Regional Modeling of Particulate Chemistry and its Effect on Cloud-Aerosol Interactions over the Southeastern Pacific Ocean

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With support from DOE's Atmospheric Sciences Program
and assistance from Robert Wood and Matthew Wyant (Univ. of Washington),
Roberto Mechoso (UCLA), and Laura Gallardo Klenner (Univ. of Chile)

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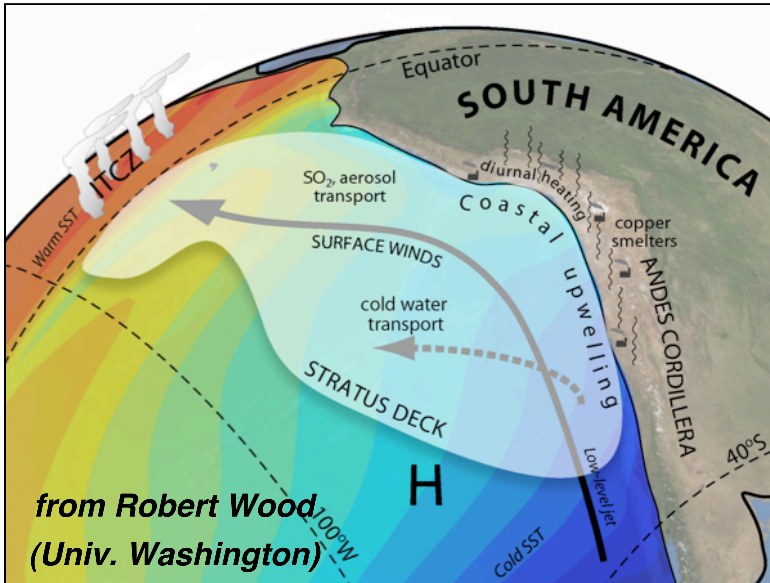
U.S. DEPARTMENT OF ENERGY

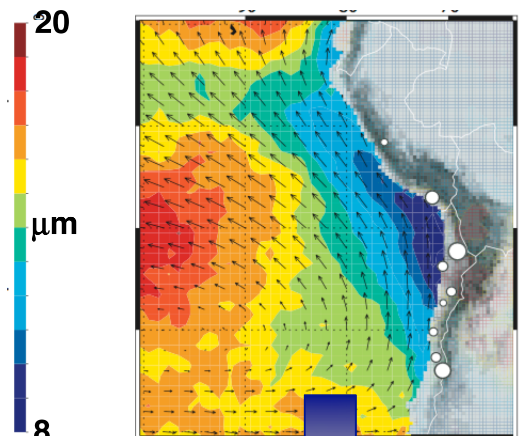
ASP

Motivation

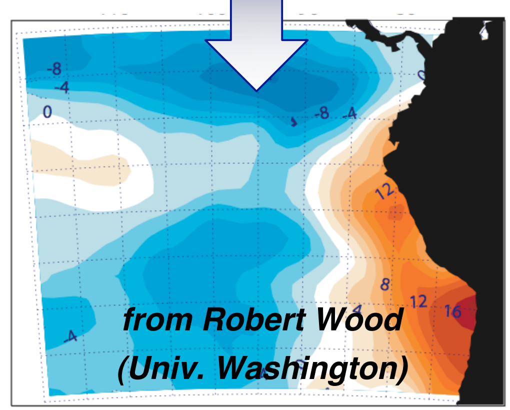
The Southeast Pacific Climate System



MODIS Cloud Droplet Effective Radius



Inferred Shortwave Cloud Forcing



- Coupled atmosphere-ocean general circulation models do not adequately simulate marine stratocumulus clouds
- Affects global climate via teleconnections
- Indirect effect of aerosols on cloud-radiative properties not fully understood
- Limited in-situ data in this region

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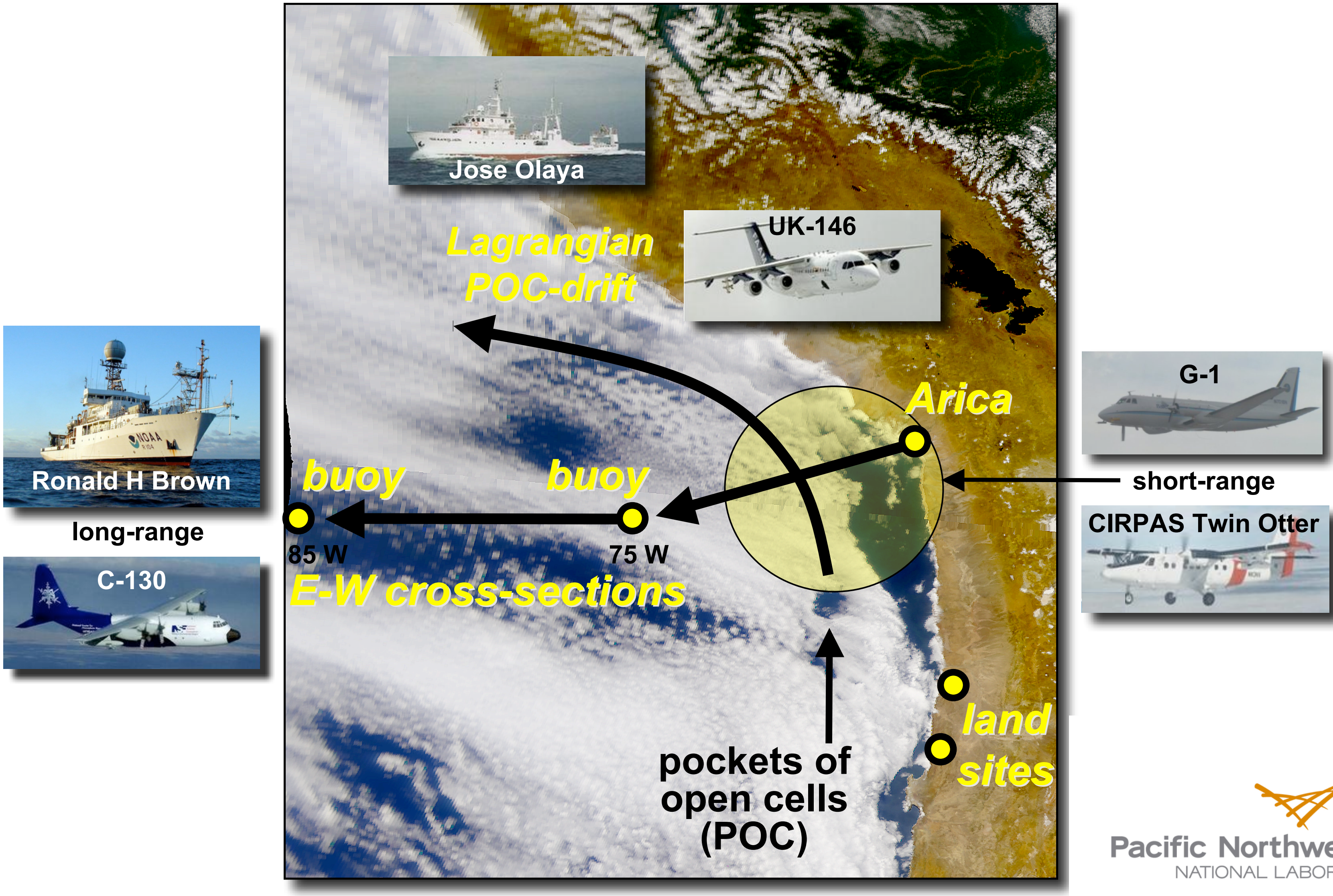
VOCALS

The VAMOS Ocean-Cloud-Atmosphere-Land Study



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Objectives

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

- What are the effects of aerosol chemistry on the evolution of CCN and stratocumulus clouds downwind of large anthropogenic point sources along the coast of Chile?
- What is the relative importance of anthropogenic (copper smelters, power plants) and natural (DMS, volcanic) and sources on cloud-aerosol interactions?
- Do aerosols play a role on the evolution of POCs?

