ASIS

Agriculture Stress Index System

MONITORING AGRICULTURE DROUGHT WITH REMOTE SENSING DATA

Global Near Real Time Cropland & grassland Agricultral Stress Index

vito
vision on technology

GIEWS
Global Information and early Warning System on food and Agriculture

Herman Eerens, Roel Van Hoolst, Dominique Haesen, Bart Deronde

Paul Racionzer, YanYun Li, Oscar Rojas

GIEWS
Global Information and early Warning System on food and Agriculture

Timeline

vito
vision on technology

Methodology for drought monitoring with satellites

- METOP
- Global
- Near Real Time
- FAO server

- Rainfall data
- More anomalies
- Maps and graphs for GIEWS website
- Per country output

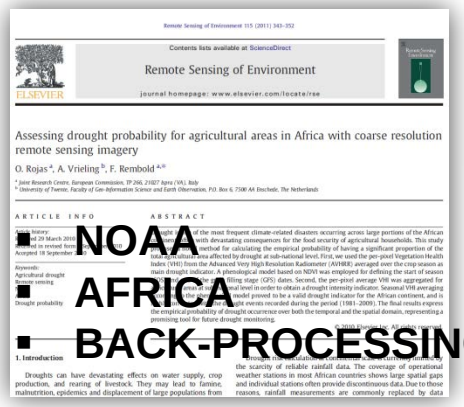
- Global adaptations
- Stand alone Tool

Rojas *et al.* (FAO) 2011

ASIS1 2012-2013

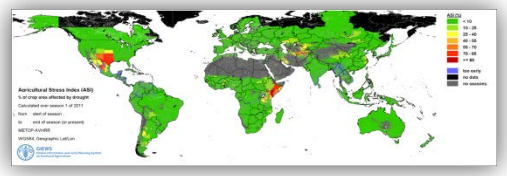
ASIS1-Bis 2014

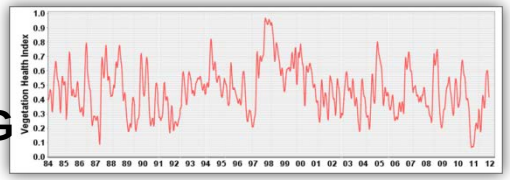
ASIS2 2015-2016

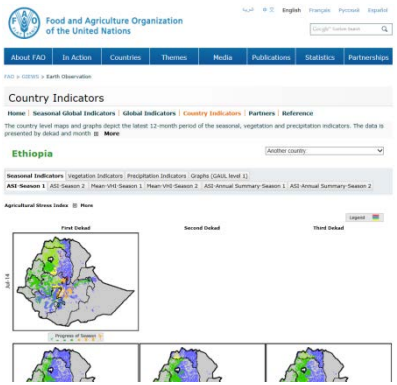

Remote Sensing of Environment

Assessing drought probability for agricultural areas in Africa with coarse resolution remote sensing imagery

O. Rojas, A. Vrieling, F. Rembold







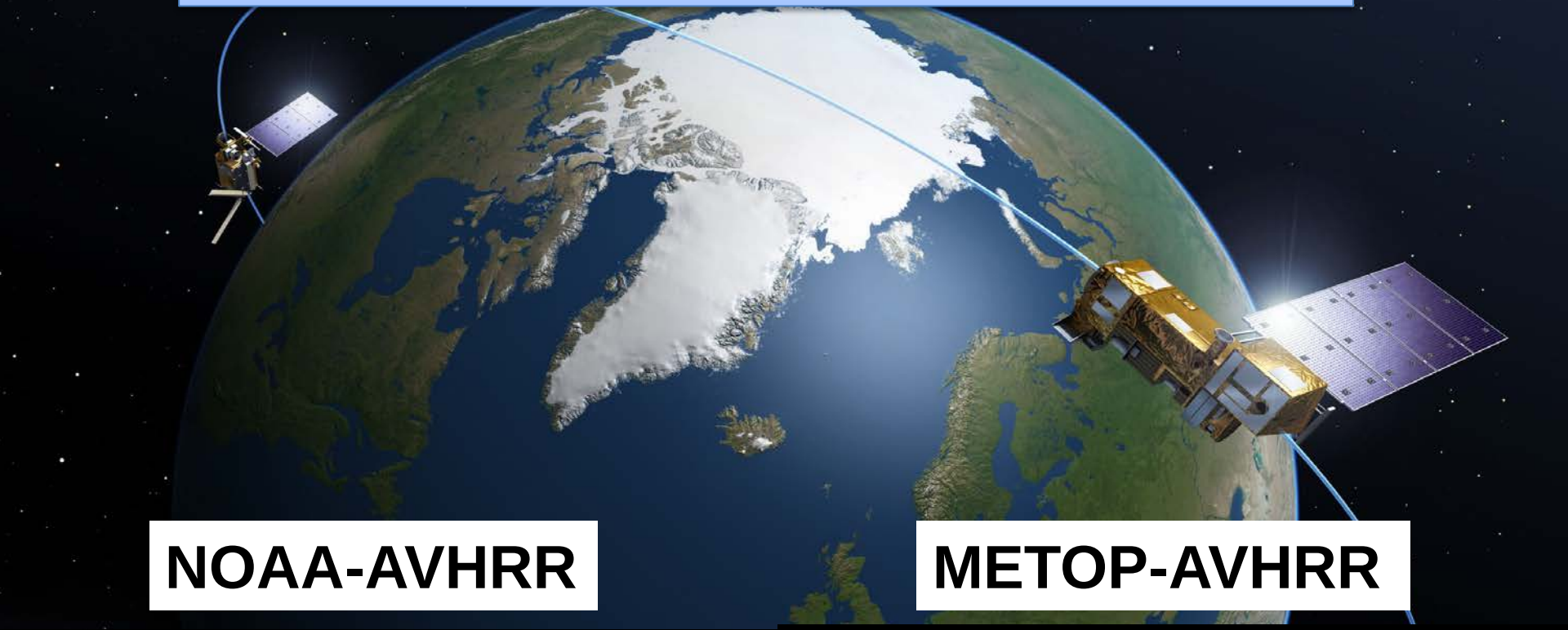
- NOAA
- AFRICA
- BACK-PROCESSING

Agricultural Stress Index (ASI)

The ASI represents:

- the percentage of "**cropped or grassland areas**"
- within each "**administrative region**"
- which are affected by "**drought**",
- as derived from "**EO-observations**"
- over the course of the "**growing season**".

“EO-observations”



NOAA-AVHRR

- Used in Rojas et al. (2011)
- Center for Satellite Applications and Research (STAR)
- star.nesdis.noaa.gov
- Combination of different NOAA’s
- Weekly at 16 km [1984-TODAY]
- In ASIS to extend METOP archive

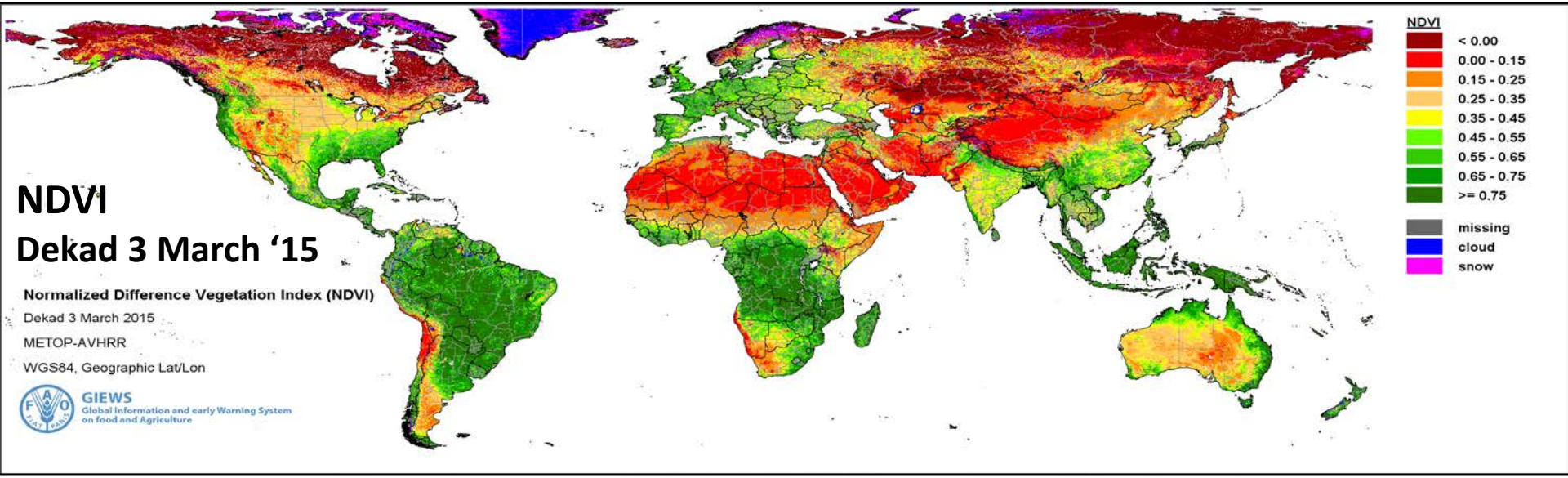
METOP-AVHRR

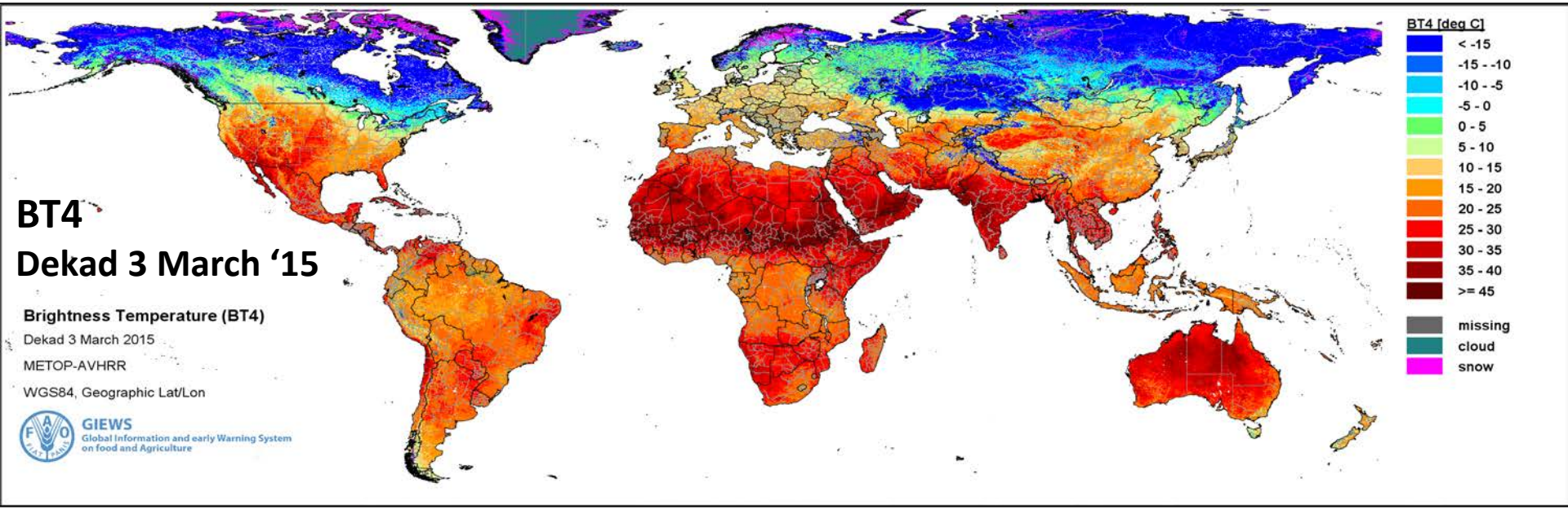
- Raw data from EUMETSAT
- Processing at VITO permises
- metops10.vito.be
- 10-daily at 1 km [2007-TODAY]
- Expected: continued delivery untill mid 2020’s

“EO-observations”

- **NDVI [land: 0.15 … 0.85]:**
  - Normalized Difference Vegetation Index
  - Combination of RED and NIR reflectances
  - Good indicator of the amount of green vegetation
- **BT4 [-50° … +50 °C]:**
  - Brightness Temperature
  - In thermal infrared band 4 (10.3 – 11.3 µm)
  - Good indicator of land surface temperature

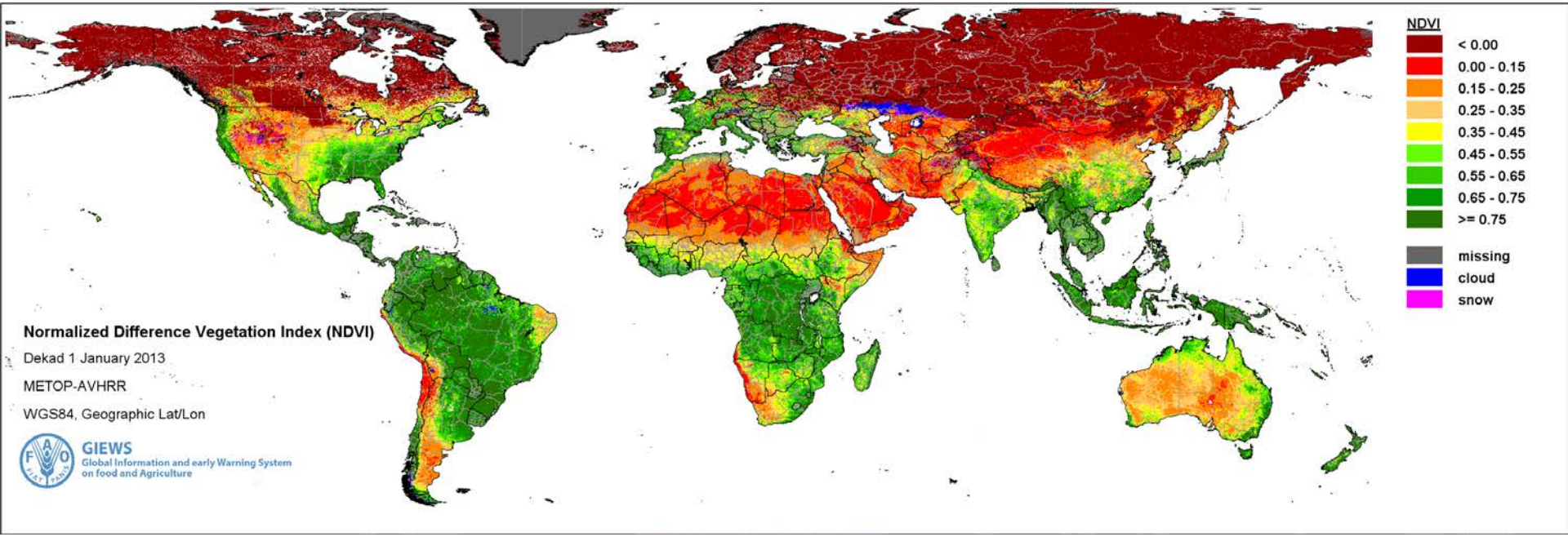
“EO-observations”





