

Numerical Hurricane Model Outputs for GIS-Based Infrastructure Damage Estimation

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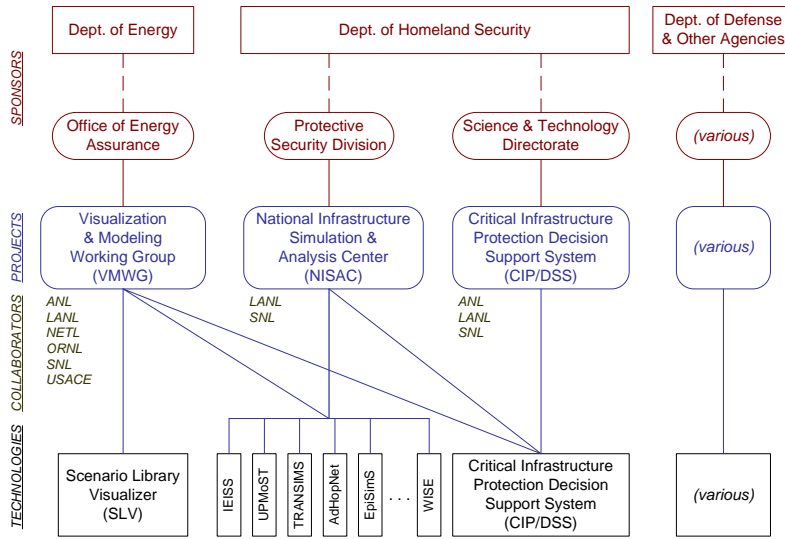
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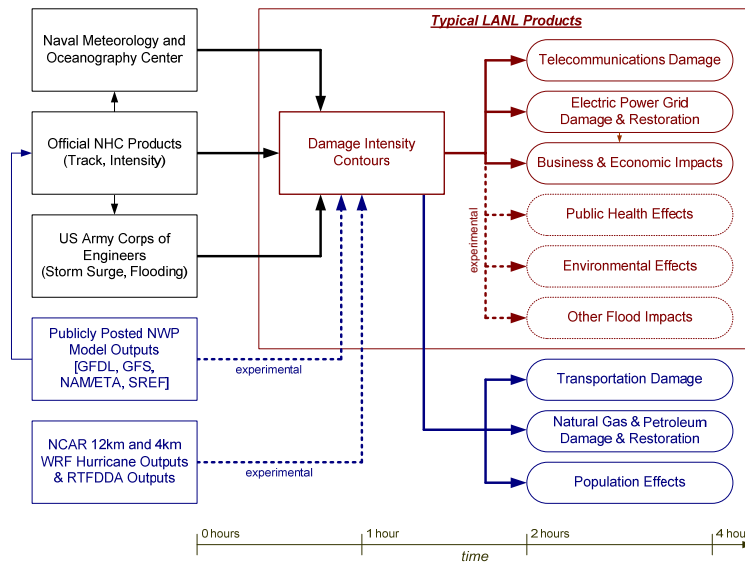
Abstract

- **The wind and precipitation fields forecast by numerical weather prediction (NWP) models, combined with the output of storm surge models, can provide estimates of damage to infrastructures such as the electric power grid several days before a hurricane makes landfall.**
- **Having the hourly forecasts of grid-based meteorological fields imported into a GIS enables an analyst to compute the cumulative effects over time of wind and rain and, subsequently, to overlay these with storm surge, elevation, and infrastructure data in order to categorize the forecast exposure of facilities to extreme weather.**
- **Calibrated heuristic models are then applied within the GIS to compute expected damage from the forecasted exposure.**
- **We provide examples for hurricanes from the 2005 season in the Atlantic Ocean and Gulf of Mexico using the output of several publicly available NWP model forecasts; similar methods apply to other types of extreme weather such as ice storms.**

