Preprocessing Atmospheric Precipitation Forecasts for Hydrologic Ensemble Forecasts: Research to Operations

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DOH Workshop
July 16, 2008

Discussion Topics

- ESP Forcing Requirements
- NCEP Ensemble Forecasts: Why is EPP needed?
- Ensemble Preprocessor (EPP) Goals
- Ensemble Preprocessor (EPP) Science Strategy
- EPP/GFS – How to use it
- Some EPP Results – What to Expect
- Present Limitations
- Future Directions

Hydrology Ensemble Forcing Requirements

- Need skillful and reliable precipitation and temperature ensemble forcing time-series for each sub-basin/segment (1-day to ~ 1-year)
- Ensemble forcing must “preserve” space-time variability of precipitation and temperature forcing.
- Uncertainty in future forcing is time and space scale dependent and this must be represented in ensemble input to ESP
- Ensemble members must be “consistent” in space and time (over entire forecast space-time domain).
  - Required to assure streamflow members can properly be routed downstream
- Ensemble members input to ESP must be “equally likely”
- Need to make “best possible” use of all weather and climate forecast information

NCEP Ensemble Forecasts: Why is EPP needed?

- Atmospheric forecasts are biased 
- NCEP ensemble forecasts do not account for all of the uncertainty
  - Spread is typically under-estimated
  - Events that might occur not well represented
  - Space-time structure of members not fully representative: i.e. space-time structure of future events is essentially unknown
- Ensemble spread is not properly related to differences between ensemble mean and observed values
- Atmospheric ensemble members are not equally likely – they are more like sensitivity analyses to estimated uncertainty in initial conditions
- Major research is needed to adjust raw atmospheric ensemble members for hydrologic application

Ensemble Preprocessor (EPP) Goals

- Create ensemble future forcing for ESP from single-value atmosoheric forecasts
- Use all available forecast information from NCEP
- Predict future MAP/MAT values that are “consistent” with historical MAP/MAT values (so that forecast models “understand” the forcing)
- Maintain “skill” of raw forecasts
- Represent future uncertainty reliably
- Include “conditional uncertainty” if possible
- Allow for multi-model forecast input
- Keep it simple as possible
- Make it “good” not “perfect”

Ensemble Preprocessor (EPP) Science Strategy

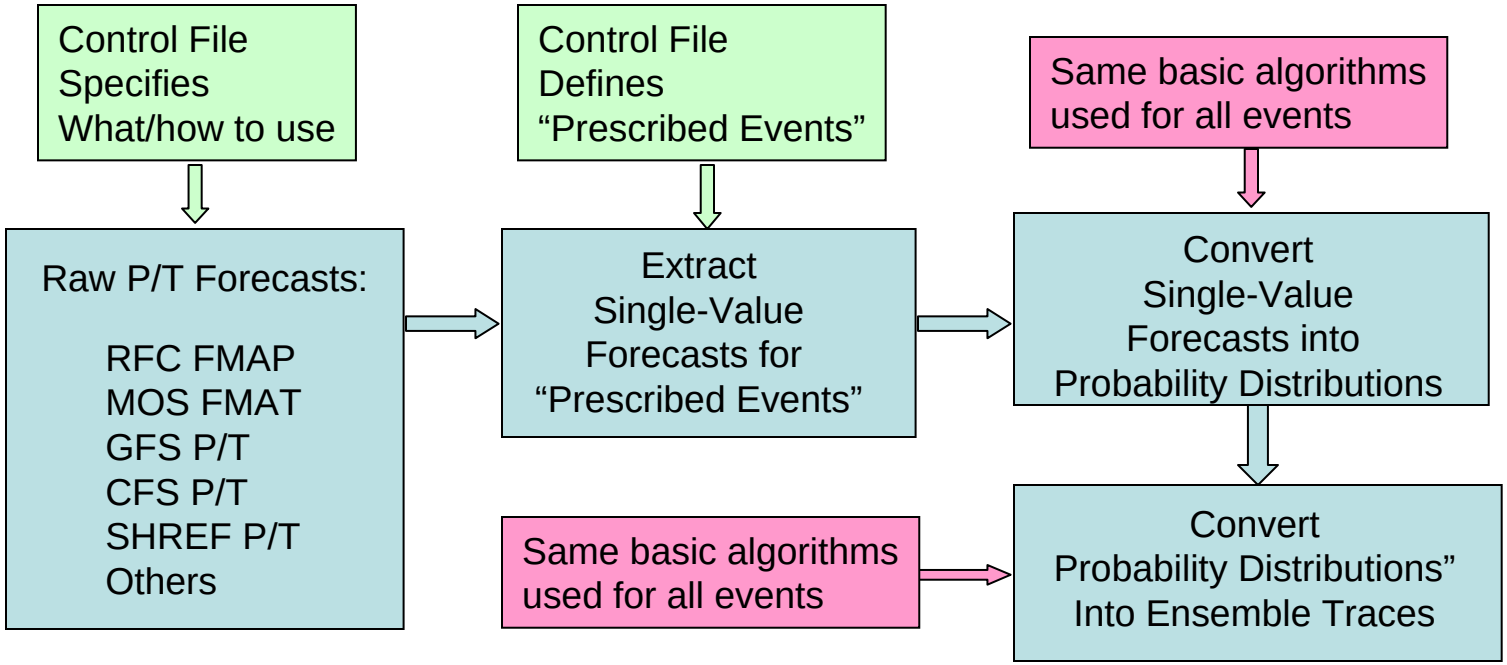
- Historical forecasts and observations are used to "calibrate" EPP
- Climatology of forecasts and observations must be "consistent" with each other
- Climatology of observations must be same as used for hydrologic model calibration
- Use GFS Ensemble Mean from "Fixed Version" of GFS for now (days 1-14).
- Use RFS single-value forecasts (archive required)
- Use MOS temperature forecasts (days 1-7)
- Use CFS forecasts beyond 2wks (single-value/ensemble-mean)

Ensemble Preprocessor (EPP) Science Strategy (Cont'd)

- Include forecast probability distributions for many overlapping future events at different space/time scales
- Use historical space-time patterns to create ensemble members with prescribed forecast probability distributions ("Schaake Shuffle")
  - 1-6hr time steps
  - 1-day to 1-year
  - for forecast basin segments
  - for entire forecast area
- Ensemble members "preserve" all forecast probability distributions
- Hindcasts from current ENS-GFS to be produced "soon" and re-calibration of EPP to be automated.

