MODIS Global Vegetation Phenology (MOD12Q2) - Validation Information

The purpose of this document is to provide guidance to users of MOD12Q2 (MODIS Global Vegetation Phenology) regarding the status and results from validation and assessment activities. Specifically, we report results from a set of activities comparing the MOD12Q2 product to various sources of in-situ measurements.

1. Validation Status

The MOD12Q2 product is deemed to be "validated level 1."

2. Validation of MODIS Phenology Using In-Situ Measurements

2.1. Harvard Forest

Observations collected at Harvard Forest include samples collected at two to five individuals of 33 native woody species located along a 2 km loop transect near the Harvard Forest headquarters (42^0 32'N, 72^0 11'W). Field measurements include budburst and leaf development from April to June, and leaf coloration and leaf drop from September to November at 3-7 day intervals. These data were collected by staff at the Havard Forest Long Term Ecological Reserve site between 2001 and 2003 and were obtained from the Harvard Forest LTER Web site (http://www.lternet.edu/hfr/). Summary results comparing phenological transition dates estimated by the MOD12Q2 algorithm versus those observed at Harvard Forest are presented in Table 1.

	Gin			Gma			Gde		Gmi			
	MODIS	ABD	BBD	MODIS	FL1	FL2	MODIS	CL	MODIS	AGD	GL	TL
2001	120±5	123±4	20	157±7	77	81	236±4	1	317±2	297±12	0.25	3
2002	122±4	118±10	50	166±3	85	90	234±9	1	315±1	304±10	1	10
2003	130±2	127±9	50	161±6	84	90	230±13	0.2	304±3	295±9	2	15

Table1. Comparison between phenological transition dates retrieved from MODIS data and in-situ data collected at Harvard Forest. Values in the columns are Julian date (DOY). For the MODIS-based estimates we provide the mean and standard deviation for the five nearest neighbor 1-km^2 cells. Gin: date of greenness increase; Gma: date of greenness maturity; Gde: date of greenness decrease; Gmi: date of greenness minimum; ABD: average date of first budburst observed in field ; BBD: percent budburst corresponding to the timing of MODIS retrieval; FL1: percent of leaves in canopy reaching their final size at the time of mean MODIS Gma; FL2: percent of leaves in canopy reaching their final size at the time of maximum MODIS Gma; CL: average percentage coloring of leaves at the time of mean MODIS Gde; AGD: average date of last green leaf coloring for each individual plant: GL: the percent of green leaves in the canopy at the time of mean MODIS Gmi; TL: the percent of leaves on trees at the time of mean MODIS Gmi.

The exact location at Harvard Forest in which the data were collected was difficult to precisely co-locate with MODIS pixels because data were collected over a large area overlapping several pixels. To reduce potential geolocation errors, MODIS retrieval results are presented using the mean and standard deviation for the five nearest neighbors to the ground location. Results from this comparison show that both the onset of greenness increase derived from MODIS and the average date of first appearance of budburst observed are much later in 2003

than those in 2001 and 2002. The MODIS retrievals differ from in-situ data by about 3 days over the three years, and represent the timing when budburst has occured for 20% to 50% of the canopy. Results also show that the estimated onset of greenness maximum corresponds to the timing at which 84-90% of individual leaves reach their final size.

It is interesting to note that leaf growth was only about 77 percent complete at the estimated date of onset of greenness maximum in 2001. This result at least in part reflects the fact that MODIS data were not acquired between DOY 166 (15 June) and 184 (11 July 2001) due to MODIS instrument problems.

The onset of greenness decrease corresponds to the onset of leaf senescence. At this stage, decreases in leaf chlorophyll and water are reflected in lower MODIS EVI values. The onset of greenness minimum is estimated to be about 10 days later than the average final date date at which green leaves were observed in the canopy, but it is identical to the timing for which all leaves have changed their colors (green leaves are less than 2%), and most leaves have fallen on ground.

Based on these results, we conclude that the four phenological transition dates retrieved from MODIS agree well with observations of vegetation phenology. In particular, estimates for the timing of greenup, maturity, and dormancy all agree very well with in-situ measurements.

