Model Answer

Twitchell Island Flux Tower (from website)
Latitude: 38.1087204
Longitude: -121.65310

Growing season (from excel file, crop.type column)
9 May 2011
14 October 2011

Nine Landsat 7 ETM+ (Path = 44, Row = 33) image dates within the growing season

2011 May 21
2011 June 22
2011 July 08
2011 July 24
2011 August 09
2011 August 25
2011 September 10
2011 September 26
2011 October 12

Landsat 7 ETM+ thermal 6-2 bands are converted from digital numbers (0-255) to top of atmosphere radiance (3.16-12.65 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$) using Equation 1 in the practical. The following table gives summary statistics for TOA radiance for each image using ENVI. <u>Remember to omit "No Data" when computing summary statistics.</u> Your values may differ slightly depending on the software you are using.

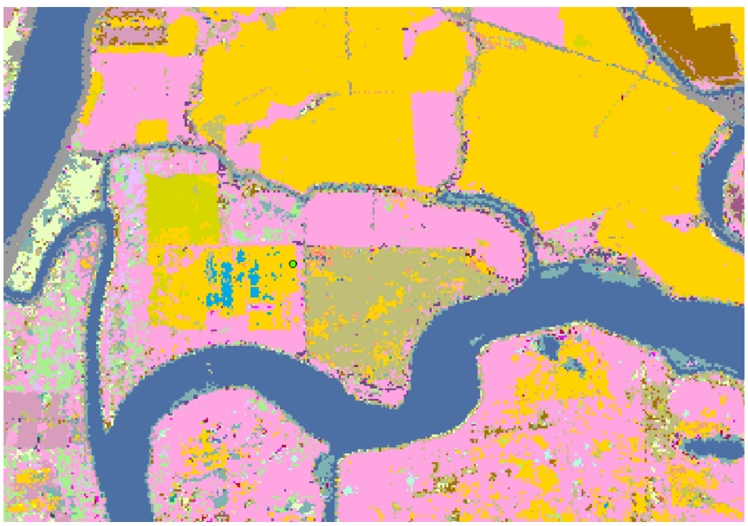
Image Date	Minimum	Maximum	Mean	Stdev
21/5/2011	3.162795	12.650000	6.357980	2.989560
22/6/2011	3.162795	12.650000	7.105508	3.632865
8/7/2011	3.162795	12.650000	7.098925	3.621618
24/7/2011	3.162795	12.650000	6.853408	3.398171
9/8/2011	3.162795	12.650000	6.989650	3.517470
25/8/2011	3.162795	12.650000	6.890194	3.441395
10/9/2011	3.162795	12.650000	6.827931	3.421318
26/9/2011	3.162795	12.650000	6.338290	2.907244
12/10/2011	3.162795	12.650000	6.127521	2.723592

The table below gives summary statistics for TOA brightness (˚C) as determined using Equation 2 in the practical.

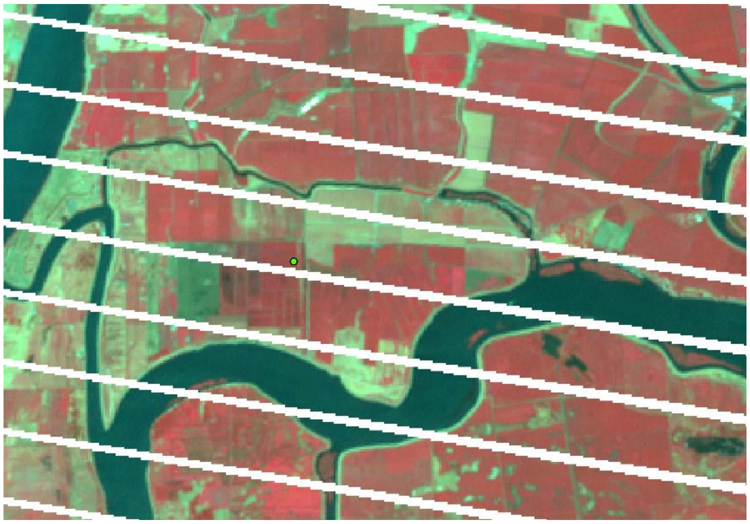
Image Date	Minimum	Maximum	Mean	Stdev
21/5/2011	-33.601822	48.930084	-2.232665	29.060815
22/6/2011	-33.601822	48.930084	3.259247	33.733802
8/7/2011	-33.601822	48.930084	3.231291	33.637973
24/7/2011	-33.601822	48.930084	1.486301	32.092650
9/8/2011	-33.601822	48.930084	2.471577	32.918503
25/8/2011	-33.601822	48.930084	1.722454	32.413310
10/9/2011	-33.601822	48.930084	1.215480	32.201354
26/9/2011	-33.601822	48.930084	-2.271676	28.561469
12/10/2011	-33.601822	40.277924	-3.910218	27.185779

