

# The GEO Global Agricultural Monitoring (GEOGLAM) Initiative

Chris Justice

GEOGLAM Co-Chair

NASA Harvest Consortium, Science Lead

Chair, Department of Geographical Sciences,

University of Maryland, USA



# GEO is the international program focused on the use of Earth Observations for societal benefit

- GEO was initiated in 2005
- Inter-ministerial body
- Agriculture is one of the GEO societal benefit areas
- GEOGLAM is GEO's Agricultural initiative





# GEOGLAM: a GEO Initiative

- Vision: the use of coordinated, comprehensive and sustained Earth Observations to inform decisions and actions in agriculture... through a system of agricultural monitoring systems
- Aim: Strengthen the international community's capacity to utilize Earth Observations to produce and disseminate relevant information on agricultural production at national, regional and global scales
- Approach: Building on existing monitoring systems – strengthening international and national capacity
- Emphasis on: producer countries (G20+), countries-at-risk and **national capacity building**

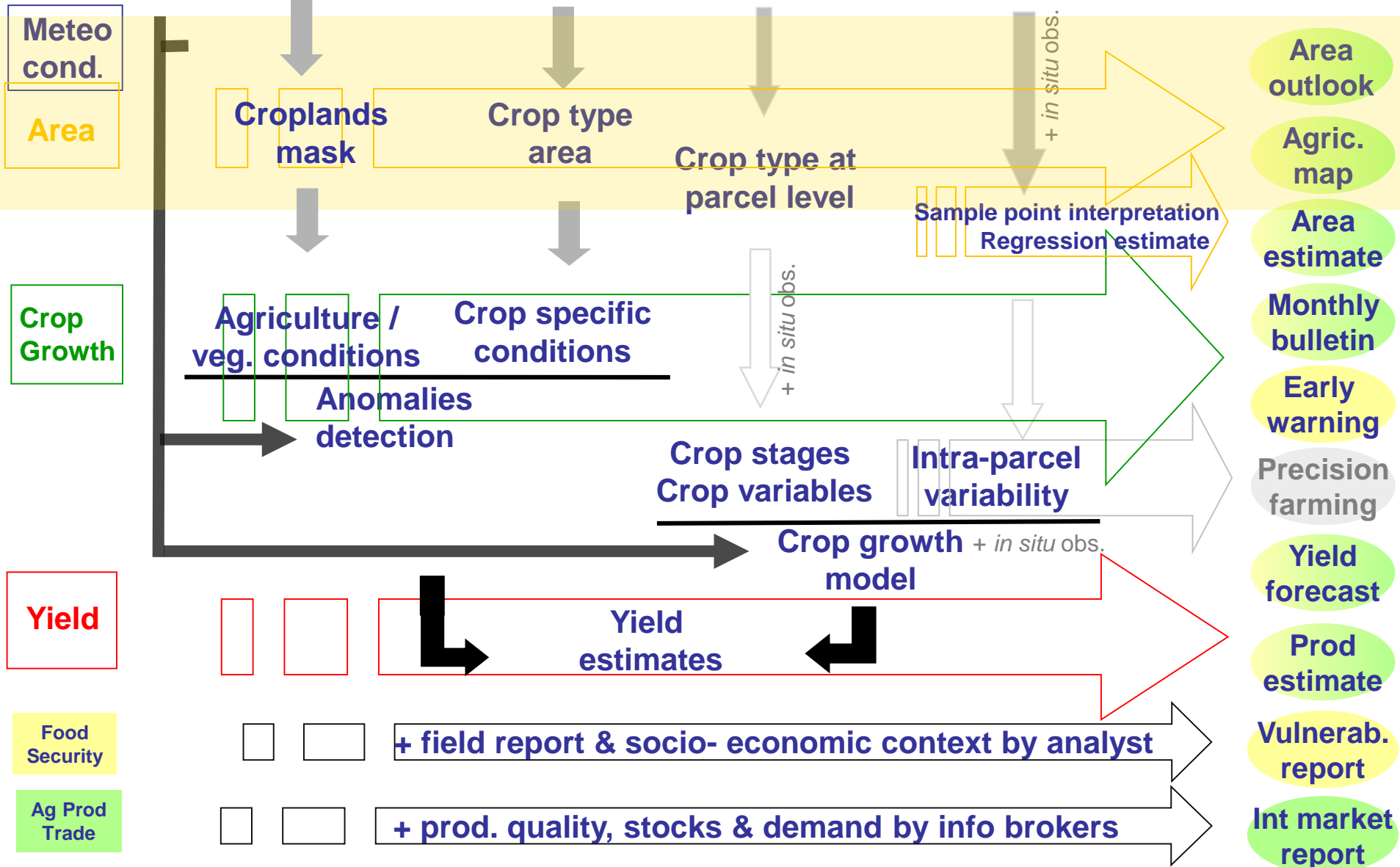
# Agricultural Monitoring : EO data and Final products

*Spatial resolution / Revisiting capacities*

**EO**



Information

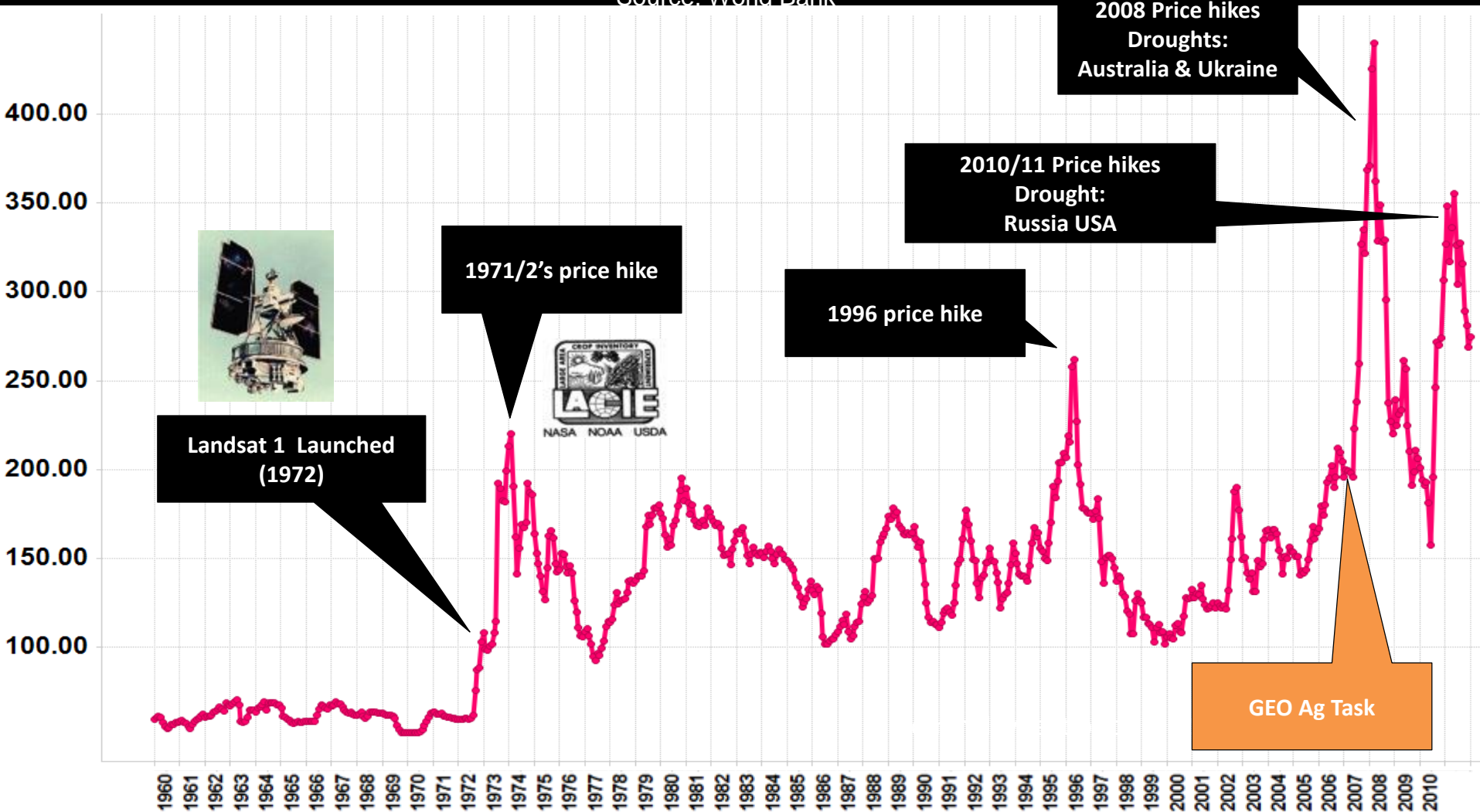




# Context For GEOGLAM

## Monthly Wheat Prices 1960-2011 (\$/Metric Ton)

Source: World Bank





International recognition of critical need for improved real-time, reliable, open information on global agricultural production prospects

Critical for agricultural policies, stabilizing markets, averting food crises and

Need to increase food production by 50%-70% by 2050 to meet demands (FAO)



THE POLICY MANDATE:  
2011 G20 ACTION PLAN ON FOOD PRICE VOLATILITY

# Policy Framework for GEOGLAM

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## G20 Final Declaration

44. We commit to improve market information and transparency in order to make international markets for agricultural commodities more effective. To that end, we launched:
- The "Agricultural Market Information System" (AMIS) in Rome on September 15, 2011, to improve information on markets ...;
  - The "**Global Agricultural Geo-monitoring Initiative**" (**GEO-GLAM**) in Geneva on September 22-23, 2011. This initiative will coordinate satellite monitoring observation systems in different regions of the world in order to enhance crop production projections and weather forecasting data.





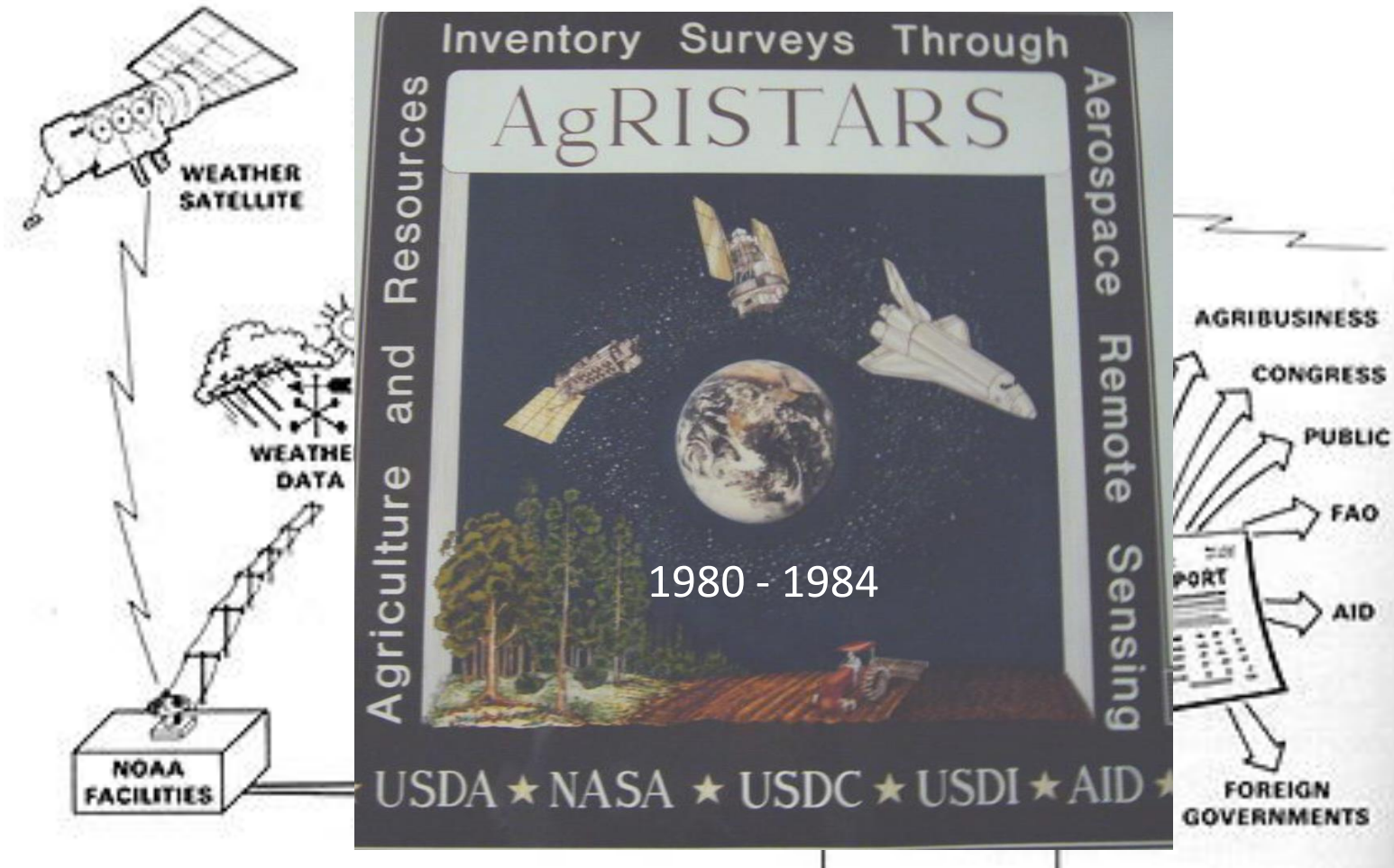
# AMIS: Agricultural Market Information System

