

Disruptions Related to Climate and Other Global Changes

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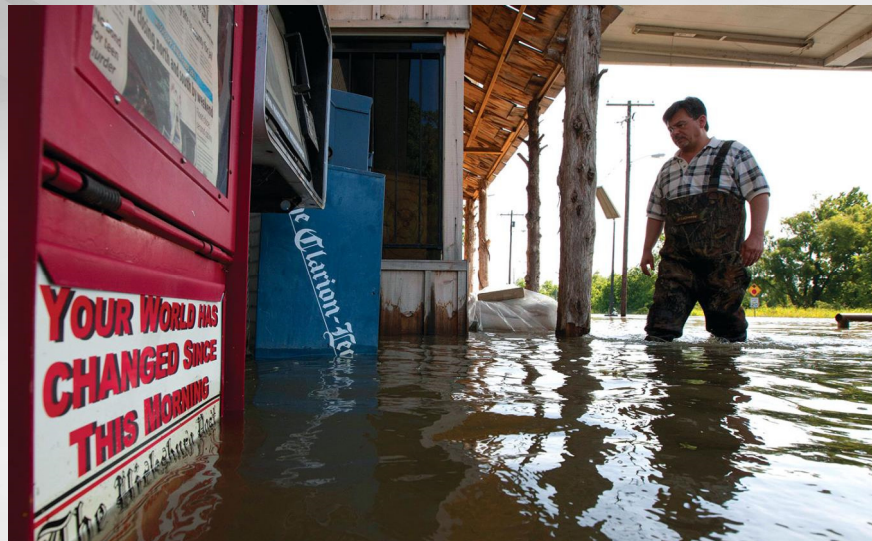
Council for Chemical Research Annual Meeting
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The basic causes and consequences of climate change are now well established



Human-induced climate change is here, now

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Climate change affects things people care about

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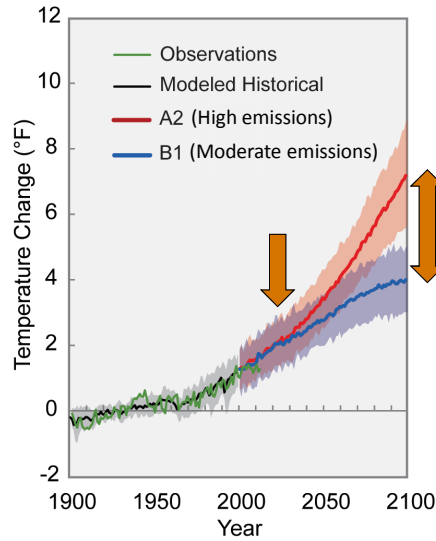


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The impacts of climate change are projected to increase...

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...but there are things we can do now to manage our risks and address expected impacts

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Change provides both challenges and opportunities for the industry

