Meteorological Modeling to Support the ROMANS Nitrogen Deposition Project at Rocky Mountain National Park

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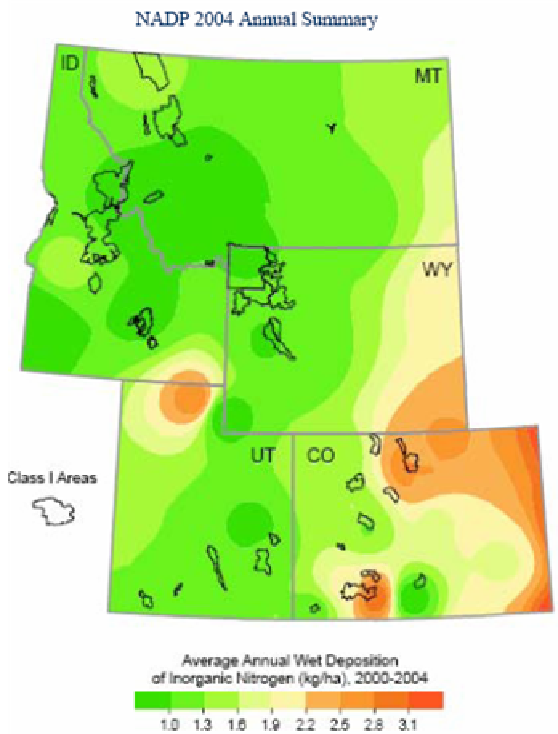
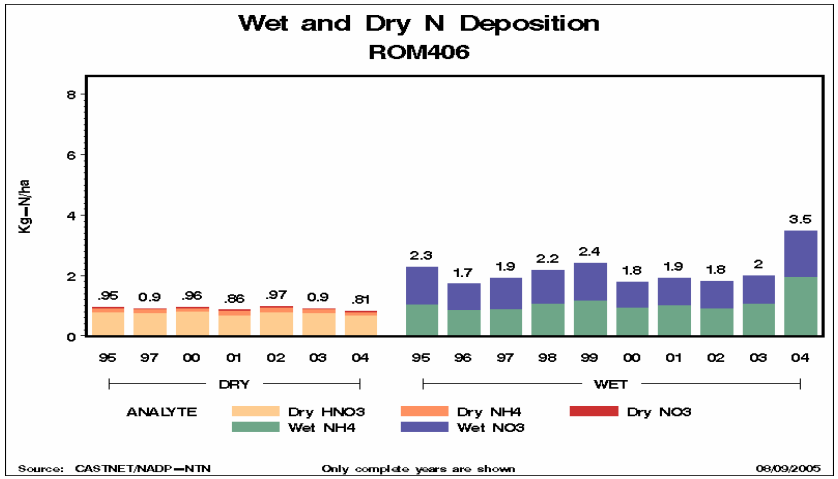
National Park Service
U.S. Department of the Interior

CIRA
Cooperative Institute for Research in the Atmosphere

Nitrogen deposition at RMNP

- N deposition increasing in the Rocky Mountains
- Alpine ecosystems are susceptible to extra N
  - N acts as a fertilizer → ecosystem change
  - changes maybe hard to reverse
  - most deposition occurs as wet dep (~2/3)
- critical load: 1.5 kg/ha/yr





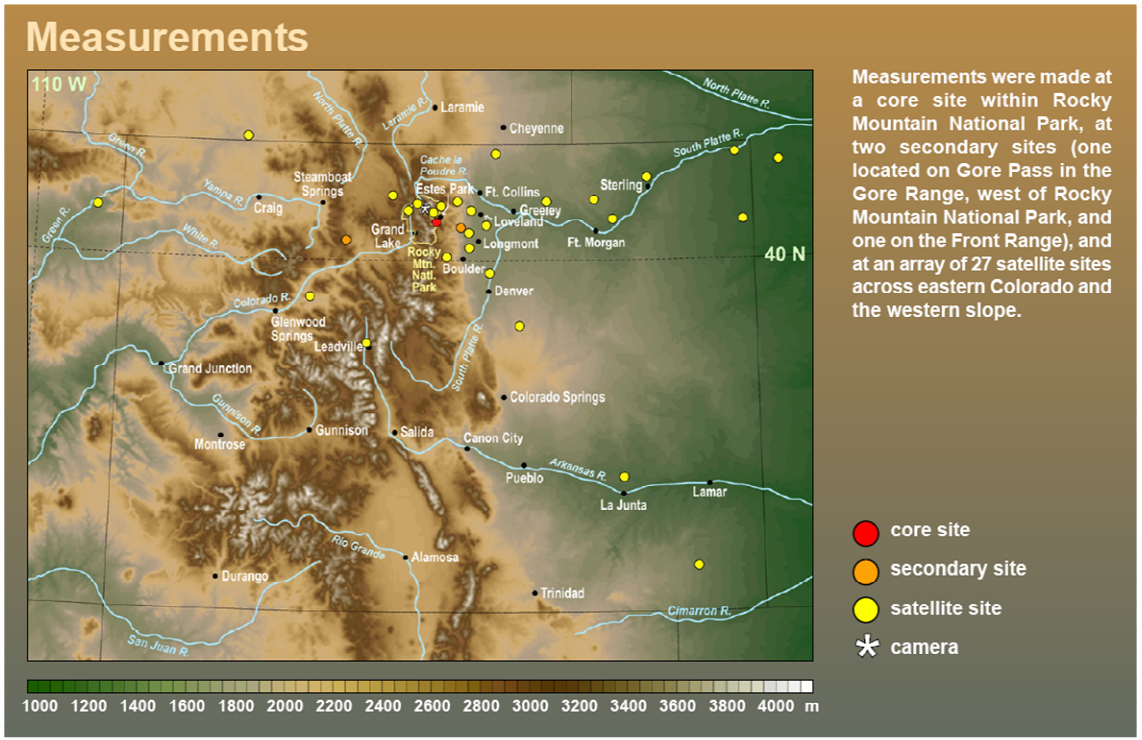
Rocky Mountains = magnificent views, fragile ecosystems, complex meteorology

- Complex (small scale) diurnal and seasonal mountain circulation patterns.
- Vertical de-coupling due to inversions and stagnation in valleys.
- Orographic precipitation & isolated convective storms
- Lack of observations in remote mountainous areas.
- We still want accurate modeled winds, moisture, temperature, precip for CAMx, trajectories.

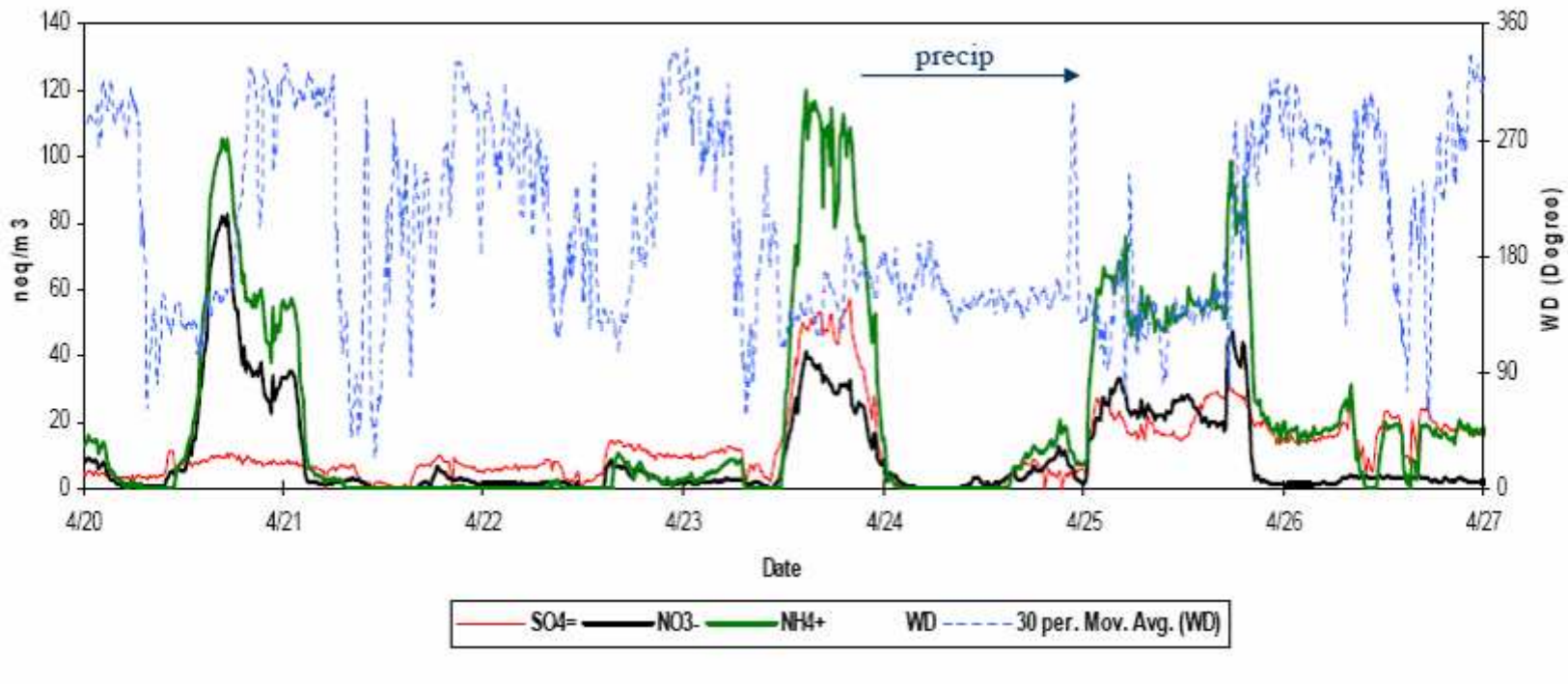
ROMANS: Rocky Mountain Atmospheric Nitrogen and Sulfur Study

- Two field campaigns conducted during spring (April) and summer (July – Aug) of 2006

  - Measure concentration and wet dep of important N and S species: NH4, NO3, NH3, NOx, SO4



spring wet dep event



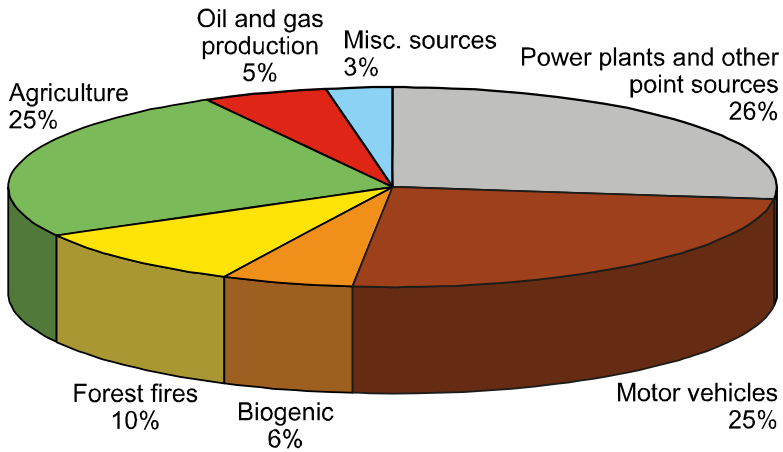
from Collett et al., 2008

MM5 is being used in ROMANS for...

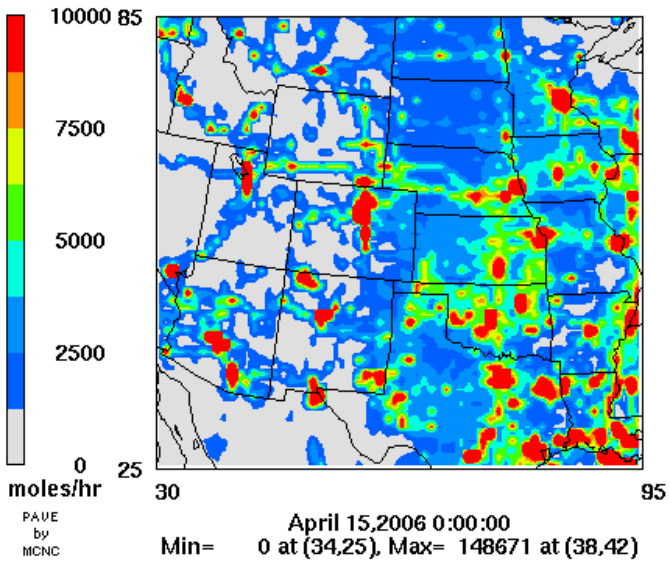
- HYSPLIT back trajectory modeling
- Airmass conditional probability
- CAMx ‘base case’ simulations
- CAMx tracer simulations (-> EOF analysis)
- CAMx source apportionment simulations

where is the nitrogen coming from?

