



A Scalable Methodology for a Frequently Updated Seasonal and Sub-Seasonal Temperature Forecast System

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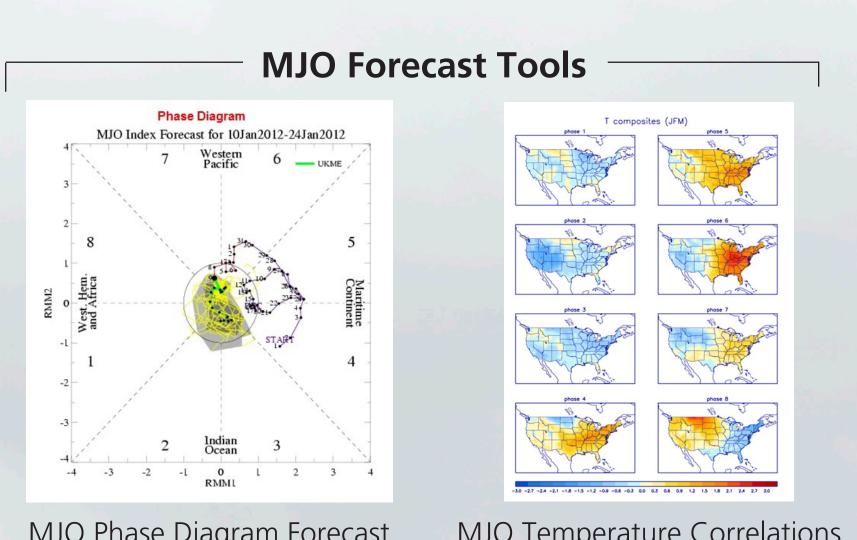
Introduction

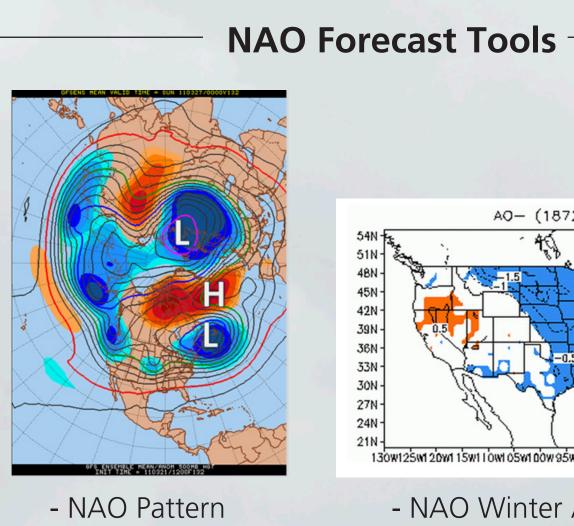
Seasonal and sub-seasonal climate forecasts have value in certain industries where there is a combination of climate predictability, user response and decision capacity to initiate that response. A skillful climate forecast reduces the uncertainty of possible outcomes for the upcoming season(s) relative to the normal climatological distribution. Much of the skill in extended range forecasts has come from extensive research that has been conducted since the late 1990's related to ENSO and its global impacts. The anticipated phase of ENSO determines the base state of the atmosphere that is forecast to prevail for the upcoming season or two. A wide array of ENSO models are available that capture a range of possible solutions to its evolution with skill extending out around six months. While the use of ENSO analogs and impacts provide useful relationships about the general character of the season, there is often variability on timescales of one to several weeks that can lead to significant fluctuations and at times deviations from the prevailing base state. Continuous monitoring of these sub-seasonal patterns is necessary to add value to the seasonal forecast in the 10-30 day forecast timeframe. Timely updating of forecasts to reflect evolving sub-seasonal patterns adds value and allows users to take action on a response during critical times of the year.

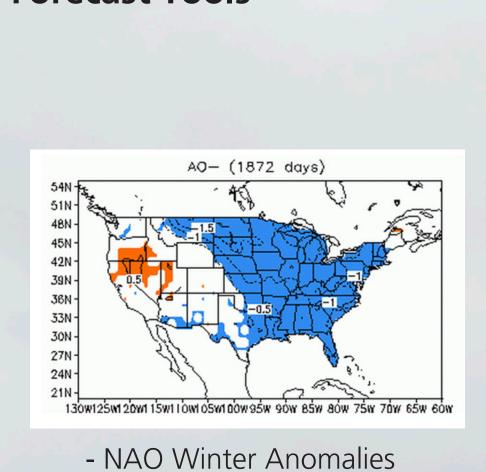
Introducing input from the various forecast sources into a final derived product that can be utilized for decision making can be a complex process due to the widely varying format of the forecast tool's output. A forecast system that allows for timely and efficient updating of seasonal forecast parameters utilizing the diverse methods, tools and datasets has been in use for several years at Telvent and will be outlined in this presentation.

