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GEOGLAM Global Agricultural Monitoring

Developing & Evaluating Space-Based Earth Observation Data Requirements for GEOGLAM

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CEOS LSI-VC Meeting
Los Angeles, CA – 20 July 2016

Policy Framework for GEOGLAM: 2011 & 2016

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.

to continue to tackle the issue of price volatility. In particular, we commit to pursue the implementation of the concrete initiatives of the 2011 G20 Action Plan on Food Price Volatility and Agriculture in dedicated forums: Agricultural Market Information System (AMIS) and the Rapid Response Forum, GEO Global Agricultural Monitoring Initiative (GEOGLAM) for market and production international monitoring, and risk management tools, such as the Platform for

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GEOGLAM Objectives

To strengthen the international community's capacity to produce & disseminate

relevant, timely, accurate and actionable

information & forecasts on agricultural production at national, regional & global scales, through reinforced use of Earth Observations

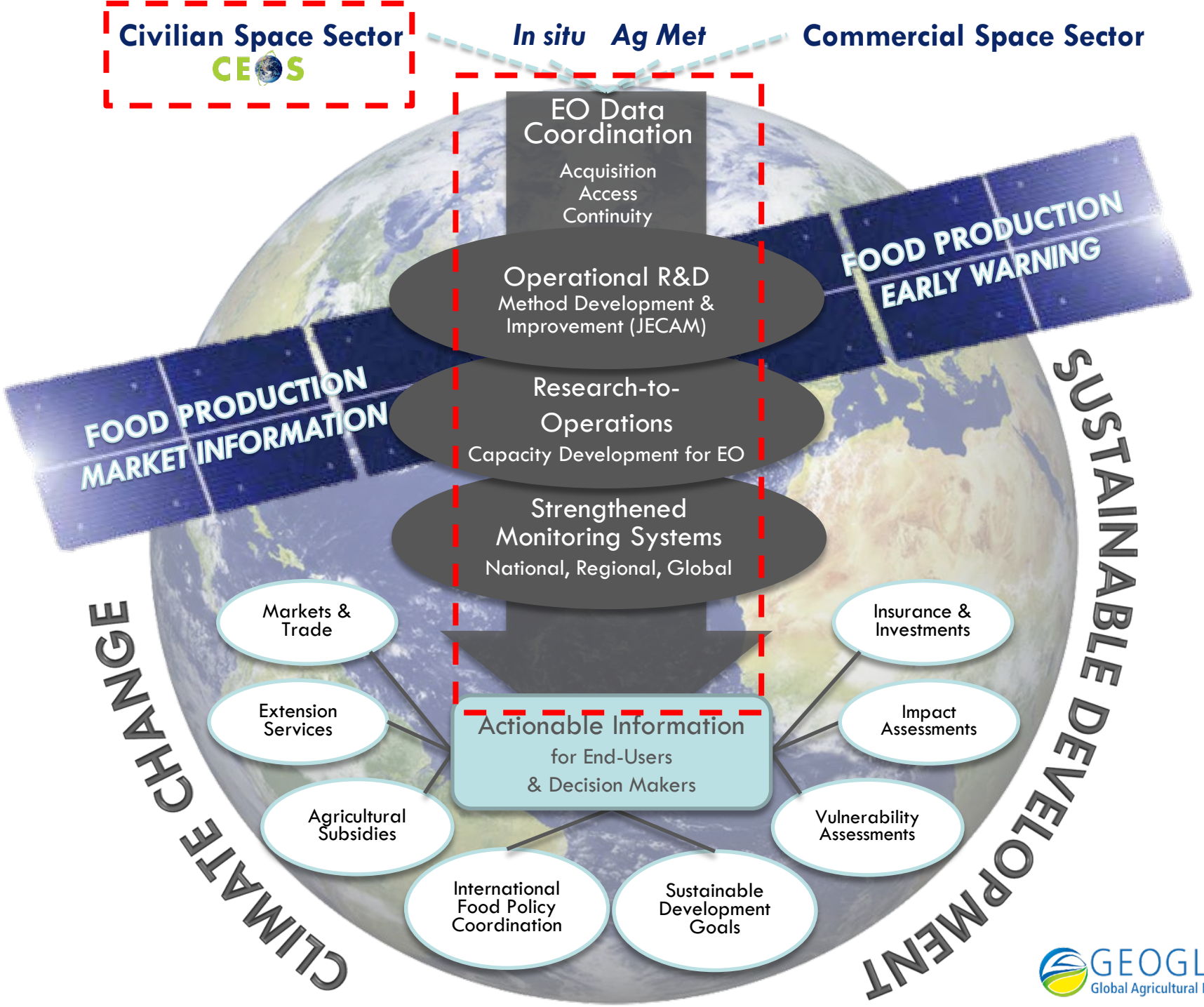
GEOGLAM is a coordination programme aiming to:

- support, strengthen, and articulate existing efforts
- develop capacity and awareness at national & global level
- enhance access to appropriate EO data (satellite and in situ)
- disseminating information

Coordination of Earth Observations for GEOGLAM Acquisition, Continuity, and Access

- Cropping systems are inherently diverse and dynamic
  - No single mission can meet the variety of EO requirements (spatial, temporal, and spectral diversity)
  - But coordinated acquisition by missions (e.g. from multiple agencies) can greatly enhance agricultural monitoring
    - *Timely, relevant, actionable information*

- In this context, GEOGLAM developed Earth Observation Requirements for agricultural monitoring, in consultation with …and conducted an analysis of present/future missions' capacity to meet these requirements


Civilian Space Sector
CEOS
In situ
Ag Met
Commercial Space Sector
EO Data Coordination
Acquisition
Access
Continuity
Operational R&D
Method Development & Improvement (JECAM)
Research-to-Operations
Capacity Development for EO
Strengthened Monitoring Systems
National, Regional, Global
FOOD PRODUCTION MARKET INFORMATION
FOOD PRODUCTION EARLY WARNING
CLIMATE CHANGE
SUSTAINABLE DEVELOPMENT
Markets & Trade
Extension Services
Agricultural Subsidies
International Food Policy Coordination
Sustainable Development Goals
Vulnerability Assessments
Impact Assessments
Insurance & Investments
Actionable Information
for End-Users
& Decision Makers
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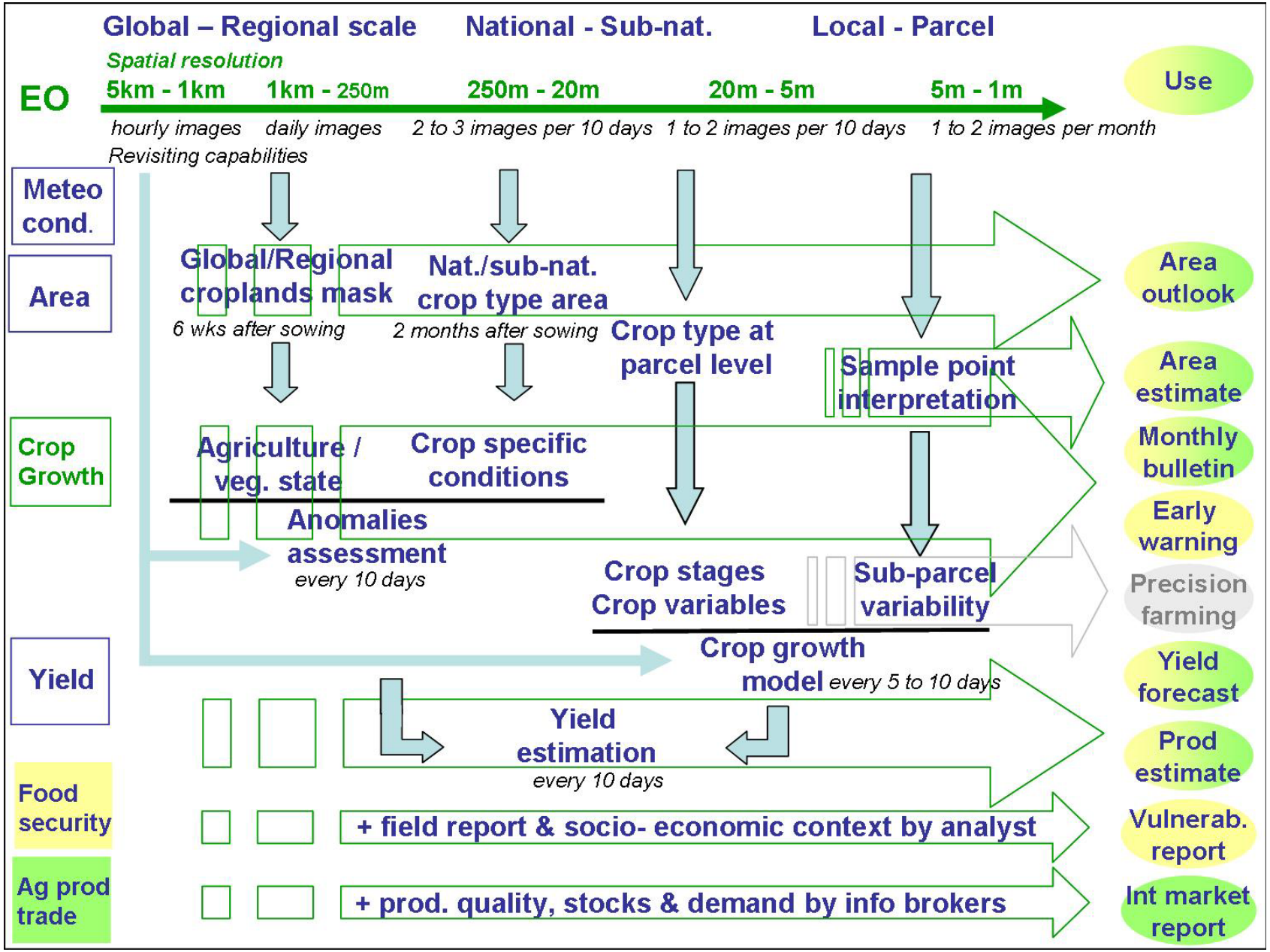

