Atmospheric Correction of Sentinel 2A Data and Influence on Winter Wheat Phenology in Kabul Region, Afghanisthan

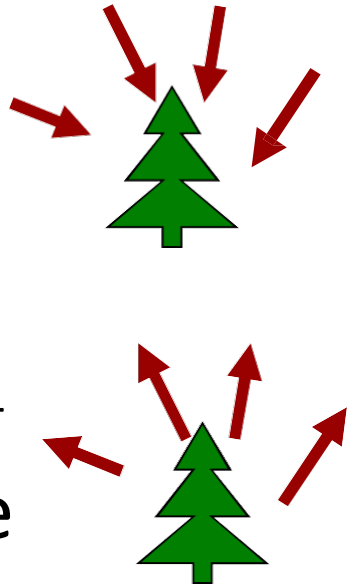
Krishna Prasad Vadrevu and Lee Ellenberg
NASA MSFC

Atmospheric Correction of Sentinel-2a Data

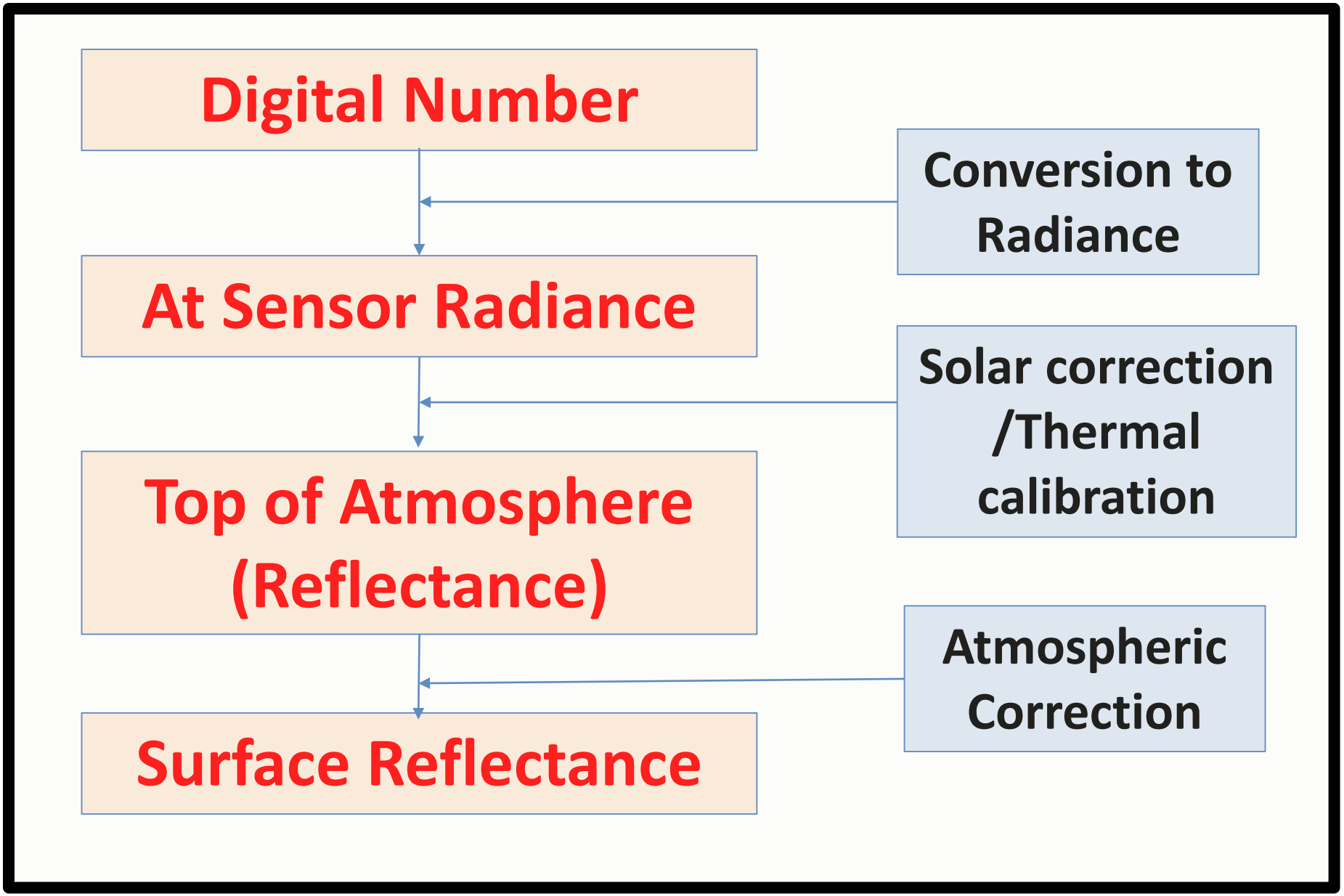
- Is Atmospheric correction needed?
- How much is the improvement in scene quality before and after atmospheric correction (specific to Kabul region in Afghanistan for NDVI)?
- Is the improvement consistent across all months?

Units of Electromagnetic Radiation

- **Irradiance** - radiant flux ***incident*** on a receiving surface from all directions, Energy per unit surface area, W m^{-2}
- **Radiance** - radiant flux ***emitted*** or scattered by a unit area of surface as measured through a solid angle, W m^{-2} sr^{-1} μm^{-1}(energy (Watt) per unit area (square meter) per solid angle per unit wavelength (µm-1))
- **Reflectance** - fraction of the incident flux that is reflected by a medium



Basic Pre-processing



Digital Number to Radiance

- **DN to Radiance Conversion**
  - L = [(LMAX - LMIN)/255] x DN + LMIN
  - Where LMAX = radiance at which channel saturates LMIN = minimum recordable radiance

At-Satellite Reflectance

To further correct for scene-to-scene differences in solar illumination, it is useful to convert to at-satellite reflectance. The term “at-satellite” refers to the fact that this conversion does not account for atmospheric influences.

At-Satellite Reflectance, $p_\lambda = (\pi \quad L_\lambda \quad d^2) / (ESUN_\lambda \quad \cos\theta)$

Where

L_λ = spectral radiance measured for the specific waveband

θ = solar zenith angle

ESUN = mean solar exoatmospheric irradiance (W m^{-2} um^{-1}), specific to the particular wavelength interval for each waveband, consult the sensor documentation.

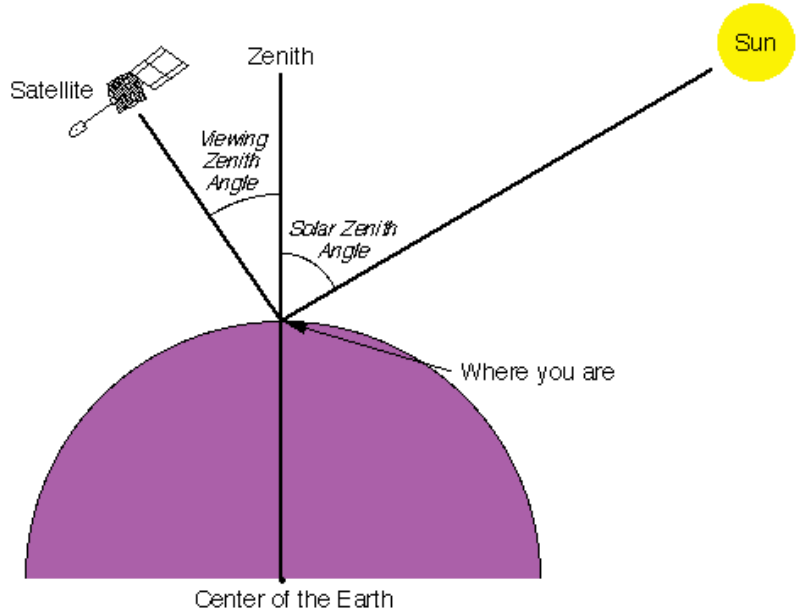
d = Earth-sun distance in astronomical units, ranges from approx. 0.9832 to 1.0167, consult an astronomical handbook for the earth-sun distance for the imagery acquisition date

Atmospheric Correction is Mandatory When Using Multi-Temporal Images

- Conversion from DN to reflectance can be affected by:
  - Illumination geometry
  - Sensor calibration
  - Atmospheric conditions

