Aspen Global Change Institute

2-7 August 2015

Use Cases for High Resolution Models and Data Sets: Urban Planning and Coastal Management

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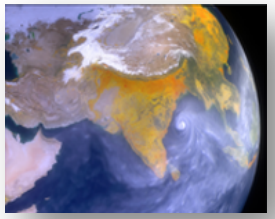
Urban Planning and Coastal Management

1. What are key climate phenomenon for assessing impacts and informing decisions?
2. How do higher resolution products enhance your work (or not)?
3. How to improve the credibility and usability of future high resolution datasets?
4. How best to combine high- and coarse-resolution simulations to explore multiple scenarios and better characterize uncertainties of extreme event dynamics?
5. What metrics can be developed to evaluate climate models and downscaling methods to convey their credibility?

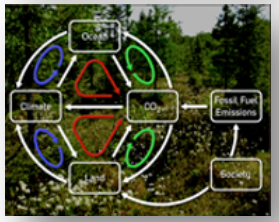
Climate Change Science Institute

Advancing the Knowledge of Climate Change and Understanding its Consequences

Director: Jack Fellows climatechangescience.ornl.gov



Earth System Modeling



Terrestrial Ecosystem and Carbon Cycle Science

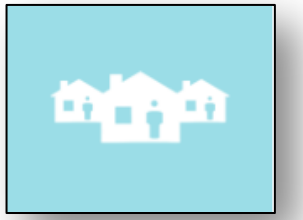
Data Integration, Dissemination and Informatics

Impacts, Adaptation, and Vulnerability Science

Urban Dynamics Institute

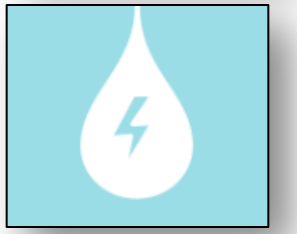
Understanding and optimizing the impact of future technologies, policies, and populations

Director: Budhu Bhaduri udi.ornl.gov



Population + Land Use

Sustainable Mobility



Water + Energy

Urban Resiliency

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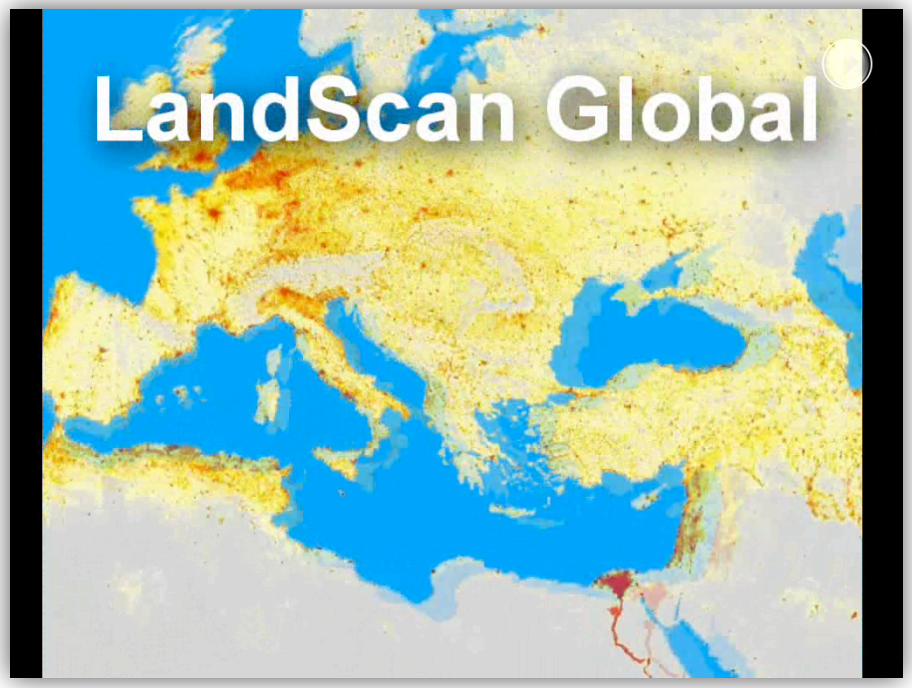
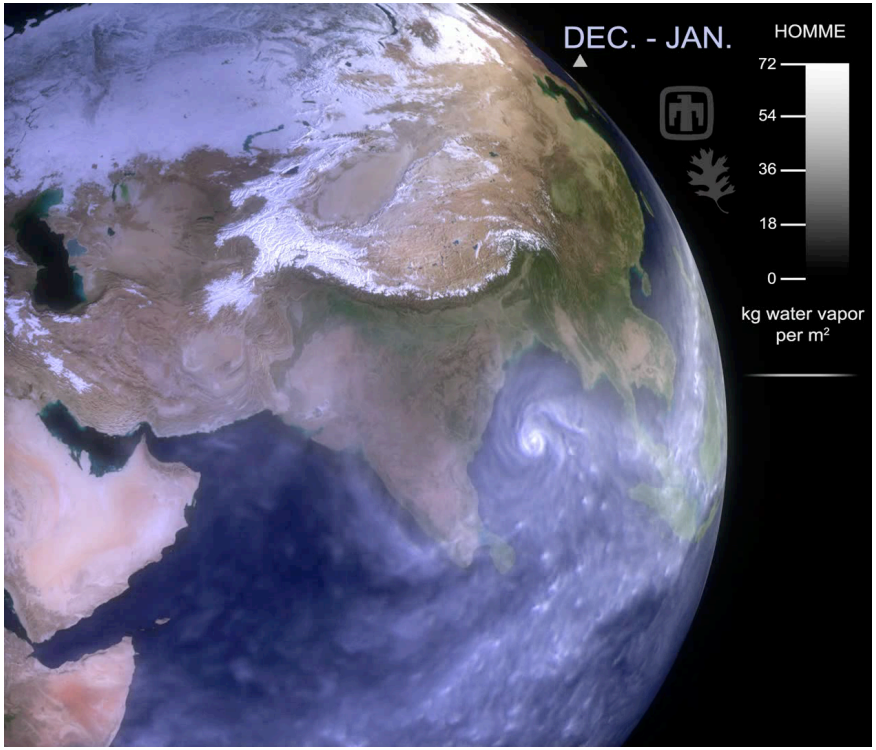
Fusing Climate-Ecosystem-Population Models and Data