Improve market information and transparency

inter-Agency Platform to enhance food market transparency and encourage coordination of policy action in response to market uncertainty

[www.amisoutlook.org](http://www.amisoutlook.org)

# The Potential of Remote Sensing of Global Agriculture



Circa 1980

## STANDARD PRODUCTS TABLE

### BLACK AND WHITE PRODUCTS

NOMINAL IMAGE SIZE	PRODUCT		PRICE
	MATERIAL	CODE	
55.8mm (2.2 in.)	Film Positive	11	\$ 8.00
55.8mm (2.2 in.)	Film Negative	01	10.00
18.5cm (7.3 in.)	Paper	23	8.00
18.5cm (7.3 in.)	Film Positive	13	10.00
18.5cm (7.3 in.)	Film Negative	03	10.00
37.1cm (14.6 in.)	Paper	24	12.00
74.2cm (29.2 in.)	Paper	26	20.00

### FALSE COLOR COMPOSITE PRODUCTS

NOMINAL IMAGE SIZE	PRODUCT		PRICE
	MATERIAL	CODE	
18.5cm (7.3 in.)	Paper	63	\$12.00
18.5cm (7.3 in.)	Film Positive	53	15.00
37.1cm (14.6 in.)	Paper	64	25.00
74.2cm (29.2 in.)	Paper	66	50.00

**PRICES SUBJECT TO CHANGE.**

TOTAL ABOVE  
TOTAL FROM PREVIOUS SHEET  
TOTAL COST

### COLOR COMPOSITE PRODUCTS

NOMINAL IMAGE SIZE	MATERIAL	CODE	PRICE

NOTE: Not applicable for RBV Subscenes. Cost of composite must be added.

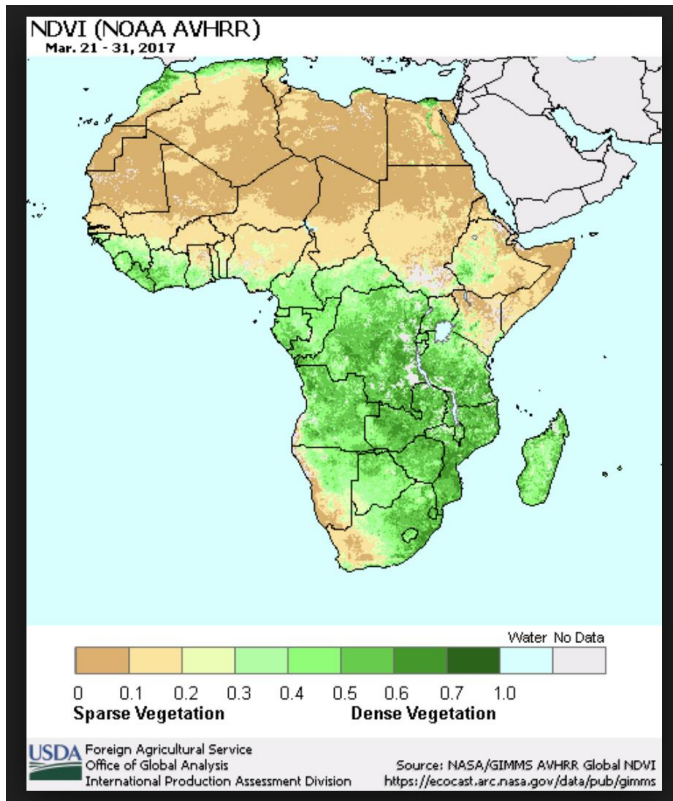
### COMPUTER COMPATIBLE TAPES (CCT)

TRACKS	BPI	FORMAT	MSS All Bands Available		RBV Single Subscene		Set of Four RBV Subscenes	
			PRODUCT CODE	PRICE	PRODUCT CODE	PRICE	PRODUCT CODE	PRICE
9	800	TAPE SET	183-B	\$200.00	183-C	\$200.00	183-D	\$400.00
9	1600	TAPE SET	184-B	200.00	184-C	200.00	184-D	400.00

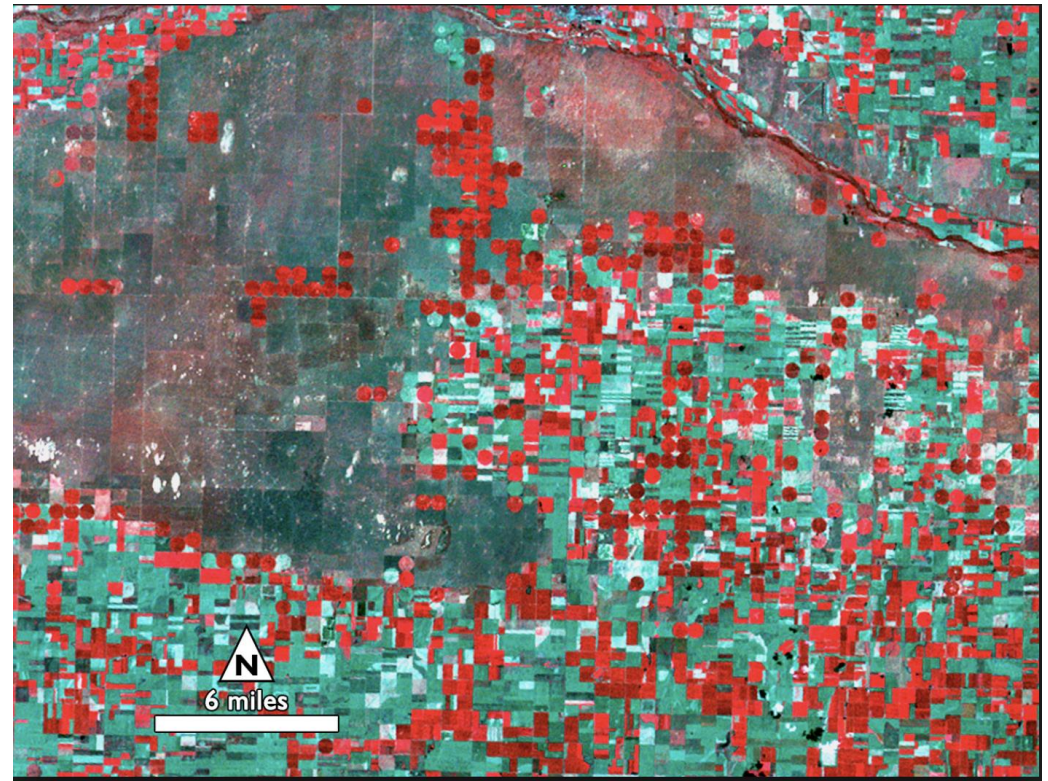
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# Monitoring Legacy AVHRR and Landsat (Capability and Limitation)



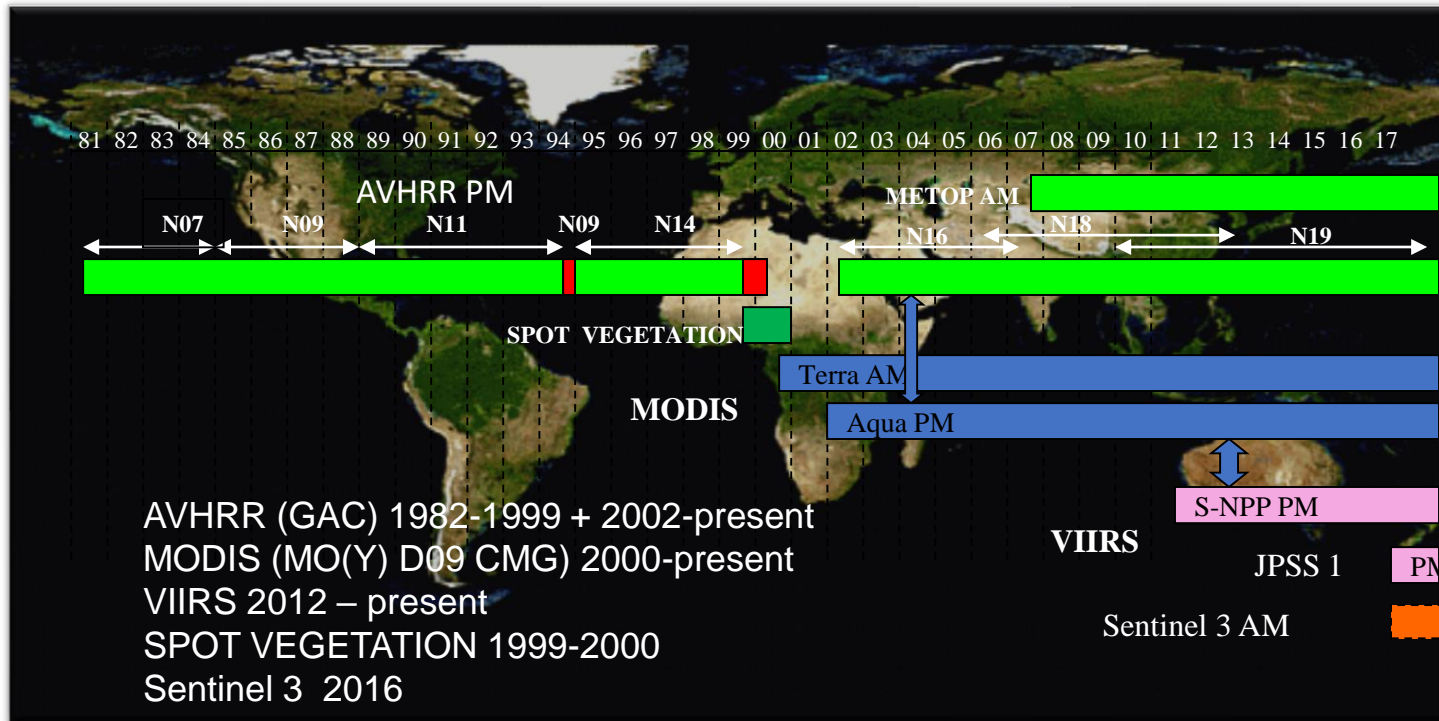
Coarse Resn 4km daily



Moderate Resn 30m every 16 days

1980 - 2000

# Coarse Resolution Data Continuity (AVHRR>MODIS>VIIRS)



NASA Long Term Data Record Product: a Multi instrument/Multi sensor Long Term Science-Quality Data Records used to quantify trends and changes - **Eric Vermote PI**

# MODIS Land Products c. 2005

- **Energy Balance Product Suite**

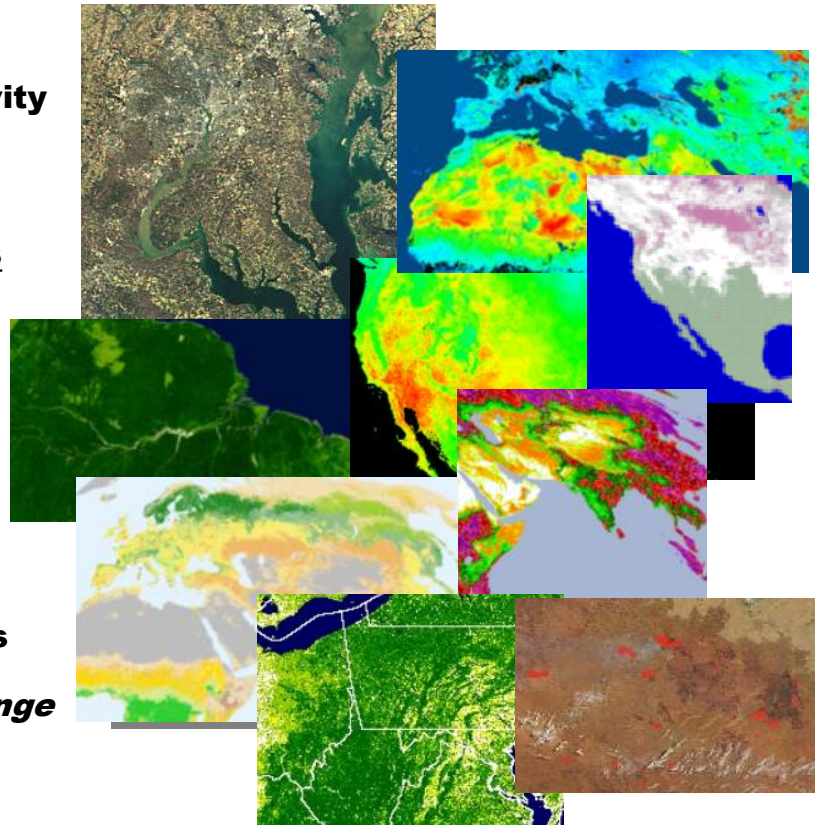
- **Surface Reflectance**
- **Land Surface Temperature, Emmissivity**
- **BRDF/Albedo**
- **Snow/Sea-ice Cover**

