

Introduction to Verification

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Outline

- Verification background
- Error overview
- Forecasting patterns
- Data Issues
- Verification application
- Results

Different
perspectives on skill

How good were
historical forecasts:
Where?
When?
Why?

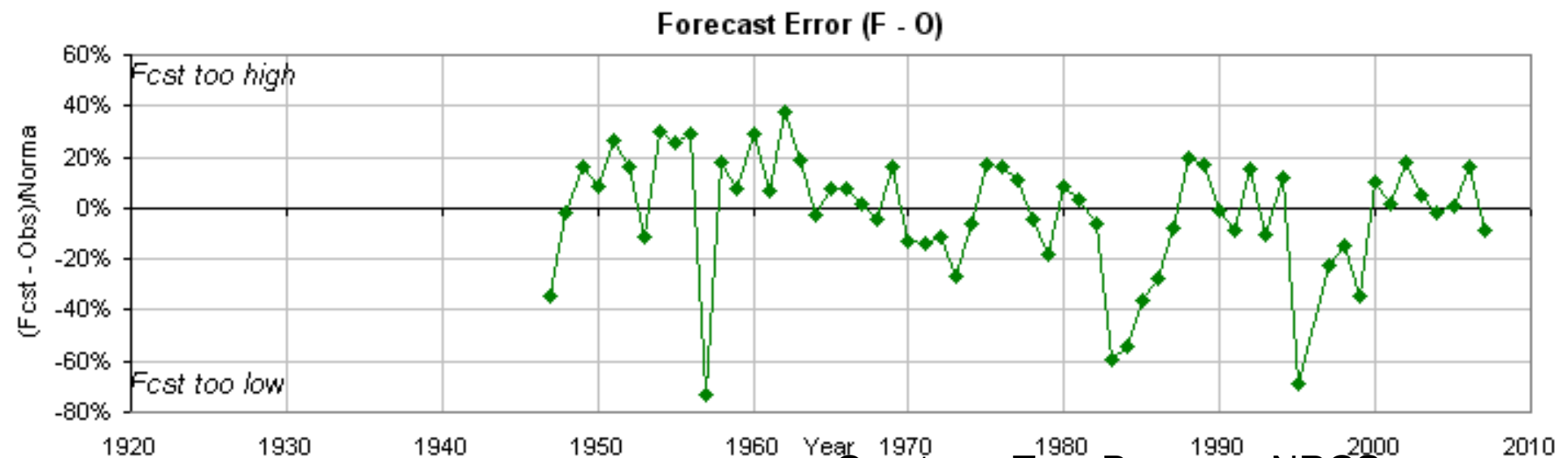
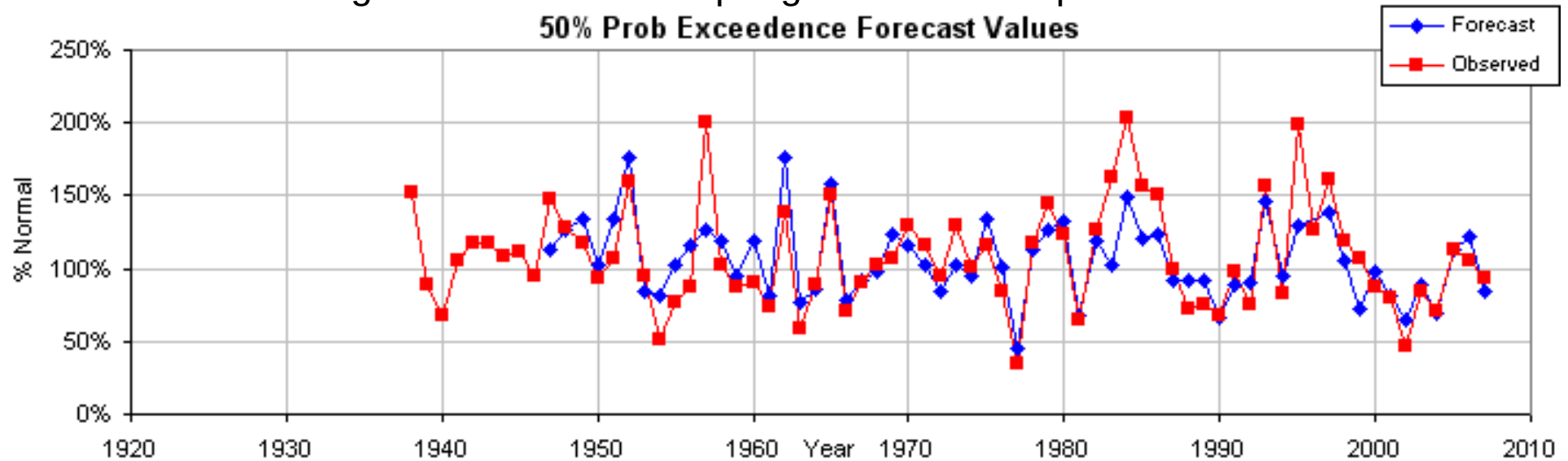
How forecasts
communicate their own skill



Courtesy: Tom Pagano - NRCS

A water manager interested in a single river
probably wants to know typical forecast error

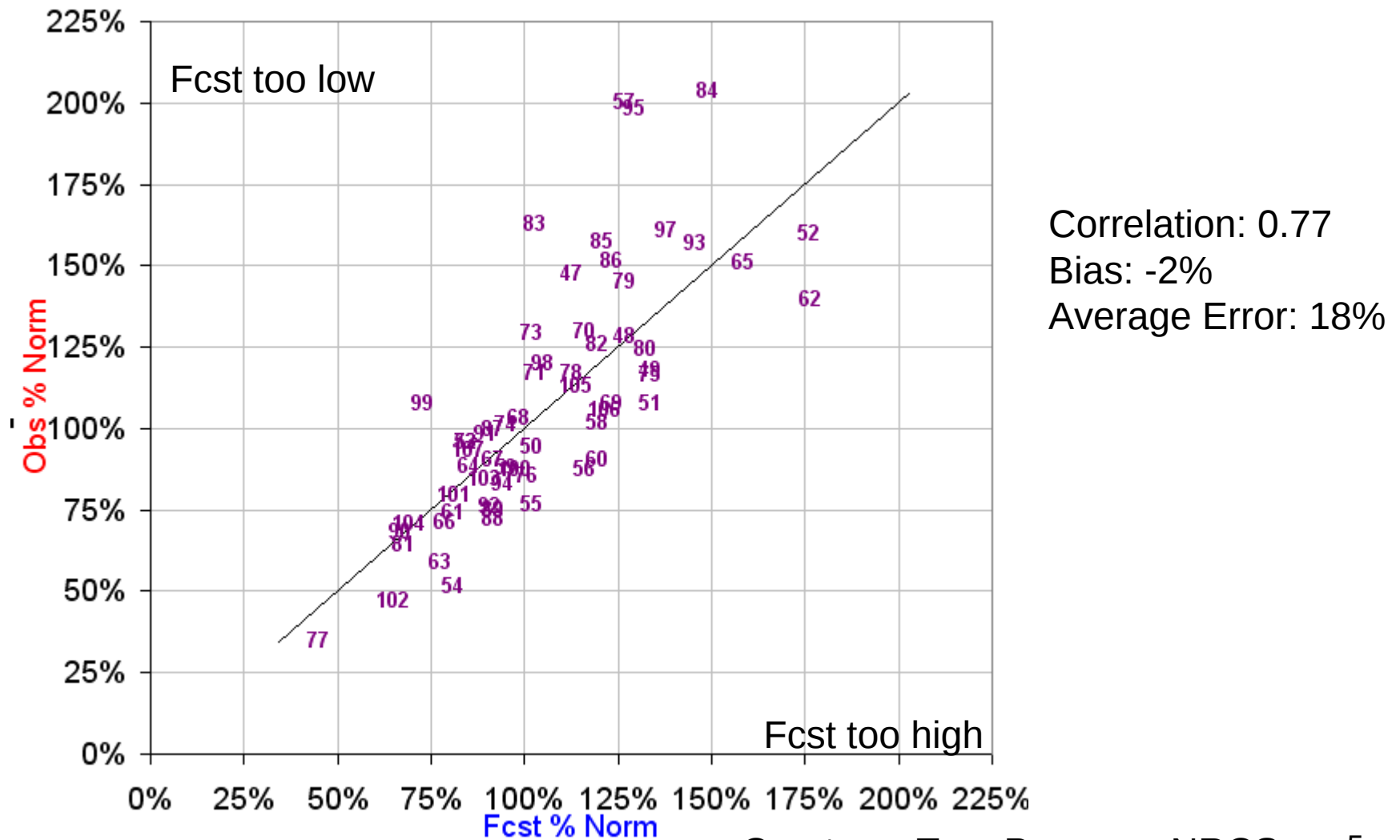
Roaring fork at Glenwood Springs 1947-2007 April 1 Forecasts



Courtesy: Tom Pagano - NRCS

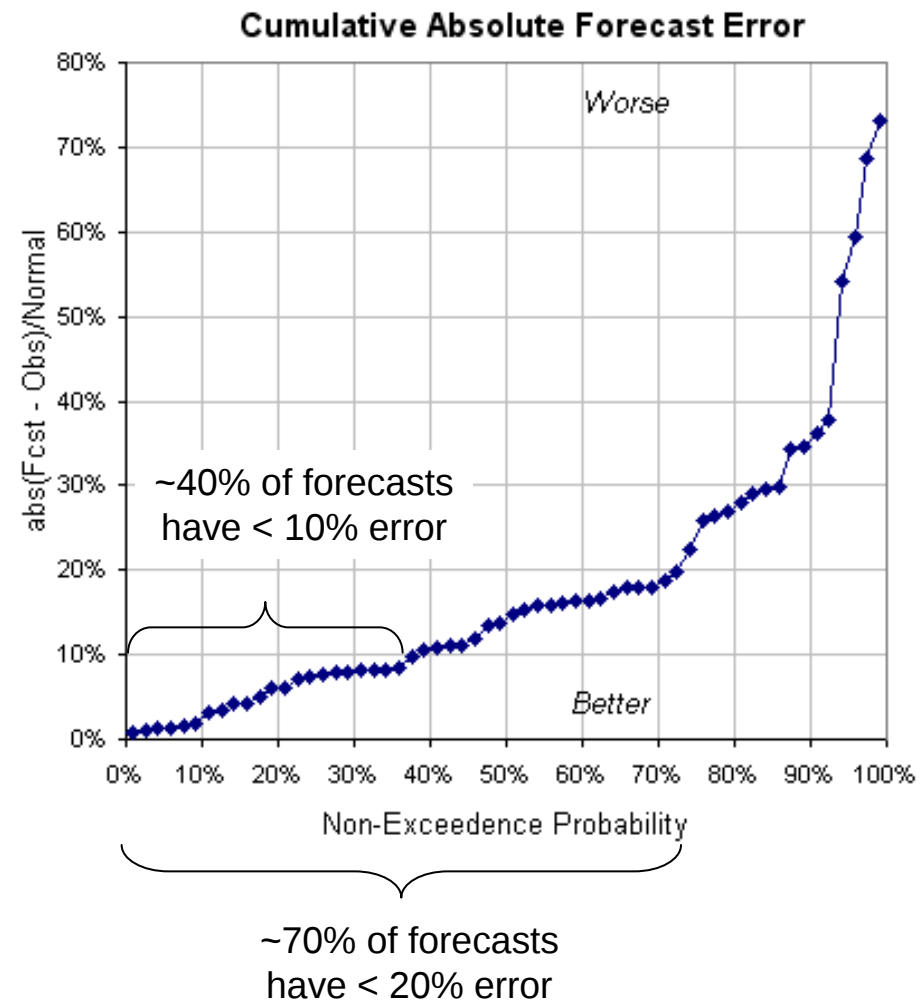
A water manager interested in a single river probably wants to know typical forecast error

