Incorporating satellite derived cloud climatologies to improve high resolution interpolation of daily precipitation.

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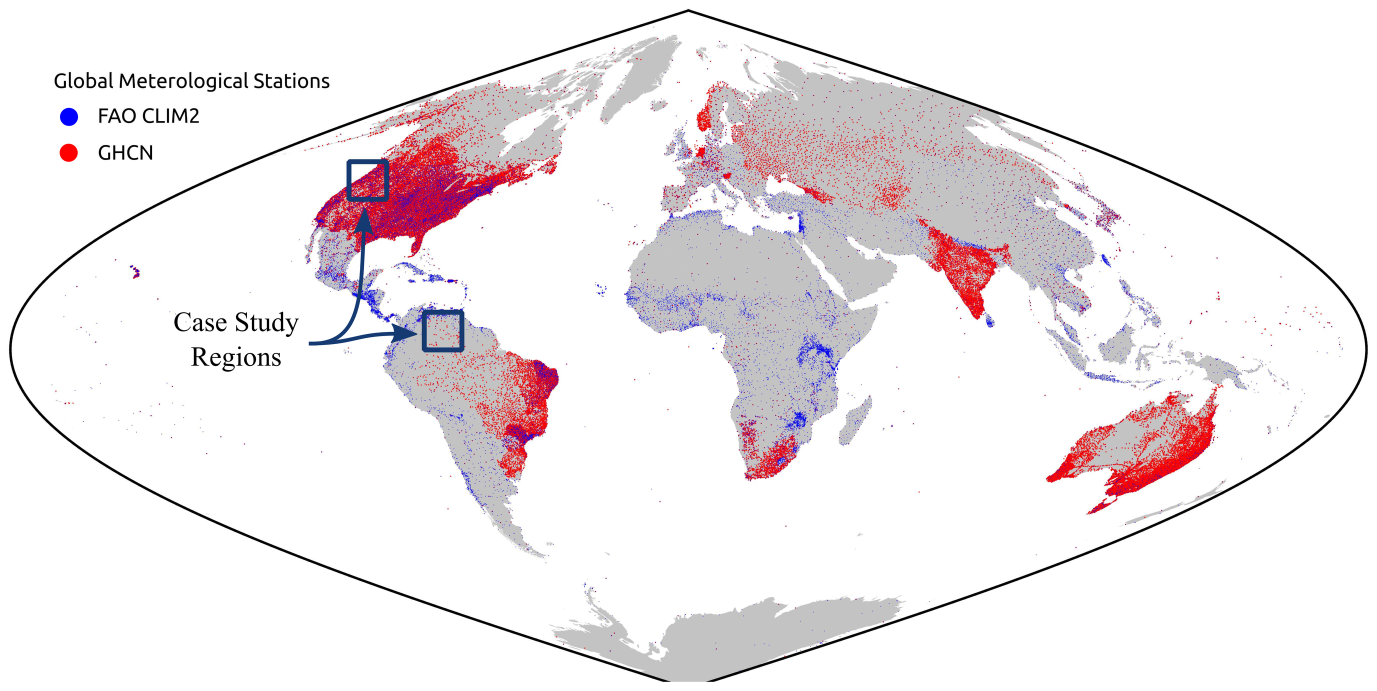
Fine-grained Climate Data is Vital for Biogeography

