A Primer on Meteorological Patterns from a Commodities Perspective

Humans have been trying to master meteorology since 3000 BC.

From ancient astronomers to Royal Nobles studying cloud patterns to today's modern supercomputers crunching trillions of calculations on a minute-by-minute basis, mother nature consistently finds a way to humble our best efforts to understand her.

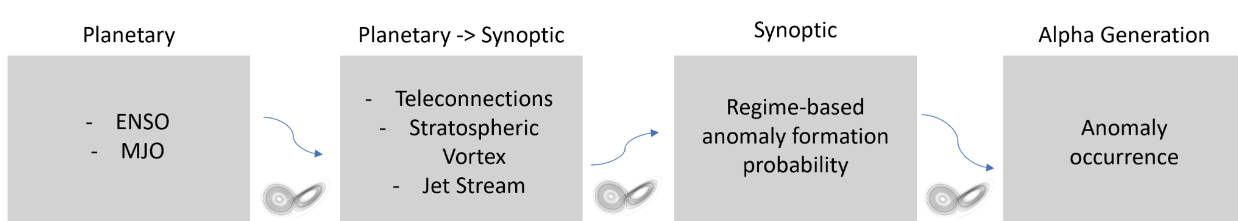
Meteorology and financial markets are similar in this way. Both are chaotic systems where nonlinear dynamic processes make fools of those who believe to know more than they do.

This doesn’t mean we can’t predict *some* aspects of the weather and then use those predictions to make positive expected value bets in certain commodities. We absolutely can. But, just as in markets and investing, the key is to know what’s a valuable signal, what’s noise, and what’s total hogwash.

The aim of this piece is to serve as a counter to the prevalence of flashy sensational weather predictions in the commodity research space, where Dunning Kruger predominates. I will show you the primary tools I learned and used in my formal training as a degreed meteorologist and my previous employment in the meteorological sector.

Consider this the first piece in a series highlighting how we can *correctly* use meteorological tools to make better-informed decisions in the commodity space.

To understand the weather, we need to first start with the larger flow behind meteorological fluctuations. From there, we’ll dive deeper into each concept.



Read this flowchart from left to right.

When forecasting meteorological patterns that influence commodities, we have to start at the planetary level and drill down in scale from there.

The strange attractor diagram at every step indicates that chaos theory is omnipresent throughout each pattern.

The Meteorological Mob-Boss | El-Nino Southern Oscillation (ENSO)

“El-Nino Southern Oscillation (ENSO)” is the phenomenon responsible for producing an El-Nino or La-Nina. These two classifications measure observed surface sea temperature anomalies (differences from average) over set regions of the Pacific Ocean.

If ENSO’s temperature departure ranges from -0.5C to 0.5C, that is referred to as ENSO-Neutral. Above 0.5C results in an El-Nino, and below -0.5C results in a La-Nina.

El-Nino is ENSO’s warm phase. Trade winds *weaken* and transport tropical waters *east* from Australia in an El-Nino and point north into the central pacific near the equator. This transport of heat then alters the dispersion of heat throughout the atmosphere.

El-Nino often teams up with a phenomenon called a **Kelvin Wave**. A Kelvin Wave is the weather equivalent of a shot of adrenaline that comes from a uniquely warmer pool of water that further fuels the El-Nino. This region of high heat can temporarily increase the strong influence that El-Nino has on global weather patterns.

The opposite effect is **ENSO’s cool phase (sub -0.5C anomalies), or La-Nina**. Trade winds *strengthen* and transport that warmer water back west.

Meteorologists have determined that El-Nino and La-Nina produce the following temperature and precipitation anomalies graphed below. While ENSO is a year-long phenomenon, its effects are more pronounced in the winter (for each hemisphere).