Because the field campaign will not be conducted until November 2008, we have run WRF-Chem for October 2006, a climatologically similar period, to "exercise" the code and participate in the **Pre-VOCALS model assessment**

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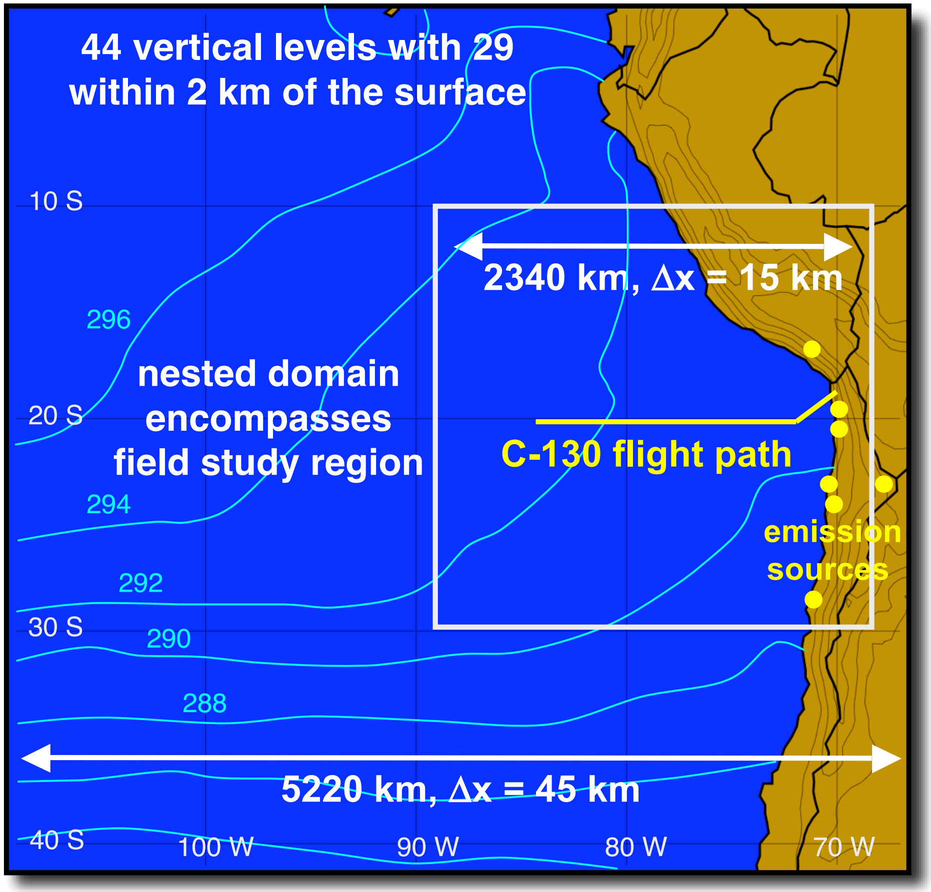
WRF-chem Version 2.2

Model Configuration and Aerosol-Radiation-Cloud Interactions

- YSU boundary-layer scheme and Lin microphysics scheme
- CBM-Z photochemistry and MOSAIC aerosols
- Boundary conditions from GFS and MOZART models
- **Direct effect** (scattering and absorption) via Goddard shortwave radiation scheme
- **First & second indirect effects** (cloud albedo, cloud life cycle) via predicted CCN and cloud droplet number in modified Lin microphysics scheme



PNNL modules that couple aerosols, radiation, & clouds updated in version 3

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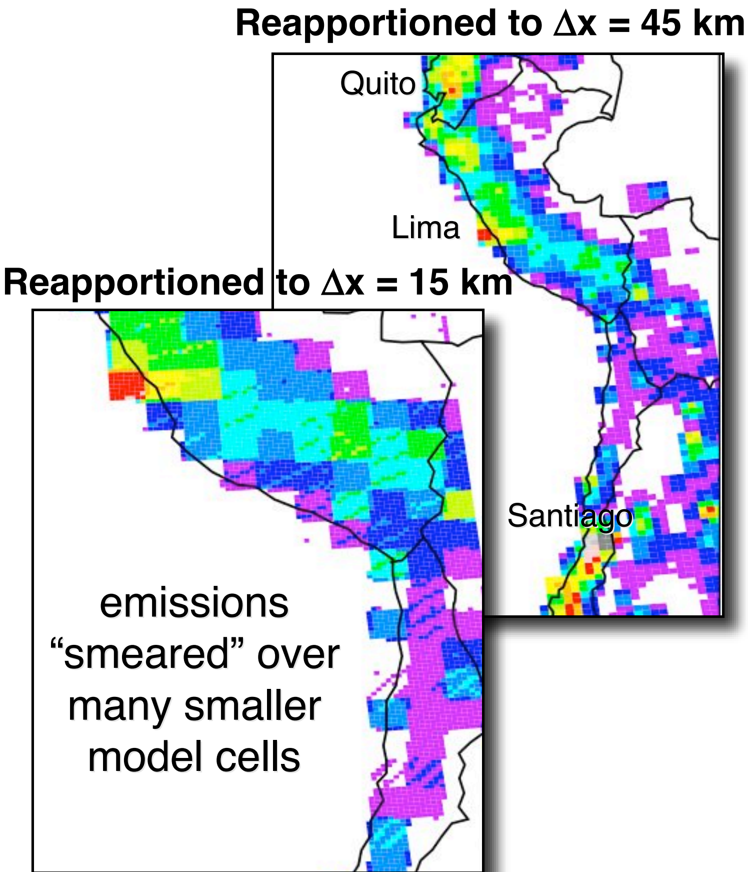
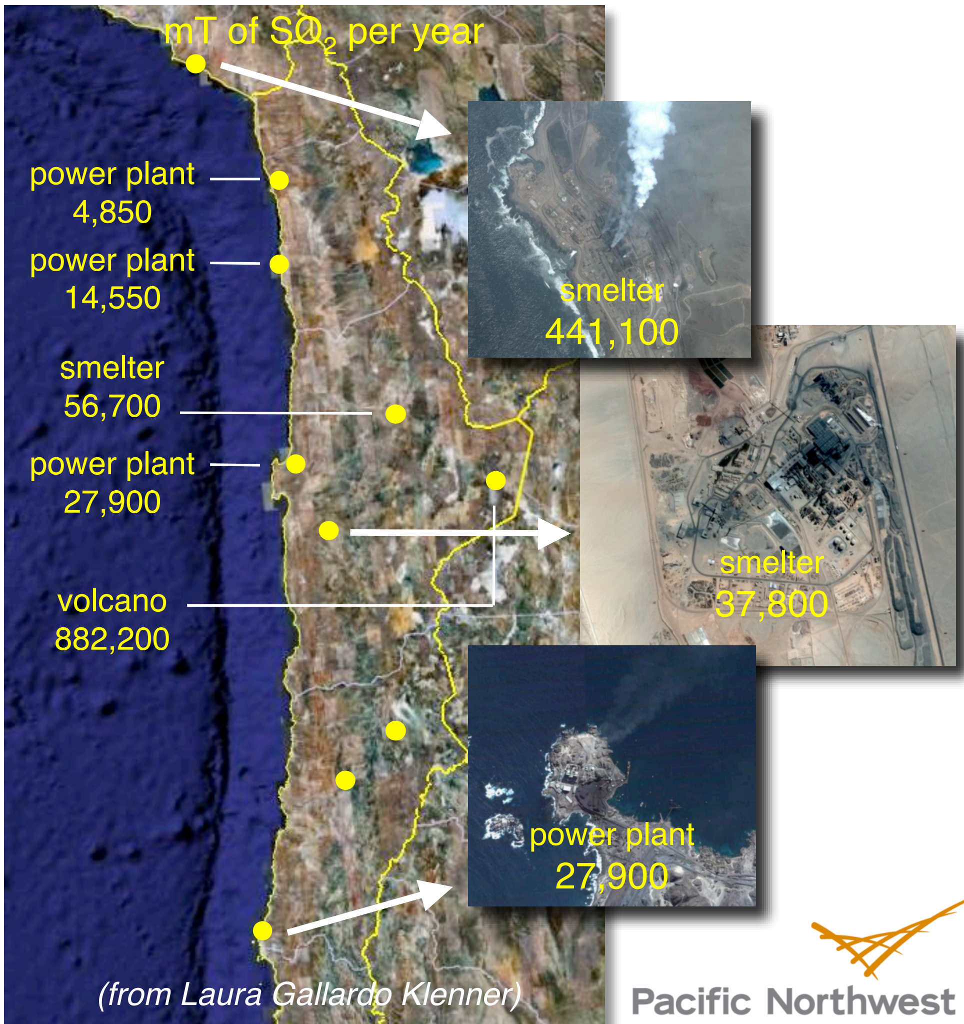
Trace Gas and Particulate Emissions