2.2. Hubbard Brook Forest

Vegetation phenology measurements at the Hubbard Brook Experimental Forest (43^0 56'N, $71^0$43'W) (http://www.hubbardbrook.org/research/data/veg/phn/phndoc.htm) are collected by the USDA Forest Service. Tree species measured in this area are American beech, sugar maple, and yellow birch, which represent the most common tree species in the forest community at this site. Vegetation phenology is measured every week at Hubbard Brokk at specific sites located in five small watersheds using the criteria in Table 2. Data from 2001 are presented in Figure 5. Since these field sites were located in very close proximity to several neighboring pixels of MODIS data, the MODIS data for these pixels were spatially averaged and used to assess the results.

MODIS phenology in 2001 compares quite well with field measured indices of phenology at Hubbard Brook. For example, MODIS estimates that the onset of greenness occurs on DOY, 128, which corresponds to an average index of 1.7 measured in the field. Inspection of Table 2, which presents information related to the ecological meaning of different values for the field index, suggests that this result is very reasonable. In regards to the other estimated transition dates, the measured index reaches its maximum value (4 = full canopy cover) about 10 days earlier on average than the estimated onset of greenness maximum, the first field observation of leaf coloration is on DOY 267 (which is much later than the MODIS onset of greenness decrease), and the end of the growing season is measured in the field is about 13 days sooner than the onset of greenness minimum estimated from MODIS.

Overall, given the limitations imposed by the data (temporal sampling, not all species sampled, etc.) the results suggest that the algorithm is performing quite well. As at Harvard Forest, the quality of the retrievals at the beginning of the growing season (onset of greenness increase and maximum) appears to be higher than those at the end of the growing season (onset of greenness decrease and minimum).

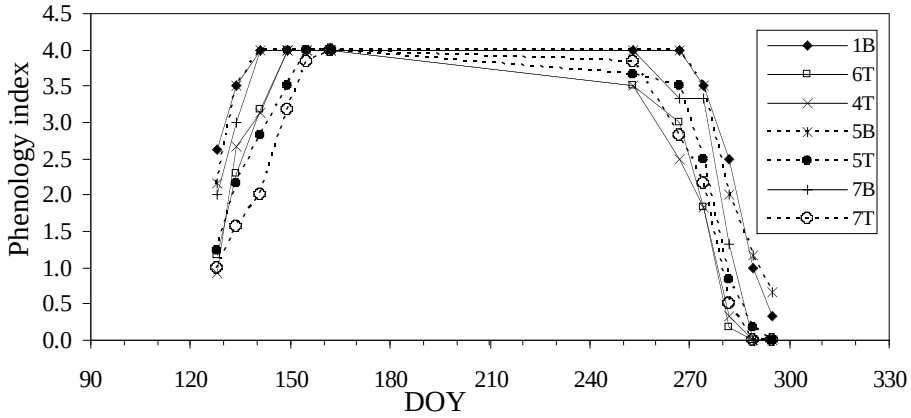

Figure 1. Phenological index measured in Hubbard Rook Experimental Forest. Different curves represent different locations indicating 1B, 6T, 4T, 5B, 5T, 7B, and 7T.

Index	Spring criteria	Fall criteria
0.5		Most leaves fallen
1	Bud swelling noticeable	No more green leaves in canopy, half of leaves fallen.
2	Small leaves or flowers visible, initial stages of leaf expansion (about 1 cm long)	Most leaves becoming yellow or red, and a few fallen leaves
3	Seaves with 1/2 of final length, or 5 cm long, or canopy obscuring 1/2 of sky	Many leaves having noticeable reddening or yellowing
4	Leaves fully expanded with little sky visible through crowns	Only scattered leaves or branches changing color

Table 2. Criteria for the field measurements of phenological index in Hubbard Brook Experimental Forest (modified from http://www.hubbardbrook.org/research/data/veg/phn/phndoc.htm).

2.3. Spring Bloom Data

The final data set that we used as a basis for validating the MOD12Q2 product is provided by Plantwatch (http://www.devonian.ualberta.ca/pwatch/index.htm), which is run by University of Alberta (Beaubien, 1997). This data set provides spring flowering time (first bloom date and full bloom date) for 182 sites distributed across North America. The flowering time for "key indicator" plant species are observed by students and the general public. Key species that are monitored include aspen poplar, prairie crocus, white trillium, western trillium, purple saxifrage, white dryad, bunchberry, bearberry, Labrador tea, tamarack, common dandelion, and common purple lilac. Flowering time is observed for only one plant at most sites, but up to 6 plants are observed at some sites.