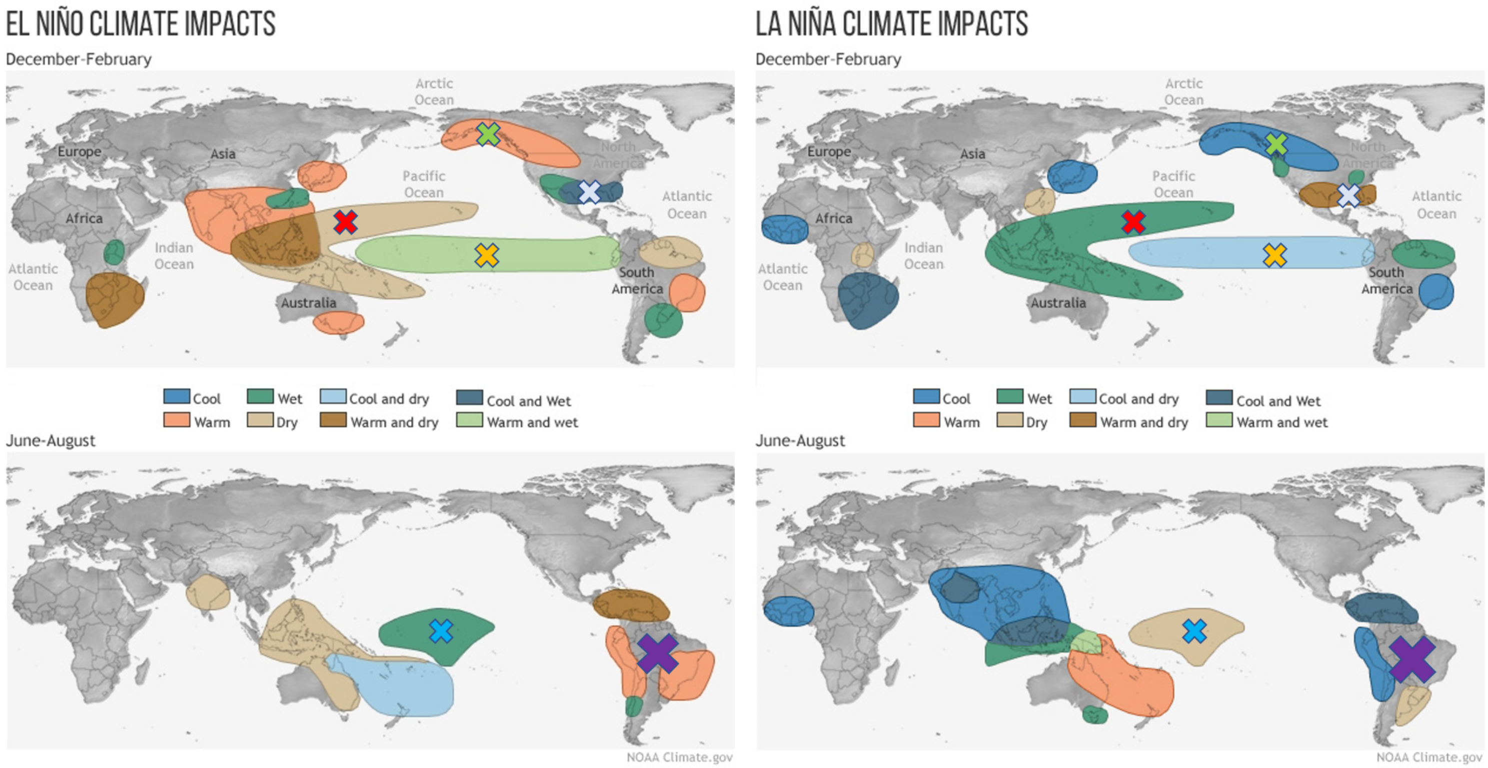


Figure 1: ENSO large-scale climate impacts in the wintertime for each hemisphere. Note the sharp contrast in temperature and precipitation anomalies for each colored 'X' pair.

How do I check the state of ENSO?

An excellent resource to check the current phase of ENSO is on the 'Summary' page of this presentation which is regularly updated (link here).

How to check the forecasted state of ENSO?

An excellent resource to check the projected state of ENSO comes from the 'IRI ENSO Forecast' webpage, under the IRI/CPC ENSO Predictions Plume section (link here).