Global 1 Degree Estimates of POA (AeroCom)



Chilean scientists to develop higher resolution and more up-to-date emission estimates

Chilean National Commission for the Environment 2005 Emission Estimates of SO_2



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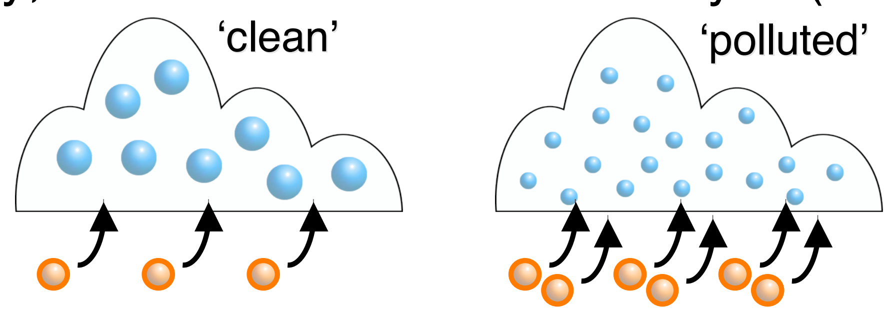
Simulations

Run	Lin et al. Microphysics	Δx (km)	Cloud-Aerosol Interactions
1a	Default	45	no
1b	Default	45 & 15	no
2a	Modified #)	45	yes (prescribed aerosol
2b	Modified #)	45 & 15	yes (prescribed aerosol
3a	Full chemistry, modified	45	yes (complex)
3b	Full chemistry, modified	45 & 15	yes (complex)



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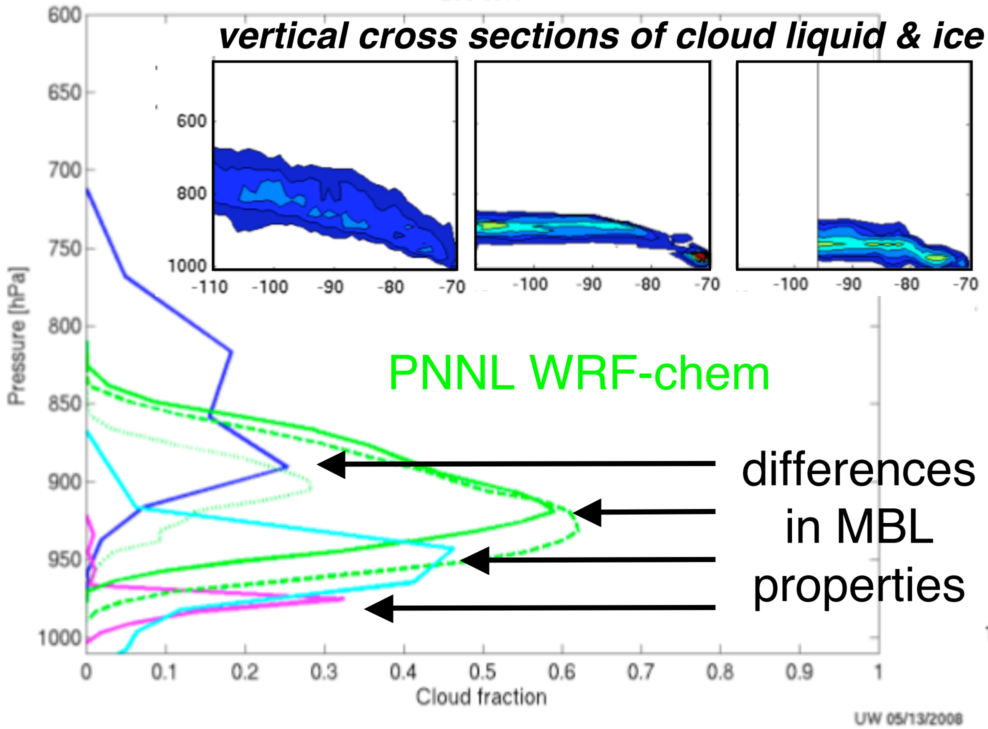
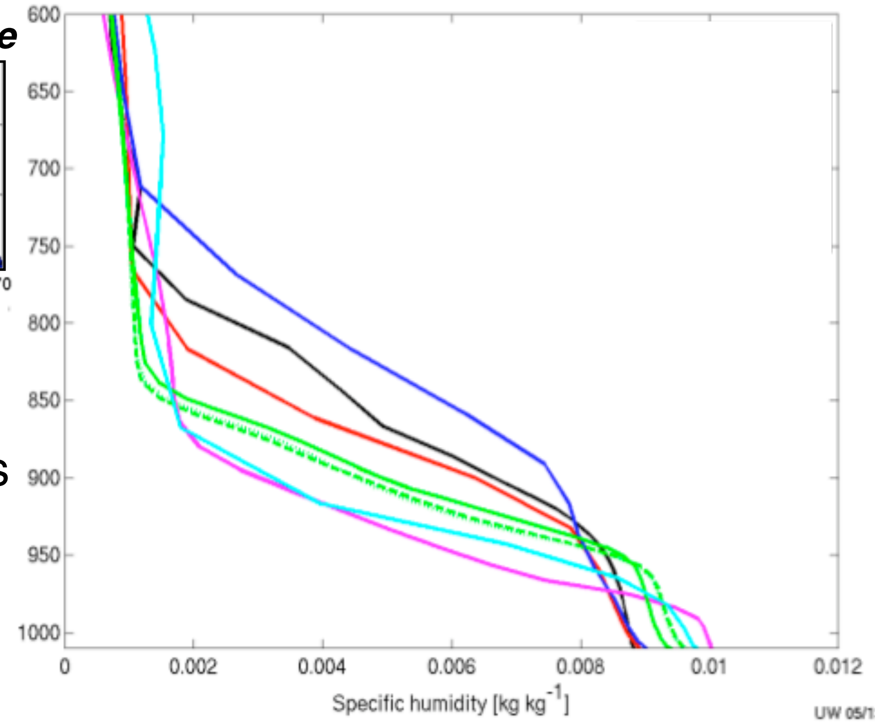
PreVOCA

