OHRFC MPE Bias Study

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A Few Details

- Operational use of Stage III & MPE since1997
- Archived data since mid-1996
- Too few hourly raingauges to adequately support MAP operationally
- Untimely reporting of hourly hourly raingauges
- Desire to push the technological envelope & work through problems
- MAP still calculated operationally
- R-hat parameter used to adjust weight of radar vs raingauges

Motivation for Radar Precipitation Study

- OHRFC operational commitment to Stage-3/MPE precipitation estimation
  - Operational use since 1997 using MAPX as sole precipitation input to NWSRFS hydrologic models
  - Inadequate raingauge support
    - Uneven spatial coverage
    - Reporting times too late to meet operational start
    - Complex terrain
- Operational biases apparent (known problem)
  - OHRFC operational experience
  - Other RFCs
  - NEXRAD radar precipitation estimation studies by Smith et al (Princeton Univ.) & others
    - Beam blockage
    - Beam over shooting
    - Range effect (spreading of the radar beam)
    - Non unique Z-R relationship
    - Hail contamination
    - Poor snow estimation
    - Orographic enhancement
    - Radar calibration
    - Truncation error (most apparent with stratiform precipitation)
    - Brightbanding
- Identify & understand all sources of biases and attempt to make corrections
- Use of nationally supported operational technology/software

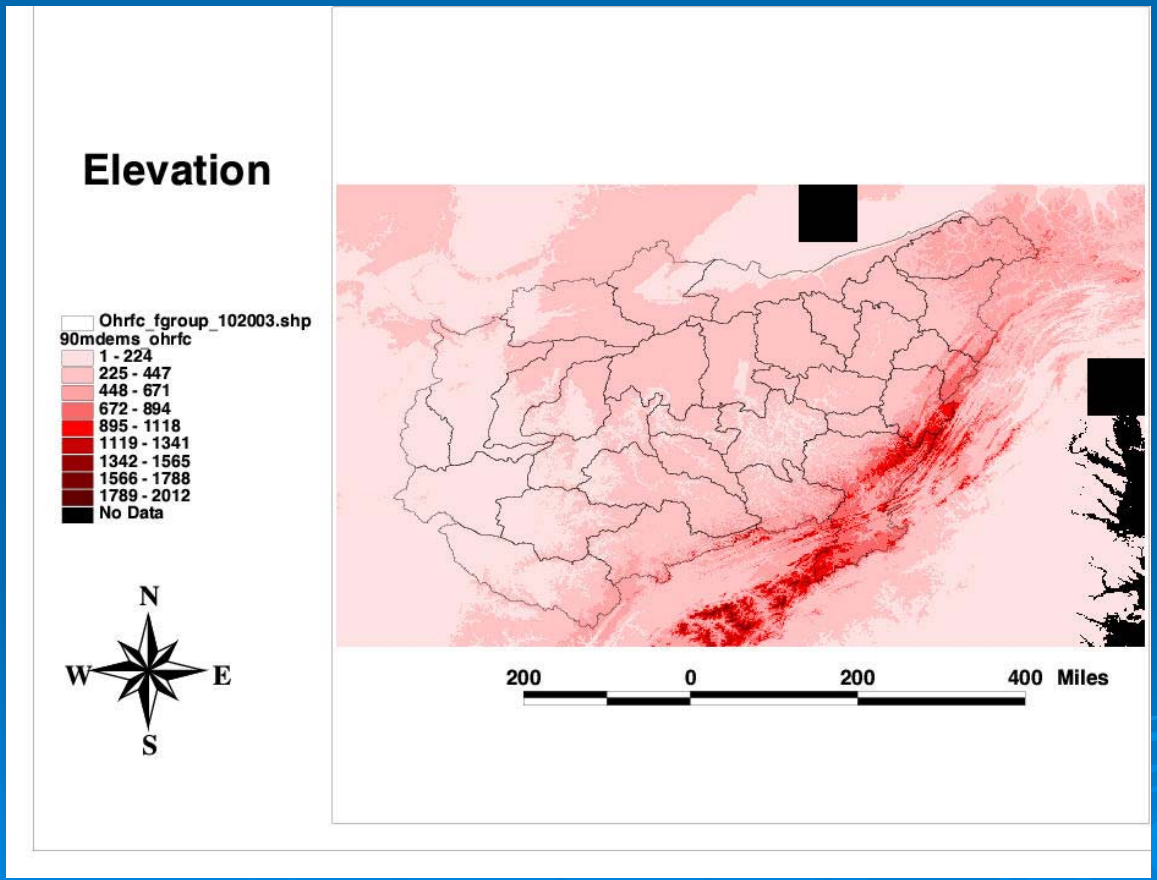
Study Methodology

- Estimate MPE bias relative to raingauge-only estimate over the OHRFC area
  - *bias* = XMRG/raingauge
  - Uniform gridded field: ~ 0.0475 deg x 0.0475 deg
- Re-gridding of cell-centered (in lat-long coordinates) HRAP XMRG daily values
- IDW (inverse distance weighting) spatial interpolation to a new grid bounding the OHRFC area
- Spatial interpolation using *Ordinary Kriging* (spherical model) of daily Co-op station reports
- Summation of the new gridded fields
  - Annual total for 2002
  - Seasonal DJF & JJA for 2002
- Statistical analyses using R
- Tools — *ArcView* 3.2 & *GRASS GIS* 5.02, *R* 1.7

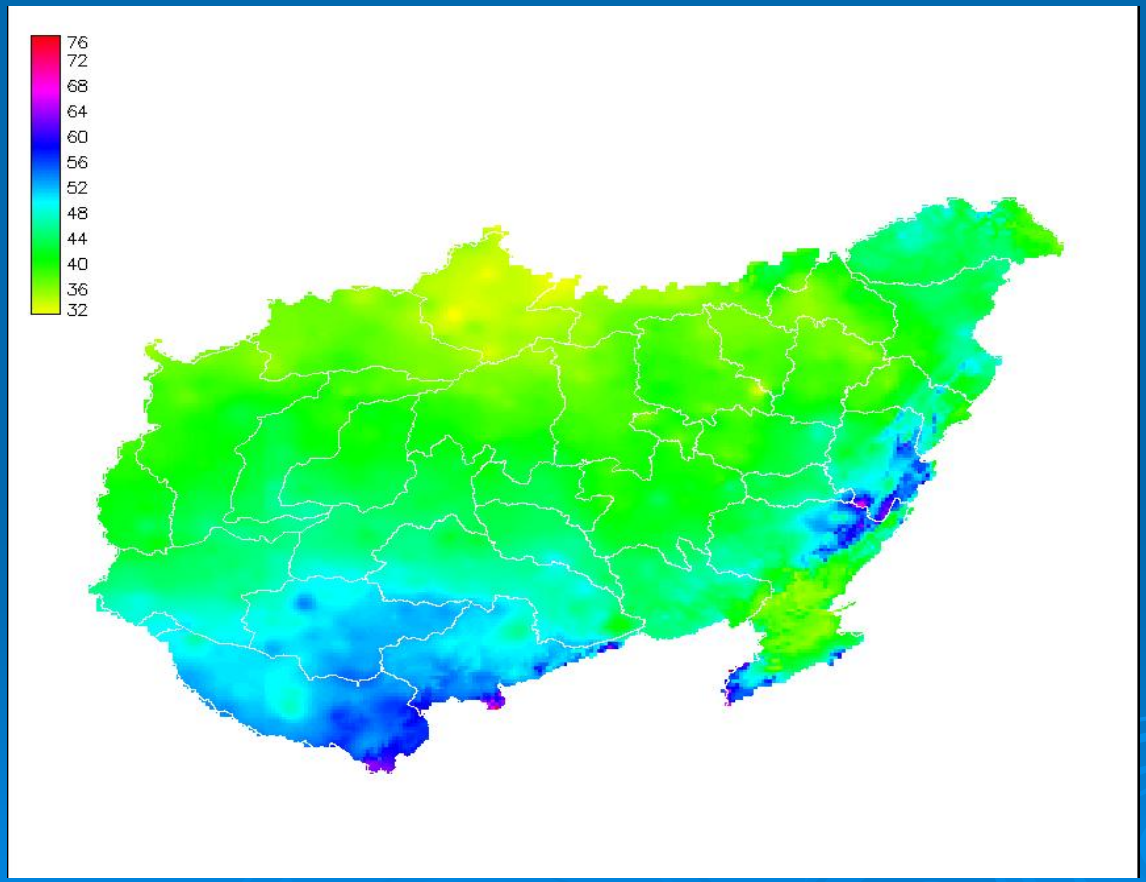
Methodological Assumptions & Issues

- Not true independence of MPE XMRG precipitation estimates and raingauge precipitation estimates — the Co-op station reports also used in MPE estimation
- Inconsistent set of raingauges used in raingauge fields — only 147 consistent for all 12 months out of ~600
- Terrain effects (orographic enhancement) not included in raingauge field precipitation estimation — *some* underestimation?
- Raingauge density inadequate to capture convective precipitation variability
- Grid comparisons based on geographic rather than HRAP grid basis
- HRAP grid missing a *small* portion of Lower Wabash River basin
- The criteria for using raingauges may be to restrictive with respect to intolerance for missing data

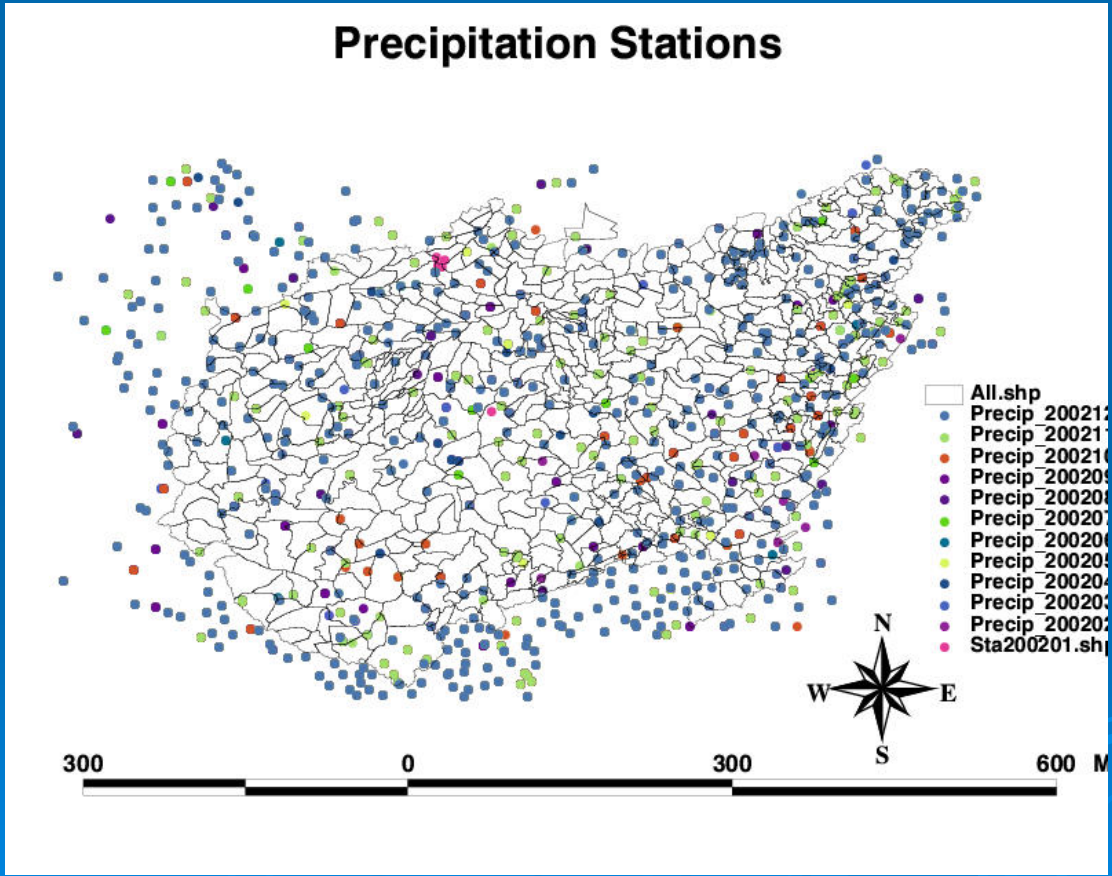
OHRFC Terrain



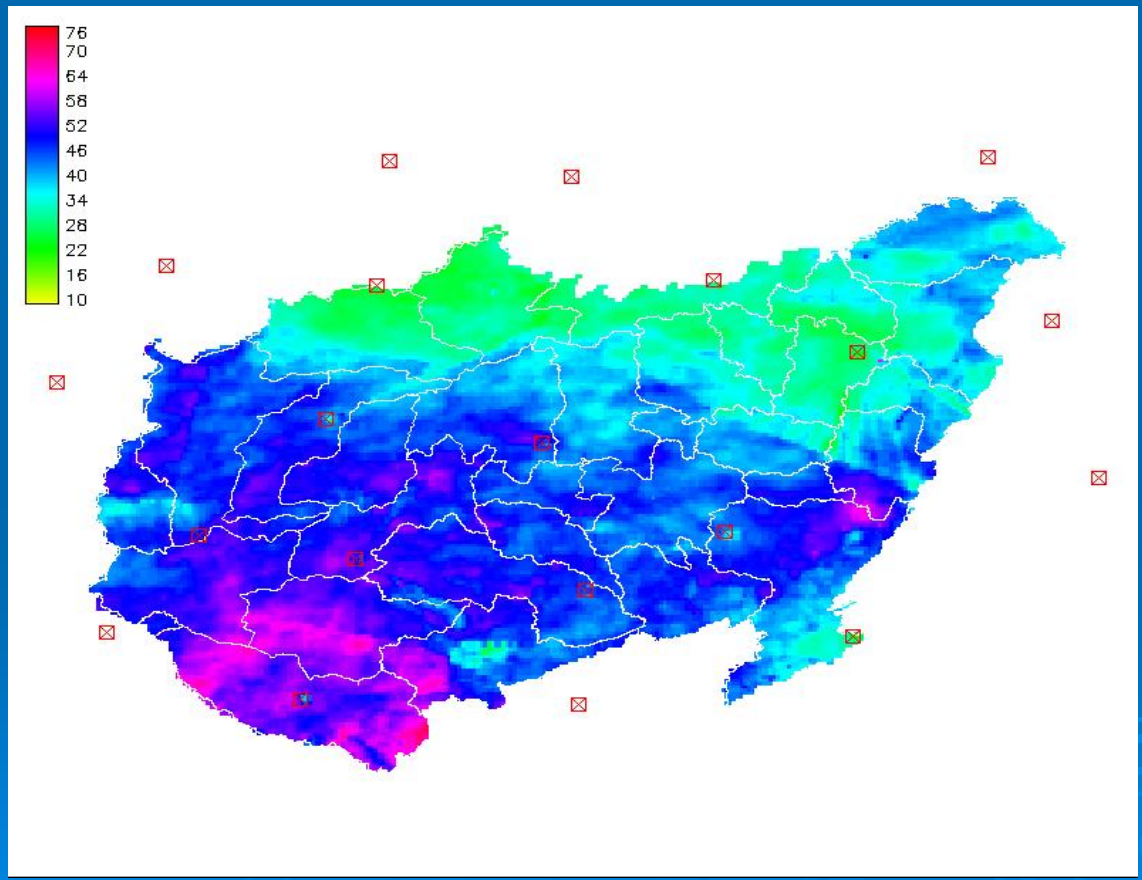
OHRFC PRISM Mean Annual Precipitation, 1961-90



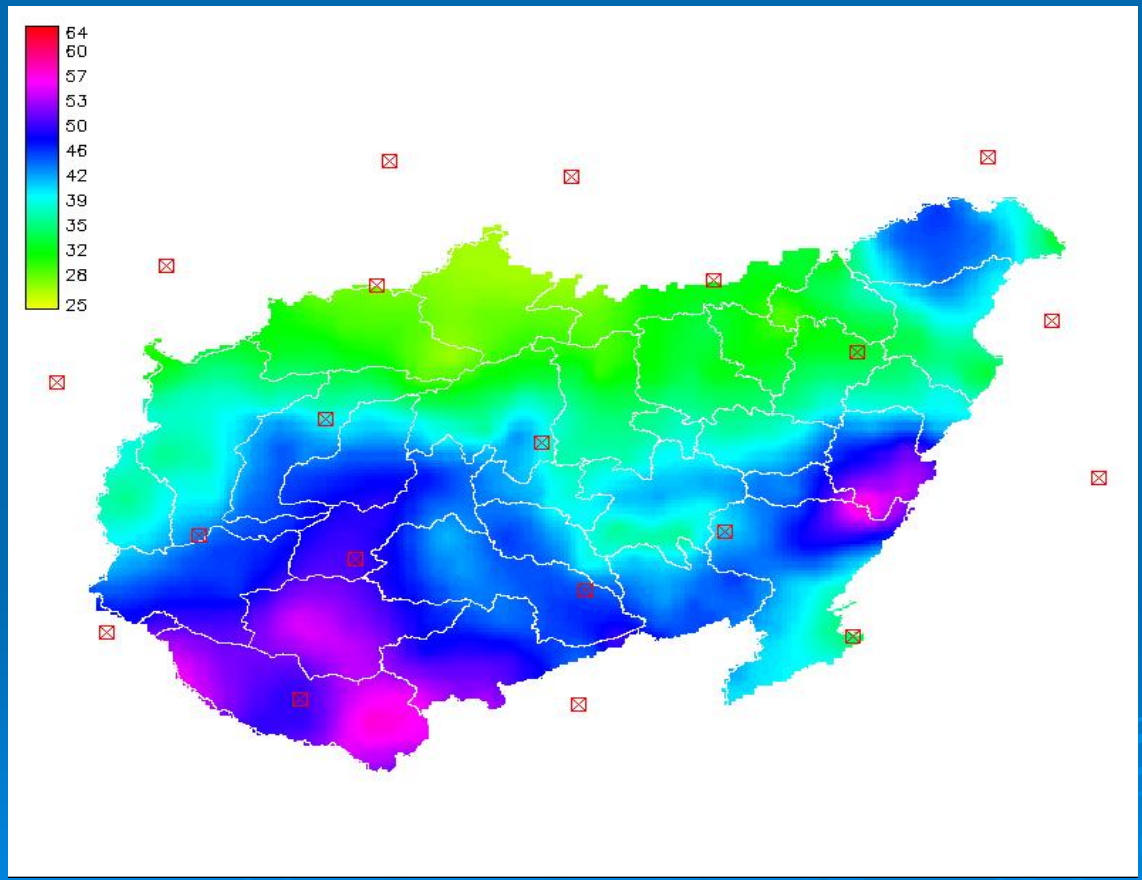
Raingauge Stations



2002 MPE xmrg Precipitation Estimate

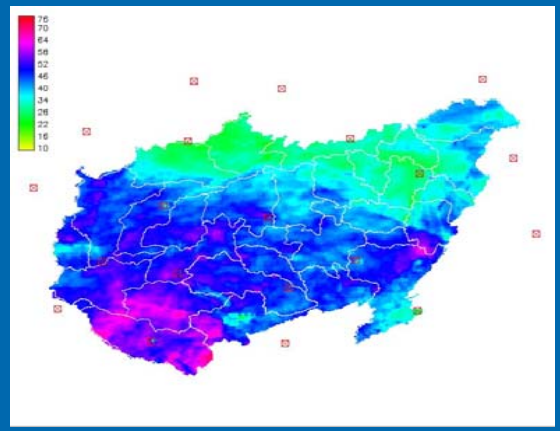


Co-op Raingauge Network 2002 Precipitation Estimate



Bias Calculation

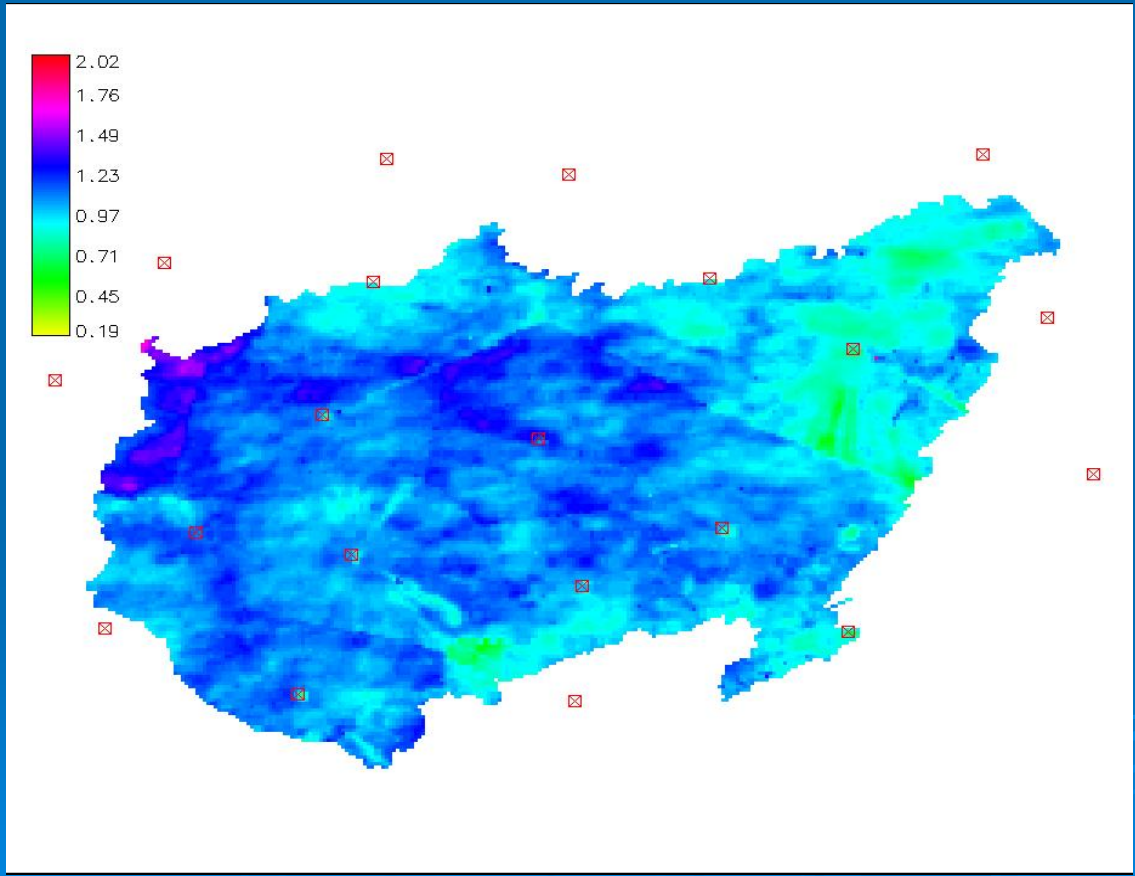
MPE xmrg precipitation



Co-op gauge network precipitation

$$bias = \frac{MPE\ xmrg\ precipitation}{Coop\ raingauge\ network\ precipitation}$$

