

Regional Climate Modeling

ESRL

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OUTLINE

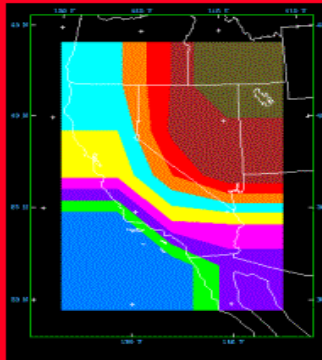
- 1) Motivation/procedure for regional climate modeling
- 2) Central/eastern U.S. precipitation example
- 3) Polar region example

Why model climate with regional rather than global models (Regional Climate Modeling -RCM)?

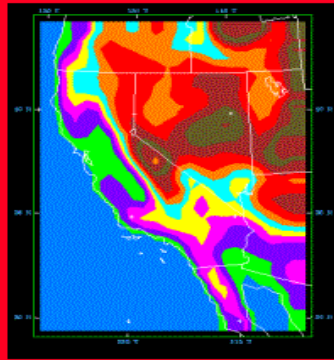
- To explicitly simulate processes for which the spatial resolution of global climate models is prohibitive.
- To provide stakeholders with climatological information at the spatial and temporal scales they need

California terrain at GCM and RCM resolutions

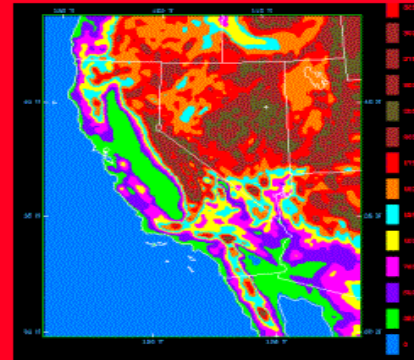
275 km



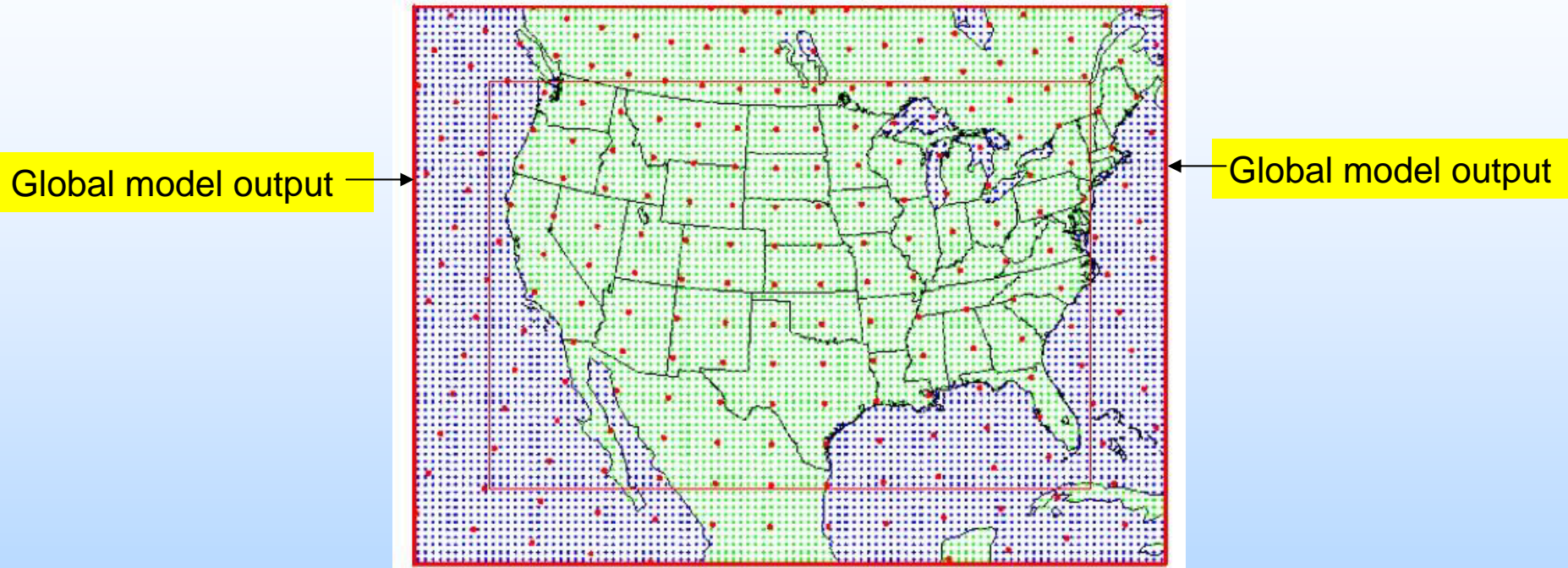
50 km



10 km



The RCM approximation for regional climate processes



- Global model output is provided as input at the boundaries of the regional model
- Regional model produces simulations within the regional model domain that may differ from the global model output over that region.
- Large red dots are an example of global model grid; small dots are an example of regional model grid.