Goal: Critically assess the ability of global (7) and regional (6) models to predict conditions over the southeastern Pacific Ocean

Cloud Fraction at 20S 85W



Specific Humidity at 20S 85W



Models are currently being evaluated, primarily with satellite data

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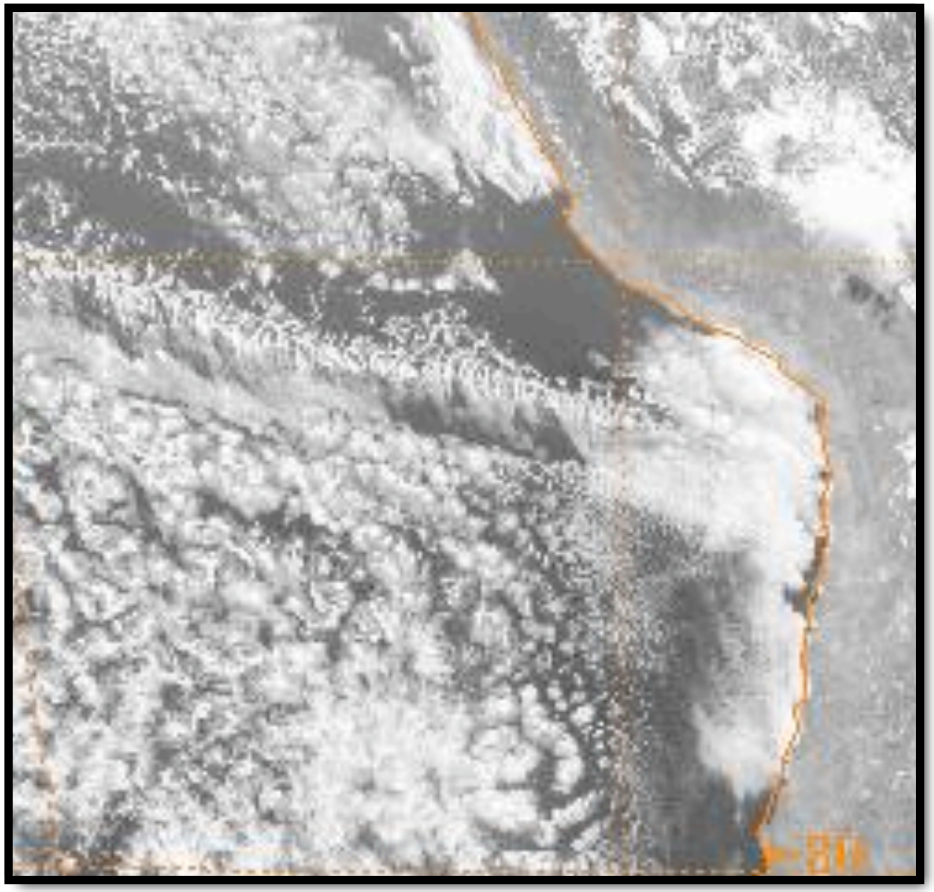
Analysis from Matthew Wyant and Roberto Mechoso

