TRACER-MIP Roadmap

Steve Saleeby and Jiwen Fan
May 2024

TRACER-MIP Objective and Hypotheses

Objectives:

- Identify each **model's deficiencies** and **measure** model performances.

- **Examine factors/processes** leading to the model biases and large model spread, both of which were not less emphasized in the previous MIP. This effort will ultimately help reduce the ACI uncertainty.

Hypotheses:

- The different **representations of condensation and ice microphysics** are the major source of inter-model spread, thus, leading to the main model differences in the simulation of ACI;
- The models that **reproduce** the observed cases and employ **explicit calculation** of condensation give **qualitatively consistent ACI effects**, particularly for the effect of ultrafine particles.

TRACER-MIP Approach

The TRACER MIP follows the protocol of the previous ACPC MIP, with the following new features:

- Extensive model evaluation against observations.
- Two golden cases with different dynamic, thermodynamic, and aerosol conditions.
- Ultrafine aerosol will be considered. Two tiers: prescribed and prognostic aerosols.
- Focus on factors/processes leading to model biases and large model spread.

TRACER-MIP Cases

Choose two cases to simulate from the “Golden” TRACER cases

Cases below were chosen since they mostly met the following criteria:
1. Data available - SMPS aerosols, soundings (5 per day), NEXRAD CAPPI, C-SAPR cell tracking
2. Convection observed and cells tracked

June 17:

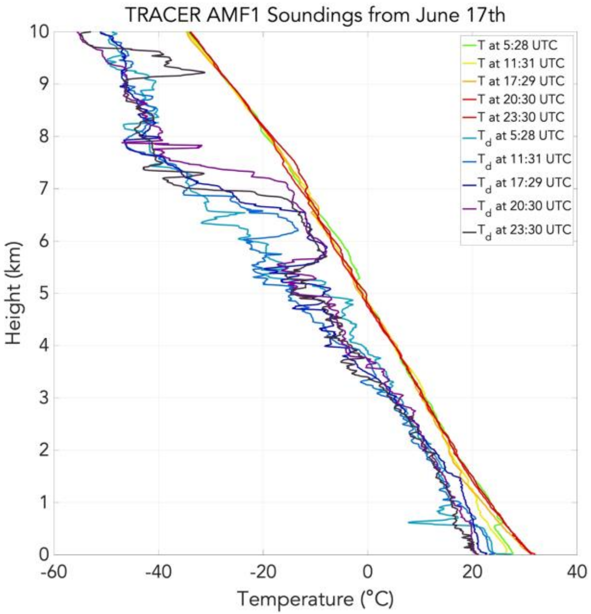
Good sea-breeze convection and large-scale convection scattered across domain.
Overlaps with ESCAPE (aircraft & ground operations).
Mostly clean marine aerosols. Yes SMPS. No ACSM.
Toshi Matsui’s NU-WRF modeling skill score: 71

Aug 07:

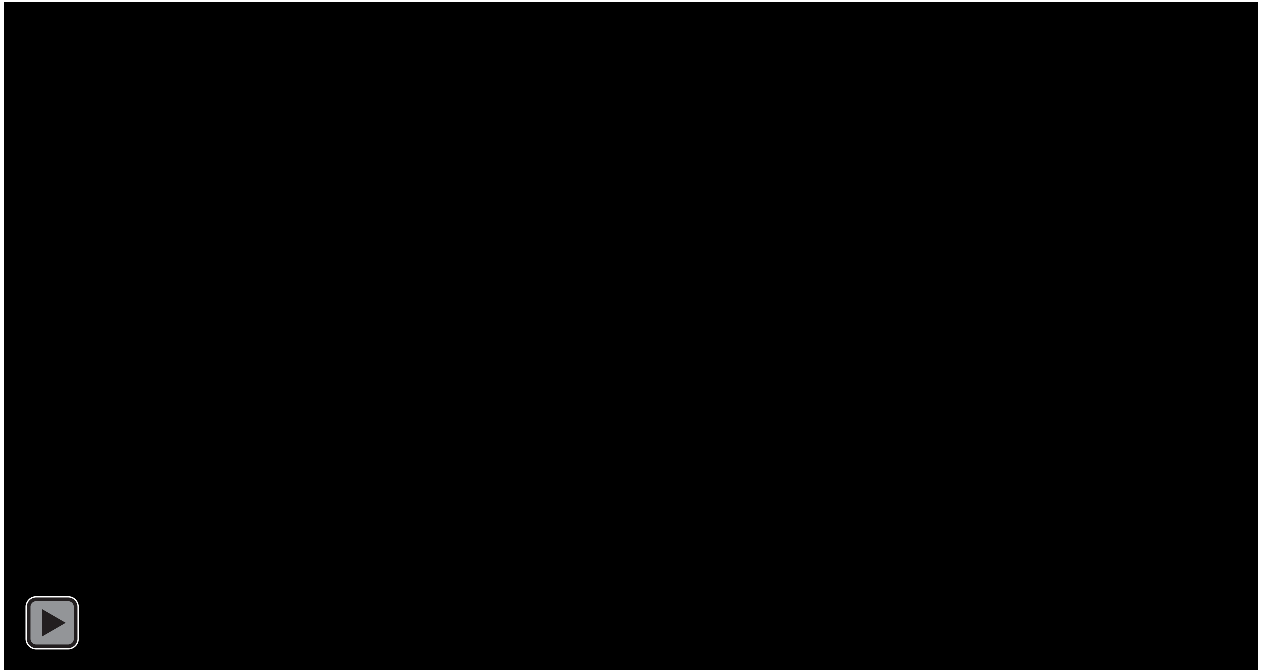
Early sea-breeze, consistent onshore flow. Isolated convection day.
Moist throughout the column.
CHIVO Radar available and TAMU Observations.
Polluted aerosols early, clean marine after sea-breeze. Yes SMPS & ACSM.
Toshi Matsui’s NU-WRF modeling skill score: 70