I selected the 25 August 2011 image for my comparison, because this is the period when most vegetation in the study area is near peak productivity (maximum NDVI). The rice fields are irrigated and the fields at this time are flooded.

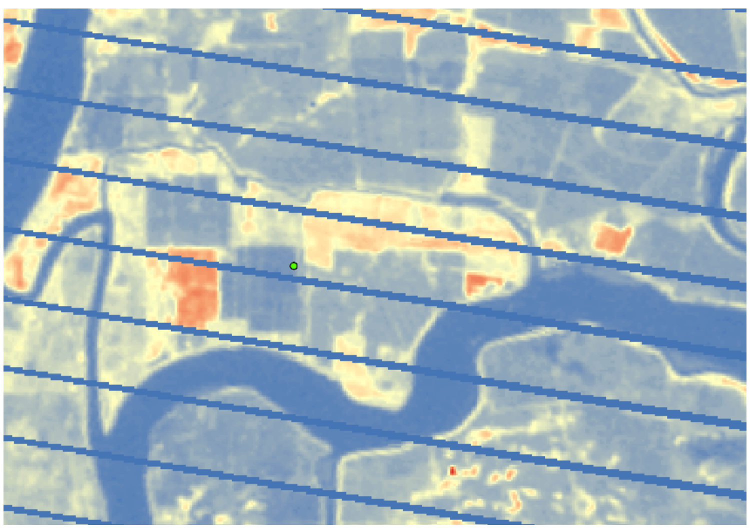
The green dot shows the location of the eddy covariance flux tower. The field just to the west of the tower is the rice field from which measurements are taken. The map is the CropScape classification. Pink, yellow, blue, brown and dark blue indicate the location of alfalfa, corn, rice, wheat, and water, respectively.



The following is the band 2 (blue), 3 (green), 4 (red) composite for the image. Red pixels are more photo-active. Bluish pixels represent bare soil, built-up or some other non-photosynthesizing surface. Most of the image is red, because crops are near peak productivity. The fields to the west and northeast of the study area corresponds to alfalfa fields. Alfalfa is harvested multiple times during the growing season. Alfalfa is used to feed cattle and provides a continuous source of supplemental income for farmers during the growing season. Most likely, the alfalfa has been recently harvested, which is why the fields appear bluish.