Time series of “EO-observations”

Animation of NDVI in 2013 (36 dekads)

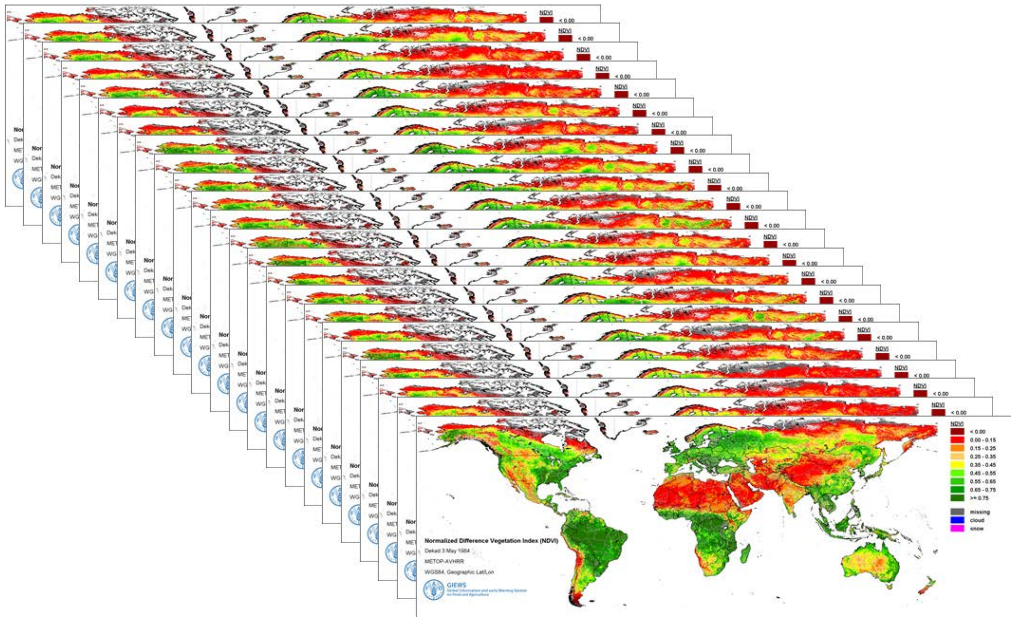


Building a 30 year archive via “DATA FUSION”:

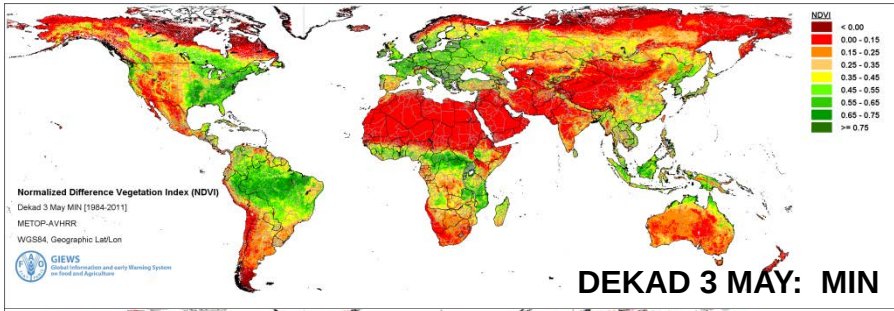
- METOP [1km] since 2007
- NOAA [16km] since 1984 → METOP “alikes” at 1 km for years 1984-2006

Time series of "EO-observations"

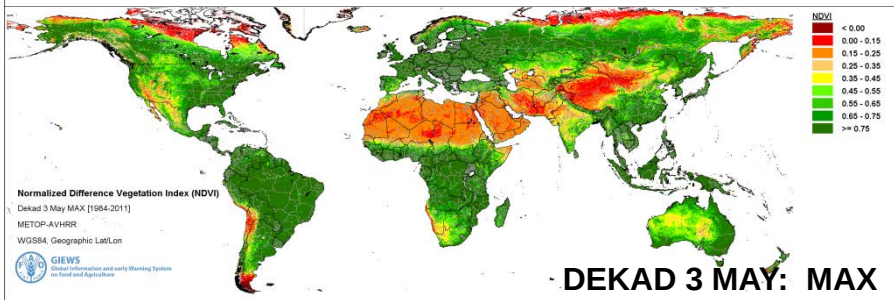
1984 – dekad 3 of MAY



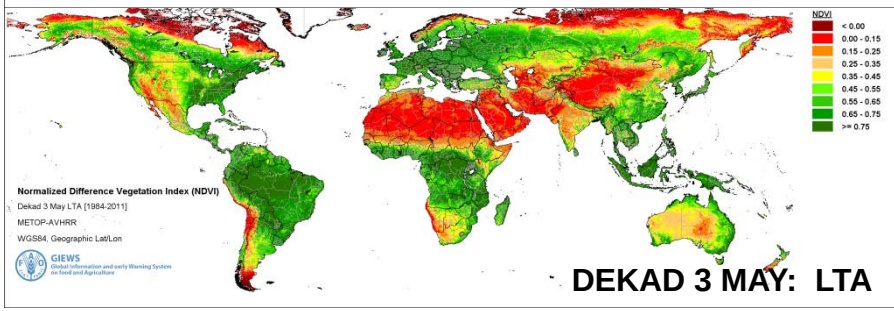
2013 – dekad 3 MAY



DEKAD 3 MAY: MIN



DEKAD 3 MAY: MAX



DEKAD 3 MAY: LTA

- 30 years of data → Long Term Statistics (LTS)
  - For each dekad: historical minimum/maximum/average
  - Separately for NDVI and BT4
- LTS used to derive:
  - Phenology (average) "growing season"
  - Anomalies (min & max) "drought"

Agricultural Stress Index (ASI)

The ASI represents:

- the percentage of "**cropped or grassland areas**"
- within each "**administrative region**"
- which are affected by "**drought**",
- as derived from "**EO-observations**"
- over the course of the "**growing season**".

"Drought" = Low plant activity & High temperatures

Anomalies: Compare actual values with historical Minimum / Maximum based on ± 30 years of observations

Vegetation condition index (VCI)

$$VCI_i = \frac{NDVI_i - NDVI_{\min}}{NDVI_{max} - NDVI_{min}}$$

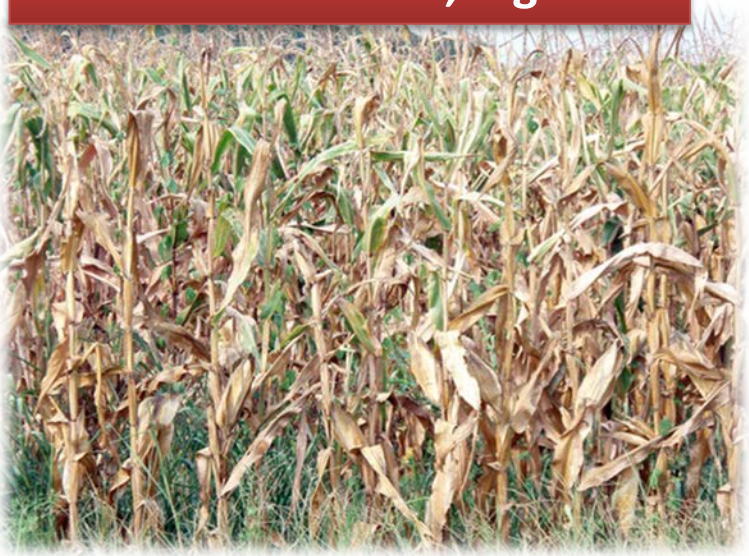
Temperature condition index (TCI)

$$TCI_i = \frac{BT_{max} - BT_{\mathrm{i}}}{BT_{max} - BT_{min}}$$

Vegetation Health Index (VHI) (Kogan *et al.*)

VHI = w*VCI + (1-w)* TCI

low VHI: low NDVI, high BT4



high VHI: high NDVI, low BT4

"Drought" = Low plant activity & High temperatures

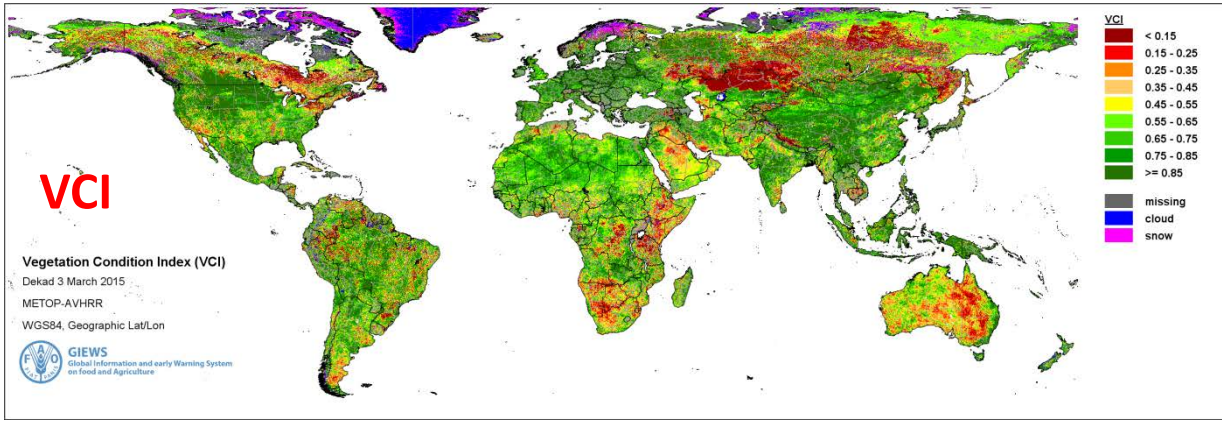
Example for:
2015, March, Dekad 3

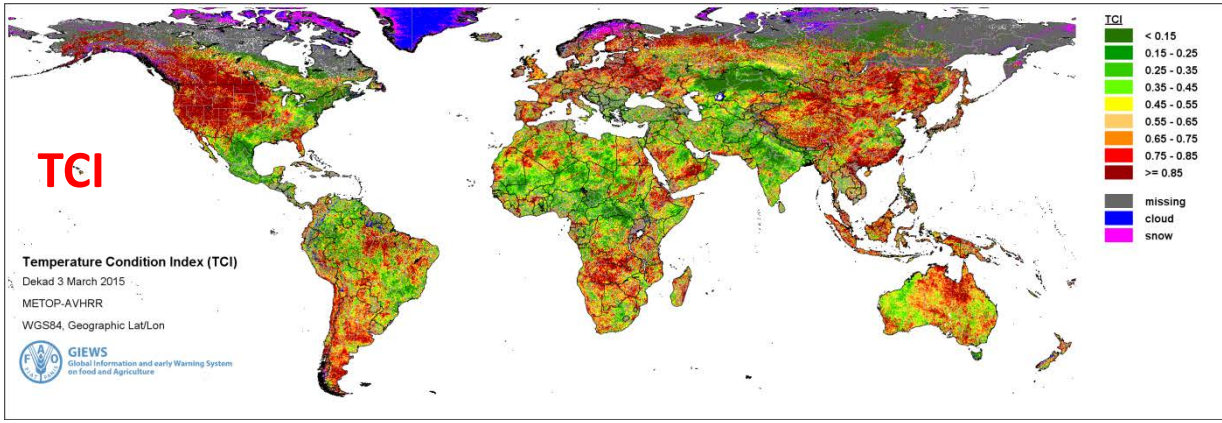
VHI = w*VCI + (1-w)*TCI

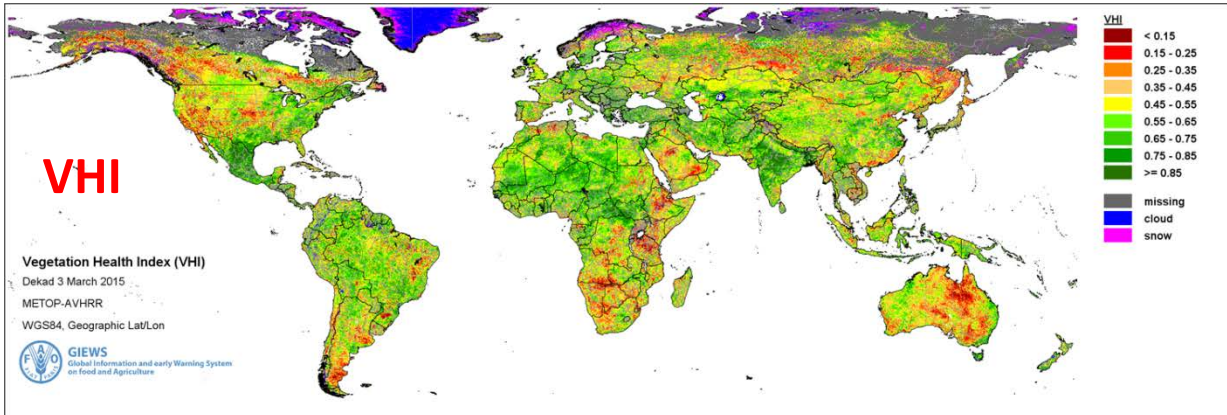
So far: w=0.5 →

VHI = 0.5*VCI + 0.5*TCI

VHI = Basic monitoring Index in ASIS (per dekad)







