National Aeronautics and Space Administration

Satellite Remote Sensing for Agricultural Applications

Sean McCartney

April 28, 2020

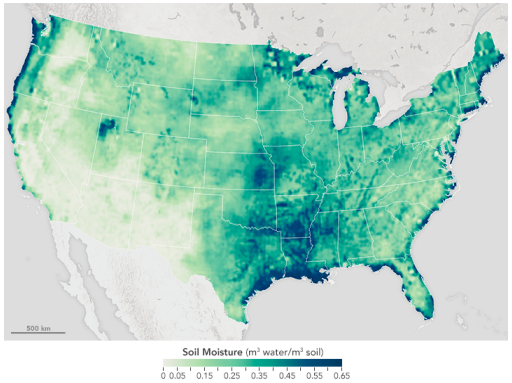
Training Outline

April 14, 2020

Overview of Agricultural Remote Sensing

https://eospso.nasa.gov/content/nasas-earth-observing-system-project-science-office

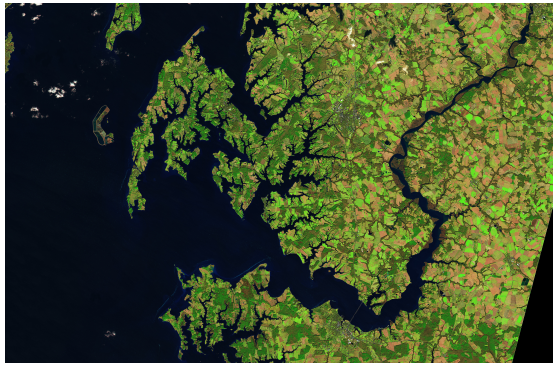
April 21, 2020



Soil Moisture for Agricultural Applications

https://earthobservatory.nasa.gov/images/87036/soil-moisture-in-the-united-states

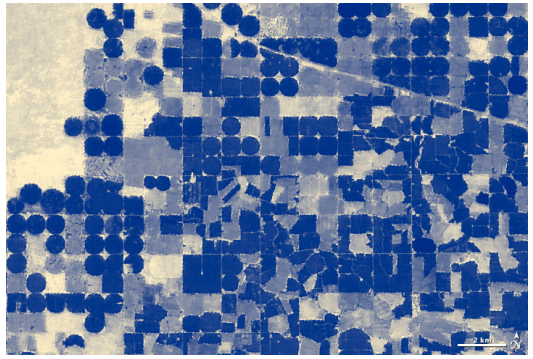
April 28, 2020



Earth Observations for Agricultural Monitoring

https://earthobservatory.nasa.gov/images/90095/satellites-eye-winter-cover-crops

May 5, 2020



Evapotranspiration & Evaporative Stress Index for Agricultural Applications

https://earthobservatory.nasa.gov/images/42428/water-use-on-idahos-snake-river-plain

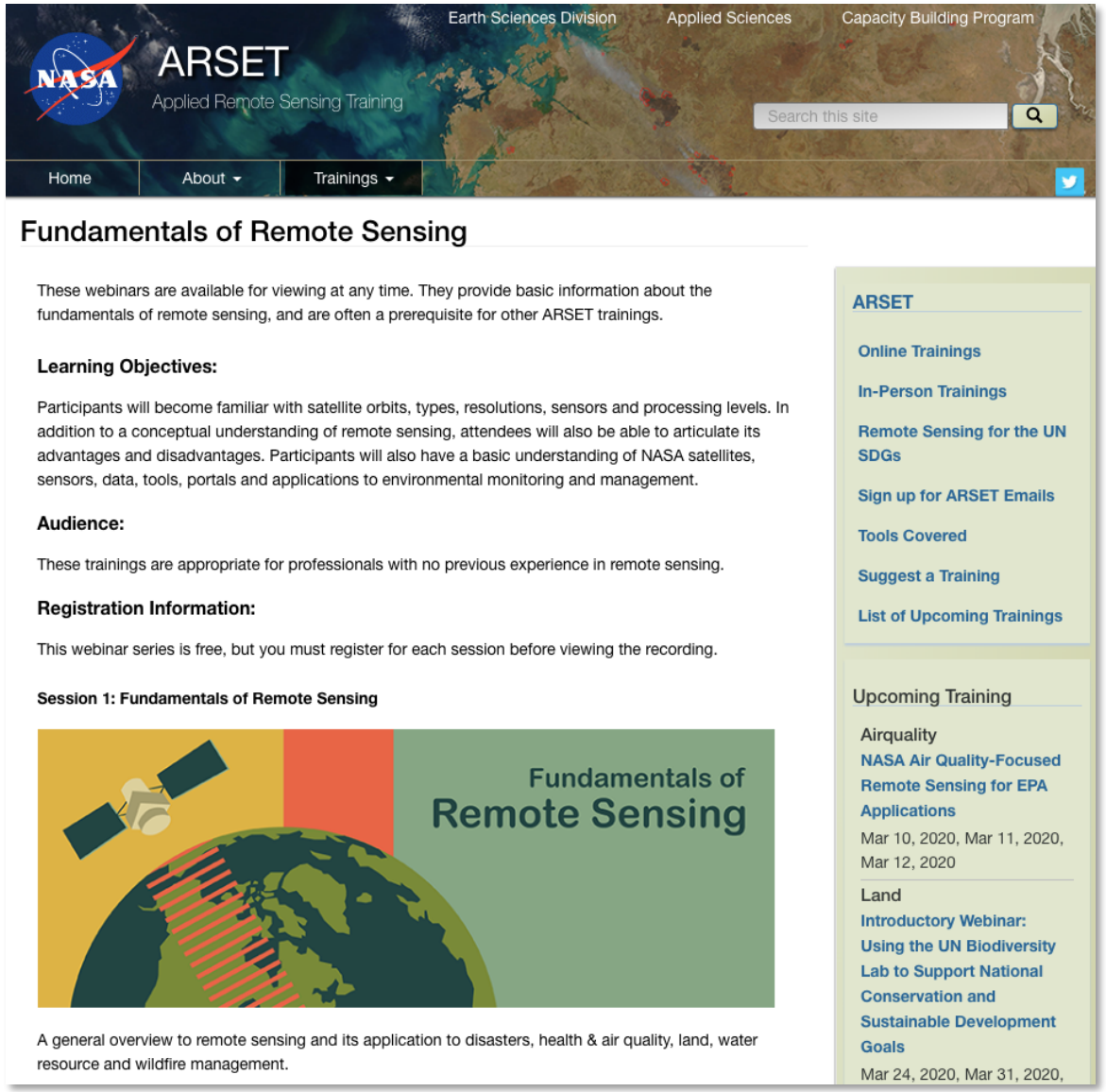
Training Format, Homework, and Certificate

- Four, 1.5-hour sessions with Q&A
- Homework Assignments will be available after parts 1 & 3 from: https://arset.gsfc.nasa.gov/water/webinars/remote-sensing-for-agriculture-20
  - Answers must be submitted via Google Form
  - Due dates: **April 28** & **May 12**
- A Certificate of Completion will be awarded to those who:
  - Attend all webinars
  - Complete all homework assignments
- You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

Prerequisite

Fundamentals of Remote Sensing

https://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing



Objectives

By the end of this presentation, attendees will be able to:

- Select some of the main variables used in agricultural monitoring
- Identify sources for timely and accurate agricultural statistics and assessment
- Give examples of global operational agricultural monitoring systems for crop condition and assessment
- Explore some of the agricultural monitoring systems for your area of interest

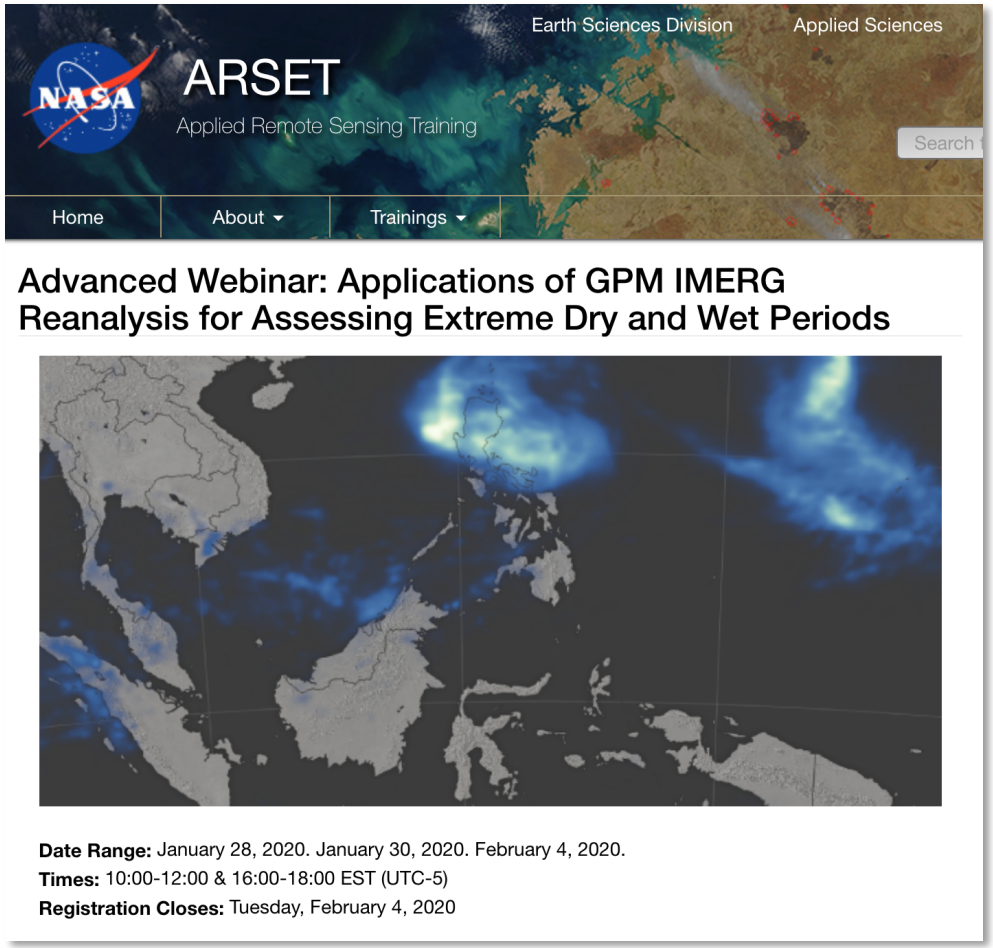
Part-3 Outline

- Previous ARSET trainings with agricultural applications
- Products and variables for cropland and rangeland monitoring
- National Agricultural Statistics Service (NASS) - CropScape
- Examples of operational global agricultural monitoring systems
- Examples of operational food security and early warning systems

