Sensitivity Of MODIS Global Terrestrial Primary Production To The Accuracy Of Meteorological Data Sets

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Abstract: The Moderate Resolution Imaging Spectroradiometer (MODIS) on-board the TERRA and AQUA, NASA satellite, dramatically improves our ability to accurately and continuously monitor the terrestrial biosphere. MODIS information is used to estimate global terrestrial primary production weekly and annually in near real-time at a 1-km resolution. MODIS terrestrial primary production requires daily gridded assimilation meteorological dataset as inputs, and the accuracy of the existing meteorological reanalysis datasets shows marked differences spatially and temporally. This study compares surface meteorological datasets from three well-documented global reanalyses, NASA Data Assimilation Office (DAO), ECMWF (ERA-40) and NCEP-NCAR reanalysis 1 (NCEP), with observed weather station data and other pseudo-observations data, to evaluate the sensitivity of MODIS global terrestrial gross and net primary production (GPP and NPP) to the uncertainties of meteorological inputs. NCEP tends to overestimate surface solar radiation, and underestimate both temperature and vapor pressure deficit (VPD). ECMWF has the highest accuracy but its radiation is lower in tropical regions, and the accuracy of the DAO lies between NCEP and ECMWF. Biases in temperature are mainly responsible for large VPD biases in reanalyses. Global total MODIS GPP and NPP driven by DAO, NCEP and ECMWF show remarkable differences (> 20 Pg C/y) with the highest estimates by NCEP and the lowest by ECMWF. Again, the DAO lies somewhere between NCEP and ECMWF estimates. Spatially, the larger discrepancies among reanalyses and their derived MODIS GPP and NPP estimates occur in the tropics. We propose improved methods to reduce the uncertainties from different reanalyses to MODIS primary production estimates.

MODIS GPP/NPP algorithm

- $GPP = APAR * \varepsilon$
- $GPP = (SWrad * 0.45 * Fpar) * \{\varepsilon_{max} * f(VPD) * f(T_{min})\}$
- $NPP = \sum GPP - R_m - R_g$

The data sets are involved in the study:

Meteorological reanalysis data sets

DAO (2000 ~ 2003)

NCEP (1961 ~ 2003)

ECMWF (1961 ~ 2001)

Observed or pseudo-observations meteorological data sets

Data from Weather stations

From USA stations with daily solar radiation obseravtions (2001 ~ 2002) (fig. 1a)

From World Meteorological Organization (WMO) weather stations (2000~2004) (fig. 1b)

Gridded by spatial interpolation

Climatic Research Unit (CRU data) from University of East Anglia , UK (1961~1990)

Surface meteorology and Solar Energy (SSE) from Langley Research Center, NASA (1983-1993)

EMDI NPP data sets for validation MODIS NPP

Fig. 1a. The distribution of weather stations in USA with daily solar radiation observations (n=323)

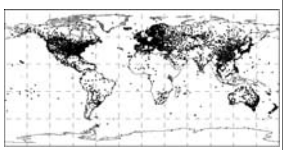

Fig. 1b. The distribution of weather stations from WMO (n > 5,000) without daily radiation observations

MODIS GPP/NPP data flow

- MODIS land cover
- MODIS 8-day Fpar/Lai
- ***Daily meteorological data(from DAO)***

→ MODIS 8-day GPP & PsnNet → MODIS annual GPP & NPP

This study compares remotely-sensed GPP and NPP driven by different meteorological reanalyses (DAO,ECMWF and NCEP) to study the sensitivity of MODIS GPP and NPP to the accuracy of meteorological data inputs

Results

A, The accuracy of meteorological reanalysis data sets by comparison to the observations

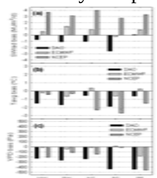

Fig. 2 . Bias of (a) daily solar radiation, (b) average temperature, and (c) vapor pressure deficits for three reanalyses compared to the observations from the stations (n=323) in five regions of USA from 2001 to 2002 (2001 for ECMWF).

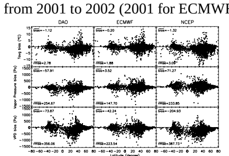

Fig. 4. Latitudinal comparison of the bias of daily average temperature, vapor pressure, and vapor pressure deficits from three reanalyses relative to observations from WMO for 2000 to 2004 (2000 and 2001 for ECMWF)

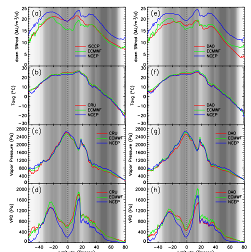

Fig.3 . Comparison of climatology zonal mean of surface downward solar radiation, average temperature, vapor pressure, and vapor pressure deficits from NCEP and ECMWF, with SSE (1983-1993) and CRU (1961-1990) datasets, respectively (a to d). Intercomparison of three reanalyses for 2000 and 2001 (e-f). These comparisons are only for data over vegetated land, and vegetated land area is shown as a gray scale, where darker shades represent more vegetated area. Vertical dotted lines denote the location of the equator.