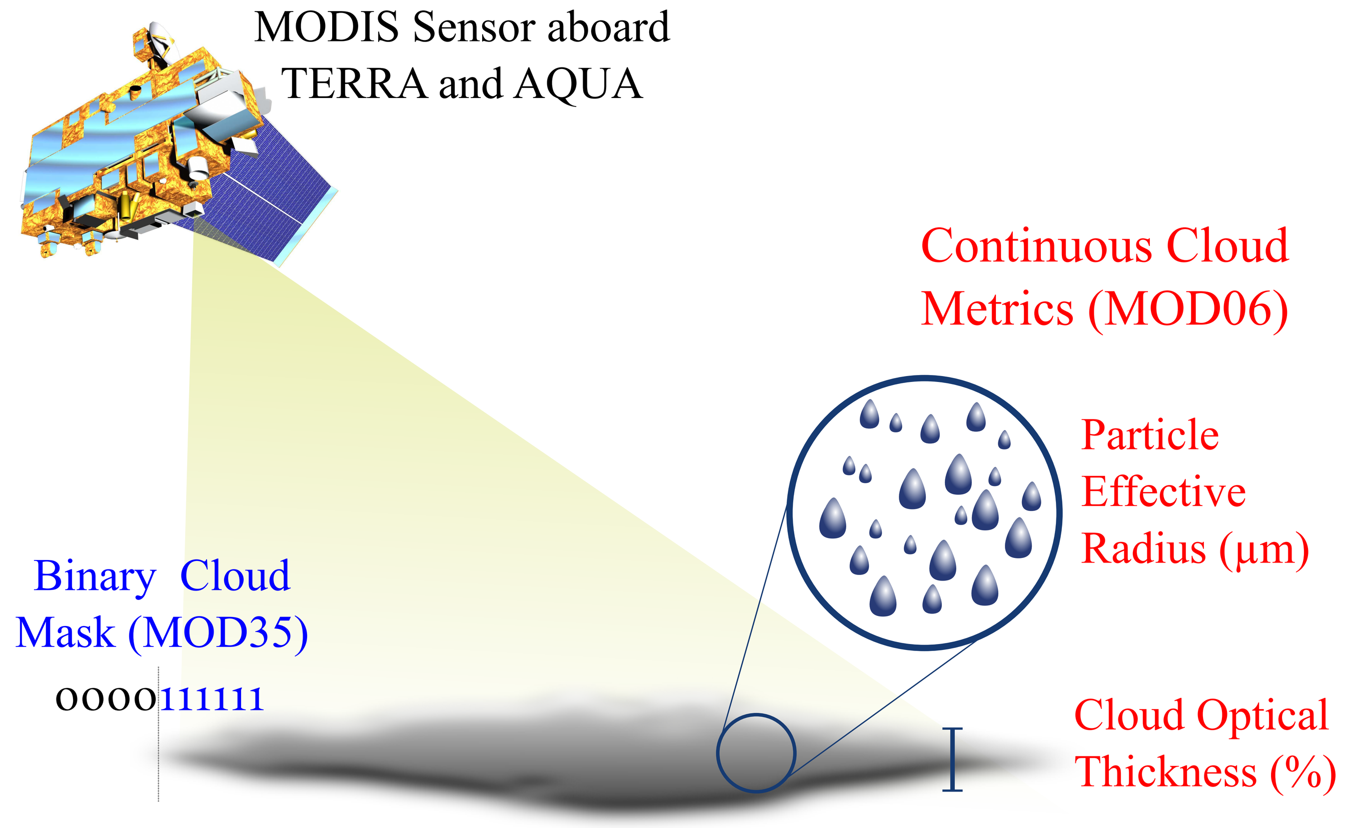
The role of climate in driving ecological processes has been known for 170+ years[1]. Precipitation and drought patterns are vital for understanding vegetation, food availability, and species distributions. At the same time, precipitation is highly idiosyncratic and heterogeneous, making it difficult to predict[2]. A limiting factor for many ecological studies is the availability of accurate weather and climate data for locations of interest[3]. Weather stations are often irregularly spaced and clustered in heavily populated, low elevation areas which may be far from where ecological

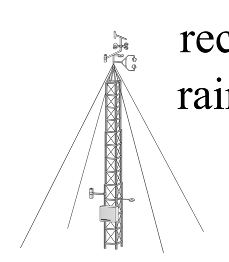


Global distribution of meteorological stations in the Global Daily Historical Climate Network (GHCN, in red) and U.N. FAO Climate Normal database (FAO CLIM2, in blue). Boxes in Pacific Northwest (Oregon, MODIS tile h09v04) and South America (Venezuela, h11v08) indicates ares used as case study regions. Note the sparse, spatially uneven station locations and vast areas of the globe with no observations.

Can satellite-derived cloud data improve interpolation of station observations?

In contrast to the binary MODIS cloud mask (MOD35), the MODIS cloud product (MOD06) uses multi-spectral reflectance to estimate continuous cloud parameters including effective radius and optical thickness at 1km resolution[4]. Precipitation falls when clouds have sufficient vertical extent (optical thickness) to facilitate the growth of particles with sufficient mass (effective radius) to overcome updraft winds. These parameters have a physical relationship with precipitation[5]. Here we explore their utility aiding the station-based interpolation of precipitation.