June 17th Case

Soundings

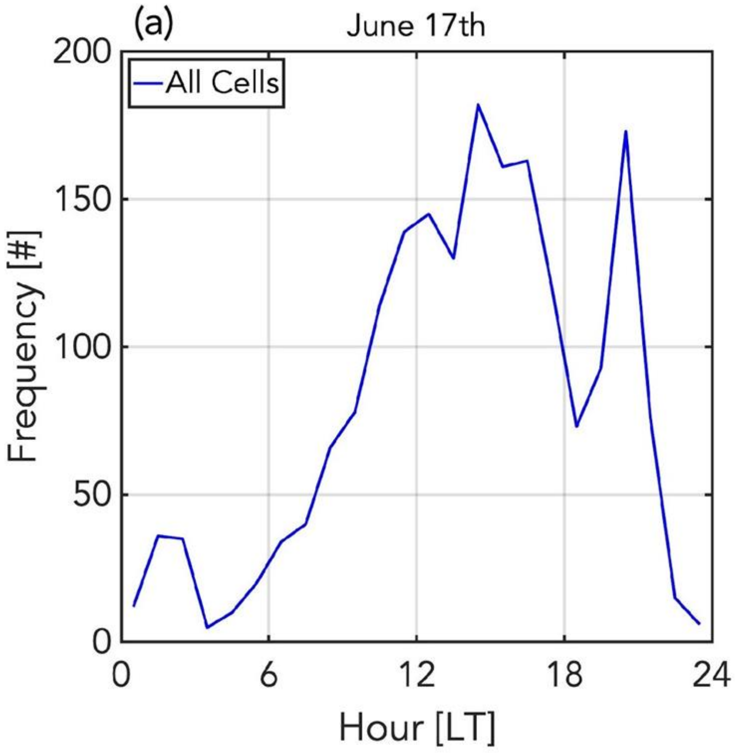


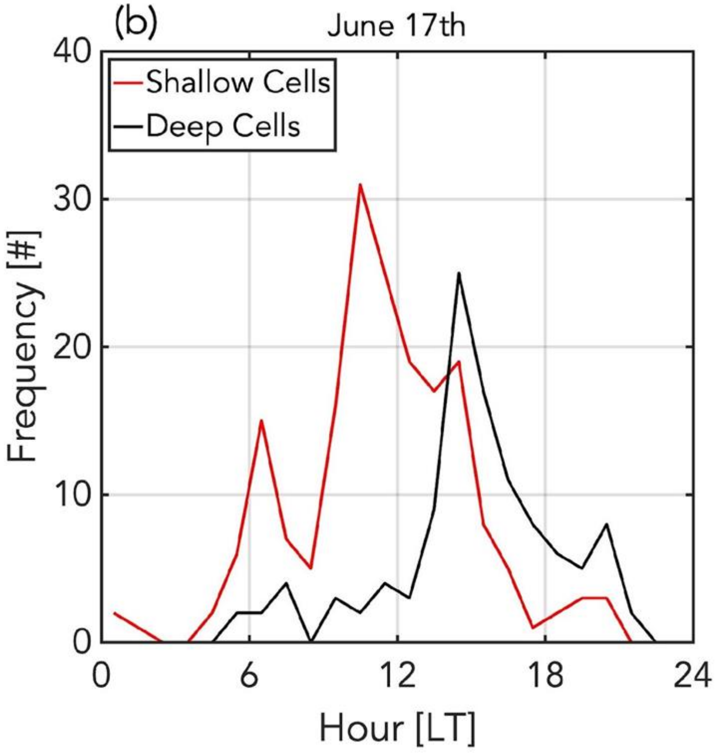
Composite radar reflectivity from WSR-88D for the convective cells in Houston (mainly 14:30-16:30 Local time)



Provided by Zack Mages (SBU)