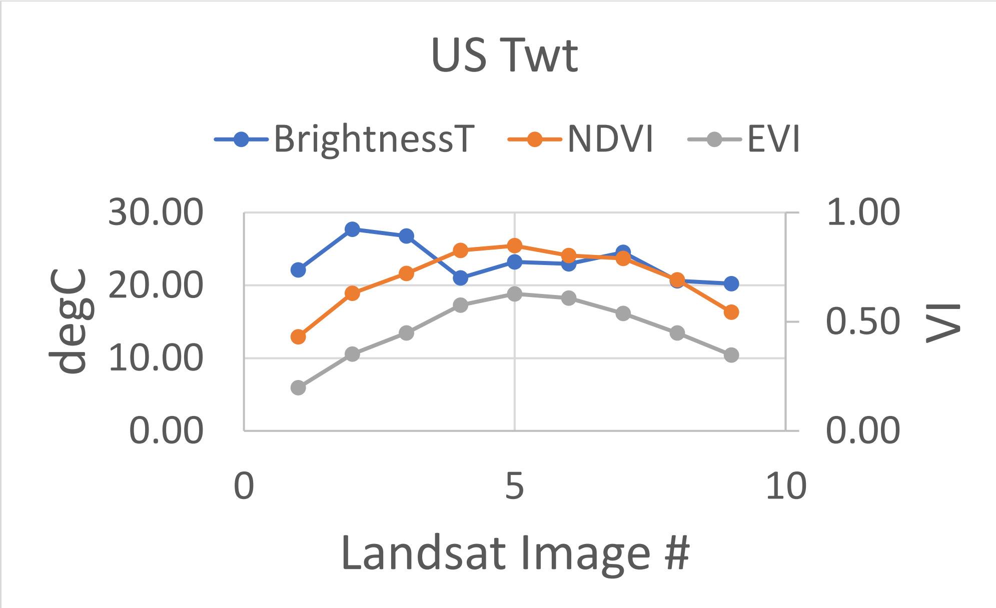


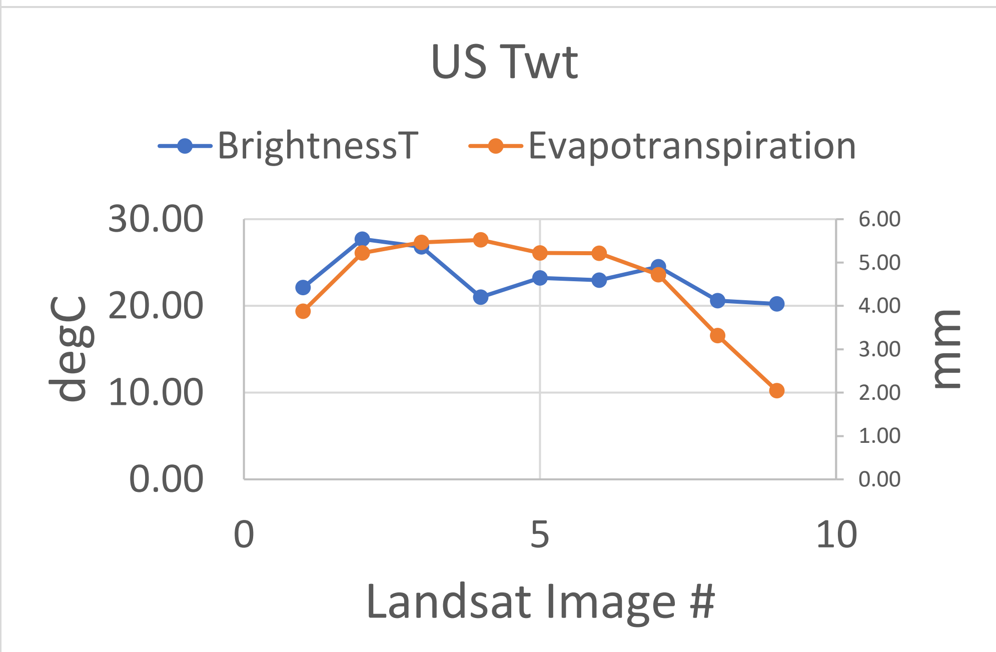
The following is the TOA brightness temperature displayed as cold (blue) and hot (red) pixels in degress celcius.



In the above image, most of the landscape is fairly cold. Water is particularly dark blue (cold). This is because the crops are at peak productivity and therefore transpiring a lot. As evapotranspiration (latent heat) increases, sensible heat and land surface temperatures decrease. The alfalfa fields to the west and northeast of the study area appear yellow-red. This is because the exposed soil absorbs more sensible heat and evapotranspiration is lower. As a result, brightness temperatures are higher.

The plots below show the brightness temperature versus the vegetation indices provided (NDVI, EVI) and evapotranspiration as measured by the eddy covariance flux tower for the nine dates on which Landsat images were provided.





As you might expect, the vegetation indices and brightness temperature tract evapotranspiration fairly well. During the early part of the growing season, the rice is either not in the field or emerging ("green-up"). The field may or may not be flooded. Productivity (NDVI, EVI) is low, so evapotranspiration is low and brightness temperature is high due to higher sensible heat. During peak productivity in June-August however, the opposite is true. The relationship reverses again at the end of the growing season, because the rice is drying out ("brown-down") and the fields may be drained. The relationship between brightness temperature and evapotranspiration is less consistent than NDVI and EVI. This could be due to the limitations of brightness temperature already discussed (e.g., sensitivity to atmospheric water vapor/clouds). The correction made in the challenge exercise should result in a more consistent relationship.