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Improving monitoring of tropical forests and their characterizations in NCEP models using GOES-R ABI land products

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Abstract

To meet increasing demands for high resolution weather forecasts and climate service products, NCEP needs an improved land surface product with fine resolution and high frequency to reflect and describe real-time conditions of vegetation dynamics in its numerical weather prediction and climate models. Unlike the maximum once per day acquisition of a polar-orbiting satellite, the Geostationary Operational Environmental Satellite-R Series (GOES-R) Advanced Baseline Imager (ABI) will provide multiple daily views and thus significantly increase the chance to produce a high quality and high frequency data product with less cloud contamination. To reduce the data noise and gaps (both in time and space), this project aims to use the GOES-R ABI product to generate, a real-time weekly/monthly cloud-free land surface dataset of normalized difference vegetation index (NDVI), green vegetation fraction (GVF) with the best quality over tropical rainforests where the data quality has been a long standing issue. Observations from the Spinning Enhanced Visible and Infra-red Imager (SEVIRI), onboard the European Meteosat Second Generation (MSG) satellite, will be used as proxy before the GOES-R ABI is available. The second equally important part of the proposed work is to examine impacts of our derived GVF datasets on numerical weather predictions. In particular, we will examine if surface temperature and precipitation forecasts will be improved using the NCEP GFS coupled with the Noah Land Surface Model.

The SEVIRI data we used contain observations of land surface at 30-minute time intervals and 3km spatial resolution. We used top of atmosphere (TOA) reflectance values from the red (0.635um), NIR (0.81um) and other satellite geometry information to calculate NDVI, angular corrected NDVI (which is used to calculate GVF) and GVF at 30-minute time interval from 2009. We generated daily, weekly and monthly NDVI and GVF datasets based on maximum NDVIs. We used daily/weekly/monthly NDVI and GVF values to examine vegetation phenology and how the magnitude in NDVI and GVF changes from wet to dry seasons in tropical regions. Our estimated phenology is compared with that from AVHRR. In year 2, we will continue the comparison between AVHRR and SEVIRI data and carry out the impact study of SEVIRI GVF on NCEP GFS model forecasts (currently NCEP models use AVHRR monthly GVF at 16km resolution as the land surface boundary condition dataset) for different scenarios. We anticipate generating a blended GVF from AVHRR and SEVIRI for EMC/JCSDA and implementation of the new technique at OSDPD for full disk daily SEVIRI NDVI and GVF product.

Goal of R3 Project

- To use the GOES-R ABI product to generate, a real-time weekly/monthly cloud-free land surface dataset of normalized difference vegetation index (NDVI), green vegetation fraction (GVF) with the best quality over tropical rainforests and to monitor tropical vegetation's response to environment change.
- To examine impacts of our derived GVF datasets on numerical weather predictions. In particular, we will examine if surface temperature and precipitation forecasts will be improved using the NCEP GFS coupled with the Noah Land Surface Model.

Accomplishments

- Development of a cloud identification method for SEVIRI data
- Completion of generating the daily NDVI, land surface water index (LSWI), angular correct NDVI and GVF datasets
- Completion of generating weekly and monthly NDVI, LSWI, angular correct NDVI, GVF datasets
- Analyses of NDVI and LSWI variations in dry and wet seasons, and comparison to MODIS NDVI products.
- Comparison of our estimated GVF with that from AVHRR

Why does NCEP need a new GVF dataset?

GVF is the fraction of a vertically viewed scene that is covered by photosynthetically active green vegetation. It is derived from NDVI product and has a liner relationship with NDVI. The Numerical Weather Prediction (NWP) and climate models need this parameter to partition the fraction of the surface in the model grid cell that is evaporating and transpiring at rates controlled by vegetation as opposed to the fraction of surface evaporation as a bare soil surface. Therefore, accurate description of GVF in numerical weather prediction models is of great importance in weather forecasting. Currently, the NCEP operational GFS model uses a 5-year averaged monthly 16-km AVHRR GVF dataset that was created based on the work of Gutman in 1998. NCEP needs an improved land surface product with fine resolution and high frequency to reflect and describe real-time conditions of vegetation dynamics in its numerical weather prediction and climate models.