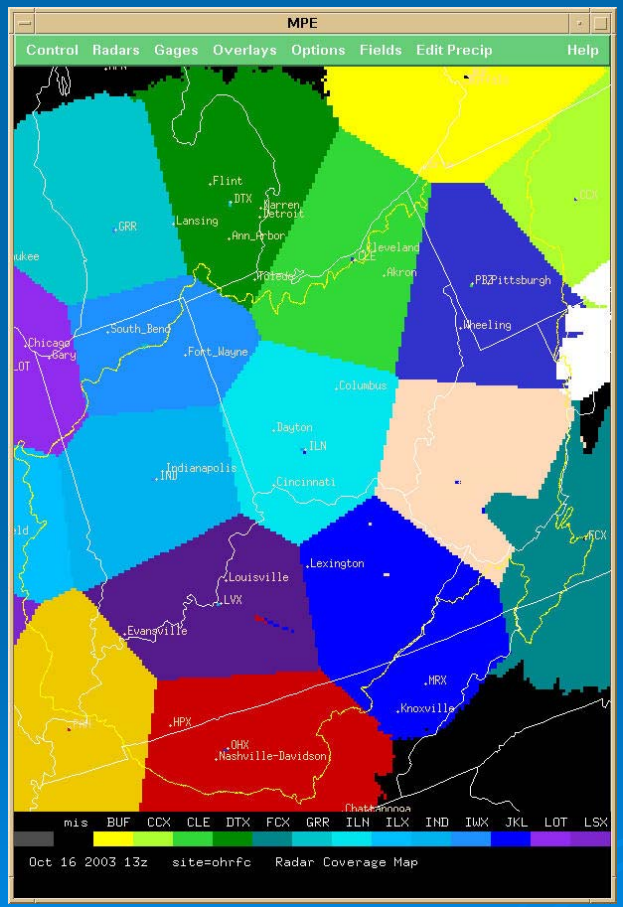
2002 Estimated MPE/xmrg Bias

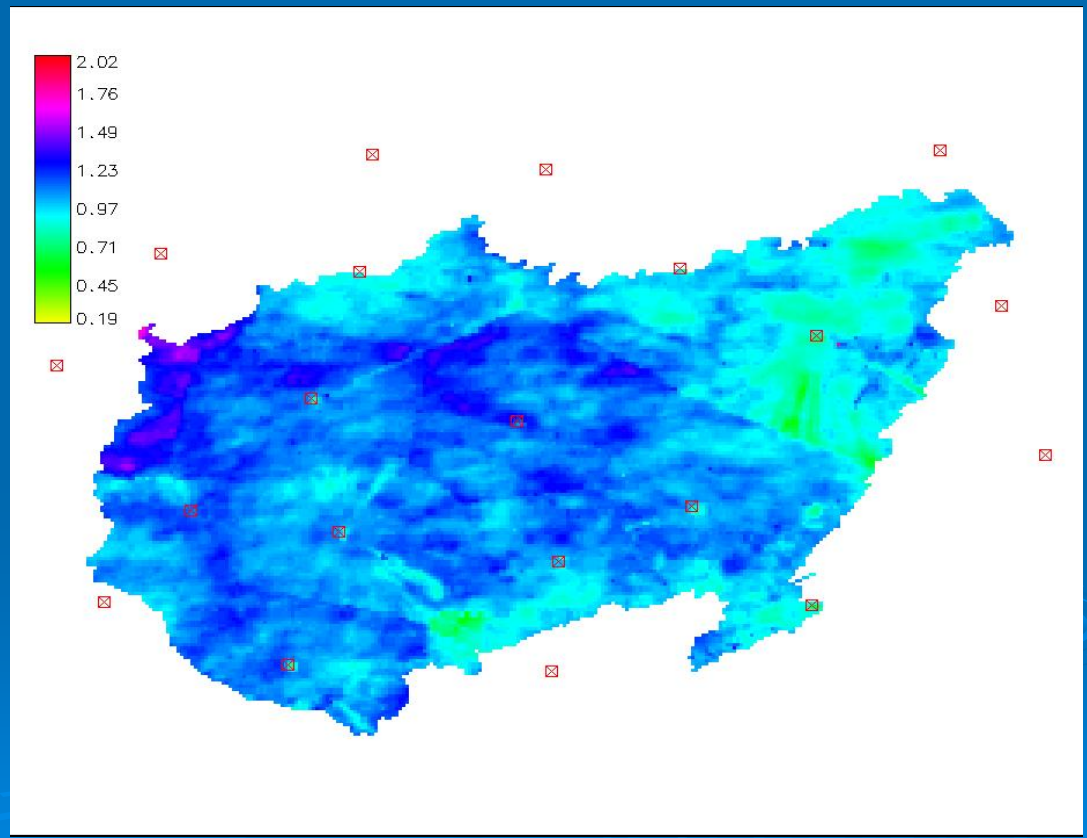


MPE/xmrg Bias Comments

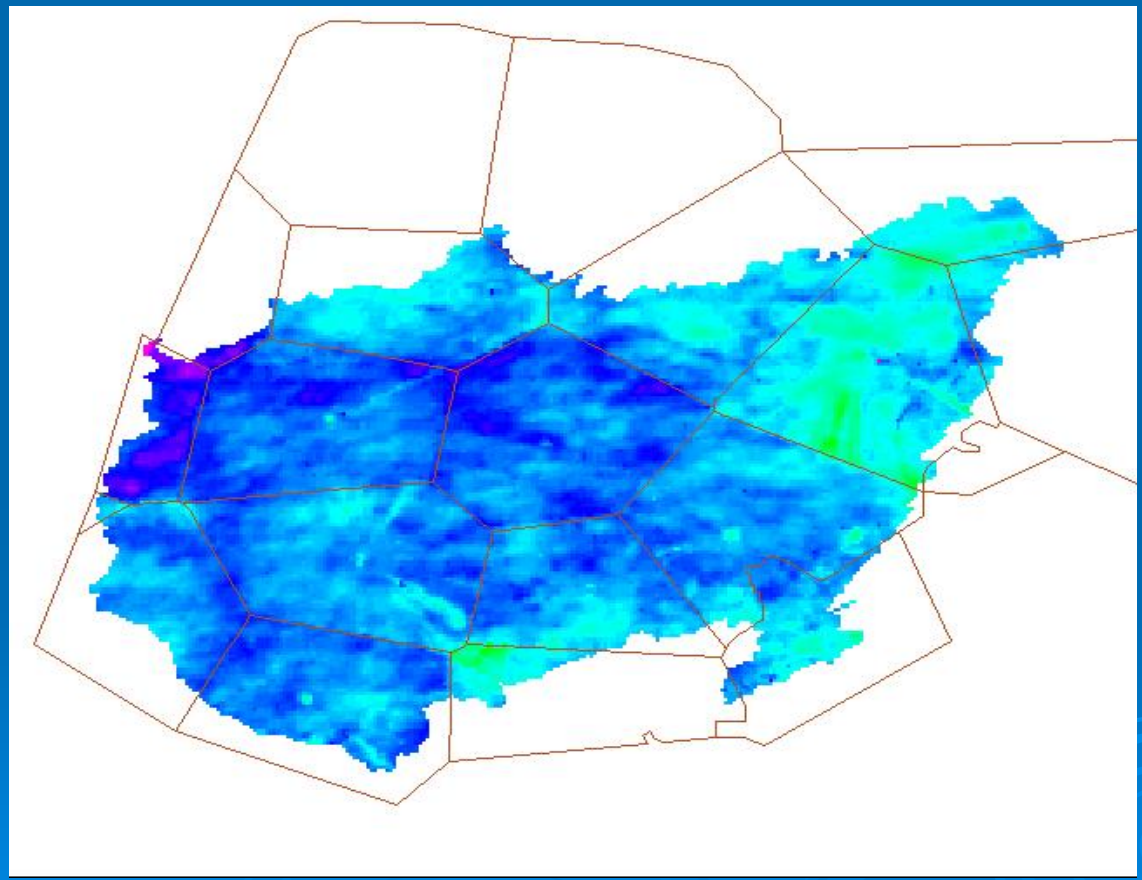
- Bias = 1.0, implies perfect agreement
  - Bias < 1.0, under-estimation
  - Bias > 1.0, over-estimation
- Distinct regions of over- & under-estimation
  - Under-estimation:
    - PBZ & BUF (Allegheny & Monongahela R. basins) and somewhat for CLE & IWX (Great Lakes drainage)
  - Over-estimation:
    - ILX, OHX, & ILN— Indiana & Ohio, Lower Cumberland R., Little Wabash, & Lower Wahash R. basins
- Features due to radar index field (*Thiessen polygons*) boundaries
- Influence of local beam blockage apparent — IND, LVX, & PBZ

MPE Radar Boundaries

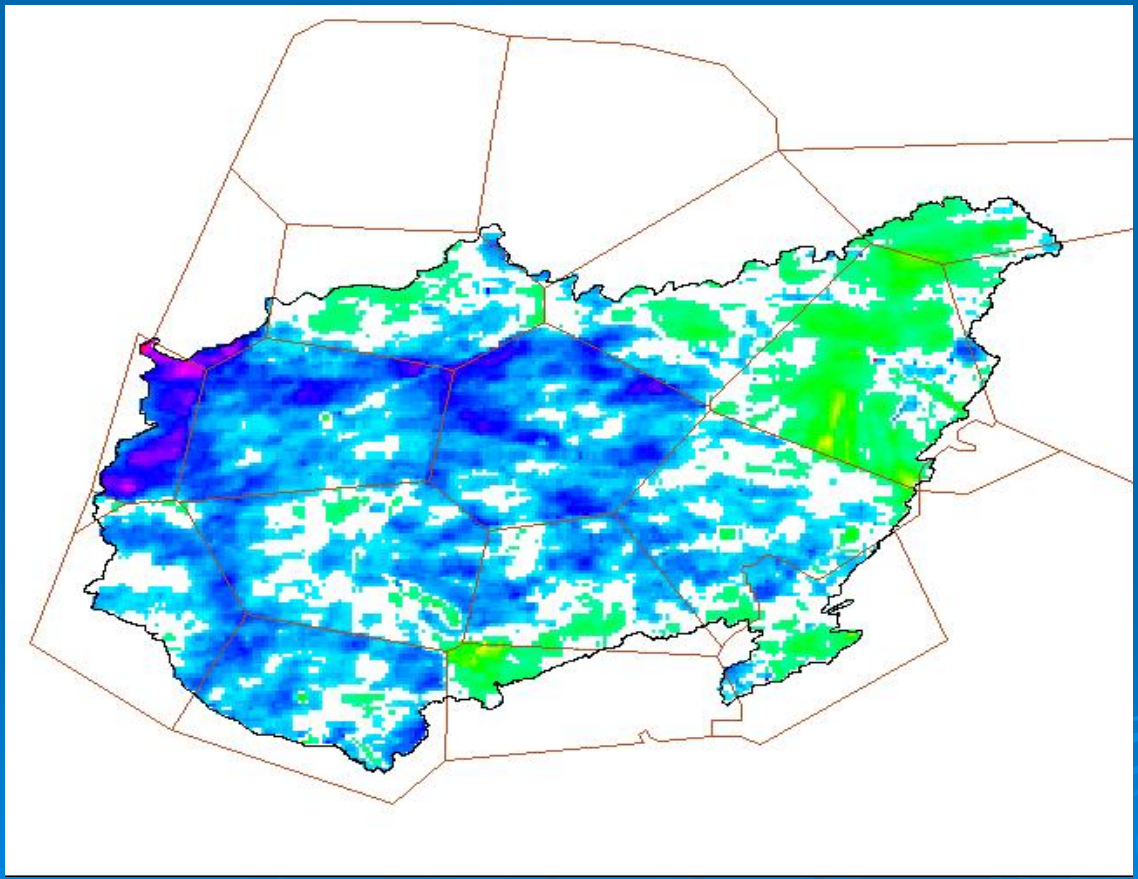




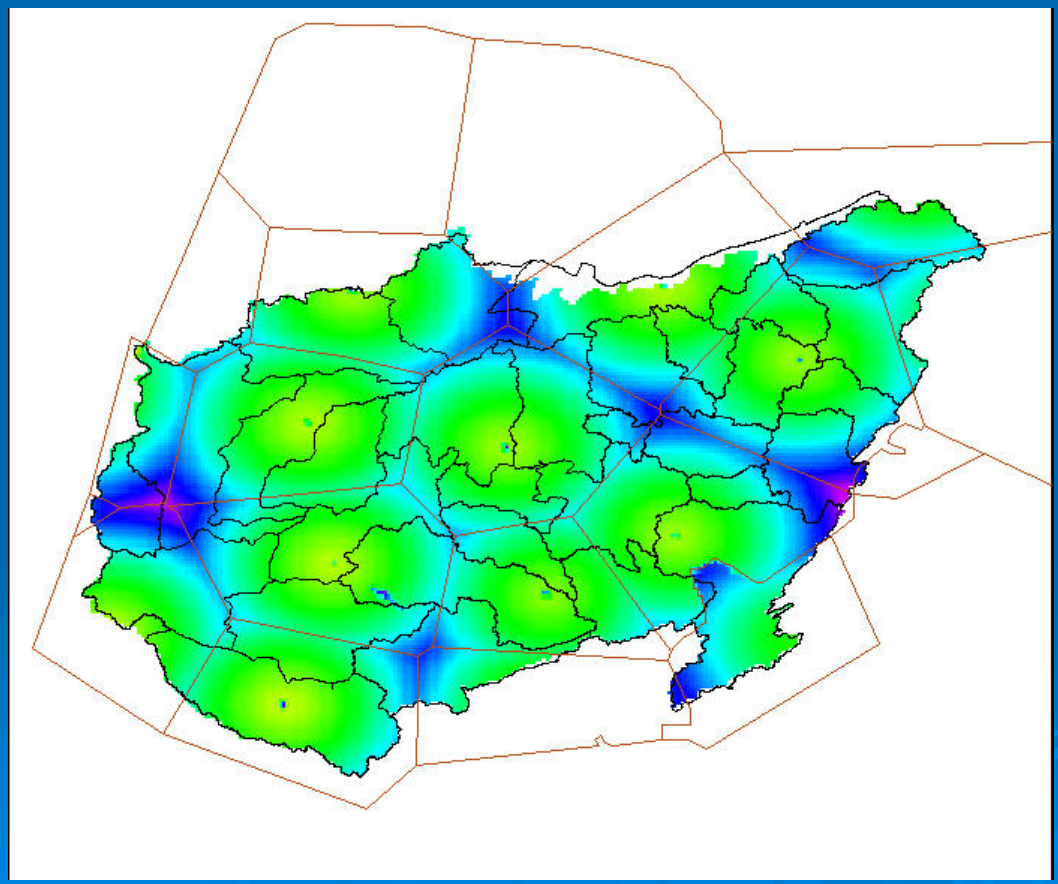
MPE Radar Boundaries (cont.)



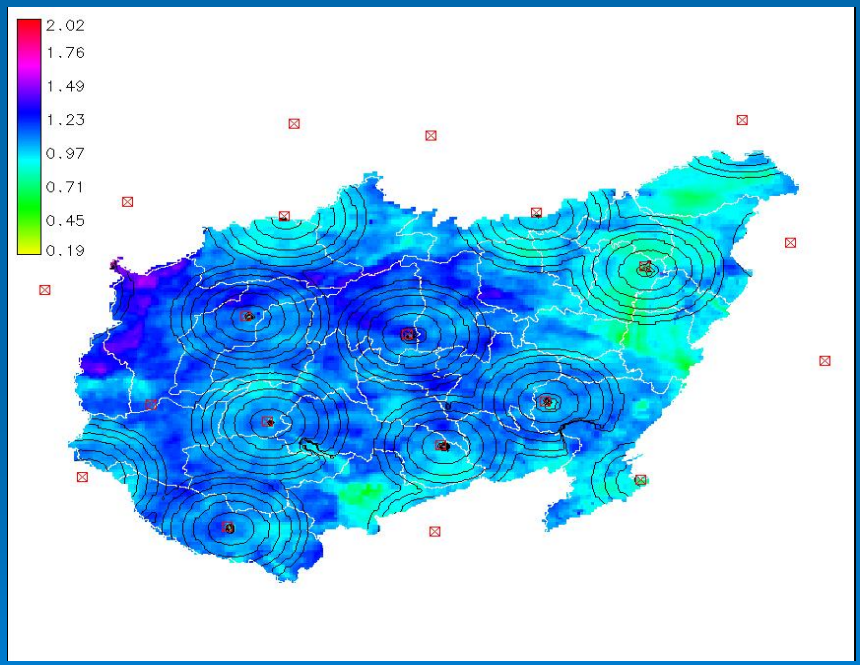
MPE Radar Boundaries (cont.)