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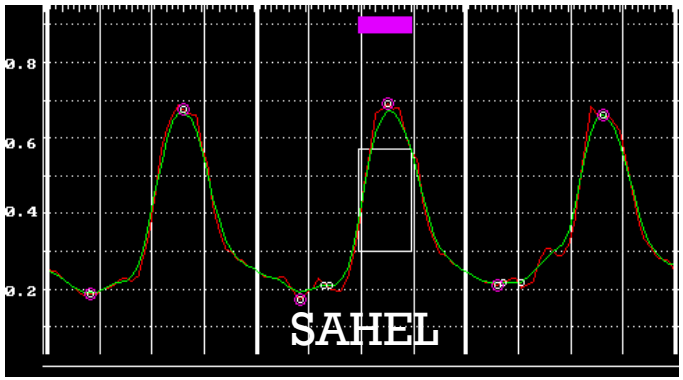
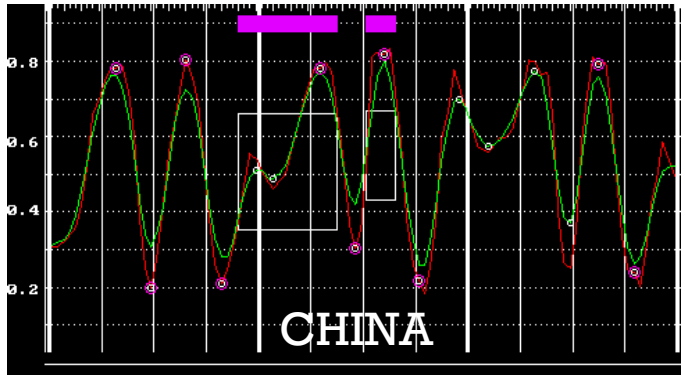
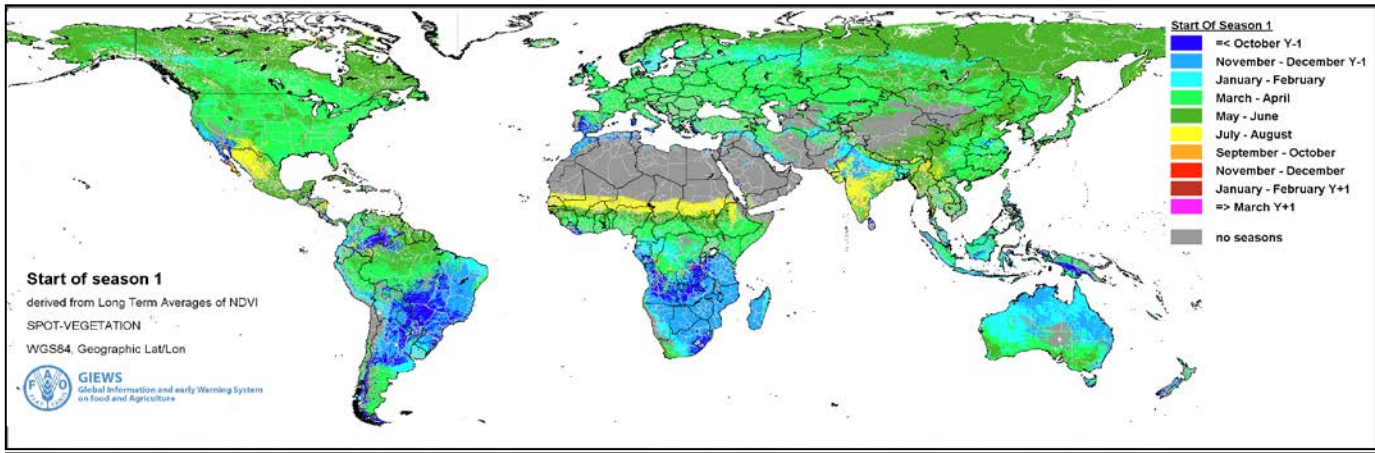
“Growing Season”: Start/End dates (SOS/EOS)

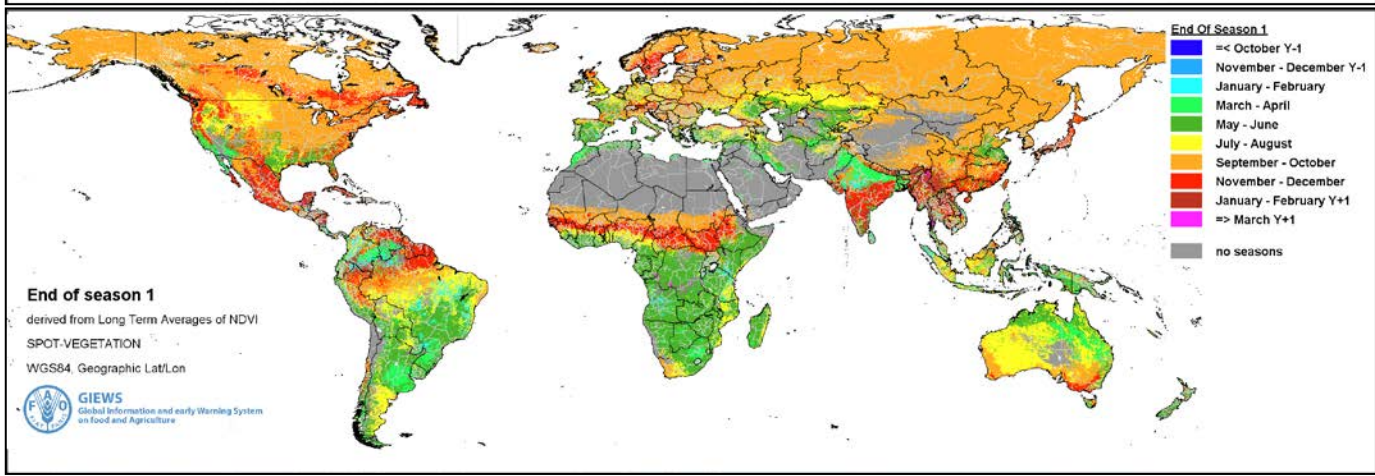
Multi-annual VI-profiles per pixel





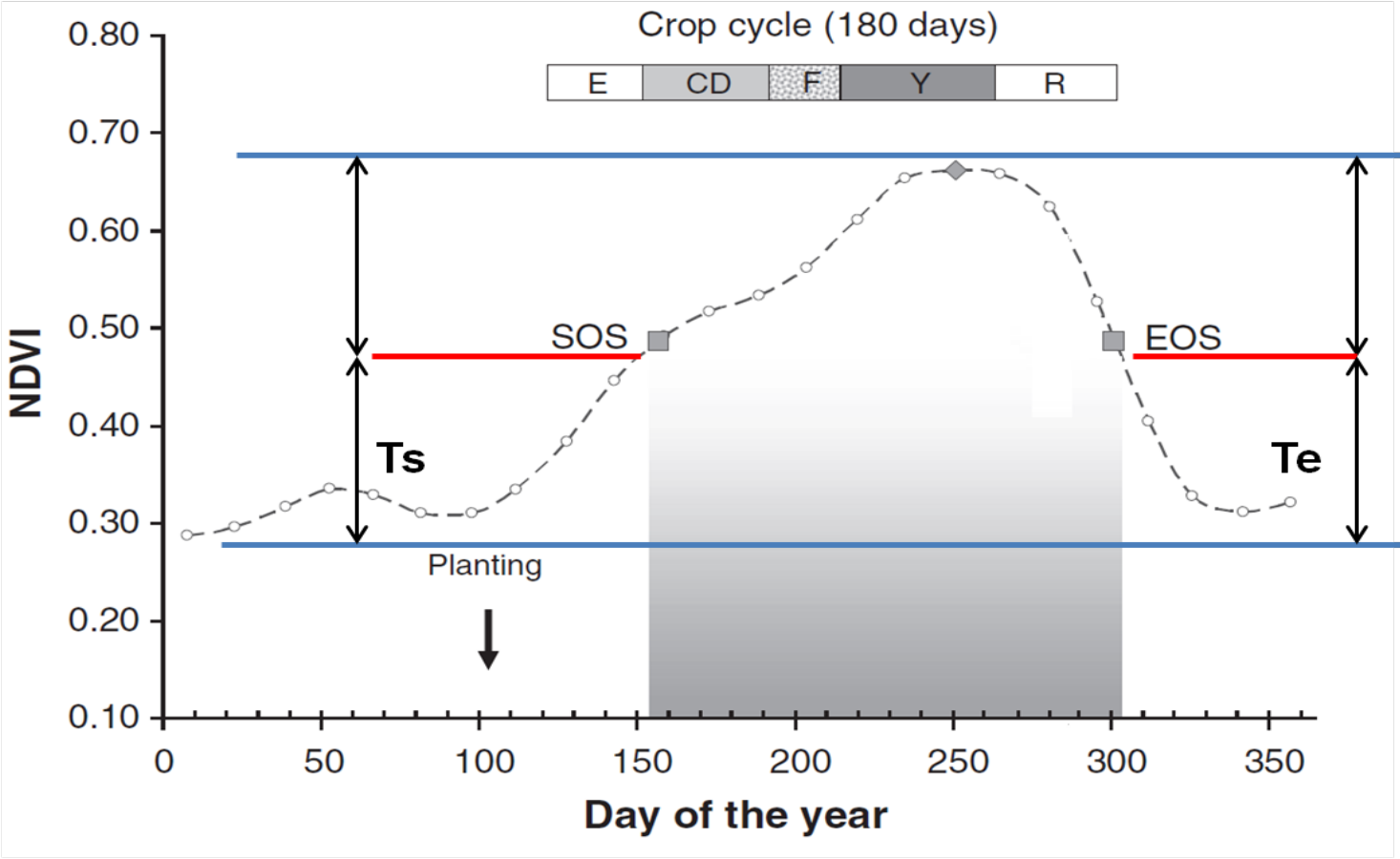
IMGs with Dates of Start and End of 1 or 2 Seasons in Central Year





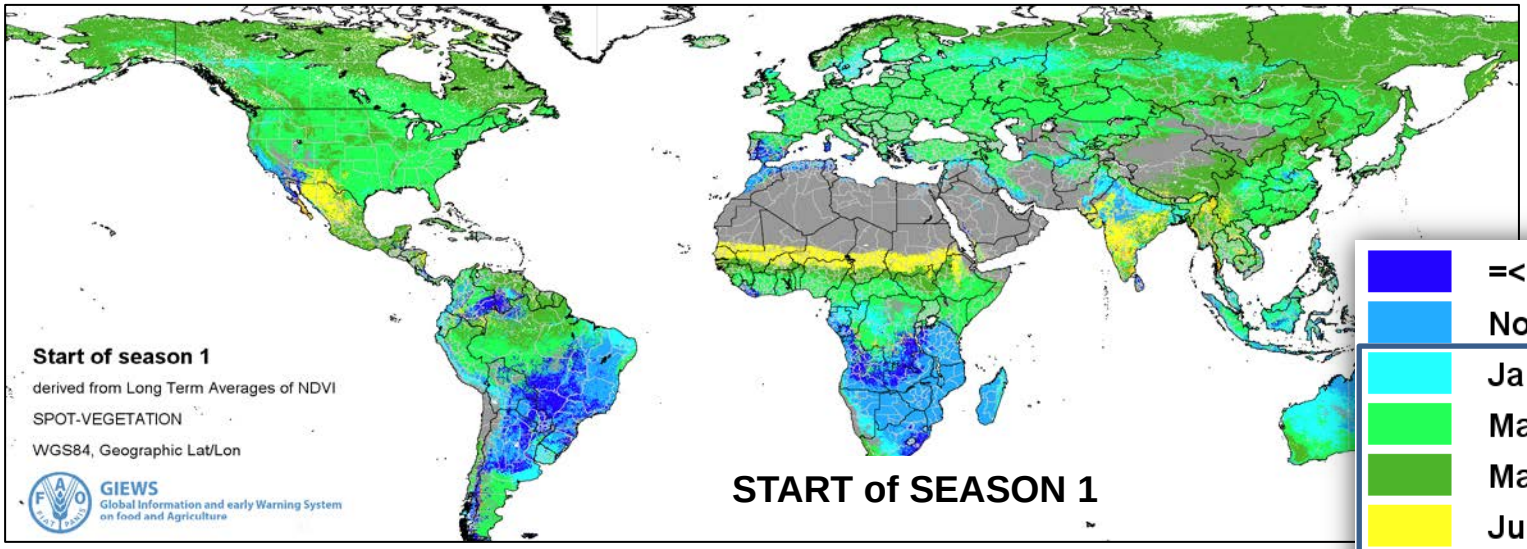
Example for NDVI-LTA of SPOT-VGT

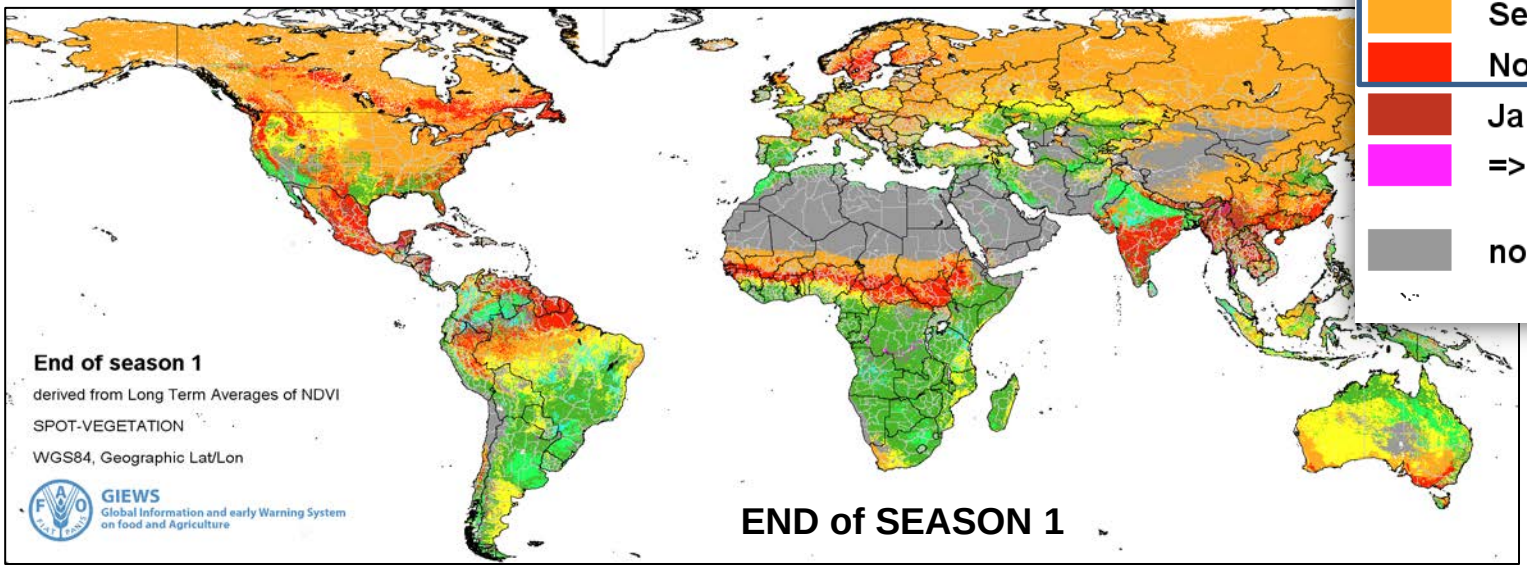
“Growing Season”: Start/End dates (SOS/EOS)



- Based on modified methodology of White et al. 1997
- Using SPOT-VGT Long Term Average of NDVI → Fixed over years
- A season is assigned to the year where the MAXIMUM NDVI occurs
- Two growing seasons allowed per year

“Growing Season”: Start/End dates (SOS/EOS)





=< October Y-1
November - December Y-1
January - February
March - April
May - June
July - August
September - October
November - December
January - February Y+1
=> March Y+1