Clear-sky Observational Statistics from SEVIRI Data

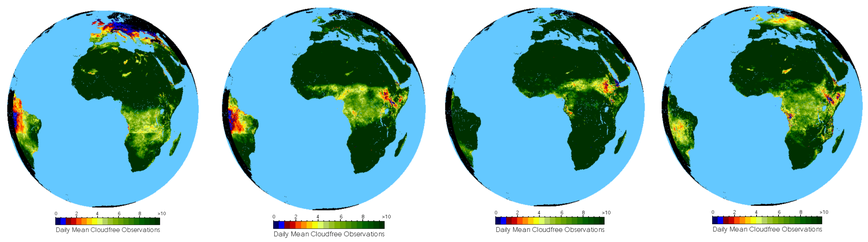

Fig. 1. Daily mean clear-sky observations (number of cloud-free observation) in Jan., Apr., Jul. and Oct.(from left to right).

Effect of cloudiness on the number of clear-sky observations

- On average, tropical regions have much less clear-sky observational chances than other regions. Tropical regions may have 4 times or less observations per day while other regions can have more than 10 times of good observations per day.
- Amazon regions have less chance to get clear-sky observations than center African regions. During the Amazon rain/wet season, some of the areas cannot get even one good observation per day.

Vegetation Seasonality over Tropical Regions

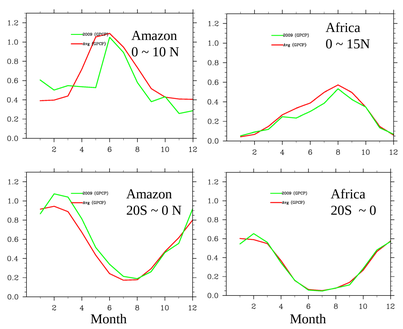

Fig. 2. Daily mean precipitation (mm/day) from NOAA GPCP (Global Precipitation Climatology Project) dataset. The red line is the multiyear average value, the green line is from the observations of 2009.

How we study vegetation seasonality over tropical region

We examined monthly NDVI, LSWI and BT differences to see how these values change with season and precipitation.

$NDVI = (R_{NIR}-R_{RED})/(R_{NIR}+R_{RED})$

$LSWI = (R_{NIR}-R_{SWIR})/(R_{NIR}+R_{SWIR})$

$BT\ difference = (BT_{11} - BT_{12})/10.0$

The LSWI is sensitive to leaf water and soil moisture, and has been used for mapping forests and agriculture. We introduced LSWI into this work to examine the sensitivity of this index to drought induced vegetation stress. The difference between the 11 and 12 micron bands in clear-sky conditions is a function of atmospheric water vapor. The value of $(BT_{11} - BT_{12})$ was approximately the same as the precipitable water (in cm) along the slant path of the satellite view direction. So the BT difference $(BT_{11}-BT_{12})$ is also called precipitable water index.

We Find

- NDVI seasonality (vegetation growth) is controlled by local precipitation. However, only forest NDVI in southern Amazon has an opposite cycle against rainfall, which is consistent with MODIS NDVI data downloaded from NASA (figures not shown). Earlier studies by others reported similar results. It was proposed that Amazon evergreen forests have deep roots system for access to water in deep soils and leaf phenology/growth for access to light during dry season.
- When $(BT_{11} - BT_{12}) > 0$, it is usually an indicator of atmospheric moisture. The larger the difference the wetter the atmosphere. It is found that forests have a larger BT difference than savannas. Wet season has a larger BT difference than dry season.
- High NDVI corresponds to high LSWI. Tropical forests generally have LSWI larger than 0.0. However, LSWI is very flat through the season in Amazon forests, indicating that LSWI is insensitive to drought in this region. LSWI is sensitive to wet/dry conditions in Africa, especially in savannas systems.

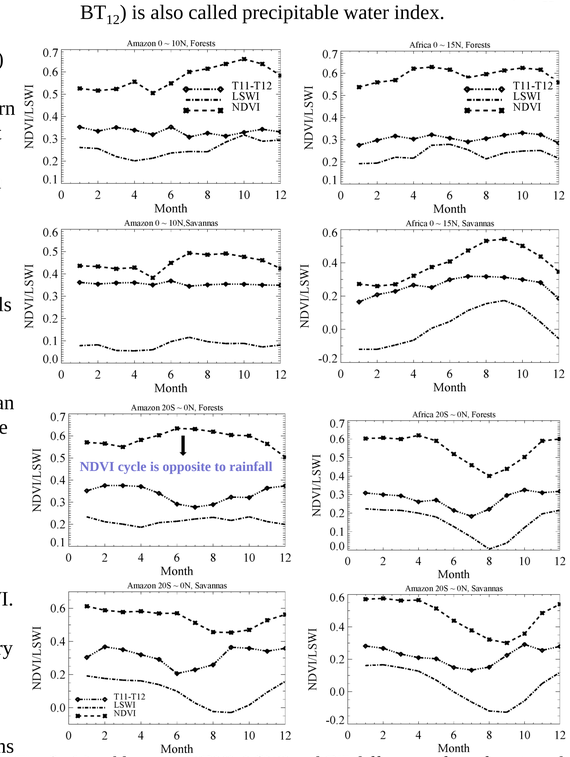

Fig. 3. Monthly mean NDVI, LSWI and BT differences from forests and savannas over Amazon and Africa in north and south of equator. Forests and savannas are two dominator vegetation types in tropical regions.