Ensemble Preprocessor (EPP) Science Strategy (Cont'd)

- Two Step Process
  - Convert single-value forecasts of "events" to probability distributions
  - Use "Schaake Shuffle" to create ensemble members that "preserve" all forecast probability distributions



EPP/GFS – How to use it

- CHPS will “wrap around” GFS Subsystem (that already includes RFC forecasts and will soon include CFS forecasts)
  - Provide user control
  - Provide user-access to diagnostic information
- System Components have control files
  - Which forecasts to use
  - What forecast lead times
  - Defines forecast “events”
- Apps default directory structure (initially)
- Calibration, Forecast/Hindcast and Diagnostic Components

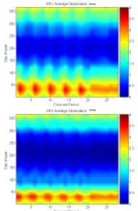
National Weather Service Hydrologic Ensemble Pre-Processor (EPP) GFS Subsystem

J. Schaake, R. Hartman, J. Demargne, L. Wu, M. Mullusky, E. Welles, H. Herr, D. J. Seo, and P. Restrepo

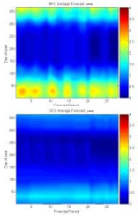
Water Predictions for Life Decisions

CPPA

Average observed values of 6-hour precipitation corresponding to RFC and GFS forecasts



Average forecast values of 6-hour precipitation for RFC and GFS



6hr RFC QPF Verifications Files and Operational MAPs

6hr MAP Calibration Files

Raw Historical Data Files

RFC-specific Utility

MAP Conversion Utility

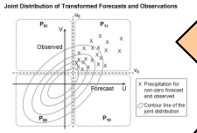
Historical 6hr RFC Operational MAP Observed Data Files

Historical 6hr RFC Operational MAP QPF Data files

Historical GFS Ensemble Mean Precipitation Forecasts

6hr MAP Unformatted Calibration Data Files

GFS Processor Historical Data Sets



Pre-Processor Precipitation Algorithms

Operational RFC QPF Files

Operational GFS Files

Operational Forecast Files

Parameter Estimator

Precipitation Parameters

Ensemble Generator

Operational Ensemble MAPs

Hindcast Ensemble MAPs

MAP Area Locations

MAP Time Series Identifiers

Index Files

Precipitation Verification

Verification Results

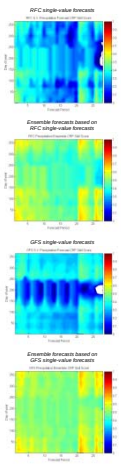
Data Analysis

Statistics

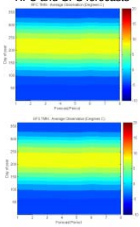
CFS Ensemble Forecast (Application Under Construction)

Precipitation Ensemble Pre-Processor

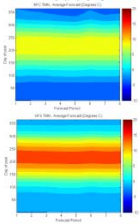
Continuous Rank Probability Skill Score (CRPSS) for 6-hour precipitation forecasts



Average observed values of daily minimum temperature corresponding to RFC and GFS forecasts



Average forecast values of daily minimum temperature for RFC and GFS



RFC TMX/TMN Forecast Verification Files and Operational Observed TMX/TMN

MOS TMX/TMN Forecast Verification Files

6hr MAT Calibration Files

Raw Historical Data Files

RFC-specific Utility

MOS Utility

6hr to TMX/TMN

TMX/TMN Calibration Data

Conversion Utility

RFC Historical Operational Observed TMX/TMN

RFC Historical Operational Forecast TMX/TMN

MOS Historical Forecast TMX/TMN

Historical GFS Ensemble Mean Temperature Forecasts

Unformatted TMX/TMN Calibration Data Files

GFS Processor Historical Data Sets

MAT Analysis

Pre-Processor Temperature Algorithms

Operational RFC QTF Files

Operational GFS Files

Operational Forecast Files

Parameter Estimator

Temperature Parameters

Ensemble Generator

Operational Ensemble MATs

Hindcast Ensemble MATs

MAT Area Locations

MAT Time Series Identifiers

Stations used for MAT Analysis

Temperature Normals

Index Files

Temperature Verification

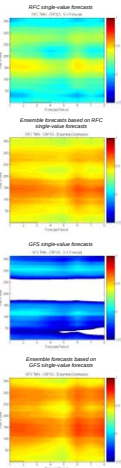
Verification Results

CFS Ensemble Forecast (Application Under Construction)

Temperature Ensemble Pre-Processor

TMX: maximum temperature *TMN: minimum temperature*

Continuous Rank Probability Skill Score (CRPSS) for daily minimum temperature forecasts



NOAA

HEPEX Hydrologic Ensemble Prediction EXperiment

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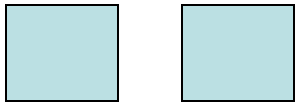
- Future Directions