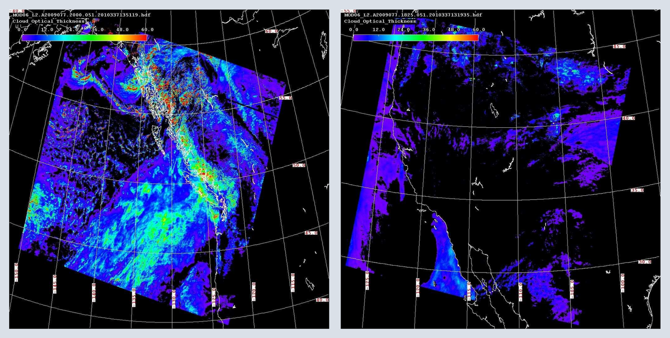




Topography from Shuttle Radar Topography Mission (SRTM)

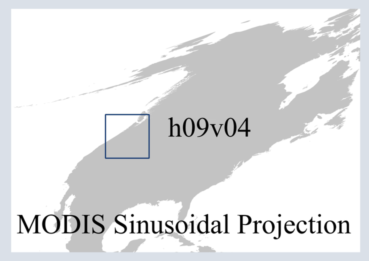
Processing Work flow

Processing MODIS (MOD06) Swath-level data



Cloud Optical Thickness over the western United States on March 18, 2009. On this day, two swath granules include data for tile h09v04. All tiles available for each day are incorporated into a daily summary before generating the monthly climatologies.

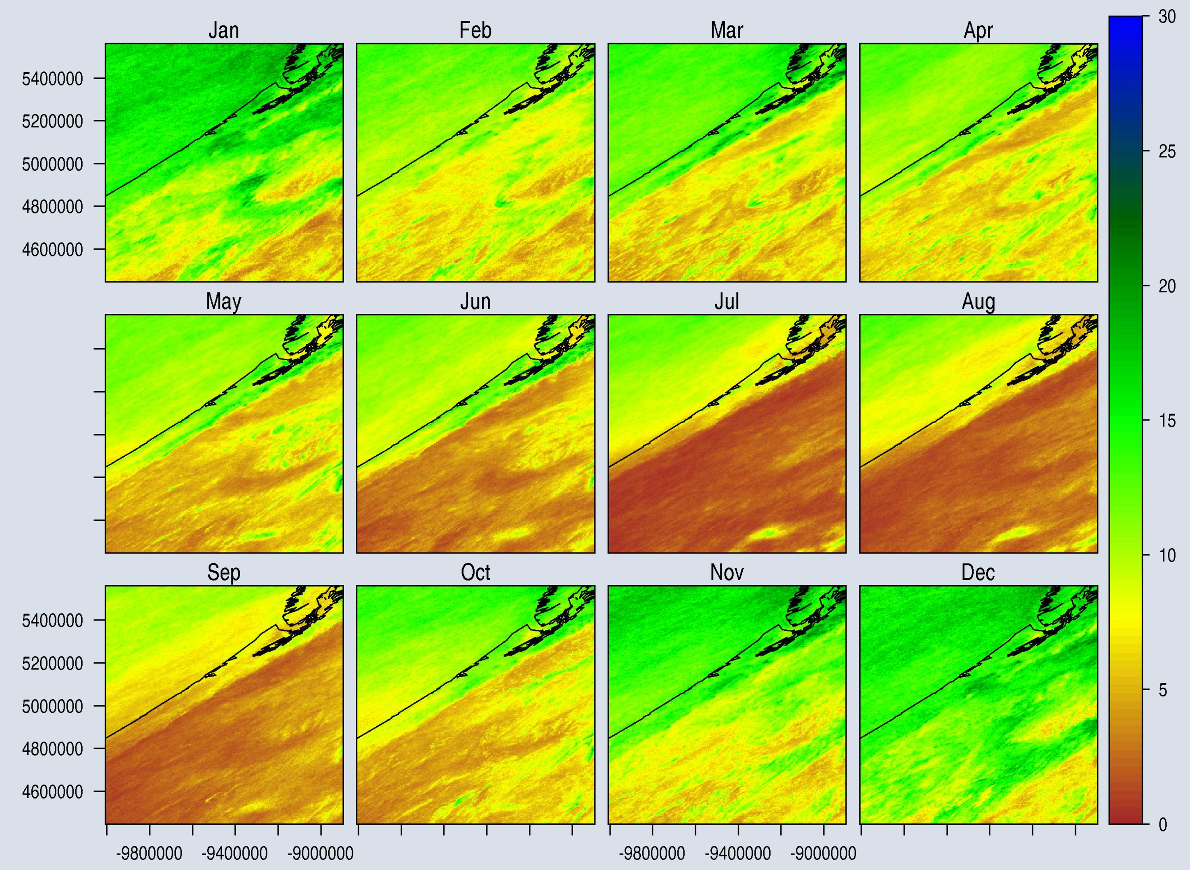
1: Grid data to MODLAND tiles using MODIS HEG Tool
2: Quality Control: Discard low quality pixels
3: Daily Composites: Average pixel values across swaths