- **Vegetation Parameters Suite**

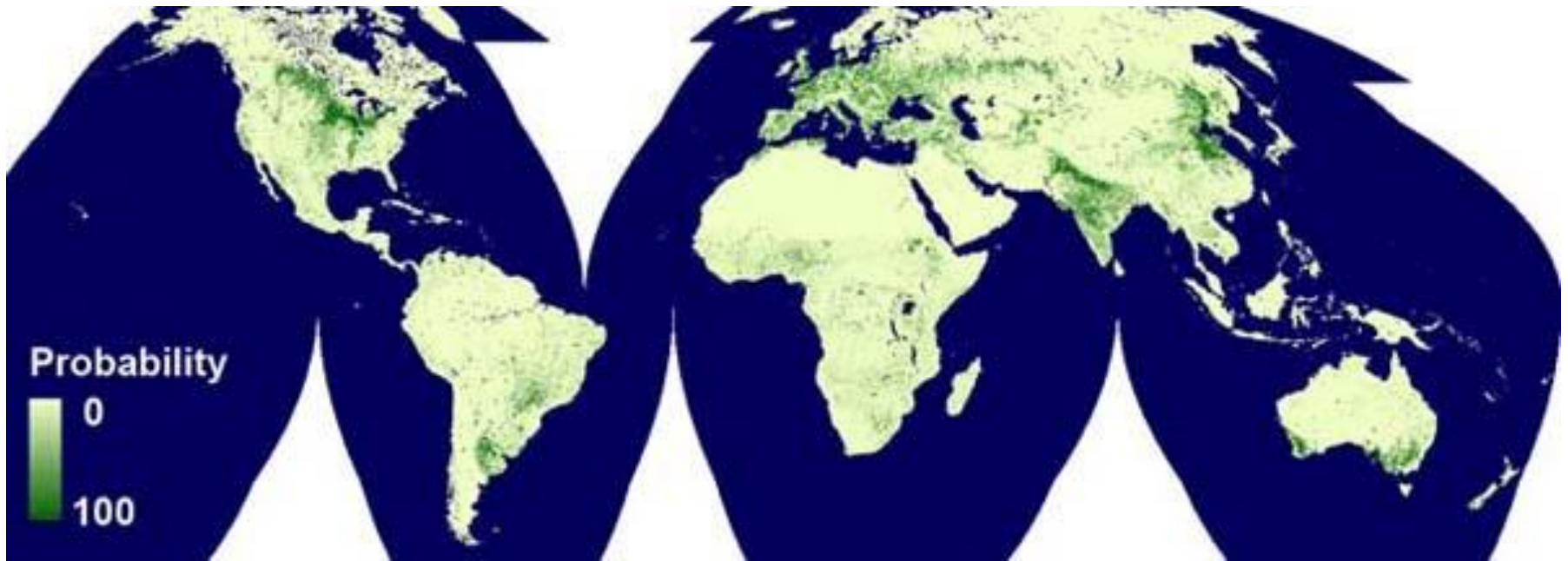
- **Vegetation Indices**
- **LAI/FPAR**
- **PSN/NPP**

- **Land Cover/Land Use Suite**

- **Land Cover**
- **Vegetation Phenology**
- **Vegetation Continuous Fields**
- ***Vegetation Cover Change***
- **Fire**
- **Burned Area**



# MODIS 250m Global Cropland Probability



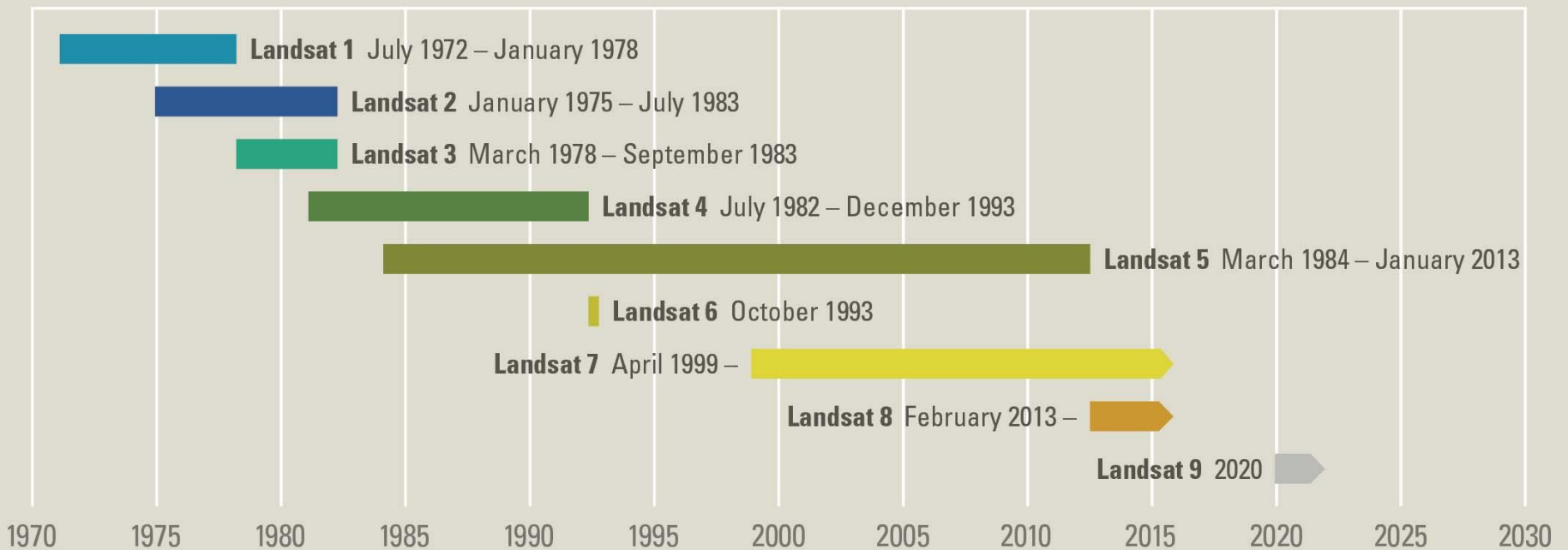
<https://glad.umd.edu/>

Global Daily Data 250m-1km Resn  
AM (Terra) and PM (Aqua)  
2000 - Present

Pitman et al 2010

# Landsat Program: dynamic data continuity

## Moderate Resolution





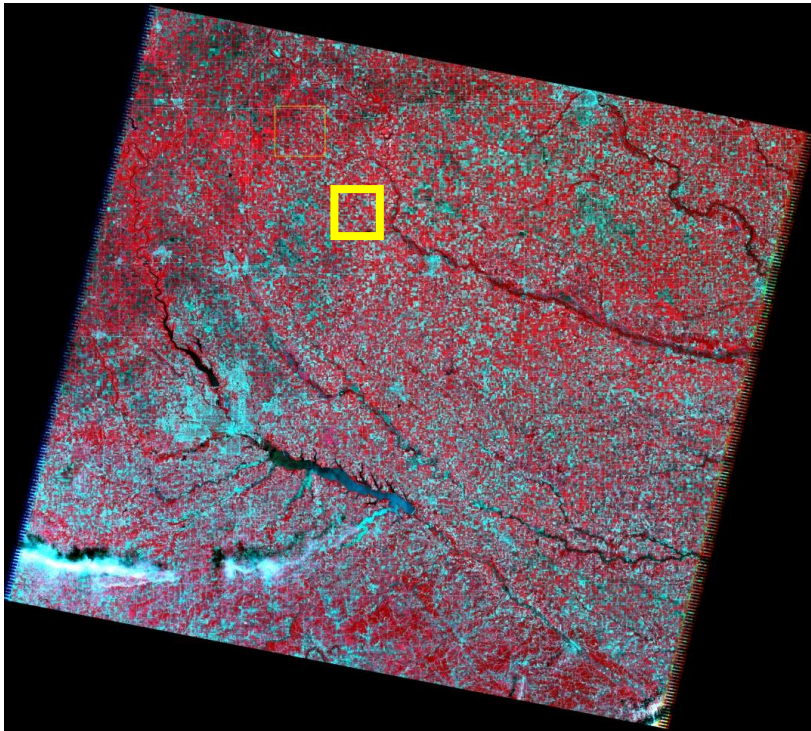
# Landsat 8 - Pan Sharpened (15m)



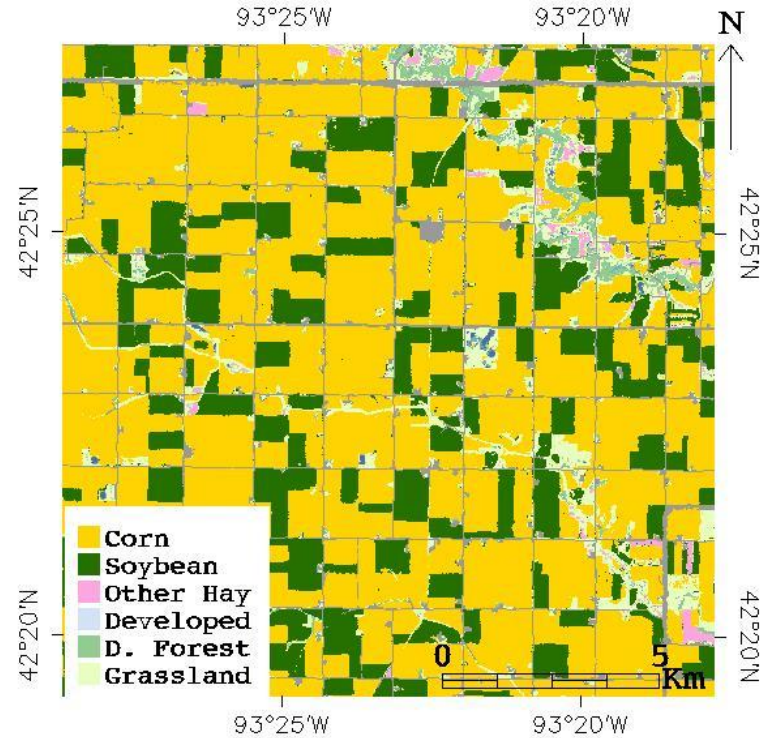
June 6 2013. Landsat 8 w. 16 day repeat – Global coverage

USGS

# USDA NASS: An Example South Fork, Iowa



WRS-2 Path 26 Row 31



USDA NASS Cropland Data Layer (2011)

(six pairs of Landsat and MODIS images from July 2 to Nov. 7, 2011)

NASS Purchased IRS and DMC Data to replace Landsat 7 after 2003



# The GEOGLAM Challenge

- Development of robust, standardized, operationally viable methods for agricultural monitoring, forecasting, and assessments of global food production applicable at field to global scales across diverse agricultural systems
- Ensure coordinated, sustained and accessible EO data
- Transition research into operational systems
  - Capacity building and sustained relationship between international and national R&D community and operational end users
- Broad and effective communication to decision makers
  - ministries, farmers, extension, private sector, insurance to policy and economics communities

**Too big for one country or agency – need for international coordination and collaboration**

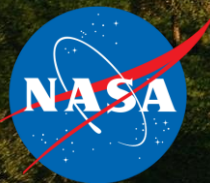


# NASA HARVEST

Earth Data for Enhancing Food Security and Agricultural Decisions  
A Contribution to GEOGLAM

**P.I. Inbal Becker-Reshef,**

*This Meeting Attendees: Chris Justice, Eric Vermote, Krishna Vadrevu,  
Christina Justice, Meghavi Prashnani*





EARTH DATA FOR INFORMED  
AGRICULTURAL DECISIONS



# NASA Harvest

Launched Dec 2017



- NASA's Applied Sciences Program on Food Security and Agriculture
- NASA's contribution to GEOGLAM
- Domestic and international focus
- End-user driven
- Demonstrate socioeconomic benefits of earth observations for agriculture
- Led by University of Maryland

[www.nasaharvest.org](http://www.nasaharvest.org)



