Corey Van Dyk
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Model Calibration and Forecast Error for NFIE-Hydro

Introduction

The forecasting component of the National Flood Interoperability Experiment (NFIE), like any predictive model, must be validated against actual data in order to show its legitimacy as a forecasting tool. Specifically, the probabilistic flood levels that are predicted using the long-term weather models, land-atmosphere models, and channel routing need to be compared to recorded flood levels. To give a better idea of what this error means, flood levels as predicted by the National Weather Service (NWS) and the European Centre for Medium-Range Weather Forecasting (ECMWF) (via Tethys, which combines the forecast with the RAPID river routing model) should be analyzed for comparison between models. The final goal is a set of error maps across the continental United States (and at finer scales) depicting how NFIE performs against reality and other models, as measured by forecasting error.

Originally, the project would focus on sensitivity analysis for the validation of the NFIE. A set of HUC-12 basins would be gathered with several basin characteristics to be studied: size of stream (base flow discharge), land use, drainage density, and climate (annual precipitation, evaporation). By comparing the predictive capabilities of pairs or sets of basins, some insight could be gained regarding which basin parameters cause the greatest departures from accurate flood levels. This information could also reveal which steps in the forecasting model need improvement. Recent meteorological history is also an essential parameter, especially as it evaluates the effect of soil moisture within the model. However, this parameter should be compared for individual basins rather than between basins. While the sensitivity analysis was deemed outside the scope of this project, it is a necessary step for evaluating NFIE, once it’s up and running.

Models

The NFIE-Hydro model combines the NWS forecast points with a land-atmosphere model and river routing model to give ensemble forecasts of flood discharge (Figure 1). (The flood

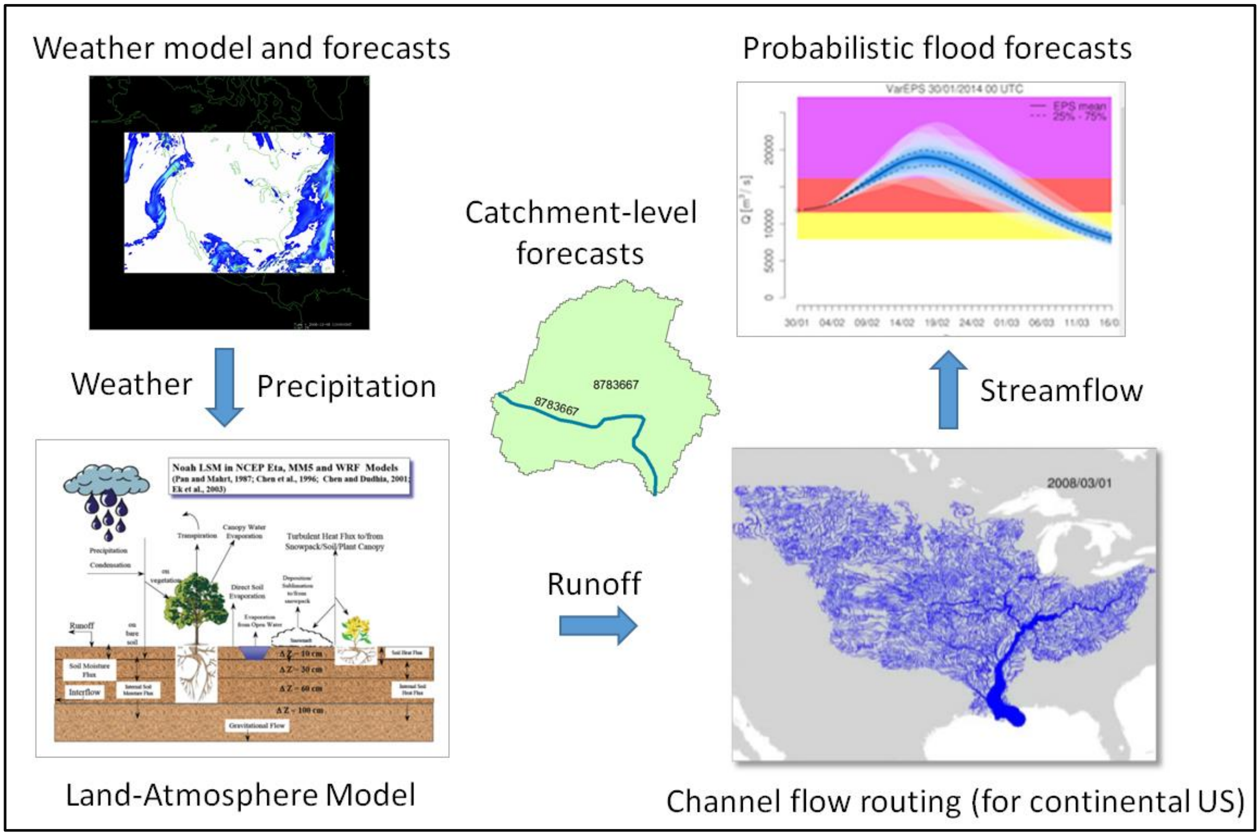

Figure 1: NFIE-Hydro workflow [from "NFIE in a Nutshell"].

discharge is then converted to flood level in NFIE-River using river cross-sections.) These flood levels are predicted on all 2.67 million reaches in the continental United States, increasing the density of flood forecasting by a factor of about 700. Currently, the NFIE model initializes its predictions at zero flow, which makes accurate comparisons difficult at this time.