OHRFC Radar Heights Field

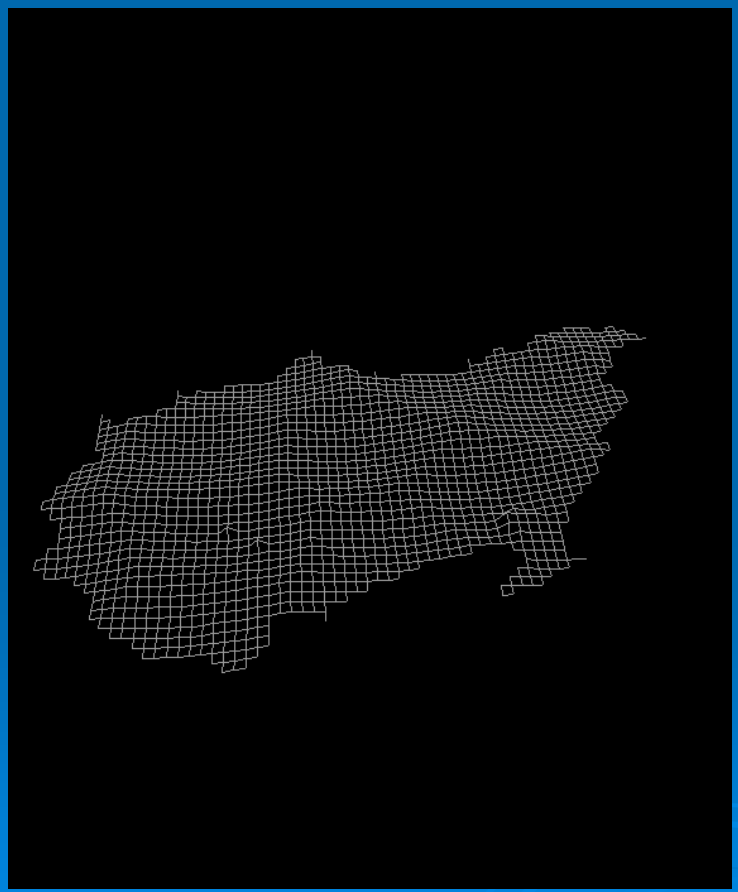


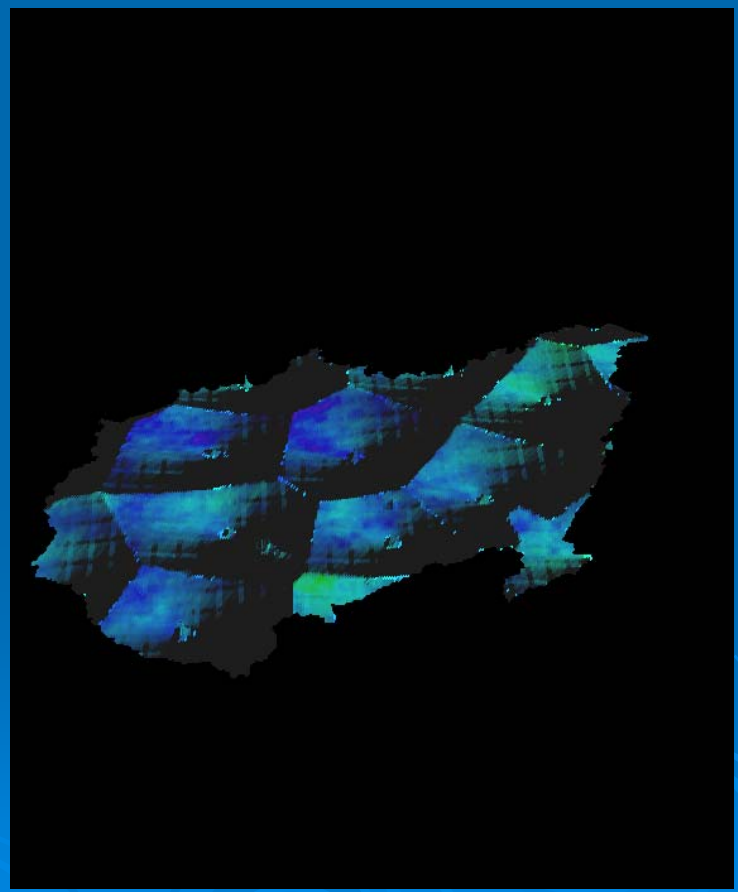
Radar Heights Overlaying Bias Field



- Difficult to discern a correlation to bias & increasing radar beam elevation
- Terrain induced under-estimation along Upper Monongahela western divide
- Blacksburg radar over-shooting in the New River Valley?

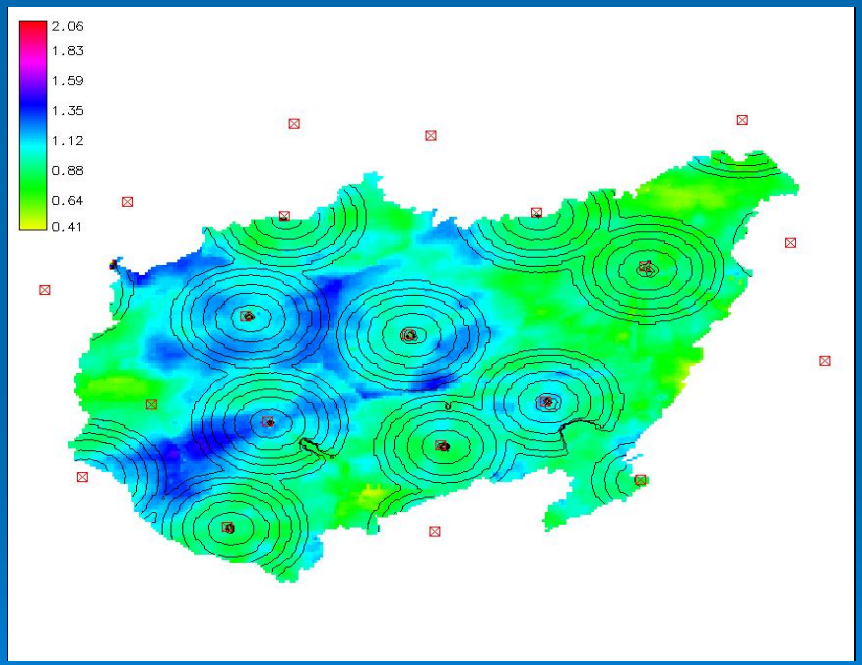
3-D Visualization Height vs Bias



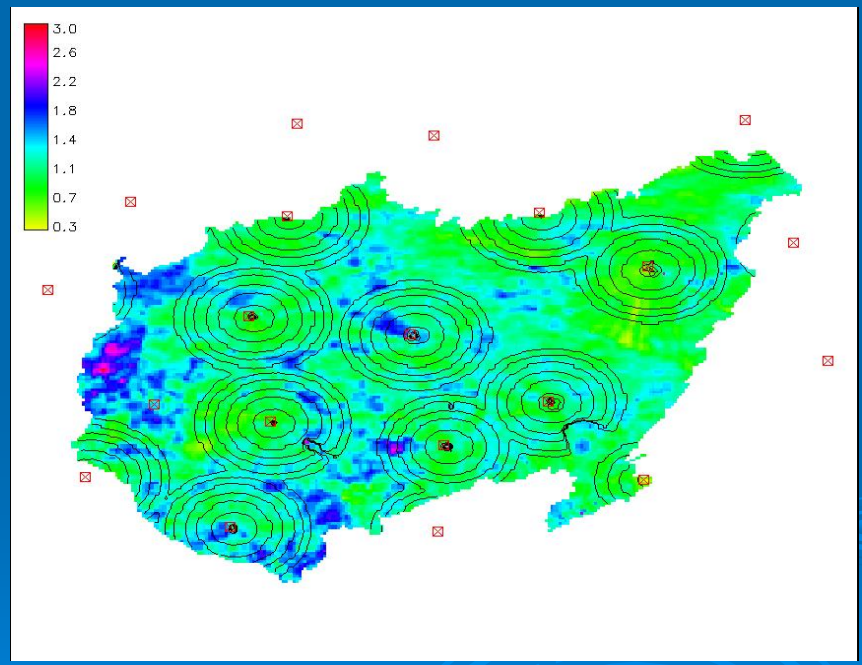


Seasonal Bias Comparison

DJF

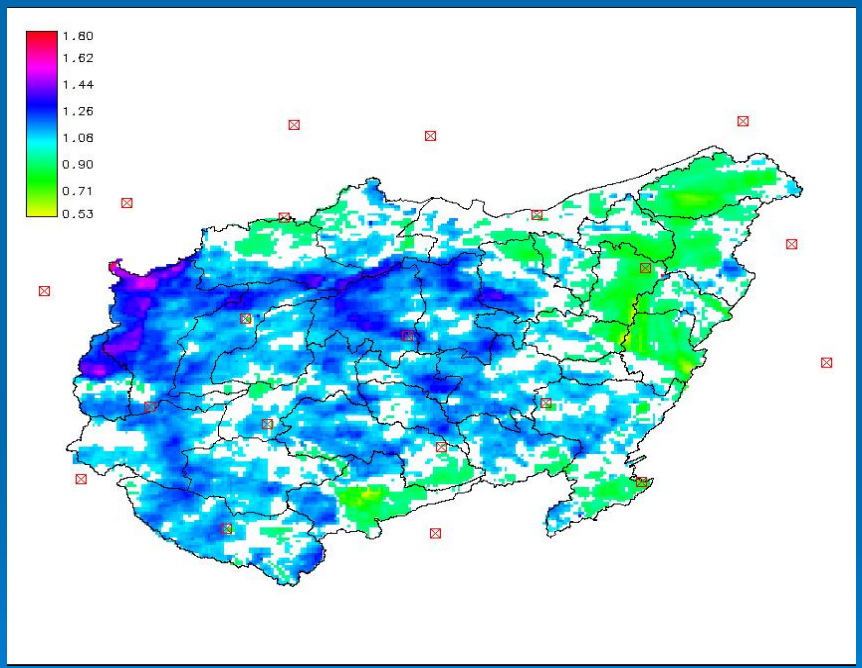


JJA

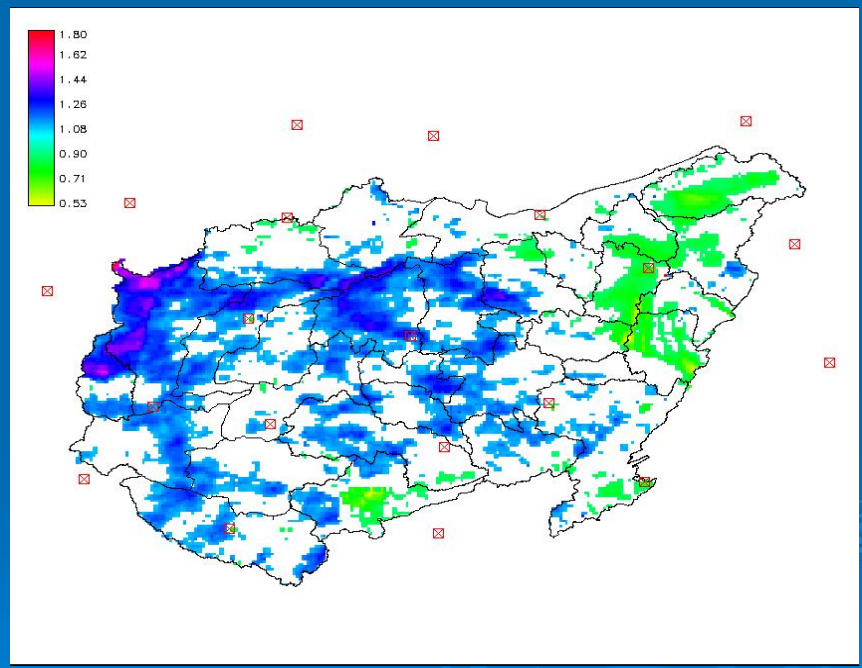


2002 Bias Comparison (cont.)

0.95 ≤ Acceptable Bias ≤ 1.05

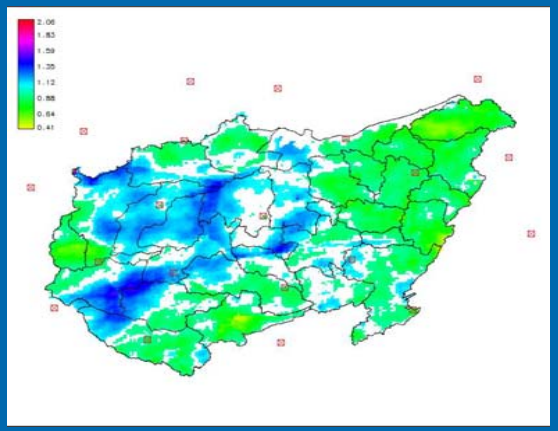


0.90 ≤ Acceptable Bias ≤ 1.10



Seasonal Bias Comparison (cont.)

DJF



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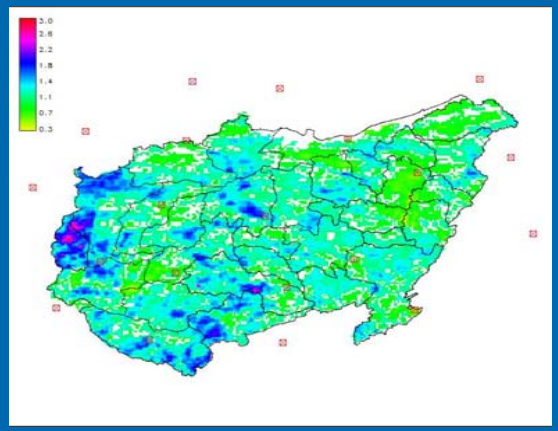
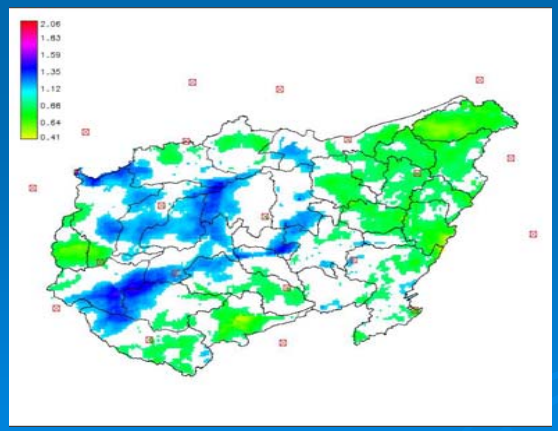
JJA





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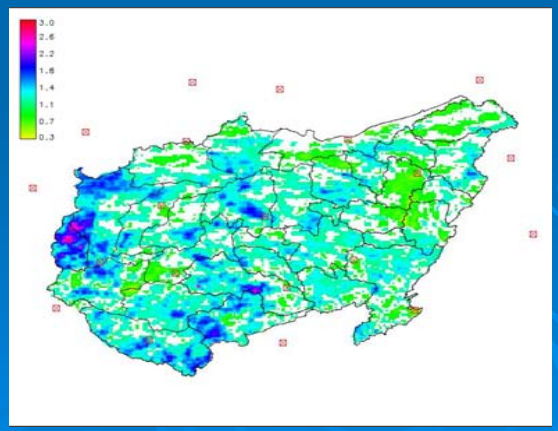
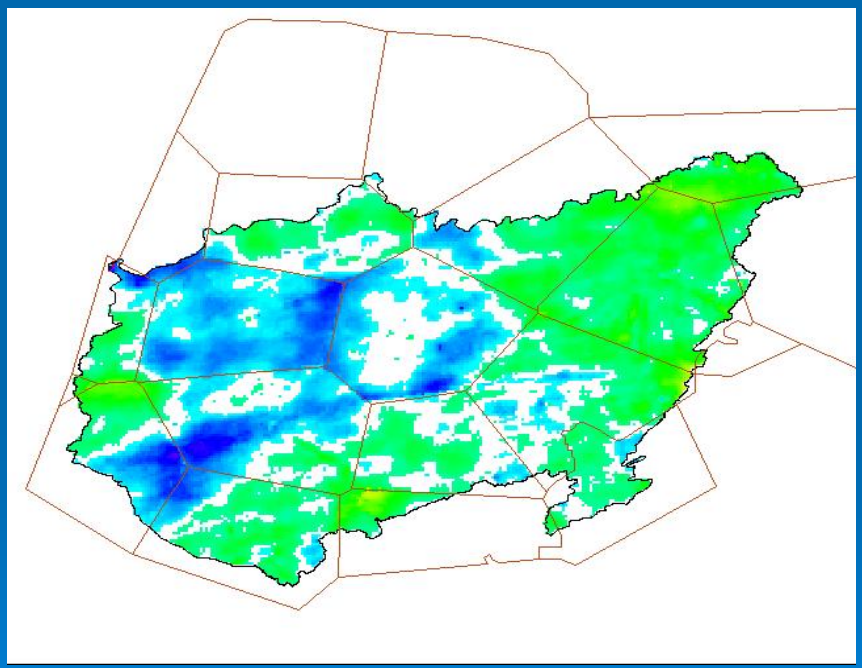
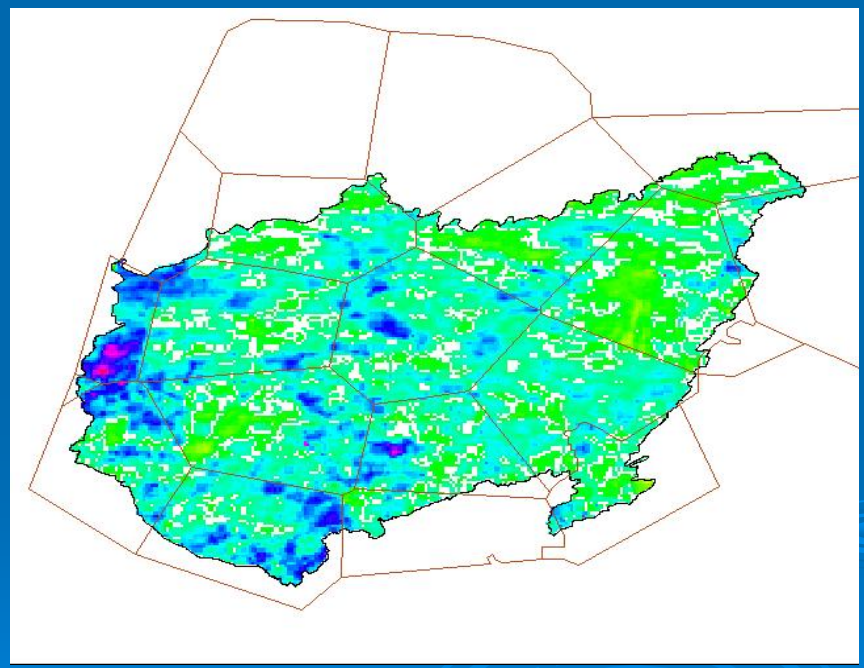


Seasonal Bias Comparison (cont.)