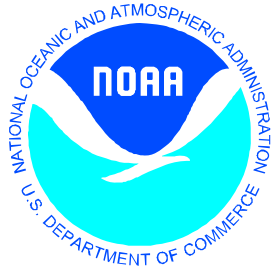


Some Present Limitations

- Atmospheric ensemble forecasts do not reliably account for uncertainty – This is our biggest problem!
- Ensemble reforecasts from *fixed forecast model* are required
- RFC short range forecasts have been archived only for last few years
- GFS re-forecasts are for “old” version of GFS
- SREF forecasts are not used
- Multi-model options are needed
- Automatic options to control use of RFC/GFS and CFS forecasts are needed
- CFS – GFS forecast information gap (weeks 3 – 6)
- Cannot make ESP hindcasts for monthly probability shifts (no archive)
- Seasonal probability shift archive begins only in 1995 (not long enough)
- Flow-dependent/Regime-dependent uncertainty is needed
  - Objective Flow/Regime classification procedures are needed
  - State of climate system conditioning

Future Directions

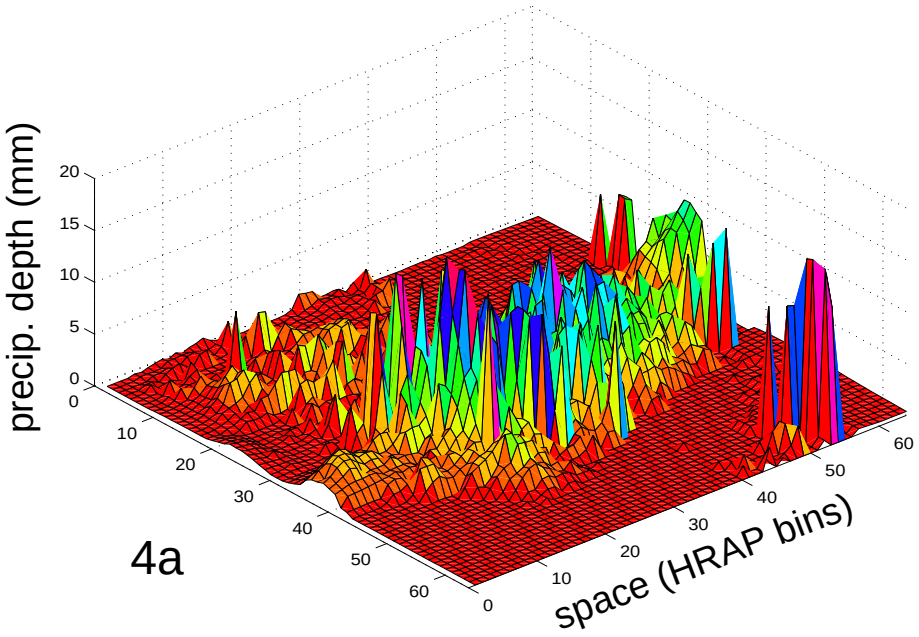
- Gridded Ensemble Pre-Processor
  - Joint effort with NCEP, HEPEX, THORPEX
  - National “coarse” space-time grid operated at NCEP
  - Local (RFC/WFO) “fine” grid and basin applications
- Integrate RFC, HPC, SREF, GFS, CPC and other forecasts into multi-model EPP functionality
- Quantify requirements for weather and climate hindcasts (e.g. Simulation Experiments)
- Improve ability to make hydrologic hindcasts using weather and climate forecasts without “long” archives – a contribution to THORPEX/TIGGE