Roaring fork at Glenwood Springs 1947-2007 April 1 Forecasts



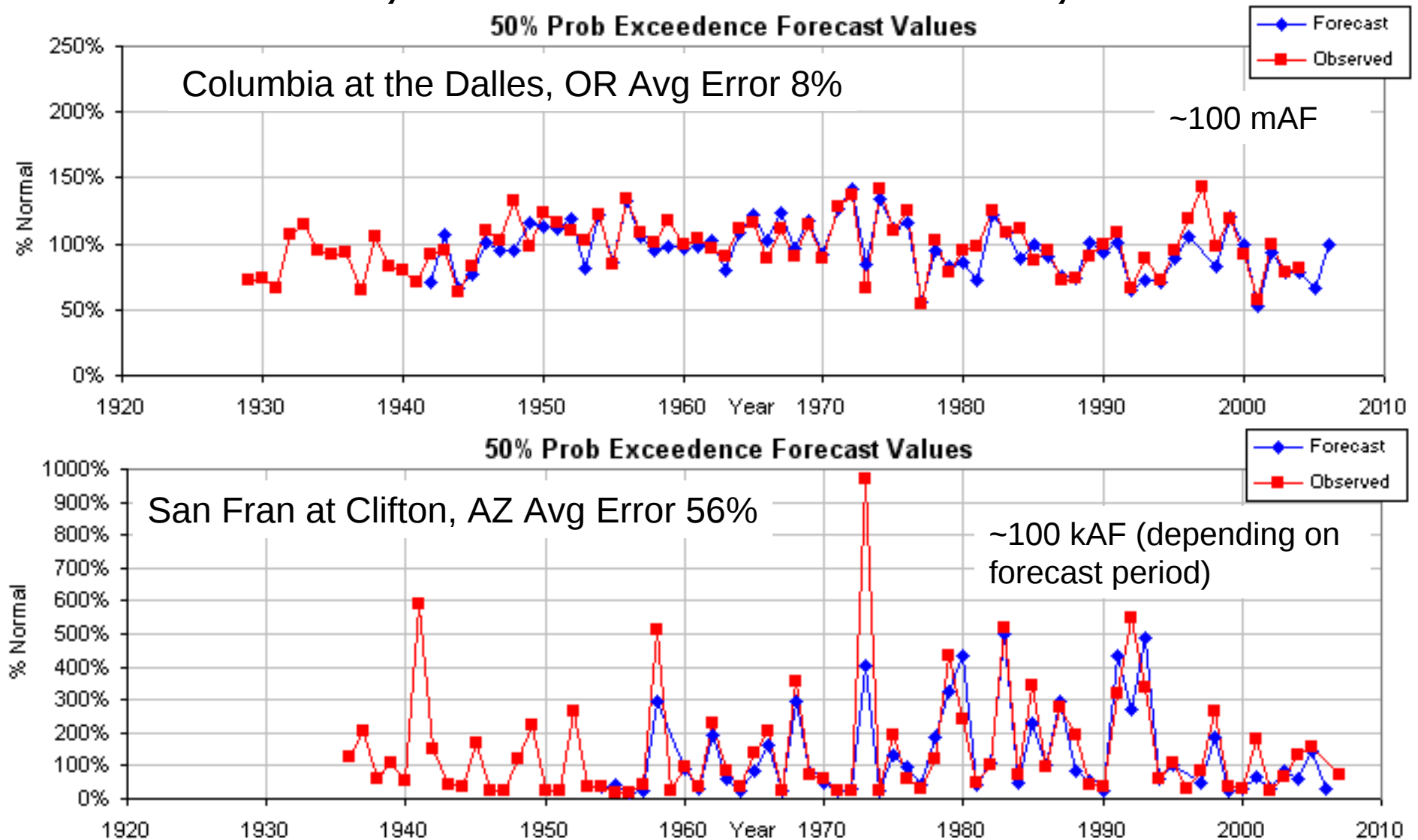
Courtesy: Tom Pagano - NRCS

Roaring Fork at Glenwood Springs 1947-2007 April 1 Forecasts



Courtesy: Tom Pagano - NRCS

However, percent of normal error is mostly determined by observed streamflow variability.



Small, variable streams have relatively more error than large ones

Basic patterns:

Snowmelt-dominated areas do best

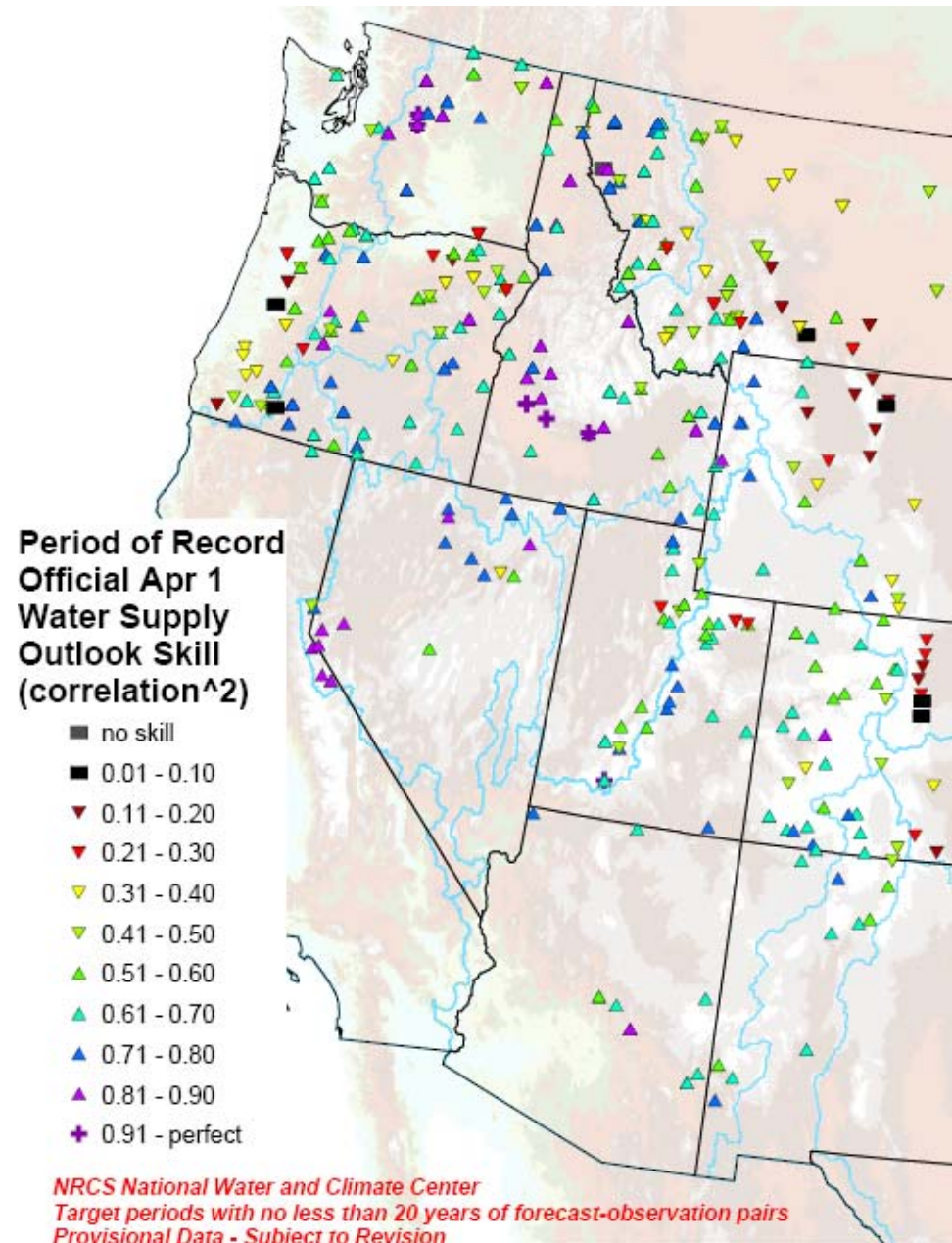
Forecasts improve with leadtime

Spring rainfall areas do poorly

Complex geology an issue

Unaccounted diversions a pain

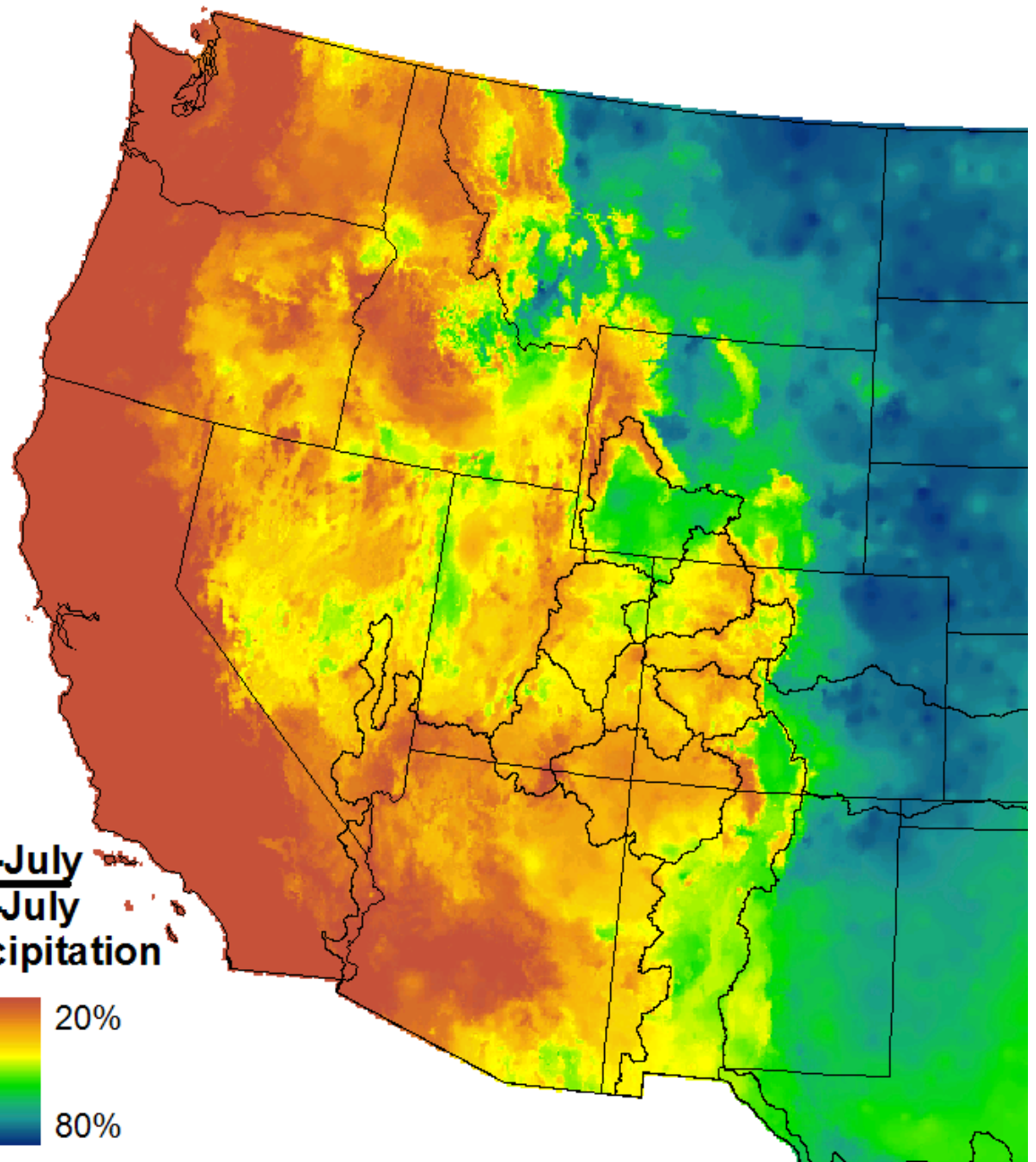
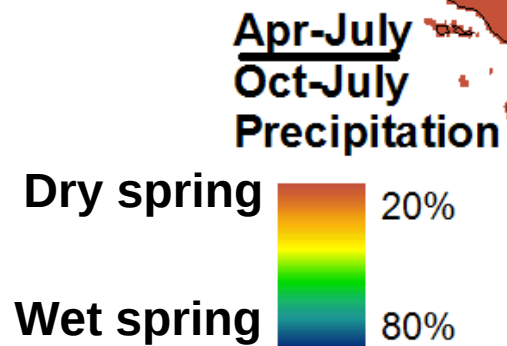
Some places just a data mess



