

2016 – 2017 Winter Forecast



Prepared for

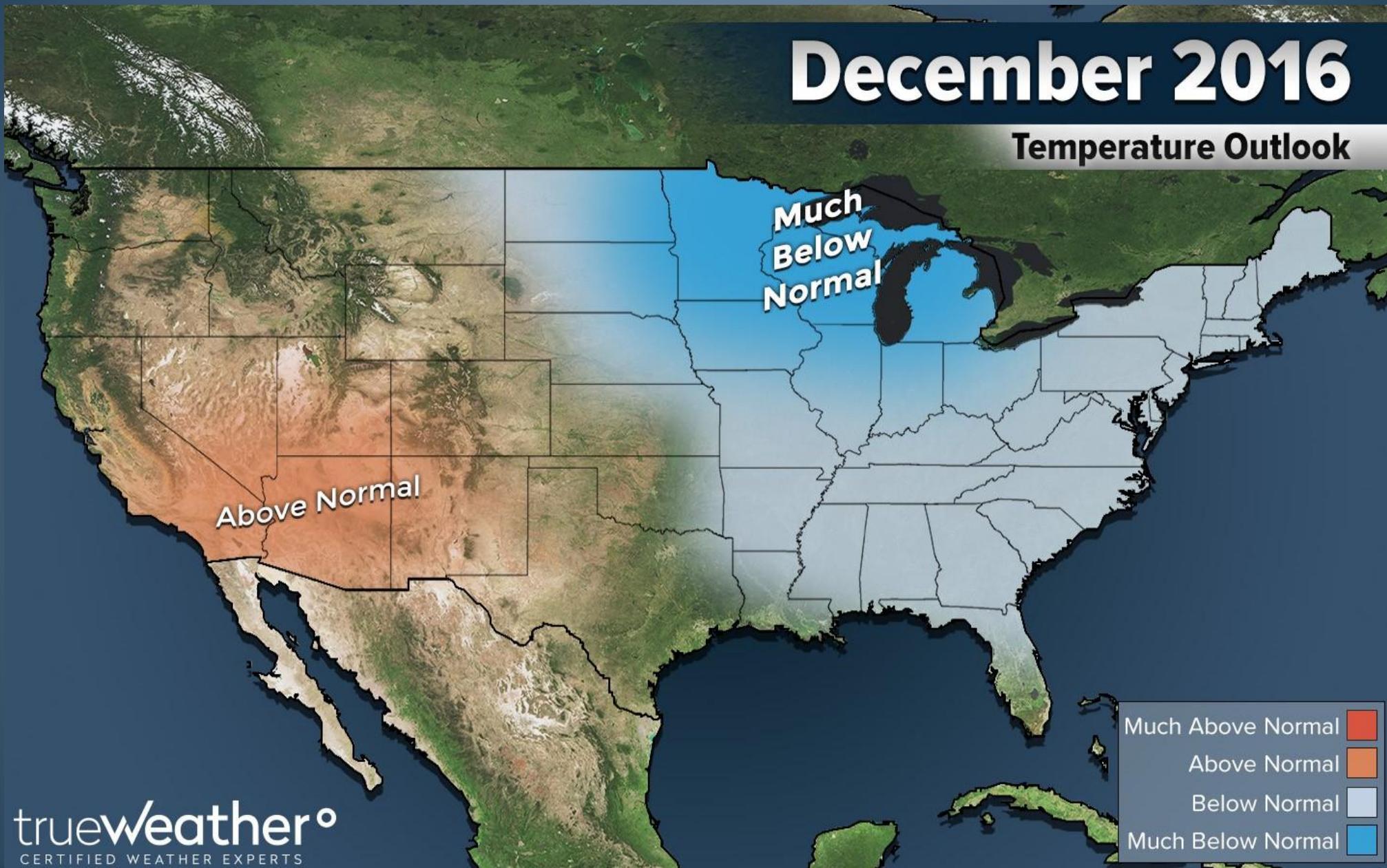


