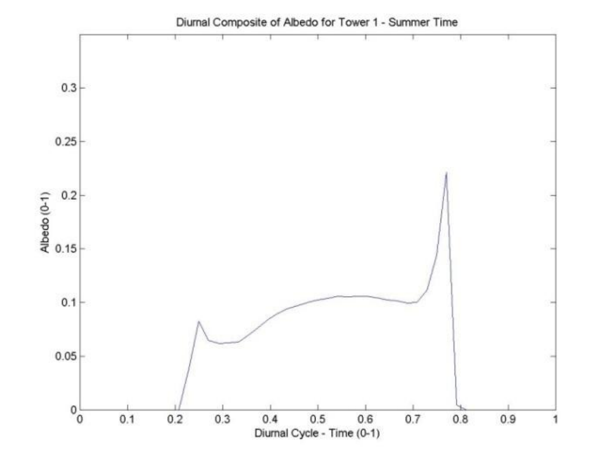


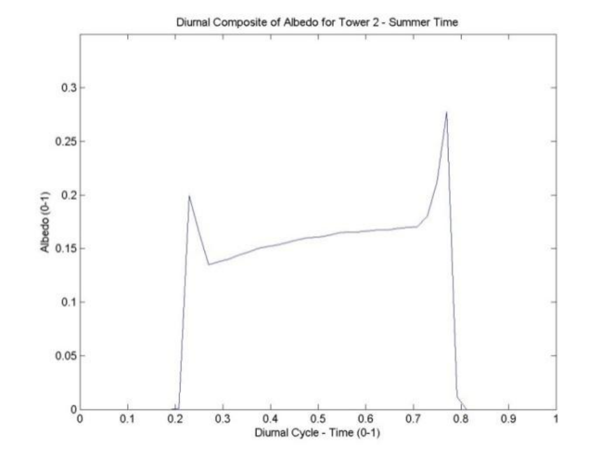
23. Discussion – Surface Roughness

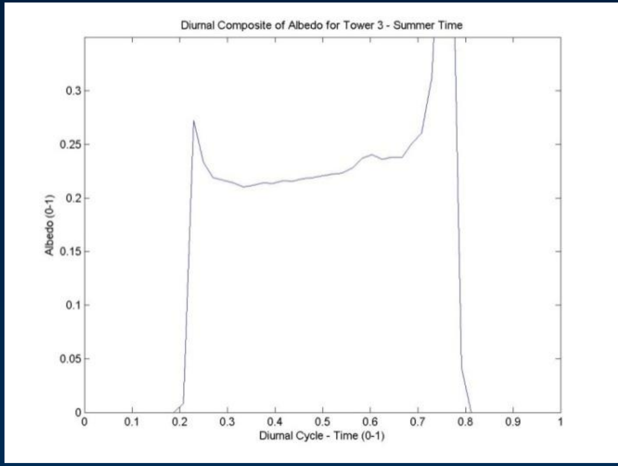
- Surface roughness calculations showed a large degree of variability but calculations of MO-buoyancy parameter showed regions of high buoyancy instability
- When incorporating results from the MO-buoyancy parameter, to remove suspect data, more consistent surface roughness values were observed.
- This implies that our large surface roughness values could be representing conditions that are buoyantly unstable

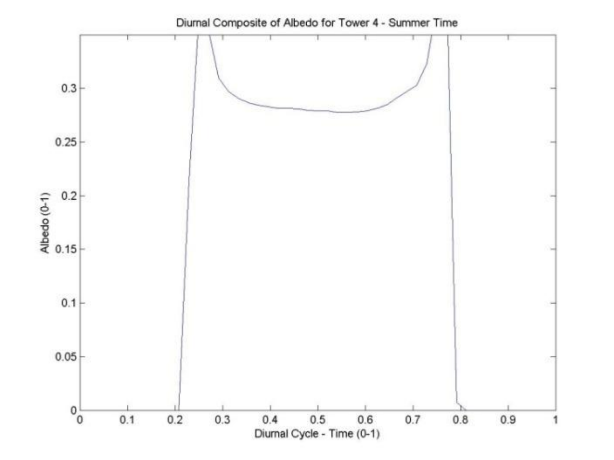
24. Surface Albedo Measurements - Summer

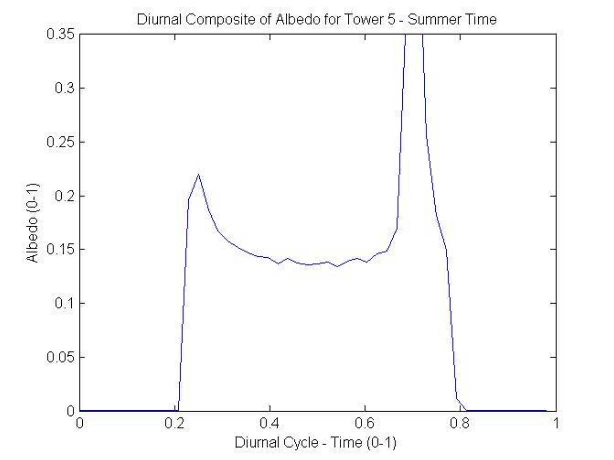
- We define summer as DOY between 135 - 225

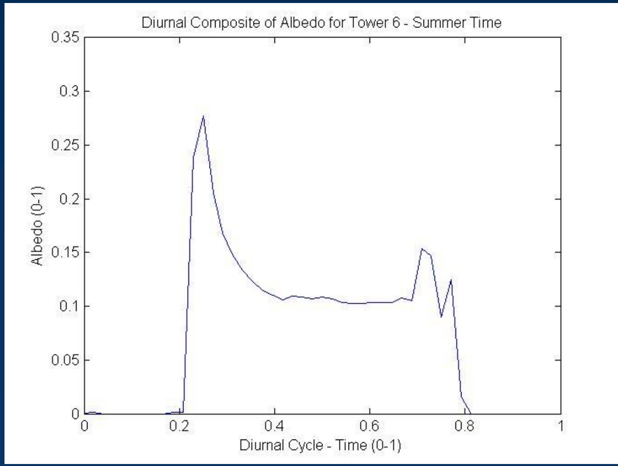






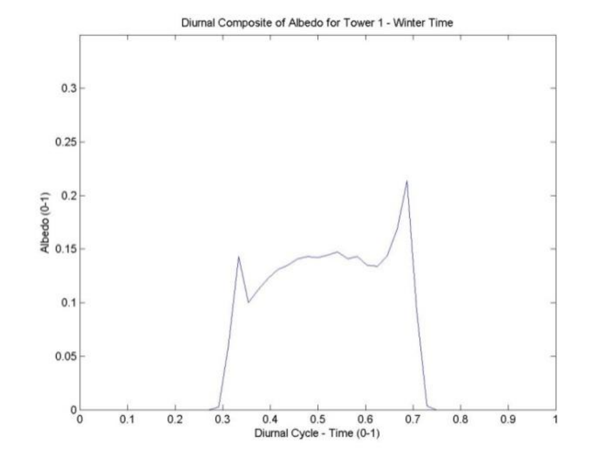


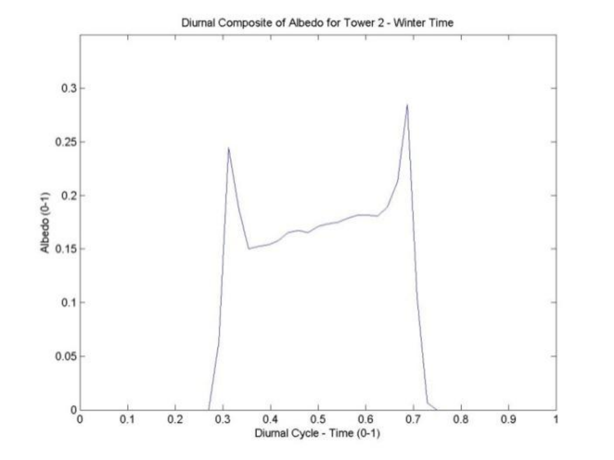


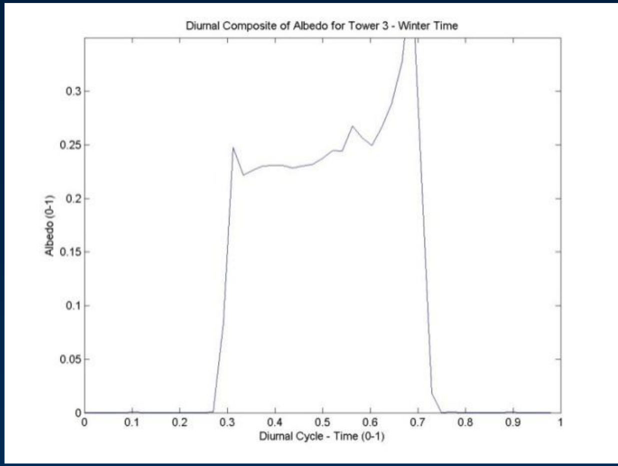


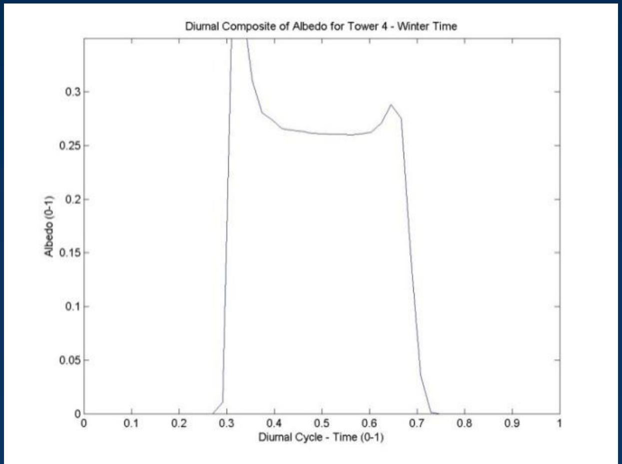
25. Surface Albedo Measurements - Winter

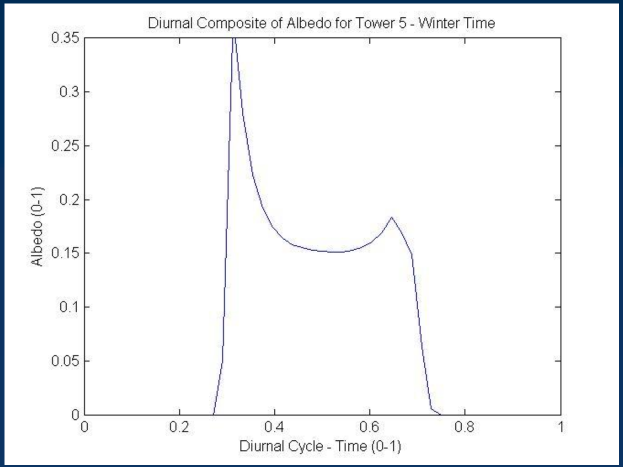
- We define winter as DOY between 320 - 045

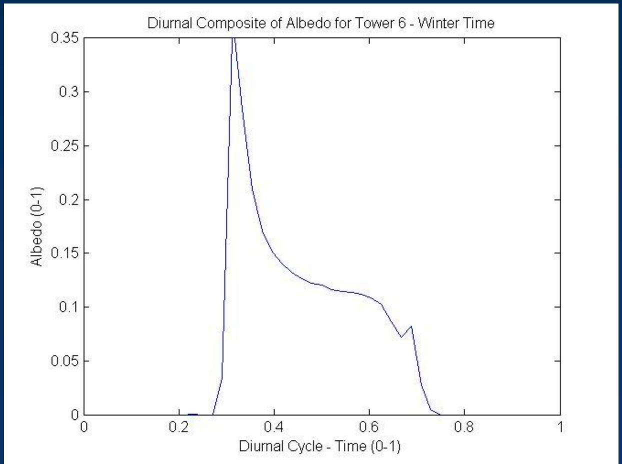










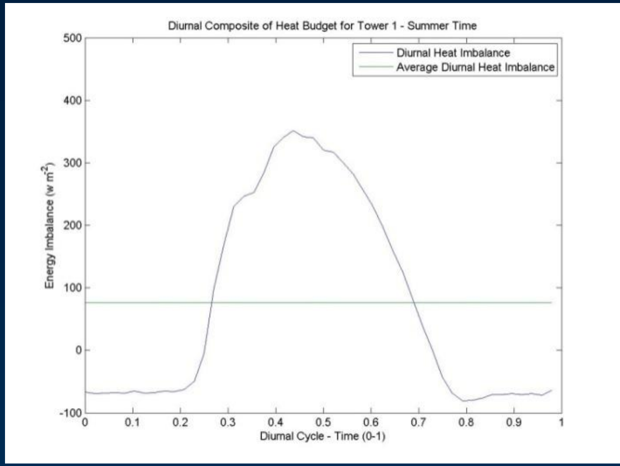


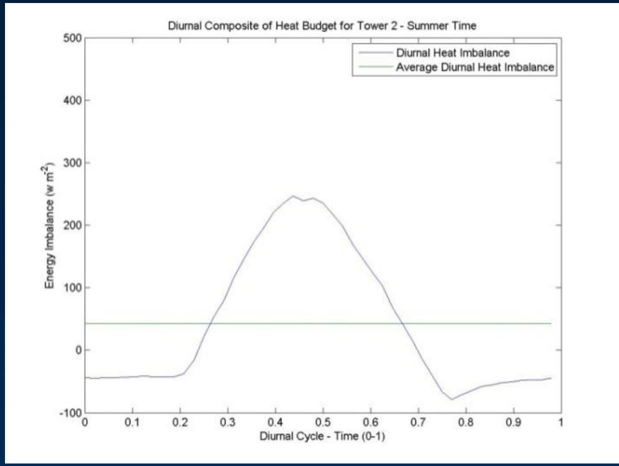
Discussion – Diurnal Surface Albedo

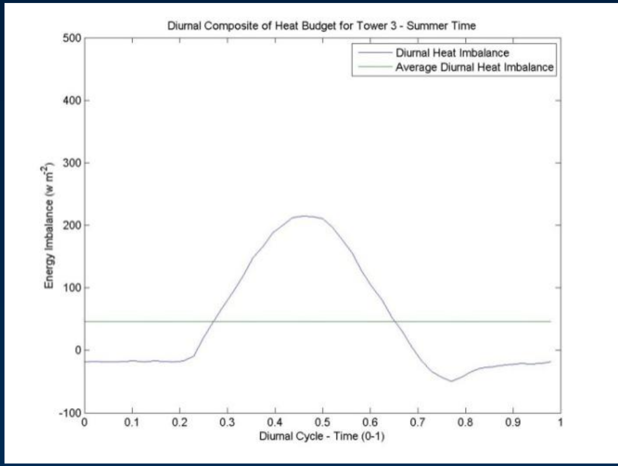
- Results show site dependent variability of the diurnally measured surface albedo, in particular the maximum albedo values
- Results also show seasonal variability diurnally measured surface albedo. As well, we observe changes in the maximum albedo values
- Albedo differences between sites and seasons can be explained by vegetation differences between FT sites

