Improving World Agricultural Supply and Demand Estimates by Integrating NASA Remote Sensing Soil Moisture Data into USDA World Agricultural Outlook Board Decision Making Environment

William Teng[1,2], Richard de Jeu[3], Paul Doraiswamy[4], Steve Kempler[1], and Harlan Shannon[5]
([1]NASA/GES DISC, [2]Wyle, [3]Vrije Universiteit Amsterdam, [4]USDA/ARS, [5]USDA/WAOB)

NASA GSFC Earth Sciences (GES)
Data and Information Services Center (DISC)
William.L.Teng@nasa.gov

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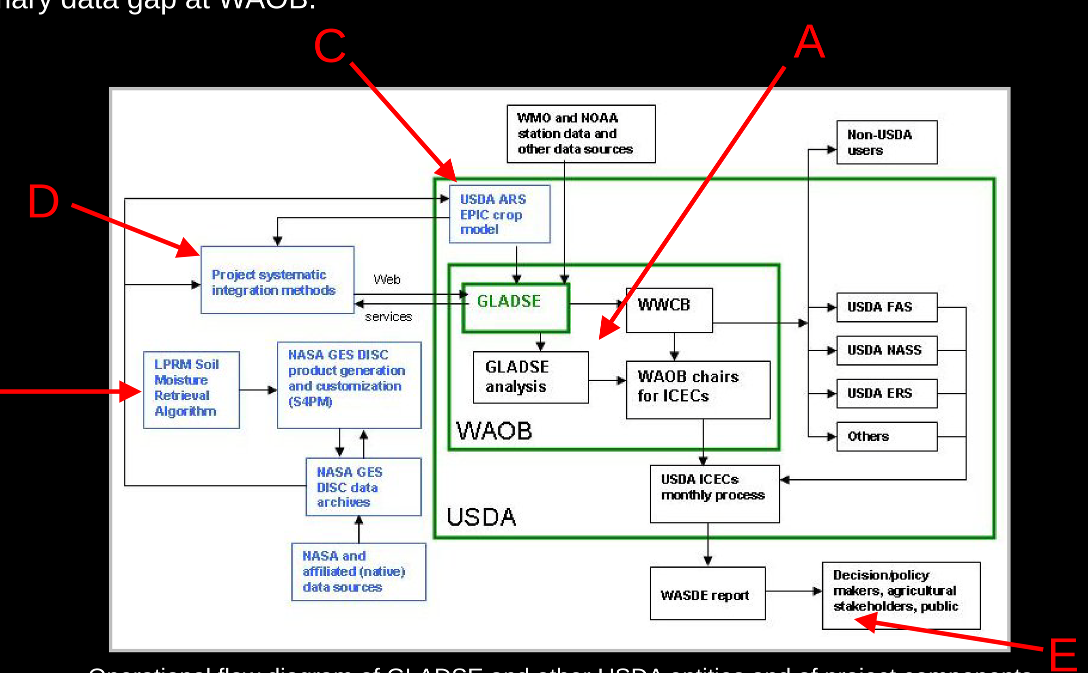
Introduction

A primary goal of the U.S. Department of Agriculture (USDA) is to expand markets for U.S. agricultural products and support global economic development. The USDA World Agricultural Outlook Board (WAOB) supports this goal by coordinating monthly World Agricultural Supply and Demand Estimates (WASDE) for the U.S. and major foreign producing countries. Because weather has a significant impact on crop progress, conditions, and production, WAOB prepares frequent agricultural weather assessments, in a GIS-based, Global Agricultural Decision Support Environment (GLADSE). The main goal of this project, thus, is to improve WAOB's estimates by integrating NASA remote sensing soil moisture observations and research results into GLADSE (See diagram below). Soil moisture is currently a primary data gap at WAOB.



