

Meteorological Modeling: **Sensitivity Analyses & Choosing A Model Configuration**



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Outline

- **Brief Introduction To The VISTAS Meteorological Modeling Project** *(Basis For Successful Steps Portion Of This Talk)*
- **Successful Steps For A Robust Meteorological Model Sensitivity Project And The Final Selection Of A Model Configuration**
- **Suggestions For Sensitivity Evaluation Plots And Metrics**
- **Questions, Comments, And Group Discussion**



Introduction

- **Visibility Improvement State and Tribal Association of the Southeast (VISTAS)**
- **Regional Planning Organization established under the 1999 Regional Haze Rule**
- **Collaborative effort of States and Tribes to support management of regional haze and related air quality issues in the Southeastern US**
- **No independent regulatory authority and no authority to direct or establish State or Tribal law or policy.**



Regional Planning Organizations





Visibility Improvement State and Tribal Association of the Southeast

VISTAS





VISTAS

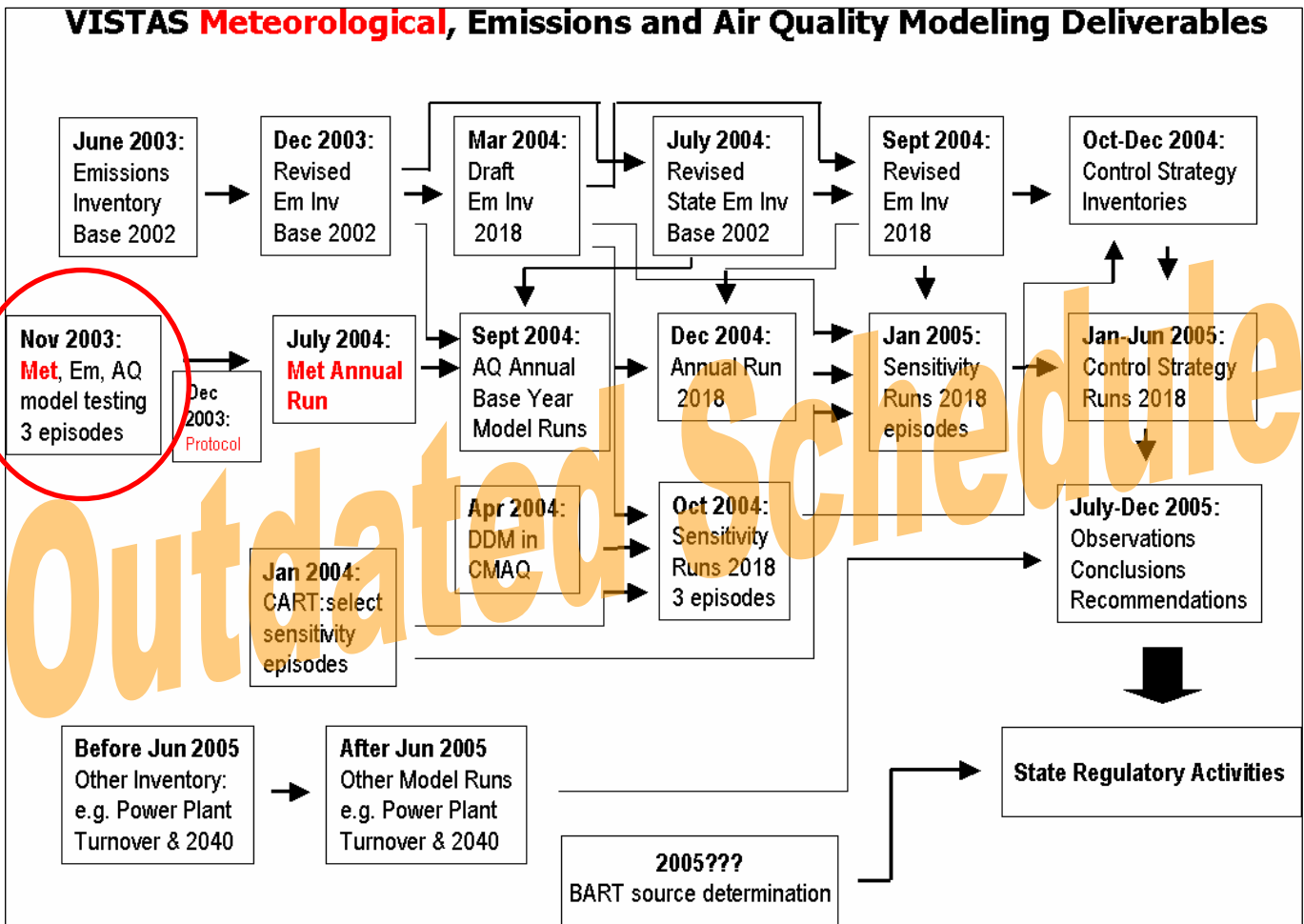
Meteorological Modeling

- **Contracted With Barons Advanced Meteorological Systems (BAMS)**
 - Formerly know as MCNC in a previous life
 - Don Olerud, Project Manager & Technical Lead
 - Aaron Sims
 - Ted Smith
- **Project Split Into Two Phases**
 - **Phase I: Sensitivity Analyses & Model Configuration Selection**
 - **Phase II: 2002 Annual Meteorological Modeling Simulation**



VISTAS

Meteorological Modeling



Phase I –
Just A Small Piece In The Complicated and Time Sensitive VISTAS Puzzle



VISTAS

Meteorological Modeling

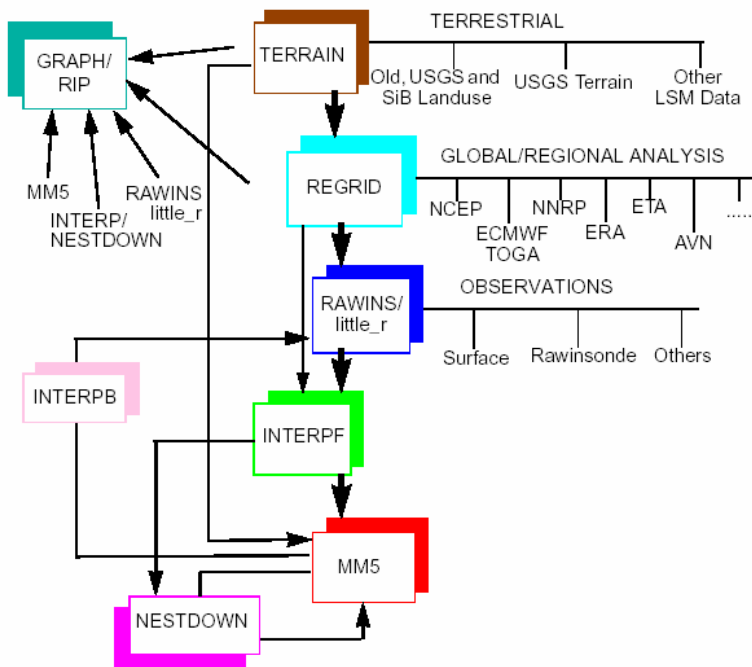
- Phase I: Test Model To Define The Appropriate Model Configuration For The VISTAS Region

Investigate -> Model -> Evaluate -> Make Decisions

Additional Capability

Main Programs

Data Sets



- Planetary boundary layer process parameterization

- o Bulk formula
- o Blackadar scheme
- o Burk-Thompson (Mellor-Yamada 1.5-order/level-2.5 scheme)
- o Eta TKE scheme (Janjic, 1990, 1994)
- o MRF scheme (Hong and Pan 1996)
- o Gayno-Seaman scheme (Gayno 1994)

