NCAR | EARTH OBSERVING LABORATORY

New Frontiers of ARM

Allison McComiskey

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U.S. Plans for Climate Change, Clean Energy, & Environmental Justice

What:

- 50-52% GHG emissions reduction by 2030 (from 2005)
- 100% carbon pollution-free power sector by 2035
- Net-zero economy by 2050

How:

- Decarbonize Electricity
- Reduce non-CO_2 emissions
- Electrification of Sectors
- Cut Energy Waste
- Scale Up CO_2 removal

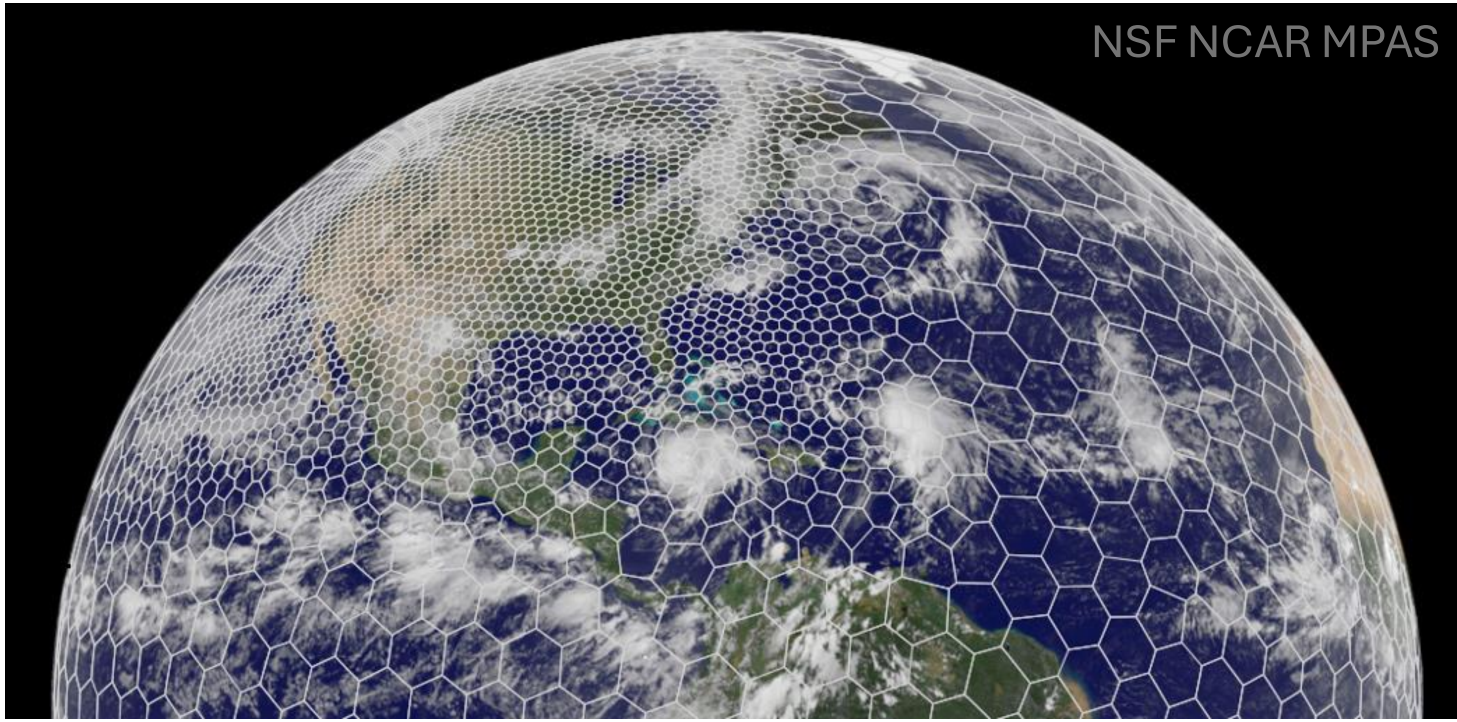
All of these actions require fundamental knowledge of Earth systems from hyper-local to global scales