Daily cloud composites to monthly climatologies

Cloud Climatologies for the Northwestern U.S.

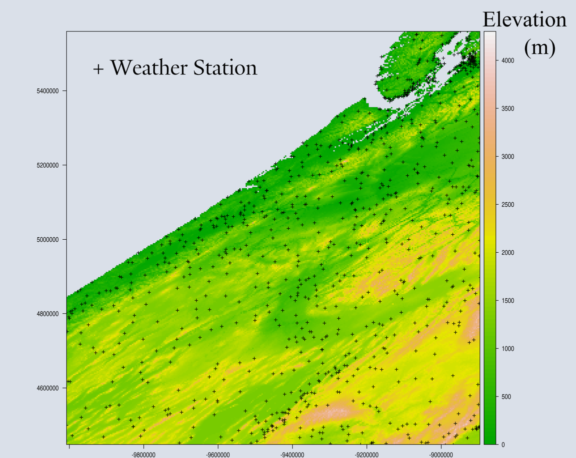
Mean Cloud Optical Thickness (%)



Monthly mean Cloud Optical Thickness (COT) over 2000-2012 for MODIS tile h09v04 (Pacific Northwestern U.S.). Note the significant spatial and temporal cloud variability. This information is incorporated to interpolate the station data. Mean Cloud Effective Radius (CER), proportion of days with a CER>20µm, and proportion of days with clouds were also processed and considered.

Cloud climatologies combined with topography and weather station data to interpolate precipitation

Elevation & Station Data

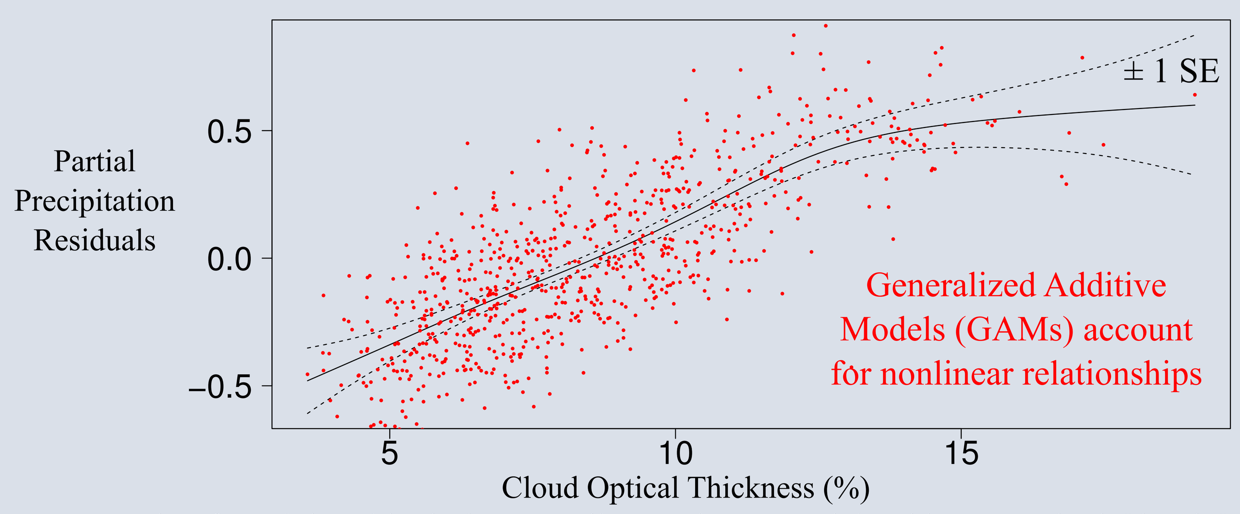


Elevation and meteorological station locations in tile h09v04.

