ENABLING HIGH-RESOLUTION HYDRO-METEOROLOGICAL MODELLING FOR OPERATIONAL SHORT-TERM FORECASTING IN RIO DE JANEIRO

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ABSTRACT

Operational, model-based forecasts at an urban scale for the Rio de Janeiro metropolitan area have been implemented to provide sufficient lead time for severe weather events. They have been coupled to an hydrological model that captures local terrain effects and simulates surface flow and water accumulation. This coupled model has enabled predictions of storm impacts on local infrastructure as well as quantification of the uncertainty associated with such forecasts.

1. INTRODUCTION

The operation of many cities is dependent to a significant degree upon weather conditions, especially with regard to relative extremes. With precipitation events, local topography and weather conditions influence water runoff and infiltration, which directly affect flooding. The city of Rio de Janeiro often faces the consequences of such events. In early April 2010, the city endured the worst rainstorms compared with the previous 48 years. As a result, there was significant loss of life and tens of thousands lost their homes.[1] There was little advance warning of the storms and their characteristics, and no opportunity for proactive response. The initial step to address this gap is the integration of advances in hydro-meteorological research.[2]

2. APPROACH

State-of-the-art NWP codes operating at the meso-γ-scale have been shown to have potential in predicting such severe events. Therefore, the Weather Research and Forecasting – Advanced Research Weather (WRF-ARW) model[3] was adapted for use in the Rio de Janeiro area. An operational configuration was developed by retrospective analysis of recent significant precipitation events. Four two-way nests focused on the Rio de Janeiro metropolitan area at 1km horizontal resolution are used to generate 48-hour forecasts. To address the orographic influence, 65 vertical levels were established (i.e., ~ 15 in the boundary layer). The WRF-ARW configuration has parameterization and selection of physics options appropriate for the range of geography in the region and the weather conditions of concern to the City Government of Rio de Janeiro.

A feasibility study was done to understand the flooding conditions and relevant data from the City Government including 1m resolution Digital Terrain Models derived from LiDAR data, and maps of soil type, land use and city structure. A mathematical model employing the shallow water equations using precipitation estimates generated by the WRF-ARW configuration as initial conditions is used to analyze if a site, which is historically prone to flood could receive a surface runoff flow, which could cause a flooding event at these locations.[4]

3. RESULTS

To illustrate the capabilities of the coupled model, the April 2010 event is discussed, specifically a model run initialized at 00 UTC on April 5 (2100 BRT). Figures 1 through 2 show results of the meteorological component, while Figures 3 and 4 depict results of the hydrological component.

In Figure 1, cloud properties are visualized as a three-dimensional isosurface of total cloud water density at a threshold of 10^{-3} kg of water from all microphysical species per kg of air. It is one frame from an animation. The isosurface is rendered in a three-dimensional coordinate system with true altitude, derived from the model's time-varying geopotential, registered with the model orography colored by other data generated by the model. It shows total precipitation as the heavy rain accumulated overnight from 5 to 6 April.

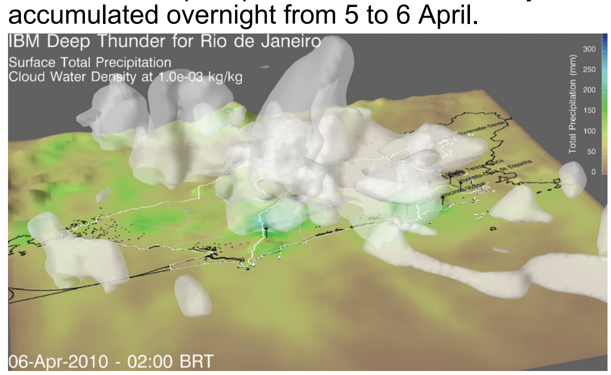

Figure 1. Cloud and Total Rainfall Hindcast during April 2010 Storm Event.

Figure 2 shows a site-specific hindcast for one of the locations of a rain gauge. Of particular note is the bottom left panel. It shows accumulated precipitation (red) and precipitation rate (blue). Given rain rates of this magnitude, the ability for this rain gauge to accurately record precipitation is unclear. However, the data did indicate an accumulated rain amount of 221.2mm as of 1749 BRT on 6 April. The hindcast had rain stopping at this location at 1800 BRT with a total of 207mm.