Forecast Methodology

Global forecast models are run at least twice per day and extend out as far as 10-15 days. In addition several of these models have ensemble runs that are useful in establishing forecast variance and confidence. Beyond this time range numerical models lack sufficient skill to predict individual synoptic weather features. A few models provide weekly or 10 day period forecasts out 1-2 months into the future, but the output consists of average anomalies during those forecast periods. General Circulation Models (GCM's) using coupled ocean-atmosphere patterns provide guidance out about 6 months into the future. These models show either monthly or seasonal anomalies for a limited set of weather elements. To help bridge the gap between numerical forecast models and the sub-seasonal to seasonal models there are sometimes opportunities to use teleconnection patterns. Transient features such as the MJO, or semi-stationary teleconnection patterns such as the NAO or PNA can provide additional forecast guidance by using correlations of temperature and precipitation information with the expected pattern evolution. Below are some examples of these global patterns and corresponding temperature anomalies that are associated with them. These medium range global patterns can be used to assess forecast model solutions and to extend the forecast out to the 2-4 week timeframe.







Extended Forecast Data Sets

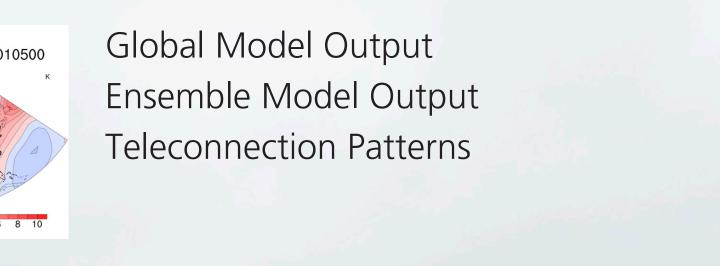
Day 4-15:

Day 15-30:

500mb Z (0bs: 13Sep2011 - 10Jan2012) NAO index

-5 1 -4 16SEP 10CT 160CT 1NOV 16NOV 1DEC 16DEC 1JAN 16JAN 2012

A wide variety of data sets are utilized to construct medium to extended range forecasts. Global forecast models and their ensemble runs provide the most detailed guidance in the Day 4-15 period. Teleconnection patterns provide guidance in extending these forecasts out beyond 15 days, but timing of individual features becomes too error prone to provide much skill. Climatology becomes a much greater input to the forecast and the forecast effort shifts toward a depiction of expected deviations from the climatic normal temperatures.



NAO: Observed & ENSM forecasts

Teleconnection Patterns

Weekly Model Anomalies



Day 90-2 years:

NWS/NCEP/CPC

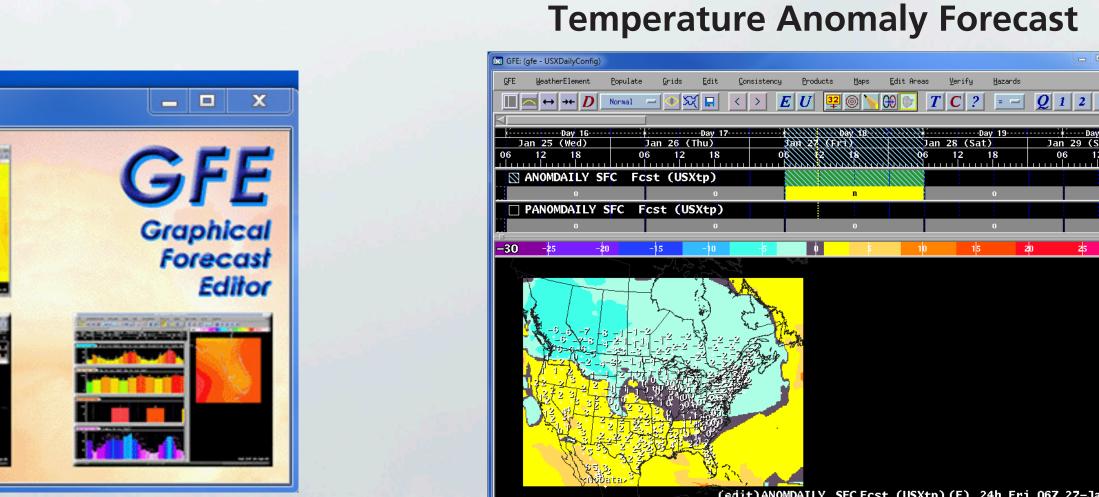
Lost update: Tue Jan 10 2012 forfide conditioner 3/0be2011-8Jan2012