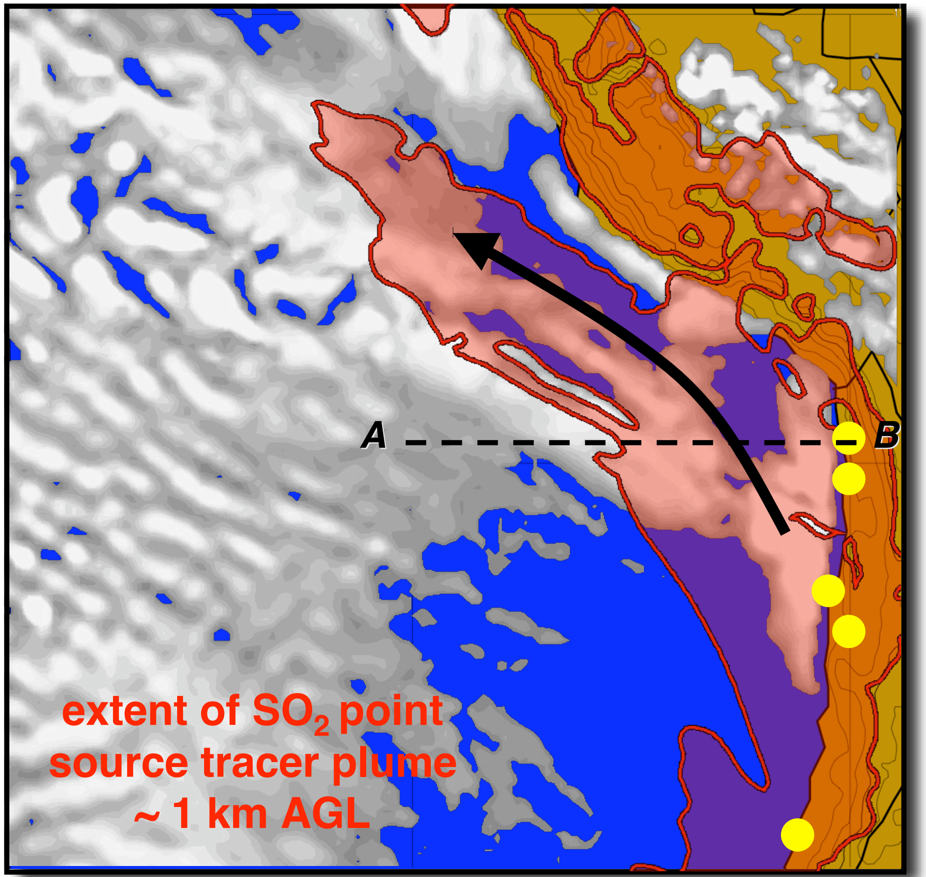
Regional Cloud Distribution

Simulated Cloud Optical Depth 12 UTC October 15, 2006

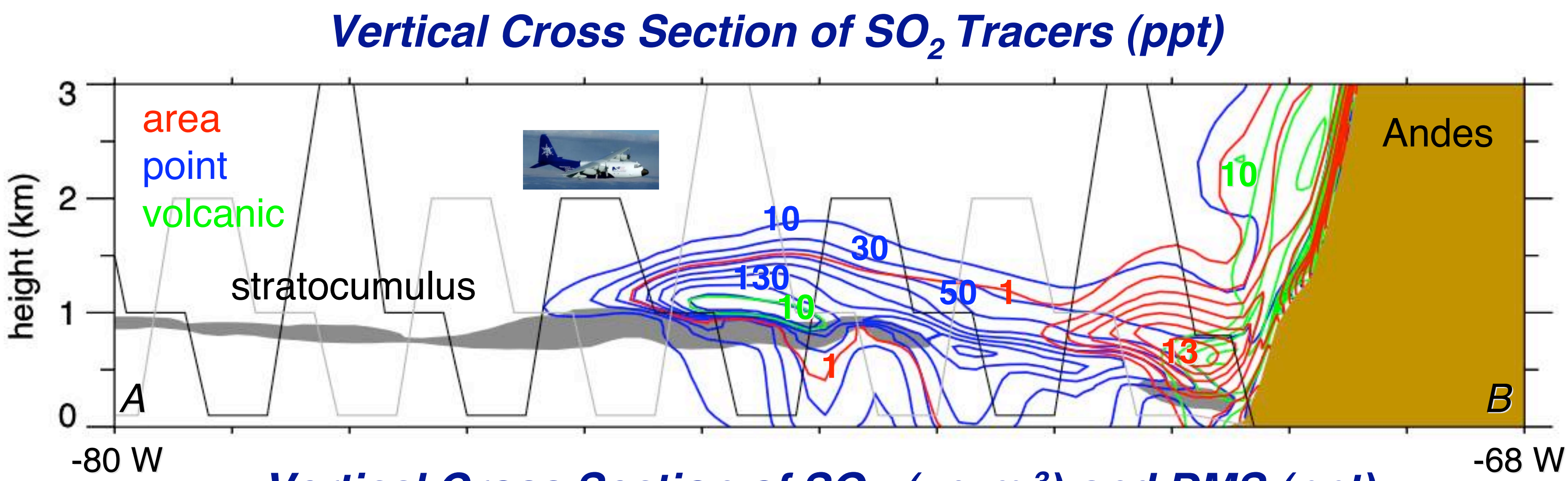
GOES Visible 18 UTC

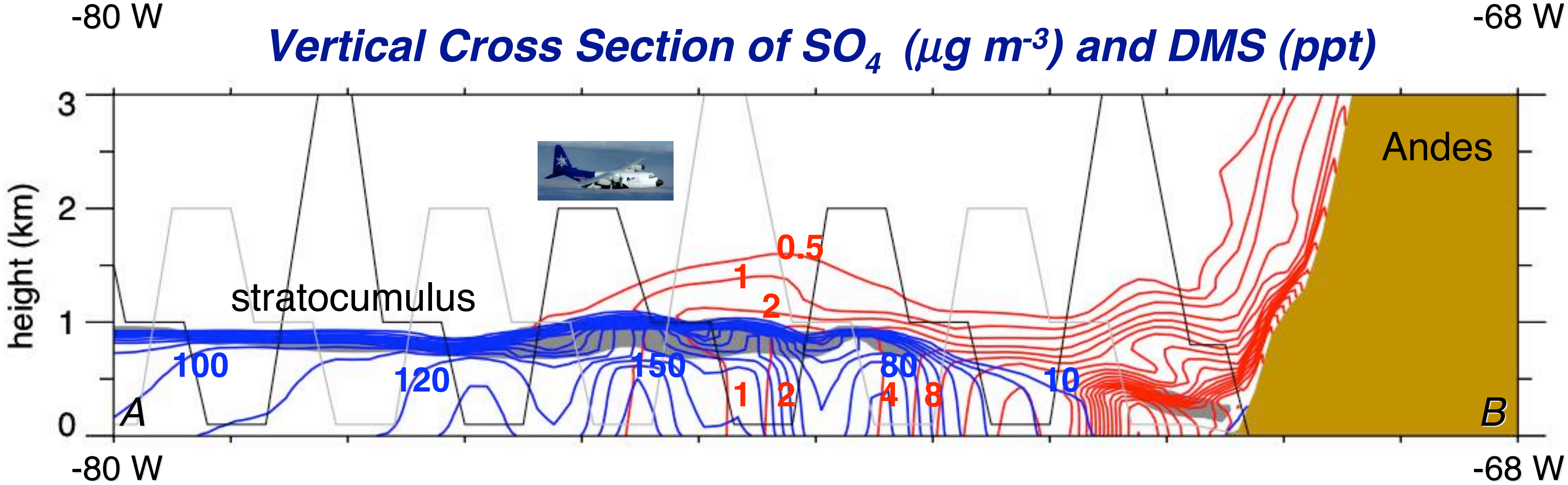


Domain 2 (Δx = 15 km)