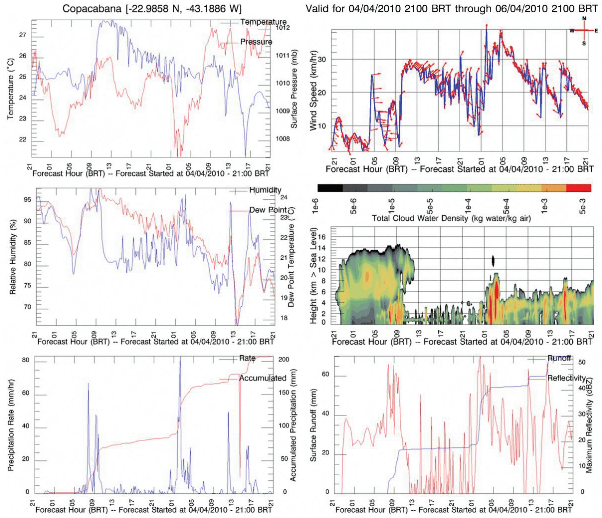

Figure 2. Site-Specific Hindcast for Rain Gauge at Copacabana for 48 Hours from 05 April 00 UTC.

Although details of the coupled flood model are discussed in a companion paper[4], Figures 3 and 4 illustrate results from the April 2010 hindcast. Figure 3 shows a relatively small portion of the city area affected by the floods during that event (highlighted in yellow), as an overlay in Google™ earth. Figure 4 depicts the hindcast results of the flood model in that area as a colored overlay.

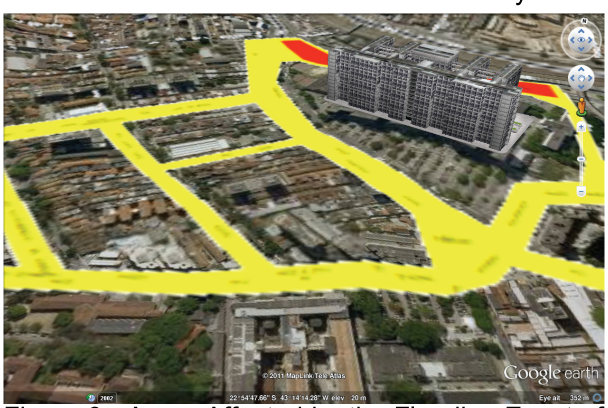

Figure 3. Areas Affected by the Flooding Event of 5-6 April 2010 in Rio de Janeiro (in yellow).

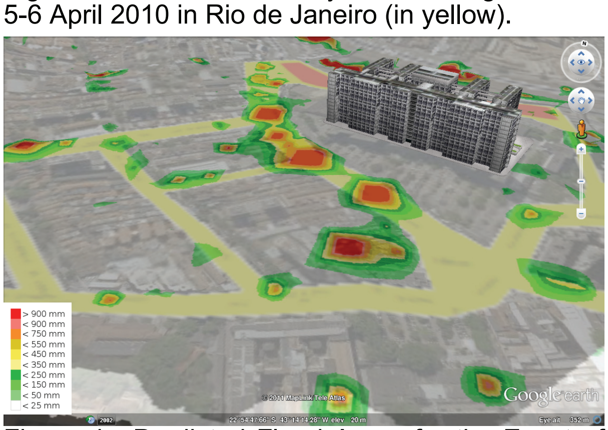

Figure 4. Predicted Flood Areas for the Event of 5-6 April 2010 (overlaid).

To comprehensively validate the precipitation forecasts, two different metrics were developed tailored to the City Government's needs using hourly rain gauge data. The first considered every 12-hour period within the 48-hour forecast cycle. The rainfall measurements and forecasts were categorized into four groups by magnitude. This approach was applied to all of the forecasts for rain events between 26 May 2011 and 06 January 2012. The accuracy for all categories was 93.6% for hours 00-12, 91.8% for hours 12-24, 93.1% for hours 24-36 and 92.8% for hours 36-48, with no tolerance at the category boundaries.

The second metric used accumulation through six-hour periods without categorization. Tolerances were introduced to determine if a point forecast is correct. If the measurement is less than 25mm within a six-hour period, a tolerance of +/-5mm is used. Otherwise, a tolerance of +/-20% of the accumulation is used. Reports are generated weekly showing forecast performance on a daily, weekly and monthly basis. Typical accuracy remains over 90% with results always over 80%.

4. CONCLUSIONS

A coupled model approach to enable highly accurate and precise, operational short-term forecasts of severe weather events has shown to be feasible for Rio de Janeiro. It has enabled the City Government to better anticipate and plan for the storm impacts on local infrastructure.

5. REFERENCES

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