June 17th Case: MCIT tracking

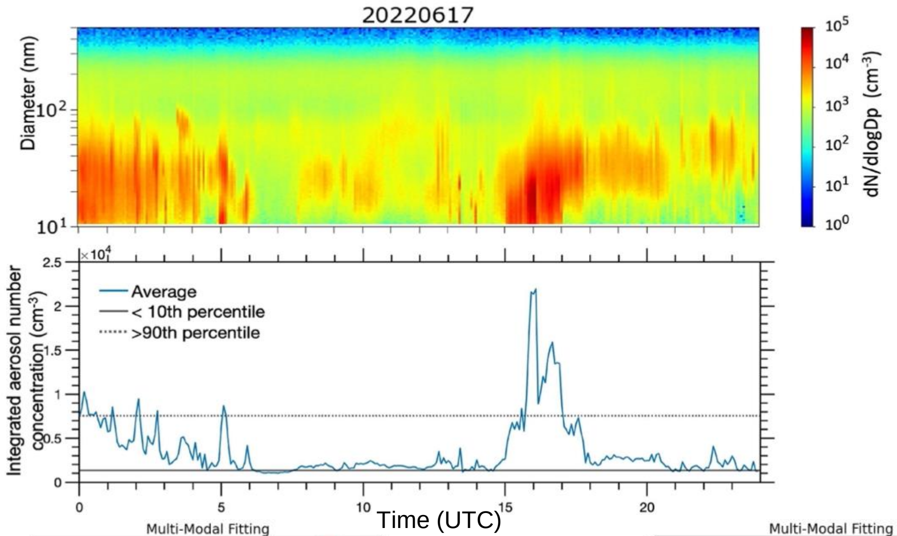




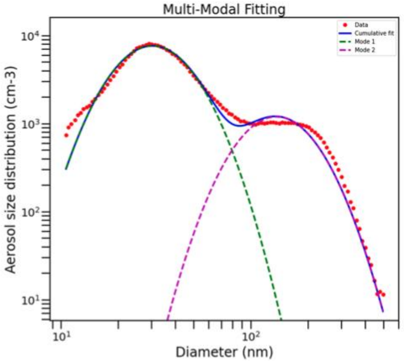
Provided by Zack Mages (SBU)

June 17th Case

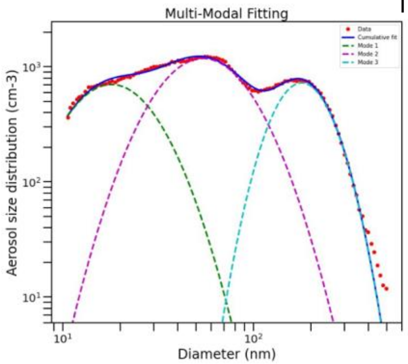
*Aerosol analysis provided by Chongai Kuang and Tamanna Subba.
From the SMPS at the ARM AMF1 site La Porte, TX.



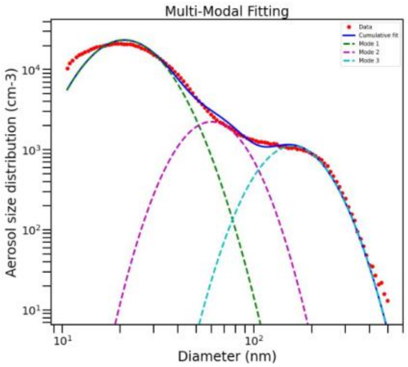
Pre-Convection Conditions



Daily 10th Percentile



Daily 90th Percentile



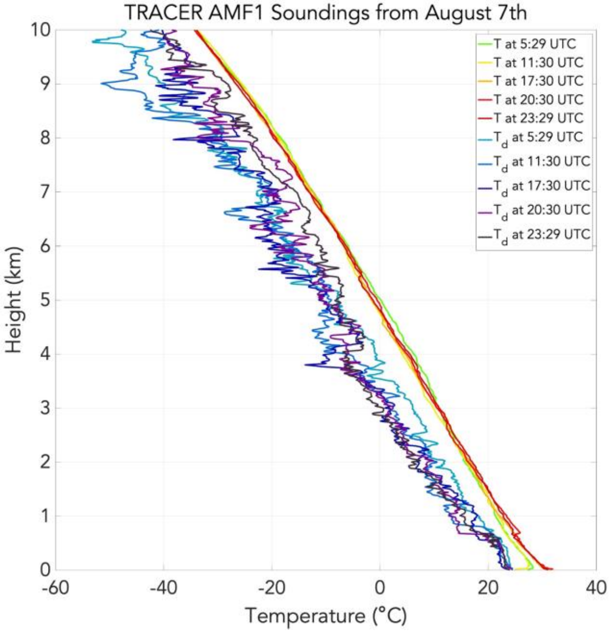
17 June 2022 – before convection- 12:00-14:00 LT	Mode 1	Mode 2	
Total number concentration	3443	531	
Median diameter	30	136	
Sigma	1.5	1.5	

17 June 2022– Clean Average	Mode 1	Mode 2	Mode 3
Total number concentration (cm^{-3})	359	624	245
Median diameter (nm)	18	54	179
Sigma	1.6	1.6	1.4