“Defourny Diagram”

circa 2010

Effort by GEO AgCoP to conceptualize EO type, resolutions and scales, and information use

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GEOGLAM CEOS Workshop on OBSERVATION REQUIREMENTS
CSA, Montreal July 10-11, 2012

Tabulating the satellite observation requirements (spatial resolution, frequency, and period of coverage) for GEOGLAM

GEOGLAM
Global Agricultural Monitoring

Observation Requirements Table (2012)

CEOS

WHAT? (Spatial & Spectral) | WHEN & HOW OFTEN? (Temporal) | WHERE? | WHY? (Monitoring Application)

Req #	Spatial Resolution	Spectral Range	Effective observ. frequency (cloud free)	Extent	Field Size	Target Products: Crop Mask	Crop Type Area and Growing Calendar	Crop Condition Indicators	Crop Yield	Crop Biophys. Variables	Environ. Variables	Ag Practices / Cropping Systems
	Coarse Resolution Sampling (>100m)											
1	500 - 2000m	optical	Daily	Wall-to-Wall	All			X		L		
2	100-500m	optical	2 to 5 per week	Cropland extent	All	X	X	X	L	L	X	L
3	5-50 km	microwave	Daily	Cropland extent	All			X	X	X	X	
	Moderate Resolution Sampling (10 to 100m)											
4	10-70m	optical	Monthly (min 3 in season + 2 out of season); Required every 1-3 years	Cropland extent (if #5 = sample, else skip)	All	X	L/M					X
5	10-70m	optical	8 days; min. 1 per 16 days	Sample (pref. Cropland extent)	All	X	X	X	X	X	X	X
6	10-100m	SAR	8 days; min. 1 per 16 days	Cropland extent of persistantly cloudy and rice areas	All	X	X	X	X	X	X	X
	Fine Resolution Sampling (5 to 10m)											
7	5-10m	VIS NIR + SWIR	Monthly (min. 3 in season)	Cropland extent	M/S	M/S	M/S					
8	5-10m	VIS NIR + SWIR	Approx. weekly; min. 5 per season	Sample	All		M/S	X		X	X	X
9	5-10m	SAR	Monthly	Cropland extent of persistantly cloudy and rice areas	M/S	M/S	M/S					M/S
	Very Fine Resolution Sampling (<5m)											
10	< 5m	VIS NIR	3 per year (2 in season + 1 out of season); Every 3 years	Cropland extent of small fields	S	S	S					
11	< 5m	VIS NIR	1 to 2 per month	Refined Sample (Demo)	All		X		X			X

Coarse (>100 m)

Moderate (10-100 m)

Fine (5-10 m)

Very Fine (<5 m)

Note:
Optical = Reflective & Emissive (Thermal)

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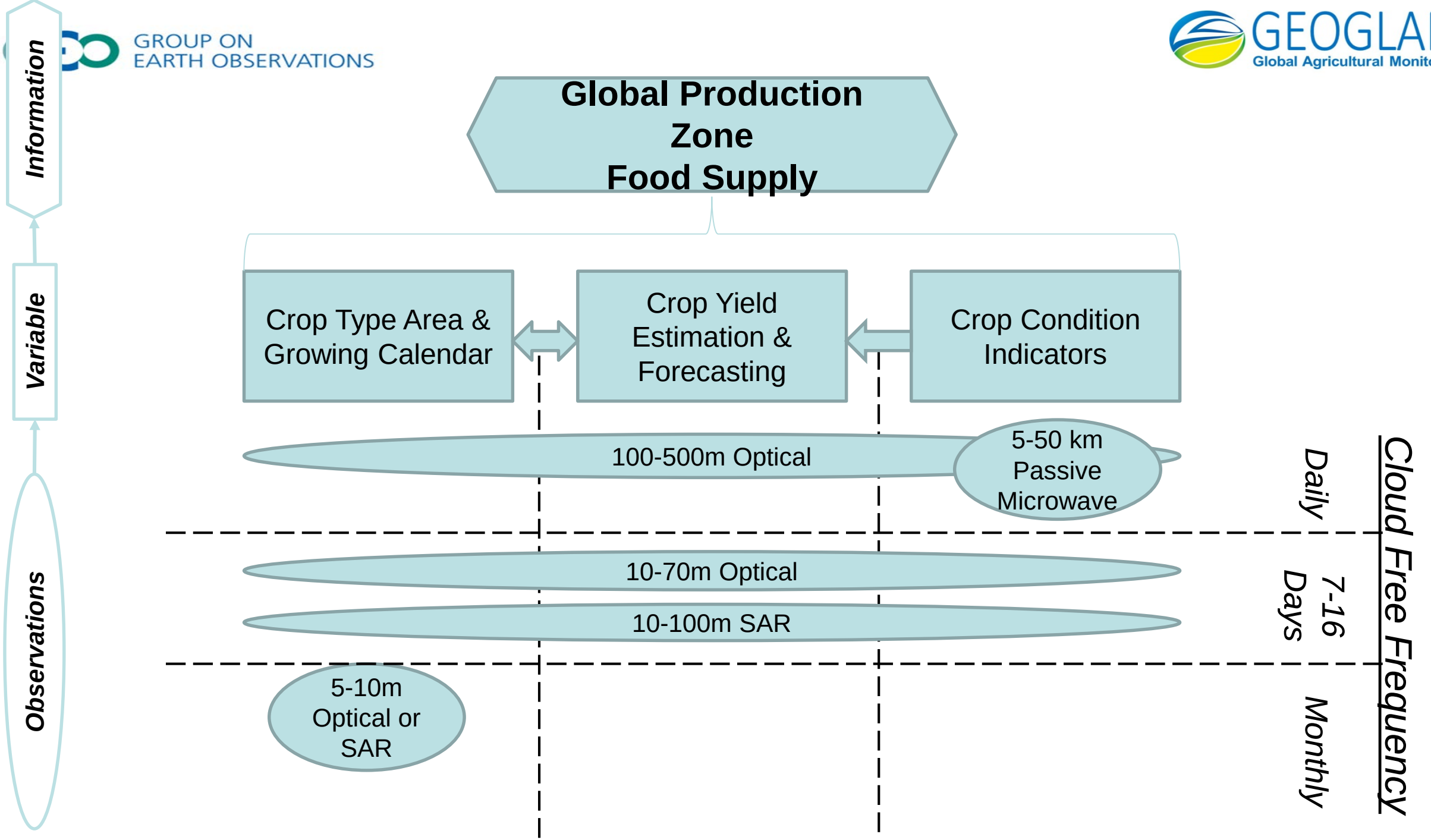