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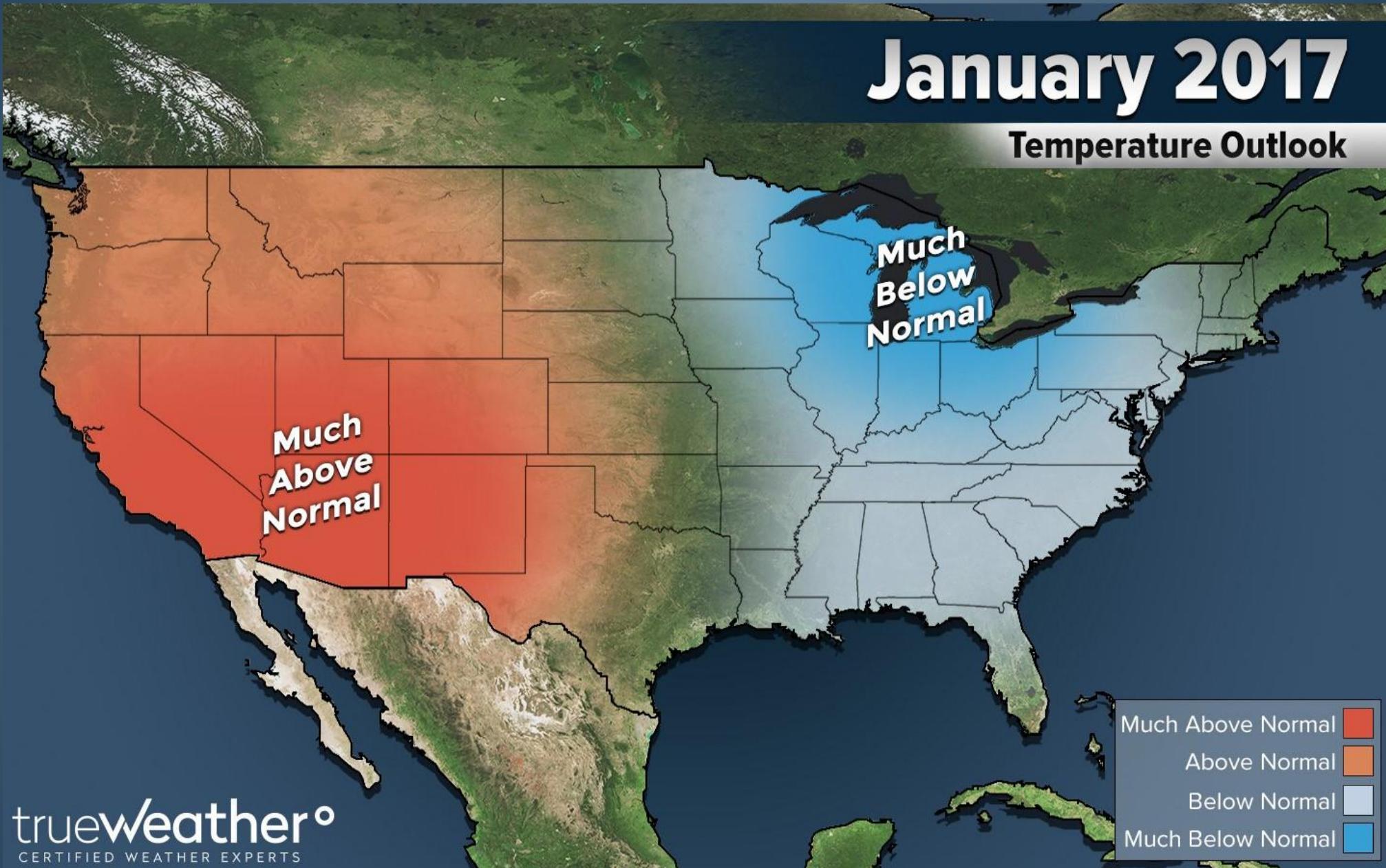
December 2016