Sulfate and its Precursors





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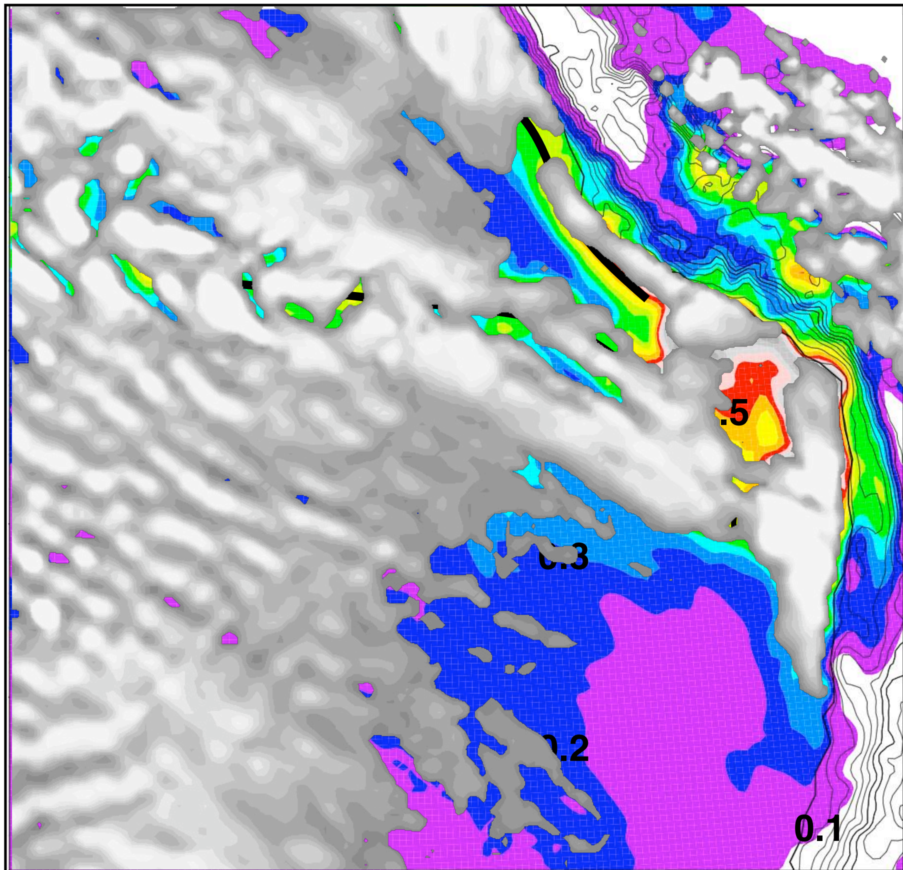
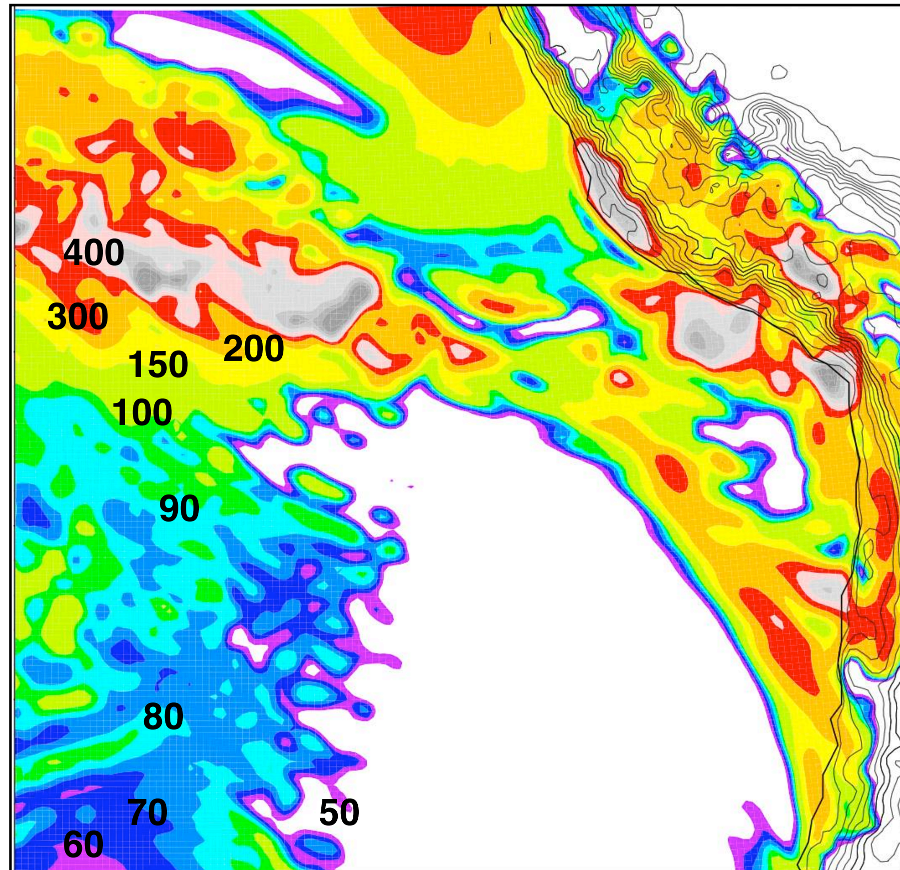
Elements of Aerosol Radiative Forcing

AOD (600 nm) 12 UTC October 15



particulates affect shortwave radiation via scattering & absorption

CCN at 0.1% SS (# cm^{-3})



CCN activation affects cloud-aerosol interactions

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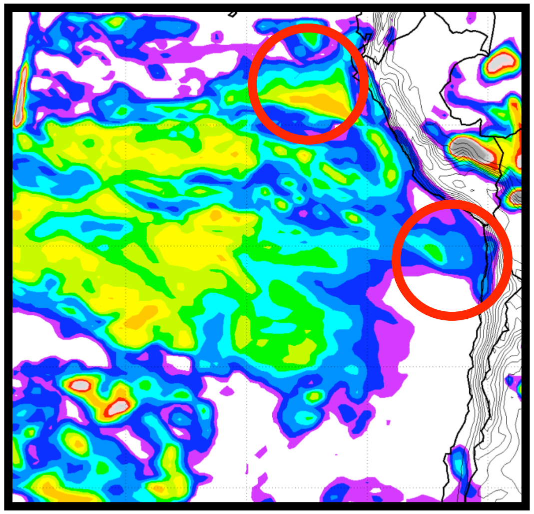
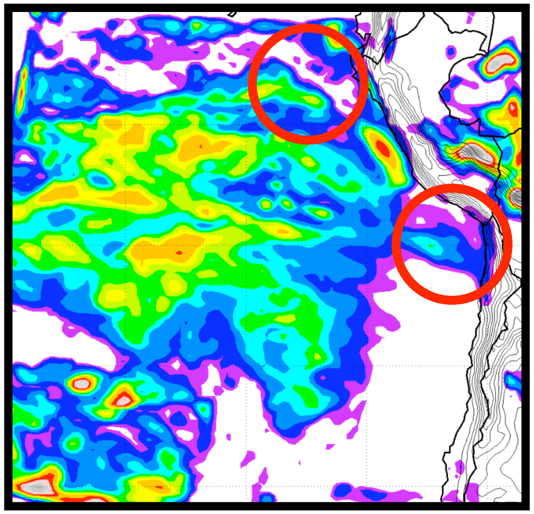
Regional Liquid Water Path