# The GEOGLAM Components

**1. Global / Regional  
Monitoring Systems**

International/Global

**2. National  
Monitoring Systems**

National / Subnational

**3. Monitoring  
Countries at Risk**

Food Insecure and Most  
Vulnerable

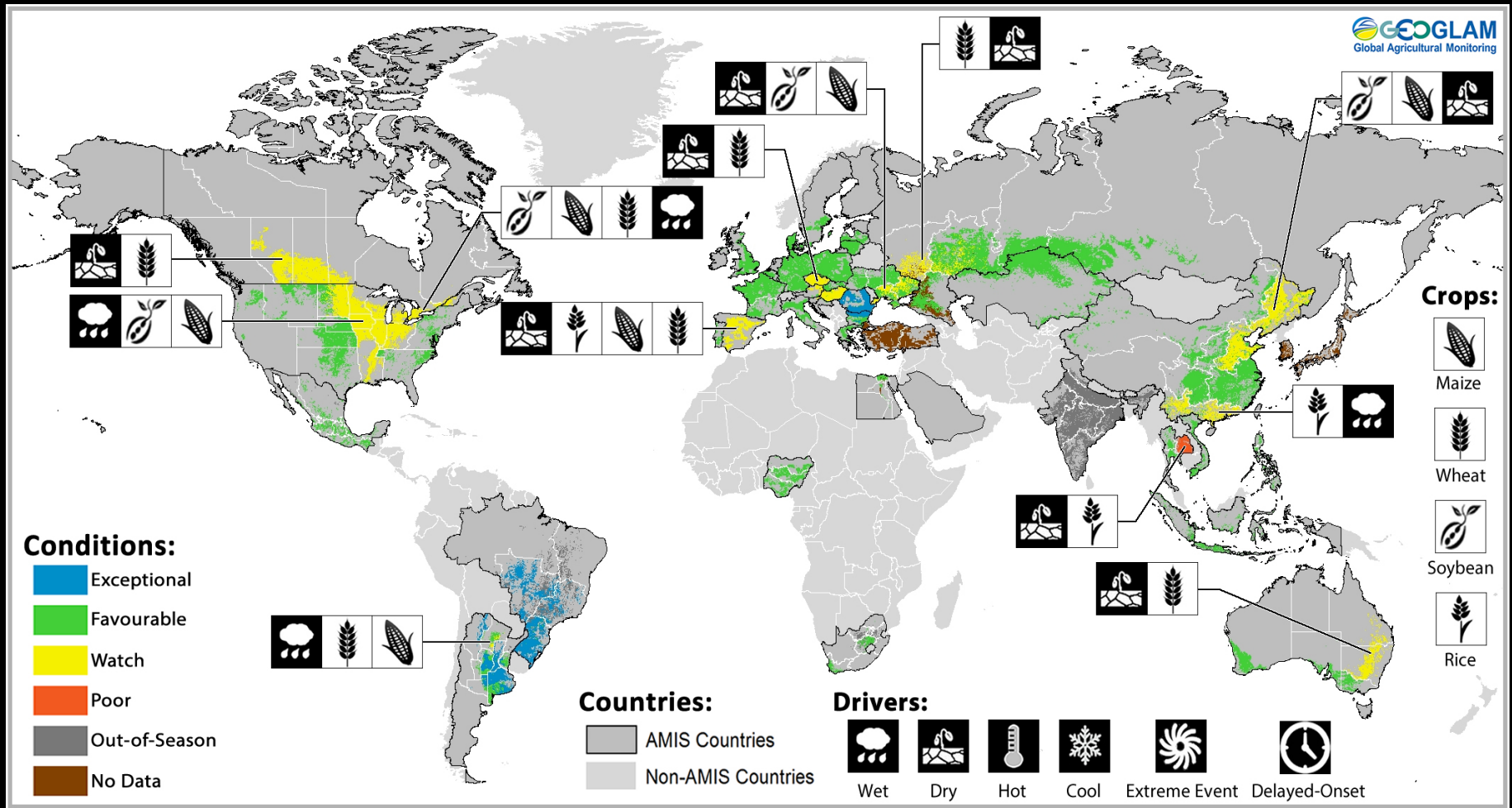
**4. EO Data Acquisition & Dissemination Coordination** 

**5. Research & Development toward Operations**

**6. Capacity Development for EO**



# GEOGLAM Crop Monitor for AMIS - June 2019





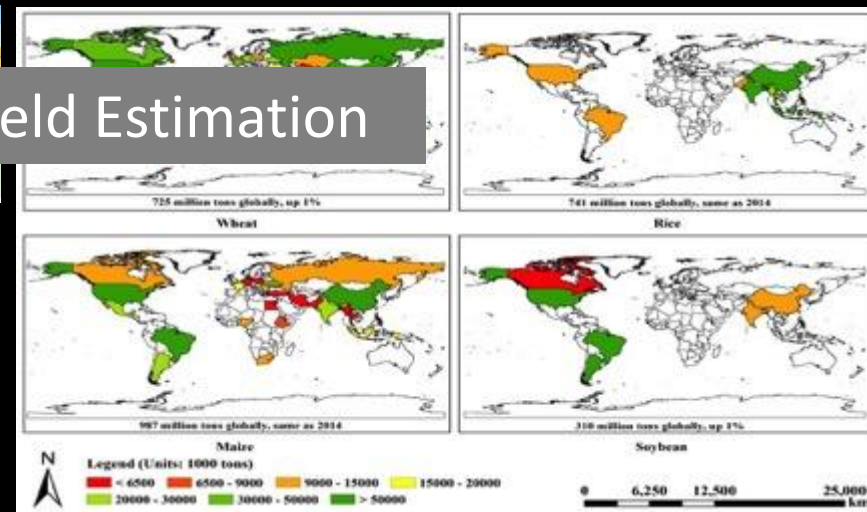


# CropWatch (CAS China)

- Serves as a science-based Chinese voice on global food security perception
- Provide additional, reliable information for developing countries to fight hunger
- Offers global information and net-based services for free
- Downloaded >27,000 times from >110 countries
- Working in the Cloud



Crop Condition > Yield Estimation



# Making RS Indicators Accessible to Non Expert Communities

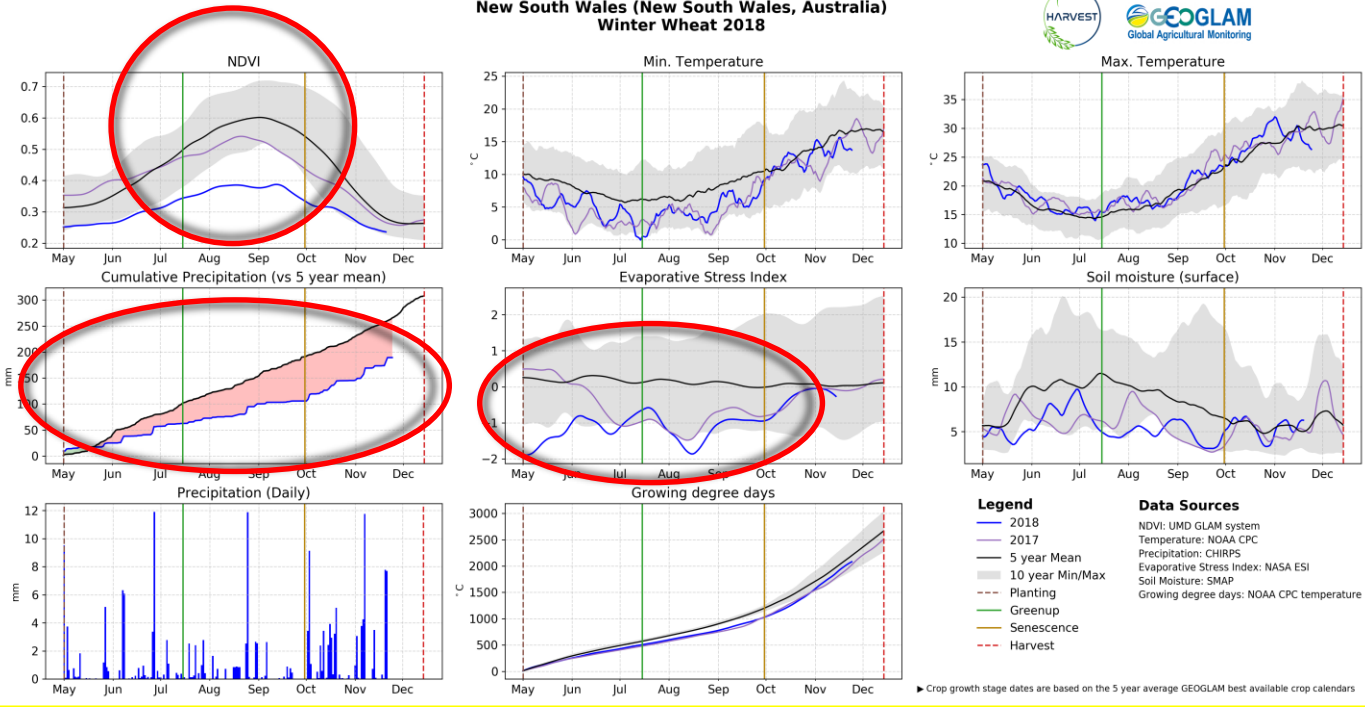
Integration into OECD Agricultural Indicators Platform



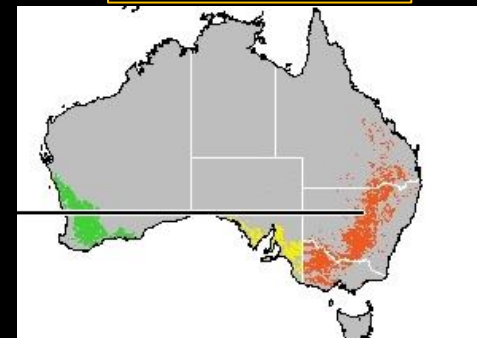
Example: Tracking Drought in Australia, 2018

