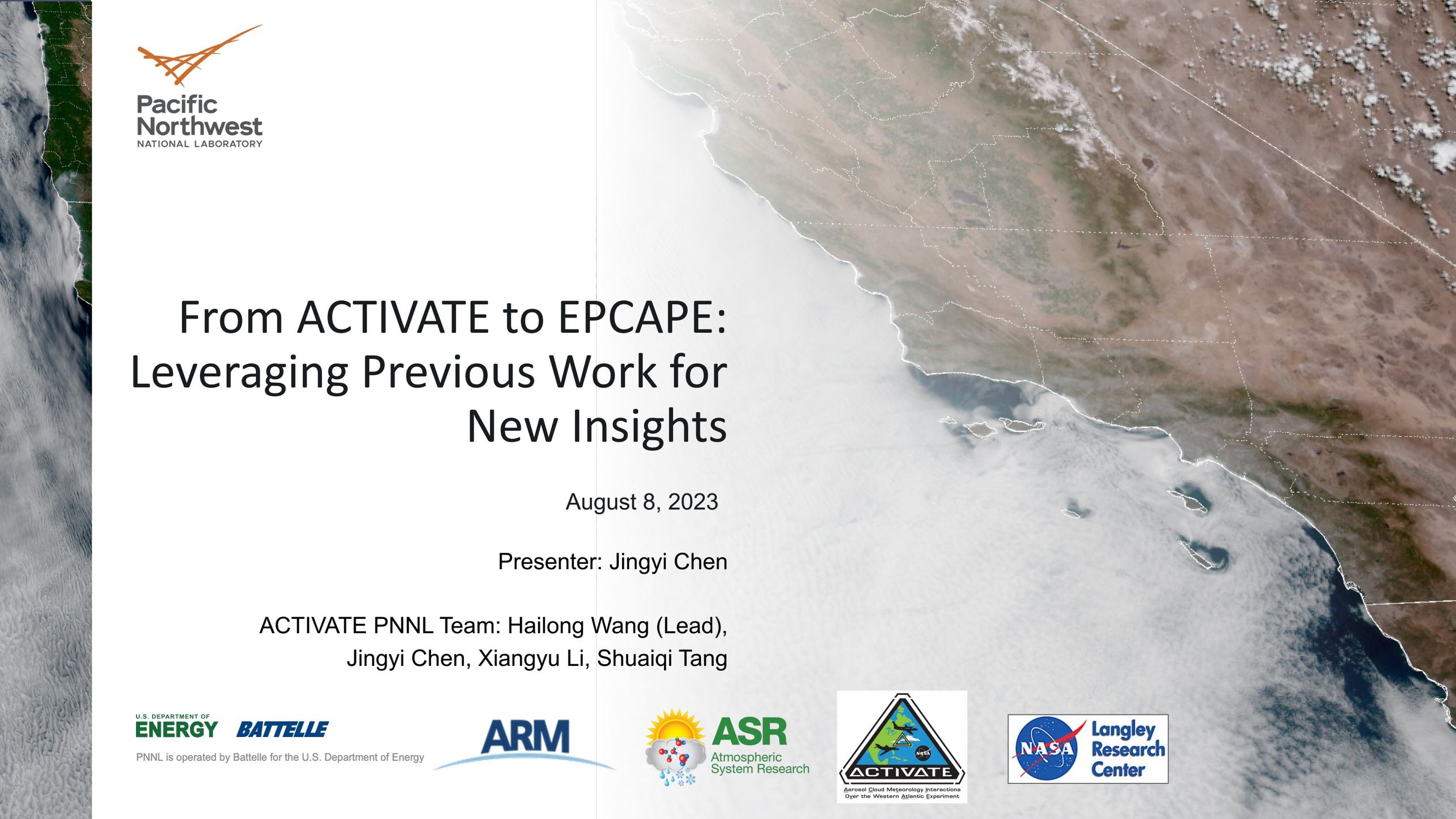


Pacific Northwest NATIONAL LABORATORY

From ACTIVATE to EPCAPE: Leveraging Previous Work for New Insights

August 8, 2023

Presenter: Jingyi Chen

ACTIVATE PNNL Team: Hailong Wang (Lead), Jingyi Chen, Xiangyu Li, Shuaiqi Tang

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

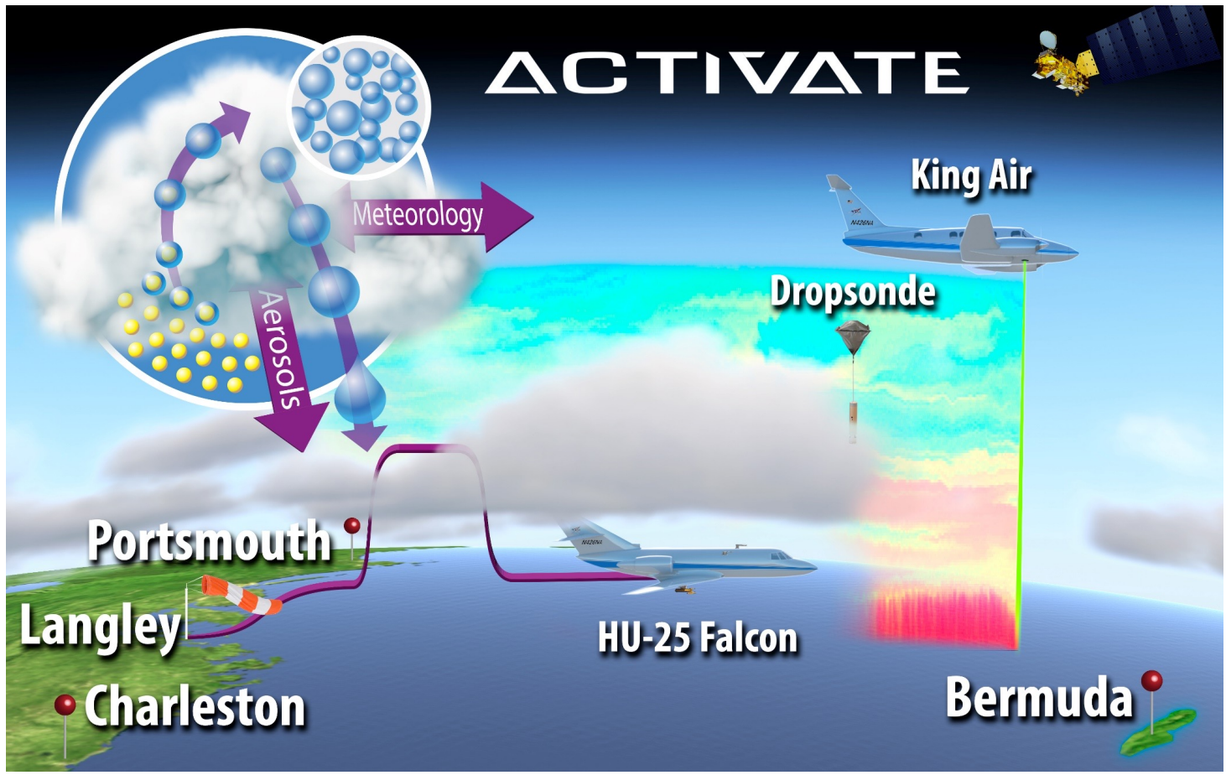
ARM

ASR Atmospheric System Research

ACTIVATE Aerosol Cloud Meteorology Interactions Over the Western Atlantic Experiment