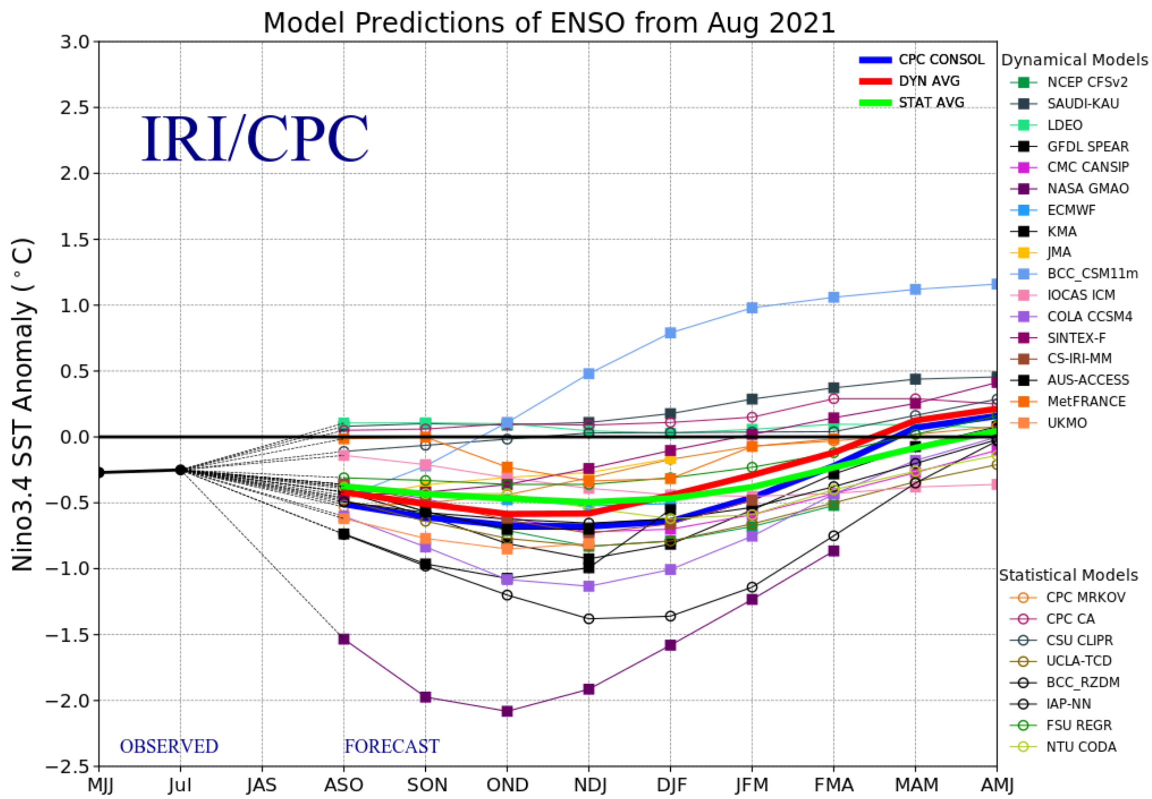


*Figure 2: Forecasted Anomalies relative to three-month forecast. Note: A mean forecast for OND just below -0.5 means for **O**ctober, **N**ovember, and **D**ecember; the mean forecasted value of ENSO is slightly less than -0.5.*

Ensemble Modeling - A Powerful Tool

The above plot can look a bit confusing, but it's relatively simple.

We want to focus on the thicker light green, red, and blue traces and where they lie about the y-axis. These are means of several classes of seasonal forecasts.

We can see that the current forecast averages hover right around -0.5C. Remember from above, -0.5C signifies a *weak* La-Nina. The forecasted value on the figure above matches what the 'Summary' slide page from the Climate Prediction Center says, as they're watching for a La-Nina to develop. As we head into the fall and winter months, I will reference the ENSO state extensively in our future commodity briefings.

You might be wondering about the other traces and whether they have any bearing on possible weather outcomes. They do, but their probabilistic weighting is significantly lower. To bet against a multi-member mean requires high conviction. Alex talks about this in markets, and the same holds for a group of meteorological models referred to as *ensemble modeling*.

Ensemble modeling is based on the same premise of the wisdom of crowds and the authority of 60 million Frenchman and all that. Another example of how meteorology and financial markets are similar. Although we don't have over a thousand simulations of ENSO, the above figure displays output from 25 different ones.

In the aggregate these simulations yield a statistically valid prediction; the uncertainty envelope is correctly modeled. Put another way, there is enough information between each ensemble member to assemble a complete picture. And the whole is greater than the sum of the parts.

In summary, so far we've discussed:

- ENSO and its attendant phases along with what to expect in each one of those phases
- Ensemble forecasting, how powerful it can be with respect to smoothing out individual error
- How long-range forecasting and financial markets are similar in form

The Atmospheric Caporegime | Madden Julian Oscillation (MJO)

The Madden Julian Oscillation is an "eastward moving disturbance of clouds, rainfall, winds, and pressure that traverses the planet in the tropics and returns to its initial starting point in 30 to 60 days." The returning factor gives rise to the oscillation component of the name, while the Madden Julian component of the name comes from the team of scientists who first discovered the phenomena.

As the MJO is in the tropics, **its position and activity determine how much moist air and heat is thrown into the atmosphere**. This then eventually propagates towards the north pole and results in a set configuration of stratospheric vortexes such as the jet stream and teleconnection patterns (the 2nd square from left in the flowchart above).

We can see the MJO denoted on the figure below via the movement of the positive precipitation anomalies (the green and blue shading at left). At right, one can connect each phase to temperature anomalies for the contiguous United States.