NDVI and GVF Products

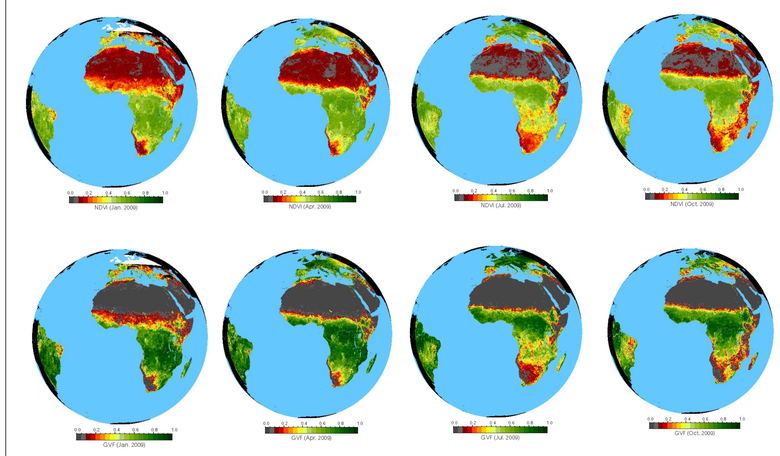

Fig. 4. Monthly NDVI and GVF products from SEVIRI fulldisk in Jan., Apr., Jul. and Oct.(from left to right). Although our research area is over tropical regions, our algorithm aims to derive NDVI and GVF over all of the observational area.

Comparison with AVHRR GVF

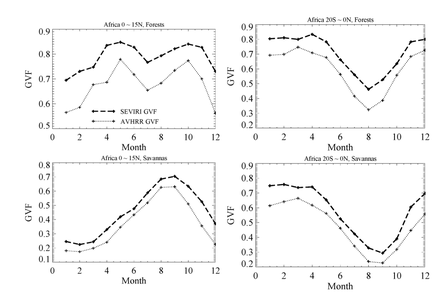

Fig. 5. Comparison of monthly GVF between SEVIRI in 2009 and AVHRR averaged in 5 years over Africa.

The SEVIRI GVF is about 0.1 larger than that of AVHRR GVF. This is due to more observations from SEVIRI data and smaller view zenith angle effects over the Africa region.

Over the Amazon region, the result is very complex and more investigation is still going on.

Accomplishments anticipated at the end of Year 2

- Data from 2010 will be processed to confirm our results from data of 2009
- The comparison between AVHRR and SEVIRI data will be finished
- Weekly data will be reprocessed. Currently, weekly NDVI and GVF data are very smooth (without smoothing) over most regions except in Amazon forests. We will try to find special smoothing methods over Amazon forests.
- The impact study of SEVIRI GVF on NCEP GFS model forecasts will be performed over the Africa region. We will run uncoupled experiments first: Noah will be run offline with atmospheric forcing.

Initial feedback from potential users

NCEP EMC land group is interested in collaborating with us on efforts to improve the GVF products. The focus of tropical regions is certainly relevant to the GFS and CFS models. It was stated "An update to the current AVHRR-based GVF climatology using the future GOES- derived GVF (over the topics) would be beneficial."

What will be accomplished with the 3rd year of funding

- The impact study of SEVIRI GVF on NCEP GFS model forecasts over the Africa region will be completed first.
- The impact study of SEVIRI GVF on NCEP GFS model forecasts will be carried out over the Amazon region and major conclusions about SEVIRI GVF impact on NCEP GFS model forecast will be drawn.
- A blended GVF from AVHRR and SEVIRI for EMC/JCSDA will be generated and the new technique at OSDPD for full disk daily/weekly SEVIRI NDVI and GVF products will be implemented

Summary

- We generated daily, weekly and monthly NDVI, LSWI and GVF datasets from year 2009. We examined the phenology of green vegetation in tropical regions. The wet season and dry season vegetation magnitude in NDVI and LSWI was revealed. All proposed work was completed within the designated time frame. We will continue our work and prepare to quantify the impact of SEVIRI GVF on NCEP forecasts.