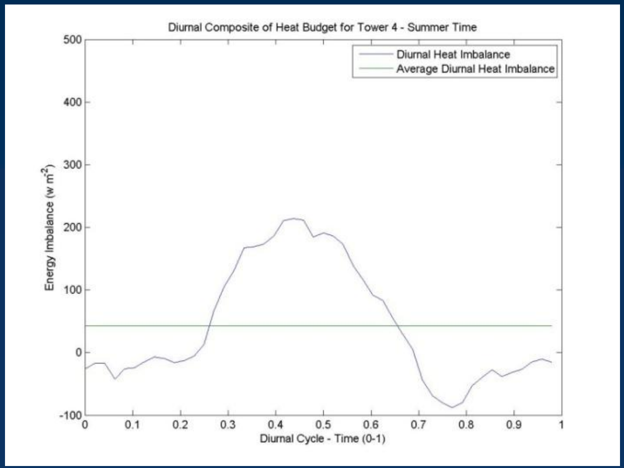
27. Surface Heat Budget- Summer

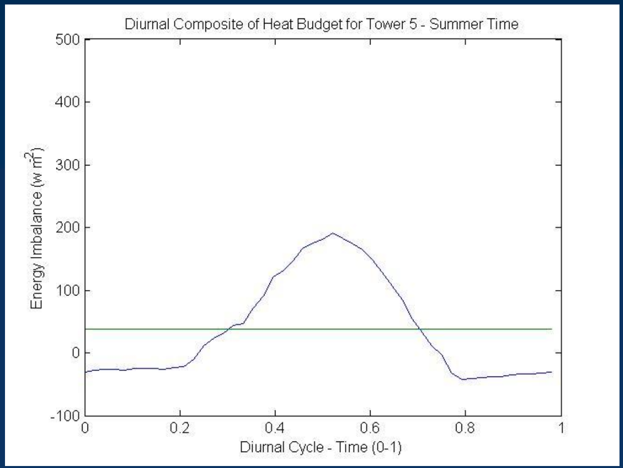
- We define summer as DOY between 135 - 225

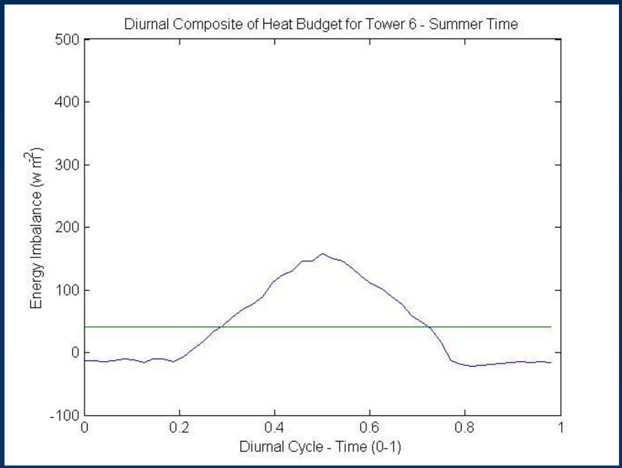






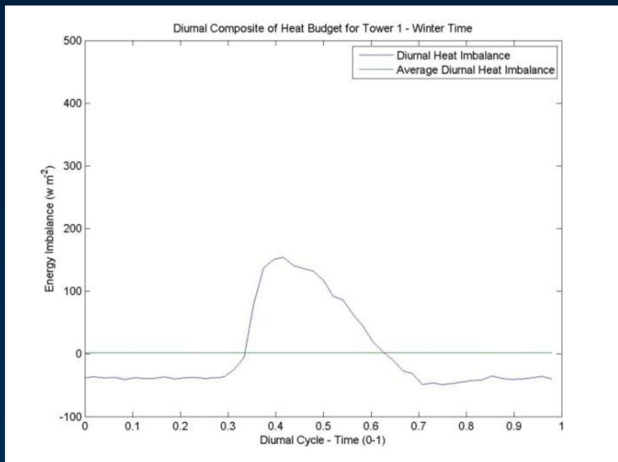


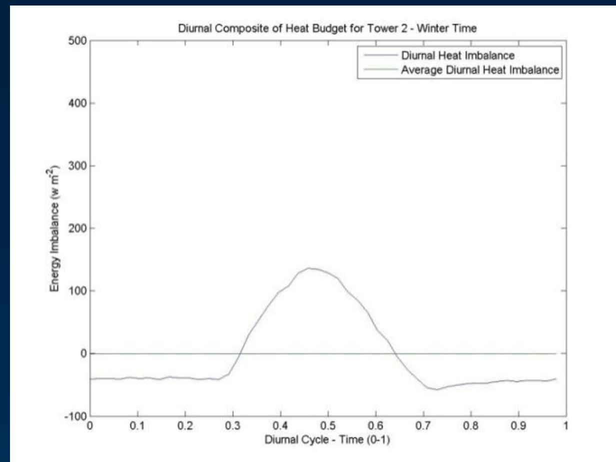


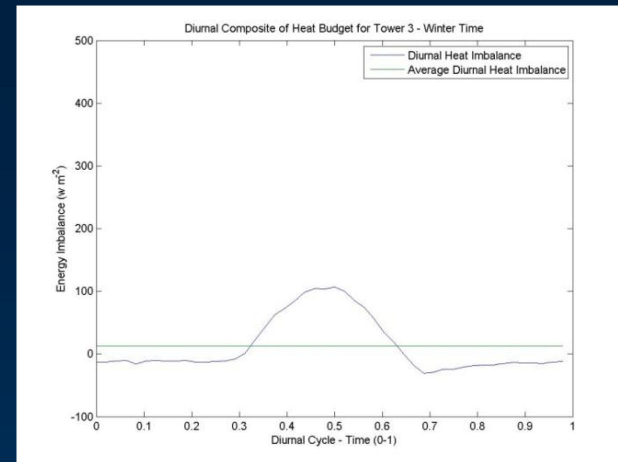


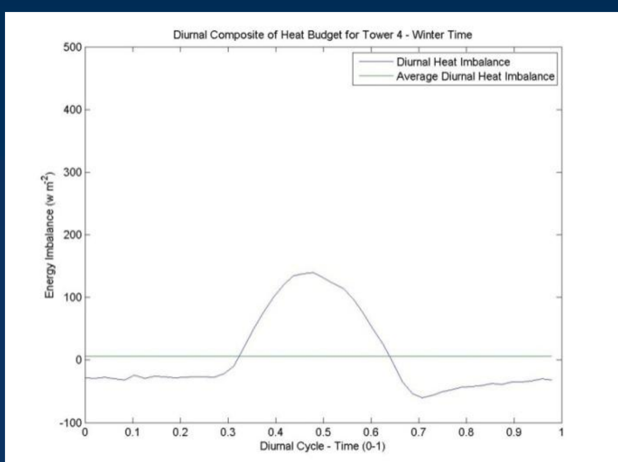
Surface Heat Budget - Winter

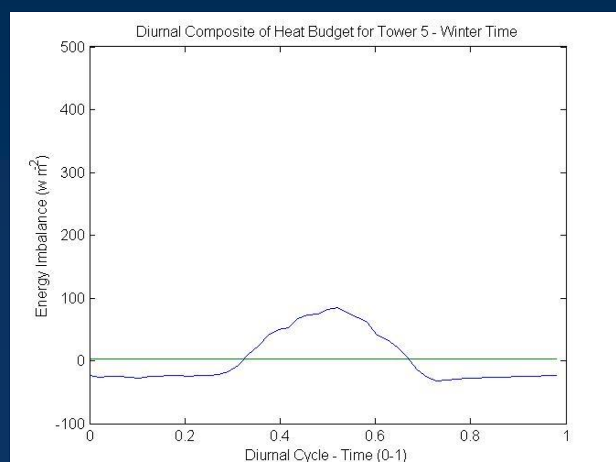
- We define winter as DOY between 320 - 045

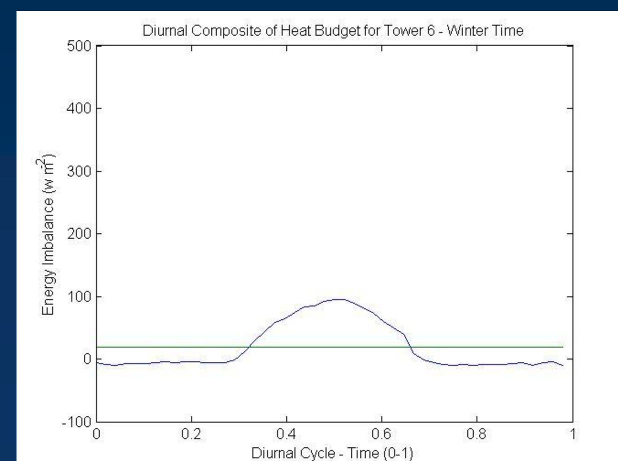










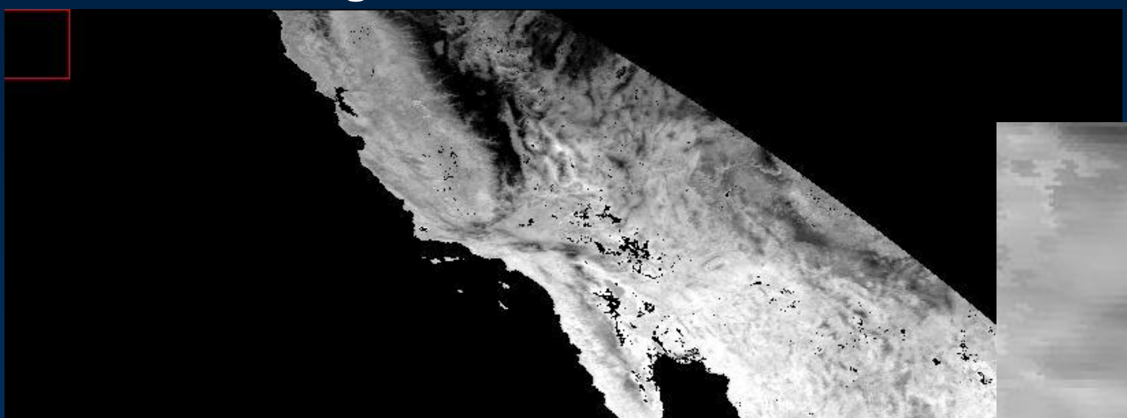


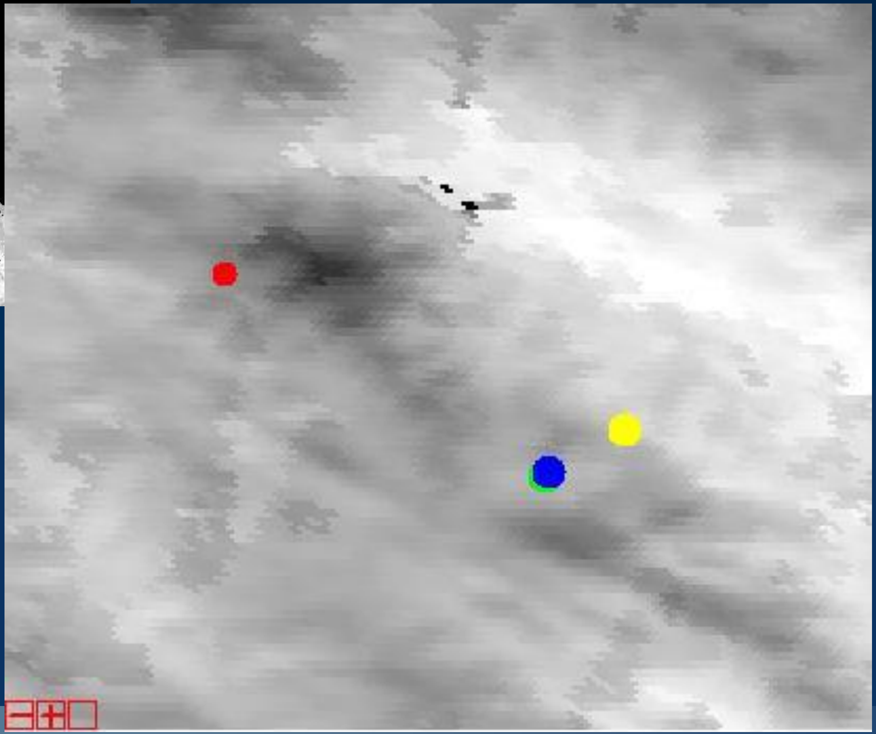
29. Discussion – heat imbalance

- Daily composites of surface heat budget show seasonal and daily variability, between FT sites
- Profiles from each tower were also unique from one another and showed site variability
- Average heat imbalances, were lowest for the winter months and the highest for the summer months
- The overall, integrated, heat imbalance is very high for all sites
- Missing ground flux could be the problem
- Instrument errors could be another explanation
- Heat budget does not balance for all sites