The NWS model makes predictions on less than half of the forecast points it includes (the double boxes in Figure 2), which limits the comparisons that can be made. The West Gulf River Forecast Center (WGRFC) was the primary source of data.

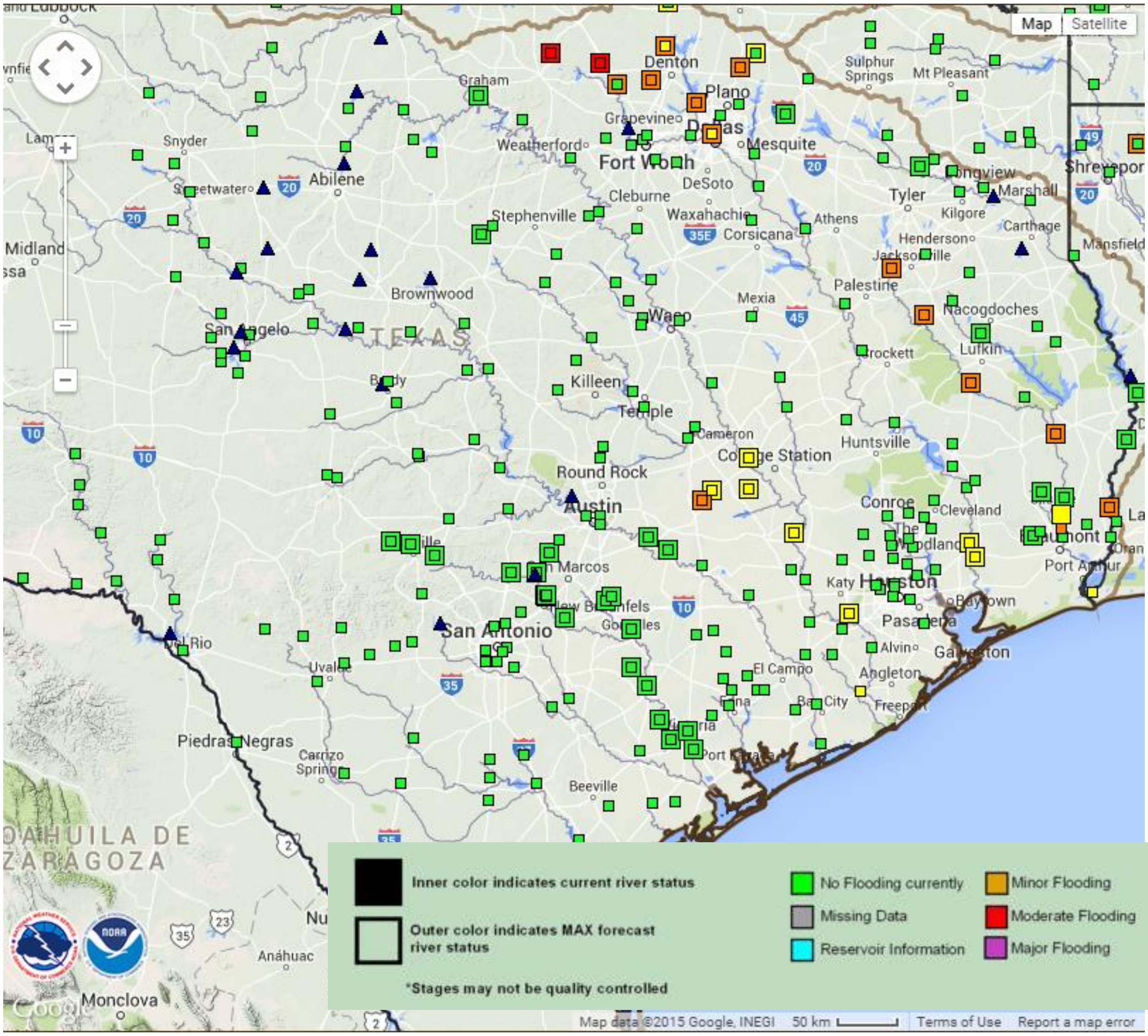

Figure 2: Sample of forecast locations from WGRFC. Only the points with double boxes include predictions [http://www.srh.noaa.gov/wgrfc/].

Finally, ECMWF (via Tethys), like NFIE-Hydro, initializes its prediction with zero flow. Although ensemble forecasts are created (Figure 3), this initialization seems to inhibit the predictive power.