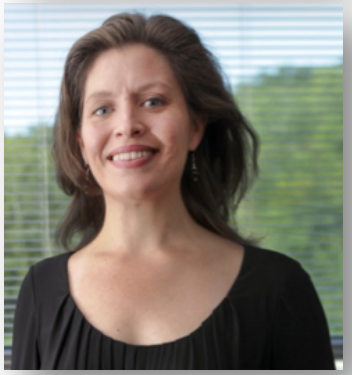
- Human Settlements and Extreme Events
- Agricultural and Energy Systems
- Coastal Infrastructure

Acknowledgements

- **Coastal Work:** **Ben Preston**, CCSI Deputy Director and Research Scientist, prestonb@ornl.gov

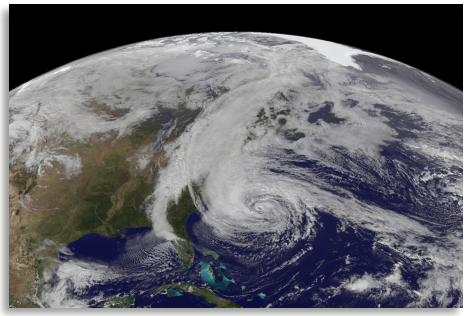
- **Urban Work**
  - **Olufemi (Femi) Omitaomu**, Computational Modeling and Simulation Research Scientist, omitaomuoa@ornl.gov

  - **Esther Parish**, Environmental Science Research Scientist, parishes@ornl.gov

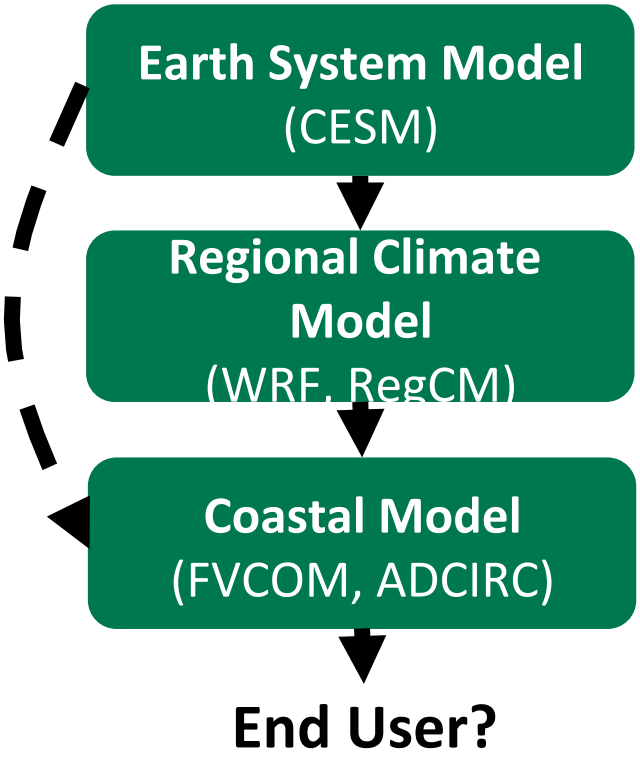


Coastal Impact Assessment

- Coastal impacts are about local extremes like storm surge and flooding from hurricanes.
- Current CM are useful for estimating sea-level rise, but not these kind of extremes.
- To get to relevant resolutions requires a multi-scale modeling approach.
  .
- Each step introduces more uncertainties and expense, so CM have had limited utility for coastal assessment.