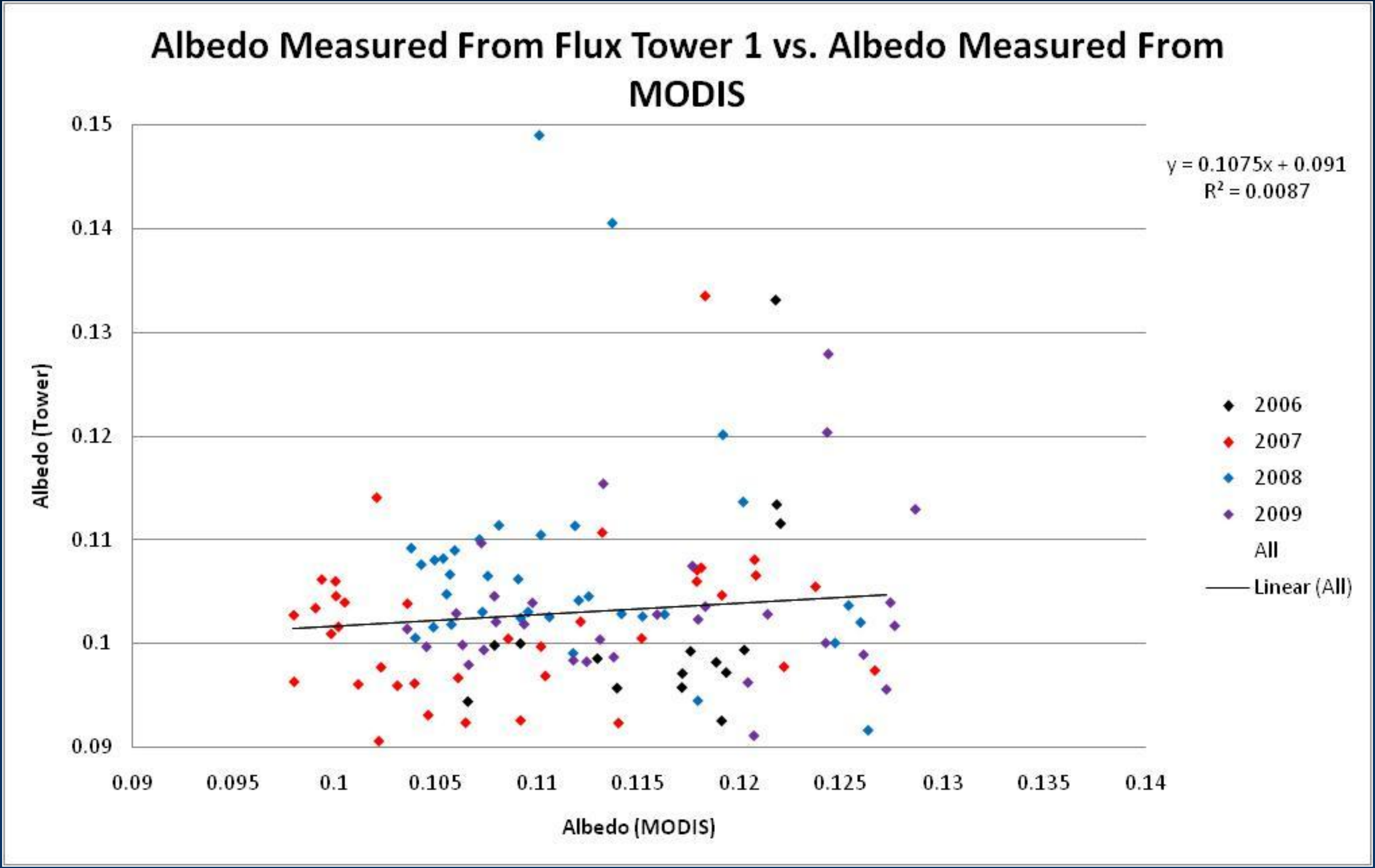
30. MODIS vs. Flux Tower Measurements

- We will be using 250 m resolution, 16 day NDVI composite MODIS images, 500 m resolution, 8 day albedo composite MODIS images and 1000 m resolution, 8 day surface temperature composite MODIS images

