Mesoscale Modeling of Marine Stratocumulus and Cloud-Aerosol Interactions

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ASP

Objectives

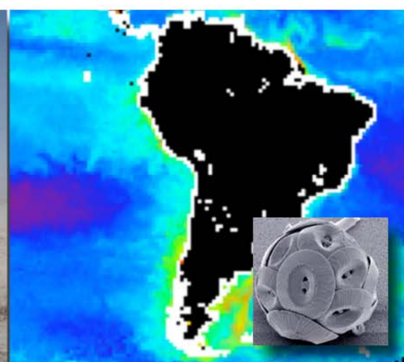
Integrate VOCALS measurements with WRF predictions to examine how particulate properties and aerosol indirect effects evolve

- What are the effects of aerosol chemistry on the evolution of stratocumulus clouds downwind of large anthropogenic point sources along the coast of Chile?
- What is the relative importance of natural and anthropogenic sources of primary particulates and particulate precursors on cloud-aerosol interactions?

anthropogenic sources

natural sources

dust



DMS via photoplankton

sea-salt

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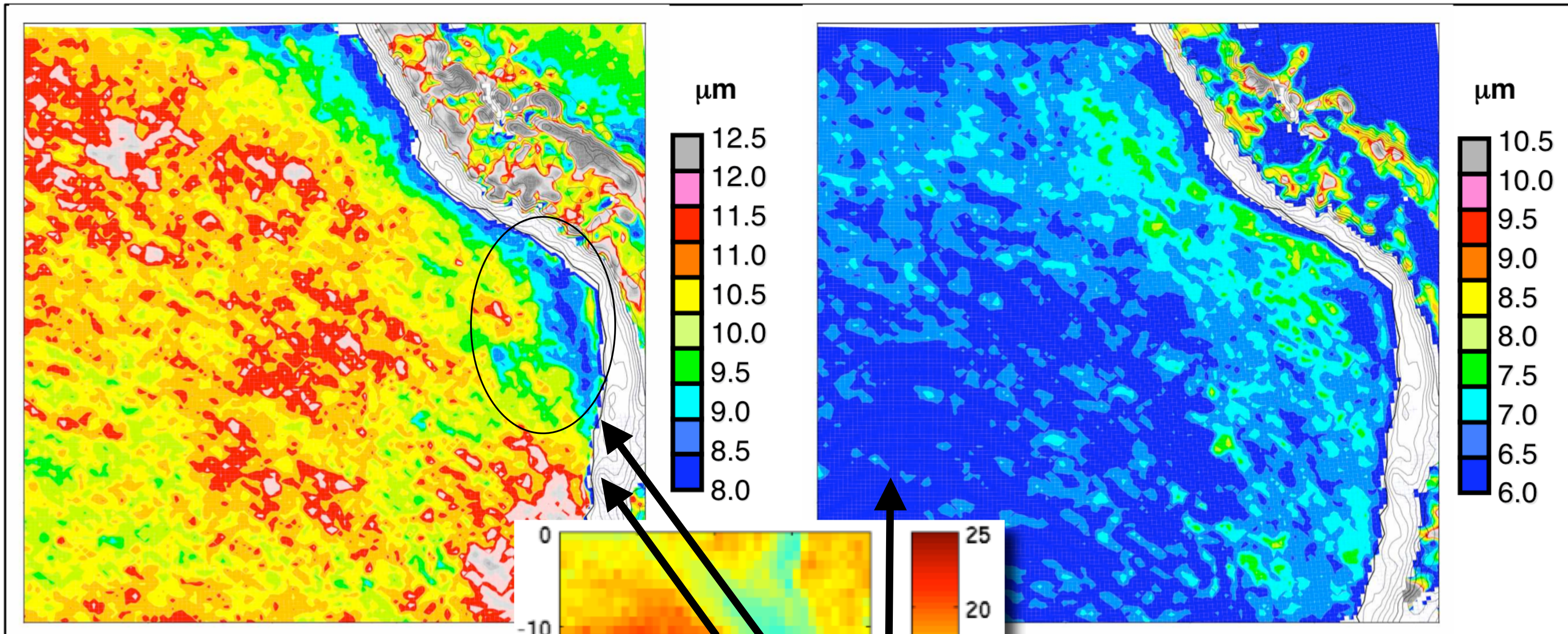
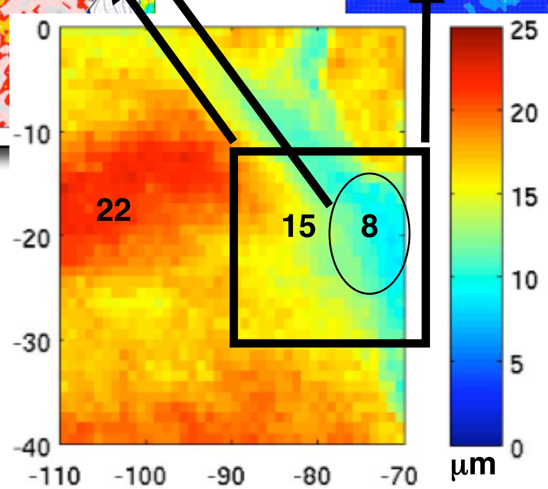
PreVOCA: Predicted Effective Radius

October 2006 Average at 18 UTC

Full Chemistry Simulation *Prescribed Aerosol # Simulation*



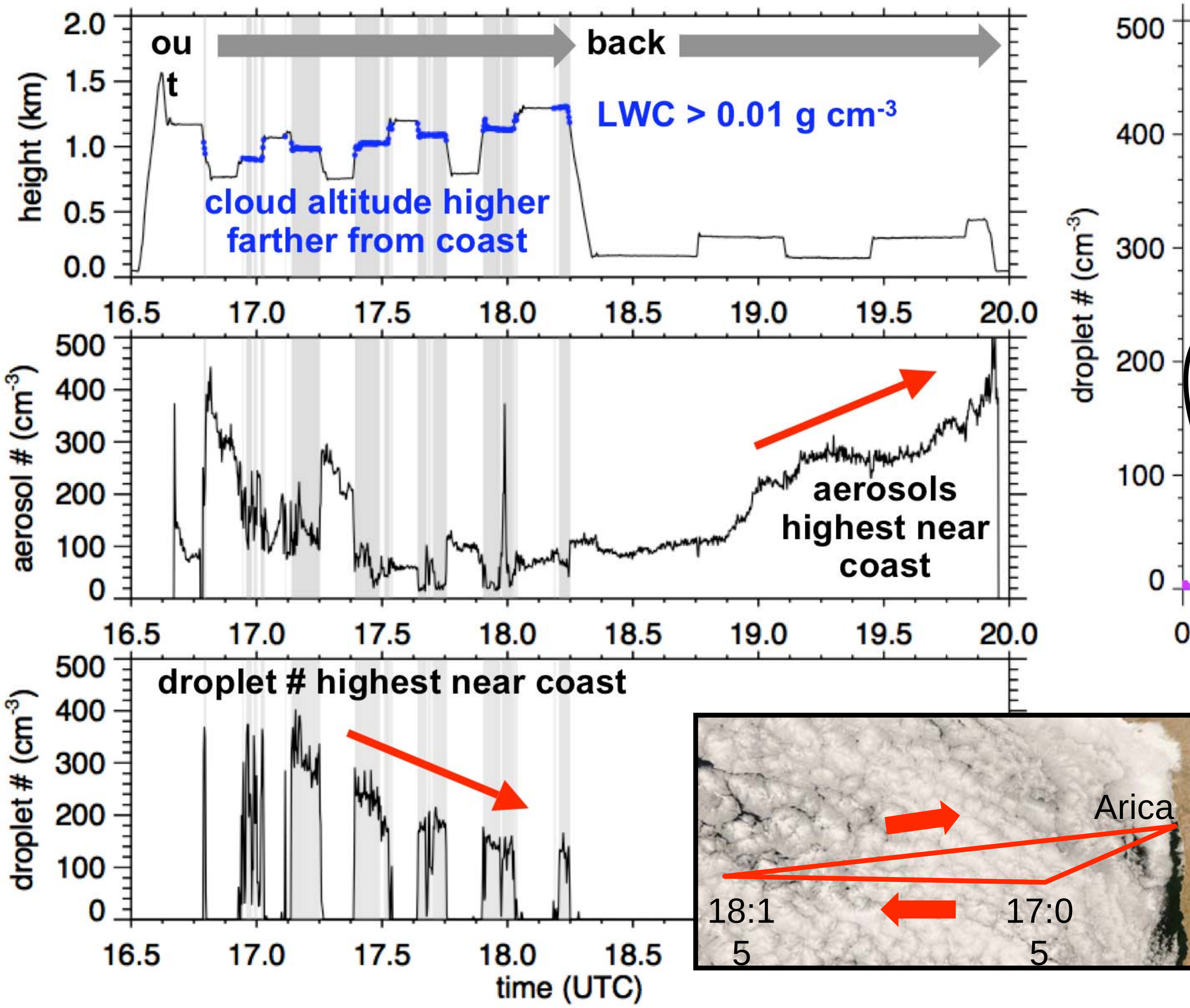


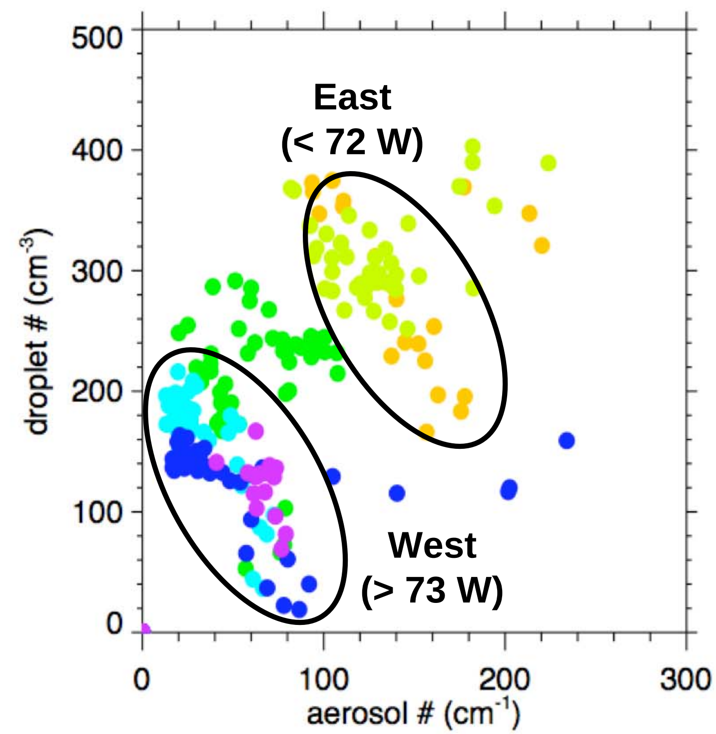
Mean MODIS Cloud Droplet Effective Radius October 2006

from Matthew Wyant (UW)

Aircraft Observations

G-1 Flight on October 22





Do models replicate this? If not, why?