Photos By NOAA

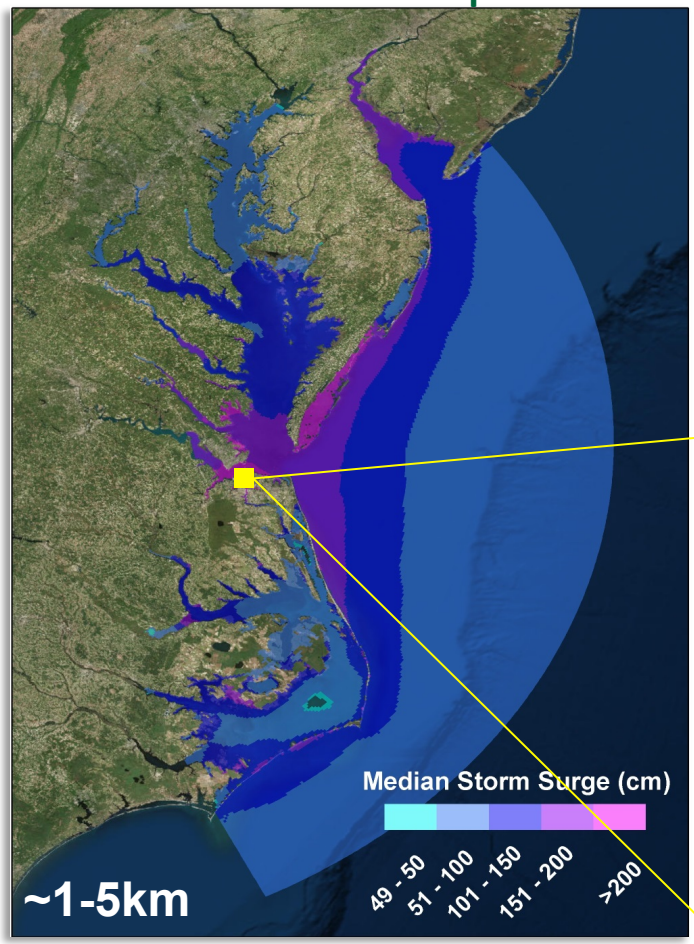


Evacuation/Storm Surge Planning

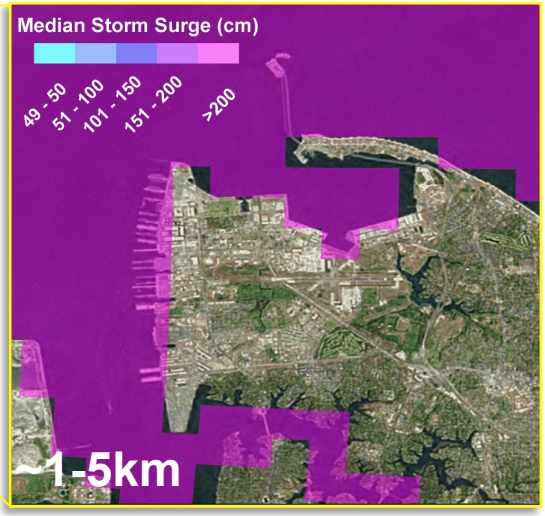
Useful vs. Usability

- Planners often sacrifice credibility for operational utility by using less complex models
- Resolutions that appear well-refined regionally (e.g., 1-5 km) are inadequate locally (10m)
- Resolution value is dependent on risk level, vulnerability, and adaptation options.

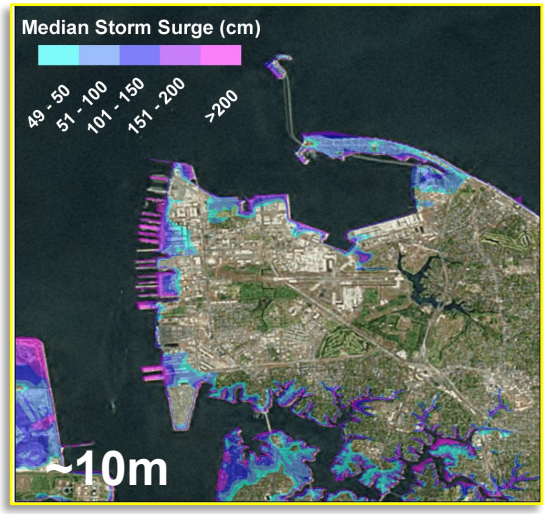
SLOSH Model:
Median Maximum Envelope of Water



SLOSH Model: Median Maximum Envelope of Water



SLOSH Reanalysis (Maloney and Preston, 2014)



Question Responses: Coastal

- **Key Climate Phenomena.** Coupling sea-level rise with extreme events:
  - Changes in the frequency, intensity, and location of coastal storm events
  - Regional rates and variability in sea-level rise (differs from global mean)
  - Rates of land subsidence (high along the Gulf Coast, but less elsewhere)
  - Rates of coastal erosion over the short-term and long-term (i.e., coasts undergo continual change independent of climate change)
  - Effects of waves (not typically included in storm surge models)
  - Interactions between surface water and coastal ocean processes (e.g., significant runoff into the ocean during high storm surge)

- **Relevant Resolution.**
  - Greater scale alignment between CMs and coastal models is important
  - Few KMs for hurricanes, regional sea-level rise, and land subsidence
  - Less than a KM for erosion, waves, and surface water flow

Question Responses: Coastal

- **Improving High-res Dataset Credibility and Usability.**
  - **Tradeoffs.** Nearly always have to make tradeoffs between credibility-usability.
  - **Credibility**. Pushing models to higher res, improve process representation, and increase capacity and transparency of model validation and metrics.
  - **Usability**.
    - Ensure the variables, scales, format, etc. are relevant to user needs and regulatory organizations.
    - Multi-model (CM-RCM-Coastal) framework remains impractical. Framework or uncertainty quantification must be simplified.
  - **False Precision.** High-res can create a sense of false precision (e.g., high-res inundation products could be based on poor elevation data).

- **Value of High/Course Resolution Data Pairing.**
  - CMs remain too course to drive coastal models directly, but high-res CMs can better simulate storm events, coastal model boundary conditions, and capture coastline and coastal bathymetry variability.

Question Responses: Coastal

- **Developing CM and Downscaling Performance Metrics.**
  - Plenty of literature on this, but still no transparent guidance for users regarding the level of confidence in particular model simulations.
  - Something as simple as a A-F rating for models is needed.
  - Tricky given the CM research community politics, the principles of model democracy, and regional climate differences.

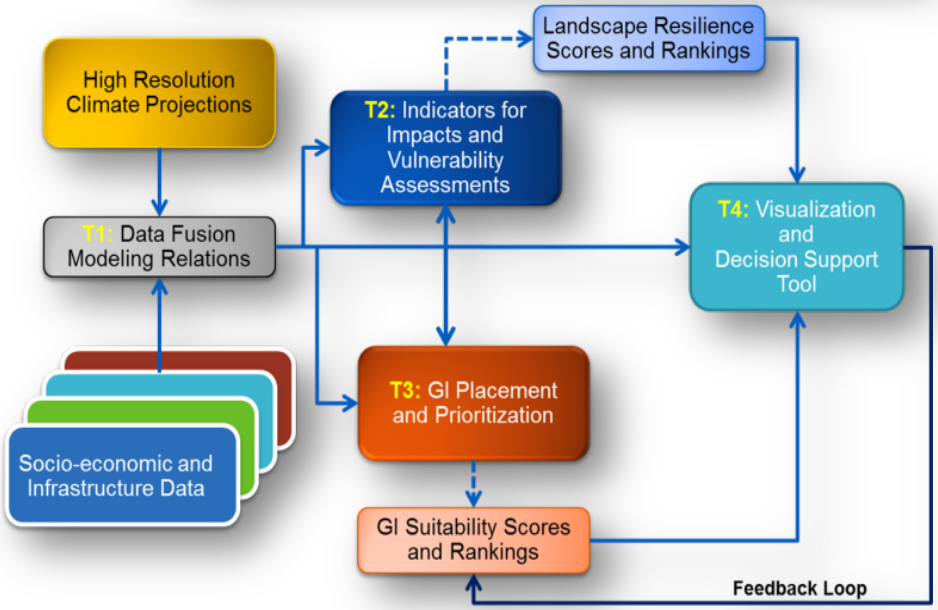
  - CMs with higher resolution, more complexity, and requiring more computation may just be impractical for most users.
  - May need boundary organizations that can take research-grade CM and make some thing useful for users.

