Integrated Precipitation and Hydrology Experiment (IPHEx) in the Southeast – Observations and Models to Improve Hydrological Forecasting in Regions of Complex Terrain

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PMM Meeting
March 2013

1. Project Overview

In anticipation of NASA's Global Precipitation Measurement (GPM) ground-validation activities in the SE United States and in synergy with NOAA's Hydrometeorology Testbed-Southeast Pilot Study (HMT-SEPS) in western North Carolina, under the auspices of the Integrated Precipitation and Hydrology Experiment (IPHEx, http://iphex.pratt.duke.edu/) , a high-resolution dataset is being developed to provide the hydrologic modeling community with common control forcing and landscape attributes to facilitate multi-scale, multi-purpose hydrologic applications ranging from flash-flood forecasting to basin-scale water resource assessments in the Southeast (IPHEx-H4SE). In the first phase of the project, the goal is to generate quality hydrometeorological forcing data sets at high spatial and temporal resolution (1km×1km, hourly time step) for the five-year time period 2007-2011 with a focus on the river basins with headwaters in the Southern Appalachians: Upper Tennessee River Basin (56,573 km^2), Savannah River Basin (27,110 km^2), Santee River Basin (39,862 km^2) and Yadkin-Pee Dee River Basin (46,310 km^2). Space-time varying land surface properties such as broadband albedo, broadband emissivity, fractional vegetation coverage and leaf area index are derived from MODIS products. The original products are re-projected and composited to the study area, bi-linearly interpolated to basin grids, and then linearly interpolated into hourly time steps. Quality-control and temporal filtering for these landscape attributes data are performed to reduce the discontinuity caused by cloud contamination. Precipitation is generated from NCEP/EMC 4KM Gridded Data (GRIB) Stage IV hourly data using bi-linear interpolation and orographic corrections. Integration of Stage IV data with precipitation observations from research networks in the region provides dynamic relationships for improving precipitation accuracy in mountainous terrain. The atmospheric forcing data are extracted from the North American Regional Reanalysis (NARR) products originally at 32-km spatial resolution and 3-hour temporal resolution. Elevation adjustments and corrections to near-surface variables are applied between NARR envelope terrain and local terrain at every time-step based on predicted atmospheric conditions (e.g. using dynamic lapse rates). Special bias corrections for downward shortwave radiation are applied through dynamical adjustment, accounting for localized elevation and topographic effects. The temporal interpolation for shortwave radiation is integrated in the topographic correction to capture the local diurnal solar cycle based on solar zenith angle. Preliminary *hydrologic modeling results over the Upper* Tennessee River Basin are provided.

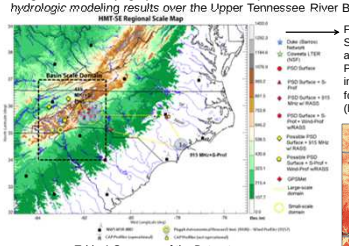


Figure 1 – – The regional map of NOAA HMT-SE Pilot Study (HMT-SEPS), which is planned for May 2013 – Sep. 2014 in western NC, aiming to address opportunities for improving Quantitative Precipitation Estimation(QPE) by coordinating a number of instruments and conducting field campaigns, to improve weather forecasts and understand the regional water cycle. (http://hmt.noaa.gov/field_programs/hmt-se/)

Table 1 Summary of the Datasets

Data Category (Source)	Fields	Unit
Soil Parameters (STATSGO)	Saturated hydraulic conductivity	m/s
	Porosity	m^3/m^3
	Field capacity	m^3/m^3
	Wilting point	m^3/m^3
Landscape Attributes (MODIS)	Albedo	-
	Emissivity	-
	Fractional vegetation coverage	-
	Leaf area index	-
Atmospheric Forcing Data(NARR)	Air temperature	K
	Atmospheric pressure	mb
	Wind velocity	m/s
	Specific humidity	kg/kg
	Incoming longwave radiation	W/m^2
	Incoming shortwave radiation	W/m^2
Precipitation(Stage IV)	Precipitation	mm/Δt

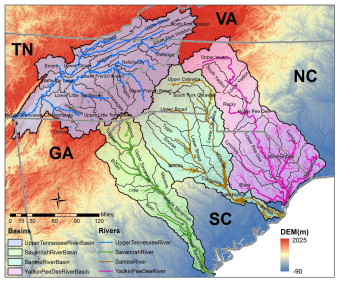
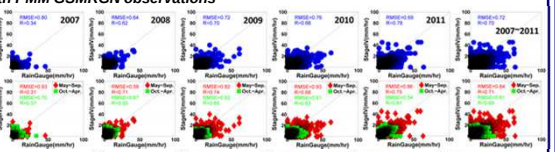


Figure 2 - The four drainage basins of interest in this project, namely Upper Tennessee River Basin(UTRB), Savannah River Basin(SVRB), Santee River Basin(SRB) and Yadkin-Pee Dee River Basin(YPDRB). The dark polygons indicate hydrological units.