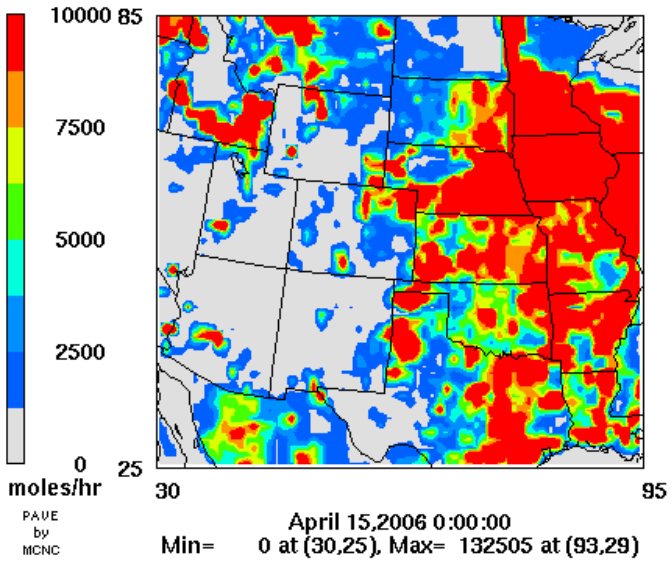
- local v. regional v. distant?
- oxidized or reduced?



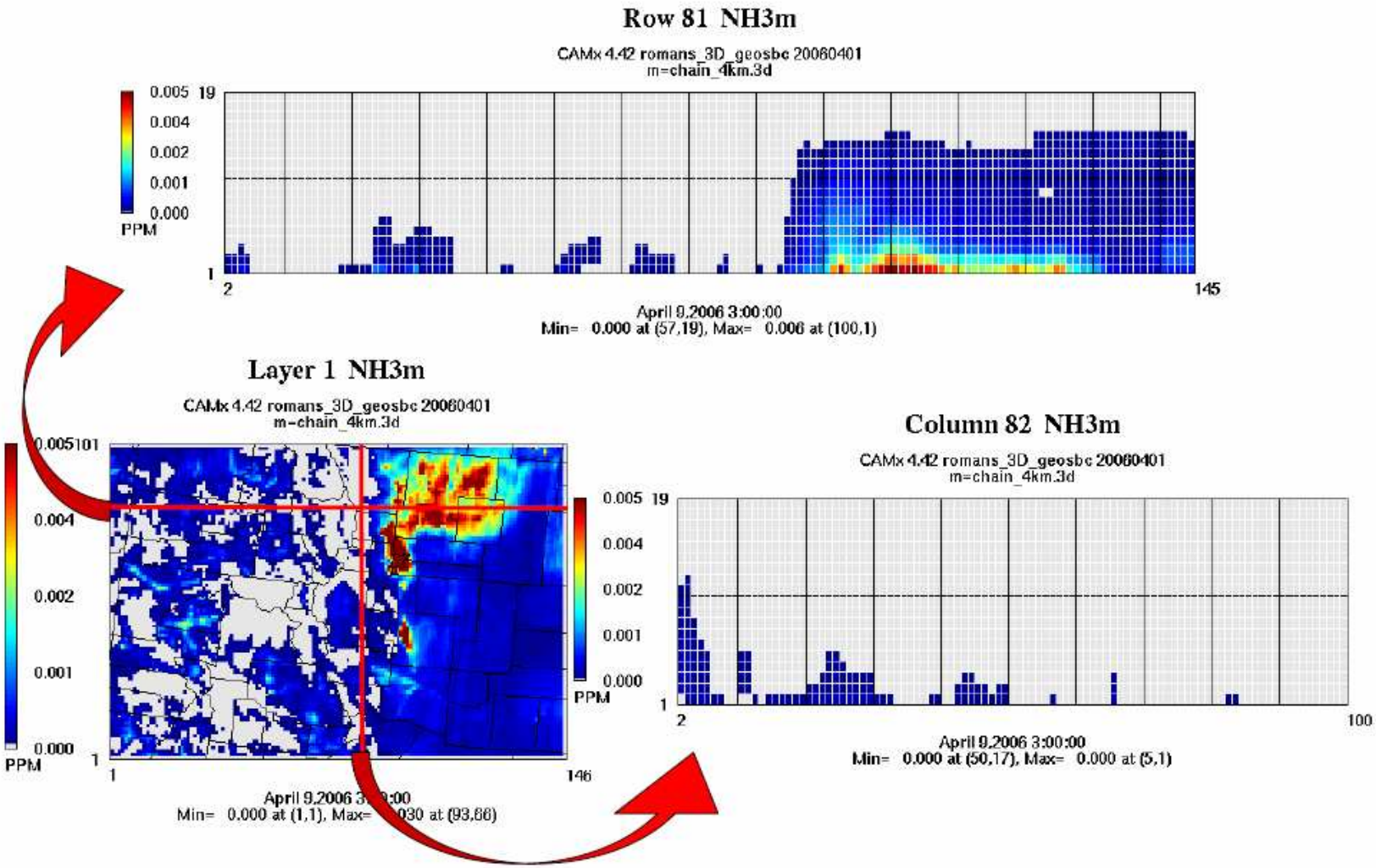
NOx



NH3



Ammonia


Row 81 NH3m
CAMx 4.42 romans_3D_geosbc 20060401
m=chain_4km.3d
0.005 19
0.004
0.002
0.001
0.000
PPM
1
2
145
April 9,2006 3:00:00
Min= 0.000 at (57,19), Max= 0.006 at (100,1)
Layer 1 NH3m
CAMx 4.42 romans_3D_geosbc 20060401
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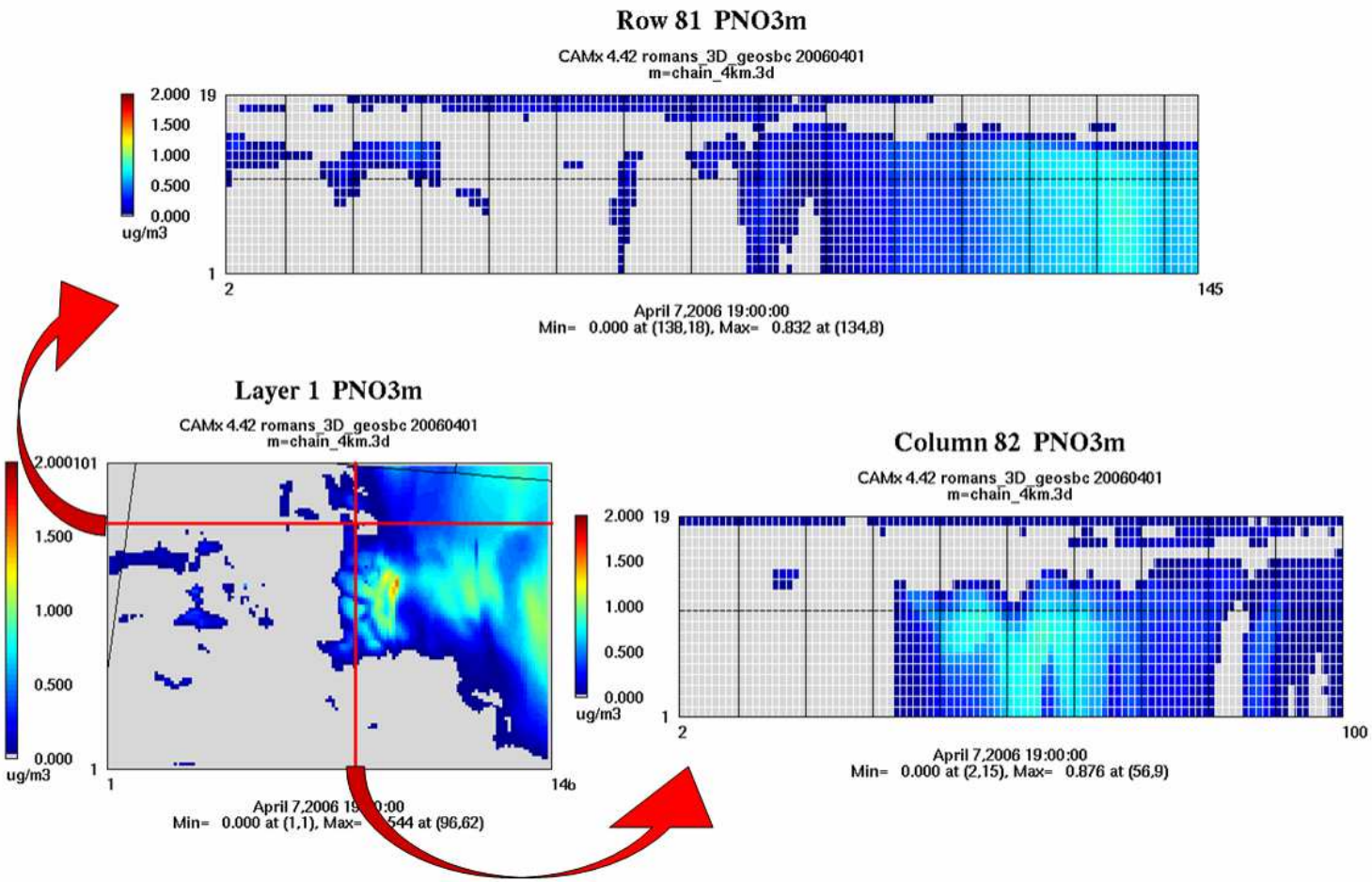
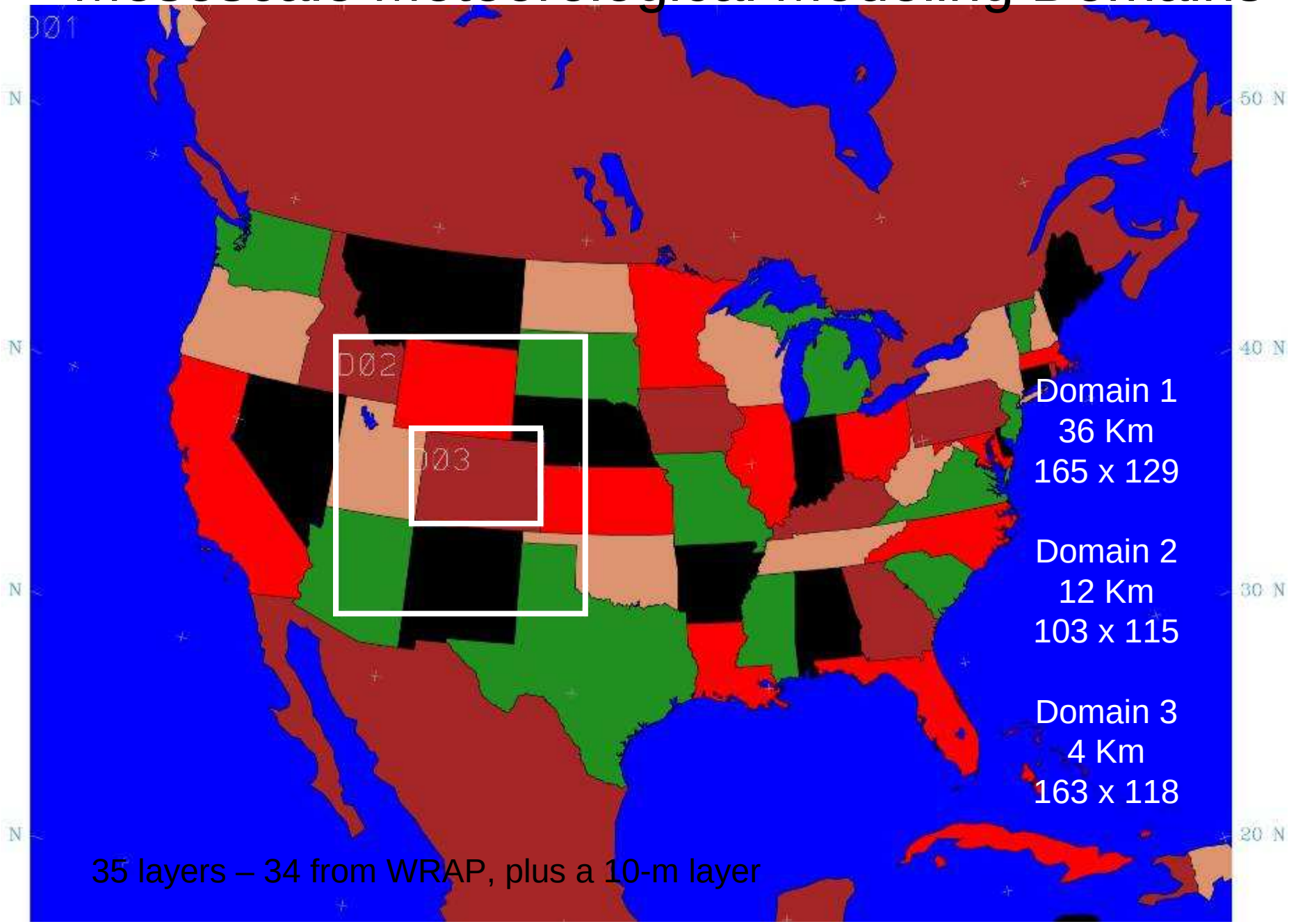
0.005101
0.004
0.002
0.001
0.000
PPM
1
1
146
Min= 0.000 at (1,1), Max=
Column 82 NH3m
CAMx 4.42 romans_3D_geosbc 20060401
m=chain_4km.3d
0.005 19
0.004
0.002
0.001
0.000
PPM
1
2
100
April 9,2006 3:00:00
Min= 0.000 at (50,17), Max= 0.000 at (5,1)