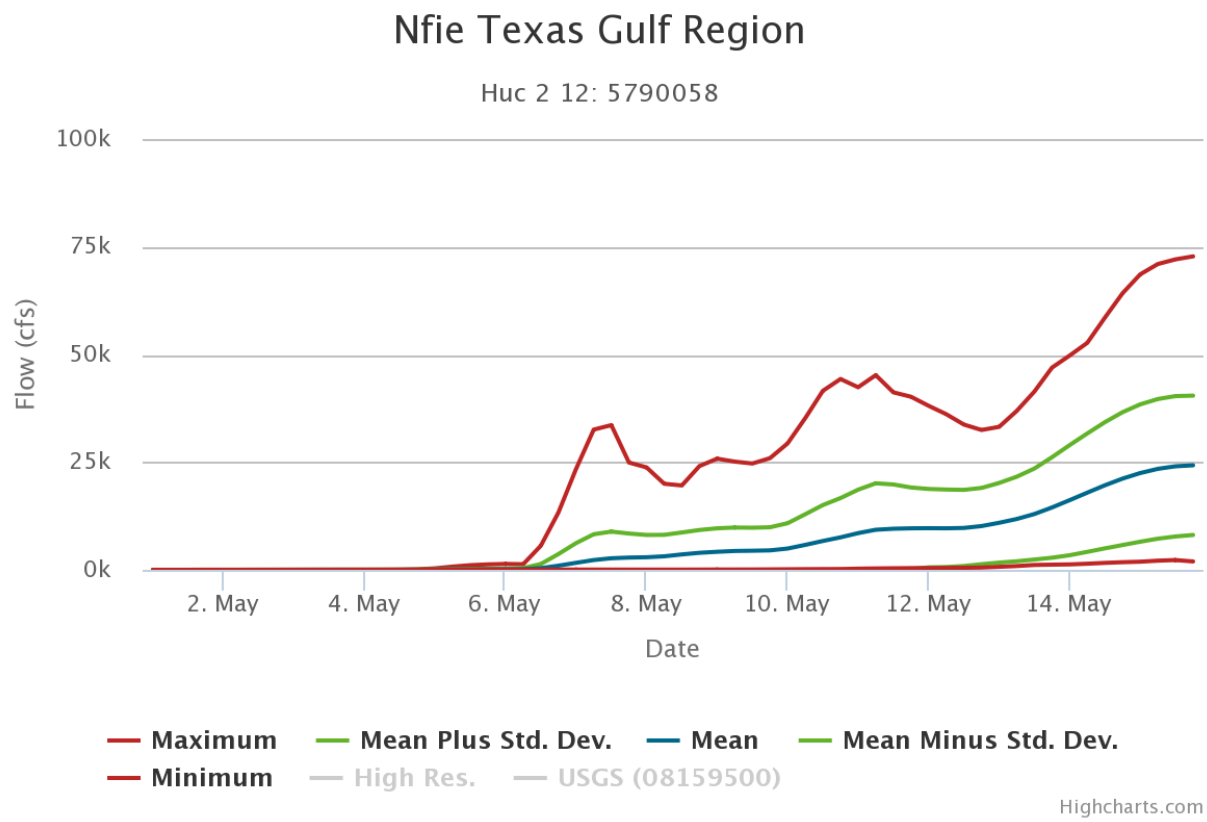

Figure 3: Sample of ensemble forecast summary as computed by ECMWF.

Model Coverage

While the error inherent in these models is of utmost importance, their efficacy also depends on their coverage. An errorless model that only functions in a single location is useless to the majority of the country; conversely, a model with nationwide coverage that always approximates reality poorly has next to no use for everyone. A balance between availability and accuracy must exist.

Both NFIE and ECMWF have the capability of predicting flow patterns on every NHDPlus reach, though validation with recorded data is only possible at USGS gauge stations. The NWS model uses forecast points for its predictions. USGS gauge stations and NWS forecast points that are in USGS Texas-Gulf Hydrologic Region (12) are shown in Figure 4.

