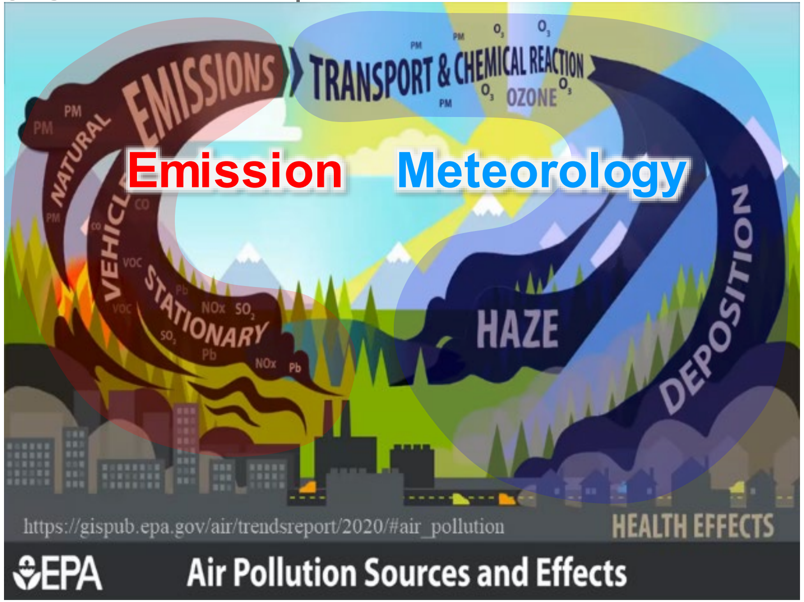
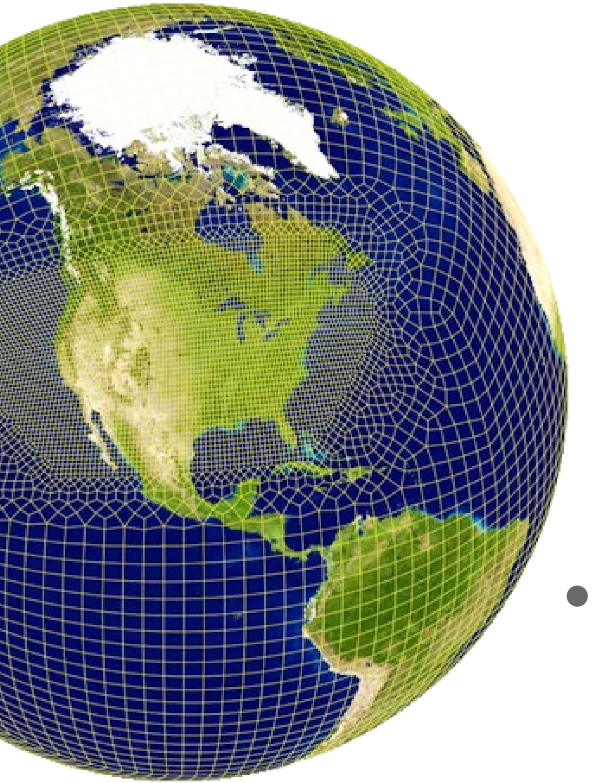
Lessons we learnt

Joshua Fu, University of Tennessee/Oak Ridge National Laboratory

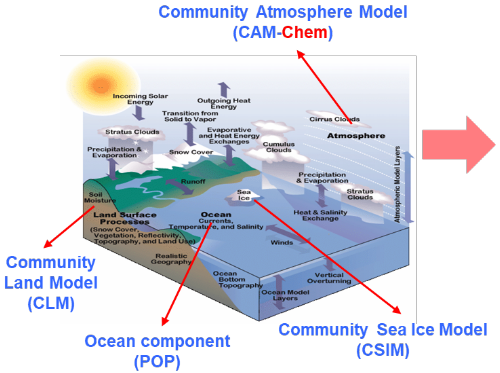
- **Meteorology** has an important influence on the formation, transport, and deposition of chem components.
- Meteorological patterns favorable the formation or accumulation of air pollutants: **extreme weather events**, such as heatwave, stagnation, or both (compound events).
- Increasing **anthropogenic emissions** lead to air pollution since the modern industrial revolution.



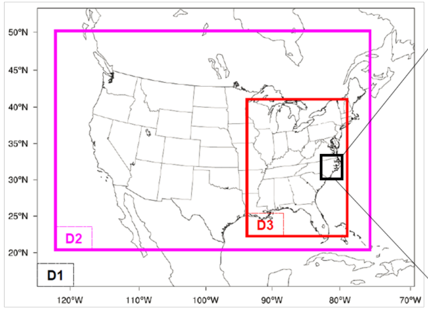
Lessons and Opportunities for Integrated Engineer
Earth Systems Science at Scale



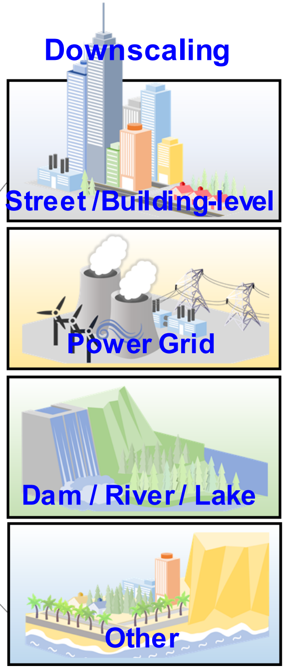
Community Earth System Model CESM 1.0



Regional Climate/Chem Model WRF 3.2.1/CMAQ 5.0



D1/D2/D3: 36-12-4 km



0.9 × 1.25 deg (~ 100 × 140 km lat/lon) → 36-12-4 km → ~ 50 m

- **High resolution regional climate and air quality modeling** is inevitable and crucial for regional engineering risk assessment and can provide important information for policymakers when taking actions on climate extreme events, mitigation, and adaptation.