Previous ARSET Trainings with Agricultural Applications

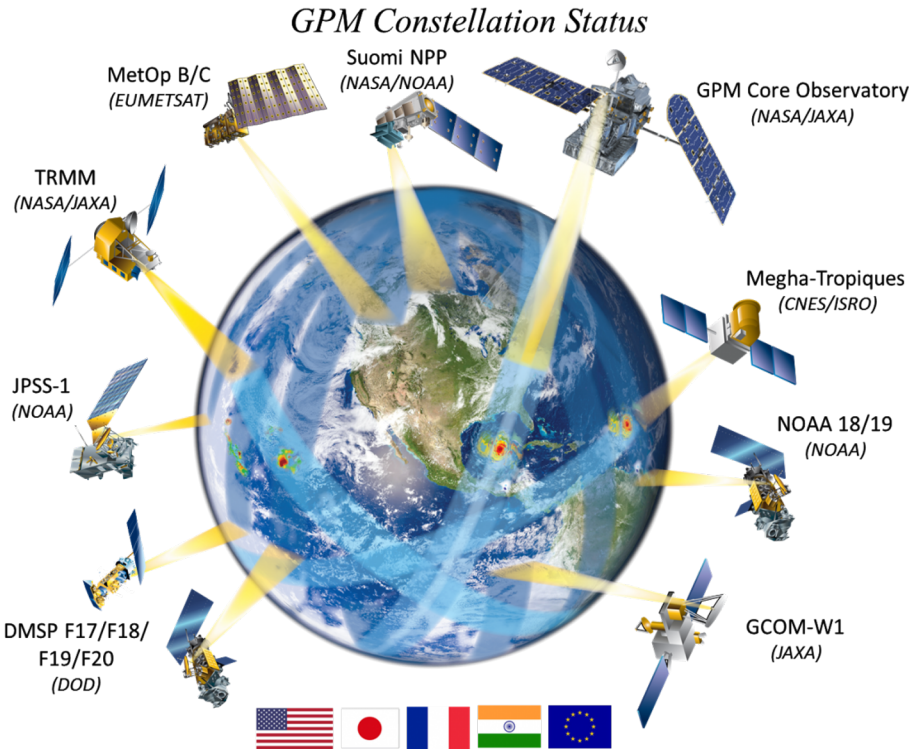
Previous ARSET Trainings with Agricultural Applications

- Advanced Webinar: Applications of GPM IMERG Reanalysis for Assessing Extreme Dry and Wet Periods
- https://arset.gsfc.nasa.gov/water/webinars/IMERG-2020
- GPM satellite used to calibrate microwave observations from a constellation of national and international satellites
- IMERG algorithm for satellite-derived precipitation estimates for near-real and post-real time
  - "Early" – 4 hr. (flash flooding)
  - "Late" – 14 hr. (crop forecasting)
  - "Final" – 3 months (research)



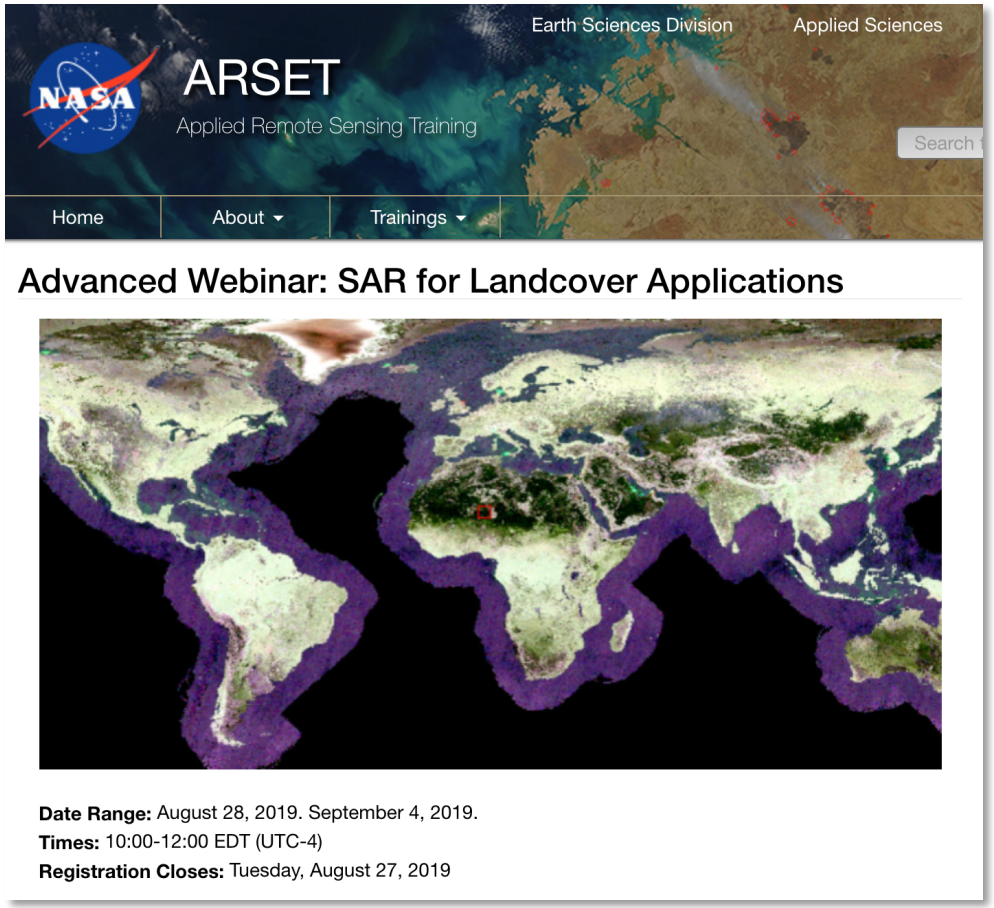
Previous ARSET Trainings with Agricultural Applications

- IMERG Reanalysis webinar focused on access and analysis of long-term IMERG precipitation data for detection of dry and wet periods
- Demonstrations and step-by-step instructions were provided to:
  - Download IMERG seasonal and monthly data
  - Calculate time series' of precipitation mean, STD, and anomalies
  - Calculate SPI using Bash and Python
  - Display and analyze precipitation anomalies
  - Analyze IMERG precipitation and socioeconomic data from SEDAC



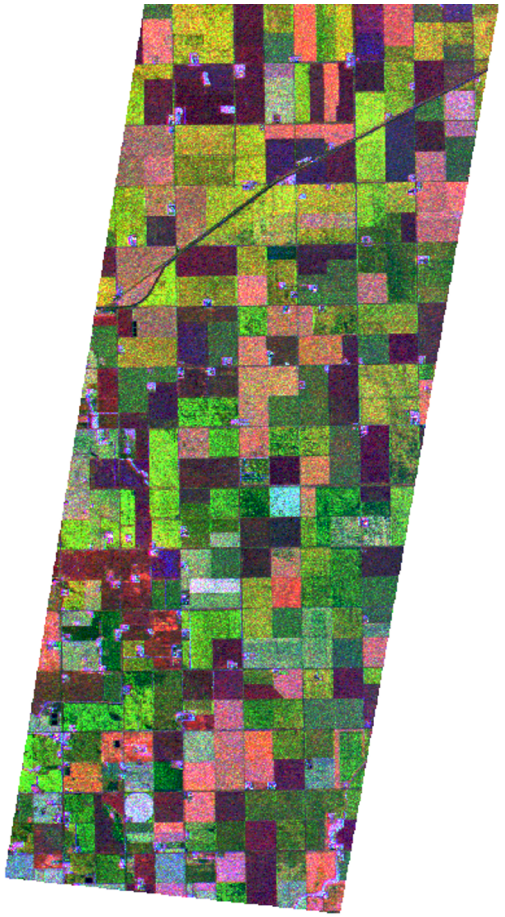
Previous ARSET Trainings with Agricultural Applications

- Advanced Webinar: SAR for Landcover Applications
- https://arset.gsfc.nasa.gov/disasters/webinars/2019-SAR
- Two-part webinar series using open source/access software and data
  - Part 1: Monitoring Flood Extent
  - Part 2: **Crop Identification** and **Condition**
- Part 2 covered the basics of radar remote sensing as related to agriculture. The remainder of the session focused on the use of SAR to retrieve soil moisture, identify crop types, and map land cover.



Previous ARSET Trainings with Agricultural Applications

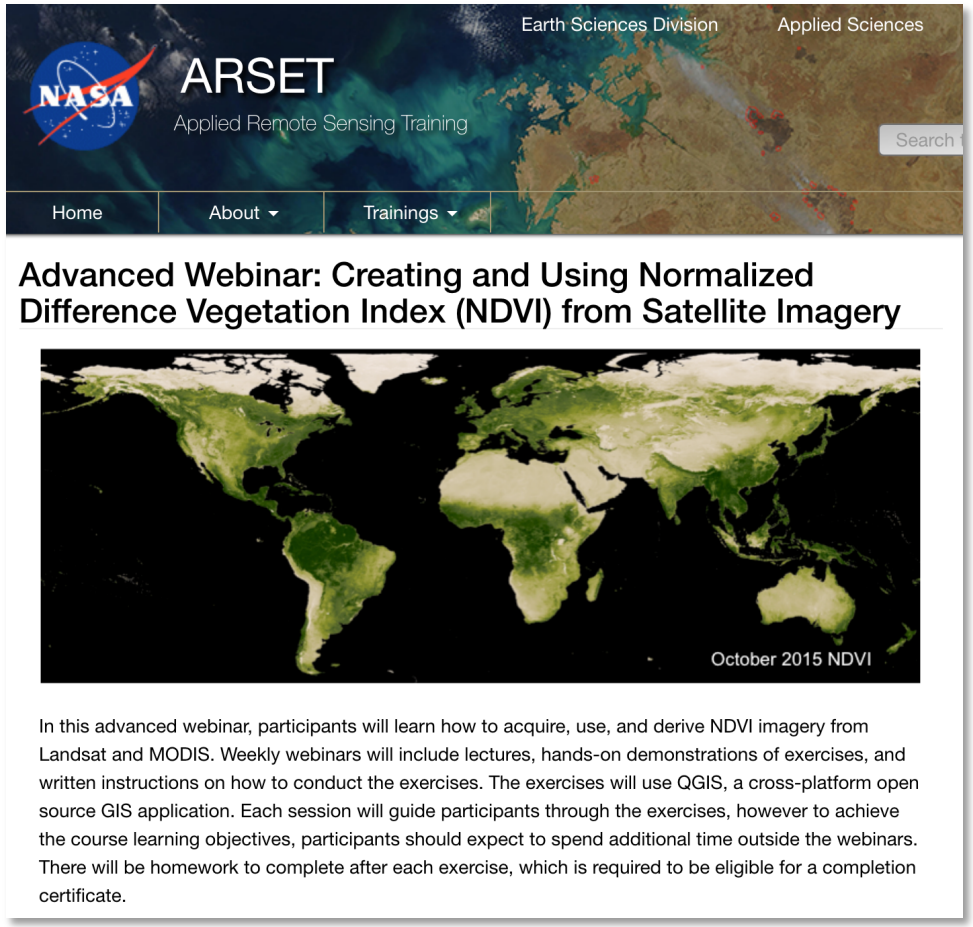
- SAR for Landcover Applications webinar provided knowledge on:
  - How SAR configurations affect response from soils and crops
  - Information content in SAR images relevant to soil and crop conditions
  - Optimal sensor parameters for agricultural applications
  - How to ingest, pre-process, and process multi-frequency SAR data for use in crop classification and soil moisture estimation
  - How to implement the Random Forest Algorithm in R to perform crop classification



Integration of data from RADARSAT-2, ALOS and TerraSAR-X, in Manitoba, Canada to map wheat, corn, soybeans, and canola. McNairn et al.