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Configuration of WRF

Weather Research and Forecasting (WRF) Model

Our goal is to *"get the right answer for the right reasons"*, therefore:

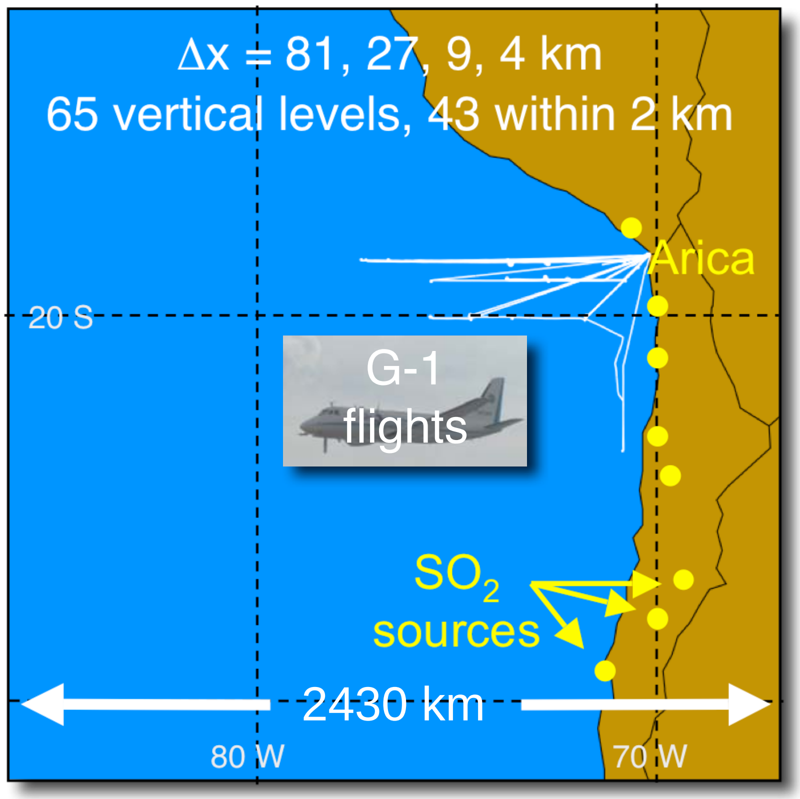
- Examine sensitivity of predicted marine stratocumulus to key PBL, microphysics, and scale issues first (**phase 1**)
- Then, include cloud-aerosol interactions (**phase 2**)

Phase 1

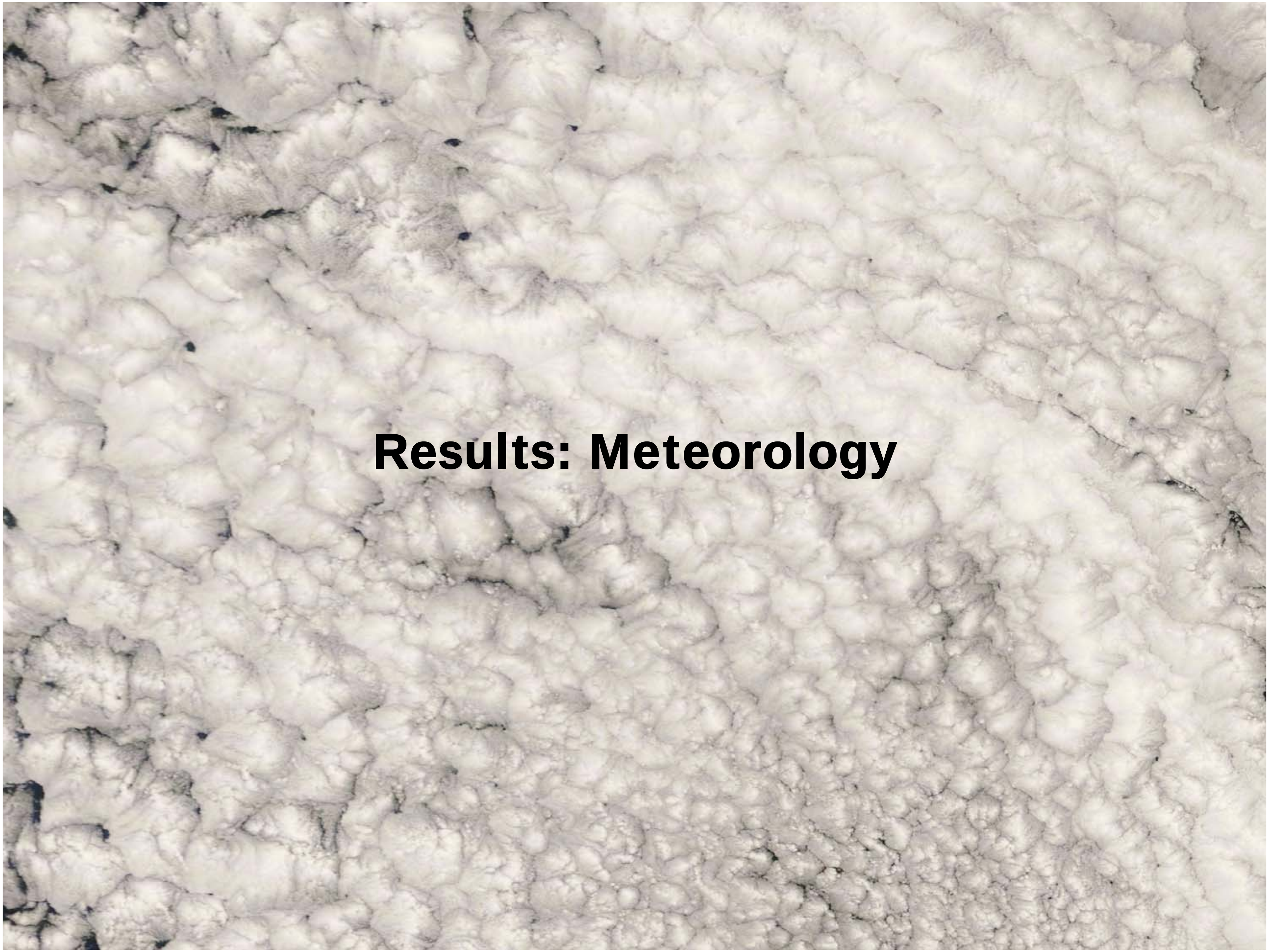
- **Boundary Layer schemes:** 5 - YSU, MYJ, MYNN5, MYNN6, ACM
- **Microphysics schemes:** 4 - Lin, Thompson, Morrison, WDM5, default droplet # set to 250 cm^{-3}
- **Boundary Conditions:** Meteorology and SST from GFS

Phase 2:

- **Chemistry:** CBM-Z photochemistry + MOSAIC aerosols
- **Aerosol-Cloud-Radiation Interactions:** methodology similar to GCMs