LWP at 12 UTC October 15, 2006

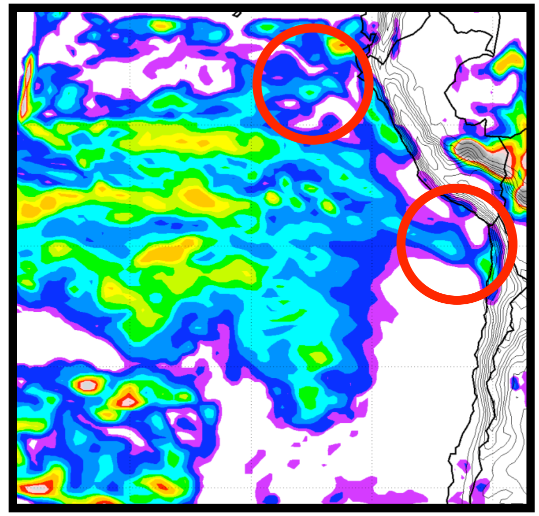
Run 1: Default



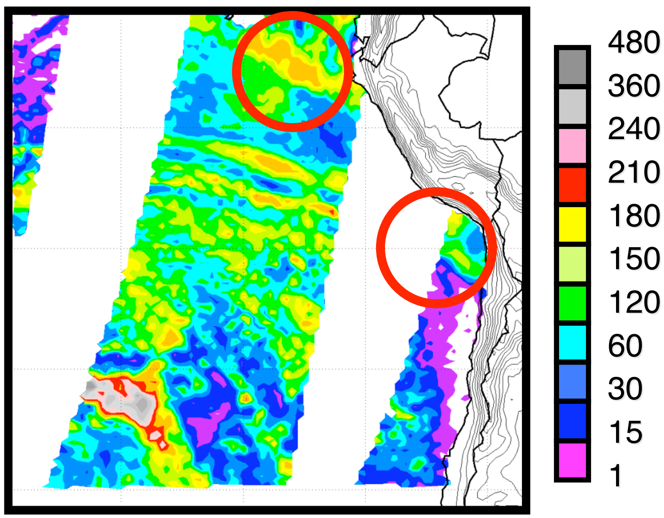
Run 2: Prescribed Aerosol #



Run 3: Full Chemistry



TRMM Satellite LWP



- TRMM data aggregated to model domain
- Simulated distribution of LWP qualitatively similar to satellite measurements
- Subtle differences in LWP distribution and magnitude among 3 simulations

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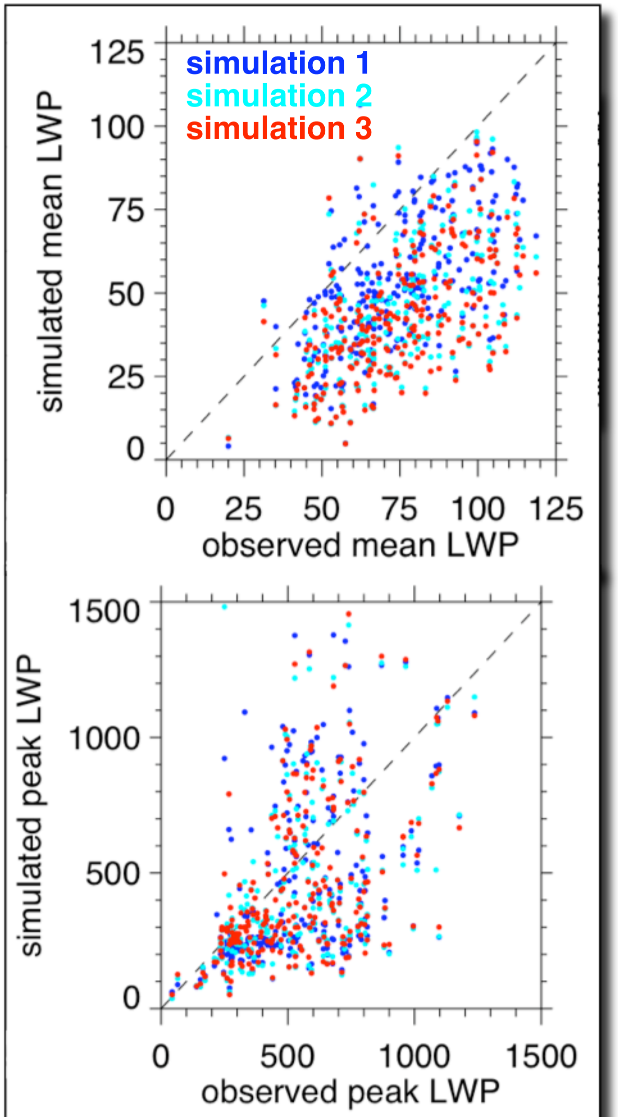
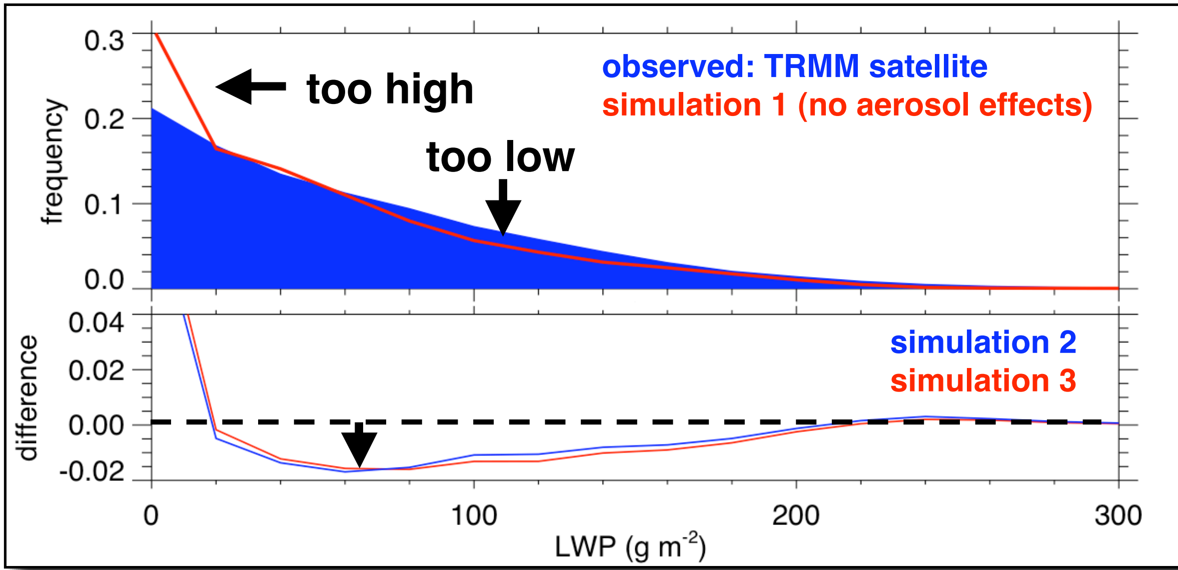
Evaluation – Liquid Water Path

Mean & Peak LWP



Frequency of Liquid Water Path



- Cloud-aerosol interactions reduce # of cells with similar LWP, except for very thin clouds
- Simulated mean LWP over domain too low
- Simulated peak LWP over domain better