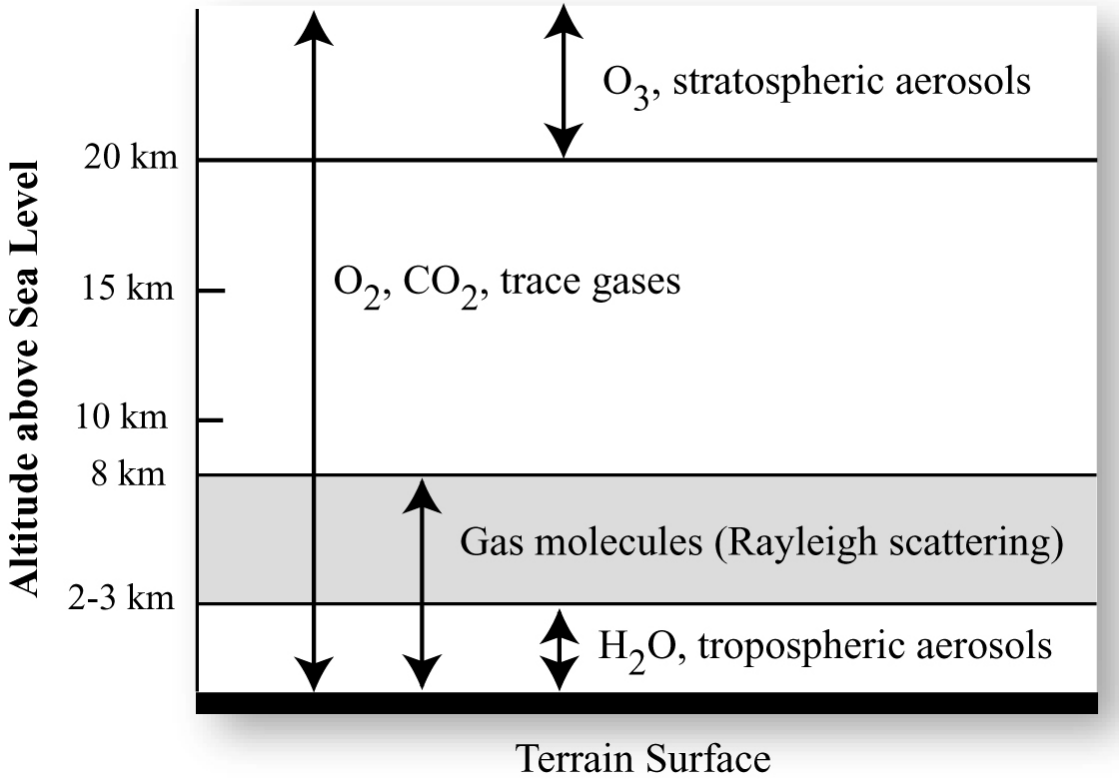
- Since Multi-temporal images are acquired
  - during different times (eg: 1st day of summer longest day of sunlight)
  - atmospheric conditions
  - solar illumination
  - sensor calibration
  - view angles

Atmospheric correction is required.



Atmospheric Layers and Constituents

Major subdivisions of the atmosphere and the types of molecules and aerosols found in each layer.

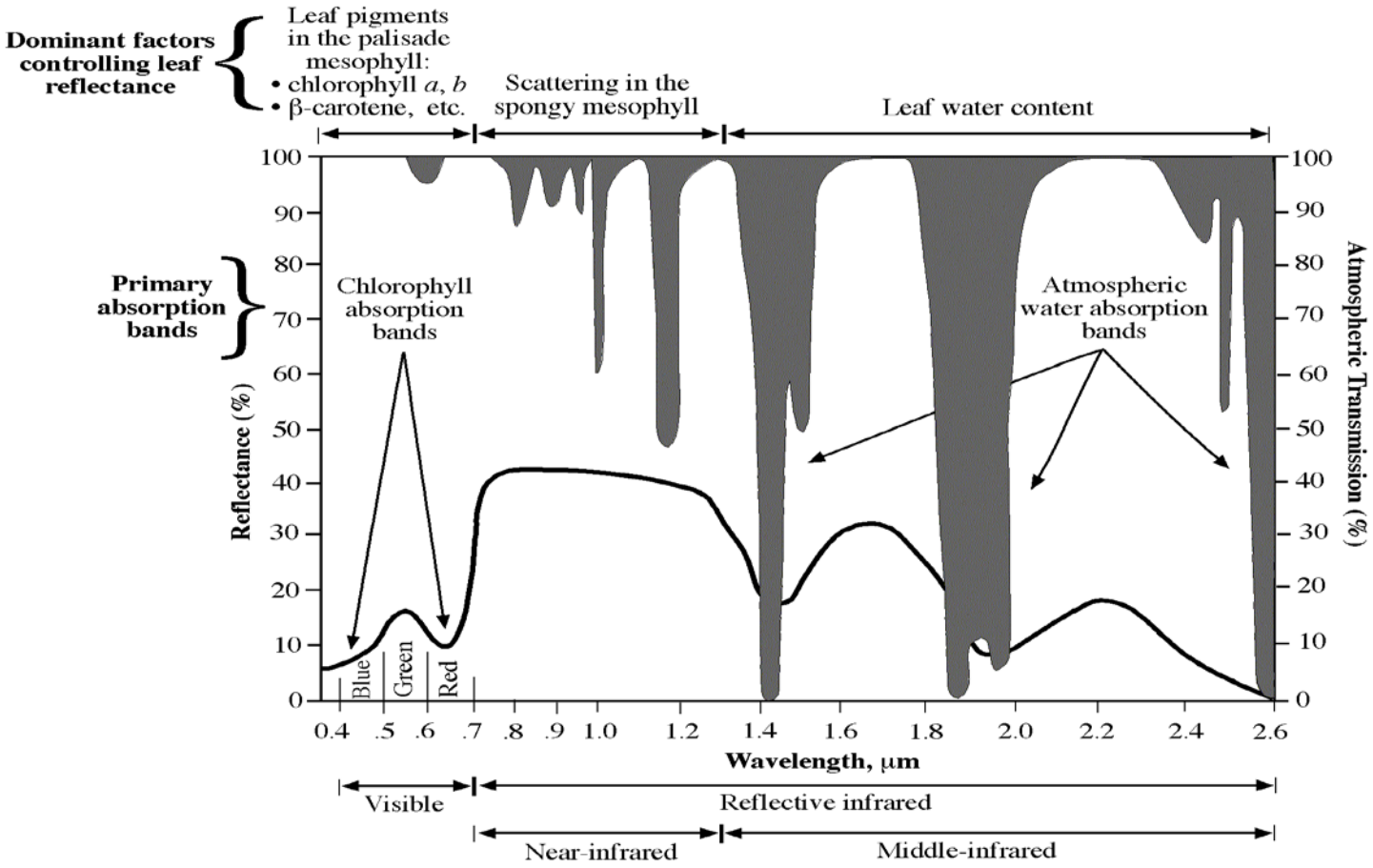


Diameter of particles less than the wavelength of radiation

Diameter of particles larger than the wavelength of radiation

Both Rayleigh and Mie scattering causes Haze and decreases Contrast !

Atmospheric Windows



Absorption is dominant process in **visible**
Scattering is dominant process in **near infrared**
Water absorption is increasingly important with increasing wavelength in the infrared.

Atmospheric correction algorithms should take into account absorption as well as scattering in different wavelengths.

Atmospheric Correction Methods

Absolute

-Methods account for view angles, atmospheric conditions, aerosol types, water vapor, gaseous absorption, etc.

-Generally Absolute methods use some sort of radiative transfer code such as MODTRAN (MODerate resolution atmospheric TRANsmission code (developed by Air Force Resarch Lab) to model atmospheric propagation of electromagnetic radiation (eg: 6S, FLAASH or, ATCOR)

-For Absolute methods, atmospheric properties as inputs are required!

Atmospheric Correction Methods

Relative

- Relative methods all proceed under the assumption that the relationship between the TOA radiances recorded at two different times *from regions of constant reflectance* is spatially homogeneous and can be approximated by a linear function.

- The normalization process can then be reduced to a linear regression calculation for each spectral band.

  -Histogram matching

  -Image regression

- ***The main difficulty of relative normalization methods is determining the landscape features whose reflectance's are nearly constant over time.***
  - ***Invariant Targets – eg: Buildings – similar solar illumination conditions and phenological conditions***

Sen2Cor - Sentinel-2a Data

- Sentinel-2A was launched on June 23, 2015.

- The atmospheric correction software Sen2Cor was implemented by Telespazio France and DLR on behalf of ESA. TPZ-F and DLR have teamed up in order to provide the calibration and validation of the Level-2A processor Sen2Cor.

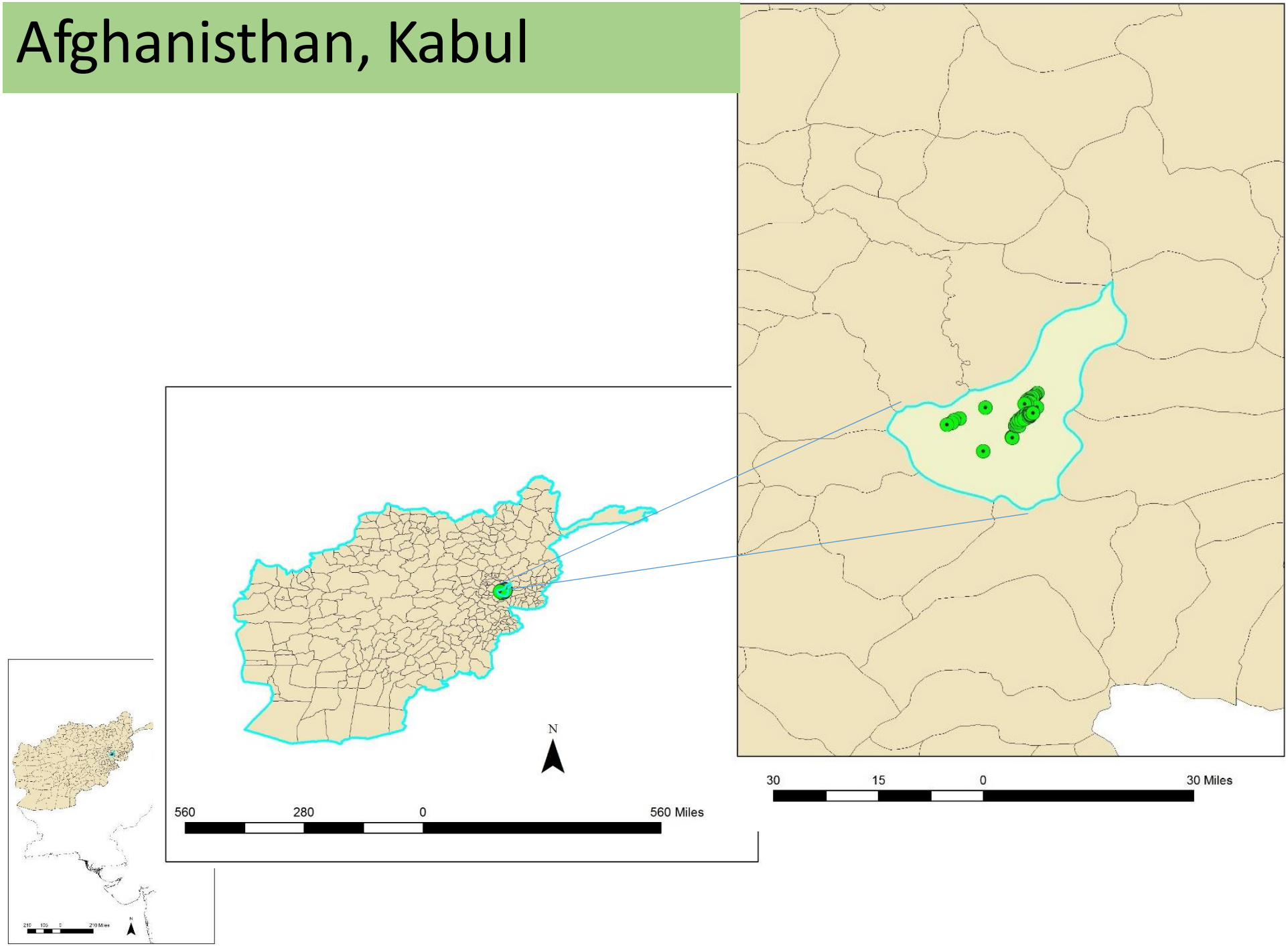
- Sen2Cor can be obtained downloading the S2 Toolbox (http://step.esa.int/main/download) and following plugins installation procedure