Interpolated using Generalized Additive Models (GAMs)

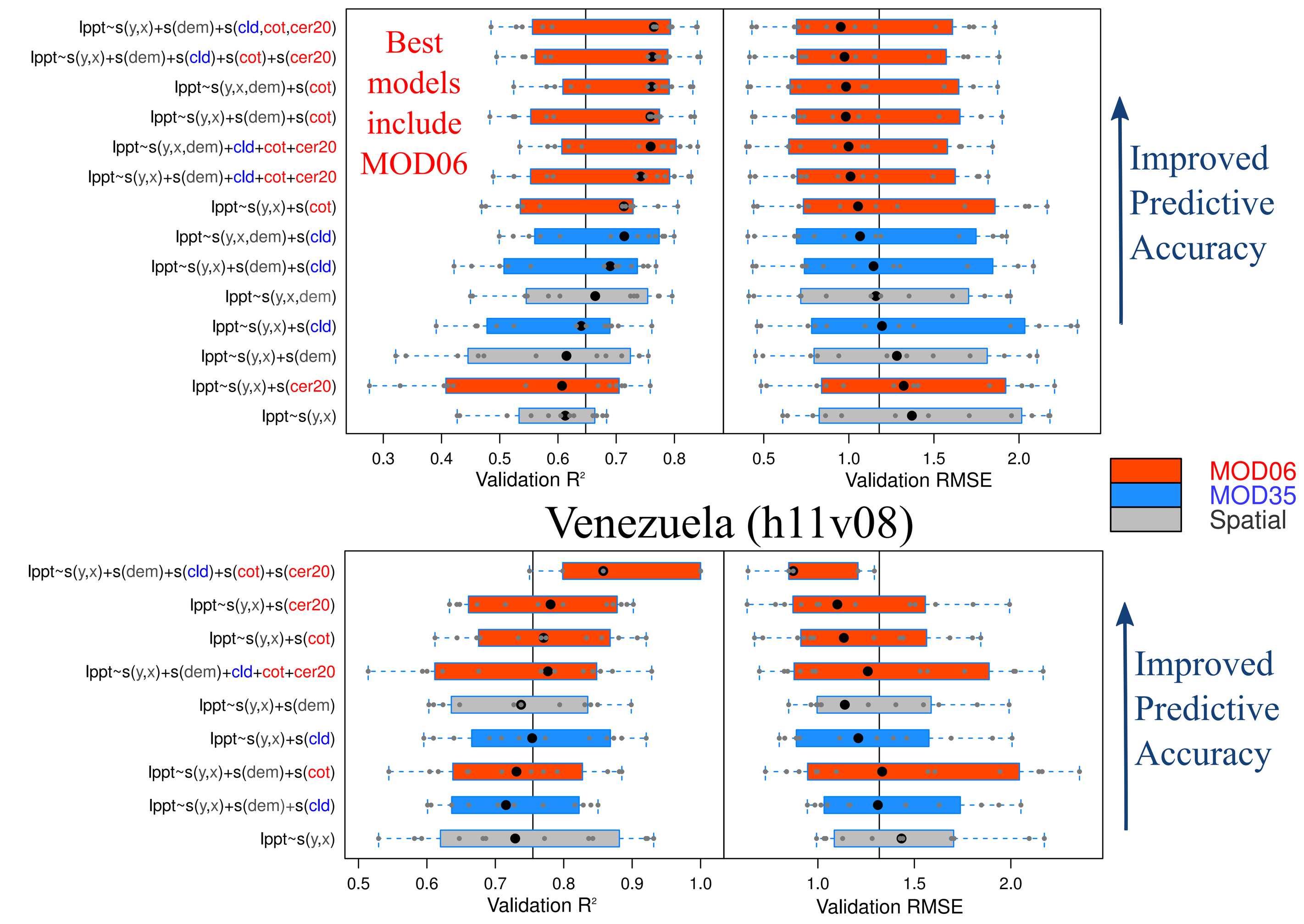
Pros:
- Non-linear relationships
- Spatial autocorrelation
- Fast