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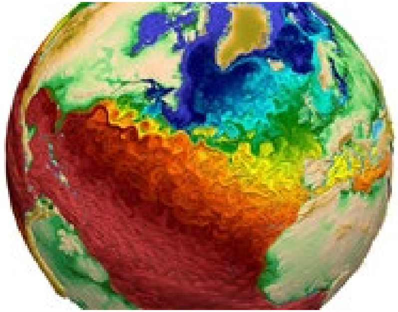
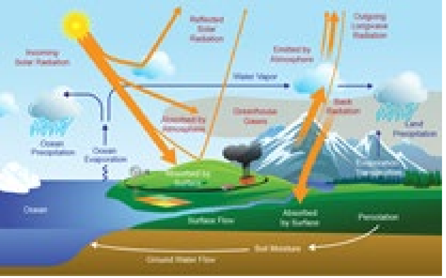
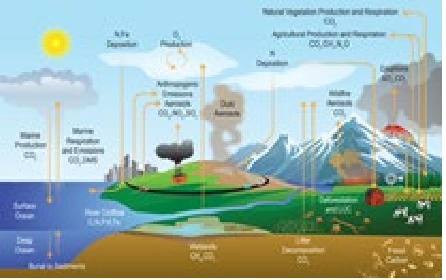


- **Predictive understanding of the Earth systems** is crucial for utilizing its energy and water resources while mitigating costly environmental hazards.
- **Increasing frequency** of weather extremes and the changing the environment poses risks to energy infrastructure and the built environment.



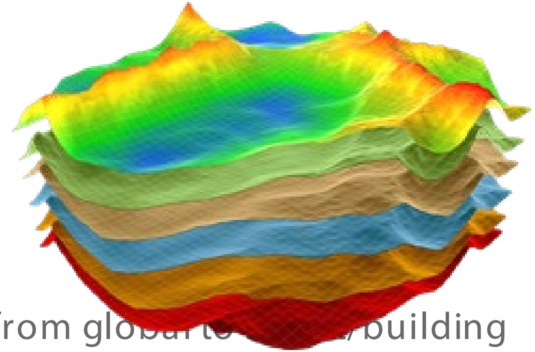
Energy & Water Cycles



Carbon & Biogeochemical Cycles

- Sparse observations and inadequate model fidelity limit the ability to identify vulnerability (e.g., power grid), mitigate risks, and respond to disasters.
- Foundational Earth systems science of complex and dynamic hydrological, biological, and geochemical processes and their interactions is required.
- **Earth system models**, **models of engineered systems**, and machine learning must be integrated to practicably predict vulnerability.

Lessons and Opportunities for Integrated Engineer Earth Systems Science at Scale

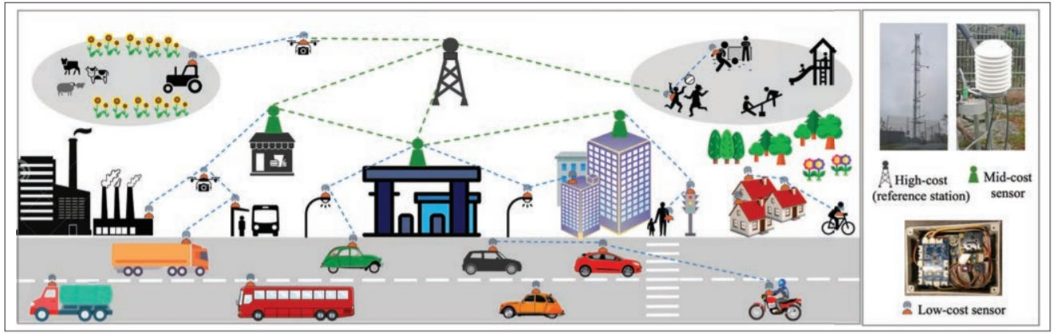


- Water resources are critical for energy production, human health, food security, and economic prosperity.
- **Water cycle extremes**, driven by weather extremes, environmental change, and disturbances such as wildfire and land-use change (e.g., roughness-dust), directly impact water availability/quantity and water quality.

- **Downscaling** the exposure from global to /building scale should not only rely on ESMs modeling, other data sources (e.g. satellite data, land-use data) or techniques (e.g. machine learning) but also should be involved to enhance the modeling accuracy.
- Building up **exposure scenario at fine spatial scale** (e.g. city or street level) is the challenge, because the estimations could be very diverse due to different **exascale models and downscaling techniques**.
- **Uncertainty** due to lack of **communication between models**, lack of **physical and chemical mechanisms at a regional scale**, and lack of **local information** need further investigations

Lessons and Opportunities for Integrated Engineer Earth Systems Science at Scale

- Artificial intelligence (**AI**) and machine learning (**ML**) methods are needed to integrate disparate and diverse **multi -scale data** with models of watersheds, rivers, water utility, civil infrastructure.
- Practicable predictions of air/water quality and quantity, as well as floods and droughts, require **data -driven models** and **smart sensing systems.**
- **Exascale computing** , **edge computing** , and **5G** offer the promise to accelerate scientific discovery and revolutionize engineering approaches through **data -driven and physics -constrained AI/ML with Earth Systems.**
- **Engineering cyber -physical system**



Questions and contact: Joshua Fu via jsfu@utk.edu