Temperature Outlook



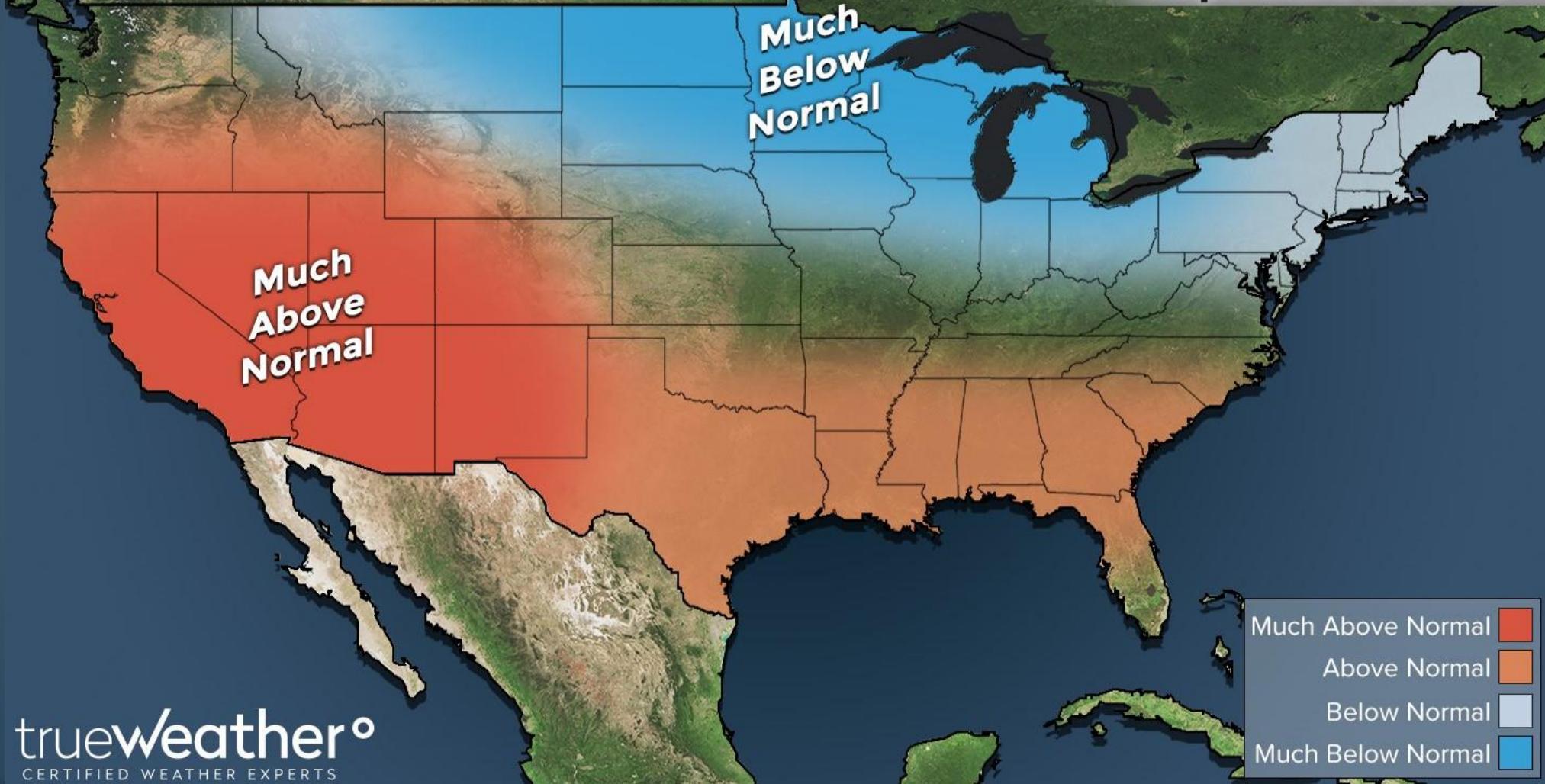
January 2017

Temperature Outlook



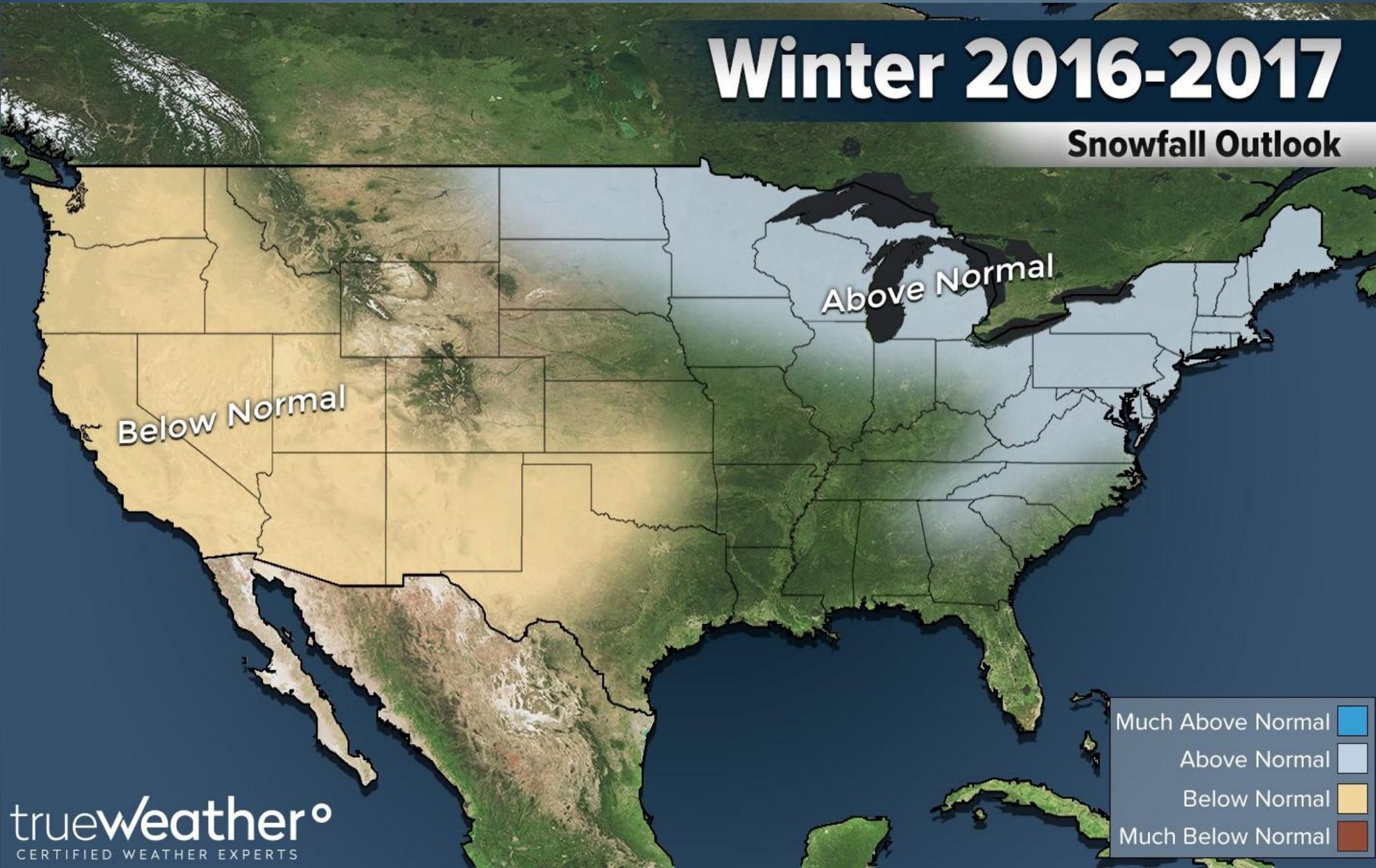
February 2017

Temperature Outlook



Winter 2016-2017

Snowfall Outlook

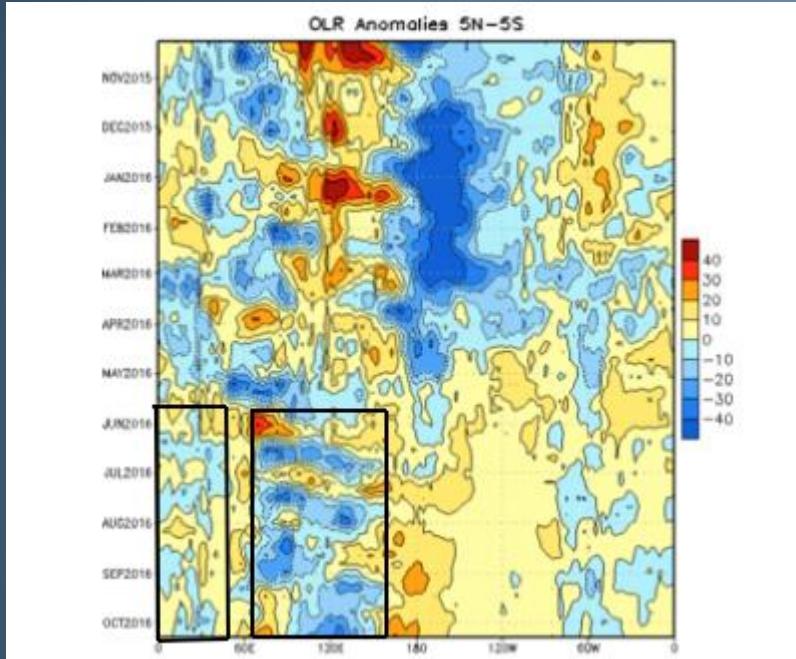


Snowfall Prediction by City

	.1-1" Events	1.1-2.0" Events	2.1 - 4.0" Events	4.1 - 6.0" Events	6.1 - 8.0+" Events	Total
Allentown, PA	9	6	4	2	2	23
Reading, PA	9	5	4	2	2	22
Harrisburg, PA	9	5	4	2	2	22
Philadelphia, PA	7	4	3	2	1	17
Bridgewater, NJ	8	5	3	2	2	20
Doylestown, PA	9	5	4	2	2	22
Lancaster, PA	8	6	3	2	2	21
Phoenixville, PA	7	6	2	2	2	19
New York City, NY	8	5	3	2	1	19

Technical Report

Indian Ocean Dipole



The very active wave train of moisture off Africa produced 9 tropical systems this year in the Atlantic . This active period can be linked to the negative phase of the Indian Ocean Dipole. With a cool pool of water in the Western Indian Ocean it favored two areas of enhanced convection.

