Enhancing USDA’s Retrospective Analog Year Analyses Using NASA Satellite Precipitation and Soil Moisture Data

CROP yield estimates derived from satellite data are closer to measured yields than are estimates derived from ground station data.

**Abstract**

The USDA World Agricultural Outlook Board (WAOB) is responsible for monitoring weather and climate impacts on domestic and foreign crop development. One of WAOB’s primary goals is to determine the net cumulative effect of weather and climate anomalies on final crop yields, based on a broad array of information. The resulting agricultural weather assessments are published in the *Weekly Weather and Crop Bulletin*. Unlike both the amount and timing of precipitation significantly affect crop yields, WAOB has often, as part of its operational process, used historical time series of surface-based precipitation observations to visually identify growing seasons with similar (analog) weather patterns as, and help estimate crop yields for, the current growing season.

As part of a larger effort to improve WAOB estimates by integrating NASA remote sensing observations and research results into WAOB’s decision-making environment, a more rigorous, statistical method for identifying analog years was developed, termed analogous index (AI) and based on the Nash–Sutcliffe model efficiency coefficient. The AI was computed for five study areas and six growing seasons of data analyzed (2003-2007 as potential analog years and 2008 as the target year). Previous results have shown that, for all five areas, crop yield estimates derived from satellite-estimated precipitation data are closer to measured yields than are estimates derived from surface-based precipitation observations (Teng and Shannon, 2011). Subsequent work has shown similar results for satellite-retrieved surface soil moisture data and from root zone soil moisture derived from the assimilation of surface soil moisture data into a land surface model. Establishing the analog methodology in station-rich areas can potentially enable WAOB to apply similar methodology in station-poor areas of the world, thus significantly extend its global coverage. WAOB is the focal point for economic intelligence within USDA, improving WAOB’s agricultural estimates will be significant for USDA and visibly demonstrate value of NASA resources for societal benefits.

**Analog Year Comparisons**

An example: …

... between a given year and historical years with similar weather patterns, from New South Wales, Australia.

2006 is the target year…

... 2002 is an analog year.

Importance of timing of precipitation relative to stages of crop development. Timely establishment in Western Australia helped elevate 2006 winter wheat yields (1.27 t/ha) to above 2002 levels (0.91 t/ha).

**Data Sets**

- **Station-based precipitation:** Regional time series derived by averaging daily cumulative precipitation from multiple surface observing stations distributed evenly throughout each study area. *Iowa, U.S., 8 stations from NOAA/NWS Cooperative Observer Program (COOP) network; Jalisco, Mexico, 4 stations from World Meteorological Organization (WMO) network; Parana, Brazil, 6 WMO stations; central Argentina, 5 WMO stations; Free State, South Africa, 5 WMO stations.

- **Crop yield:** U.S., annual state-level corn statistics from USDA National Agricultural Statistics Service (NASS). Mexico, Secretary of Agriculture, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA); Brazil, annual soybean statistics from Instituto Brasileiro de Geografia e Estatística; Argentina, Ministerio de Agricultura, Ganadería y Pesca (MAyP); South Africa, National Estimates Network (NEC).

- **TRMM Multi-satellite Precipitation Analysis (TMPA, 3842)** (Huffman et al., 2007): 0.25-deg; daily (averaged from 3-hourly); source data sets merged (TRMM, AMSR-E, SSM/I, others); temporal coverage 1998-present.

- **LPRM soil moisture** (Ove et al., 2008, de Jeu et al., 2008): 0.25-deg; daily: (a) AMSR-E (06/1992-10/03/11); (b) TMI (12/08/97-present); (c) WindSat (10/02/07-07/31/12); (d) ENKF-Parlmer RZSM (06/2002-12/31/10) (Bolton et al., 2010; Bolton and Cross, 2012). LPRM-TMI and WindSat were mitigations in response to demise of AMSR-E in Oct. 2011. RZSM data, from Wade Crow (USDA ARS), currently end on 12/31/10.

- **Results**

  • For all five study areas, OBS-SFC > OBS-SAT (TMPA) > OBS-RZSM
  • Except for Iowa, OBS-SFC > OBS-AMSR-E
  • Results for TMI mixed (data gaps, X-band only)
  • Traditional, visual method of identifying analog years also improved with addition of satellite data

**Integration into WAOB Operational Environment**

Giovanni … Quick access to soil moisture and related data

**Importance of forward-processed data stream…**

- Extend WindSat coverage and possibly estimates forward data stream.
- Establish forward RZSM data stream.
- Apply LPRM to AMSR-E on NASA’s GCOM-W1.

**References**

Huffman et al., 2007. The TRMM Multi-satellite Precipitation Analysis: Quasi-global, multi-year, combined-sensor precipitation estimates at fine scale, *J. Hydrometeor.,* 8, 38-55.

**Acknowledgement**

The work is supported by NASA BOSSES NHH017D001N-DECISIONS and by project team members, USDA WAOB, VUA, and GIS DISC. The authors are grateful for contributions provided by Robert Parinussa (VUA) and Fan Fang, Guang-Dih Lei, and Hualan Rui (GES DISC/ADNET).

**Data Sets (cont.)**

**Results (cont.)**

- Crop yield estimates derived from satellite-based precipitation and soil moisture data are closer to measured yields than are estimates derived from surface-based precipitation measurements.
- Establishing analog methodology in station-rich areas and apply in station-poor areas of the world potentially can significantly extend WAOB’s global coverage.

- **Sample soil moisture map from LPRM-AMSR-E (courtesy of Robert Parinussa, VU/ University of Amsterdam, VUA)**
- **Five major agricultural regions worldwide were analyzed. The size of individual study areas selected depends on the variability of weather within each area and the availability of crop yield data.**

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