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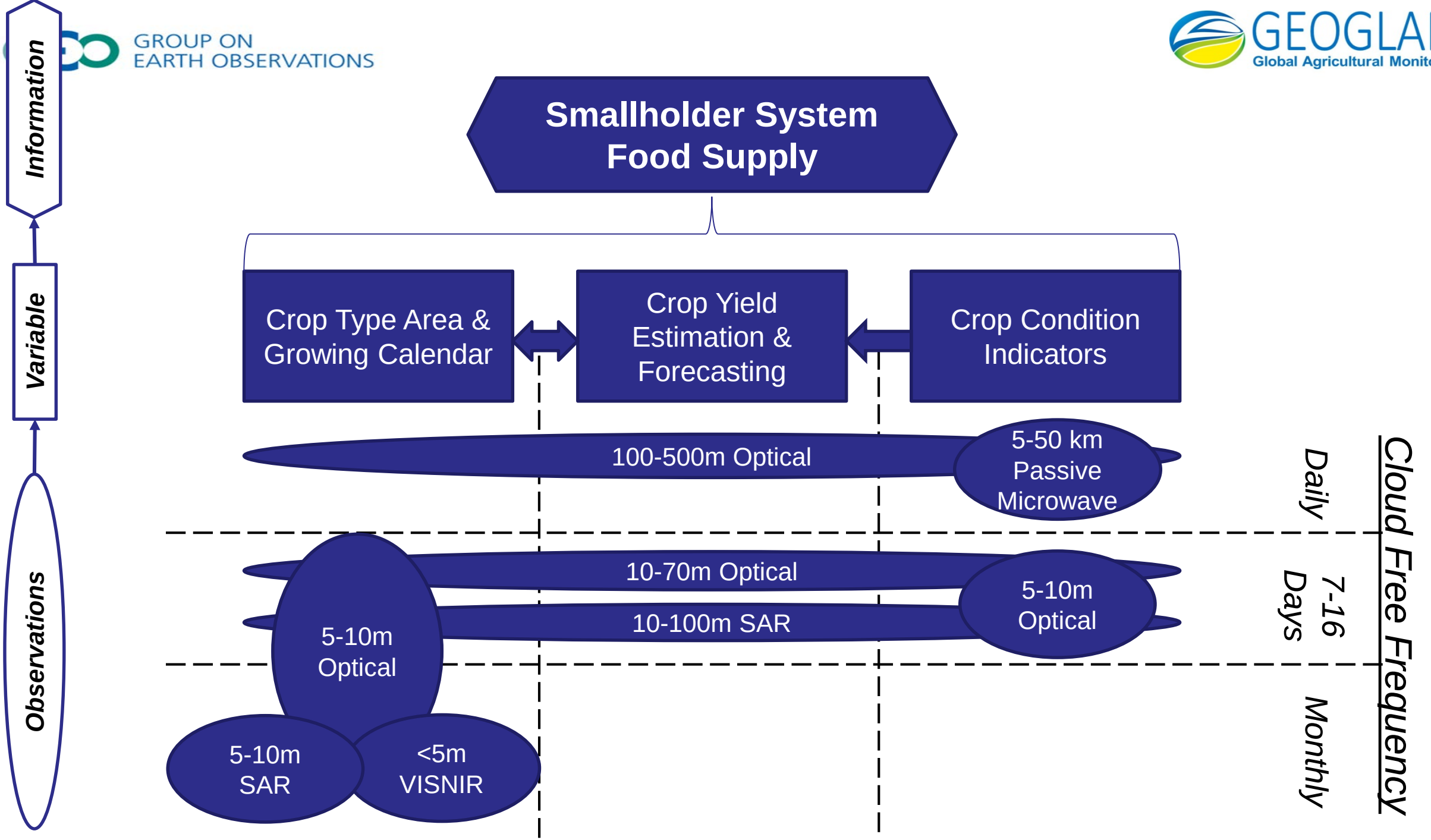

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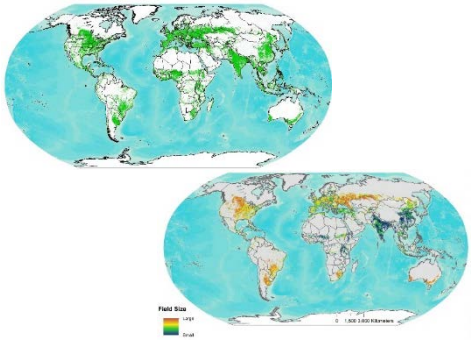
Key Components of Spatially Explicit EO Requirements

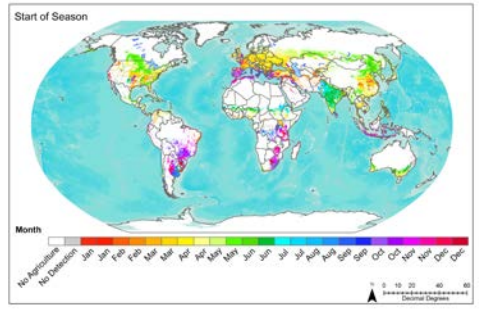
Where to image?

'best-available' cropland mask + field size distribution (e.g. Fritz et al., 2015)



When to image?

Agricultural growing season calendars (e.g. Whitcraft et al., 2014)



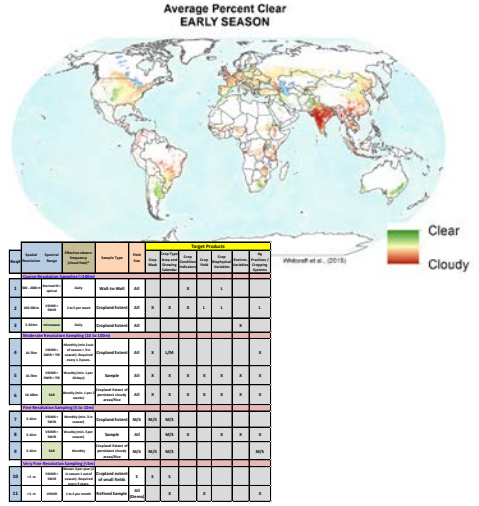
How frequently to image?

At what spatial & spectral resolution [instrument type] to image?

Cloud cover info (e.g. Whitcraft et al., 2015a)

+

GEOGLAM Requirements Table



(How) can we meet these requirements?