Particulate nitrate



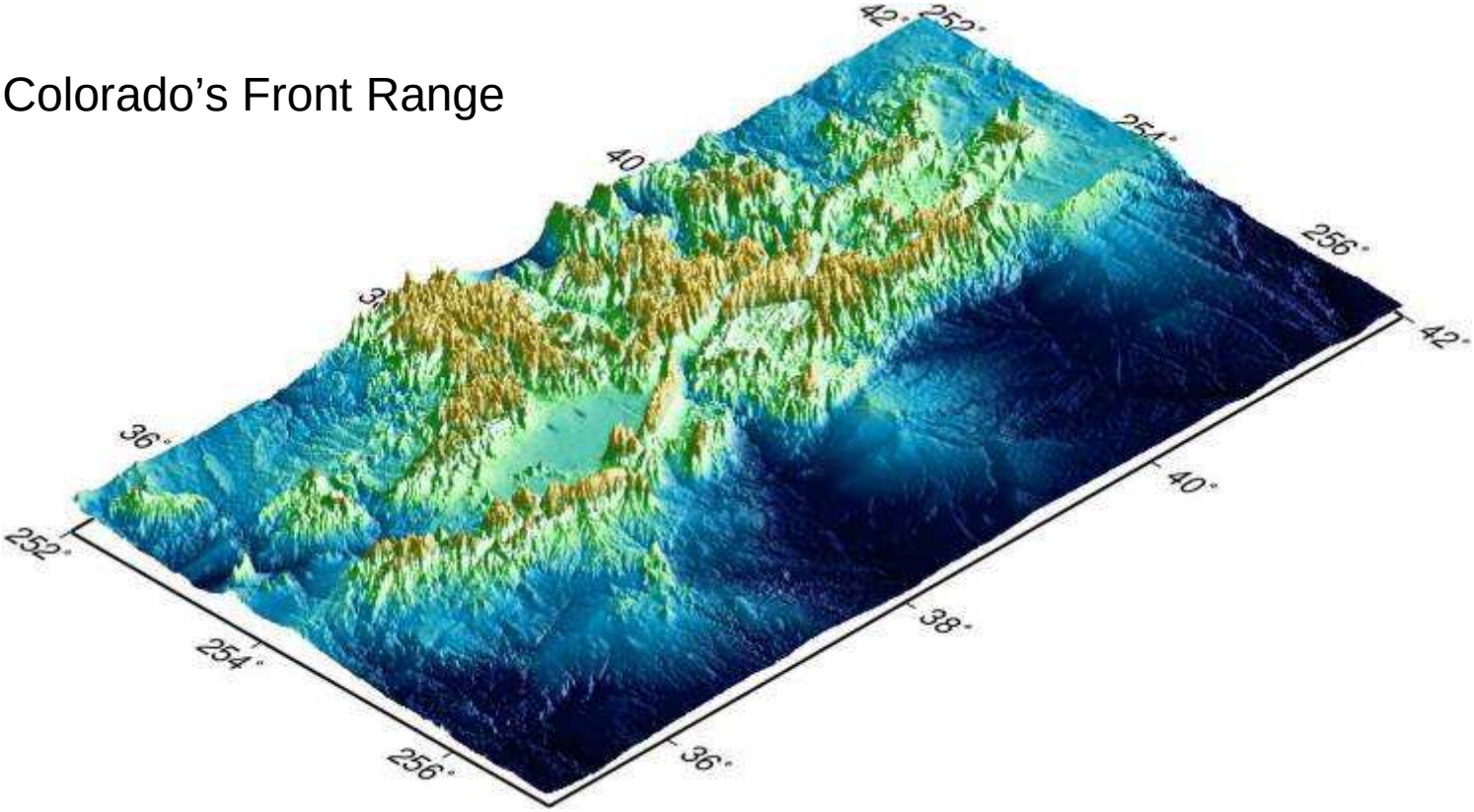
Mesoscale Meteorological Modeling Domains



35 layers – 34 from WRAP, plus a 10-m layer

deposition in complex terrain

Colorado's Front Range



deposition flux = (concentration) * (v_d or Λ)

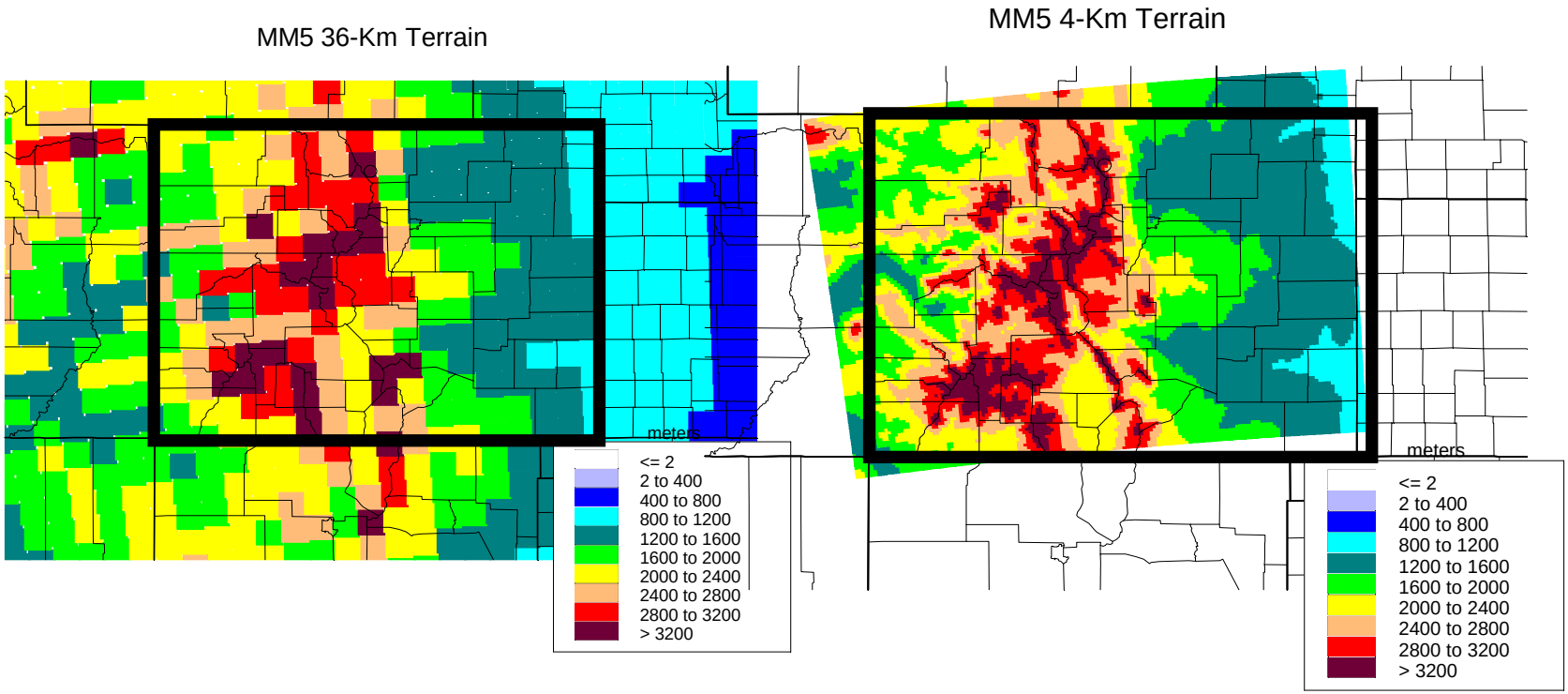
v_d = dry dep velocity

Λ = wet dep scavenging

36 Km vs 4 Km Terrain Over Colorado

36 Km Domain

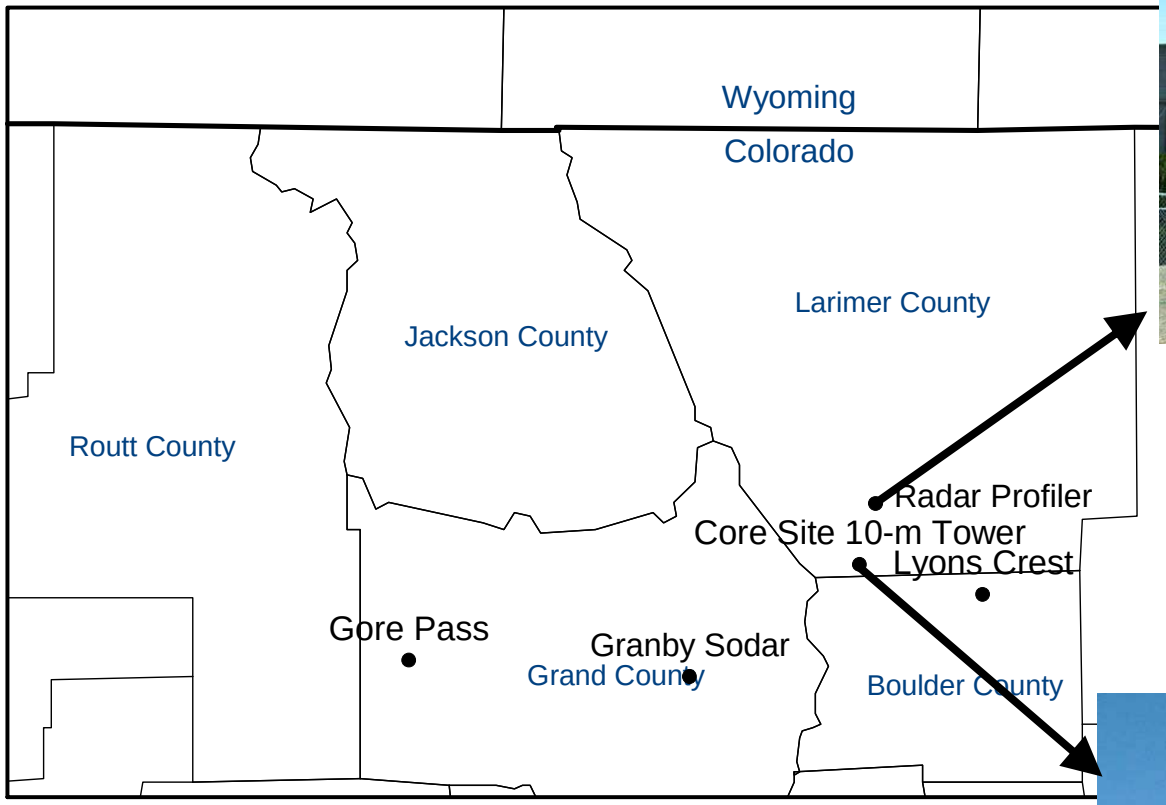
4 Km DOMAIN



Major MM5 Modeling Choices

Parameter	Choice
Vertical Layers	WRAP 34 layers plus additional layer at 10 m.
Forecast Length	3.5 day duration with 12-hour spinup overlap
Initial/Boundary Conditions	NARR – 3 hrs, 32 Km resolution
Nudging	3-hr analysis on 36 Km, 1-hr obs on 4 Km
Microphysics	Reisner2
Cumulus Parameterization	Kain-Fritsch2 on 36 & 12 Km, none on 4 Km.
PBL Scheme/Land Surface Model	MRF / NOAH LSM