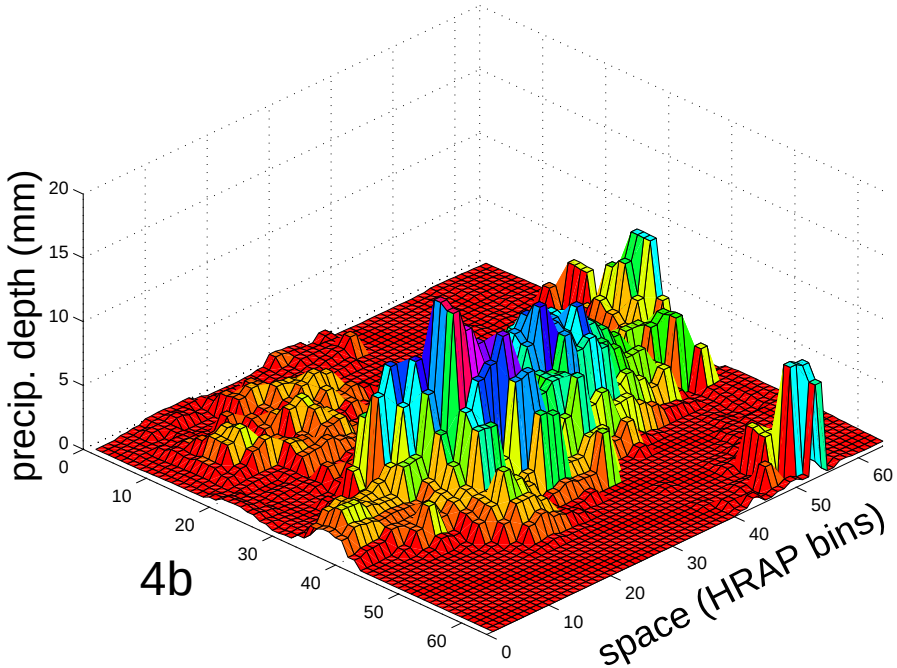


Thank You

Water Predictions for Life Decisions

HEPEX
Hydrologic Ensemble Prediction EXperiment


precip. depth (mm)
space (HRAP bins)
4a


precip. depth (mm)
space (HRAP bins)
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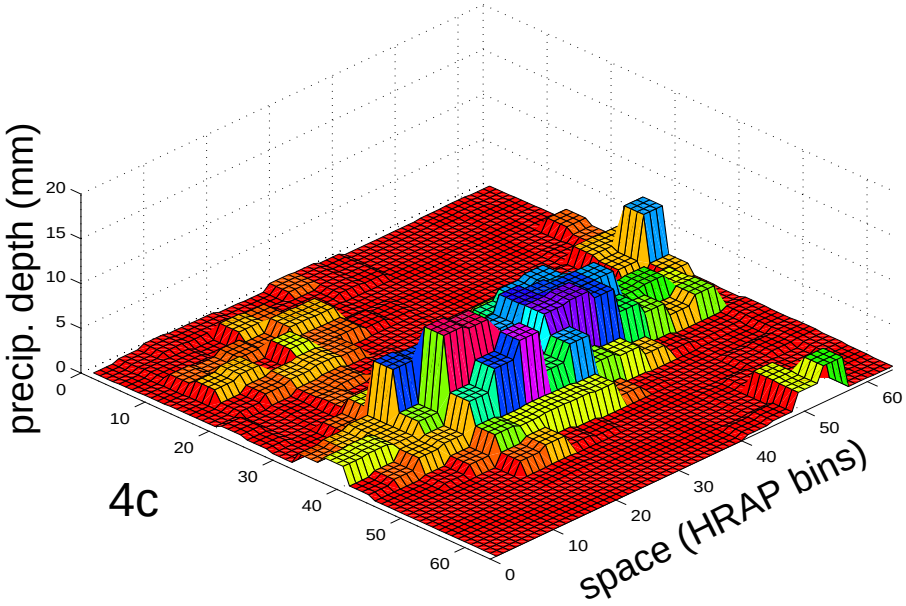
precip. depth (mm)
space (HRAP bins)
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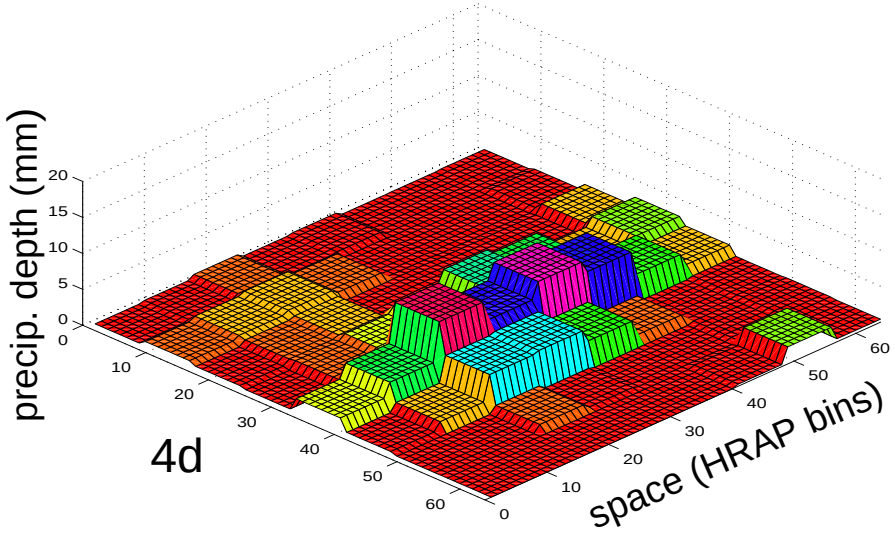
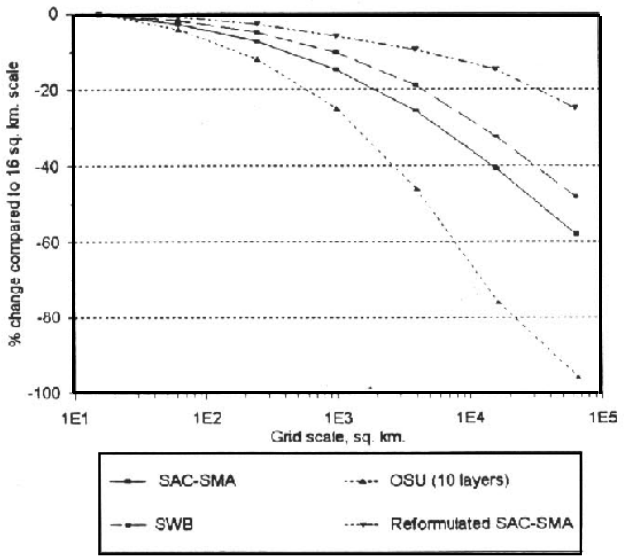