LANL Critical Infrastructure Projects & Technologies



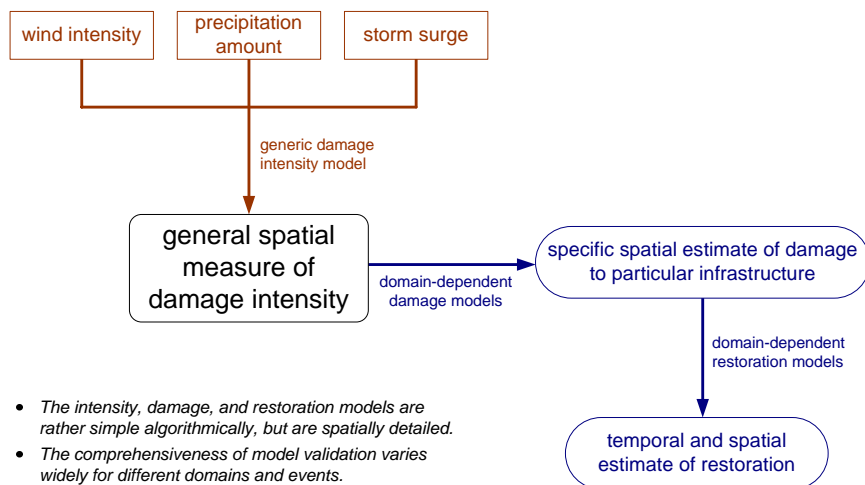
Quick-Response Process



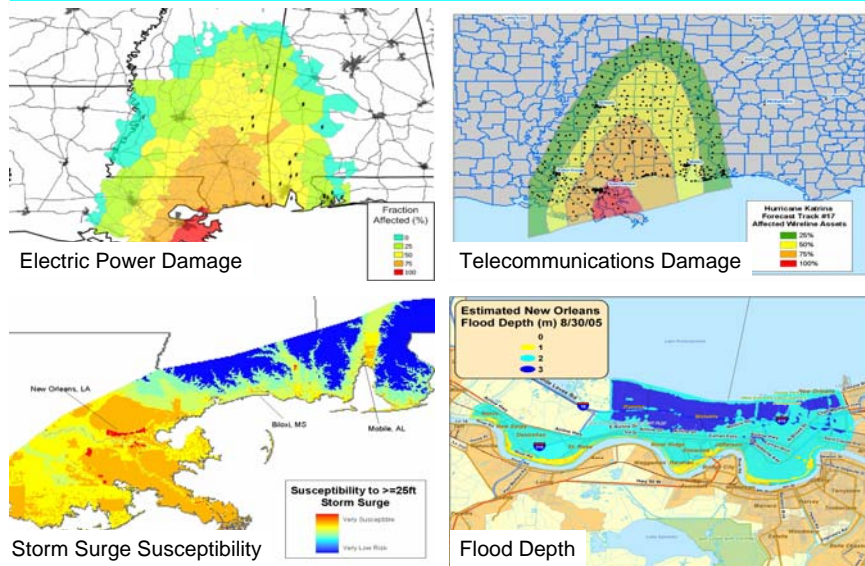
Typical Applications

- **Situational awareness**
- **Contingency planning**
- **Independent assessment & verification**
- **Event reconstruction**
- **Consequence assessment**
- **Recovery & restoration operations**
- **Security & reliability improvement**
- **Deployment of protective forces**