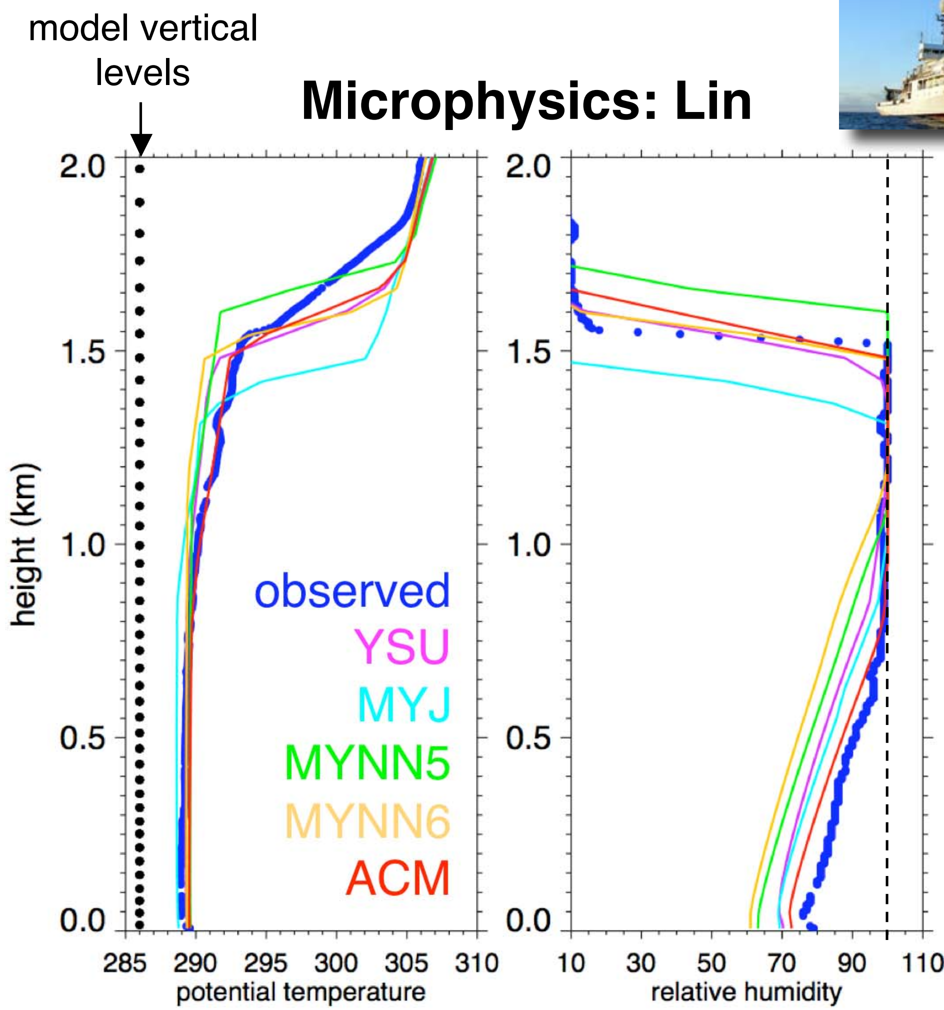
Results: Meteorology



Example Radisonde Profiles

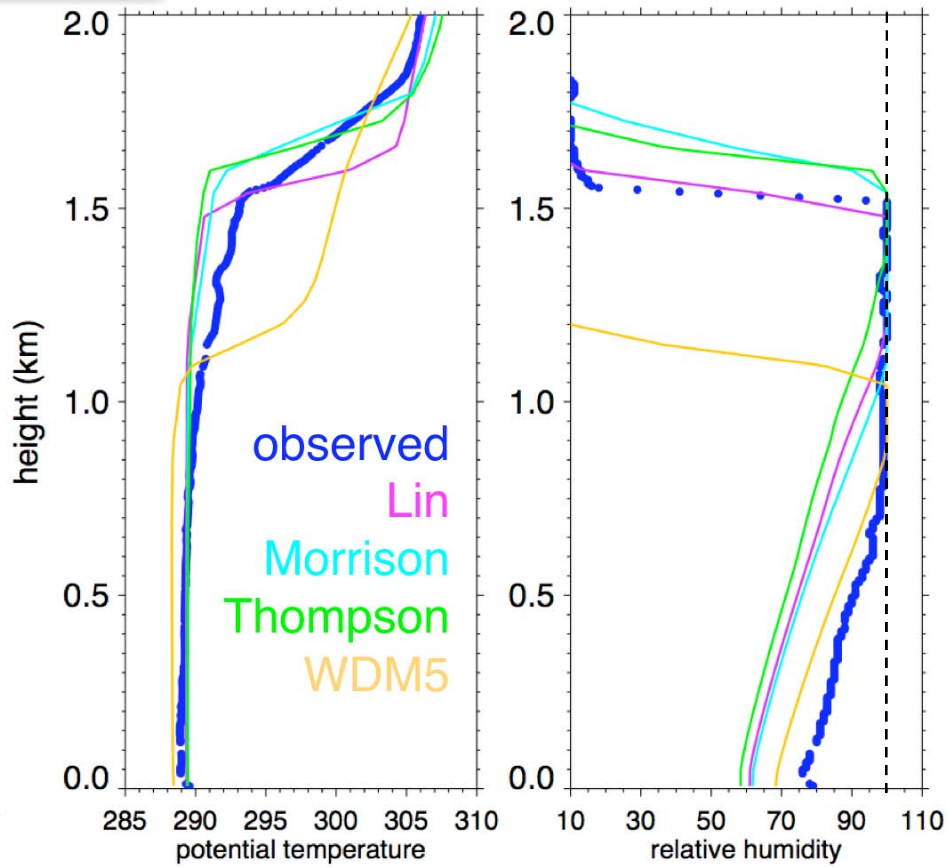
0330 UTC October 28

Microphysics: Lin



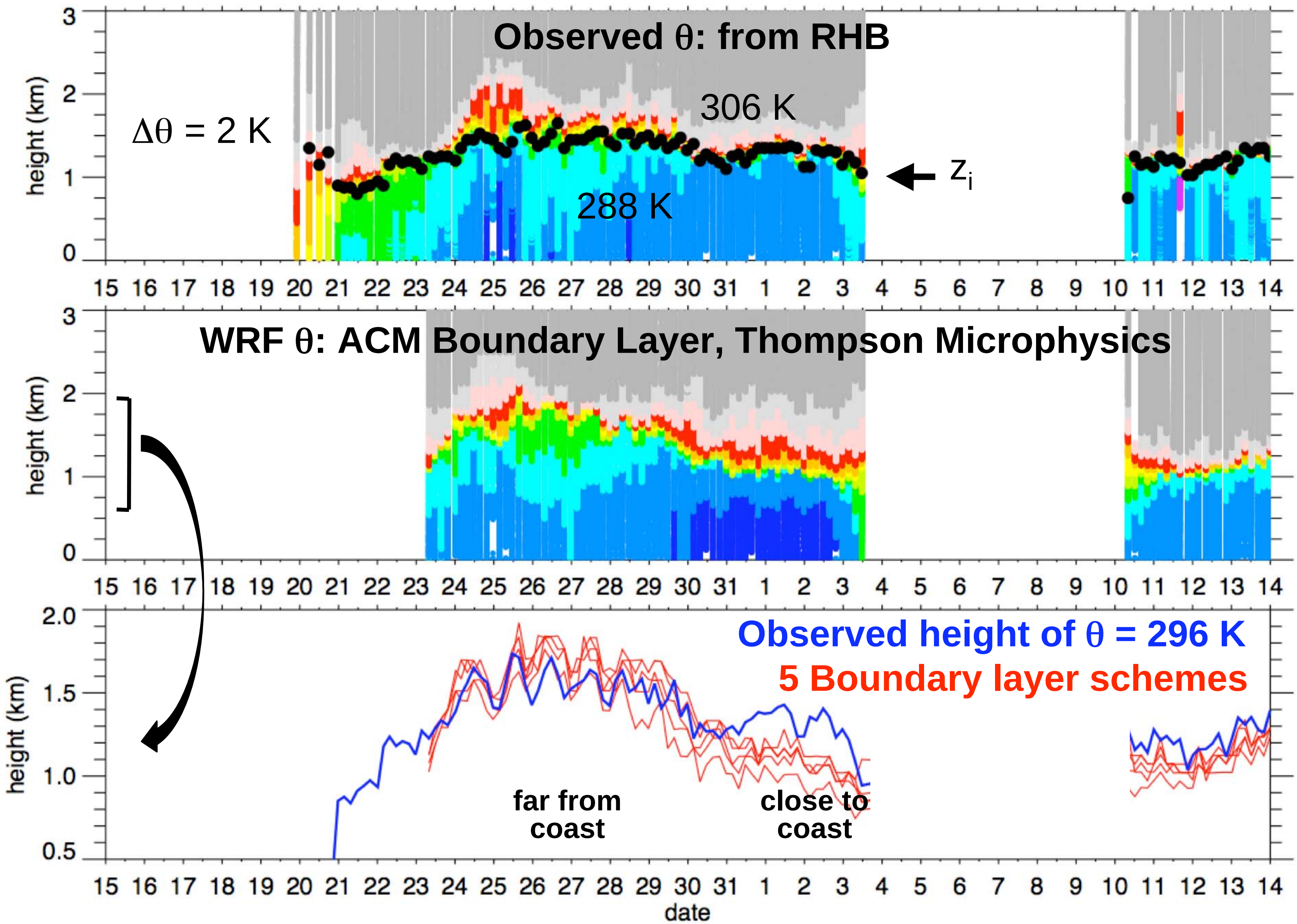
sensitivity to boundary layer scheme

Boundary Layer: ACM



sensitivity to microphysics scheme

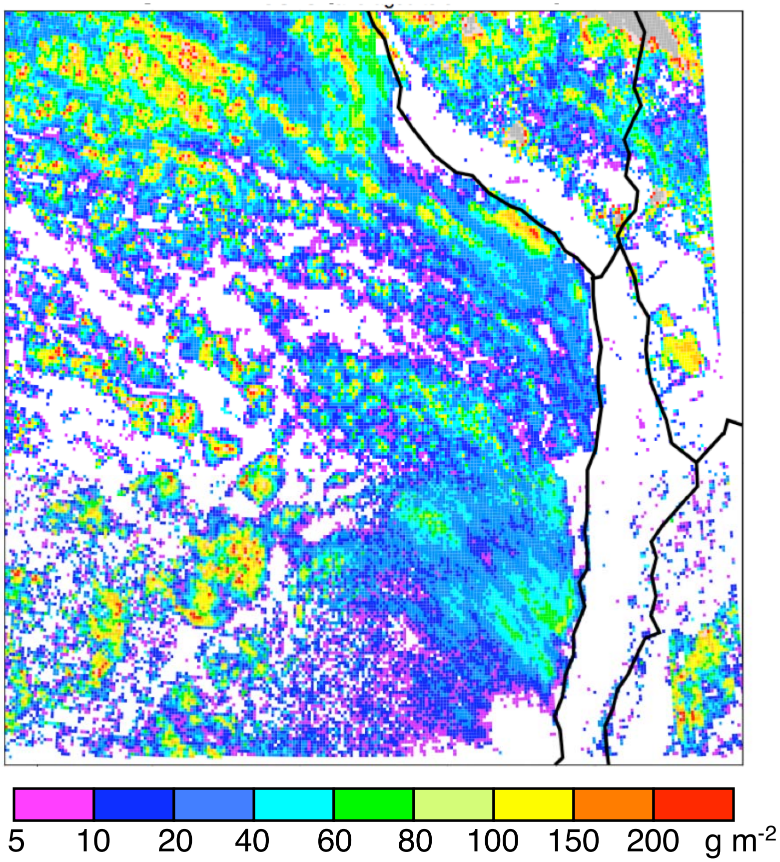
All Radisonde Profiles



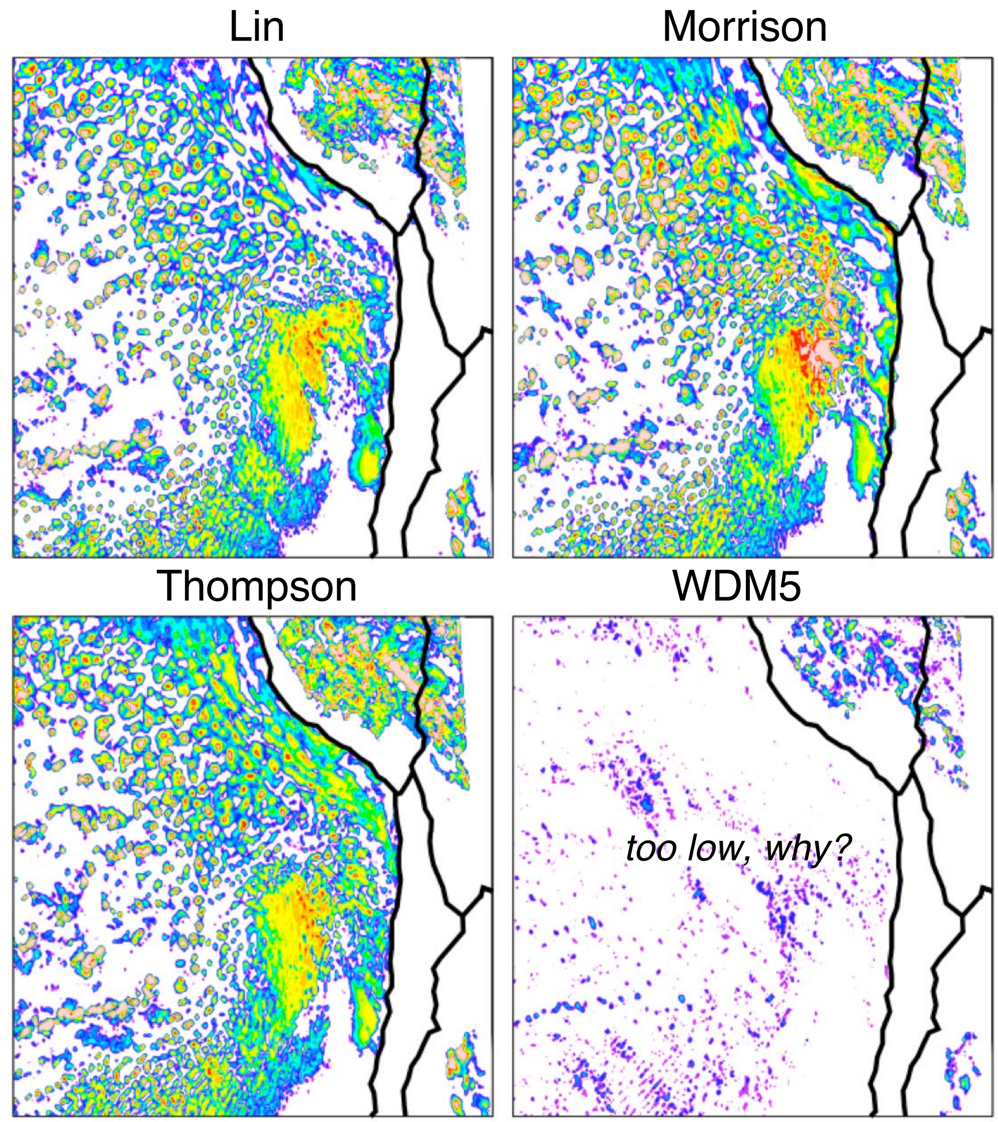