precip. depth (mm)
space (HRAP bins)
4d

Return

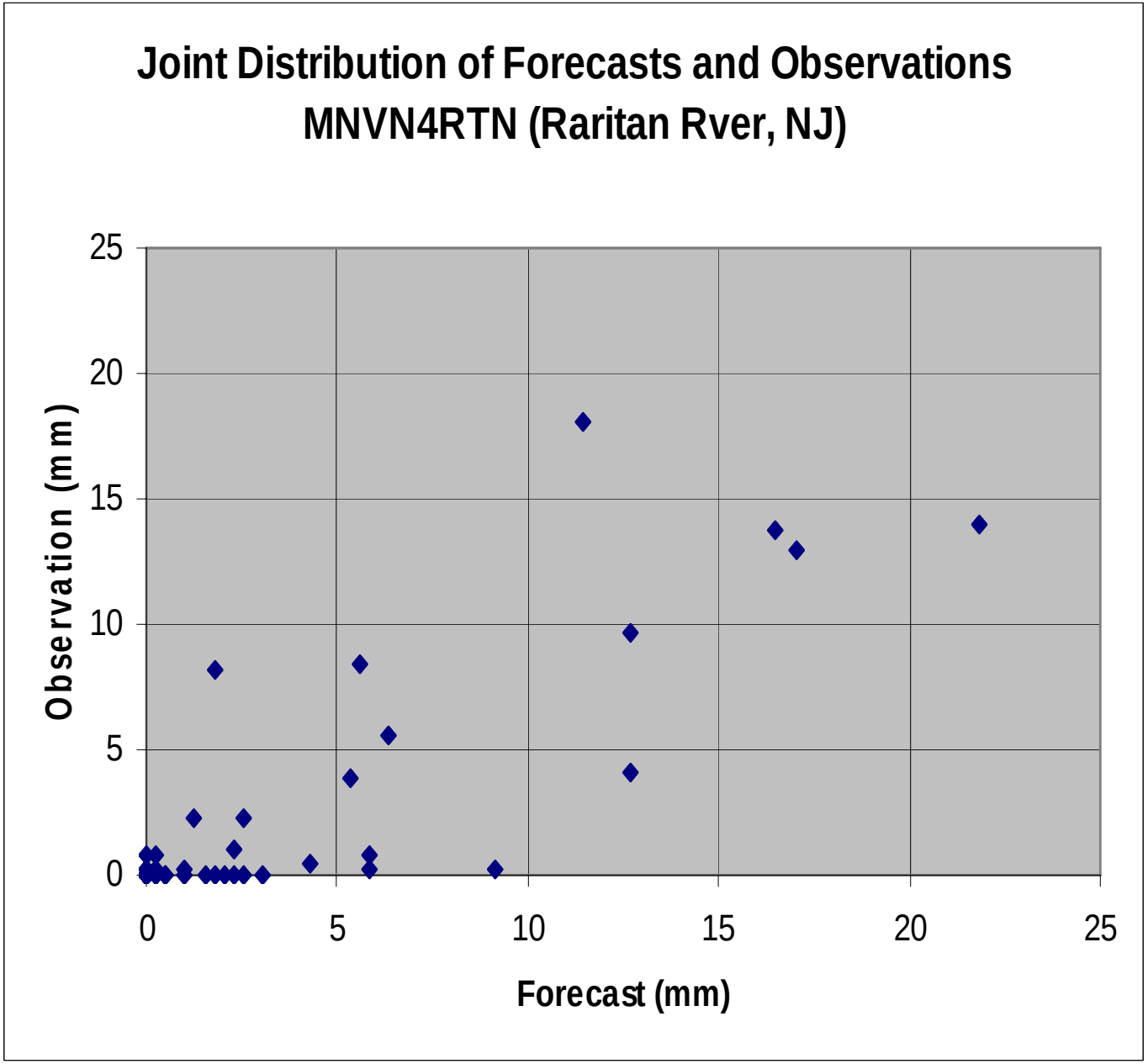
Hydrology is Sensitive to Precipitation Variability: Spatial Scale Dependency Example

- Total runoff from 64x64 4km grid domain
- Several years of Stage III, 1-hr, QPE
- 7 Area Segmentations: 1,2,4,6,16,32,64 pixels
- Same model/parameters used for each segmentation
- Graph shows different runoff totals vs size of area segment
- Some models more scale dependent than others
- Scale dependency is a result of non-linearity

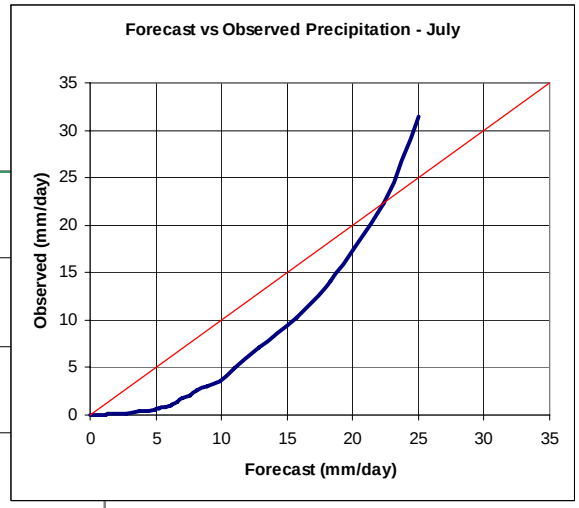


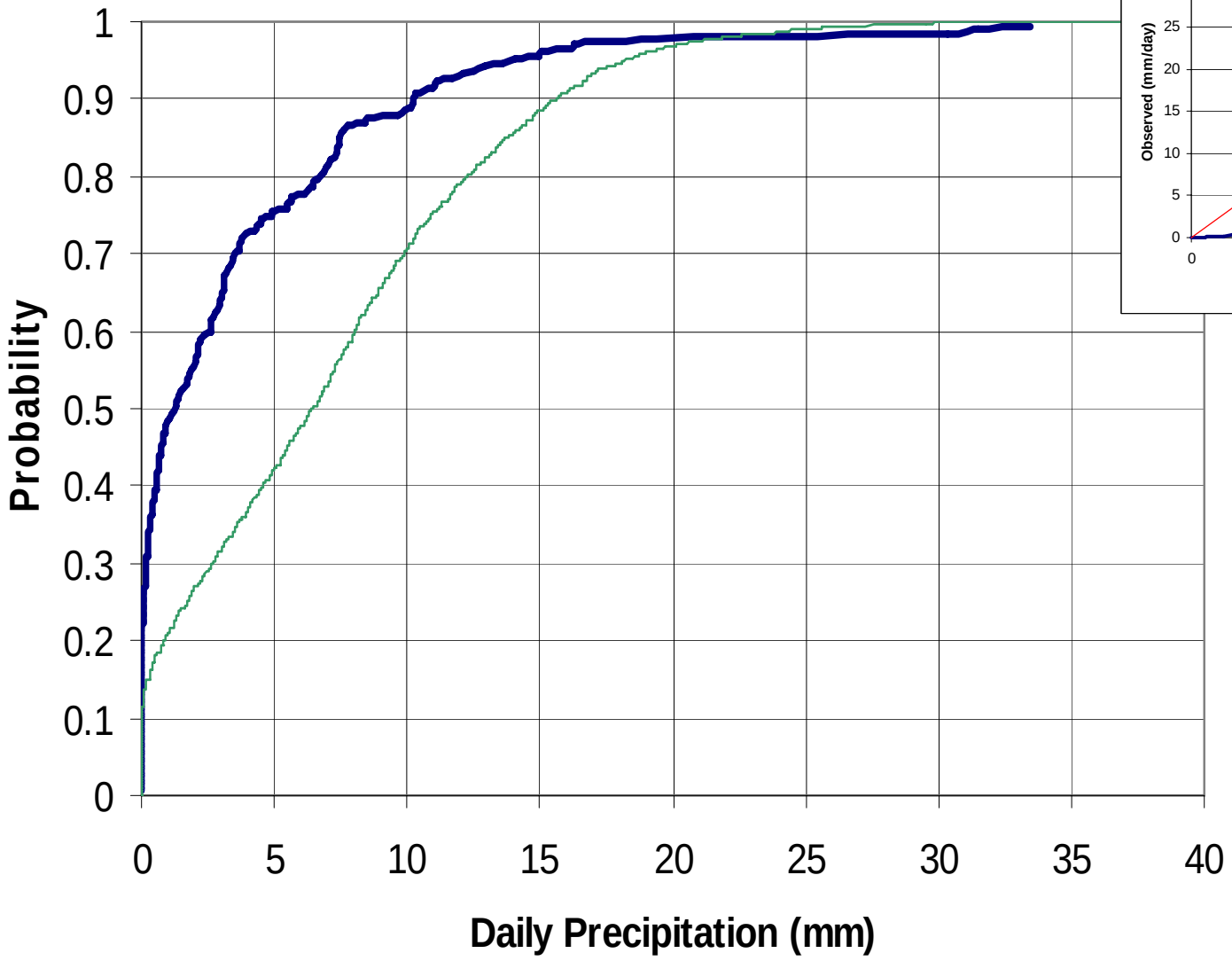
THEREFORE: Space/Time Variability of Ensemble Forcing Will Have a Primary Effect on Hydrologic Ensemble Response