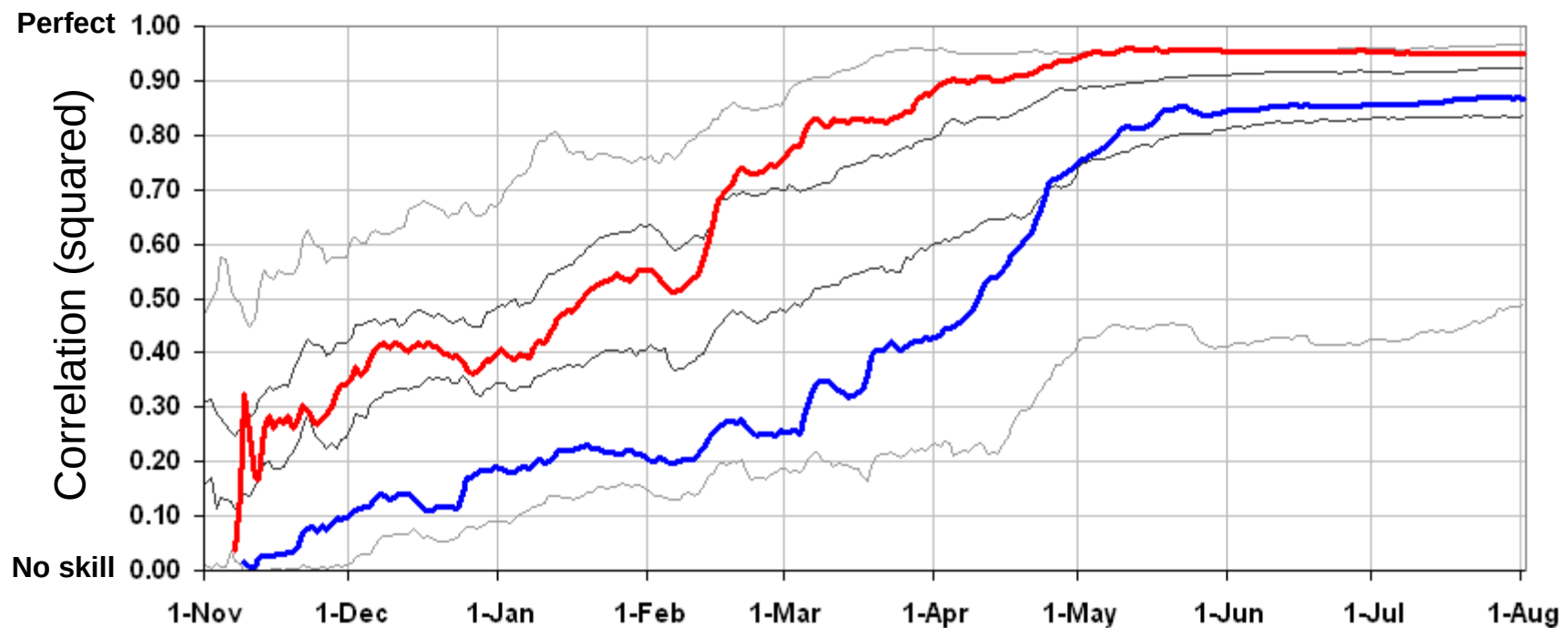
Courtesy: Tom Pagano - NRCS

**Most east-slope
basins are heavily
influenced by
spring precipitation.**

**Water supply forecasts
have unavoidably high
uncertainty because
spring precipitation
is unknown there.**



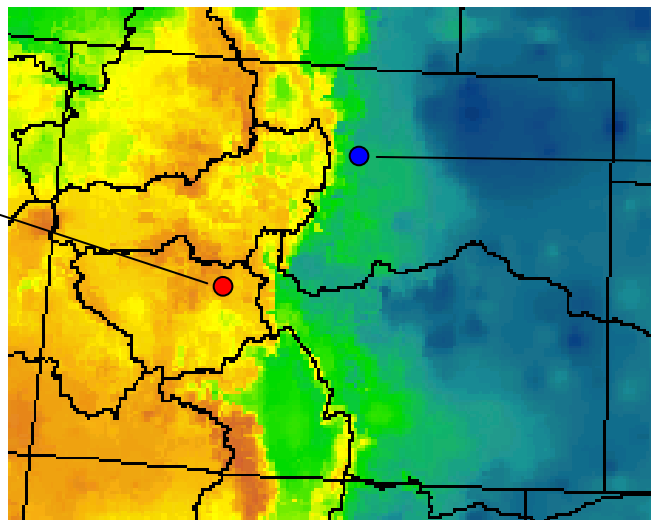
Courtesy: Tom Pagano - NRCS



East River at Almont
Winter precipitation
dominated...
High skill by April 1

Dry spring

Wet spring



Boulder Ck nr Orodell
Spring precipitation
dominated...
Low skill by April 1

Courtesy: Tom Pagano - NRCS

Incomplete historical records

Getting the right “observed”

Changes in forecast system

**Getting the right balance between
usefulness and understandability**



Incomplete historical records:

**To get a stable set of data,
you often need decades of old forecasts,
which often aren't available.**

Lake Powell Inflow Example:

1947: April 1 forecasts start (Apr-Sep target)

1947-1963: Gage moves 4 times (or is just the name changed?)

~1960: February and March 1 forecasts start

1960: Apr-July target now available

1980: January 1 forecasts start

1980's: NRCS-NWS coordination starts

NRCS digital records missing: 1981, 1985-1989, 1996

Getting the right observed:

**But this is just comparing “today’s” version of the observed.
The old forecasters could’ve been shooting at a different target.**

Types of streamflow:

**Observed
Actual
Modified
Unregulated/Regulated
Adjusted/Unadjusted
Natural
“Lewis and Clark” flow**

Types of adjustments:

**Reservoir storage
Diversions
Consumptive use
Transpiration
Changing demand
Land use change
Evaporation from reservoirs
Bank storage
Surface/Groundwater interactions**

Do users even know the target of the current forecasts?

www.nwrfc.noaa.gov/westernwater/beta

NOAA/NWS Water Resource Forecasts

water supply map water supply forecasts ensemble forecast verification climate scenarios data checkout about western water

Location: No Location Selected

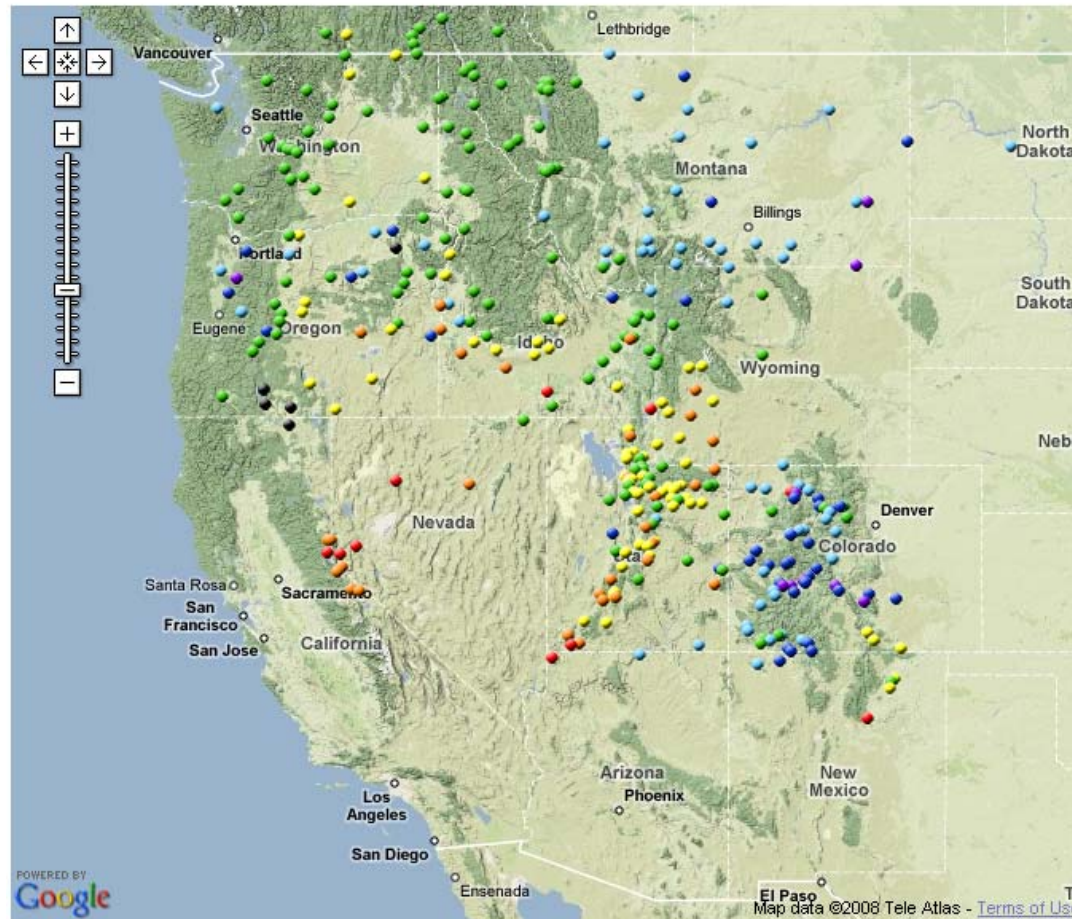
change location

clear location

Search: Go

Browse: Select State Select State First Select State First

Water Supply Forecasts Map



Options

Map Display

- ☒ Water Supply Forecast
- ☐ Water Resource Outlook
- ☐ Monthly Observed Flow
- ☐ Climate Change

Map Options

Legend

- > 150% of Normal
- 130% - 150% of Normal
- 110% - 130% of Normal
- 90% - 110% of Normal
- 70% - 90% of Normal
- 50% - 70% of Normal
- < 50% of Normal
- No Normal

Application

- Map
- Water Supply Forecasts
- Verification
- Data Checkout

Verification Capabilities

The screenshot shows the NOAA/NWS Water Resource Forecasts website. At the top is a navigation bar with links: NOAA/NWS Water Resource Forecasts, water supply map, water supply forecasts, ensemble forecast, verification, climate scenarios, data checkout, and about western water. Below this is a blue header area with the text 'Location: Invalid Location' and two buttons: 'change location' and 'clear location'. Below the header is a search area with a 'Search:' label, a text input field, and a 'Go' button. Below the search area is a 'Browse:' label followed by three dropdown menus: 'Select State', 'Select State First', and 'Select State First'. Below the browse area is a grey message box that says 'Location must be selected before verification data can be displayed'. At the bottom is a dark grey footer bar with the text 'Water Supply Forecast Application - version 2.0 (beta 1)' on the left and 'National Weather Service' on the right.

NOAA/NWS Water Resource Forecasts

water supply map water supply forecasts ensemble forecast verification climate scenarios data checkout about western water

Location: Invalid Location [change location](#) [clear location](#)

Search: Go

Browse:

Location must be selected before verification data can be displayed

Water Supply Forecast Application - version 2.0 (beta 1) National Weather Service

- Search By
 - Station ID
 - State, River, Location
- Location
 - Change
 - Clear
 - Return to main menu

Verification Capabilities

NOAA/NWS Water
Resource Forecasts

water supply
map

water supply
forecasts

ensemble
forecast

verification

climate
scenarios

data
checkout

about
western water

Location: Blue at Dillon Res, Colorado (DIRC2 - CBRFC)

change location

clear location

Seasonal Forecast Verification and Analysis

1 Select Period:

Select Period ▼

2 Select Years:

Select Period First ▼

3 Select Data Sources:

- ☒ Coordinated Forecast
- ☒ National Weather Service
- ☒ Natural Resource Conservation Service
- ☒ Statistical Water Supply
- ☒ California Department of Water Resources
- ☒ Ensemble Streamflow Prediction
- ☐ Ensemble Streamflow Prediction - Empirical
- ☐ Ensemble Streamflow Prediction - Normal
- ☐ Ensemble Streamflow Prediction - Lognormal
- ☐ Ensemble Streamflow Prediction - Wakeby
- ☐ Ensemble Streamflow Prediction - Logwiebull
- ☐ Ensemble Streamflow Prediction - Weibull
- ☐ Ensemble Streamflow Prediction - Loglogistic

Verification Capabilities

4 Select Plot Type:

- ☒ Historical
- ☐ Streamflow Histogram
- ☐ Scatterplot
- ☐ Mean Absolute Error (Lead Time)
- ☐ Mean Absolute Error (Years)
- ☐ Root Mean Squared Error (Lead Time)
- ☐ Root Mean Squared Error (Year)
- ☐ Skill Score (Lead Time)
- ☐ Skill Score (Years)
- ☐ Percent Difference
- ☐ Probability of Detection Above Threshold
- ☐ Probability of Detection Below Threshold
- ☐ False Alarm Rate Above Threshold
- ☐ False Alarm Rate Below Threshold
- ☐ Rank Histogram
- ☐ Rank Histogram (Lead Time)
- ☐ Climate Variability
- ☐ Contingency Table

Load Statistics

About Forecast Verification

Forecast verification provides meaningful information about the quality of forecasts. Verification is an important for assessing past forecast performance and providing information about current forecast confidence. The seasonal forecast verification application allows users to obtain relatively simple plots and statistics explaining past performance. The application allows the user to choose (1) a forecast period (season), (2) the forecast years, (3) forecast types, and (4) verification metric. All data supporting the plots are archived in a database and may be accessed separately through the data checkout application as well.