Spatial Distribution of LWP

Sensitivity to Microphysics Schemes

Observed LWP from GOES 18 UTC October 22



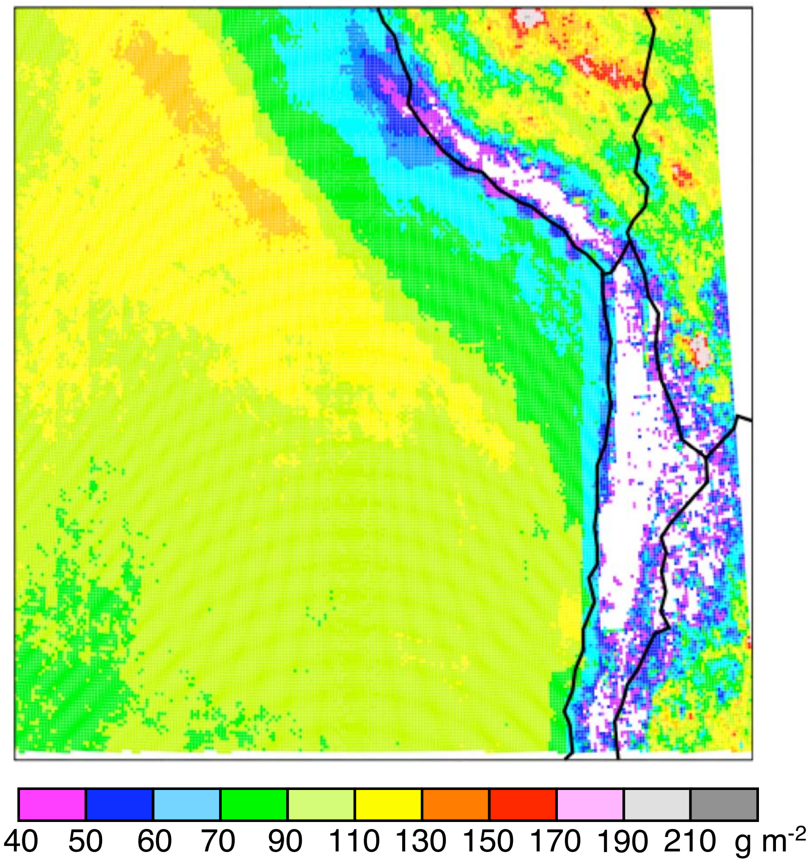
Simulated: ACM Boundary Layer, Δx = 9 km



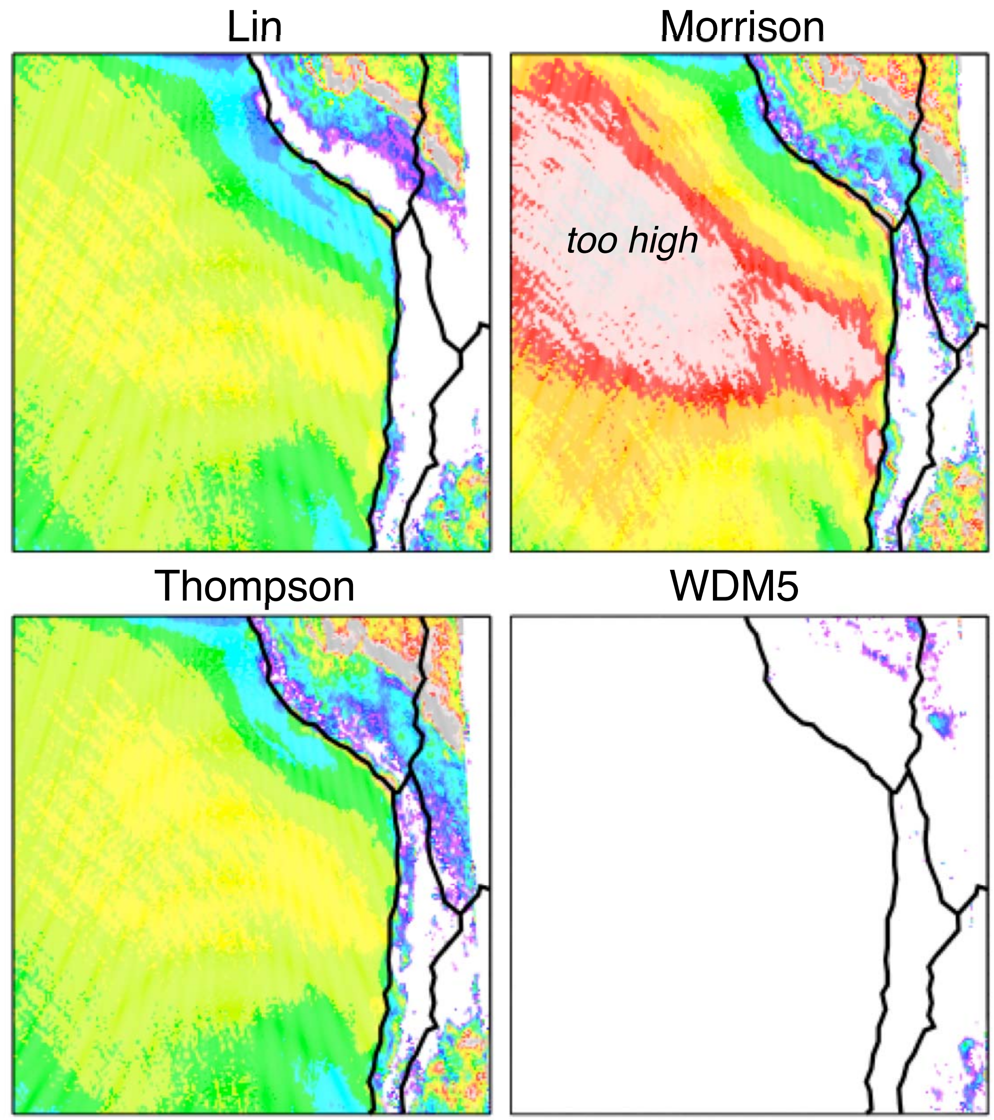
Monthly Averaged LWP

Sensitivity to Microphysics Schemes

Observed LWP from GOES
October 15 – November 15



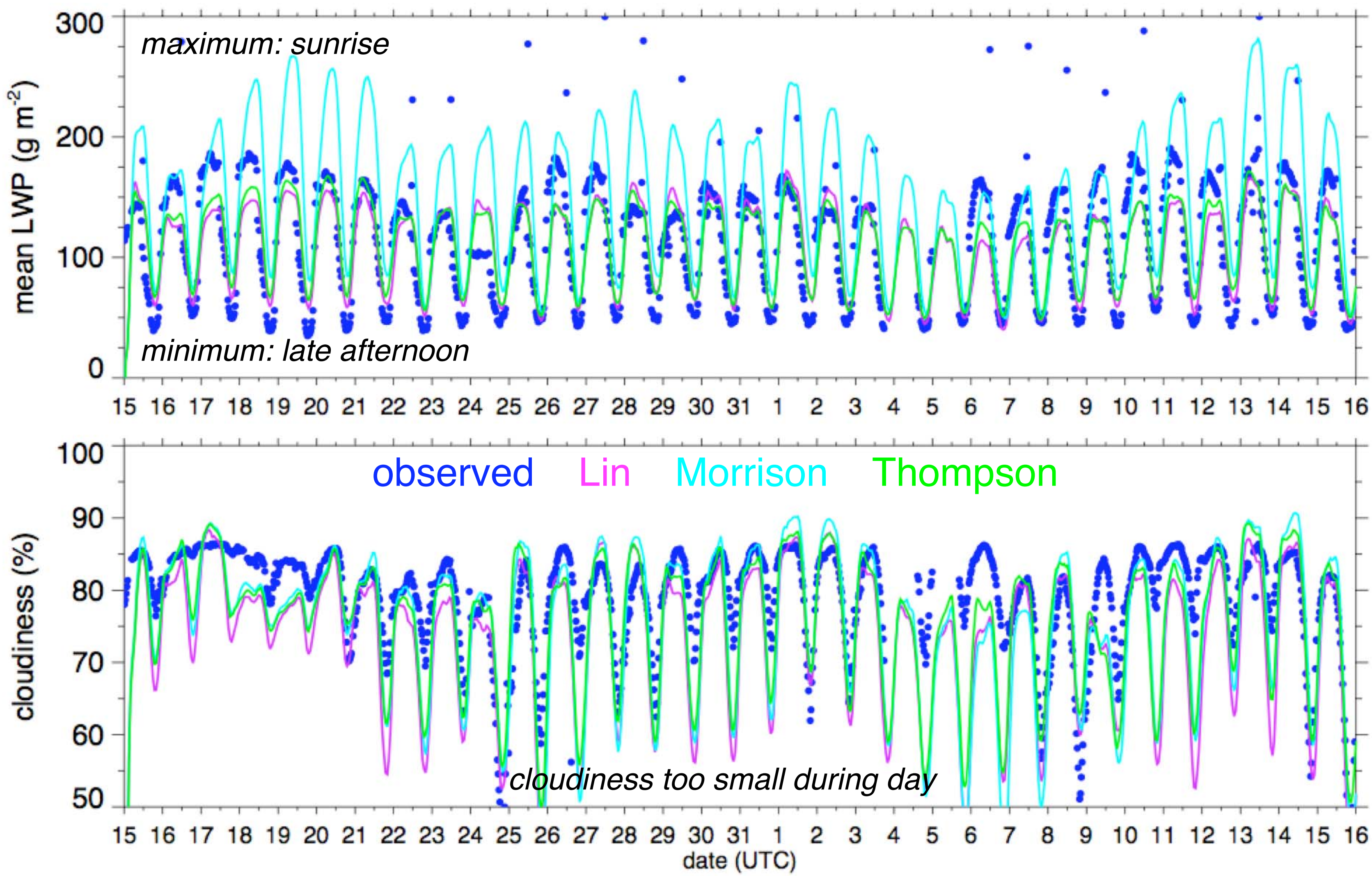
Simulated: ACM Boundary Layer, Δx = 9 km