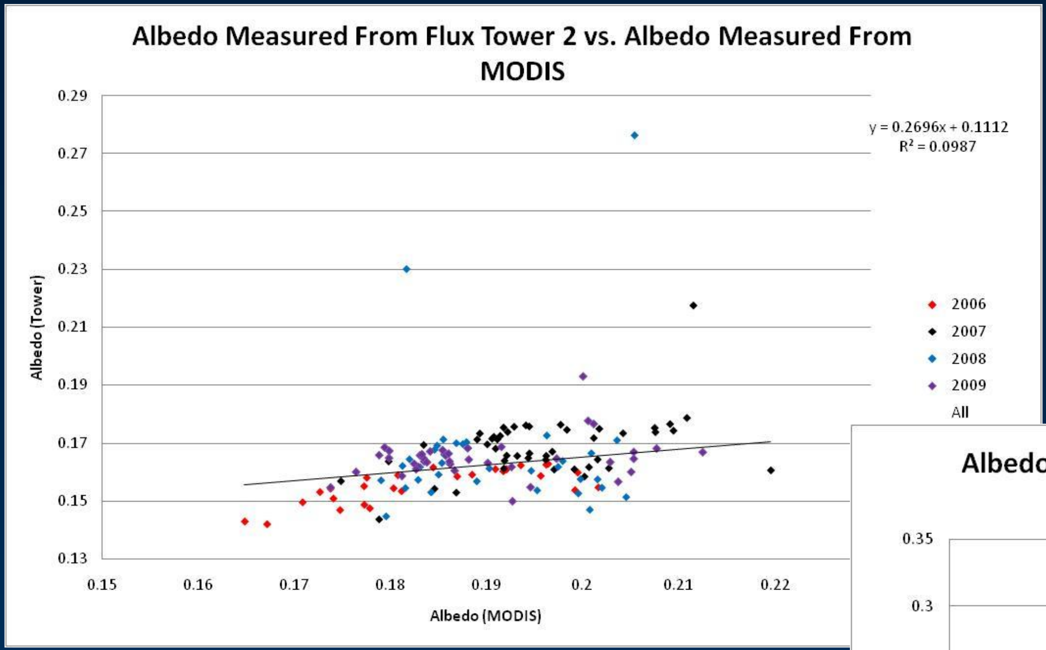


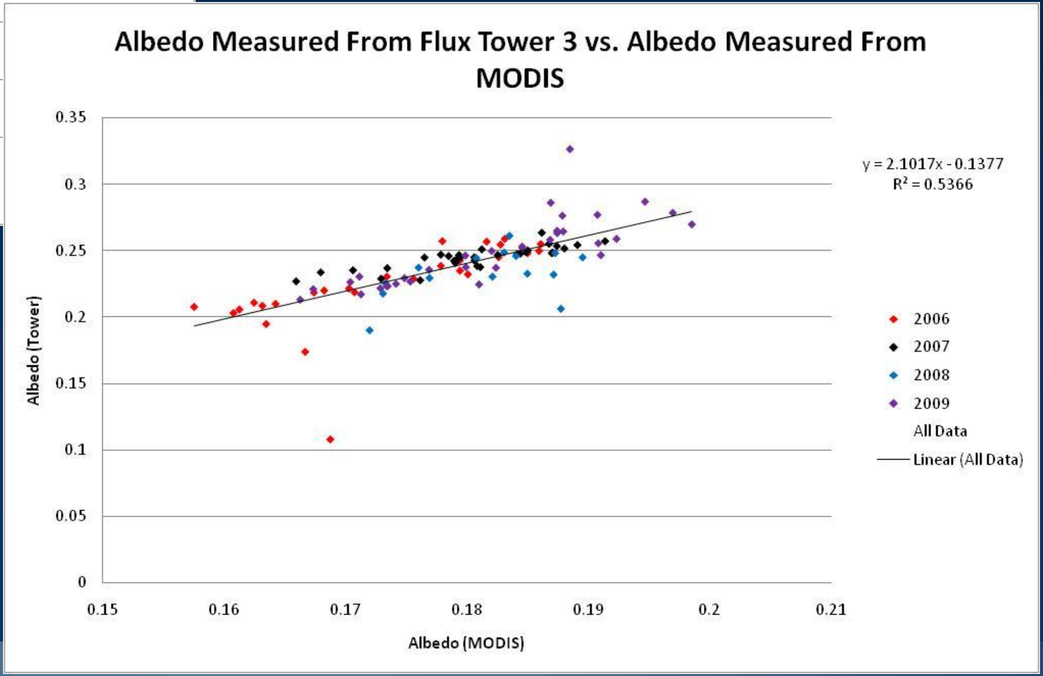


31. Comparison: Tower Measured Albedo vs. MODIS Measured Albedo – Tower 1

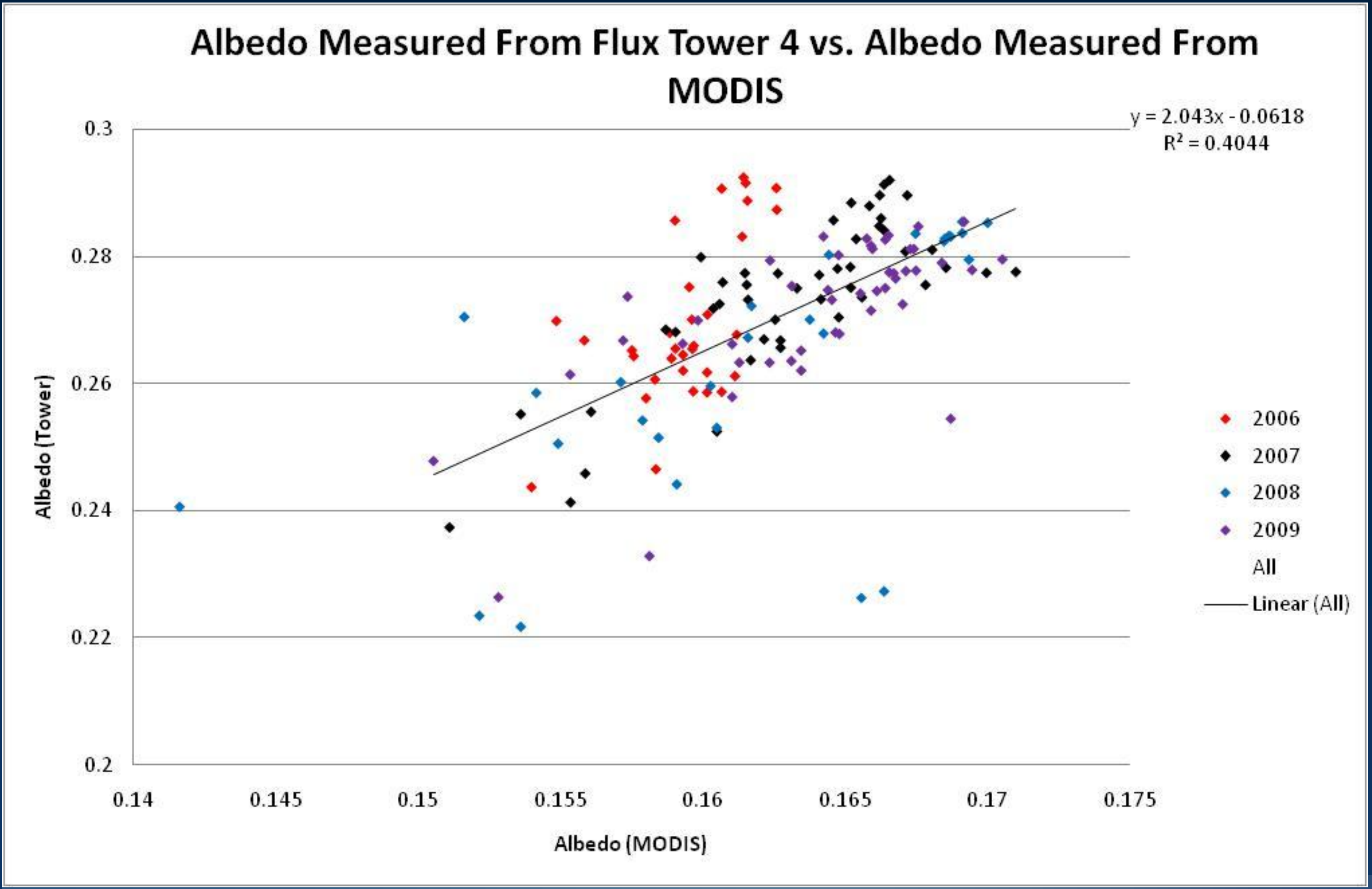


32. Comparison: Tower Measured Albedo vs. MODIS Measured Albedo – Tower 2 and 3

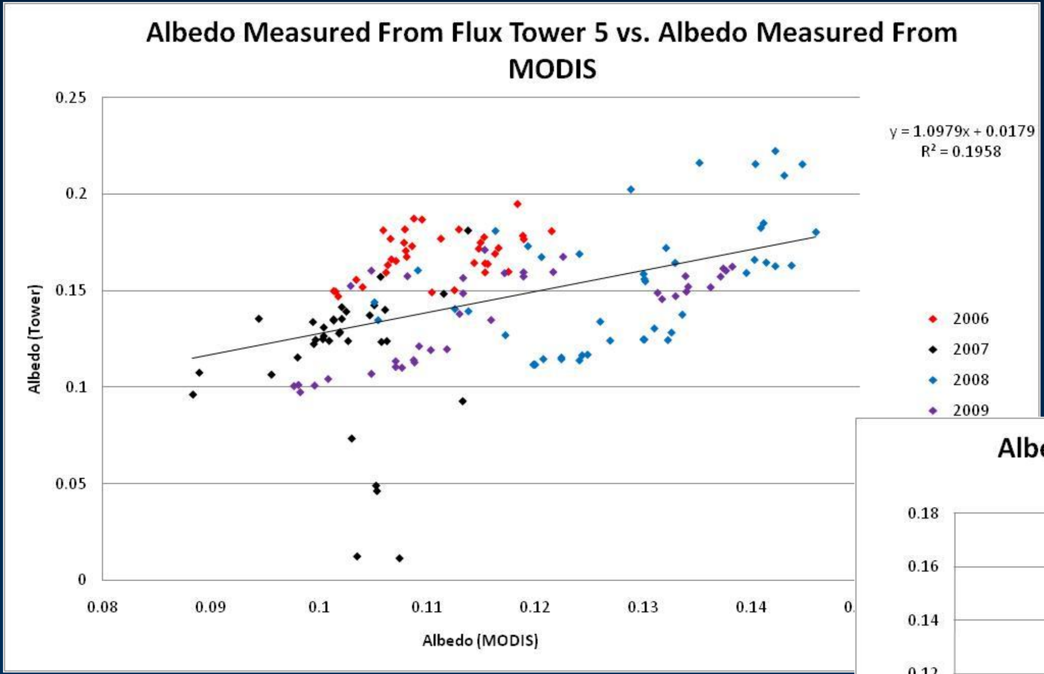


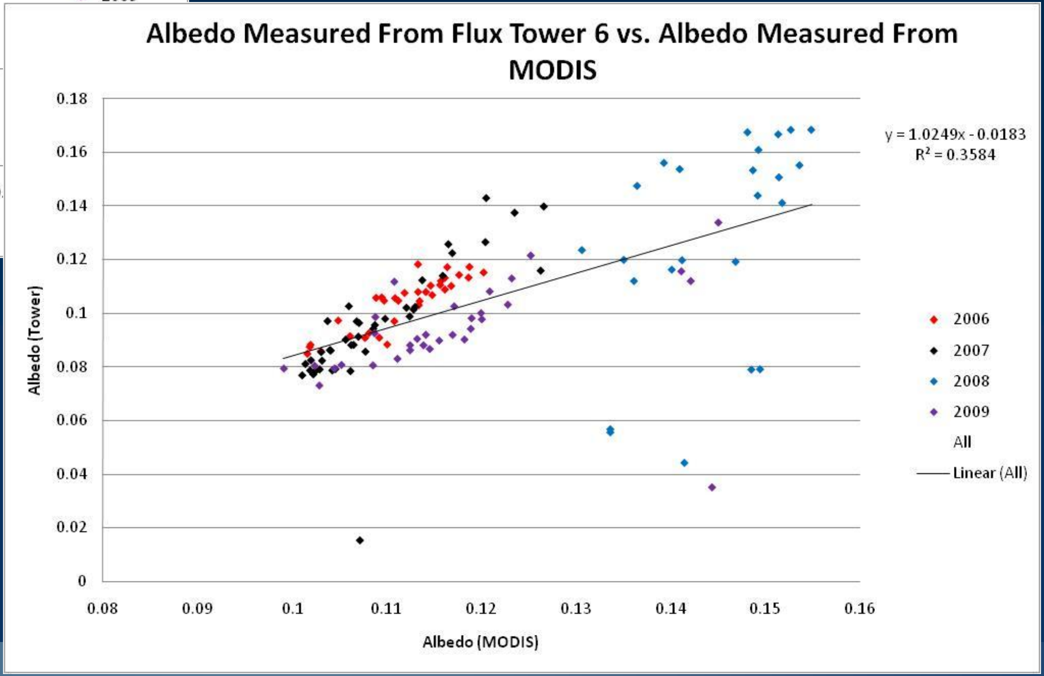


Comparison: Tower Measured Albedo vs. MODIS Measured Albedo – Tower 4



34. Comparison: Tower Measured Albedo vs. MODIS Measured Albedo – Tower 5 and 6

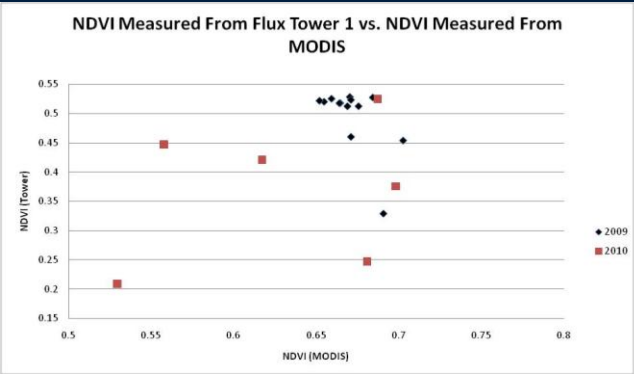


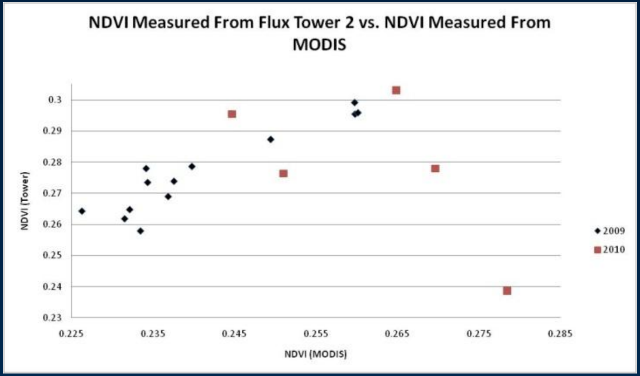


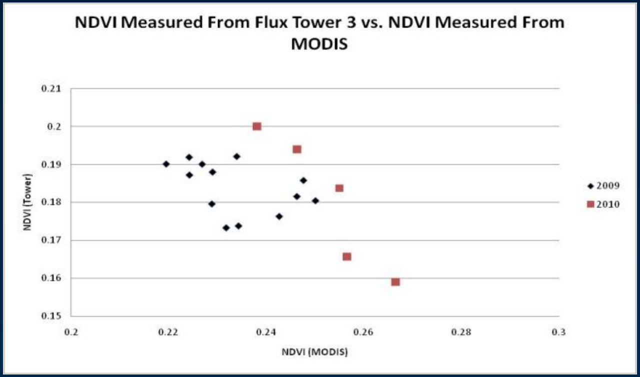
35. Discussion – MODIS vs. flux tower measured surface albedo - correlations

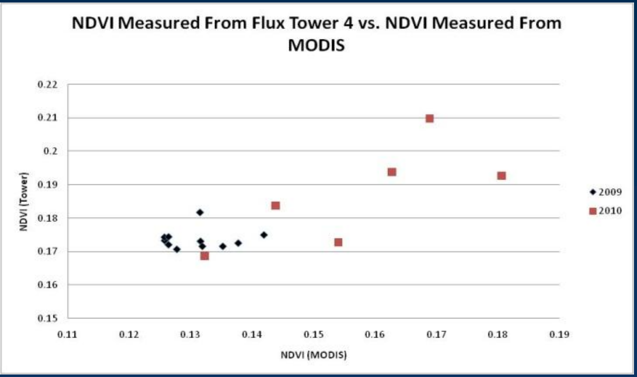
- FT-1 a forested area had the lowest correlation. This would appear to be, possibly, closely related to previous studies, where it has been observed that measuring surface changes for heavily vegetated areas, can be very difficult
- Areas of less dense vegetation showed the best correlations. FT 3, 4, 5, and 6 all showed correlations of fairly close magnitude
- It was observed that the fitted lines for FT's 5 and 6 had slopes close to 1
- Data also showed annual, and inter-annual variability with albedo measurements

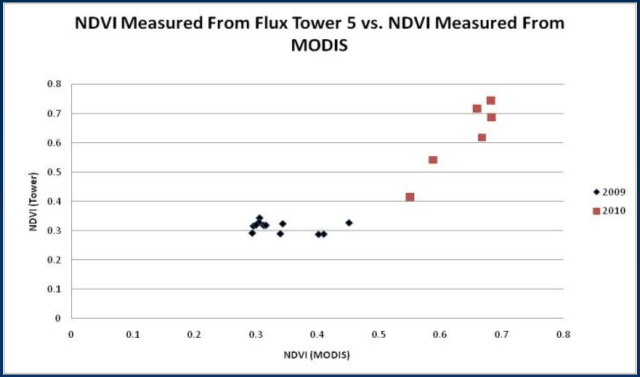
36. Comparison: Tower Measured NDVI vs. MODIS Measured NDVI – Individual Towers