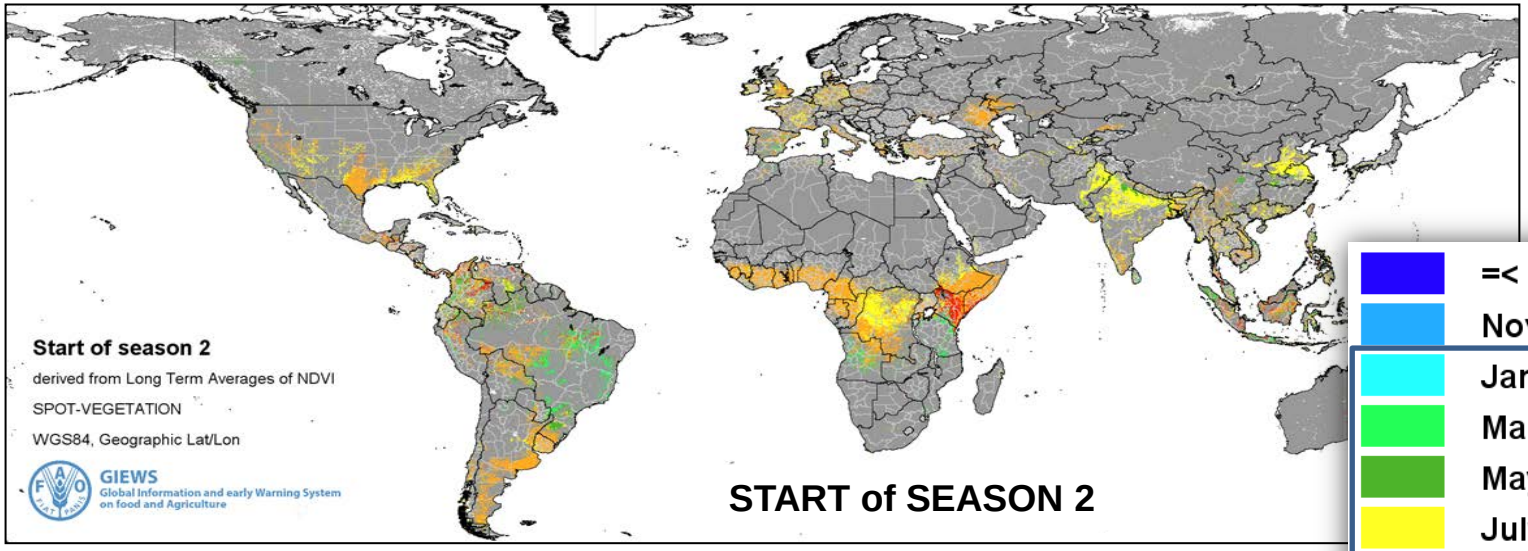
no seasons

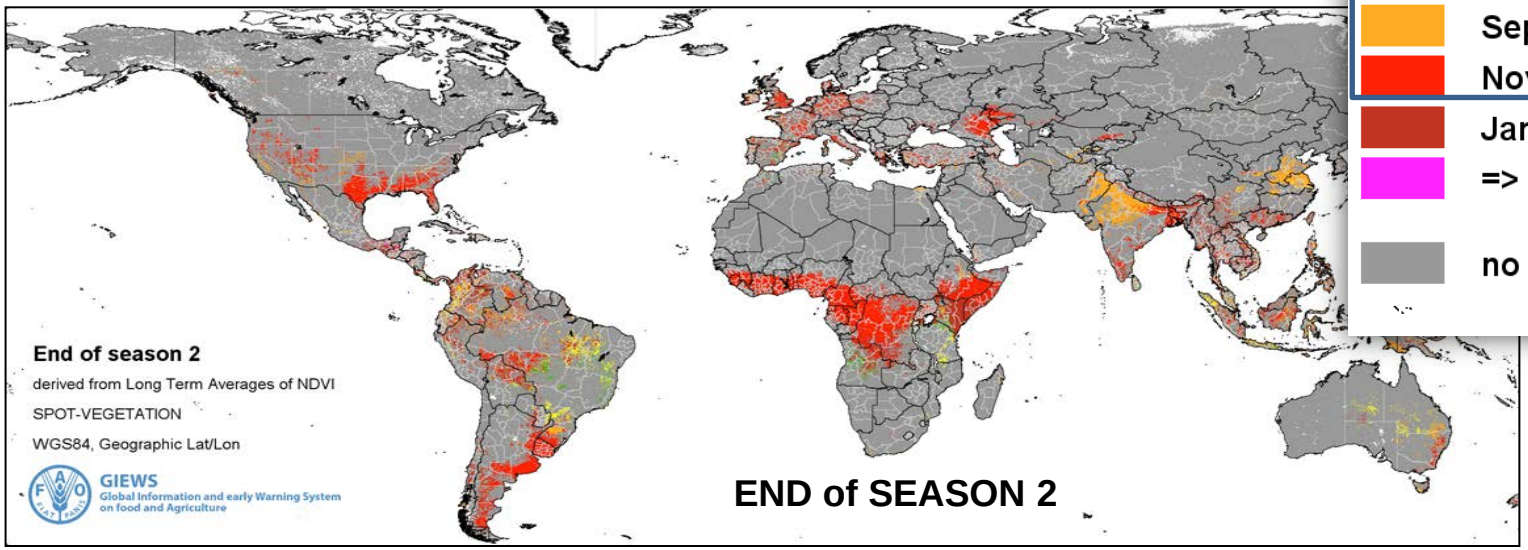
*SOS and EOS of the **first season**, as derived from the long term NDVI averages of SPOT-VGT*

Y-1 = season with MAX NDVI in current year starts in previous year

Y+1 = season with MAX NDVI in current year ends in next year

“Growing Season”: Start/End dates (SOS/EOS)





=< October Y-1
November - December Y-1
January - February
March - April
May - June
July - August
September - October
November - December
January - February Y+1
=> March Y+1
no seasons

*SOS and EOS of the **second season**, as derived from the long term NDVI averages of SPOT-VGT*

Y-1 = season with MAX NDVI in current year starts in previous year

Y+1 = season with MAX NDVI in current year ends in next year

Agricultural Stress Index (ASI)

The ASI represents:

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- within each "**administrative region**"
- which are affected by "**drought**",
- as derived from "**EO-observations**"
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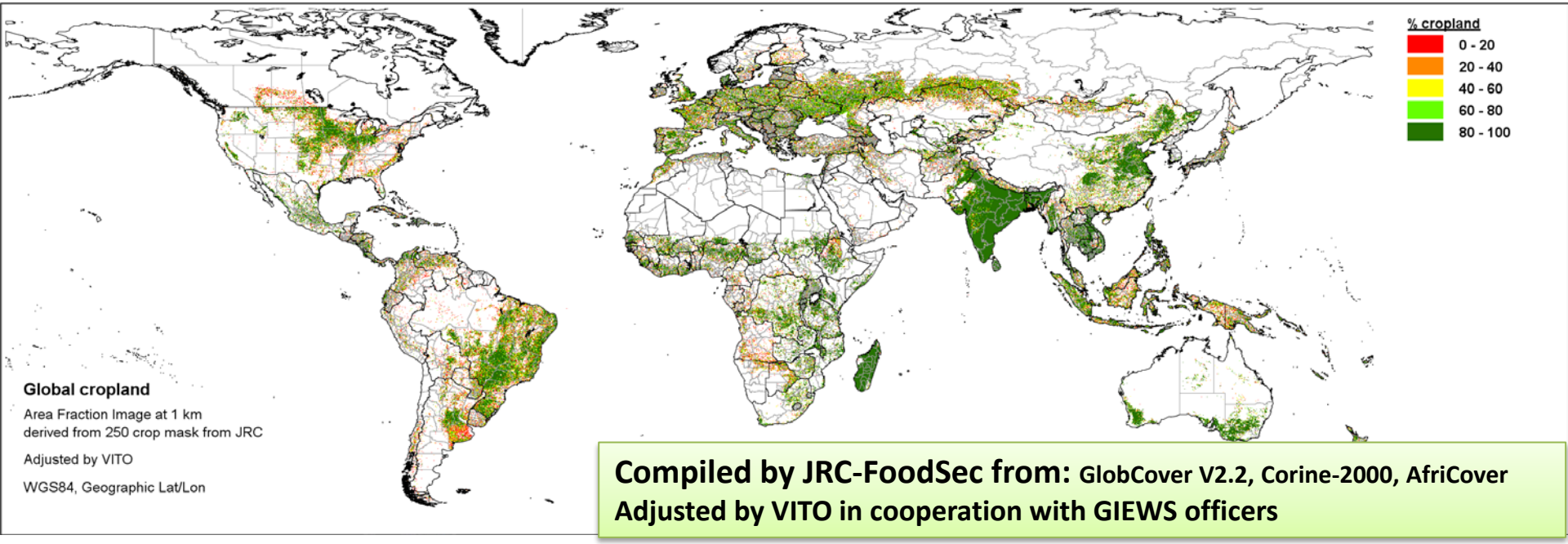
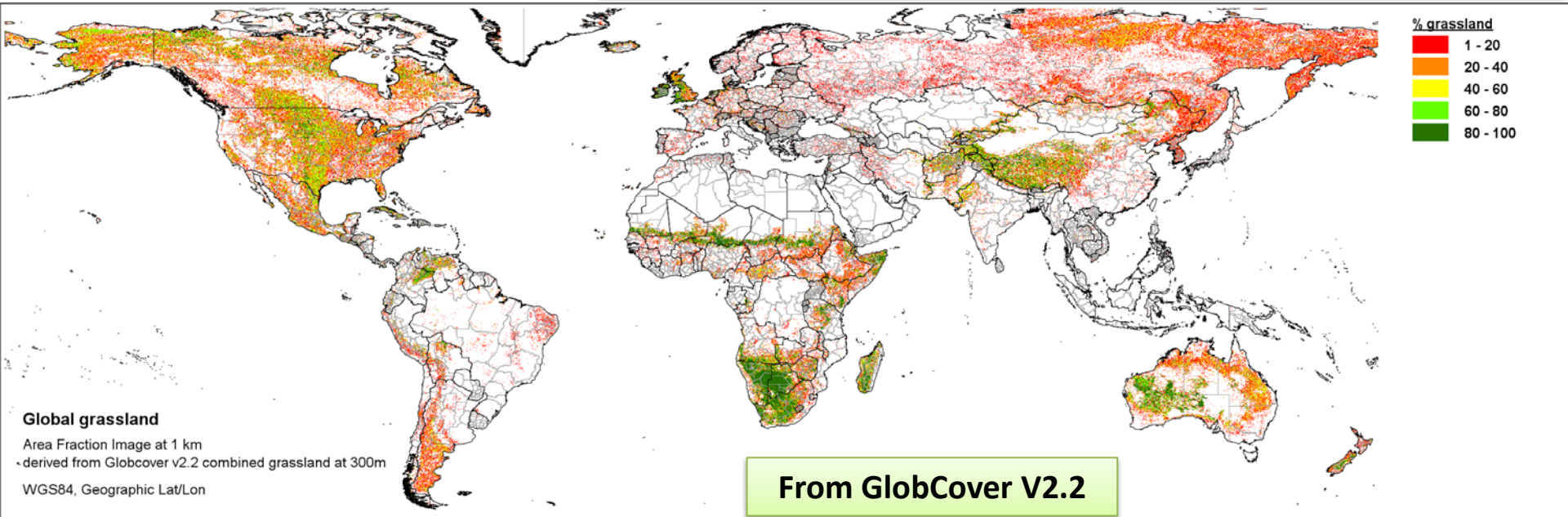
“Cropped or Grassland Areas”



Compiled by JRC-FoodSec from: GlobCover V2.2, Corine-2000, AfriCover
Adjusted by VITO in cooperation with GIEWS officers



From GlobCover V2.2

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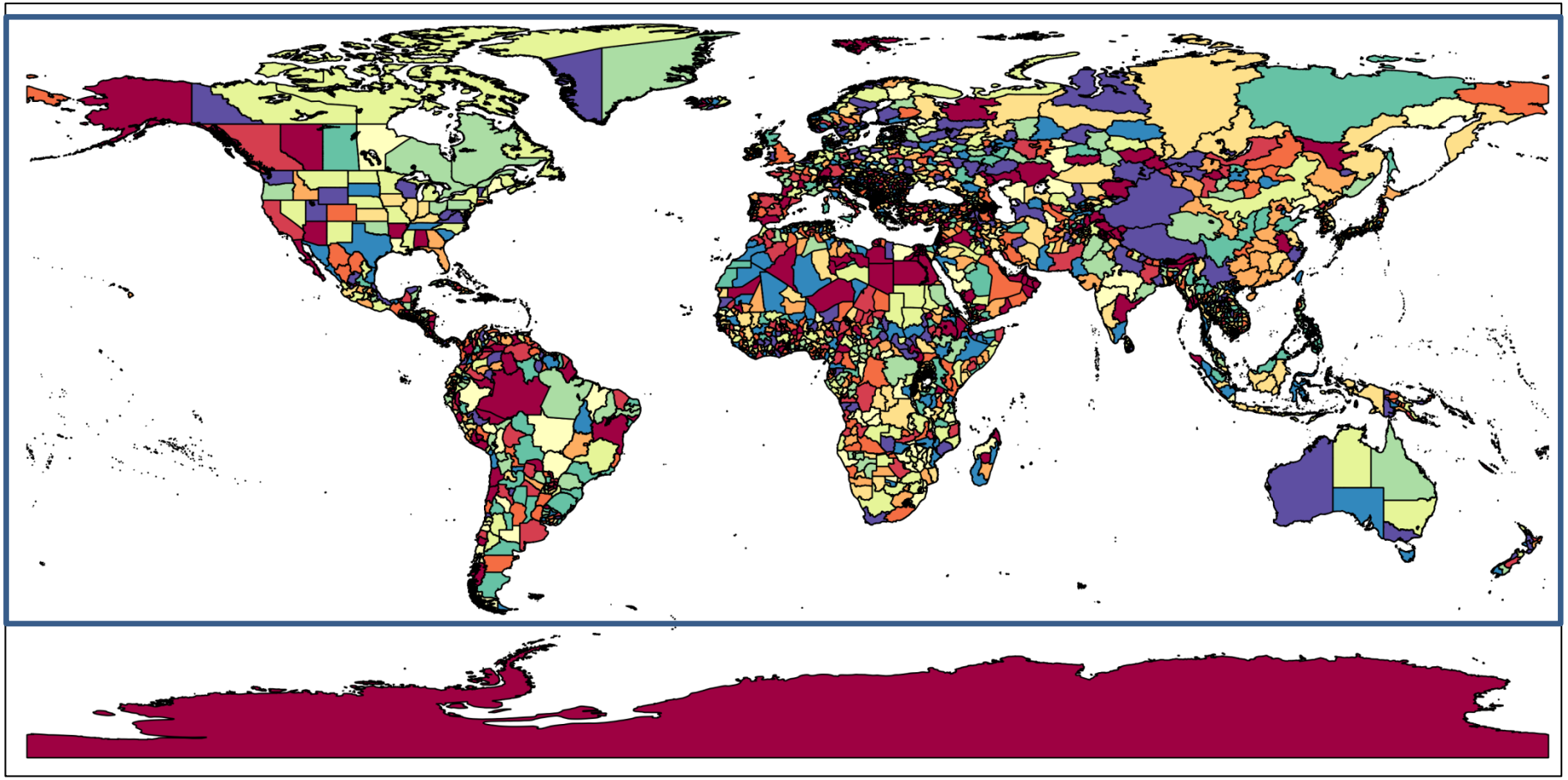
“Administrative Region”