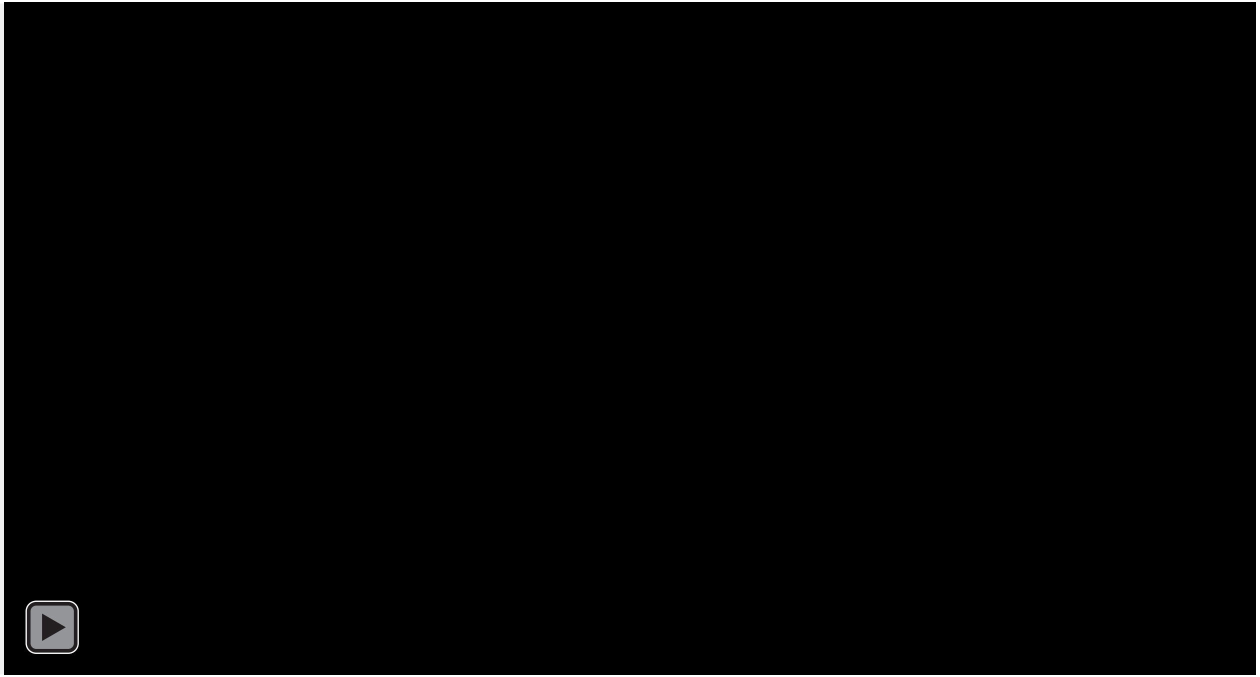
17 June 2022– Polluted Average	Mode 1	Mode 2	Mode 3
Total number concentration (cm^{-3})	10331	825	425
Median diameter (nm)	21	60	159
Sigma	1.5	1.4	1.4