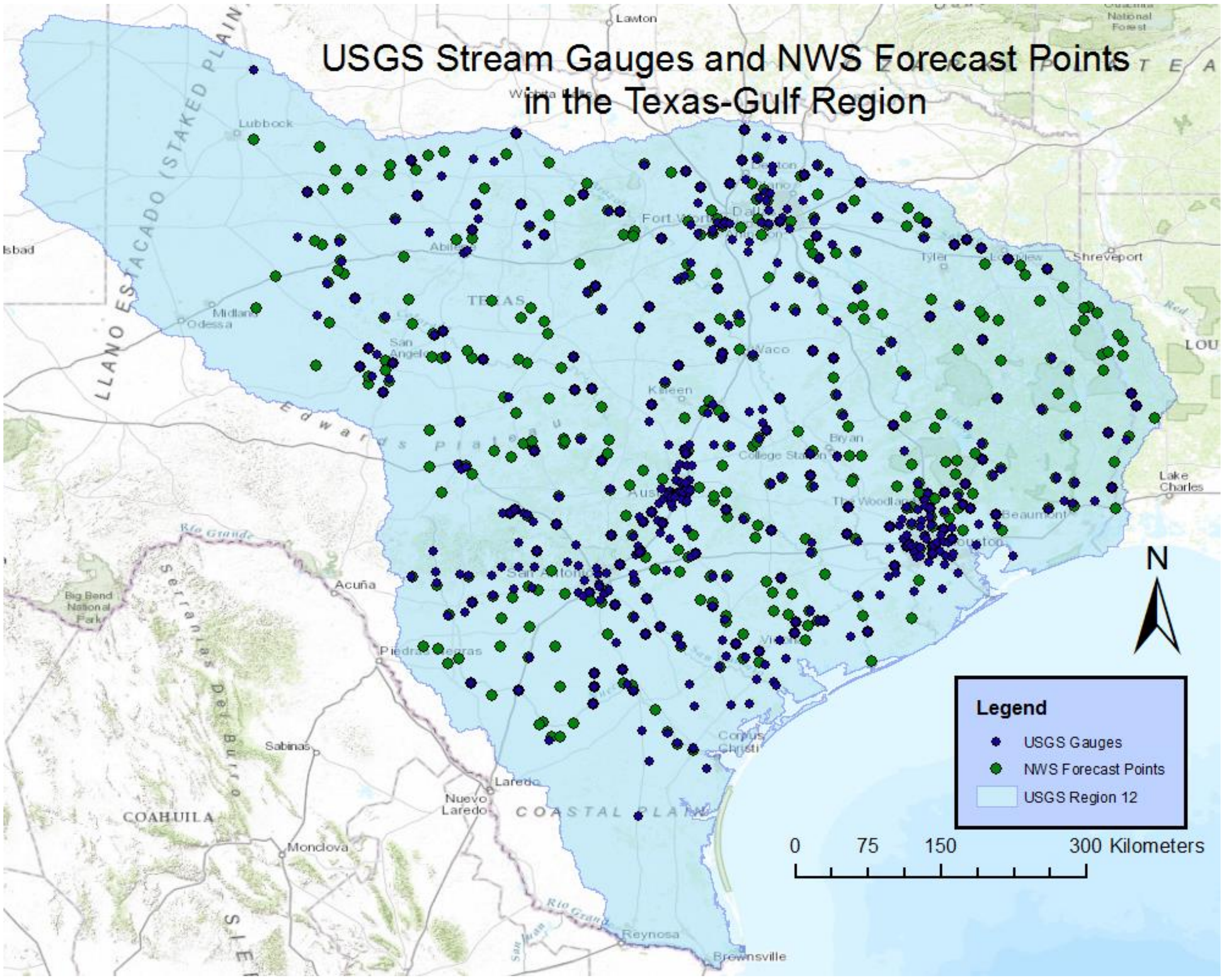

Figure 4: Stream gauges and forecast points in Region 12.

There are 413 USGS gauging stations in the region, and 447 NWS forecast points. However, this is insufficient in determining the coverage of these two features. To better understand how these data are distributed, each set of points was joined with the counties in Texas to create a histogram (Figures 5 and 6). There are more counties in Texas without a USGS gauge than there are without NWS forecast points. However, USGS has better coverage in large cities, given by the much higher extremes in Figure 5 than Figure 6. This can also be seen in Figure 4, where the locations of Houston, Dallas-Fort Worth, San Antonio, and Austin can clearly be determined by the blue circles. The concept that NWS points are more evenly spread out is supported by the histogram, which shows a much more gradual drop off than the USGS Gauge histogram.