Example 1: Warm Season Precipitation in the Central and Eastern US

- Spring/summer precipitation in the central and eastern US produced by clusters of thunderstorms
- Global models cannot explicitly simulate these thunderstorm clusters
- Resolution of RCM needed to study how climate change has affected the frequency of heavy precipitation events and floods

An Example: How does Gulf of Mexico SST warming relate to precipitation intensity?

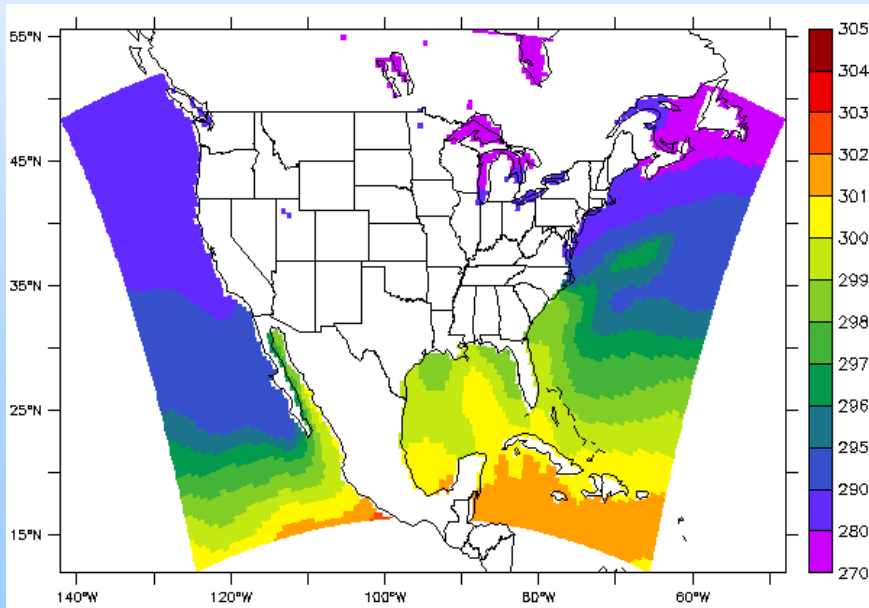
- Much of the water vapor that falls as precipitation in central/eastern U.S. originates over the Gulf of Mexico.
- SST is directly related to evaporation.
- 2002-2006 GoM SSTs approximately 0.4 K greater than 1992-1996 SSTs
- more water vapor may be available for precipitation.

Quick and Dirty Experiment

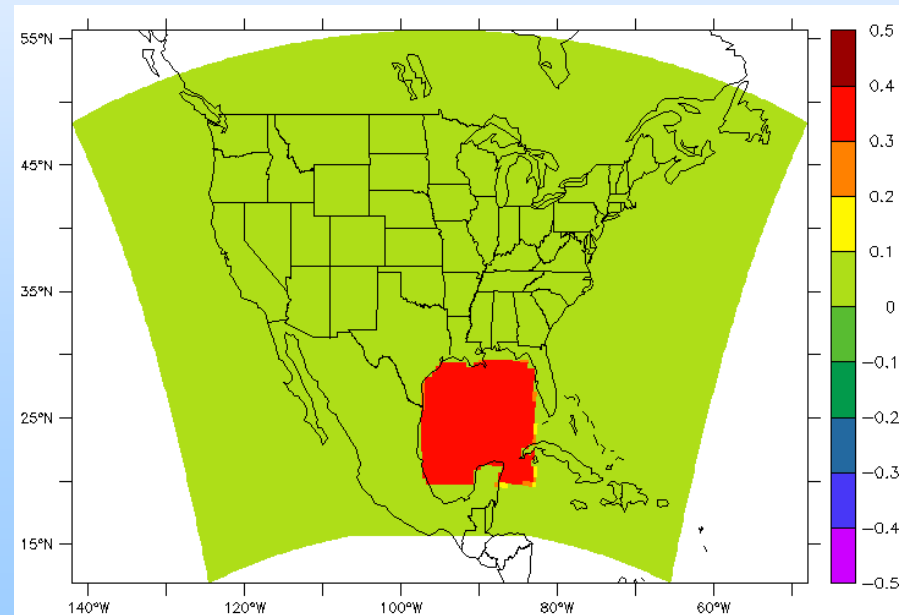
- The 1993 June-July Midwestern flood had an unusually high fraction of precipitation that originated as evaporation from the Gulf of Mexico and Caribbean Sea.
- Might the 1993 flood be more intense if the conditions were to occur during the current period of warmer Gulf of Mexico SST?