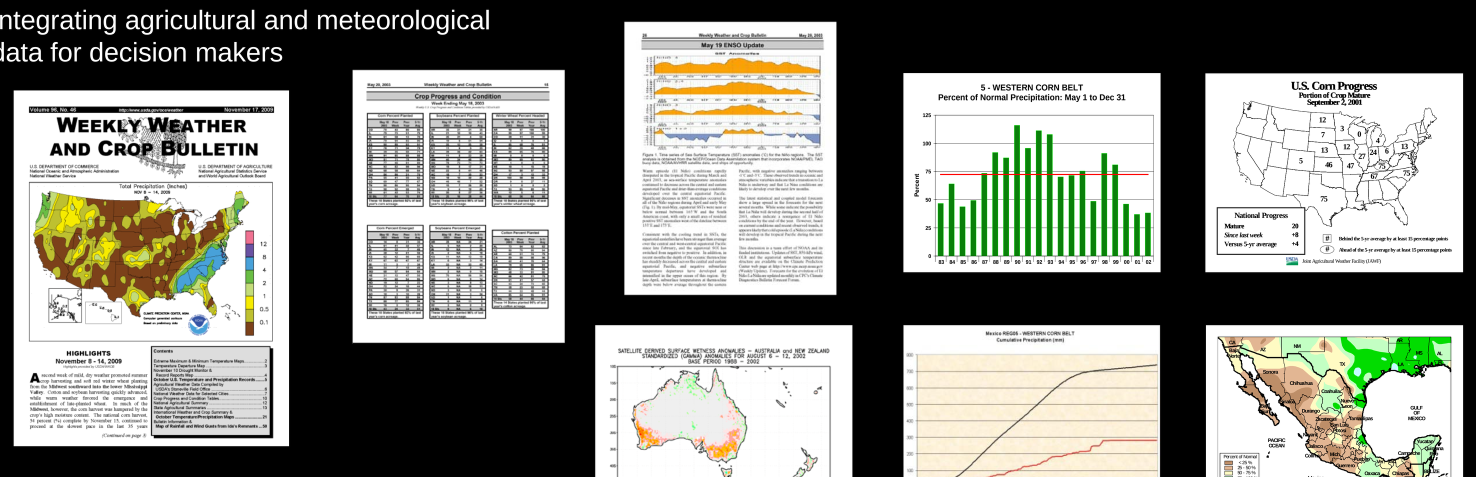
Operational flow diagram of GLADSE and other USDA entities and of project components (in blue). Labels A-E refer to the other five panels of this poster, in which the labeled parts are expanded with more details.

Objectives:

- To integrate, as seamlessly as possible, WAOB-customized LPRM soil moisture data and an LPRM-enhanced EPIC crop model into the operational WAOB GLADSE and, thus, to improve the WAOB's decision-making process.
- To leverage existing Web services at the GES DISC to mediate and facilitate the integration of project products into GLADSE.
- To systematically and rigorously evaluate and benchmark the impact of the integration of NASA data and technologies on GLADSE forecasts with three of the major agricultural regions worldwide for which WAOB has responsibility.
- To implement a detailed plan for transferring the expected successful project results to, and their sustained long-term use by, WAOB.

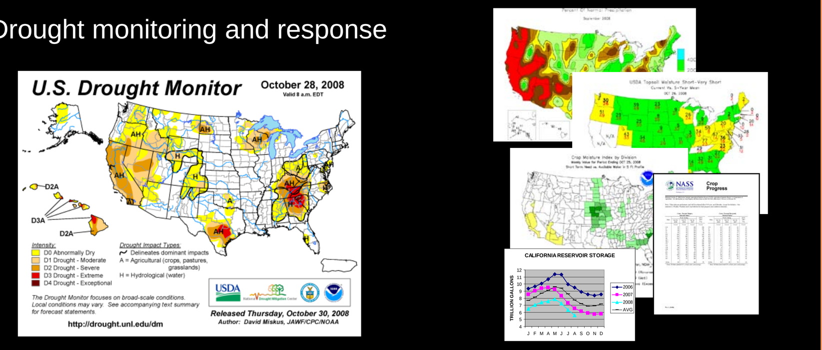
A USDA WAOB's Global Agricultural Decision Support Environment (GLADSE)*

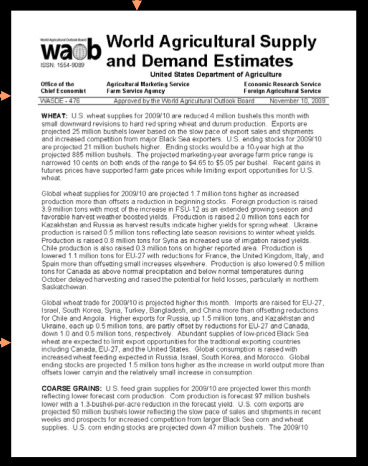
Integrating agricultural and meteorological data for decision makers



