Develop an Interface to the Google Earth Engine to implement a Deep Convective Cloud based Calibration process on Landsat 8

SDSU

Ruchi Dubey
Advisor: Larry Leigh
SDSU - LST
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South Dakota State University
Image Processing Lab

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Motivation

- The cirrus band is centered at 1375 nm. At this wavelength there is a high level of water vapor absorption.
- Deep Blue is highly influenced by Aerosol scattered light.
- Calibration using other standard vicarious methods is not possible due to low standard level of the surface.

Objective

- With Ground based targets being highly impacted by atmospheric absorption and scatter for the wavelengths under investigation, pervious work has shown that Deep Convective Clouds high in the atmosphere are minimally impacted, are bright but “move”.
- Search for the Deep Convective Clouds (DCC) in an automated way on a global scale by interfacing with Google Earth Engine
- Use DCC analysis to perform a band-to-band calibration of Landsat 8 bands.

Background

Deep Convective Clouds (DCCs)

- DCCs are very cold and bright clouds extending up to 14 to 19 km in the Tropopause layer.
- The Tropical Western Pacific, African, and South American regions are identified as dominant DCC domains.
- Why to use DCC for calibration?
  - DCCs can be easily detected using simple IR threshold.
  - They have highest signal to noise ratio and under non oblique viewing and illumination conditions, they acts as near Lambertian solar reflectors.
  - The radioactive impact of atmospheric water vapor absorption, aerosol and ozone is minimal at that height.

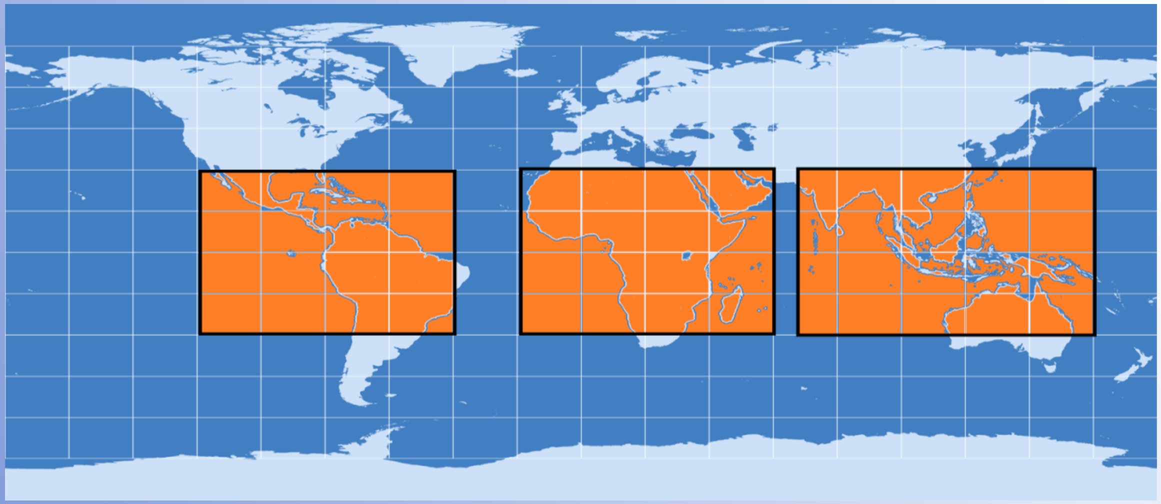


Figure 1 : A world map showing three main DCC domains (yellow regions) between 30 N and 30 S

Background
Google Earth Engine (GEE)

- Google Earth Engine is an online environment monitoring platform that makes available to the entire world a dynamic digital model of our planet that is updated daily.
- It brings together over 40 years of historical and current global satellite imagery, and provides the tools and computational power necessary to analyze and mine that vast data warehouse.
- The platform was developed by Google, in partnership with Carnegie Mellon University, NASA, USGS and TIME.

Previous Work

- **Suman Bhatta** developed an algorithm that identified Deep Convective Clouds with the Help of **NASA Langley** and determined the absolute gain for the coastal aerosol band and cirrus band in Landsat 8 using SCIAMACHY spectra as a calibration source.
- The research work determined the calibration coefficients for coastal aerosol and cirrus bands.
- But the relative gains were derived using only 69 different DCC scenes. The work will be better in a statistical sense, if more DCC scenes are used for derivation.

