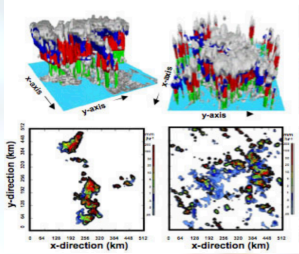


Toward Formulation of a Semi-Permanent Supersite for Cloud, Convection, and Precipitation Processes at Wallops Flight Facility

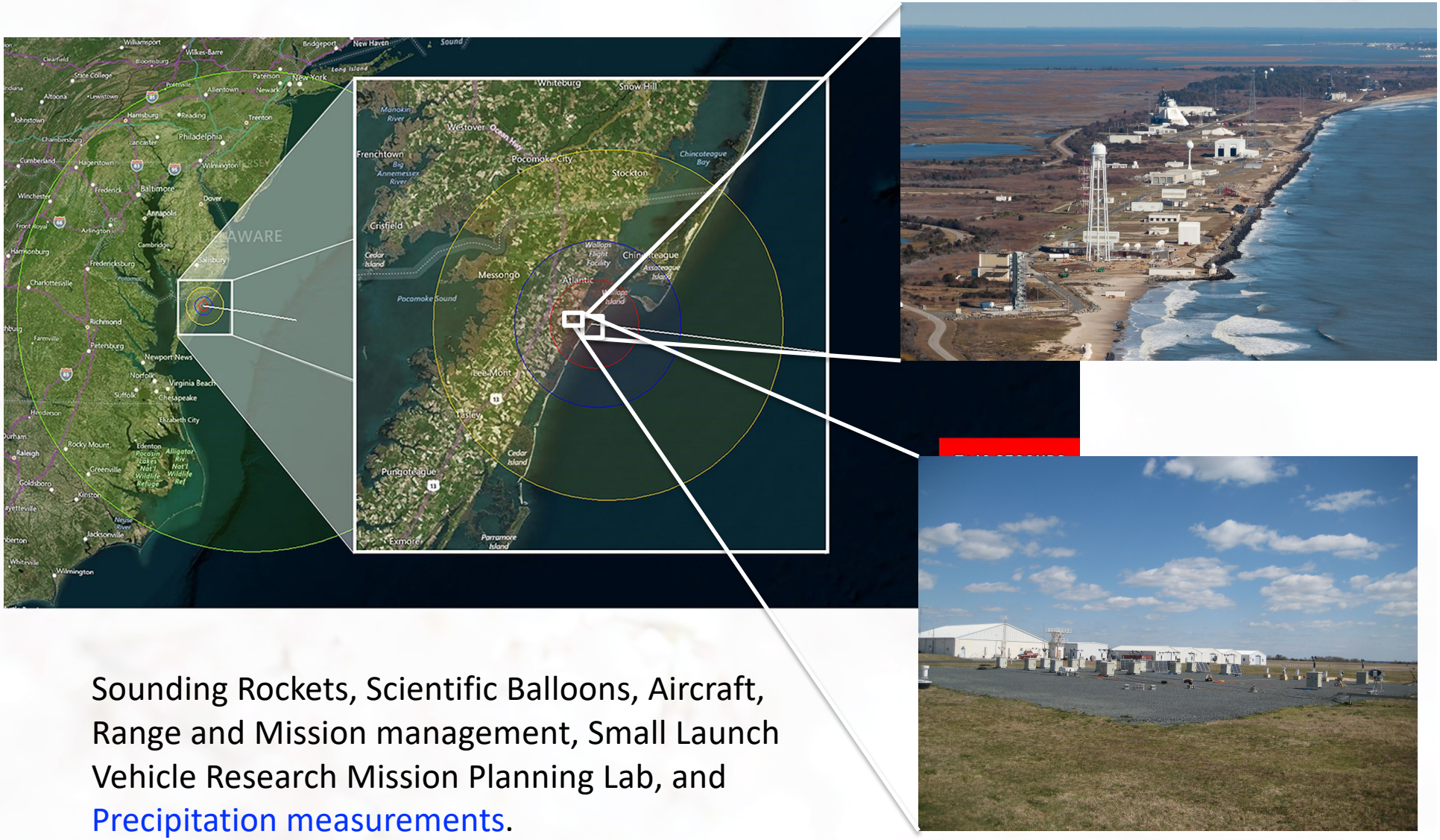
Preliminary Formulation of the

BiLateral Operational Storm-Scale Observation and Modeling (BLOSSOM) Project

Core Team: T. Matsui, D. Wolff, K. Mohr, S. Lang

Collaborators: M. Zhang, S. Xie, B Dolan, V. Chandra

NASA Wallops Flight Facility (WFF)