- Surface layer process parameterization

- o fluxes of momentum, sensible and latent heat
- o ground temperature prediction using energy balance equation
- o variable land use categories (defaults are 13, 16 and 24)
- o 5-layer soil model
- o OSU land-surface model (V3.1 - V3.5)
- o Noah land-surface model (since V3.6)
- o Pleim-Xiu land-surface model (V3 only)

- Atmospheric radiation schemes

- o Simple cooling
- o Dudhia's long- and short-wave radiation scheme
- o NCAR/CCM2 radiation scheme
- o RRTM long-wave radiation scheme (Mlawer et al., 1997) (V3 only)

- Precipitation physics

- o Cumulus parameterization schemes:

- Anthes-Kuo
- Grell
- Kain-Fritsch
- New Kain-Fritsch (including shallow convection physics)
- Betts-Miller
- Arakawa-Schubert

- o Resolvable-scale microphysics schemes:

- Removal of supersaturation
- Hsieh's warm rain scheme
- Dudhia's simple ice scheme
- Reisner's mixed-phase scheme
- Reisner's mixed-phase scheme with graupel
- NASA/Goddard microphysics with hail/graupel
- Schultz mixed-phase scheme with graupel



Successful Steps

- **Understand The Larger AQ Modeling Project Objectives And Deliverable Schedules**
 - AQ pollutants that are of most concern
 - Full period sensitivities might be ideal, but episodic sensitivities are all that time allows
- **Summary Of Recent And Relevant MM5 Sensitivity Studies**
 - Learn from what others have done
 - Inter-RPO collaboration, conference calls, and ad-hoc meetings
 - Served as a starting point for VISTAS



Successful Steps

- **Appropriately Define Sensitivity Tests**
 - **Episodic sensitivities:**
 - Episodes should reflect meteorology and air quality during the full period of interest
 - Pick episodes with robust observational datasets to aid in evaluation
 - When possible, use episodes that other groups have modeled or are modeling
 - **Consider a series of sensitivities based on:**
 - **Domain resolution** (36km / 12km / 4km / 1.3km)
 - **Vertical layer structure** (Think about AQ model also)
 - **Model physics options** (The met model Rubix's Cube)





Successful Steps

- **Develop The Model Sensitivity Evaluation Plan**
 - Recommend this step prior to starting any model sensitivity runs
- **Collect The Necessary Model Evaluation Data**
 - Recommend starting this step before running the model
 - Be sure and actually “look” at and understand the caveats of the data you collect
- **Communicate And Collaborate Your Intended Sensitivity Test With Others**



Successful Steps

- **Execute The Sensitivity Model Runs!**
- **Model Sensitivity Evaluation** *(Follow Your Plan)*
 - **Assessing model performance**
 - Conceptual understanding correct?
 - What of the placement, timing of features?
 - Are diurnal features adequately captured?
 - Are clouds reasonably well modeled?
 - Are precipitation fields reasonable?
 - Do wind fields generally match observations?
 - Do temperature and moisture fields match observations?



Successful Steps

- **Model Sensitivity Evaluation**
 - **Feedback loop** (*Meteorological Sensitivities*)
 - Is there a model configuration with overall “acceptable” model performance?
 - Or, is there a need for additional sensitivity runs?
 - Slight alterations to current set of sensitivities
 - Holistic shift in the sensitivities
- **“Final” Selection Of A Model Configuration**
 - Million dollar question... Do the meteorological fields produce acceptable air quality model results / performance?
 - **Feedback loop** (*Air Quality Sensitivities*)



Successful Steps

- **Documentation, Documentation, Documentation!**
 - It is essential to document your work during every step of the model sensitivity and configuration selection project
 - Final documentation really should be a process of combining documentation already produced during the project
- **Peer Review** *(Time Permitting)*
 - Present your final documentation to the larger meteorological modeling community for comments prior to any "Phase II" modeling exercises



Suggestions For Evaluation Products

- **Statistical Tables**

- Good for overall model performance determination or “Reality Check”
- Likely the easiest evaluation metric to create
- However, statistical tables provide few specific details on problem areas

Total stats	bias	abserr	r2	ia	rmse
Temperature (K)	-0.16	1.62	0.877	0.964	2.1443
Mixing Ratio (g/kg)	-0.17	1.47	0.809	0.947	1.9714
Rel. Humidity (%)	-0.28	9.78	0.672	0.904	13.0680
Wind Speed (m/s)	-0.20	1.24	0.429	0.772	1.6149
Clouds (%)	1.38	27.52	0.134	0.635	37.9526

Wind stats	bias	abserr	uerr	verr	uverr
Wind (deg, m/s)	2.010	32.37	1.2469	1.3037	1.8040

Pcp Threshold (in)	Acc	Bias	FAR	POD	CSI	ETS	TSS	HSS
0.01	0.7375	0.8822	0.2501	0.6616	0.5420	0.3067	0.4663	0.4694
0.05	0.7578	1.0815	0.4105	0.6376	0.4415	0.2794	0.4470	0.4368
0.10	0.7807	1.2392	0.5089	0.6085	0.3732	0.2511	0.4363	0.4014
0.25	0.8387	1.5406	0.6509	0.5378	0.2685	0.2008	0.4137	0.3345
0.50	0.9052	1.6829	0.7565	0.4098	0.1803	0.1482	0.3416	0.2582
1.00	0.9715	1.5577	0.8696	0.2030	0.0862	0.0782	0.1849	0.1450

Total stats	bias	abserr	r2	ia	rmse
Temperature (K)	0.06	0.07	0.011	0.003	0.0879
Mixing Ratio (g/kg)	0.00	0.00	0.002	0.000	0.0121
Rel. Humidity (%)	-0.13	0.23	0.014	0.005	0.3027
Wind Speed (m/s)	0.00	0.01	0.008	0.005	0.0113
Clouds (%)	0.33	0.19	0.004	0.002	0.2725

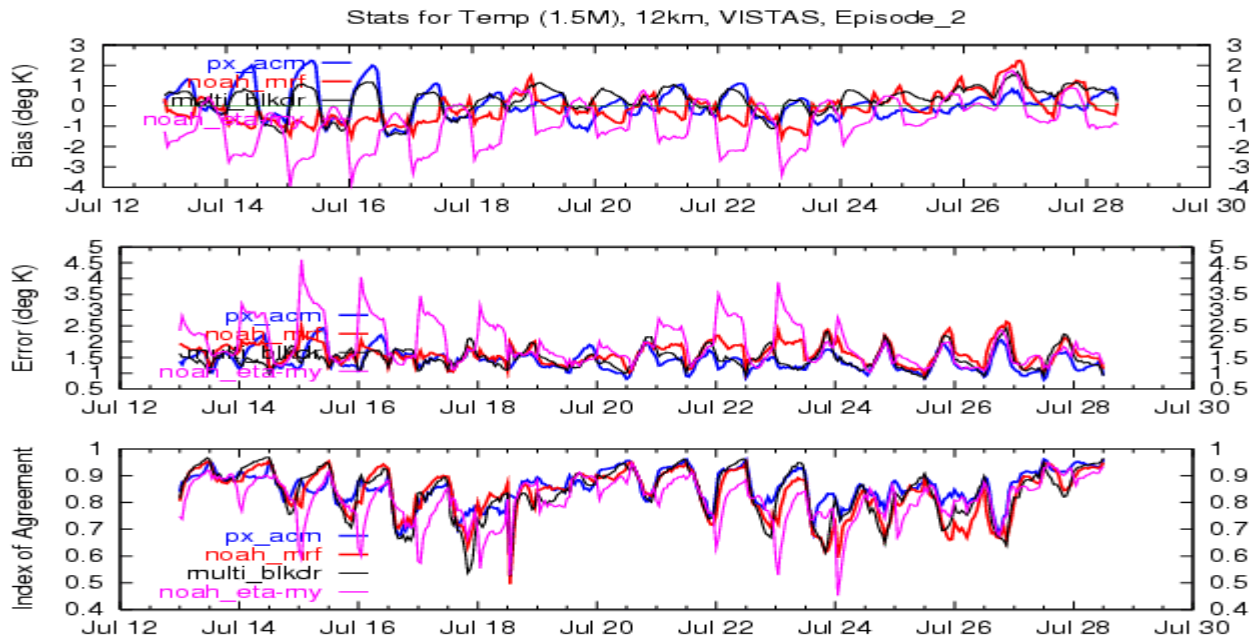
Wind stats	bias	abserr	uerr	verr	uverr
Wind (deg, m/s)	-0.250	0.26	0.0091	0.0118	0.0148