Diurnal LWP

Sensitivity to Microphysics Schemes

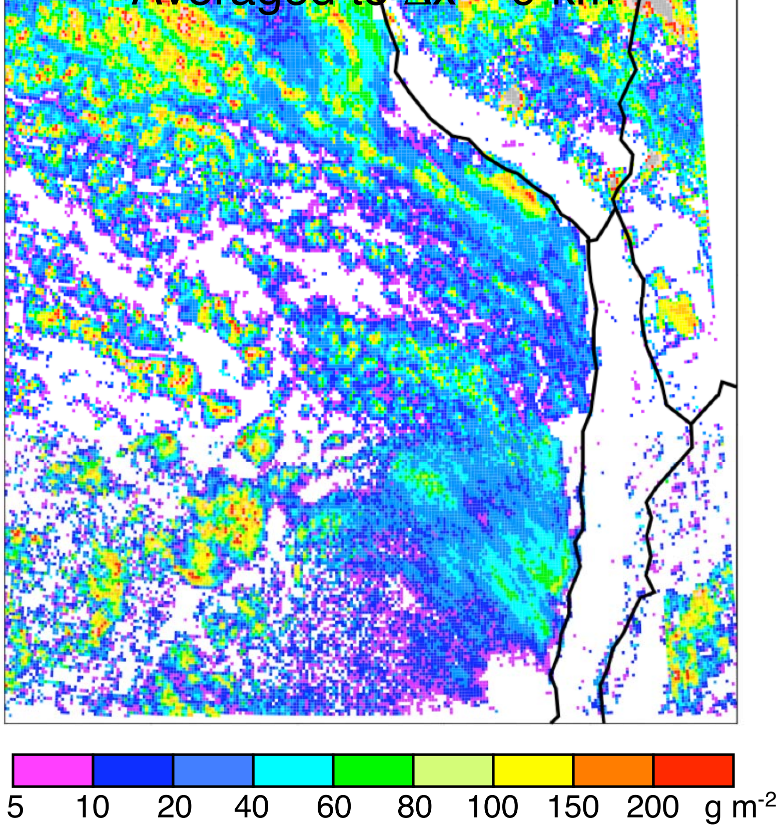
Domain Averaged LWP over Ocean (ACM Boundary Layer, Δx = 9 km)



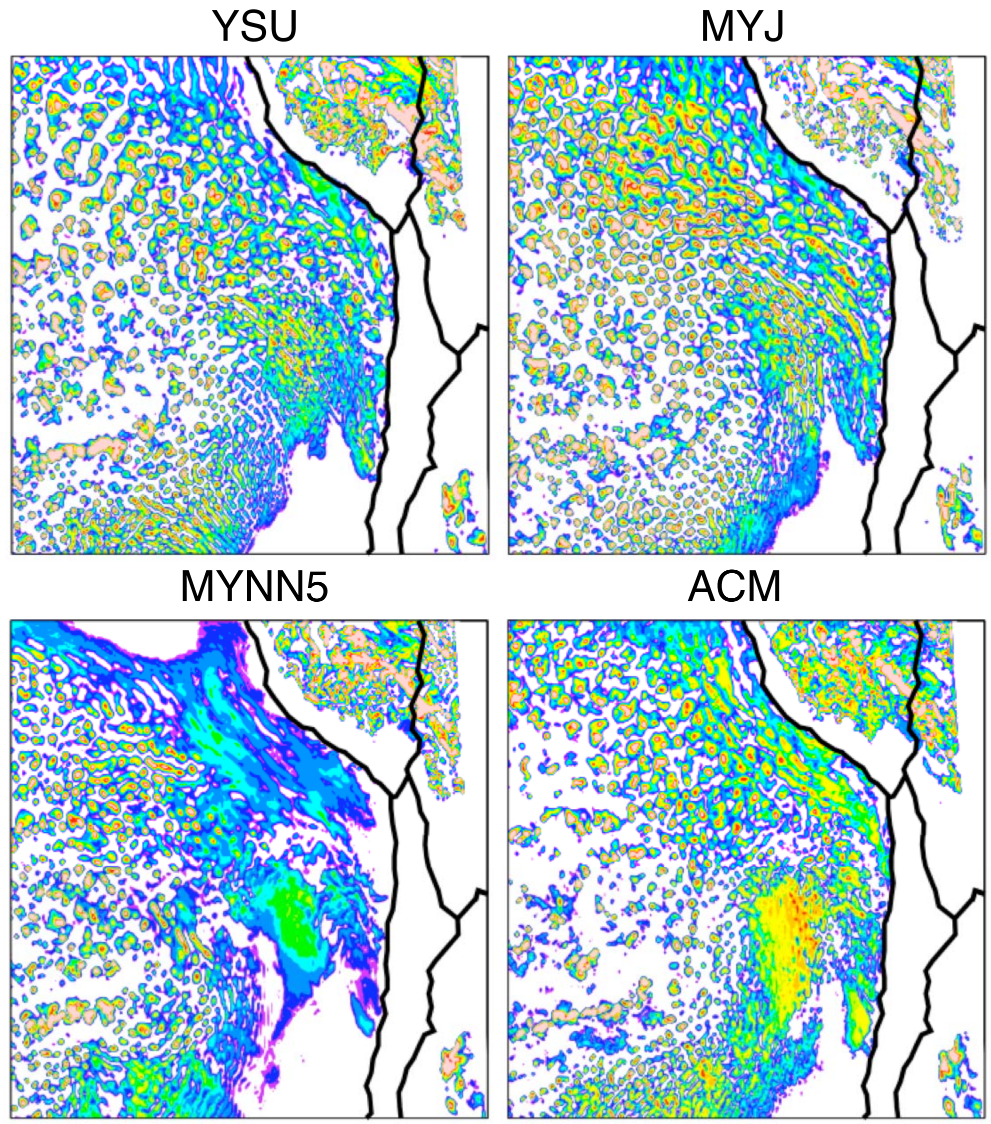
Spatial Distribution of LWP

Sensitivity to Boundary Layer Schemes

Observed LWP from GOES
18 UTC October 22
Averaged to Δx = 9 km



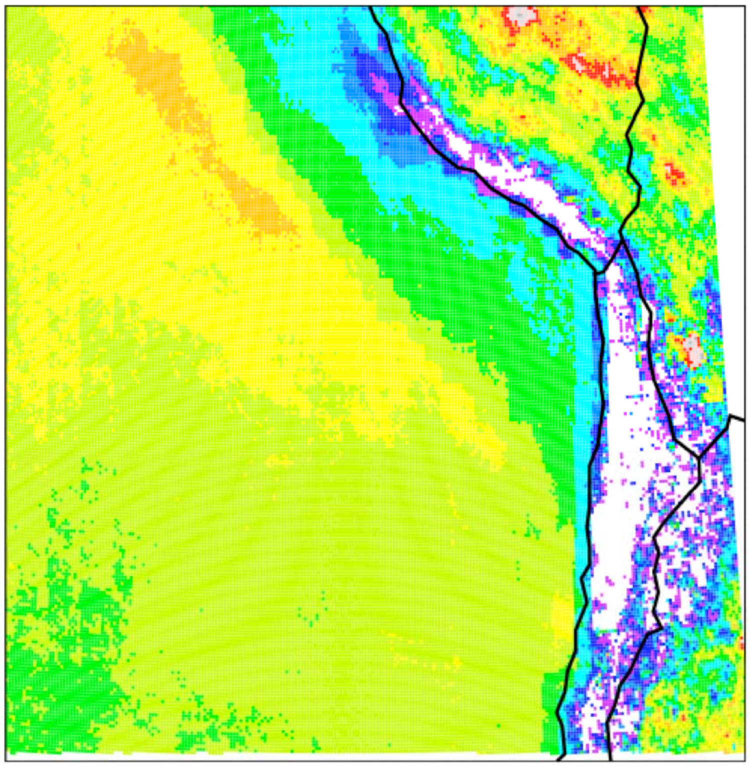
Simulated: Thompson Microphysics, Δx = 9 km

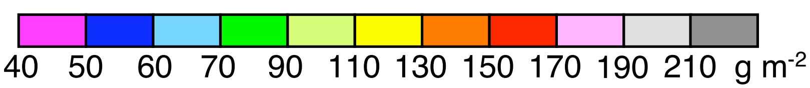


Monthly Averaged LWP

Sensitivity to Boundary Layer Schemes

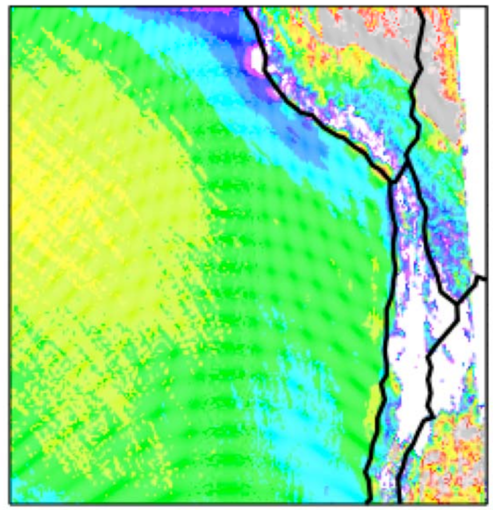
Observed LWP from GOES
October 15 – November 15