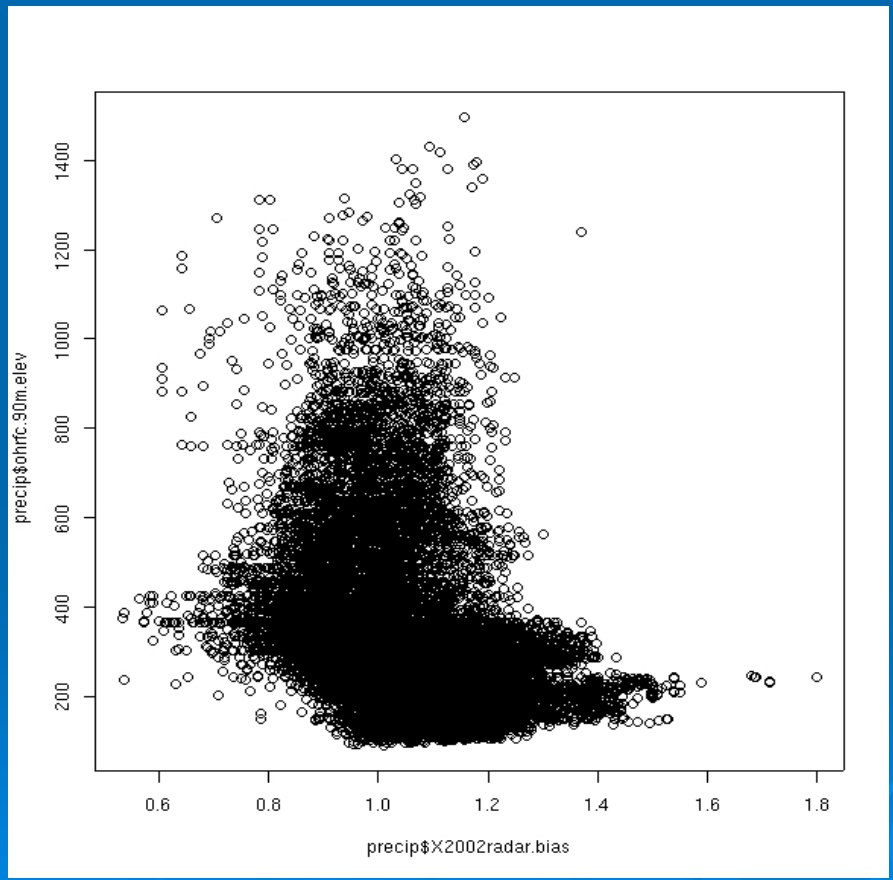
DJF



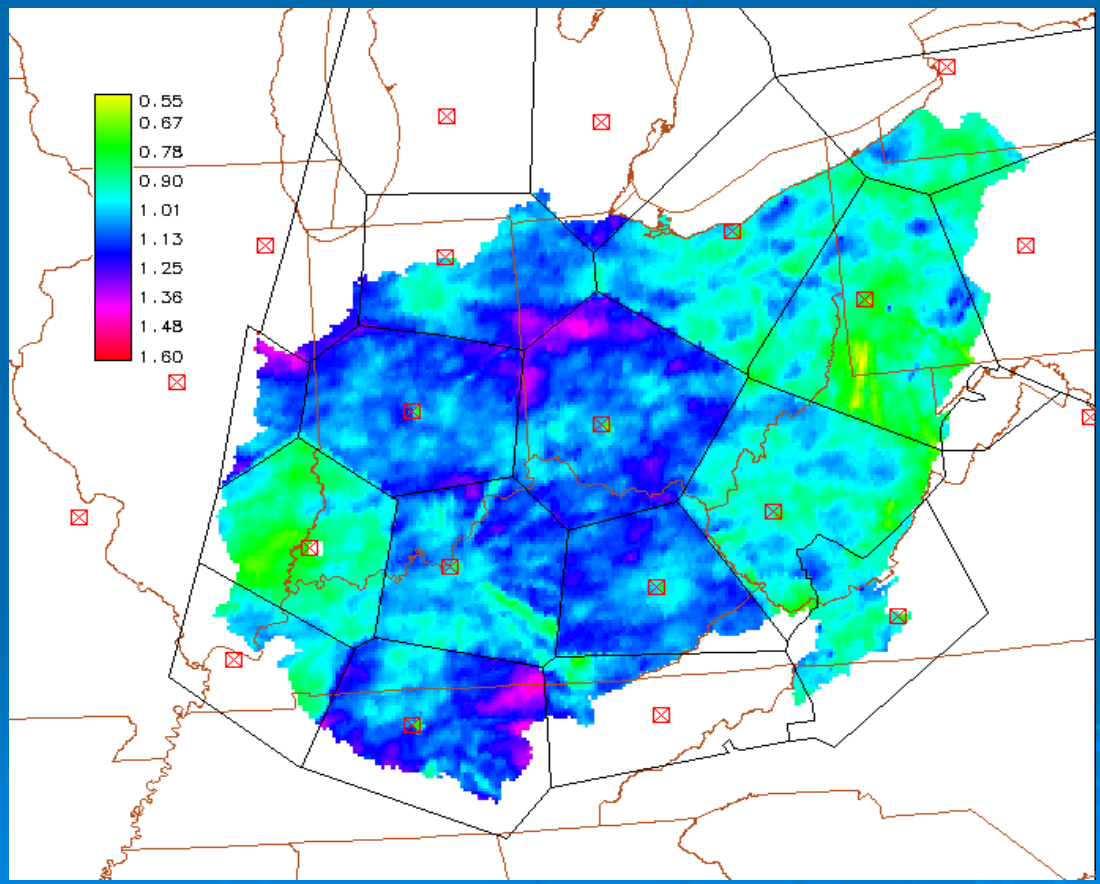
JJA



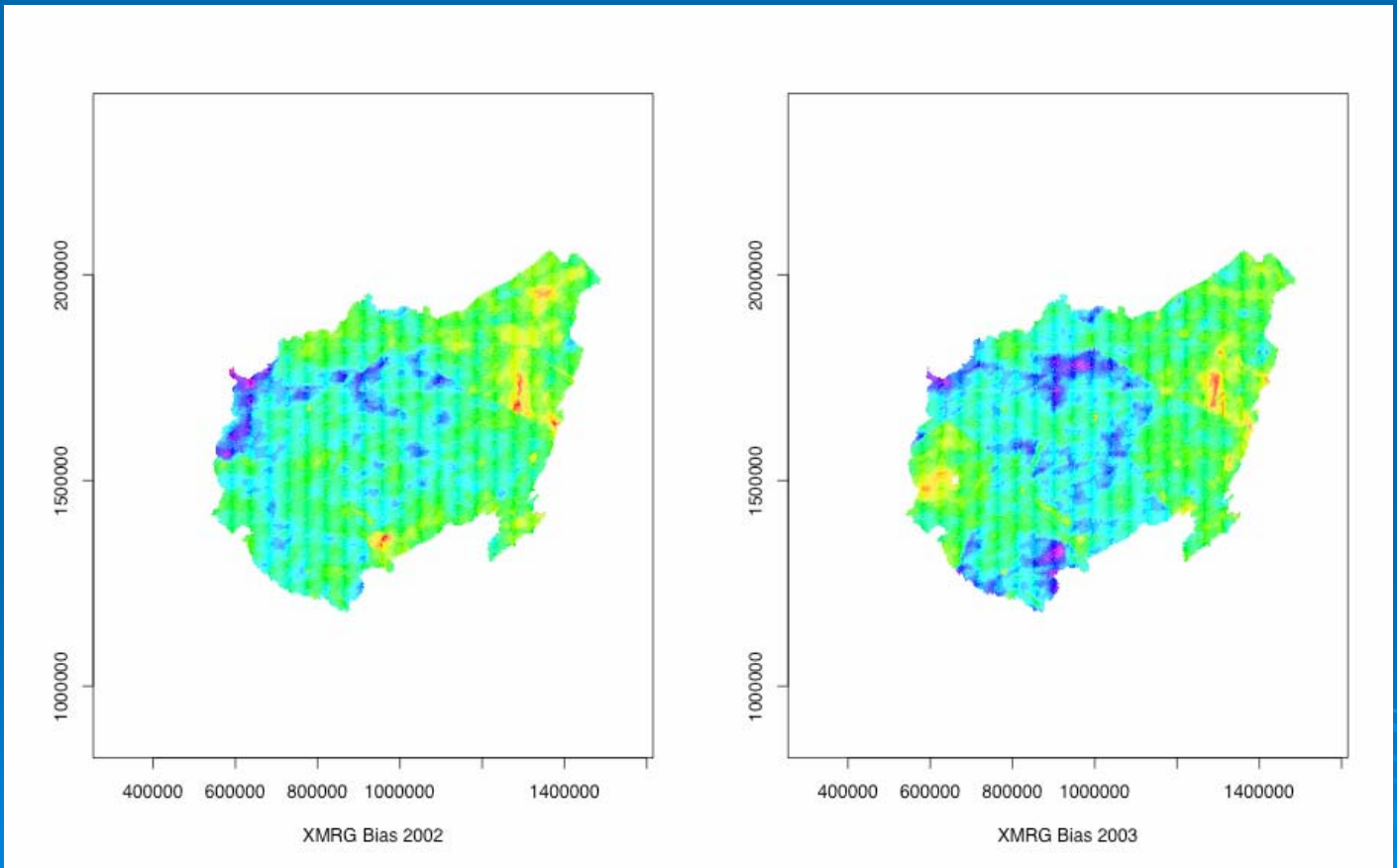
Bias as a Function of Radar Beam Height



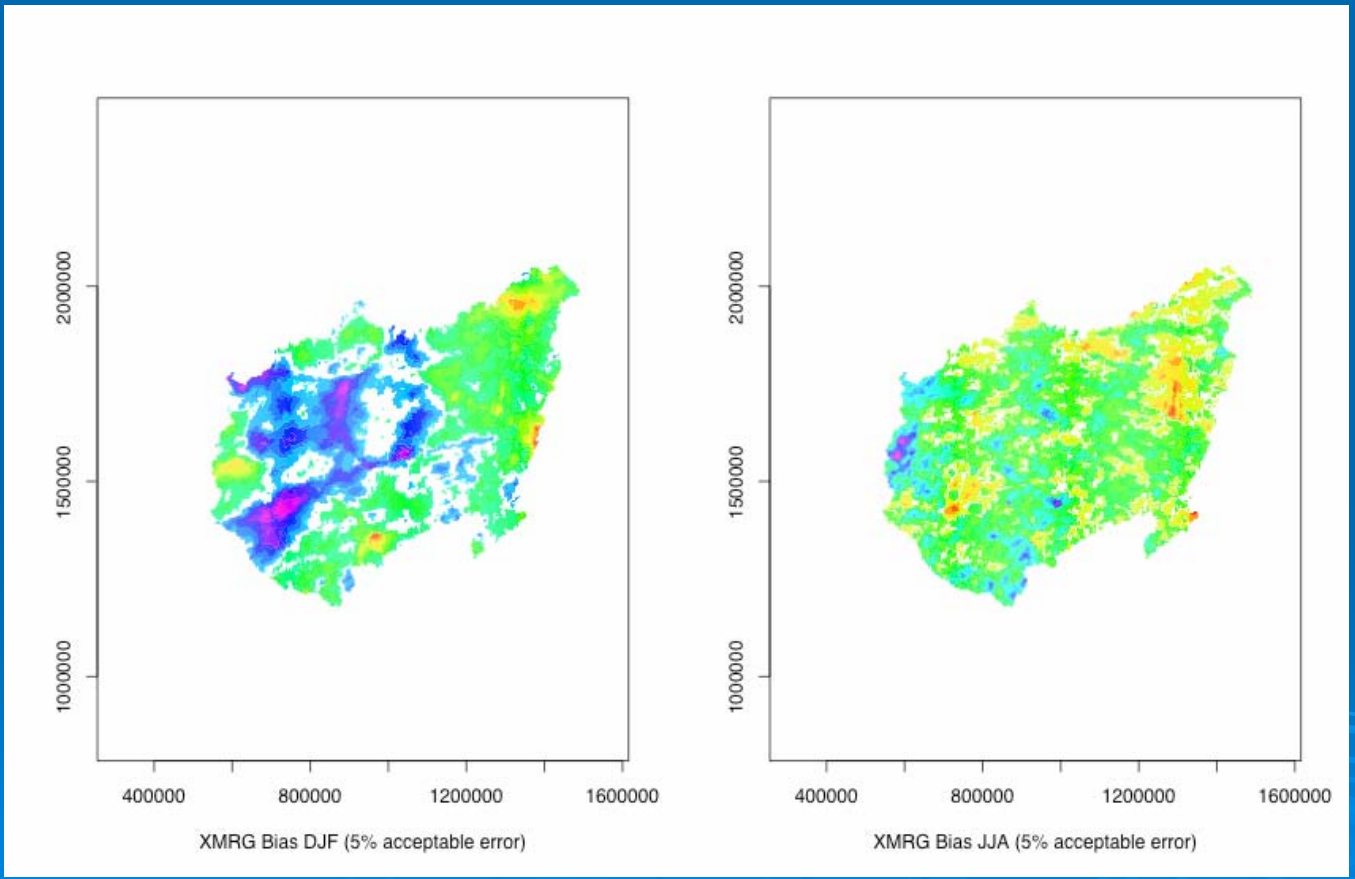
2003 Annual Bias



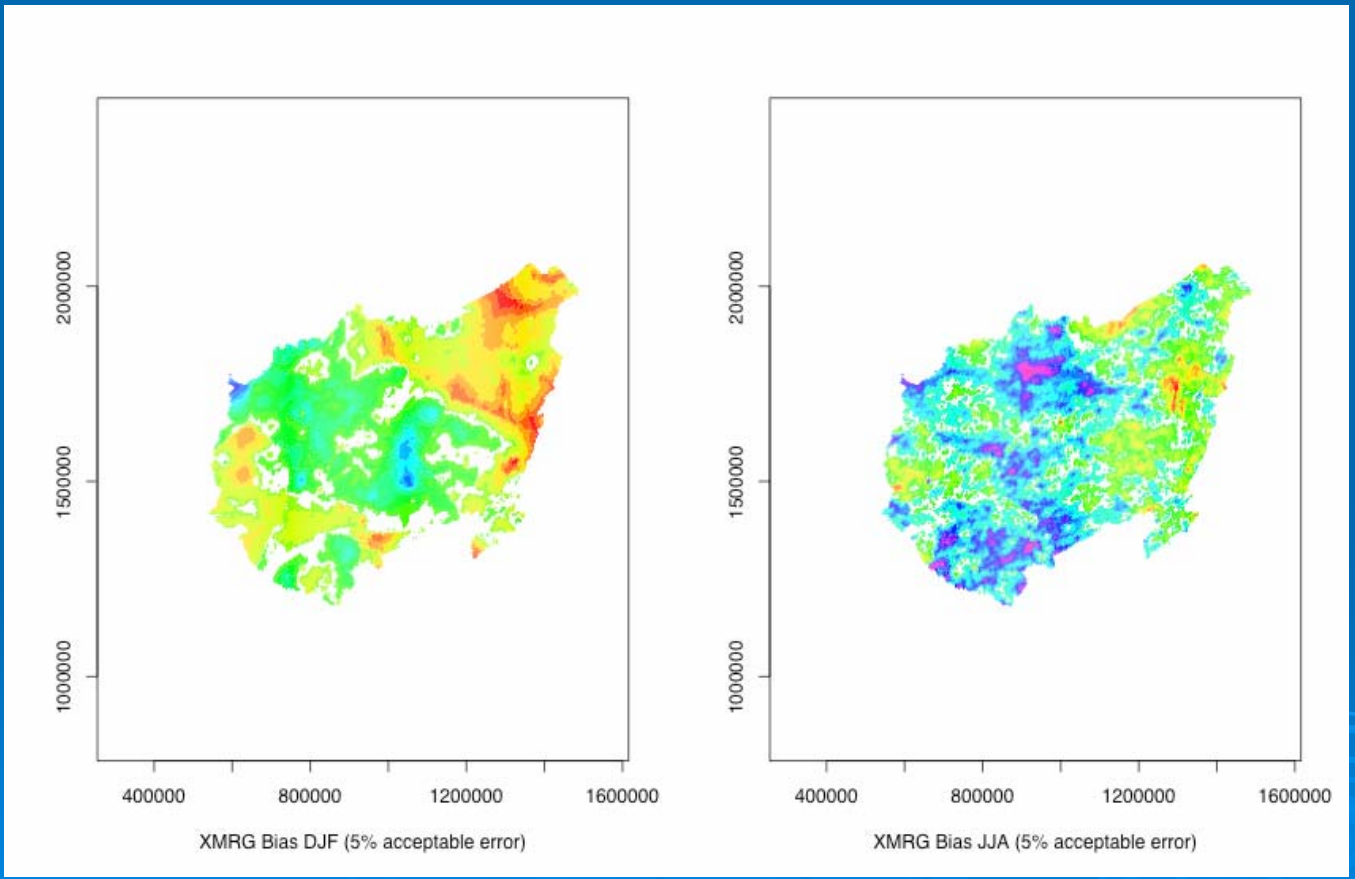
2002 & 2003 Comparison



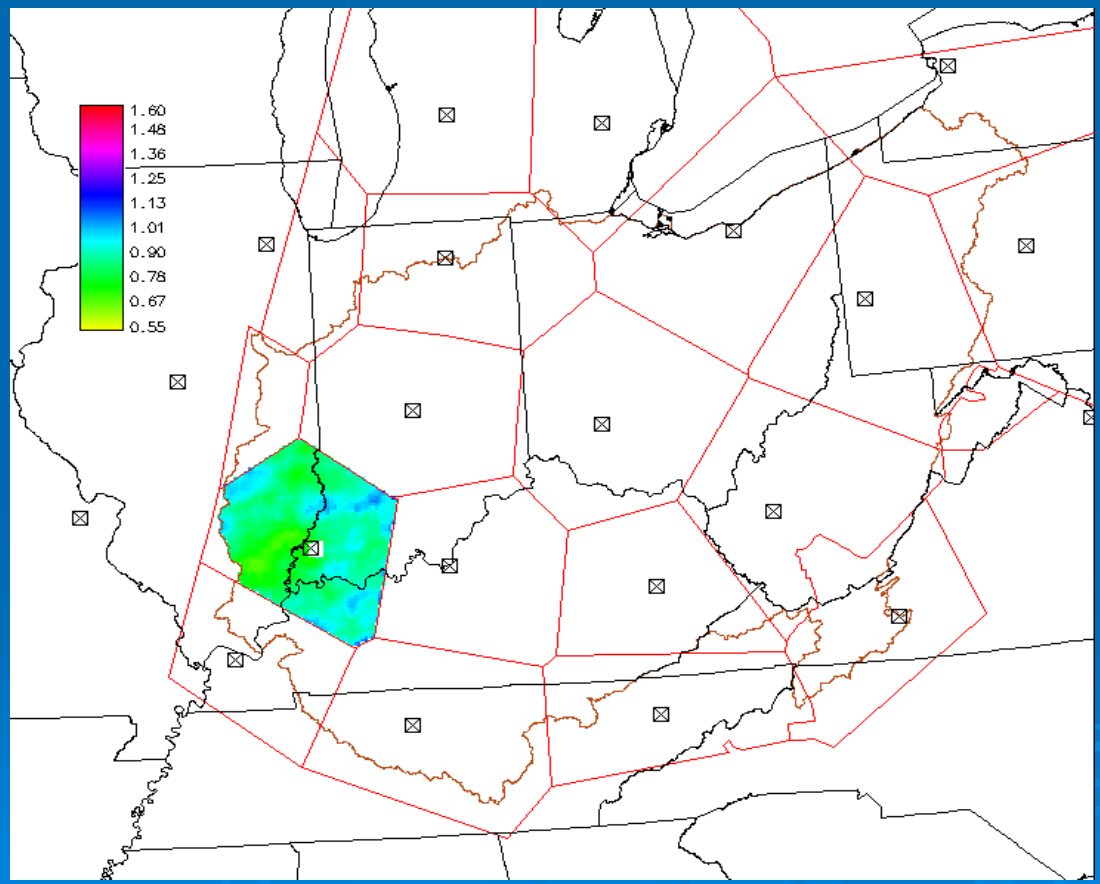
2002 Seasonal Comparison



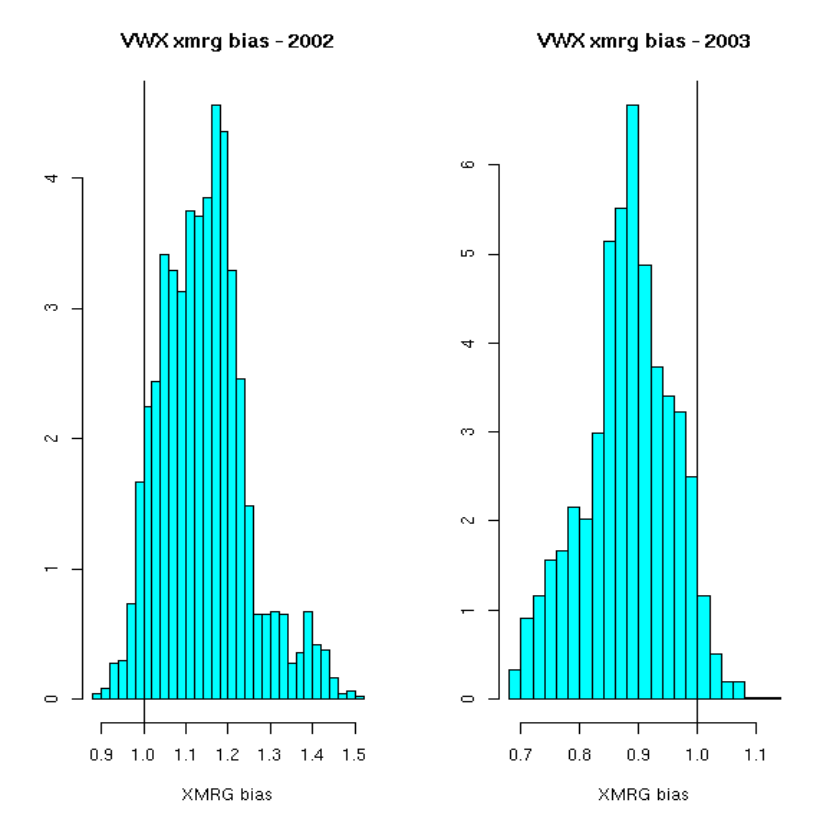
2003 Seasonal Comparison

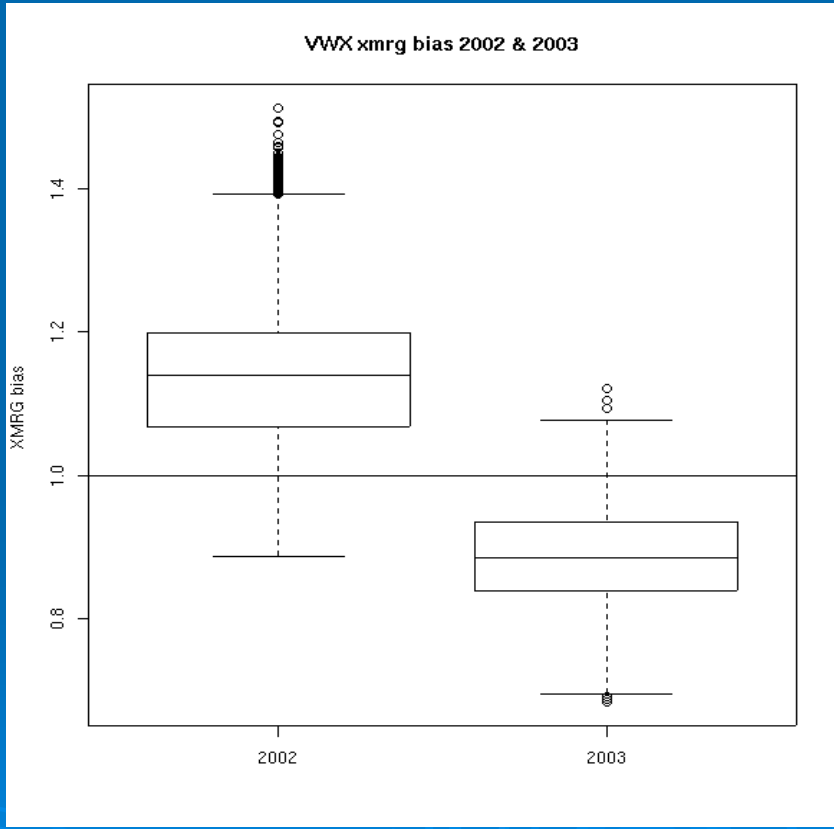


Evansville Radar (VWX)