STAGE 1: DCC DETECTION

Algorithm Development

1. Obtain Image Collection from GEE
2. Select the region of interest
3. Identify DCC scenes
4. Find DCC pixels per scene

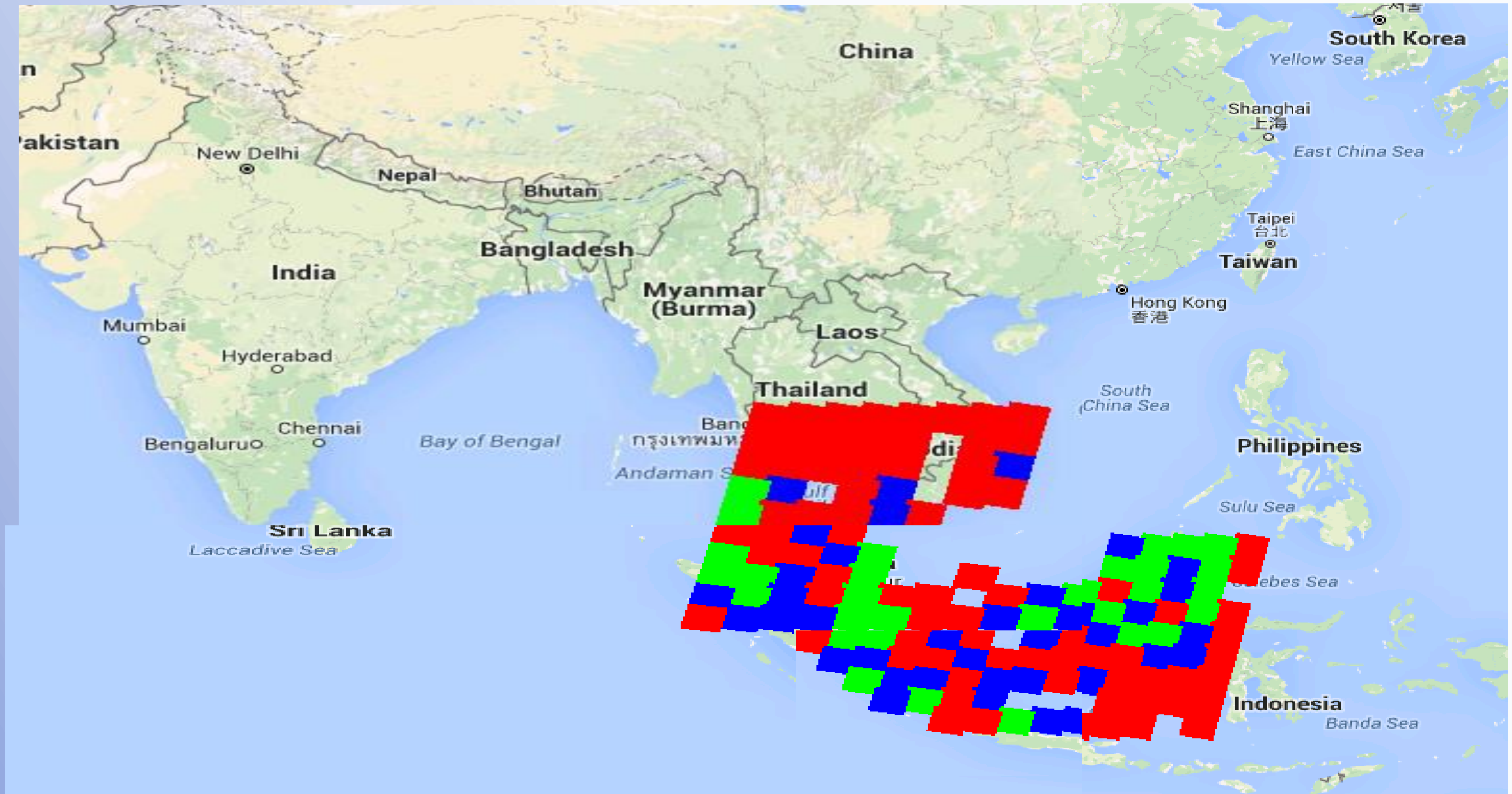
Identify DCC Scenes

- Objective: Detect the scenes that may potentially contain Deep Convective Clouds over a time period.
- Approach: Take mean of Band 10 values of each scene and the ones with values less than 275 K will possibly contain DCCs.
  - We took threshold as 275 K by taking a mean of the maximum pixel value and DCC standard threshold value 205 K derived from previous work.