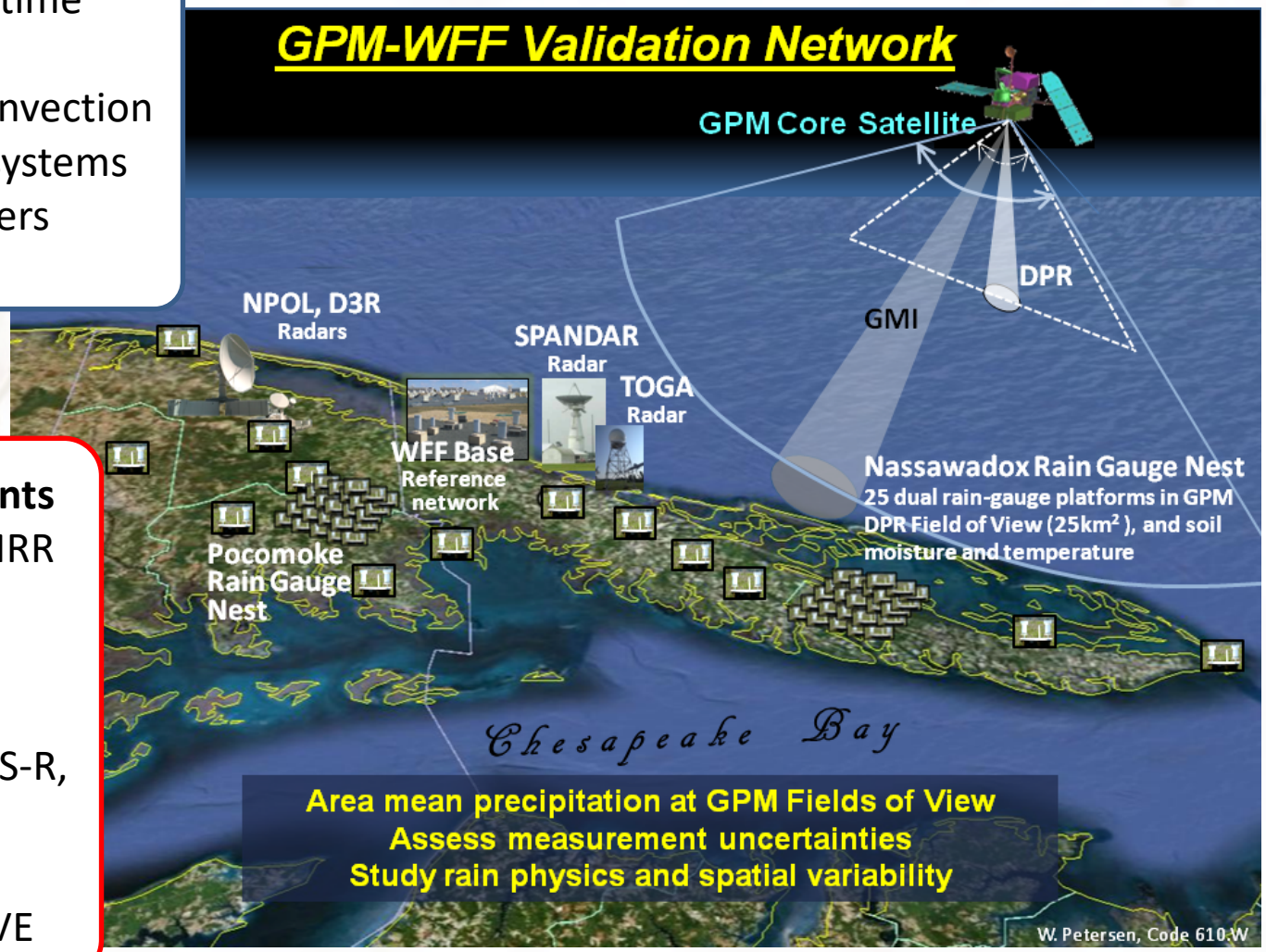


Sounding Rockets, Scientific Balloons, Aircraft, Range and Mission management, Small Launch Vehicle Research Mission Planning Lab, and Precipitation measurements.

NASA Wallops Flight Facility (WFF)

Precipitation Systems

- Continental and maritime organized convection
- Sea-breeze-driven convection
- Mid-latitude frontal systems
- Winter-time nor'easters
- Tropical cyclones

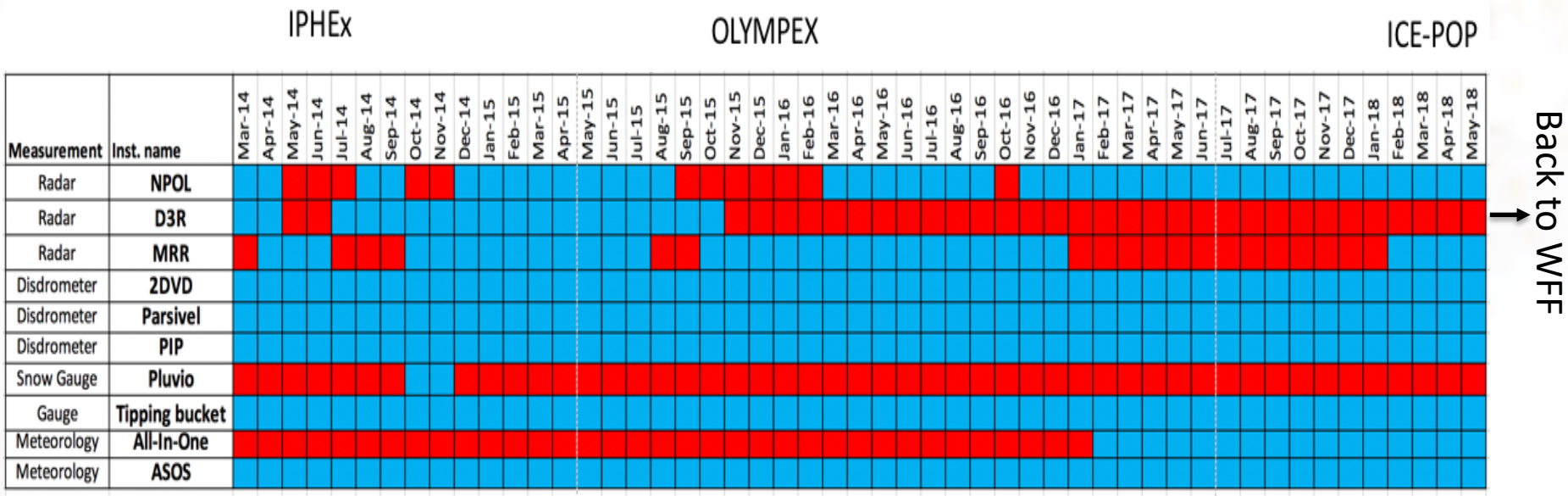


World-Class instruments

- **Radar**: NPOL, D3R, MRR
- **In-situ**: 2DVD/Parsivel/PIP, Gauge, All-in-One
- **Satellites**: GPM, GOES-R, Terra/Aqua/Suomi
- **Trailers**: SMART, COMMIT, and ACHIEVE

NASA Wallops Flight Facility (WFF)

-Instruments-



- WFF instruments has been relocated time-to-time during NASA's GPM field campaigns.
- There are no more planned GPM field campaign.
- These world-class instruments are basically used to validate GPM core satellite only.
- These observations are not used for model validation and improvement or understanding physical process like DOE ARM super sites.

-BLOSSOM-

BiLateral Operational Storm-Scale Observation and Modeling

1) *Develop semi-permanent super site for validation satellite observation/concept and studying cloud, convection and precipitation processes.*

2) *Provide meteorological large-scale forcing (LSF) input to drive different CRMs, large-eddy simulation (LES) models, and single-column models (SCMs) for improvement of parameterizations.*

3) *Provide routine storm-scale CRM ensemble simulations and evaluation to bridge remote sensing observations and CCP processes (shallow-deep precipitating convection).*

4) *Provide bundled database for ground-based observations, CRM, and NASA satellite observation to enhance usability among different PMM users.*

During this 3yr cycle, we prove the concept through a few case studies.