Meteorology Monitoring Locations - ROMANS Study



Distances from Core Site:

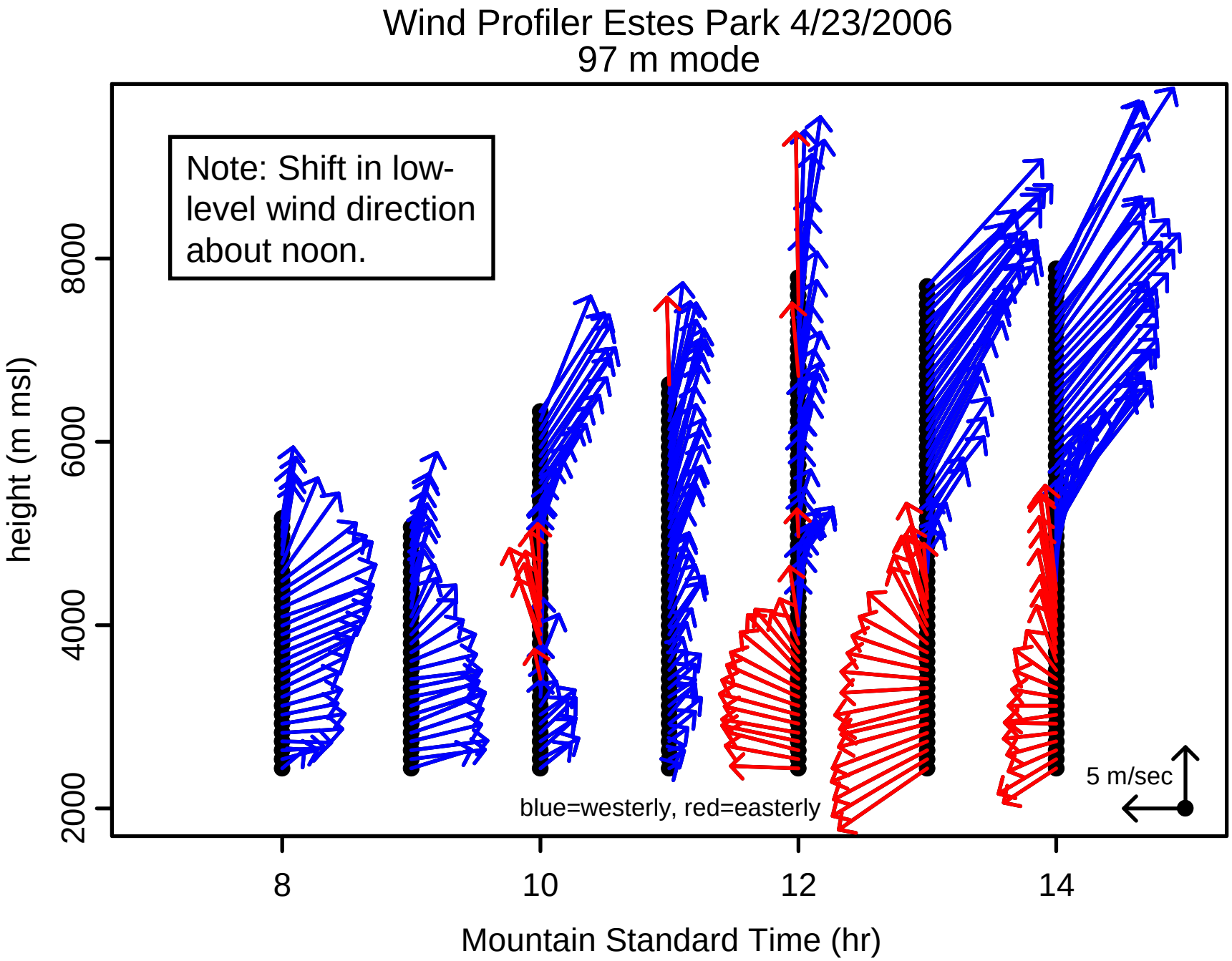
to Estes Park Radar Profiler = 12 Km

to Lyons = 24 Km

to Granby SODAR = 37 Km

to Gore Pass = 86 Km

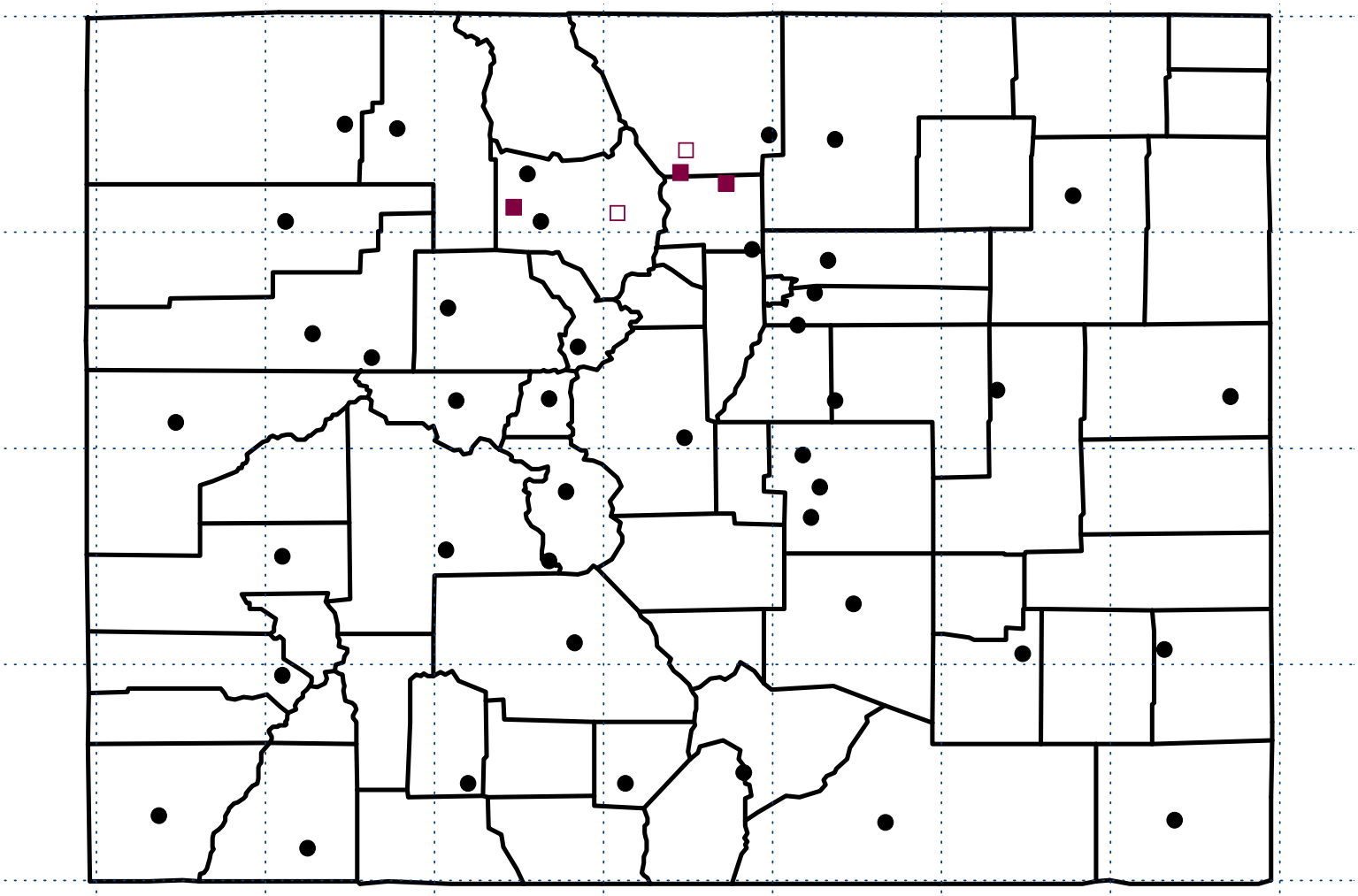
ROMANS Meteorological Measurements


Wind Profiler Estes Park 4/23/2006
97 m mode
Note: Shift in low-level wind direction about noon.
blue=westerly, red=easterly
5 m/sec
height (m msl)
2000
4000
6000
8000
8
10
12
14
Mountain Standard Time (hr)