For the comparison presented here, flowering times in 2001 were acquired from the Plantwatch Website and compared with MODIS retrievals. Note that flowering time is clearly different from the “greenness” phenology that the MOD12Q2 product measures. However, the phenology of leaves and flowers is highly correlated, and flowering dates therefore provide a

useful surrogate for leaf phenology at the start of the growing season. Note, however, that there is a significant mismatch in the measurement scales between the data collected on the ground and the 1-km^2 MODIS footprint.

The results are presented in Figure 3 and clearly show that the MODIS phenology retrievals and ground samples are strongly correlated and distributed along a 1:1 line. The onset of greenness increase is significantly correlated with both the date of first bloom (R^2=0.60), and the date of full bloom (R^2=0.64). However, inspection of the root mean square error (RMSE) reveals that the onset of greenness increase is much closer in value to the date of first bloom (RMSE =10.8 days) than to the date of full bloom (RMSE =14.0

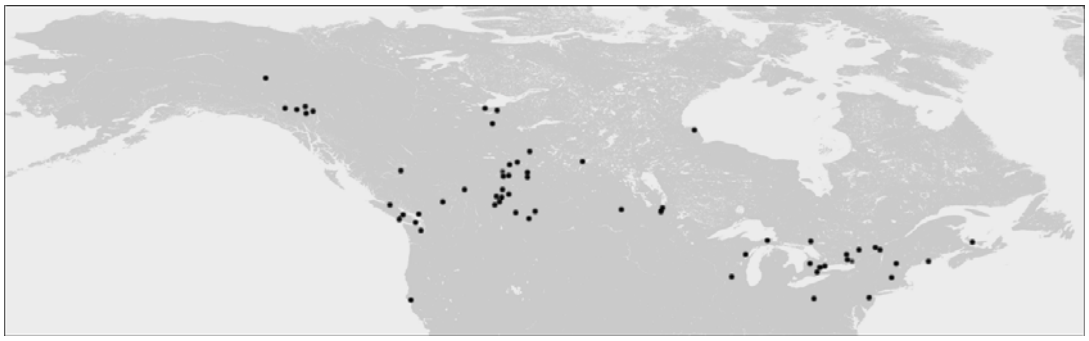

Figure 2. Distribution of field sites from Plantwatch. Note that one black dot may cover several field sites of measurements since it is impossible to display each site in a 1-km pixel.

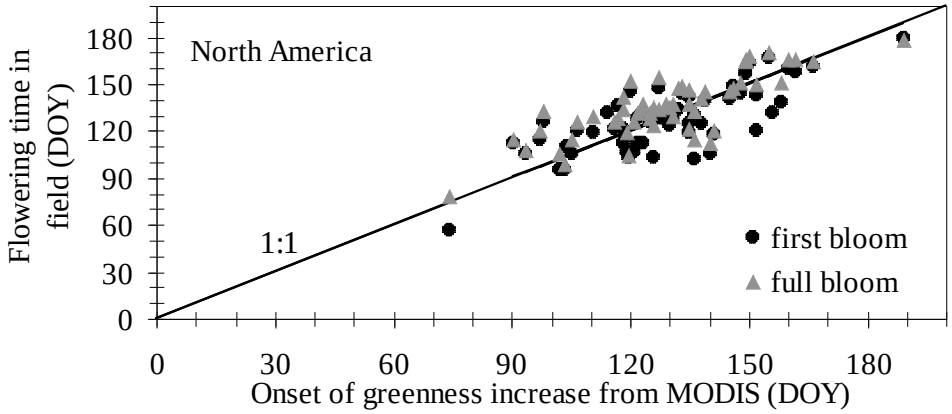

Figure 3. Correlation between flowing time measured in field and the onset of greenness increase retrieved from MODIS data.

3. Summary

Retrievals of vegetation phenology from MODIS compare well with in-situ measurements from three different sources. The MODIS global vegetation phenology product is therefore deemed to be "validated, level 1."

References Cited

Beaubien, E.G.,1997. Plantwatch: Tracking the biotic effects of climate change using students and volunteers. Is spring arriving earlier on the prairies?, in *Ecological Monitoring and Assessment Network Report on the 3rd National Science Meeting*, pp.66-68, Environment Canada, Saskatoon, January 1997.