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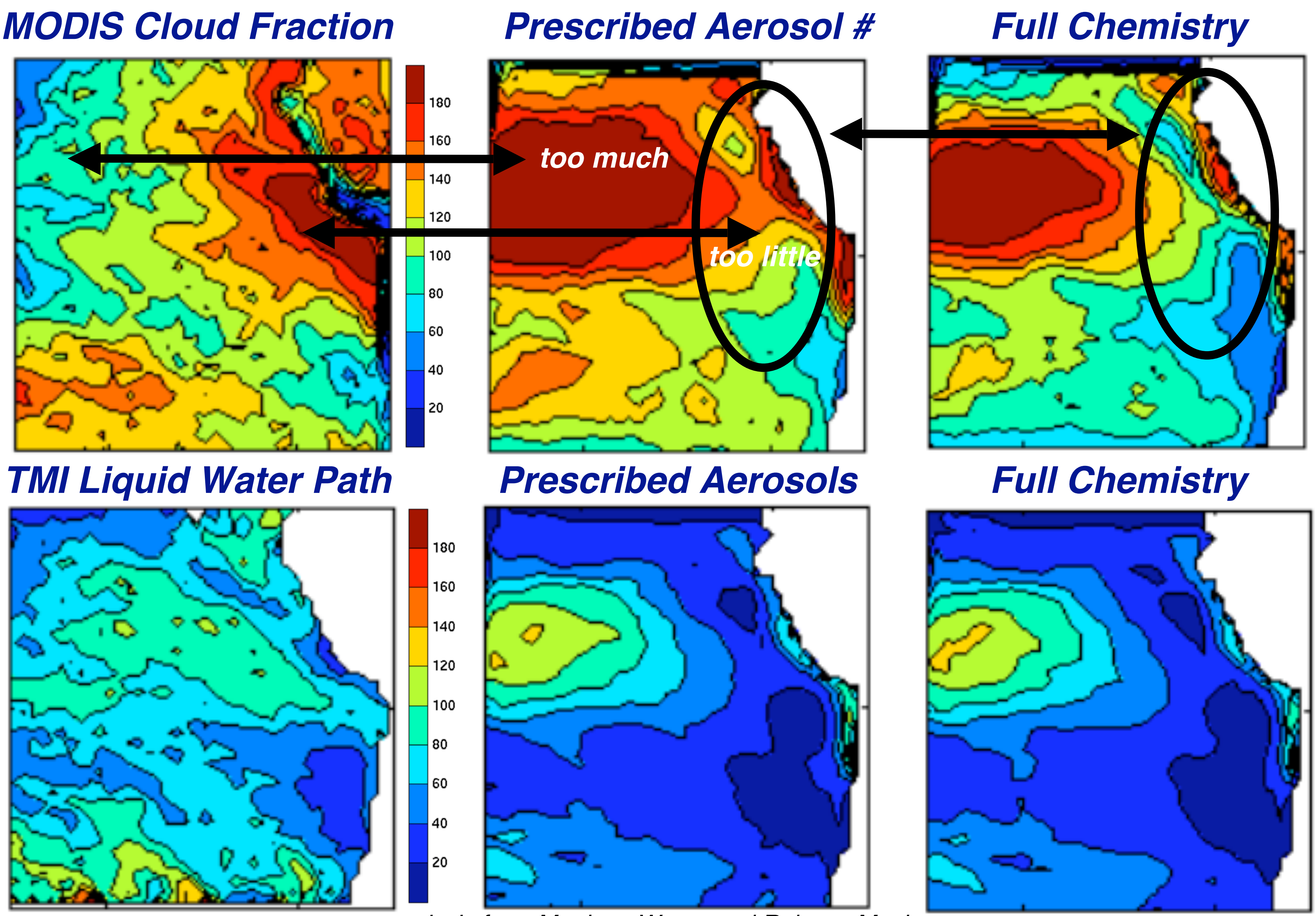
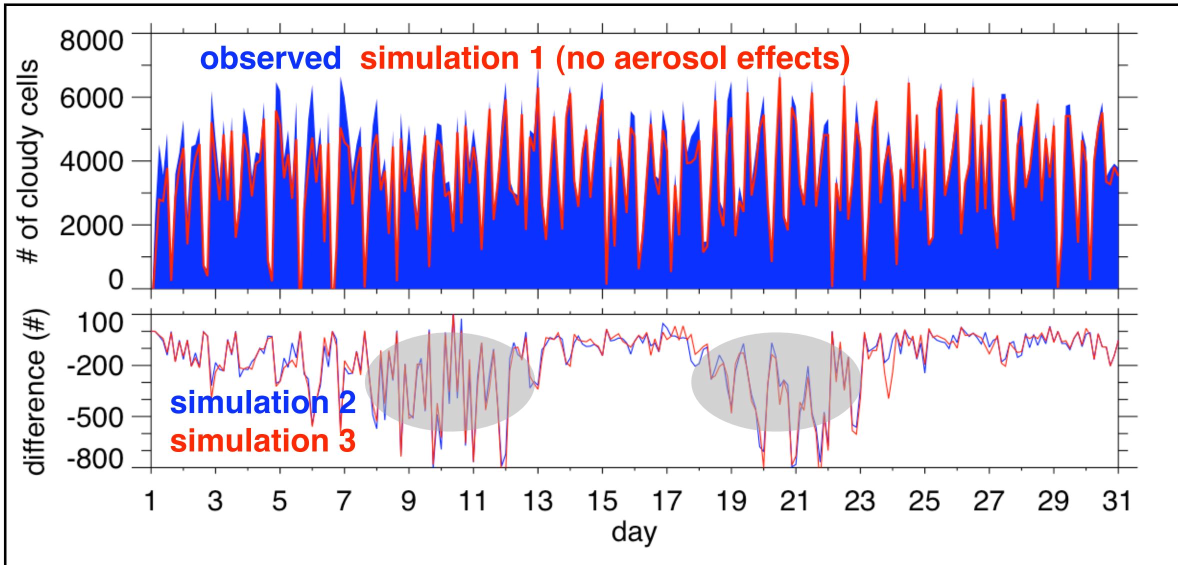
Regional Cloudiness



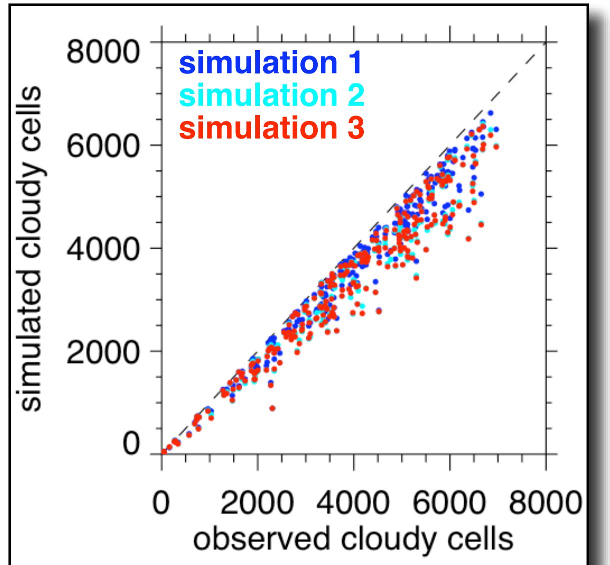
analysis from Matthew Wyant and Roberto Mechoso

Evaluation - Cloudiness

Temporal Variation of # of Cloudy Cells



Cloudy Cells



- Simulated diurnal variations similar to observed
- Cloud-aerosol interactions reduce cloudiness
- Influence of cloud-aerosol interactions larger during 2 periods
- Overall, “full-chemistry” and “prescribed aerosol” simulations similar

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Summary and Next Steps

- Model performance is mixed, with room for much improvement
  - *Is large-scale subsidence, boundary layer mixing, and low-level jet simulated adequately?*
  - *How important is high-resolution SST?*
  - *Which WRF microphysics scheme is most appropriate to simulate marine stratus?*
  - *Is the current simulated impact of aerosols too large?*
- Even though extensive data will be collected during the VOCALS field campaign, evaluating predictions of aerosol chemistry and its effect on cloud-aerosol interactions will be very challenging