Experimental Design

- **Weather and Research Forecast Model (WRF); 1 June - 30 July, 1993**
 - NCEP/DOE Reanalysis-II for atmospheric, surface, and SST initial and boundary conditions.
 - WRF 48-km grid point spacing
 - NCAR core, Kain-Fritsch convective parameterization, Schultz microphysics, MYJ PBL parameterization
- **Control Simulation** - all input data as-is
- **Experimental Simulation** - add 0.4 K to GoM SST

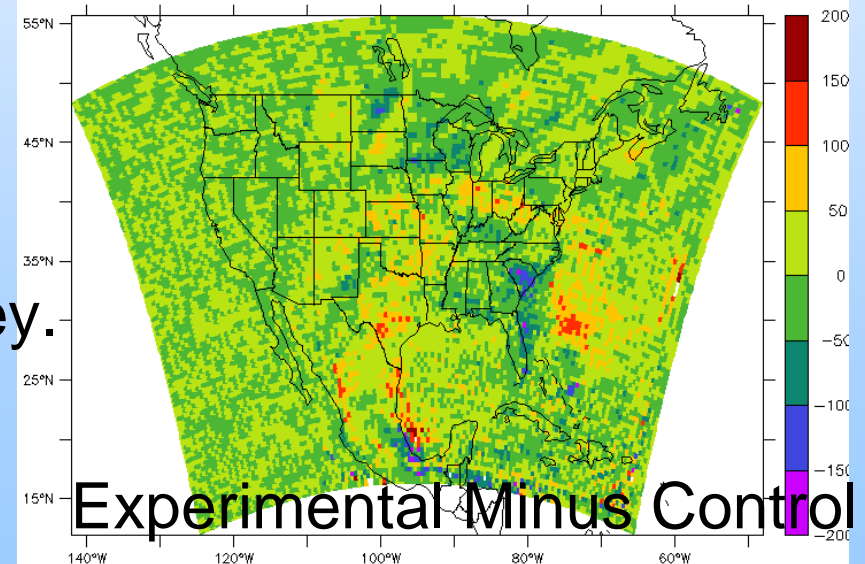
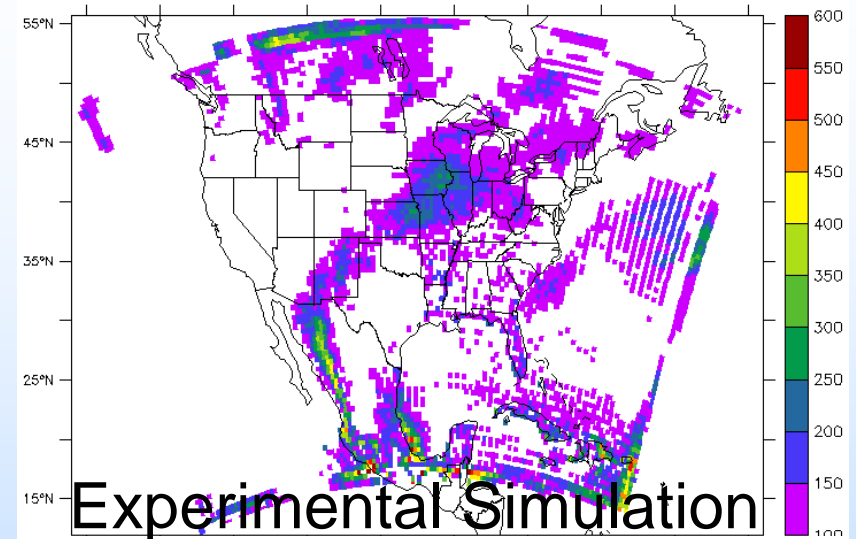
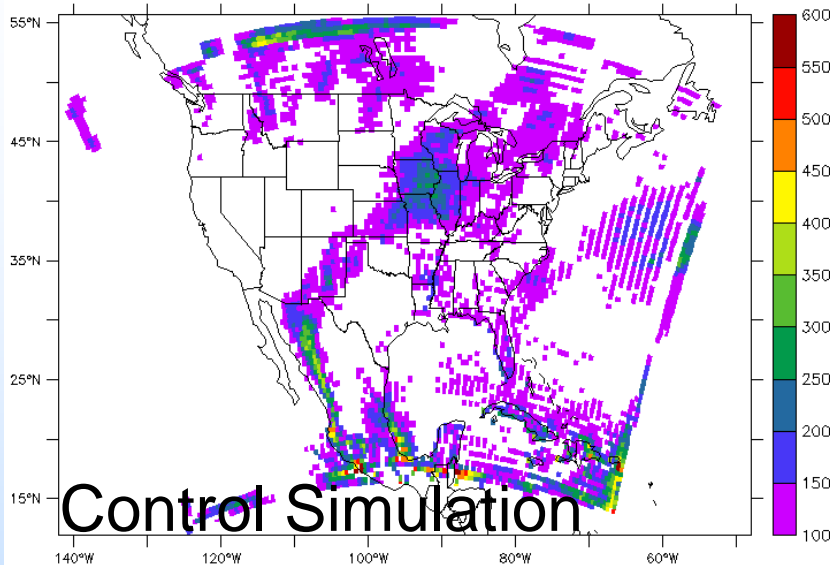


SST IC with SST perturbation added



Perturbation SST

Changes in Precipitation July Accumulation



Units: mm

- Increases of 15-20% in KS, IA.
- Increases of 50% in Ohio Valley.
- Additional reduction of rainfall over South Carolina.