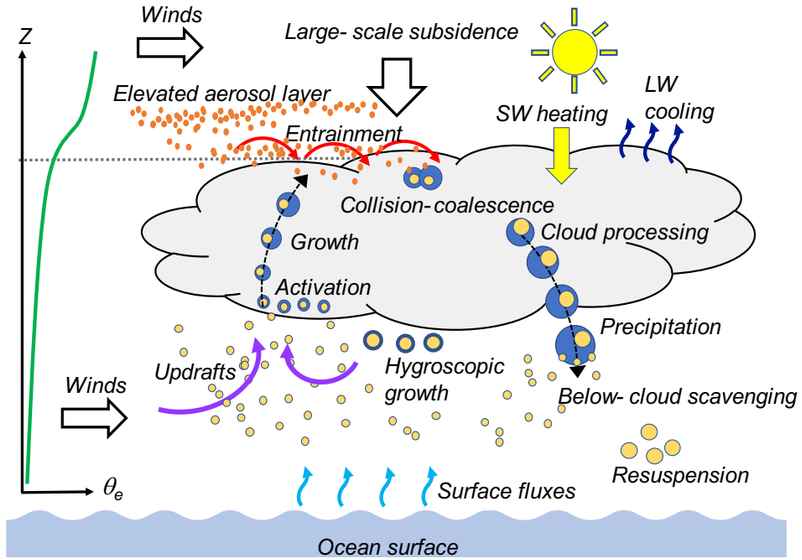
NASA Langley Research Center

Overview of ACTIVATE Project



Aerosol Cloud meTeorology Interactions oVer the Western Atlantic Experiment (ACTIVATE)

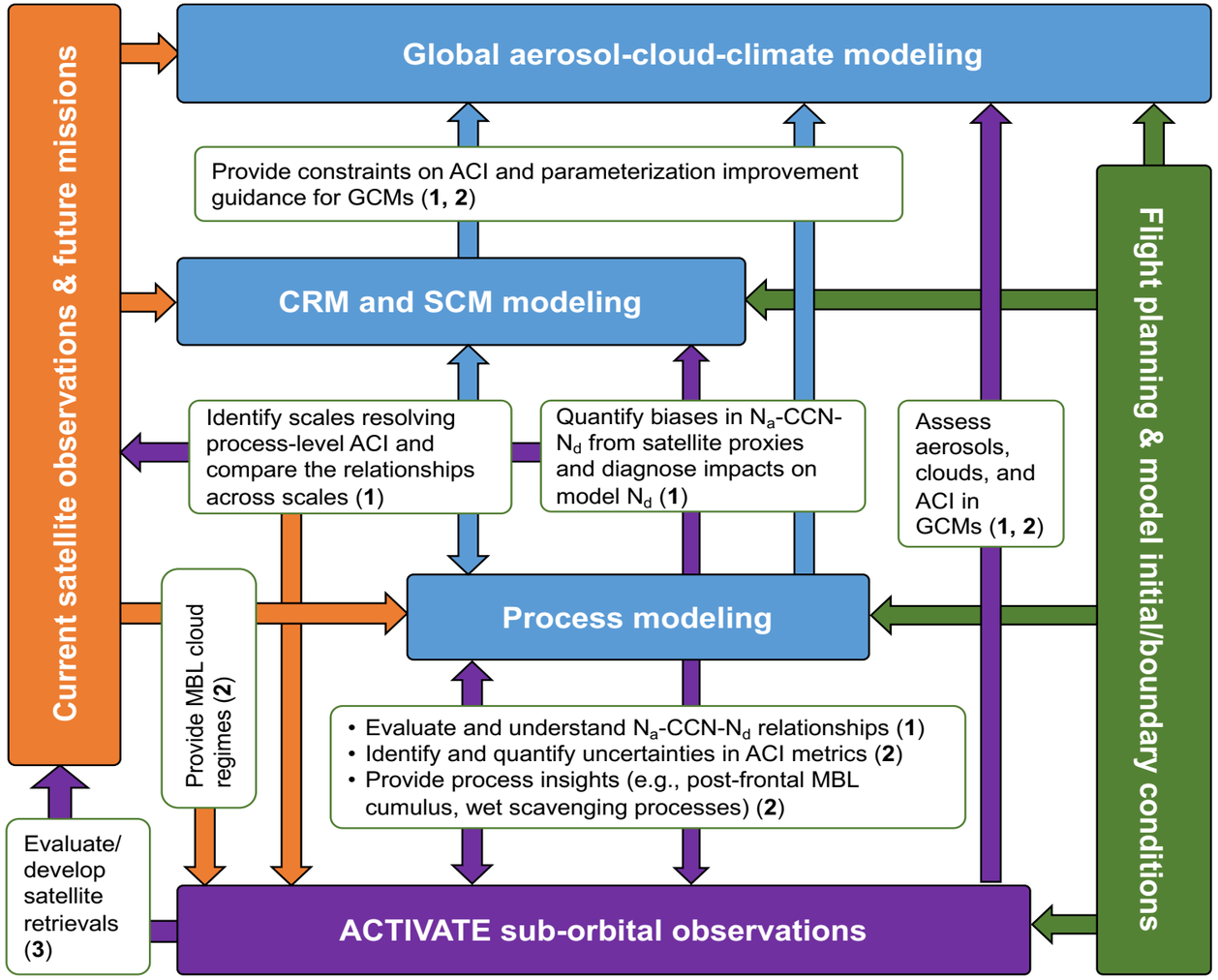
PI: Armin Sorooshian



Sorooshian et al. (2019), BAMS

Science: Build **unprecedented dataset** to better understand aerosol-cloud-meteorology interactions, improve physical parameterizations for Earth system and weather forecasting models, assess remote sensing retrieval algorithms, and guide plans for future satellite missions.