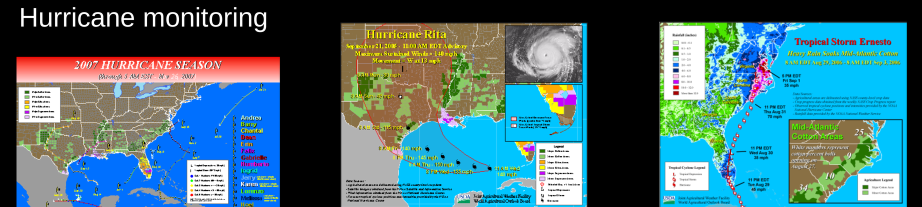
WWCB by Joint Agricultural Weather Facility (JAWF) between NOAA and USDA

Drought monitoring and response





Hurricane monitoring



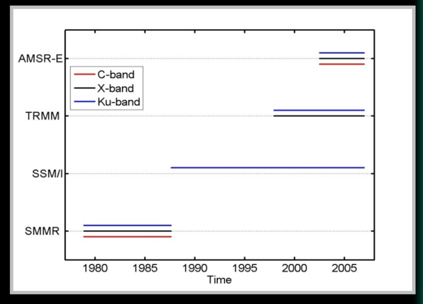
Pre-storm forecast maps

Post-storm crop condition analyses

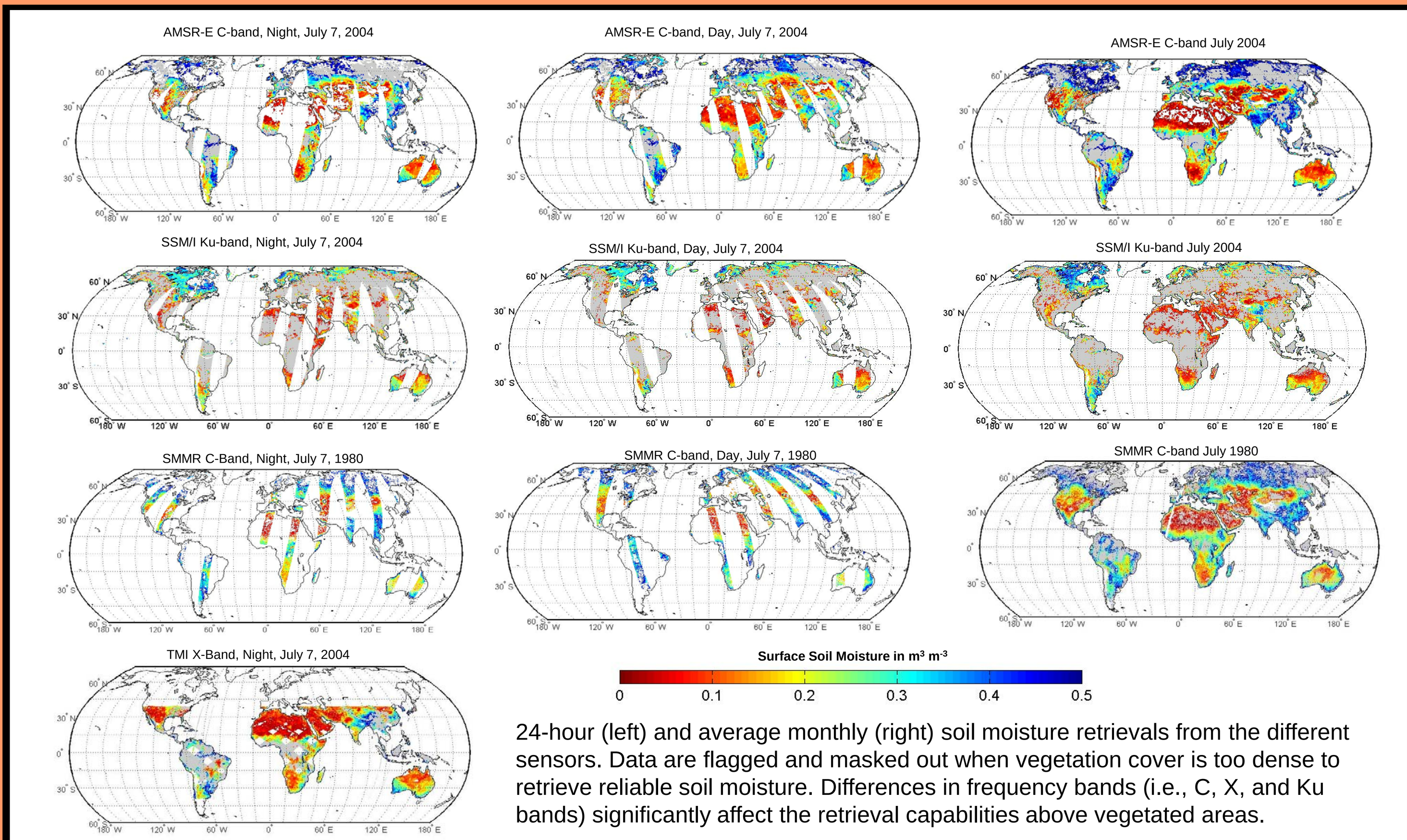
* Sources for products shown are USDA WAOB or its collaborating partners.