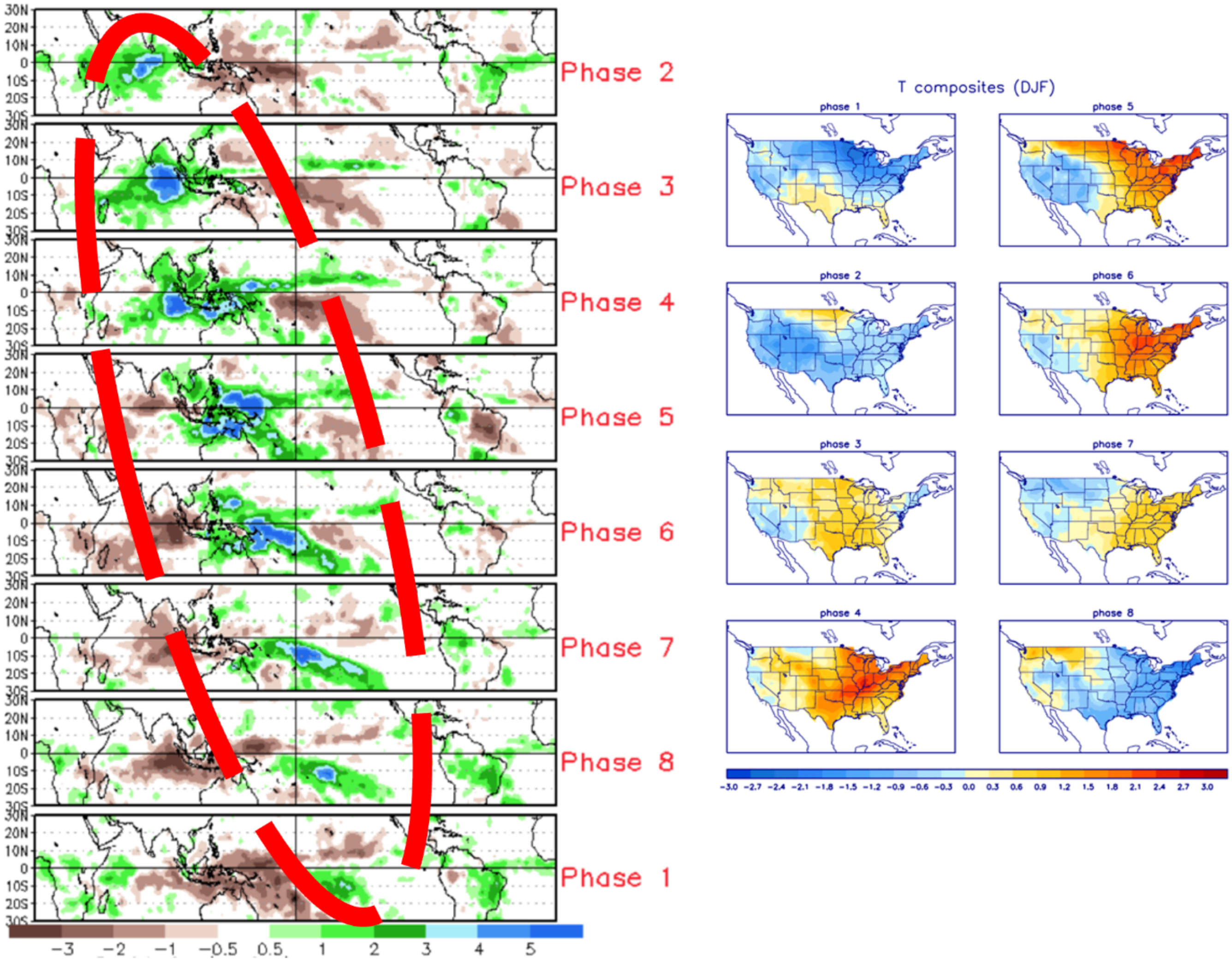
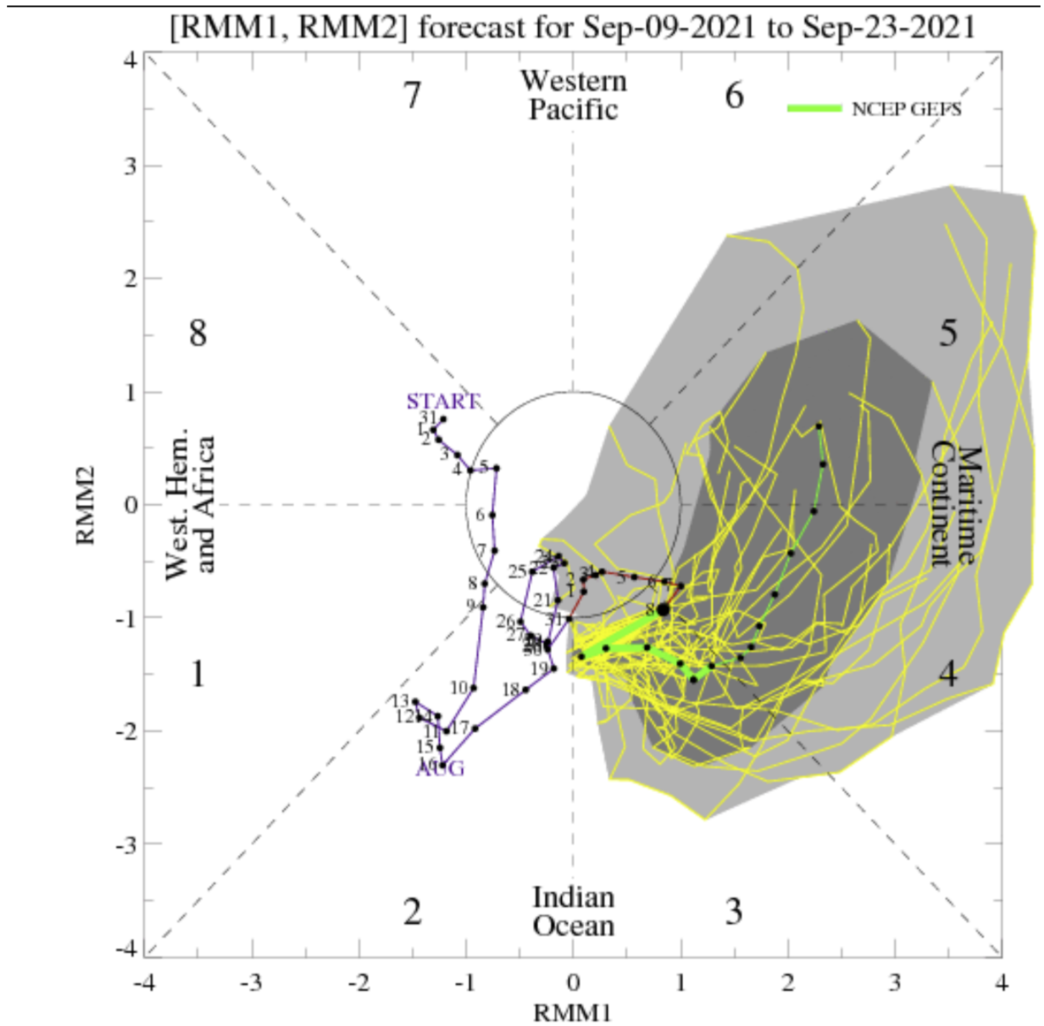