Better knowledge of foundational atmospheric and Earth processes that control weather and climate patterns at all scales is required to develop the tools needed to meet the challenges of climate change

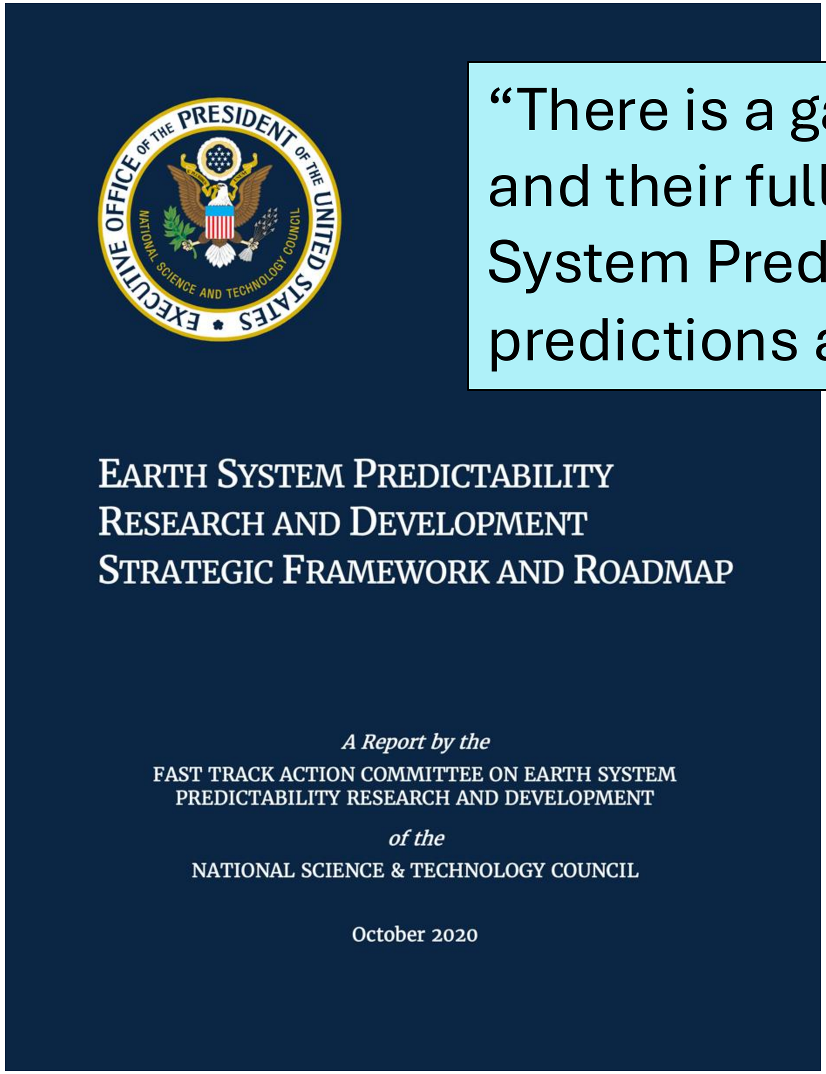
New questions and challenges…Societal applications on global, regional, municipal, and neighborhood scales

New models and applications…MPAS, E3SM 3 km atmosphere, ultrafine-resolution models for clean energy applications and climate solutions

New computational methods… Direct Numerical Simulation, data assimilation, AI/ML, Digital Twins



…what does this mean for observations?


EARTH SYSTEM PREDICTABILITY
RESEARCH AND DEVELOPMENT
STRATEGIC FRAMEWORK AND ROADMAP

A Report by the

FAST TRACK ACTION COMMITTEE ON EARTH SYSTEM PREDICTABILITY RESEARCH AND DEVELOPMENT

of the

NATIONAL SCIENCE & TECHNOLOGY COUNCIL

October 2020

"There is a gap between available observations from all platforms and their full utilization to address the understanding of Earth System Predictability and accelerate the advancement of predictions and projections."