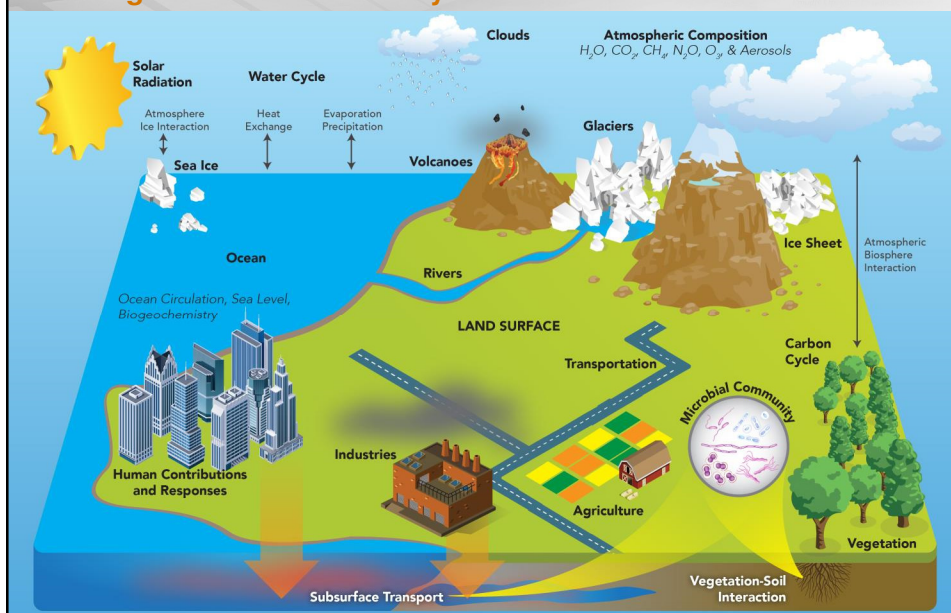
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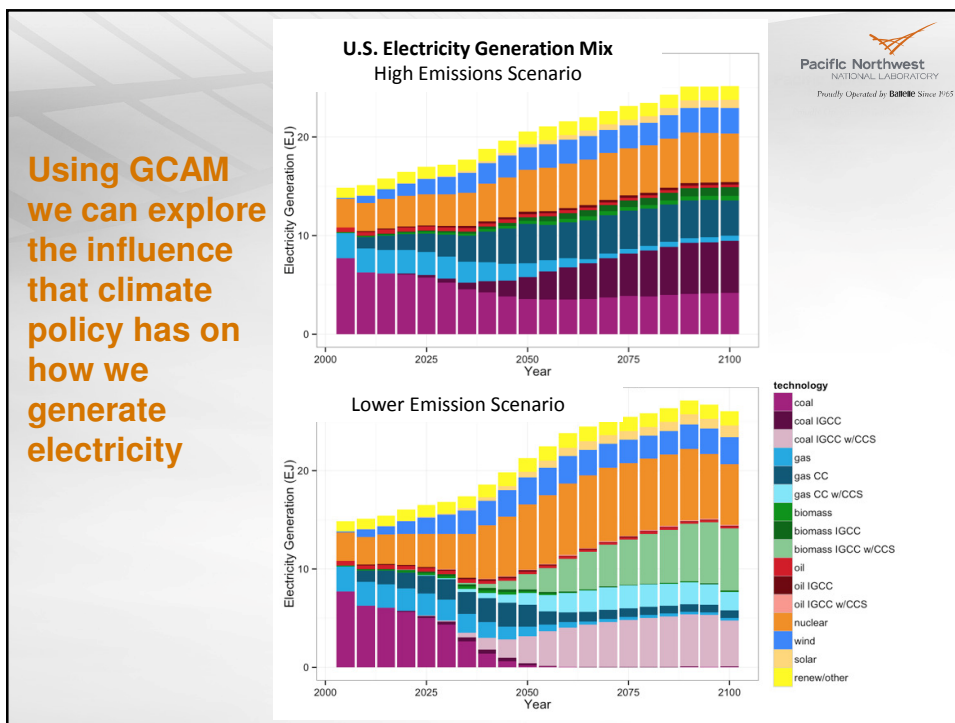
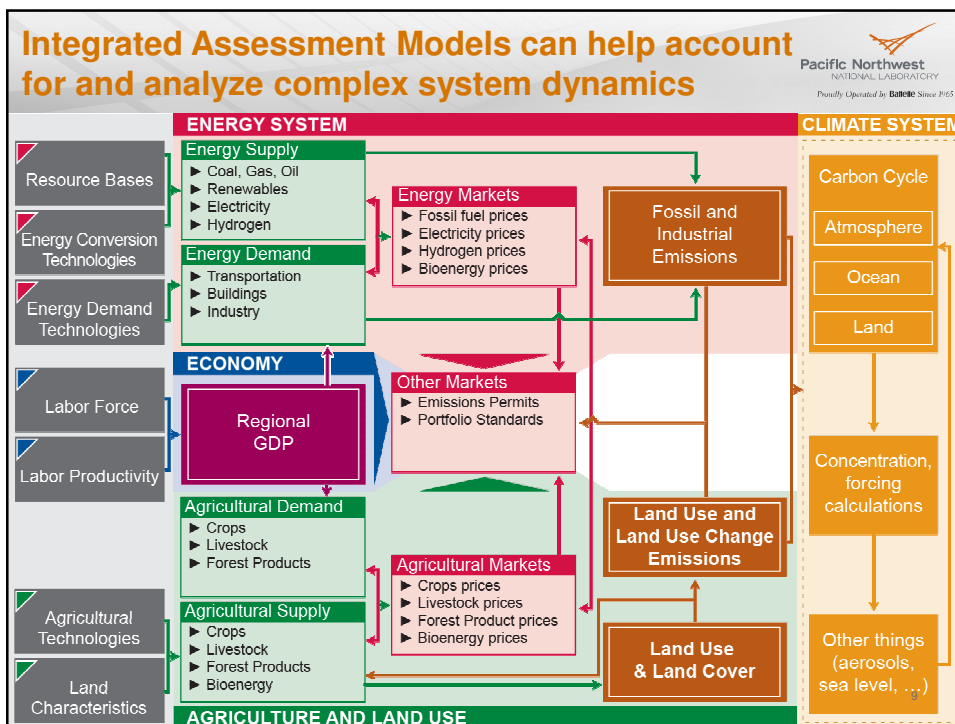
- ▶ Changing resource availability for operations (e.g., energy & water)
- ▶ Changes in extreme events (flood, drought, heat waves, etc.) that impact infrastructure and/or facilities
- ▶ Potential disruption of supply chains
- ▶ Implications of climate mitigation policy, and lack of international standards
- ▶ New product directions and opportunities
- ▶ Disruptive technologies
- ▶ And the list goes on.....