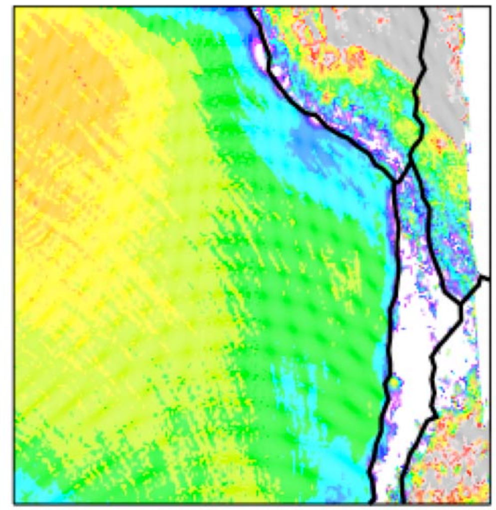


Simulated: Thompson Microphysics, Δx = 9 km

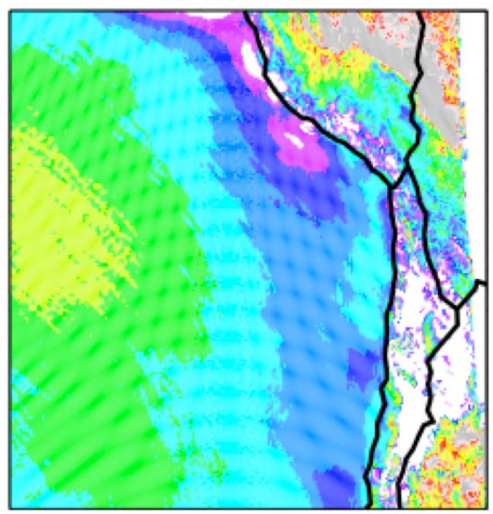
YSU



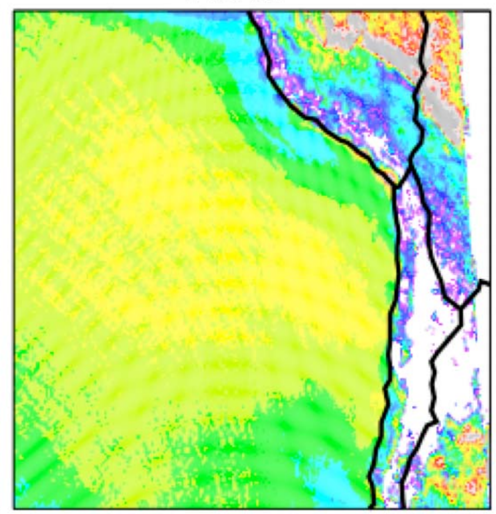
MYJ



MYNN5



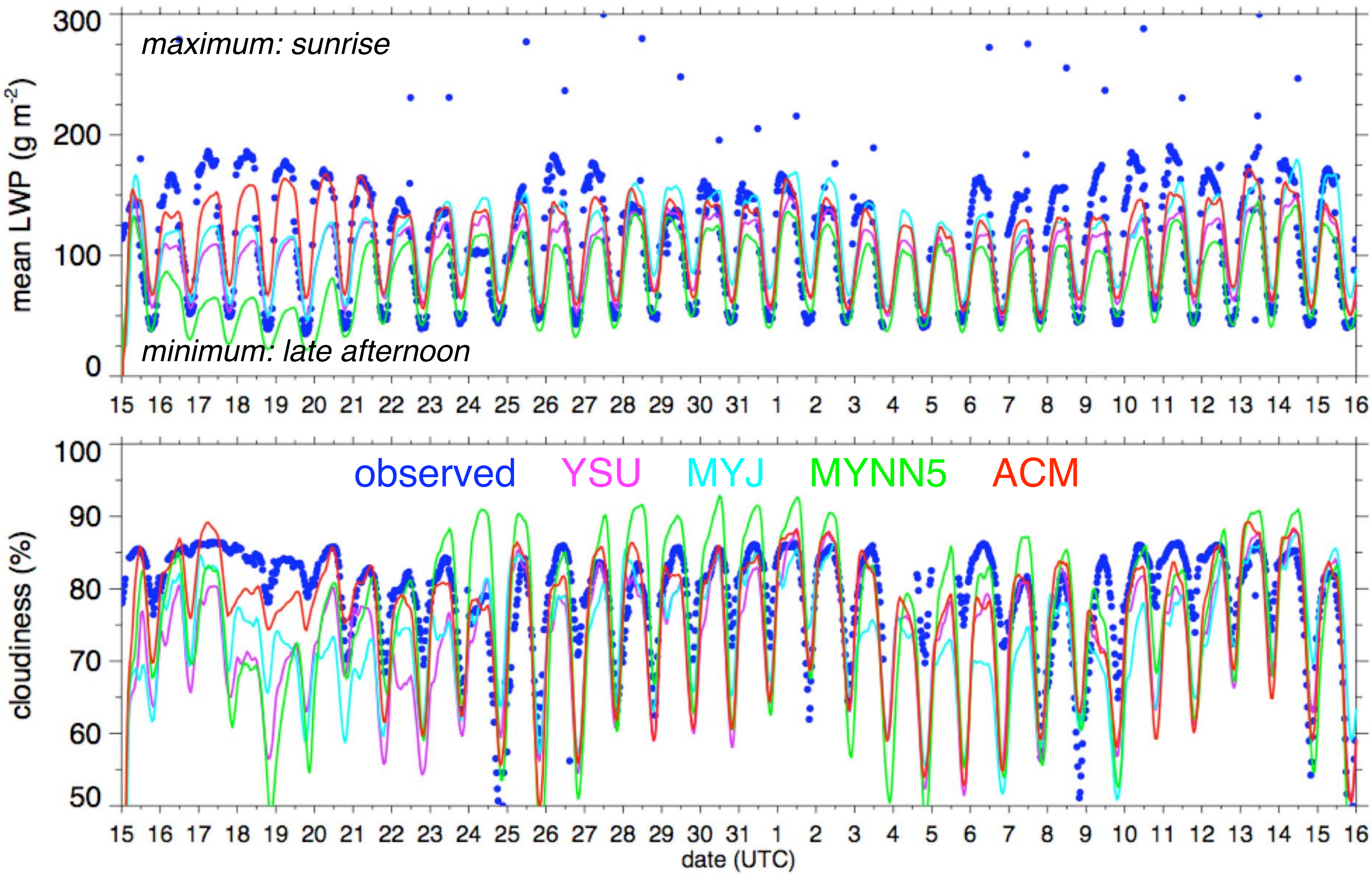
ACM



Diurnal LWP

Sensitivity to Boundary Layer Schemes

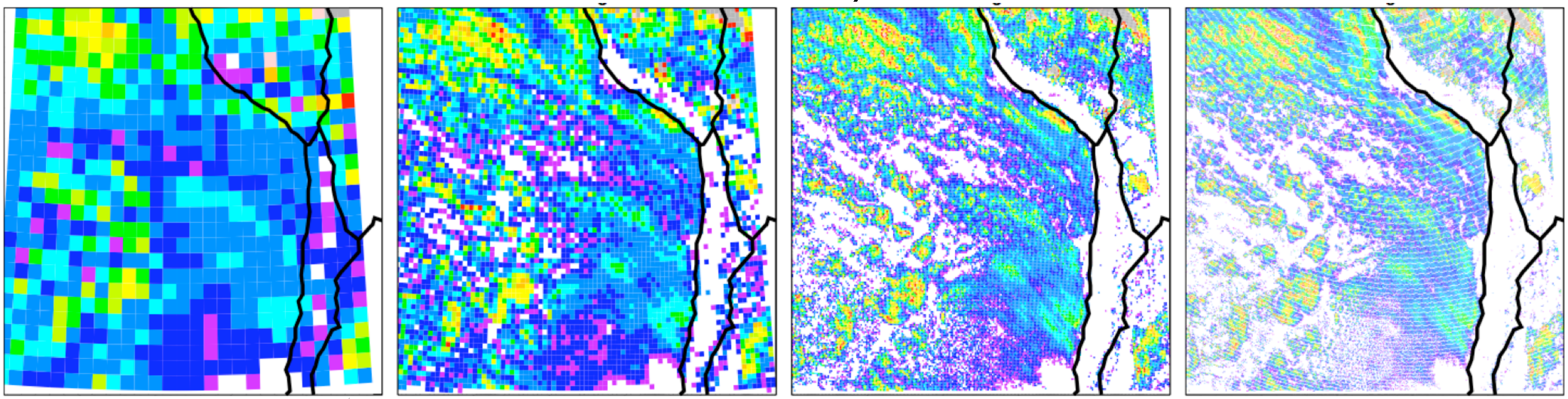
Domain Averaged LWP over Ocean (Thompson microphysics, Δx = 9 km)



Spatial Distribution of LWP

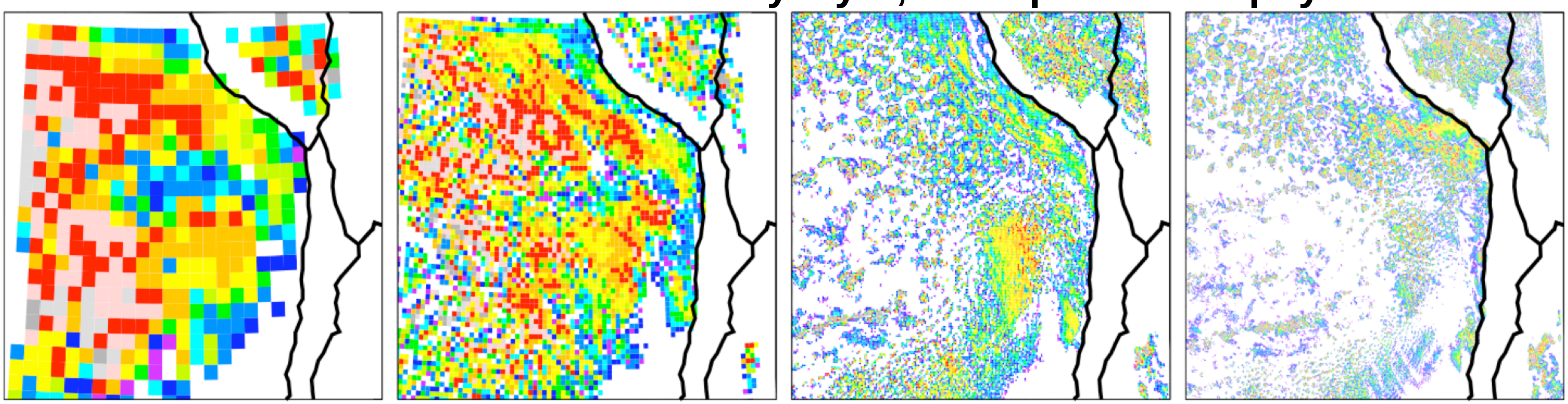
Sensitivity to Spatial Resolution

Observed LWP from GOES, 18 UTC October 22



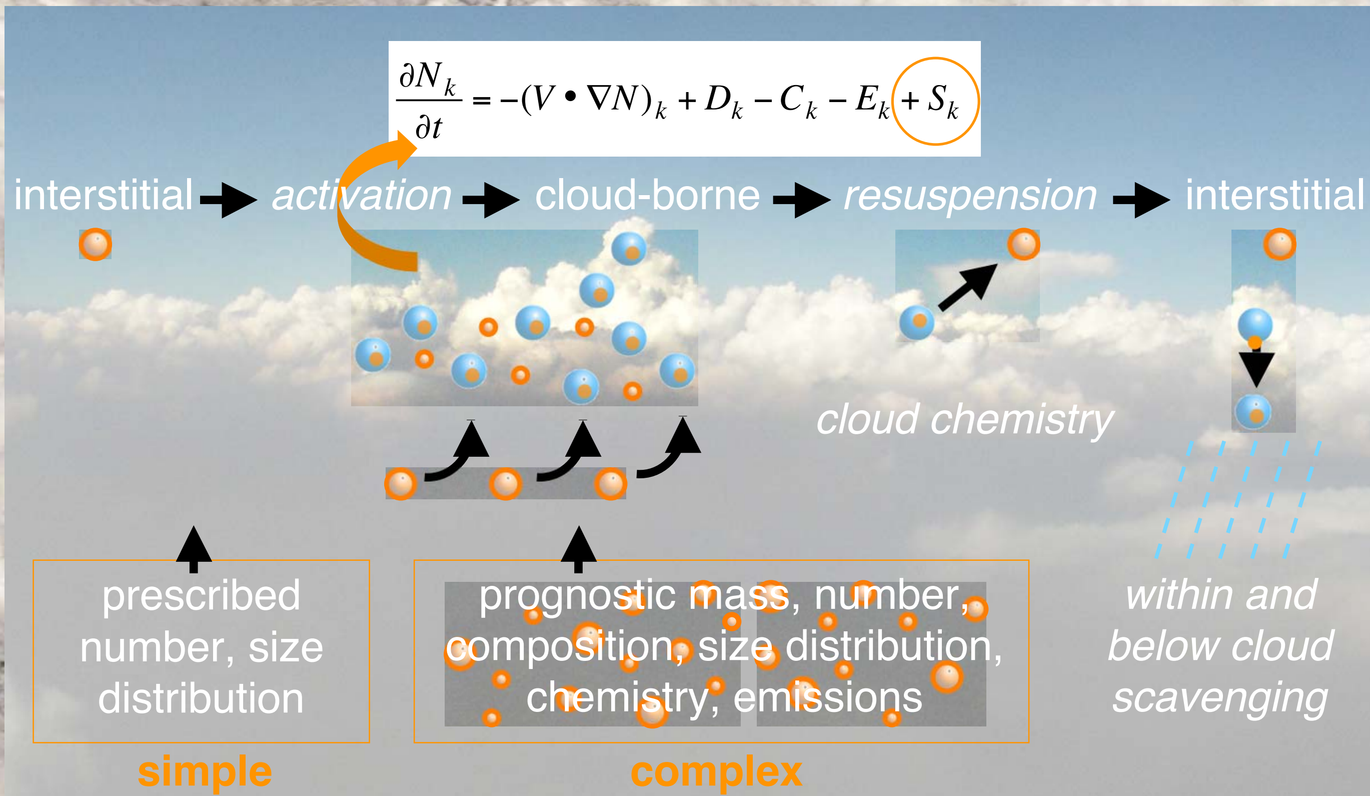
Δx = 81 km **Δx = 27 km** **Δx = 9 km** **Δx = 4 km**