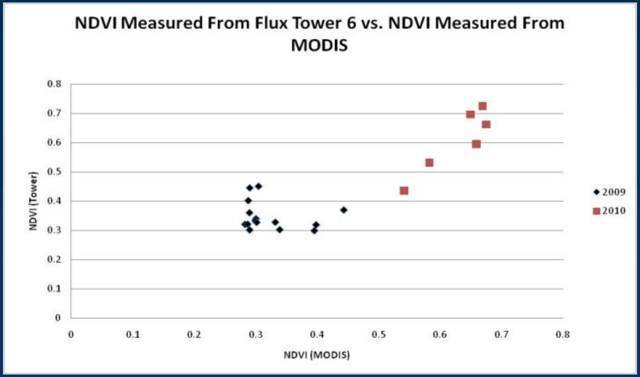




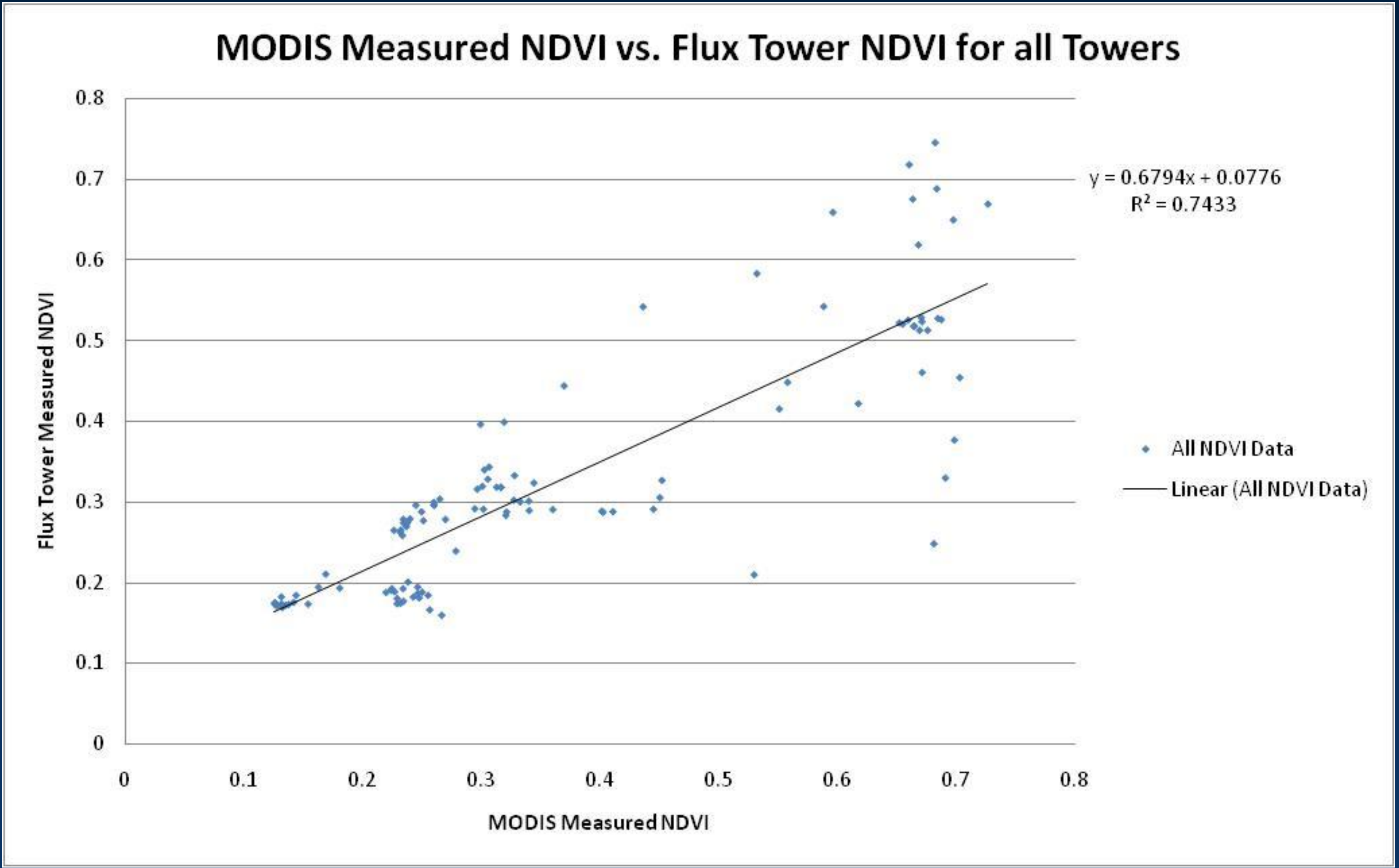




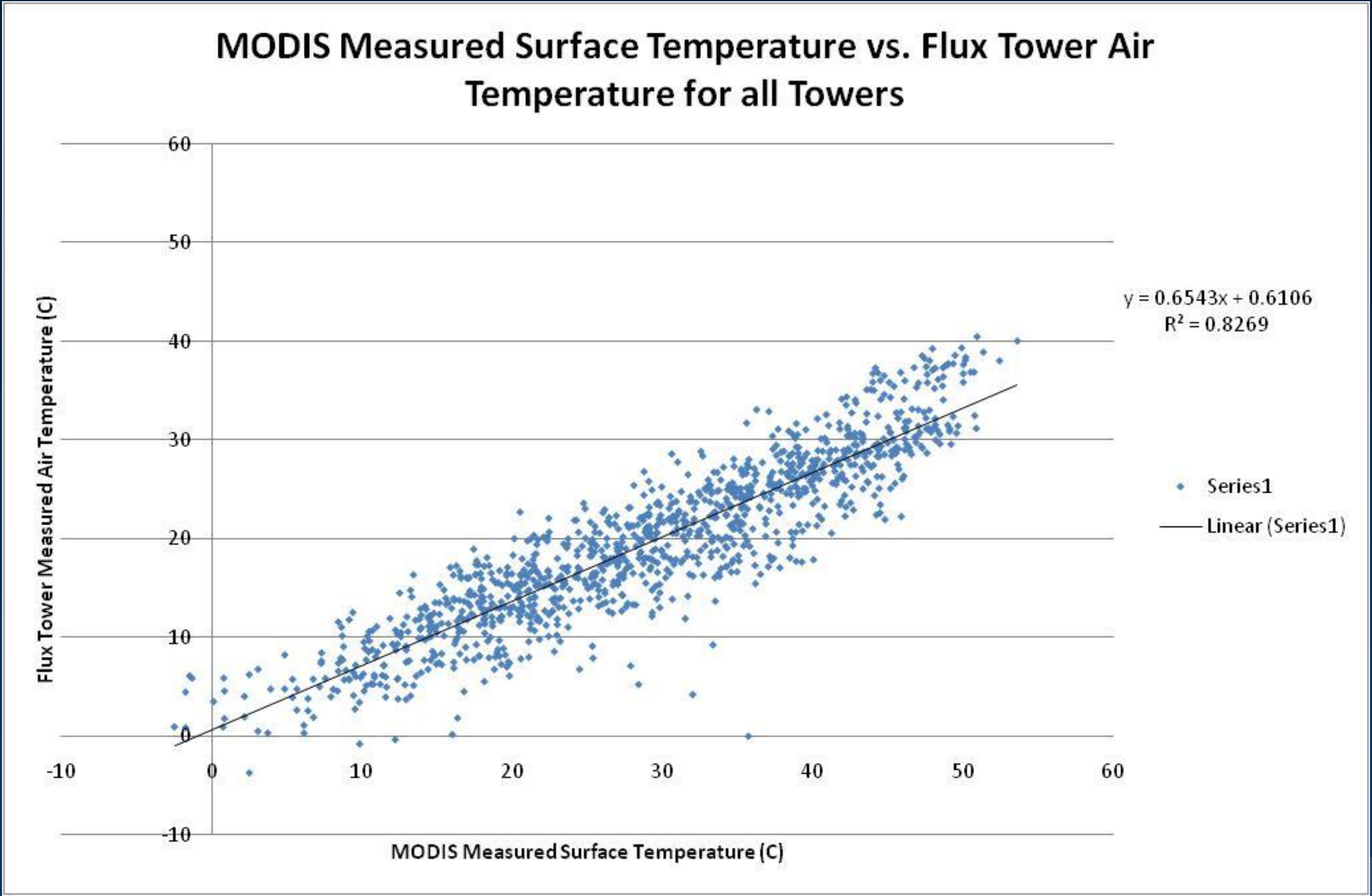




37. Comparison: Tower Measured NDVI vs. MODIS Measured NDVI – All Towers



38. Comparison: MODIS Measured Surface Temperature vs. Tower Measured Air Temperature – All Towers

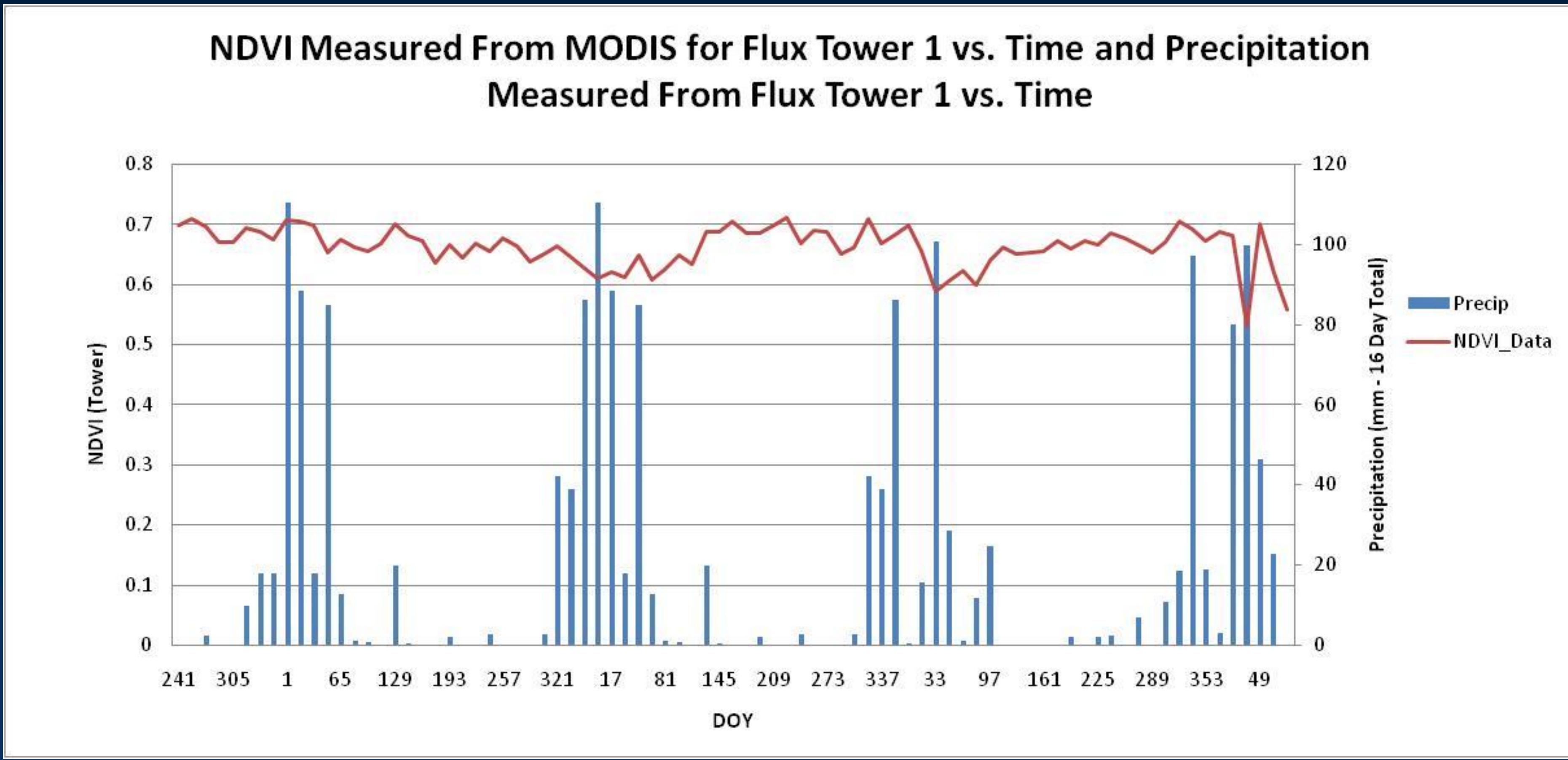


39.

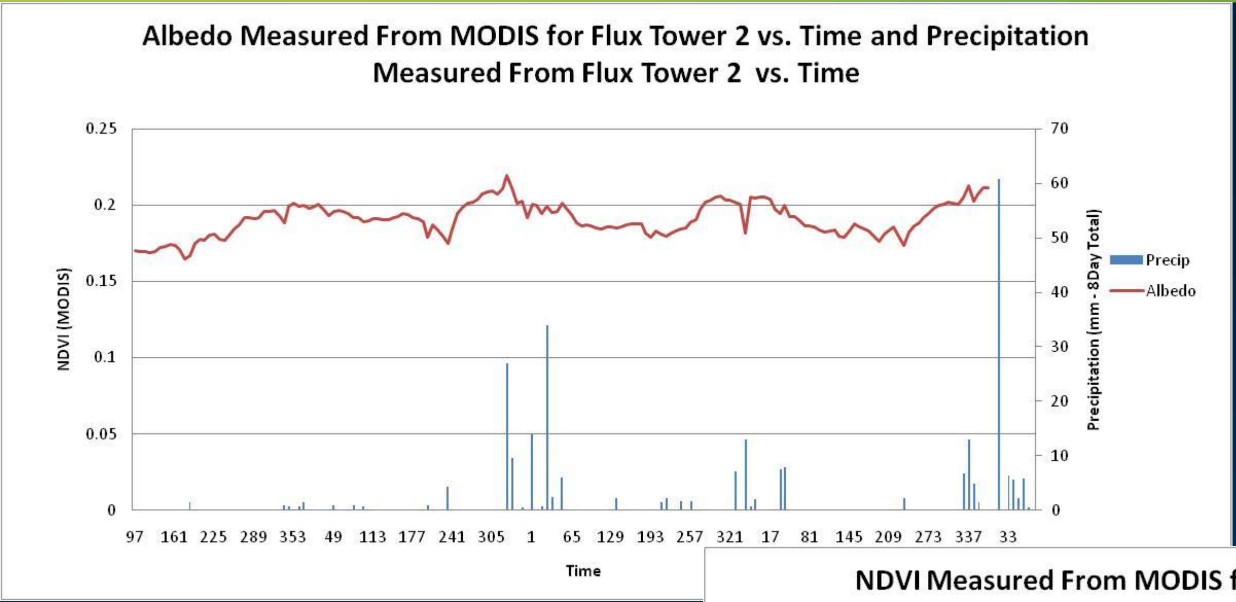
Discussion – NDVI and temperature measurements

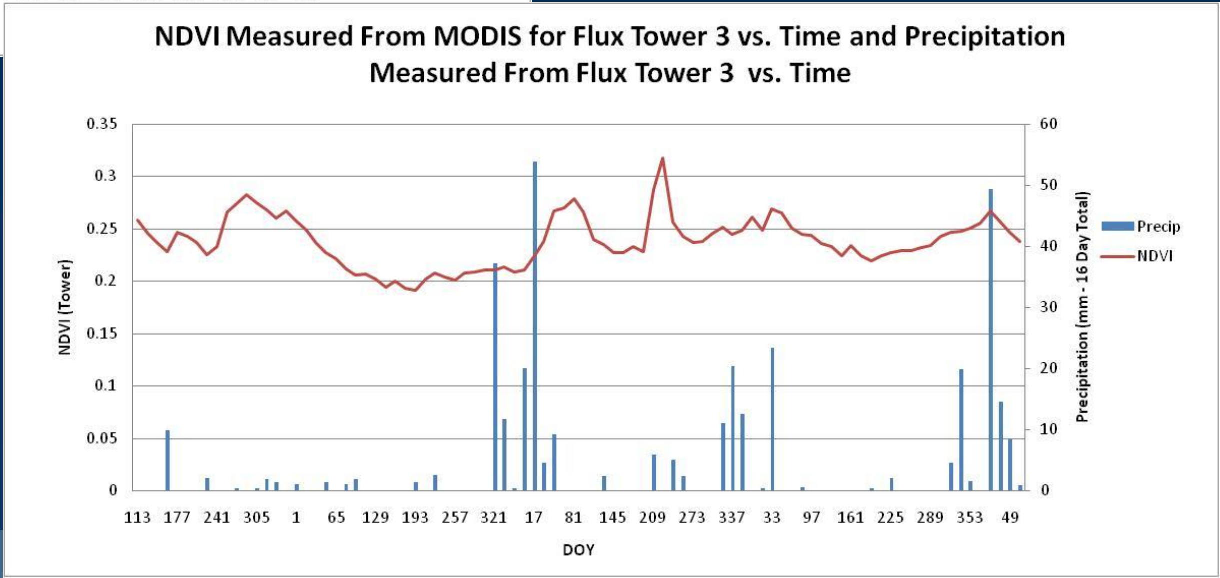
- Low amount of FT NDVI data
- Hard to draw any conclusions from looking at individual towers
- When examining all of the NDVI data together shows a better correlation. Data shows clustering of data, each cluster representing an individual site
- FT's lack surface temperature measurement. We use air temperature in place and find it correlates well with satellite measurements of surface temperature