METSTAT Plots – Results Averaged Over Sites

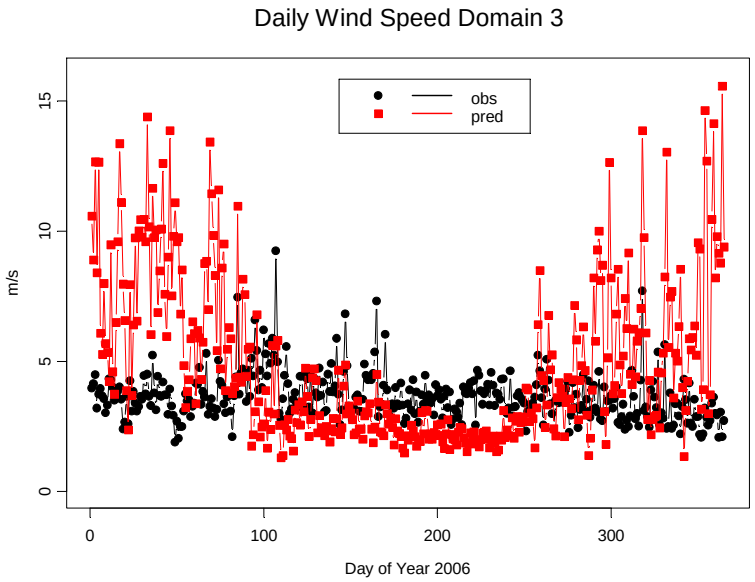
DS464 surface Obs Locations

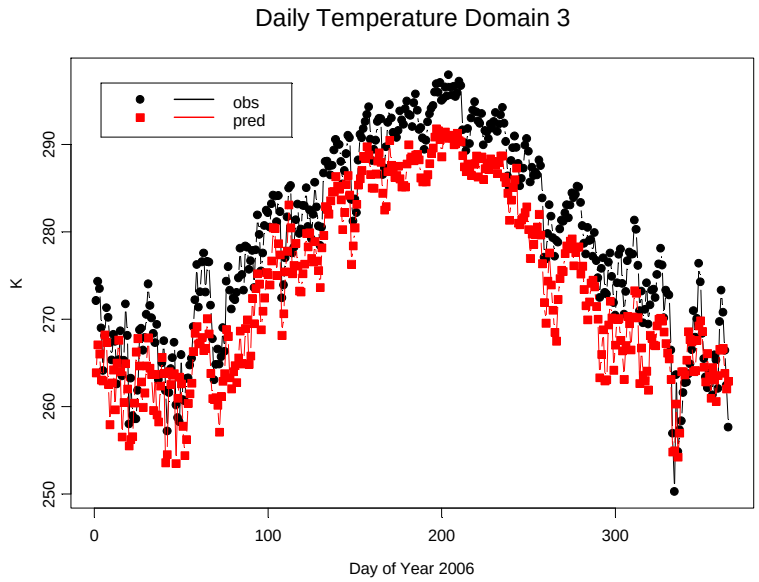
Filled Squares = ROMANS Sfc Sites

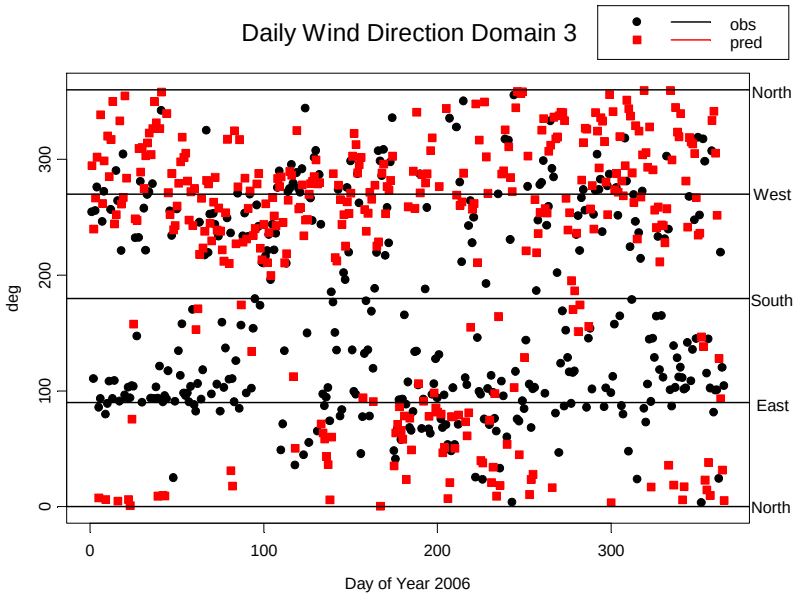


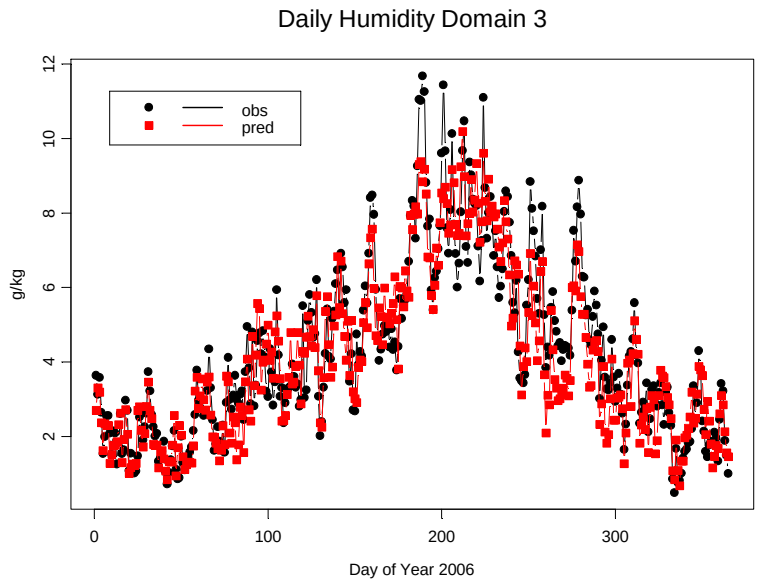
Open Squares = ROMANS Upper Air Sites

Predicted v. observed met in Colorado



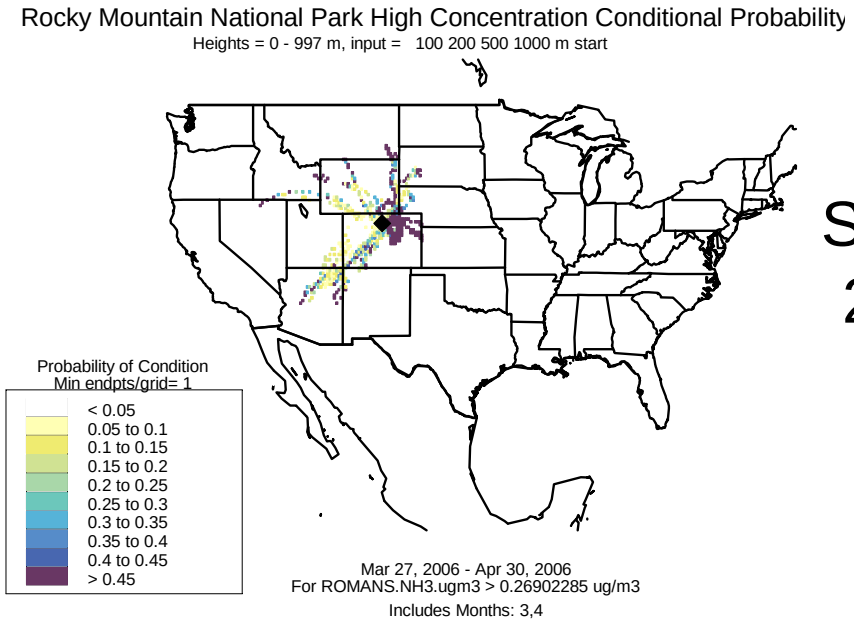


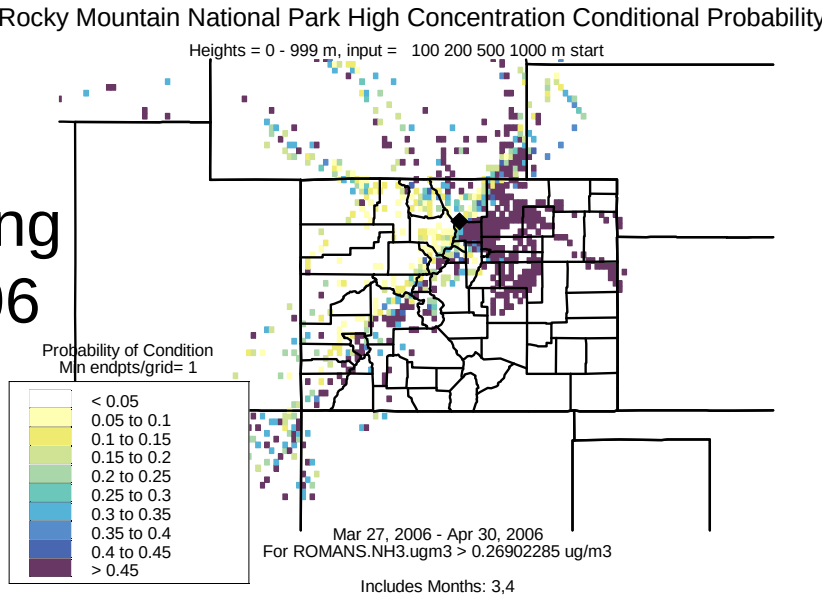




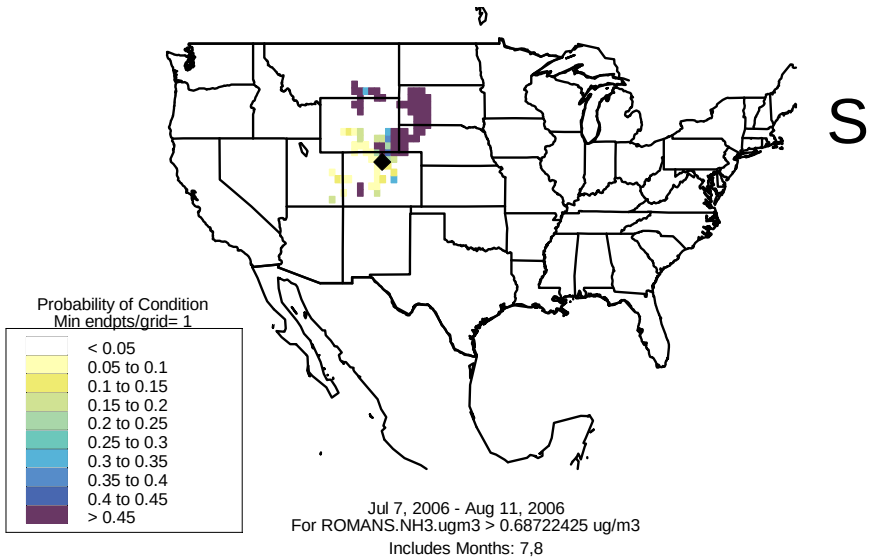
NH_3 Conditional Probability

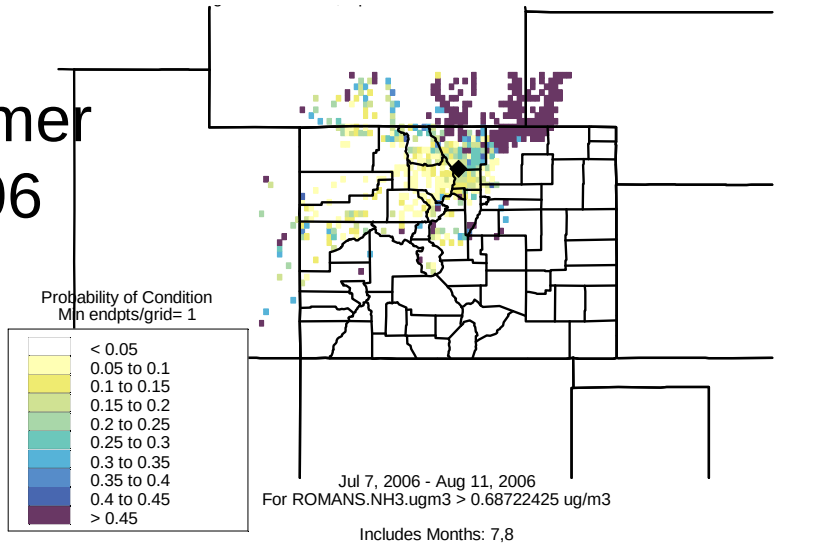
Spring 2006