August 7th Case

Soundings

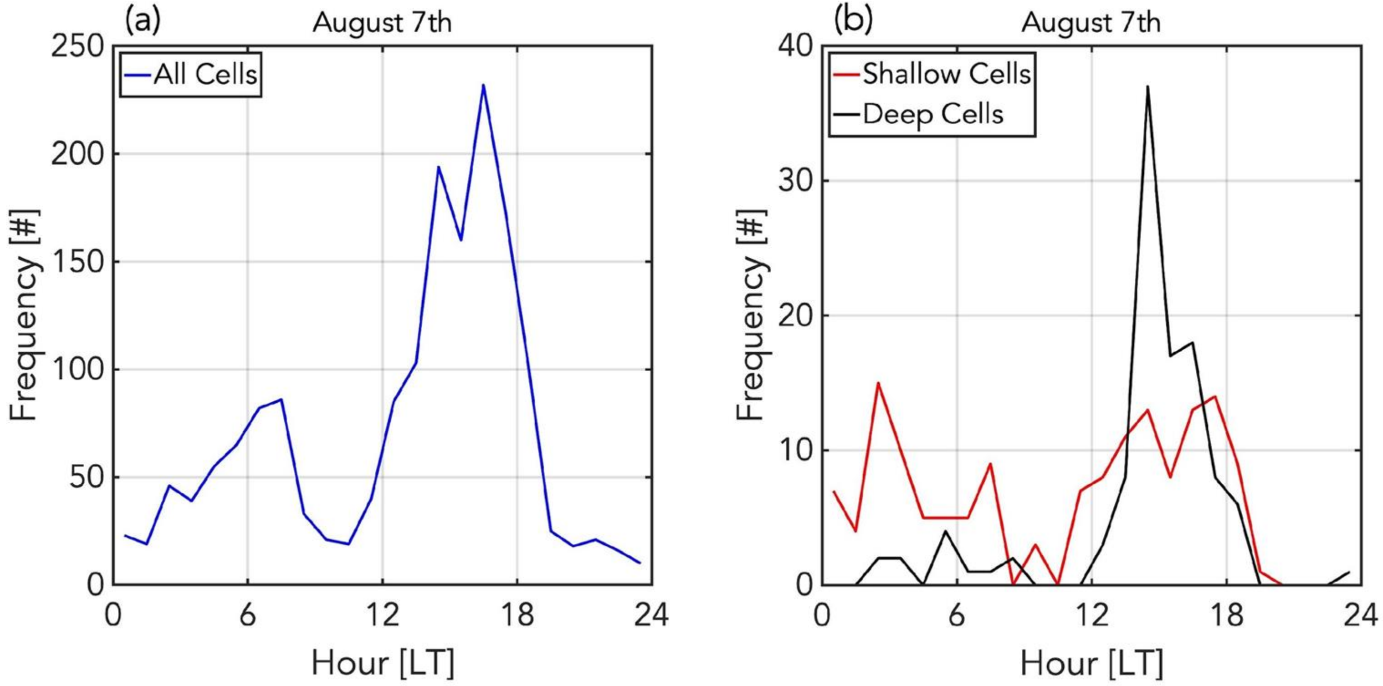


Composite radar reflectivity from WSR-88D for the convective cells in Houston (mainly 13:30-15:30 Local time)



Provided by Zack Mages (SBU)

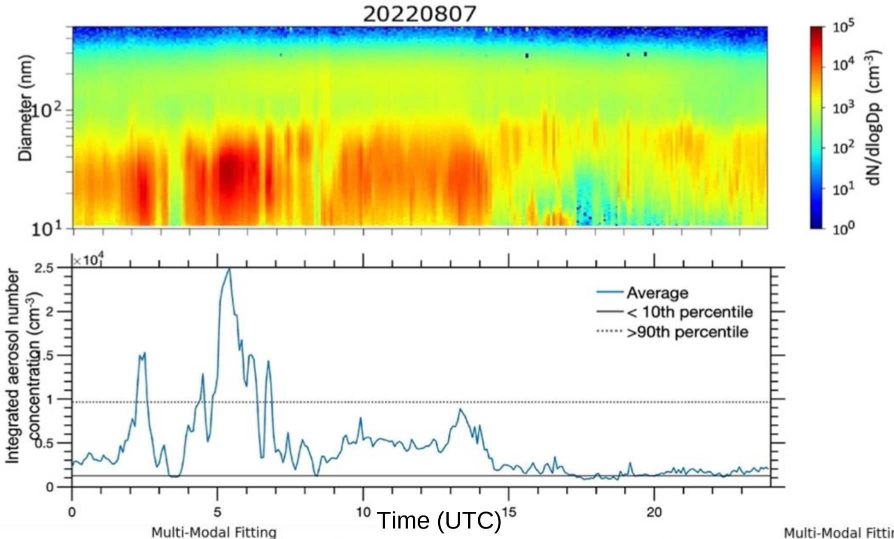
August 7th Case: MCIT tracking



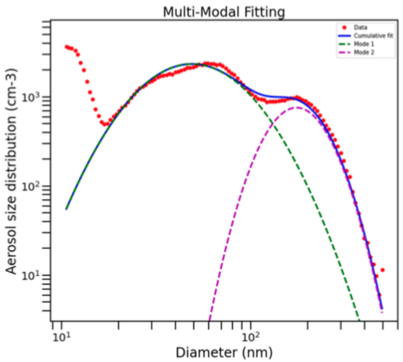
Provided by Zack Mages (SBU)

August 7th Case

*Aerosol analysis provided by Chongai Kuang and Tamanna Subba.
From the SMPS at the ARM AMF1 site La Porte, TX.

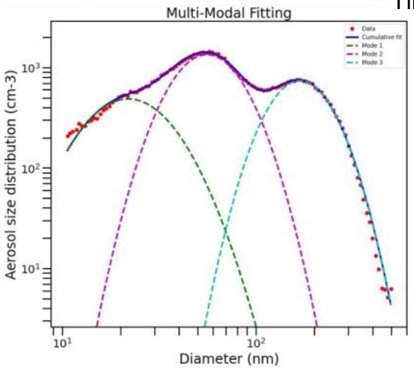


Pre-Convection Conditions



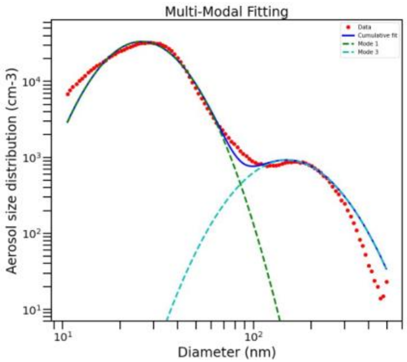
07 August 2022 – before convection- 11:00-12:00 LT	Mode 1	Mode 2
Total number concentration	1425	263
Median diameter	49	175
Sigma	1.8	1.4