(Whitcraft et al., 2015c)

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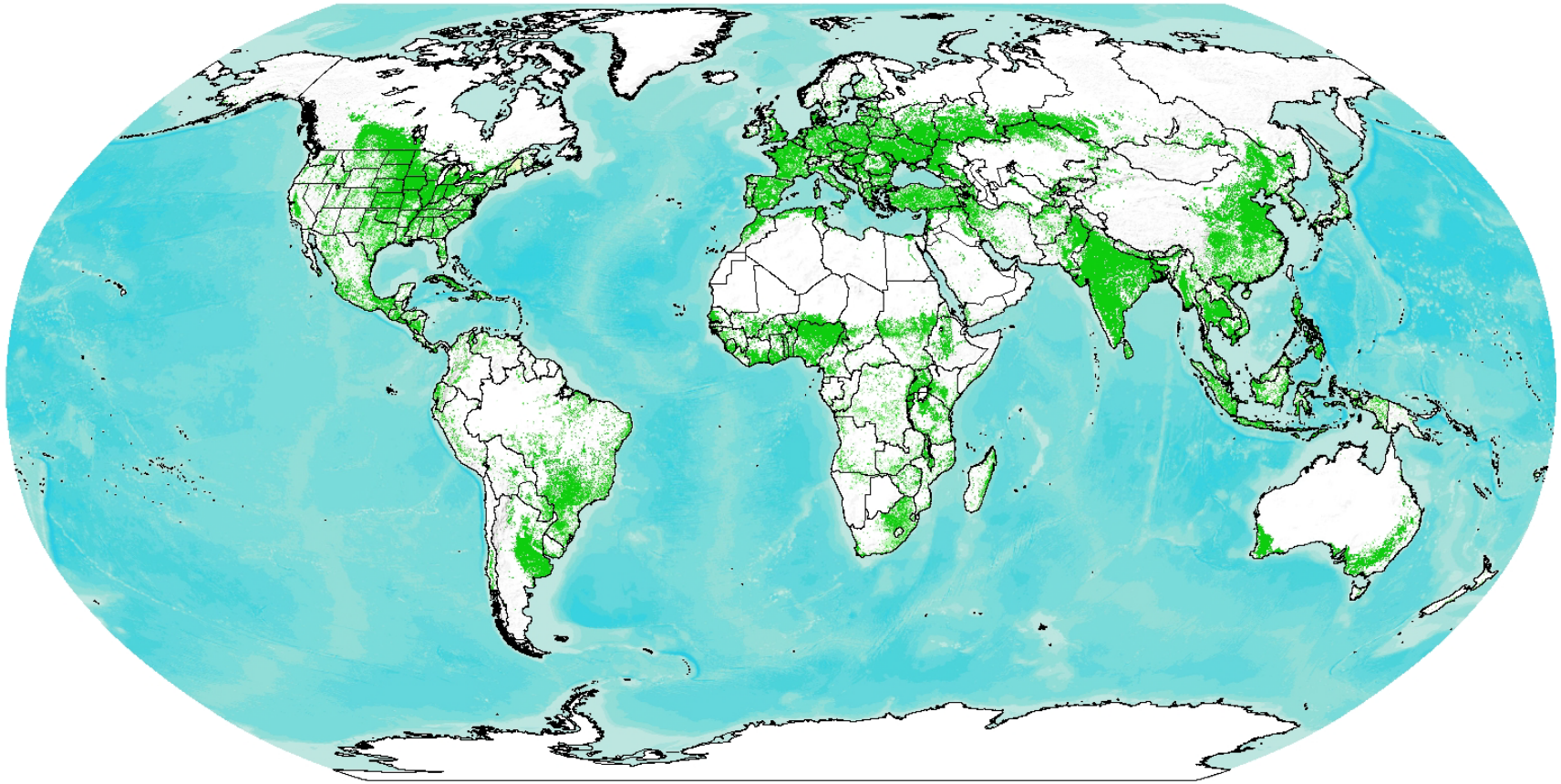
Where to Image?
Best Available Cropland Distribution



Source: Fritz et al. (2015), *Global Change Biology*

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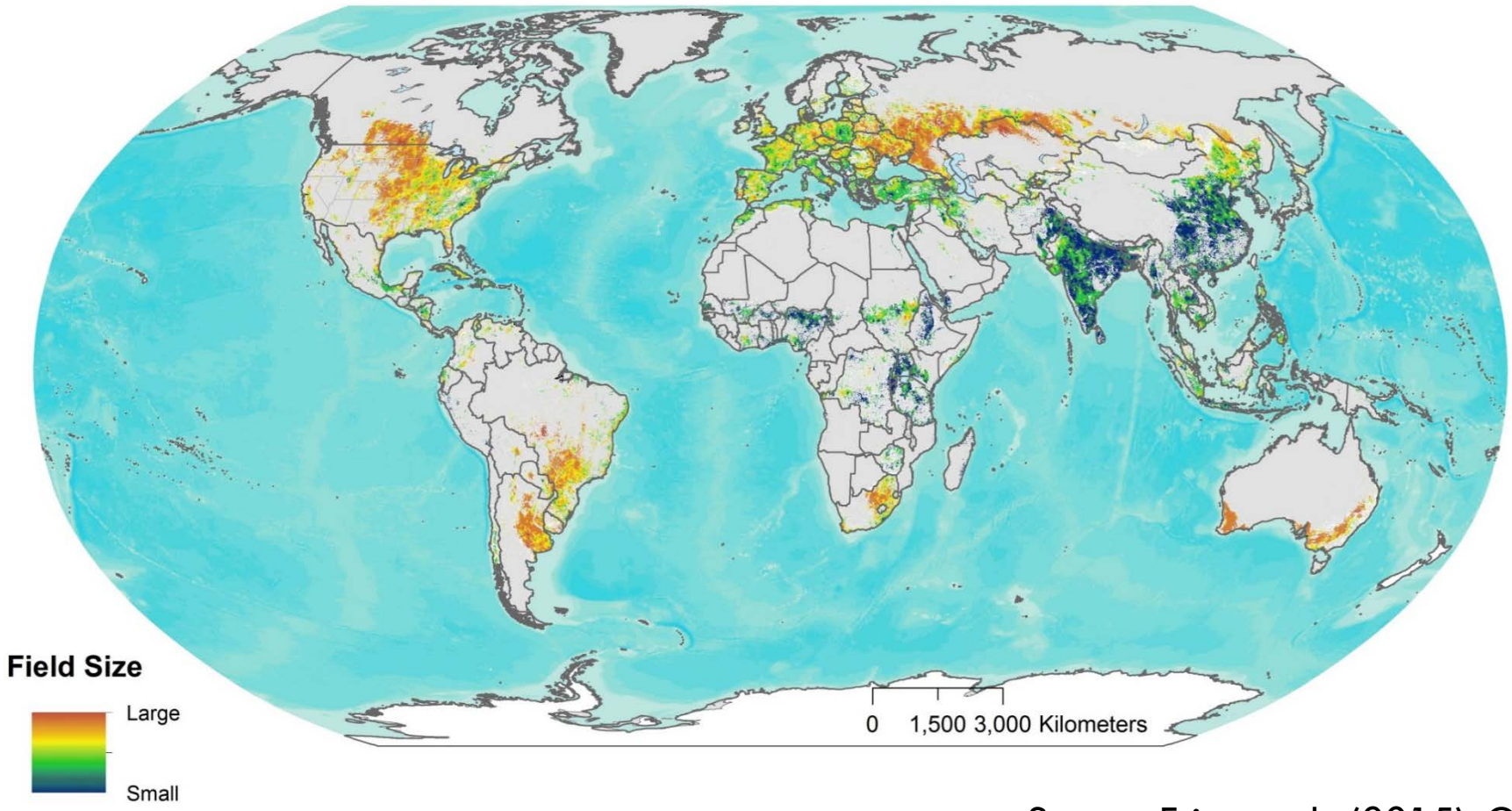
Where to Image?

Field Size Layer (beta version)