Sen2Cor – Inputs/Outputs

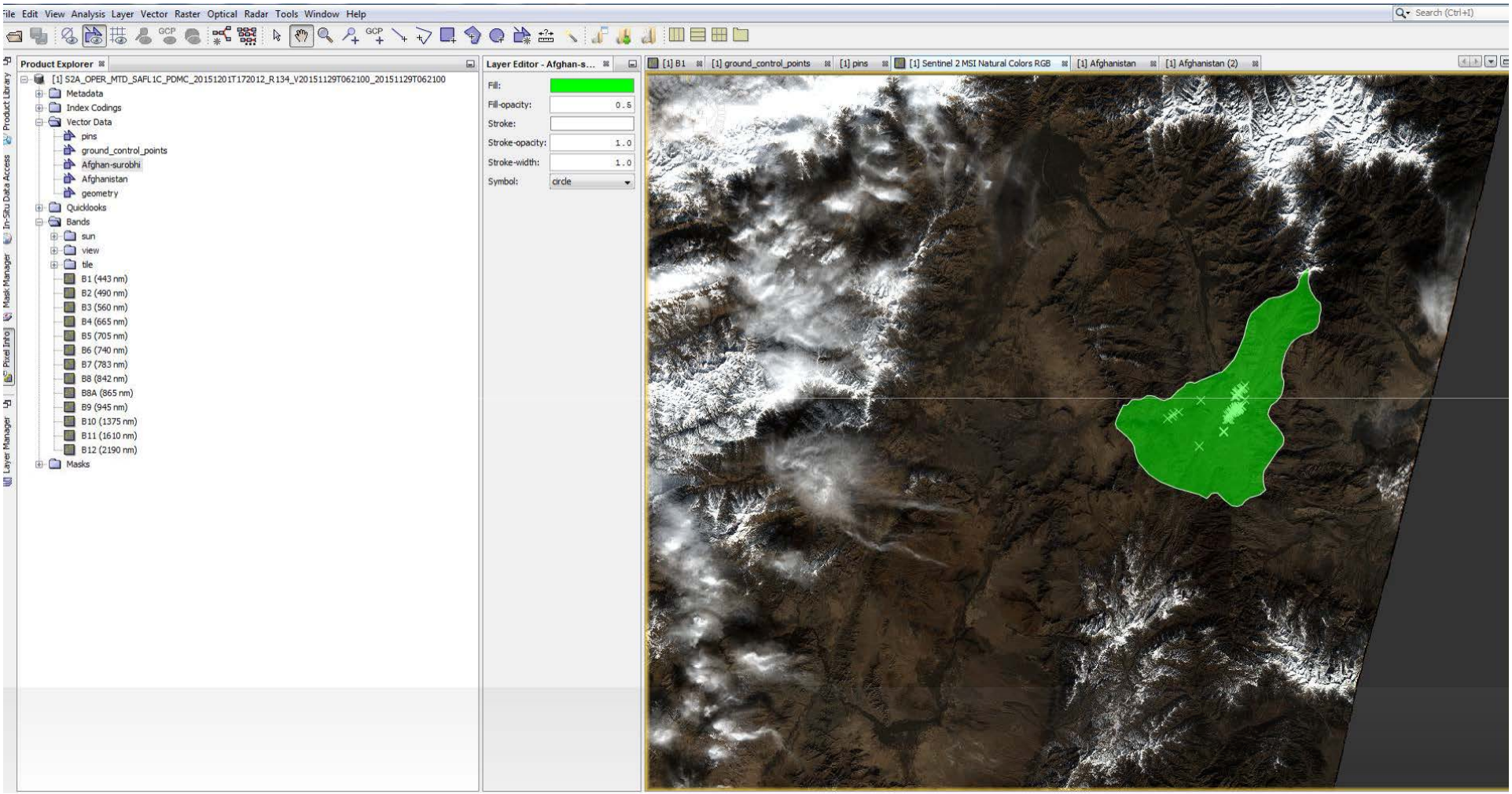
- Input: Level-1C ortho-image Top-Of-Atmosphere (TOA) reflectance products

- Output (60m, 20m, 10m)
  - Bottom-Of-Atmosphere (BOA) corrected reflectance
  - Aerosol Optical Thickness (AOT) map
  - Water Vapour (WV) map
  - Scene Classification (SC) map (cloud, dark areas, bare soil, vegetation, cloud probabilities, snow, etc.)
  - Quality Indicators for cloud and snow probabilities