Challenges for Earth System Predictability:

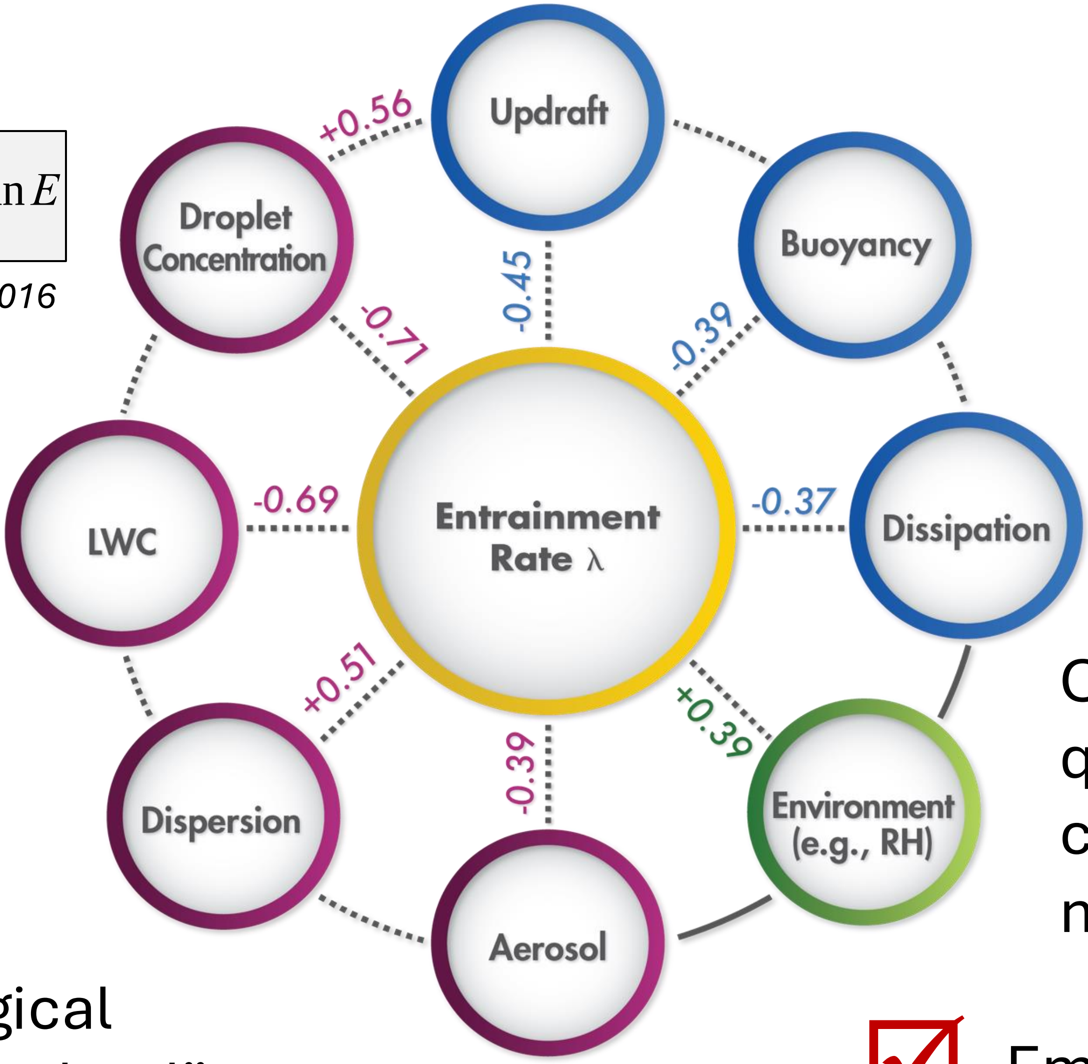
- Representation of complexity
- Bridging scales
- Bringing observations to models / prediction tools