Applications of BLOSSOM

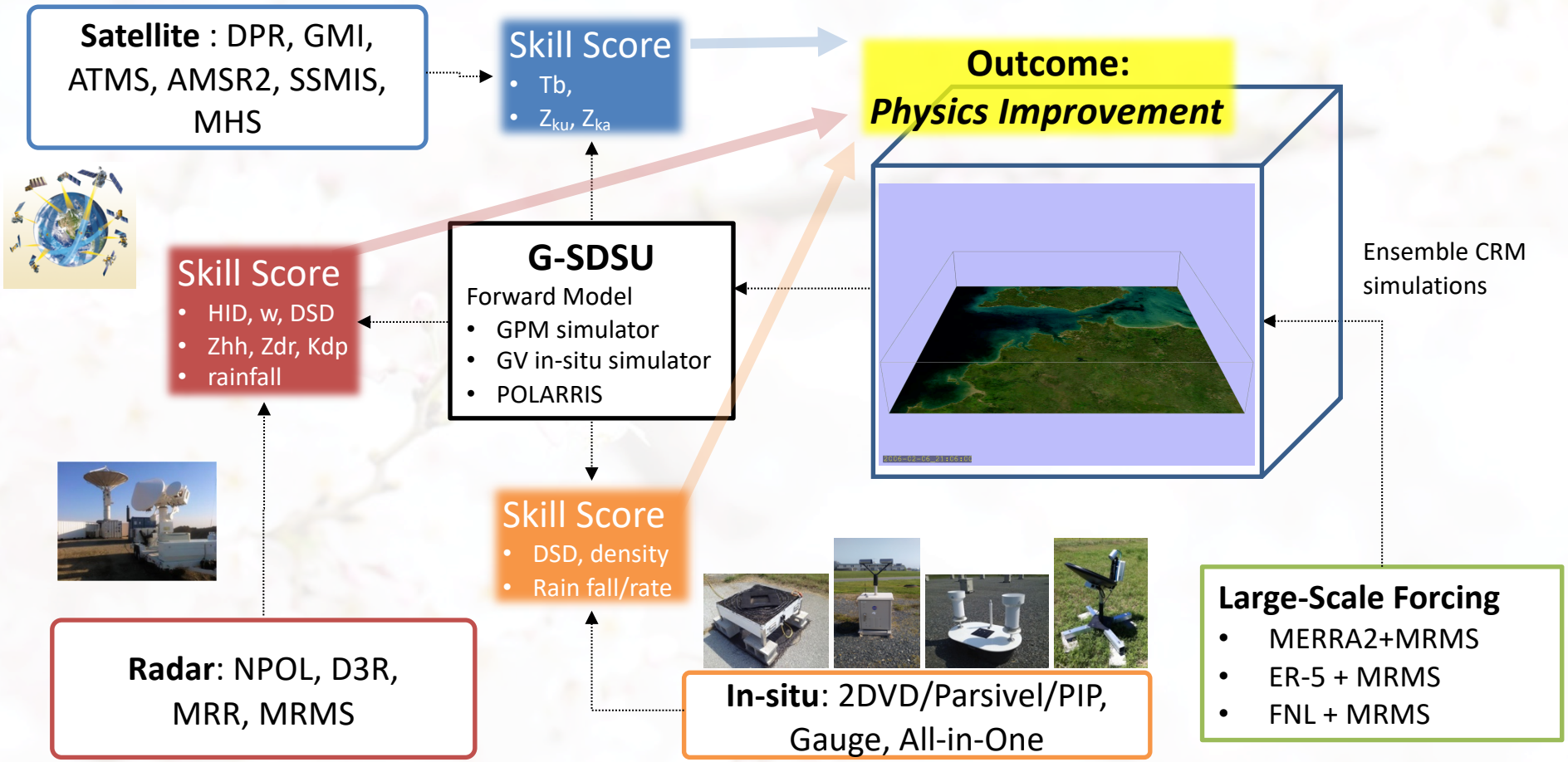
Remote Sensing

- For Satellite Remote Sensing
  - Verify operational satellite products from ground-based observations.
  - Design future satellite missions (e.g., A-CCP) from the ground-based radar and CRM modeling using satellite simulators (forward models).
- For Ground-based remote sensing
  - Elucidate unobservable cloud processes and properties from process models (microphysics process, phase change, evaporation/condensation, latent heat, etc.).
  - Develop more complex algorithms from the process modeling and a forward model (simulator).

Atmospheric Modeling

- Process Modeling (CRM, LES)
  - Microphysics evaluation and development.
  - Study dependency of resolution and turbulence.
  - Study convection process (thermal, PBL, and microphysics).
- Climate Modeling (SCM)
  - Evaluate mean state parameters from remote sensing data with different parameter spaces.
  - Develop physics parameterization and sub-grid co-variability from the process modeling and ground-based observations.

BLOSSOM Flow Chart



Large-Scale Forcing

- Long-term large-scale forcing will be generated over WFF for supporting diverse modeling community (LES, CRM, SCM).
- VARiational ANAlysis (VARNAL) approach [Zhang and Lin 1997, Zhang et al. 2001, Xie et al. 2004] will be implemented to constrain atmospheric states from reanalysis products by MRMS surface rainfall rate and CERES energy budgets data.
- Create ensemble large-scale forcing from different renalaysis products, MERRA2, ERA-5, FNL

Potential Temperature tendency:

$$\frac{\partial \theta_m}{\partial t} = \left(\frac{\partial \theta_m}{\partial t}\right)_{\text{phy}} - (\mathbf{V} \cdot \nabla \theta)_{\text{LS}} - \omega_{\text{LS}} \frac{\partial \theta_m}{\partial p}$$

Moisture tendency:

$$\frac{\partial q_m}{\partial t} = \underbrace{\left(\frac{\partial q_m}{\partial t}\right)_{\text{phy}}}_{\text{Model Physics}} - \underbrace{(\mathbf{V} \cdot \nabla q)_{\text{LS}} - \omega_{\text{LS}} \frac{\partial q_m}{\partial p}}_{\text{Large-Scale Forcing}}$$

From Zhang et al. 2001

Large-Scale Forcing

- Zhang et al. 2001 (1997): Variational Analysis-

Mass:

$$\frac{1}{g}\frac{\partial p_s}{\partial t} = -\langle \nabla \cdot \mathbf{V} \rangle;$$