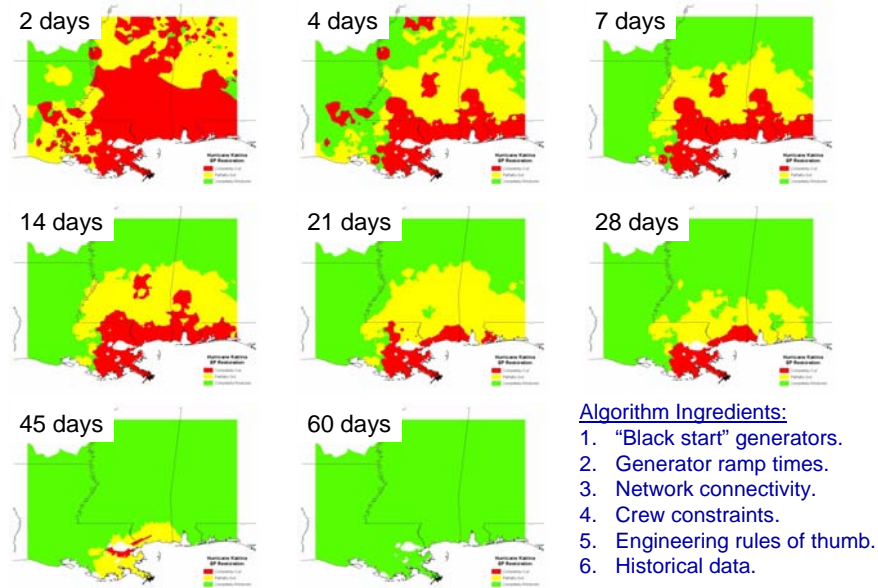
General Methodology



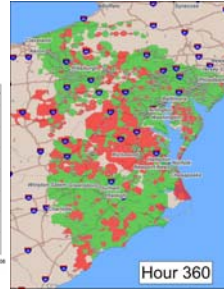
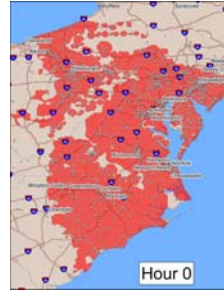
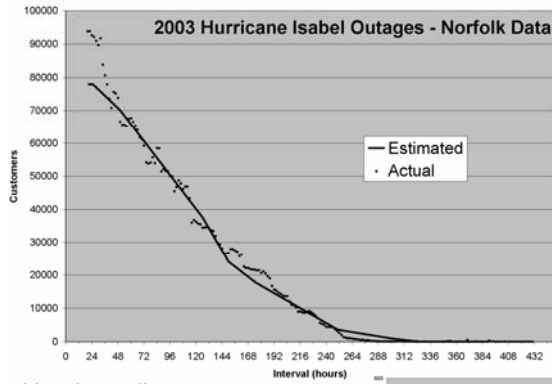
Typical Products for Katrina (2005)



Typical Electric Power Products for Katrina (2005)

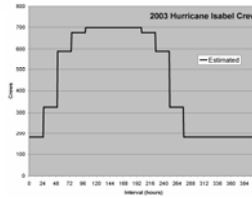


Example Validation for Electric Power Restoration



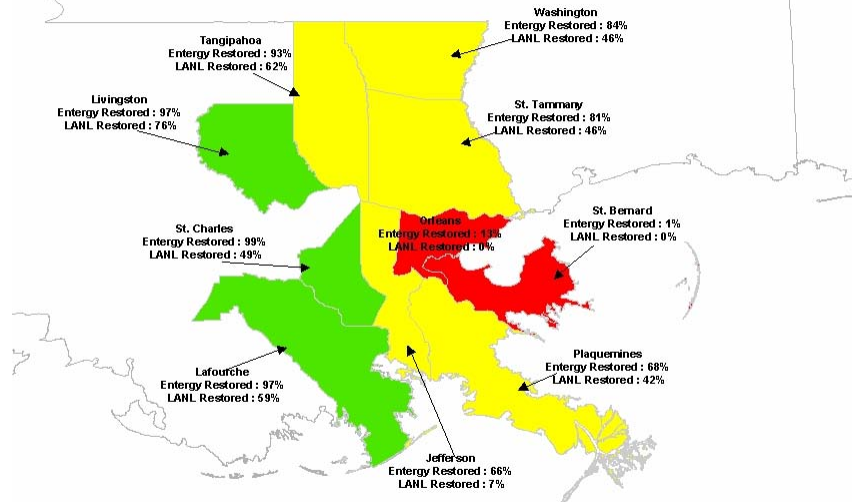
Algorithm Ingredients:

1. "Black start" generators.
2. Generator ramp times.
3. Network connectivity.
4. Crew constraints.
5. Engineering rules of thumb.
6. Historical data.



