Validating MODIS Terrestrial Ecology Products: Linking In Situ and Satellite Measurements

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MODIS (the Moderate Resolution Imaging Spectrometer) is the principal high temporal frequency global mapping sensor on-board NASA's Earth Observation System (EOS) (http://modarch.gsfc.nasa.gov/MODIS/). The MODIS instrument views the entire Earth's surface every 1-2 days, acquiring data in 36 spectral bands at spatial resolutions from 250 m to 1 km (Running et al., 1994). The specifications for the MODIS instrument push the limits of engineering (Barnes et al., 1998), and MODIS data volumes will be several times that of the NOAA-AVHRR (Masuoka et al., 1998). MODIS data are processed to provide well-quantified and calibrated data sets of the Earth's surface, corrected for instrument radiometry, geometric distortions, atmospheric attenuation, and cloud effects (Justice et al., 1998a). As these data are used, they will improve our understanding of global dynamics and processes occurring on the land surface and in the oceans and atmosphere.

This unprecedented data volume has led the MODIS instrument team to develop a number of derived data products, with the intent of reducing the burden of data processing on the user. A series of land product algorithms were selected by open competition and have been peer-reviewed twice during their development. The MODIS Land Discipline Group (MODLAND) has been charged with development of the MODIS-based algorithms, the generation of the associated geophysical products, and their validation. These MODLAND data products include surface reflectance, spectral albedo, land surface temperature, spectral vegetation indices, leaf area index and the absorbed fraction of photosynthetically active radiation (LAI/fAPAR), fire, snow, ice, and land cover, and net primary productivity (NPP). These and other, higher-order products derived from MODIS data will play an important role in measuring and monitoring surface variables and in the development of global, interactive Earth-system models that are able to predict global change accurately enough to assist policy makers in making sound decisions concerning the management of our environment. MODIS data will be used to parametrize and/or validate models of land-atmosphere interactions, ecosystem processes, biogeochemical cycles, surface hydrology, land cover, and land use.

Validation of these global data products is crucial, both to establish the accuracy of the products for the science-user community and to provide feedback so that the data processing algorithms and product-oriented models can be improved. The MODLAND validation approach developed around the hierarchical test-site concept of the Terrestrial Observation Panel for Climate (GCOS, 1997). The intensive study sites which form a major component of the MODLAND validation plan have evolved into a number of Core Land Validation Sites for the EOS program (Justice et al., 1998b) (http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL). The MODLAND group has coordinated a number of EOS land validation prototyping experiments at the site level using ground measurement, aircraft, and satellite data.

Recognizing the new challenge of validating global products, NASA formed an EOS Validation Program to assist the instrument teams with product validation.
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MODIS land products. At a workshop held in
May 1996 the decision was made to develop the articles
for this special issue, summarizing the results of this ex-
ploratory research. In 1998, the LTER validation scient-
ists reorganized their validation scaling activities around
four sites containing eddy-covariance flux towers, strengthened their linkages to the MODIS instrument
instrument team, and developed a follow-on proposal to the NASA Terrestrial Ecology Program. This follow-on project,
named “BigFoot,” is now funded and focused on scaling up from in situ ground measurements to the moderate spatial resolution of the MODIS data products (http://
www.fsl.orst.edu/larse/bigfoot).

Flux towers have a variable-sized “footprint” over
which gas flux data are collected. The size, shape, and
orientation of the footprint varies with height of the gas
sensors above the local vegetation, the wind speed and
direction, and associated factors, but is generally about 1
km or less (Baldocchi et al., 1996). The BigFoot project
sites are centered around flux towers; however, because
of a need to define a site containing multiple MODIS
pixels, the extent of BigFoot sites is 25 km². Hence the
derivation of the project’s name.

The BigFoot project will focus on validation of the
MODIS land cover, LAI/FAPAR, and NPP products.
These interrelated MODIS products represent critical
variables for monitoring the impact of humans and cli-
mate change on the Earth system. BigFoot will develop
gridded data layers based on field data, Landsat ETM+, and
geospatial and ecological models at each of the
project’s four sites using standardized procedures. The
sites include a boreal forest in northern Manitoba (the
Northern Study Area of the BOREAS project), a mixed
deciduous—coniferous forest in Massachusetts (Harvard
Forest LTER site), a tallgrass prairie in Kansas (Konza
LTER site, where the FIFE project was staged), and an
agroecosystem consisting of a mix of corn and soybeans
in west-central Illinois. The main goal in developing the
biophysical data layers at each site is to produce grids
that have ecological significance and a high degree of ac-
curacy at the local site level. Errors in each data layer
will be characterized using an independent set of ground
reference data.