Urban-CAT: Urban Climate Adaption Tool

Partnership: Knoxville, CCSI, and UDI

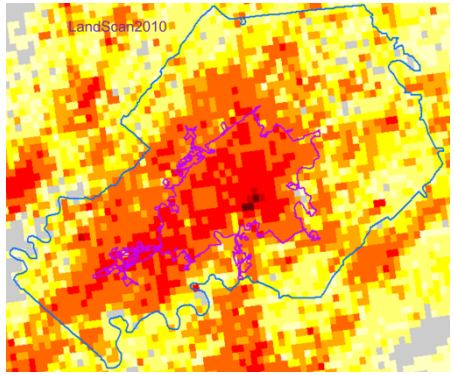
- **Issue:** Mid-size cities house ~50% of urban dwellers and typically lack the resources to address climate-related vulnerabilities.

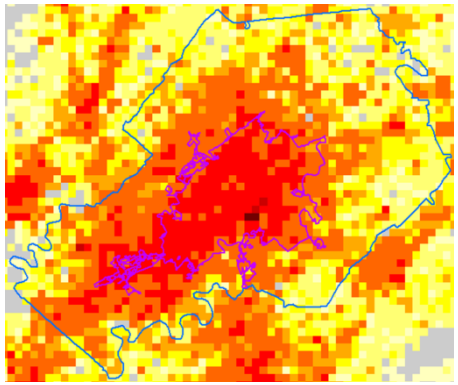
- **Goal:** Create a tool with simple interface that can answer:
  1. What are stormwater runoff patterns for different combinations of climate and population projections?
  2. How to best characterize infrastructure vulnerabliity and risk?
  3. How to prioritize green infrastructure locations (available parcels, flood history, etc.)?
  4. What are the benefits and costs of green infrastructure options under present and future conditions?

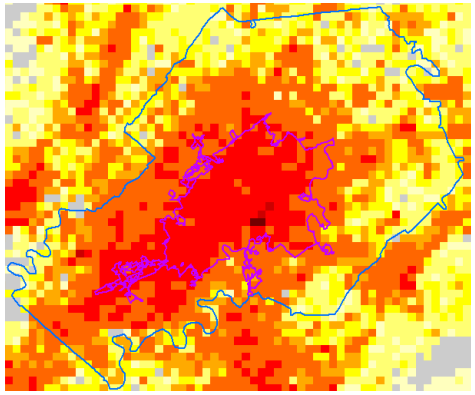


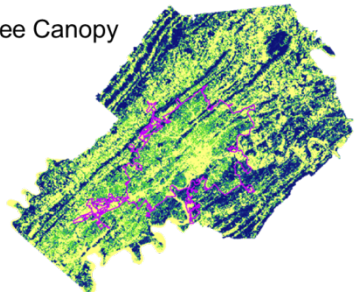
Indicators to Quantify Urban Vulnerability and Resilience

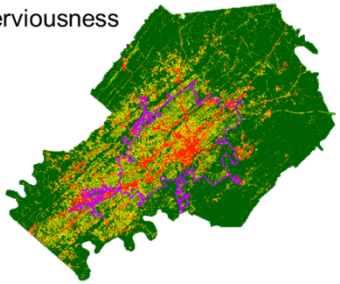
- Quantified indicators developed in consultation with city staff
- Sample Indicators
  - Climate-related: Surface temperature; Palmer drought severity index; relative-drought index
  - Population-related: Urbanization index; Disaster-impact index
  - Water Cycle and Management: Heavy precipitation; stream flow indicators
  - Imperviousness:Tree canopy; ratio of impervious area