## New South Wales, Australia, Wheat

New South Wales (New South Wales, Australia) Winter Wheat 2018



NSW: 60% decline in production relative to average



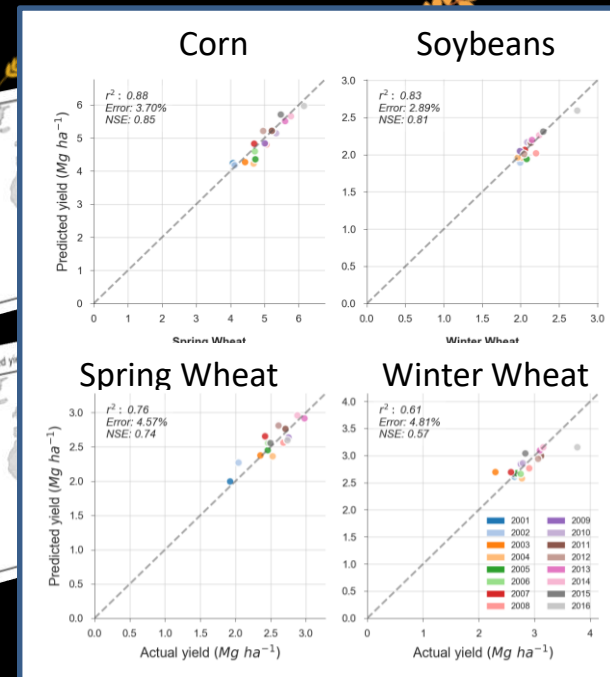
**REUTERS**

### Australia cuts wheat harvest forecast to 10-year low

Decline in exports expected as drought reduces crop

03 DECEMBER 2018 - 16:33 by REUTERS

# Crop Yield Forecasting of Major Export & Producer Countries



Sahajpal et al. UMD

**Reliable Forecasts within 3-5% 2 months prior to harvest**

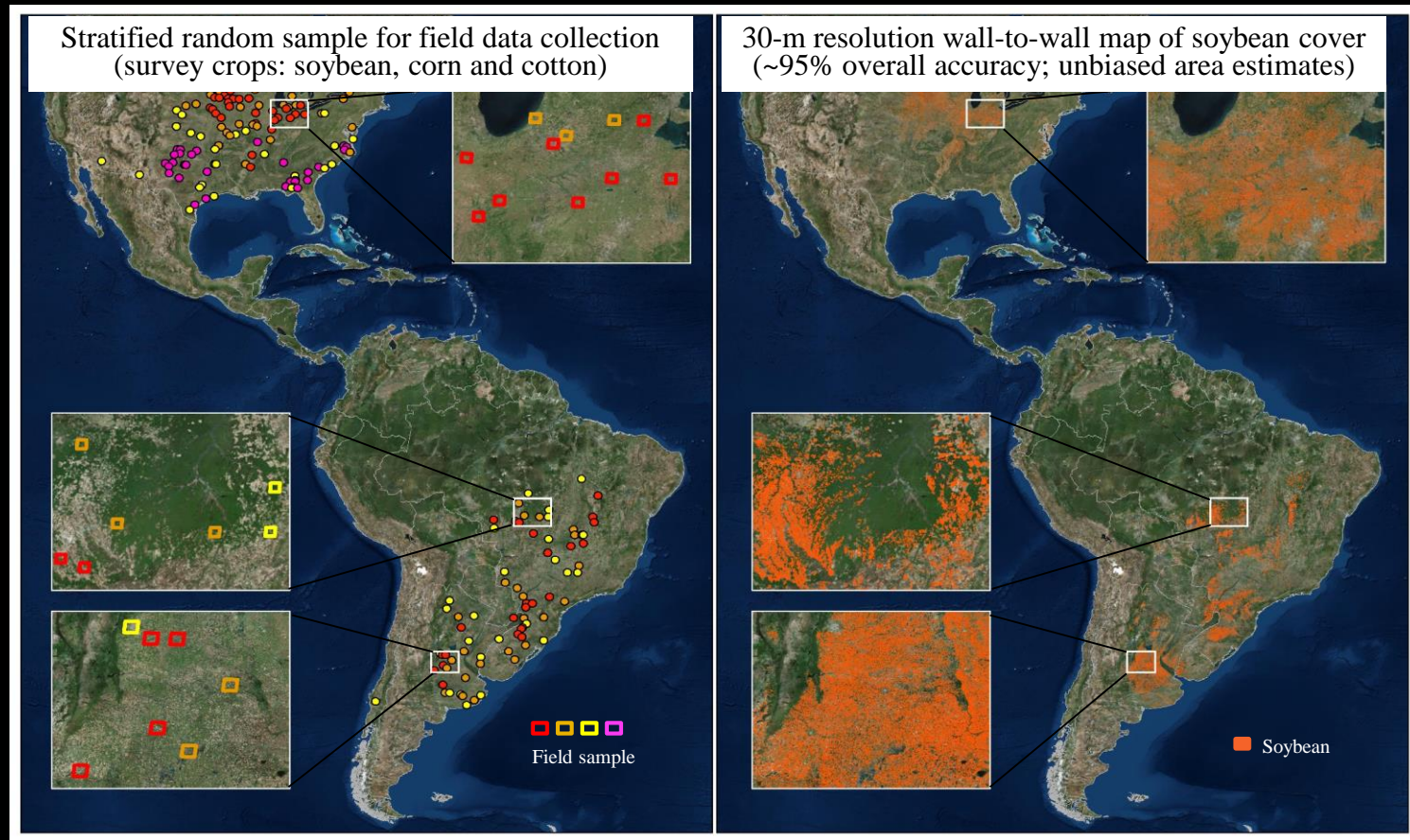


# Asia-RiCE (JAXA) Regional Activity with National Collaborations

- Agencies in Asia launched Asia-RiCE (Asia Rice Crop Estimation & Monitoring) program as a contribution to GEOGLAM
- **Objective:** to estimate rice crop area and production using available radar and other satellite data with ground observation data and statistical information (test-sites in Indonesia, Thailand and Vietnam)
- Led by Japan (JAXA), with collaborations in ASEAN+3 countries and India



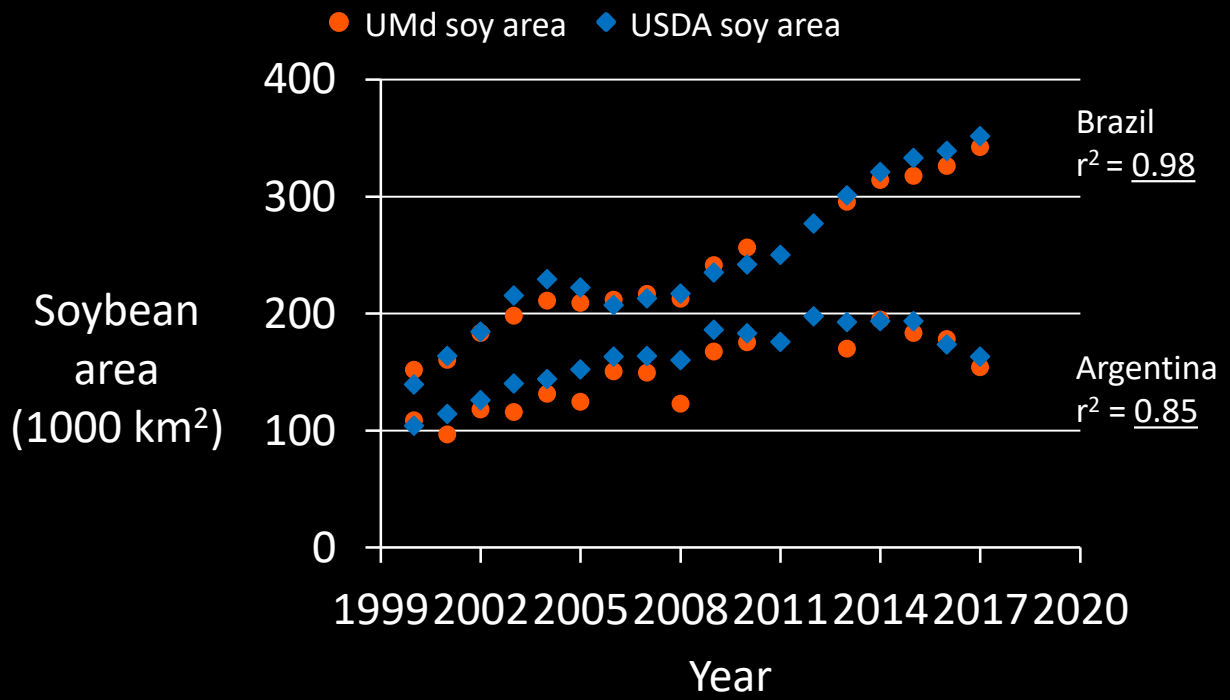
# National-to-continental Scale, In-season Crop Area Estimation & Mapping



Hansen,  
Song et al.



# Soybean area expansion in South America 2000 - 2017



Exploring transferability of these approaches to small-holder systems

Hansen, Song et al.



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6. Capacity Development for EO

# Top priority : open source system to deliver Sen2-Agri products within season



*in line with the GEOGLAM core products*

Monthly cloud free surface reflectance composite at 10-20 m

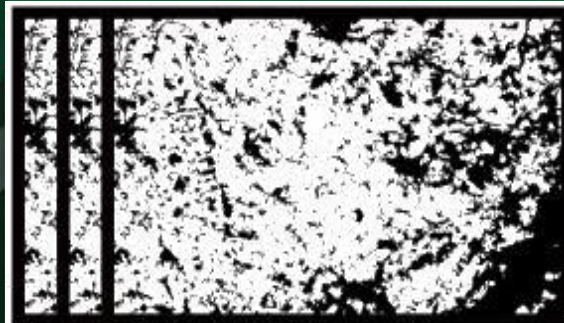
## CLOUD FREE SURFACE REFLECTANCE COMPOSITES



Growing season (monthly updates)

Vegetation status map at 10 m delivered every week (NDVI, LAI, pheno index)

## DYNAMIC CROPLAND MASK



Growing season (monthly updates)

Open source toolbox  
Capacity building and training

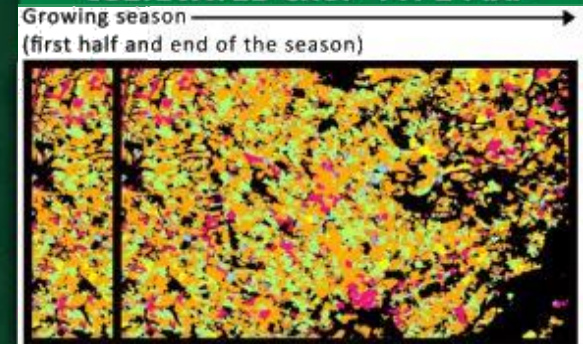
## VEGETATION STATUS



Growing season (weekly updates)

Binary map identifying annually cultivated land at 10m updated every month

## CULTIVATED CROP TYPE MAP



Growing season (first half and end of the season)

Crop type map at 10 m for the main regional crops including irrigated/rainfed discrimination



# Sen2Agri system implemented on commercial cloud infrastructure for operational NRT services



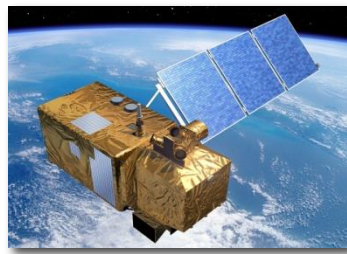
Fully scalable

Close to the Data  
(reduced bandwidth)

Continuous Monitoring

Operational context  
(e.g. timeliness)

Sept.-Nov. 2017,18

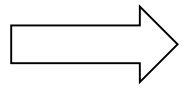


Copernicus

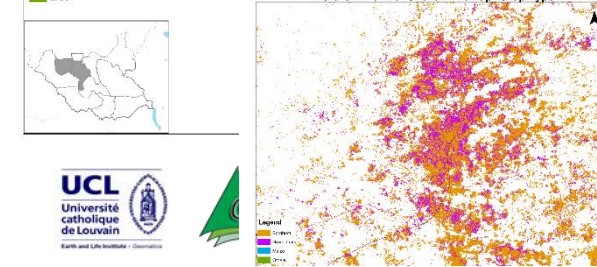
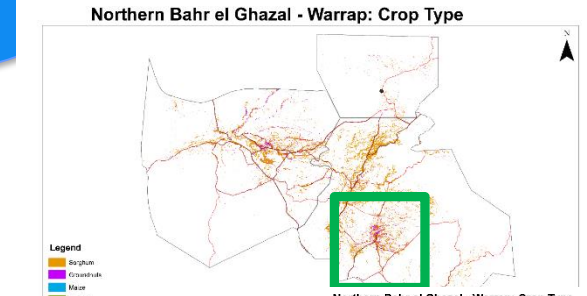
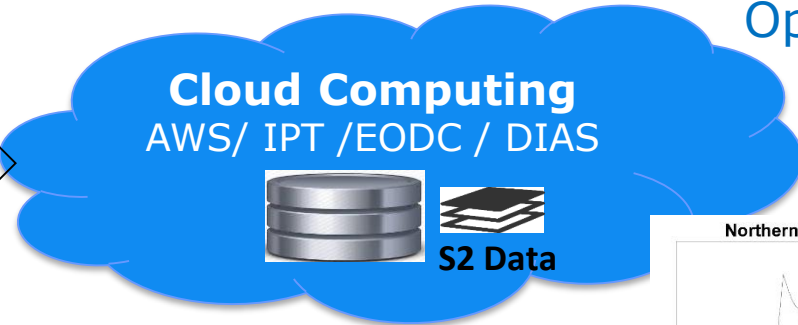
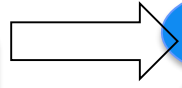


Open Source  
**sentinel-2**

→ AGRICULTURE



In situ Data  
with GeoODK



→ AGRICULTURE



# Software User Manual and Technical Documents

Bi-monthly Webinar focused on different topics

e-Training session for beginners and for advanced users

Check the **Product sheets** and the **Product data structure summary**



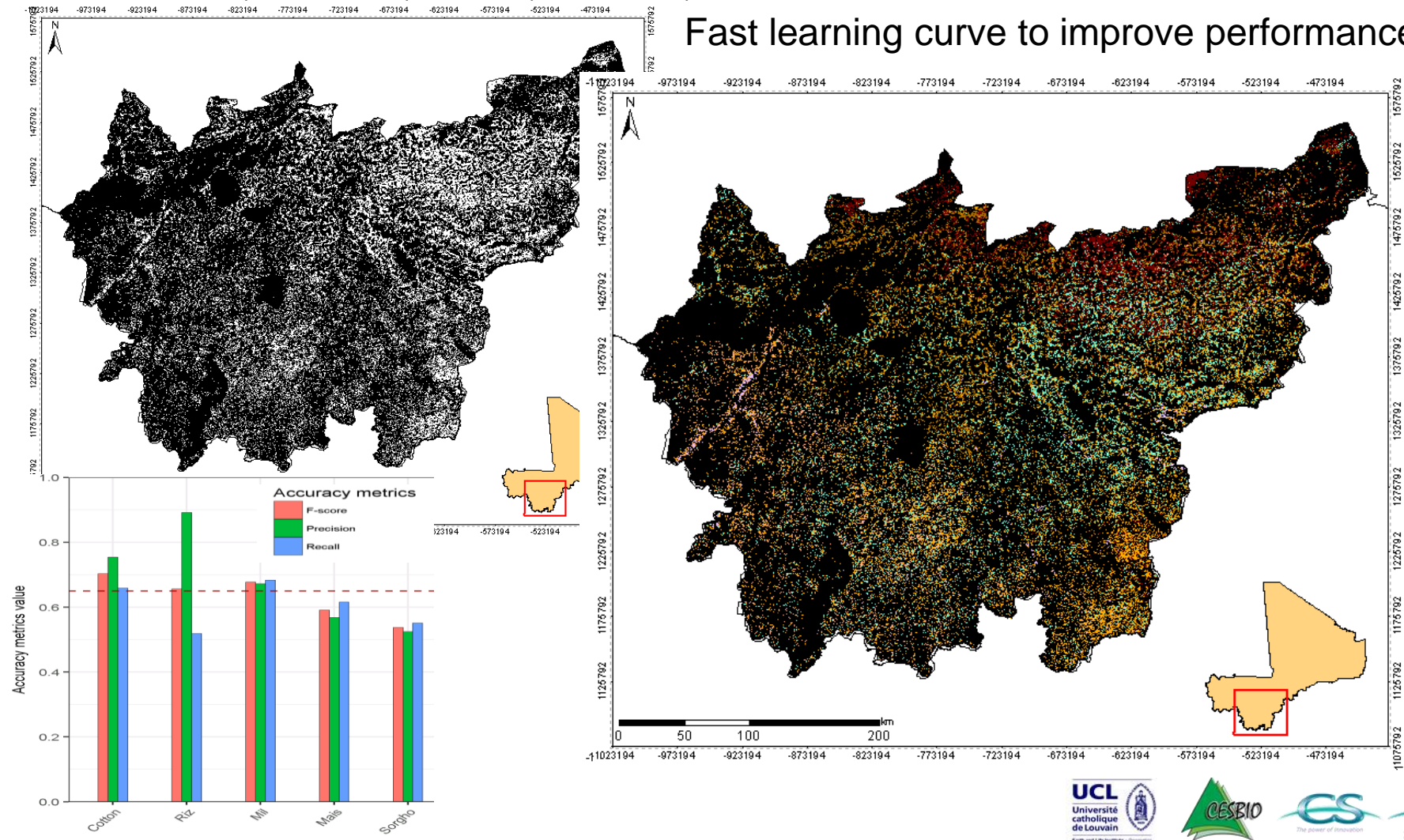
# Sen2-Agri continuation by national demo partners building on lessons learnt – crop type map in Mali