Simulated LWP: ACM boundary layer, Thompson microphysics



Δx = 81 km **Δx = 27 km** **Δx = 9 km** **Δx = 4 km**

Cloud-Aerosol Interactions



Coupled with Microphysics

- Lin (released v3.1)
- Thompson (currently testing)
- Morrison (currently testing)

Methodology similar to that used in CAM3

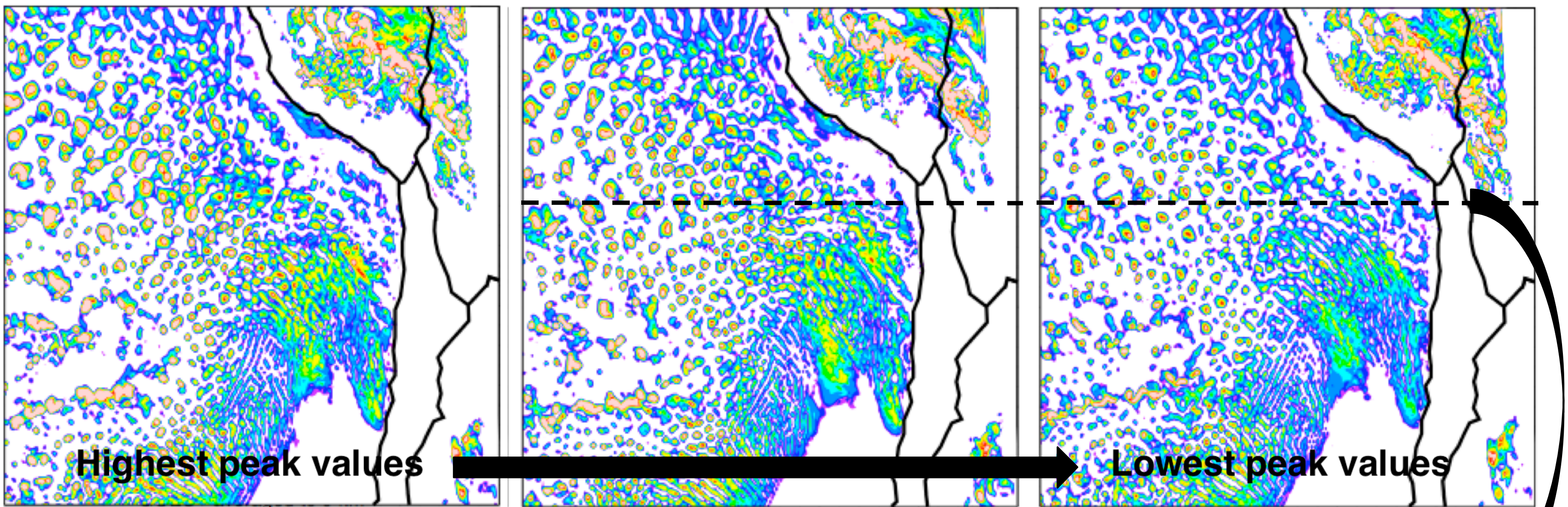
Prescribed #
150 & 600 cm^{-3} based on G-1 data

Full Chemistry
Variable aerosols

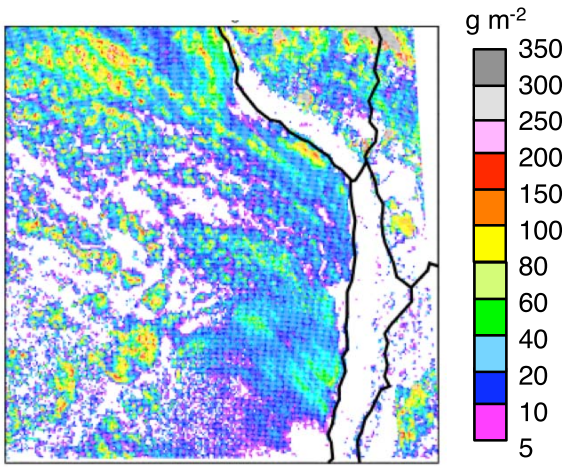
Lin Microphysics + YSU Boundary Layer

Sensitivity to Prescribed Aerosols

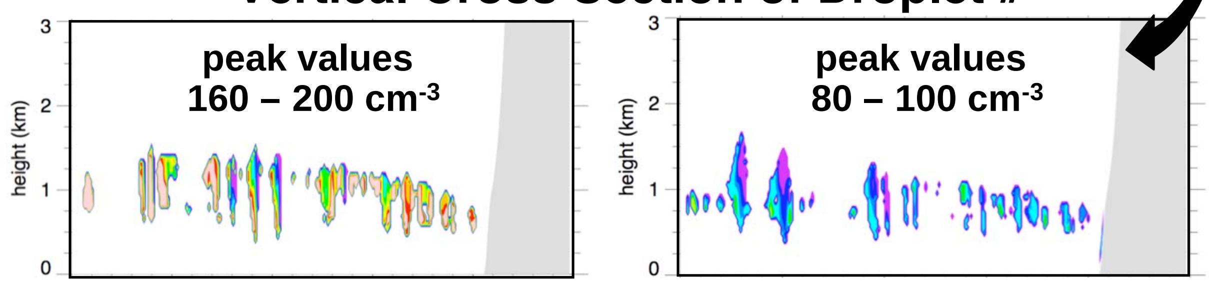
Default | **Aerosol # = 600 cm^{-3}** | **Aerosol # = 150 cm^{-3}**



Observed LWP from GOES



Vertical Cross Section of Droplet #



observed peak values
150 cm^{-3} (west) – 400 cm^{-3} (east)

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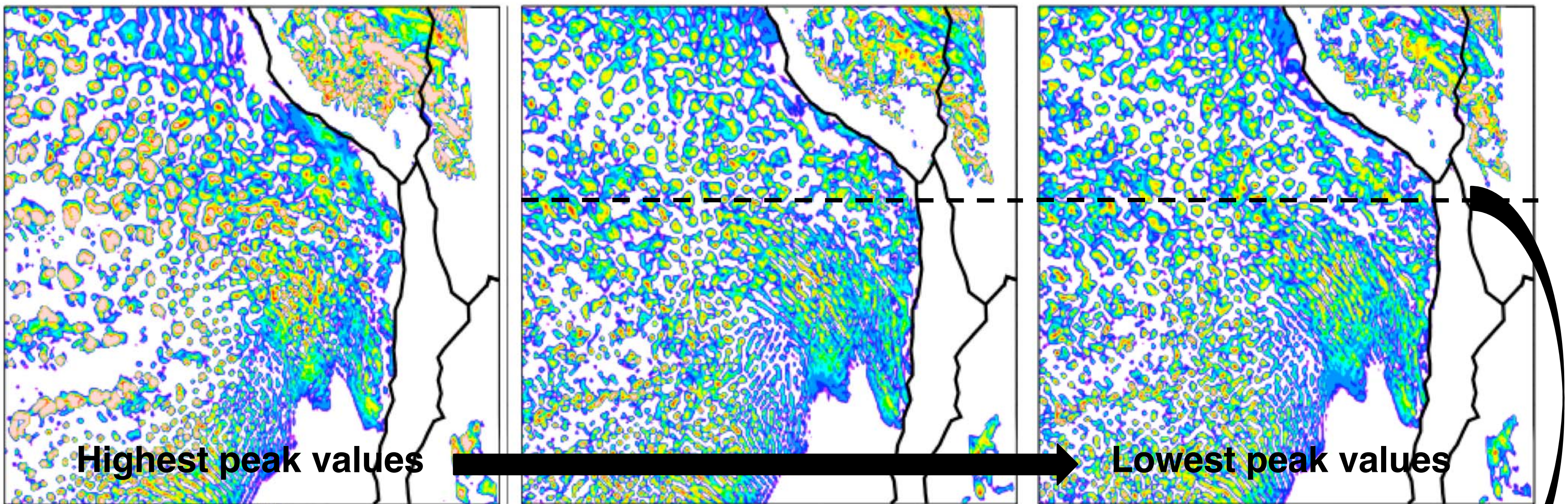
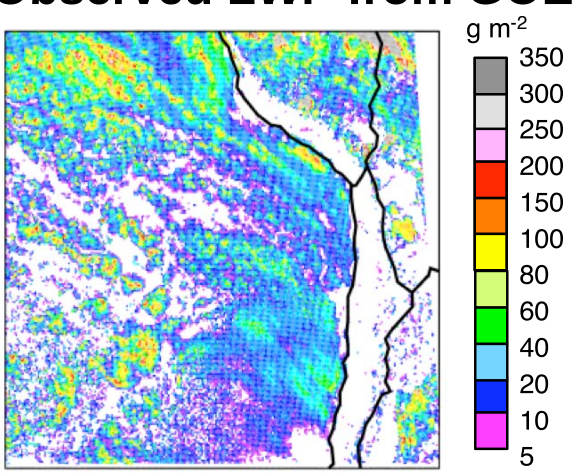
Morrison Microphysics + YSU Boundary Layer

Sensitivity to Prescribed Aerosols

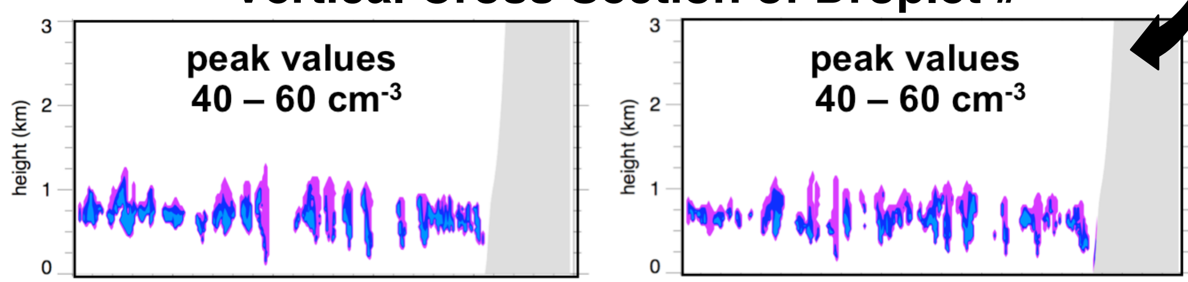
Default | **Aerosol # = 600 cm^{-3}** | **Aerosol # = 150 cm^{-3}**