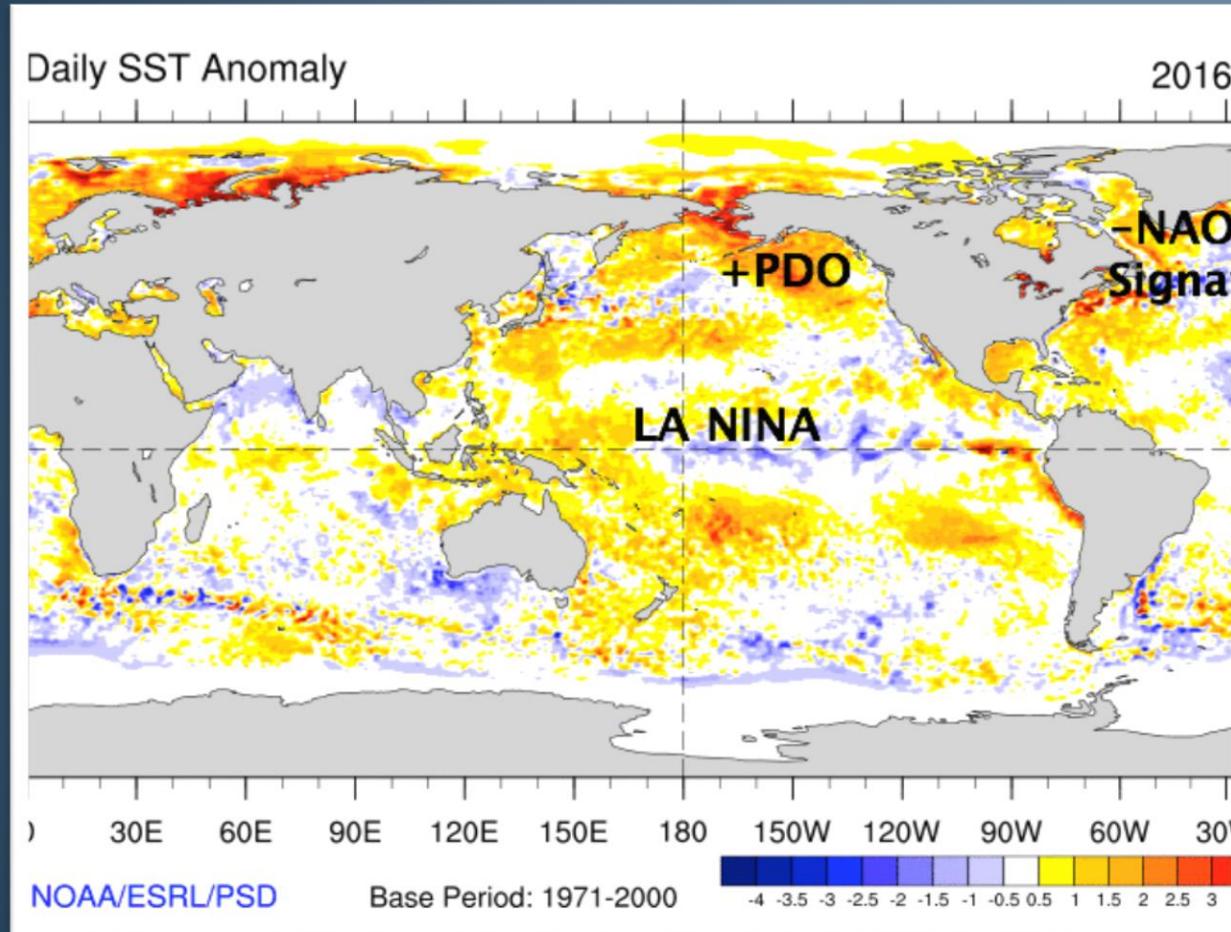
- 1) Across the Maritime Continent
- 2) Across Africa

The land heating up along the coast of Africa was able to pull in the moisture from the Indian Ocean. This sent a very active African wave train with several disturbances forming into Tropical systems. Most notable would be Hermine and Matthew.

Looking back through several summers, negative drops of the Indian Ocean we see a clear signal for cold air to make an appearance in the CONUS for December. Many of the winters featured a cold Eastern US with a few very cold. The theory behind this cold signal is the forcing across the Indian Ocean/Africa resembles a phase 8-1-2 in December, which supports the cold pattern.

Years with previous Summer -IDO and following December weather	
1980: Cold Eastern US	1981: Cold Eastern US
1985: Cold Eastern 2/3 US	1989: Very cold Eastern 2/3
1990: Warm East/cold Western US	1992: Cold Western US
1995: Cold Eastern US	1996: Cold Upper Midwest
1998: Warm	1999: Warm
2000: Very cold Eastern 2/3	2001: Warm
2002: Cold Eastern US	2004: Cold Eastern US
2008: Cold Northern US	2009: Cold
2010: Cold Eastern US	2013: Cold, only SE warm

Sea Surface Temperature Anomalies



Equatorial Pacific: Cold anomalies extend further west than most La Niña's, with warming in the eastern basins. This usually does not bode well for cold winters in the Eastern US, as this keeps the tropical forcing over the Maritime Continent. However, since a bottoming out of the cooler water anomalies are expected to occur before winter we should start to see this signal reverse or become less of a dominant factor.

Northeast Pacific: In the cold and active winter of 2013-14 this warm pool of water ran the pattern despite the lack of an -NAO. It forced the ridge in the Western US and troughiness in the Eastern US. This will once again play a significant role in this winter forecast by displacing cold air into the CONUS. If we see this warm pool erode towards winter or a strong polar vortex that breaks down any ridge attempt we could see a drastically different outlook.

North Atlantic: The cold pool in the North Atlantic was in a promising spot last winter, but the warm anomalies across Greenland eroded and allowed a dominant area of low pressure to stay at a higher latitude resulting in a +NAO for the winter. Currently we see an even more promising that may be able to form a -NAO with indications of a weaker polar vortex than last winter. The current indications are more favorable for a -NAO blocking pattern giving the horseshoe appearance of the warm anomalies around the cold pool.