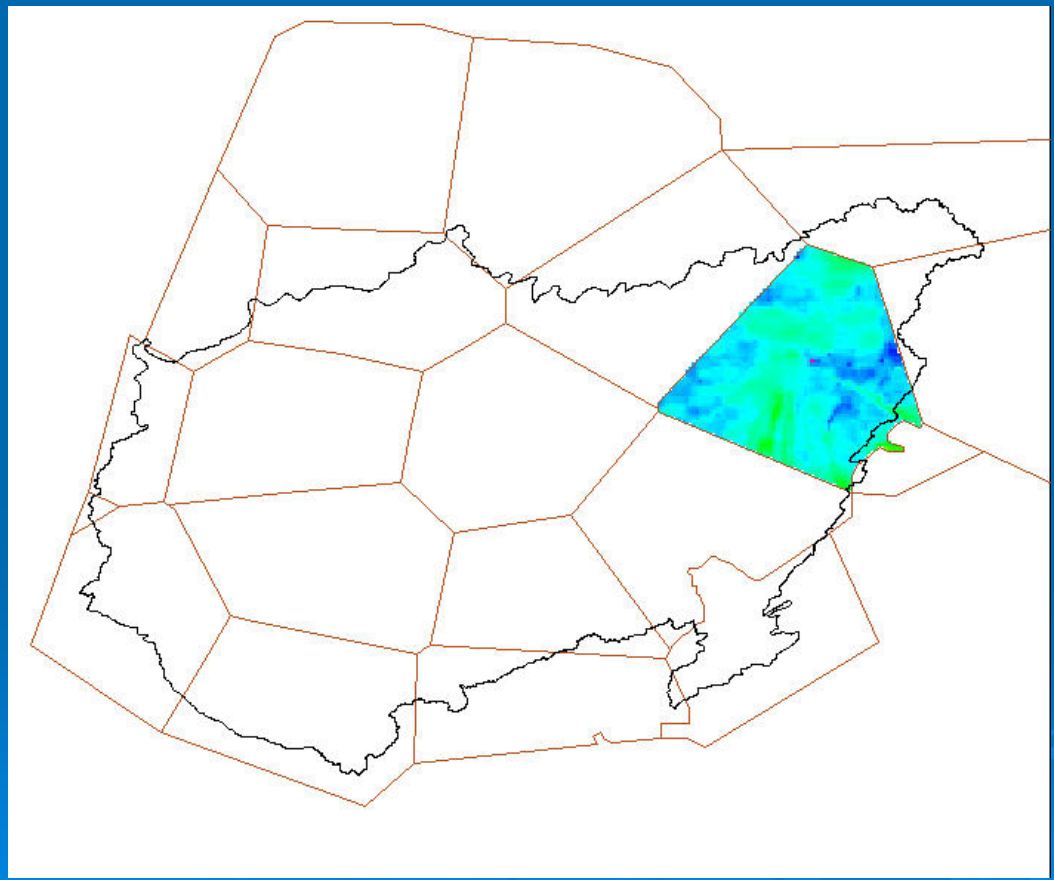


Evansville XMRG Biases

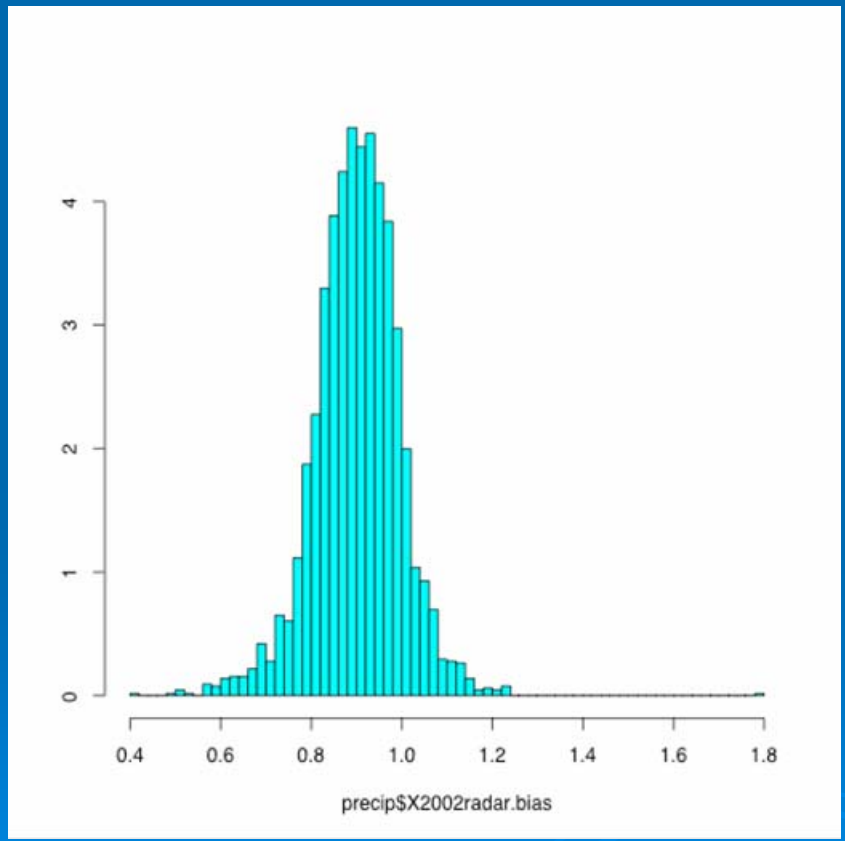


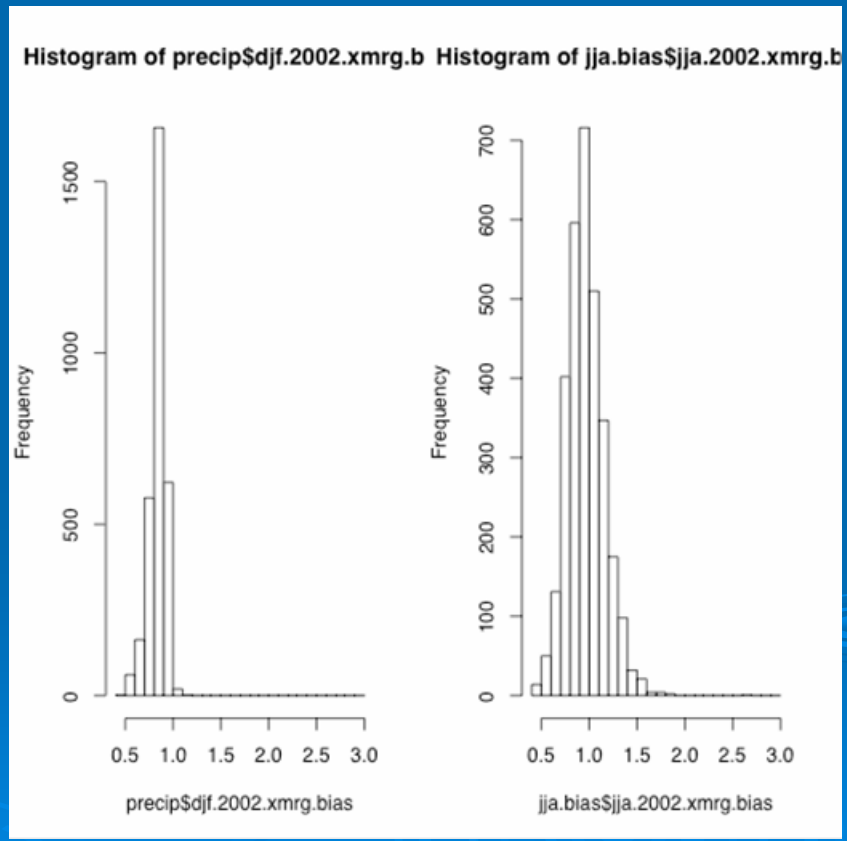


PBZ

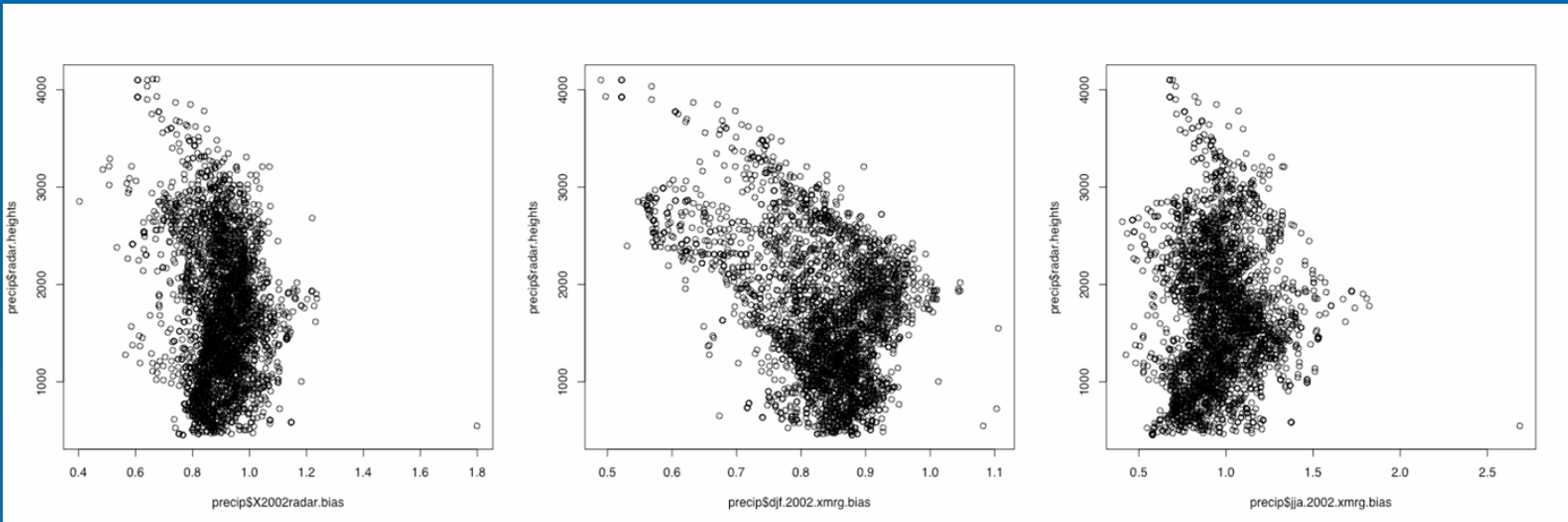


PBZ (cont.)

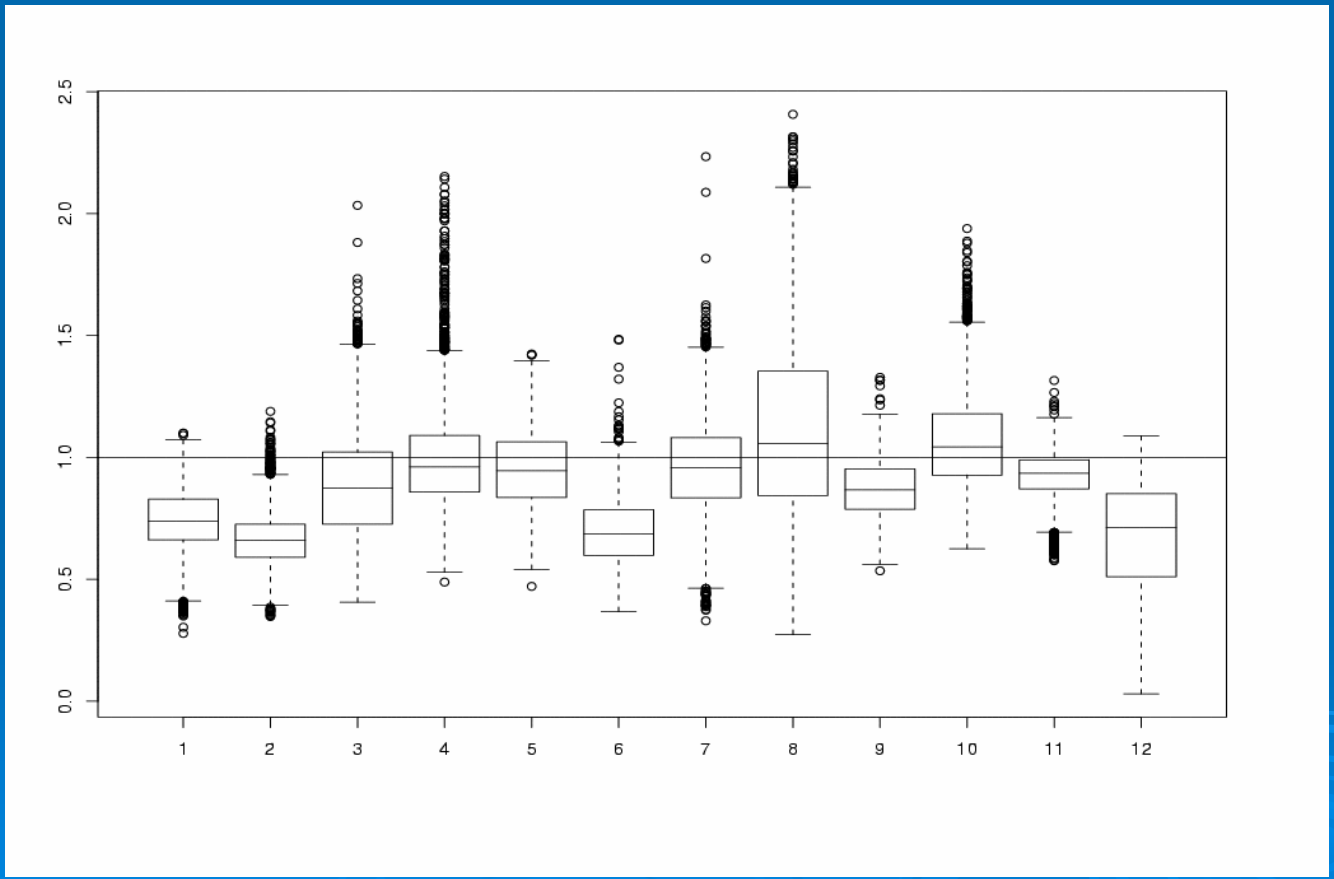

0
1
2
3
4
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
precip$X2002radar.bias


Histogram of precip$djf.2002.xmrg.b
Histogram of jja.bias$jja.2002.xmrg.b
Frequency
0
500
1000
1500
0.5
1.0
1.5
2.0
2.5
3.0
precip$djf.2002.xmrg.bias
Frequency
0
100
200
300
400
500
600
700
0.5
1.0
1.5
2.0
2.5
3.0
jja.bias$jja.2002.xmrg.bias

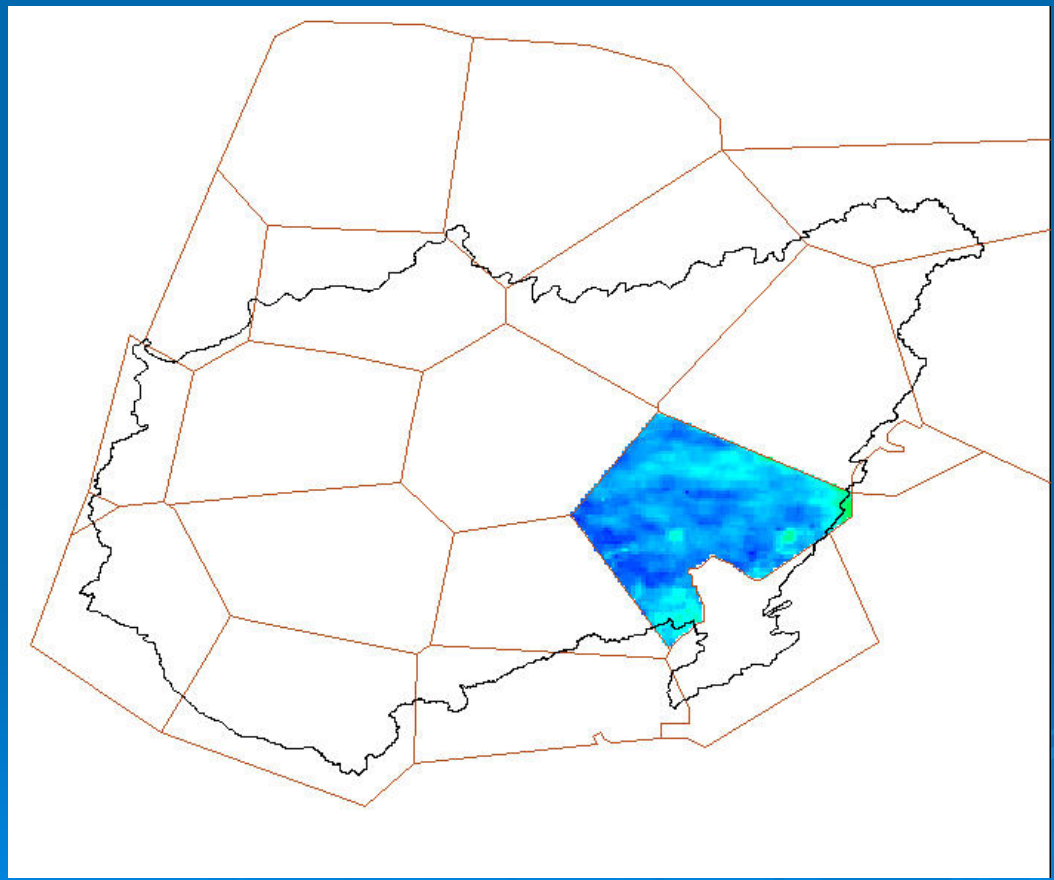
PBZ (cont.)


precip$radar.heights
precip$X2002radar.bias
precip$djf.2002.xmrg.bias
precip$jja.2002.xmrg.bias

