Operational Challenges to Contemporary Satellite Imagery Characterization

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Outline:

1. Share USDA Office of Global Analysis-International Production Assessment Division’s mission (*what we do and why*)

2. Share *some* operational *challenges* related to satellite earth observations

3. *Listen* to your perspective
Overview:

USDA-Office Global Analysis
International Production Assessment Division

- The Foreign Agricultural Service’s (FAS) Office of Global Analysis (OGA) serves as a major source of objective and reliable global agricultural production information to the World Agricultural Outlook Board (WAOB), the primary source of USDA’s global commodity outlook.

- The USDA’s outlook reports provide public access to information and data affecting world food security and are crucial in decisions affecting U.S. agriculture, trade policy, and food aid.

- The reports provide monthly regional, national and subnational monitoring and analysis of crop conditions, yield forecasts, and the impact of events affecting crop production.

- In addition, the FAS OGA provides support and maintenance of USDA’s global database of (1) Crop Area, Yields, and Production (PSD); (2) Weather and Soil Moisture; (3) Monthly Crop Growth Stage and Harvest Calendars; (4) Global Agricultural Monitoring (GLAM); (6) and others.
USDA’s SIA Program

- The satellite imagery resources are managed through the USDA’s Satellite Imagery Archive (SIA) program.

- The SIA program was established by USDA’s Remote Sensing Coordinating Committee (RSCC) which is chaired by the USDA’s Office of the Chief Information Officer.

- The SIA fulfills its mission of providing USDA-wide cost effective data-sharing of satellite data through a centralized purchasing, receipt, inventory, storage, and dissemination of satellite imagery to USDA agencies and their affiliates:
  - Foreign Agricultural Service (FAS),
  - Risk Management Agency (RMA),
  - National Agricultural Statistics Service (NASS),
  - Forestry Service (FS),
  - Natural Resources Conservation Service (NRCS),
  - Agricultural Research Service (ARS), and
  - Farm Service Agency (FSA).

- The SIA facility is managed through the online Archive Explorer (AE) system at http://www.pecad.fas.usda.gov/archive_explorer/default.cfm. The AE is a web-enabled browse and search tool, that allows users to browse, select, and retrieve the contents of the Satellite Imagery Archive.
OGA-IPAD Actionable Situation/Outlook Report

Data:
Soils, Crop, Weather

Satellite observations
(physical – chemical characterization of the earth surface)
Field Measurements, Field surveys

Extract Relevant data & Information

Actionable Knowledge

Analysis, Interpretation, etc.:
visual or automated
--community of practitioners

Domain specific...:
meaning + understanding
---agricultural industry

Policy-Decision making
--farmers, traders, politicians

Actionable statistical Insight

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Policy-Decision making
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**Practical significance**

**Statistical significance**

**Acquisition---Analysis---Interpretation---Translation**
Data-Information Translation:
reference points or benchmarks:
all about relativity: previous year, average, record, drought year

- Statistics: Area, Yield, Production
- Time of sowing: early, late, normal...
- Seasonal crop & weather anomalies: normal, favorable, unfavorable (excess, drought, etc.)
- State of plant growth and development
- Phenological phase: vegetative, flowering, physiological maturity, harvest
Major Crop Monitoring Parameters

What We Monitor and the Underlying Assumptions:

1. **Crop Growth:**
   - Driven by temporal (seasonal) soil moisture (rainfall)
   - We generate global vegetation conditions to monitor photosynthetic activity
   - NDVI, ET provide metrics of crop growth, agricultural ecosystem functions and health

2. **Crop Yields:**
   - Dependent on accumulated biomass, available soil moisture, etc
   - A function of time and rainfall (length of growing & harvest period)

3. **Planted/Harvested Cropland**
   - Dependent on start of sowing rains
   - Length of planting window
   - Socio-economic factors (market prices, government incentives, etc.)
Operational *Challenges* Related to Satellite Earth Observations

1. Workflow integration
2. Data quality
3. Data processing
4. Data archive: big data problem
Goals: Operational vs. Science/Research/Deployment

- Operational:
  - High quality deliverables (*reliability, credibility, legitimate*)
  - Data value defined in terms of the accuracy and quality of the outputs and outcomes: similarity/dissimilarity to reality
  - Ensure effectiveness/seamless protocols
    - fitting data seamlessly into existing workflows
  - Too time consuming or cumbersome data integration routines result in limited or no use

- Science/Research/Deployment:
  - Often related to *spatial, spectral, radiometric, temporal sensitivity*
Challenge 1: Data Quality

MONITORING CROP CONDITIONS

......INDIA MONSOON SEASON
India: Monitoring *Kharif* (monsoon) Season Crops

- **Landsat, MODIS, + Other**
  - India’s major crop season, *kharif* (monsoon season)
    - Data gaps almost the entire season makes it difficult to generate reliable + consistent indicators/deliverable products
    - Cloud minimizing protocols (in-house) much more time consuming and costly to fix
    - More rework and assumptions resulting in extremely poor overall quality of deliverables

*A simple case with serious crop forecasting implications: cotton, rice, soybeans... India’s monsoon reason data gaps*
No meaningful data interpolation, extrapolation, manipulation, etc.