Quasi-Biennial Oscillation

Monthly mean zonal wind components (0.1 m/s)
at Singapore (48698), 1N/104E

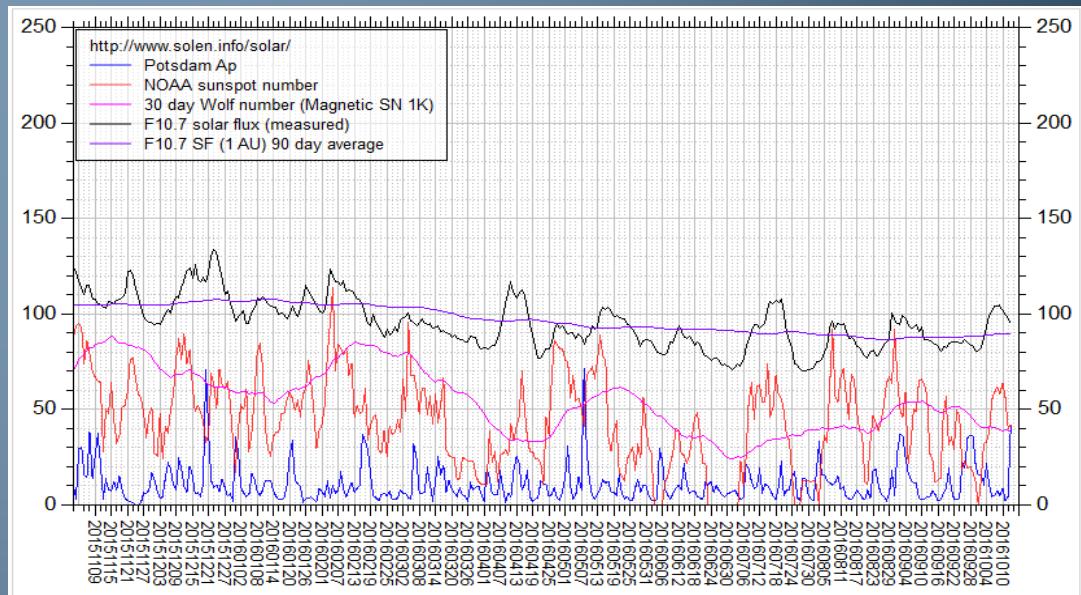
hPa	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
10	-231	-205	-148	-11	45	24	16	25	17			
12	-145	-109	7	62	65	43	32	50	39			
15	-15	49	90	113	88	57	61	89	95			
20	91	135	123	115	92	76	90	123	125			
25	108	120	112	94	104	91	96	141	143			
30	100	95	21	-14	53	70	105	157	152			
35	31	16	-99	-152	-47	23	88	139	141			
40	-17	-66	-155	-226	-204	-100	20	103	129			
45	-6	-13	-10	-148	-261	-220	-69	28	87			
50	51	48	57	-54	-183	-234	-162	-34	31			
60	100	87	77	38	-40	-138	-183	-179	-96			
70	27	54	50	2	24	-73	-90	-117	-112			
80	-30	14	7	-26	-18	-44	-64	-102	-116			
90	-51	-26	-14	-13	-83	-61	-98	-153	-114			
100	-18	-62	-11	12	-115	-114	-136	-222	-192			

The easterly phase never came to replace the westerlies during the Summer/Fall. The oscillation measures winds in the tropical stratosphere, which shift from west to east with a mean period of ~28months, with the easterly phase usually being the longer of the two. In this case, the strong El Nino likely caused a set back in the easterlies dropping down. This is significant for several reasons:

1. With low solar activity, an easterly QBO would have supported the case for high latitude blocking.
2. Westerly QBO increase the pole to equator thermal gradient resulting in enhanced westerlies. This puts the polar vortex in a position to rapidly develop and keep the cold air bottled up in the Arctic. The low solar does have an impact on this by lessening the gradient.

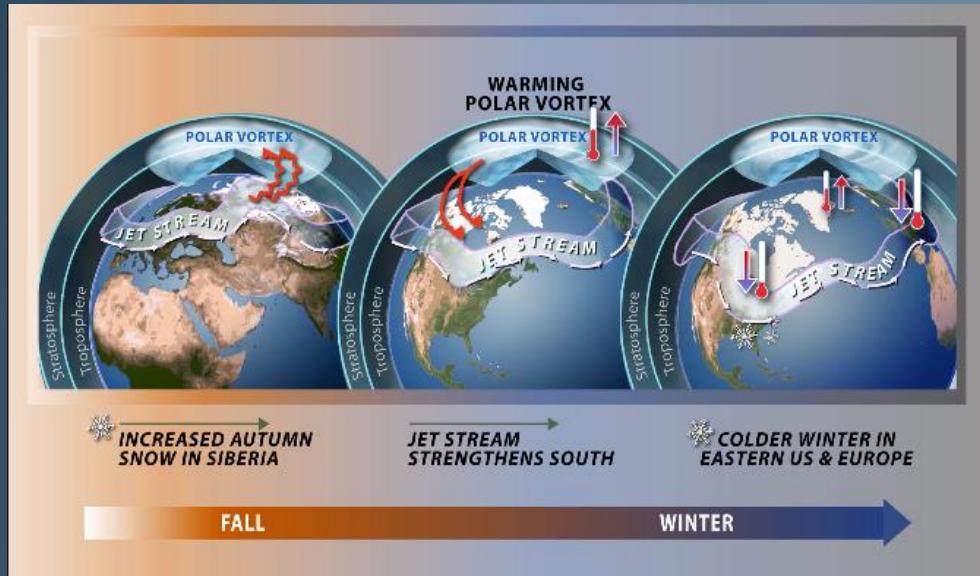
The easterlies remain absent in the upper levels, but the low positive values aloft suggest a weakening of the westerly QBO as we head towards winter. This would allow a weakening thermal gradient from pole to equator reducing the westerlies and making the polar vortex more susceptible to poleward heat fluxes. Current SST analog configuration does suggest that the pattern will favor a reduction in the westerly winds.