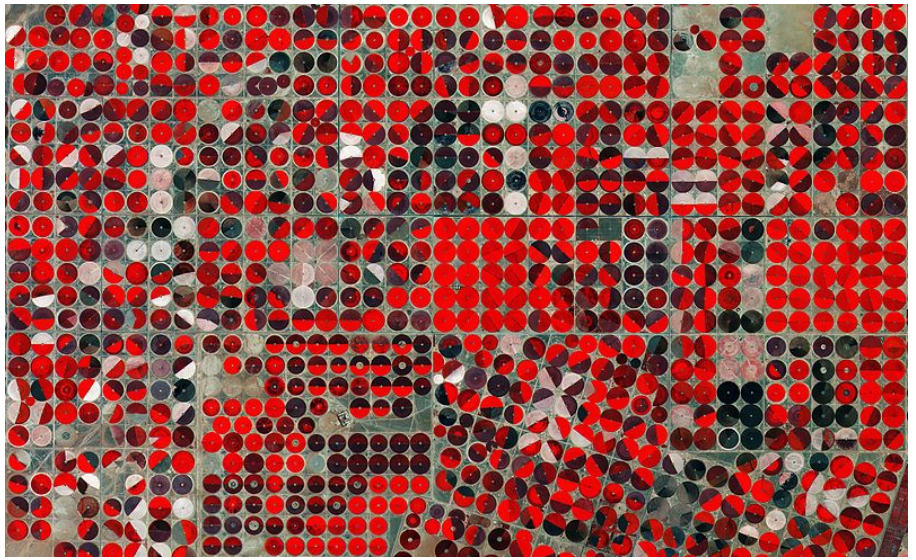
Previous ARSET Trainings with Agricultural Applications

- Advanced Webinar: Creating and Using Normalized Difference Vegetation Index (NDVI) from Satellite Imagery
- https://arset.gsfc.nasa.gov/land/webinars/advancedNDVI
- Multi-part webinar series using open source software and data
  - Deriving NDVI from Landsat imagery using QGIS
  - Calculating NDVI Anomalies (MODIS)



Previous ARSET Trainings with Agricultural Applications

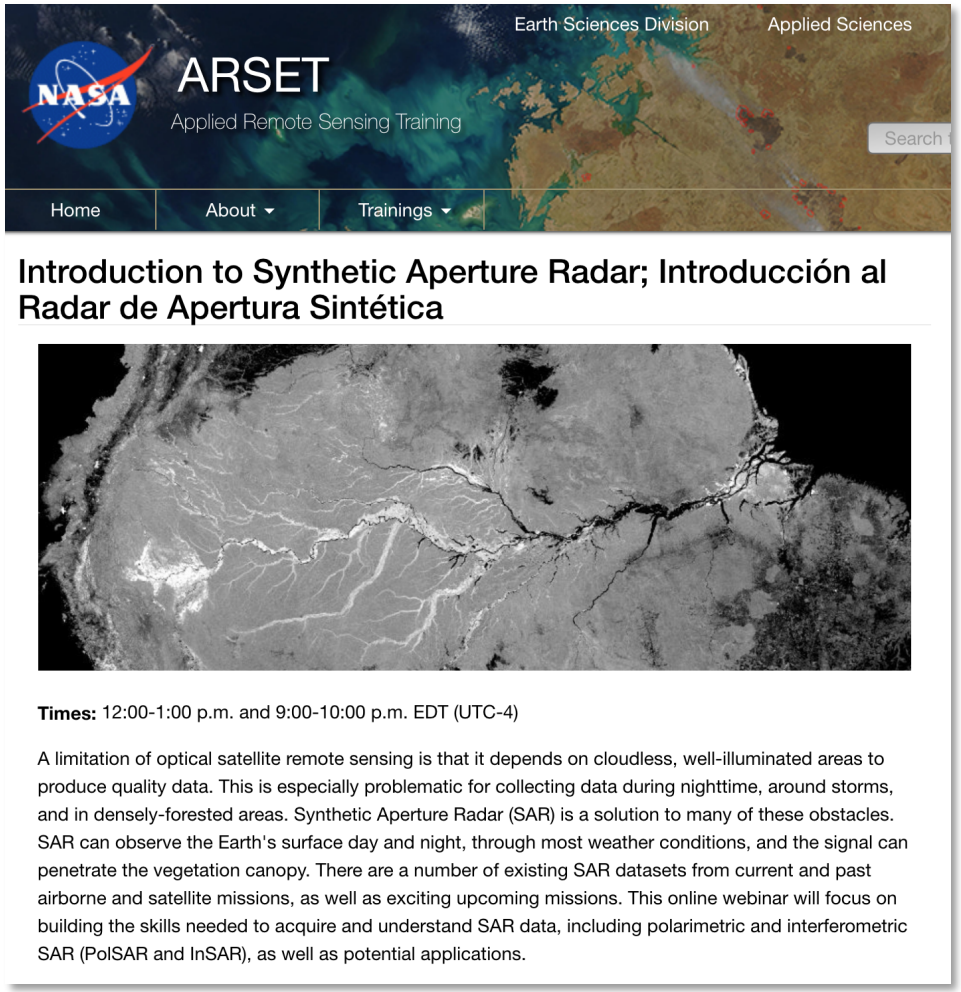
- NDVI webinar provided knowledge on:
  - Normalized Difference Vegetation Index (NDVI) calculation and applications
  - How to acquire, use, and derive NDVI imagery from Landsat and MODIS
  - Using MODIS NDVI images to derive time series' and NDVI anomaly maps
  - Visualize MODIS/NDVI time series' using the GIMMS Global Agriculture Monitoring (GLAM) Project



Agricultural structures near Tubarjal, Saudi Arabia. Circles come from a central-pivot irrigation system. Credit: ESA

Previous ARSET Trainings with Agricultural Applications

- Introductory Webinar: Introduction to Synthetic Aperture Radar
- https://arset.gsfc.nasa.gov/disasters/webinars/intro-SAR
- Bilingual (English & Spanish)
- Multi-part webinar series
- Webinar series focused on building the skills needed to acquire and understand SAR data, including polarimetric and interferometric SAR (PolSAR and InSAR)
- Highlighted applications of SAR data



Products and Variables for Cropland and Rangeland Monitoring

Applications for Cropland & Rangeland Monitoring

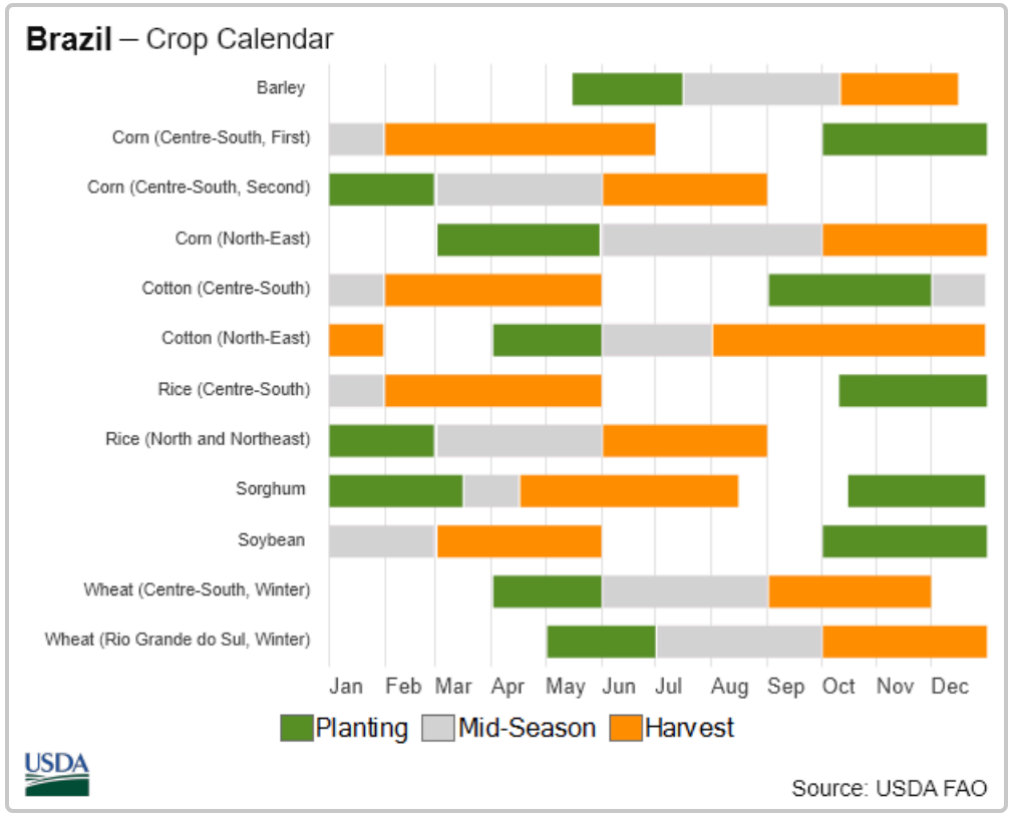
- Agricultural monitoring was probably the first civilian application of satellite remote sensing data.
- Remote sensing allows gathering information about the biophysical state of vegetation over large areas with high revisit frequency.
- Provides timely, objective, local-to-global coverage
- Contributes to the accurate and timely reporting of agricultural statistics
- Permits accurate forecasting of yield or shortfalls in crop production and food supply per region and country
- Promotes market stability through reduced price volatility by anticipating market trends with reduced uncertainty
- Enhances early warning capability by monitoring food security in high-risk regions worldwide