GAUL = Global Administrative Unit Layer (FAO)



GAUL0 (country), **GAUL1** (province), **GAUL2** (district)

Agricultural Stress Index (ASI)

The ASI represents:

- the percentage of "**cropped or grassland areas**" within each "**administrative region**"

  → SPATIAL AGGREGATION (per region x LU-type)

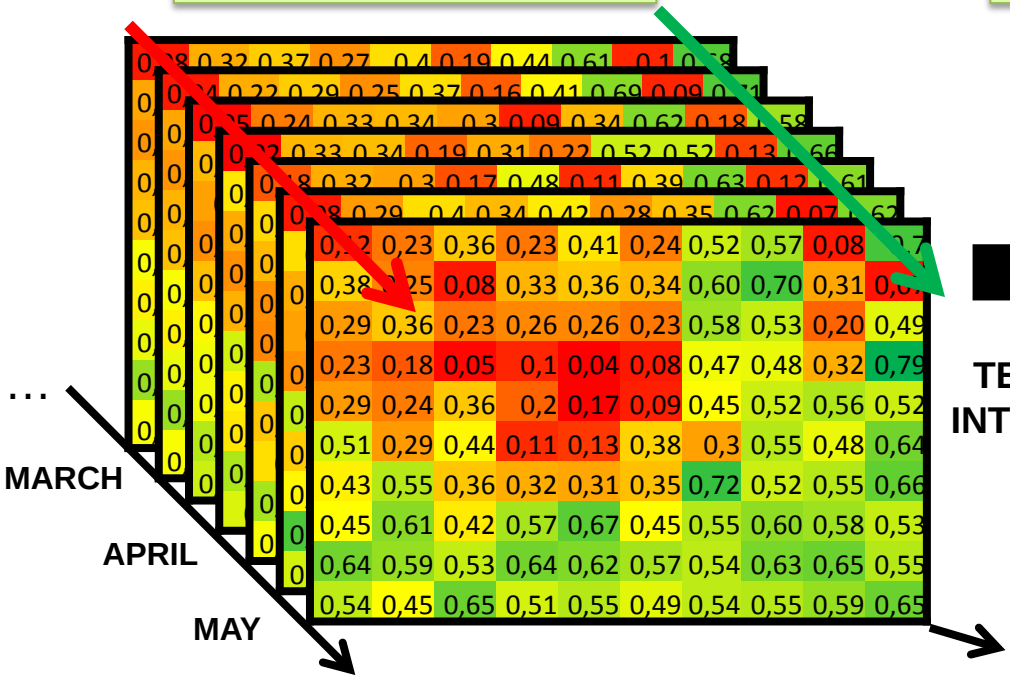
- which are affected by "**drought**", as derived from "**EO-observations**"
- over the course of the "**growing season**".

  → TEMPORAL INTEGRATION (per pixel)

ASI: Temporal Integration (per pixel)

Dekadal VHI images

Mean VHI image over the crop season

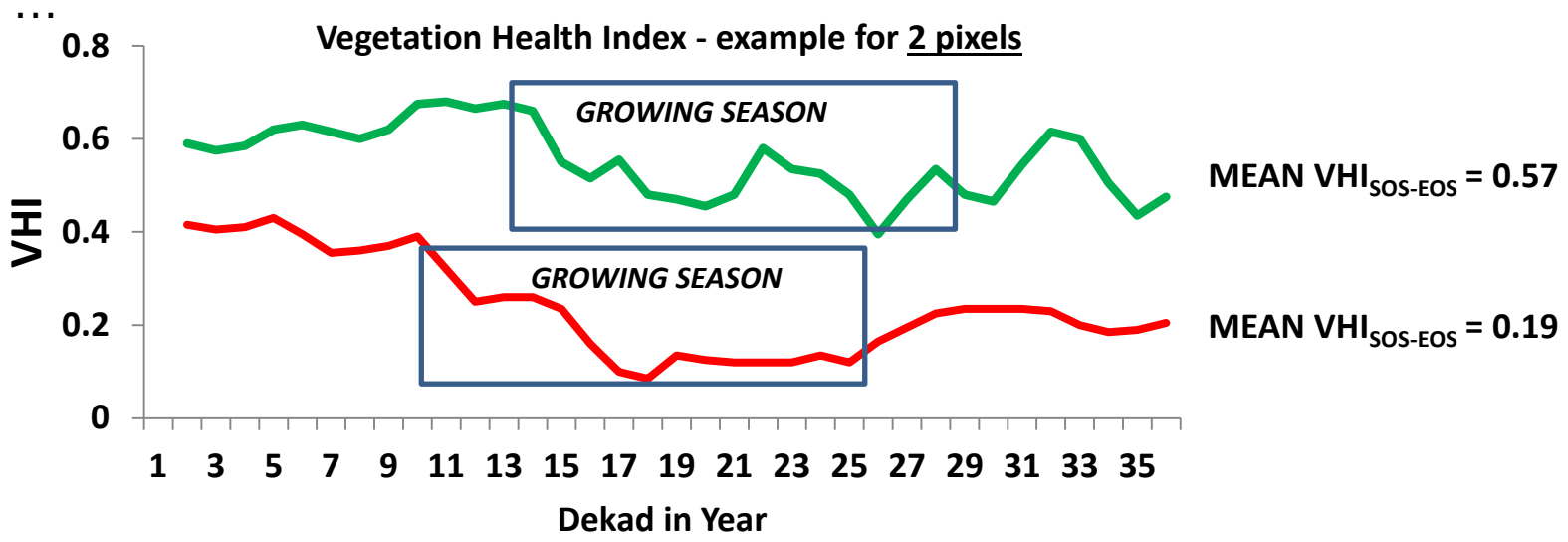


(1)

TEMPORAL INTEGRATION

0,19	0,24	0,33	0,18	0,34	0,1	0,34	0,54	0,06	**0,57**
0,29	0,23	0,01	0,27	0,34	0,32	0,57	0,6	0,25	0,05
0,24	0,3	0,21	0,21	0,22	0,17	0,52	0,43	0,16	0,45
0,31	0,16	0,03	0,07	0,03	0,06	0,37	0,46	0,25	0,76
0,26	0,19	0,34	0,16	0,09	0,03	0,44	0,50	0,50	0,42
0,39	0,27	0,34	0,07	0,07	0,35	0,26	0,50	0,45	0,60
0,38	0,48	0,30	0,26	0,21	0,28	0,69	0,44	0,51	0,58
0,40	0,60	0,41	0,48	0,57	0,43	0,54	0,59	0,50	0,46
0,50	0,52	0,51	0,57	0,52	0,51	0,45	0,54	0,58	0,54
0,43	0,44	0,56	0,46	0,52	0,46	0,46	0,48	0,56	0,55

GAUL REGION (10 x 10 pixels)



ASI: Spatial Aggregation (per region x LU-type)

Mean VHI image over the crop season

0,07	0,24	0,33	0,18	0,34	0,10	0,34	0,54	0,06	0,66
0,29	0,23	0,01	0,27	0,34	0,32	0,57	0,6	0,25	0,05
0,24	0,30	0,21	0,21	0,22	0,17	0,52	0,43	0,16	0,45
0,31	0,16	0,03	0,07	0,03	0,06	0,37	0,46	0,25	0,76
0,26	0,19	0,34	0,16	0,09	0,03	0,44	0,50	0,50	0,42
0,39	0,27	0,34	0,07	0,07	0,35	0,26	0,50	0,45	0,60
0,38	0,48	0,30	0,26	0,21	0,28	0,69	0,44	0,51	0,58
0,40	0,60	0,41	0,48	0,57	0,43	0,54	0,59	0,50	0,46
0,50	0,52	0,51	0,57	0,52	0,51	0,45	0,54	0,58	0,54
0,43	0,44	0,56	0,46	0,52	0,46	0,46	0,48	0,56	0,55

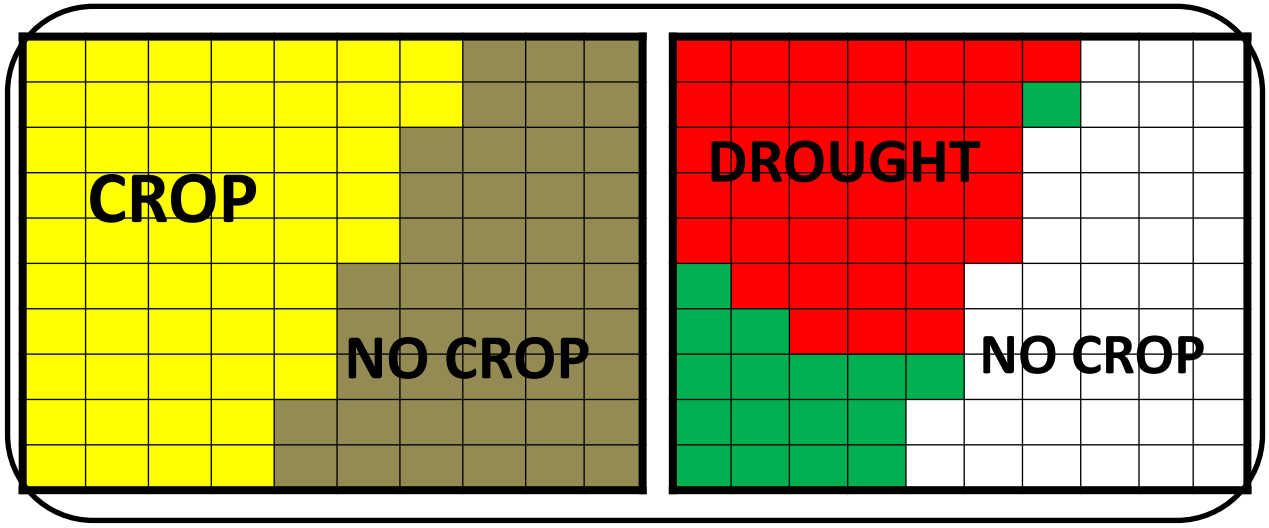
(2) THRESHOLD

PIXELS with MEAN VHI < 35%

0,07	**0,24**	**0,33**	**0,18**	**0,34**	**0,10**	**0,34**	0,54	**0,06**	0,66
0,29	**0,23**	**0,01**	**0,27**	**0,34**	**0,32**	0,57	0,60	**0,25**	**0,05**
0,24	**0,3**	**0,21**	**0,21**	**0,22**	**0,17**	0,52	0,43	**0,16**	0,45
0,31	**0,16**	**0,03**	**0,07**	**0,03**	**0,06**	0,37	0,46	**0,25**	0,76
0,26	**0,19**	**0,34**	**0,16**	**0,29**	**0,03**	0,44	0,50	0,50	0,42
0,39	**0,27**	**0,34**	**0,07**	**0,07**	**0,34**	**0,26**	0,50	0,45	0,60
0,38	0,48	**0,3**	**0,26**	**0,21**	**0,28**	0,69	0,44	0,51	0,58
0,40	0,60	0,41	0,48	0,57	0,43	0,54	0,59	0,50	0,46
0,50	0,52	0,51	0,57	0,52	0,51	0,45	0,54	0,58	0,54
0,43	0,44	0,56	0,46	0,52	0,46	0,46	0,48	0,56	0,55