Pcp Threshold (in)	Acc	Bias	FAR	POD	CSI	ETS	TSS	HSS
0.01	0.0040	0.0122	0.0014	0.0104	0.0077	0.0074	0.0088	0.0086
0.05	0.0011	-0.0235	-0.0002	0.0136	0.0064	0.0052	0.0094	0.0063
0.10	-0.0018	-0.0272	-0.0032	0.0094	0.0016	0.0004	0.0045	0.0005
0.25	-0.0019	-0.0089	-0.0049	-0.0044	-0.0039	-0.0042	-0.0060	-0.0059
0.50	-0.0023	-0.0344	-0.0080	-0.0054	-0.0055	-0.0058	-0.0076	-0.0088
1.00	0.0002	-0.0058	0.0064	0.0109	0.0048	0.0048	0.0109	0.0082



Suggestions For Evaluation Products

- **Statistical Time Series**
 - Visualization of the statistics with time
 - Easily pick out temporal problems
 - Comparison of multiple model runs





Suggestions For Evaluation Products

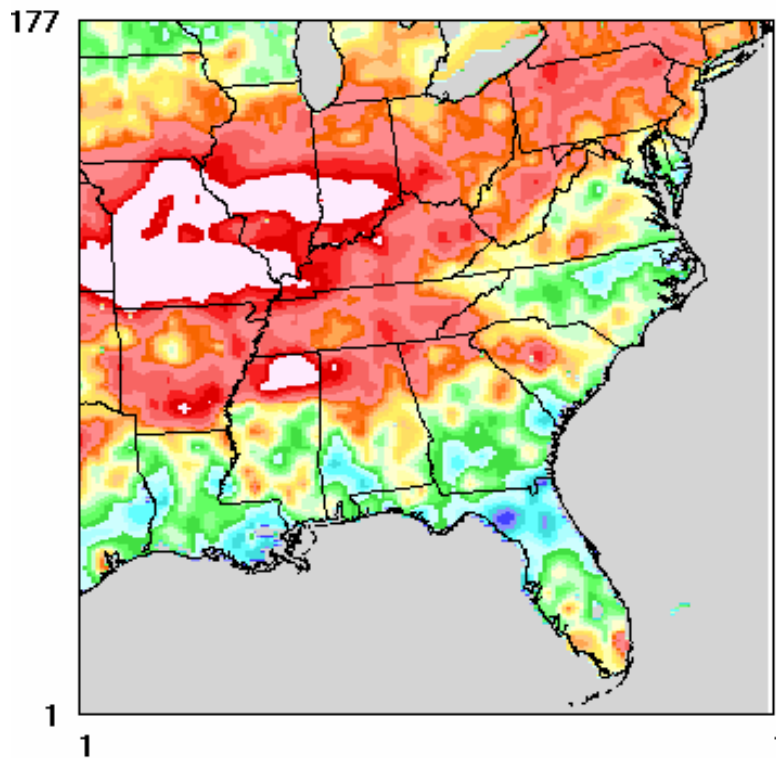
- **Spatial Plots**
 - **Extremely useful in analyzing parameters where there are huge caveats with the observations**
(Precipitation, Clouds, Wind Vectors)
 - **Allows the evaluation of the meteorological model's ability to replicate patterns**
 - **Subjective analysis of the model with and without observations**



Spatial Plot Examples – Observation To Model

Monthly Total Precipitation (Obs)

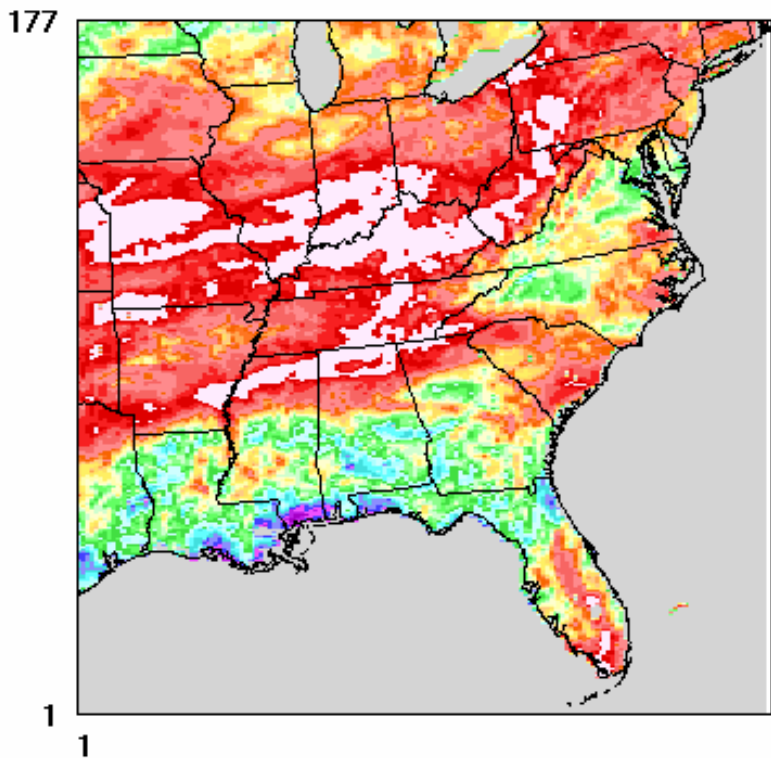
(may02, Full: 12km, v02_aaa)



May 31, 2002 12:00:00
Min= 0.00 at (1,1), Max=15.26 at (40,115)

Monthly Total Precipitation (MM5)

(may02, Full: 12km, v02_aaa)



May 31, 2002 12:00:00
Min= 0.00 at (1,1), Max=15.29 at (128,12)

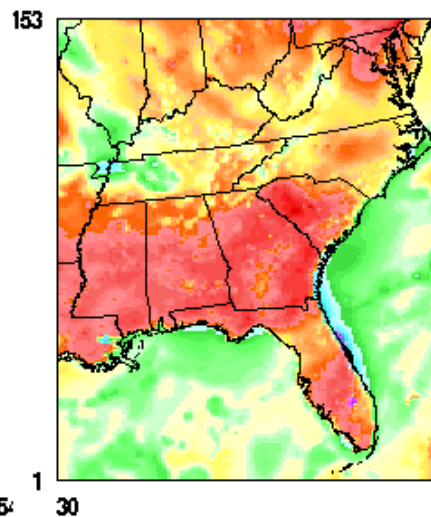
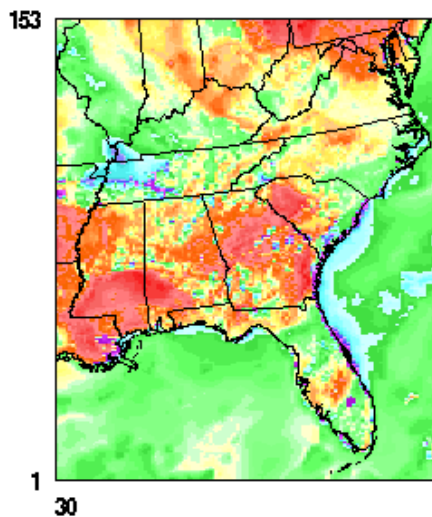
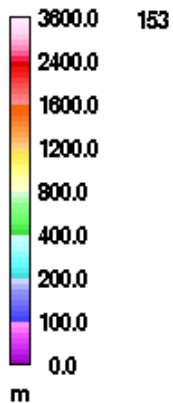
168in
PAVE
by
MCNC