Return


Joint Distribution of Forecasts and Observations
MNVN4RTN (Raritan Rver, NJ)
Observation (mm)
25
20
15
10
5
0
0
5
10
15
20
25
Forecast (mm)

Observed vs Global Ensemble Climatologies
(July, Lat = 35.0, Lon = 82.5)





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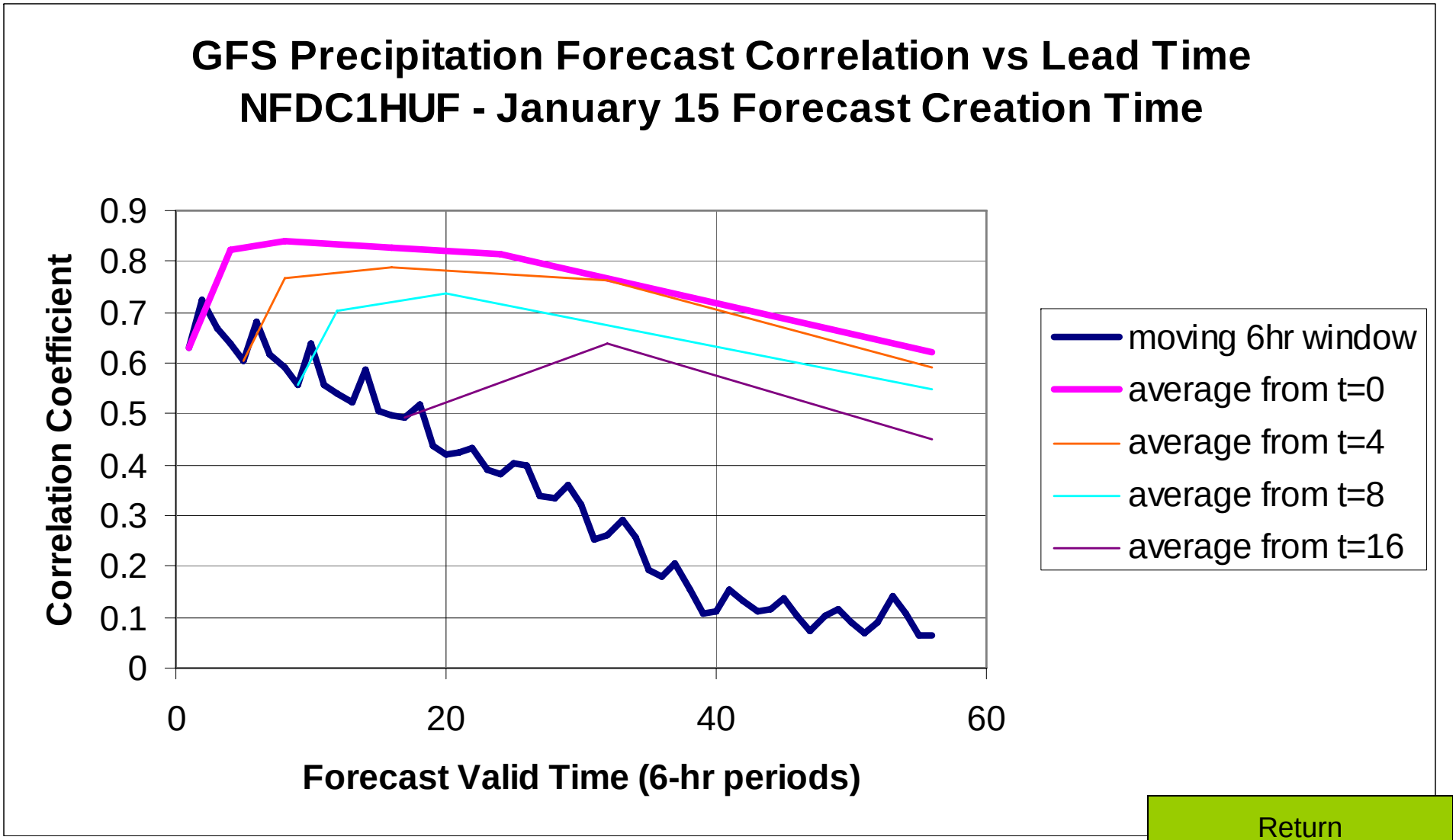
Temporal Scale Dependency of Precipitation Forecasts