Complexity

$$\mathrm{D}R = R\frac{d\ln R}{d\ln t}\frac{d\ln t}{d\ln N_d}\frac{d\ln N_d}{d\ln CCN}\frac{d\ln CCN}{d\ln E}\mathrm{D}\ln E$$

Ghan et al. 2016

Chain of one-way mechanisms limits characterization of range of responses under a range of environmental regimes

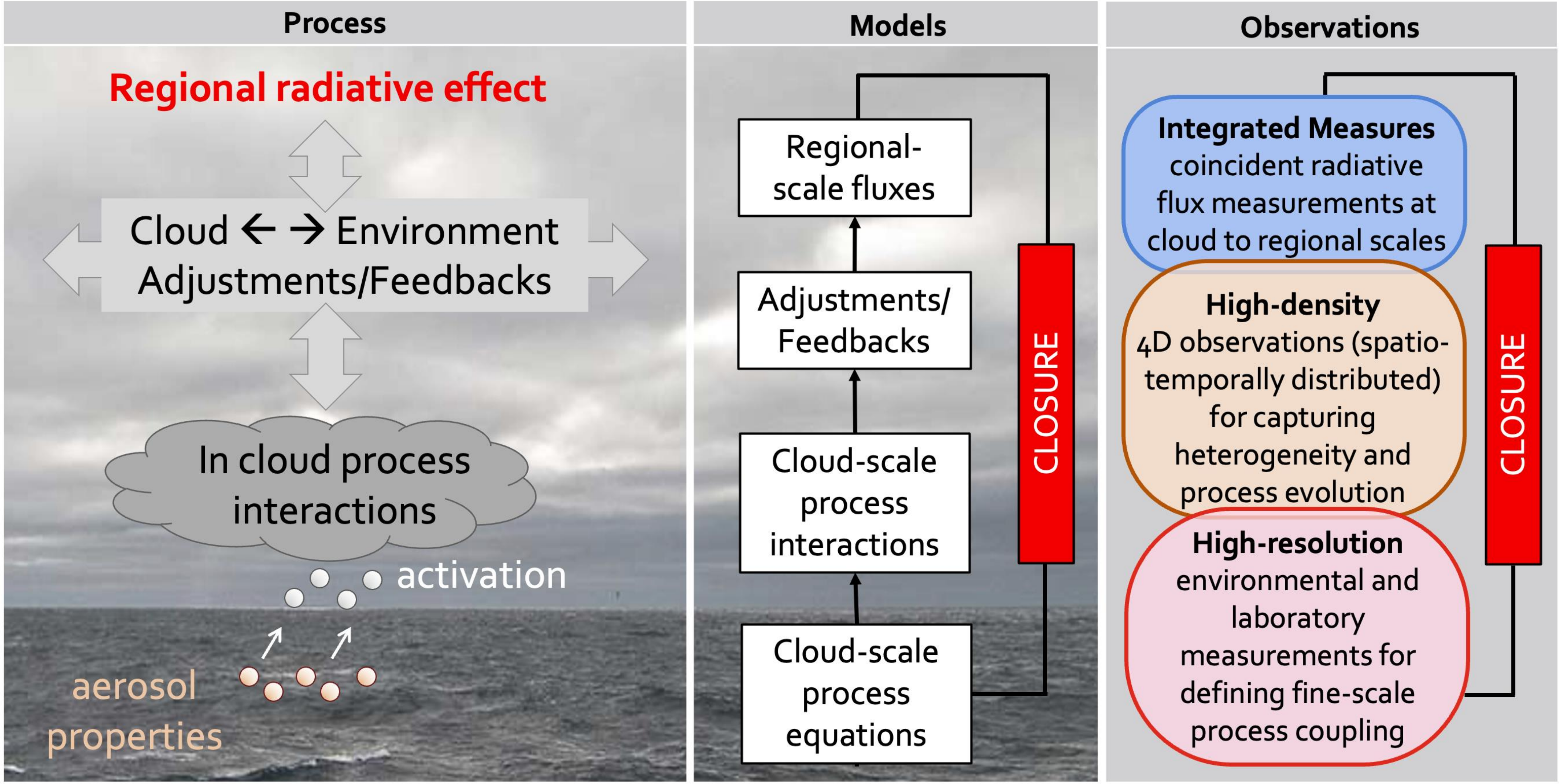


Observe and quantify the complex (maybe non-linear) system

✗ "untangling meteorological and aerosol impacts on cloud"