40. Correlation: Precipitation vs. MODIS Measured NDVI – Tower 1

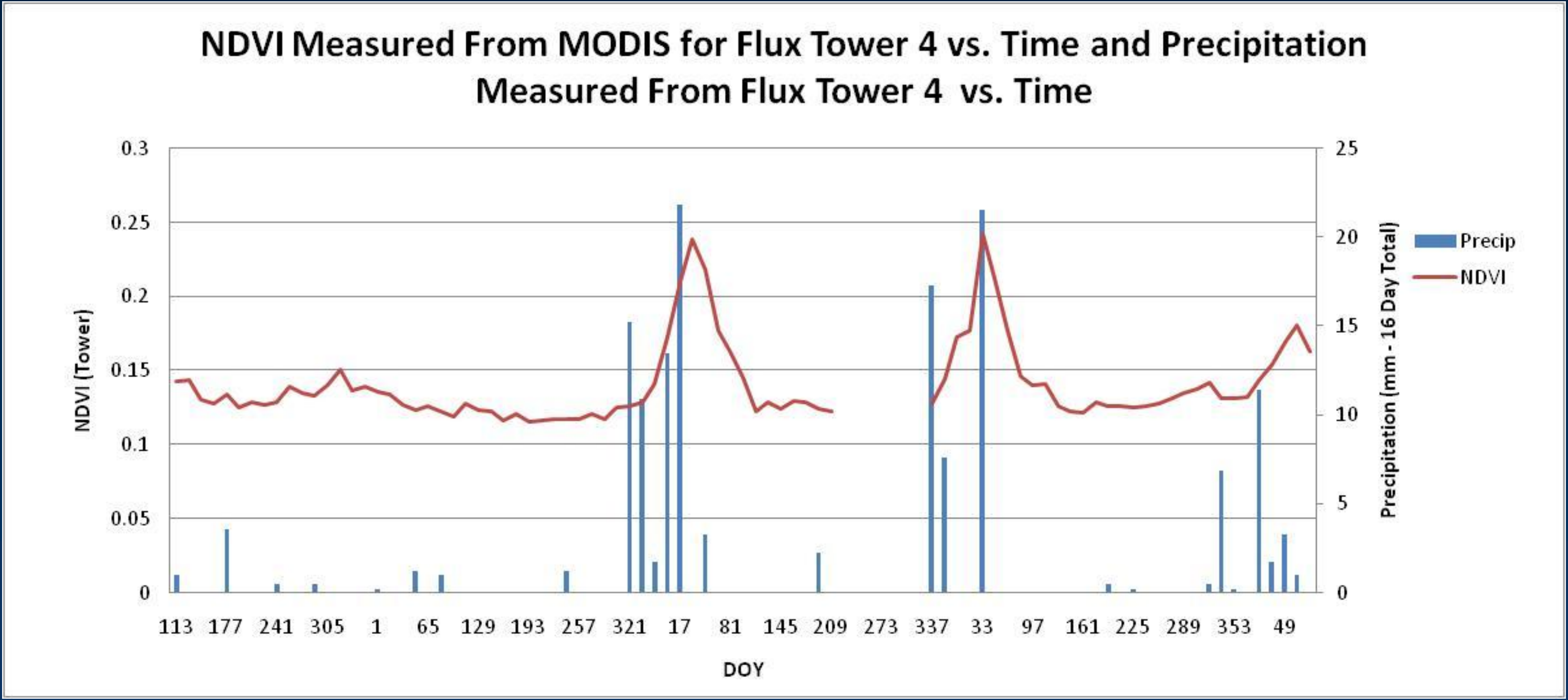


41. Correlation: Precipitation vs. MODIS Measured NDVI – Tower 2 and 3

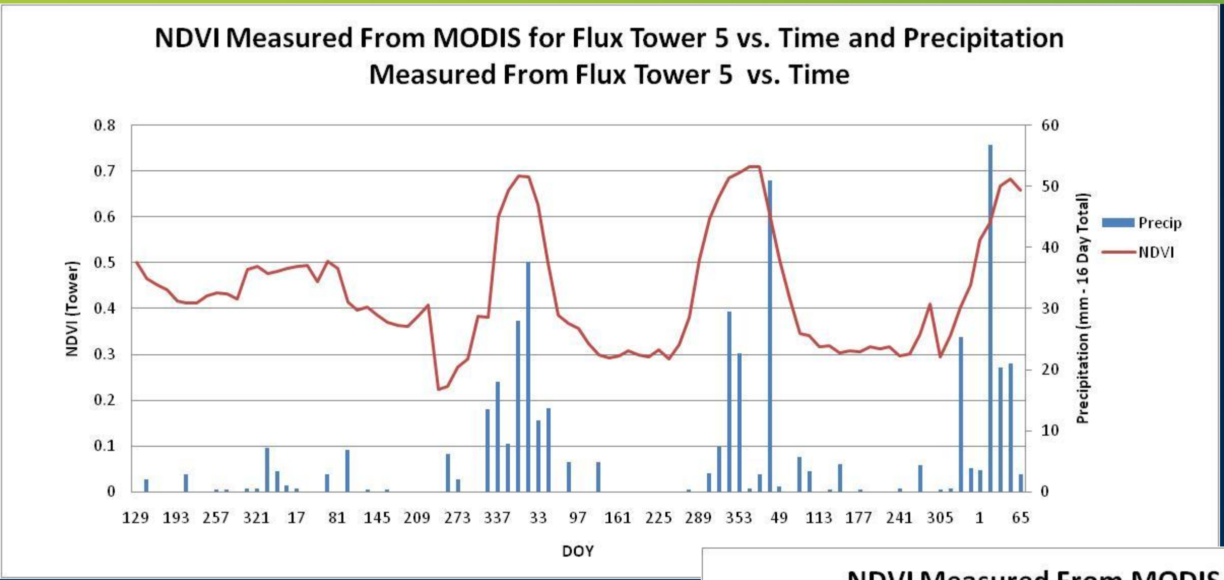


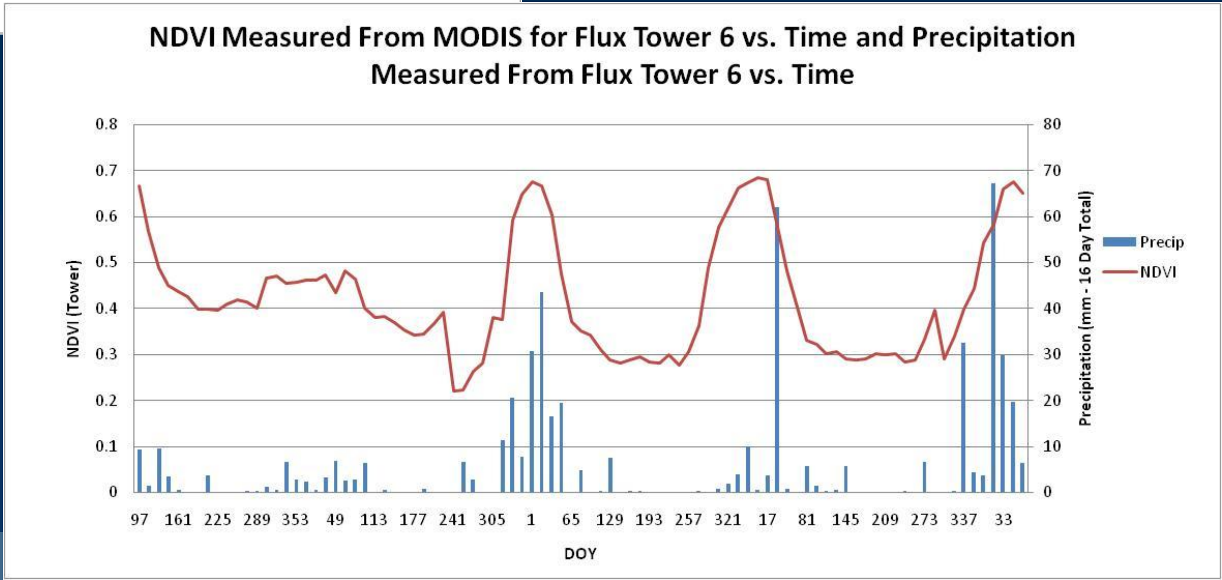


42. Correlation: Precipitation vs. MODIS Measured NDVI – Tower 4



43. Correlation: Precipitation vs. MODIS Measured NDVI – Tower 5 and 6

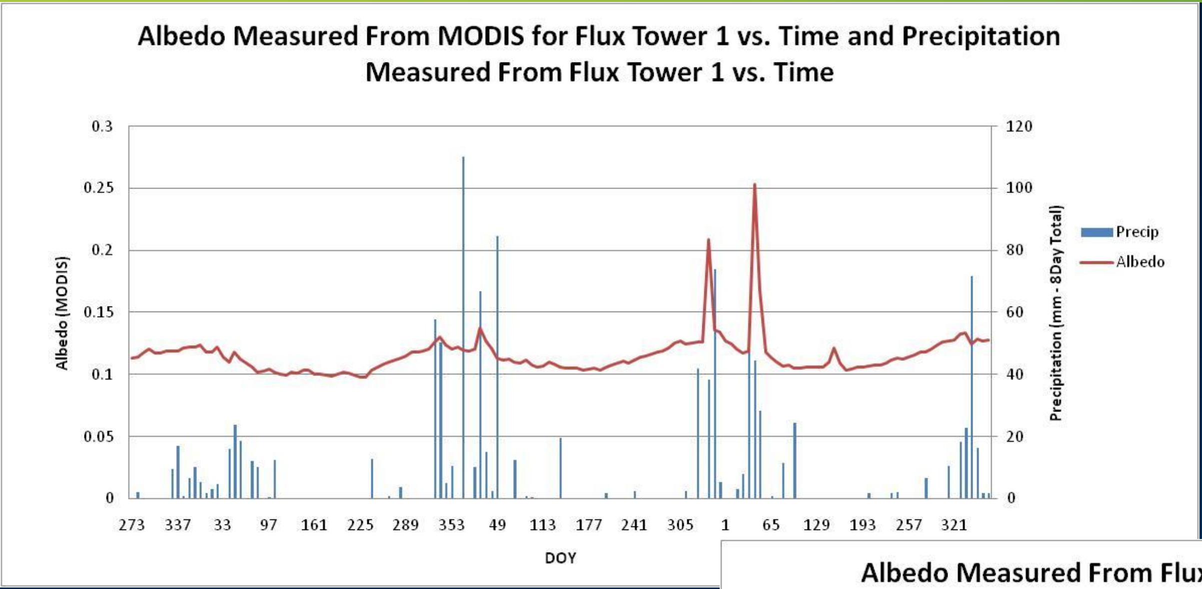


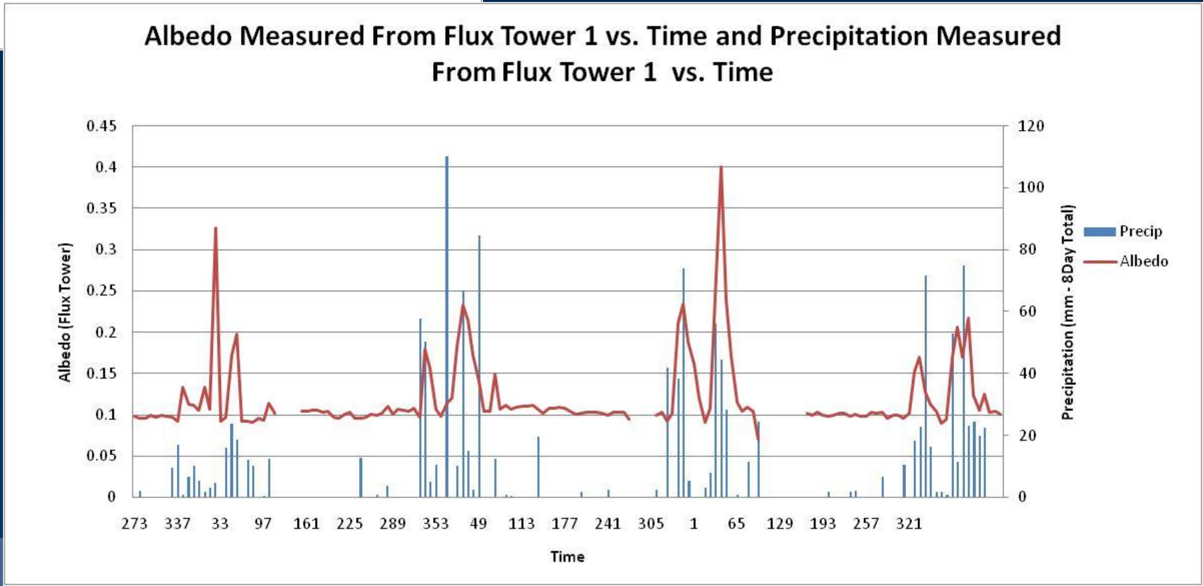


44. # Discussion – time series MODIS measured NDVI vs. precipitation

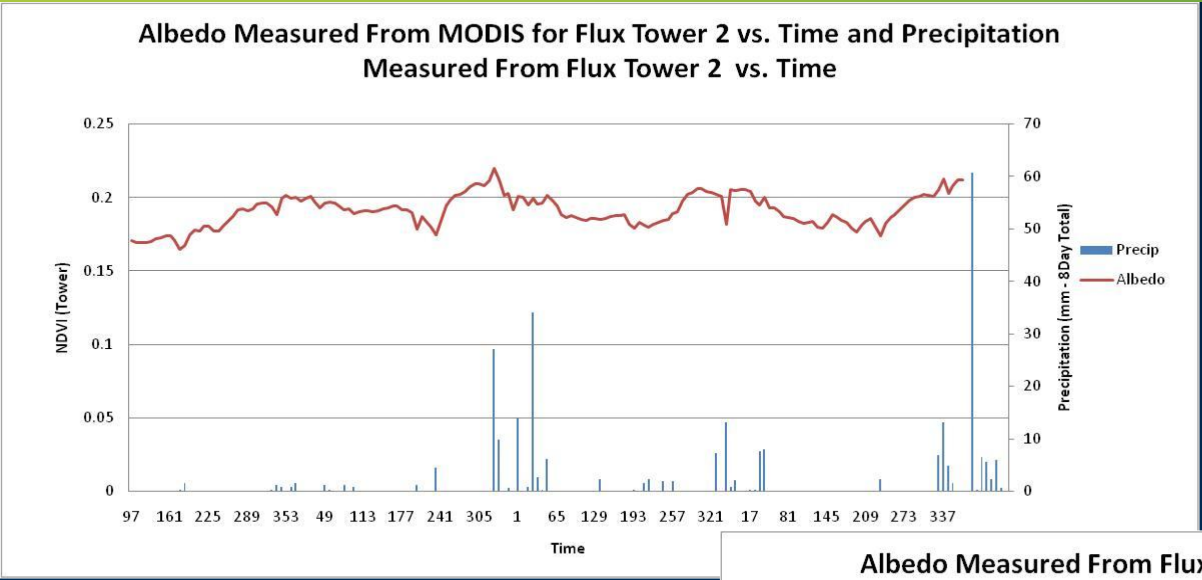
- FT-4, 5, and 6 showed some response in NDVI from precipitation events
- It should be notes that the change in NDVI appeared to be deplayed
- FT-1, 2 and 3, did not show the same level of response when compared to FT-4, 5, and 6
- It would appear that for areas of heavier vegetation, NDVI does not response as clearly, on MODIS images when compared to areas of less vegetation