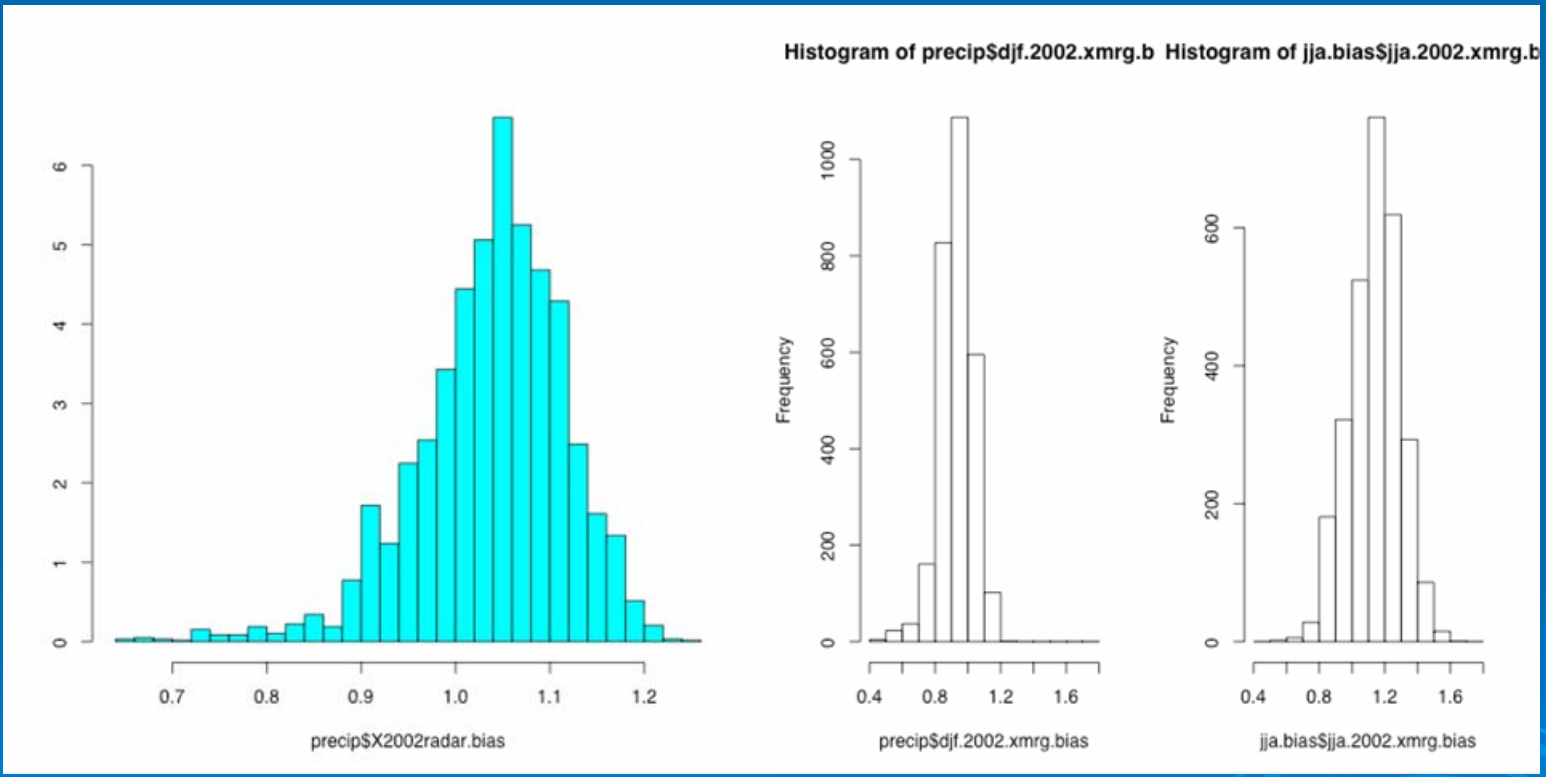
PBZ 2003 XMRG Bias by Month



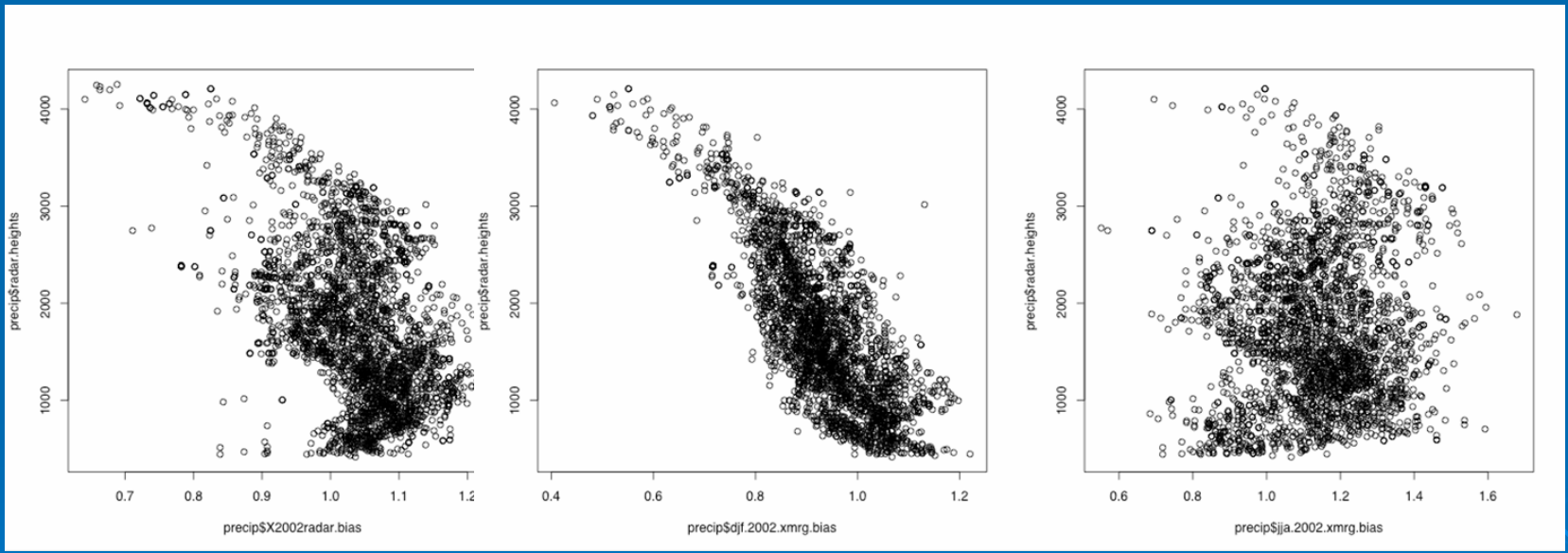
RLX



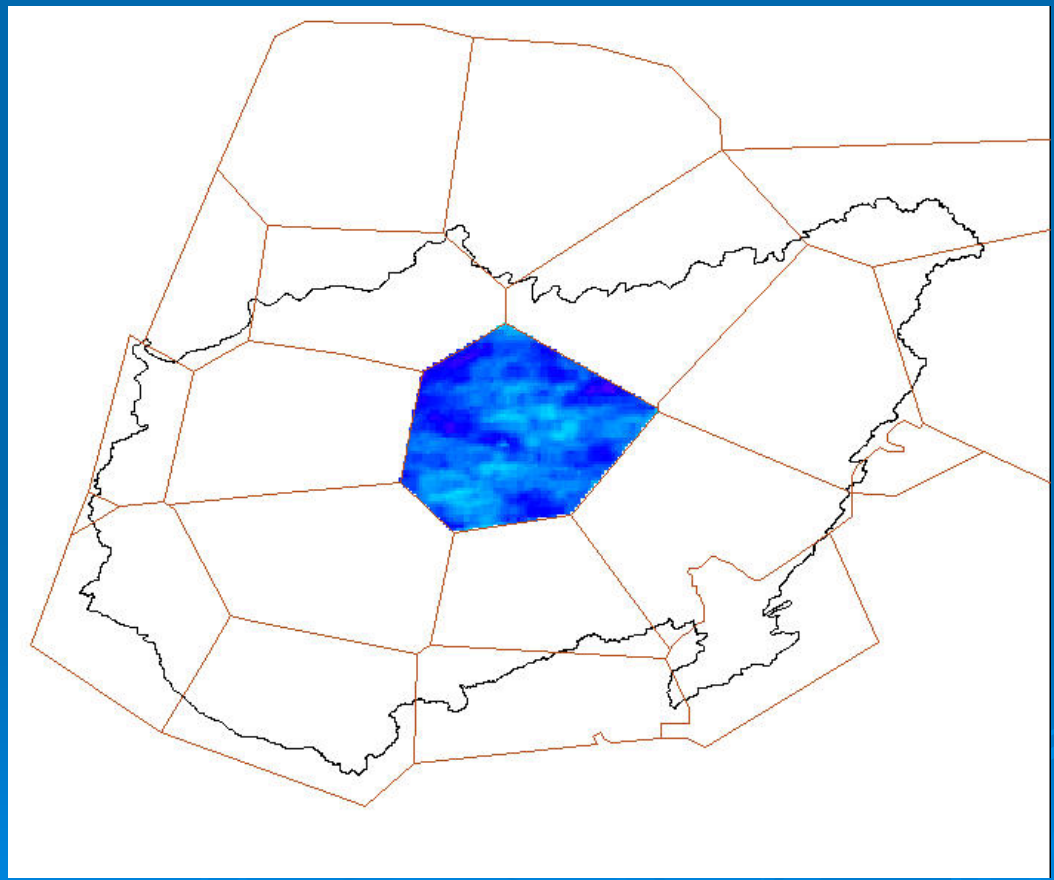
RLX (cont.)


Histogram of precip$djf.2002.xmrg.b
Histogram of jja.bias$jja.2002.xmrg.b
Frequency
precip$X2002radar.bias
precip$djf.2002.xmrg.bias
jja.bias$jja.2002.xmrg.bias

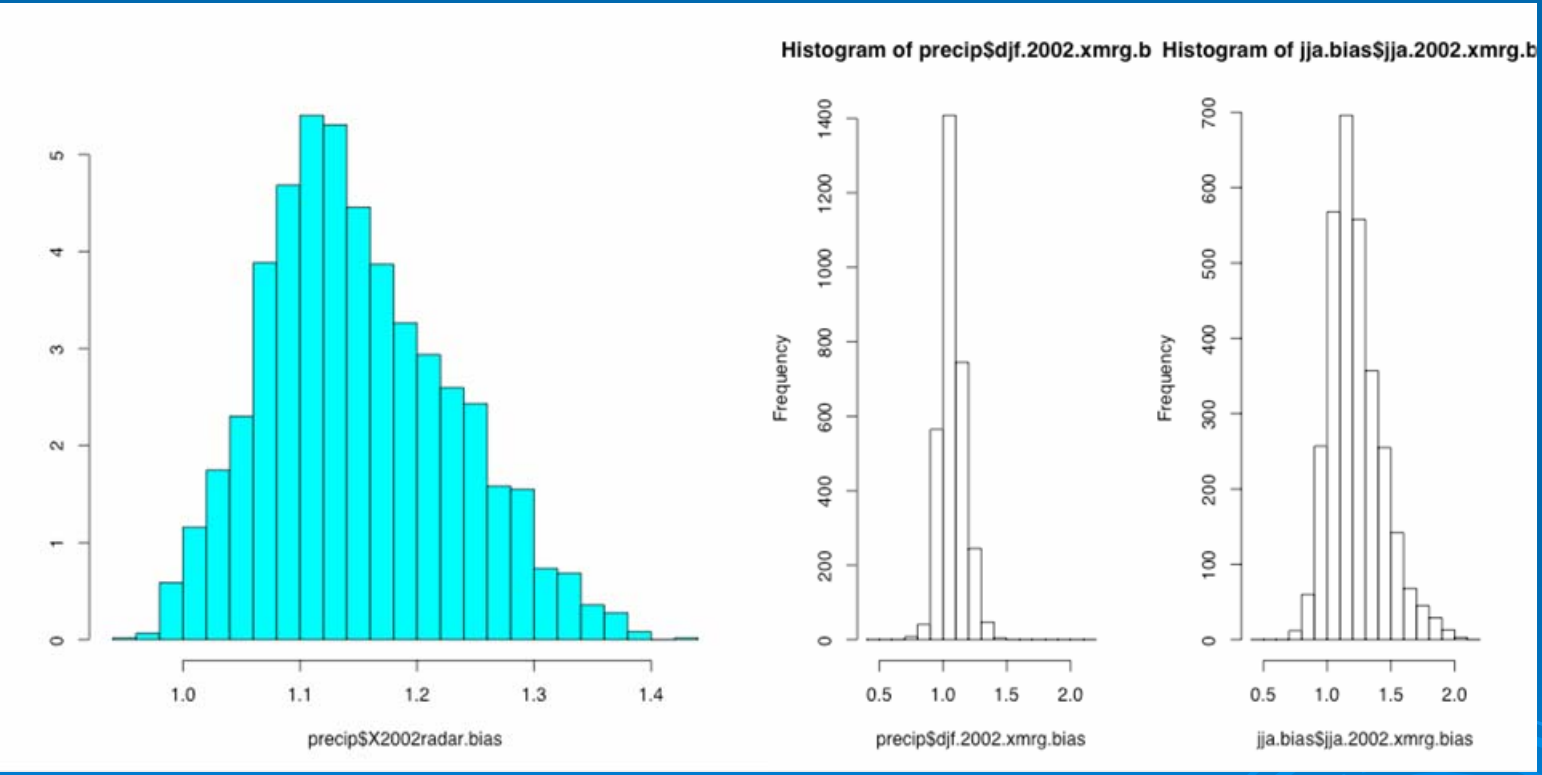
RLX (cont.)


precip$radar.heights
precip$X2002radar.bias
precip$djf.2002.xmrg.bias
precip$jja.2002.xmrg.bias

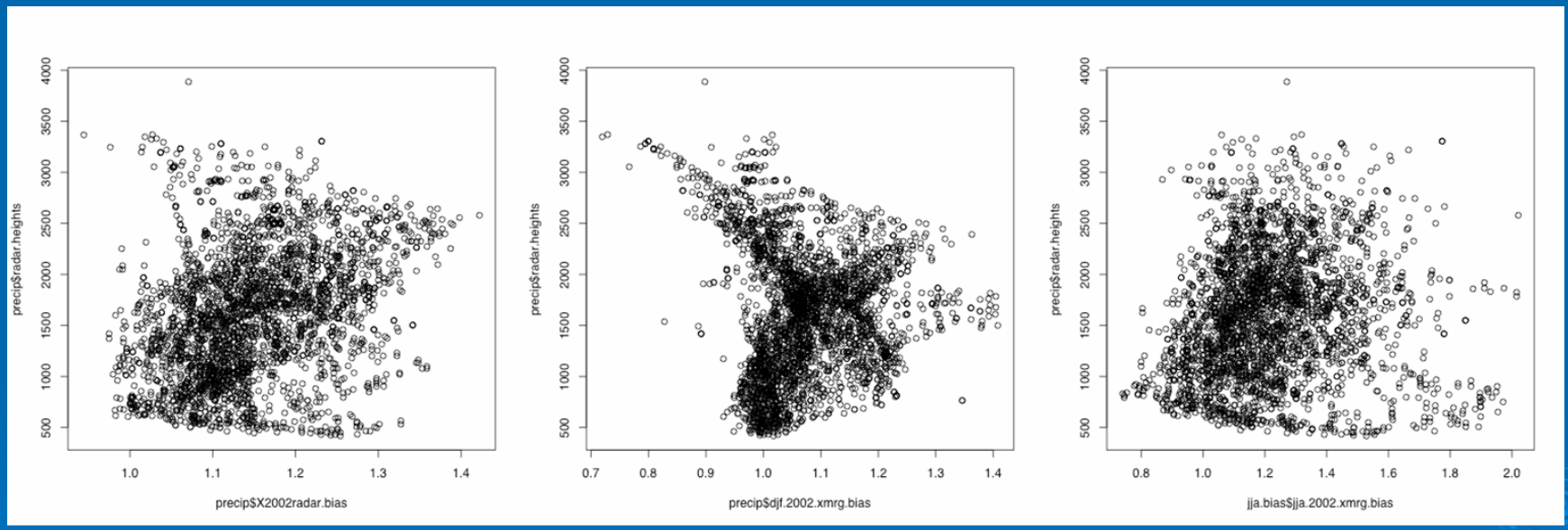
ILN



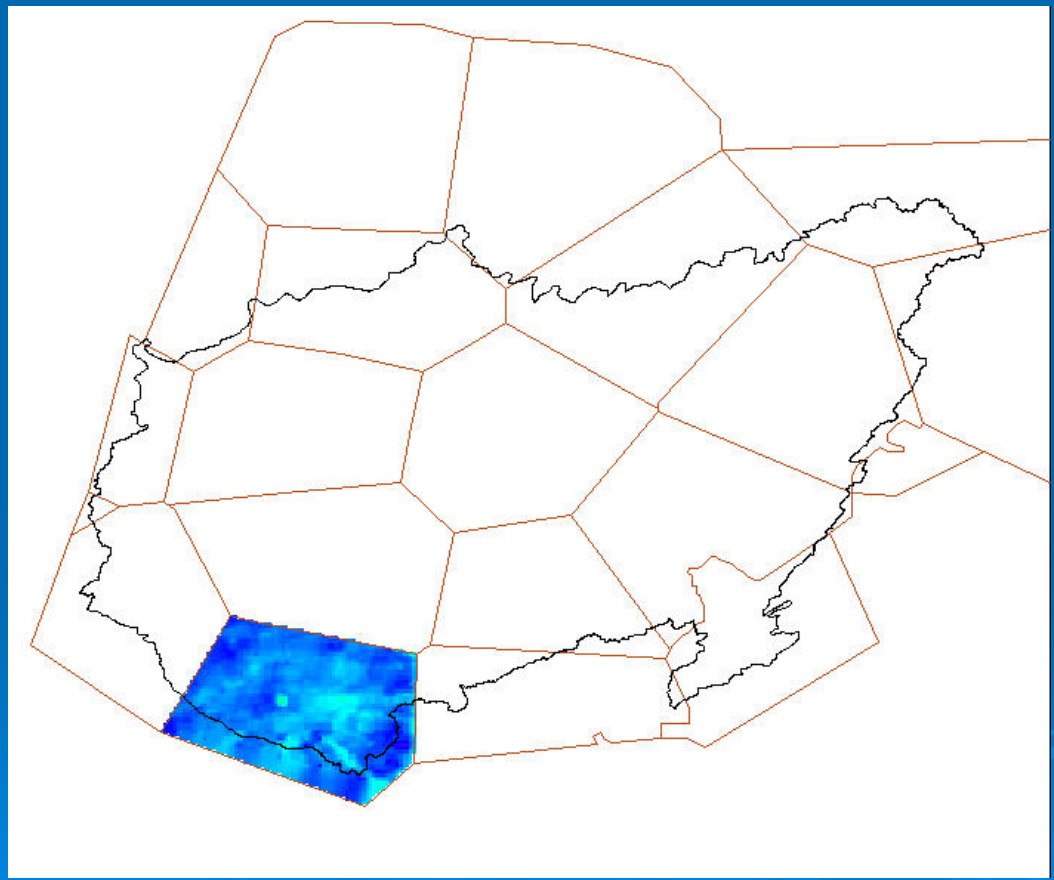
ILN (cont.)


Histogram of precip$djf.2002.xmrg.b
Histogram of jja.bias$jja.2002.xmrg.b
Frequency
Frequency
precip$X2002radar.bias
precip$djf.2002.xmrg.bias
jja.bias$jja.2002.xmrg.bias

ILN (cont.)


precip$radar.heights
precip$X2002radar.bias
precip$djf.2002.xmrg.bias
jja.bias$jja.2002.xmrg.bias

OHX



OHX (cont.)


QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.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OHX (cont.)