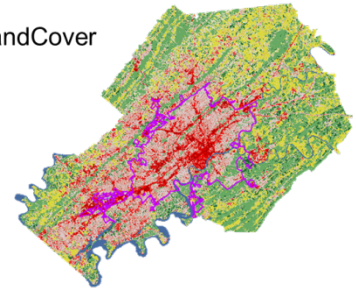


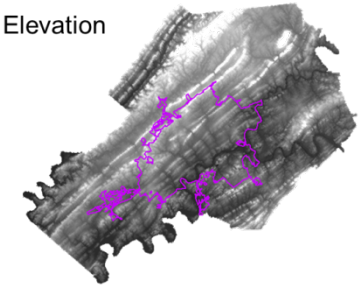








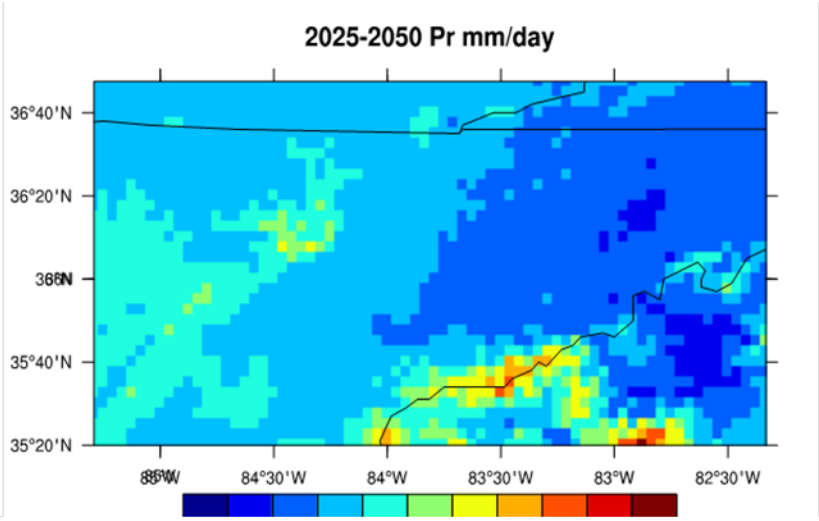


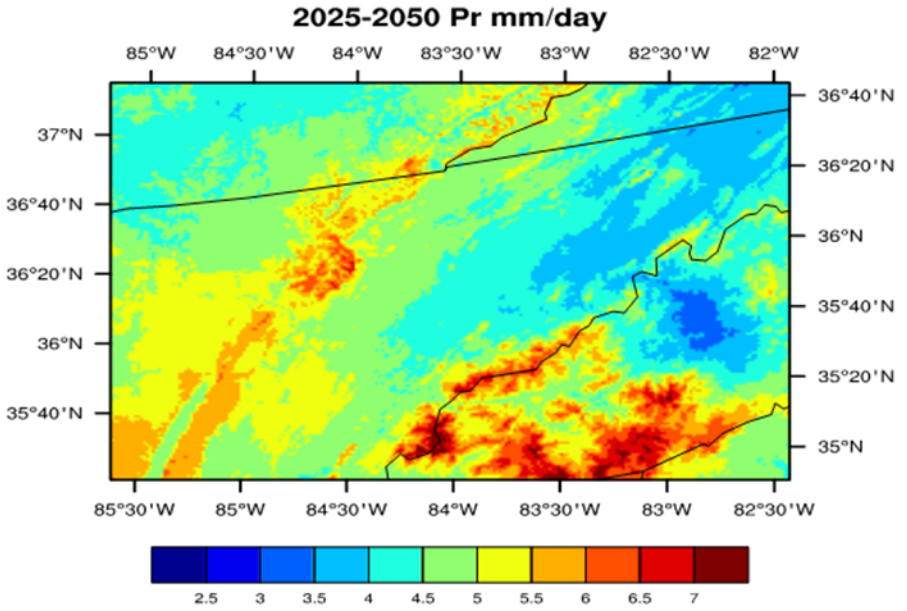


Climate Data at a Scale Appropriate for Urban Planning

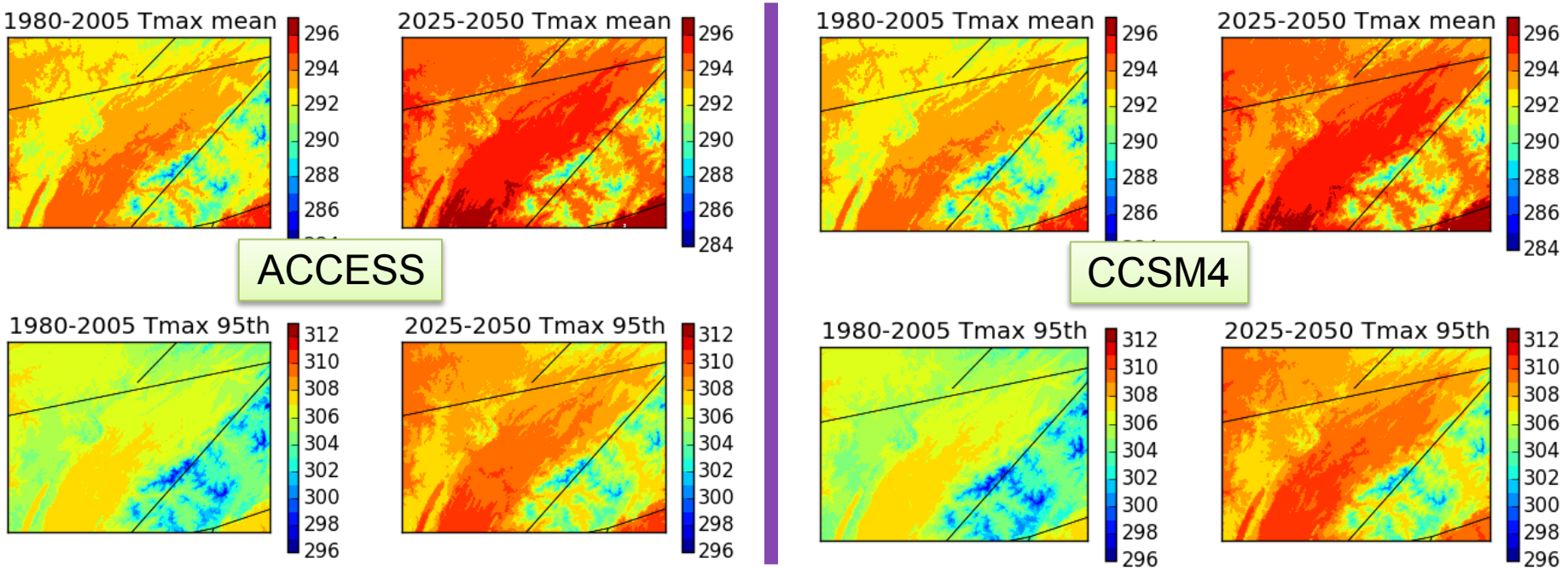
- 4KM Data Set
  - Used 10 CMIP5 global climate models (100KM) with RCP8.5 scenario for 1965-2005 and 2010-2050.
  - RegCM was used to downscale these projections to 18KM
  - PRISM observational reference data set used for bias-correction and spatial disaggregated to 4KM

- 1KM Data Set
  - RegCM 18KM projections statistically downscaled using 1KM DayMet data set for 1980-2005 and 2025-2050