Figure 2: Adapted from link 1 and link 2

Depending on the phase (1 through 8) of the MJO, this configures the atmosphere to produce positive or negative temperature departures over the Continental United States. Like ENSO, the phase of the MJO is at maximum influence in the winter months. As we head into the fall and the winter months, I will reference the MJO extensively in future commodity weather briefings.

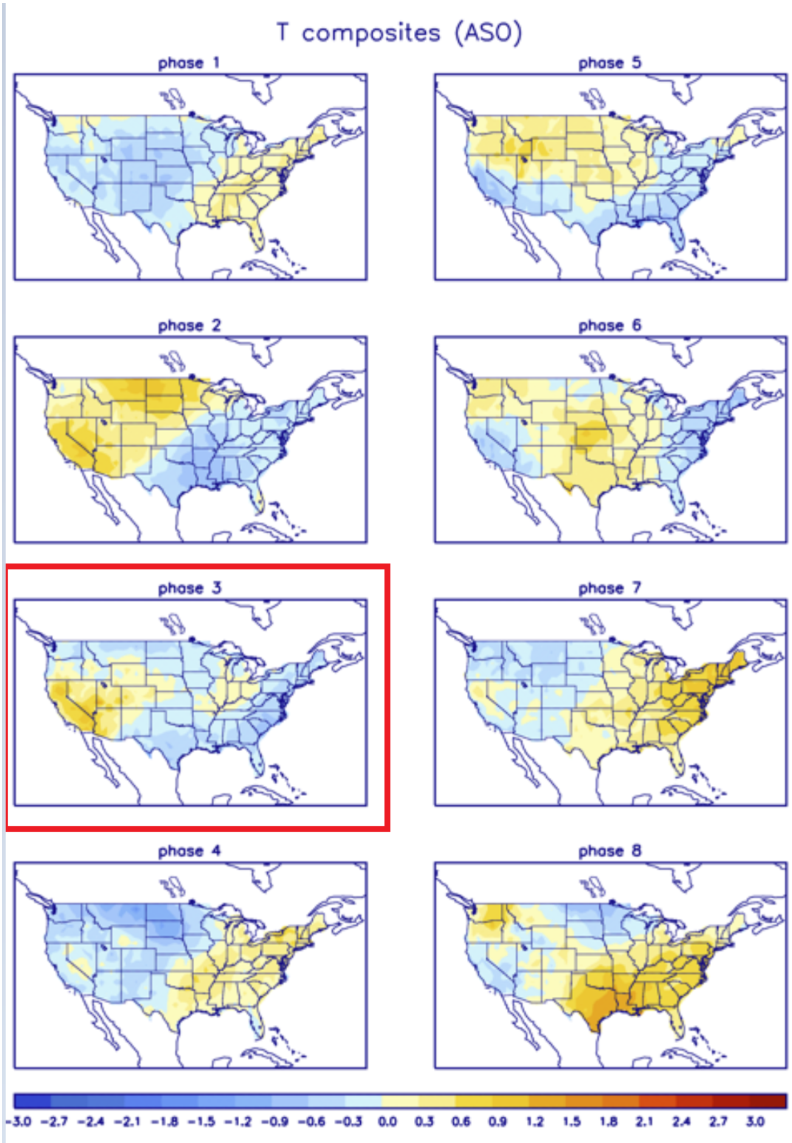
To track the current phase of the MJO, go to this link here.