Daily 10th Percentile



07 August 2022– Clean Average	Mode 1	Mode 2	Mode 3
Total number concentration (cm^{-3})	251	547	273
Median diameter (nm)	22	56	168
Sigma	1.6	1.5	1.4

Daily 90th Percentile

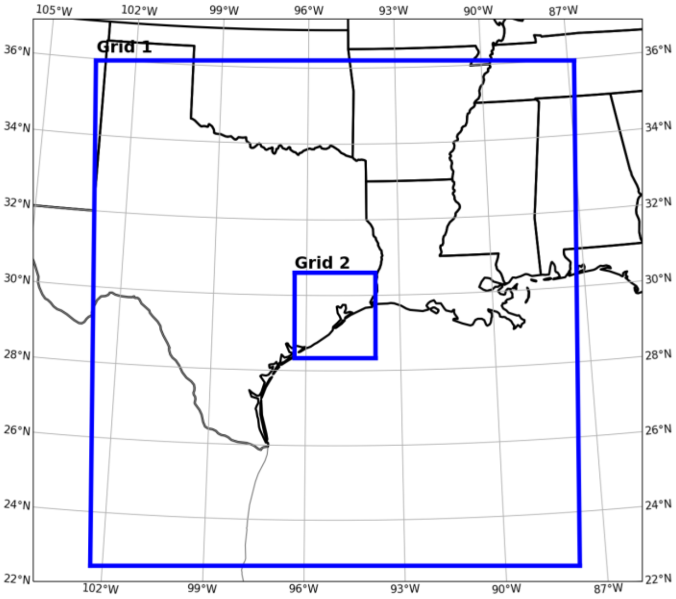


07 August 2022 – Polluted Average	Mode 1	Mode 2	
Total number concentration (cm^{-3})	14744	468	
Median diameter (nm)	26	150	
Sigma	1.5	1.6	

TRACER MIP Domain Setup

Grid-1: 2000 m dx - 750 x 750 points
Grid-2: 500 m dx - 500 x 500 points

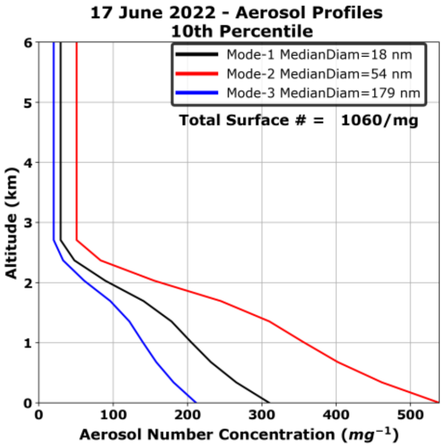
Common Grid Centers & Pole Lat/Lon:
Latitude: 29.4719, Longitude: -95.0792

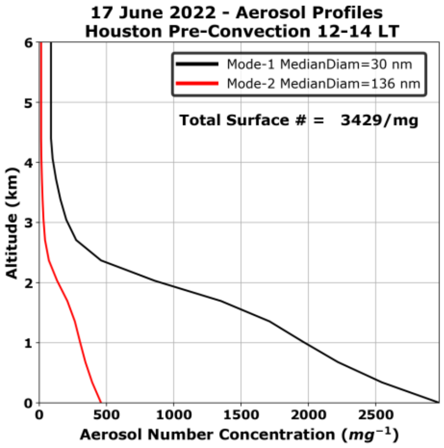


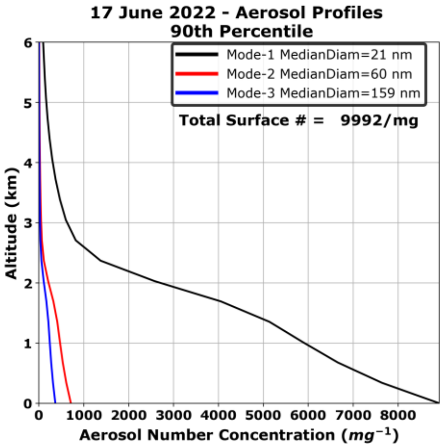
- ❖ Coriolis turned on.
- ❖ No radiation - aerosol interactions.
- ❖ Use best model options for radiation, land-surface, diffusion/PBL.

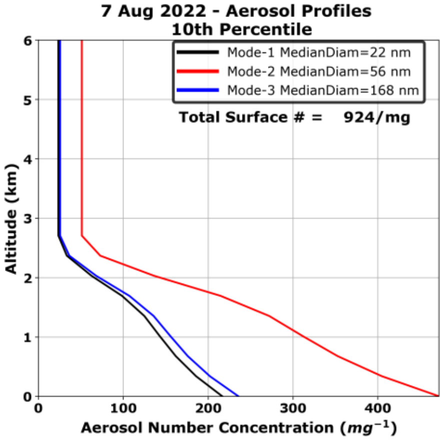
Other Model Configuration	Setup
Simulation Start	0600 UTC 17 June & 0600 UTC 7 Aug 2022
Runtime	24 hours
Timestep	Grid-1: 3 sec, Grid-2: 1.5 sec
Model Projection	polar stereographic or similar model option
Grid Nesting	one-way nesting only
Vertical Levels	95 (same as ACPC MIP, see appendix) Model top ~ 22 km / 50 hPa
Frequency of radiation call	60 sec
Convection	No convection or cumulus schemes
Cloud microphysics	Two-moment bulk or bin scheme. Interactive aerosol processing optional. Initial aerosol profiles to be provided.
Frequency of model output	Grid-1: 60-min full simulation Grid-2: 10-min full simulation Grid-2: 2-min (for cell tracking) from 15 UTC case day - 01 UTC next day (10 AM LST - 10 PM LST Houston, TX)