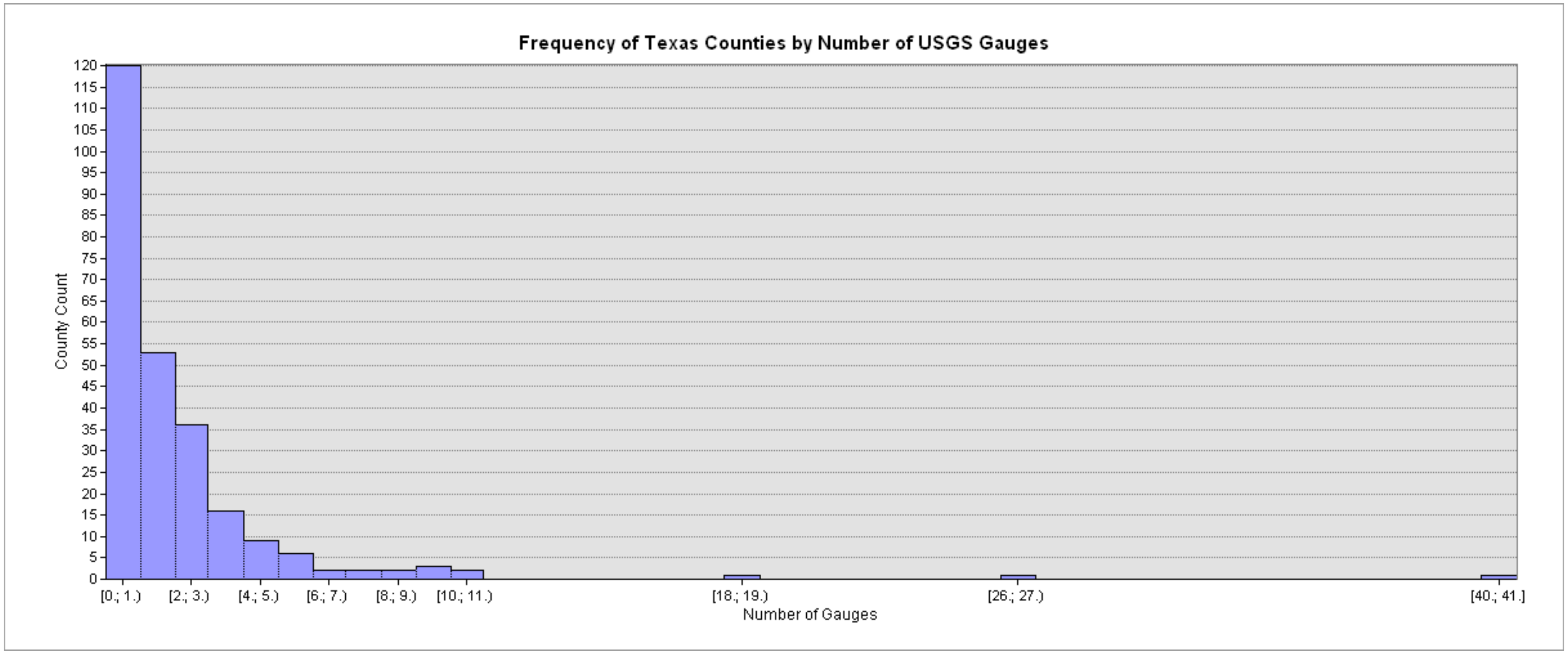

Figure 5: Histogram of Texas counties by number of gauges.

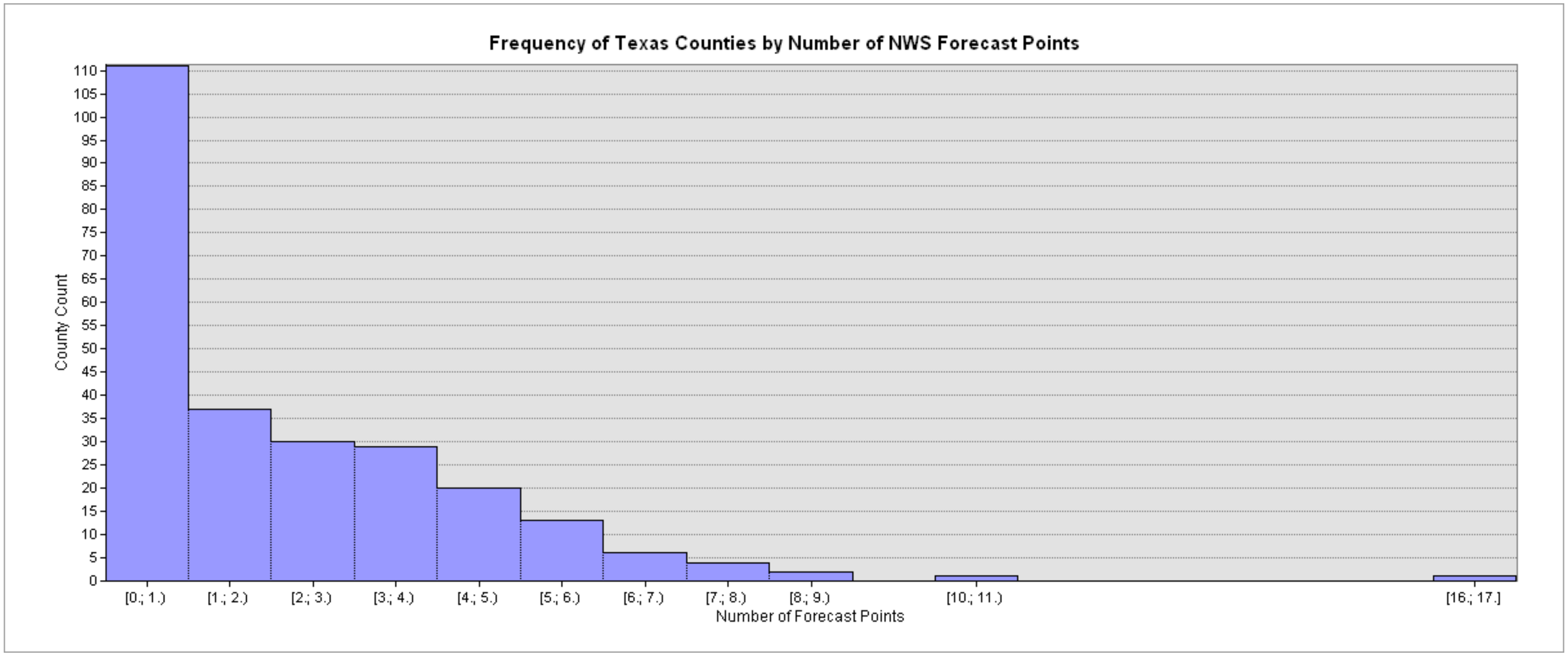

Figure 6: Histogram of Texas counties by number of forecast points.