B, The uncertainties of MODIS global GPP and NPP propagated by meteorological reanalysis data sets

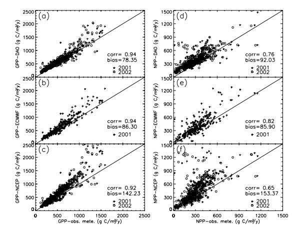

Fig. 5. Comparison of MODIS GPP, NPP driven by three reanalyses with these driven by the observations from weather stations in USA (n = 323) from 2001 to 2002.

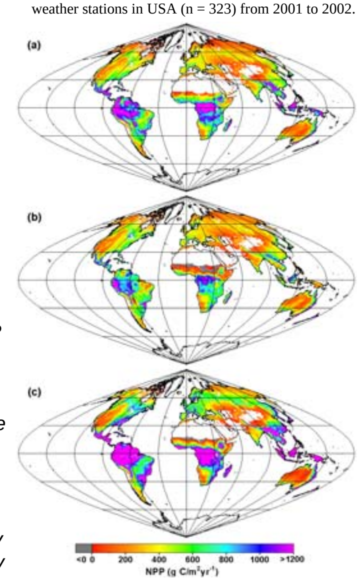

Fig. 6. Results of annual averaged 4-year (2000-2003) 1-km MODIS NPP derived using (a) DAO, (b) ECMWF, and (c) NCEP. Only two years of data (2000-2001) for ECMWF

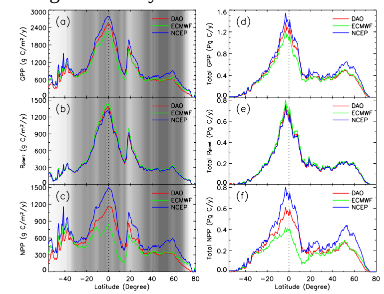

Fig. 7. Comparison of zonal mean of annual GPP, R_{plant}, and NPP (a-c), and corresponding zonal totals (d-f) driven by the three reanalyses for 2000 and 2001

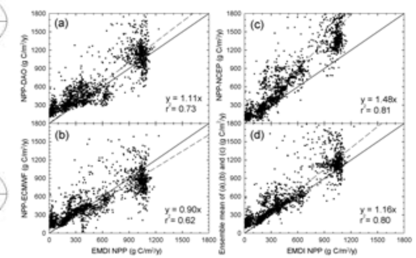

Fig. 8. Comparison of average NPP for 2000 and 2001 driven by the three reanalyses with EMDI NPP (a, b and c), and the mean NPP from averaged NPP by three reanalyses against EMDI NPP (d).

Year		2000	2001	2002	2003
DAO	GPP (Pg C)	108.42	110.76	107.82	107.50
	NPP (Pg C)	56.06	57.74	55.53	54.80
ECMWF	GPP (Pg C)	101.79	102.71	N/A*	N/A*
	NPP (Pg C)	46.71	46.59	N/A*	N/A*
NCEP	GPP (Pg C)	124.82	125.75	123.40	123.72
	NPP (Pg C)	73.80	73.73	72.22	72.29

* ECMWF reanalysis data (ERA-40) are not available past Aug. 31, 2002.

Table 1. Comparison of global total MODIS GPP and NPP driven by different meteorological datasets from 2000 to 2003.

Conclusions:

The study reveals that differences in meteorological reanalyses can introduce considerable uncertainties in GPP and NPP estimates. Overestimated NCEP SWrad and underestimated NCEP VPD are the dominant factors responsible for the highest GPP and NPP estimates by NCEP. Underestimated ECMWF SWrad in the tropics is the main reason for the lowest GPP and NPP by ECMWF for tropical forests, and ECMWF has the most accurate temperature and VPD. Underestimated VPD from DAO overestimates GPP and NPP from 5ºS to 30ºN. It is worth noting that large VPD uncertainties in reanalyses are mainly caused by relative small uncertainties in temperature, not by VAP, due to the magnification effect of the non-linear relationship between temperature and SVP, implying the importance of some non-linear processes in the model.