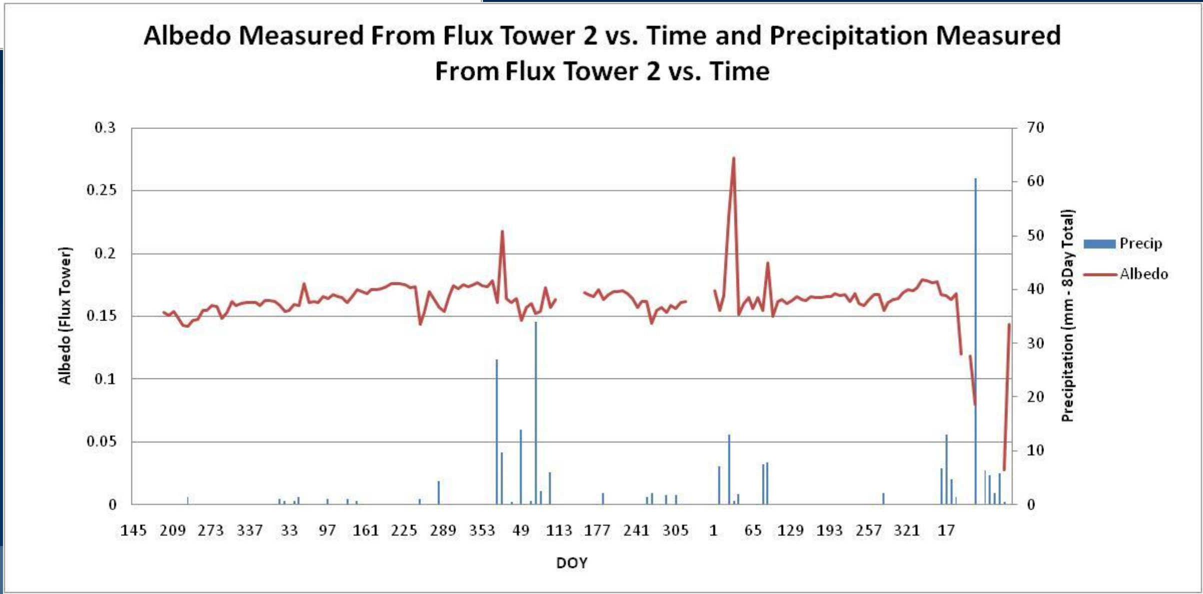
45. Correlation: Precipitation vs. MODIS Measured Albedo and Tower Measured Albedo – Tower 1



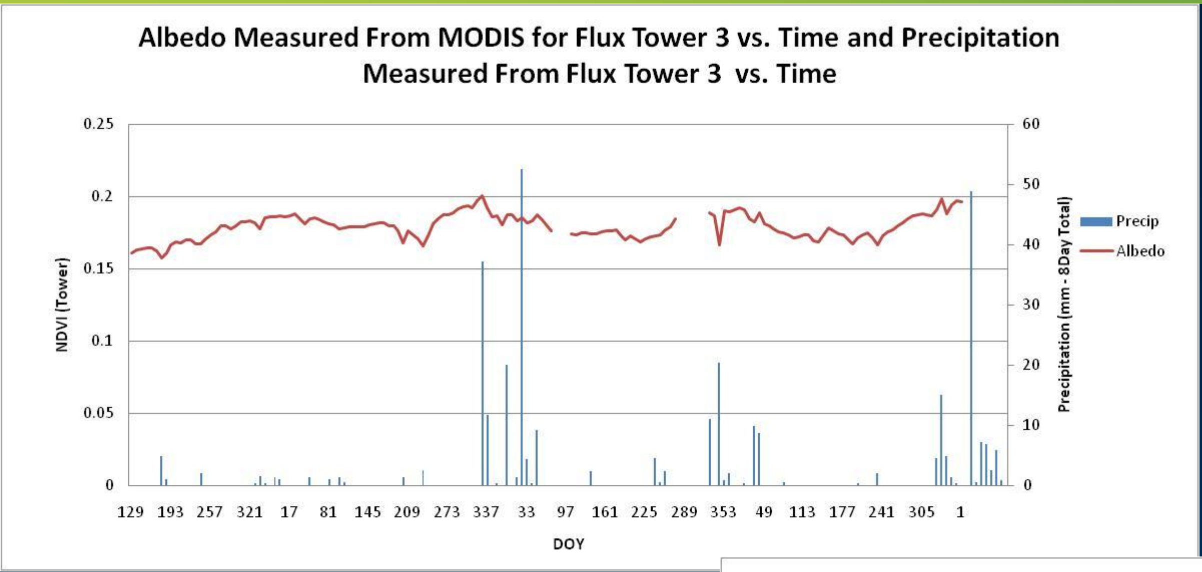


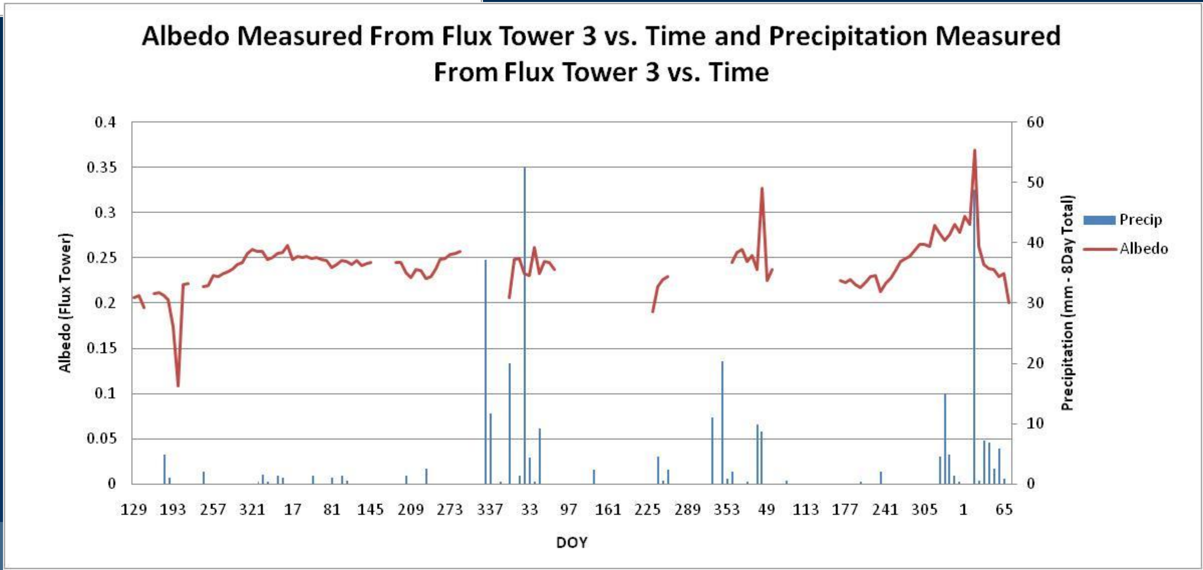
46. Correlation: Precipitation vs. MODIS Measured Albedo and Tower Measured Albedo – Tower 2



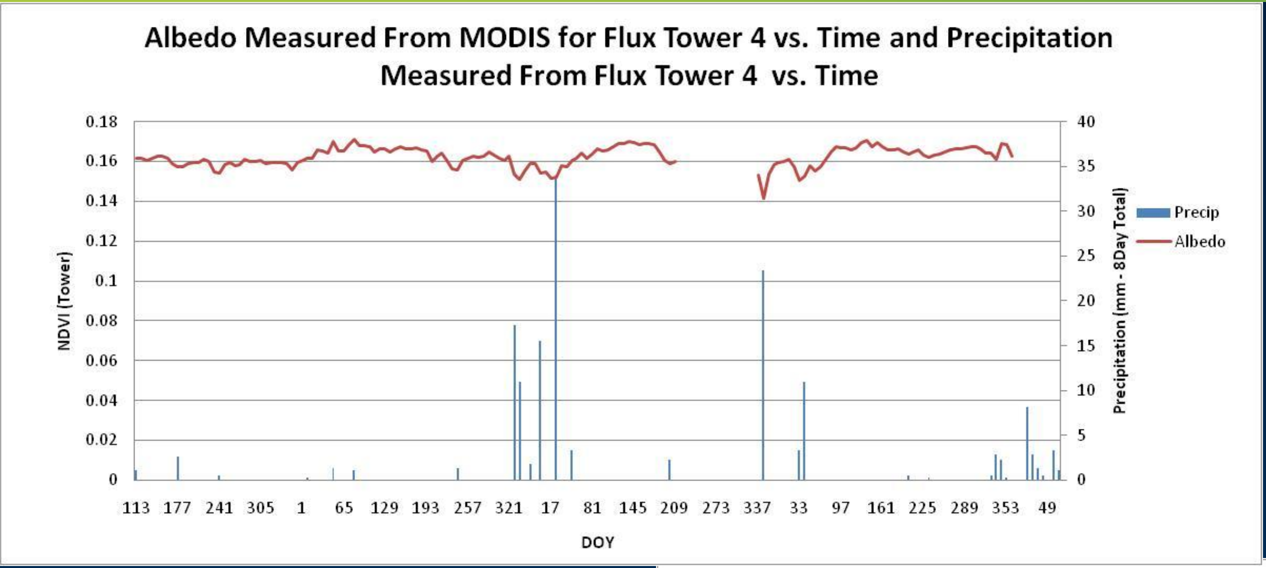


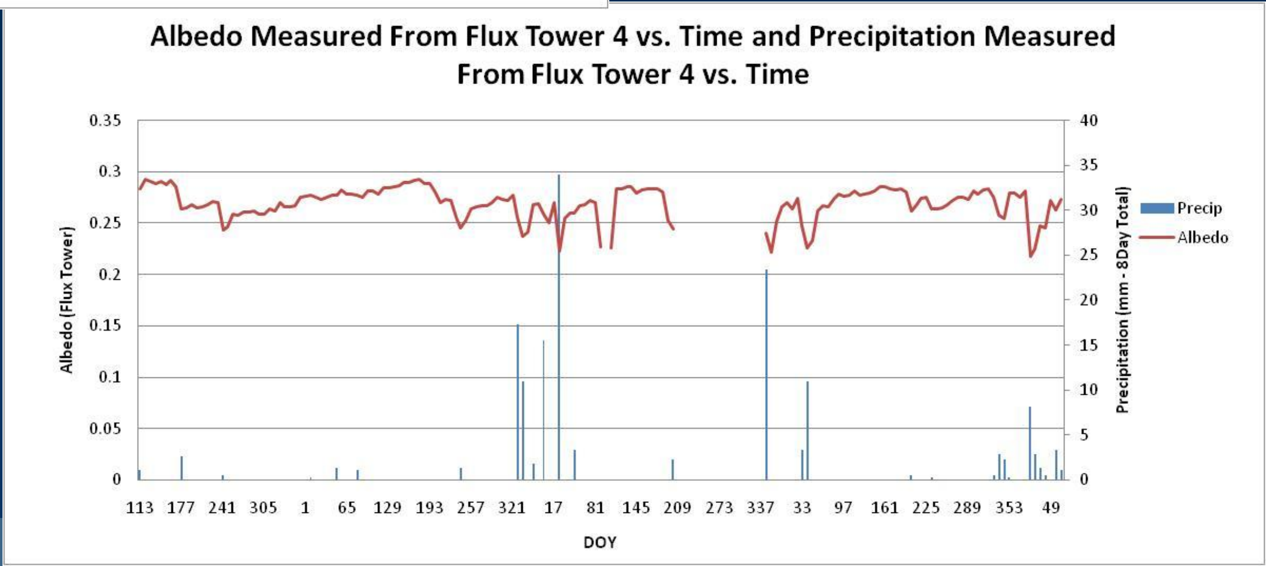
47. Correlation: Precipitation vs. MODIS Measured Albedo and Tower Measured Albedo – Tower 3



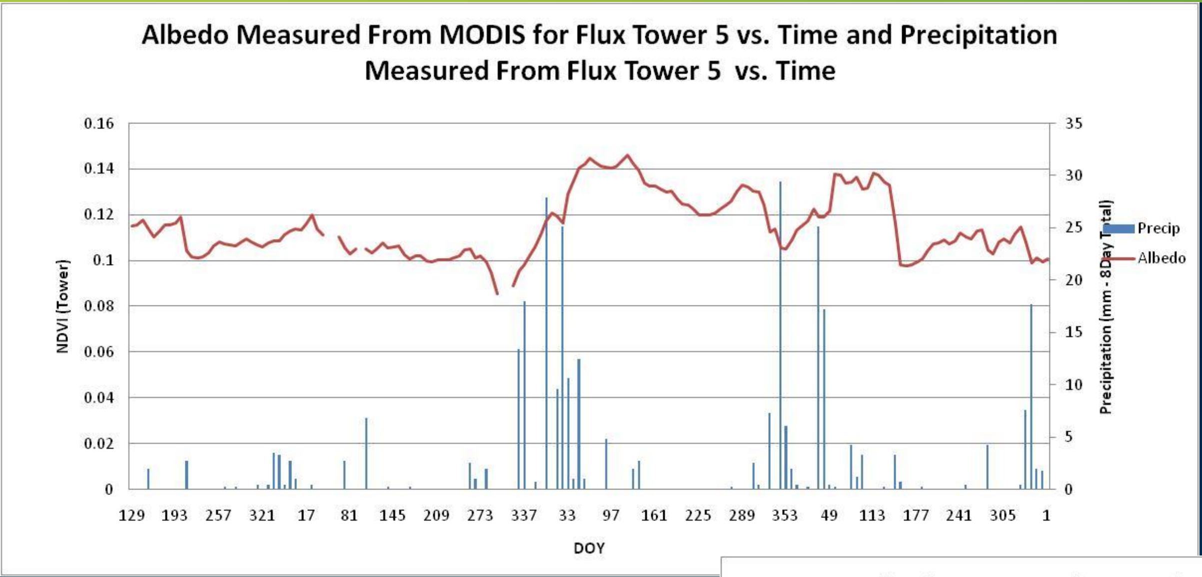


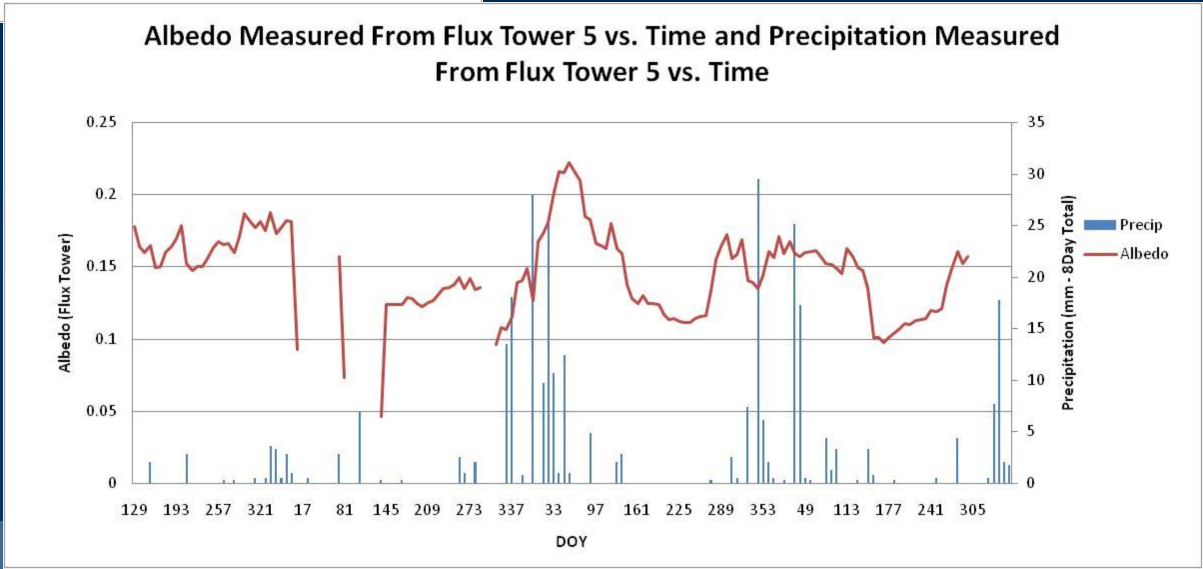
48. Correlation: Precipitation vs. MODIS Measured Albedo and Tower Measured Albedo – Tower 4