Water Vapor:

$$\frac{\partial \langle q \rangle}{\partial t} = -\langle \nabla \cdot \mathbf{V} q \rangle + E_s - \mathrm{Prec};$$

MRMS

Heat:

$$\frac{\partial \langle s \rangle}{\partial t} + \langle \nabla \cdot \mathbf{V} s \rangle = R_{\mathrm{TOA}} - R_{\mathrm{SRF}} + L_v \mathrm{Prec} + \mathrm{SH} + L_v \frac{\partial \langle q_l \rangle}{\partial t}; \quad \text{and}$$

CERES

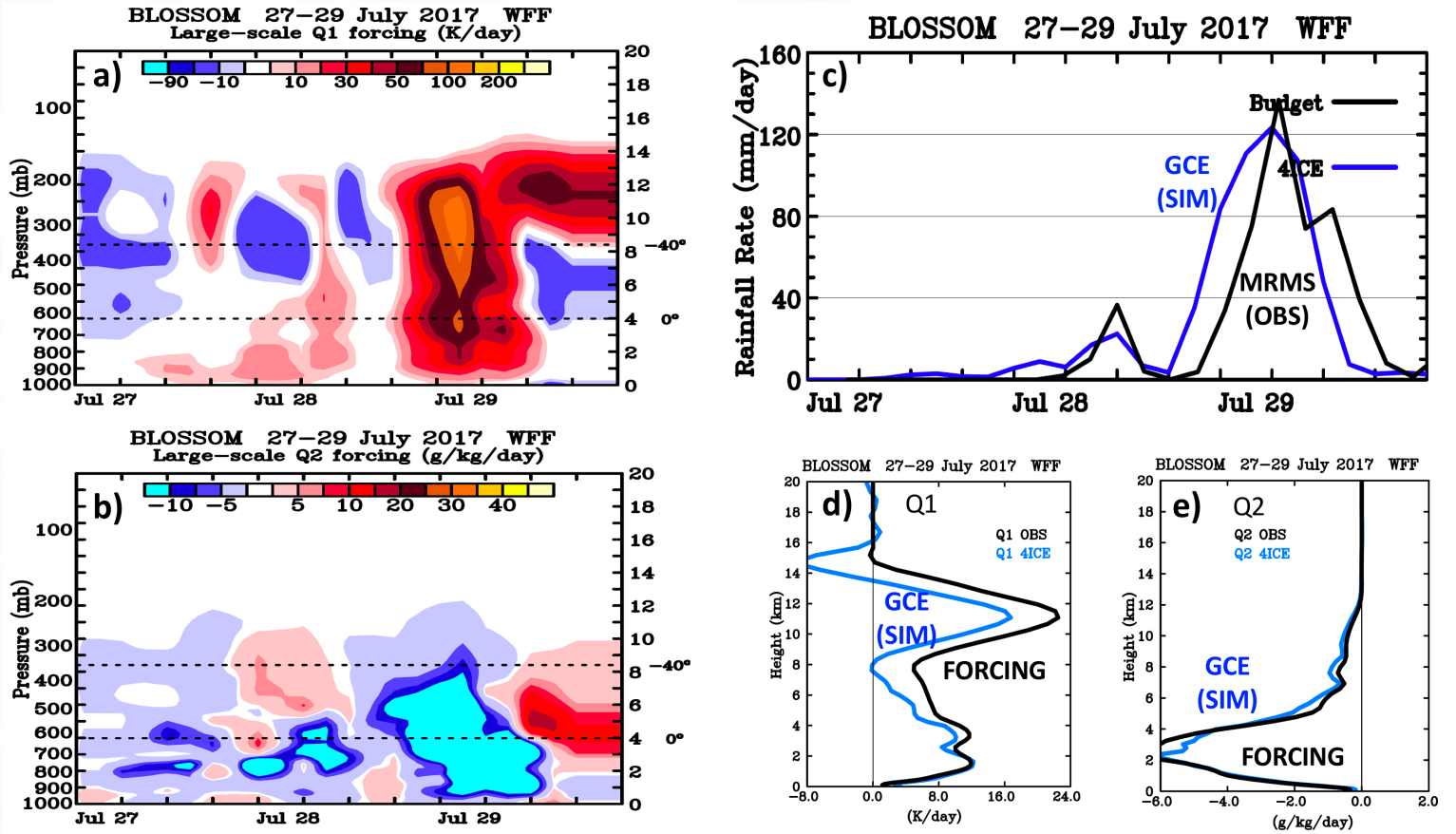
Momentum:

$$\frac{\partial \langle \mathbf{V} \rangle}{\partial t} + \langle \nabla \cdot \mathbf{V}\mathbf{V} \rangle + f\mathbf{k} \times \langle \mathbf{V} \rangle + \nabla \langle \phi \rangle = \boldsymbol{\tau}_s .$$

Initial State: Reanalysis → Prec, R_{TOA}, R_{SRF} are assimilated from observations via 1Dvar.
Esp, Prec is the most important parameters to constrain the atmospheric column budget.