ACTIVATE Modeling Approach (PNNL)



PNNL Team Lead: Hailong Wang

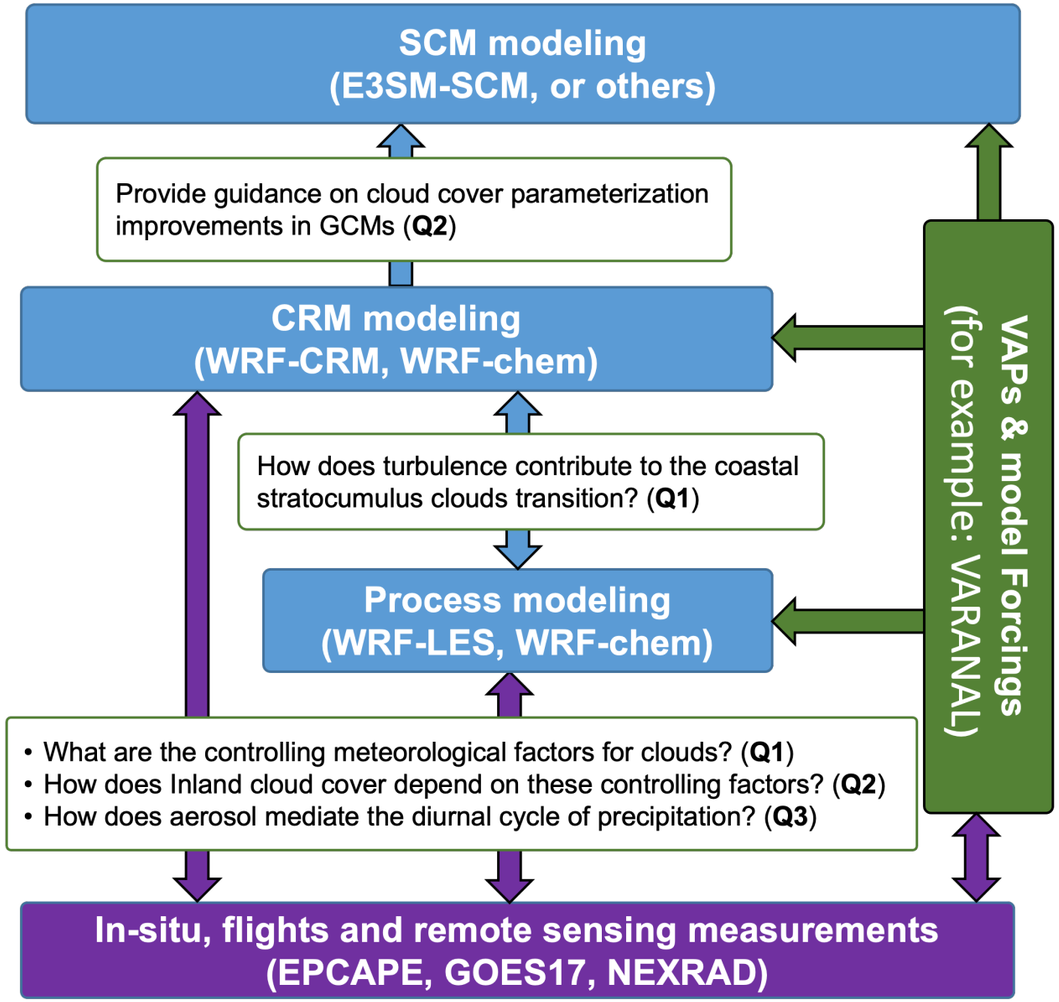
- To provide process insights and quantify N_a-*CCN*-N_c relationships under different meteorological conditions with observational constraints from the measurements
  - WRF Large-Eddy Simulation (LES)
  - WRF Cloud-Resolving Modeling (CRM)
- To evaluate/improve the representation of ACI processes in ESMs
  - Diagnostic package for ESMs
  - Sing-column E3SM model simulations
  - Global model simulations

Outline of Planned EPCAPE Modeling Approach

- What are the key controlling factors and properties associated with meteorological conditions for marine stratocumulus clouds at the coast? How does inland cloud cover depend on turbulence, cloud microphysical, and cloud radiative properties? (Q1 and Q2)
  - WRF-CRM
  - E3SM-SCM

- To evaluate/improve the representation of ACI processes in Models (Q3)
  - WRF Cloud-Resolving Modeling (CRM)
  - WRF Large-Eddy Simulation (LES)
  - WRF-Chem Simulations

EPCAPE Modeling Plan



Measurements serve as input for the model and are used to evaluate the simulation.

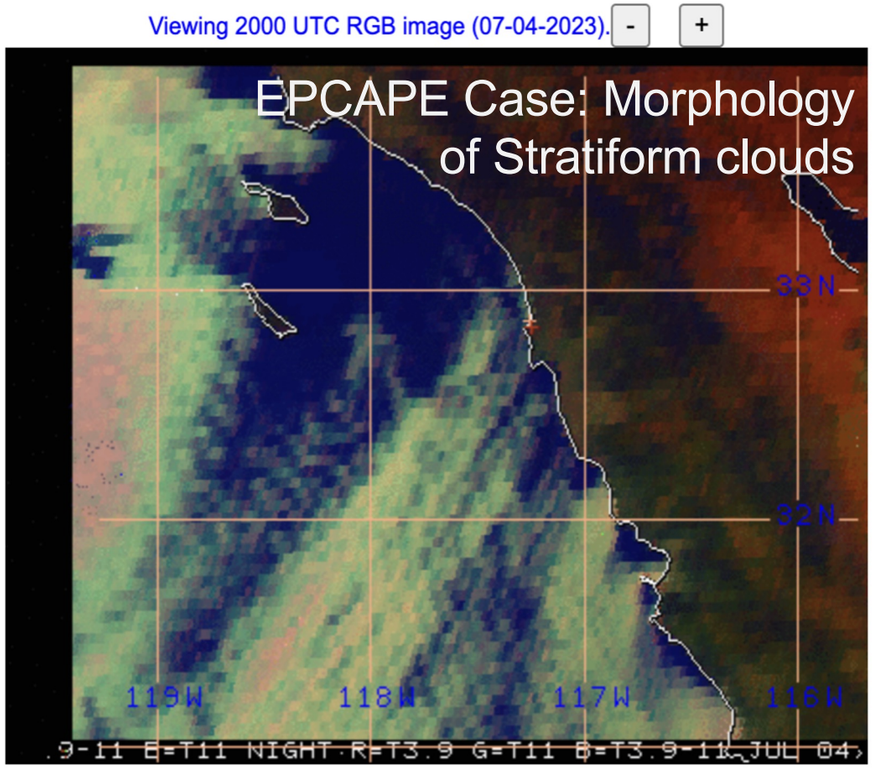
Modeling Plan 1: WRF-CRM and Implications for cloud cover parameterization in ESMs

EPCAPE Scientific Questions

Q1: What are the key controlling factors and properties associated with meteorological conditions for marine stratocumulus clouds at the coast?