Afghanisthan, Kabul

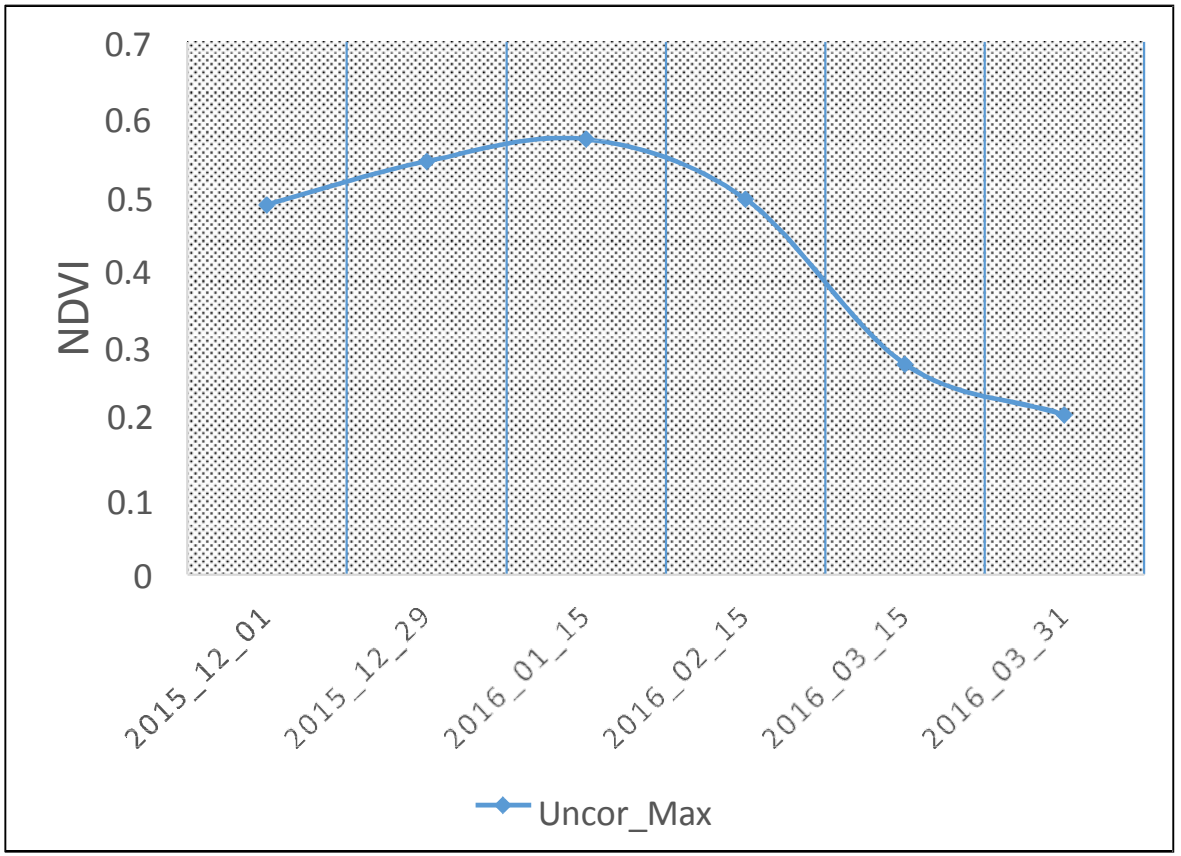


Kabul Region Overlay over Sentinel-2a Data

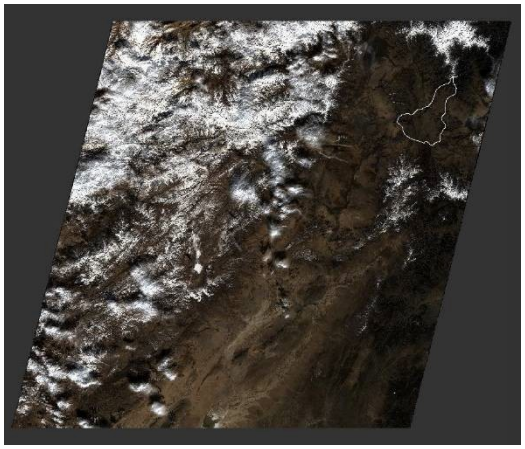


Winter Wheat Phenology - Kabul

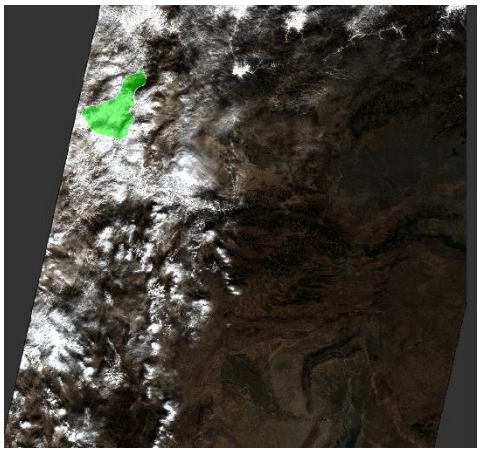
2015_Nov_29	1
2015_Dec_01	2
2015_Dec_29	
2016_Jan_15	4
2016_Feb_15	5
2016_Mar_15	6
2016_Mar_31	7
2016_Apr_14	8
2016_Apr_27	9



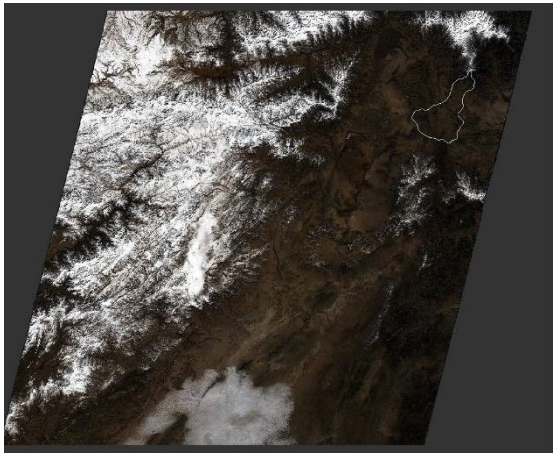
Only part of the Wheat Growing Season images could be used due to too bad image quality !