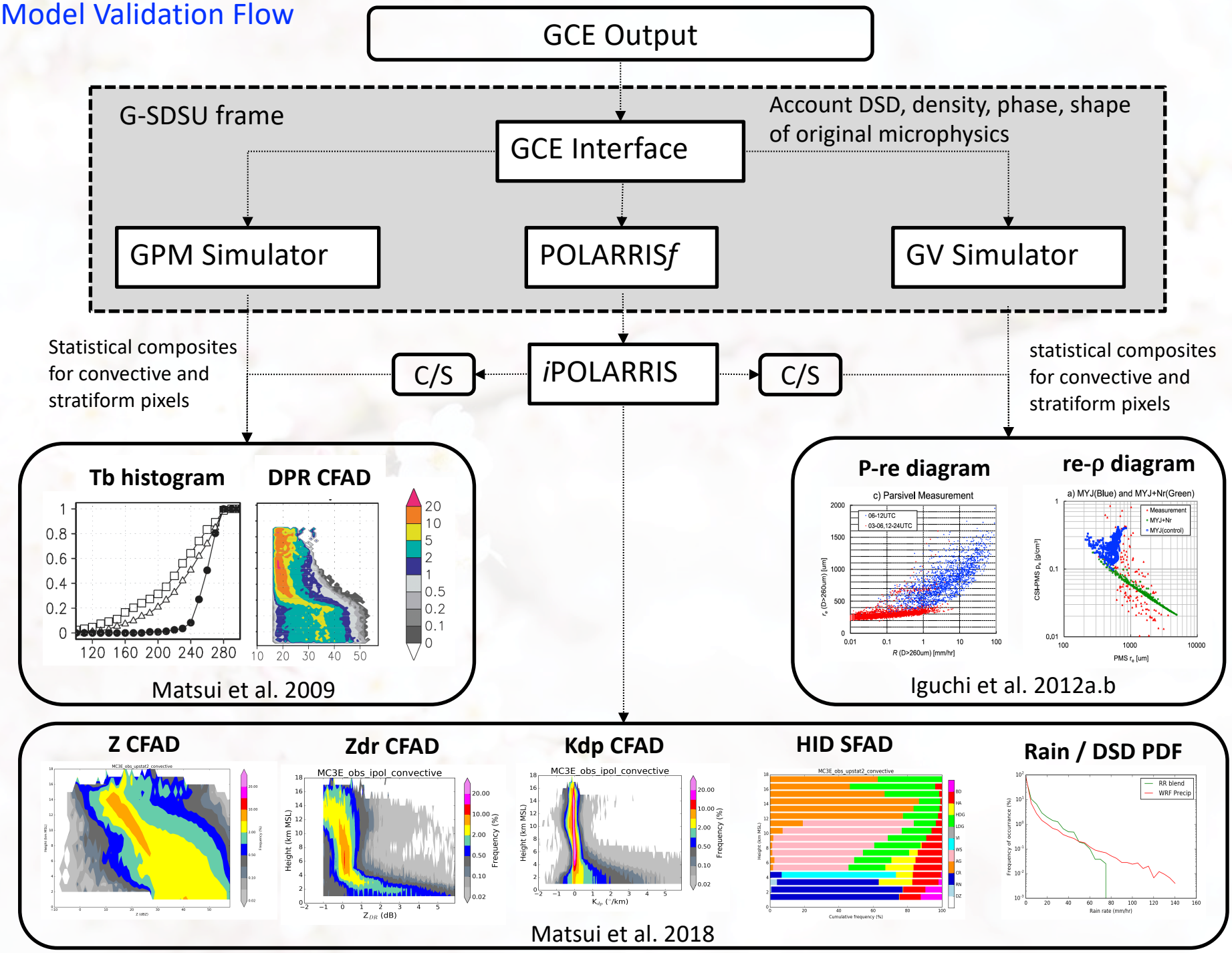
BLOSSOM Large Scale Forcing

MERRA2+MRMS +CERES



MERRA2-based large-scale forcing of a) Q1 and b) Q2 budget profiles from VARNAL. c) Time series of surface rainfall generated by Goddard Cumulus Ensemble (GCE) simulations and observed by the MRMS rainfall data. Time integrated d) Q1 and e) Q2 profiles from the GCE simulation and large-scale forcing.

Model Validation Flow



BLOSSOM Data Processing System

-Data Bundle

Data Search Algorithm

Operation: 12hr-24hr frame for daily time frame.

User Request: User-requested time frame less than a one-week period.

Main Driver
Input: Start/end time, Data Process Switch
Function: Call data module

Radar data module
Input: processing time frame
Function: Radar data search

NPOL(S)
KDOX(S)
D3R(Ku,Ka)
MRR(K)

In-situ data module
Input: processing time frame
Function: in-situ data search

Parsivel

2DVD

PIP

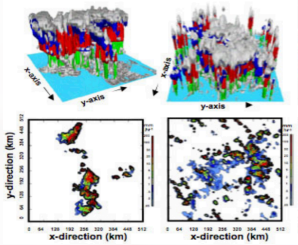
Satellite data module
Input: processing time frame
Function: satellite data search