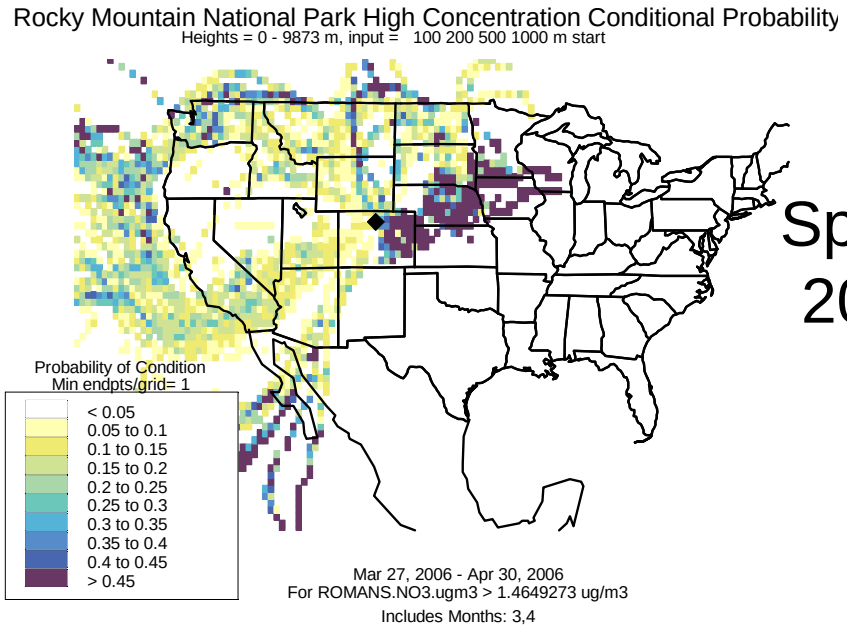
Summer 2006

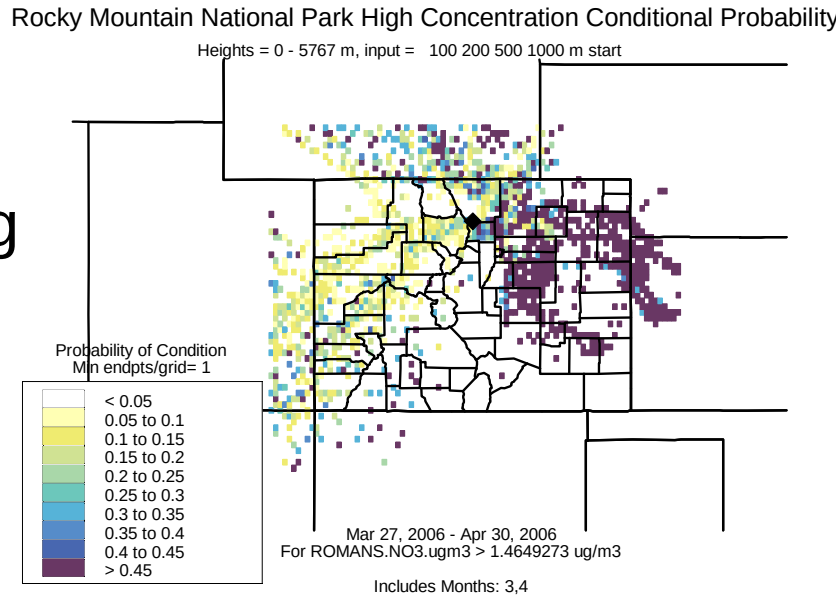




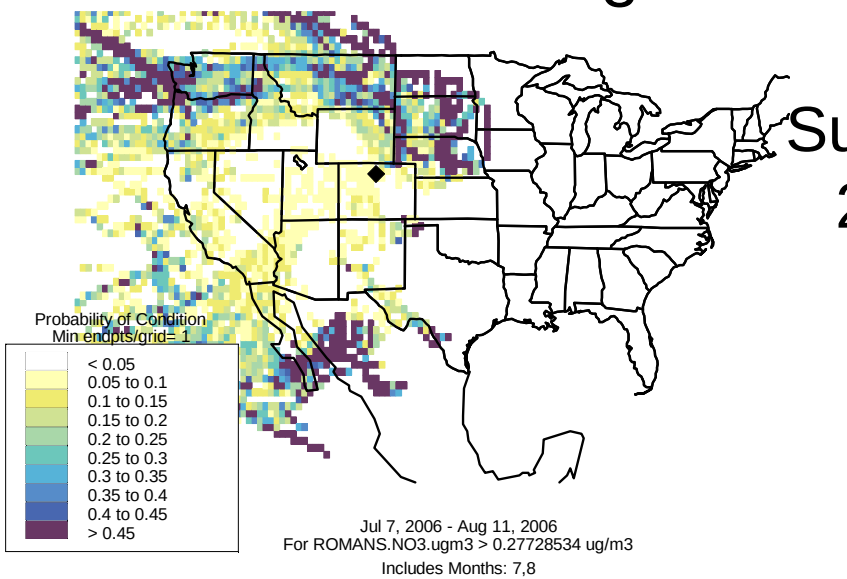
NO_3 Conditional Probability

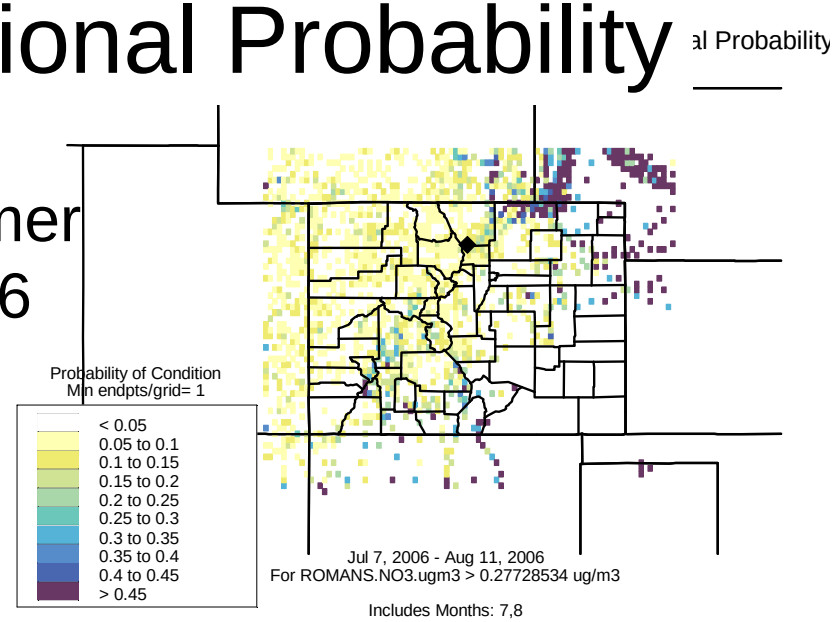
Spring 2006





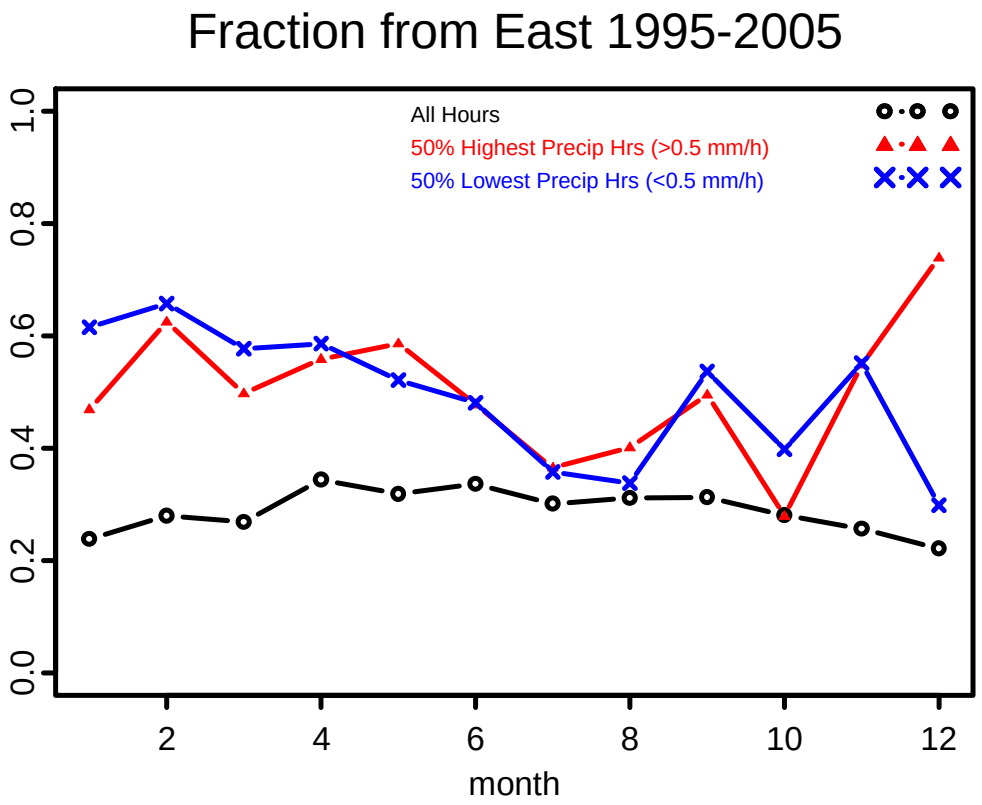
Summer 2006





More Easterlies During Precipitation Events

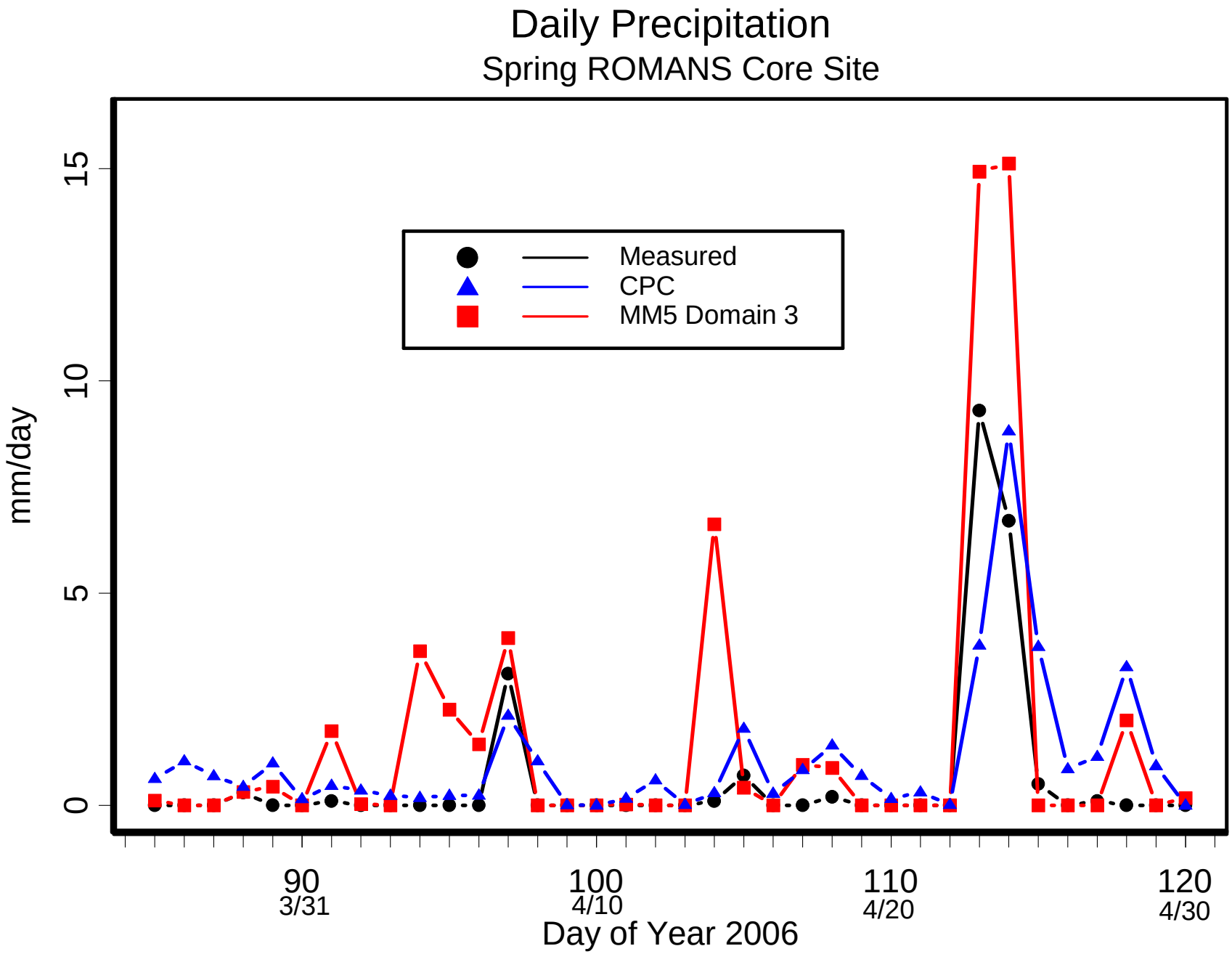
Fraction of hours in during each month of the year (left) and each hour of the day (right) when wind is from the east. Black is all hours; red is hours with precipitation > 0.5 mm/hr and blue is hours with precipitation< 0.5 mm/hr.