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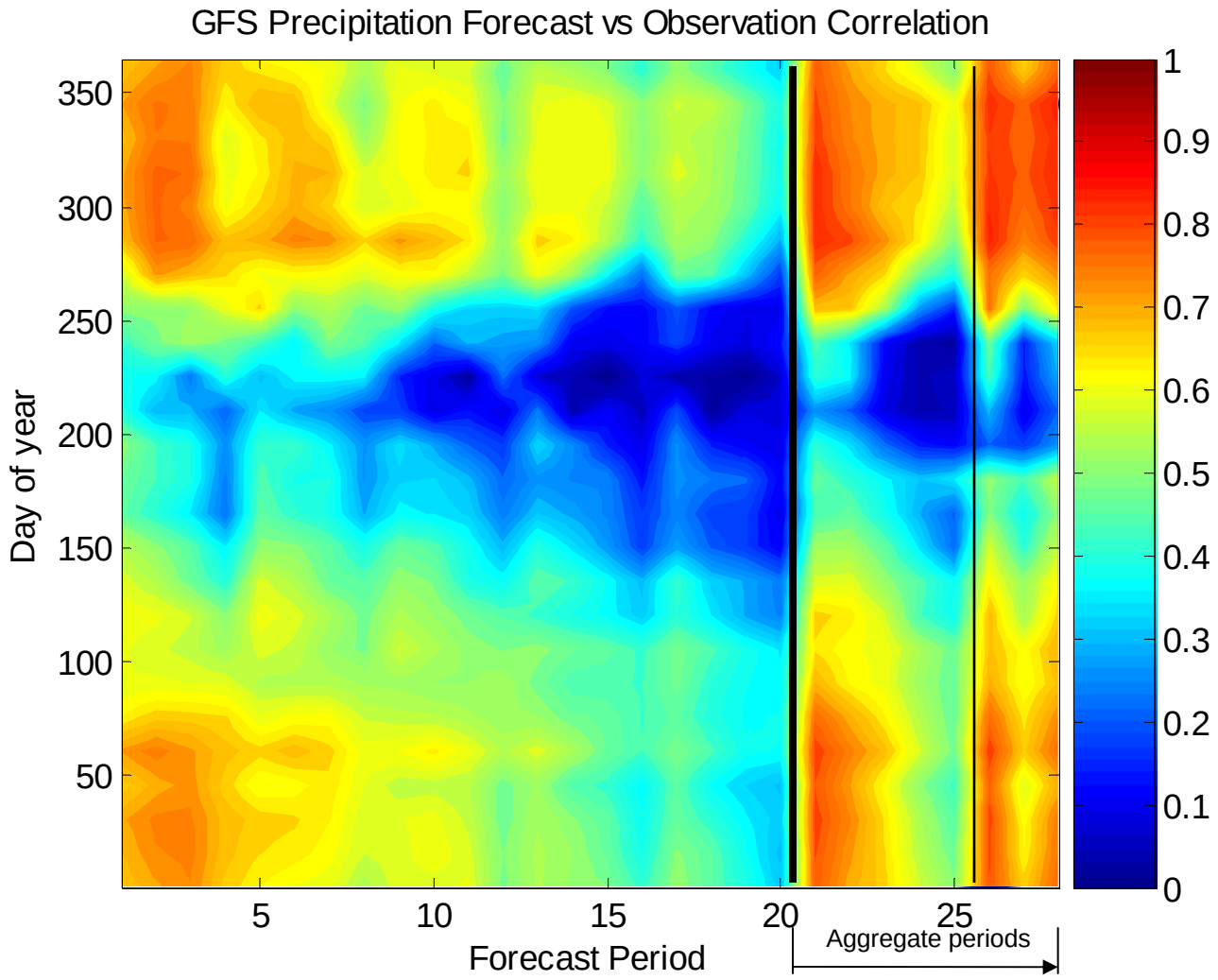
Correlation Coefficient
GFS Precipitation Forecast vs Observation
North Fork American River

Forecast Uncertainty Depends on both Lead-Time and Aggregation-Time



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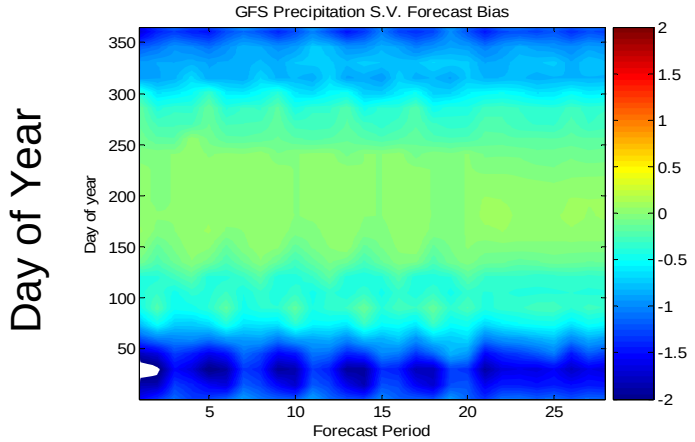
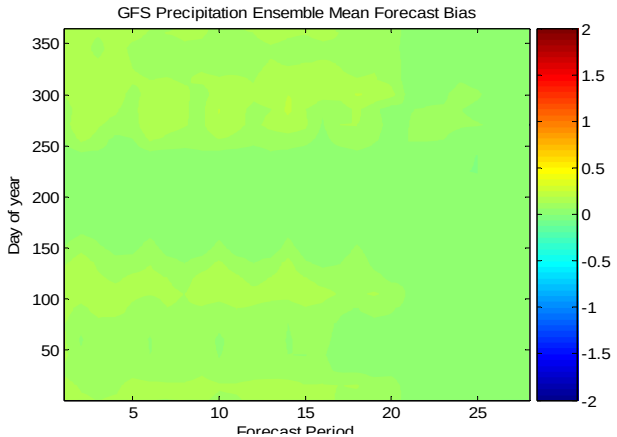
GFS Precipitation Forecast Verification
North Fork American River