Products and Variables for Cropland & Rangeland Monitoring

- Crop Calendar
- Crop Condition
- Crop Mask
- Crop Type Mask
- Evapotranspiration
- Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
- Growing Degree Days (GDD)
- Phenology
- Precipitation
- Soil Moisture
- Temperature
- Vegetation Indices (NDVI & EVI)
- Yield Forecast

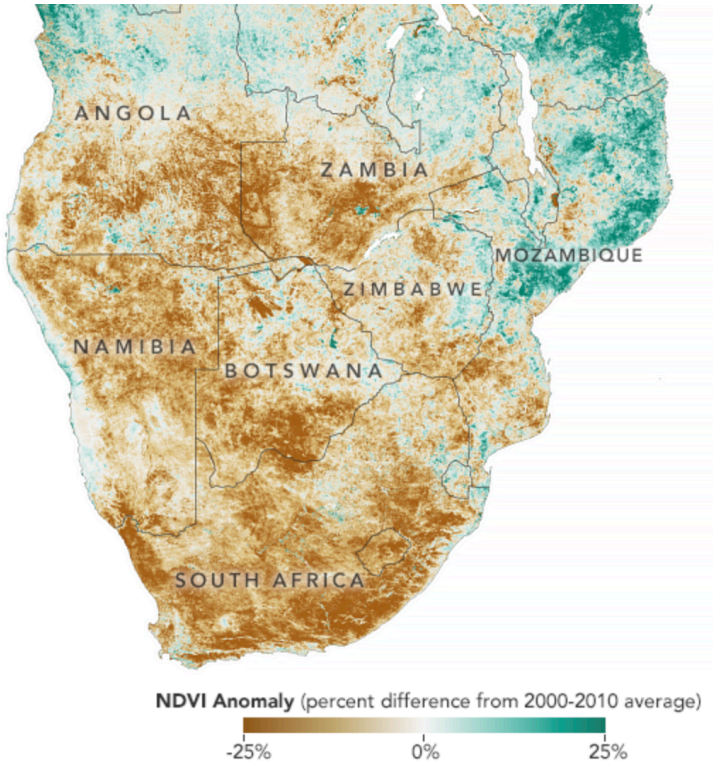
Products and Variables for Cropland & Rangeland Monitoring

- Crop Calendar
  - Fundamental component of agricultural monitoring systems
  - Helps analysts focus on the seasons when different crop types are growing in the field
  - Provides crop-specific key phenological timings, such as sowing, growing, and harvesting
  - FAO and USDA make available crop calendars at national level



Products and Variables for Cropland & Rangeland Monitoring

- Crop Condition
  - Assessment in the early growing stage is essential for crop monitoring and yield prediction.
  - Analysis is based on the comparison of the actual crop status to previous seasons or to what can be assumed to be the average or "normal" condition.
  - Detected anomalies are used to draw conclusions on possible yield limitations.
  - NDVI-based methods are typically applied.

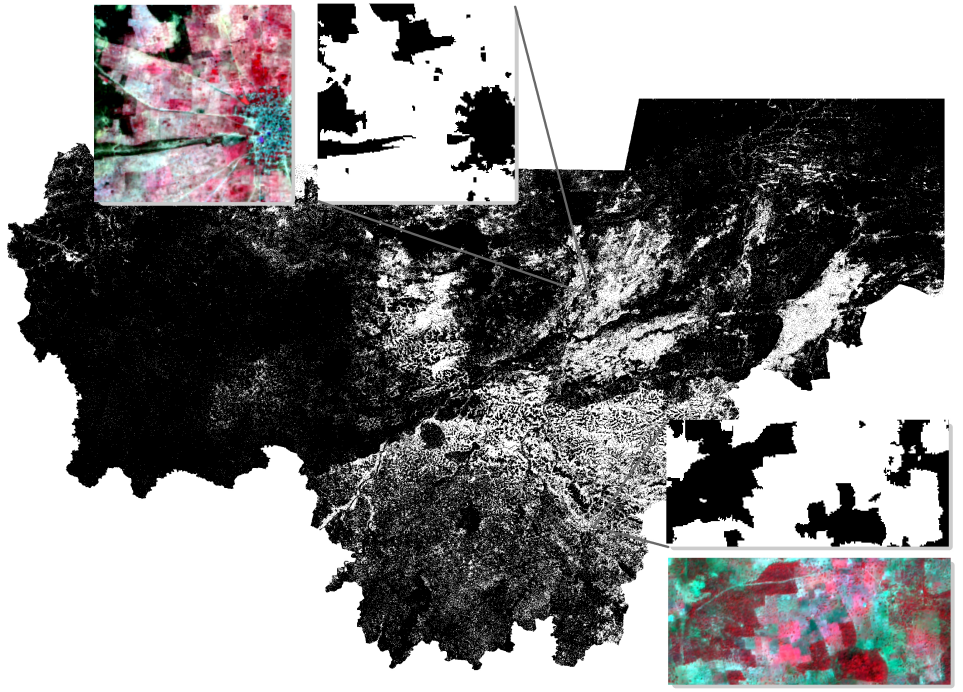


September 10 - December 8, 2019

This NDVI anomaly map, based on data from Terra MODIS, compares the health of vegetation in southern Africa from the dry season in 2019 versus the same period from 2000-2010. Brown areas show where plant health, or "greenness," was below normal. Greens indicate vegetation that is more widespread and abundant than normal.
Image Credit: NASA Earth Observatory

Products and Variables for Cropland & Rangeland Monitoring

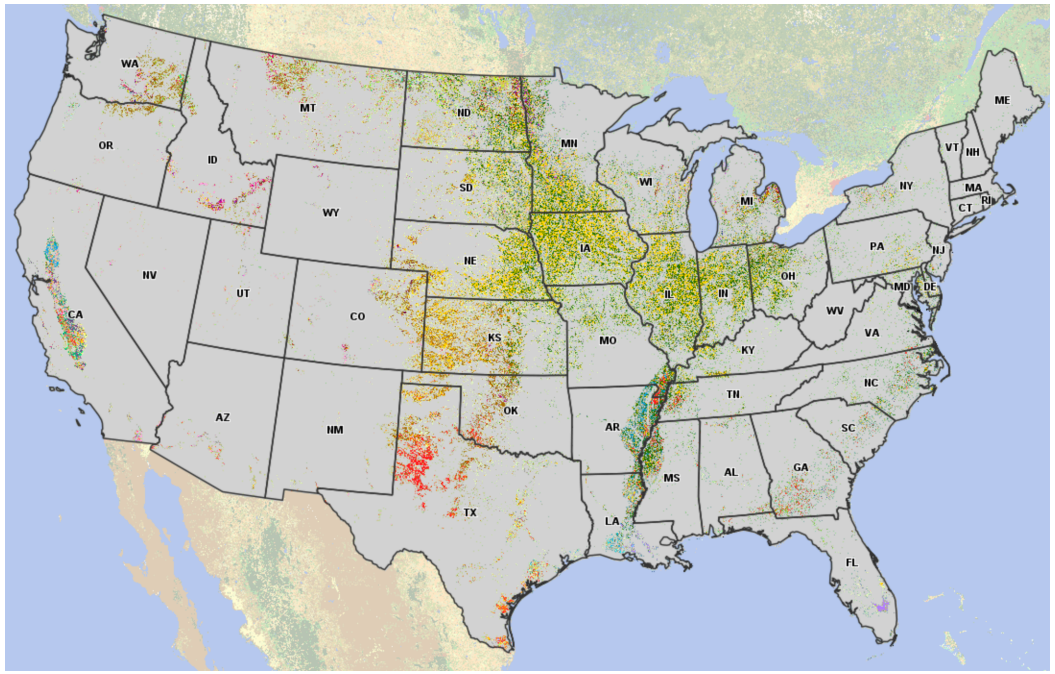
- Crop Mask
  - Simply looking at a map of vegetation greenness can be misleading; partly because the data doesn't distinguish between planted crops and non-target vegetation.
  - Identifying the exact areas where crops are growing, called crop masking, is a critical first step, and vegetation indices play an important role in this process.
  - Crop masking is a critical early step for building yield models.



Binary crop mask created in the country of Mali.
Image Credit: ESA

Products and Variables for Cropland & Rangeland Monitoring

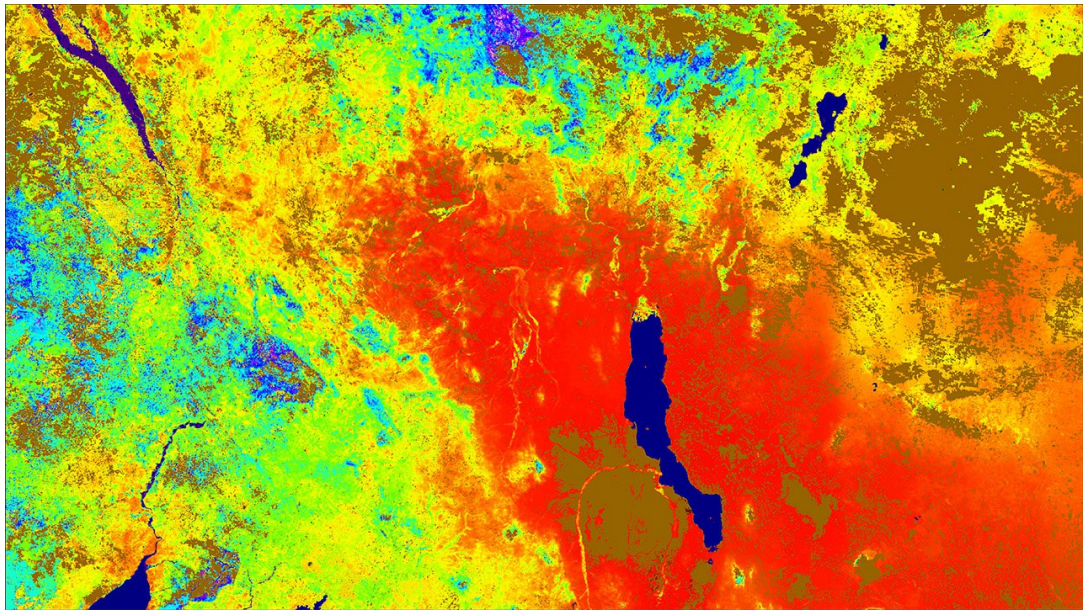
- Crop Type Mask
  - By compiling satellite images of a given area, it's possible to determine where a specific crop is growing and where it is not growing.
  - To adequately assess the health of a crop using satellite-derived data, it is necessary to exclude signals that stem from extraneous plants to focus solely on the information for the crop of interest.
  - The first step is identifying the vegetation that follows the typical crop growth cycle of the targeted crop for a region.