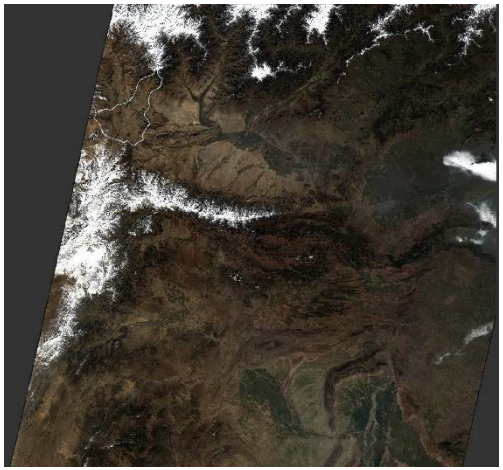
2015_12_01 - YES



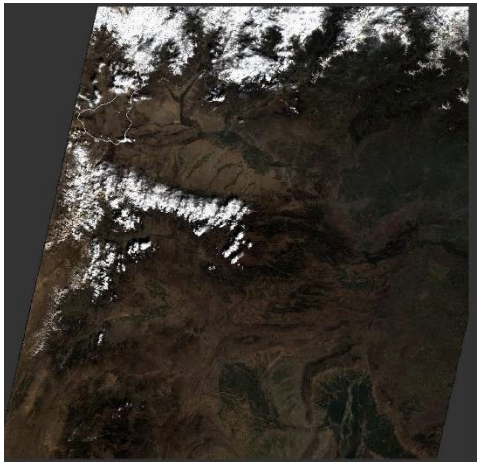
2015_12_16 - NO



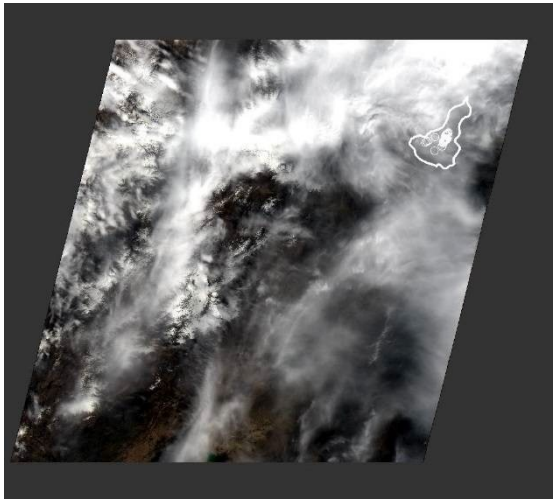
2015_12_29 - YES



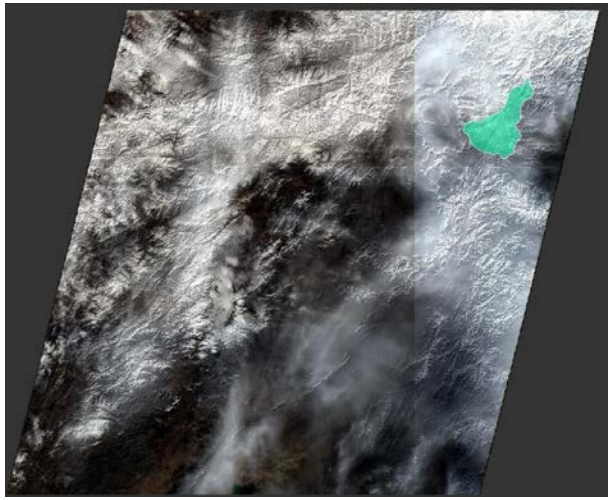
2016_01_15 - YES



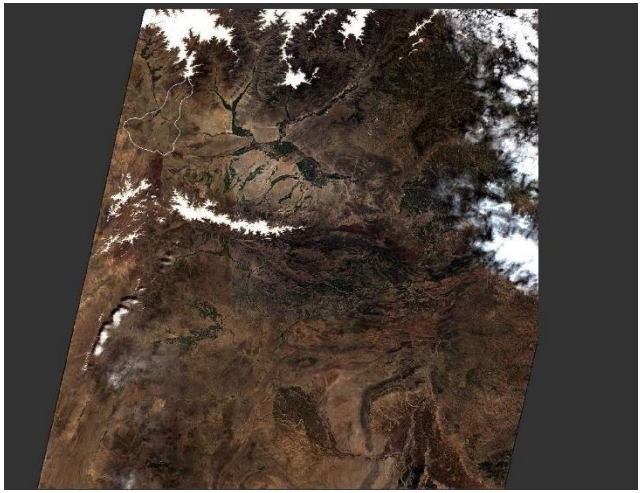
2016_02_15 - YES



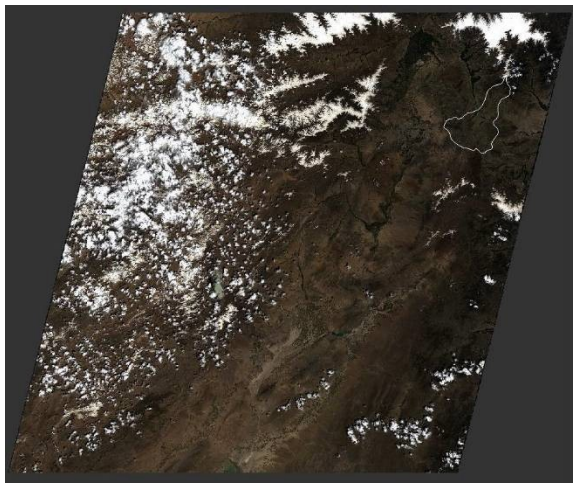
2016_03_28 - NO



2016_03_31 - YES

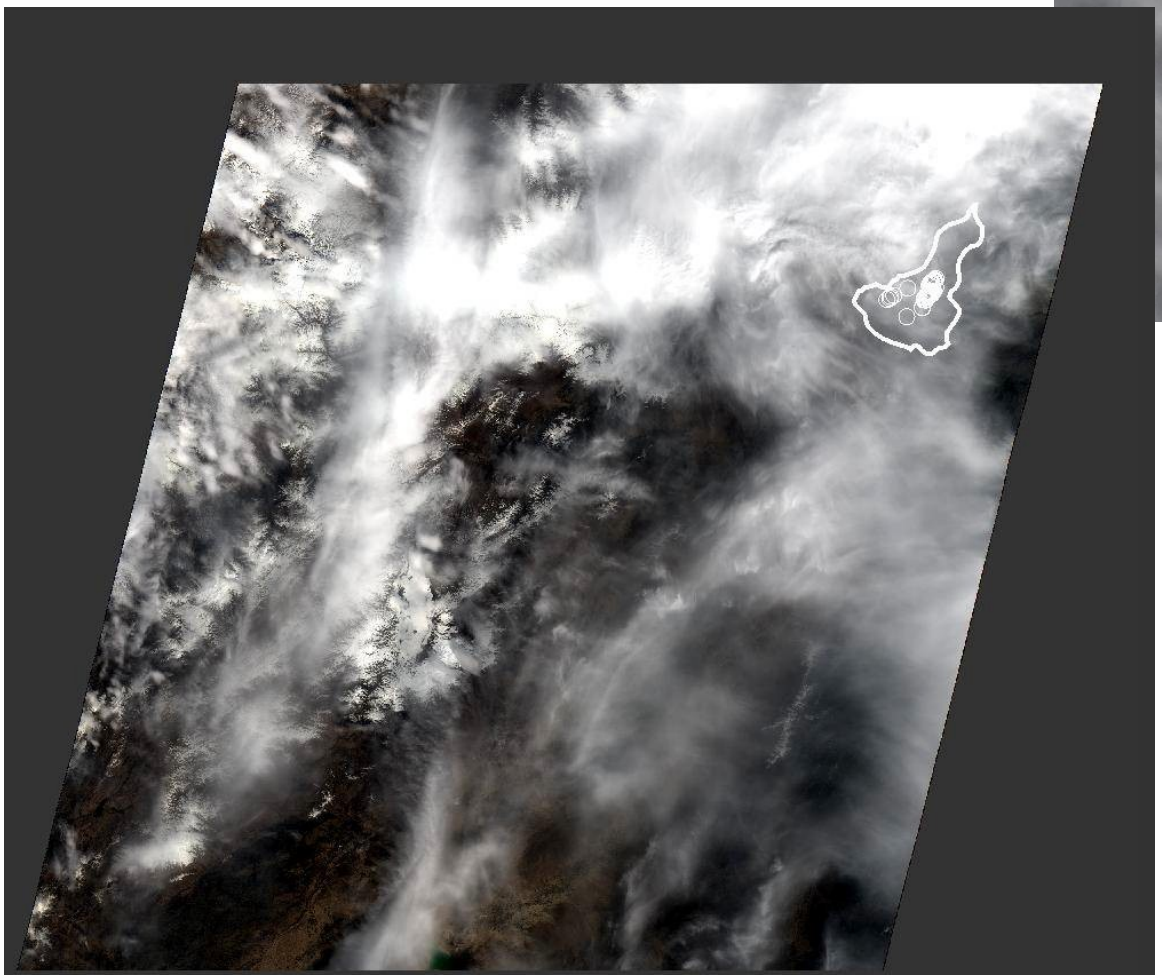


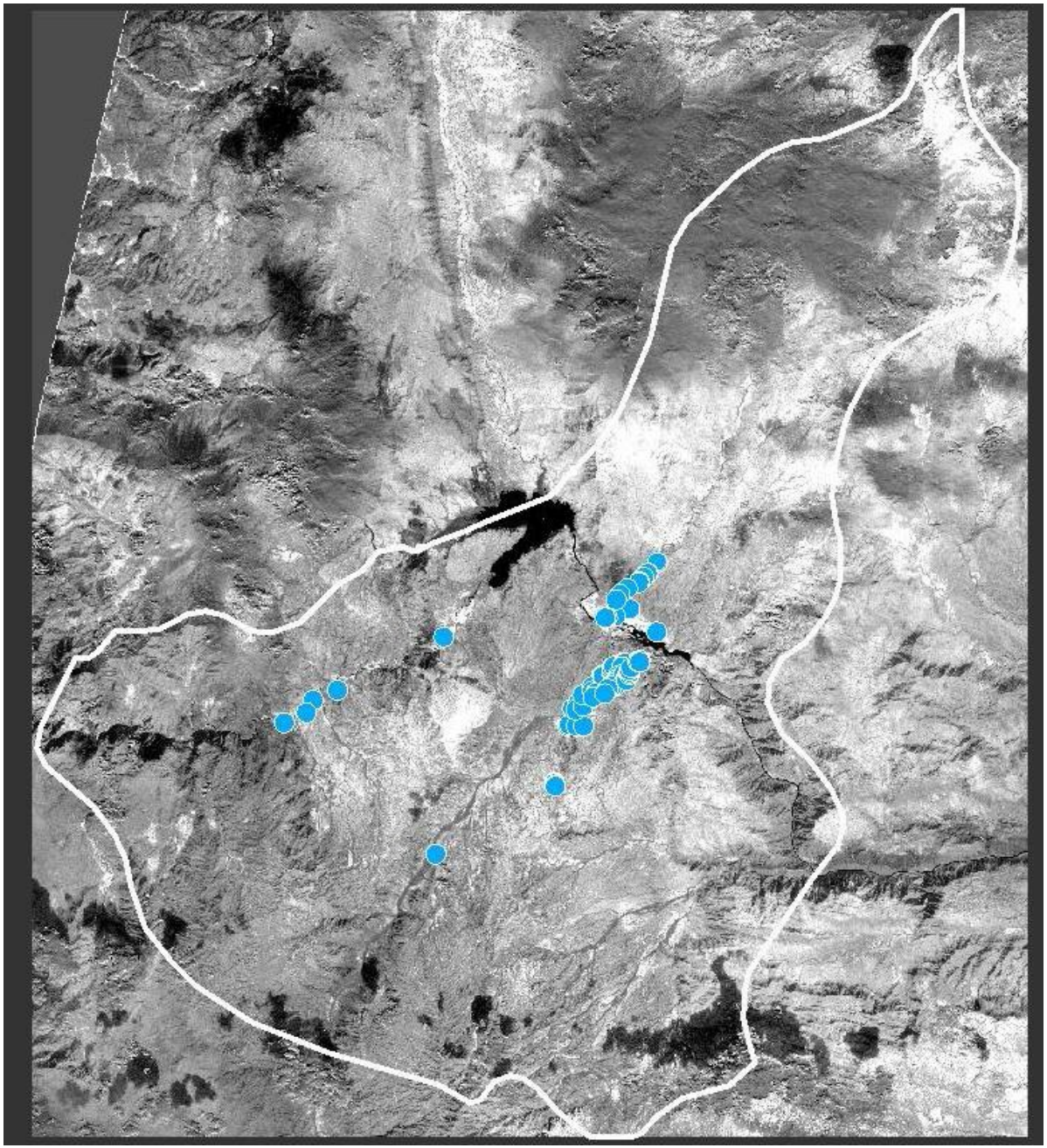
2016_04_14



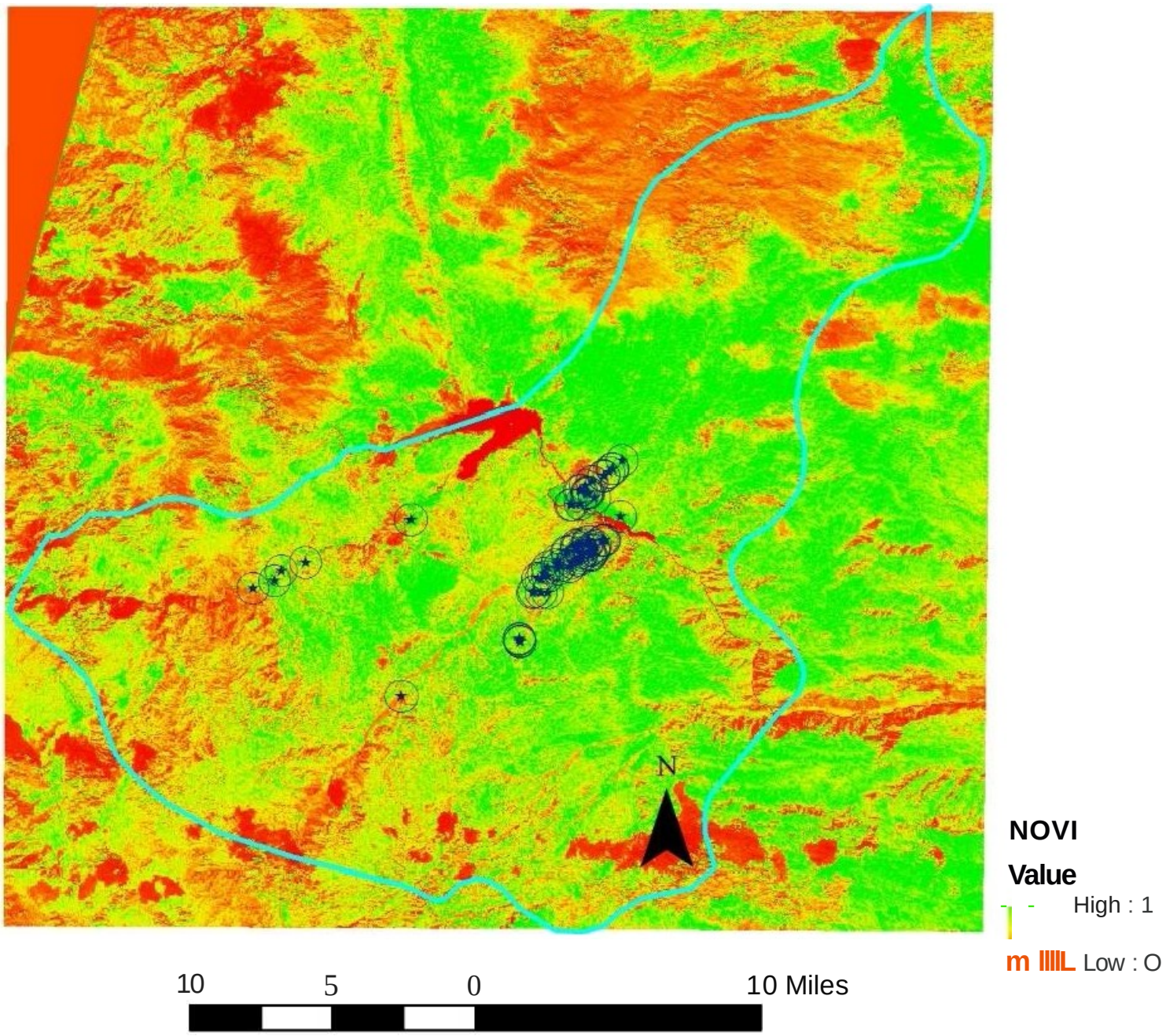
2016_04_27

2016_03_31
RGB!