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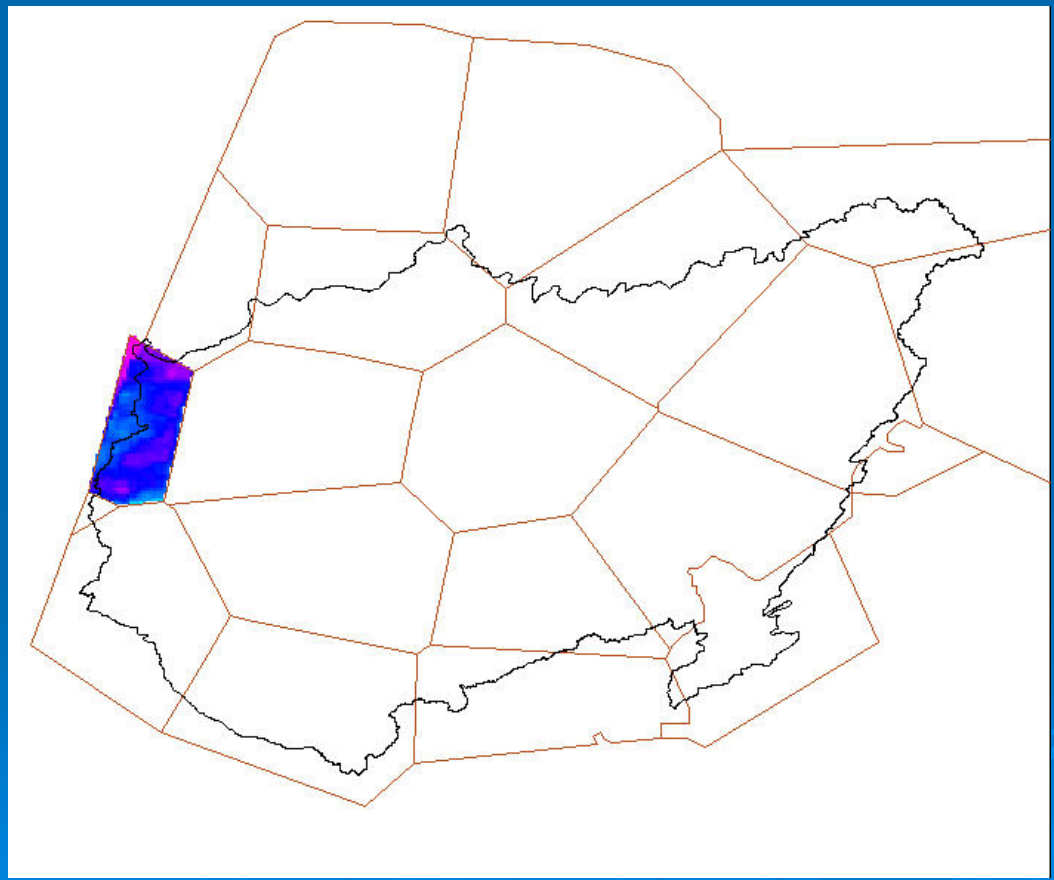
ILX



ILX (cont.)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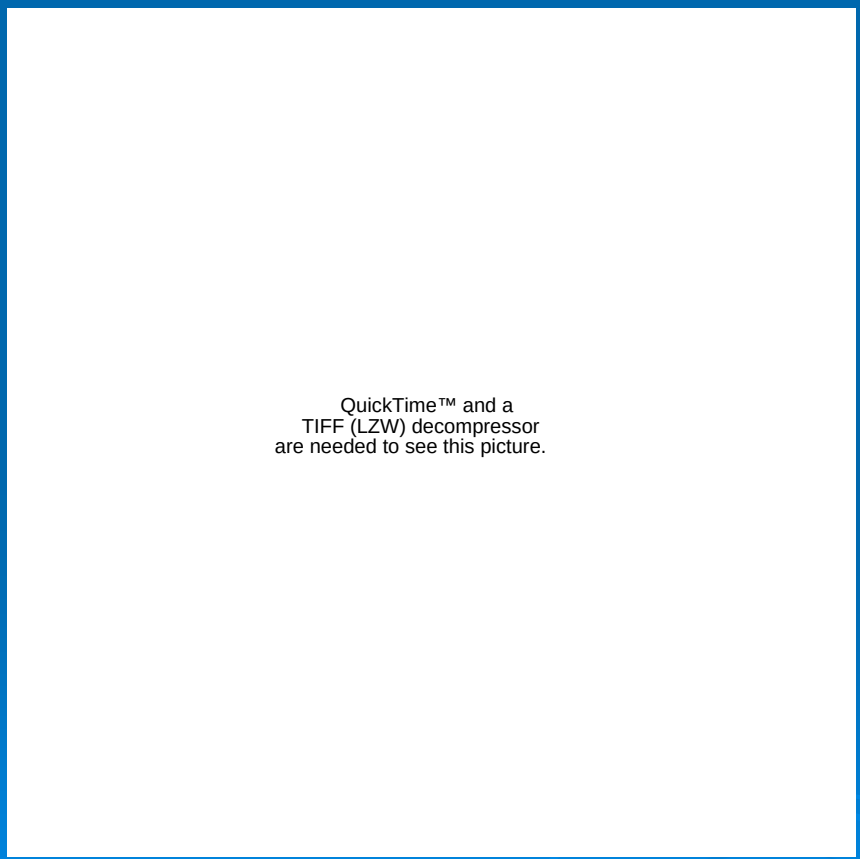
are needed to see this picture.

ILX (cont.)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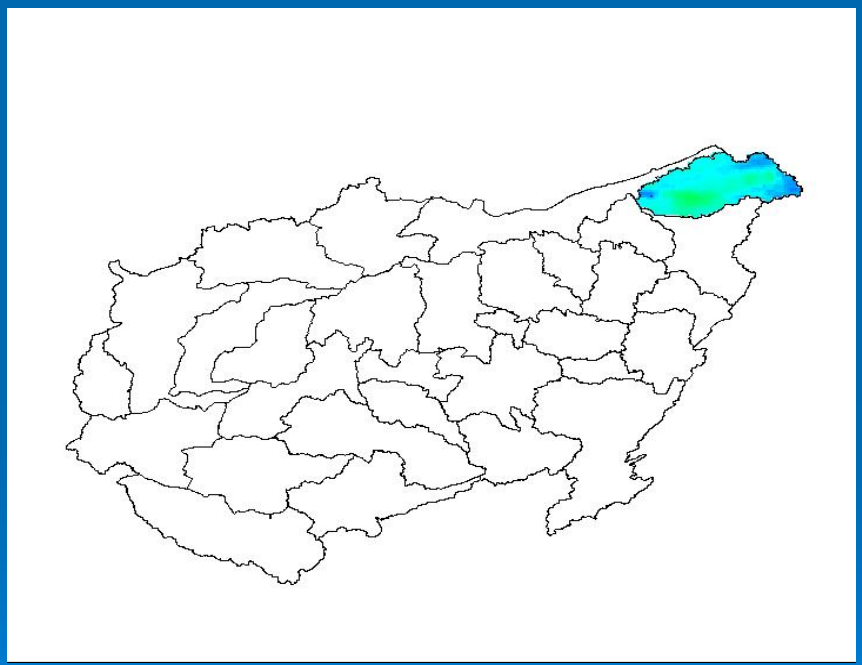
AGU



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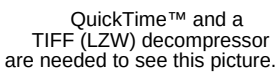
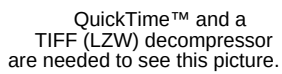
AGU (cont.)

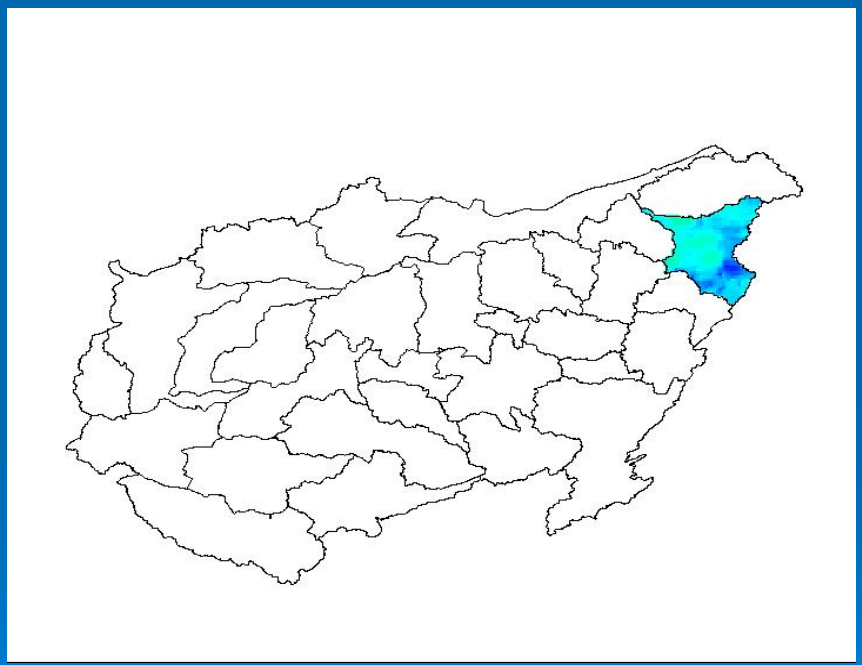
DJF



JJA



AGL



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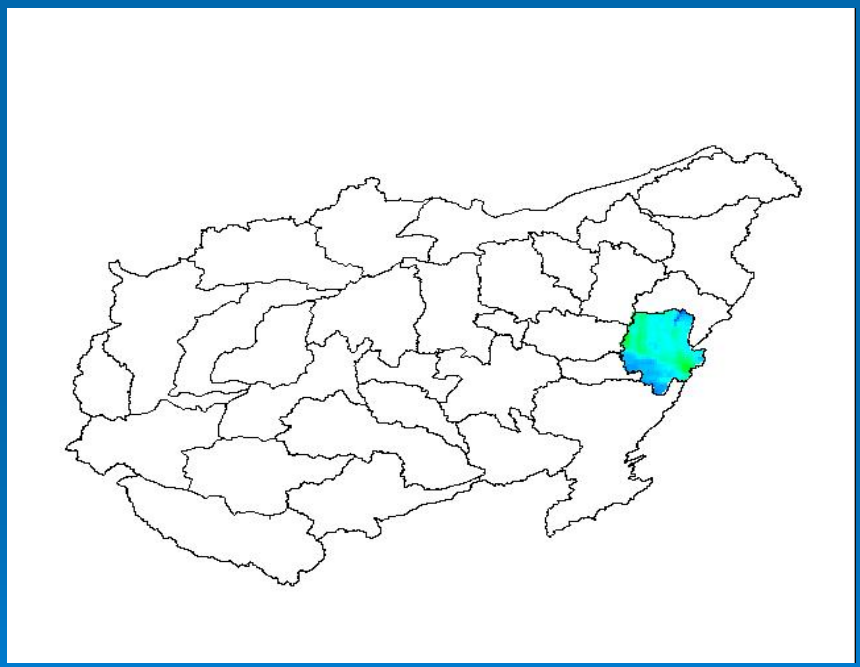
MNU



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MNU (cont.)

DJF

QuickTime™ and a
TIFF (LZW) decompressor
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JJA

QuickTime™ and a
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MNL

QuickTime™ and a
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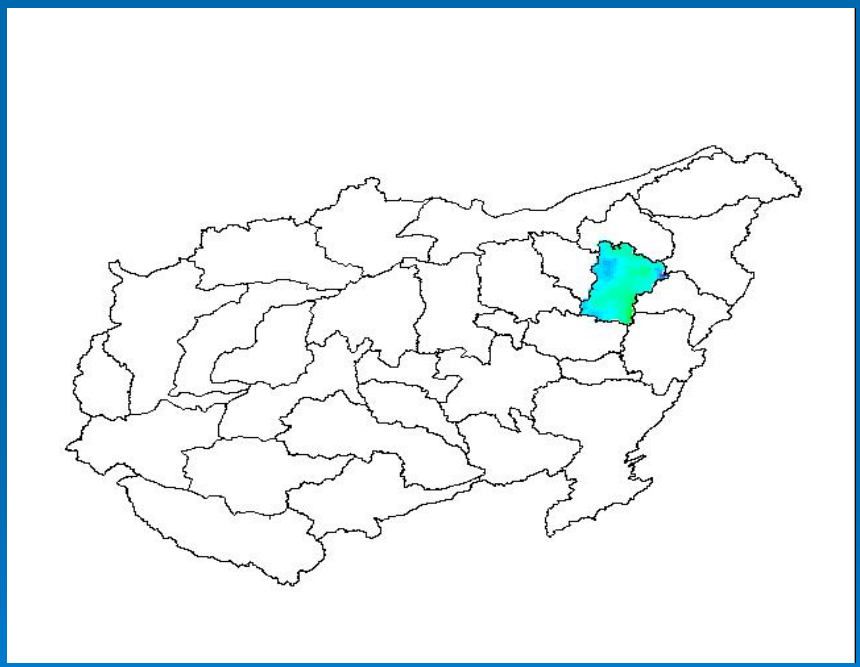
OHW



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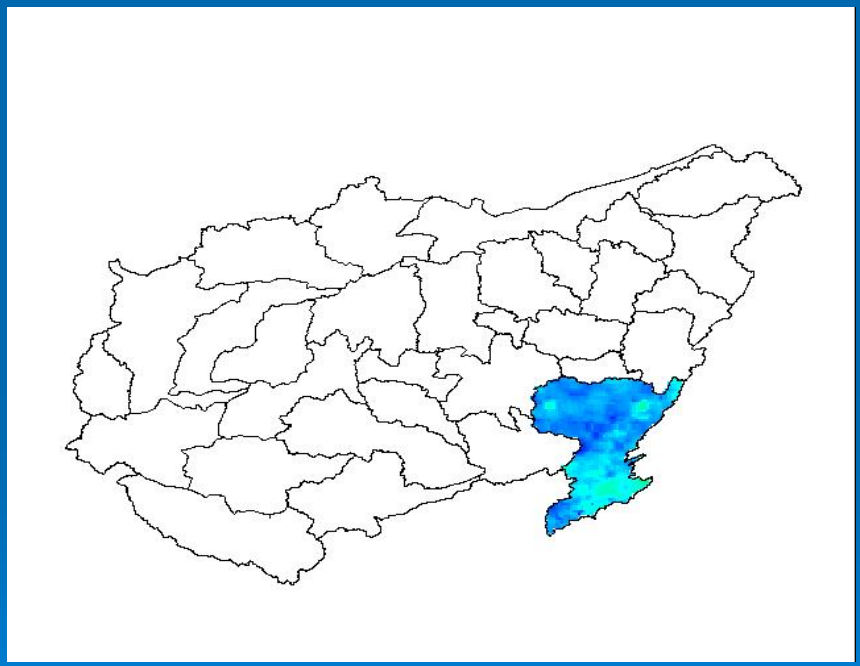
KAN



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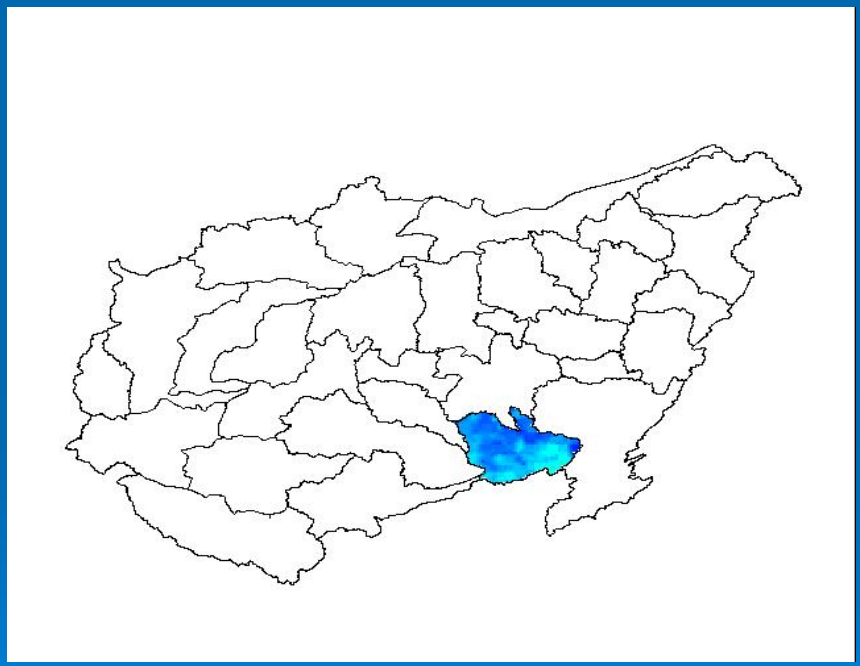
SAY



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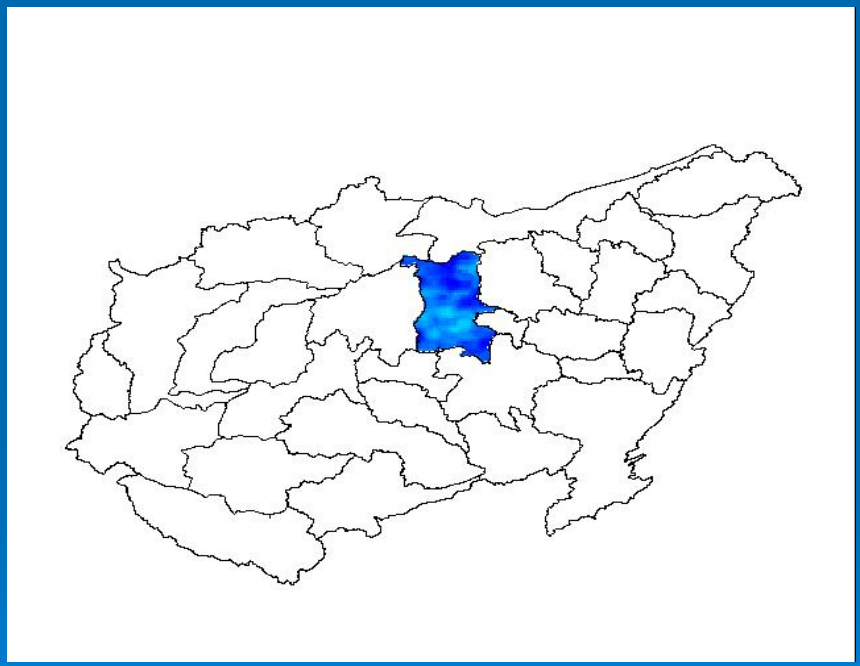
SCI



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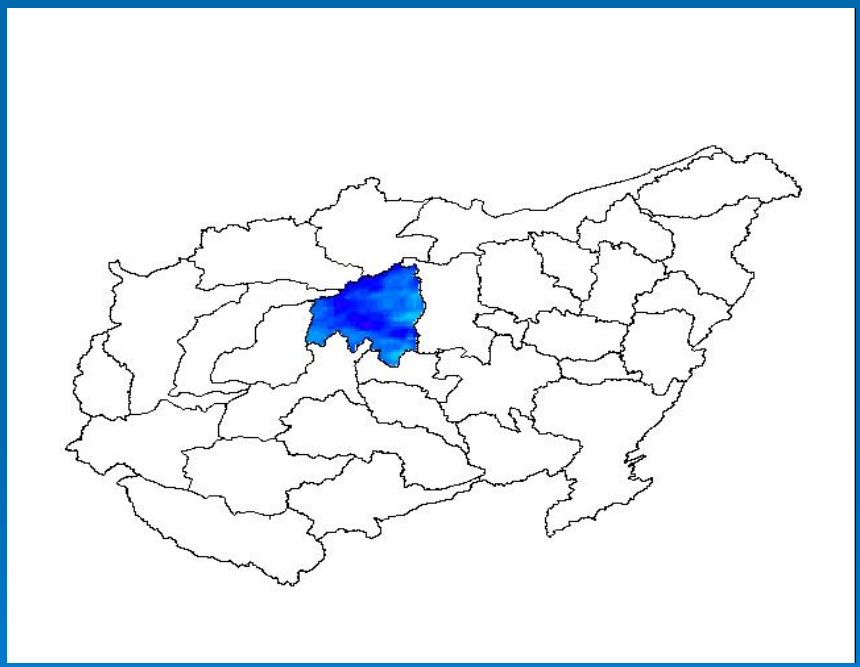
MIM



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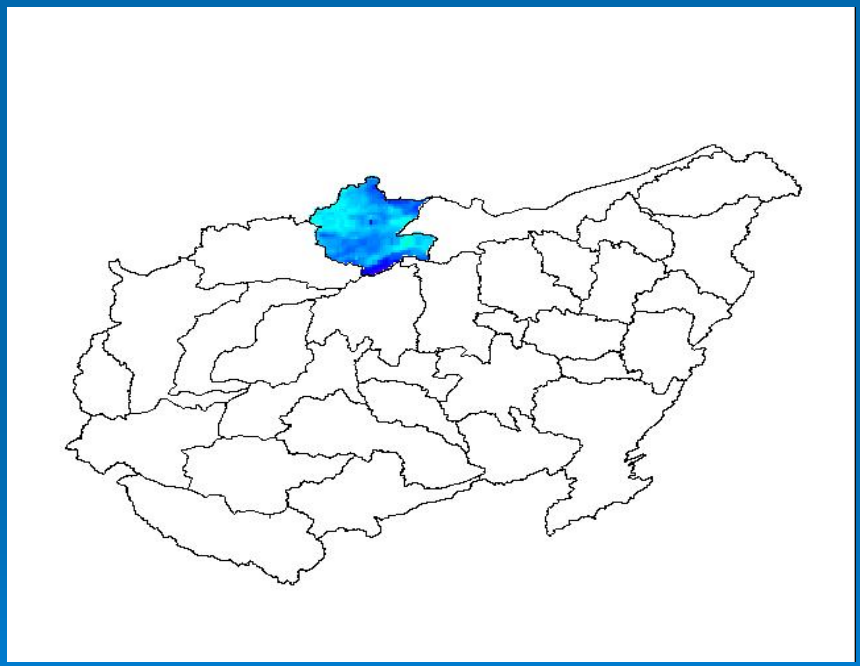
MAU



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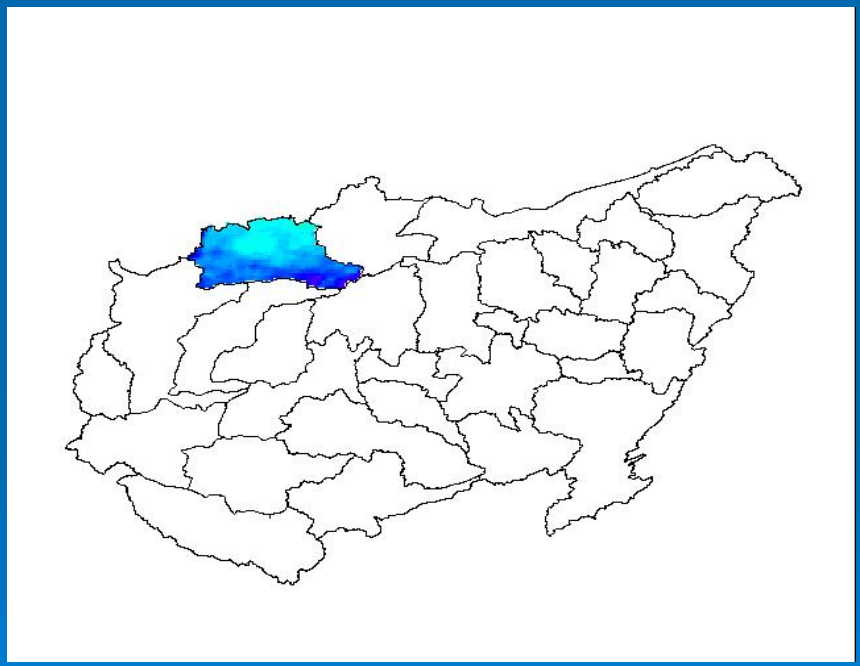
WBU



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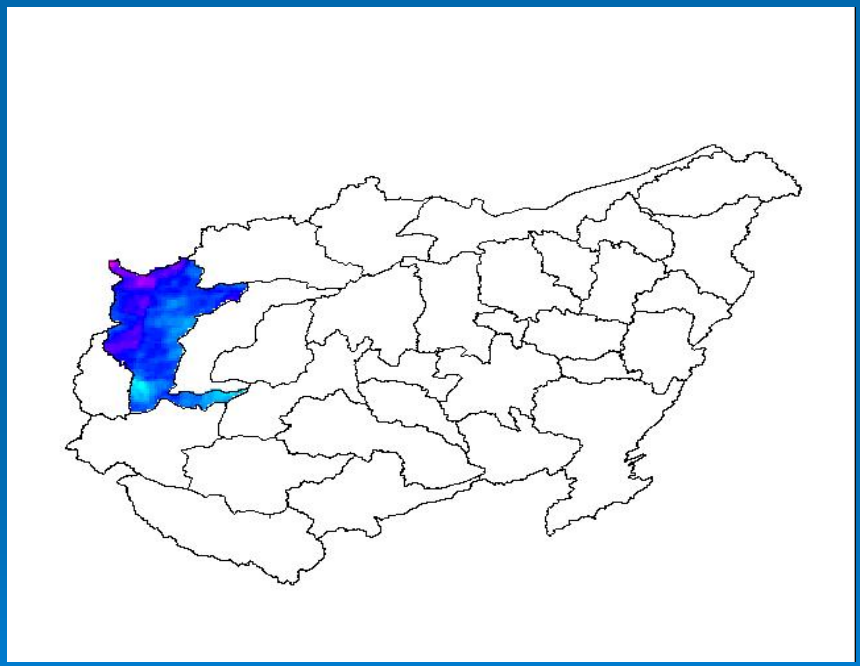
WBL



QuickTime™ and a
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WBL (cont.)