This looks like spilled spaghetti, and you're right. The technical term for this plot is actually a "spaghetti plot". Remember the ensemble member discussion from above? Each yellow line represents an individual ensemble member's prediction of what phase (1-8 numbers in each octal) the MJO is forecasted to reside within. The green line denotes the mean of the ensemble forecast.

To translate this into actionable information, take the forecasted phase number (say phase 3), note the current month (September), and visit this page (link here).

Match the phase forecast with the current mid-month, example (ASO) for August, September, and October;



We can see that although the MJO isn't too strong in the late-summer months, it establishes a background state of colder than average temperatures in the east coast and warmer than average in the western areas of the United States.

To summarize, the MJO is:

- An area of convection that moves around southeast Asia and the western Pacific
- It disperses heat which reorganizes weather patterns in the United States and Europe, determining areas of warmer and colder than usual weather in addition to precipitation anomalies
- Along with ENSO, it is of greatest influence in the winter, playing a heavy role in setting the stage for floods, droughts, and cold outbreaks

NatGas and Teleconnections

We've learned about ENSO and the MJO, so now it's time to understand how these two influence a meteorological phenomenon known as "teleconnections."

Teleconnections are smaller in geographical coverage relative to ENSO and MJO but are "a recurring and persistent, large-scale pattern of pressure and circulation anomalies that spans vast geographical areas."

They arise from the current configuration of, and the interaction between both ENSO and MJO. These are at maximal influence in the winter and spring months and play a prominent role in shaping the weather over North America and Europe (think NatGas when you're reading about them below)

There are three significant teleconnections:

- ➢ North Atlantic Oscillation (NAO)
- ➢ Arctic Oscillation (AO)
- ➢ Pacific North American Oscillation (PNA)

Here are some examples of how these variations affect a particular market, such as NatGas.

A Bearish Setup for NatGas

The North Atlantic Oscillation pertains to the orientation of high and low-pressure systems over Greenland and surrounding regions. The Arctic Oscillation measures the strength of the polar vortex, which helps keep cold air up where it should be, in the arctic.

When the NAO and AO are in their positive phase, the colder air is kept closer to the arctic circle as the polar vortex is strong. Think of the polar vortex like a stationary spinning top.

A positive NAO and AO result in warm air over the major population centers of the United States resulting in less demand for NatGas.

A Bullish Setup for NatGas

When the NAO and AO are in their negative phase, colder air spills down into the major population centers of the US.

The AO can be forced to weaken when the MJO disrupts the “arctic top” spinning. This disruption causes the “top” to slow in spin, leaking cold air and dipping down into southern Canada. This drives demand for Natural Gas to spike.

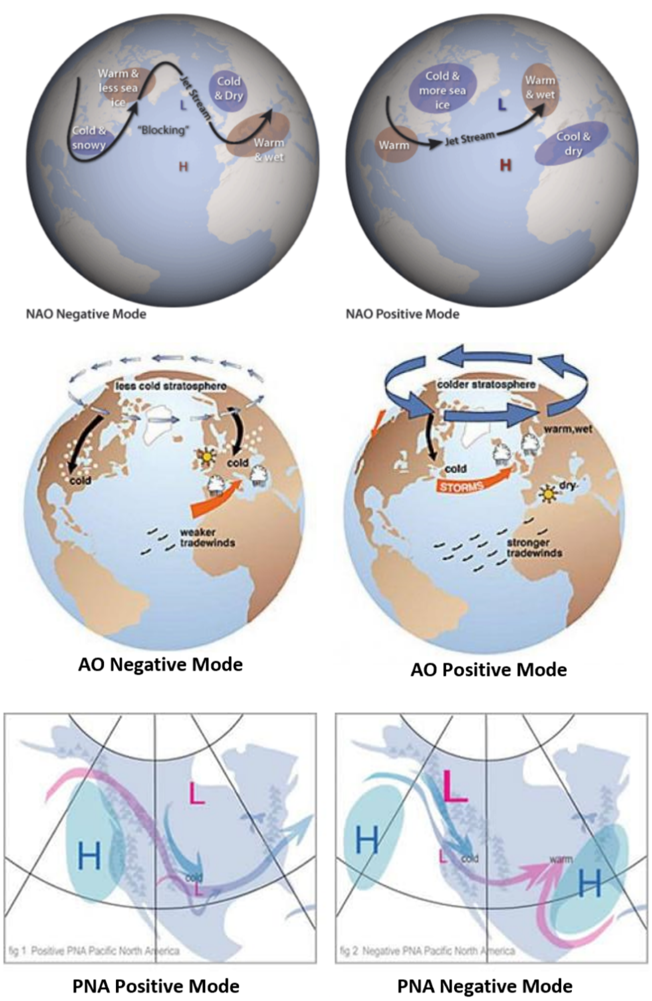
However, the PNA gets the final say concerning how cold and stormy things will get, as it controls the path of high and low-pressure systems over the North American Continent.