POLAR REGIONAL CLIMATE MODELING

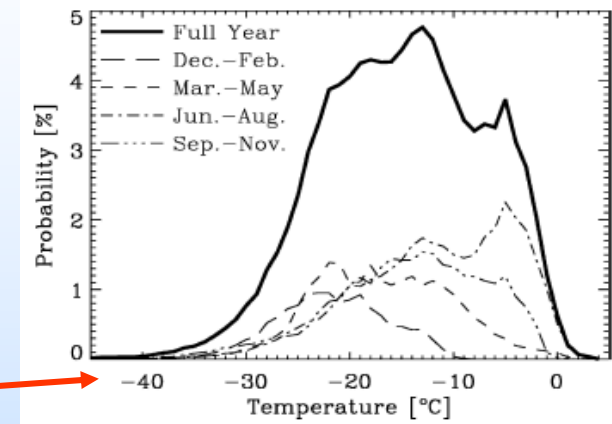
Ultimate Objectives:

- 1) Provide understanding of physical processes determining polar climate
- 2) Provide assessment of spatial representativity of the few SEARCH long-term observatories representing the Arctic

Unique Polar Atmospheric Structure

- major impacts on polar climate

- 1) Omnipresent Arctic inversion- great stability, complex layered structures in lowest 1.5 km
- 2) Large impact of radiative fluxes
- 3) Presence of supercooled liquid water to -38°C



Observed probability distribution of mixed-phase clouds at SHEBA (Shupe et al 2006)

Unique Aspects Must Be Well Represented

- 1) high vertical resolution below 1500 m
- 2) **sophisticated microphysical treatment of clouds**
 - double-moment rather than single-moment microphysics
 - allows for greater longevity of supercooled water
 - improves surface radiative fluxes
- 3) stable boundary-layer physics

Global climate models often weak on these aspects

- e.g., significant surface radiation errors in Arctic

ARM Mixed-Phase Arctic Cloud Experiment (M-PACE)

- North Slope of Alaska, October 6- 10 2004
- roll clouds forming as cold air over pack ice passes over relatively warm water before reaching Barrow
- intensive ground, remote sensing, aircraft, and radiosonde measurements
- verify the microphysical characteristics of the model's simulation of mixed- phase clouds

Barrow

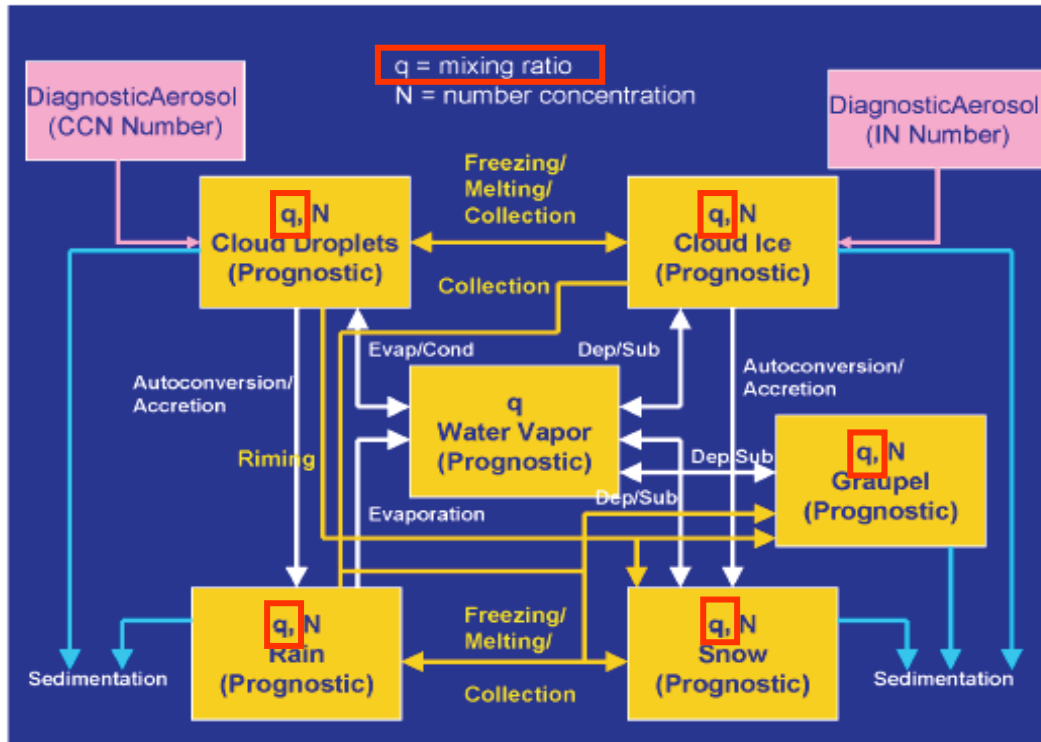
X

Evaluate/improve model's ability to simulate:

- a) **the maintenance of liquid water in clouds at low temperatures,**
- b) the role of ice nuclei concentrations in glaciating Arctic clouds,
- c) vertical air motions within the clouds, and the
- d) **radiation effects of microphysics**
- e) direct and indirect radiation effects of aerosols

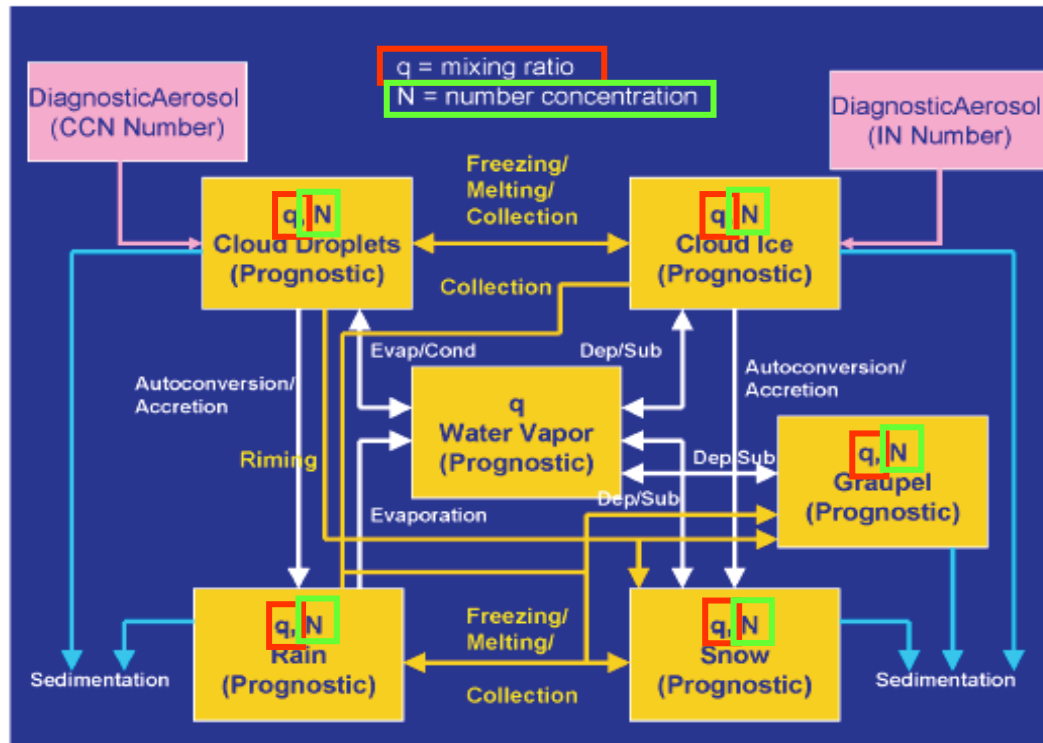
Method: Replace typical one- moment cloud scheme with two- moment scheme

Single-Moment Microphysics



Prognostic variables include mixing ratios (q) of cloud ice, cloud droplets, snow, and rain.