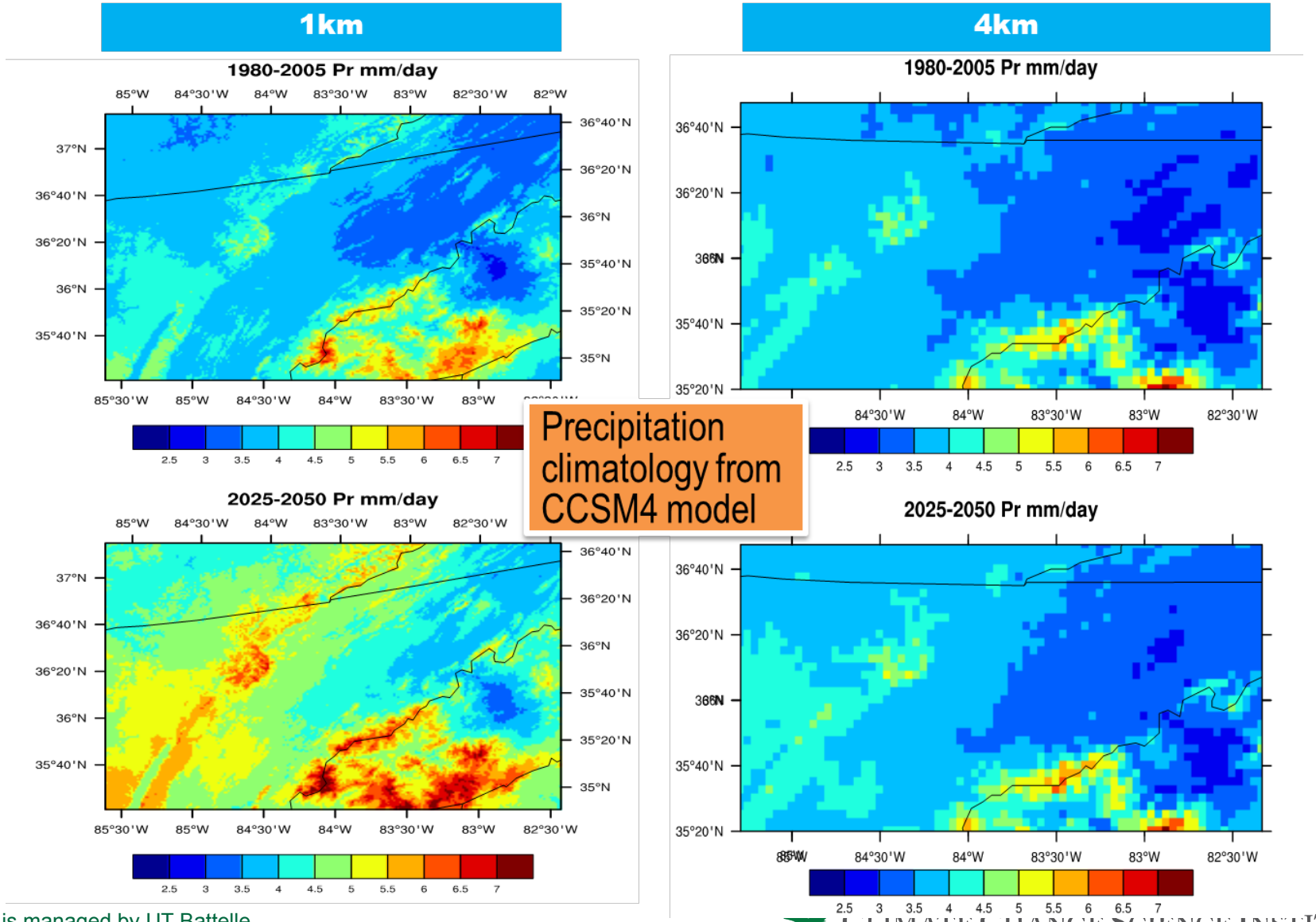


Uncertainties Between Models



Computed statistics (e.g., Tmin, Tmax, Precip, etc.) to demonstrate the uncertainty among models (e.g., ACCESS and CCSM4)

Visual Scale Comparison



Question Responses: Urban

- **Key Climate Phenomena.** For Urban stormwater management:
  - Rainfall intensity is key: will the city need to plan for a different 24 hour rainfall distributions in the future?
  - Regulations require GI infiltrating first inch of rain – 85th percentile storm under current climate conditions.

- **Relevant Resolution.**
  - City rainfall spatial resolution is ~5 km and 15 minute time resolution.
  - Climate model ≠ weather model and 15 min resolution are expensive and probably not be reliable
  - 1 km better capturing extremes in Knoxville topography, but may not make a difference for stormwater planning.

Fig. B-1. SCS 24-hour rainfall distributions (SCS, 1986):
(y-axis reads "Fraction of 24-hour rainfall" and x-axis reads "Time, hours")

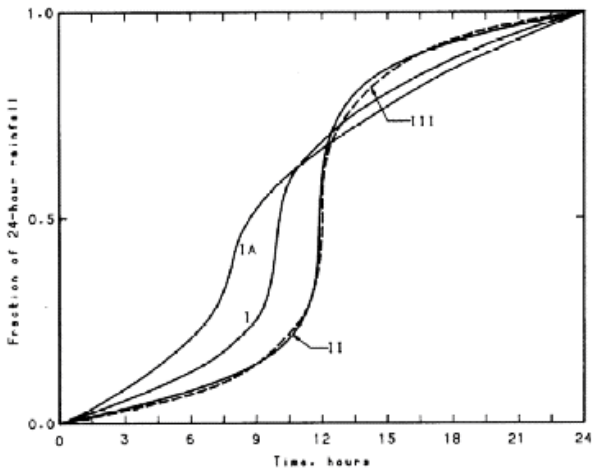


Figure B-1.—SCS 24-hour rainfall distributions.

- Knoxville plans for Type II storms
- 15 minute intense storm can cause more flooding than 100-year storm over several days.

Question Responses: Urban

- **Improving High-res Dataset Credibility and Usability and Developing CM and Downscaling Performance Metrics.**
  - Downscale with local historical data (DayMet) and used City rain gauge data for hindcast comparisons.
  - Statistical representations of extremes improve with higher resolution and likelihood of extremes are very important to city planners.
  - Working on characterizing the CMs ensemble uncertainties, and may aggregate projections into high, medium, and low.
  - Plan to incorporate tool in Urban-CAT to allow users to prepare their own statistics based on their own criteria/thresholds.
  - Will be using Urban-CAT to explore the relative contributions of climate, infrastructure, and socio-economic information to decision outcomes.