Daytime PBL average

(18Z - 21Z)
(Episode 2, VISTAS: 12km, px_acm)

noah_mrf



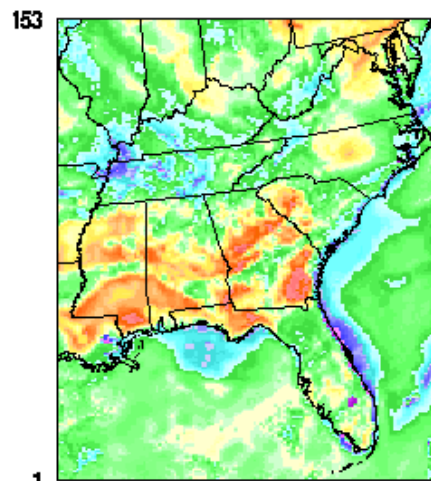
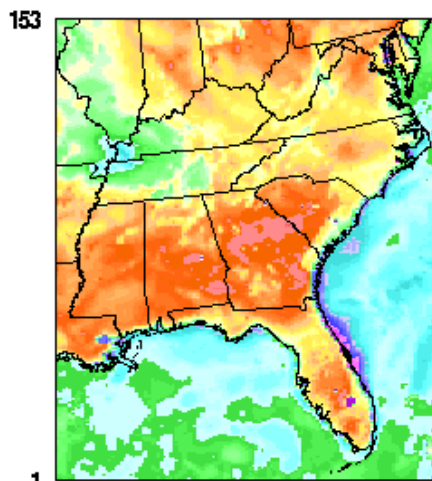
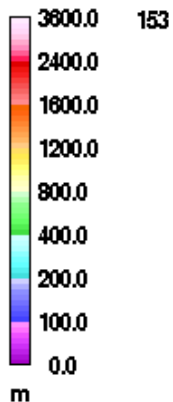
PAVE
km

July 19, 2001 0:00:00

multi_blkdr

July 19, 2001 0:00:00

noah_eta-my

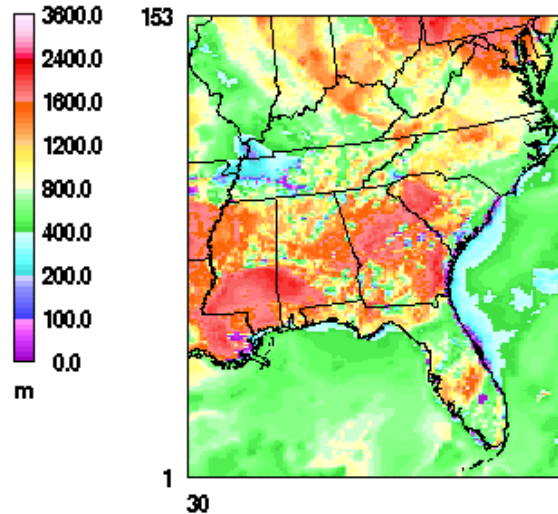


Spatial Plot
Examples –
Model To Model
(Comparison)

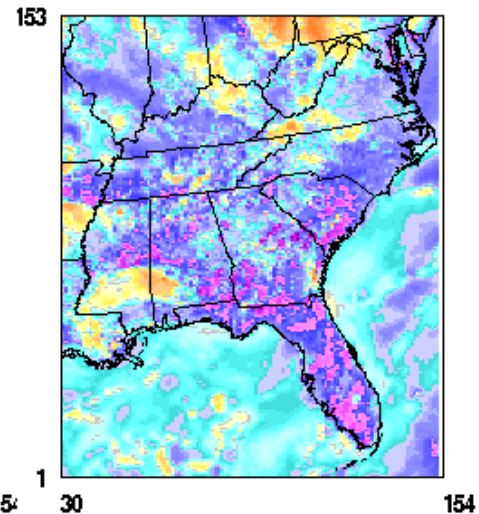


Daytime PBL average

(18Z - 21Z)
(Episode 2, VISTAS: 12km, px_acm)



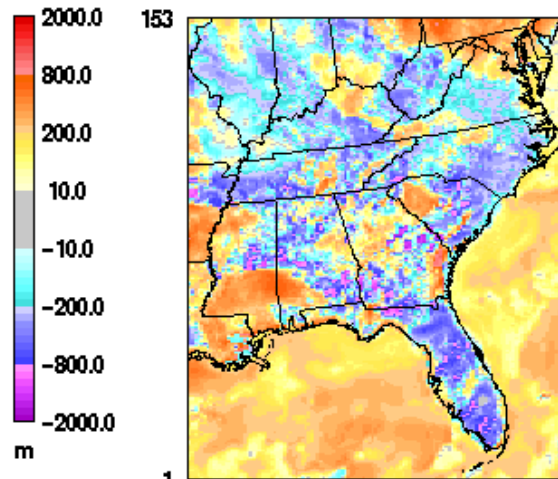
px_acm - noah_mrf



PAVE
km

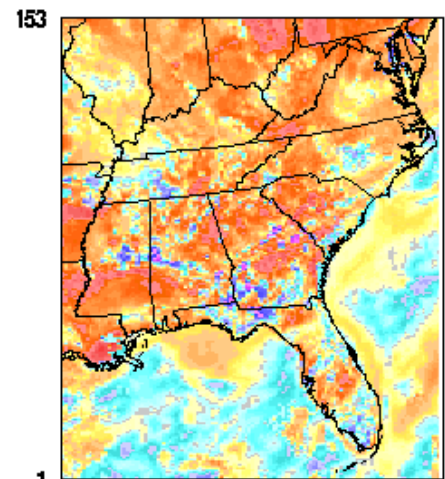
July 19, 2001 0:00:00

px_acm - multi_blkdr



July 19, 2001 0:00:00

px_acm - noah_eta-my



Spatial Plot
Examples –
Model To Model
(Difference)