DROUGHT

(3) ONLY CROP AREA



(4) PIXEL COUNTING

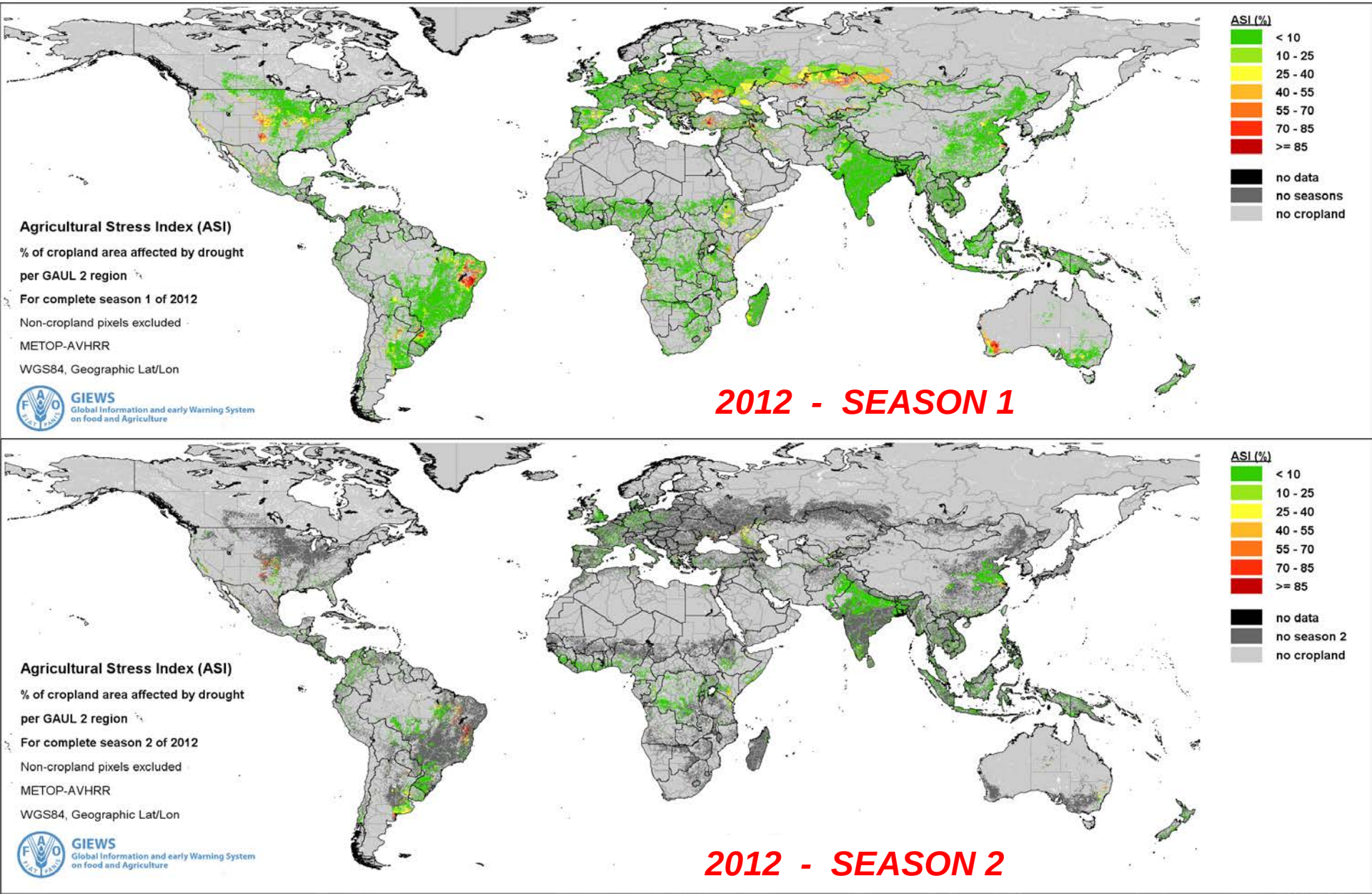
Agricultural Stress Index

ASI

70%

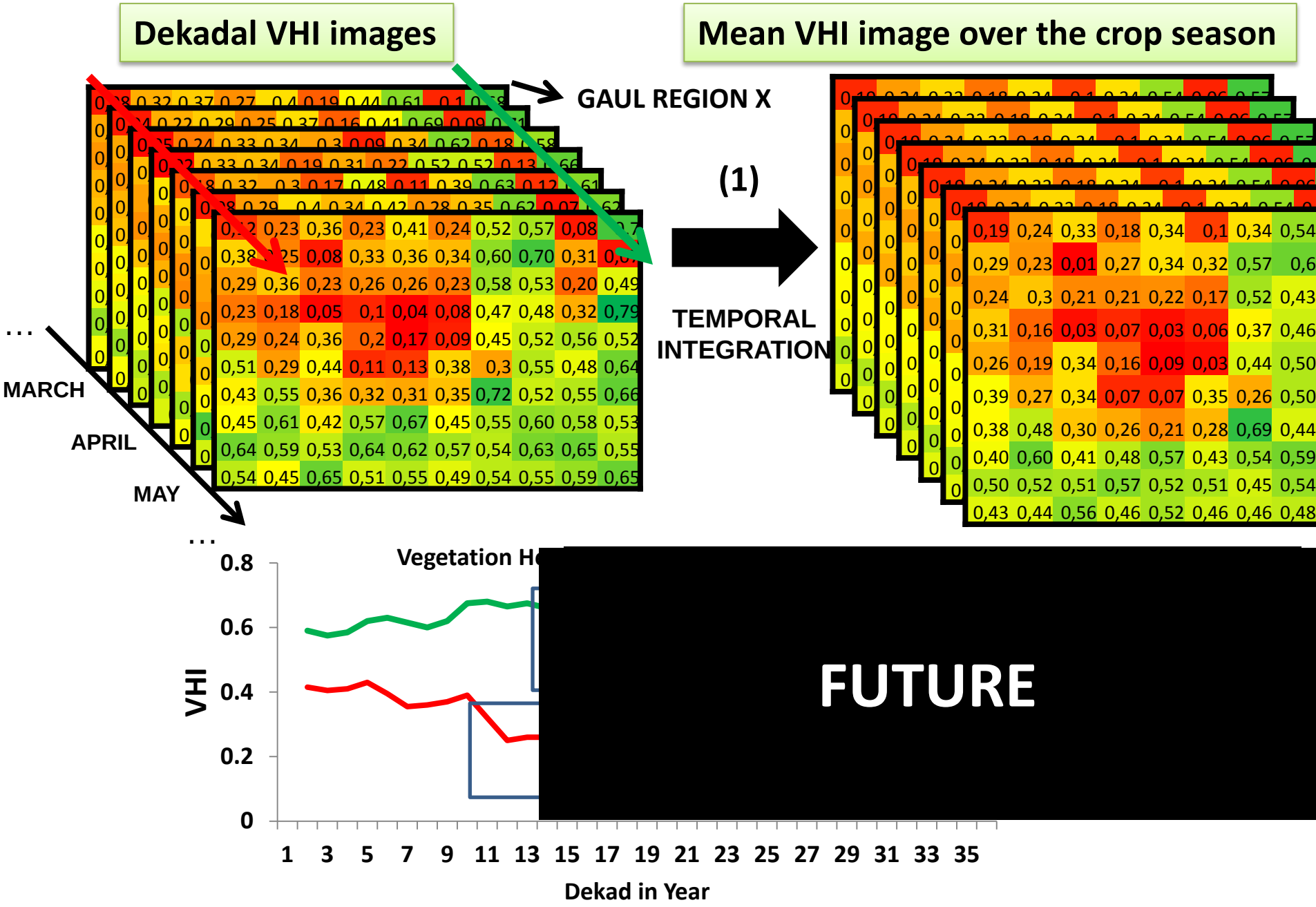
$$\frac{\#\text{drought pixels (38)}}{\#\text{total crop pixels (55)}} = \pm 70\% \text{ of crop area affected by drought}$$

ASI: Back-Processing of Previous Years (1984-2015)

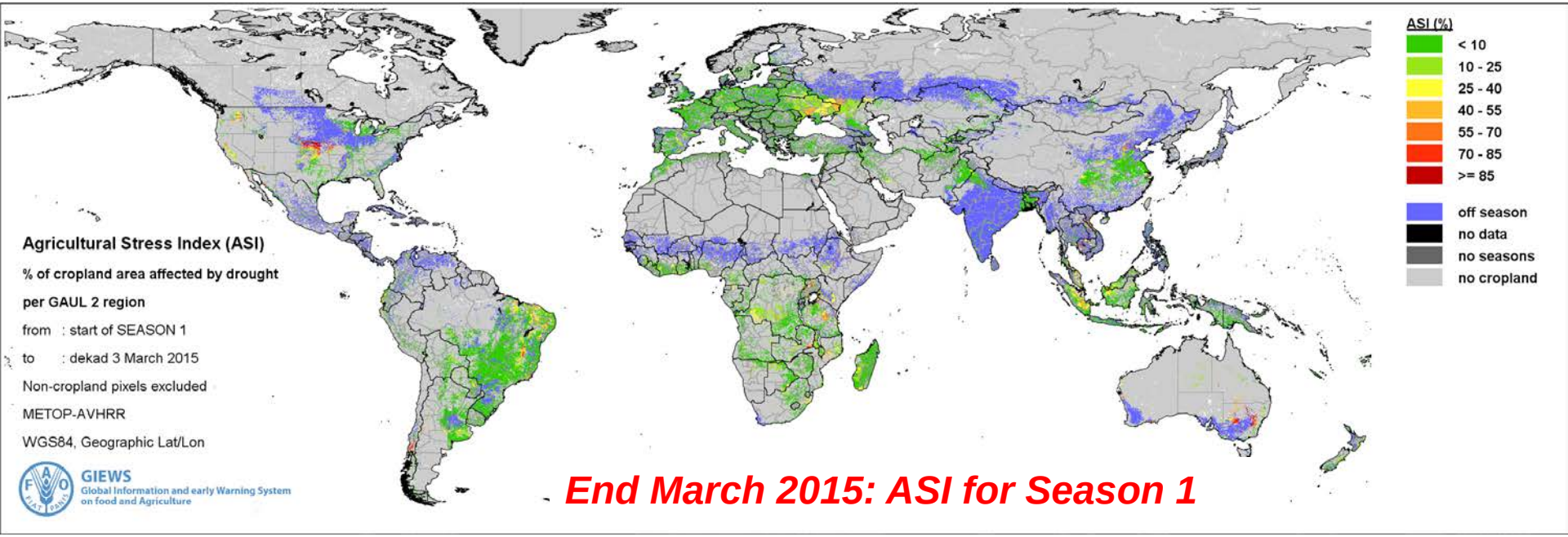


OUTPUTS per YEAR → Validation

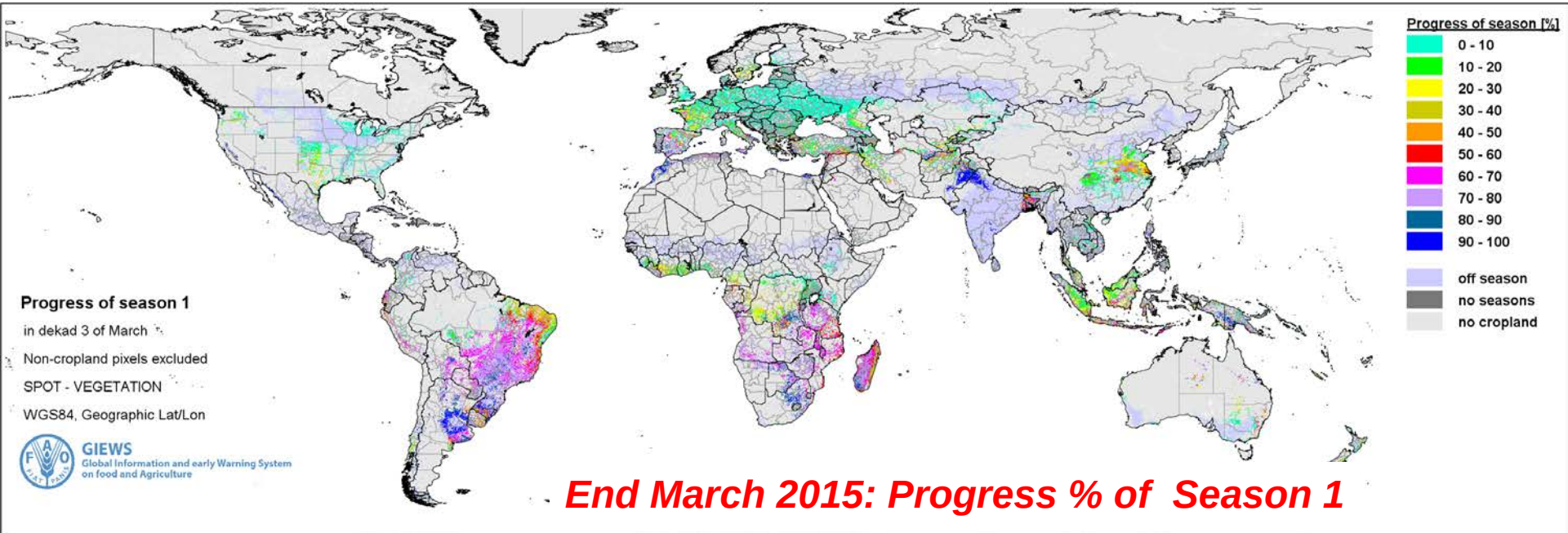
ASI: NRT-Processing of Current Year (2016)



ASI: NRT-Processing → Drought Monitoring & Early Warning



End March 2015: ASI for Season 1



End March 2015: Progress % of Season 1

GIEWS
Global Information and early Warning System on food and Agriculture

Timeline

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Methodology for drought monitoring with satellites

- METOP
- Global
- Near Real Time
- FAO server

- Rainfall data
- More anomalies
- Maps and graphs for GIEWS website
- Per country output

- Global adaptations
- Stand alone Tool

Rojas et al. 2011

2011

ASIS1

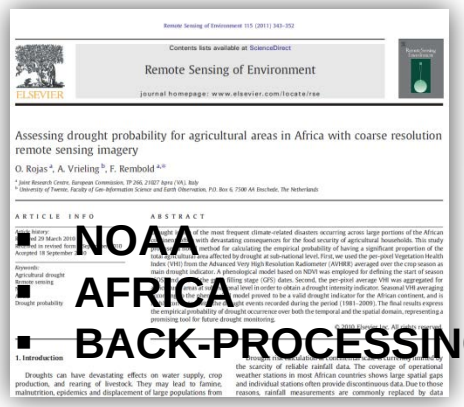
2012-2013

ASIS1-Bis

2014

ASIS2

2015-2016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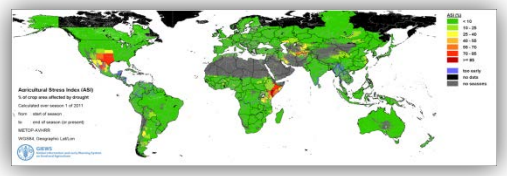
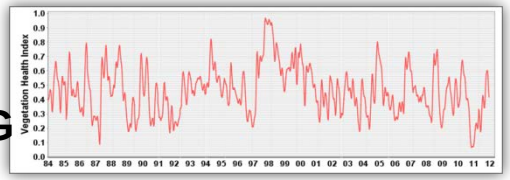
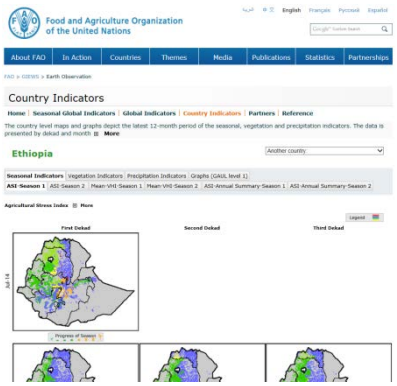
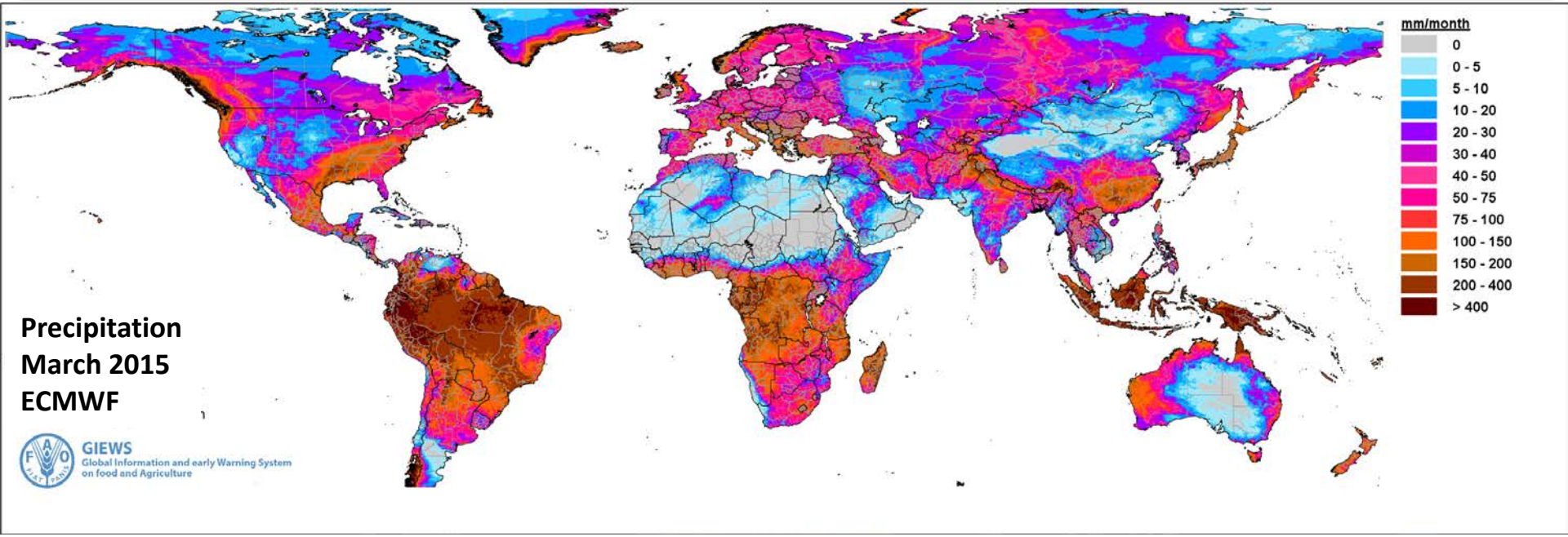