Cons:
- Risk of over-fitting data
- Increased model complexity



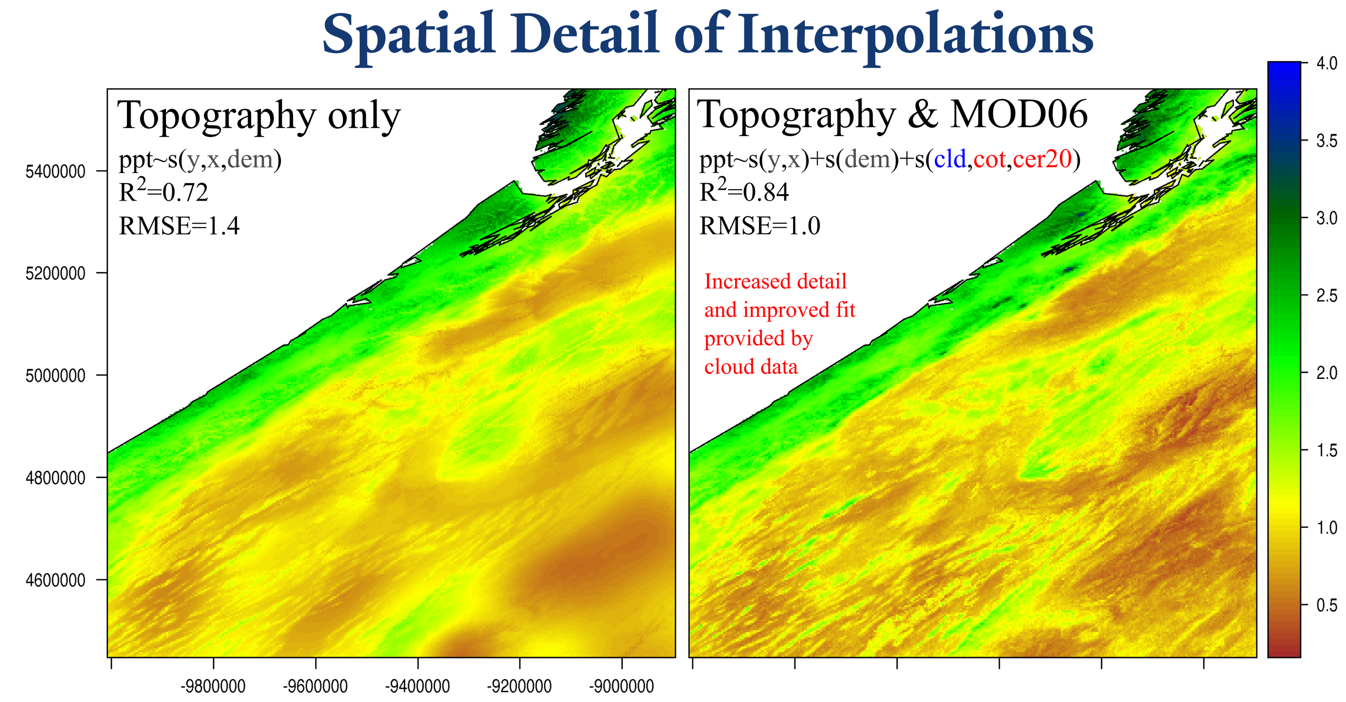
Example of partial residual plot revealing variance explained by smoothed Cloud Optical Thickness (COT) after accounting for other variables in tile h09v04 in April.
Full model: lppt~s(y,x)+s(dem)+s(cld)+s(cot)+s(cer20)

Cloud Climatologies Improve Predictive Accuracy of Interpolation



Validation results (R^2 and RMSE) for all monthly models (detailed on the left) based on 100 holdouts (10%) of repeated random sub-sampling from the two case study regions (fewer models were considered in h11v08 due to fewer available stations). s(...) indicates a smoothed relationship estimated using Generalized Cross Validation (GCV) within the GAM. The gray points indicate each of the 12 months and the black points indicate the overall median for that model.

Cloud Climatologies Increase Spatial Detail of Interpolations



Predictions for mean precipitation in h09v04 in March using a GAM with space and elevation (left) and one that includes several MOD06 cloud parameters (right). The model with MOD06 parameters explains more of the variation in precipitation (R^2=0.84 vs. 0.72) and has smaller predictive errors (RMSE=1.0 vs 1.4).

Toward global 1km precipitation products

Incorporating satellite derived data into station interpolation has enormous potential to improve the quality of high resolution global climate layers[6,7]. Through climate-aided interpolation[8], these climate layers can be used to estimate variability across finer temporal scales (monthly or daily). Our plan is to scale up this approach and develop global 1km daily precipitation surfaces that can then be summarized into biologically meaningful metrics such as drought length and intensity. High quality, high resolution precipitation data are invaluable for biodiversity analysis in the face of global change.

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