Based on interpolation of 50,000 GEOWIKI validation points



Source: Fritz et al., (2015), *Global Change Biology*

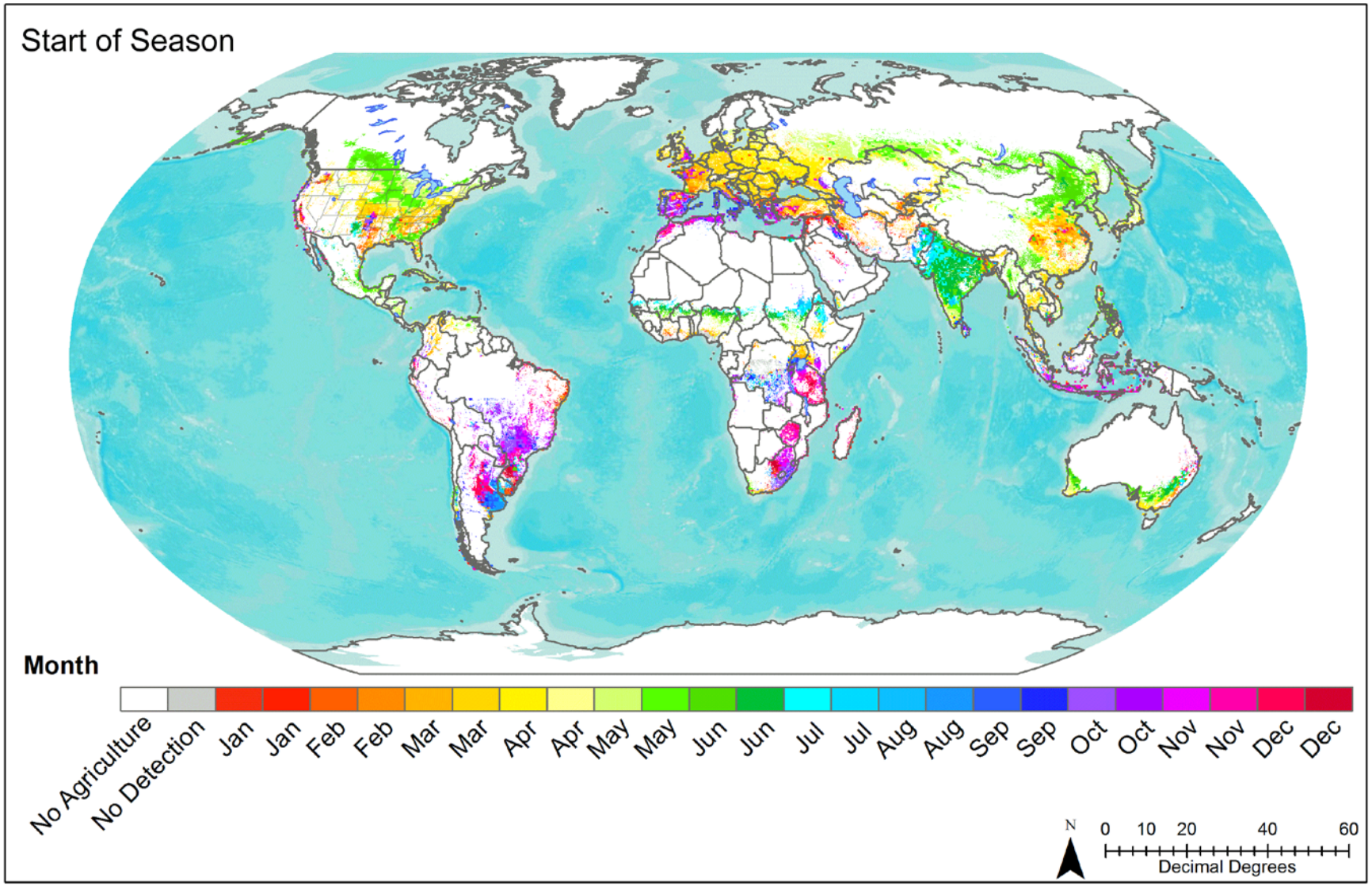
When are Imagery Required?

- Data are required throughout the period during the agricultural growing season (crop type, yield, forecasting), and sometimes during the non-AGS (detecting changes in land use, crop calendar, cropping pattern)

- Efforts within GEOGLAM Crop Monitor ongoing to update crop specific calendars (9 total region/cycle combos) – still not done

- Defining EO requirements necessitates a **spatially explicit characterization** of when crops are actively growing in agricultural areas, globally

Median observed 2001-2010



Whitcraft et al. (2014), *IJDE*

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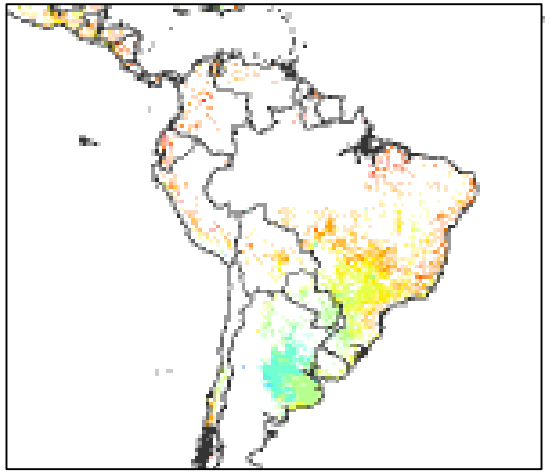
*What is the **impact of cloud cover** on our ability to view croplands on the Earth's surface using passive optical data throughout the agricultural growing season?*

- Twice daily average over 2000-2012 [Terra-AM] & 2002-2012 [Aqua-PM]
- Aggregated over different portions of the agricultural growing season

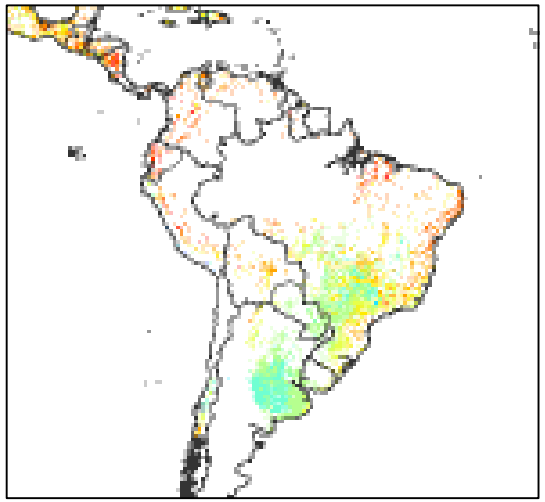
Whitcraft et al. (2015),
Remote Sensing of Environment