Site Options

Previous 5 Locations Viewed

GBYC2

Print Graph

Display Raw Data

Verification Capabilities

NOAA/NWS Water Resource Forecasts	water supply map	water supply forecasts	ensemble forecast	verification	climate scenarios	data checkout	about western water
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Location: Blue at Dillon Res, Colorado (DIRC2 - CBRFC) change location clear location

Seasonal Forecast Verification and Analysis

1 Select Period: Select Period ▼

2 Select Years: Select Period First ▼

3 Select Data Sources:

- ☒ Coordinated Forecast
- ☒ National Weather Service
- ☒ Natural Resource Conservation Service
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- ☐ Ensemble Streamflow Prediction - Weibull
- ☐ Ensemble Streamflow Prediction - Loglogistic

- Select Forecast Period
- Forecasts Available
- Climatology Available

Verification Capabilities

NOAA/NWS Water Resource Forecasts water supply map water supply forecasts ensemble forecast verification climate scenarios data checkout about western water

Location: Blue at Dillon Res, Colorado (DIRC2 - CBRFC) [change location](#) [clear location](#)

Seasonal Forecast Verification and Analysis

1 Select Period: Apr-Jul

2 Select Years:

3 Select Data Sources:

- ☒ Coordinated Forecast
- ☒ National Weather Service
- ☒ Natural Resource Conservation Service
- ☒ Statistical Water Supply
- ☒ California Department of Water Resources
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- ☐ Ensemble Streamflow Prediction - Weibull
- ☐ Ensemble Streamflow Prediction - Loglogistic

•Select Years

•Appear on Period Selection

•Select any set of years available

Verification Capabilities

NOAA/NWS Water
Resource Forecasts

water supply
map

water supply
forecasts

ensemble
forecast

verification

climate
scenarios

data
checkout

about
western water

Location: Blue at Dillon Res, Colorado (DIRC2 - CBRFC)

change location

clear location

Seasonal Forecast Verification and Analysis

1 Select Period:

Apr-Jul

2 Select Years:

2002
2003
2004
2005
2006
2007
2008

3 Select Data Sources:

- ☒ Coordinated Forecast
- ☒ National Weather Service
- ☒ Natural Resource Conservation Service
- ☒ Statistical Water Supply
- ☒ California Department of Water Resources
- ☒ Ensemble Streamflow Prediction
- ☐ Ensemble Streamflow Prediction - Empirical
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- ☐ Ensemble Streamflow Prediction - Weibull
- ☐ Ensemble Streamflow Prediction - Loglogistic

• Select Data Source

• Six Main Sources Selected by Default

• ESP option additional

Verification Capabilities

4 Select Plot Type:

- Select Plot Type
- Historical By Default

- ☒ Historical
- ☐ Streamflow Histogram
- ☐ Scatterplot
- ☐ Mean Absolute Error (Lead Time)
- ☐ Mean Absolute Error (Years)
- ☐ Root Mean Squared Error (Lead Time)
- ☐ Root Mean Squared Error (Year)
- ☐ Skill Score (Lead Time)
- ☐ Skill Score (Years)
- ☐ Percent Difference
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Site Options

Previous 5 Locations Viewed

[GBYC2](#)

Print Graph

Display Raw Data

Verification Capabilities

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•Load Statistics

Load Statistics

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- ☐ Rank Histogram (Lead Time)
- ☐ Climate Variability
- ☐ Contingency Table

- About Verification
- General description
- Changes based on Statistic to explain graph

Load Statistics

About Forecast Verification

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Previous 5 Locations Viewed

GBYC2

Print Graph

Display Raw Data

Verification Capabilities

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Load Statistics

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Site Options

Previous 5 Locations Viewed

GBYC2

Print Graph

Display Raw Data

•Previous Sites

•Remembers last 5 visited

•Go to Data Checkout

•Print Graph

Verification Capabilities

- **Plot Area**
 - Auto scroll when needed
 - Clearly labeled with legend



Verification Capabilities

- **Side Options**
 - Statistic
 - Forecast Type/Data Source
 - Time Scale
 - Threshold
 - Data Source Information
 - Graph Options



Verification Capabilities

Options

Statistic

☒ Historical

The Historical displays forecast streamflows for the selected period from all agencies and observed streamflows from past years while referencing the historical maximum, minimum, and average.

☐ MAE (Lead Time)

☐ MAE (Years)

☐ RMSE (Lead Time)

☐ RMSE (Year)

☐ Skill Score (Lead Time)

☐ Skill Score (Years)

☐ Percent Difference

☐ POD Above Threshold

☐ POD Below Threshold

☐ FAR Above Threshold

☐ FAR Below Threshold

☐ Rank Histogram

☐ Rank Histogram (Lead Time)

☐ Climate Variability

☐ Contingency Table

Data Sources

Time Scale

Threshold

Data Source Information

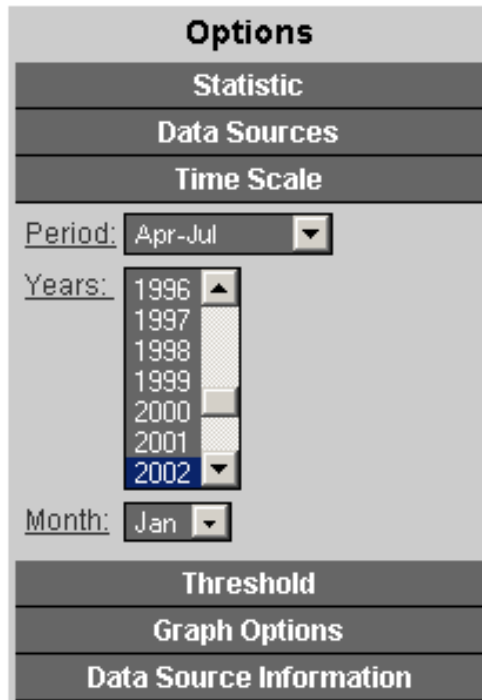
- **Statistic**
 - 18 Statistic choices
 - Graph change on click
 - Mouse-over displays info about graph
- **Group Titles**
 - Mouse and click to display other options

Verification Capabilities

Options
Statistic
Data Sources
☒ <u>Coordinated Forecast</u>
☒ <u>National Weather Service</u>
☒ <u>Natural Resource</u>
<u>Conservation Service</u>
☒ <u>Statistical Water Supply</u>
☒ <u>California Department of Water</u>
<u>Resources</u>
☒ <u>Ensemble Streamflow</u>
<u>Prediction</u>
☐ <u>Ensemble Streamflow</u>
<u>Prediction - Empirical</u>
☐ <u>Ensemble Streamflow</u>
<u>Prediction - Normal</u>
☐ <u>Ensemble Streamflow</u>
<u>Prediction - Lognormal</u>
☐ <u>Ensemble Streamflow</u>
<u>Prediction - Wakeby</u>
☐ <u>Ensemble Streamflow</u>
<u>Prediction - Logwiebull</u>
☐ <u>Ensemble Streamflow</u>
<u>Prediction - Weibull</u>
☐ <u>Ensemble Streamflow</u>
<u>Prediction - Loglogistic</u>
Time Scale
Threshold
Data Source Information

- **Forecast Type**
 - Change Data Sources to be displayed
 - Graph change on click

Verification Capabilities



The screenshot shows a software interface with a menu titled "Options". The menu is expanded, showing several options: "Statistic", "Data Sources", "Time Scale", "Threshold", "Graph Options", and "Data Source Information". The "Time Scale" option is selected, and its sub-menu is visible. It contains three main sections: "Period:", "Years:", and "Month:". The "Period:" section has a dropdown menu showing "Apr-Jul". The "Years:" section has a list of years from 1996 to 2002, with 2002 selected. The "Month:" section has a dropdown menu showing "Jan".

Options	
Statistic	
Data Sources	
Time Scale	
Period:	Apr-Jul
Years:	1996 1997 1998 1999 2000 2001 2002
Month:	Jan
Threshold	
Graph Options	
Data Source Information	

- **Time Scale**
 - Change Period
 - Modify Years
 - Graph change on click
 - Month
 - Only displayed when Contingency Table Statistic is chosen
 - Change the month the table displays

Verification Capabilities

Options	
Statistic	
Data Sources	
Time Scale	
Threshold	
Threshold Value:	mean (KAF)
Data Source Information	

- **Threshold**
 - Default is Climatology / Historical Average
 - Enter value in KAF and press enter
 - Type 'mean' to return to default
 - Valid option for all but Rank Histogram statistic options.
 - Graph change on 'Enter'

Verification Capabilities

Options	
Statistic	
Data Sources	
Time Scale	
Threshold	
Data Source Information	
COORD	100%
NWS	60%
NRCS	60%
SWS	60%
CADWR	0%
ESP	56.7%

- **Data Source Information**
 - Calculated the percent of forecasts available
 - Keep in mind; can skew thoughts about statistics

Example

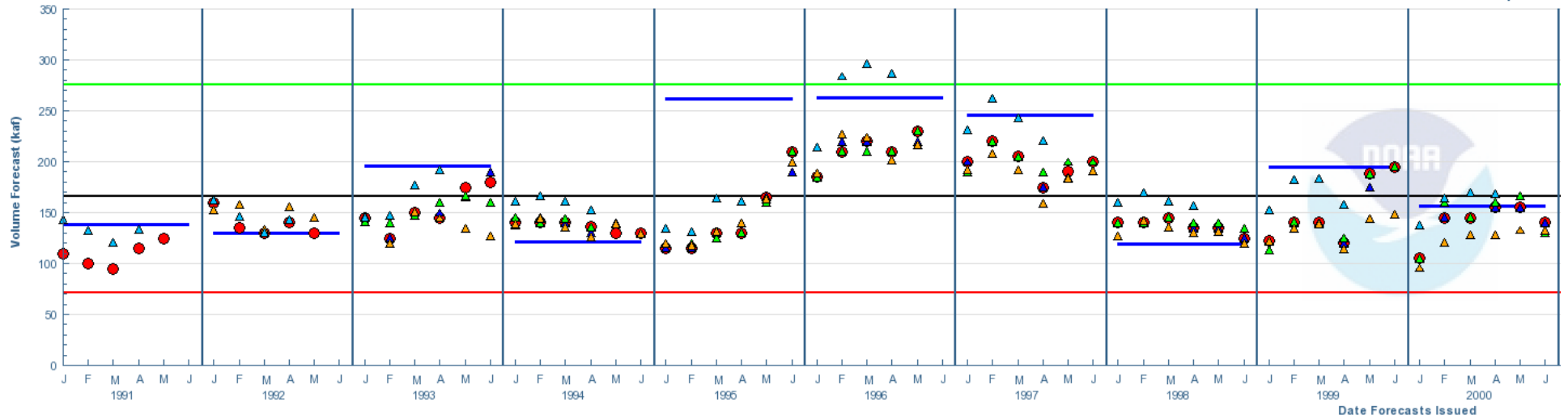
DIRC2

1991 – 2008 Forecast Available

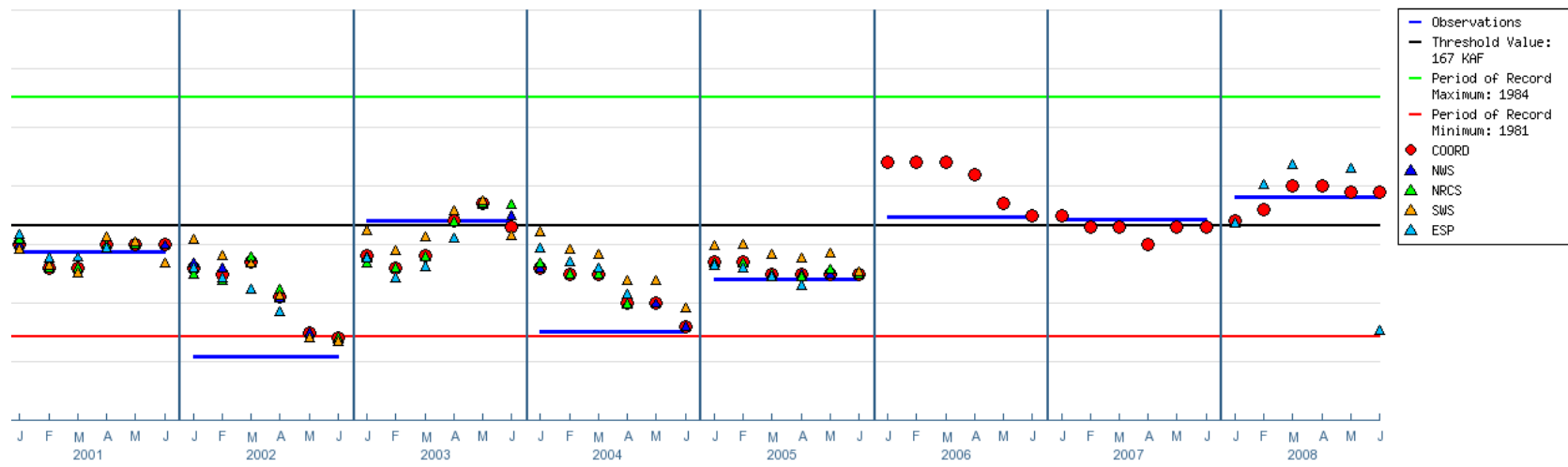
Historical

Historical - BLUE - DILLON RES

Forecast Period: Apr - Jul

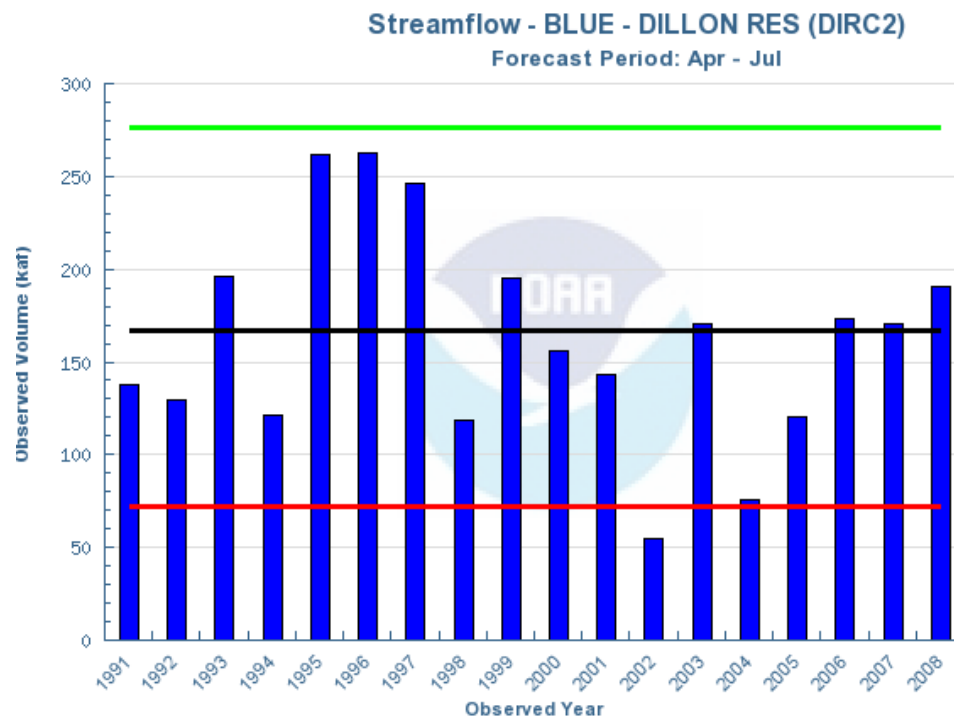


(DIRC2)