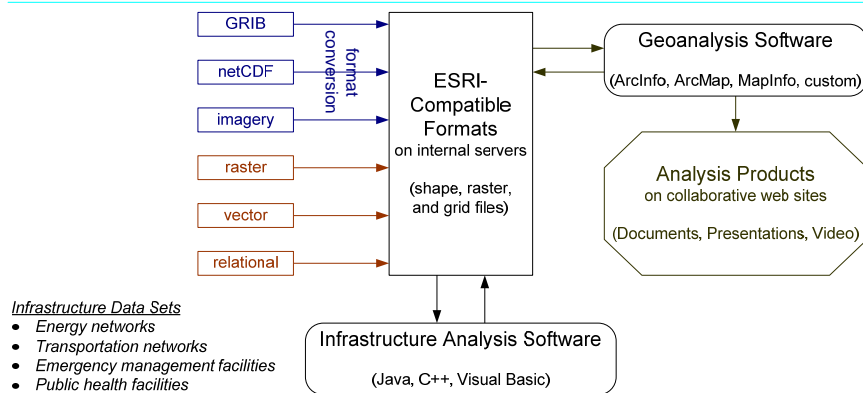
Electric Power Restoration Comparison to Actual Restoration

at 7 days prior to LANL-predicted restoration



Entergy Inc. supplied data

Geographic Information Engineering



Infrastructure Data Sets

- Energy networks
- Transportation networks
- Emergency management facilities
- Public health facilities
- Demographics (daytime/nighttime)
- Business locations and activity

Geographic Coverage

- Full CONUS coverage is regularly maintained.
- Limited specialized (e.g., OCONUS) coverage exists, but most is out-of-date unless it is from a recent analysis.

Terminology

- **Numerical Weather Prediction (NWP) Model:**
 - A numerical simulation forecasting future weather conditions.
 - Examples:
 - *WRF/ARW*: The Weather Research & Forecasting Model (WRF), with the Advanced Research WRF (ARW) core
 - *RT-FDDA(MM5)*: Real Time Four Dimensional Data Assimilation (RT-FDDA) using the PSU/NCAR mesoscale model (MM5)
 - *GFDL Hurricane*: The Geophysical Fluid Dynamics Laboratory (GFDL) Hurricane Dynamics Model
- **Forecast Initialization/Cycle Time:**
 - The time of the last data used to initialize the NWP model run. This constitutes “hour zero” of the forecast.
- **Forecast Valid Time:**
 - The time at which an NWP output is valid.

Data Processing Challenges

- **Heterogeneous raw data:**
 - Different data services: FTP, HTTP, MSS.
 - Different data formats: text, netCDF, GRIB2.
 - Different metadata: netCDF, GRIB2, file names, e-mail.
 - Different time samples: hourly, six-hourly, irregular.
 - Different field names and definitions.
 - Different domains, grids, and projections.
- **Large data sets:**
 - E.g., WRF hurricane run is ~30GB per 72-hour forecast.
 - WRF is run twice daily, RT-FDDA eight times daily, GFDL four times daily.
- **Goals:**
 - Achieve a uniform visual representation.
 - Maintain full precision of raw data.
 - Navigate and compare forecasts easily and quickly.
 - Synchronize presentation of time series.

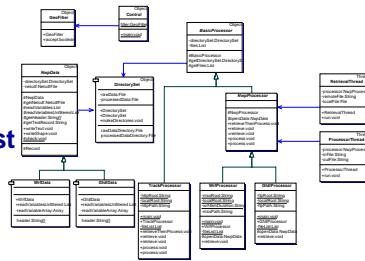
NWP Data Processing Details

1. **Java client downloads and processes raw data (tracks or output from WRF/ARW, RT-FDDA(MM5), GFDL, or HRD analysis).**
2. **Visual Basic scripts load data into ArcMap, apply legends, and export images.**
3. **Linux scripts combining images into movies.**

General data-processing philosophy: Do as much as the processing work in the Java client because of its portability, basis in standards, and its enabling of developer productivity and quality assurance.