West Hem

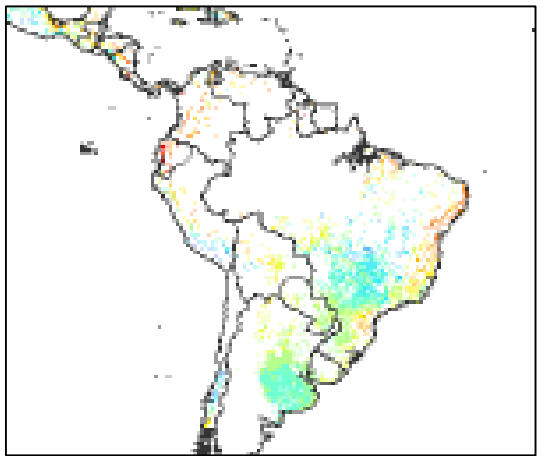
Early



Mid

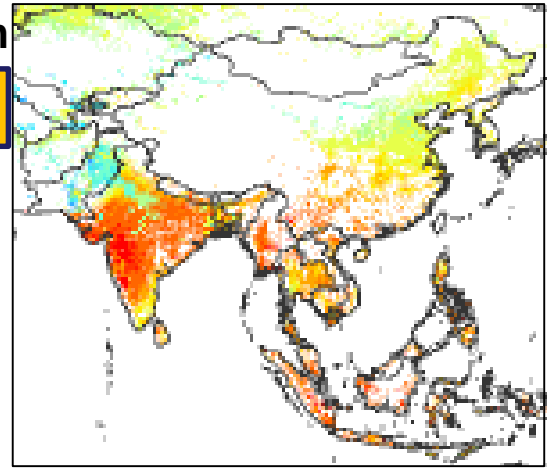


Late



East Hem

Early



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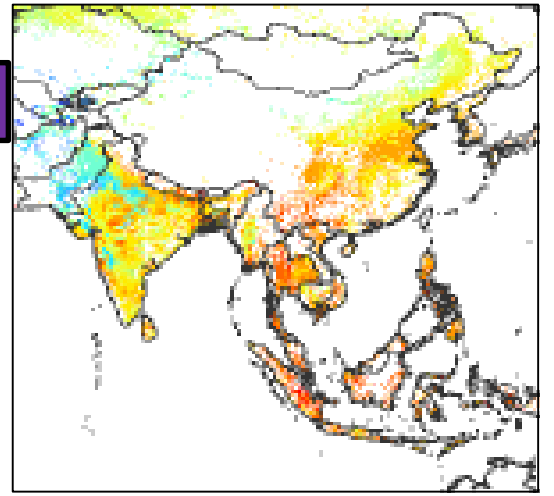
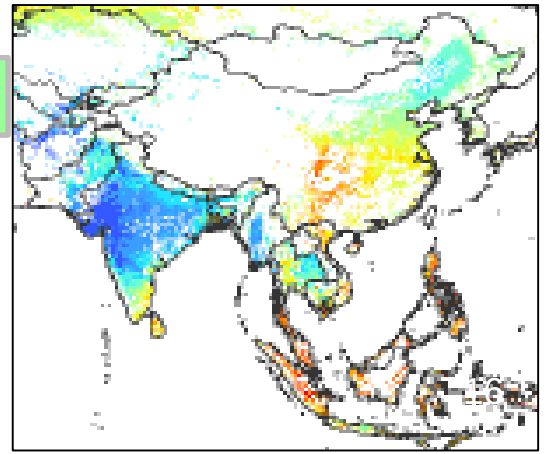
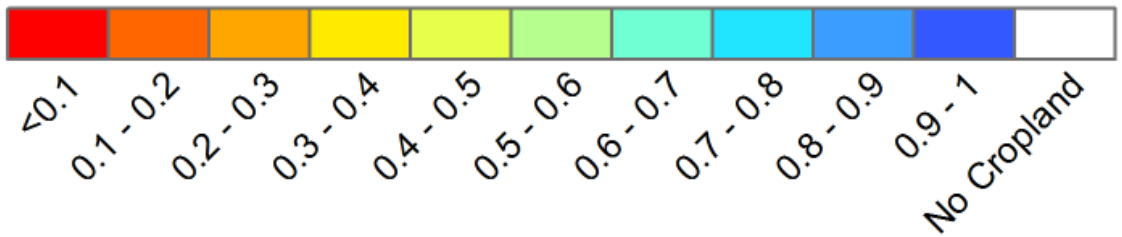


Late



Average Percentage Clear/100



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WHAT? WHEN? HOW OFTEN? WHERE? WHY?

A	B	C	D	E	F	G	H	I	J	K	L	M
						Target Products						
Req#	Spatial Resolution	Spectral Range	Effective observ. frequency (cloud free)	Extent	Field Size	Crop Mask	Crop Type Area and Growing Calendar	Crop Condition Indicators	Crop Yield	Crop Biophysical Variables	Environ. Variables	Ag Practices / Cropping Systems
4	10-70m	optical	Monthly (min 3 in season + 2 out of season); Required every 1-3 years	Cropland extent (if #5 = sample, else skip)	All							X
