

## Background: Importance of Clouds



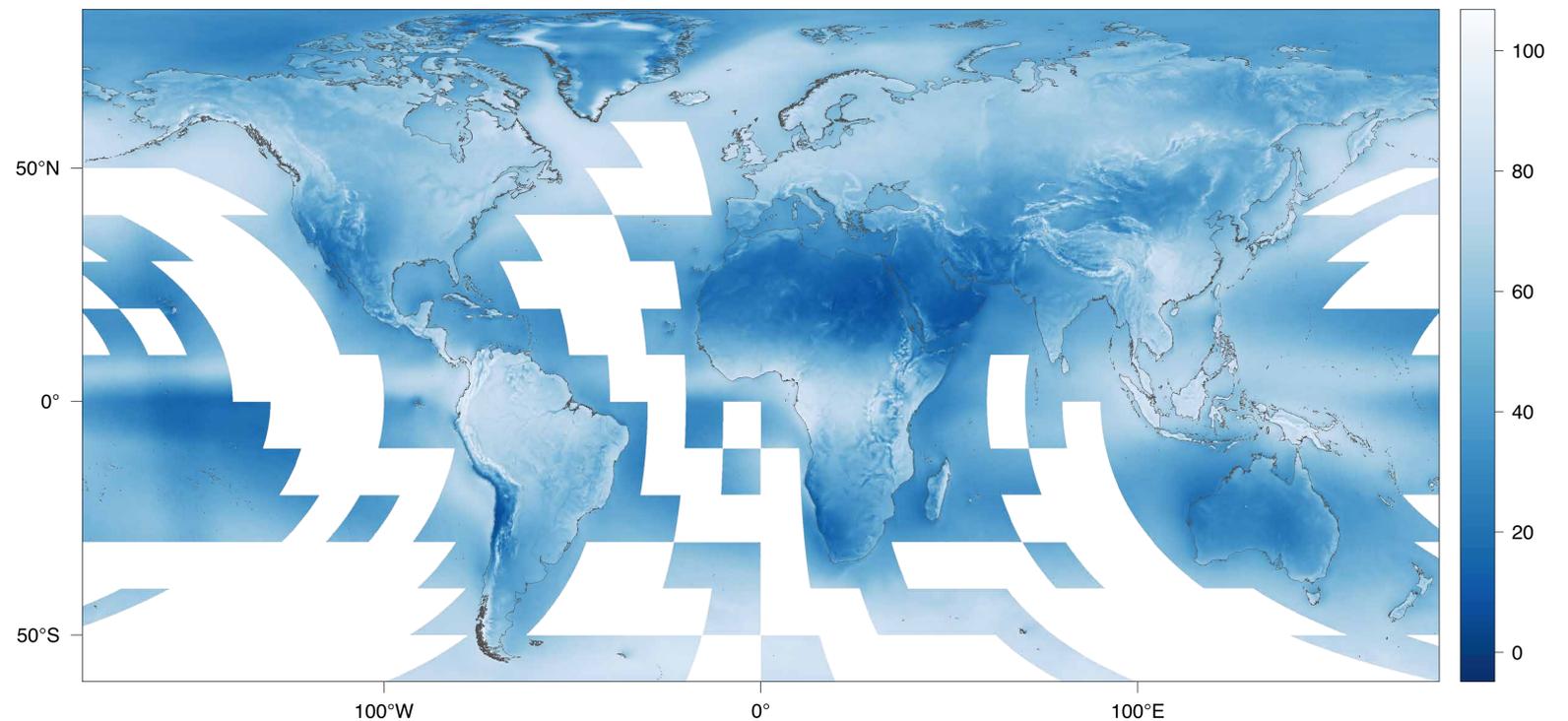
Solar radiation  
Precipitation  
Evaporation  
Soil Moisture  
Leaf-wetness  
Drought-stress  
Photosynthetic Activity  
Animal Behavior  
Growth rate

Clouds are an extremely important component of the earth system and directly affect energy and moisture transport, which in turn affect many biological processes. Cloud dynamics can vary drastically over small spatial (~2 km) grains due to atmospheric circulation, topography, and even land cover. However, existing cloud products are available only at relatively coarse spatial grains (8-110 km). Furthermore, the standard MODIS cloud flag (MOD35) contains significant land-cover and processing artifacts that make it unsuitable for spatially consistent high-resolution analyses (Wilson, Parmentier, and Jetz, 2013).

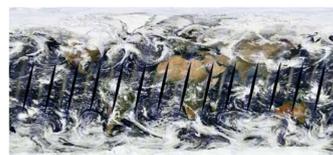
In this study we develop a new MODIS-derived 1-km cloud climatology (MODCF) for use in ecological and species distribution modeling.

## Results

### Mean Annual Cloud Frequency (%)

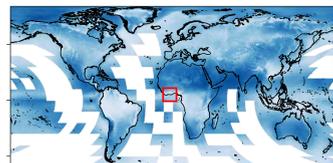


## Methods: MODIS Climatology



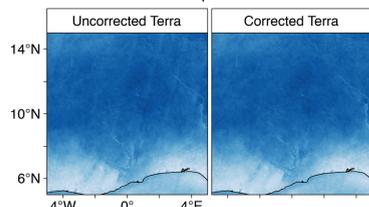
### Daily MODIS Cloud Flags

Cloud flags from the 1-km MOD09GA (PGE11) algorithm were extracted from February 2000 - March 2014 (~250TB) and summarized into monthly cloud frequencies (proportion of days with positive cloud flag).