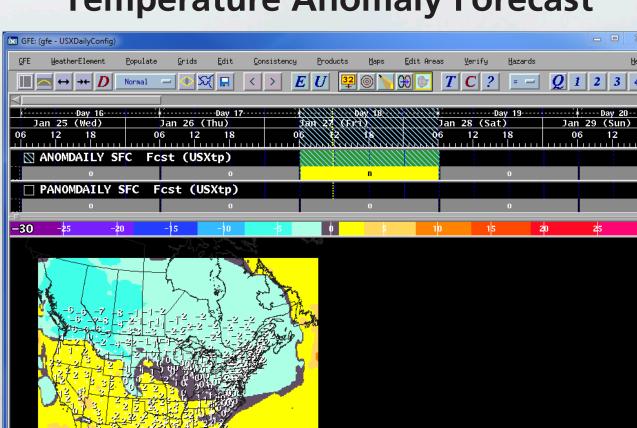
CFSv2 forecast Nino3.4 SST anomalies (K)

ENSO Forecasts and Analogs General Circulation Models (GCM's)

Graphical Forecast Editor (GFE) Used For Input of Anomalies

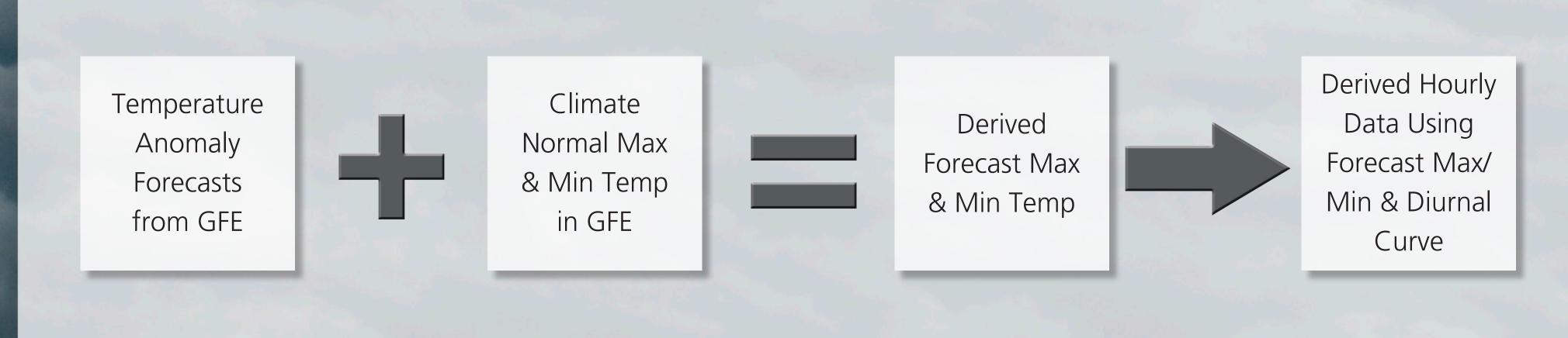
Once an assessment of the available forecast guidance and techniques is made by a long range forecaster, a final prediction of temperature anomalies is constructed. With a requirement to provide extended forecasts over vast geographic regions, an efficient method was needed to apply these temperature departures to the climatic normal values for hundreds of individual locations. The Graphical Forecast Editor (GFE) tool was selected for this purpose due to its capability to graphically edit weather fields and fit that data into a high-resolution (5km) grid. GFE which was originally developed by NOAA's Earth System Research Laboratory has been in use by the National Weather Service since 2001 and has been in operation for short and medium range forecasts at Telvent since 2004. Depending on the time range of the forecast, departures from normal temperatures can be edited on a daily basis for Days 15-30. Edits of departures are done on a weekly basis for Days 31-60, monthly for Days 61-150 and quarterly for Days 150- 2 years. The finished anomaly forecasts for all regions are published to a forecast database where further processing is done to extract extended range forecasts for individual locations.