Identify DCC Scenes

- Algorithm:
  - Iterate until complete area is included in the required ROI.
    - Derive an image collection by defining its WRS Path and Row.
    - Calculate mean of each image in the collection.
    - Keep only the images whose mean < 275 K.
    - Convert the Image Collection to a Feature Collection.
    - Calculate the count of images in the collection.

DCC Scenes Located (2014)



DCC Count <= 2 | 2 < DCC Count <= 4 | DCC Count > 4

This verifies the capability to automatically detect DCCS in the GEE environment, and outlines a good test region to focus on for further algorithm development.

Deeper DCC Detection - New Thresholds

- DCCs have cold anvils surrounding the cold core of the cloud. Only the center of such cloud represents the deep convection.
- To capture this core, we applied few new thresholds:
  - Scene level:
    - Keep images with B4 mean reflectance value > 0.5 (derived from previous work).
    - Keep images with B9 value reflectance value > 0.2 (derived from previous work).
  - Pixel Level:
    - Keep pixels with band 10 value < 195 K.
    - Apply Spatial Homogeneity Threshold.

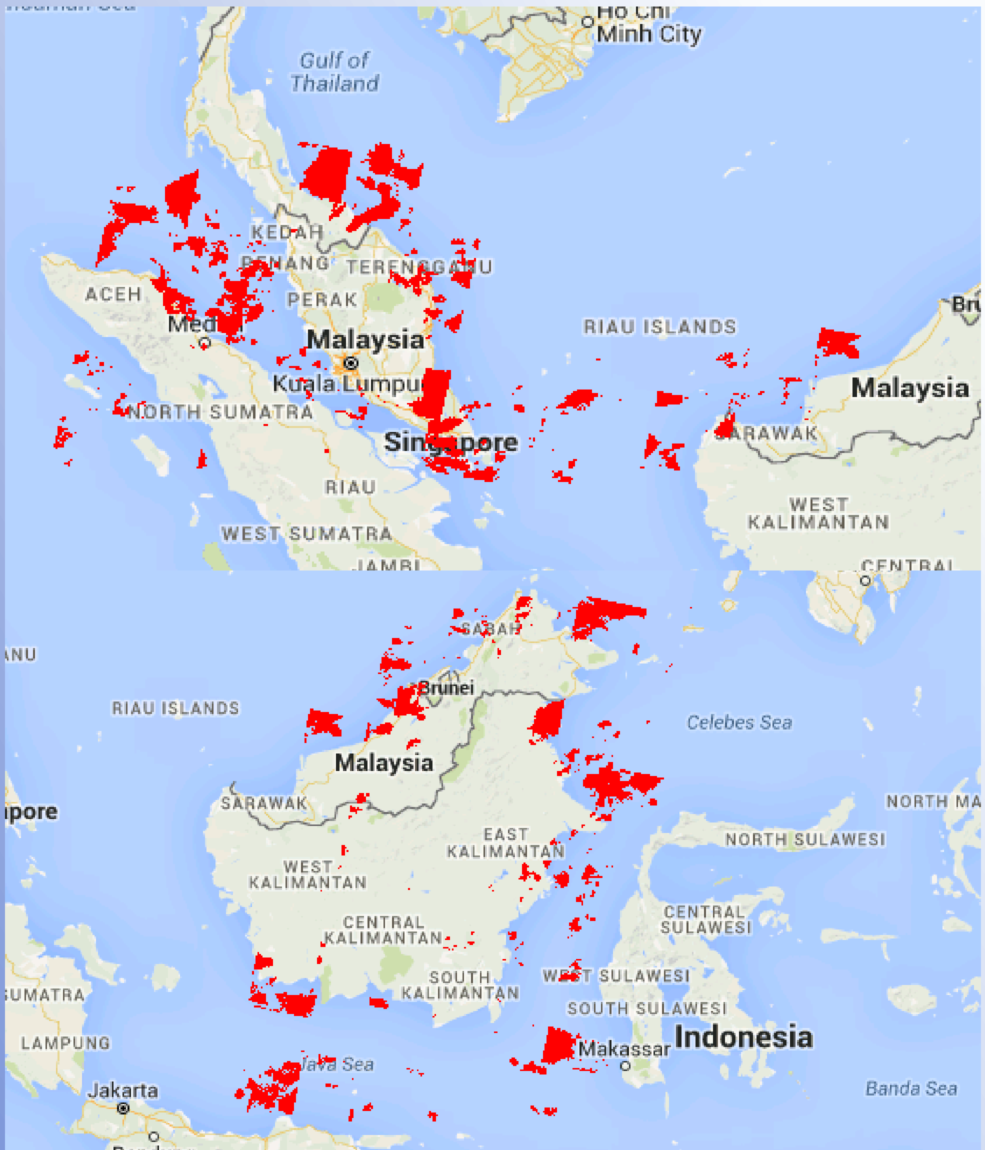
Spatial Homogeneity Threshold