Crop type mask layers provided by CropScape – Cropland Data Layer (2019). Image Credit: USDA NASS

Products and Variables for Cropland & Rangeland Monitoring

- Evapotranspiration
  - Sum of evaporation from the land surface plus transpiration in vegetation
  - Highly variable in space and time
  - Critical component of the water and energy balance of climate-soil-vegetation interactions
  - Extremely useful in monitoring and assessing water availability, drought conditions, and crop production
  - Remote sensing has long been recognized as the most feasible means to provide spatially distributed regional evapotranspiration (ET) information over land surfaces



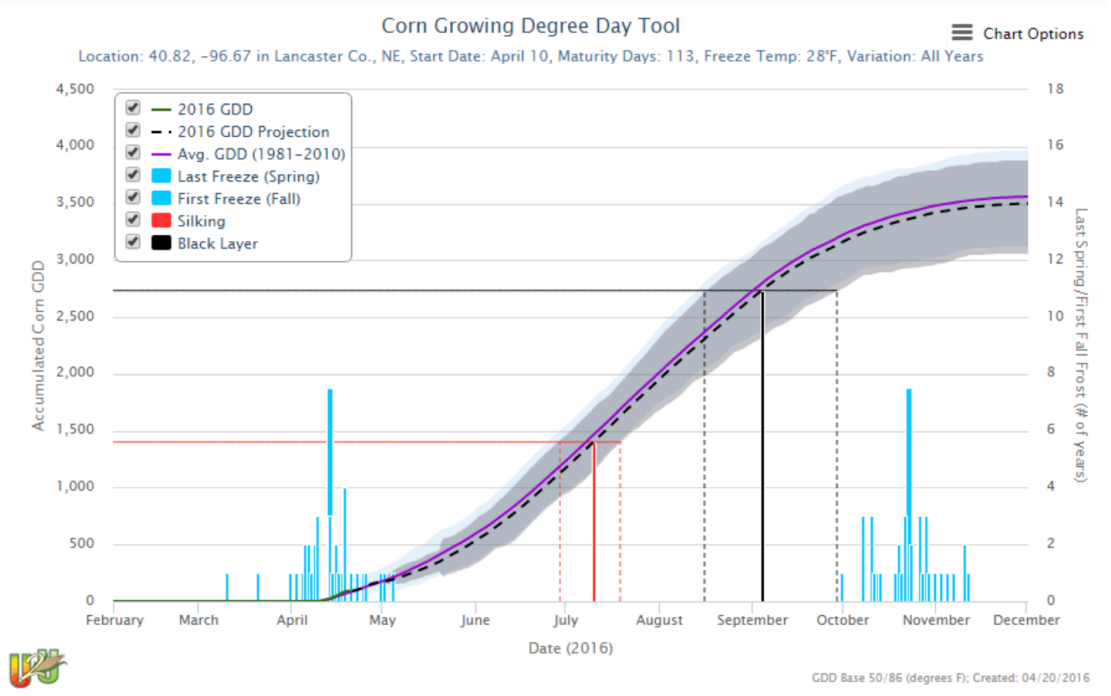
Products and Variables for Cropland & Rangeland Monitoring

- Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
  - Fraction of photosynthetically active radiation (PAR) absorbed by a vegetation canopy. PAR is the solar radiation reaching the canopy in the 0.4–0.7 µm wavelength region.
  - Suitable to reliably monitor the seasonal cycle and inter-annual variability of vegetation activity related to photosynthesis
  - Can be used as an indicator of the state and evolution of the vegetation cover, advantageously replacing NDVI

Canola Fields
Image Credit: Steve Buissinne

Products and Variables for Cropland & Rangeland Monitoring

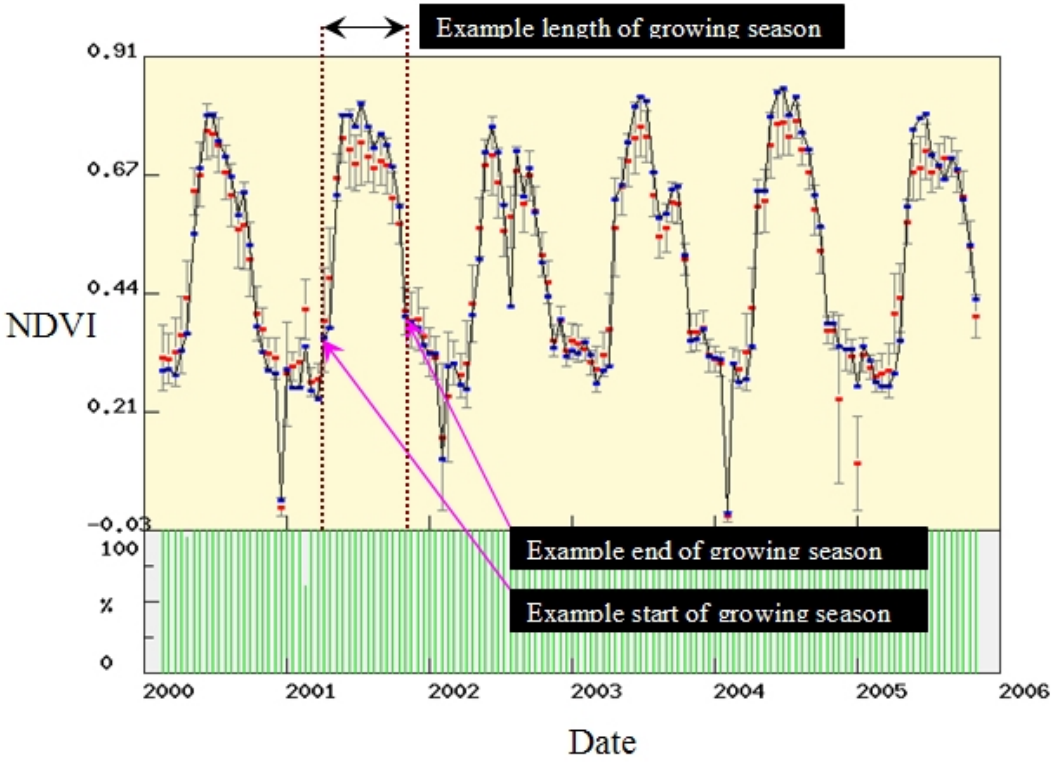
- Growing Degree Days (GDD)
  - GDD = $((T_{max} + T_{min})/2) - T_{base}$
  - Defined as the number of degrees the average daily temperature exceeds a base temperature, or the temperature below which the organism will remain in dormancy.
  - Growing Degrees are accumulated daily, following a specified start date, by adding each day's total to all previous days' totals.
  - Use of GDD and accumulated GDD (AGDD) can improve phenological analyses and crop yield models.



Corn Growing Degree Day Tool
Image Credit: University of Nebraska-Lincoln

Products and Variables for Cropland & Rangeland Monitoring

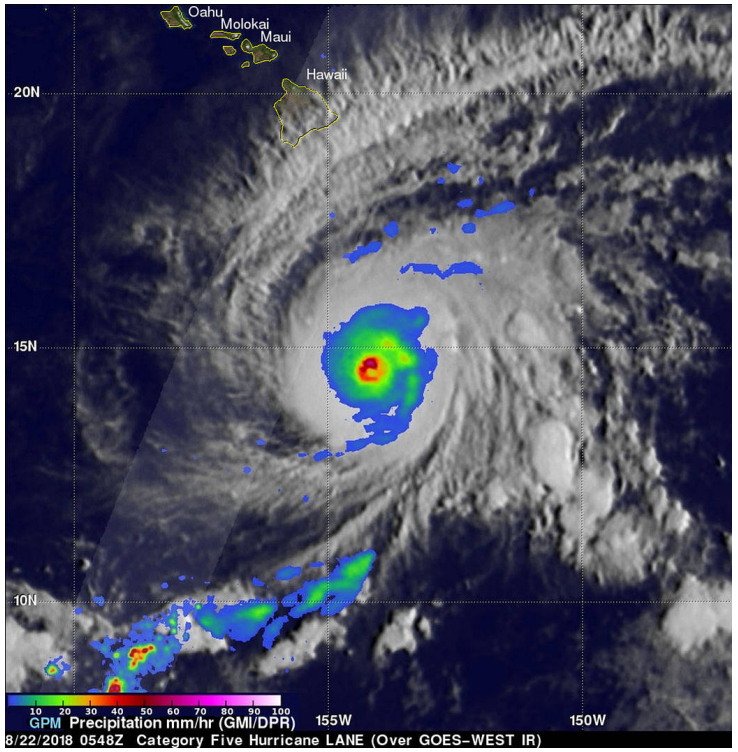
- Phenology
  - Vegetation phenology is the description of periodic plant life cycle events across the growing seasons.
  - Vegetation phenology with remote sensing is typically monitored by means of time series' of vegetation indices.
  - Divided into vegetative (emergence and "green up") and reproductive stages (anthesis to senescence).
  - Vegetation indices address the amount of green biomass and allow the differentiation of the intensity of photosynthetic activity.