✓ Embrace complexity

Bridging Scales

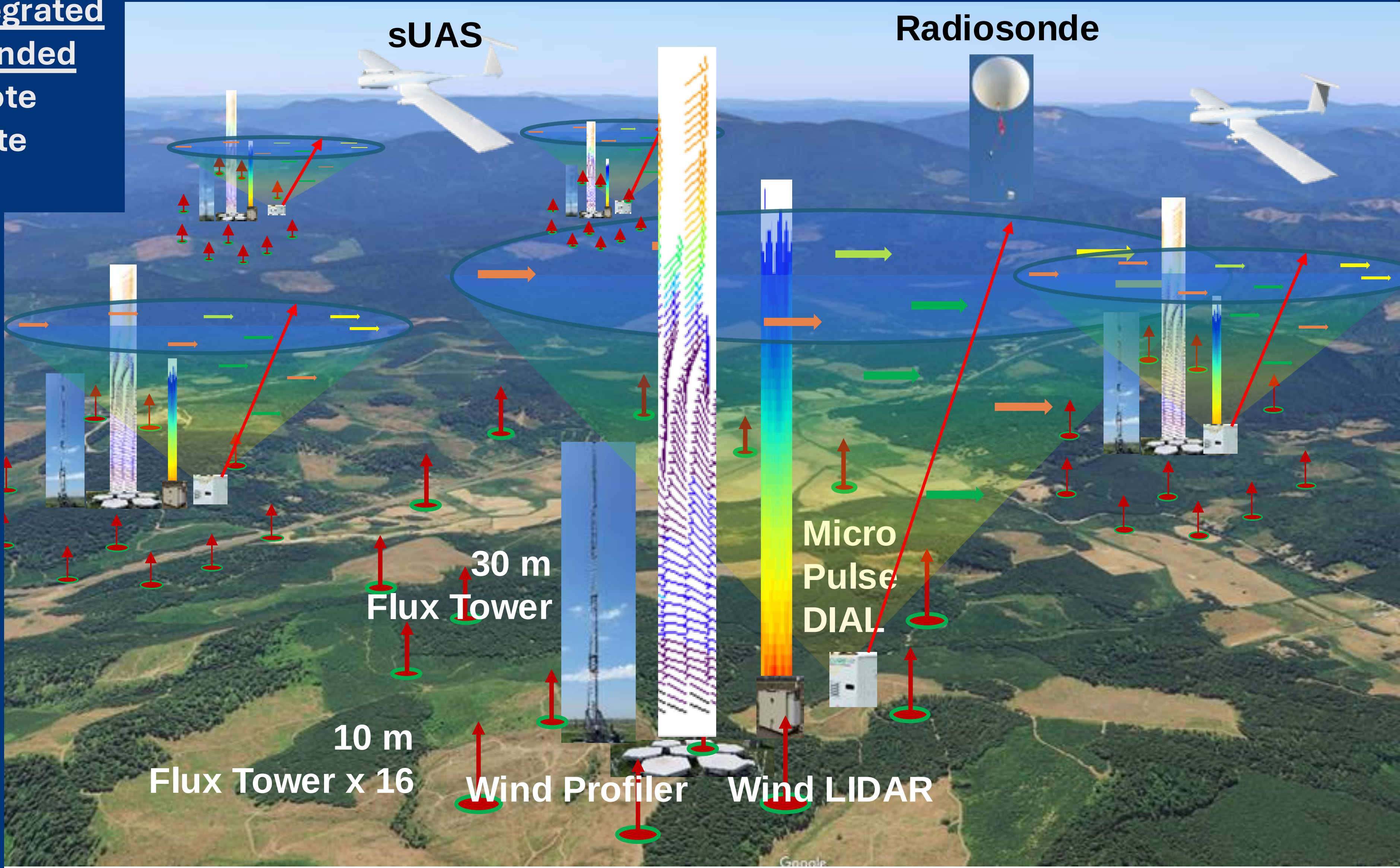


Bringing Observations to Prediction and Predictability

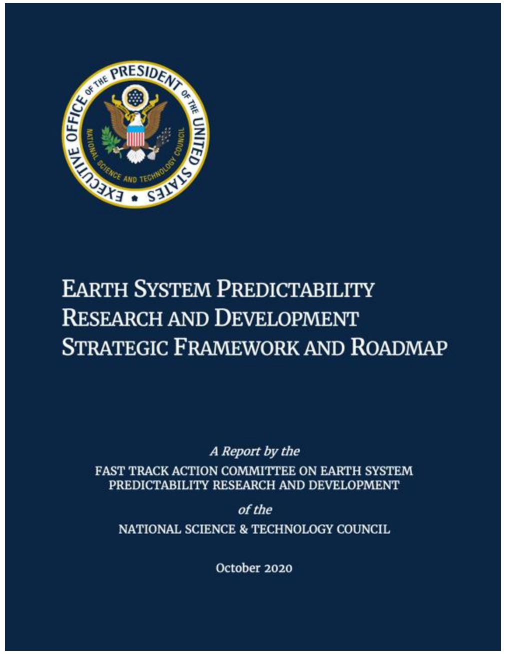
LOTOS: LOwer Troposphere Observing System

Configurable and scalable integrated suite of automated and unattended ground-based in-situ and remote sensors for weather and climate research

- Quasi-3-D sensing of the lower troposphere with horizontal distribution of properties at the Earth's surface
- Full kinematic and thermodynamic profiles at five nodes
- Multiple observations of exchange processes across the land-surface interface and between BL and the free atmosphere



Data Quality Assurance & Characterization for Earth System Predictability



"There is a gap between available observations from all platforms and their full utilization to address the understanding of Earth System Predictability (ESP) and accelerate the advancement of predictions and projections."

- ***Error characterization*** is essential for every data application from basic process research, to theory and model evaluation, to data assimilation/fusion, and other advanced computational approaches such as ML/AI. It is required for cross-disciplinary collaboration among Earth system, computational, and data scientists.
- ***Uniformity of data calibration, collection, processing, and formatting*** promotes error characterization and combining data from different platforms and across agencies/organizations. It is required for ensuring community access to data, developing partnerships, and building collaborations across research organizations, networks, and centers that is needed for advancing ESP.
- These are consequential barriers to progress in ESP including aerosol-cloud interaction research.

"Agencies and departments could enhance their existing coordination and collaboration on investments for the infrastructure necessary to handle the large amounts of data generated by all observational platforms to ensure data are findable, accessible, interoperable, and reusable…" (FAIR).

Earth Observations for Climate Predictability and Solutions for Society

Predictability of Complex Systems

- Systems theory
- Holistic systems study – observational & experimental approaches
- Novel computational approaches

Focus on interfaces

- Relationships and non-linearities

End-to-end approach to Observing

- Co-Design: Purposeful observation and experimentation
- Optimal Experimental Design
- Uniform and accessible data structures
- Integration with modeling and novel computational frameworks

expertise + capabilities

grand challenges + opportunities

partnerships