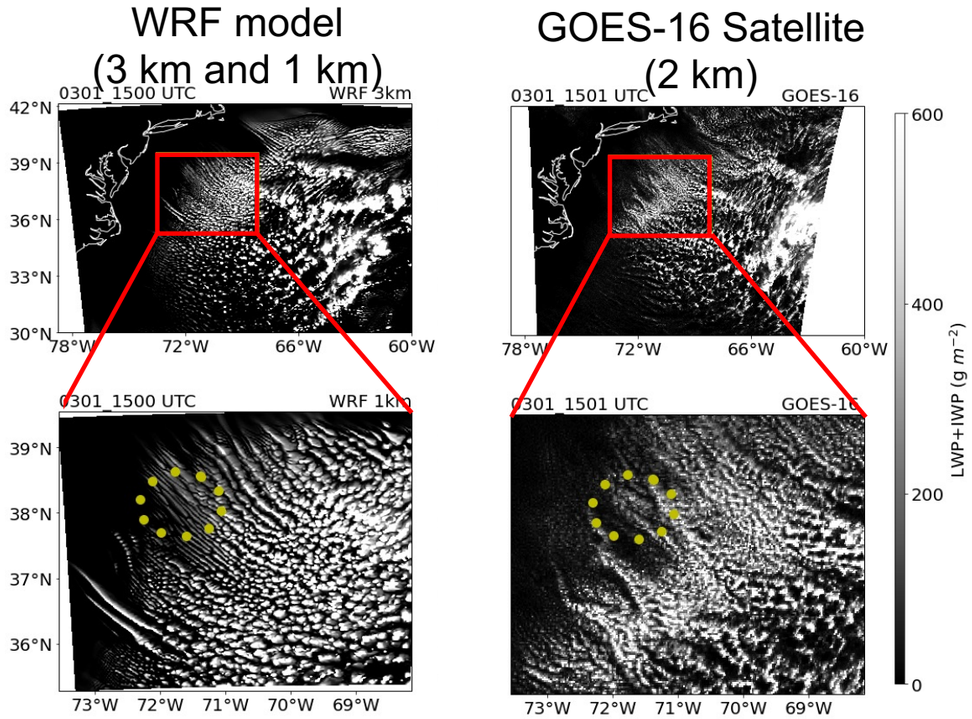
Q2: How does inland cloud cover depend on turbulence, cloud microphysical, and cloud radiative properties?

WRF-CRM simulations will be used to identify the key factors impacting the cloud cover



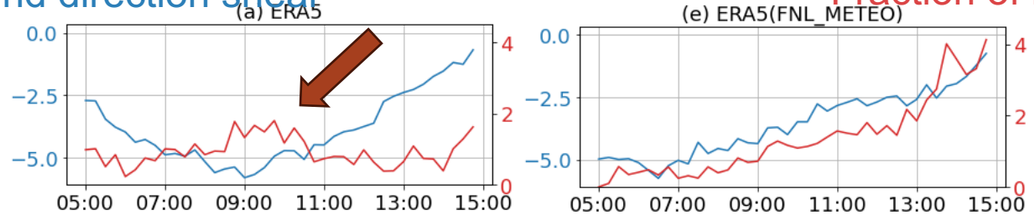
- WRF-CRM simulations with different forcings
  - at ~km grid spacings, 24 hrs run
- Uniqueness in EPCAPE:
  - Diurnal Cycle measurements (Sondes)
  - Cloud cover that extends inland
  - VAPS, for example: VARANAL

CRM Example: Chen et al., 2022, JAS



Left y-axis:
Wind direction shear

Right y-axis:
Fraction of long rolls

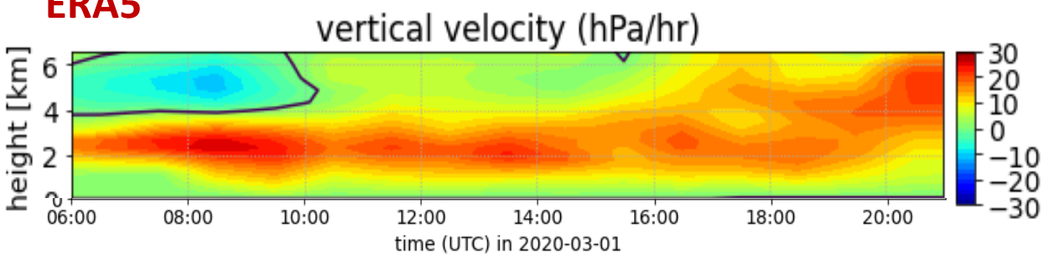


E3SM SCM will be used to identify the bottleneck in cloud cover parameterization

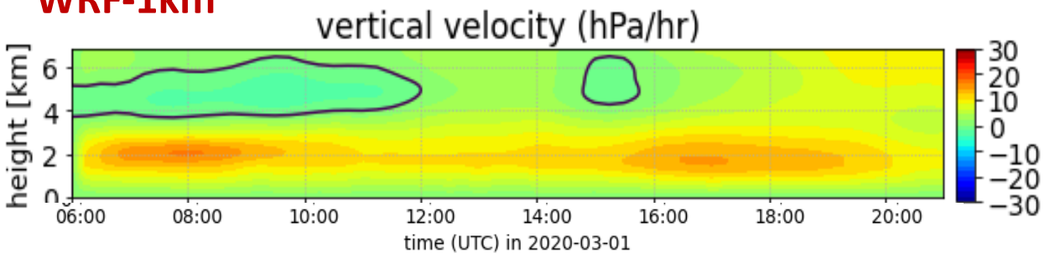
Large-scale forcing:

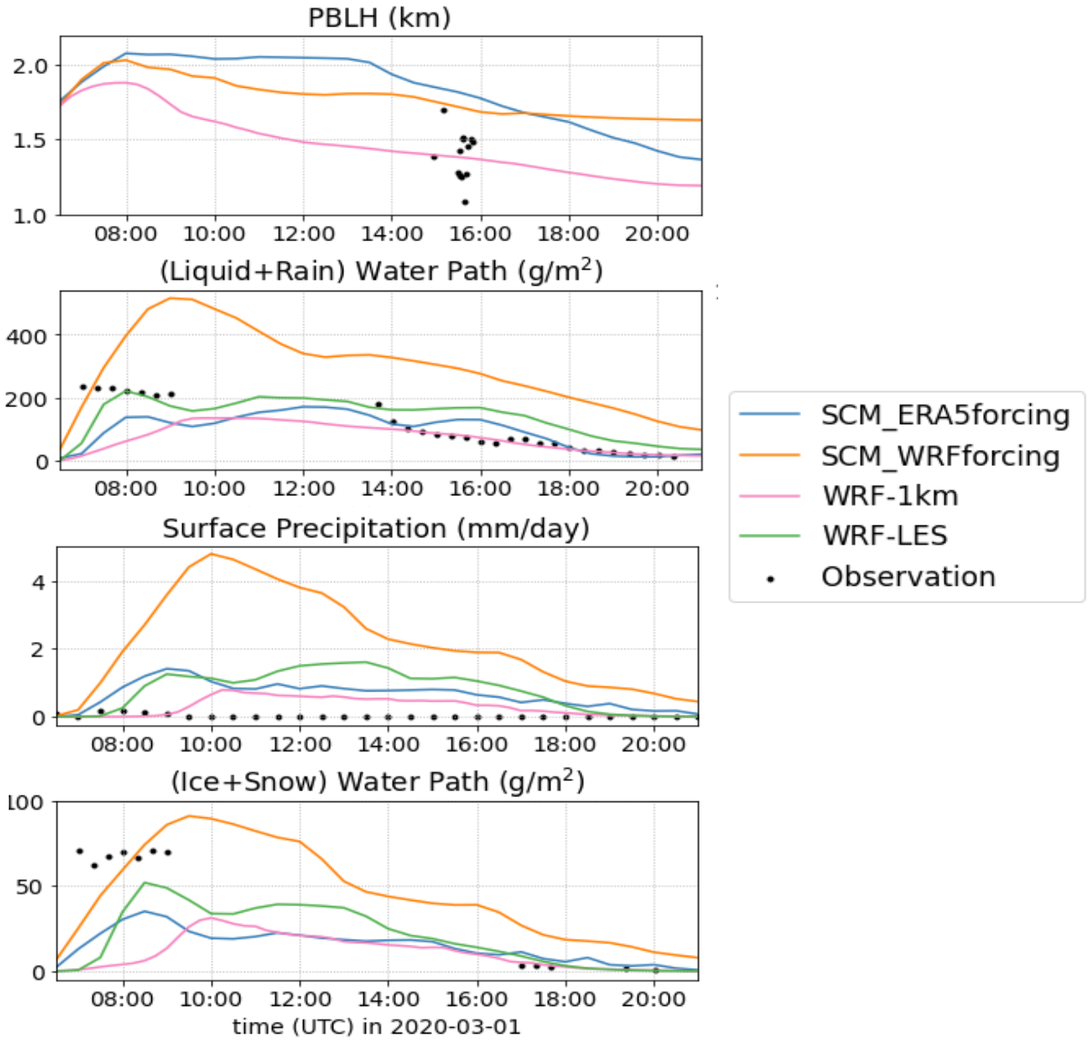
1. From ERA5 reanalysis
2. From WRF nested simulation (WRF-1km)

ERA5



WRF-1km





Tang et al., 2023, In prep.

Modeling Plan 2: WRF-CRM and WRF-LES for ACI studies

EPCAPE Scientific Questions

Q1: How does the contribution of turbulence to coastal stratocumulus clouds change? Do other factors like aerosol play a role?

Q1: How much do giant CCN and turbulence contribute to droplet spectral broadening?

Q3: How are aerosols processed in a cloud and what is the role of entrainment and detrainment? Do these processes feedback onto the cloud properties?

Q3: How does aerosol mediate the diurnal cycle of precipitation? Does this vary depending on either aerosol amount or CCN spectrum (activation curve as a function of supersaturation) associated with different air mass regimes?

WRF-LES, with Lagrangian forcings, will enable exploring the influence of diurnal cycle in cloud cover.

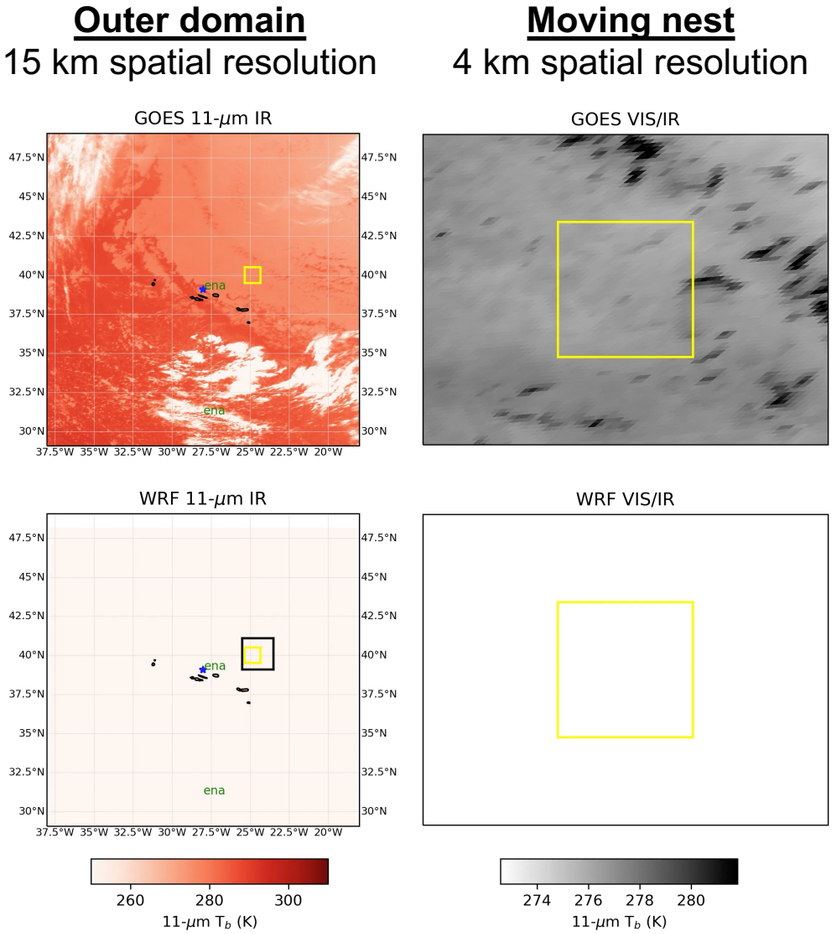


Figure Courtesy of Matthew Christensen

- Simulate fast evolving cloud systems with complex dynamics, cloud morphology, and moisture source using WRF-LES driven by Lagrangian heterogeneity (boundary conditions, large-scale forcings).