5	10-70m	optical	8 days; min. 1 per 16 days	Sample (pref. Cropland extent)	All						X	X
6	10-100m	SAR	8 days; min. 1 per 16 days	Cropland extent of persistantly cloudy and rice areas	All						X	X

*What is the revisit frequency required to probabilistically return a **reasonably cloud free view** after **8 days** over croplands of all sizes?*

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What is the revisit frequency required (RFR) to probabilistically return a reasonably cloud free clear view within 8 days over croplands of all sizes? (Req #5)

When? *Where?* *Revisit Frequency Required?*

[GSCs] + [crop mask + field size] + [cloud cover impacts + req table]

Two thresholds of acceptable clarity:

≥70%

≥95%

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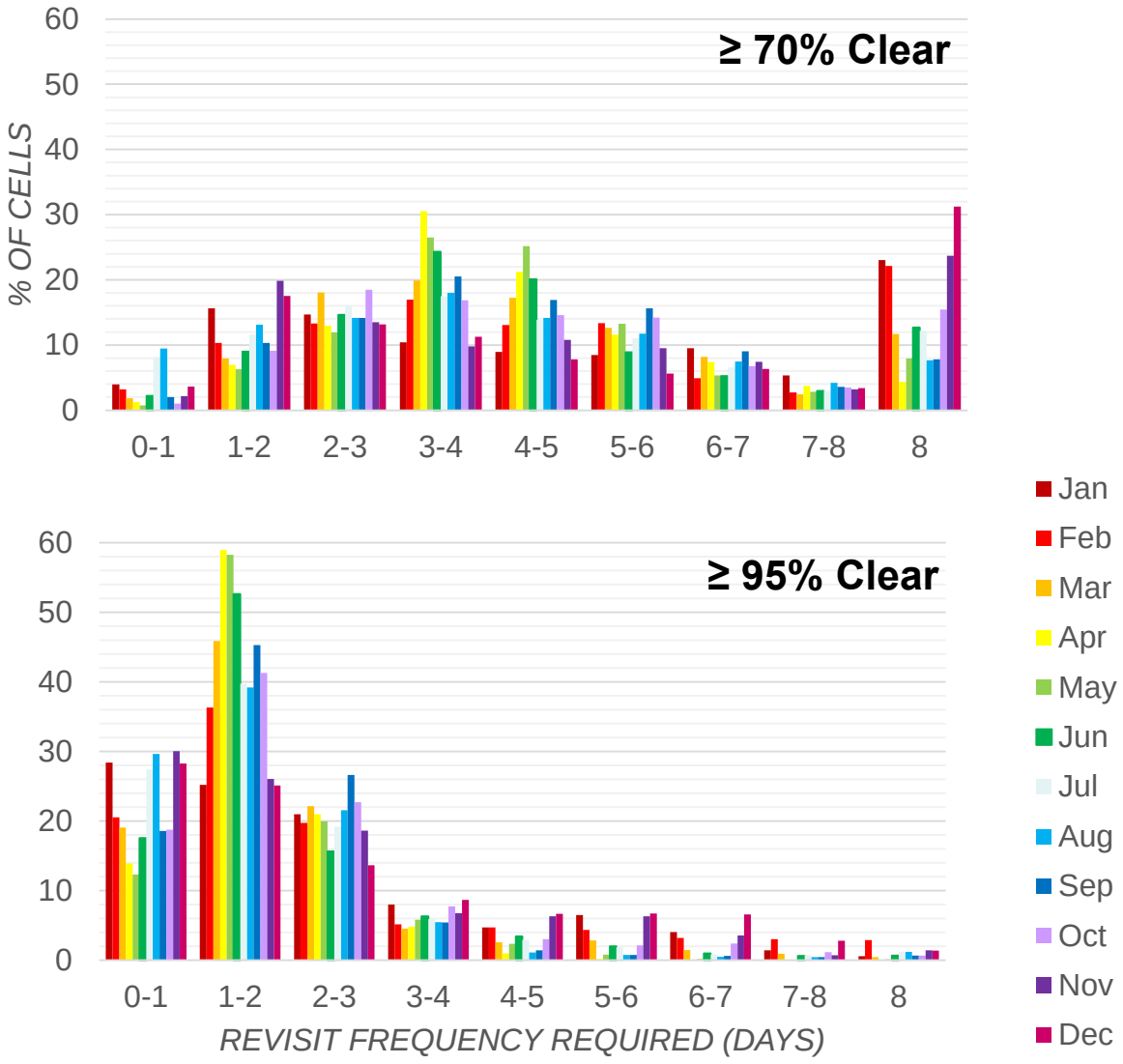
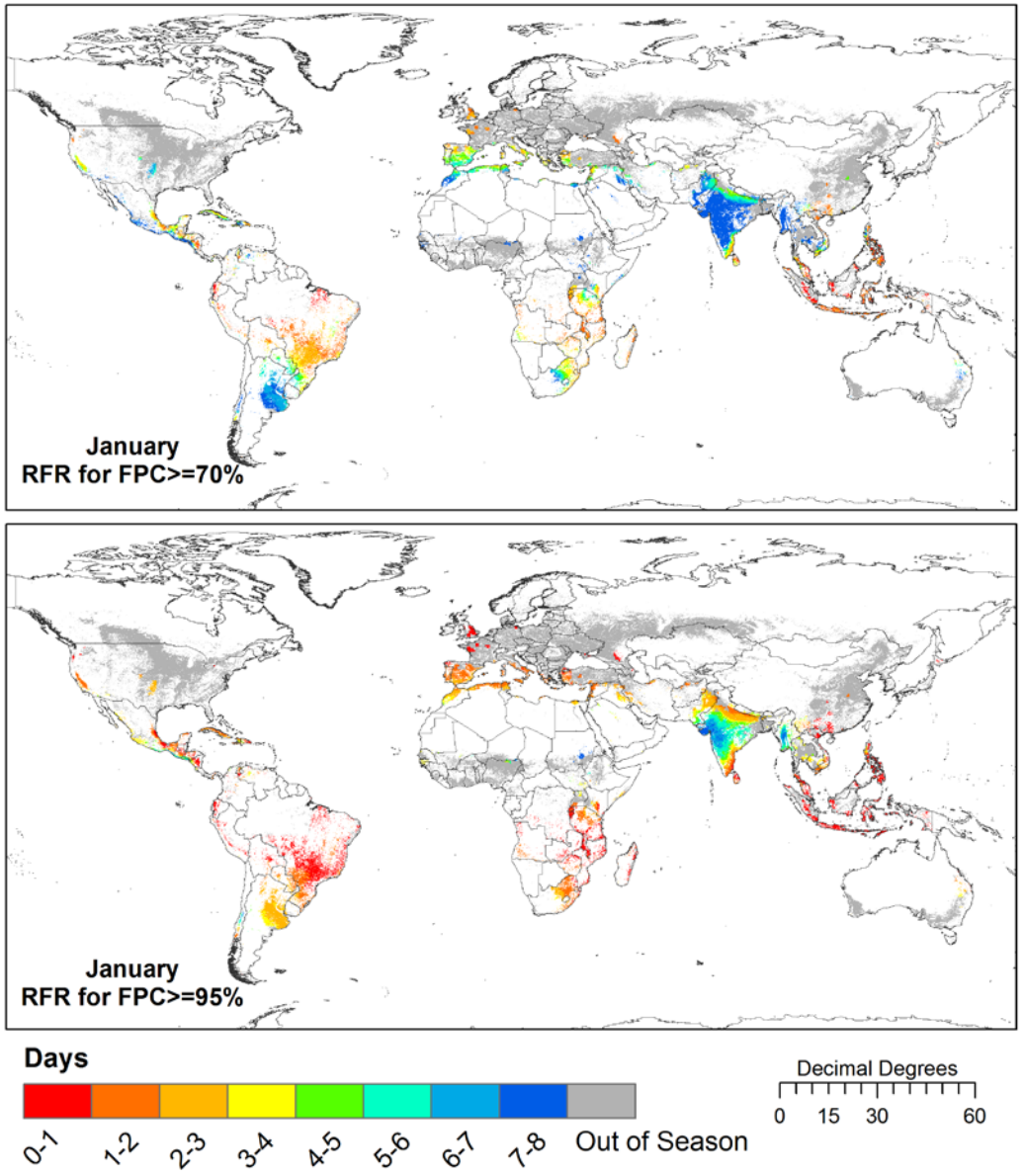