- Spatial homogeneity threshold is the key method through which we get hold of the cold cores of the clouds.
- Here we analyze each pixel to its surrounding by putting some thresholds for standard deviation values of red band (band 4) and TIRS 1 band (band 10) of DCC pixels located.

Final DCC Detection Algorithm

- Derive an image collection by defining the region of interest.
- Calculate mean of each band of each image in the collection.
- Apply the thresholds on scene
  - **Keep images with B10 mean BT value < 275 K.**
  - **Keep images with B4 mean reflectance value > 0.5.**
  - **Keep images with B9 value reflectance value > 0.2.**
- Apply thresholds on pixels
  - **Filter out the pixels with B10 values less than 195 K.**
  - **Apply Spatial Homogeneity Threshold**
    - Keep pixels with B4 std. deviation < 0.1340.
    - Keep pixels with B10 std. deviation < 5.4386 K.

DCC Pixels Located (2014)



Landsat Id	BT Mean Value
LC81270552014163LGN00	203.421
LC81270552014275LGN00	204.747
LC81270552014291LGN00	194.061
LC81270552014339LGN00	201.246
LC81280552014138LGN00	193.798
LC81280552014266LGN00	198.945
LC80010602014160LGN00	202.107
LC81150562014239LGN00	203.736
LC81150562014335LGN00	203.051
LC81160562014182LGN00	203.381
LC81160562014214LGN00	203.797
LC81160562014230LGN00	200.893