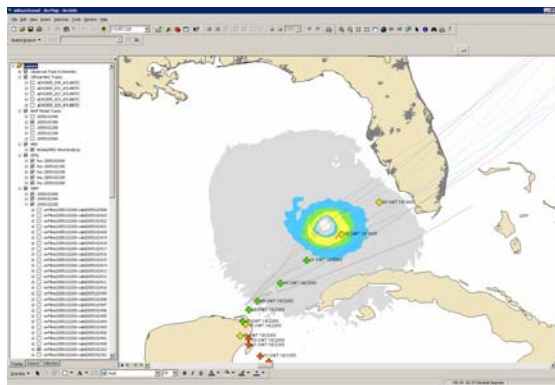
Functionality of Java Client

- **Command-line driven** so it can be run automatically as a “cron” job.
- **Data downloaded via FTP, HTTP, or MSS**, depending on the type of data.
- **Data sets are downloaded and processed in a parallel “pipeline”**, so the processing is complete shortly after last file in data set is downloaded.
- **Partial downloads can be restarted**, which is useful when there is an interruption in internet connectivity.
- **Raw data sets are archived in a clearly defined directory hierarchy.**
- **Separate shape files are generated for each forecast hour.**
- **Processed data is stored in separate directories for each model and forecast initialization time**, with standardized directory and file names.



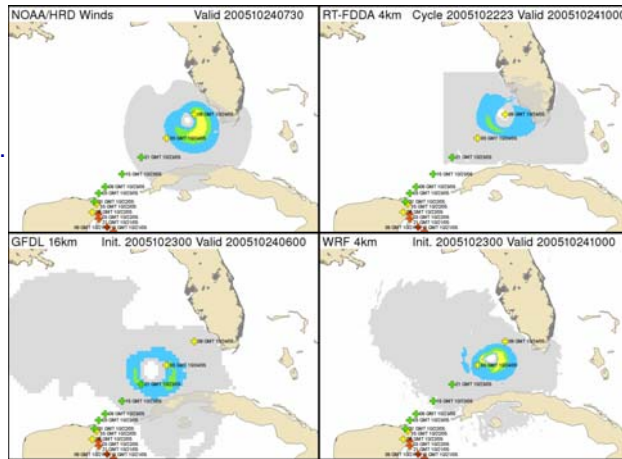
Functionality of Visual Basic Scripts

- **Loading data:**
 - Quickly load dozens of shape files into ArcMap.
 - Organize explorer bar.
 - Apply standard legends, transparency, etc.
- **Exporting images:**
 - Cycle through models, initializations, and forecasts to generate bitmap images for each.
 - Include user-defined background layers.
- **Estimating damage:**
 - Apply damage algorithms.
 - Apply restoration algorithms.
 - Export textual and graphical results.



Functionality of Linux Scripts

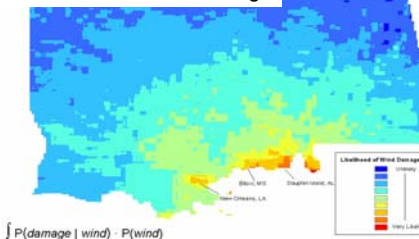
- **Generate movies from images:**
 - One per model and initialization time.
 - MPEG & AVI formats.
- **Compare forecasts:**
 - Arrange several forecasts in a panel.
 - One per initialization time.



Experimental Products for 2005 Season

- **NWP outputs were used as inputs for experimental damage estimation products for the 2005 Hurricane season.**
 - These products provide much higher spatial and temporal resolution, and consequently require more effort to validate than lower resolution products.
 - The existence of multiple NWP model forecasts has opened the possibility of using ensemble methods for statistical and probabilistic damage estimate forecasts.
- **Based on lessons learned in 2005, we are using GIS technologies to streamline and further automate our quick response damage-estimation capabilities.**

Likelihood of Wind Damage



Damage to Electric Power Infrastructure



Acknowledgements & Thanks

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