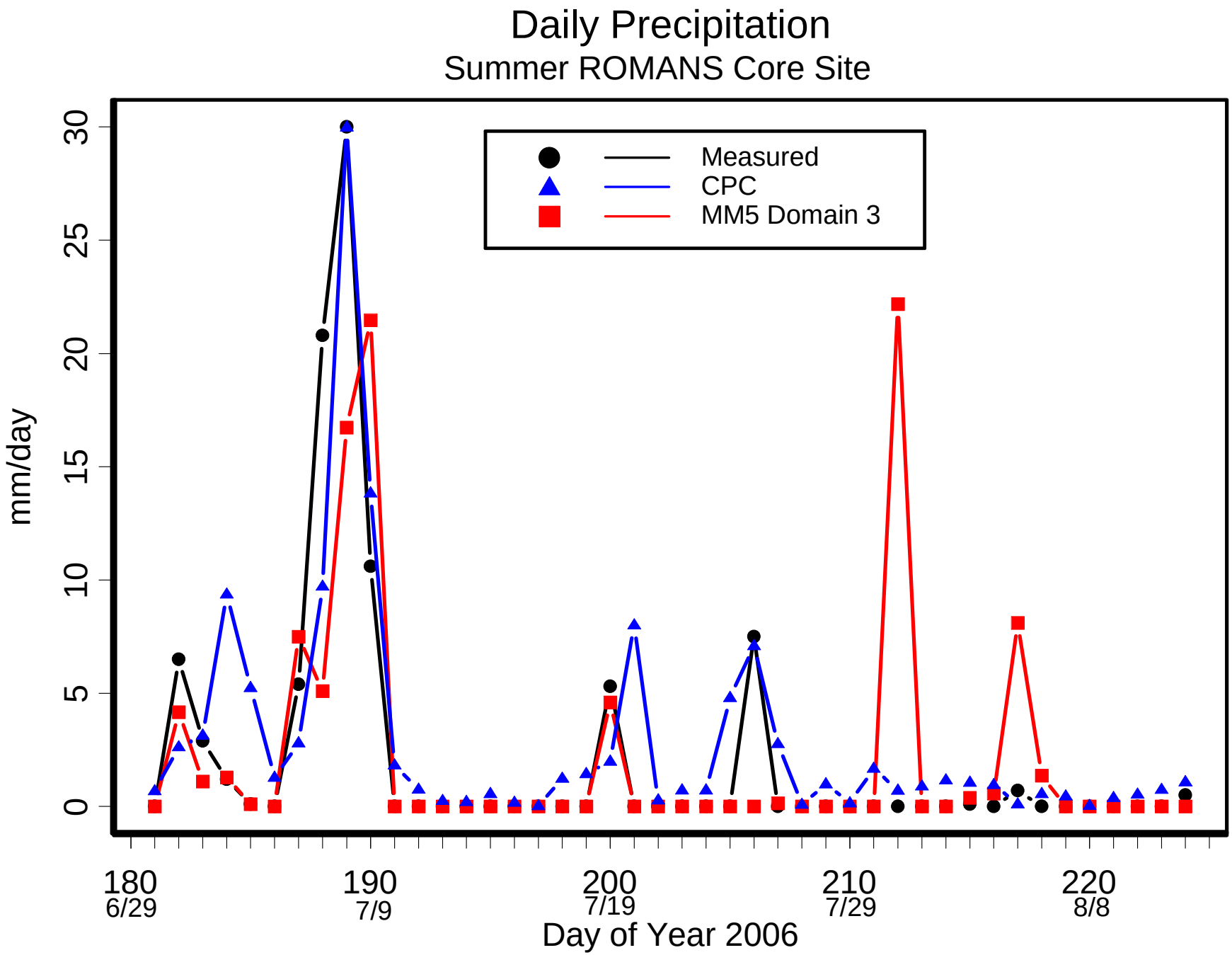


National Weather Service
Climate Prediction Center (CPC) Daily Precipitation Analysis

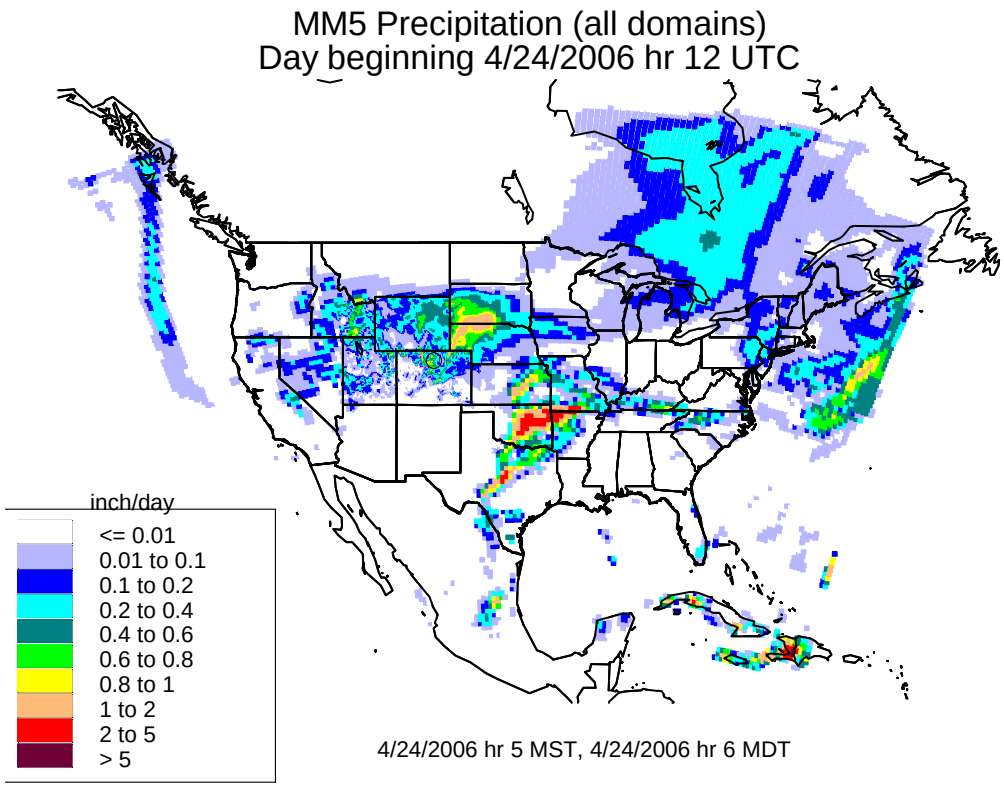
Is it observed precipitation in complex terrain?

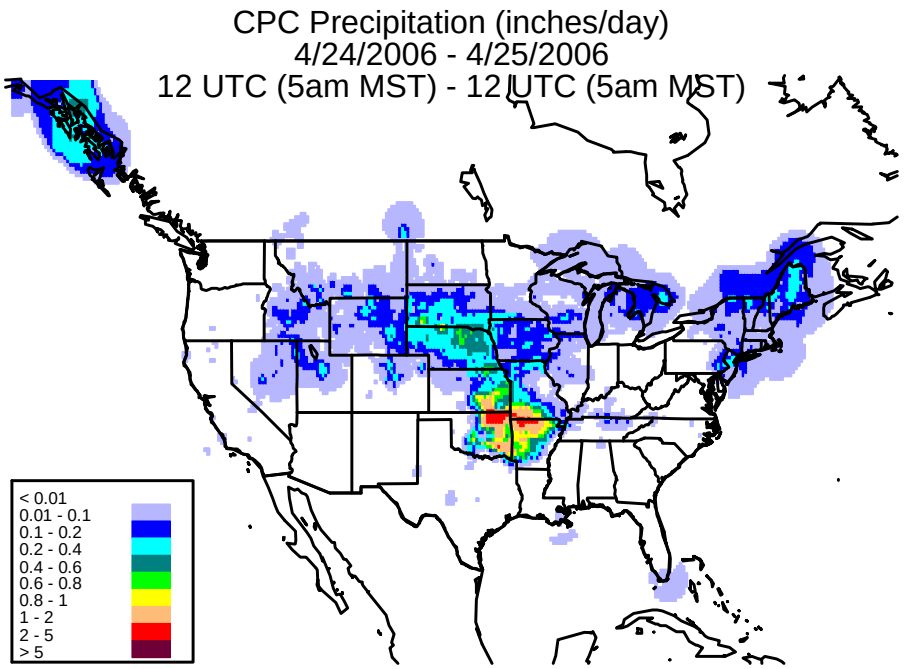
- **Resolution:** 0.25 degree x 0.25 degree
- **Domain:** 10 N - 60 N, 140 W - 60 W
- **Interpolation:** Modified Cressman Scheme
- **Data from:** > 8000 stations, US & Mexico:
  - World Meteorological Organization (WMO)
  - Global Telecommunications System (GTS) sites
  - SHEF (Standard Hydrologic Exchange Format) - from River Forecast Centers
  - Hydrometeorological Automated Data System (HADS)
  - SNOTEL (SNOwpack TELemetry) dataset,
  - Mexican National Weather Service.


Daily Precipitation
Spring ROMANS Core Site
Measured
CPC
MM5 Domain 3
mm/day
0
5
10
15
90
3/31
100
4/10
110
4/20
120
4/30
Day of Year 2006

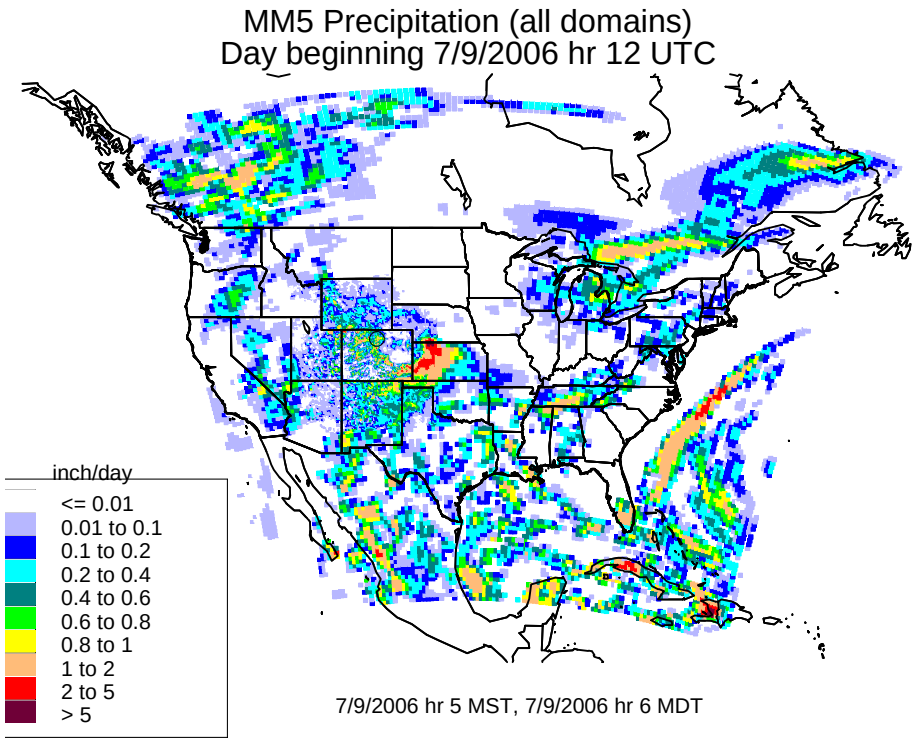

Daily Precipitation
Summer ROMANS Core Site
Measured
CPC
MM5 Domain 3
mm/day
0
5
10
15
20
25
30
180
6/29
190
7/9
200
7/19
210
7/29
220
8/8
Day of Year 2006