UT

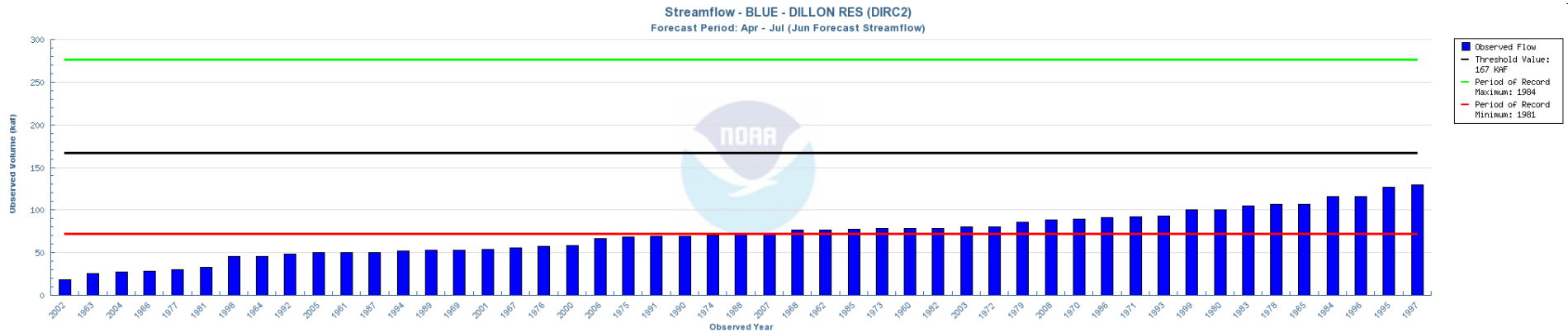
Streamflow Histogram



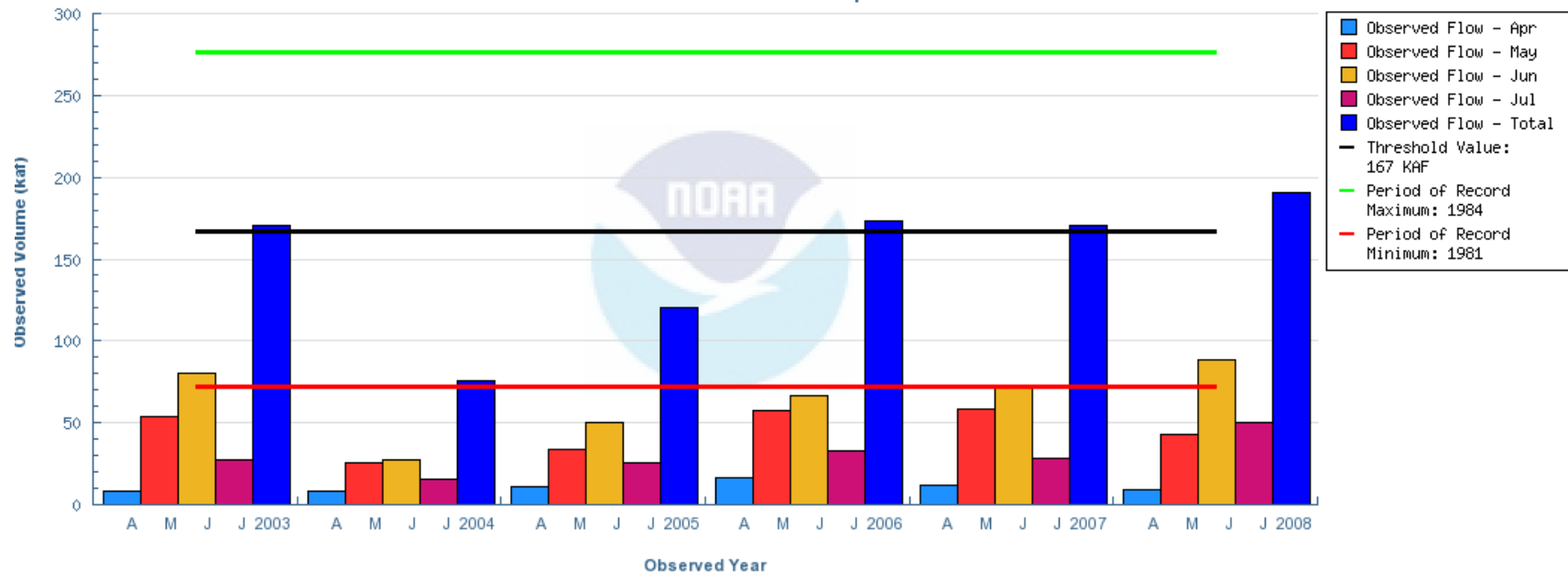
Options	
Statistic	
Data Sources	
Time Scale	
Threshold	
Graph Options	
Sortable:	Unsort
Years:	Selected
Months:	Sum
Data Source Information	

- **Graph Options**
 - Any Combination of Options
 - Sort/Unsort Years
 - Display selected Years or All Observed Years
 - Display Summed Months
 - Individual Months
 - Each Month and Summed

Streamflow Histogram

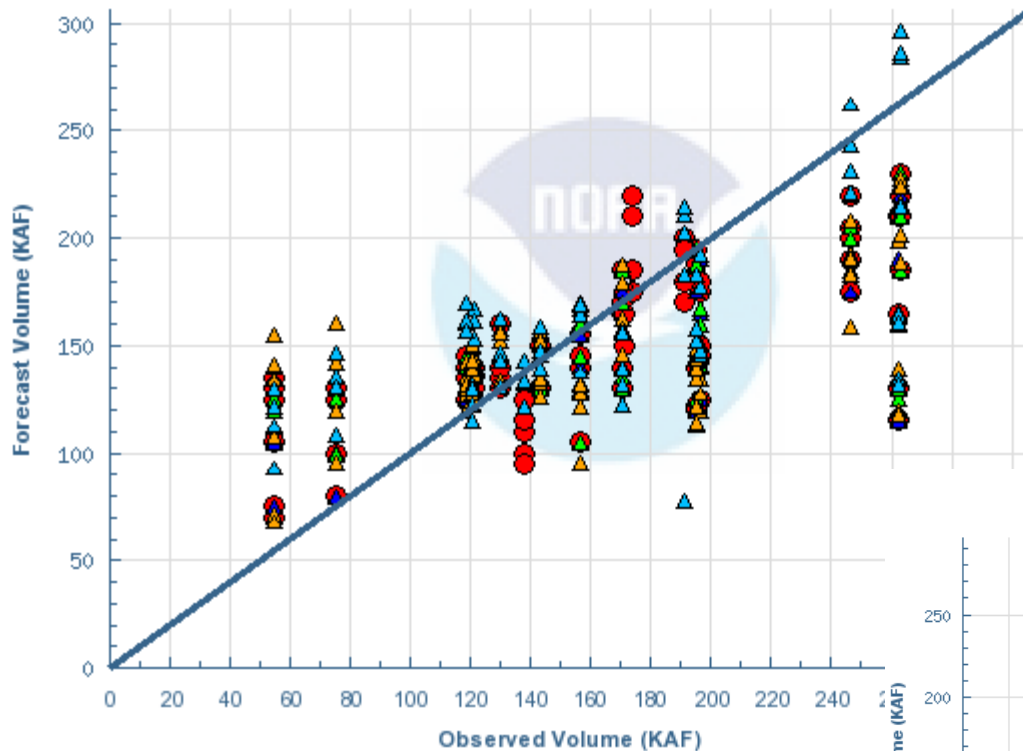


Streamflow - BLUE - DILLON RES (DIRC2)
Forecast Period: Apr - Jul



Scatterplot

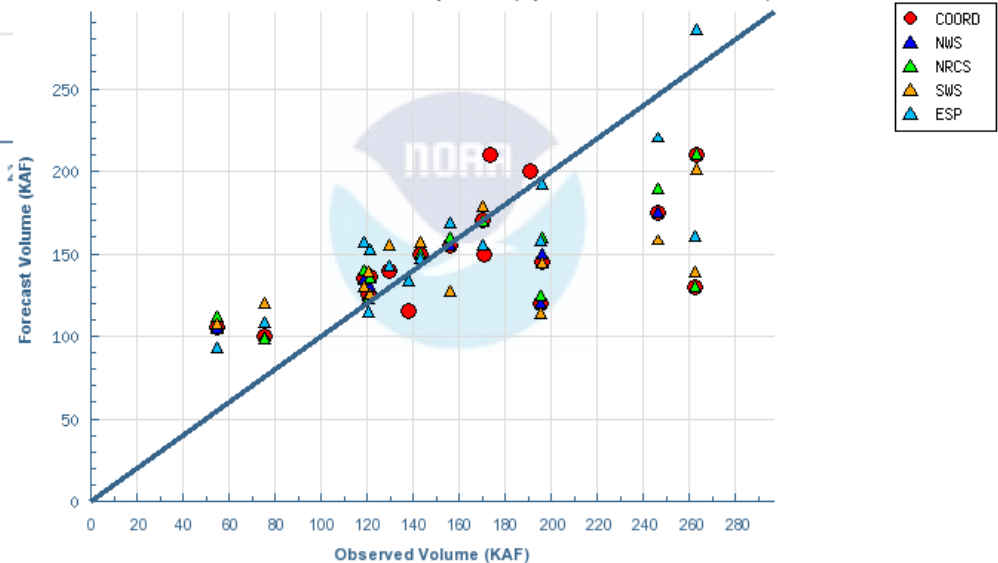
Streamflow - BLUE - DILLON RES (DIRC2)
Forecast Period: Apr - Jul



Options	
Statistic	
Data Sources	
Time Scale	
Threshold	
Graph Options	
Months:	All
Data Source Information	

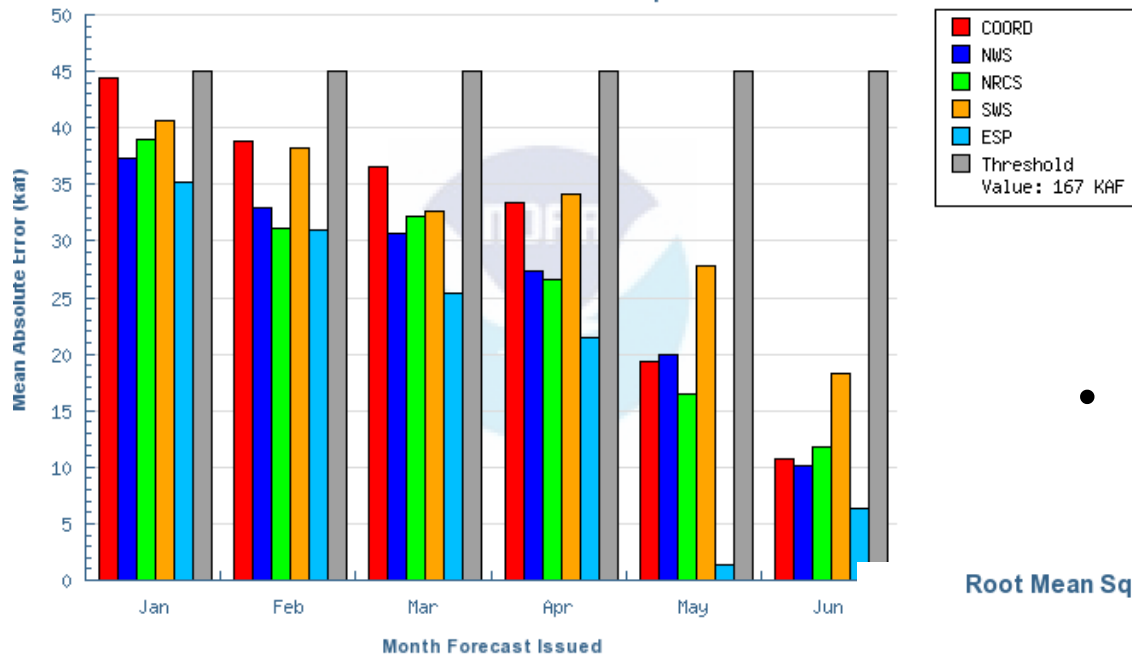
- **Graph Options**
 - Display All Months or Specific forecast Month

Streamflow - BLUE - DILLON RES (DIRC2)
Forecast Period: Apr - Jul (Apr Forecast Streamflow)