Finally, 25-km buffers were used on both sets of points to determine which covered more area, and thus more fully described the region. Figure 7 shows the buffers overlaid on Region 12.

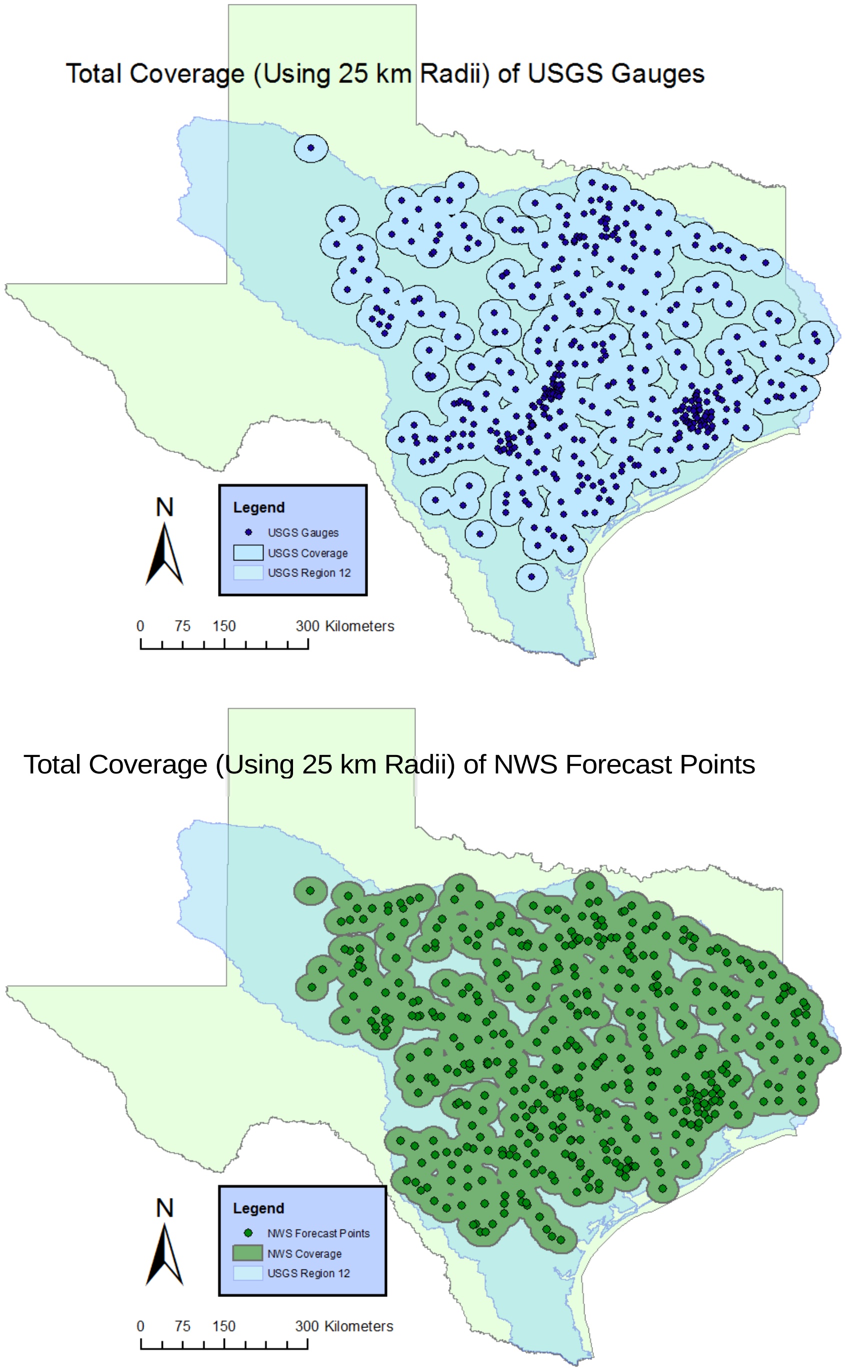

Figure 7: Total coverage of land for each set of points, based on each point forecasting for everywhere within 25 km.

Confirming the idea that the USGS points are more concentrated, only 292,928 square kilometers are covered by the gauges, while the NWS forecast points cover 335,820 square kilometers.

The coordinates of many of the USGS Gauges are slightly off than their actual location. In order to determine how many of NWS forecast points are associated with these gauges, the portion of data within two kilometers of gauges was selected, yielding 206 USGS-NWS matching pairs. Some pairs of points were investigated manually and were found to refer to the same location, even if they were greater than two kilometers away. However, there were other pairs that did not match, yet they were within three or four kilometers. The conservative approach, while excising some data, was determined preferable as it avoided adding un-matching pairs. Some examples are shown in Figure 7, 8 and 9. Figure 7 shows two pairs in which the gauge and forecast point refer to the same site (NWS data requires an online search to confirm site name, so labels are not available), both properly within two kilometers of each other. Figure 8 shows two pairs that refer to the same site, but on the map are located about five kilometers away. Figure 9 demonstrates why increasing the two kilometer threshold is dangerous, as the two points, just over two kilometers away from each other, do not refer to the same site (the NWS forecast point refers to "Guadalupe Rv at Canyon Lake").