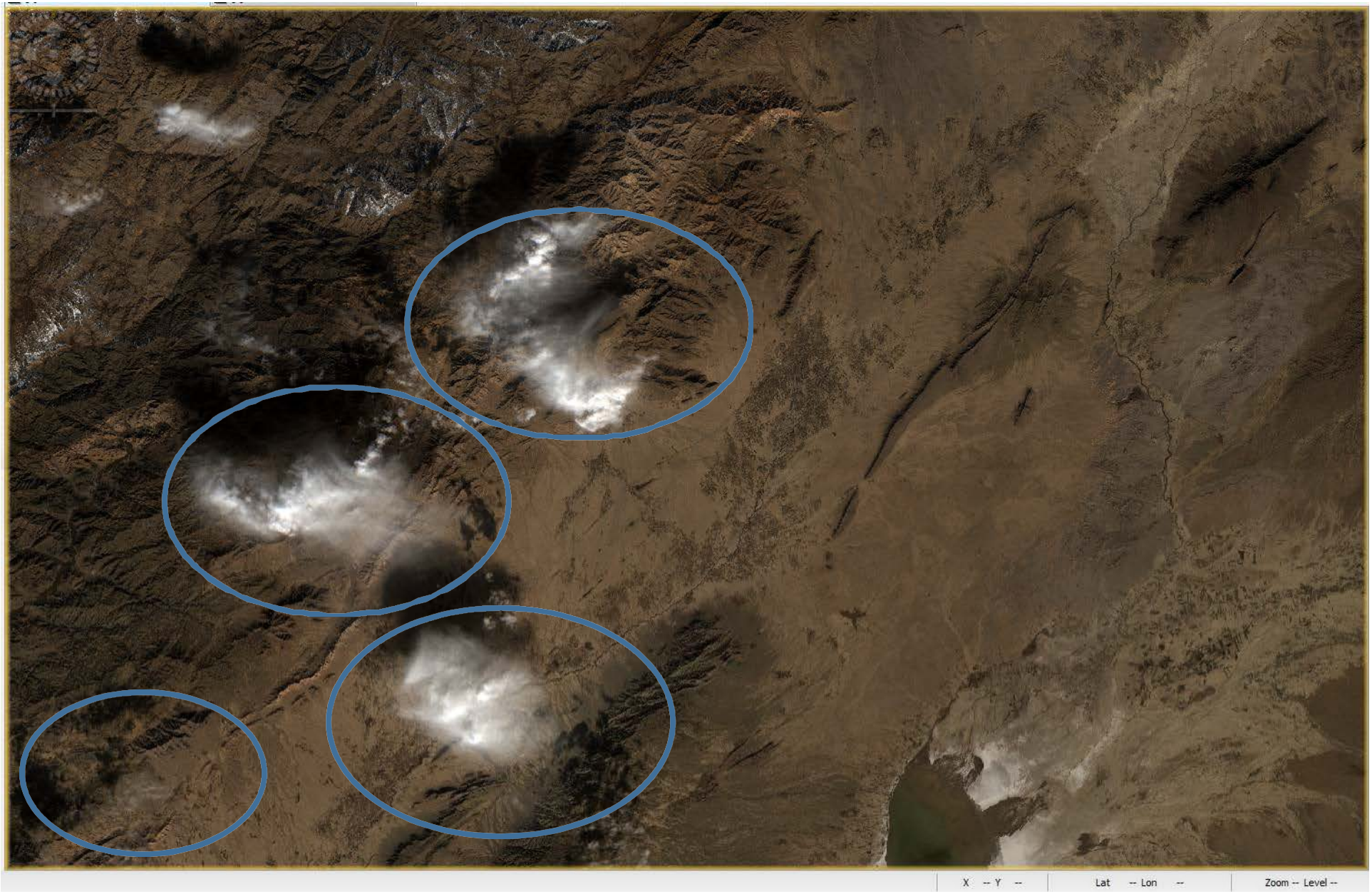


2015_12_29 - NDVI


N
NOVI
Value
High : 1
Low : O
10
5
0
10 Miles

Clouds -
Before and After Correction

2015-12-01 – Sentinel2- L1C (RGB)



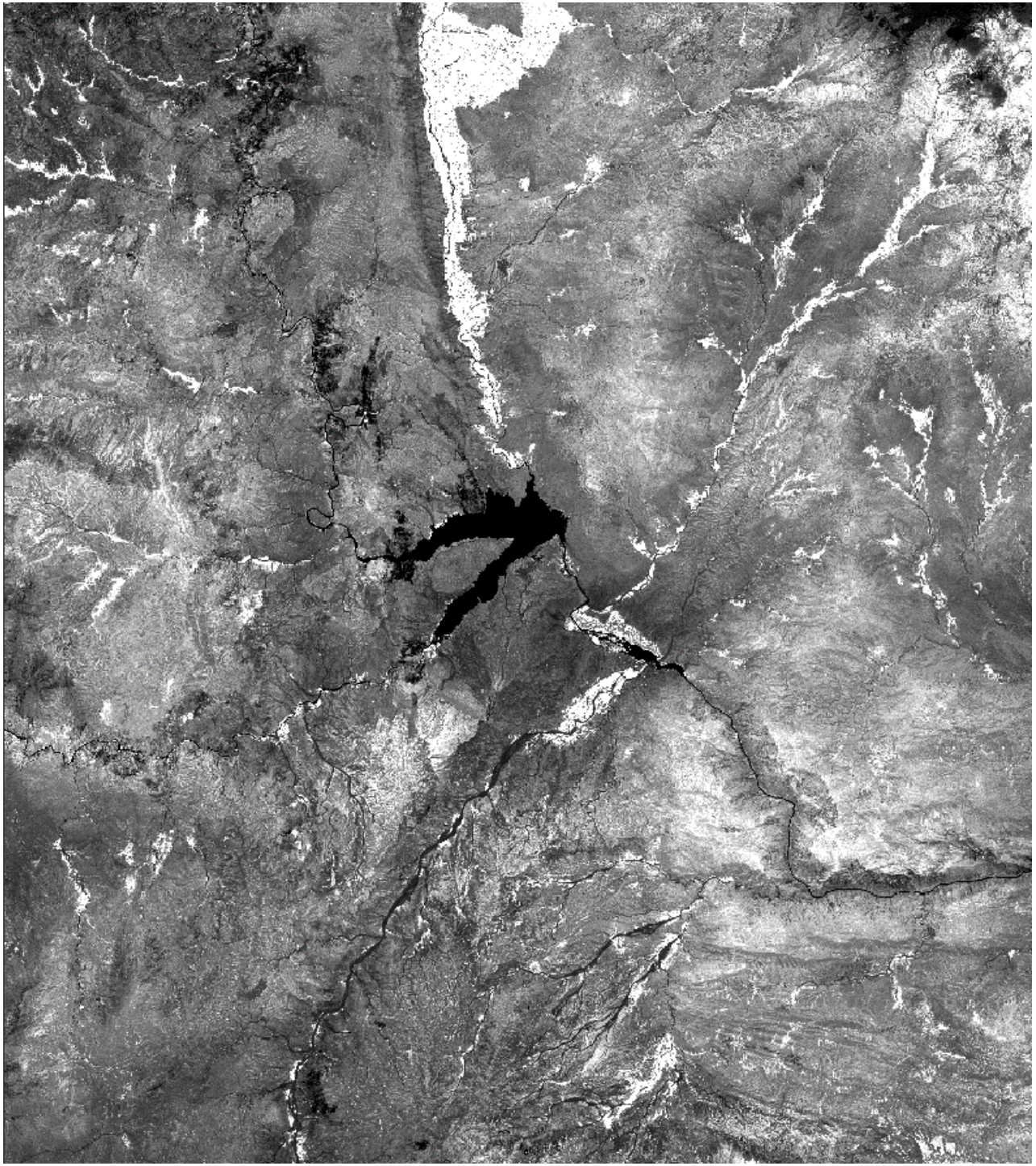
2015-12-01 – Sentinel2- L2C (RGB)

Haze-
Before and After Correction

Haze before correction; 2015-12-01 – Sentinel2- L1A (B1)

Haze removal after correction; 2015-12-01 – Sentinel2- L2C (B1)