Double-Moment Microphysics

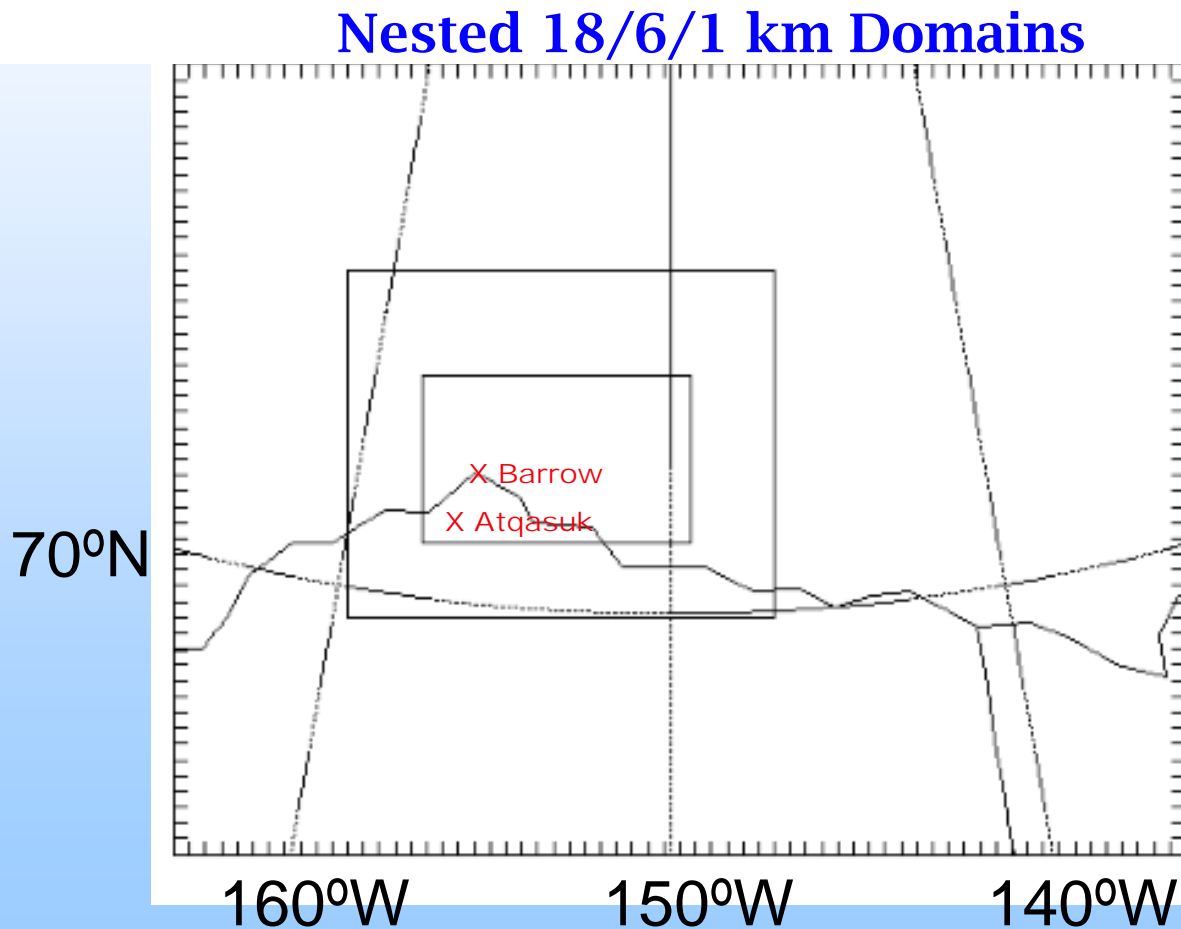


Prognostic variables include mixing ratios (q) and number concentrations (N) of cloud ice, cloud droplets, snow, and rain.

Model Configuration

Simulated atmospheric fields were generated using WRF V2.2, initialized at 12 UTC 8 Oct 2004 using 1° GFS data. The simulations were run for 48 hours with 18/6/1 km horizontal grid spacing and 50 vertical levels (20 levels below 800 hPa).

Control Integration: Two-Moment microphysics, CAM Radiation, 3D PBL mixing in the 1km grid (YSU PBL in 18/6 km grids), NOAA LSM, Two-way feedbacks between grids