WRF-LES will be used for ACI with measured aerosol size distributions from coastal sites and IOP flights

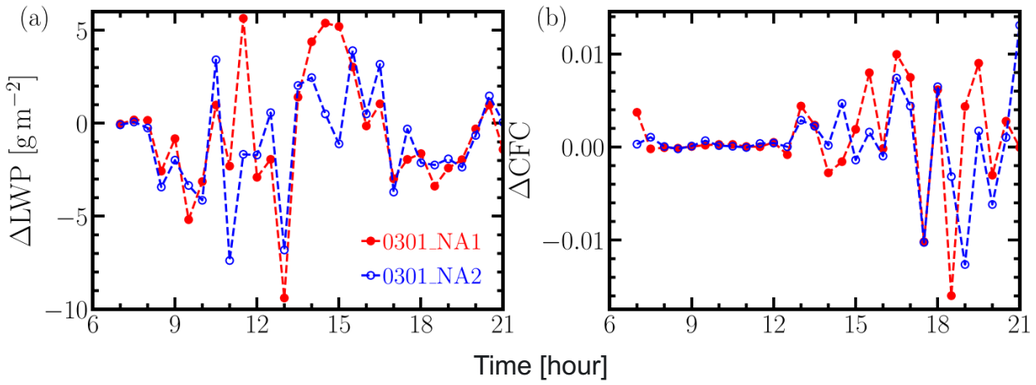
Sensitivities of clouds to aerosols

Measured Aerosol Size Distribution

TABLE 2. Fitted parameters of the aerosol size distribution for the 1 Mar case shown in Fig. 2.

		N (cm^{-3})			μ (nm)			σ		
BCB leg	Time (UTC)	N_1	N_2	N_3	μ_1	μ_2	μ_3	σ_1	σ_2	σ_3
BCB1	1453:22–1501:45	940	645	—	22.4	104.2	—	1.51	1.47	—
BCB2	1551:21–1555:06	996	1192	1118	19.0	30.2	102.3	1.49	1.31	1.51

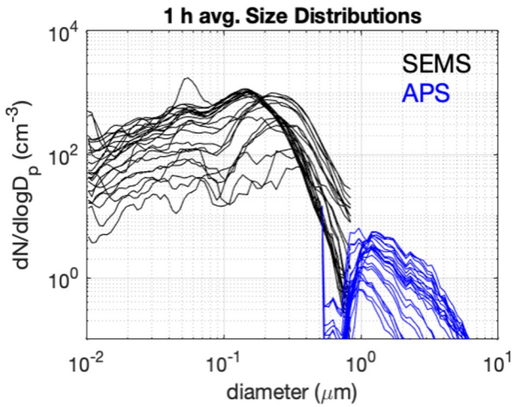
Y-axis: Differences between measured and assumed constant values.



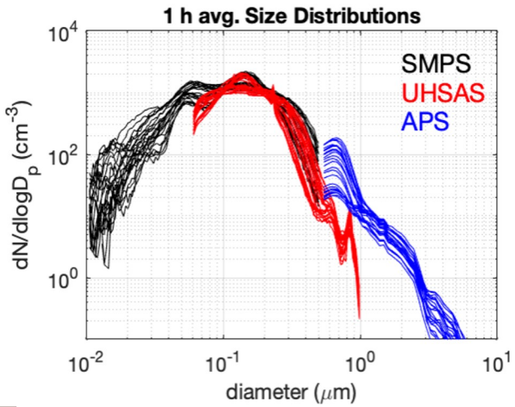
WRF-LES example (Li et al., 2023, JAS)

EPCAPE Aerosol Size Distribution

Mt. Soledad



Scripps Pier



- WRF-LES simulations with different aerosol size distribution
  - Measured aerosols v.s. idealized aerosols
  - Perturbed number concentration
  - Perturbed size distribution

WRF-Chem will be used for studying the impacts of aerosol sources on cloud morphology and cloud cover

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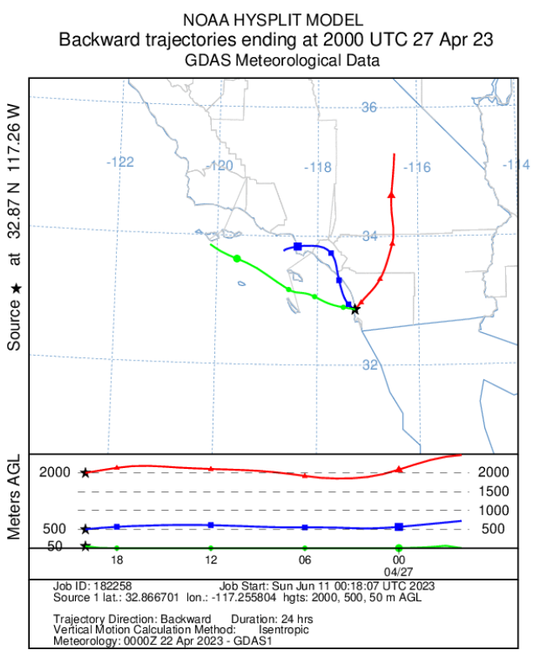
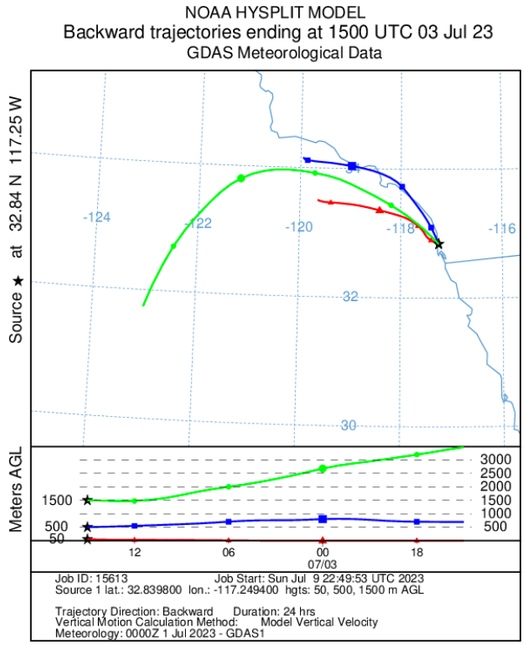
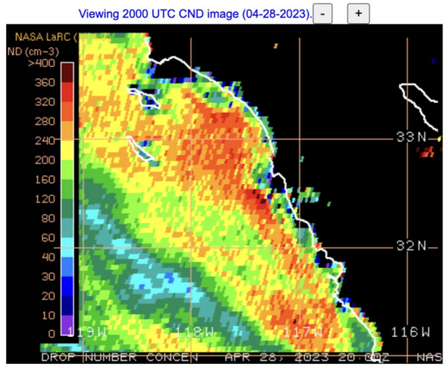
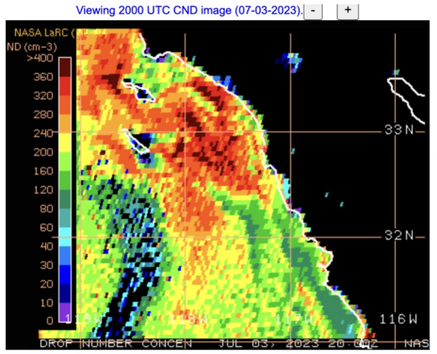
EPCAPE examples