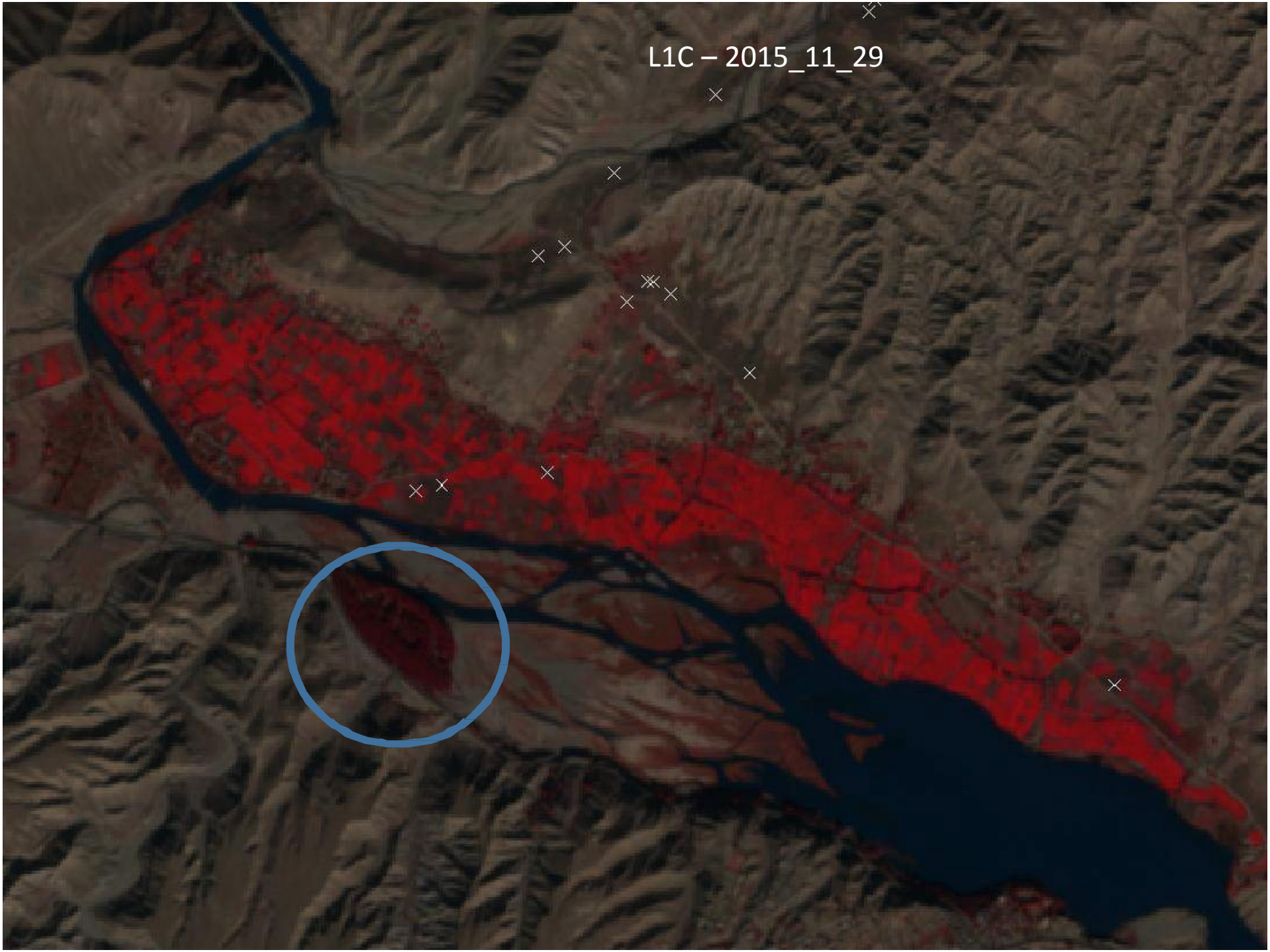
NDVI -
Before and After Correction

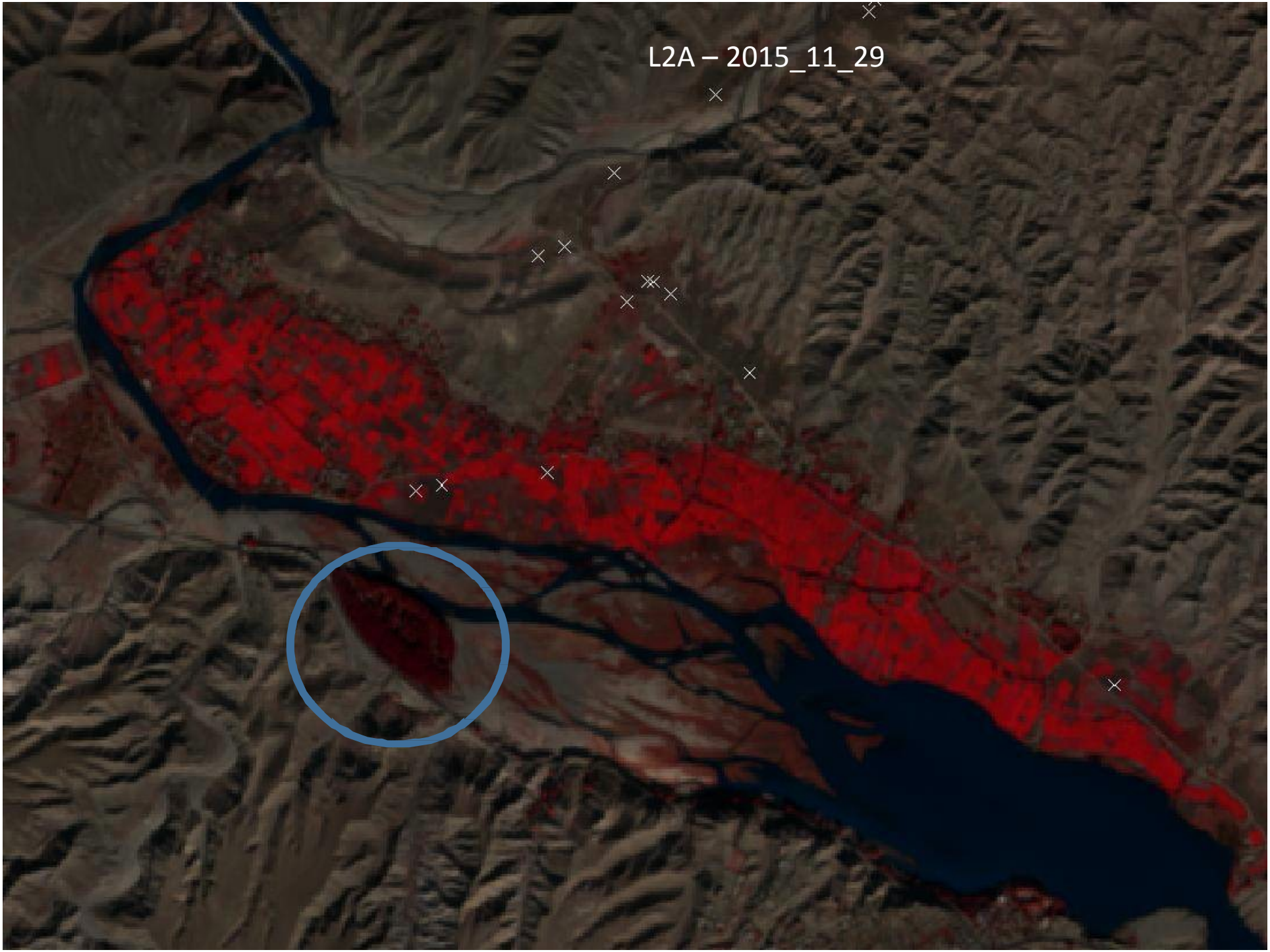


2016_04_27
NDVI -
Before

2016_04_27
NDVI –
After

False Color Composite - Sentinel- 4,3,2


L1C – 2015_11_29


L2A – 2015_11_29

Afghanistan Crop Calendar for Wheat

(by Agricultural Region)

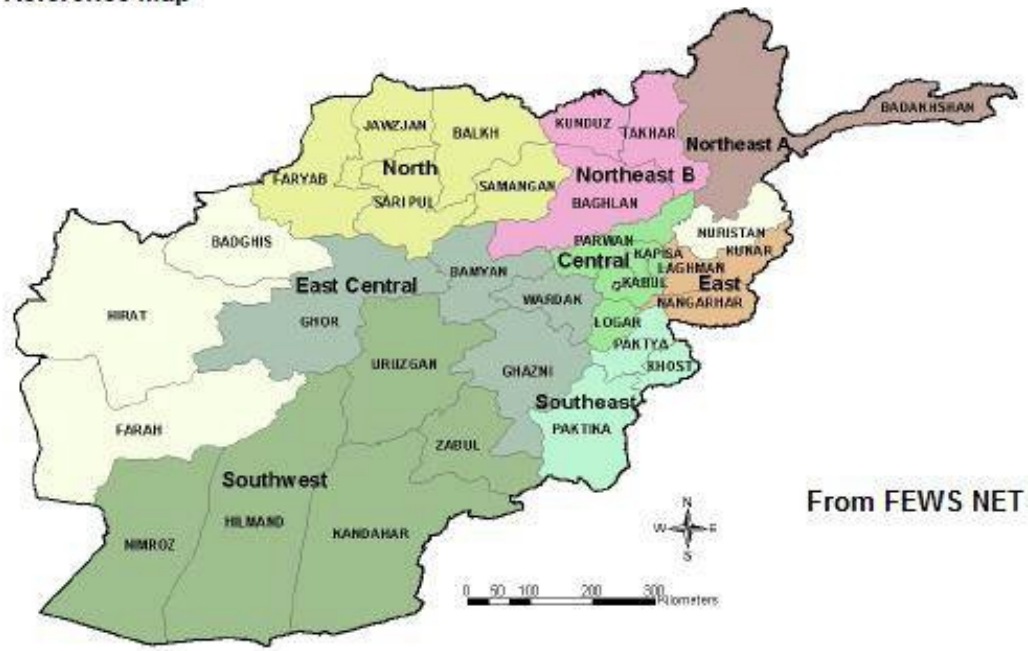
Production Areas	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
North			Autumn Planting					Spring Planting						
Northeast A									Spring Planting				Harvest	
Northeast B			Autumn Planting					Spring Planting			Harvest			
East Central		Autumn Planting							Spring Planting				Harvest	
Central		Autumn Planting											Harvest	
Southeast			Autumn Planting							Harvest				
East			Autumn Planting							Harvest				
Southwest				Autumn Planting						Harvest				