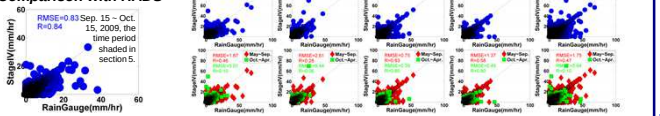
2. Precipitation – Stage IV

A. Comparison with PMM GSMRGN observations

Stage IV data used here is without landform corrections. These will be applied in the next phase of the project. Note that, in Section 2.B, the Stage IV algorithm relies on HADS as one of the data sources, but scatter plots show strong terrain complexity effects.

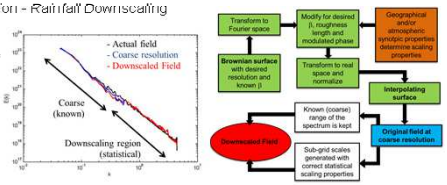


B. Comparison with HADS



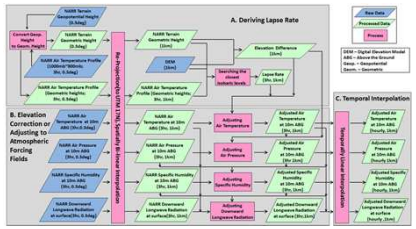
C. Ongoing Data Set Generation - Rainfall Downscaling

Rainfall with a given spectrum (black) at a coarse resolution (4km), obtains only a portion of the spectrum (blue). The fractal interpolation scheme can be used to downscale the precipitation from coarse resolution to fine resolution(1km), where the known part of the spectrum is kept, and the sub-grid scales have the correct scaling properties.



3. Atmospheric Forcing Datasets - NARR

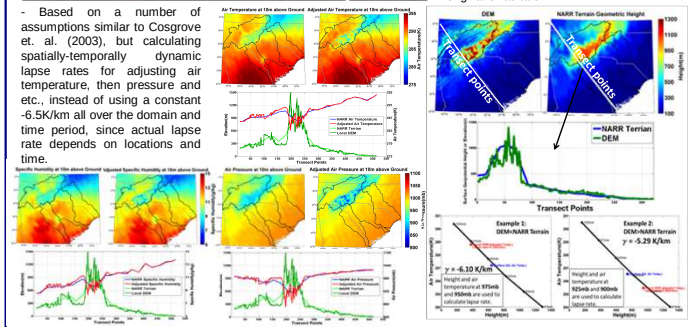
A. Elevation Correction



---Flowchart for elevation correction to NARR to air temperature, air pressure, specific humidity and downward longwave radiation .

The lapse rate was calculated from the NARR air temperature profile at low levels (1000mb to 800mb) at each pixel for each time step. Instead of using NARR terrain as the reference level, the two closest isobaric levels to NARR terrain and local DEM were utilized to calculate lapse rate, which then is used to adjust air temperature from NARR terrain to local DEM, and then to adjust air pressure, specific humidity and longwave radiation.

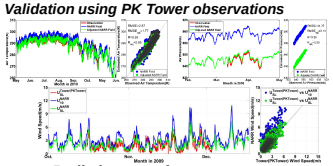
- Based on a number of assumptions similar to Cosgrove et. al. (2003), but calculating spatially-temporally dynamic lapse rates for adjusting air temperature, then pressure and etc., instead of using a constant -6.5K/km all over the domain and time period, since actual lapse rate depends on locations and time.



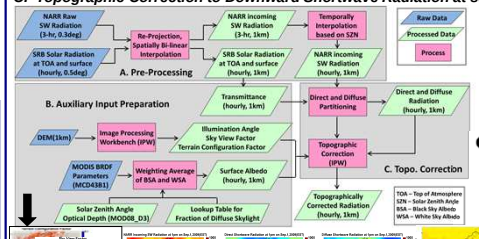
B. Wind Speed Adjustment

- First, friction velocity is retrieved from NARR wind speed at 10m and 30m above ground, then adjusted to fine resolution (1km) accounting for surface heterogeneity based on Lettau's relationship between geostrophic drag coefficient and Rossby number, and then the wind speed is recalculated using the logarithmic formula with land cover dependent roughness length and displacement height.