Table 1: Shows the DCC scenes and their Band 10 mean values

STAGE 2: BAND-TO-BAND CALIBRATION

Band-To-Band Calibration Process

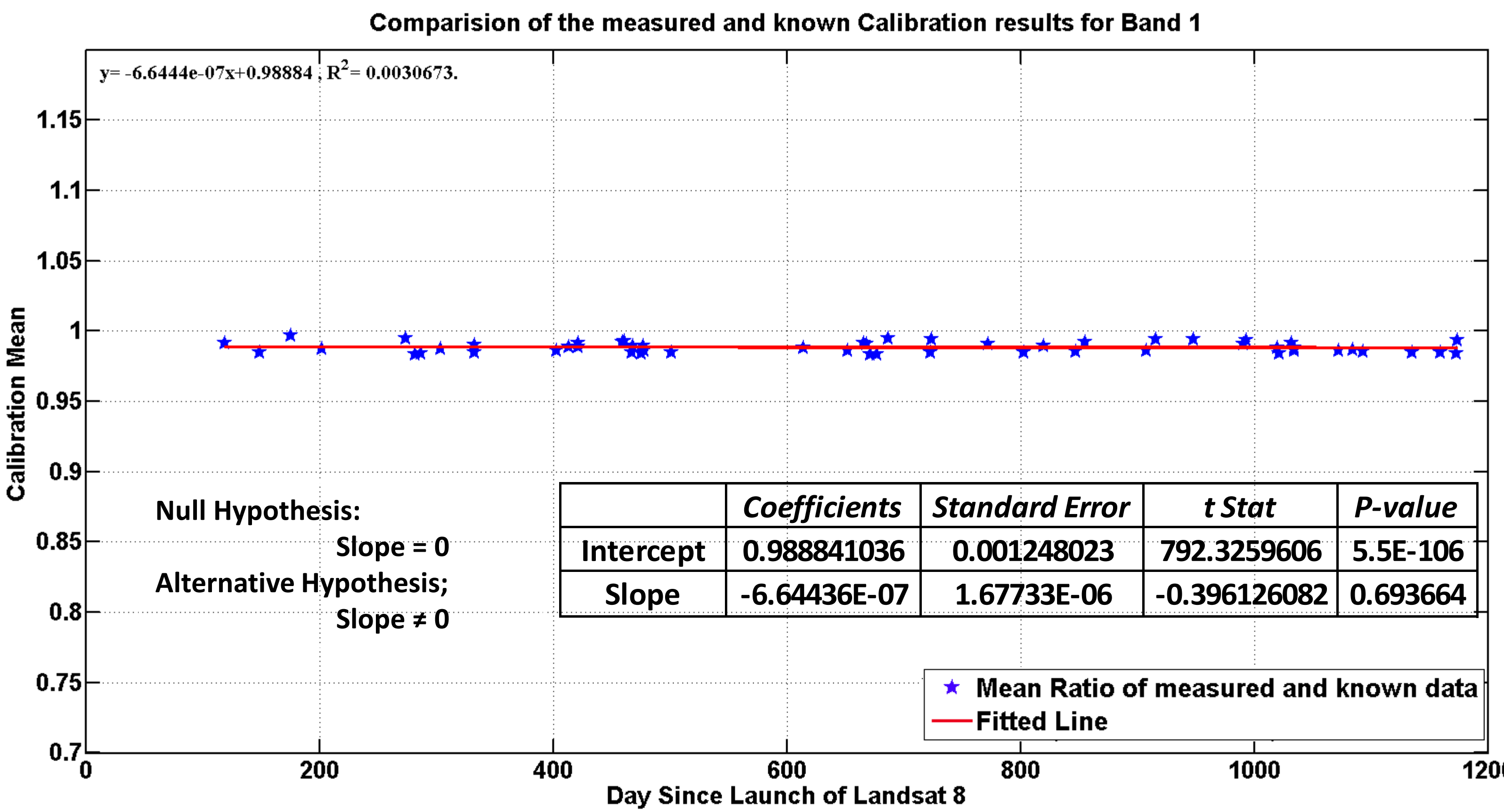
- Our aim was to calibrate coastal aerosol and cirrus band with the blue, green and red bands and plot the results.
- The equation that we used to normalize the measured reflectance to the predicted reflectance,

$$\text{Band 1: } Mean\left(\frac{\left(\frac{B1}{B2}\right)_{measured}}{\left(\frac{B1}{B2}\right)_{known}}, \frac{\left(\frac{B1}{B3}\right)_{measured}}{\left(\frac{B1}{B3}\right)_{known}}, \frac{\left(\frac{B1}{B4}\right)_{measured}}{\left(\frac{B1}{B4}\right)_{known}}\right)$$

$$\text{Band 9: } Mean\left(\frac{\left(\frac{B9}{B2}\right)_{measured}}{\left(\frac{B9}{B2}\right)_{known}}, \frac{\left(\frac{B9}{B3}\right)_{measured}}{\left(\frac{B9}{B3}\right)_{known}}, \frac{\left(\frac{B9}{B4}\right)_{measured}}{\left(\frac{B9}{B4}\right)_{known}}\right)$$

- The "$measured$ " values are the values derived from my research and the "$known$" values are the ones taken from previous work done by Suman, based on a hyperspectral SCIAMACHY survey of DCCs.