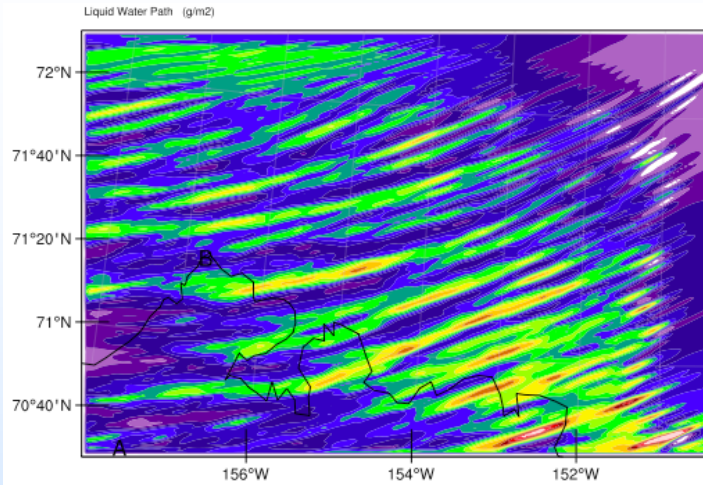


Sensitivity to Cloud Microphysics

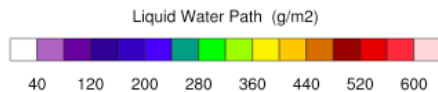
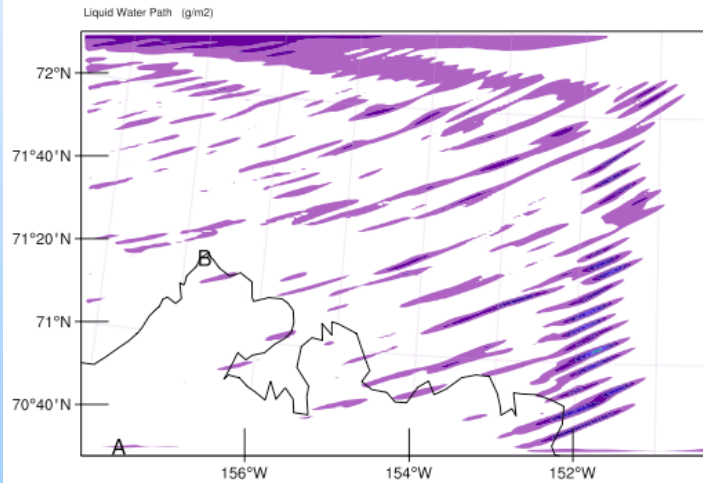
(All figures one-hour averages at Oct 10 0Z 2004)

Liquid Water Path (column integrated LW)

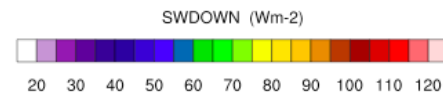
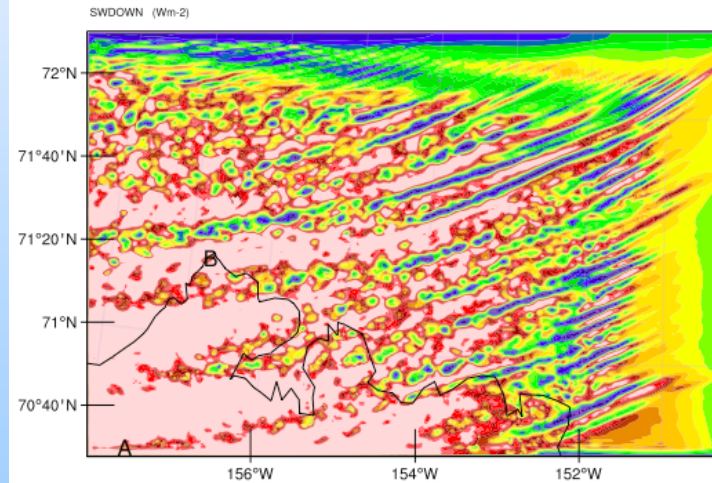
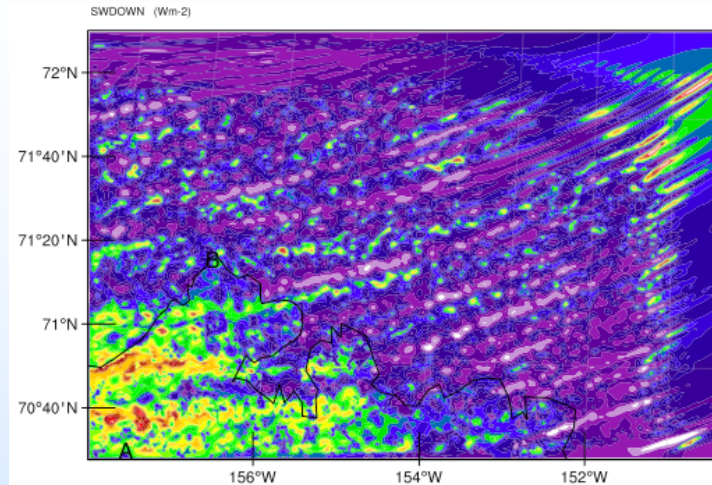
Two-Moment