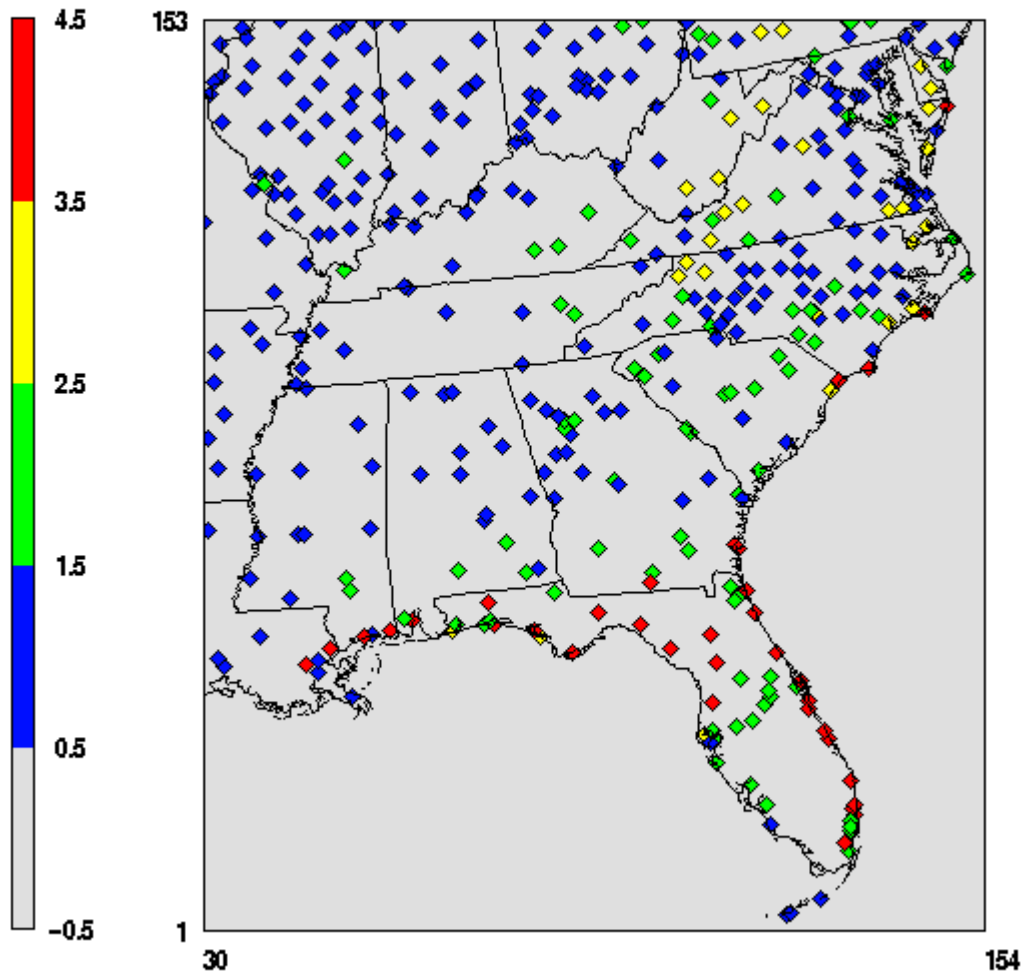
Suggestions For Evaluation Products

- **Spatial Statistical Plots**
 - Outstanding method to evaluate multiple model sensitivities geographically for various statistics
 - Each sensitivity is assigned to a specific color and the best sensitivity is displayed on the plot
 - One caution: There possibly could be only minute differences in a particular statistic between each of the sensitivities



Total Cross-Sensitivity Temperature (1.5m) Error

(Episode 1, VISTAS: 12km, Best Sensitivity Plotted)
(px_acm2=blue, noah_mrf=green, multi_blkdr=yellow, noah_eta=red)



PAVE
by
MCNC

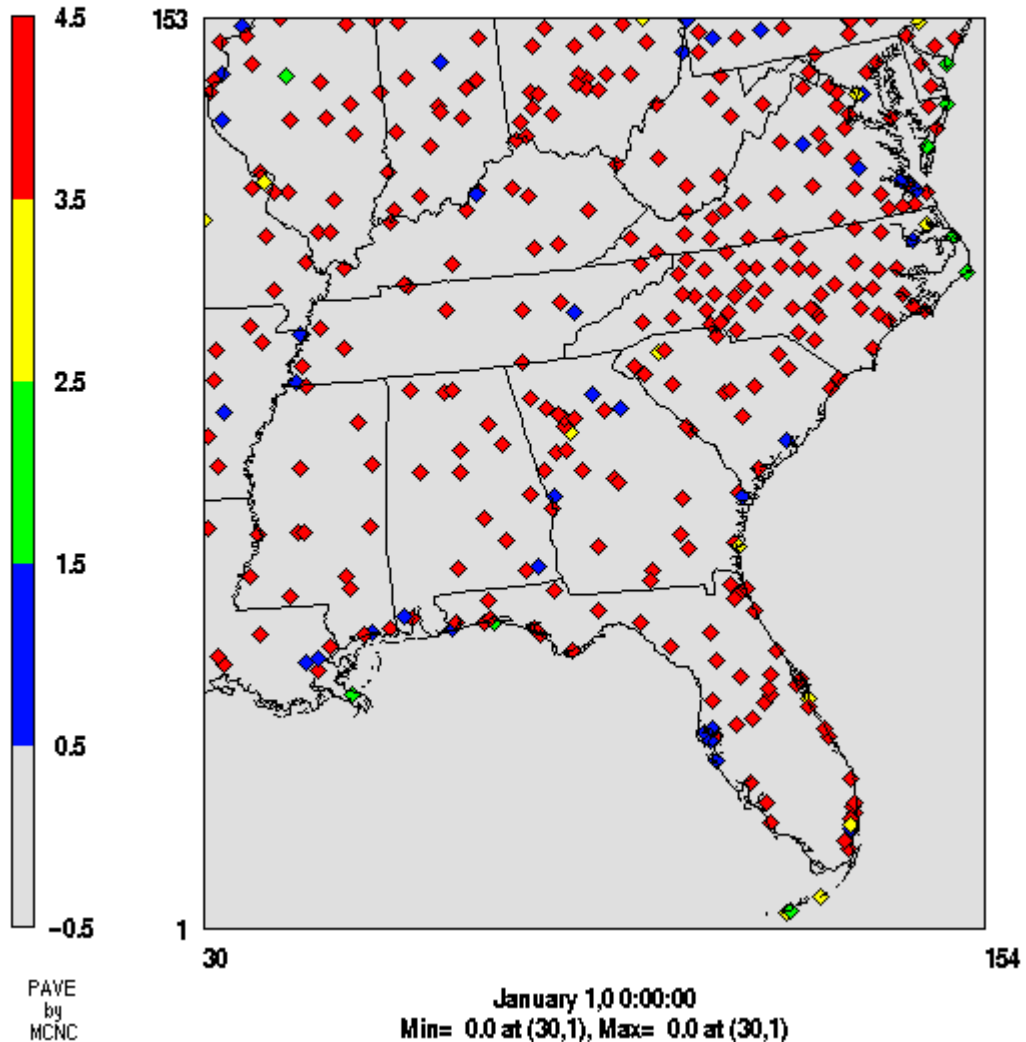
January 1, 0:00:00
Min= 0.0 at (30,1), Max= 0.0 at (30,1)

**Spatial
Statistical Plot
Examples –
Model To Model
(Geographic
Winners)**



Total Cross-Sensitivity Magnitude of Error Vector:

(Episode 2: July 13-27, 2001; VISTAS: 12km, Best Sensitivity Plotted)
 (px_acm=blue, noah_mrf=green, multi_blkdr=yellow, noah_eta=red)