The weakening westerly QBO along with the weakening La Nina signal builds the case for winter to stay around in the second half of winter. A weakening thermal gradient from pole to equator along with an increasing AAM environment in the tropics/subtropics would favor a reduction in the westerlies in the mid/polar latitudes.



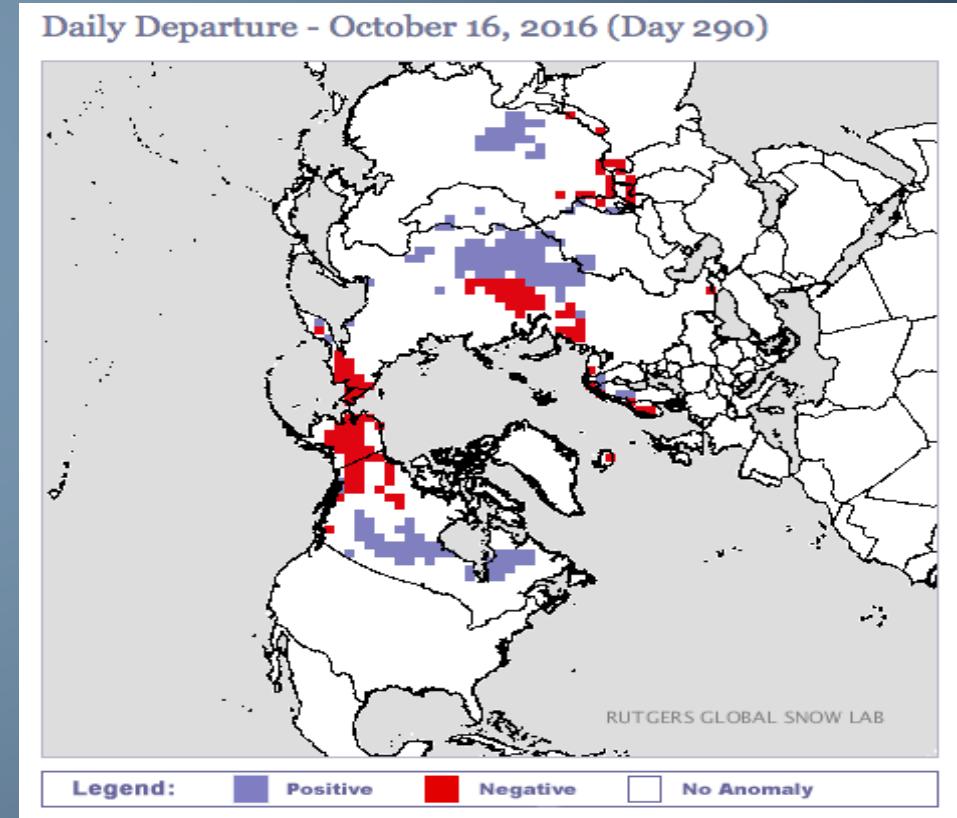
Last major update issued on October 14, 2016 at 03:50 UT.

Eurasian Snow Coverage



The image above explains how the build up of snow cover over Eurasia can impact the winter forecast. A quick build up of snow cover in the Fall has been linked to the negative Arctic Oscillation during the winter months. The thinking behind this is the snow cover leads to the colder more dense (higher pressure) air over Siberia. This intensifies the poleward heat flux weakening the polar vortex (cold anomaly). When you weaken the polar vortex, the cold arctic air becomes displaced from the higher latitudes and heads south into the Mid-Latitudes.

The latest analysis from the Rutgers Snowlab shows we are above normal through October 16th. If this trend continues it will build the case for more high latitude blocking in the winter, particularly after mid January.