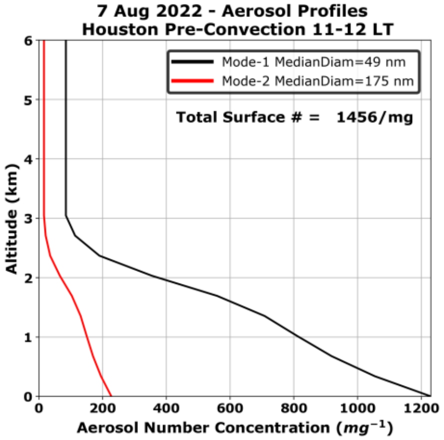
Aerosol Initial Vertical Profiles

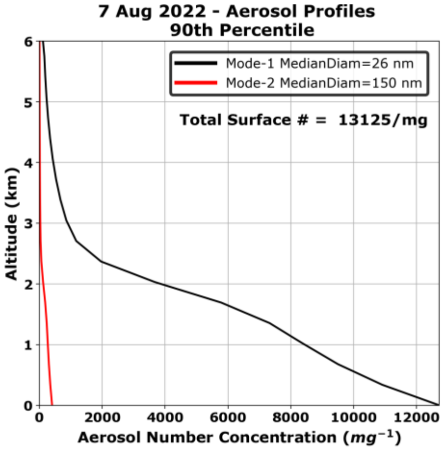






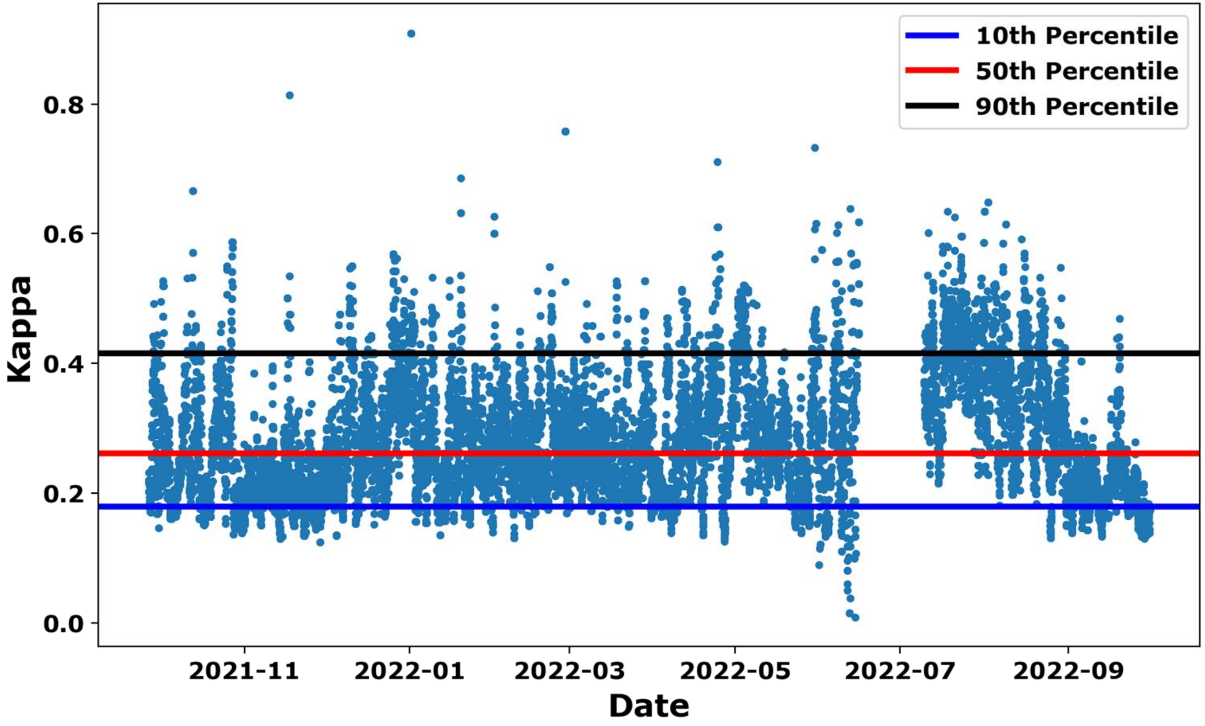






*Vertical profile curve fits provided by Bo Chen (TAMU)