S2A&B: 0.82T of L1C and 3.5T of L2A products (S2A : 1239 products, S2B : 572 products)

Field observation : Cropland : 6332 samples, Non-cropland: 2150 samples

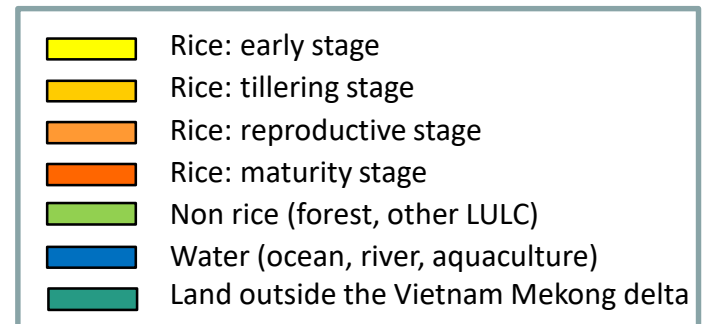
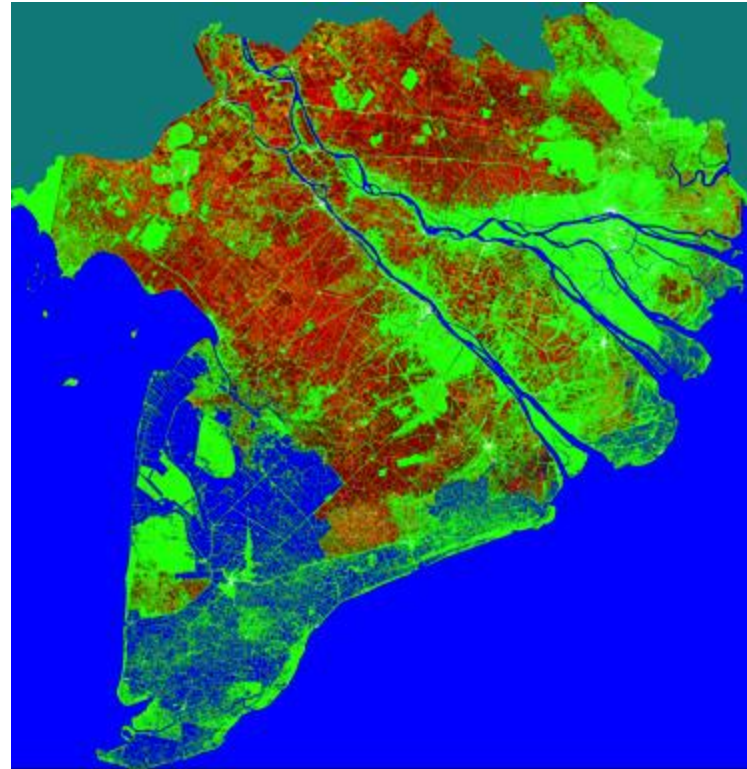
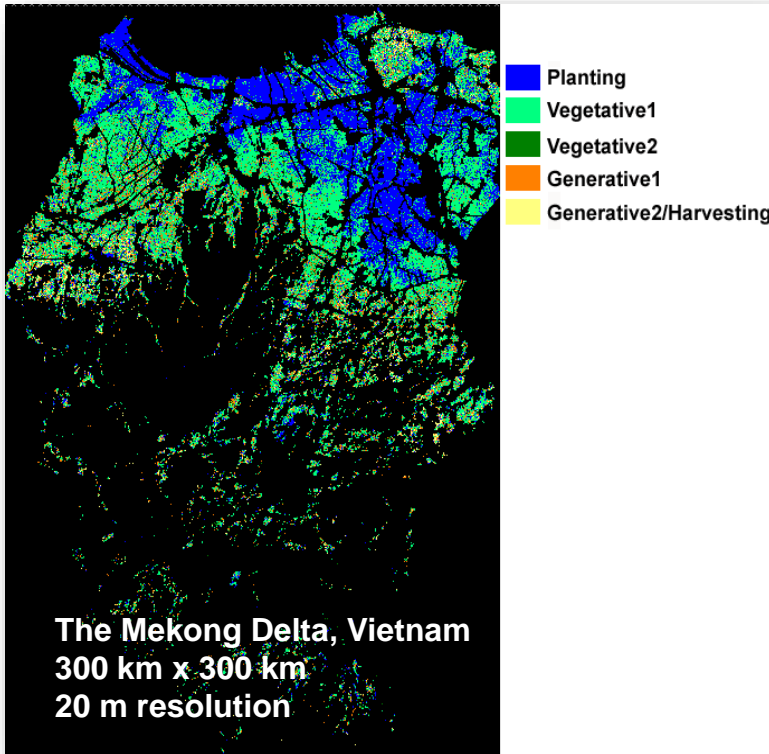
## Fast learning curve to improve performance



# Vietnam Rice Crop Area Estimates/Maps



## Setinel-1a rice crop monitoring in Vietnam



**Rice Phenological Stages Classification using Radarsat-2 Data (VH\_VV)**  
29 July 2014 (Subang Area, West Java) by MOA, LAPAN with JAXA



# Enhancing National Capability with the National Agro-Meteorological Agency, Mozambique using CropWatch Cloud

officially incorporated into the Bulletin in June 2018

Developed by RADI/CAS and deployed via Alibaba Cloud, CropWatch Cloud providing a Portuguese language interface and incorporating local crop phenology and various administrative units..

The Minister of Agriculture and Food Security said “[Mozambique] welcomes the customized CropWatch Cloud, because it might be cost-effective when compared with traditional system.”

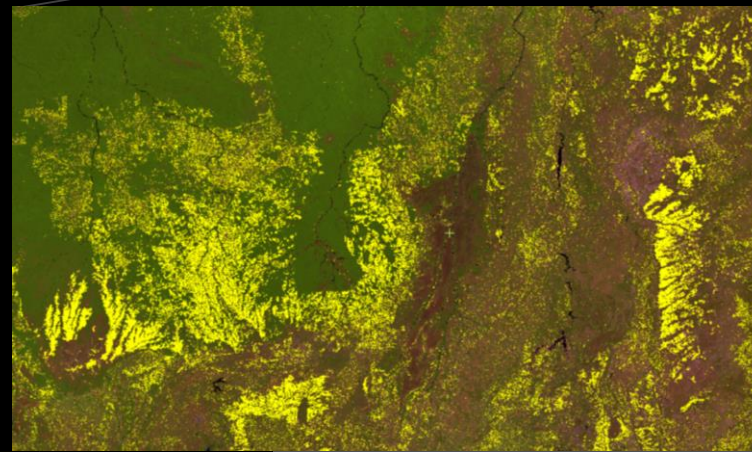


Staff from national and provincial Crop Monitoring and Early Warning departments receive training in Maputo, September 2018

# Enhancing National Scale Cropland Mapping & Capacity Building



- 2017 national cropland extent, 30m spatial resolution
- Participants:
  - Mexico (SIAP)
  - Brazil (CONAB)
  - Argentina (MinAgro)
  - Chile (INIA)
- Initial accuracies ~80%
- Follow up workshop held in Brazil, 8 August 2018 → toward unbiased area estimators



cropland





# The GEOGLAM Components

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**6. Capacity Development for EO**

# Developing the EO Data Requirements for GEOGLAM: through a CEOS/GEOGLAM Ad Hoc Working Group

## Goals of the EO Data Coordination Component.

- Articulate data requirements for agricultural monitoring
- Coordinate international satellite acquisition over agricultural areas during the growing season
- Promote near-real time data availability
- Increase the frequency of moderate resolution data
- Promote standardize processing of data, facilitating data interoperability and inter use
- Promote easy data access for operational users
- Advocate for continuity of critical data streams/products

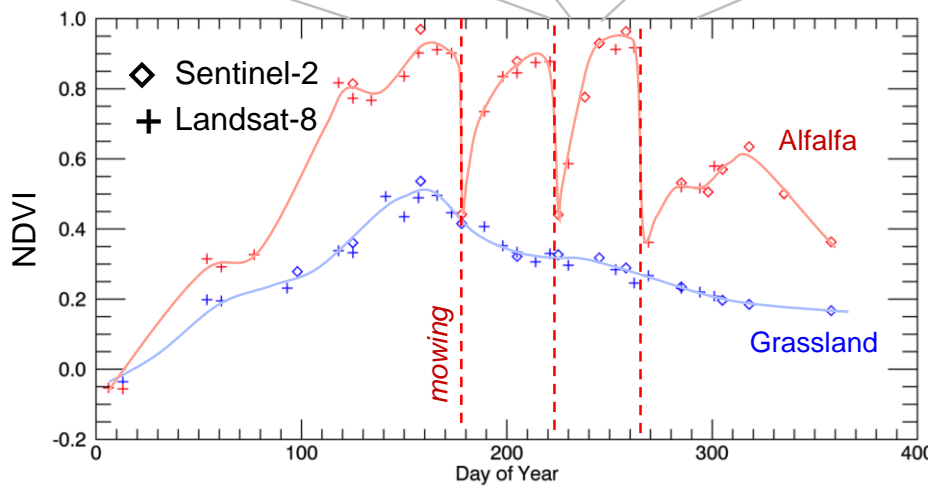
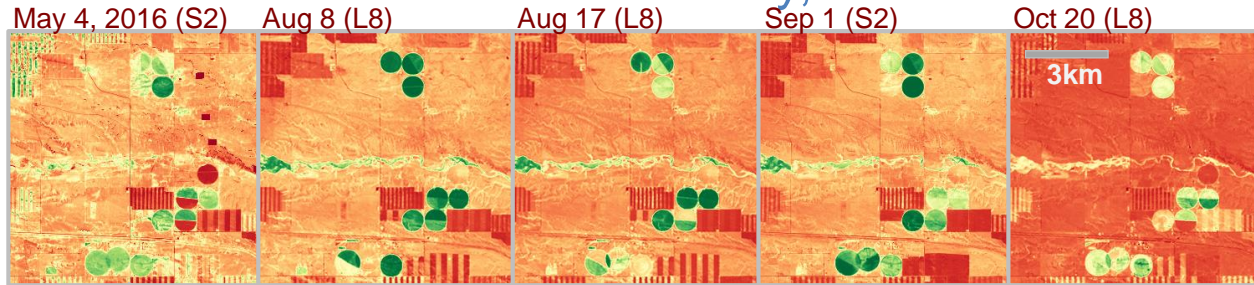
Recognition that cropping systems are inherently diverse which dictates the monitoring observations and methods and that New Sensing Systems are being developed