Error and Skill By Lead Time

Mean Absolute Error - BLUE - DILLON RES (DIRC2)
Forecast Period: Apr - Jul



Options

Statistic

Data Sources

Time Scale

Threshold

Graph Options

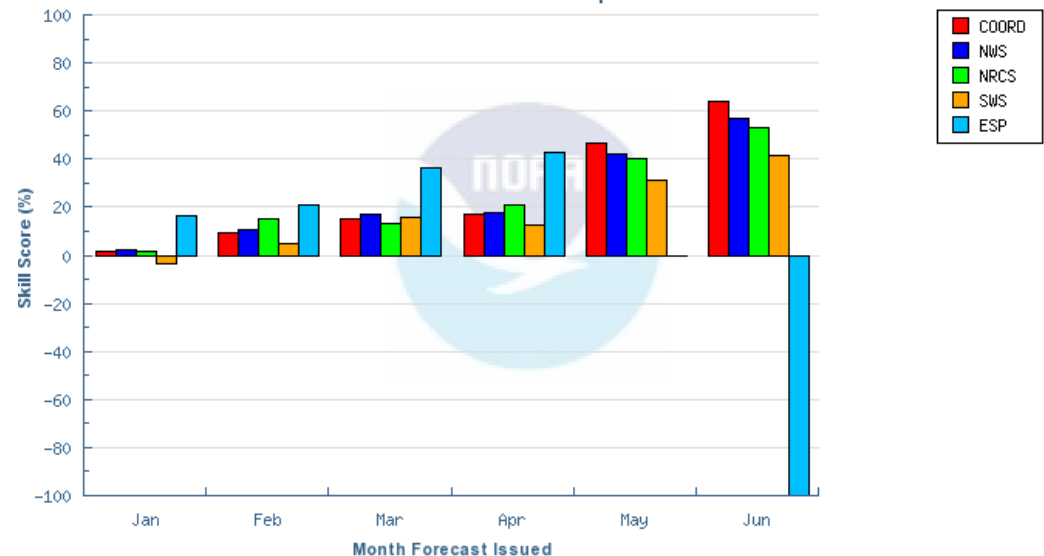
Years:

Data Source Information

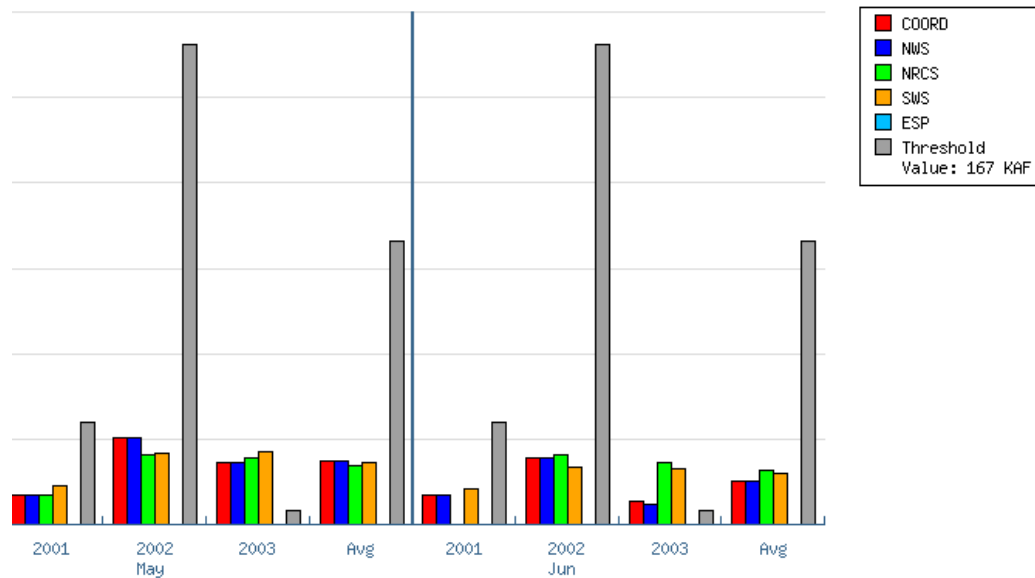
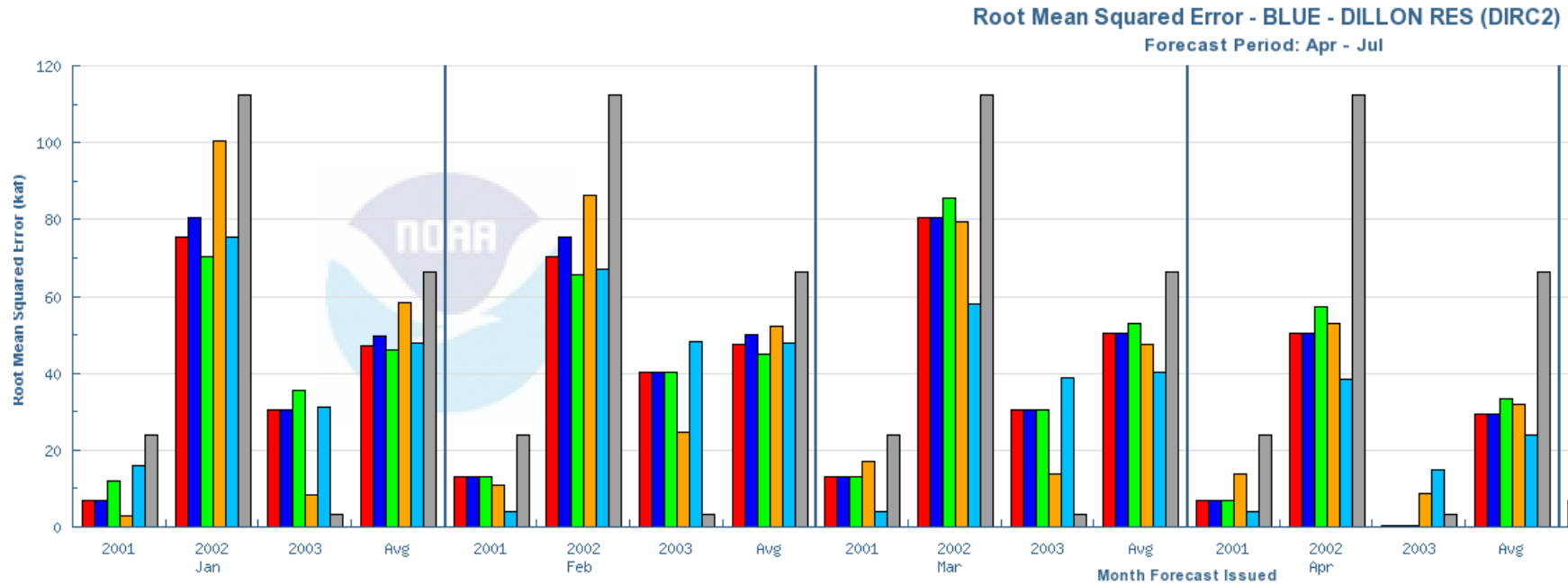
- **Graph Options**
 - Display/Undisplay years within the months

- Comparison of forecast error to “average” error useful diagnostic tool

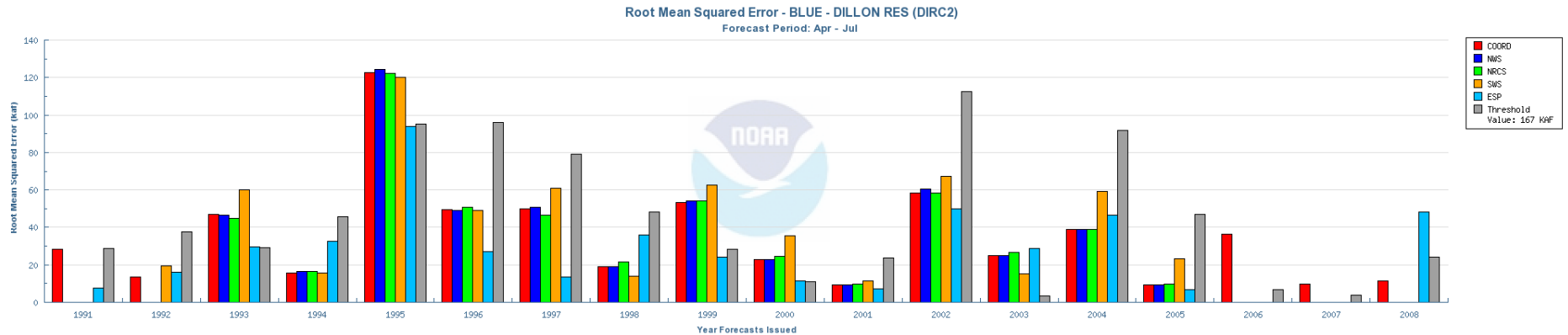
Root Mean Squared Error Skill Score Relative to Threshold - 167 KAF
BLUE - DILLON RES (DIRC2)
Forecast Period: Apr - Jul



Error and Skill By Lead Time



Error and Skill By Year



Options

Statistic

Data Sources

Time Scale

Threshold

Graph Options

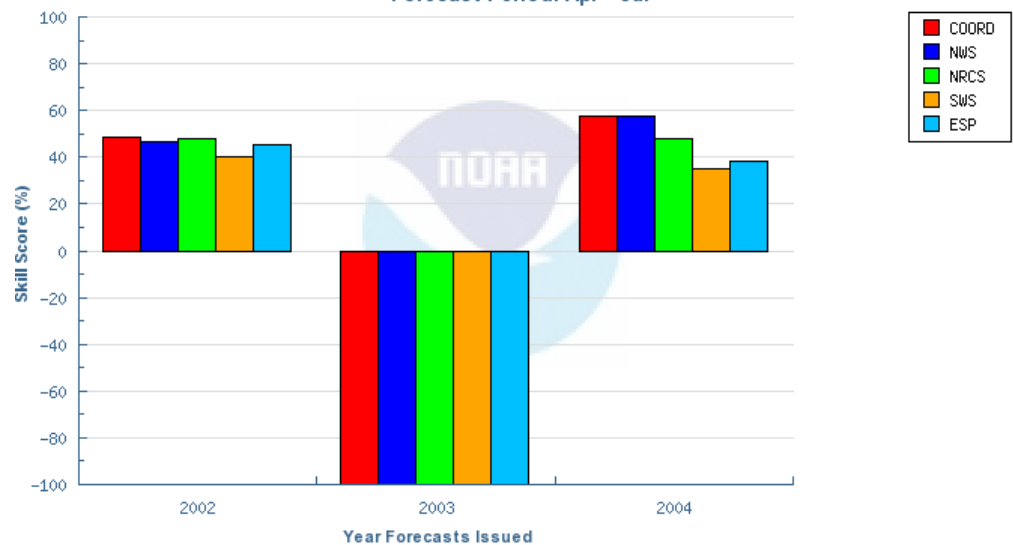
Months: Undisplay

Data Source Information

- Graph Options**

- Display All Months or Specific forecast Month

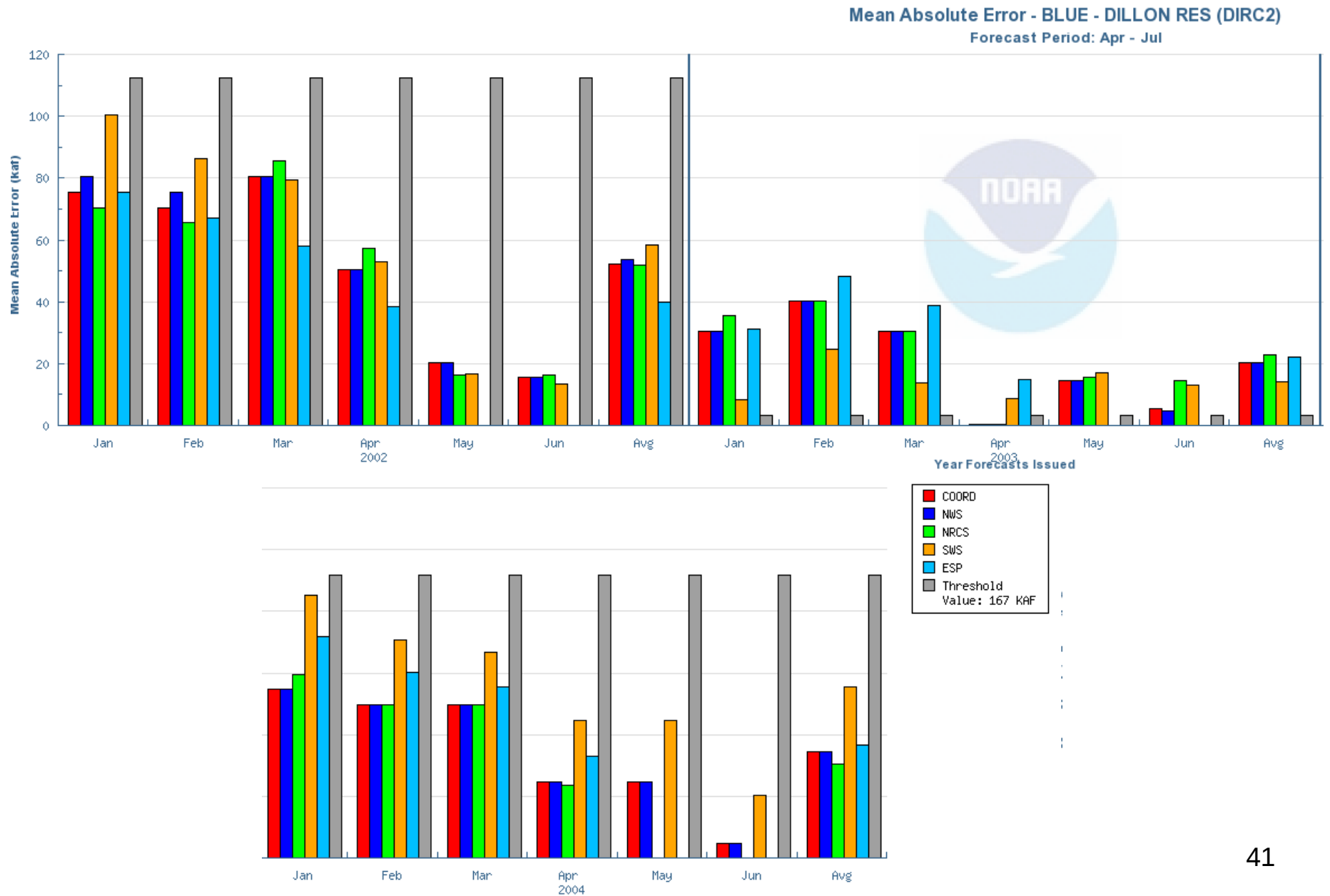
Root Mean Squared Error Skill Score Relative to Threshold - 167 KAF
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Forecast Period: Apr - Jul