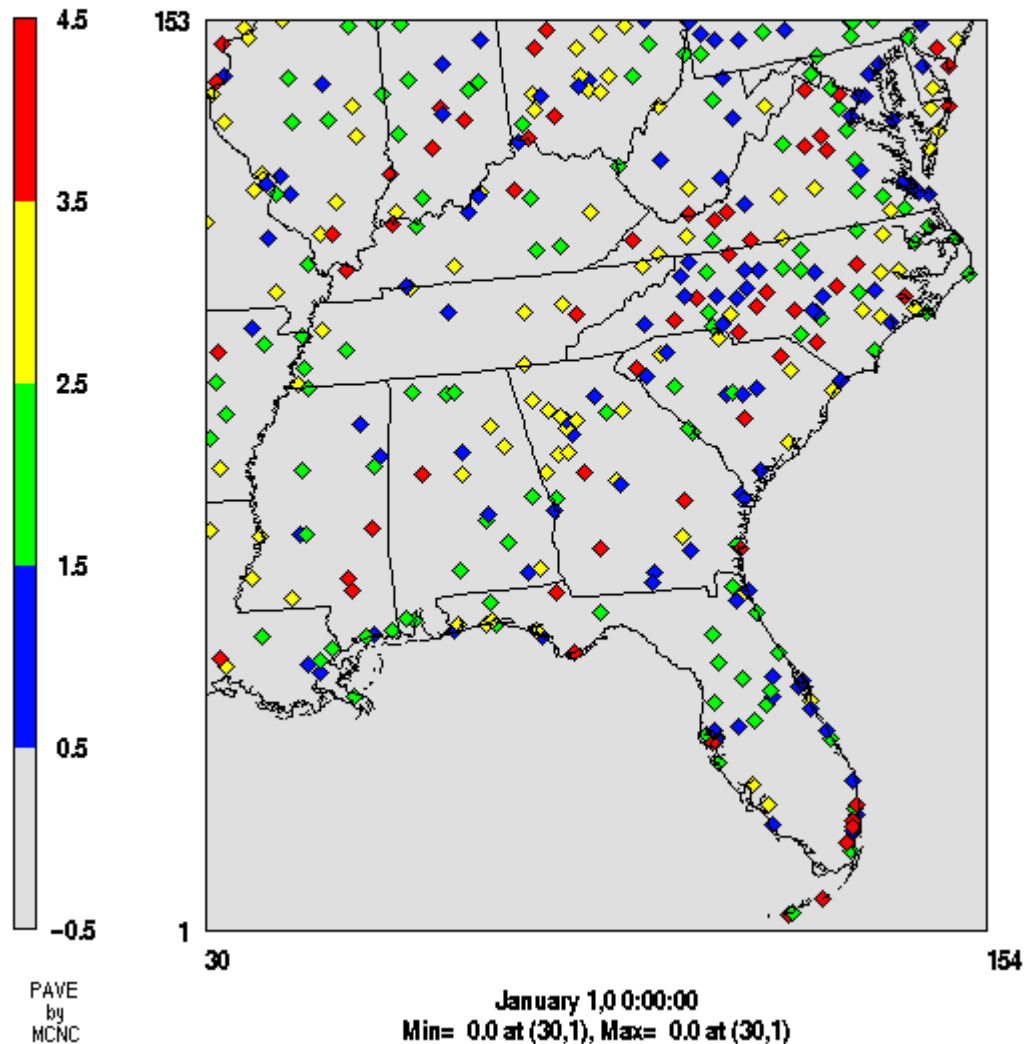


**Spatial
 Statistical Plot
 Examples –
 Model To Model
 (Domain Wide
 Winner)**



Total Cross-Sensitivity Relative Humidity Error

(Episode 2: July 13-27, 2001; VISTAS: 12km, Best Sensitivity Plotted)
(px_acm=blue, noah_mrf=green, multi_blkdr=yellow, noah_eta=red)



**Spatial
Statistical Plot
Examples –
Model To Model
(No Winner)**



Suggestions For Evaluation Products

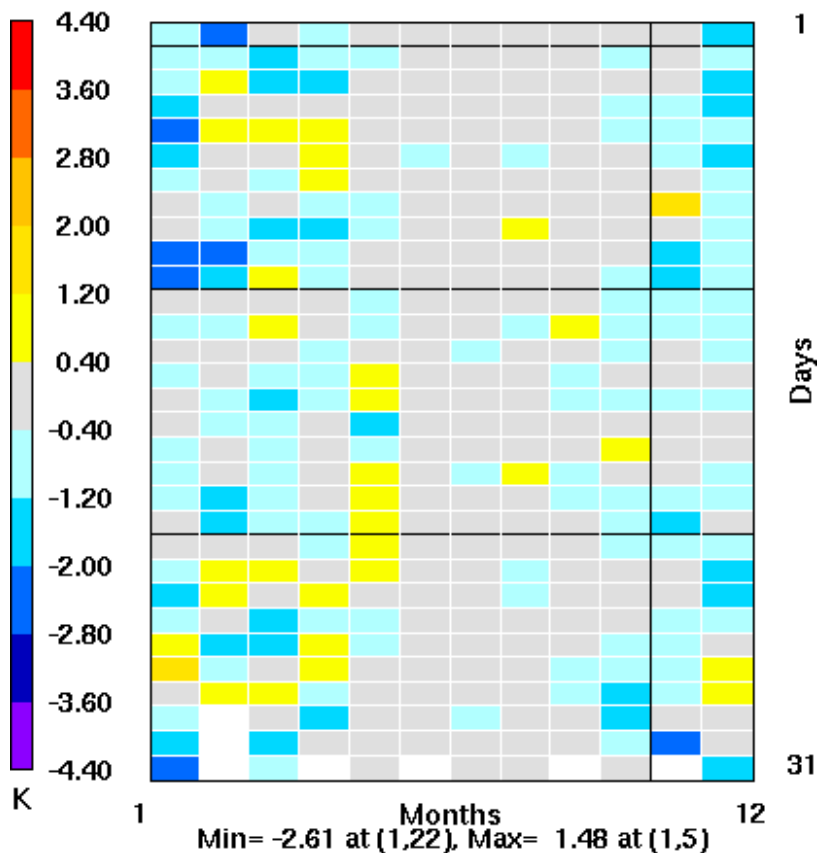
- **Annual “Bakergrams”**
 - **Ingenious statistical evaluation product that is a growth from Inter-RPO collaboration and the imagination of Kirk Baker**
 - **Ability to quickly and easily present a wealth of information in a single product**
 - **Color coded table or grid with each cell representing a day and each column representing a month in a calendar year**
 - **The color coding is based on the daily magnitude of a particular statistical metric**



Annual Bakergram Examples

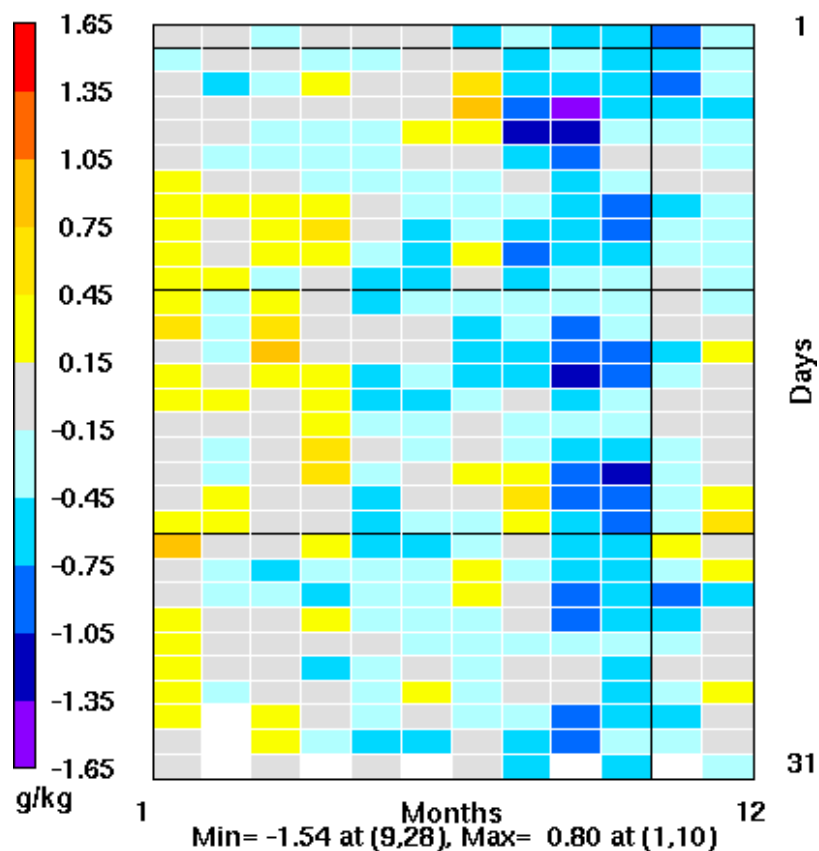
Temperature Bias

(2002, VISTAS: 12km, v02_aaa, 1.5m)