The research presented in this special issue was in-
strumental in the development of the BigFoot concept.
Explicit examination of scaling from field measurements
to MODIS grids is a central theme of BigFoot. Because
MODIS grids are being developed to capture global
trends, the data, models, and algorithms used are highly
generalized. BigFoot grids which are developed at the
site level, using extensive field data, higher spatial resolu-
tion satellite data, and less generalized models and algo-
rithms, should be more accurate at the site level. The
juxtaposition of MODLAND and BigFoot grids will per-
mit a series of exercises that are designed not simply to
test the accuracy of MODLAND products, but also to
gain an understanding of the causes of errors in MOD-
LAND products and thus provide feedback for potential
improvement in second-generation MODIS products. An
important criterion for success of MODLAND products
is whether they reveal the proper trends across biomes.
A simple cross-site comparison of MODLAND and Big-
Foot data layers permits this, but also facilitates an exam-
ination of product accuracy at the biome (or site) level.
Given the generalized nature of MODLAND products,
we expect site-level errors in estimates for each variable,
and BigFoot will isolate and test several factors that
might contribute to errors in MODLAND products.

The articles contained in this special issue provide
the foundation for the research questions that will be ad-
ressed by BigFoot. BigFoot will focus on the NPP
product and the contribution of using a global land cover
classification scheme versus a site-specific scheme
(Thomlinson et al.) to model NPP. We will also turn our
attention to the examination of relationships between
spectral vegetation indices (SVIs) and LAI (Turner et
al.). Of great importance is our examination of observa-
tional grain size (Milne and Cohen). As the scale of ob-
servation (i.e., spatial resolution) increases, especially in
a heterogeneous landscape, functionally-important vege-
tation patches become unresolvable. We hypothesize that
there is a fundamental grain size of each landscape (or
biome) above which error rates accelerate when model-
ing NPP, and we will test this hypothesis explicitly using
field data, Landsat ETM+, and geostatistical models.

To the extent possible, BigFoot will use standardized
procedures for field data collection, analyses, and model-
ing, as the following brief summary of the articles con-
tained in this special issue indicates. The article by Ouai-
drari and Vermote describes the approach we will use to
atmospherically correct the Landsat data which will pro-
vide the high resolution site-specific spatial characteriza-
tions. Thomlinson et al. discuss issues related to land
cover mapping across multiple sites for the purpose of
validating MODLAND and related global land cover
products. Gower et al. discuss the measurement and
quantification of LAI, FAPAR, and NPP of terrestrial
ecosystems. The importance of this article is that it syn-
thesizes the relevant literature, bringing us up to date on
the assumptions and inconsistencies among various
methods, as well as suggesting both indirect (optical) and
direct measurement and analysis standards for these eco-
system attributes. The article by Turner et al. evaluates relationships between common SVIs and LAI across three distinct vegetation regions in North America. Reich et al. provide a biological framework linking ecosystem attributes and carbon flux at several scales and summarize the state of knowledge and models in these areas. Milne and Cohen discuss options for scaling continuous and class data from plots to MODIS-sized cells, aimed at preserving both the mean and the multifractal properties of a landscape. Olson et al. describe a data and information system model that facilitates assembling, managing, and sharing diverse data from multiple disciplines, scales, and sites to support integrated ecological studies. Running et al. describe the overall framework for validating MODLAND NPP products within which BigFoot will operate. The truly visionary package of field data, flux tower measurements, remote sensing, and ecological models presented in this article launches remote sensing and related modeling activities into the 21st century.

We hope you enjoy this special issue, and through the articles contained herein, can more fully appreciate the tremendous leap forward that NASA’s EOS Program affords the Earth science community, and that MODIS provides the ecological modeling segment of that community.

Three special notes of thanks are in order. Were it not for the solid, unwavering support of Dr. Diane E. Wickland, Manager of NASA’s Terrestrial Ecology Program, the research presented in this special issue and the BigFoot project would not have been possible. Dr. Wickland’s encouragement for the involvement of LTER scientists in NASA programs is much appreciated, providing an important link between field ecologists, in situ measurements, and remote sensing. To the reviewers of this special issue we owe tremendous thanks for excellent feedback that greatly improved individual articles and the special issue as a whole. Finally, we want to thank Dr. Bauer for working with us over the past few years to help us get this special issue in order.

REFERENCES