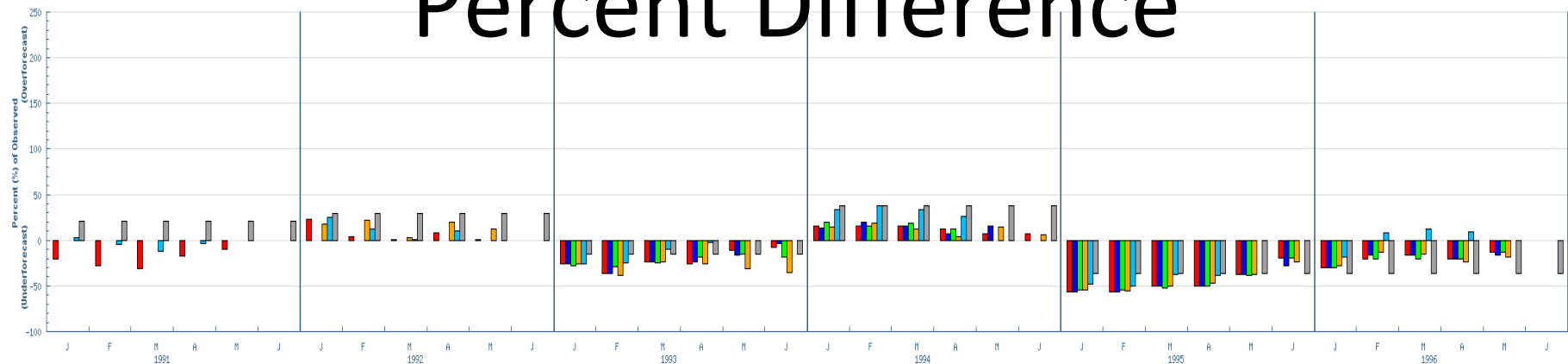
- Warning**

- SS can be miss leading when observed close to threshold (2003)

Error and Skill By Year

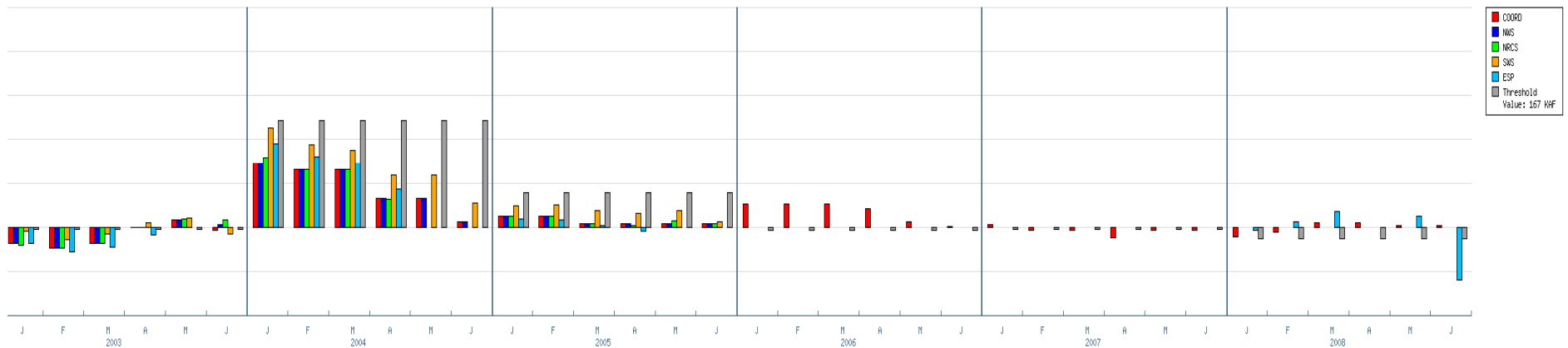
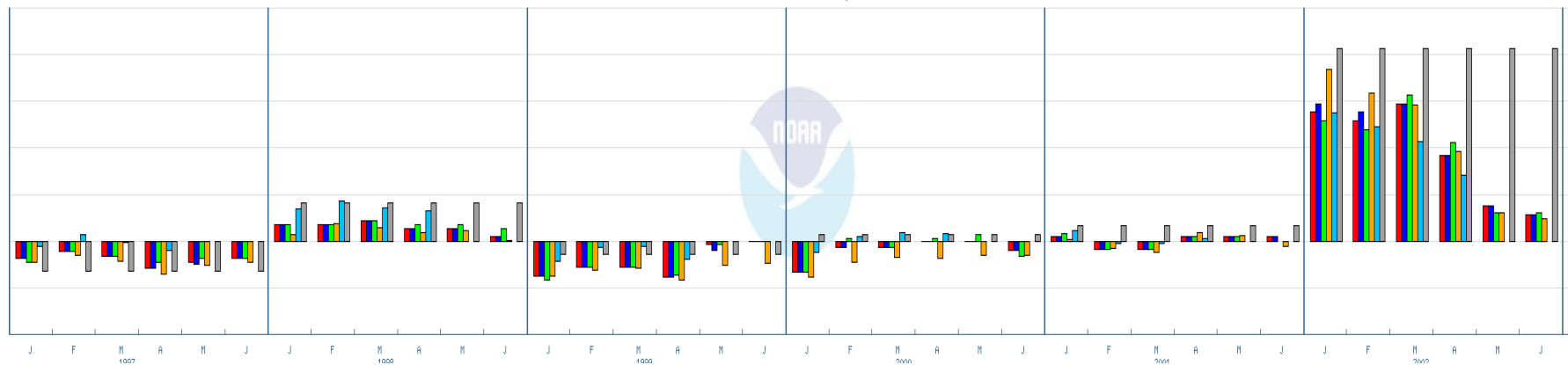


Percent Difference



BLUE - DILLON RES (DIRC2)

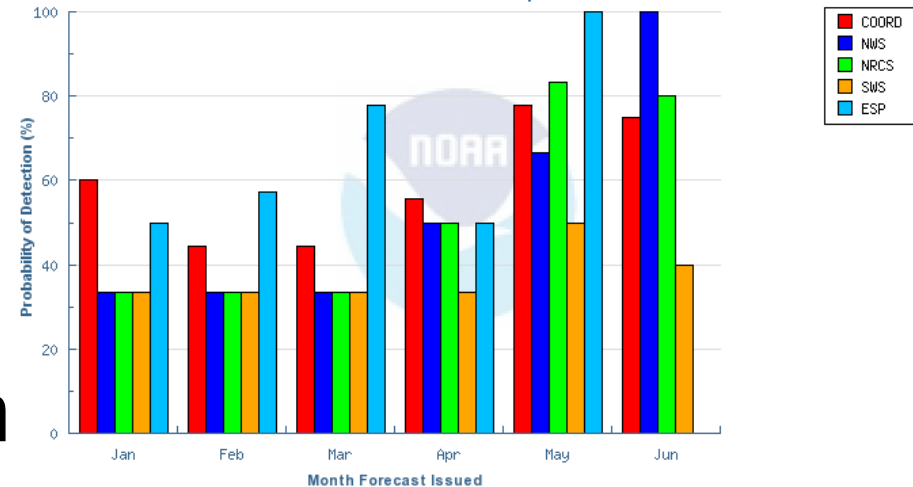
Forecast Period: Apr - Jul



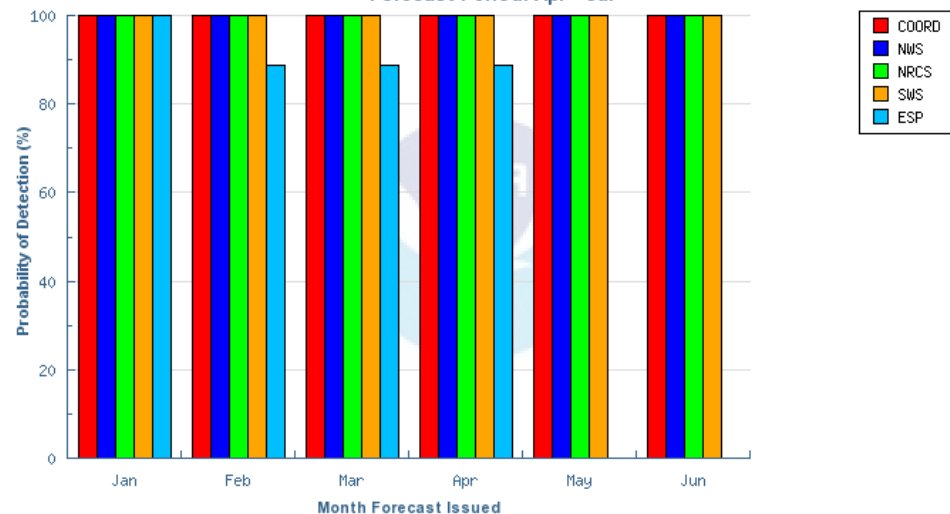
Probability of Detection

- High years much for difficult to detect in the early season
- All forecasts during low years have been for low volumes

Probability of Detection - BLUE - DILLON RES (DIRC2)
Volumes Above Threshold - 167 KAF
Forecast Period: Apr - Jul



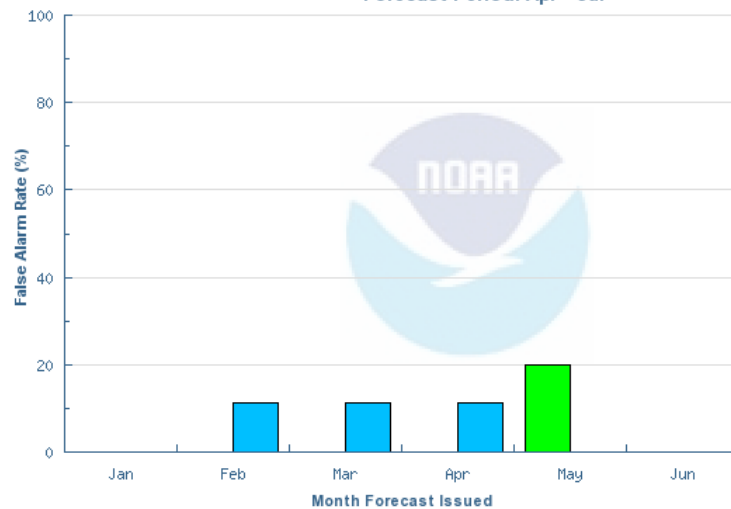
Probability of Detection - BLUE - DILLON RES (DIRC2)
Volumes Below Threshold - 167 KAF
Forecast Period: Apr - Jul