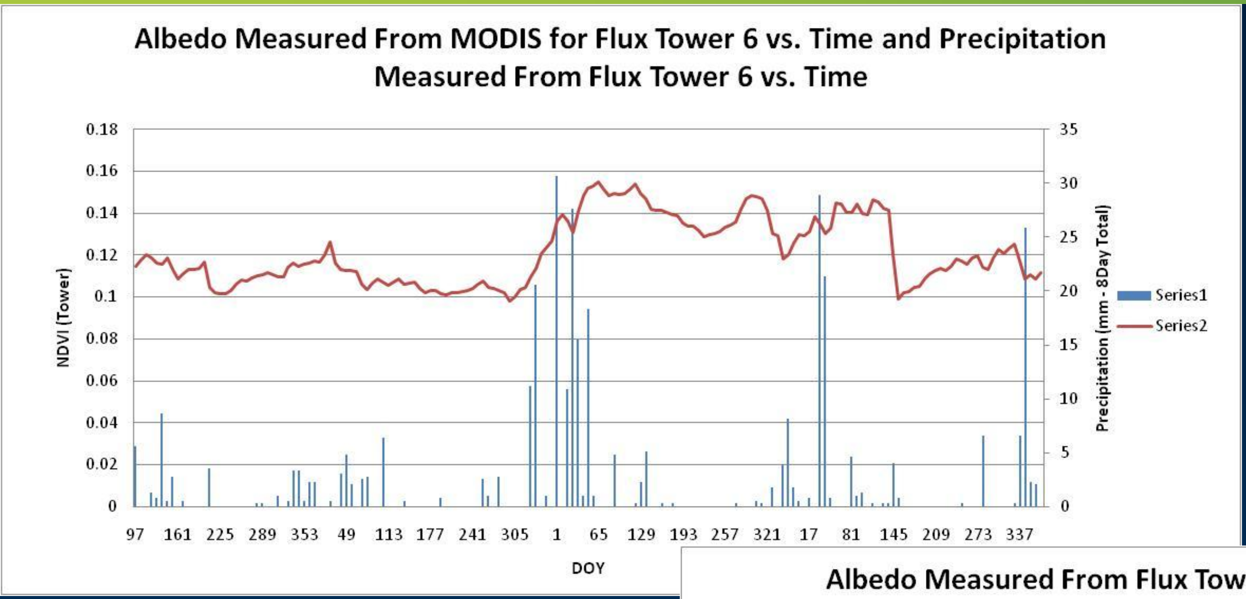


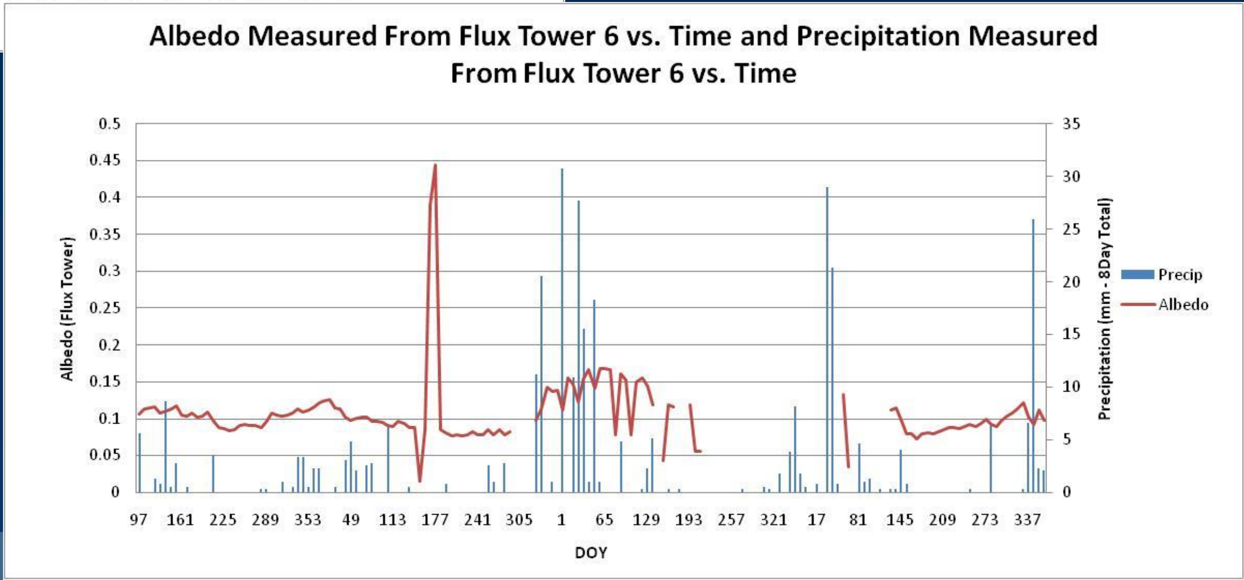
49. Correlation: Precipitation vs. MODIS Measured Albedo and Tower Measured Albedo – Tower 5





50. Correlation: Precipitation vs. MODIS Measured Albedo and Tower Measured Albedo – Tower 6





51. Discussion – time series albedo vs. precipitation

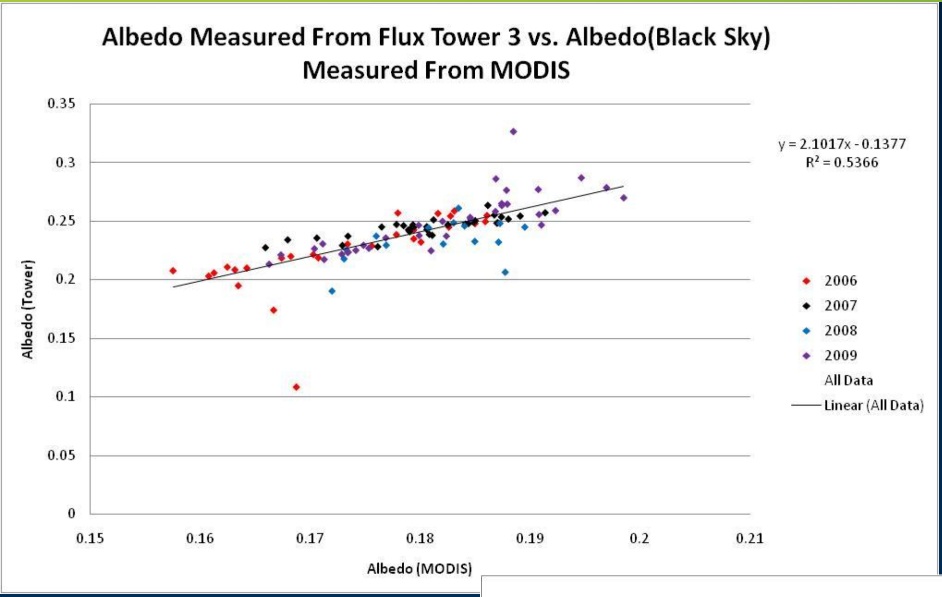
- FT-1 shows response to precipitation but is most likely caused by snow fall
- Overall, all towers do not show a strong link between precipitation events and albedo changes
- It would appear that areas of lower vegetation show a more significant response to precipitation events than areas of heavier vegetation.

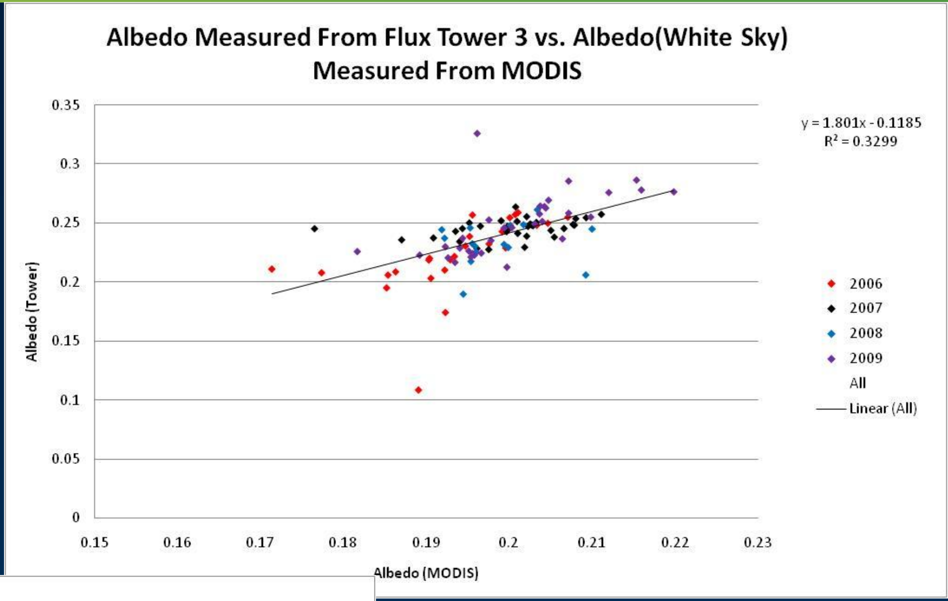
52. MODIS – Albedo Determination from Conversion Coefficients

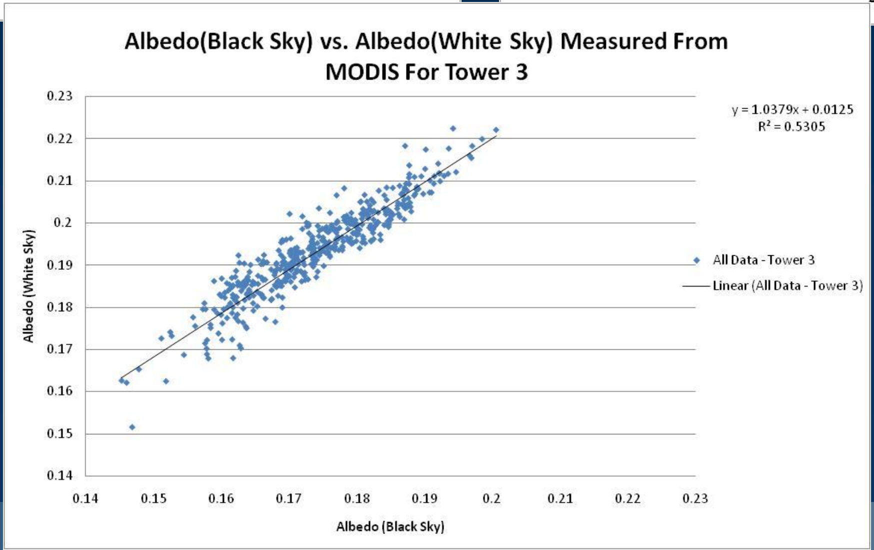
- Surface albedo is determined largely based on conversion coefficients from Liang et al. (1999)
- Conversion coefficients were determined using ground truthed satellite surface reflectance spectra, in a computer simulation to mimic varying atmospheric conditions
- In total, 20 different landcover, ground surface reflectance spectra's were used
- The resulting reflectance results are analyzed using a neural network to create correlation and conversion coefficients linking top of the atmosphere (TOP) reflectance's to surface albedo
- Our results could offer additional data in the development of these coefficients and algorithms
- Since the conversion coefficients encompass a large number of different landcovers, could explain any discrepancies we have

Liang, S., A. H. Strahler, and C. W. Walthall, Retrieval of land surface albedo from satellite observations: A simulation study, J. Appl. Meteorol., 38, 712-725, 1999.

53. MODIS – Black Sky and White Sky Albedo vs. Flux Tower Measured Albedo – Tower 3







Conclusions

- Data quality results produced intuitive and predictable results
- Indicates that tower data is possibly of good quality and represents true conditions
- Comparisons of flux tower measured albedo to satellite measured albedo showed some strong correlations
- Results indicate that albedo correlations are dependent on land cover
- Comparisons of flux tower measured NDVI to satellite measured NDVI showed correlations no real correlations in sites but as a total data set showed correlations
- NDVI response to precipitation stresses showed a possible dependency on landcover. Areas of less vegetation responded stronger than areas of less vegetation
- Both MODIS and FT measured Albedo response to precipitation stresses showed very little response
- It would appear that areas of sparse vegetation, in a semi-arid region, is the easiest to measure and to have its feedback mechanisms characterized using satellite and flux tower measurements
- Results from this style of study could be incorporated in MODIS algorithms and conversion coefficients