Deriving Hourly Forecast Data

The next step in the process is to apply the forecast temperature anomalies that were input into GFE by the long range forecaster to the climate normal values for individual locations. The normal maximum and minimum temperature for each forecast site is modified by the appropriate anomaly at each time range. Using the normal values for each location helps to preserve local effects that might otherwise be washed out at long time ranges. The resulting daily maximum and minimum temperature reflects a departure from the normal daily values based upon the input of the forecaster. Hourly data is then derived from the new maximum and minimum values using a diurnal temperature curve.



Forecast Output

After the diurnal curve is used to generate an hourly dataset, individual forecast files are generated for nearly 100 locations in North America with a more limited set in northern Europe. The format of the forecast dataset consists of a string of hourly values including:

- temperature - dew point
- relative humidity
- heat index
- wind chill
- wind direction
- wet bulb temperature
- cloud coverage
- minutes of sunshine
- The forecast data can be ingested into a clients own models, or used in a spreadsheet analysis.

Hourly Forecast Output Example

 KORD
 2011/11/30 12
 41
 20
 43
 41
 35
 290
 9
 33
 47
 31
 11/30/2011 05:33
 F

 KORD
 2011/11/30 13
 43
 20
 40
 43
 38
 280
 9
 34
 45
 33
 11/30/2011 05:33
 F

 KORD
 2011/11/30 14
 43
 19
 38
 43
 38
 266
 9
 34
 47
 31
 11/30/2011 05:33
 F

 KORD
 2011/11/30 15
 43
 18
 37
 43
 38
 270
 9
 34
 51
 29
 11/30/2011 05:33
 F

 KORD
 2011/11/30 16
 41
 16
 36
 41
 35
 258
 9
 32
 52
 10
 11/30/2011 05:33
 F

 KORD
 2011/11/30 17
 38
 16
 41
 38
 33
 244
 7
 30
 48
 0
 11/30/2011 05:33
 F

 KORD
 2011/11/30 18
 35
 1

Hourly forecast fields are used in: Load Forecast Models - Trading Applications

Uses and Users of Extended Forecasts

The primary users of extended forecasts are utilities that produce power and suppliers of energy such as oil and natural gas producers. Retail Energy Providers are one of the larger users of these forecasts. They are involved in both the supply and demand aspects that determine near-time market pricing, but they are also involved in power purchase agreements that sets that pre-market price between the producer, seller and eventually the buyer. Utilities can ingest the hourly forecast data into their load models that predict power requirements. When conditions warrant a utility can procure extra energy supplies, while producers can shift supplies to areas that will require it if the lead time is sufficient. Purchasing power ahead of time when demand will be high helps to avoid buying it on the spot market, which often carries a much higher price.

In addition to Energy users, large Retail organizations incorporate these forecasts into their long range planning. Many businesses begin to plan their annual merchandise sales based on conditions that existed in the previous year. For some retail items, weather is a factor in positioning those products, so a more enhanced outlook for the upcoming seasons can be utilized to purchase and position these items.

- Scheduling Equipment Maintenance - Retail sales planning



Extended range forecasts of temperature are used by several industries to make long range planning decisions. There is a desire by users of these forecasts to improve upon straight climatological values. In addition there is a requirement to provide higher temporal resolution content that includes hourly values in lieu of daily data. There has been an increase in the skill in recent years in extending forecasts out several seasons into the future. The tools and datasets that are used in creating these forecasts are not in a consistent format that facilitates ease of use in constructing a forecast. Human input is needed in the process to integrate the various forecast methods and datasets. Using a graphical interface tool such as GFE allows for the efficient creation of extended forecast datasets which can then be applied to climatology for the final derived product. Future enhancements to the process may include a probabilistic assessment of the forecast values.

Hansen, T. L., Mark A. Mathewson, Mike Romberg, 2000: Forecast Methodology using the GFESuite. Preprints, Seventeenth Conference on Weather Analysis and Forecasting, Norfolk, VA, Amer. Meteor.

Keller, L. M., David D. Houghton, Michael C. Morgan, 2007: The Future of Medium – Extended-Range Weather Prediction User Perspectives. Bulletin of Amer. Meteor. Soc., 88, 634-637.

LeFebvre, T. J. M. Mathewson, T. Hansen, and M. Romberg, 2000: Injecting Meteorology Into the GFE Suite. Preprints, Seventeenth Conference on Weather Analysis and Forecasting, Albuquerque, NM, Amer. Meteor.