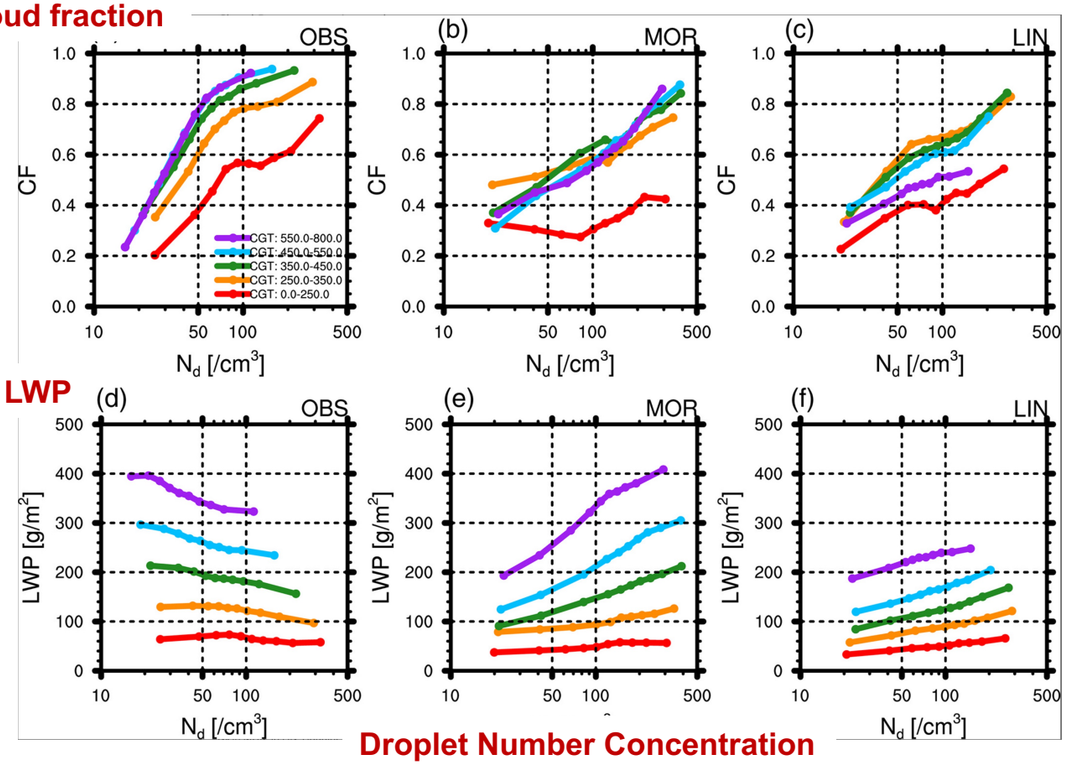
N_d





Cloud fraction

LWP

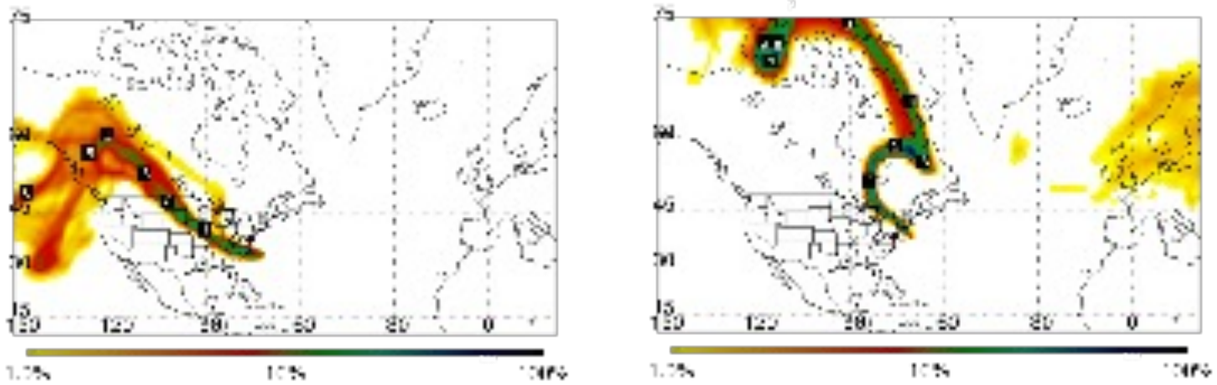


Droplet Number Concentration

Liu et al., 2020, JGR

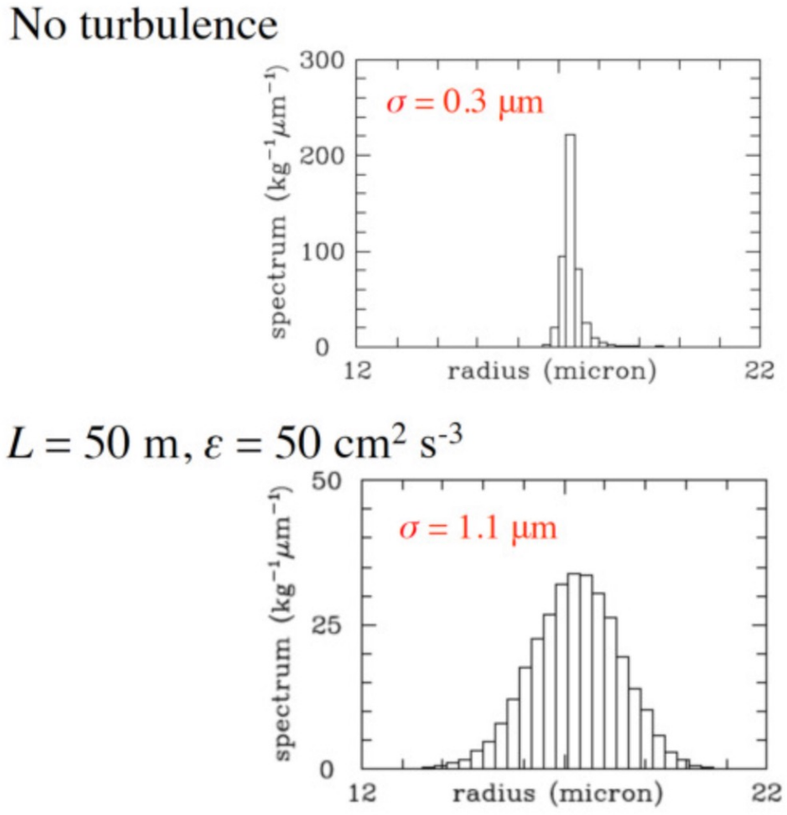
- EPCAPE cases with contrast aerosol sources from land and ocean

WRF-LES ensemble trajectories will enable exploring spectral broadening in parcel model with bin/super-droplet setups



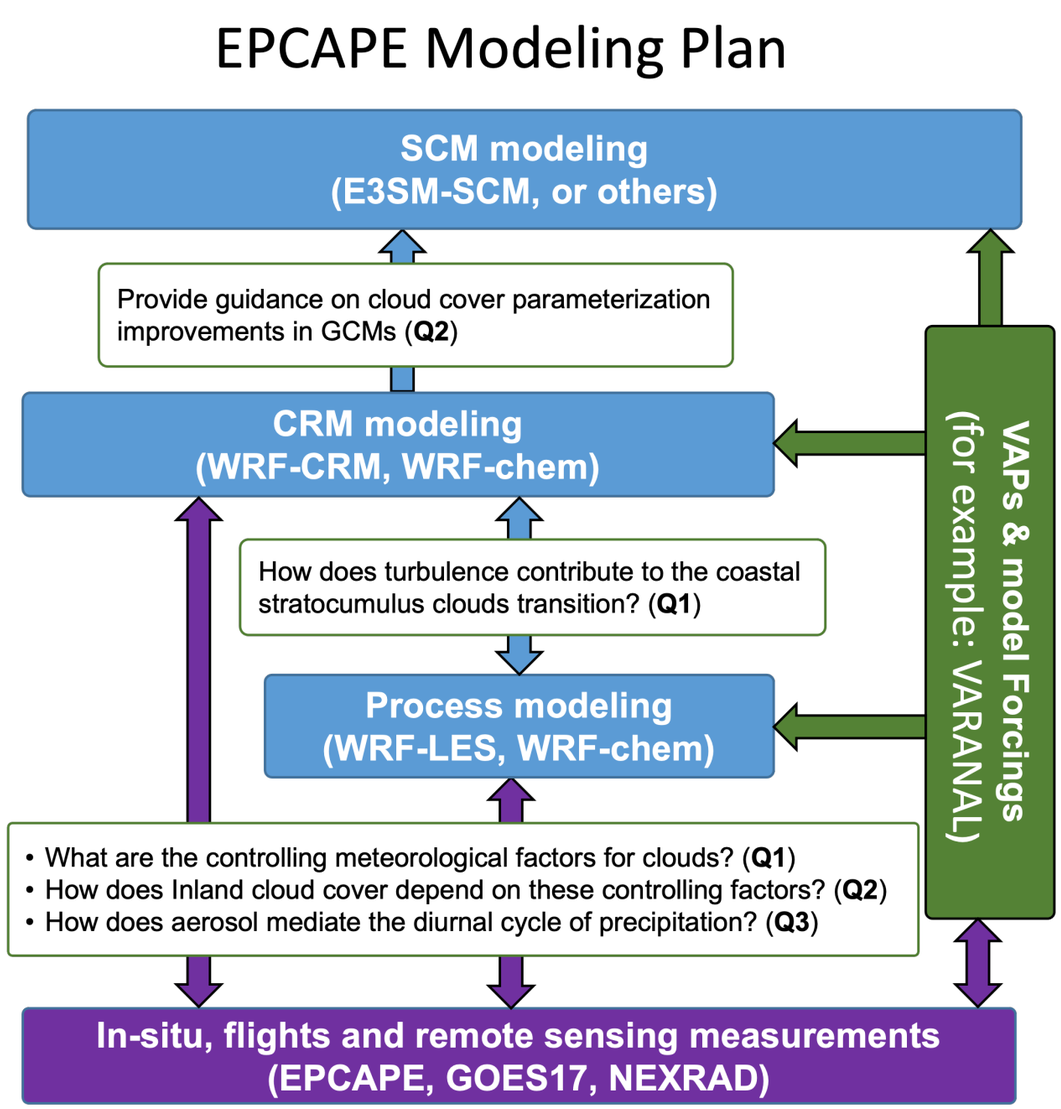
Flexpart Trajectories from GOES (Figure Courtesy of B. Zhang)

- WRF-LES with flexpart provides the turbulent ensemble trajectories.
- Enable exploring impacts of aerosol sources and spectral broadening on the formation of rain drops.
- Q3: How does aerosol mediate the diurnal cycle of precipitation? Does this vary depending on either aerosol amount or CCN spectrum (activation curve as a function of supersaturation) associated with different air mass regimes?



Grabowski W and G Abade. 2017

Summary of EPCAPE Modeling Plan and Potential Collaborations



- **Idealized-case WRF-LES**
  - Low Cloud Cases
  - Driven by Lagrangian and Eulerian forcings
  - Driven by measured aerosol conditions
  - Ensemble trajectories
- **Real-case WRF-CRM**
  - Low Cloud cases
  - Sensitivity tests with different boundary conditions (reanalysis, VARANAL, etc.)
- **WRF-Chem with bin (or super-droplet) scheme**
  - Low Cloud cases
  - Sensitivity test with different aerosol number or CCN spectrum
- **WRF output in netcdf**
  - State variables (T, P/Z, Q, U, V, W)
  - Shortwave and longwave radiative fluxes
  - Turbulent fluxes, cloud and other hydrometeors
  - Every 30 minutes
- **Climate model simulations**
  - E3SM SCM results

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Thank you

Questions:
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