- **Value of High-Coarse Resolution Data Pairing.**
  - That is the goal of dynamical downscaling in this project (the regional CM is run at high-res, but driven by the course-res global CM)

Thank You!

CCSI Team

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Backup Slides

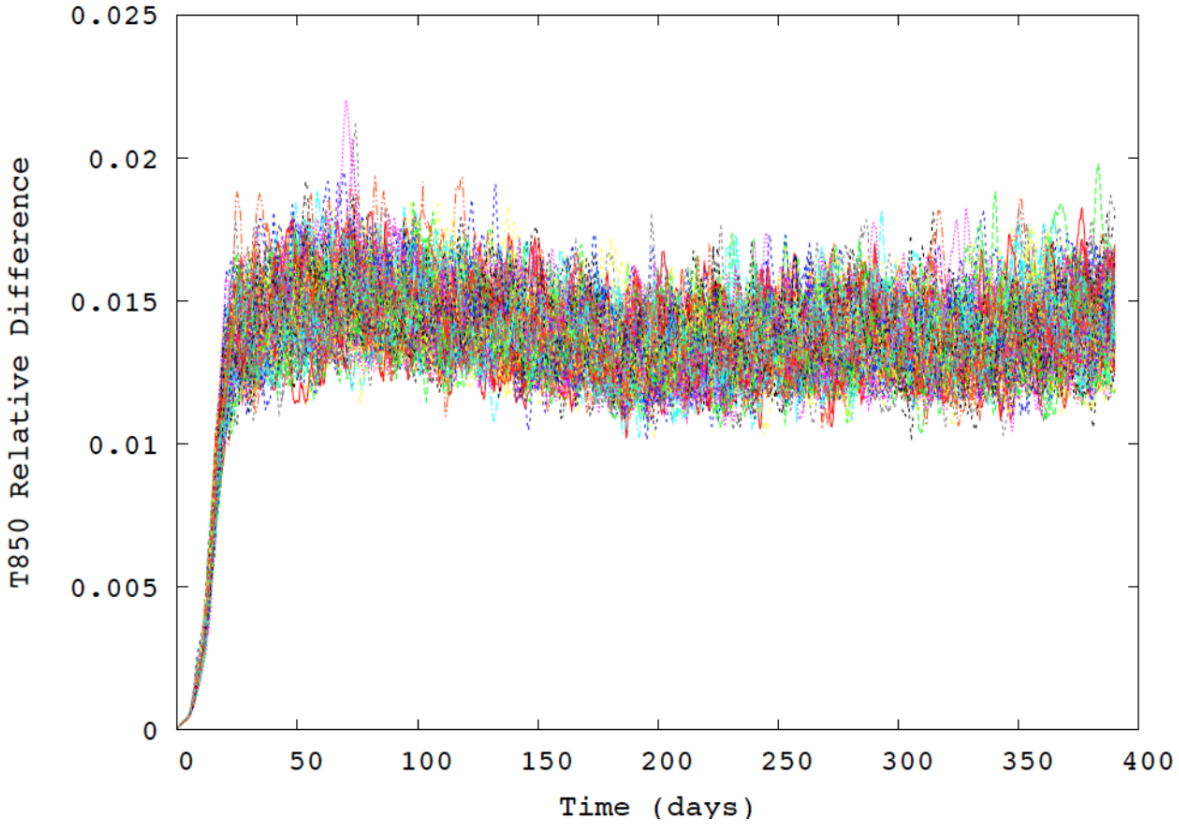
Limits of Predictability

Do regional CMs used for downscaling capture the variability of CM initial states used to force the regional CM?

Figure. Spatially averaged daily 850mb temperature differences for 100 single year simulations with the ACME atmosphere model with tiny (10^{-14}) random initial condition differences.

Weather vs. Climate. The slight initial condition differences grow rapidly until they get as "different as they will get" (completely different weather states) in ~23 days (theoretical limit of predictability).