**KEEP
CALM
AND
STUDY
CHEMISTRY**

Understanding and responding to climate change requires accounting for the complex dynamics of the integrated human-Earth system

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And the systems dynamics analysis can lead to surprisingly unexpected results....

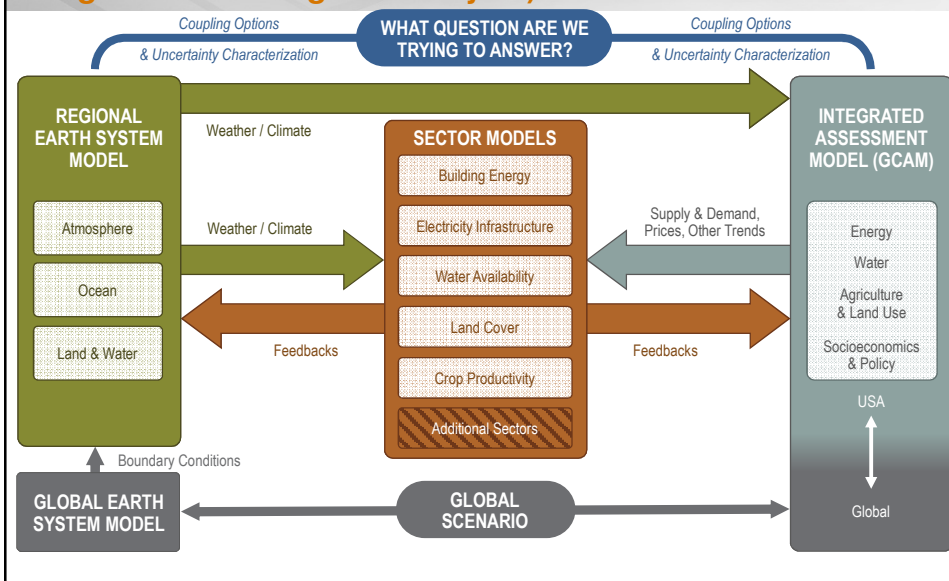


McJeon et al., 2014


- ▶ Natural gas emits less carbon dioxide than coal, leading many to think the natural gas boom would help mitigate climate change
- ▶ However, a PNNL-led study (using ours and four other integrated assessment models) showed that, on a global basis, abundant natural gas would:
 - Also displace carbon-neutral energy technologies like nuclear, wind, and solar
 - Accelerate economic growth and overall energy use
- ▶ Unless policies are enacted to ensure natural gas only displaces coal, the increasing availability of inexpensive natural gas will not slow climate change

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New questions are demanding higher resolution - so we developed PRIMA (platform for regional integrated modeling and analysis)



PRIMA climate and hydrologic models provide high-resolution water availability



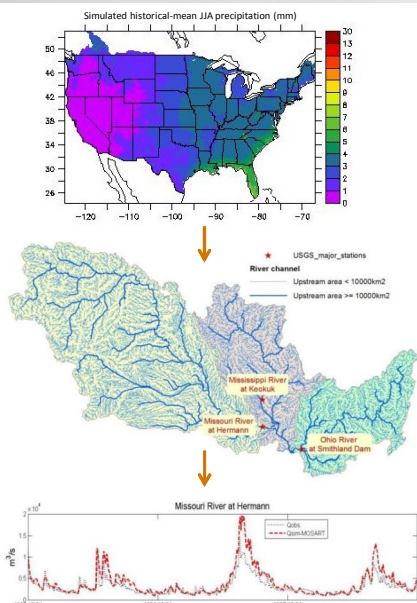
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Regional Earth System Model (RESM)