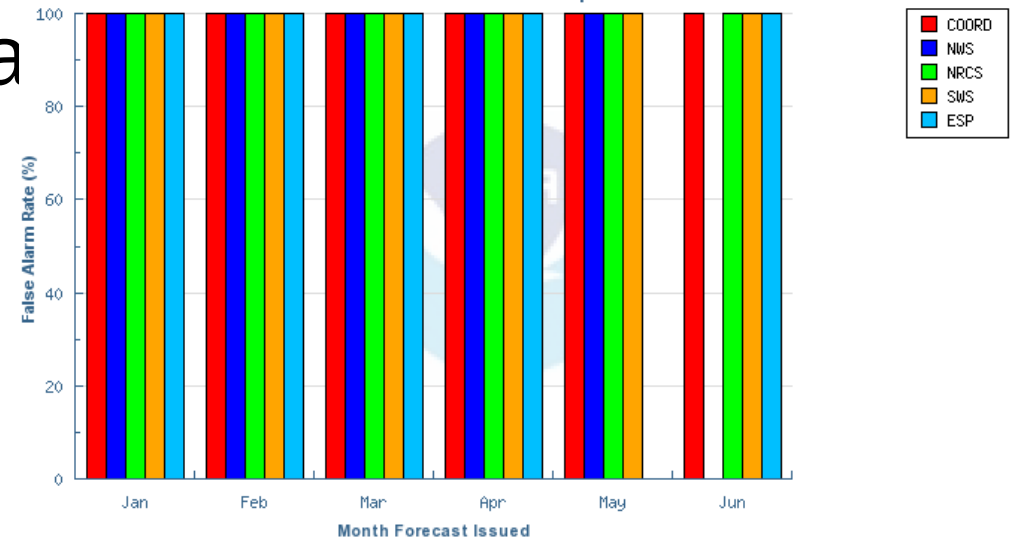
False Alarm Rate

- Similar story here a with POD

False Alarm Rate - BLUE - DILLON RES (DIRC2)
Forecasts Below Threshold - 167 KAF
Forecast Period: Apr - Jul

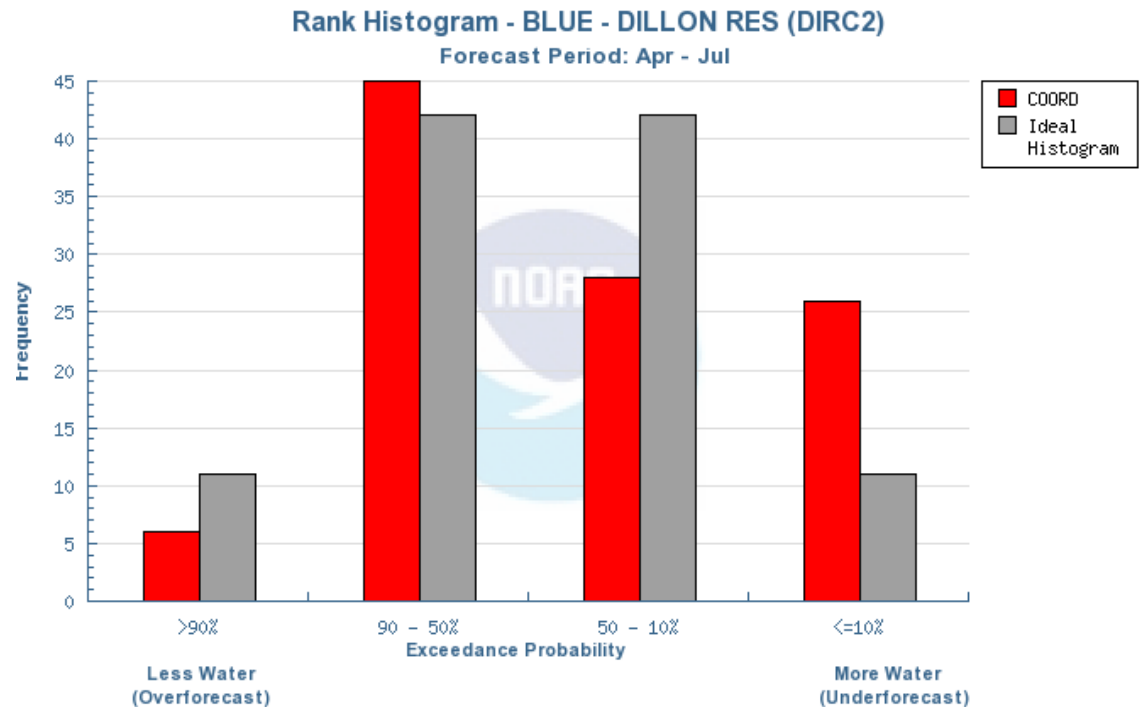


False Alarm Rate - BLUE - DILLON RES (DIRC2)
Forecasts Above Threshold - 167 KAF
Forecast Period: Apr - Jul

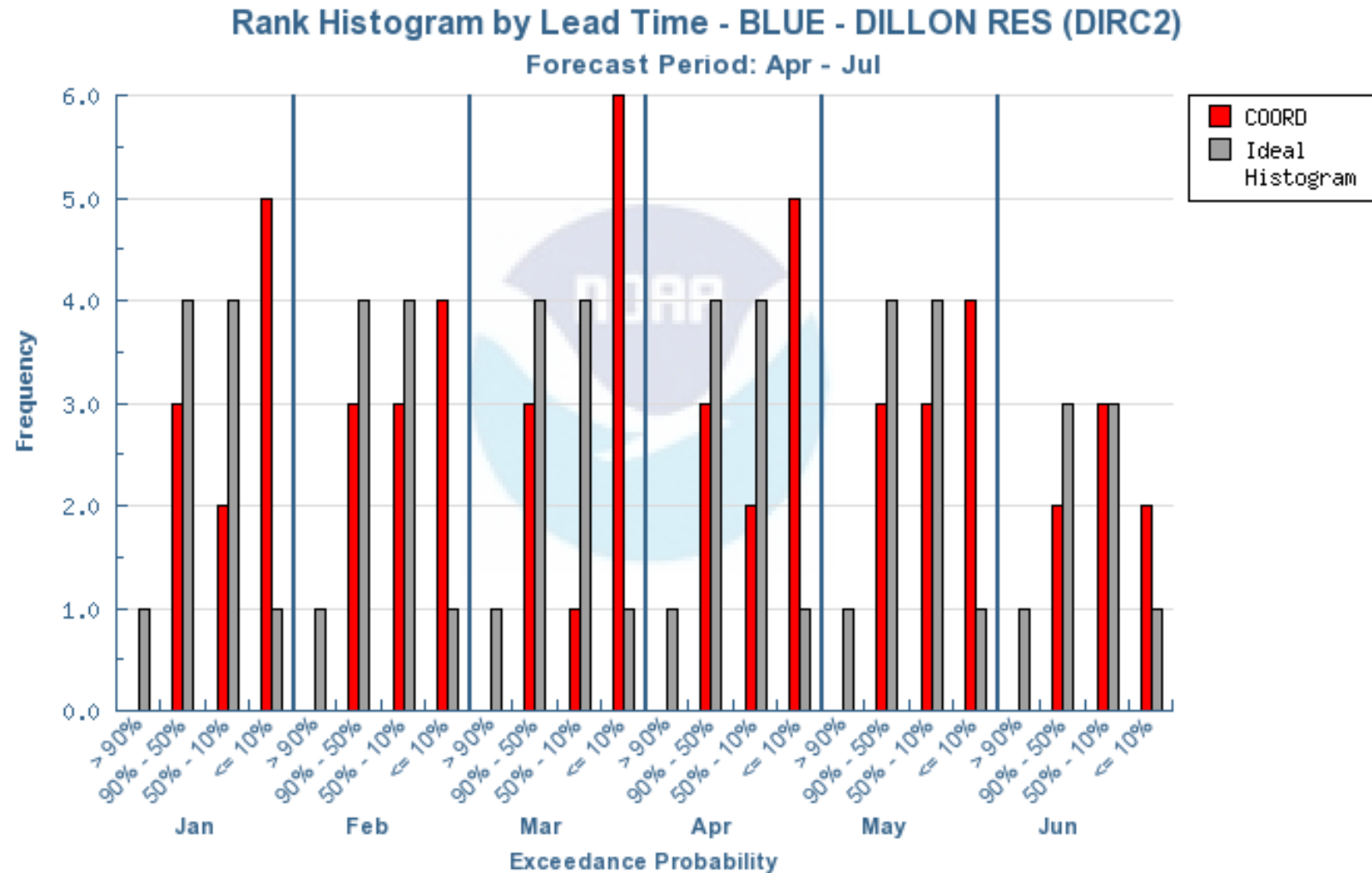


Forecast Distribution

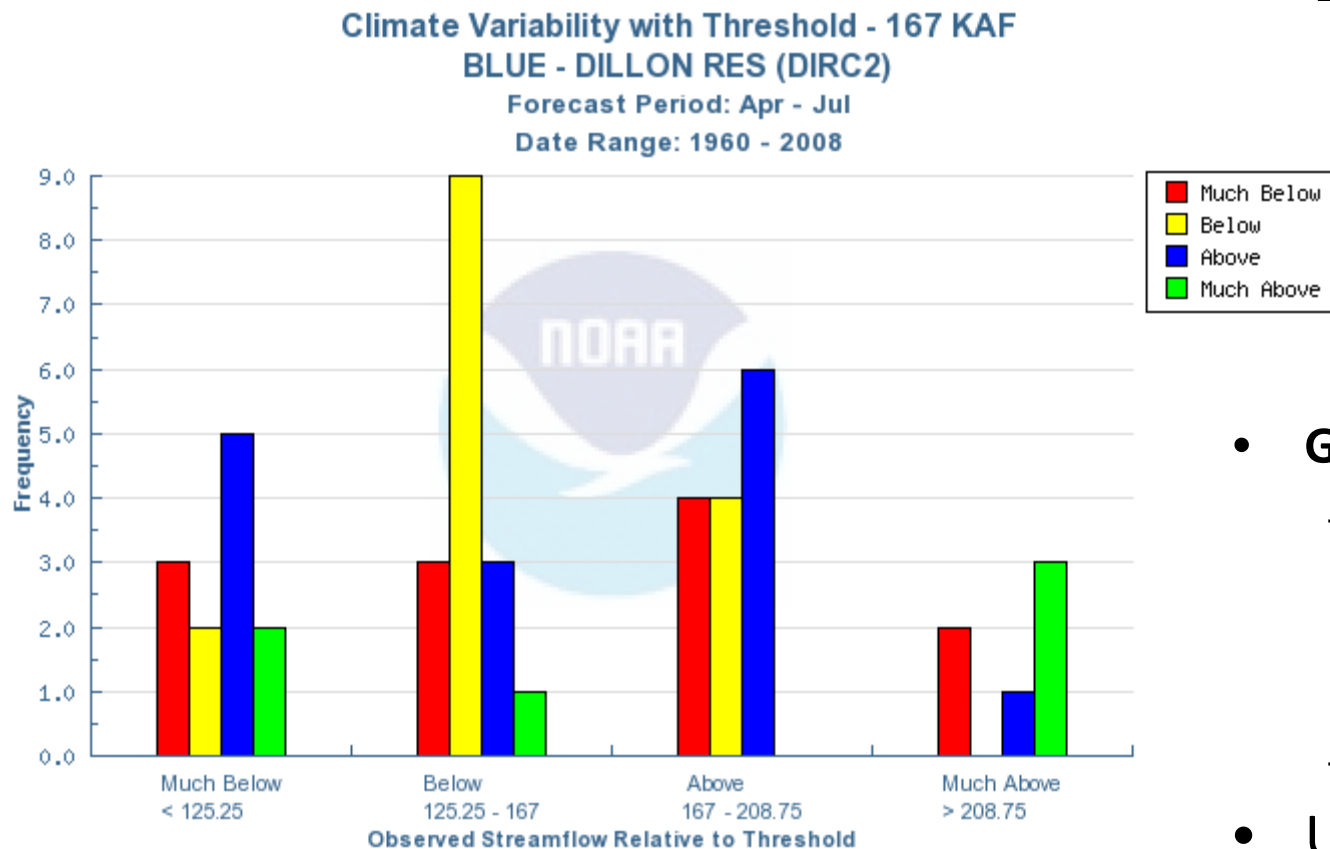
- Some tendency to underforecast
- 26% of observed streamflow falls above the 10% exceedance forecast value
- Reasonable max not so reasonable
- Results very dependent on years selected



Forecast Uncertainty by month



Observed Lag-1 Analysis Climate Variability



Options	
Statistic	
Data Sources	
Time Scale	
Threshold	
Graph Options	
Percent:	25
Data Source Information	

- **Graph Options**
 - Select the percentage to adjust the categories
 - 25% Default
- Uses all observed years in database

Contingency Table

Contingency Table for Jan with Threshold - 167 KAF
BLUE - DILLON RES (DIRC2)

COORD NWS NRCS SWS ESP		Observed Streamflow			
		Much Below < 125.25 KAF	Below 125.25 - 167 KAF	Above 167 - 208.75 KAF	Much Above > 208.75 KAF
Forecast Streamflow	Much Below < 125.25 KAF	2002	1991 2000 2000 2000 2000	1999 1999 1999 1999	1995 1995 1995 1995
	Below 125.25 - 167 KAF	1994 1998 2002 2004 2005 1994 1998 2002 2004 2005 1994 1998 2004 2005 1994 1998 2002 2004 2005 1994 1998 2002 2004 2005	1992 2001 2001 2001 1992 2001 1991 1992 2000 2001	1993 2003 1993 2003 1993 2003 1993 2003 1993 1999 2003	1995
	Above 167 - 208.75 KAF			2007 2008 2008	1996 1997 1996 1997 1996 1997 1996 1997
	Much Above > 208.75 KAF			2006	1996 1997

Options	
Statistic	
Data Sources	
Time Scale	
Threshold	
Graph Options	
Percent:	25
Data Source Information	

- **Graph Options**
 - Select the percentage to adjust the categories
 - 25% Default
 - Month Displayed January by default