B Land Parameter Retrieval Model (LPRM) Soil Moisture

- Soil moisture data, generated by the Land Parameter Retrieval Model (LPRM, developed by NASA GSFC and Vrije Universiteit Amsterdam, Owe et al., 2008) and customized to WAOB's requirements, will be directly integrated into GLADSE, and indirectly via the USDA Agricultural Research Service (ARS)'s Environmental Policy Integrated Climate (EPIC) crop model.
- LPRM data provide global soil moisture with high temporal (day, night) resolution and 0.25 degree spatial resolution, for the top few cm of the soil column.
- LRPM is a three-parameter retrieval model for passive microwave data and is based on a microwave radiative transfer model that links surface geophysical variables (i.e., soil moisture, vegetation water content, and soil/canopy temperature) to the observed brightness temperatures.
- LPRM soil moisture has been extensively validated over a large variety of landscapes, using in situ, models, and other satellite soil moisture products, and has an accuracy of about 0.06 m³ m⁻³ for sparse to moderate vegetated regions (De Jeu et al., 2008).



Timeline of the different microwave satellite sensors used in LPRM.

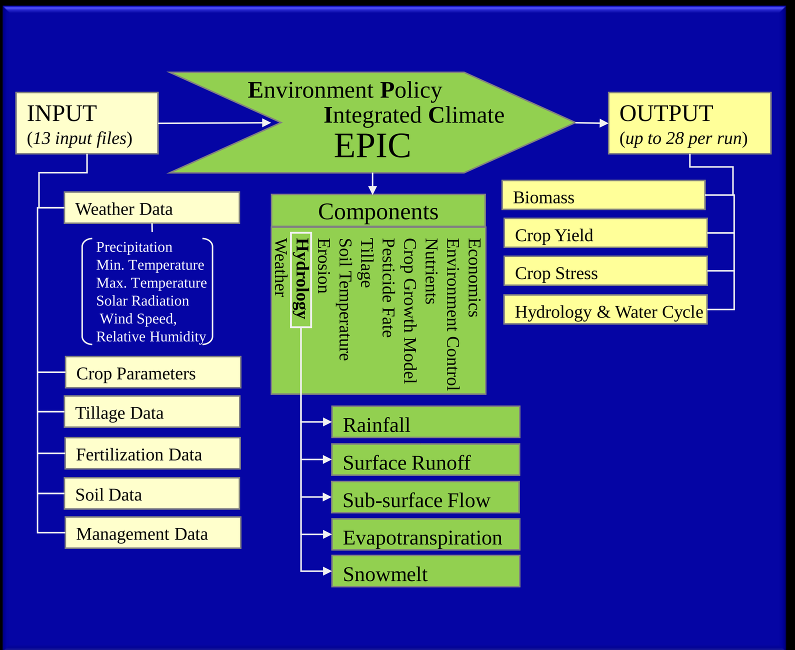


24-hour (left) and average monthly (right) soil moisture retrievals from the different sensors. Data are flagged and masked out when vegetation cover is too dense to retrieve reliable soil moisture. Differences in frequency bands (i.e., C, X, and Ku bands) significantly affect the retrieval capabilities above vegetated areas.