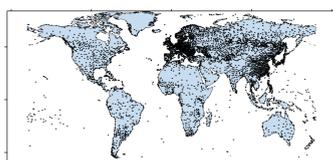
### Monthly Climatologies

The monthly cloud frequencies were summarized into the inter-annual mean (and standard deviation) cloud frequencies.



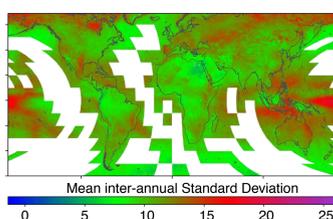
### Removal of Orbital Artifacts

A Bayesian image restoration method (Fehrenbach, et.al, 2012) was used to identify and remove bands resulting from variable observation frequency due to the MODIS orbit.



### Validation

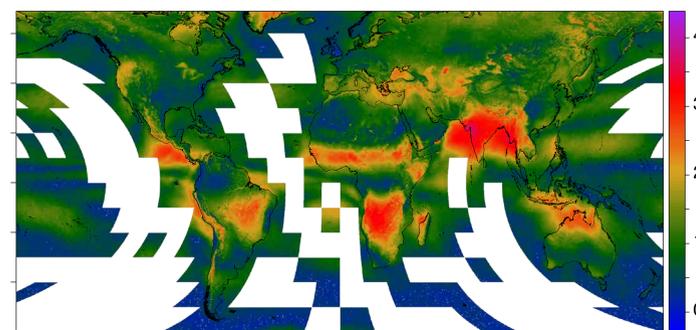
The monthly cloud frequencies were validated using a global observational dataset of synoptic weather reports collected at over 5,300 stations over 1971-2009 (Eastman and Warren 2012).



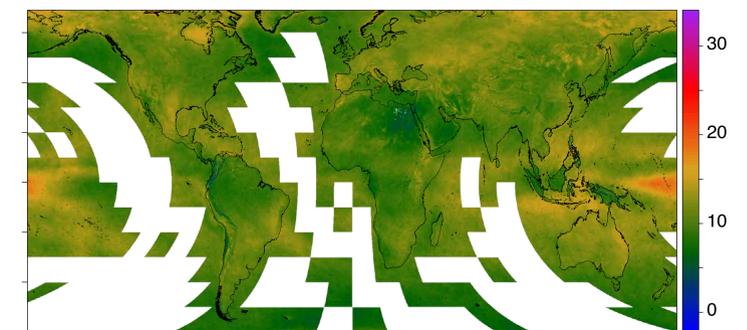
### Derived Metrics

The monthly mean and standard deviation were used to generate additional biologically relevant metrics such as inter- and intra-annual variability.

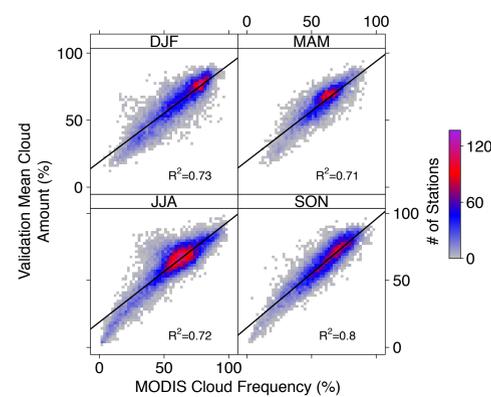
### Intra-annual Standard Deviation



### Inter-annual Standard Deviation



## Validation



### Seasonal Validation

MODIS cloud frequency explains 71-80% of the seasonal variability in the station record.

### Multi-Decadal Validation

MODIS cloud frequencies explained 74% of the variability in the full (1970-2009) station record and 78% of the MODIS era record (2000-2009). This confirms it is a useful metric of multi-decadal fine-grain spatial patterns of cloud frequency.

## Conclusions & Applications

### Conclusions

The MODIS MOD09GA cloud flag was used to develop a 1-km global cloud frequency dataset (MODCF) useful for ecological and biogeographical research.

MODCF captures nearly 80% of the variability in cloud cover observed at a global set of validation stations.

MODCF was nearly as accurate over the full time period (1970-2009) versus the MODIS-era (2000-2009) alone, suggesting that it is a useful metric of multi-decadal fine-grain cloud frequency.

### Applications

MODCF will contribute to a set of 1-km environment and climate layers developed for global biodiversity and ecosystem modeling under the NASA sponsored EarthEnv project (see earthenv.org).

MODCF is currently being used to develop global 1-km solar radiation maps and will soon be applied in the interpolation of precipitation.

## References

- Eastman, Ryan, and Stephen G. Warren. 2012. "Land Cloud Update, 1997-2009, Appended to Cloud Climatology for Land Stations Worldwide, 1971-1996." NDP-026D. Oak Ridge, Tennessee: Climate Change Research Division. Office of Biological and Environmental Research. U.S. Department of Energy. <http://cdiac.ornl.gov/epubs/ndp/ndp026d/ndp026d.html>.
- Fehrenbach, Jérôme, Pierre Weiss, and Corinne Lorenzo. 2012. "Variational Algorithms to Remove Stationary Noise: Applications to Microscopy Imaging." Image Processing, IEEE Transactions on 21 (10): 4420-30.
- Wilson, Adam M., Benoit Parmentier, and Walter Jetz. 2014. "Systematic Land Cover Bias in Collection 5 MODIS Cloud Mask and Derived Products — A Global Overview." Remote Sensing of Environment 141 (February): 149-54. doi:10.1016/j.rse.2013.10.025.

## Acknowledgments



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