Analogs

- 1959-60: This analog matches very closely to current SST anomalies heading into October. This winter started with a lot of warm air throughout the CONUS in December. The cold pushed into the Western US in January and eventually made it east for February. Despite the warm December, Philadelphia made it out with 5.7" of snow. This analog is a prime example of how the favorable SST configuration could back fire for the cold and snowy forecast. However, in this winter the high solar/+QBO contributed greatly to the warmth. We do not have to worry about the high solar, which mitigates the weight of this analog. But tropical forcing will play a role as we get closer. This is the only analog that shows no cold in the CONUS for December.
- 1961-62: This winter was a neutral ENSO with very La Nina like impacts. The southeast ridge kept areas up to Kentucky under a warming influence. In the Middle Atlantic/New England, temperatures averaged slightly below with the core of the cold in the North Central regions. Similarities include +QBO, Low Solar, and a similar cold pool in the North Atlantic ocean. This SST configuration favored the –NAO that took place in December, but this faded and led to a +NAO/AO for Jan-Feb. This winter featured a cold PDO with cold SST anomalies along the Western US, which played a role in the core of the cold dumping in Central US.
- 1966-67: Neutral ENSO with a cold PDO. The cold PDO led to the lack of cold in this winter as a strong pacific jet emerged from the +EPO. This isn't a top analog because of the lack of warmth anywhere on the SST anomalies heading into winter. The high solar/+QBO configuration also likely led to the lower heights dominating in the northern latitudes fueling the Pacific Jet.
- 1980-81: This year featured a +PDO but was not aggressive with the northeast warm pool. The PDO look comes from the colder SST anomalies centered over central Pacific. This allowed a very strong +PNA with the warmer anomalies reaching into the Central US. Coldest air this winter was found in the Eastern US.
- 1983-84: This weak La Nina winter featured the core of the cold being dumped in the South Central/back to the Rockies. SST anomalies are good match in the Pacific but not in the Atlantic. In the Atlantic we see a horseshoe pattern favoring a +NAO signal. This resulted in a very strong Atlantic Jet/+NAO. Other differences include the –QBO.
- 1985-86: On paper this is one of my favorite analogs for this upcoming winter. A cool, but neutral ENSO was present for this winter. The QBO was positive with low solar activity. Core of the cold this winter was in the Midwest with slightly below average temperatures pushing eastward into most of the Eastern US. Southwest/Southcentral locations were very warm.

- ◎ 1992-93: This analog shows the warm concerns, but one of the least favorites out of all the analogs. Cold is in the Western US with warming in the Eastern US. This strong Pacific Jet winter can be seen on the SST anomalies with cooler anomalies over northern Gulf of Alaska. The +QBO/High Solar combination allowed a very strong polar vortex to persist keeping things warm. SST anomaly configuration in the Atlantic also showed the +NAO signal that unfolded.
- ◎ 1995-96: This remains one of our top analogs despite the changes in the stratosphere with the QBO. Outside of a weakly negative QBO this winter has a lot of similarities with the SST anomaly configuration. The La Nina signal is away from the 1+2 regions with a warm PDO. The Atlantic is also warm, but the cold anomalies stay around Greenland. Despite the cold anomalies around Greenland we saw the winter end with a -NAO. Core of the cold extended from the Upper Midwest into the Eastern US with the warmer anomalies in the Southwest. This winter also featured low solar activity.
- ◎ 1996-97: The borderline weak La Nina Winter was not a good one for the Eastern US if you like cold. The SST anomalies show us what went wrong, the cold pool in the Gulf of Alaska (despite a rather warm PDO look otherwise) led to a +EPO winter. This allowed cold anomalies to enter the Upper Midwest, but elsewhere was warm to very warm in the Eastern US. QBO was negative going towards positive, with low solar, AO was negative Dec-Jan. This analog raises concerns of the warm Pacific backfiring into a much warmer look. In addition, a very warm Maritime continent likely kept the tropical forcing in an unfavorable location for cold in Eastern US.
- ◎ 2008-09: Borderline weak La Nina winter with a lot of similarities but missing the warm PDO. The cold PDO dominated the weather pattern allowing for a warm winter across the Southern US into the Middle Atlantic. January was cold across the Eastern US.
- ◎ 2013-14: Another borderline weak La Nina winter with a very similar SST configuration to the current pattern. November 2013 matches very close to current SST anomalies across Pacific and in the Atlantic. This drove the pattern with a strong ridge along the Western US and a trough into the Central/Eastern US. The +QBO/High Solar can explain the +AO/+NAO, but we did see noticeable displacements of the cold into the Eastern US.
- ◎ **Two winters that fit the description of the La Nina/+QBO set up are 71-72 (weak La Nina) and 75-76 (moderate to strong La Nina). These winter weren't terribly warm but 75-76 featured a very warm Feb-Mar...71-72 had a warm Dec-January. Both these winters are not analogs because of the complete opposite SST analog configuration of 71-72 and the strength of La Nina for 75-76.

Summary

Taking this all into consideration we could see an active winter that goes from December through February/March. The core of the cold will likely be in the North-Central locations with the cold extending eastward. With low solar/+QBO we could build the argument for a 2013-2014 winter with more high latitude blocking. But if we see a shift in the Northeast Pacific warm pool we could make the argument for more warm air to dominate the CONUS. Right now I have a tough time seeing the warm pool being displaced/weakening drastically. The weakening +QBO/low solar builds the case for a weaker polar vortex more susceptible to being weakened/displaced.

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