DJF

QuickTime™ and a
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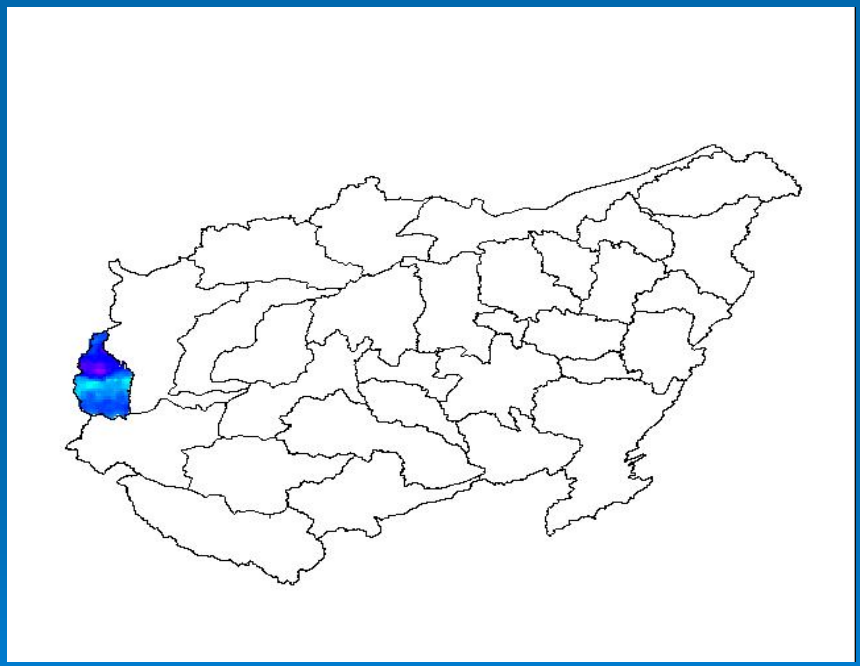
are needed to see this picture.

JJA

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

LWA



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LWA (cont.)

DJF

QuickTime™ and a
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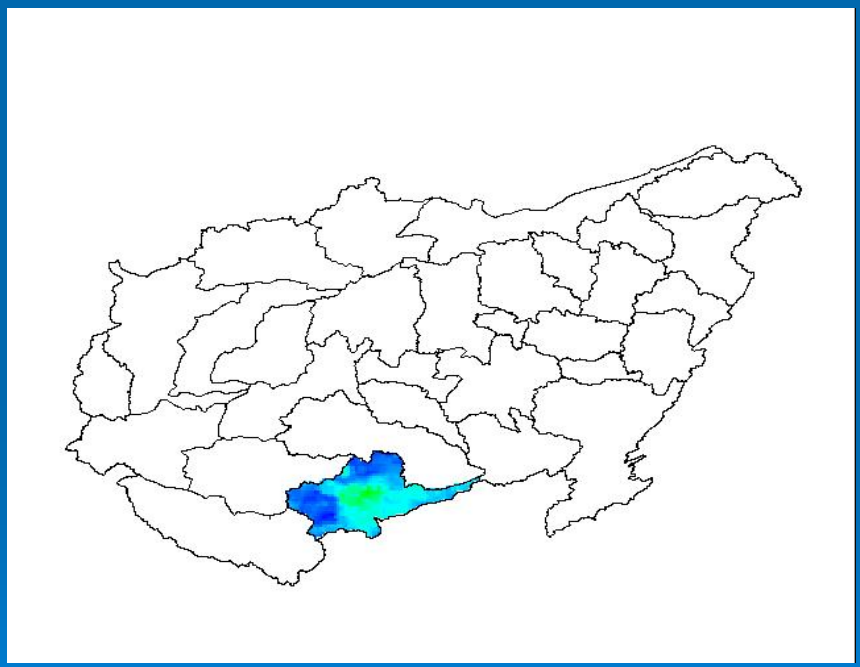
are needed to see this picture.

JJA

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

CMU



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CMU (cont.)

DJF

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

JJA

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Bias Summary 2002 by Basin

Basin	Min.	1st-Qu.	Median	Mean	3rd-Qu.	Max.
AGU	0.6645	0.8527	0.9010	0.9004	0.9428	1.2200
AGL	0.7640	0.8980	0.9476	0.9546	1.0050	1.2360
MNU	0.5342	0.8307	0.8979	0.8929	0.9641	1.1530
MNL	0.6157	0.9012	0.9481	0.9412	0.9843	1.1410
OHW	0.5646	0.8312	0.8717	0.8779	0.9250	1.7990
KAN	0.6586	0.9771	1.0400	1.0260	1.0810	1.3690
SAY	0.8347	1.0000	1.0620	1.0560	1.1160	1.2330
SCI	0.9795	1.0870	1.1390	1.1410	1.1930	1.3360
MIM	0.9820	1.1160	1.1600	1.1730	1.2310	1.3740
MAU	0.8378	0.9801	1.0360	1.0430	1.0970	1.3810
CMU	0.5372	0.9071	0.9946	0.9951	1.1060	1.2540
WBU	0.8223	0.9592	1.0520	1.0580	1.1300	1.4350
WBL	0.8854	1.1430	1.2130	1.2220	1.2920	1.7130
LWA	0.8854	1.0770	1.1680	1.1710	1.2610	1.5270

Bias Summary DJF 2002 by Basin

Basin	Min.	1st-Qu.	Median	Mean	3rd-Qu.	Max.
AGU	0.4642	0.6622	0.7241	0.7310	0.7890	1.0970
AGL	0.5750	0.7925	0.8463	0.8490	0.8993	1.1400
MNU	0.4897	0.7558	0.8285	0.8113	0.8838	0.9968
MNL	0.6294	0.8309	0.8719	0.8623	0.9059	1.1060
OHW	0.6491	0.8428	0.8701	0.8656	0.8911	1.0820
KAN	0.5215	0.8864	0.9291	0.9381	0.9907	1.2200
SAY	0.8083	0.9416	0.9716	0.9816	1.0230	1.2170
SCI	0.9171	1.0200	1.0620	1.0730	1.1150	1.4080
MIM	0.8275	1.0070	1.0630	1.0940	1.1650	1.3600
MAU	0.6927	0.8907	0.9539	0.9541	1.0090	1.2050
CMU	0.4685	0.7949	0.8936	0.8605	0.9446	1.2090
WBU	0.7852	0.9213	1.0160	1.0230	1.0970	1.4220
WBL	0.5208	0.9663	1.0710	1.0540	1.1530	2.0640
LWA	0.5511	0.7054	0.8267	0.8015	0.8929	1.0080

Bias Summary JJA 2002 by Basin

Basin	Min.	1st-Qu.	Median	Mean	3rd-Qu.	Max.
AGU	0.5779	0.8518	0.9298	0.9419	1.0150	1.4070
AGL	0.6979	0.9563	1.0640	1.0910	1.1930	1.8220
MNU	0.4051	0.8464	0.9874	0.9919	1.1600	1.5160
MNL	0.4819	0.8871	1.0130	0.9922	1.0930	1.5100
OHW	0.4262	0.7305	0.8246	0.8444	0.9410	2.6860
KAN	0.2876	1.0040	1.1230	1.1240	1.2450	2.2980
SAY	0.6842	1.0140	1.1700	1.1500	1.2810	1.7540
SCI	0.8257	1.0600	1.1440	1.1710	1.2550	1.7560
MIM	0.7451	1.0980	1.2320	1.2750	1.4020	2.0150
MAU	0.6897	1.0370	1.1840	1.1860	1.3390	1.9800
CMU	0.5152	1.1050	1.3320	1.3310	1.5360	2.3410
WBU	0.7537	0.9569	1.0580	1.0870	1.1960	1.7750
WBL	0.3004	1.1730	1.4180	1.4150	1.6250	2.6010
LWA	0.9977	1.4960	1.7040	1.7320	1.9500	2.9910

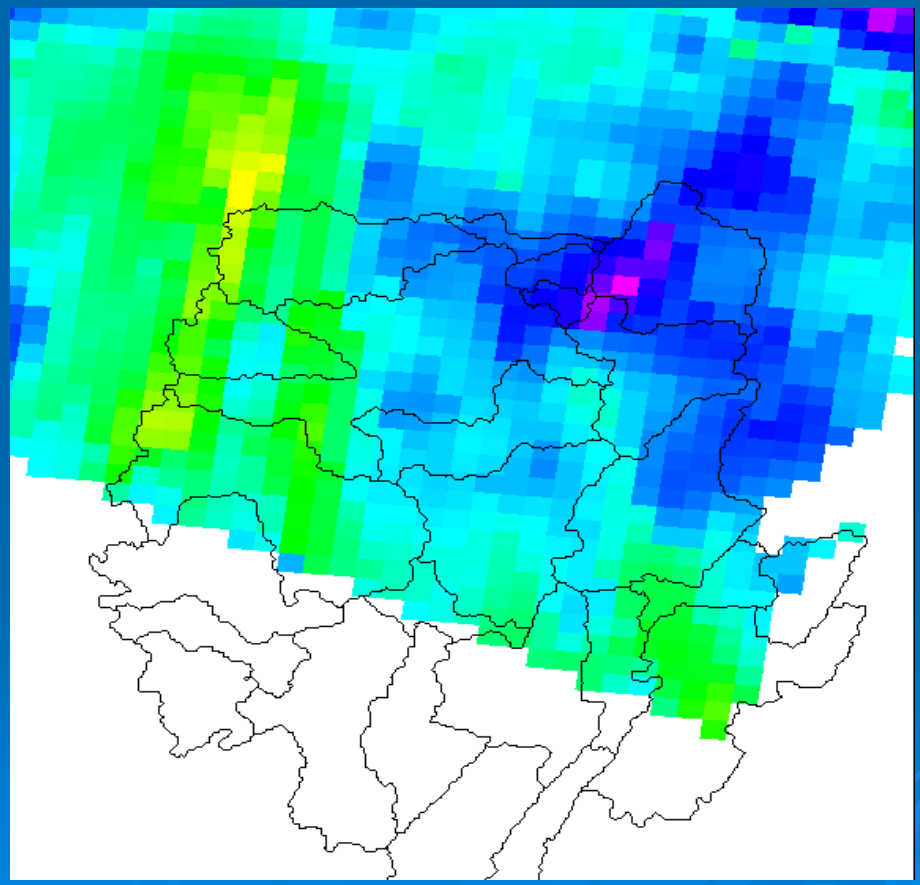
Conclusions

- Radar calibration problems at PBZ (consistent under-estimation for all seasons), ILX, ILN, & OHX and somewhat at CLE & IWX
- Z-R relationship possibly contributing to biases on an event basis
- Open RPG or MPE algorithm issues, or brightbanding problems for ILN, IND, & OHX radars
- Terrain induced DJF (winter) under-estimation due to orographic enhancement and snow
- Beam blockage effects at PBZ (over- & under-estimation), IND (under-estimation) and LVX (under-estimation)
- Possible under-estimation in the New River Valley by RNK radar due to mountain top placement
- Other apparent random over- & under-estimation may be due to sparce raingauge network — noticeable during JJA
- Raingauge under-catch during the winter

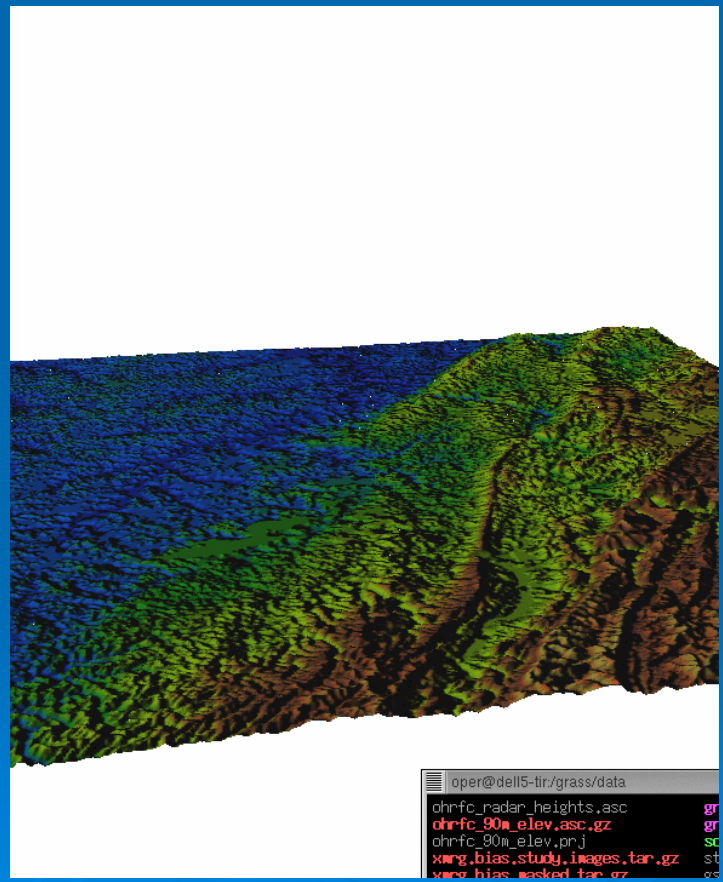
Future Directions

- Analyze data for 2003 (and previous & subsequent years)
- Analyze data with respect to all subbasins and radar coverage areas
- More detailed analyses of radars:
  - Calibrations
  - Default *Z-R* relationship
  - Causes of beam blockage
  - HAS-led questionnaire of HAS radar operations
- Evaluate runtime Mod use versus bias estimates
- Analyses of individual events
- Produce Journal article

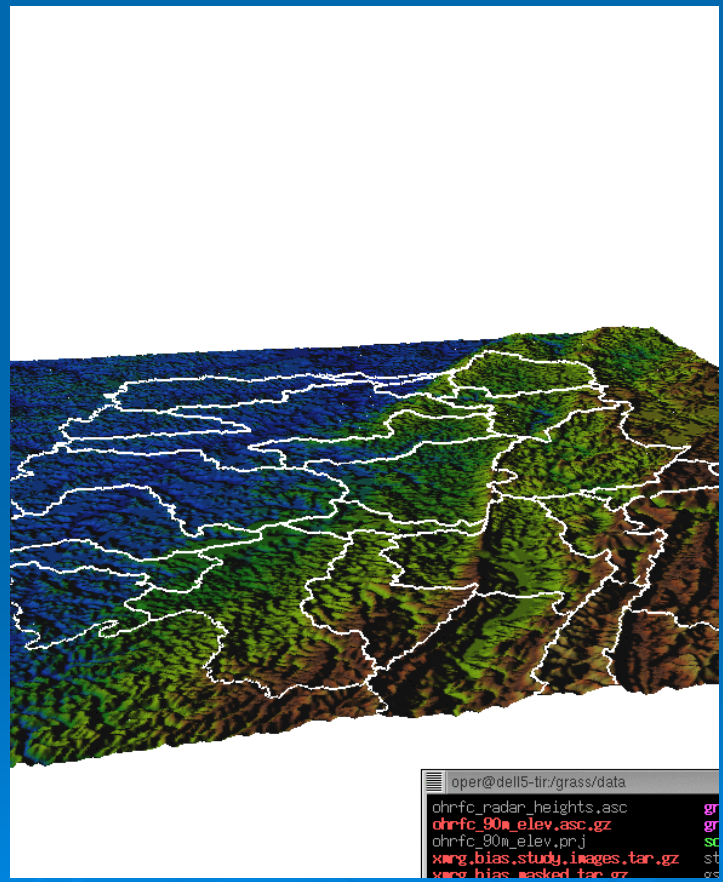
Example of Local Bias



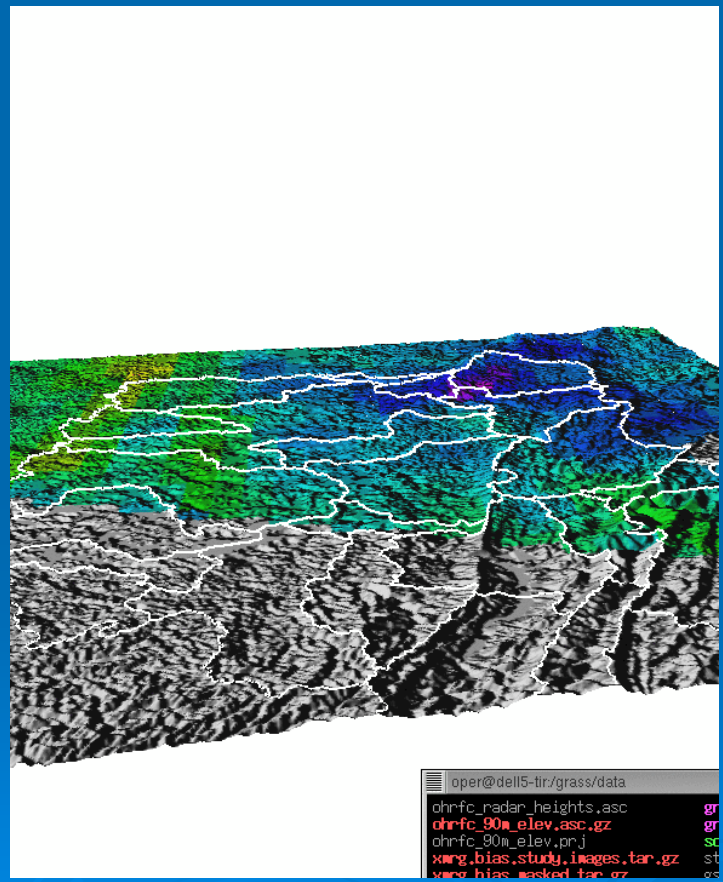
MNU Topography



MNU Topography with Basin Boundaries



MNU Bias Draped over Topography



Comparison of Bias — PBZ Uncorrected & Corrected