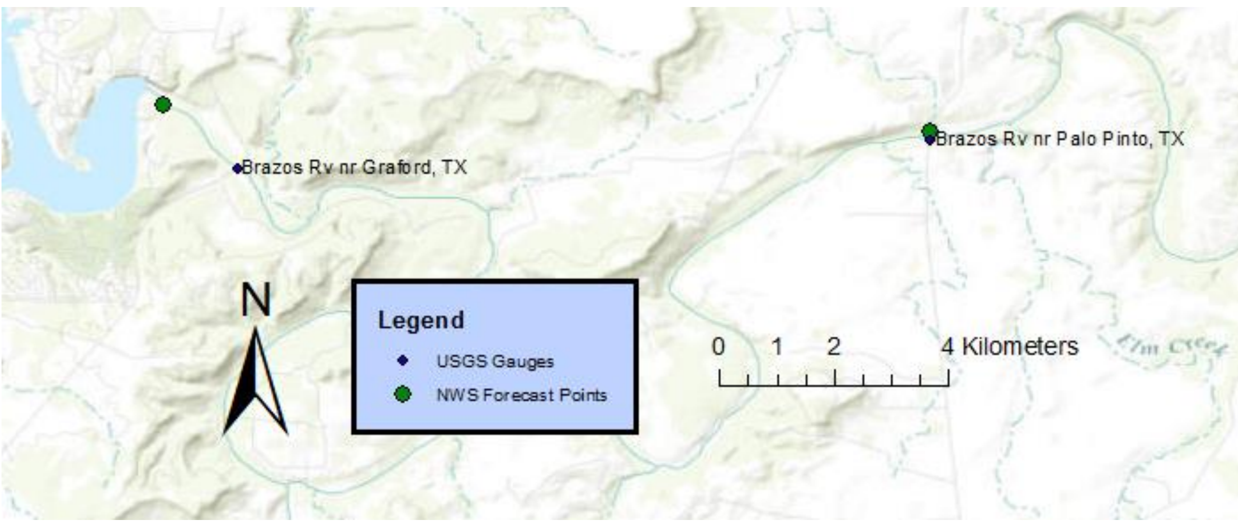

Figure 8: Two pairs of data points that match *and* are within two kilometers of each other.

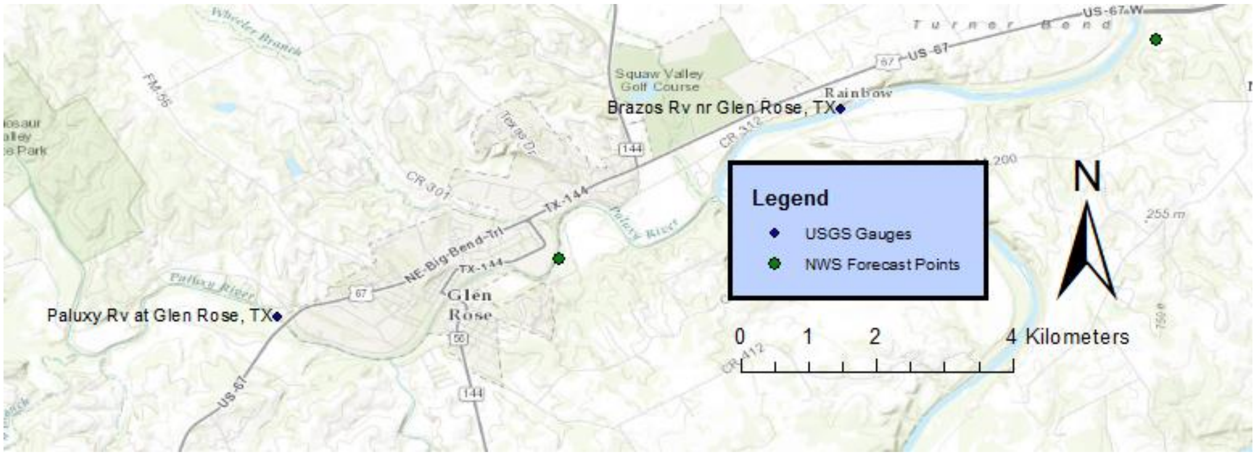

Figure 8: Two pairs of data points that match but are *not* within two kilometers of each other.