When the PNA is in its positive phase, it lays out the red carpet for colder air to come down and Nor’Easters, but its negative phase can block any cold air intrusion even if the NAO and AO are favorable.

To get a very bullish setup for NatGas, you need the three to be in harmony. A mildly bullish setup for NatGas occurs when the AO and NAO are in harmony with the PNA being out of phase and weak.

That’s all a bit wordy, so here’s a summary graphic and table below:

Bullish NatGas | **Bearish NatGas**



Bullish NatGas	Bearish NatGas
Negative NAO	Positive NAO
Negative AO	Positive AO
Positive PNA	Positive PNA
MJO phase 7-1	MJO Phase 2-6

So to put this all together, what type of winter will there be for 2021-2022?

The short and honest answer is that it's too early to make a high confidence call at this time. The current confluence of cyclical patterns combined with the extended time interval until winter means we can't have high conviction on any call yet.

However, given that ENSO is forecasted to be in a weak La-Nina state my first guess calls for a slightly colder and wetter than average western US while the east is slightly warmer and drier.

This would present a slightly bearish outlook for NatGas prices. As the fall season comes to a close in late November, MJO progression, teleconnection orientation, and vortex strength will all come into focus allowing me to iterate along the bayesian chain. This will enable us to hone in on what will occur with a higher degree of confidence in a subsequent update around that time.

How Weather Models Work | Which is the Best Weather Model?

Now that we've covered planetary oscillations (ENSO / MJO) and teleconnections, it's time to put all of these together to identify forecasted temperature and precipitation anomalies.

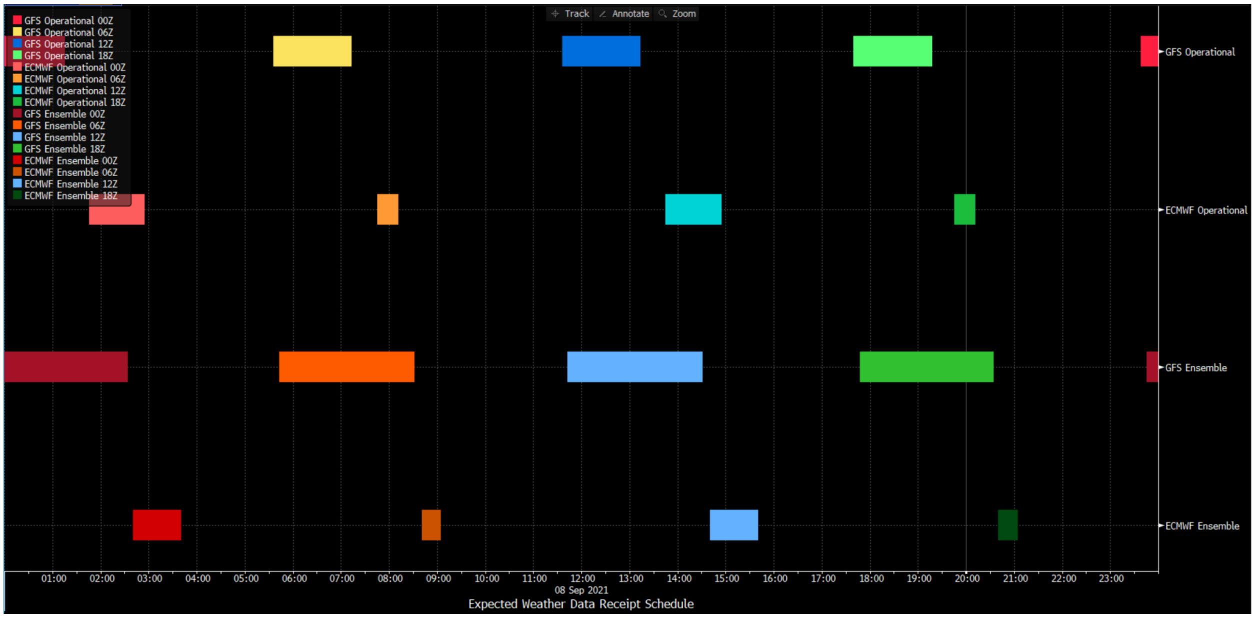
Numerical weather prediction models (NWPs), similar to the ones above in the IRI/CPC chart, run daily. They ingest current observations and integrate those observations forward in time to identify temperature and precipitation anomalies.

But, there are a few caveats to attaining a reliable forecast; chaos theory and error growth over time.