One-Moment



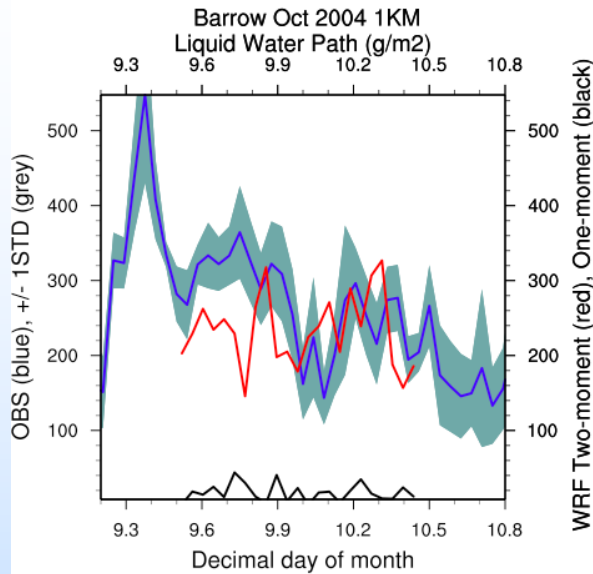
Downwelling SW Radiation



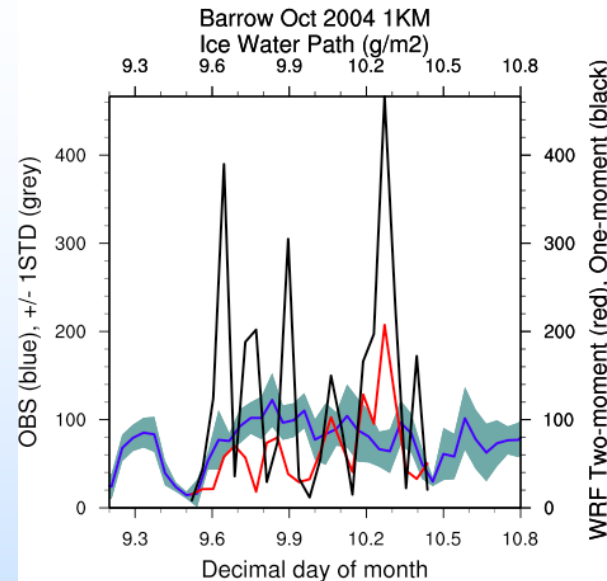
Model Verification at Barrow, Alaska: Two-moment vs One-moment Microphysics

— Observations

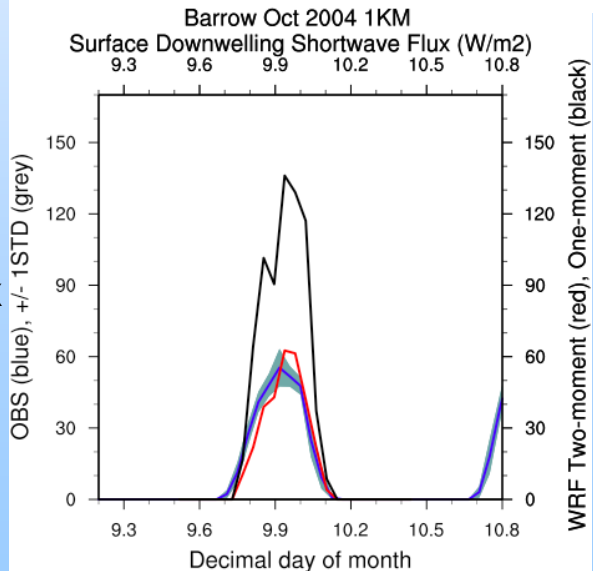
Liquid Water Path



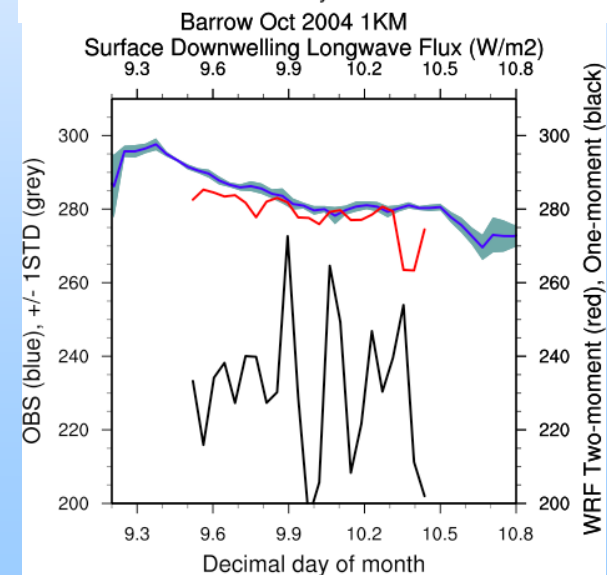
Ice Water Path



Downwelling Shortwave Flux
($\sim -60 \text{ W m}^{-2}$)



Downwelling Longwave Flux
($\sim +40 \text{ W m}^{-2}$)



Summary

Regional climate modeling at ESRL is being (will be) used as a tool for:

a) understanding physical processes important for regional climates

- Gulf of Mexico SST anomalies appear important for midwest/eastern U.S. warm season precipitation events
- increasing GoM SSTs suggests that future midwest/eastern warm-season major precipitation events may be stronger
- unique polar processes require better representation of cloud microphysics than currently done for global and even most regional models
- double-moment microphysics scheme improves maintenance of liquid water in Arctic clouds and surface radiative fluxes

b) understanding spatial representativity of the few observations in data-sparse regions, such as near the SEARCH polar observatories

ESRL Theme Summary

- ✧ ESRL performing a broad range of research using regional models and assimilation
 - ✧ Model development
 - ✧ Data assimilation
 - ✧ Ensembles and post processing
 - ✧ Air quality
 - ✧ Air-sea interaction
 - ✧ Regional Climate
- ✧ ESRL playing a key role in development of operational systems and performing phenomenological research
- ✧ Through ESMF and the DTC, good connectivity will be maintained with the research and operational communities

Date of Meeting

Meeting Title