GPM

L1D
IMERG

CRM data module
Input: processing time frame
Function: CRM data search

GCE

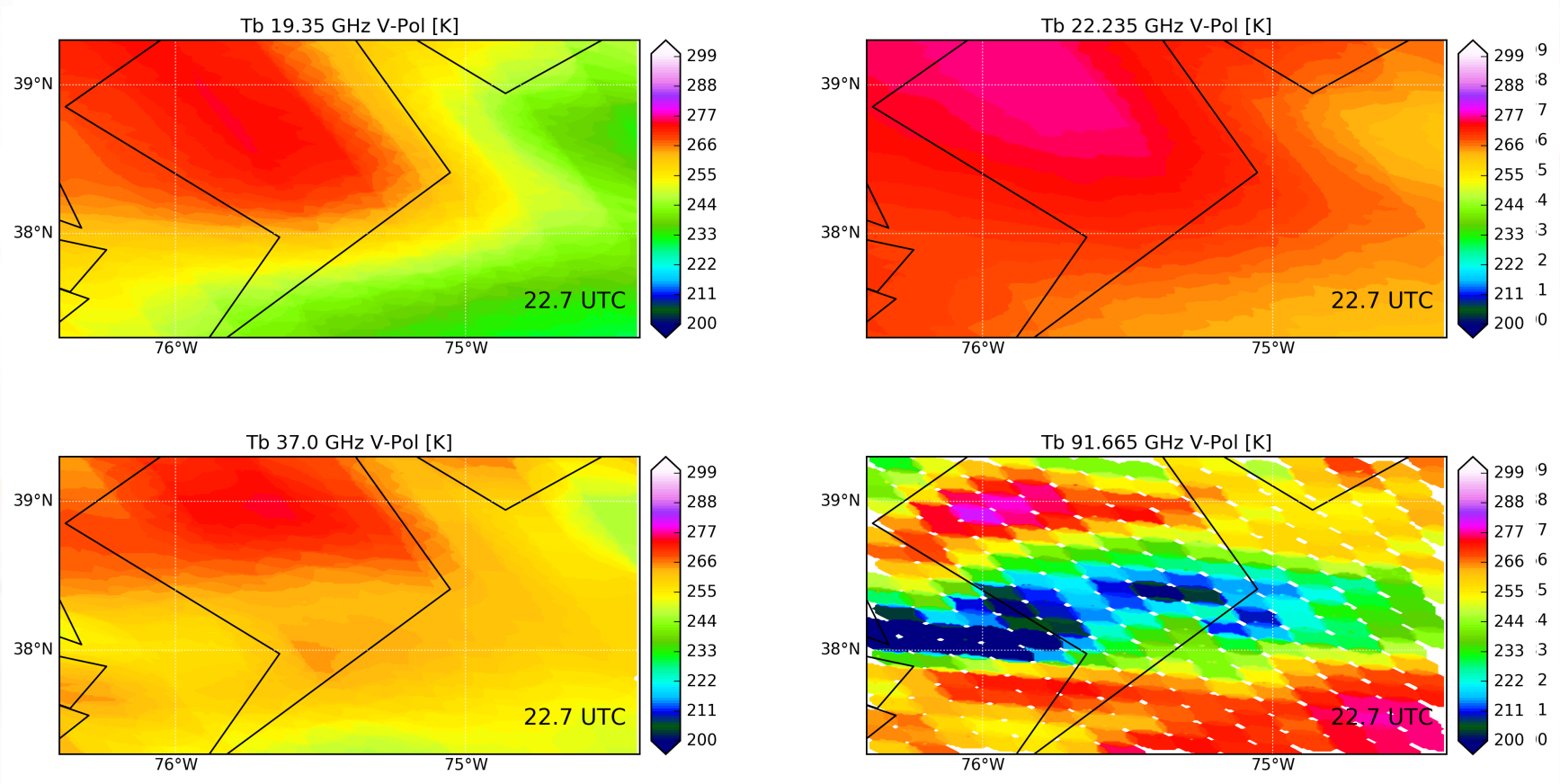


Simulated
Instrument
Signals

Generate bundled database in self-described NetCDF format.

GPM L1D and L2D data

ATMS→AMSR2→GMI→SSMIS



From beam widths, FOVs and Sat geo-locations, Tbs are estimated at 0.01deg grid, making easier to compare with gridded radar data. → PPS will help operational production.

GSFC's SMART, COMMIT, and ACHIEVE ground-based mobile laboratories

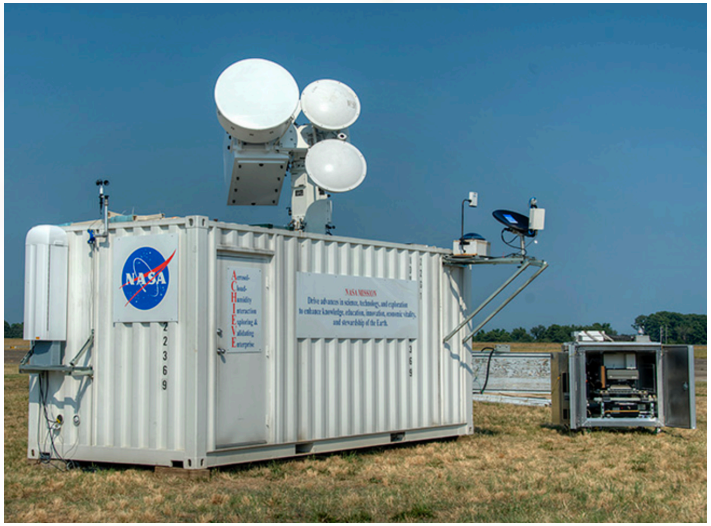
SMART

Surface-sensing Measurements for Atmospheric Radiative Transfer

COMMIT

Chemical, Optical, and Microphysical Measurements of In-situ Troposphere

ACHIEVE



Aerosol, Cloud, Humidity, Interactions Exploring and Validating Enterprise

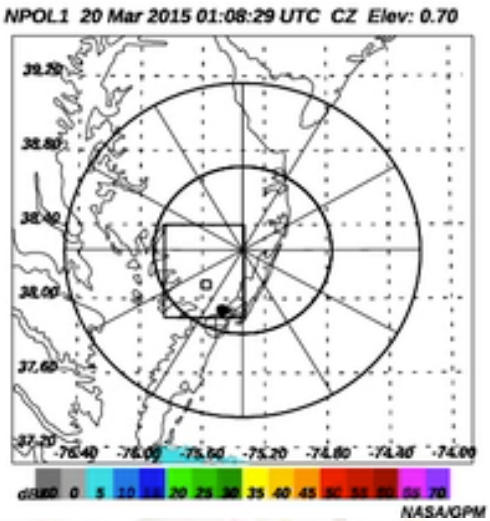
These mobile labs provide additional X/K/W-band Doppler radars, aerosol/CCN measurements, radiation measurements.

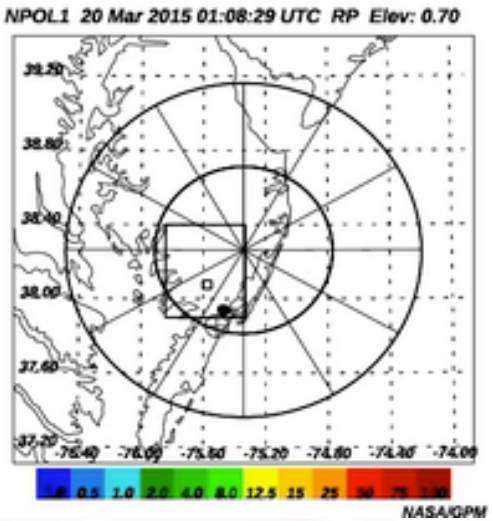
Aerosol, Cloud, Convection and Precipitation ALL TOGETHER

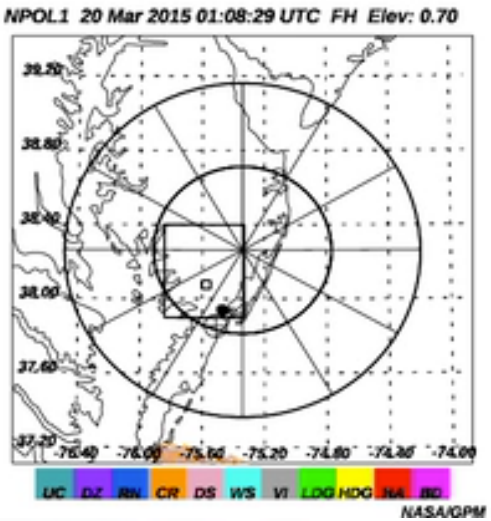
Discussion Points

- Radar polarimetry and scanning strategies.
  - NPOL
  - D3R
  - ACHIEVE W/X band radar
  - Phased array radar (PAR) available?
- Scientific Priorities
  - Ice crystals size/shape/density, mixed phase, 3D structure, connections to operational retrievals, ACCP, etc….