Aerosol Kappa



10th Percentile = 0.17
50th Percentile = 0.26
90th Percentile = 0.41

*Provided by Maria Zawadowicz (from the Aerosol Chemical Speciation Monitor - ACSM)

MIP Simulation Summary

- Simulation days: **June 17, 2022** & **Aug 7, 2022**
- Starting 0600 UTC on each case day; run for 24 hours each.
- For each day, initialize aerosol profiles horizontally homogeneous with:
  (1) Pre-convective aerosol profiles
  (2) 10th percentile profiles (low aerosol concentration)
  (3) 90th percentile profiles (high aerosol concentration)

Link to python Jupyter notebook with list of vertical levels and for plotting vertical profile; code can be adapted to individual MIP model coding language (e.g. Fortran) for initializing aerosol profiles:
https://drive.google.com/file/d/1HoEj3_AiKNdtiBybcknlCwqtAj5MMVgf/view?usp=share_link

TRACER MIP Model Output

Atmospheric State
Pressure (hPa)
Height (m)
Air density (kg/m^3)
U-wind (m/s) (east is +)
V-wind (m/s) (north is +)
W-wind (m/s) (up is +)

If possible, provide full model output data on native grids: (1 file per grid per output time containing all variables) along with documentation of the variable names.

We are working to obtain data storage through the DOE for MIP model output.

Aerosol Variables
Aerosol mass mixing ratio (kg/kg) (separately for all available aerosol modes)
Aerosol number concentration (#/kg) (separately for all available aerosol modes)
Aerosol effective radius or median radius of the distribution (m) (separately for all available aerosol modes)

Microphysical Process Rates
Latent heating/cooling (K/sec) *(heating +, cooling -)*
Liquid condensation, Liquid evaporation
Ice deposition, Ice sublimation
Melting, Freezing (*totals from various mechanisms*)
Cloud droplet nucleation, Ice crystal nucleation
Riming of cloud droplets, Riming of rain drops
Autoconversion+Accretion *(conversion of cloud to rain)*
**For all process rates aside from latent heating, units are (kg/kg/second) or (kg/kg/integrated-time) where "integrated-time" is the sum of the rates between output writing times. "Integrated-time" is preferred so the average rate between model output writing time can be computed.*

Water Variables
Water vapor mixing ratio (kg/kg)
Cloud water mixing ratio (kg/kg)
Cloud droplet number concentration (#/kg)
Rain water mixing ratio (kg/kg)
Rain drop number concentration (#/kg)
qX, nX (kg/kg, #/kg) Provide hydrometeor mass mixing ratios and number concentration for each X hydrometeor class in your model.

2D Variables
Geographic latitude / longitude (degrees)
Topography (m)
Surface precipitation rate (kg/sec/m^2) (mm/sec)
Accumulated surface precipitation (kg/sec/m^2) (mm/sec)
Sea-level pressure (hPa)
Surface sensible and latent heat fluxes (W/m^2)
Surface albedo (fraction)
Surface and TOA upward and downward SW and LW radiative fluxes (W/m^2) (8 total radiation variables here)

Observational Data Needs

Needs for model evaluation and analysis

- Precipitation, radar reflectivity, cloud top height, vertical velocity, etc.
- Meteorological conditions, sea breeze analysis, and PBL properties.
- Will use TOBAC for cell-tracking of model output and CR-SIM on tracked cells for statistical comparison to radar-observed cells.

Participation groups from the previous MIP

Original MIP Models	Institution	Collaborators
Consortium for Small-scale Modeling	Karlsruhe Inst. of Technology	Hoose, Barthlott, Barrett
Meso NH Model	Meteo-France	B. Vie
Regional Atmos. Modeling System	Colorado State Univ.	S. van den Heever, P. Marinescu
Icosahedral Non-Hydrostatic Model	Univ. of Leipzig	J. Quaas, R. Cherian
Unified Model	Univ. Leeds	A. Miltenberger
Weather Research & Forecasting Model (w/ Morrison Micro)	Univ. of Oxford	P. Stier, M. Heikenfeld, B. White
NASA Unified WRF	NASA Goddard	A. Fridlind, T. Matsui
WRF – Spectral Bin Microphysics	Pacific Northwest National Lab	J. Fan, Y. Zhang, J Shpund

Sign up the participation of TRACER MIP at
https://docs.google.com/spreadsheets/d/1iRrJNdxoiE_6woOzaAW7NG198zMgq7eS/edit?usp=sharing&ouid=102577881835256187192&rtpof=true&sd=true

Discussion

For those who use WRF models:

Suggest coordinate to use the same WRF version so that we can get simulations with the same dyn cores but only changing cloud microphysics, which would allow us gain further insights about the variability contributed by microphysics parameterization only.

Condensation calculation:

Since prognostic supersaturation is important to aerosol impact on condensation, for the schemes that use the saturation adjustment approach, if you like, replacing the saturation adjustment approach with the condensation and evaporation calculation based on an explicit representation of supersaturation over a time step, as shown in Zhang et al., 2021 and Lebo et al. 2012.