- ▶ Provides high-resolution (~15km) dynamically downscaled climate information to the other PRIMA component models
- ▶ Integration of atmosphere, land, and ocean models captures key regional processes
- ▶ Other regional climate models/data can be substituted → modular framework

Regional Water/Hydrology Models

- ▶ Links into the Community Land Model
- ▶ New scalable, physically based river routing model
- ▶ Water management model includes generic representation of regional reservoir operations & regulated flows

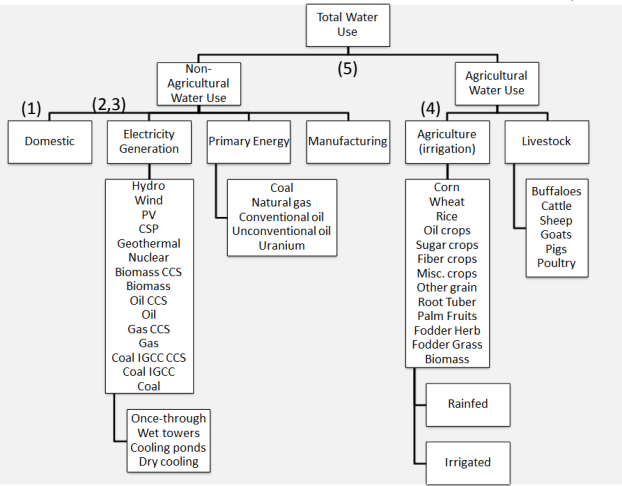


GCAM can estimate changes in water demand associated with different sectors

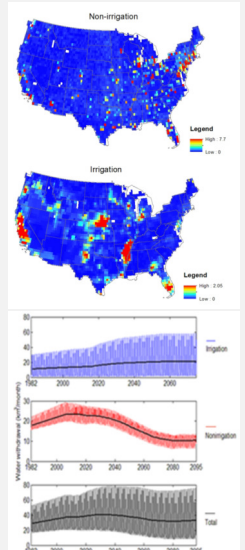


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Representation of water demand sectors in GCAM

