P-063

MODELING SPATIAL PRECIPITATION PATTERNS USING GIS

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Spatial precipitation non-uniformity is accounted for by a number of factors, of which amount of moisture contained in air masses, their movement relative to geographical barriers, and underlying surface characteristics are among the major controls. State-of-the-art modeling methods, GIS technologies, and digital elevation models (DEM) enabled consideration of geophysical factors deemed to be the most important in our study area.

A weak point is that the weather stations providing data for calculating precipitation are few and sparsely distributed. To fill precipitation data gaps, precipitation information available in climate reference books needs to be added by snow pack depth measurements along ground observation transects.

The relationship between precipitation and topography is known to vary among landscapes (Onuchin and Burenina 2002). Therefore, precipitation distribution modeling requires to delineate landscape taxons differing in precipitation / geophysical parameter link.

Our project focused on developing models of precipitation dependence on landscape geophysical parameters and using these models to build a multi-year average precipitation map for the southern near-Yenisei part of Siberia.

This area was selected as the test site because it stretches for a long distance latitudinally, is highly complicated geomorphologically, and, hence, encompasses a great variety of local climatic conditions.

The precipitation map building included DEM processing and analysis and development of regression models describing precipitation dependence on the parameters of interest. The map development algorithm we used consisted of several steps:

Develop a raster layer of elevations above sea level (a.s.l.)

A raster layer of elevations a.s.l. was built for the area of interest using the existing Shuttle Radar Topographic Mission DEM (SRTM-3-DEM). This layer can also be obtained using elevation isoclines interpolation. Elevation data are provided in topographic maps.

Determine the types of the landscapes most common in the test site

Using the experience gained in this type of studies reported in (Onuchin and Burenina 2002), we identified three landscape types in the test site. The ‘plain’ landscape type was assigned to Yenisei Plain. The ‘upwind’ landscape type was represented by the Yenisei Mountain Ridge west-facing slope located at a right angle to the prevailing wind. The ridge east-facing slope, which occurs in wind shade due to the prevailing west-eastward atmospheric moisture transfer and, as a result, in precipitation shade, fell within the ‘shaded’ landscape type.

Delineate different landscape types

The landscape types were delineated based on ‘barrier-caused shading effects’. Their geographical boundaries, deemed to be constituted by orographic barriers or mountain massif foothills, were identified using standard GIS methodologies that allowed to determine flow direction, stream catchment boundaries, the major watershed locations. These watersheds function as orographic barriers.

The SRTM-3-DEM enabled separation of the ‘shaded’ from the ‘upwind’ landscape type along the boundary between the two major watersheds occurring along the Yenisei Mountain Ridge axis. The boundary between the ‘plain’ and ‘upwind’ landscape types was located along the ridge foothills, where elevation a.s.l. exhibits a sudden increase.

Build snow distribution regression models for each landscape type

The distribution of annual snow amount values was derived from multiyear weather station data and ground transect-based snow measurements considering topographic sample and weather-station site characteristics, such as elevation a.s.l., latitude, longitude, and distance from an orographic barrier and it foothills meeting water-carrying air masses. Three snow distribution regression models were obtained, one for each landscape type.

Build a snow distribution raster layer for each landscape type

Snow distribution raster layers, one for each landscape type, were generated using spatial analysis of SRTM-3 DEM and the regression models obtained.

Develop a map of snow distribution

At the final step, these raster layers were combined. The overlap area is replaced by a linear interpolation of the pixels in the overlap. A pixel in the middle of the overlap area is 50% of each of the corresponding pixels in the overlapping images. A pixel 1/10 of the overlap from an edge would be 90% one images and 10% the other.

Develop a map of average annual precipitation distribution for the test site

To build the average multiyear for the test site, snow contribution to annual precipitation was estimated. The test site weather station data were based upon to develop a multiple regression equation describing annual precipitation amount dependence on snow contribution and weather station location.

This dependence was used to develop the map of average annual precipitation distribution across the test site.

Precipitation, a major source of moisture, directly controls forest ecosystem diversity and dynamics. The findings of this study regarding precipitation distribution across the southern near-Yenisei part of Siberia were based upon to develop a map of forest site conditions for the test site.

References

Onuchin AA, Burenina TA (2002) Modeling spatial and temporal precipitation patterns. In 'The Yenisei Meridian Forest Ecosystems' (Eds FI Pleshikov, EA Vaganov, EF Vedrova) pp. 50-54. (The Russian Academy Publishing: Novosibirsk).

Shuttle Radar Topography Mission Digital Elevation Model (SRTM-3-DEM) http://www2.jpl.nasa.gov/srtm/