NDVI temporal profile for a typical patch of coniferous forest over a period of six years. Data and graph are based on the MODIS sensor. Data archived at the ORNL DAAC.
Image Credit: Dr. Robert Cook (ORNL DAAC)

Products and Variables for Cropland & Rangeland Monitoring

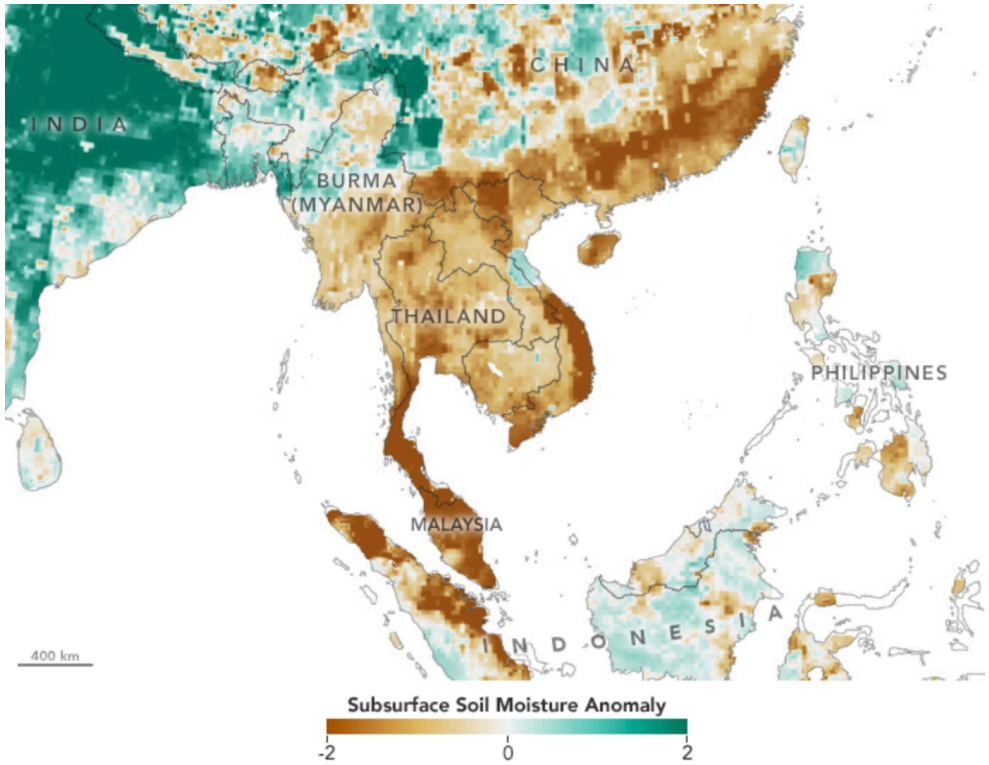
- Precipitation
  - A key component of the water cycle and difficult to measure, since rain and snow vary greatly in both space and time.
  - Satellites provide frequent and accurate observations and measurements, especially where ground-based data are sparse.
  - Precipitation anomalies provide information of total precipitation deviation from the long-term average over that same period.
  - Need to know the timing and amount of precipitation to forecast crop yields as well as freshwater shortages.



Hurricane Lane about to drop heavy rains on Hawaii
Observed by the GPM satellite: 8/22/2018
Image Credit: NASA

Products and Variables for Cropland & Rangeland Monitoring

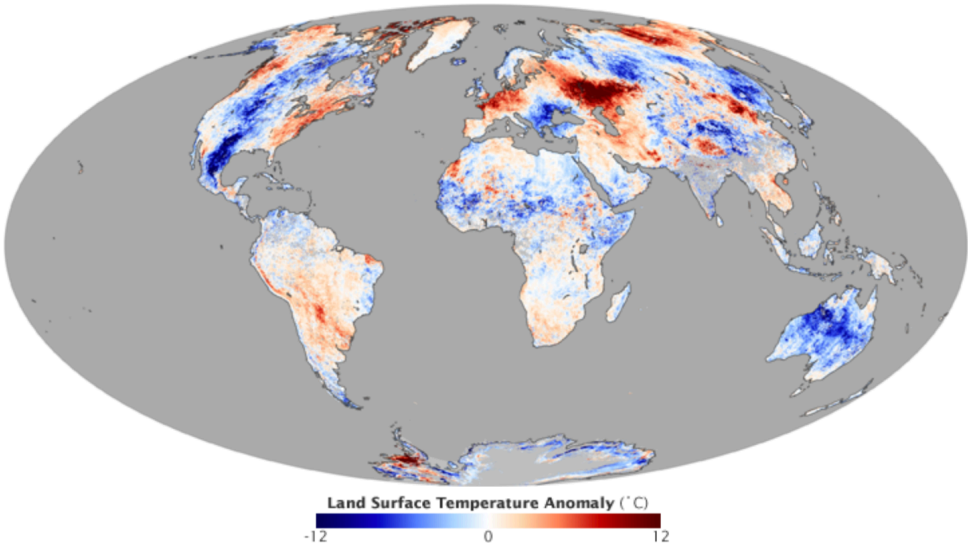
- Soil Moisture
  - Water is the defining link between climate and agriculture. To improve agricultural drought decision support systems and ensure food security, better quality and better use of Soil Moisture is vital.
  - SMAP soil moisture data has been incorporated into the Crop Explorer website of the USDA's Foreign Agricultural Service, which reports on regional droughts, floods, and crop forecasts.
  - A crucial requirement of global crop yield forecasts is the regional characterization of root-zone soil moisture.



SMAP soil moisture anomalies in southeast Asia from January 1 to February 7, 2020.
Image Credit: NASA Earth Observatory

Products and Variables for Cropland & Rangeland Monitoring

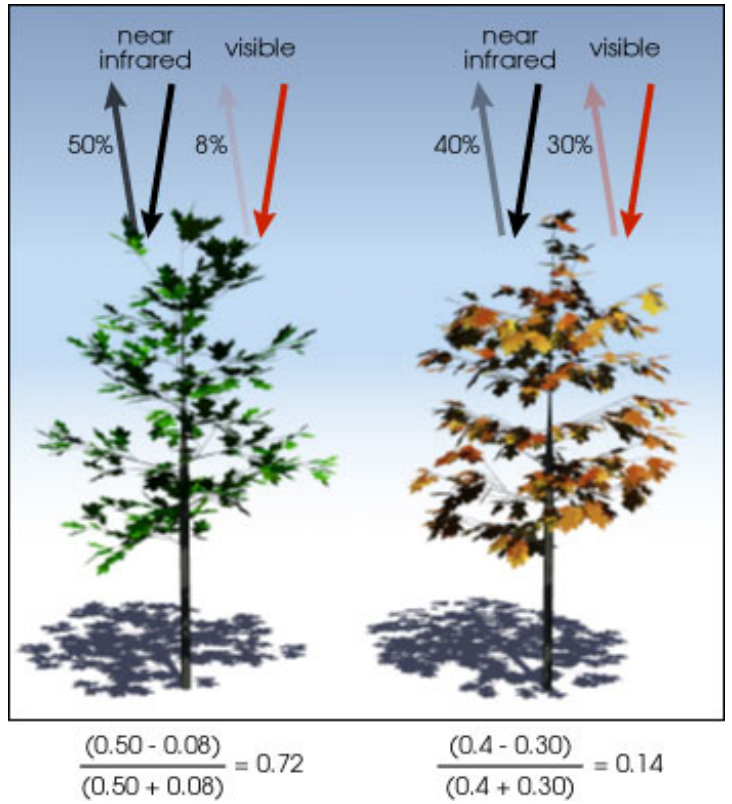
- Temperature
  - All biological and chemical processes taking place in the soil relate to air temperature.
  - The heat supply of crops is characterized by a sum of average daily air temperatures that are higher than the biological minimum during a vegetation period.
  - There are three distinct temperature points of growth:
    - Minimal temperature, which is enough for growth to start.
    - Optimal temperature, which is the most advantageous for growth processes.
    - Maximum temperature, where growth stops.



Global map showing temperature anomalies for July 4–11, 2010, compared to temperatures for the same dates from 2000 to 2008. The anomalies are based on land surface temperatures observed by MODIS on NASA's Terra satellite.
Image Credit: NASA Earth Observatory

Products and Variables for Cropland & Rangeland Monitoring

- Vegetation Indices
  - Healthy vegetation reflects more near-infrared and green light compared to other wave-lengths while absorbing more red and blue light.
  - Analyzing a plant's spectrum of both absorption and reflection in visible and in near-infrared wavelengths allows the calculation of NDVI for large-scale vegetation monitoring.
  - Anomaly maps of NDVI are routinely used to detect anomalous crop and rangeland development compared to what can be assumed to be the average or "normal" situation.



Example of NDVI being calculated for healthy green vegetation and senescing vegetation. Credit: Robert Simmon, NASA

Products and Variables for Cropland & Rangeland Monitoring

- Yield Forecast
  - Remote sensing performs a central role within statistical programs in the estimation of crop area and yields.
  - Crop yield can be estimated either empirically, with vegetation indices derived from satellite reflectance, or mechanistically, by combining remotely sensed Green Area Index with process-based crop growth modeling.
  - The advantage of empirical estimation lies in its simplicity, but it comes at the cost of collecting ground data and difficulty to extrapolate in time and space.
  - The model selected depends on the data access and quality available in individual countries and the ultimate purpose of the forecasting.

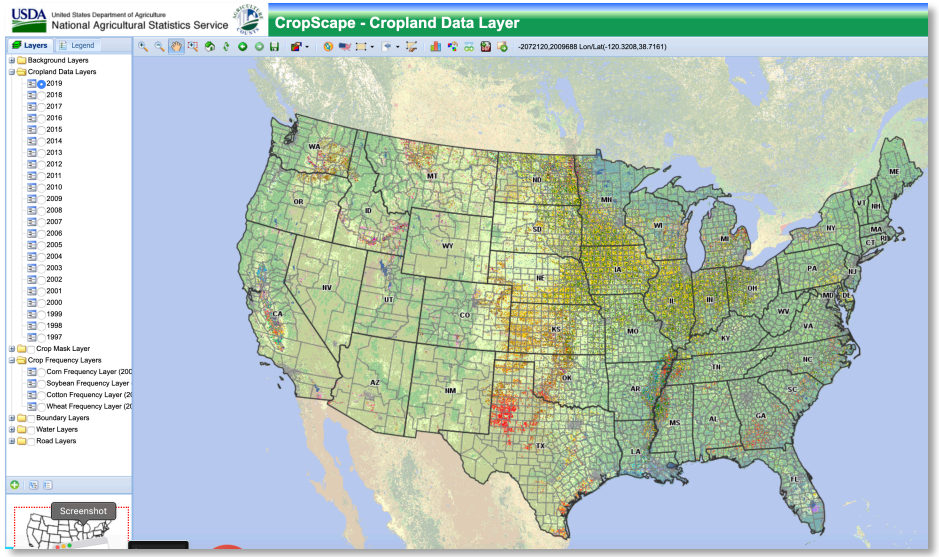
U.S. Department of Agriculture
National Agricultural Statistics Service (NASS)

National Sources for Agricultural Statistics

- USDA National Agricultural Statistics Service (NASS)
- https://www.nass.usda.gov/
- NASS conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture.
- Committed to providing timely, accurate, and useful statistics in service to U.S. agriculture.
- Across the country, field officials visit farms and measure acreage and condition of planted fields throughout the growing season.