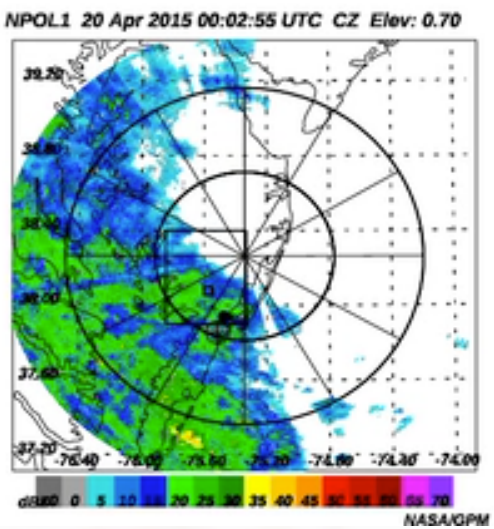
Continental Airmass

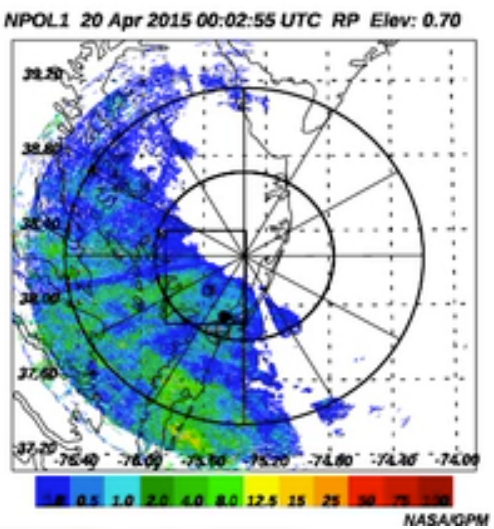


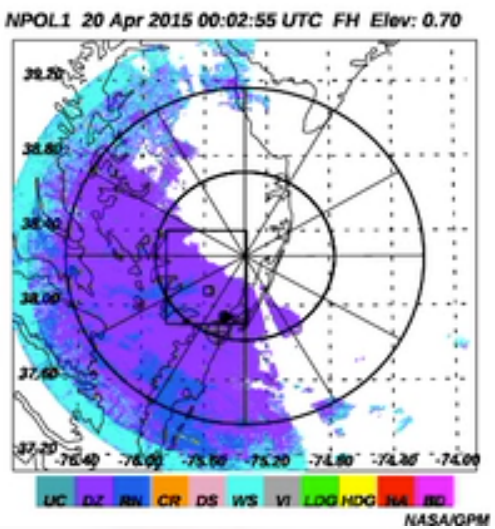




Maritime Airmass



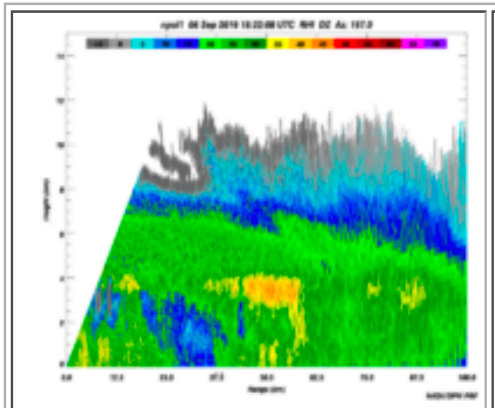




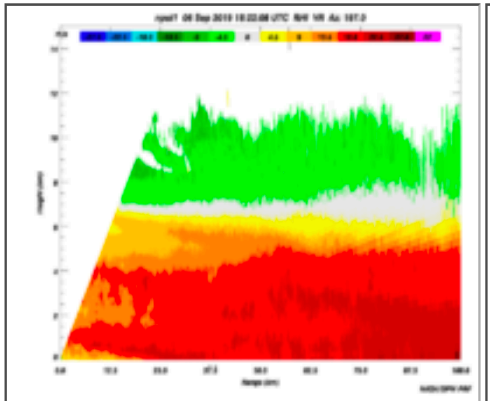
Hurricane Dorian

Current Sounding: Current Sounding: 09/06/2019 @ 18 UTC.

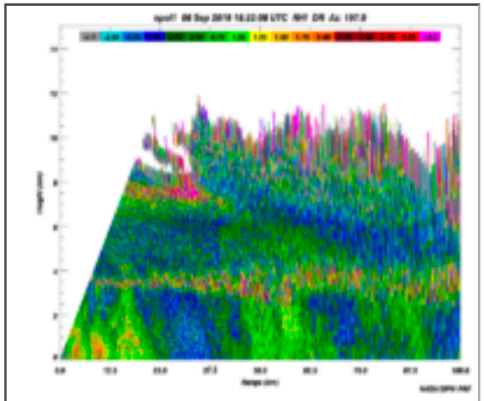
Current Sounding: Current Sounding: 09/06/2019 @ 18 UTC.