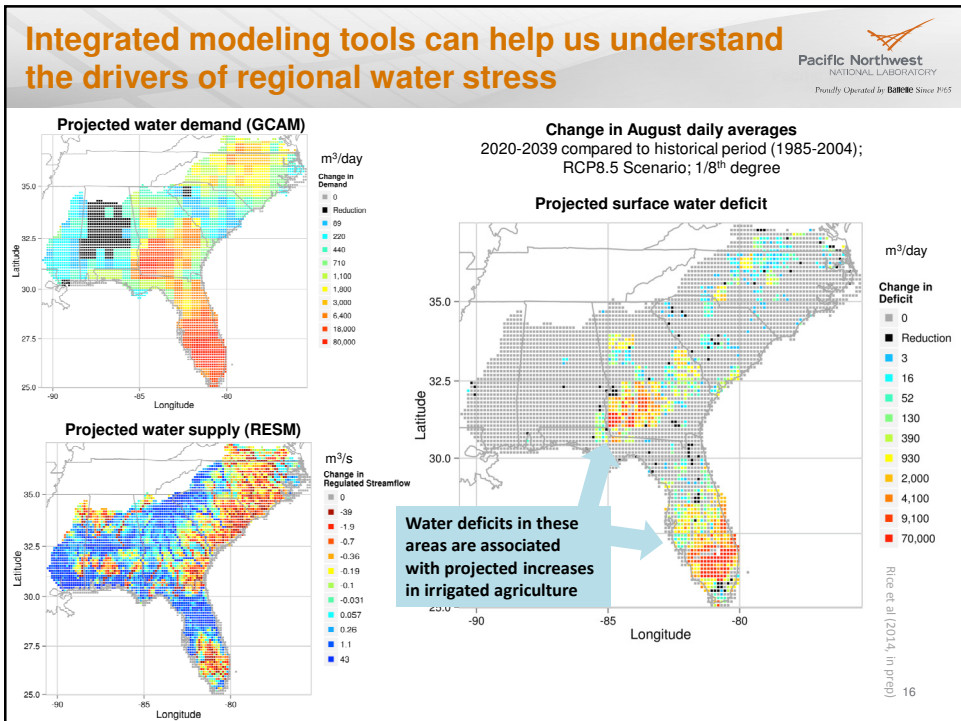
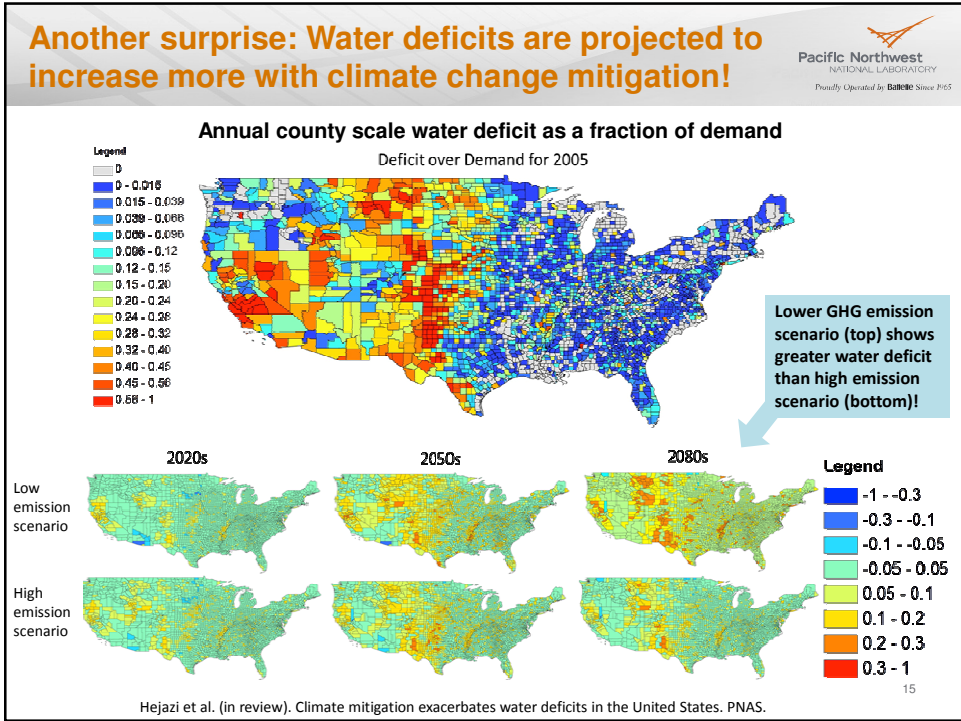


Spatial/temporal downscaling



(1) Hejazi et al. (2013). Hydrological Sciences Journal.
 (2) Kyle et al. (2013). International Journal of Greenhouse Gas Control.
 (3) Davies et al. (2013). Advances in Water Resources.
 (4) Chaturvedi et al. (2013). Mitigation and Adaptation Strategies for Global Change.
 (5) Hejazi et al. (2014). Technological Forecasting and Social Change

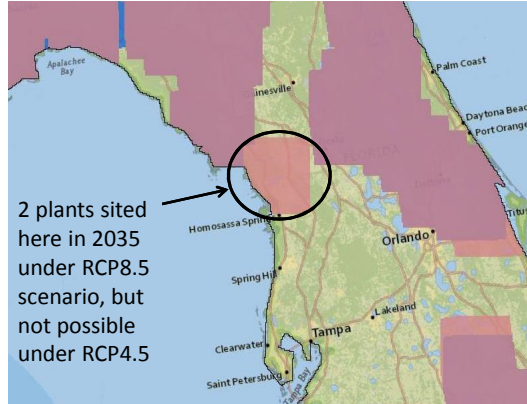
Voisin et al. (2013a). HESS.



Climate change and climate policy can also constrain energy sector planning



- Integrated assessment model indicates where new electricity generation capacity is needed on a regional basis
- GIS-based power plant siting model used to identify possible locations for new power plants using natural resource availability, economic factors, and other criteria
- Changes in water availability (due to climate, climate policy, and/or regional water demands) may significantly constrain siting of baseload power plants