National Sources for Agricultural Statistics

- Since 2009, NASS has drawn on Landsat data to monitor dozens of crops in the continental U.S. as part of the **Cropland Data Layer** (CDL) program.
- The CDL is a raster, geo-referenced, crop-specific land cover layer created annually since 1997.
- 2008 was the first year that the entire Continental United States was covered by the CDL.
- The purpose was to use satellite imagery to provide acreage estimates to the Agricultural Statistics Board for major commodities.
- NASS publishes the CDL through the **CropScape** website: https://nassgeodata.gmu.edu/CropScape/



Demo – CropScape

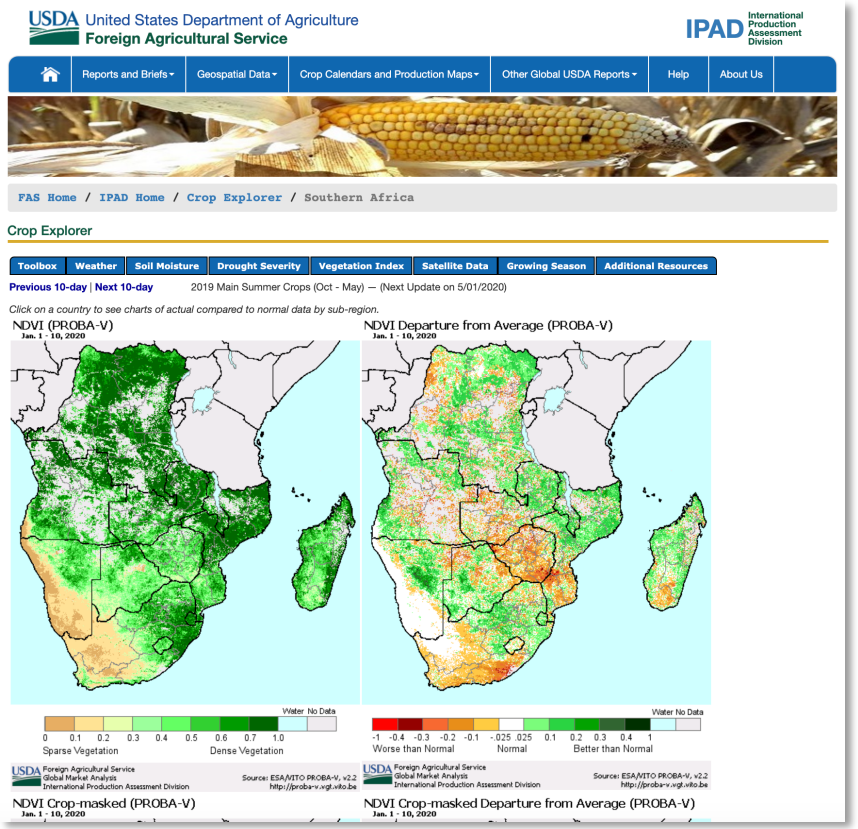
Examples of Operational Agricultural Monitoring Systems

Operational Agricultural Monitoring Systems

	DSS for Early Warning	Regional	Global	Website
USDA Foreign Agricultural Service (FAS)	X	X	X	https://ipad.fas.usda.gov/
FAO Global Information and Early Warning System (GIEWS)	X	X	X	http://www.fao.org/giews/en/
Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM)	X	X	X	http://earthobservations.org/geoglam.php
World Food Program Seasonal Monitor	X	X	X	https://www.wfp.org/publications/seasonal-monitor https://dataviz.vam.wfp.org/
Institute of Remote Sensing and Digital Earth at the Chinese Academy of Sciences - Crop Watch	X	X	X	http://www.cropwatch.com.cn/
Anomaly Hot Spots of Agricultural Production (ASAP)	X	X		https://mars.jrc.ec.europa.eu/asap/index.php
Mars Crop Yield Forecasting System	X	X		https://marswiki.jrc.ec.europa.eu/agri4castwiki/index.php/Welcome_to_WikiMCYFS
Famine Early Warning Systems Network (FEWS NET)	X	X		https://fews.net/

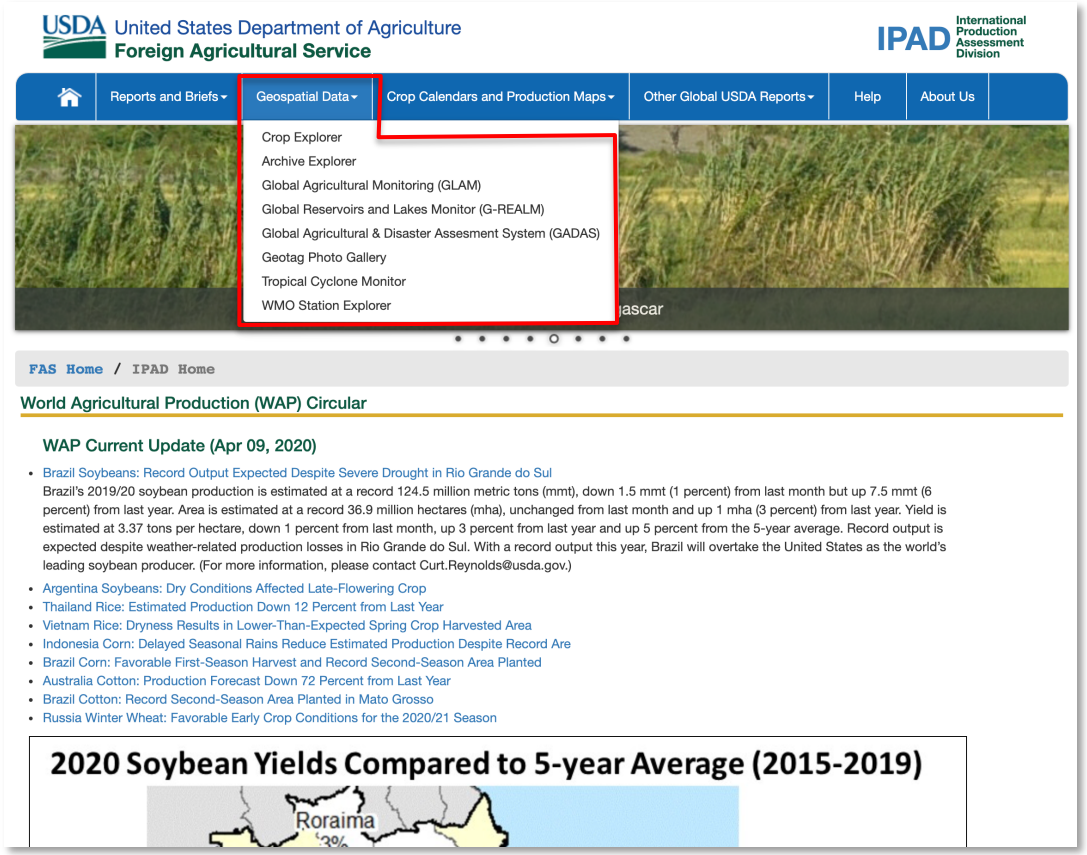
Operational Agricultural Monitoring Systems

- The International Production Assessment Division (**IPAD**) of the USDA's Foreign Agricultural Service (**FAS**)
  - Responsible for global crop condition assessments and estimates of area, yield, and production for grains, oilseeds, and cotton.
  - In 2001, FAS began the **Crop Explorer** service, which provides remote sensing-based information used by agricultural economists and researchers to predict global crop production.
  - Mid-season to end-of-season yield estimates and maps are produced using regression and analog year algorithms derived from MODIS NDVI data.
  - https://ipad.fas.usda.gov/cropexplorer/



Operational Agricultural Monitoring Systems

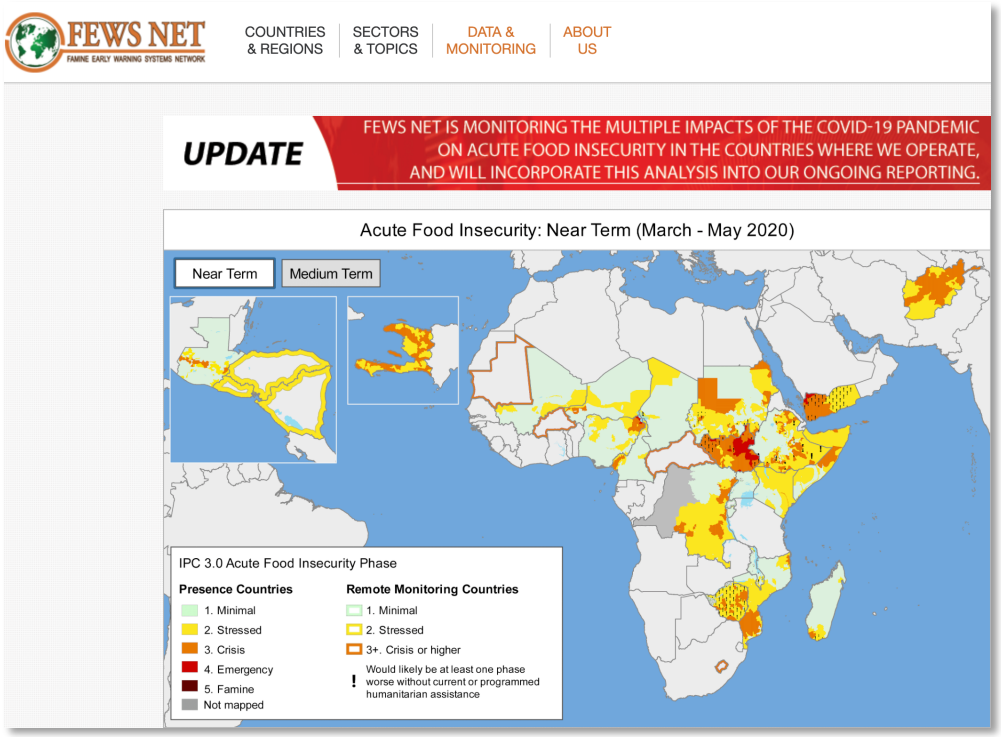
- Global Agricultural and Disaster Assessment System (**GADAS**)
  - State-of-the-art, web-based GIS system
  - GADAS is a powerful visualization tool based on an ArcGIS platform that enables FAS-IPAD analysts and other users to rapidly assess real-time crop conditions.
  - Used for global agricultural monitoring and commodity forecasting
  - https://geo.fas.usda.gov/GADAS/