Whitcraft et al., (2015a), *Rem. Sens.*



Requirement #5

What is the revisit frequency required (RFR) for a view at least 70% or 95% cloud-free within 8 days over in-season global croplands?

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(How) can we meet these requirements for optical, moderate resolution (10-70m) data within 8 days during the growing season with current & planned missions?

	Agency, Satellite, Sensor	Revisit	Spatial Res
L7	NASA/USGS Landsat 7 ETM+	16 Days	30-60 m
L8	NASA/USGS Landsat 8 OLI, TIRS	16 Day	30-100 m
S2A	ESA Sentinel-2A MSI	10 Days	10-20 m
S2B	ESA Sentinel-2B MSI	10 Days	10-20 m
R2	ISRO Resourcesat-2 AWiFS	5 Days	56 m

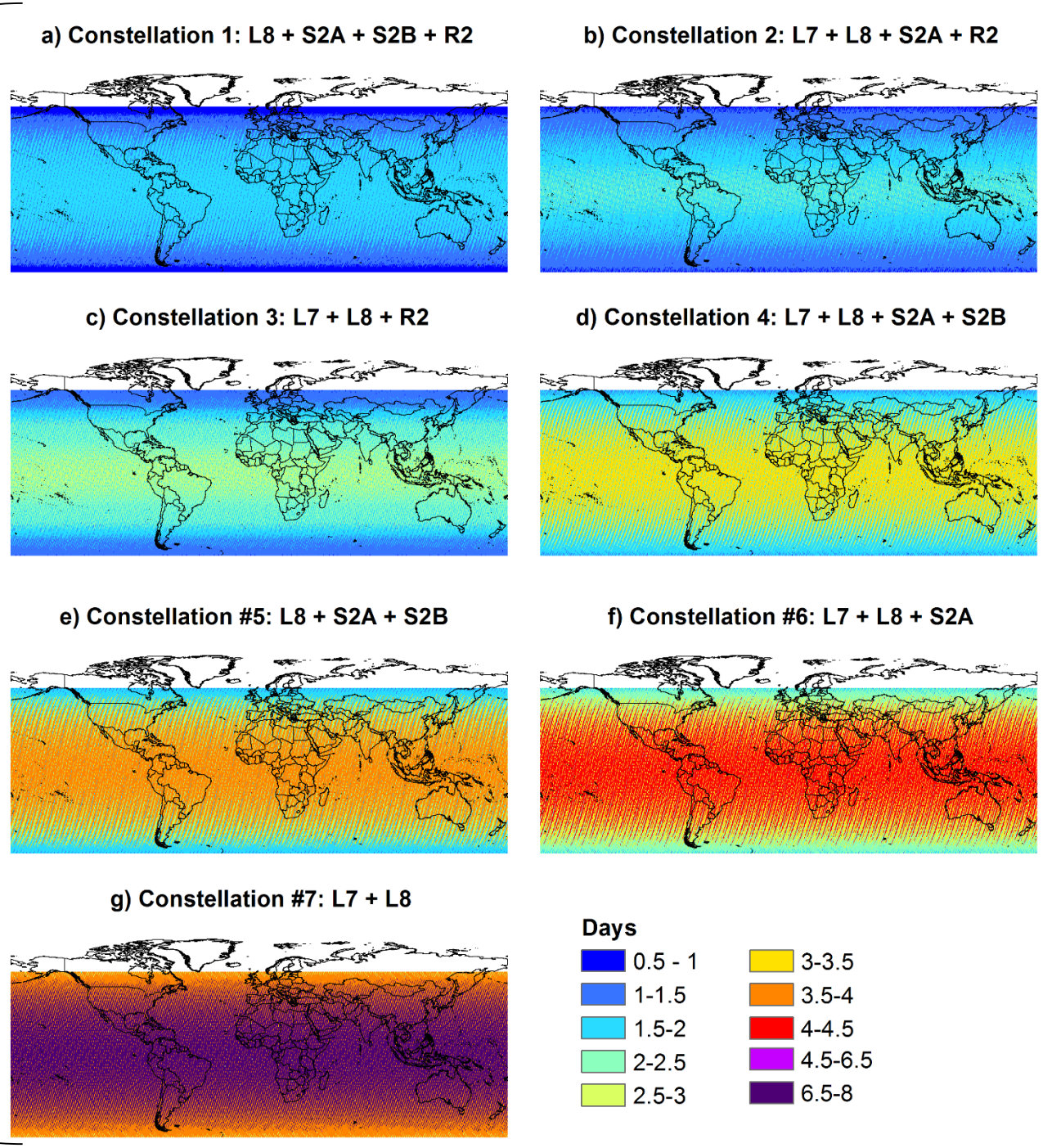
Revisit Capabilities

of the

7 Hypothetical Constellations

Overpass Analysis:
CEOS SEO

Whitcraft et al., (2015b), *Rem. Sens.*



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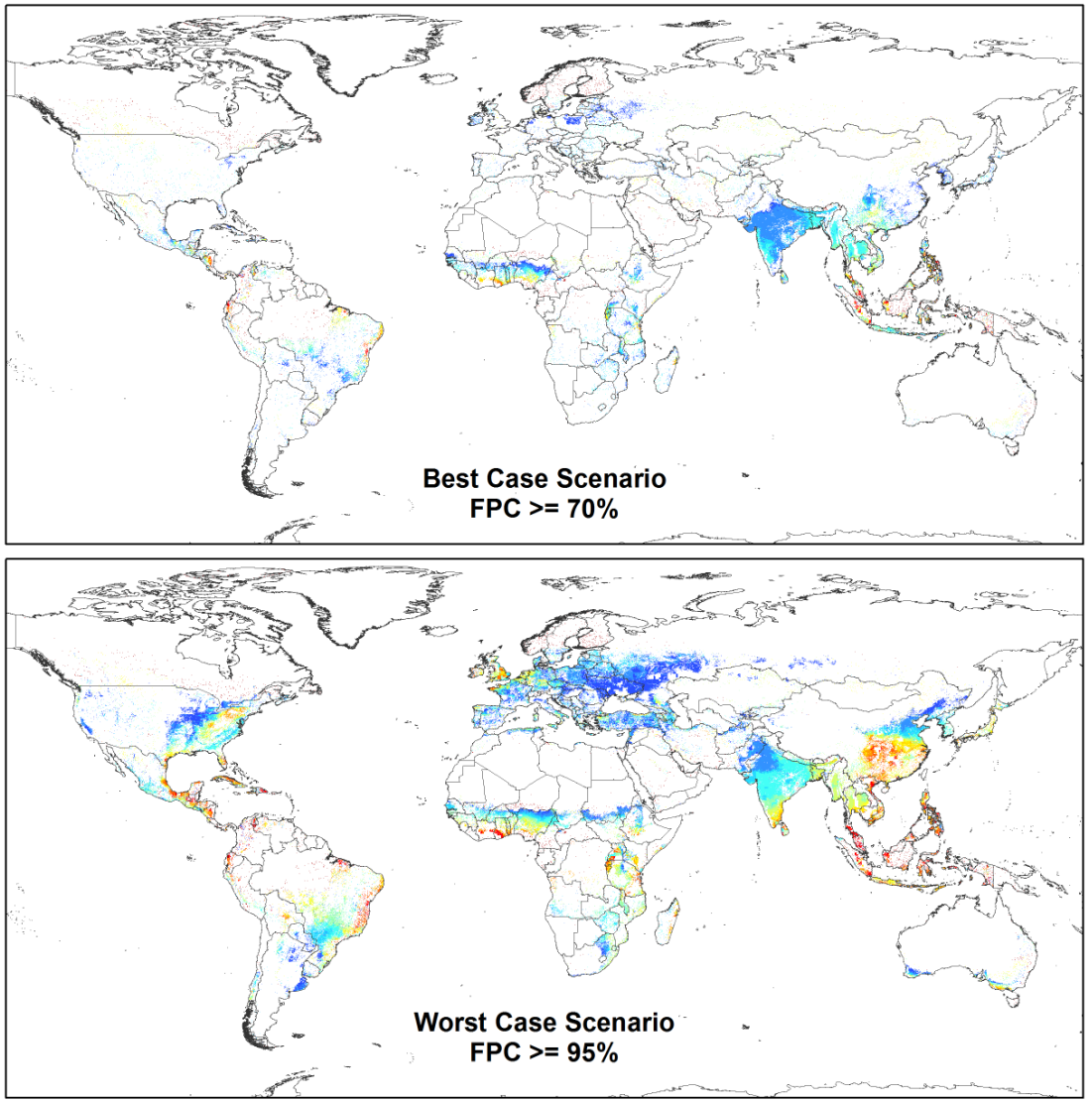
Requirement #5

Meeting the Requirement for a view **≥ 70% Cloud Free** within 8 days
(over global in season croplands)

Meeting the Requirement for a view **≥ 95% Cloud Free** within 8 days
(over global in season croplands)

#	Satellites
1	L8, S2A, S2B, R2
2	L7, L8, S2A, R2
3	L7, L8, R2
4	L7, L8, S2A, S2B
5	L8, S2A, S2B
6	L7, L8, S2A
7	L7, L8

Months without Requirements Met (Consider SAR)



Whitcraft et al., (2015b), *Rem. Sens.*

SAR Data for Agricultural Monitoring

- Historically, not prioritized for agriculture
- Main usage = “rice + persistently cloudy areas”
- Science and recent operations (JRC-MARS, Canada) have shown that SAR is as useful for monitoring as optical – **expand coverage beyond “rice + very cloudy”**
  - Fueled by increase in free, open SAR from **Sentinel-1**!
- Concept Note for CEOS from GEOGLAM – open access to SAR is a game changer

To frequently monitor the status of global crops across diverse landscapes, the remote sensing community within the Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) Initiative has exploited the satellite-based data available to them – optical and synthetic aperture radar (SAR) alike – toward providing key information on crop conditions to decision makers. Still, there remain critical gaps in EO data and methods adoption, which could be bridged by:

- *A continued and expanded commitment by space agencies to provide fully free and open access to systematically pre-processed, analysis-ready data;*
- *Sufficiently frequent (SAR and optical) acquisition over agricultural areas (consistent with GEOGLAM’s data requirements; Whitcraft et al., 2015 (Table 1));*
- *Space agency commitments to ensure data continuity for the coming decades, for SAR missions properly configured for agricultural/vegetation monitoring applications;*
- *Support for training and knowledge transfer surrounding SAR and SAR-optical fusion techniques for monitoring agriculture.*

(Whitcraft, McNairn, Lemoine, LeToan, and Sobue)

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We are not meeting all of our moderate resolution requirements

BUT – we can get close with current/near-term, if we can coordinate!

Still, some areas are just persistently cloudy… diminishing marginal returns on optical systems.
Need to consider alternatives to polar-orbiting optical - SAR & SAR-optical fusion

Only way to meet high temporal + moderate/fine spatial at present is through coordination between multiple missions & space agencies

CEOS

Acquisition Plan for GEOGLAM

- Annually updated plan for satellite data acquisition submitted to CEOS Plenary
  - When, where, how often… what systems?
  - Endorsed in 2013, 2014, and 2015
- At present, most data in the acquisition plan are acquired for JECAM, SIGMA, and Asia-RiCE
- Challenges:
  - Scaling up to national coverage
  - Coordinated imaging & interoperability
  - Accessing fee-based or restricted datasets and engaging the commercial sector
    - *e.g. ResourceSat-2, TerraSAR-X, RadarSat-2… Digital Globe*
  - Data access – "the last, longest yard" = getting the data to the user in "analysis-ready format

Summary of Requirements

- Framework developed for characterizing requirements in a volumetric, spatially explicit way
  - Potential gaps in coverage analyzed
  - In this presentation, an example for Requirement #5 (8 days, all croplands) demonstrated
- Descriptive characterizations of requirements (spectral & temporal emphasis) come from the literature and "best practices" – drawing on a community of practice
  - Several years of thinking (Defourny Diagram) coalesced in focused, 2-day working meeting (CSA, Montreal 2012)
    - *End users vs. remote sensing analyst user*
  - Radiometric, signal-to-noise, GSD, latency, error, etc. are *not* (yet) characterized
  - But they evolve, and updates are needed
- Spatially explicit datasets are key – when, where, cloud cover (if relevant)
- In terms of meeting requirements… coordination is key!
  - Interoperability between datasets

Next Steps

- EO data requirements need to be updated
  - Any evaluation of capacity should include updated missions, capacities, and could also evaluate a reality check (what have we indeed gotten so far?)
- In situ & agrometeorological data needs yet to be similarly organized and addressed
- This is about acquisition… there are crucial other factors to EO method adoption:
  - Availability: data policy, latency
  - Access & Utilization: methodological improvement, ARD, data dissemination systems, capacity development etc.
  - Continuity
- The requirements ARE NOT the same as requests
  - Remote sensing analysts are not necessarily ready (and willing) to take on large volumes of data
  - We have a Data Request Submission Tool – a mechanism to communicate through GEOGLAM to CEOS agencies when users are “ready” for data.

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Thank you!

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