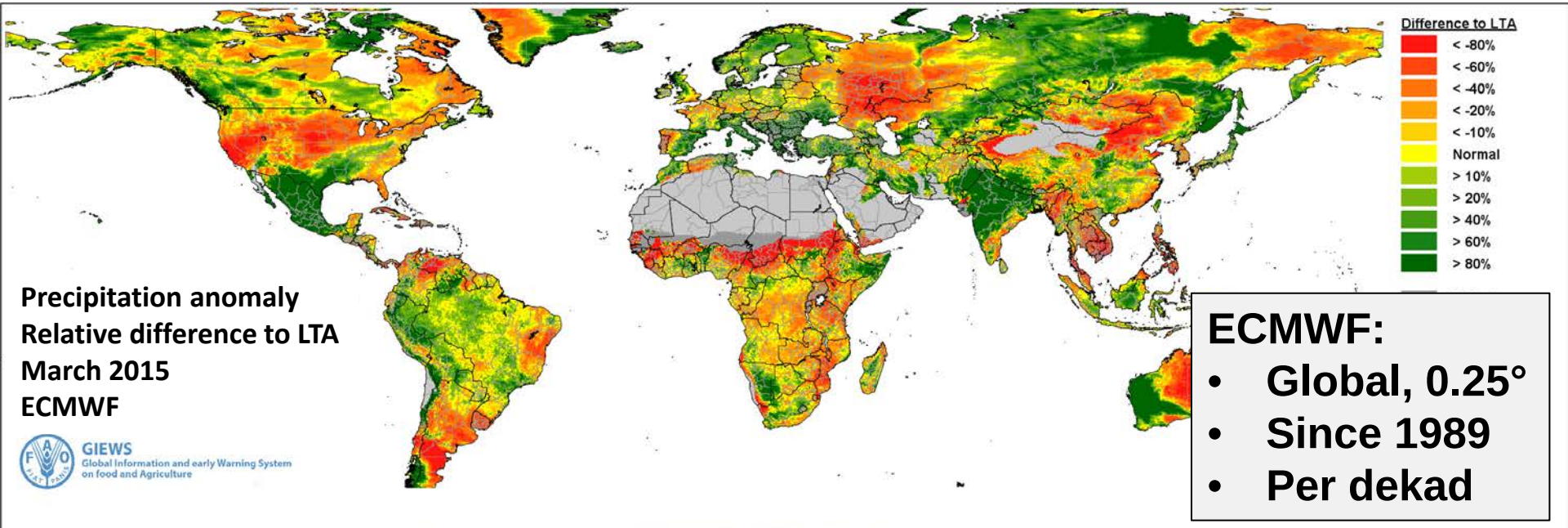




- NOAA
- AFRICA
- BACK-PROCESSING

ASIS1-Bis: Rainfall per Dekad from ECMWF (Global)

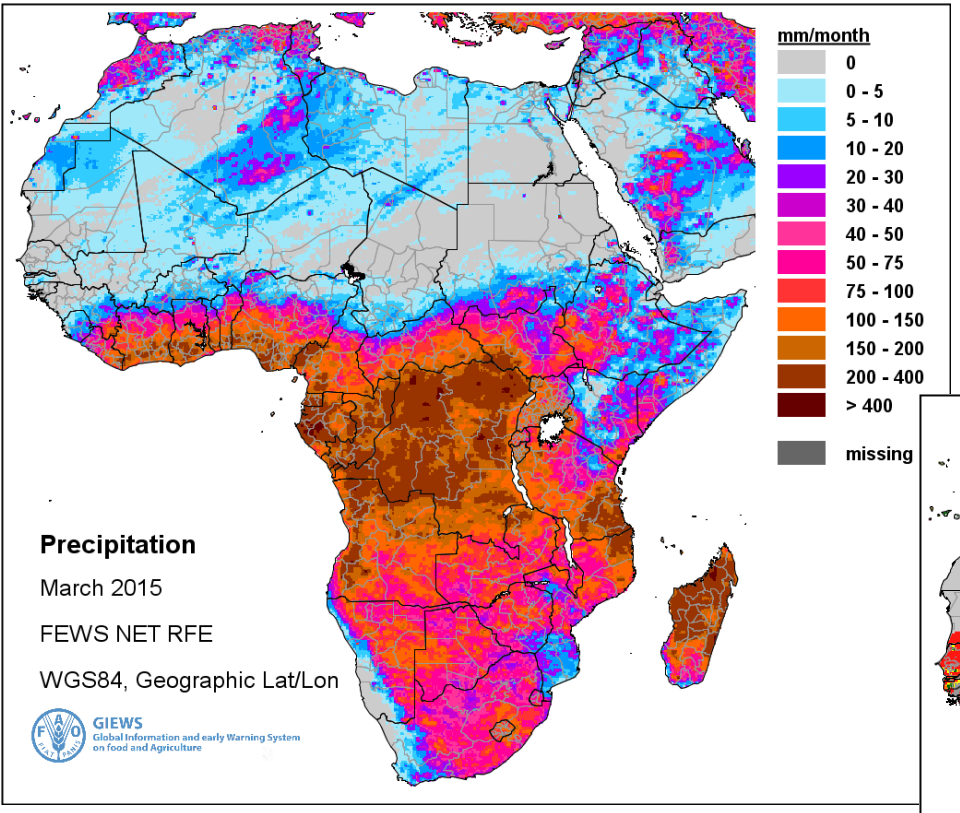




ECMWF:

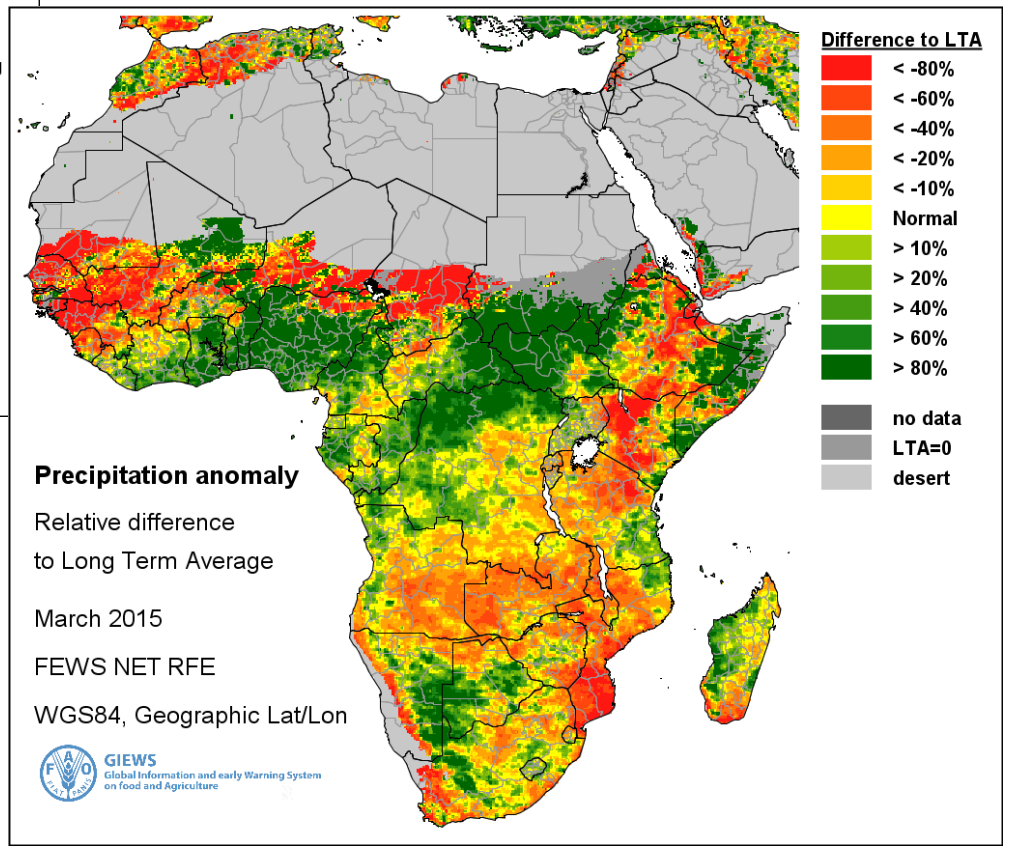
- **Global, 0.25°**
- **Since 1989**
- **Per dekad**

ASIS1-Bis: Rainfall from FEWS NET (Africa)



RFE from FEWS-NET:

- **Africa, 8 km**
- **Since 1995**
- **Per dekad**



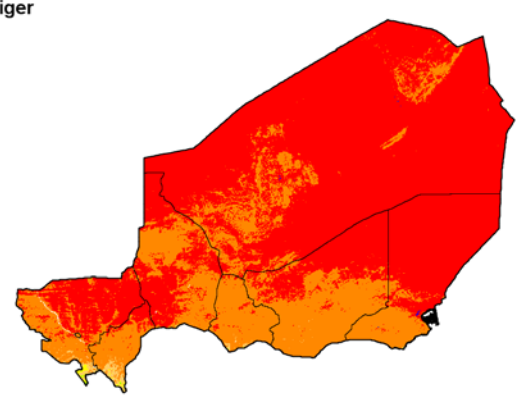
ASIS1-Bis: Data per ROI (ca. 200 countries)

Uganda

Normalized Difference Vegetation Index (NDVI)
Dekad 3 May 2013
METOP-AVHRR
WGS84, Geographic Lat/Lon

GIEWS

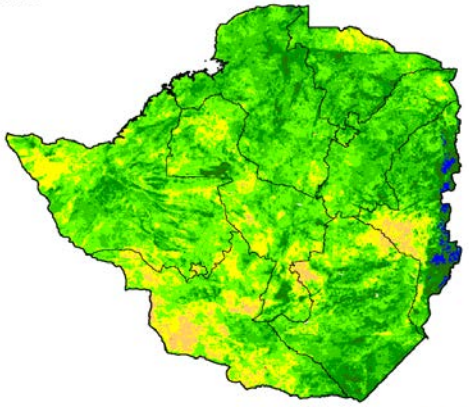
Niger



Normalized Difference Vegetation Index (NDVI)
Dekad 3 May 2013
METOP-AVHRR
WGS84, Geographic Lat/Lon

GIEWS

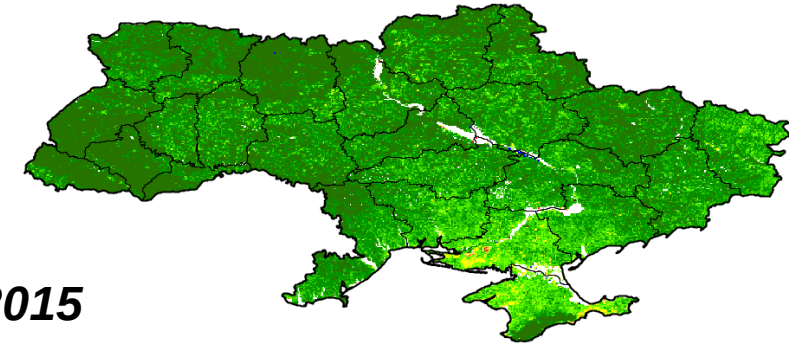
Zimbabwe



Normalized Difference Vegetation Index (NDVI)
Dekad 3 May 2013
METOP-AVHRR
WGS84, Geographic Lat/Lon

GIEWS

Ukraine



Normalized Difference Vegetation Index (NDVI)
Dekad 3 May 2013
METOP-AVHRR
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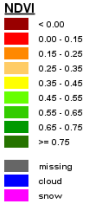


GIEWS

Honduras

Normalized Difference Vegetation Index (NDVI)
Dekad 3 May 2013
METOP-AVHRR
WGS84, Geographic Lat/Lon

GIEWS

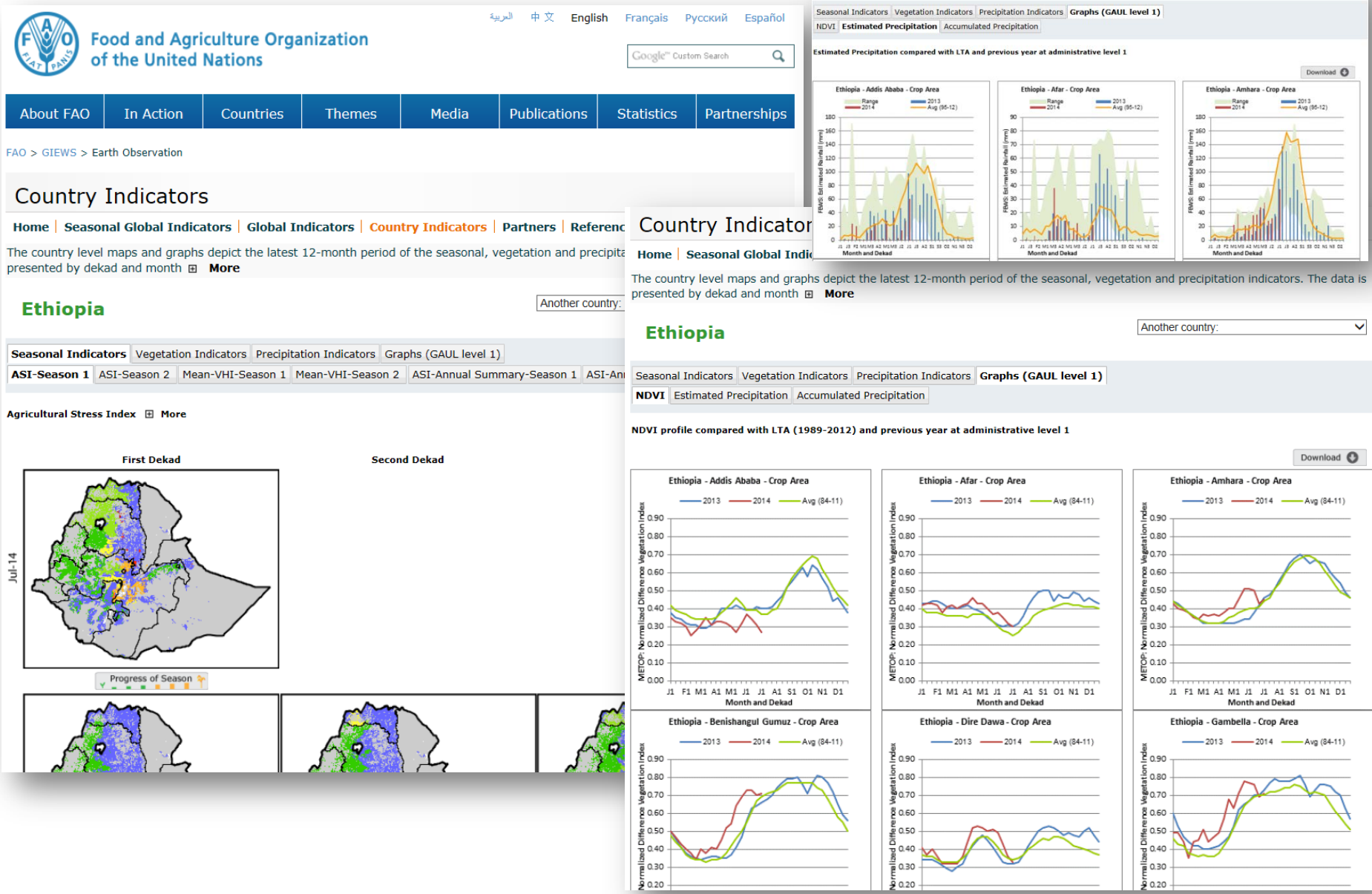
For 5 countries:

NDVI

At Dekad 3 of May 2015

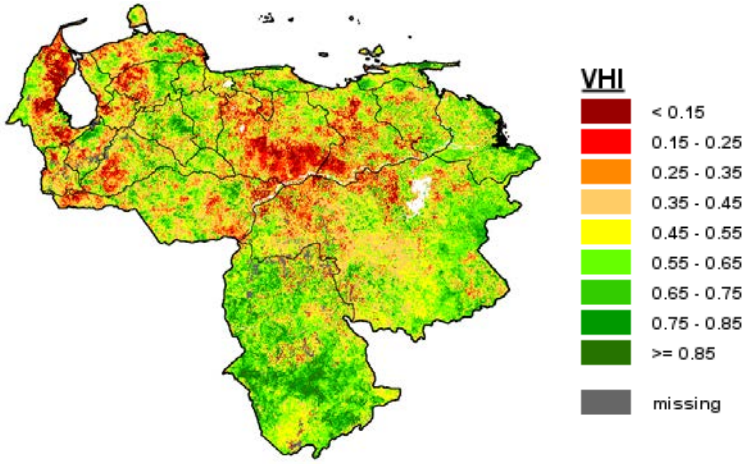
ASIS1-Bis: FAO-GIEWS Data Portal

http://www.fao.org/giews/earthobservation

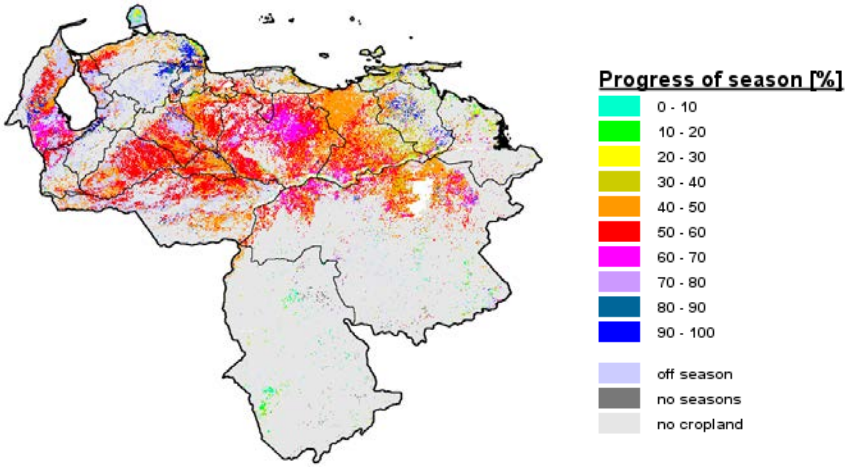


RECENT DROUGHT EVENTS – NRT ANALYSIS

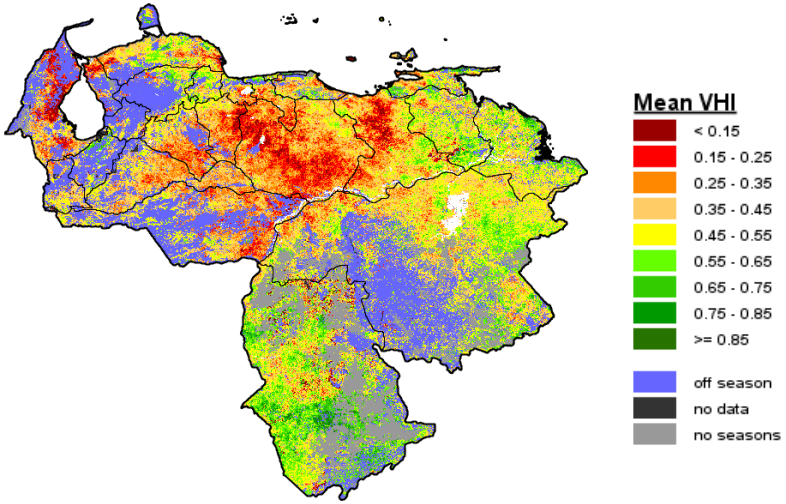
VENEZUELA – end of August 2014



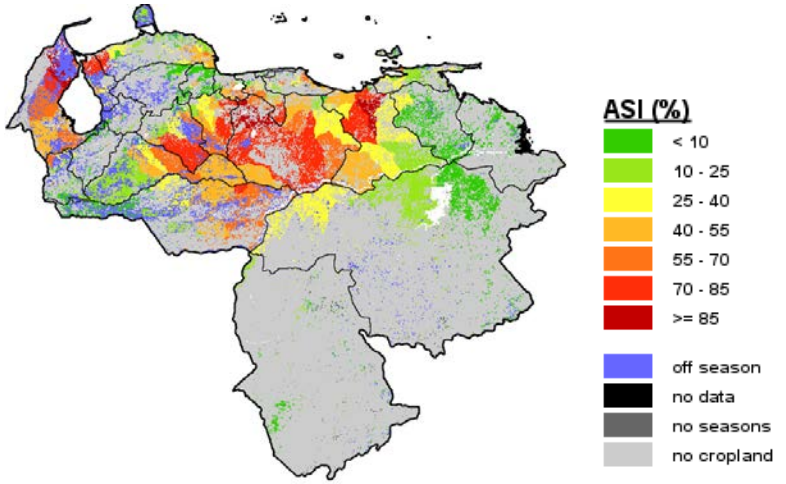
Vegetation Health Index



Progress of season



Mean VHI over the season



Agricultural Stress Index
% crop area affected by drought

Case Study

FAO: Watching Agricultural Drought Worldwide - from Space

In the framework of the EU/FAO Improved Global Governance for Hunger Reduction Programme, the Food and Agriculture Organization of

applied in many different environmental conditions around the globe, including in Asia, Africa, Europe, North America and South America.

partner in scientifi
development, simula
into the NOAA-AV
through an "inter-ca
obtain a time series f
The ASIS database
years of agricultural
with the year 1984 w
severely affected by

ASIS@fao.org
www.fao.org/climatechange/ASIS

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Deployment

The standalone version of ASIS is designed to be deployed at the national level in different institutions (Ministries of Agriculture, National Meteorological Services, Ministries of Environment, etc.) that can strengthen National Early Warning Systems for food security.

Capabilities

Possible applications include: assessing the impact of climate variability in agriculture (crops and pasture), supporting remote sensing-based insurance indexes, crop monitoring and yield forecasting.

FAO ASIS
Agriculture Stress Index System

The global ASIS will strengthen the crop and vegetation monitoring work of FAO's Global Information and Early Warning System (GIEWS). The standalone version of ASIS will support national food security early warning systems. The development of ASIS is included in the EU/FAO Programme on "Improved global governance for hunger reduction".

Partners in scientific and technical development

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FAO ASIS
Agriculture Stress Index System

Monitoring Agriculture Drought with Remote Sensing Data

FAO's Global Information and Early Warning System (GIEWS) and the Climate, Energy and Tenure Division are developing a system for detecting agricultural

ASIS
Agriculture Stress Index System

MONITORING AGRICULTURE DROUGHT WITH REMOTE SENSING DATA

WHY ASIS?

Drought is the world's most destructive natural hazard, having devastating impacts on food security and damaging the food production base.

Episodes of drought increased in frequency and intensity over the past two decades as a result of climate change impacts, and this trend is expected to continue.

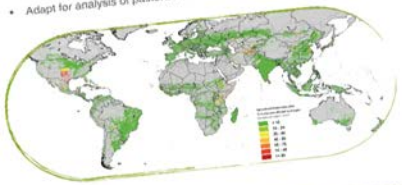
Timely and reliable information of the condition of food crops in all regions and countries in the world is essential to mitigate the impact of agricultural drought.

FAO's Global Information and Early Warning System (GIEWS) along with the Climate, Energy and Tenure Division are implementing a system for detection of agricultural areas with a high likelihood of water stress (drought) on a global scale.

Through monitoring vegetation indices across global crop areas during the growth season, ASIS will detect "hotspots" around the globe where crops may be affected by drought.

ASIS AS A MONITORING TOOL CAN:

- Show areas at risk from drought across the globe at a glance through map products
- Provide near real time analysis (every 10 days) based on METOP-AVHRR 1 km resolution data
- Adapt for analysis of pastoral or forest areas



POTENTIAL

Adaption of global ASIS to specific regional or country situations would support improved crop monitoring and yield forecasting at regional or national level and could provide input for index based crop insurance schemes.

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30 June 2014

GIEWS Update

Ethiopia: El Niño-Southern Oscillation (ENSO) and the main *Kiremt* rainy season

An assessment using FAO's Agricultural Stress Index System (ASIS)

1. DEFINITION

An El Niño is a recurrent weather phenomenon that takes place approximately every two to seven years and usually lasts between 12 and 18 months. An El Niño event is defined by a high Oceanic Niño Index (ONI), which is based on Sea Surface Temperature (SST)

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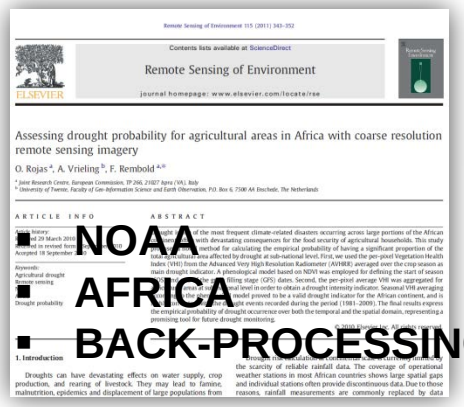
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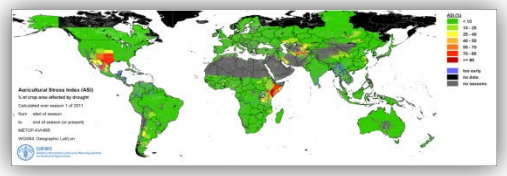
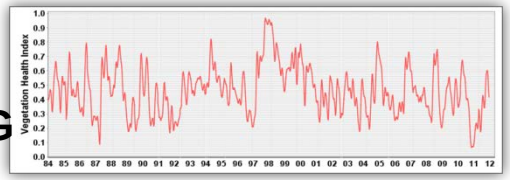
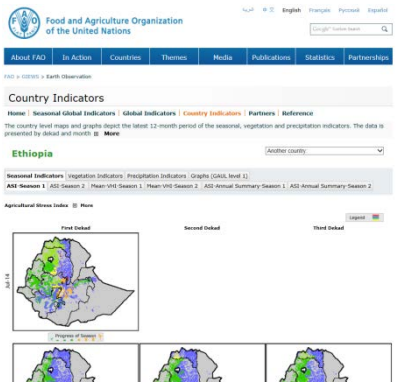






- NOAA
- AFRICA
- BACK-PROCESSING

ASIS2: Recent Developments

1. Update of the GLOBAL system (+ 200 ROIs) :

- New ancillary maps: GAUL & Land Use (GLC-SHARE)
- Updated LTS (1984-2014) + Anomalies (VCI, TCI, VHI)
- New procedures and indicators…

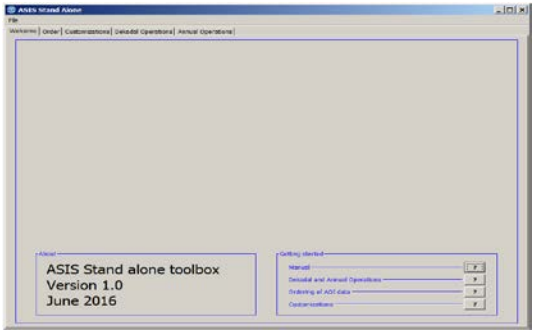
2. ASIS Stand-Alone ToolBox

- Users: FAO Regional Officers
- AOI: Their "Area of Interest" (mostly one country)
  FAO delivers basic inputs (VCI, TCI, …)
- Objective: Local adaptation & optimization of all parameters:
  . New ancillary maps (regions, land use)
  . Adaptation of phenologies (maybe season 3 or even 4)
  . Weights $\boldsymbol{w}$ in VHI=$\boldsymbol{w}$.VCI + (1-$\boldsymbol{w}$).TCI
  . In computation of μ_{VHI}: dekads are weighted $\approx K_c$ factors
- Graphical User Interface

Technical Workflow

BASIC INPUTS

VCI, TCI



VITO delivers every Dekad (FTP):

- NDVI and BT4 from METOP
- Precipitation from ECMWF

ASIS SERVER at FAO

- Further processing
- Hardware: Windows 2010 server
- Software: GLIMPSE, Scripts (bat, Python), etc.
- 2 x 11 TB hard disks
- FAO maintains GIEWS website

FAO REGIONAL OFFICES

- Receive data over their AOI
- ASIS2 ToolBox: Optimize parameters

http://www.fao.org/giews/earthobservation:

ASIS maps and graphs per country

Van Hoolst R, Eerens H, Haesen D, Royer A, Bydekerke L, Rojas O, Li YanYun & Racionzer P, 2016: *FAO's AVHRR-based Agricultural Stress Index System (ASIS) for global drought monitoring,* International Journal of Remote Sensing, Volume 37, Issue 2, 2016. **DOI:** 10.1080/01431161.2015.1126378.

GIEWS
Global Information and early Warning System on food and Agriculture

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Rotterdam (NL) – May 25, 2016