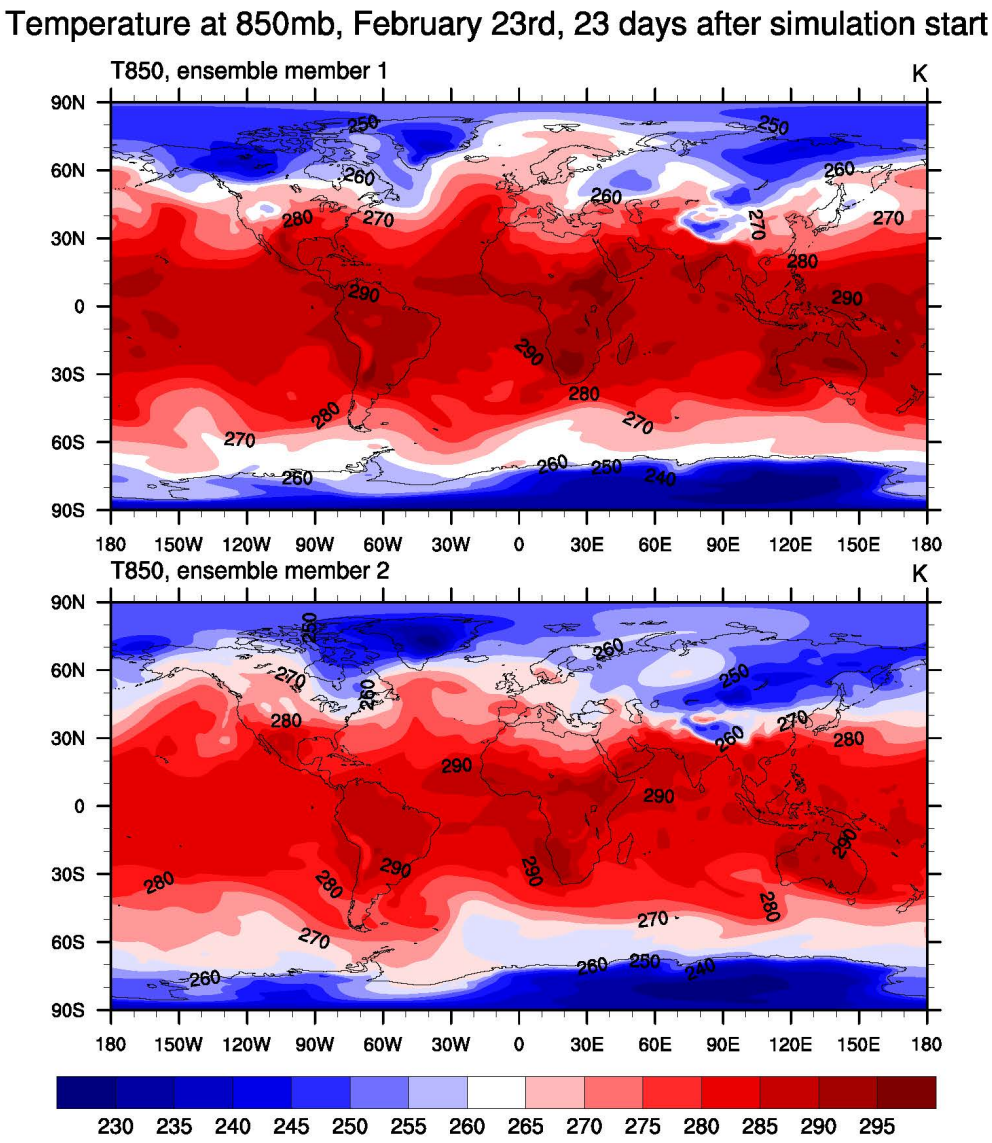
Limits. Unlikely that CMs can provide convection-scale or sub-daily predictions because of this chaotic nature – but can provide important and useful trends.



Difference between one ensemble (model + initial temp field) and the next for 100 ensembles over the course of 400 days for ACME atmosphere-only simulations. It begins at zero and appears to saturate at about 23 days and remain roughly constant from there.

Limits of Predictability

- Two climate simulations at 23 days with initial temperature differences of only 10^{-14} degrees.
- Zonal average climate roughly the same (cold at the poles and warmer toward the tropics).
- However, top simulation warmer in the tropics and colder in the Himalayas – two different weather states!

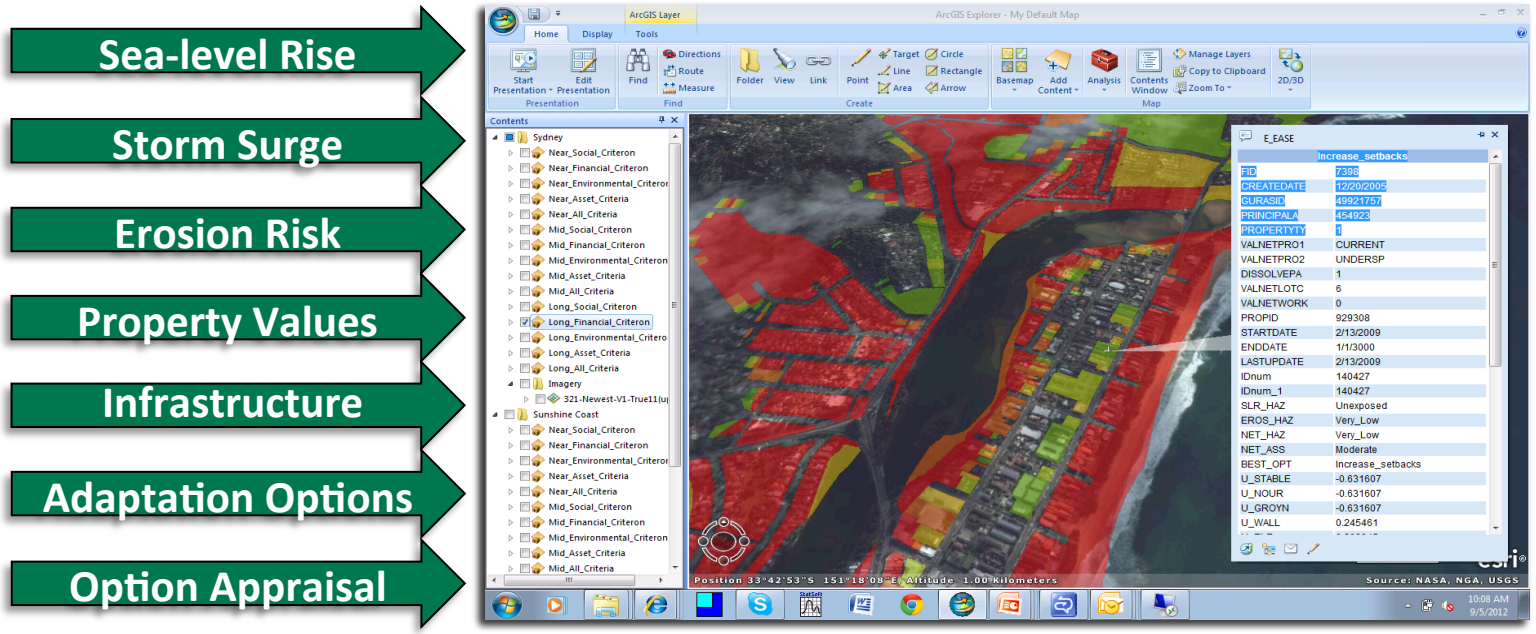


Climate Data Is Just One Information Need
(and maybe not the most important)

- High-res coastal hazards information is meaningless without high-resolution information on what is at risk

- A comprehensive system of high-res coastal modeling, asset management, risk analysis, adaptation assessment, and visualization tools would allow evaluating the sensitivity and value of high-res climate information.

Coastal Adaptation Information System



Preston et al. (2013)