De Jeu, R., W. Wagner, T. Holmes, A. Dolman, N. van de Giesen, and J. Friesen (2008), Global soil moisture patterns observed by space borne microwave radiometers and scatterometers. *Surv. Geophys, 29*, 399-420, doi: 10.1007/s10712-008-9044-0.
Owe, M., R. De Jeu, and T. Holmes (2008), Multisensor historical climatology of satellite-derived global land surface moisture. *J. Geophys. Res., 113*, F01002, doi:10.1029/2007JF000769.

C Environmental Policy Integrated Climate (EPIC) Crop Model

- Comprehensive crop growth and environmental assessment model developed by the USDA-ARS (Williams et al., 2006, 2008). Provides continuous daily simulation of the growth of many crops, soil moisture profile, hydrology, erosion, sedimentation, and management practices and their impacts on crop growth and environment sustainability.
- Several studies have validated the model simulations of soil moisture availability and crop yield/soil moisture responses (e.g., Doraiswamy et al., 2003).
- Integrating the LPRM soil moisture product into EPIC and replacing the current EPIC surface soil moisture simulated and interpolated from World Meteorological Organization (WMO) and other local station data should provide better spatial surface soil moisture and reduce model uncertainty.
- EPIC also uses surface soil moisture and soil profile characteristics to determine the down profile to derived subsurface (root zone) soil moisture. Re-computing the model subsurface soil moisture based on the LPRM surface soil moisture should reduce model uncertainty.



3 major agricultural regions worldwide for validation of project results.

U.S. Midwest (corn, soybeans)

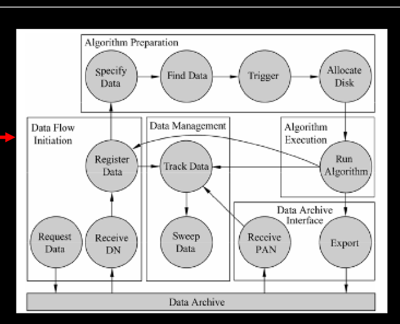
Southern Brazil (Soybeans)

Southeastern Australia (winter wheat)

Doraiswamy, P.C., S. Moulin, P.W. Cook, and A. Stern (2003), Crop yield assessment from remote sensing. *Photogrammetric Eng'g. & Remote Sensing, 69*, 665-674.
Williams, J.R., R.C. Izaurralde, and E.M. Steglich (2008), Agricultural Policy / Environmental eXtender Model Theoretical Documentation v. 0604.
Williams, J.R., E. Wang, A. Meinardus, W.L. Harman, M. Siemers, and J.D. Atwood (2006), EPIC User Guide v. 0509.

D Integration into WAOB via Web services

LPRM (B)



- Simple, Scalable, Script-Based Science Processor for Missions (S4PM) provides highly automated processing of science data at the GES DISC (Lynnes, 2006).
- Simple, Scalable, Script-Based, Science Product Archive (S4PA) provides users with operational online access to data.
- Customization for WAOB (e.g., subsetting, re-formatting, re-gridding) ensures the data can be directly and easily integrated into GLADSE, in a form that is usable and effective.

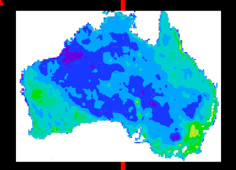
Existing operational Web services will be leveraged and tested for optimal use by WAOB.

GrADS Data Server (GDS)

Web Map Service (WMS)

Web Coverage Service (WCS)

Coverage



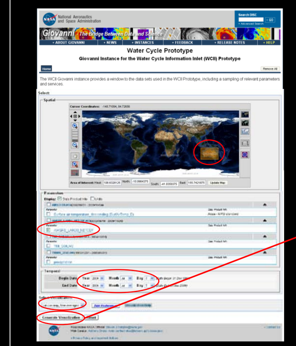
NB

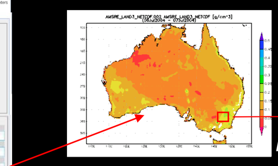
(Machine-to-machine)