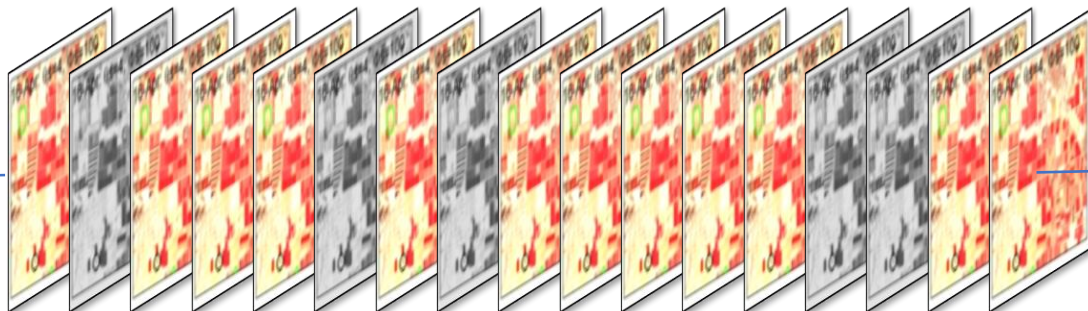


# NASA Harmonized Landsat / Sentinel-2 Products

## Laramie County, WY

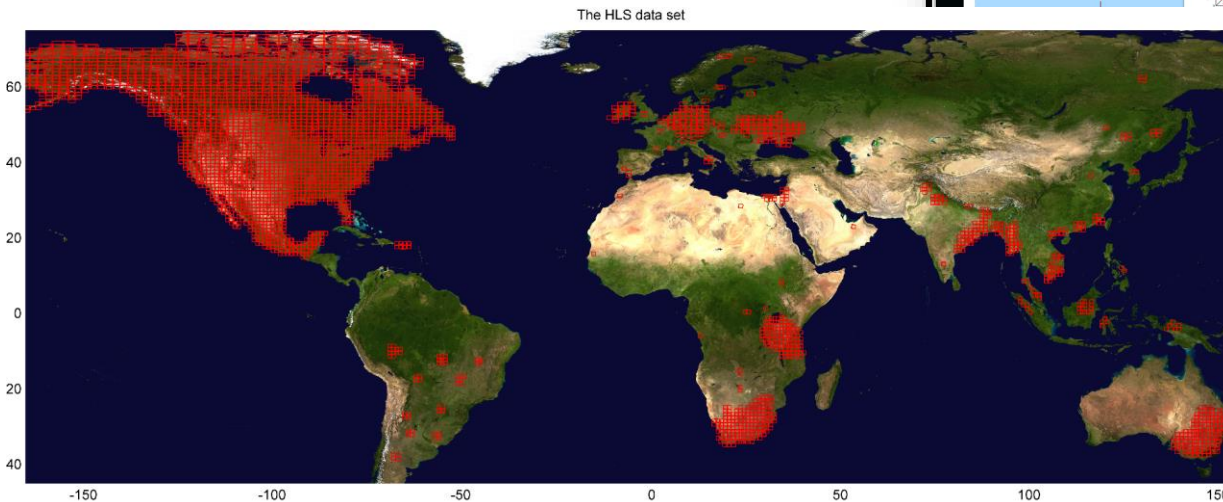
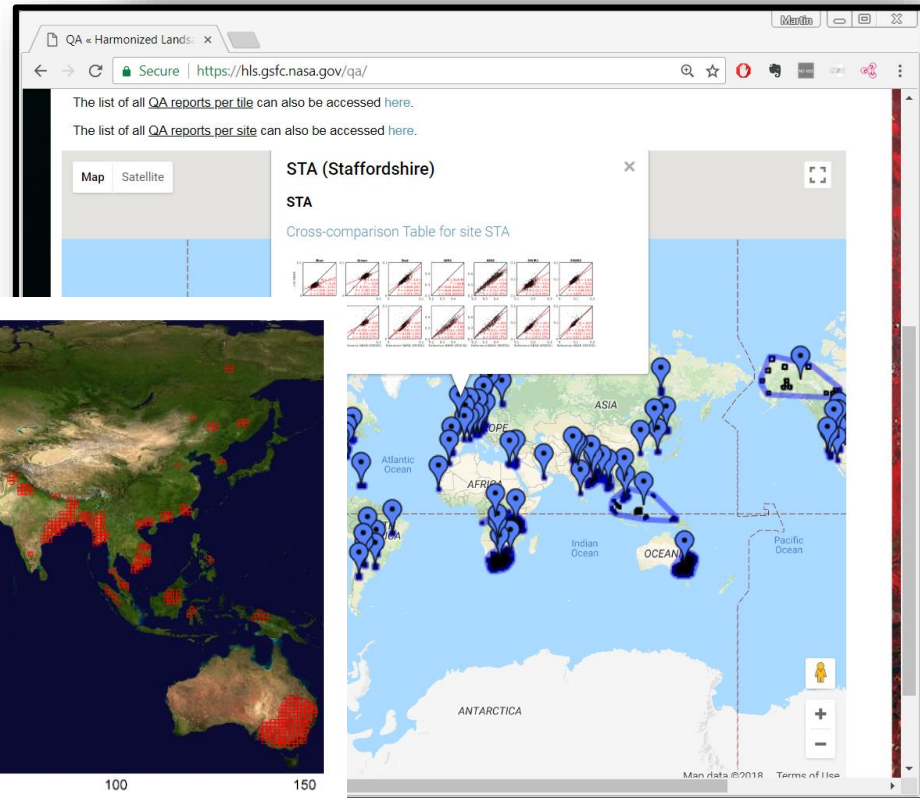
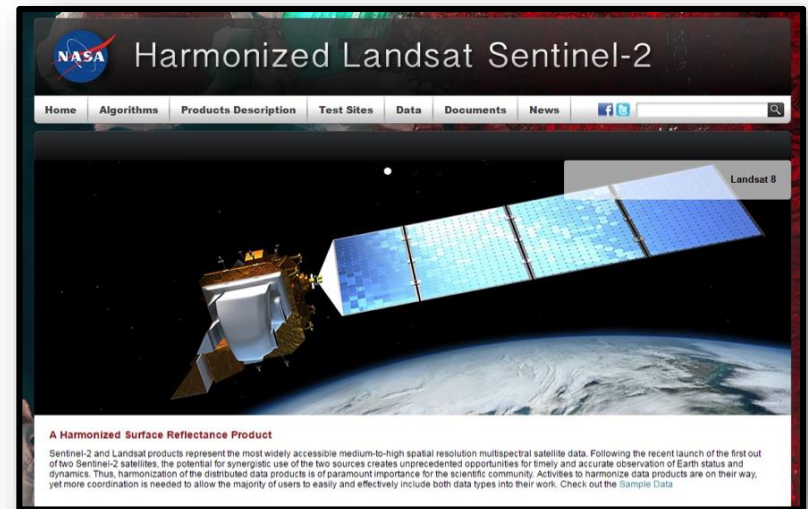


Seasonal phenology (greening) for natural grassland (blue line) and irrigated alfalfa fields (red line) near Cheyenne Wyoming observed from Harmonized Landsat/Sentinel-2 data products. The high temporal density of observations allows individual mowing events to be detected within alfalfa fields. HLS Products available from <https://hls.gsfc.nasa.gov>



# HLS Website and Public Interface

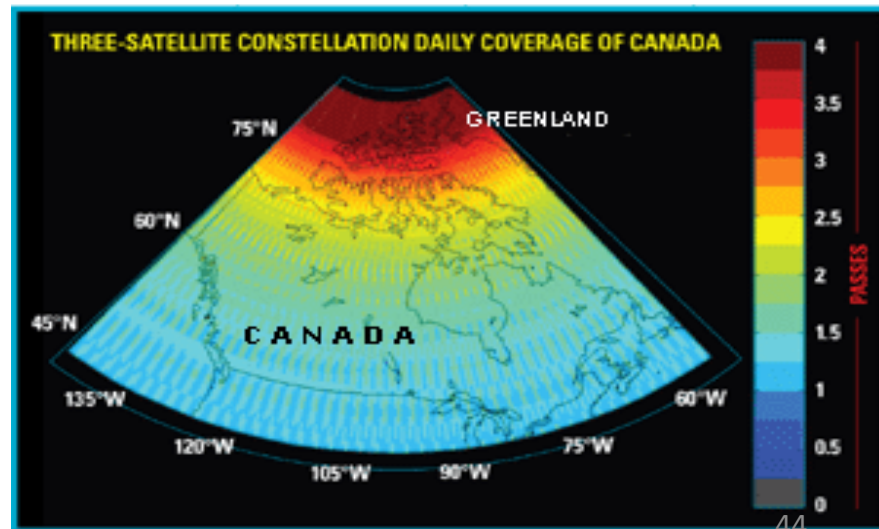
- <https://hls.gsfc.nasa.gov>
- Public access
- S30, L30 data available (via HTTPS)
- QA, Product documentation
- Products also available via S3 storage for AWS users



# RADARSAT Constellation Mission

<http://www.asc-csa.gc.ca/eng/satellites/radarsat/default.asp>

- Evolution of the RADARSAT Program → 3 satellites – 600 km orbit, 32 minutes separation
- Multi-pol and fully polarimetric, high-resolution
- 15 min/orbit imaging (avg) x 3 satellites
- Average daily global access; 4-day exact repeat
- Focus on Marine Surveillance, Disaster Management and Ecosystem Monitoring (*including Agriculture*)
- Open data policy ?



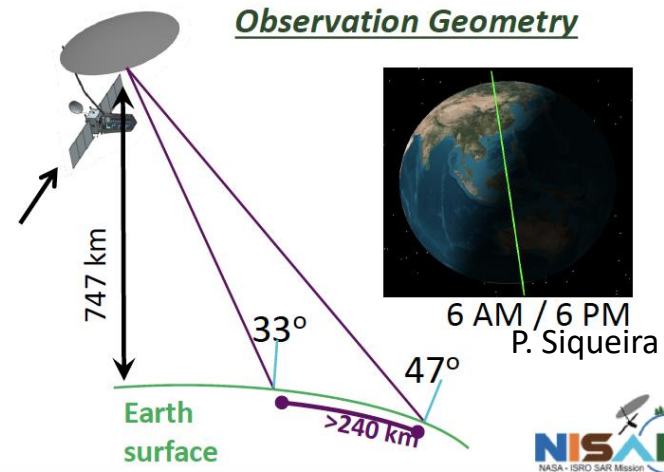
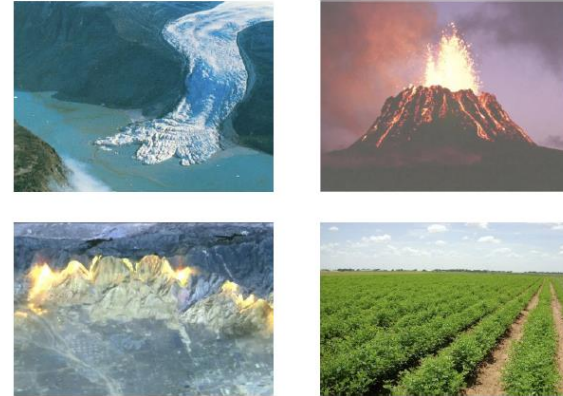
# NISAR



## NASA ISRO Synthetic Aperture Radar – Launch 2021

NISAR Characteristic:	Would Enable:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 years science operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
> 30% observation duty cycle	Complete land/ice coverage cycle
Left/Right pointing capability	Polar coverage, north and south

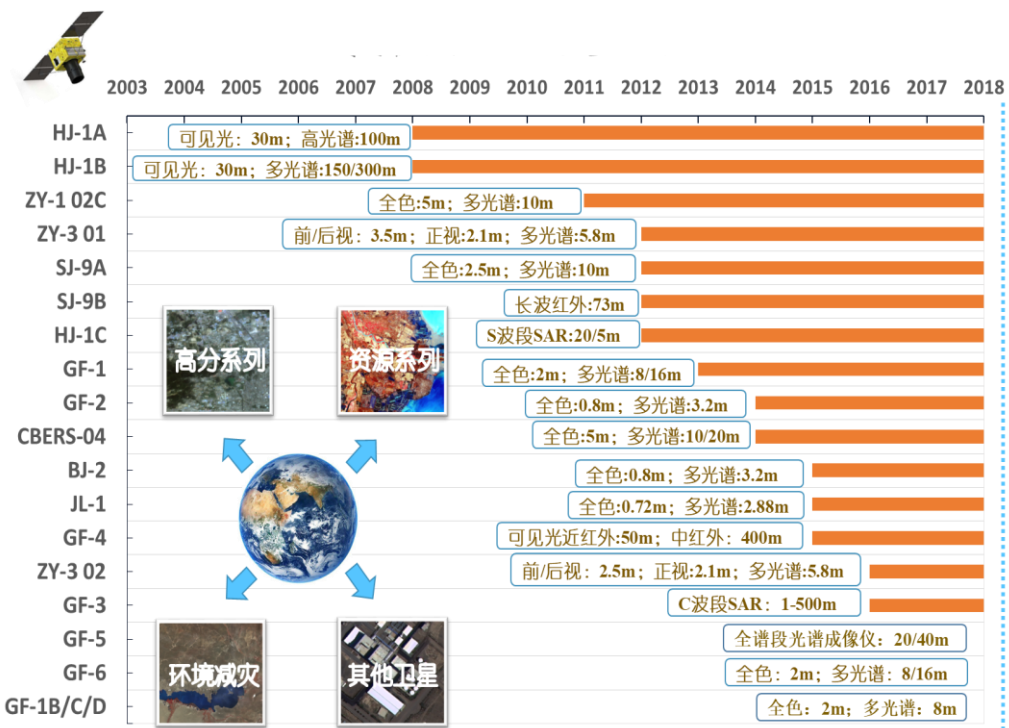
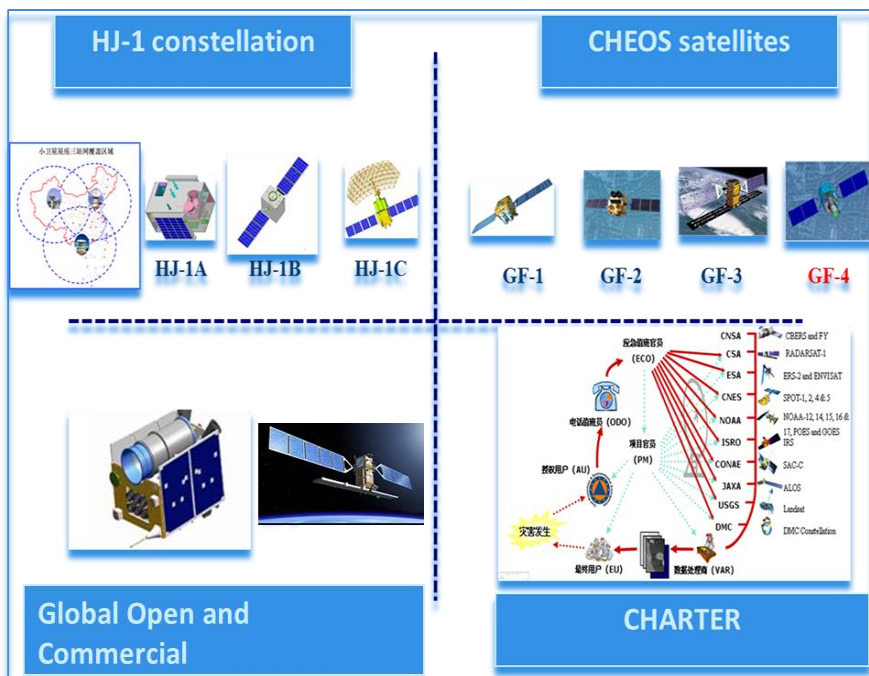
### NISAR Would Uniquely Capture the Earth in Motion