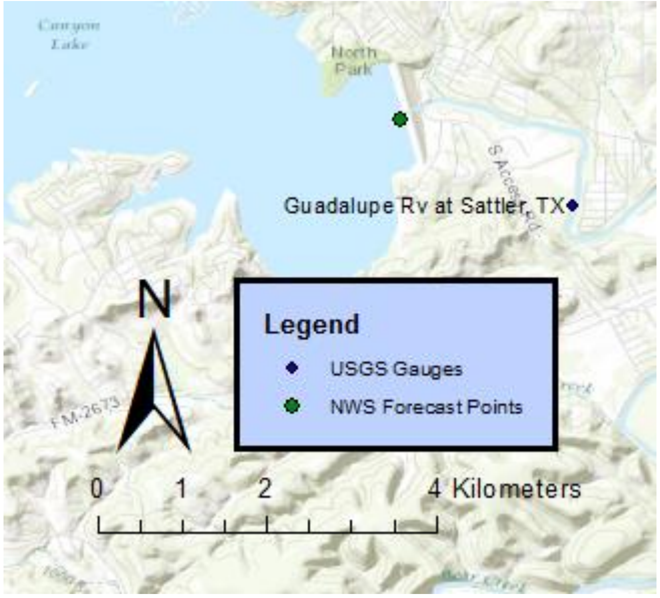

Figure 9: One pair of data points that do *not* match but *are* within two kilometers of each other.

Model Error

The predicted discharge for a creek about 80 kilometers east of Austin is determined by the NWS and ECMWF (Tethys) models. The predicted values with a recorded discharge from the USGS gauge are shown in Figure 10. While a comparison against the actual data was not performed, it appears that the NWS model gives a more realistic extrapolation of the recorded data. This is largely due to ECMWF's initial value of no flow and exacerbated by the fact that Tethys' interface doesn't currently allow a simulation to start more than a few days prior to the present time (this may be a bug, as this problem didn't exist a few weeks ago).

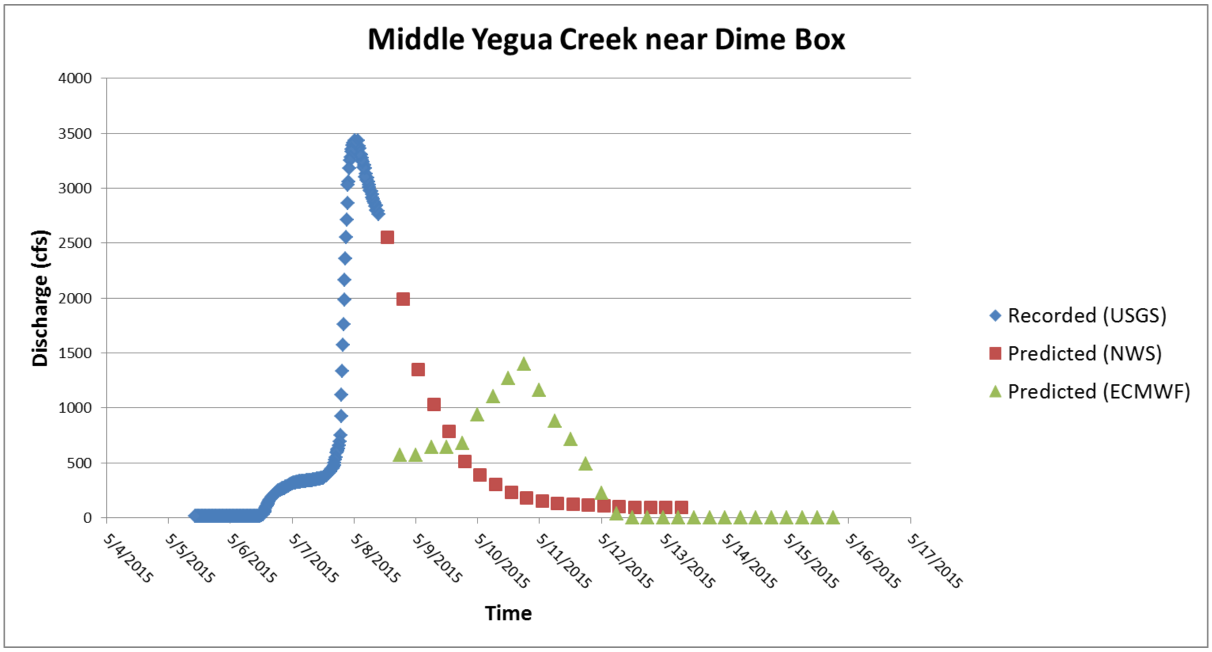

Figure 10: Recorded and predicted flow at a central Texas creek.

While work is being done to alter the current initialization, NFIE-Hydro also starts at no flow, so similar predictions to ECMWF would be expected.

Conclusions and Future Work

At this point, it is clear that the NWS model gives the best predictive performance of the three models. Of course, this will need to be reevaluated once NFIE-Hydro is completed and has a reasonable initial value. NWS also has more forecast points in the Texas-Gulf Region that USGS has gauges, and they are more spread out. However, since the most dangerous flooding usually occurs in urban environments, using the USGS gauges may be of greater value, since they are more abundant in Texas' major cities. For this reason, NFIE-Hydro could have an advantage (once completed).

Future work includes downloading and analyzing the NetCDF files for NFIE-Hydro, once they are initialized to a realistic starting point. After that, the association between the gages and the river reaches in the model must be determined, after which the flow can be extracted from each reach for comparison to the NWS and ECMWF models. Once this is done in enough locations, error maps can be created to show where the models perform well and how they vary. At this point, sensitivity analysis on NFIE-Hydro can be done by comparing error maps for the basin sets discussed earlier.