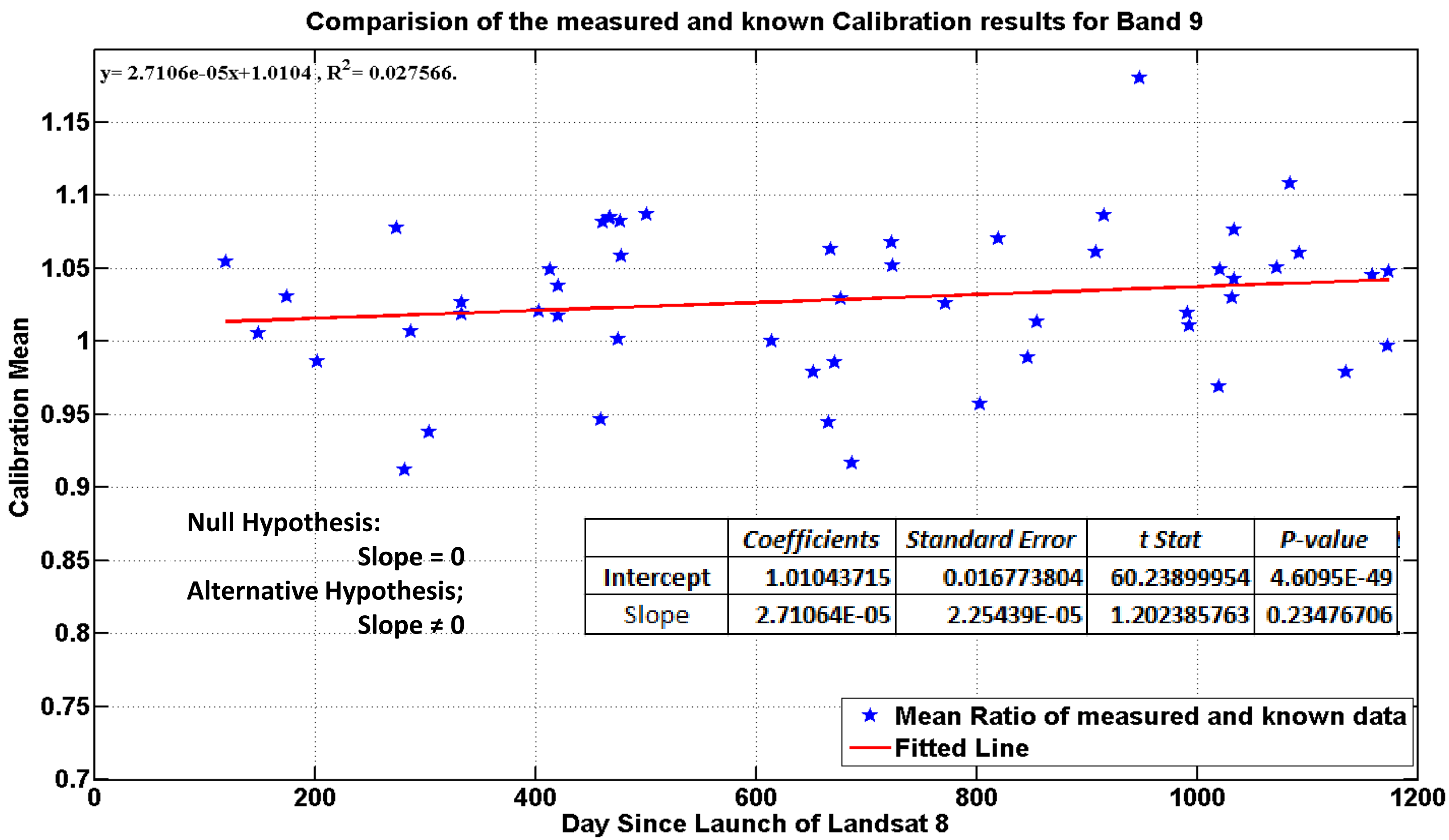
Coastal Aerosol Band Calibration



	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.988841036	0.001248023	792.3259606	5.5E-106
Slope	-6.64436E-07	1.67733E-06	-0.396126082	0.693664

- Since p value for the slope of line is greater than 0.05, we fail to reject null hypothesis.

Cirrus Band Calibration



	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.01043715	0.016773804	60.23899954	4.6095E-49
Slope	2.71064E-05	2.25439E-05	1.202385763	0.23476706

- Since p value for the slope of line is greater than 0.05, we fail to reject null hypothesis.

Conclusion

- The proposed algorithm detects the Deep Convective Clouds for the entire time period of Landsat 8.
- The calibration results show that the measured data is in accordance with the data known from the previous work.

Future Work

- Perform the detection and calibration process on the whole globe on a “operational” basis.

Thank you!!

Any Questions??