Raw GFS Ensemble Mean

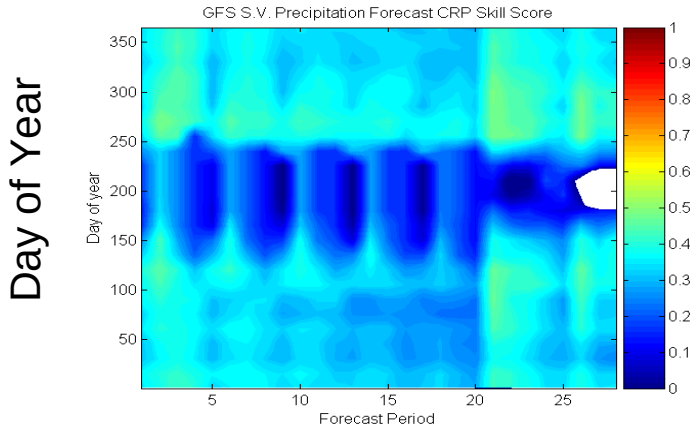
GFS EPP Prototype

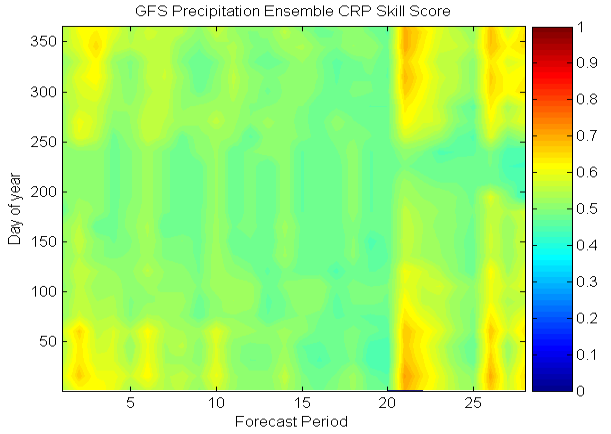
Bias





CRPSS



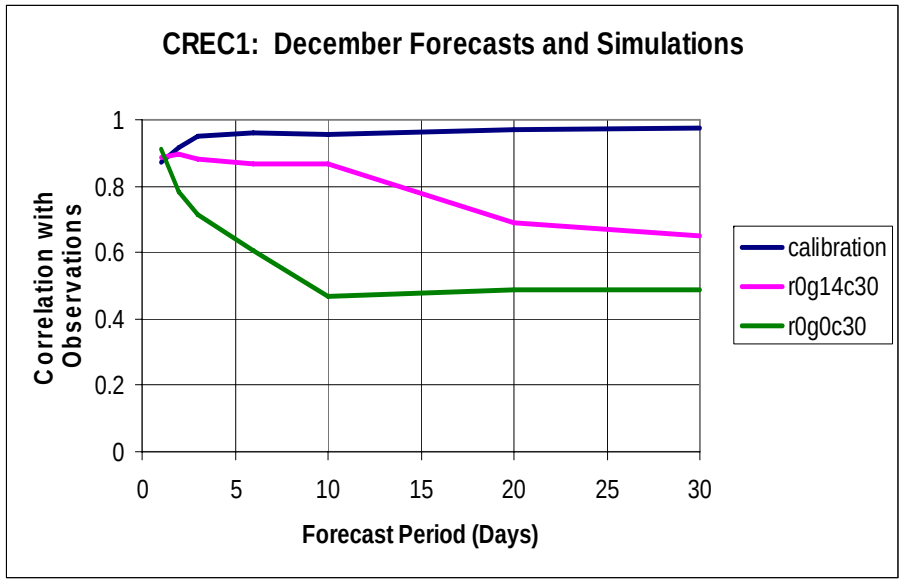


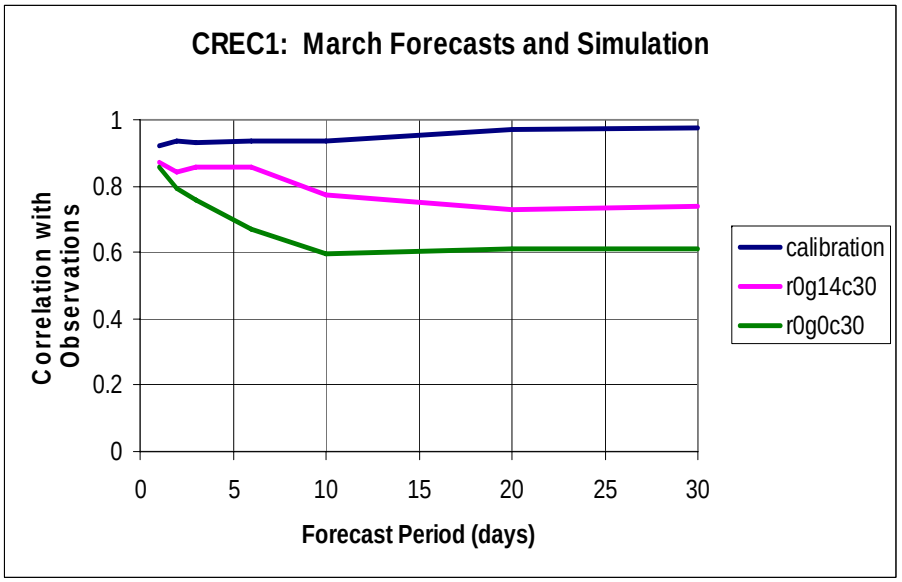
Forecast Period

Forecast Period

Return

CREC1 – Forecasts and Simulations





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