D. Validation using PK Tower observations

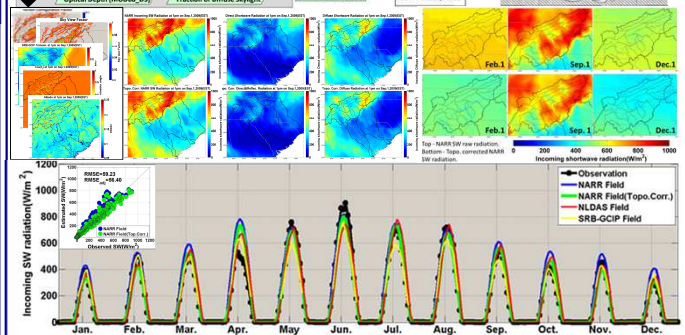


C. Topographic Correction to Downward Shortwave Radiation at Surface

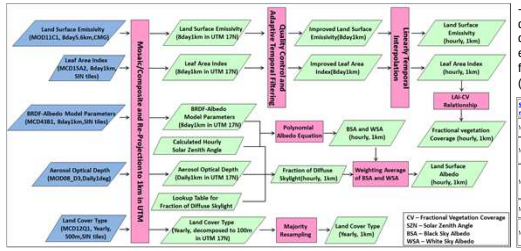


---Flowchart for topographic correction to NARR downward shortwave radiation at surface. The total incoming solar radiation in mountainous region includes three components, ① direct irradiance from the Sun, ② diffuse irradiance from the sky, and ③ the irradiance reflected from the nearby terrain.

(Dubayah, 1995)

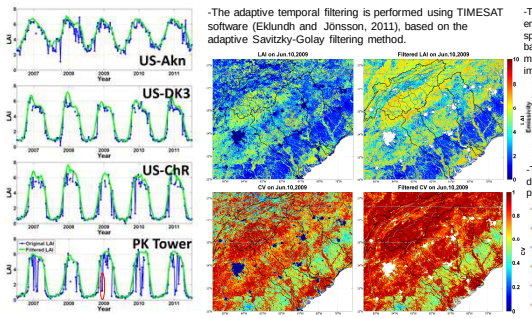


4. Landscape Attributes Datasets - MODIS

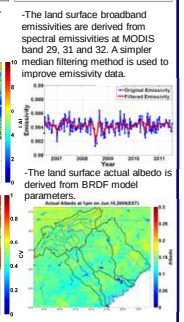


---Flowchart for generating quality landscape attributes datasets, including albedo, emissivity, LAI and CV, from MODIS products (shown below).

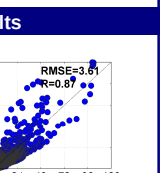
Short name	Platform	MODIS Product	Raster type	Res	Temporal Granularity
MCD15A2	Combined	Leaf Area Index - FPAR	Tile	1000m	8 day
MOD11C2	Terra	Land Surface Temperature & Emissivity	CMG	5600m	8 day
MCD43B1	Combined	BRDF-Albedo Model Parameters	Tile	1000m	8day (16 days acquisition interval)
MCD12Q1	Combined	Land Cover Type	Tile	500m	Yearly
MOD08_D3	Terra	Atmosphere Daily Global Product	Gridded	1degree	Daily



-The adaptive temporal filtering is performed using TIMESAT software (Eklundh and Jönsson, 2011), based on the adaptive Savitzky-Golay filtering method.



-The land surface broadband emissivities are derived from spectral emissivities at MODIS band 29, 31 and 32. A simpler median filtering method is used to improve emissivity data.



-The land surface actual albedo is derived from BRDF model parameters.

5. Upper Tennessee River Basin – First Evaluation Results

Hydrological Application using Uncalibrated Hydrologic Model (LSHM)

6. Reference and Acknowledgement

[1] Eklundh, L. and Jönsson, P., 2011, Timesat 3.1 Software Manual, Lund University, Sweden.

[2] Dubayah, R., Paul, M., 1995. Topographic solar radiation models for GIS. International Journal of Geographical Information Systems, 9(4): 405-419.

[3] Cosgrove, B.A. et al., 2003. Real-time and retrospective forcing in the North American Land Data Assimilation System (NLDAS) project. Journal of Geophysical Research-Atmospheres, 108(D22).

– **Acknowledgments:** This research was supported by the NASA PMM program