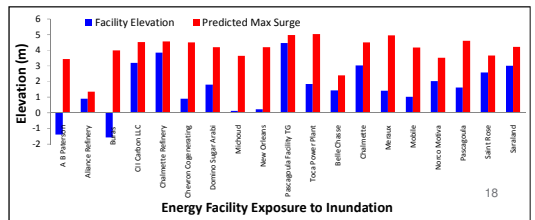
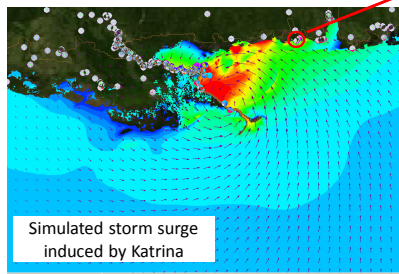
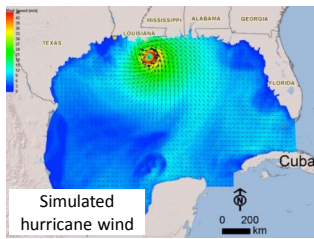
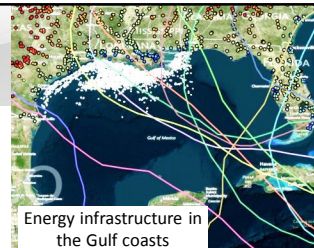


Sufficient cooling water for advanced nuclear
 Pink = RCP 8.5 (high emissions)
 Blue = RCP 4.5 (medium emissions)
 Purple = both RCPs (similar water availability)

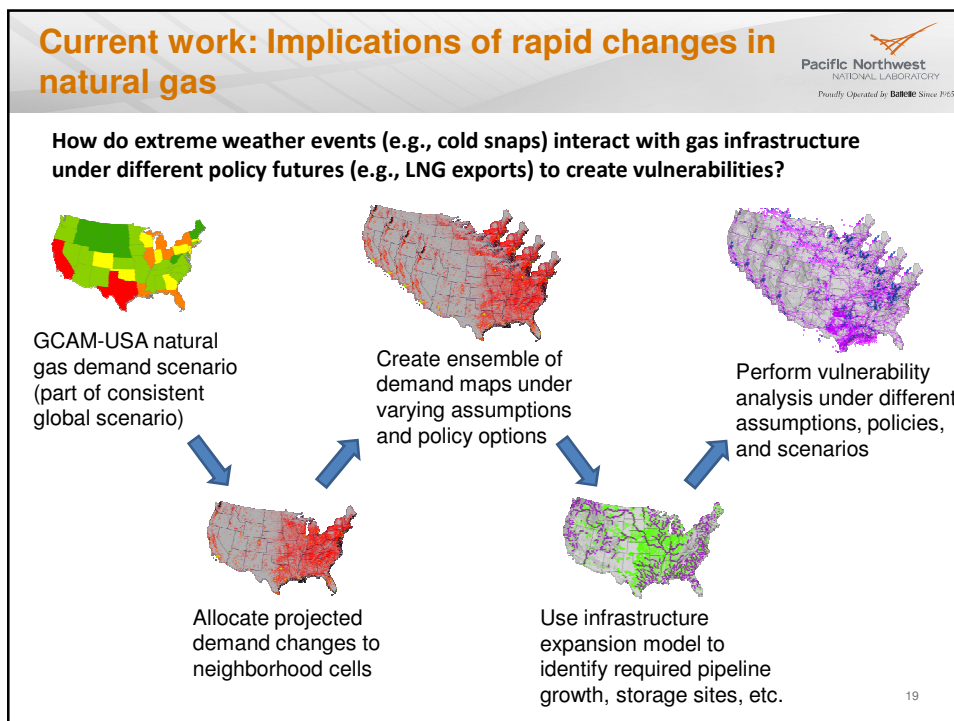
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Simulating storm surge impacts on coastal energy infrastructure

- ▶ Evaluate vulnerability of Gulf Coast energy infrastructure to hurricane-induced storm surges under different scenarios of climate change, sea level rise, and land subsidence
- ▶ Combines global and regional climate models, storm surge/inundation model, and GIS-based infrastructure exposure/impacts model
- ▶ Storm surge model has been validated, currently working on impacts model



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In closing.....

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- ▶ The climate system is an extremely complex enterprise where the interaction of coupled natural and human systems has often unexpected consequences
- ▶ Climate and environmental change are integrally linked to decisions we make about land use, water use, our energy systems, and evolving infrastructure
- ▶ Future decisions for long term investments must be based on projections of a future world, not the one we live in today – exploring those possibilities engages one of the greatest strengths of this industry – understanding and managing risk.....
- ▶ There are also opportunities for the chemicals industry to provide innovative solutions that can make a difference – from new materials and products, to energy sources and storage, to creating solutions to climate change based on fundamental chemistry

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