The observations fed into these models often contain minor errors at the start (the temperature at a location may be 75.03F instead of 75F). While these errors may seem slight, in a weather model they compound significantly over time. A tiny error creates a reflexive loop that propagates itself out to other regions, making the resultant forecast less accurate over time.

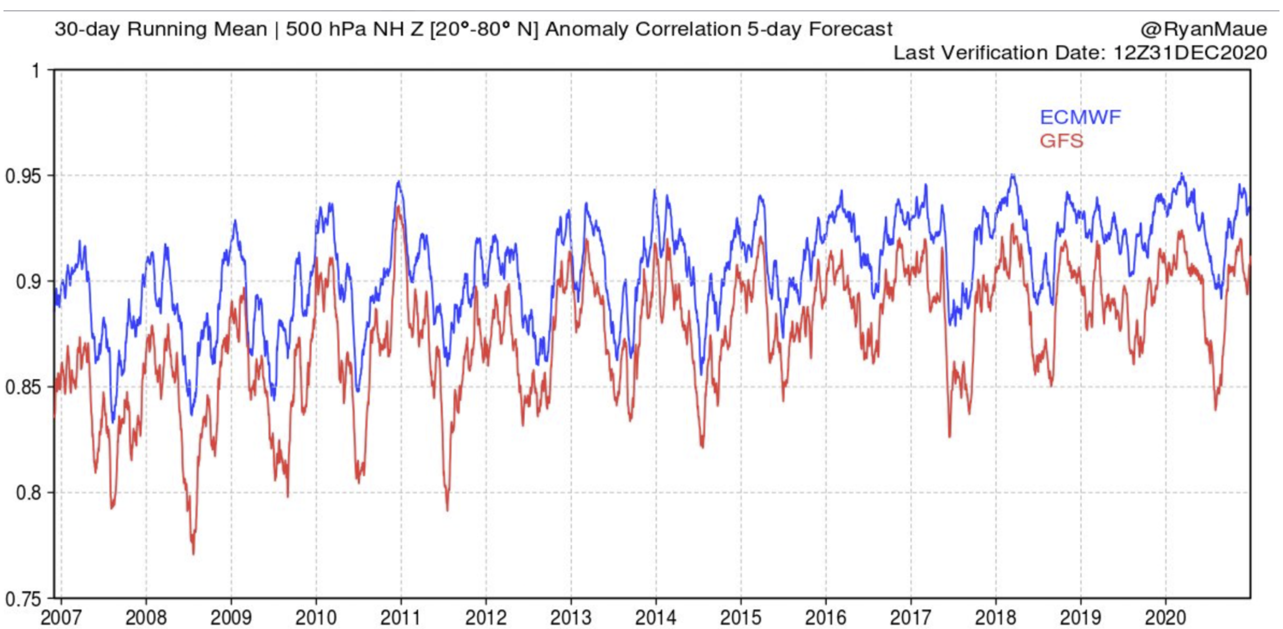
Using the ensemble member approach that we outlined above, this error growth is mitigated but not completely erased. Thus, the longer you run a weather model out in time, the more error-prone it'll be.

NWP physics also differs between models. Two primary models produce forecasts pertaining to commodities, the American (GFS) and European Model (ECMWF). These models run multiple times over a day.



The GFS and its ensemble members run first, leading the market, with the ECMWF running ~3.5 hours behind it.

While the GFS is less reliable, weather-dependent commodity markets still react to it. And a secondary reaction is observed when the ECMWF and its ensemble members run, confirming or denying any new trend the GFS might have sniffed out.



Dr. Ryan Maue shows the European Model's increased skill (ECMWF) relative to the American Model (GFS).

Where do I get this model data?

I use weatherbell.com to get precipitation and temperature anomaly data off of the ECMWF Model and its ensemble grouping, as it's the source that has the best visualizations and the most significant amount of actionable data. While this data is behind a paywall, Collective members will get access to it through our future commodity reports.

What models and setups do I trade?

I don't like to trade off the GFS. While you can capture the initial reaction, you're likely to get whipsawed as its run-to-run deltas are pretty significant compared to the ECMWF's ensemble groupings.

If the ECMWF confirms what the GFS trends toward, this is like entering on a confirmed breakout and results in less whipsaw action.

I'll be posting my thoughts regarding NatGas setups in the Collective this winter. Regarding Ags, I monitor crop calendars and pay serious attention to meteorological arrangements during a crop's critical planting and harvest periods. Typically, I scan WeatherBELL's ECMWF output to spot precipitation or temperature anomalies and determine how that will disrupt a yield (event duration, recovery duration, background macro environment).

Will this be distilled for me, or will I have to get it from the abovementioned sources?

As a collective member, you'll get access to the commodity reports I write. Suppose there's a weather event of note on the horizon. In that case, I'll advise on the possibility and confidence that I have in it occurring, along with a short synopsis of the meteorological setup.

Your Commodity (and Weatherman) Operator,

Steve