Mixing Ratio Bias

(2002, VISTAS: 12km, v02_aaa, Layer 1)





Suggestions For Evaluation Products

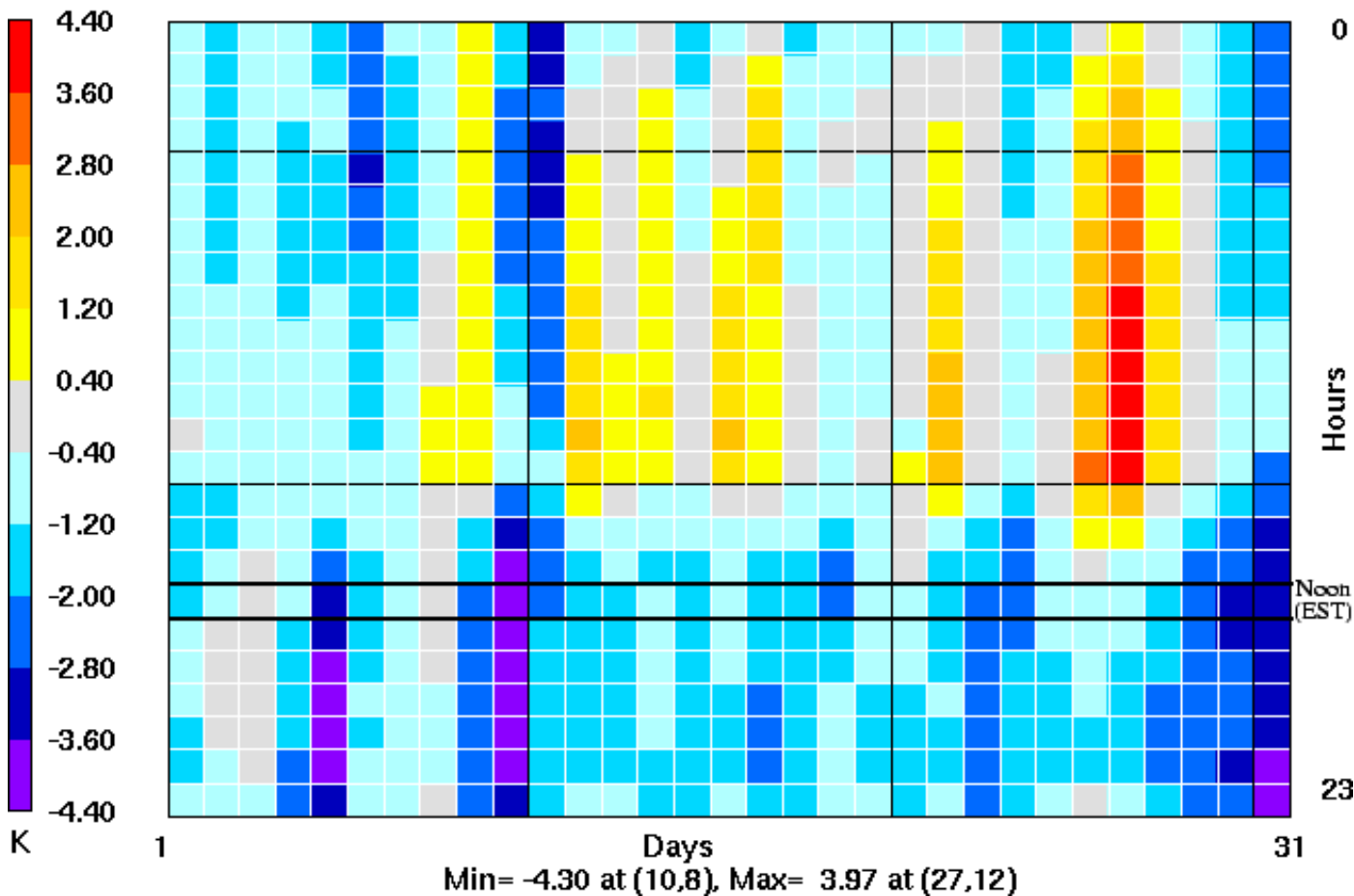
- **Monthly “Bakergrams”**
 - Very similar to the Annual Bakergrams
 - Each grid cell represents an hour and each column represents a day in the month
 - Again, the color coding is based on the daily magnitude of a particular statistical metric
 - This has become one of the most useful evaluation and modeling presentation products



Monthly Bakergram Examples

Temperature Bias

(jan02, VISTAS: 12km, v02_aaa, 1.5m)