GetCoverage

GetMap

Giovanni, a Web-based application developed by the GES DISC, provides a simple and intuitive way to visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data (Berrick et al., 2009)





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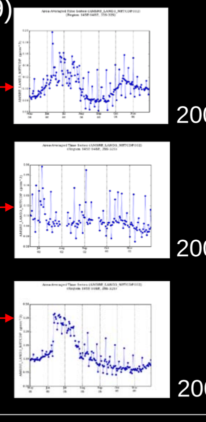


2006

2002

2005

(Analyst interactive)

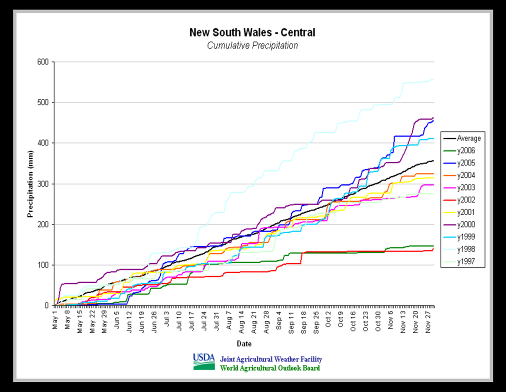
NB: All maps and time series shown are of the standard AMSR-E soil moisture product of the EOS Aqua mission. They will be replaced by the LPRM product.

EPIC (C) WAOB GLADSE (A)

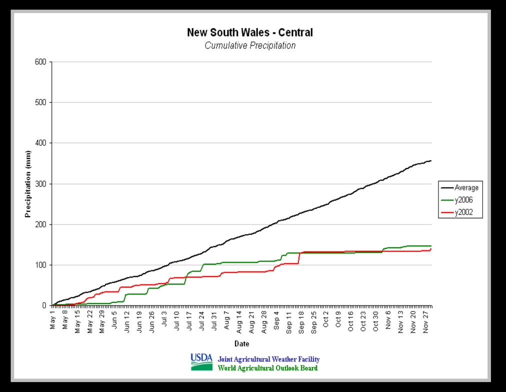
Berrick, S., G. Leptoukh, J. Farley, and H. Rui (2009), Giovanni: a Web services workflow-based data visualization and analysis system. *IEEE Trans. Geosci. Remote Sens., 47*(1), 106-113.
C. S. Lynnes (2006), The Simple, Scalable, Script-based Science Processor. *In* Earth Science Satellite Remote Sensing, vol. 2, Beijing: Tsinghua Univ. Press and Berlin: Springer-Verlag, pp. 146-161.

E Metrics and Expected Results

Project benchmarking will be based on retrospective analyses of WAOB's analog year comparisons, between a given year and historical years with similar weather patterns. Below is an example from New South Wales, Australia.



2006 is the target year…
…what year(s) are similar?



2006 is the target year…
… 2002 is an analog year.

Actual Winter Wheat Yields	
Year	ΔYield from Trend (ton/hec)
2006	-1.63
2005	-0.05
2004	-0.51
2003	-0.42
2002	-1.38
2001	0.15
2000	0.00
1999	0.40
1998	-0.01
1997	-0.03

In 2006, drought in New South Wales threatened to reduce winter wheat yields, a reduction estimated by WAOB meteorologists to be similar to those of 2002, based on analog analyses of precipitation time series. Indeed, following the harvest, wheat yields were found to be well below the trend. Although the weather was similar in both years, yields differed. This variability can be attributed to a number of factors, including subtle differences in the timing of the rainfall, varieties of wheat planted, and amount of wheat grazed rather than harvested.

- Field validation at the three study regions will enable the benchmarking of improvements to the EPIC model by the enhancement of LPRM.
- Once validated at ARS, the LPRM-enhanced EPIC model will be integrated into GLADSE and applied to other major agricultural regions worldwide for which WAOB has responsibility.
- Together, the integration of LPRM and LPRM-enhanced EPIC into GLADSE is expected to significantly improve the WAOB's forecasting capabilities.
- WAOB is the focal point for economic intelligence within the USDA. Thus, improving WAOB's agricultural estimates by integrating NASA satellite observations and model outputs will visibly demonstrate the value of NASA resources and maximize the societal benefits of NASA investments.

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