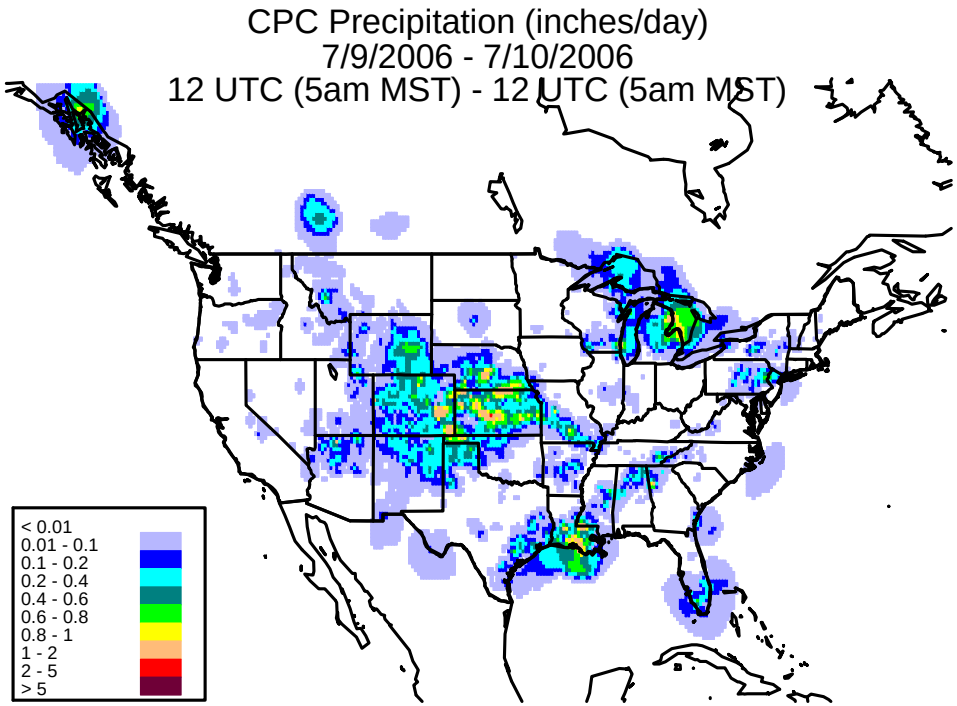
April ROMANS Episode





July ROMANS Episode

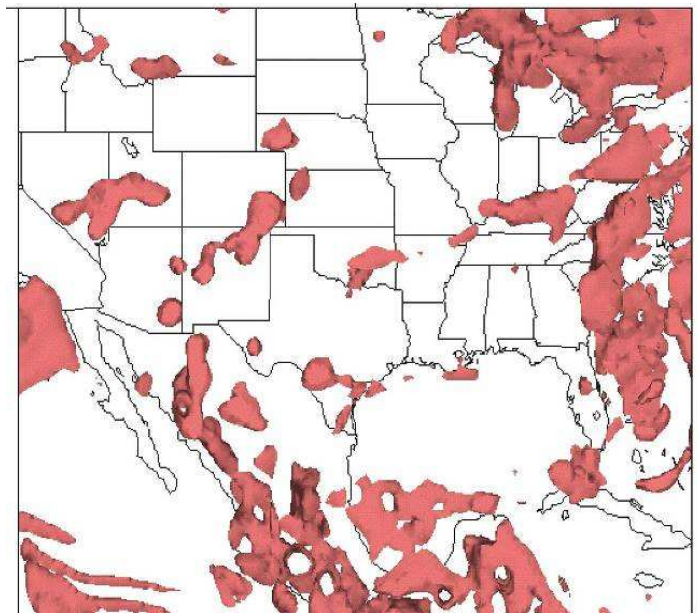




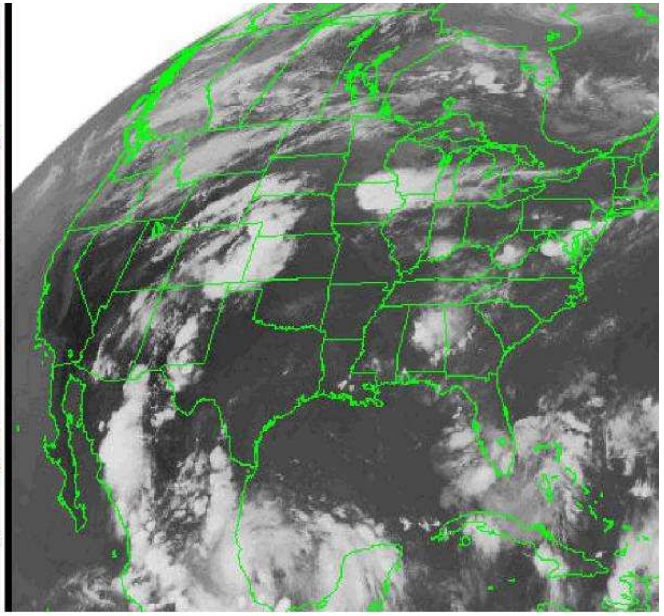
Clouds

- Clouds are important in CAMx:
  - Aqueous chemistry for soluble species
  - Wet deposition
- How to evaluate?

BRAVO MM5

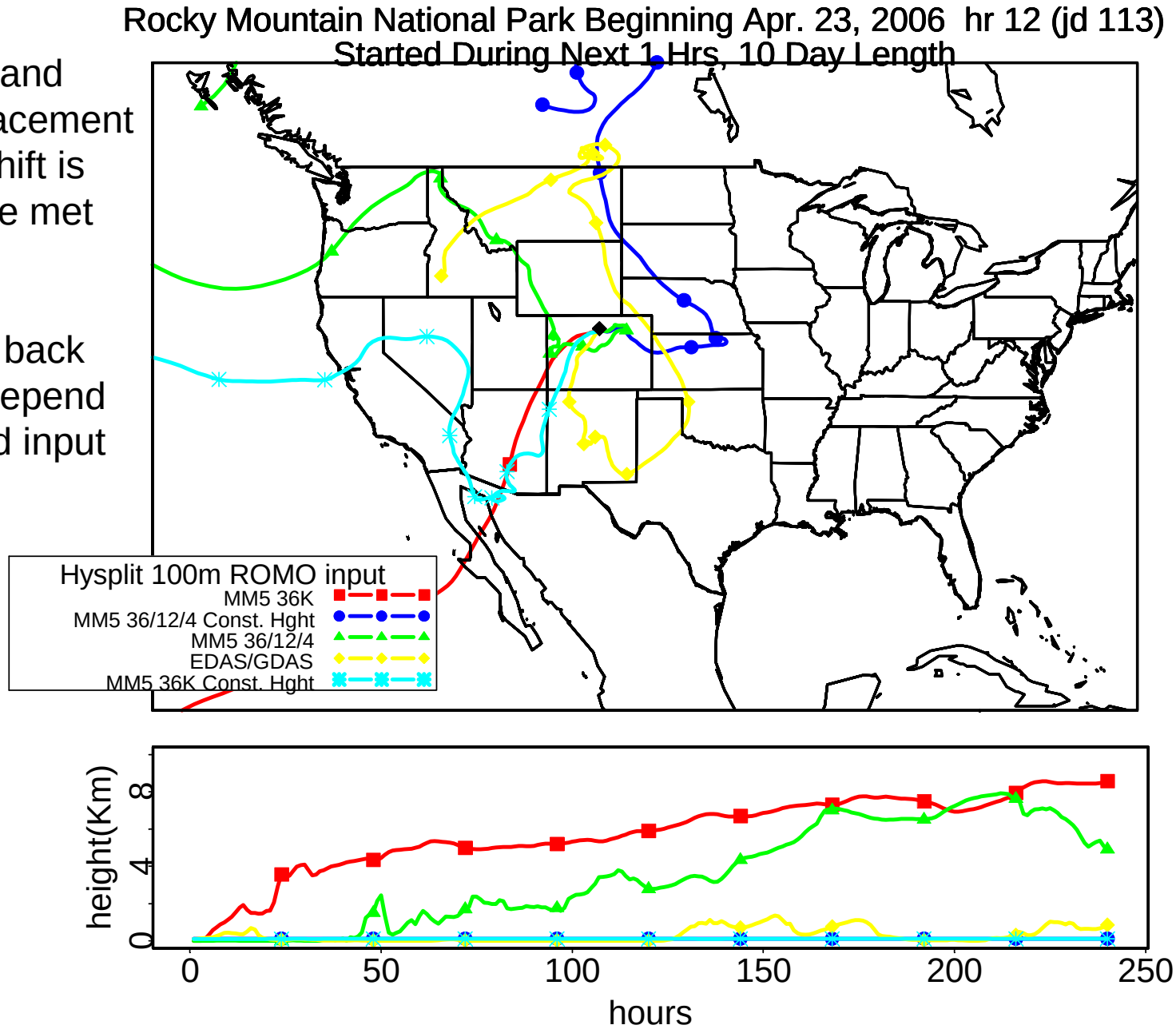


GOES-East

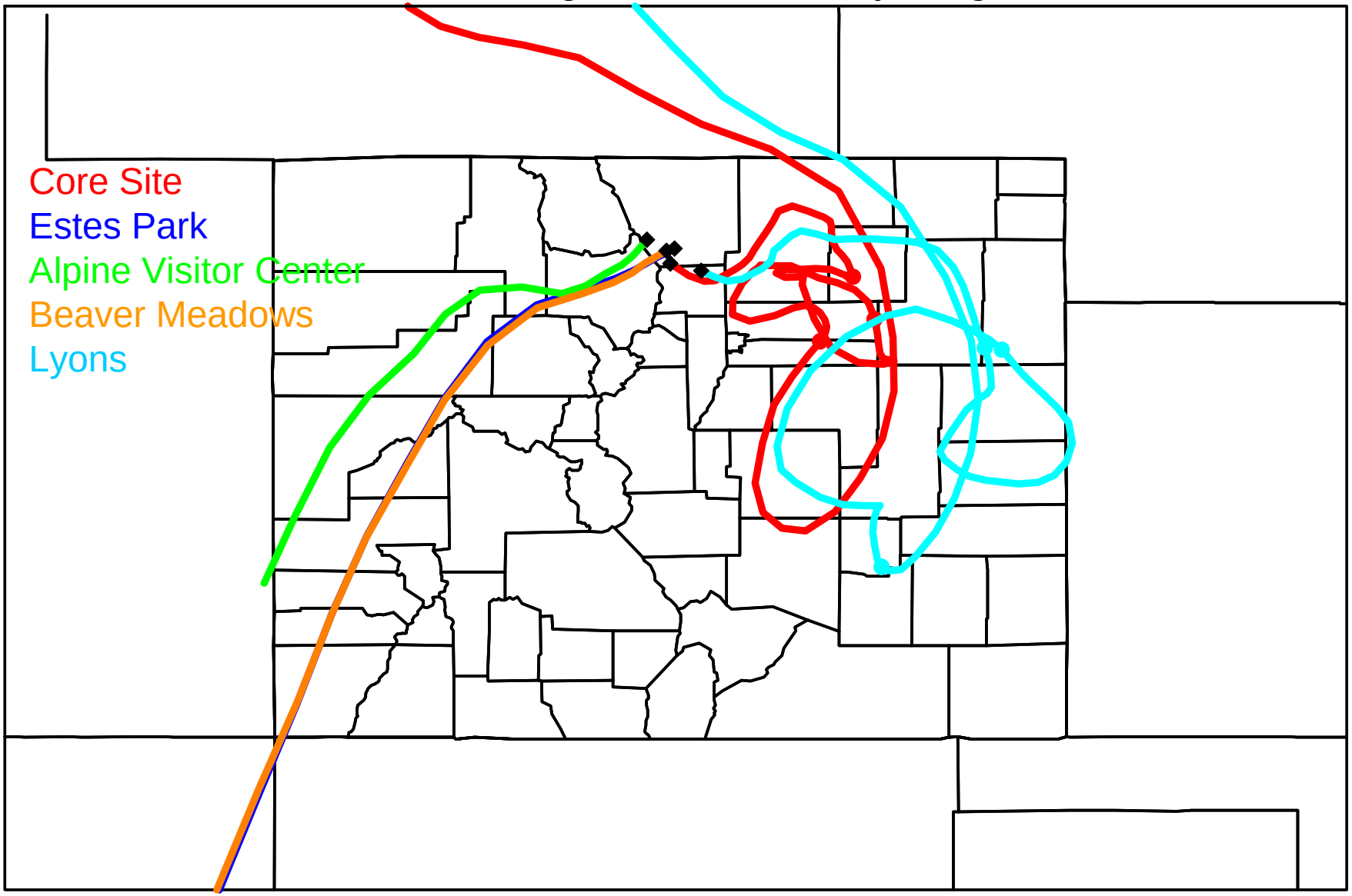


Exact timing and horizontal placement of the wind shift is difficult for the met models.

Directions of back trajectories depend on height and input data.



Rocky Mountain National Park Beginning Apr. 23, 2006 hr 11 (jd 113)
Started During Next 1 Hrs, 5 Day Length



Conclusions

- 36/12/4 km MM5 simulations with obs nudging have been created for 2006 ROMANS study
- RMNP is (obviously) in a region of complex terrain – requires nudging with surface obs and radar profiler to capture upslope flow
- Transport from the east less frequent, but associated with both higher precip and N concentrations
- Even with nudging, wind speeds are too high in winter and too low in summer for CO sites

Conclusions (cont'd)

- Precip estimates at core site aren't bad
  - Main events captured
  - A few false positives
  - Replace MM5 precip results with daily CPC?