Observed LWP from GOES



Vertical Cross Section of Droplet #



observed peak values
150 cm^{-3} (west) – 400 cm^{-3} (east)

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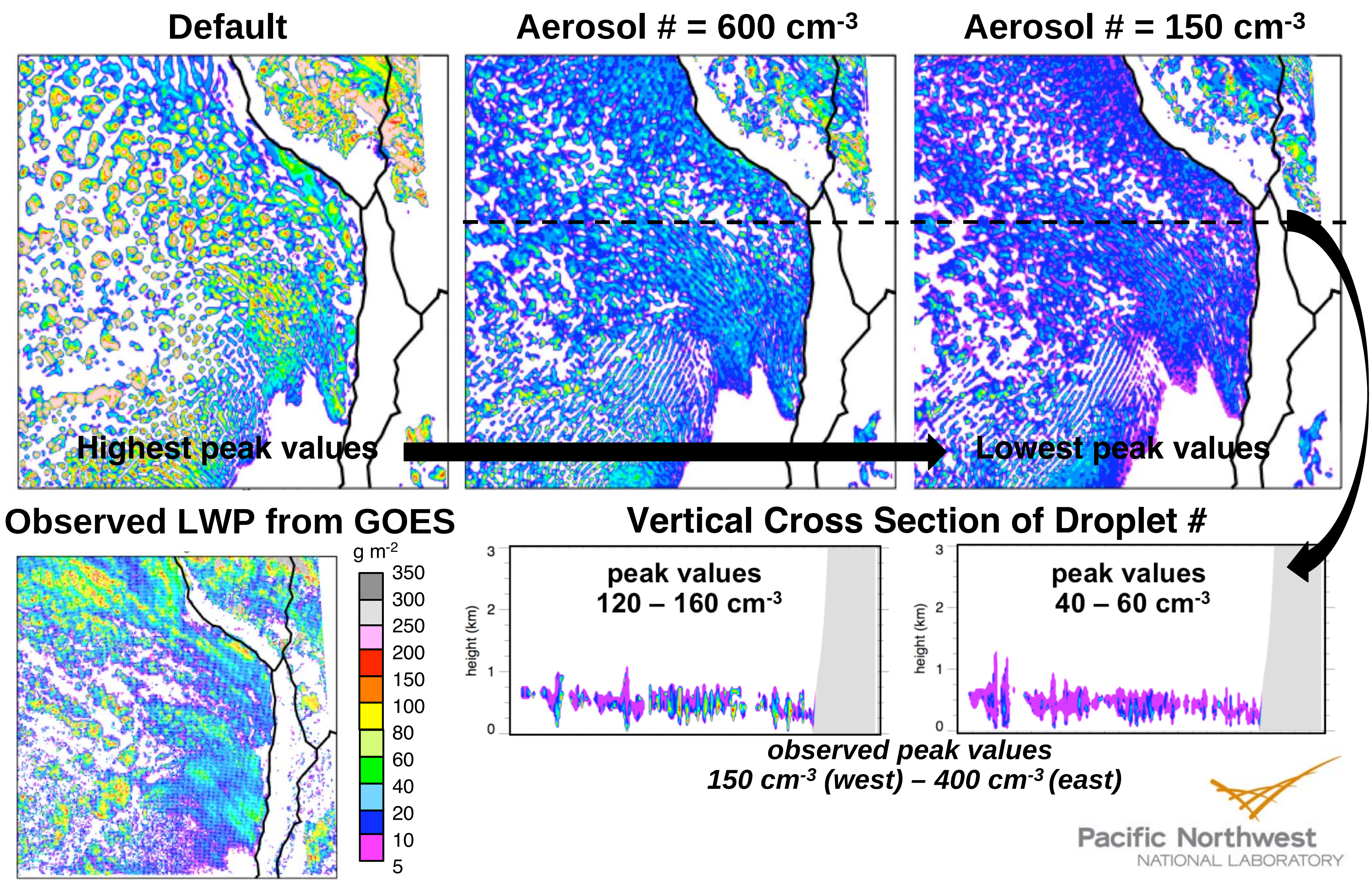
Thompson Microphysics + YSU Boundary Layer

Sensitivity to Prescribed Aerosols



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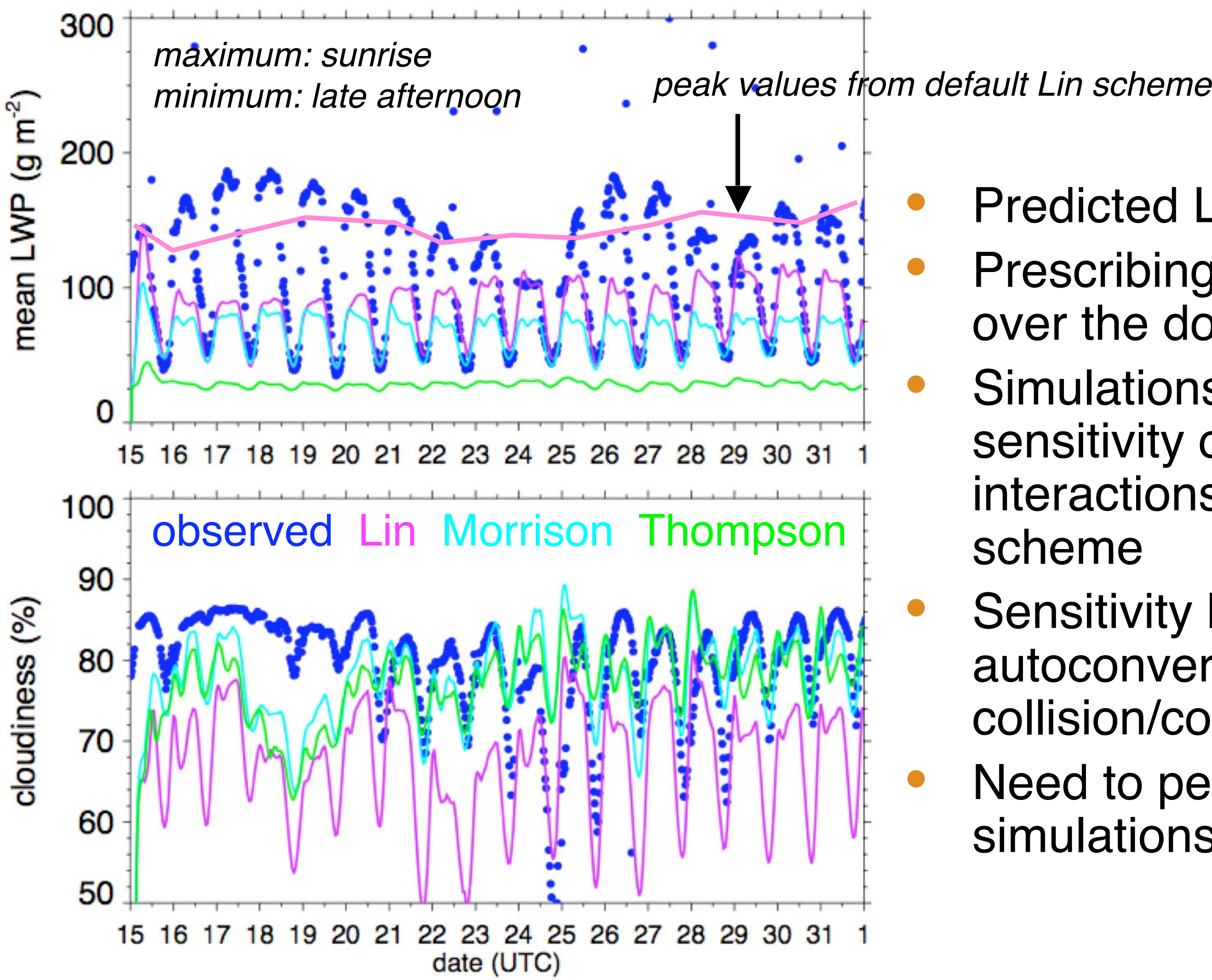
Diurnal LWP

Domain Averaged LWP over Ocean (YSU Boundary Layer, Δx = 9 km)



- Predicted LWP too low, but …
- Prescribing constant aerosol # over the domain **not realistic**
- Simulations useful to check the sensitivity of cloud-aerosol interactions to microphysics scheme
- Sensitivity likely due to how autoconversion and collision/coalescence is treated
- Need to perform **full-chemistry** simulations next

Summary and Next Steps

- Results are preliminary - **more statistics** needed to assess predicted PBL structure and cloud properties using in situ and satellite data
- **On-going testing** of cloud-aerosol interactions coupled with Morrison and Thompson microphysics schemes
- **Differing sensitivity to aerosols** among microphysics schemes probably due to varying treatments of drizzle
- Effect of cloud-aerosol interactions on cloud properties **as large as** sensitivity to choice boundary layer and microphysics schemes
- Need to examine details of **vertical mixing within clouds**
  - Small changes in mixing can affect cloud-aerosol interactions
  - Exchange coefficients not yet available for all schemes
- Next steps: **Add full chemistry** to have realistic aerosol distributions

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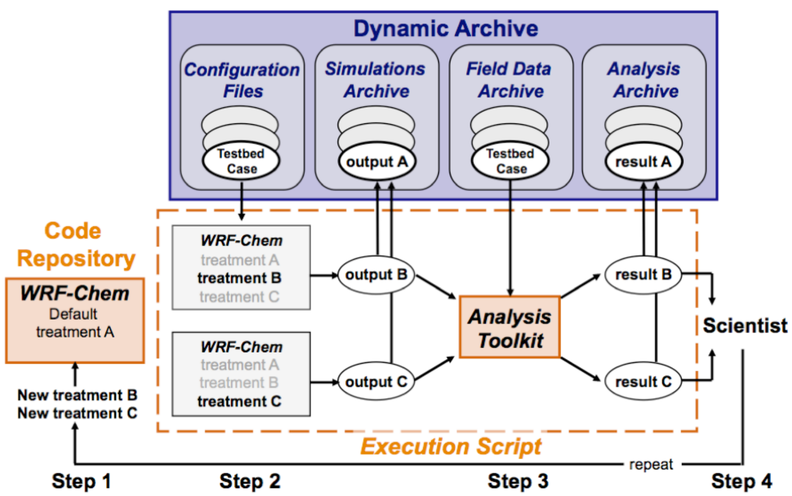
Related Research

- New Project: **"Investigation of Multiple Aerosol-Cloud Equilibrium Regimes during VOCALS"** funded by NOAA Atmospheric Composition & Climate Program, Principal Investigator: William Gustafson Jr.

  Examine the plausibility of aerosol-cloud equilibrium states that preferentially lead to open and closed cellular convection and the ability of models to reproduce the resulting radiative effects from global to cloud-resolving scales

- **Aerosol Modeling Testbed**



  - Methodology to systematically evaluate aerosol process modules
  - Tools to facilitate model evaluation using field campaign data
  - VOCALS data currently being ported into the testbed

http://www.pnl.gov/atmospheric/research/aci/aci_proj_testbed.stm

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