Meeting the data challenge: 85 Terabytes per day - 140 Petabytes in 3 year mission



# Satellite-based EO for China



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International/Global

**2. National  
Monitoring Systems**

National / Subnational

**3. Monitoring  
Countries at Risk**

Food Insecure and Most  
Vulnerable

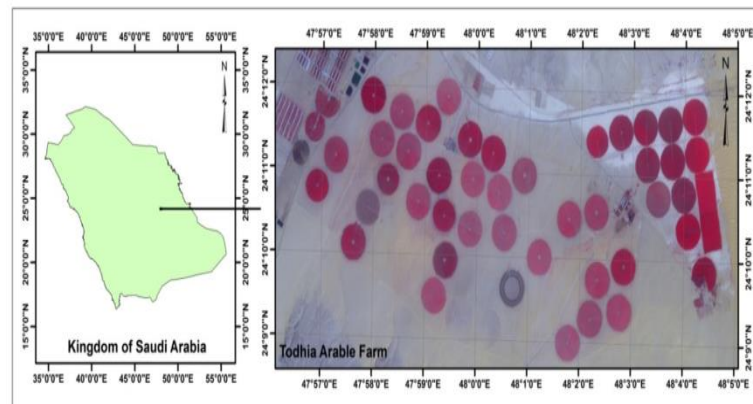
**4. EO Data Acquisition & Dissemination Coordination** 

**5. Research & Development toward Operations**

**6. Capacity Development for EO**

## JECAM Summary

- Large global research network developing and sharing data, science towards the development of operational tools and products
- Develop common standards and ultimately best practices
- Examples include Sen2Agri tools and current activity to develop SAR tools for crop type and condition mapping





## Global network of voluntary research sites



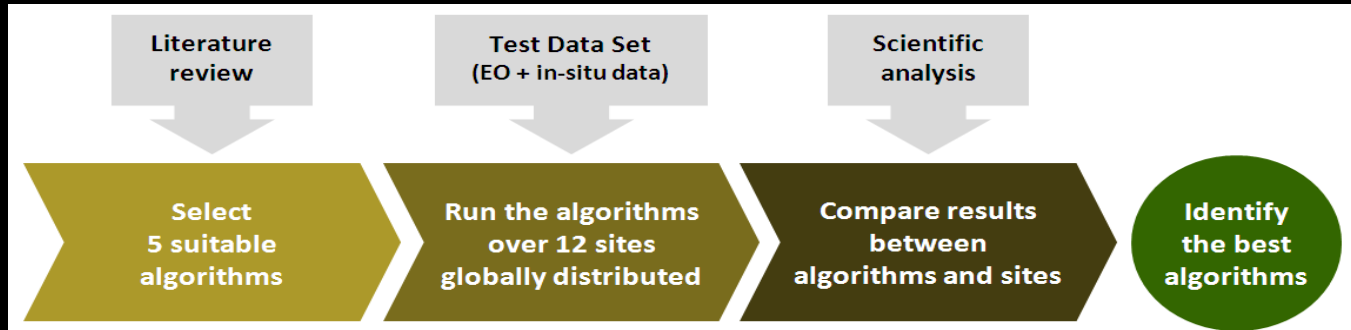
# Research Foci at the Joint Experiment for Crop Assessment and Monitoring (JECAM) Sites

## Comparing Methods for:

- Crop Type mapping
- Crop Condition monitoring
- Yield Estimation modeling
- Soil Moisture estimation
- Residue and Tillage monitoring
- SAR data for agricultural monitoring
  
- **Best Practices Documents - a major deliverable of JECAM**

# JECAM

## Benchmarking for selecting the best algorithms for each product



12 test sites, relying on JECAM network, spread over the world, which represent more than 17 major crop types



# **GEOGLAM Areas for Operational Research and Development (1)**

## **Research on Essential Agricultural Variables**

- **Within Season Crop Type Map and Area Estimation**
- **Crop Condition Assessment**
- **Crop Yield Estimation and Forecasting**
- **Drought Risk and Impact Assessment**
- **Agricultural Land Use Change**

## **Research on Supporting Variables**

- **Hydrological Variables - Soil Moisture and ET, Irrigated Area, Water Productivity**
- **Agricultural Practices and Land Management – Nitrogen Content Est., Till-no till, Crop Intensification, Crop Disease, Fallow and Pasture**
- **Rangeland Productivity and Quality**

# **GEOGLAM Areas for Operational Research and Development (2)**

## **Research into New Technologies and Methods**

- **Big Data and Cloud Computing**
- **Machine Learning and Artificial Intelligence**
- **Sensor Data Fusion**
- **Product Accuracy Assessment**
- **Object or Event Detection**
- **Data Integration/Assimilation**

## **Research into New Sensors**

- **ESA Sentinels, CSA Radarsat, NISAR, BIOMASS, Ecostress, GEDI, Smallsats**

# Small Sat optical constellations 3m-70cm

## A Changing and Visible Playing Field



Planet Labs, New Zealand. March 26, 2016



# GEO & GEOGLAM aligning with UN SDGs



End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Multinational and user-driven development efforts  
have the most impact due to  
trustworthy, transparent, & collaborative agenda

(AidData, “Listening to Leaders” 2015)

These are GEOGLAM’s core principles!

and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed

## 2.a INTERNATIONAL COORDINATION FOR R&D

Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries

## 2.b

Correctly identify, measure, monitor and analyze trade flows and market trends, including those with high potential, and address the negative effects of agricultural export subsidies and other trade measures in order to facilitate timely access to market information

## 2.c REDUCE PRICE VOLATILITY

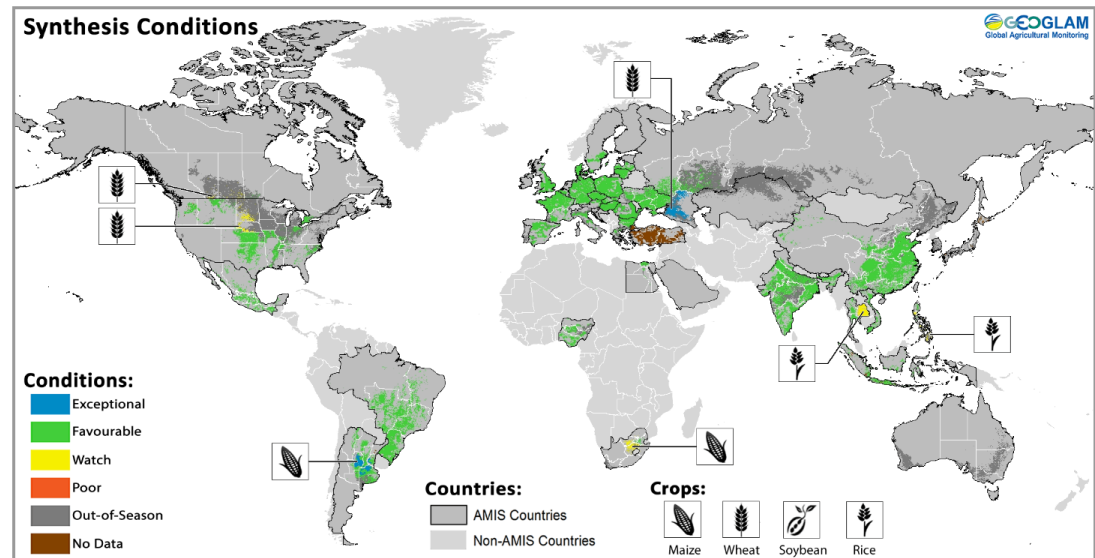
Address the underlying causes of food price volatility and its effects, including through commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility

## Mapping GEOGLAM to the SDG's

April 2019 AMIS Crop Monitor

### Example:

- Since 2013 GEOGLAM has delivered information to AMIS, helping to limit extreme food price volatility, directly contributing to target 2.c, Food Price Volatility





# Essential Agriculture Variables (EAV's) for GEOGLAM

## EAV's: A Practical Approach to Support Complex and Evolving Policy Needs

- The concept of Essential Variables (EV's) suggests a minimum set of fundamental variables required to characterize state and change in a system.
- EAV's will help
  - Scope R&D and Operational priorities
  - Clearly define data needs ( CEOS-Analysis Ready Data)
  - Support integration across science disciplines (common language) towards integrated solutions
- A draft white paper and working group has been established to move this forward <sup>7</sup>



# Potential GEOGLAM Support for the Paris Climate Accord

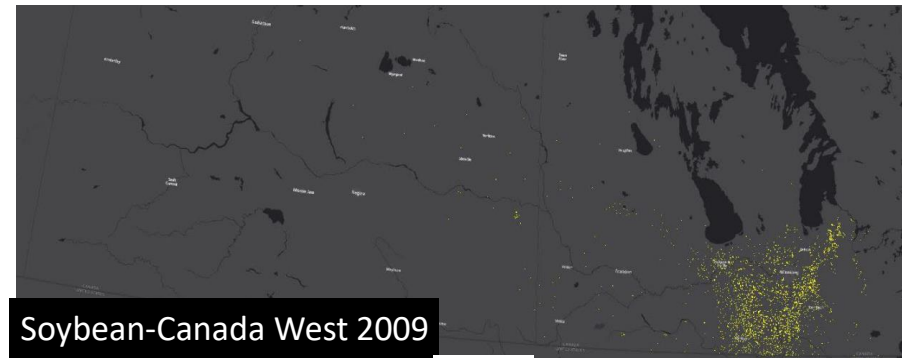
## The Impact of Climate Change on Agricultural Landscapes

### GEOGLAM is Already Supporting

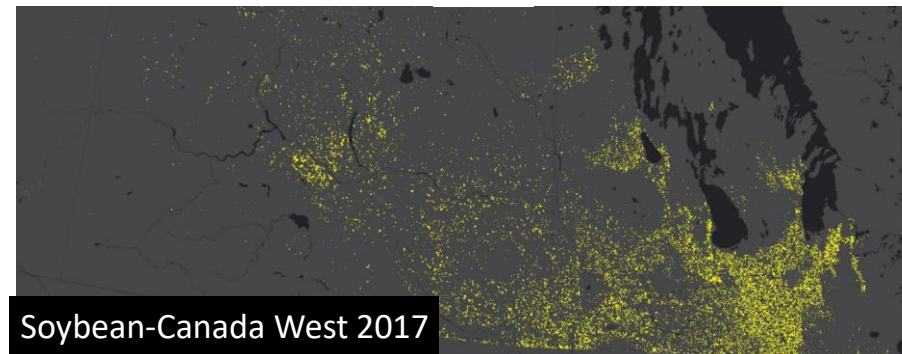
- Tracking Agricultural Land Use State and Change; Impact of Climate on Ag Production; Developing national Capacity

### Example

- Crop mapping provides quantifiable insights into how the agricultural landscape is adapting to climate change



← 1200 km →



## So in summary what is GEOGLAM doing?

- **Increasing communication and sharing experience amongst the Ag Monitoring Community of Practice & with related programs**
- Promoting EO-based approaches for operational agricultural monitoring
- Method testing & inter-comparison, developing best practices
- R and D to develop new monitoring capabilities & products
- Translating EO data into policy relevant information
- Articulating and advocating community requirements to EO data providers
- **Helping improve national and international agricultural monitoring systems**

Terima Kasih