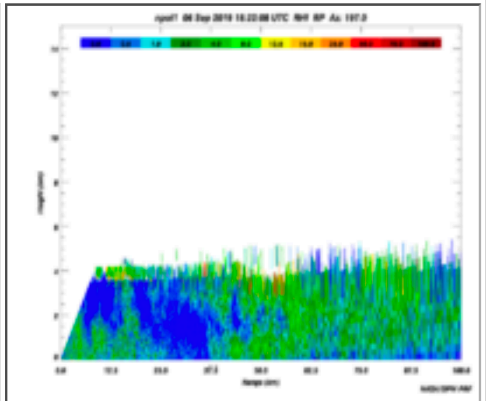
Reflectivity



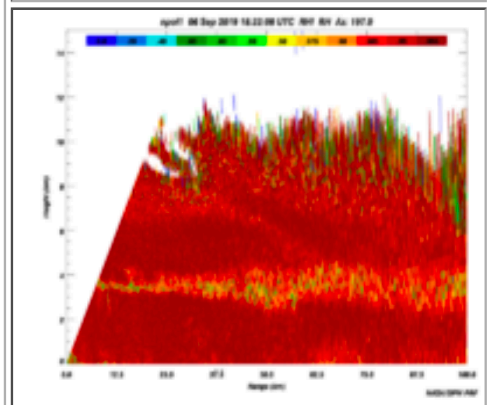
Velocity



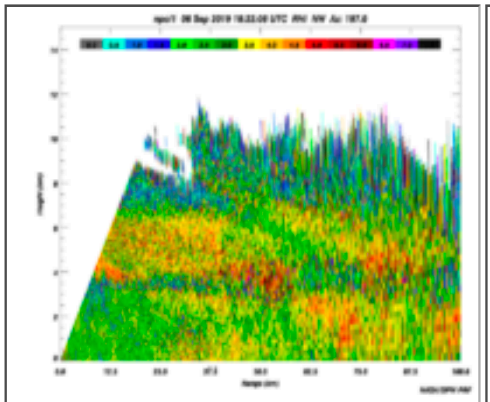
Diff. Reflectivity



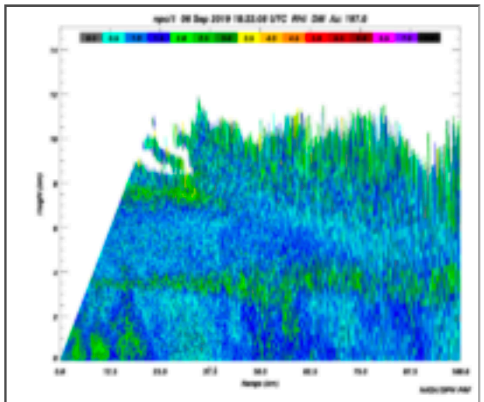
Rain Rate



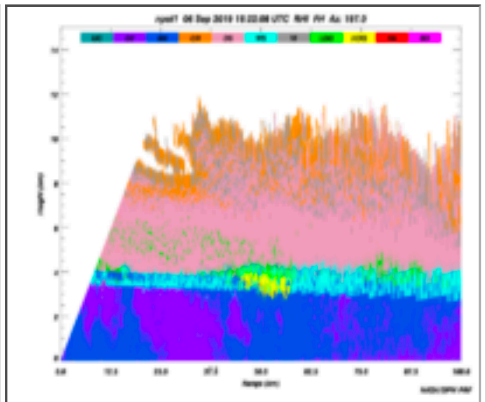
Correlation



Intercept (Nw)



Mass-Weighted Diameter

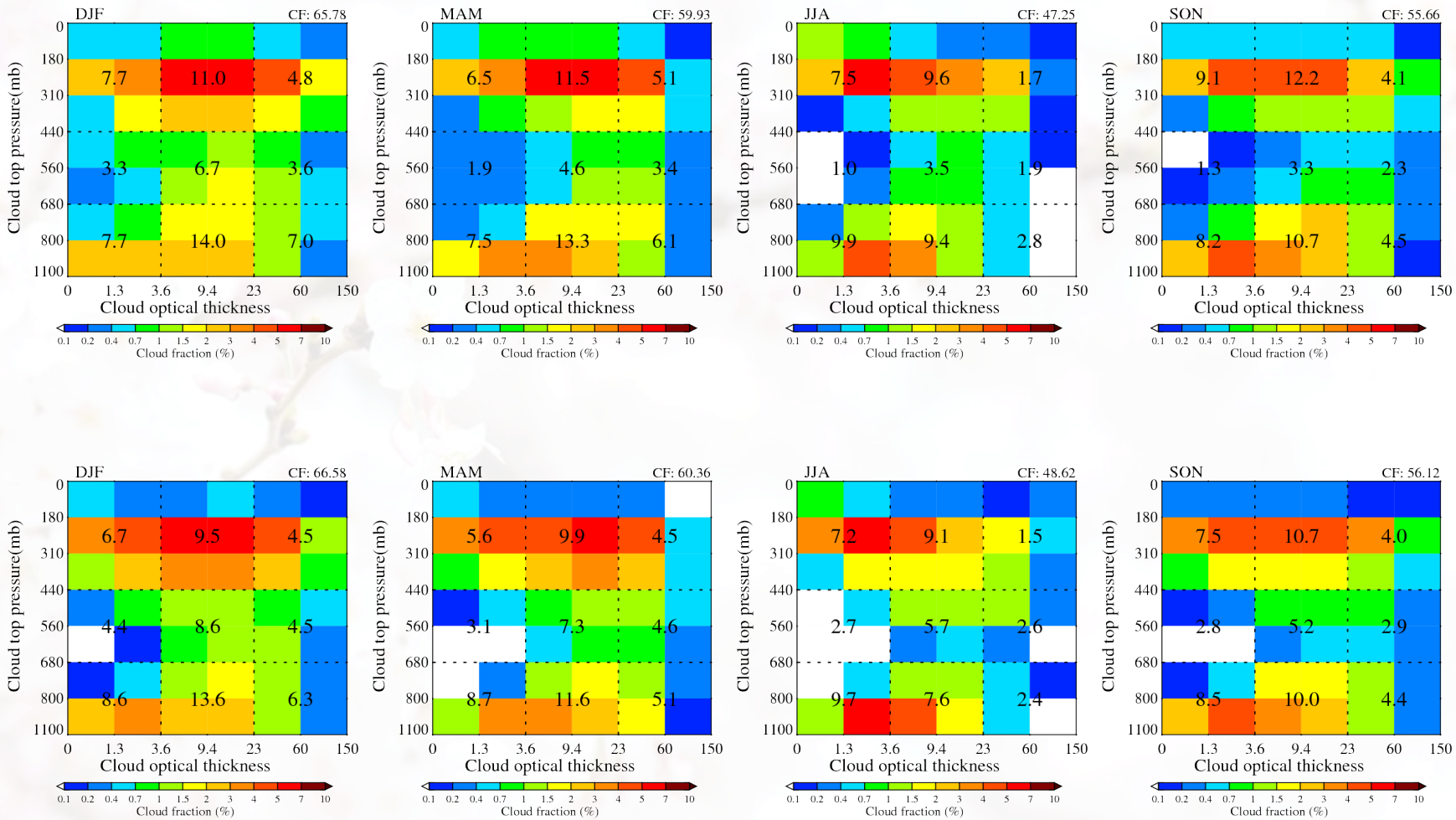


Hydrometer ID

Seasonal variability of ISCCP-like MODIS cloud type
- WFF domain -

Terra-MODIS

Aqua-MODIS



Lot of low and cirrus clouds, too

From Laz Orepoulos Group@C613