Autumn Planting

Spring Planting

Harvest

Reference Map



From FEWS NET 2003

Planting

October-November

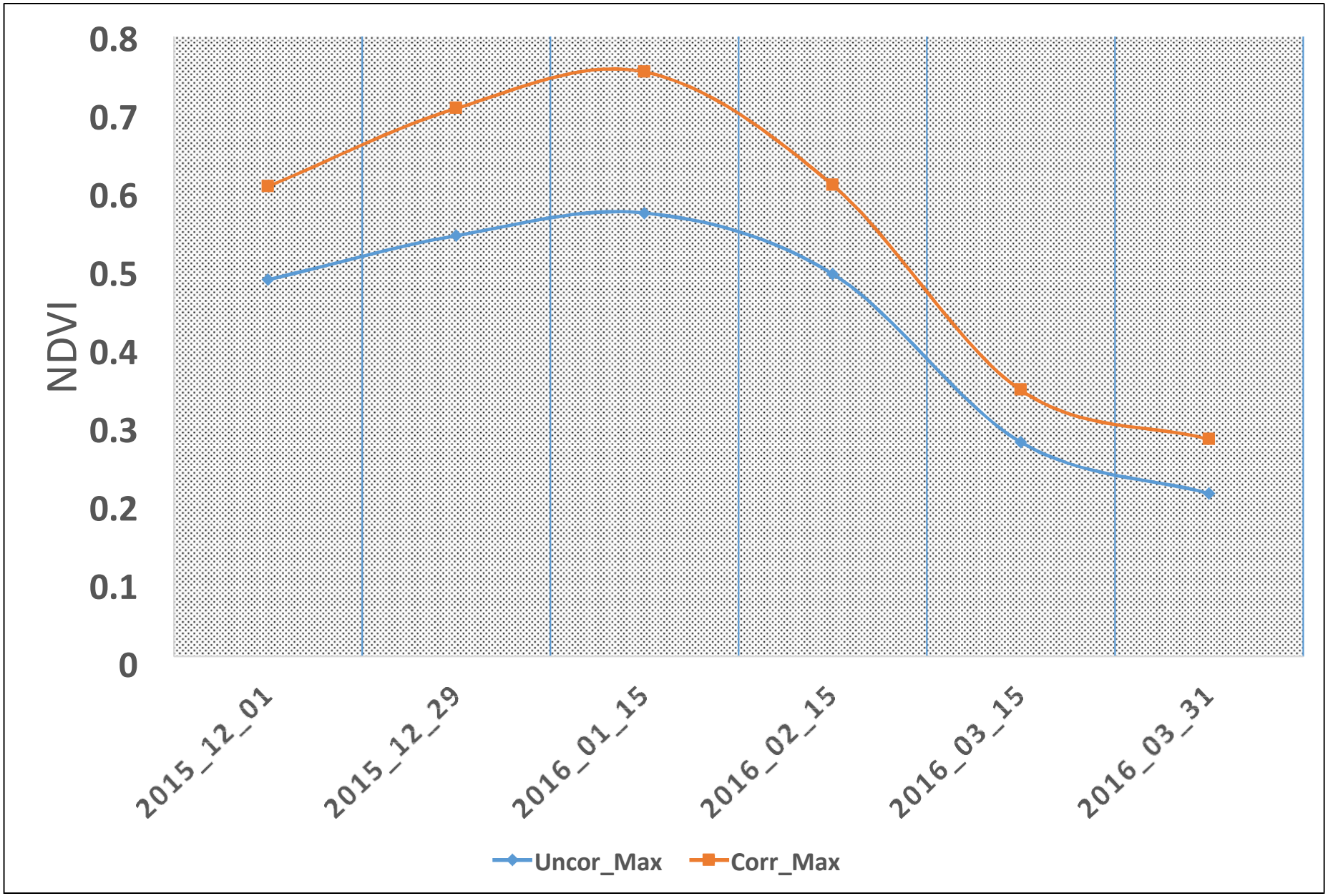
Harvest

January-February

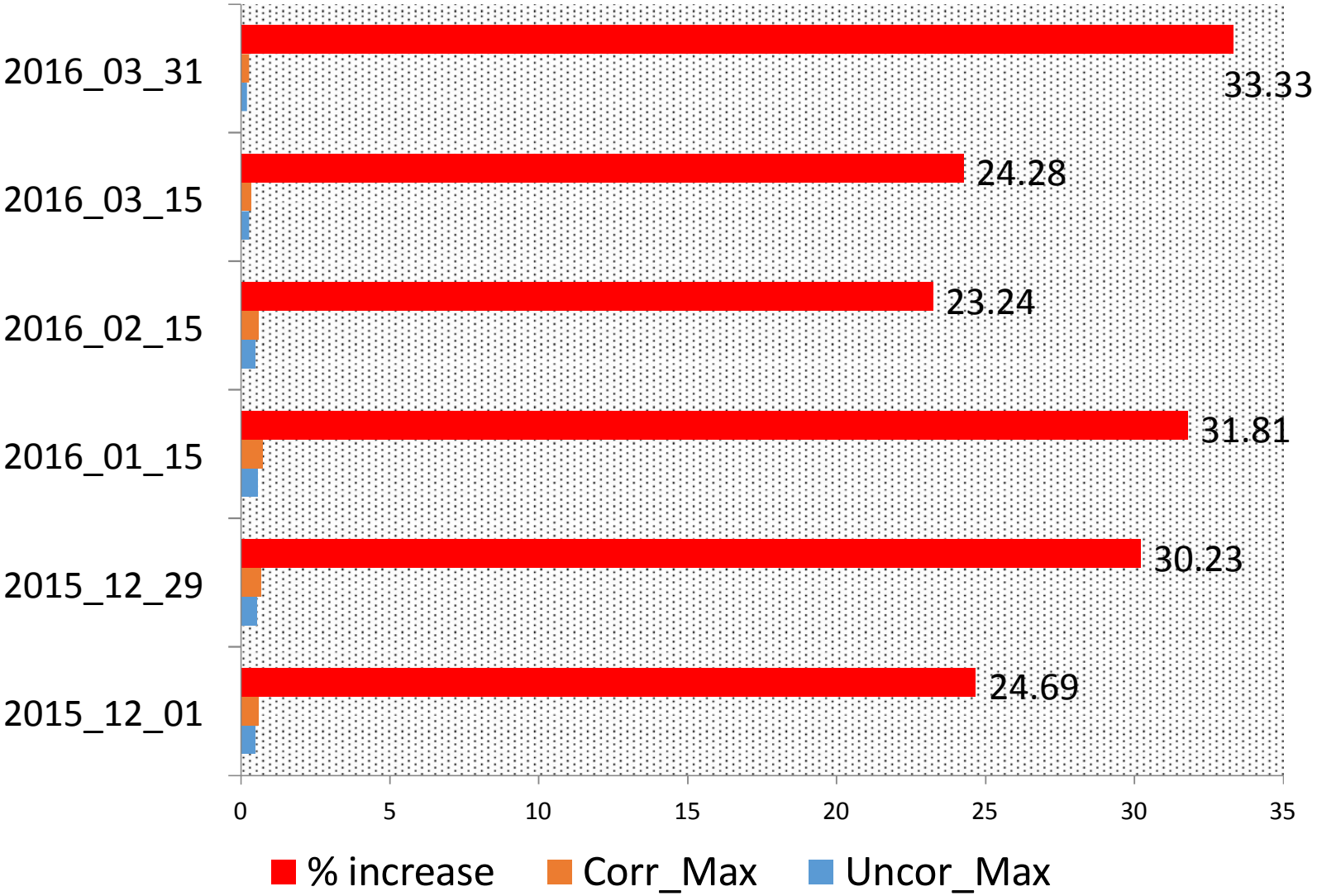
Questions - Revisited

- Is Atmospheric correction needed?
- How much is the improvement in scene quality before and after atmospheric correction?
- Is the improvement consistent across all months?

Results – Uncorrected vs. Corrected NDVI for Wheat



Percent Increase In Surface Reflectance



Results

- Across all images, on an average 27.93% improvement has been observed after correction.
- The improvement ranged from 23.24% - 33.33%.
- It is worth using surface reflectance images rather than top of reflectance images (over the Kabul region in Afghanistan)
- Next Step – compare 6S with Sen2Cor

ACIX: CEOS-WGCV Atmospheric Correction Inter-comparison Exercise (ESA/NASA/UMD)

The exercise aims to bring together available AC processors (**actually 14 processors including SEN2COR, MACCS, L8-S2-6SAC, …**) to generate the corresponding SR products.

The input data will be **Landsat-8 and Sentinel-2 imagery** of various test sites, i.e. coastal, agricultural, forest, snow/artic areas and deserts.

Objectives

- To better understand uncertainties and issues on L8 and S2 AC products
- To propose further improvements of the future AC schemes

* 1st Workshop in June 21st-22nd 2016 @ University of Maryland: to elaborate concepts, protocols and guidelines for the inter-comparison and validation of SR products

- 2nd workshop in April 2017
- Results to be finalized in fall 2017

https://earth.esa.int/web/sppa/meetings-workshops/acix

Demonstration of tool with much more specifics (on atmospheric parameterization file) will be presented after Day-2 - Krishna