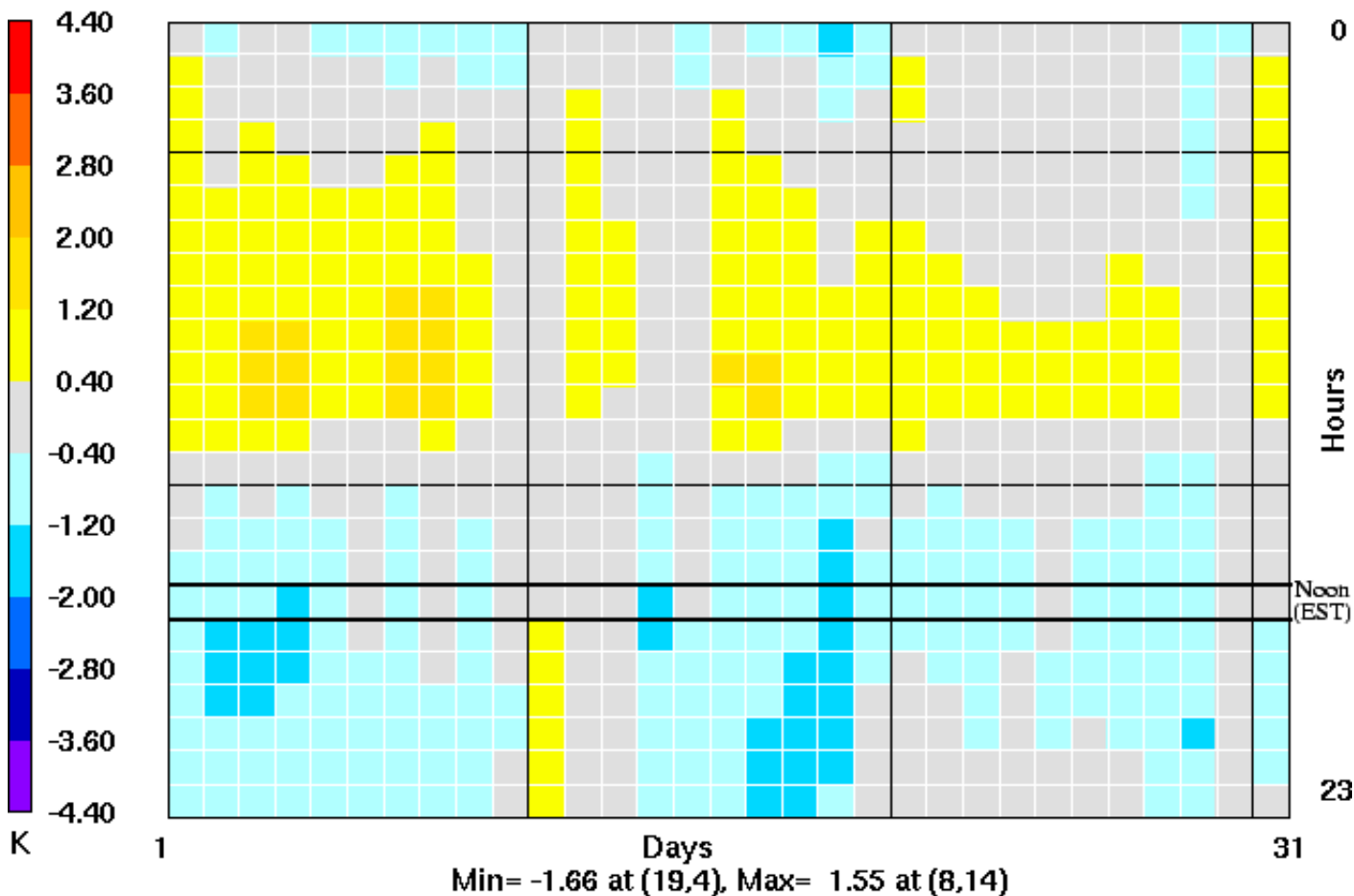




Monthly Bakergram Examples

Temperature Bias

(jul02, VISTAS: 12km, v02_aaa, 1.5m)

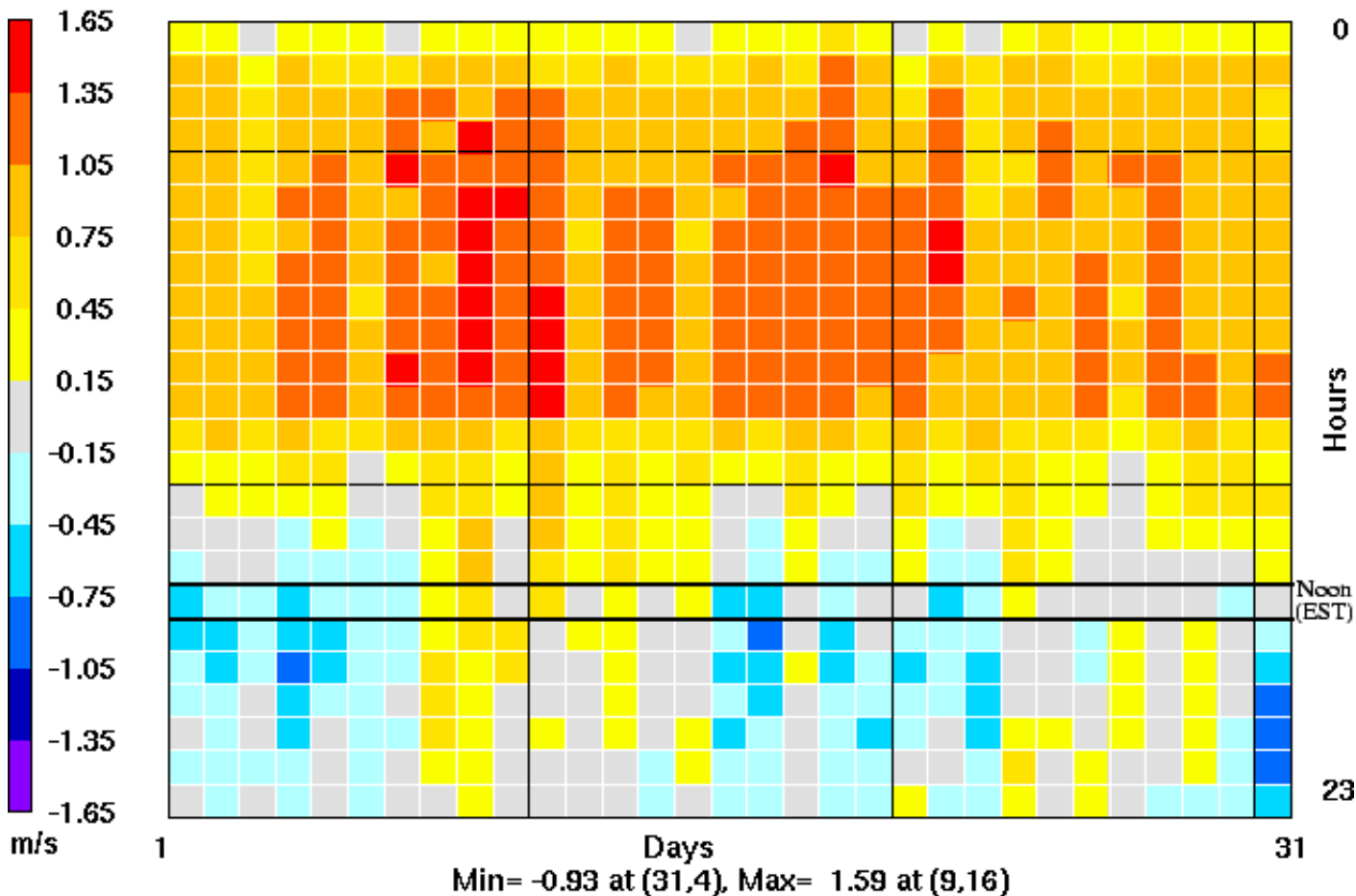




Monthly Bakergram Examples

Wind Speed Bias

(jul02, VISTAS: 12km, v02_aaa, 10m)





Suggestions For Evaluation Products

- **Qualitative Evaluation Summary Table**
 - Uses only the Time Series statistics
 - Based on overall trend and model performance
 - Not based on any quantitative values, although bias and error trends are considered
 - **Air Director Friendly!** *(Just remember it is a subjective approach)*

good	Correct trends and overall errors and biases are small for most of the time period
fair-good	
fair	Correct trend for the most part, significant errors or biases for some or much of the time period
poor-fair	
poor	Incorrect trend or large errors for some or most of the time period



Suggestions For Evaluation Products

- Qualitative Evaluation Summary Table

Episode 1
January 2002
VISTAS 12 KM

Variable	PX-ACM	PX-ACM2	NOAH MRF	Multi Blackadar	NOAH ETA MY
<i>wind speed</i>	Fair-Good	Fair-Good	Poor	Poor-Fair	Fair-Good
<i>wind direction</i>	Good	Good	Good	Good	Good
<i>temperature</i>	Poor-Fair	Fair-Good	Fair	Poor	Poor-Fair
<i>humidity</i>	Fair	Fair	Fair	Poor	Poor
<i>Mixing Ratio</i>	N/A	Good	Good	Fair	Fair

Episode 2
July 2001
VISTAS 12 KM

Variable	PX-ACM	NOAH MRF	Multi Blackadar	NOAH ETA MY
<i>wind speed</i>	Fair	Poor	Poor	Fair-Good
<i>wind direction</i>	Fair-Good	Good	Good	Fair-Good
<i>temperature</i>	Good	Good	Good	Fair
<i>humidity</i>	Fair-Good	Fair	Good	Good
<i>Mixing Ratio</i>	Fair-Good	Fair	Fair-Good	Good

Episode 3
July 1999
VISTAS 12 KM

Variable	PX-ACM	NOAH MRF	Multi Blackadar	NOAH ETA MY
<i>wind speed</i>	Fair-Good	Poor	Poor-Fair	Fair
<i>wind direction</i>	Fair-Good	Fair	Fair	Good
<i>temperature</i>	Fair	Good	Fair-Good	Poor-Fair
<i>humidity</i>	Good	Poor-Fair	Fair-Good	Poor-Fair
<i>Mixing Ratio</i>	Fair-Good	Poor-Fair	Fair-Good	Good



Contact Information

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