Demos – Crop Explorer & GADAS

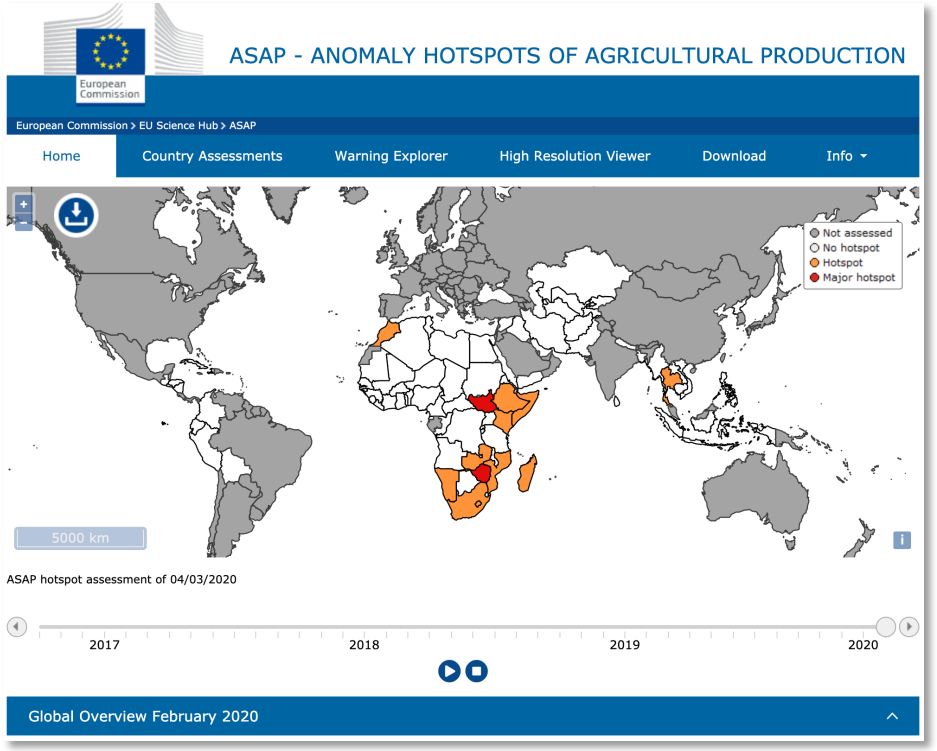
Operational Agricultural Monitoring Systems

- Famine Early Warning Systems Network (**FEWS NET**)
  - Created in 1985 by the US Agency for International Development (USAID) after devastating famines in East and West Africa.
  - FEWS NET is a leading provider of early warning and analysis on food insecurity.
  - The objective is early identification of food production anomalies in regions of subsistence agriculture and pastoralism.
  - Provides evidence-based analysis for 28 countries.
  - https://fews.net/



Operational Agricultural Monitoring Systems

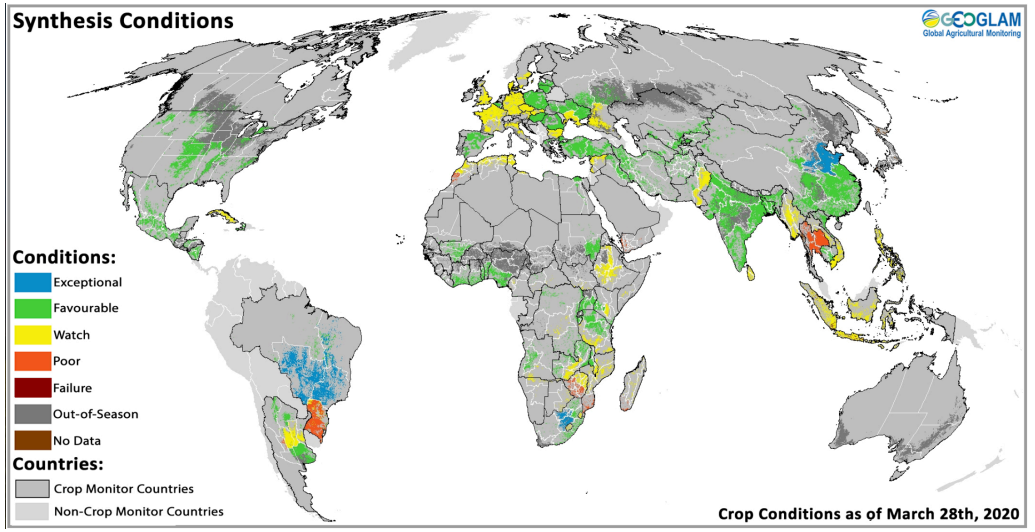
- Anomaly Hot Spots of Agricultural Production (**ASAP**)
  - ASAP aims to provide timely information about possible crop production anomalies.
  - Directly supports multi-agency early warning initiatives such as the GEOGLAM Crop Monitor for Early Warning
  - NDVI & rainfall estimates
  - Crop and rangeland masks
  - Satellite-derived phenology
  - High resolution data
  - Media monitor
  - https://mars.jrc.ec.europa.eu/asap/



Demo – ASAP

Operational Agricultural Monitoring Systems

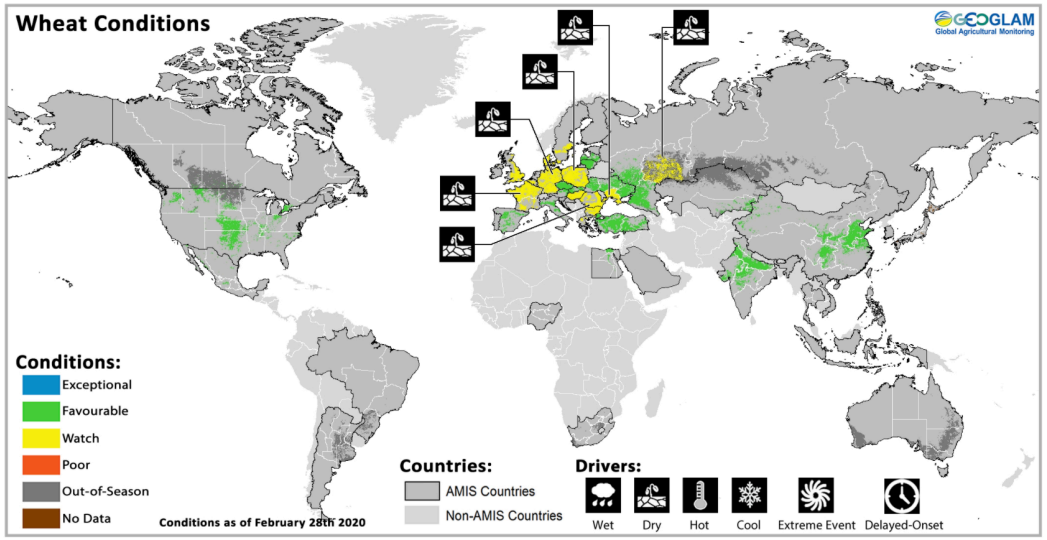
- Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM)
  - Purpose is to increase market transparency and improve food security
  - Reinforces the international community's capacity to produce and disseminate relevant, timely, and accurate projections of agricultural production at national, regional, and global scales
  - Achieves this by strengthening the international community's capacity to utilize coordinated, comprehensive, and sustained Earth observations
  - http://earthobservations.org/geoglam.php

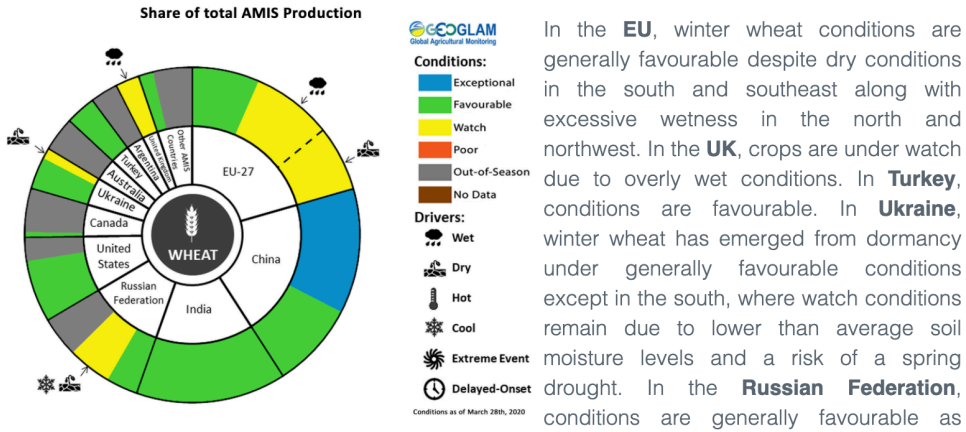


Operational Agricultural Monitoring Systems

Two monthly global crop condition reports have been established within GEOGLAM:

- Crop Monitor for the Agricultural Monitoring Information System (AMIS)
  - Major producing and trading countries for the four primary crops monitored by AMIS (wheat, maize, rice, and soy)
- Crop Monitor for Early Warning (CM4EW)
  - Monitoring of countries at risk of food production shortfalls and where food security is extremely vulnerable
- https://cropmonitor.org/





In the **EU**, winter wheat conditions are generally favourable despite dry conditions in the south and southeast along with excessive wetness in the north and northwest. In the **UK**, crops are under watch due to overly wet conditions. In **Turkey**, conditions are favourable. In **Ukraine**, winter wheat has emerged from dormancy under generally favourable conditions except in the south, where watch conditions remain due to lower than average soil moisture levels and a risk of a spring drought. In the **Russian Federation**, conditions are generally favourable as

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National Aeronautics and Space Administration

Next week: Evapotranspiration & Evaporative Stress Index for Agricultural Applications

May 5, 2020

Question & Answer Session

- Please enter your questions in the chat box.
- We will post the questions and answers to the training website following the conclusion of the course:

  https://arset.gsfc.nasa.gov/water/webinars/remote-sensing-for-agriculture-20

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Appendix

Ancillary Datasets

- Sen2-Agri system:
  - Free and open source, operational, standalone processing system generating agricultural products from Sentinel-2 (A&B) and Landsat 8 time series' along the growing season
  - http://www.esa-sen2agri.org/
- GEOGLAM Rangeland and Pasture Productivity (RAPP)
  - Global Monitoring System
- UN Food and Agriculture Organization (FAO)
  - Harmonized World Soil Database v1.2
- USGS – Global Hyperspectral Imaging Spectral-Library of Agricultural Crops for the Conterminous United States (GHISACONUS)
  - Hyperspectral Library developed for all major world agricultural crops