Monsoon season: June - September

Data source: 16-day MODIS
No meaningful data interpolation, extrapolation, manipulation, etc.
Monsoon season: June - September

Data source: 16-day MODIS

India, North
2013-Sept-14 to Sept-29
MOD44-16-day
No meaningful data interpolation, extrapolation, manipulation, etc.

Monsoon season: June - September

Data source: 16-day MODIS
India *Kharif (monsoon)* Season Landsat Imagery
India *Kharif* (monsoon) Season Landsat 8, 7 Imagery
Challenge 2: Massive datasets

MONITORING EXTREME EVENTS

...excess rainfall, flooding, drought...
Monitoring Crop Impacting Events:

- **Event progress**: determine reasonable-practical frequency
  - daily, weekly, etc...
  - spatial extent; depth, length of time

- **Crop Monitoring**:
  - Crop types (major) identification
  - Crop stage identification
    - Resilience, survival rate, compensatory growth etc..

- USGS Hazards Data Distribution System is key for major disasters
Evaluation-Monitoring Crop Impacting Events
Data Selection, Processing, Analysis:
.....for regional, national, subnational analysis

MODIS
- Sampling frequency (daily/composite)
- Daily event progression
- Conditions within crop type (variability within type)

ODOE
- Lengthy frequency (8-16 days)
- Crop type identification (variability between type)
- Spatial extent

WorldView 2
- Reference data “ground truth”

incorporation of ancillary and derived data sets
Category 5 Typhoon Haiyan in Philippines, Nov 8\(^{th}\), 2013

Synoptic Scale Assessment: MODIS (500m)

- Composites of rapid-response/daily imagery
- Pre-Post Storm NDVI difference
Cropland Identification
Crop Condition Assessment: Landsat

- Compiled cloud-free Landsat imagery
- Cross-referenced with high-resolution crop masks
- Assessed crop condition and potential damage
WorldView2: Reference data ("ground truth") provided large/local scale cropland assessment:
Use of Ancillary Data

- Assess potential flooding damage using derived flooding maps (UNOSAT)
Challenge 3: Satellite Imagery Archive:
BIG DATA PROBLEM
Satellite Imagery Archive Program: Big Data Problem

The amount of imagery in SIA and being collected is presenting:

- Storage capacity problems
- A daunting high storage cost
SIA Big Data Problem:

- **Landsat 5; 7:**
  - VNIR Spectral bands:
    - 6 optical, 1 thermal
    - 6 optical, 2 thermal
  - Radiometric resolution/information depth
  - 8 bit imagery

- **SIA pack: 3 bands**
  (2 visible + NIR)

- **Landsat 8:**
  - VNIR Spectral bands:
    - 8 optical, 1 pan, 2 thermal
  - Radiometric resolution/information depth
  - 16 bit imagery

- **SIA pack: ????

> More bands better characterize the physical and chemical nature of earth observations
> lower resolution color bands (multispectral) can be enhanced/pan-sharpened with the panchromatic band
The issue is: ...How Do We.......

- Handle & manage the volume of imagery we already have:
  - What should be stored & processed, given storage costs and limited storage resources
  - Storage Scalability: e.g. retention period: 0, 1, 2, 3 years?

- Handle & manage the volume of new imagery we are adding every day:
  - What should be stored & processed, given limited storage resources
  - Storage Scalability: e.g. retention period: 1, 2, 3 years?
## Proposed Solutions

- No more storage of L5, L7 datasets
  - must be removed completely
- Take advantage of image access developments:
  - USGS infrastructure, ArcGIS Online, Google Earth, etc.
  - Conform with the need to process large areas at near-real-time speeds
- Adopt low-volume storage strategies (zip?)
- Reduce storage retention period, 3 to 2 years

- Cloud computing
  - proposition
Cloud Computing Model:

........Things to consider........

- Continued fast access and processing capabilities
- Does it affect applications: hardware-software
- Re-locating datasets plus processing infrastructure
- Short-long term impact on SIA members’ workflows
- Sharing pool computing resources, e.g. SIA members, other users (licensing implications)
  - Cloud computing model provides network access to networks, servers, storage, applications, services, etc.
- Determine who the primary Service Provider or else??
  - How to manage interactions
Applications: access + processing

Storage - Infrastructure

...Cost, time, efficiency, sustainability.
Contact:

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International Production Assessment Division
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Browse Our Extensive Web Content at:

http://www.pecad.fas.usda.gov/

See Our Global Crop Explorer Site at:

http://www.pecad.fas.usda.gov/cropexplorer
Thanks...

Questions

Comments