Semi-Annual Report

Predictability of High Impact Weather during the Cool Season over the Eastern U.S: From Model Assessment to the Role of the Forecaster

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Collaborative Science, Technology, and Applied Research (CSTAR) Program

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1. Background

Using verification, data assimilation, and multi-model ensemble approaches, this project evaluates and improves operational ensembles for high impact weather and develops probabilistic tools for the forecaster. The project focuses on the predictability of extratropical cyclones (and associated Rossby wave packets) over the eastern U.S. and adjacent offshore waters for the days 1-7 predictions and select mesoscale phenomena associated with cyclones (1-2 day predictions), with particular emphasis on precipitation bands. There are substantial interactions with several NWS forecast offices, the Environmental Modeling Center (EMC) of NCEP, the Hydrometeorological Prediction Center (HPC) of NCEP, Ocean Prediction Center (OPC) of NCEP, and the NOAA Earth System Research Lab (NOAA-ESRL). NWS forecasters play an integral part in this project, both in using the tools developed and by thoroughly assessing their value in collaboration with Stony Brook University (SBU).

2. Scientific Objectives and Accomplishments

2.1. Automated Wave Packet Tracking and Climatology

During this second six months of the project Stony Brook University further developed and tested an automated Rossby wave packet cyclone tracking algorithm as part of Matthew Souder’s M.S. thesis. Many previous studies have utilized cyclone tracking programs, but this is the first attempt to track wave packets over several decades in order to develop a climatology that will help forecasters understand these features in relation to high impact weather. In order to track continuously through time, a way of converting a wave-like signal to a positive definite amplitude modulation envelope is required (as seen in Fig. 1 from Zimin 2003). Wave processing is a common problem in many scientific disciplines and the most common approach to handling periodic signals is the fast fourier transform (FFT). Zimin (2003) took this one step further for the atmosphere and proposed a Hilbert transform technique to give a spatial map of wave packet amplitude (WPA). He further refined this method by using a time-averaged wind field to determine the wave guide, rather than assuming that wave packets propagate zonally (Zimin 2006). A 14-day running mean basic state flow was used for this process. The raw data was then spectrally filtered using a Cholesky decomposition (e.g. Houtekarner and Mitchell 2001) at T21 resolution to reduce local noise (shown in Fig. 2).

Hodges’ (1999) “TRACK” algorithm was selected to accurately follow the sometimes chaotic movements of local maxima in WPA (Hodges 1999, software updated 2009). This method produces tracks based on a cost optimization approach (similar to 3D variational data assimilations, e.g. Courtier et al. 1998) and is therefore less subject to sequential errors in tracking caused by close proximity of unrelated WPA maxima when the features being tracked. TRACK allows the user to select a minimum feature intensity to observe, as well as the maximum displacement distance (in great circle degrees) between two points in the same track, the smoothness parameter in the cost function for any given propagation speed (called adaptive tracking, Hodges 1999), and the minimum size of the objects being tracked. Here, smoothness refers to the tendency of a feature to track with a smoothly varying velocity (producing a path that is predictable, rather than ragged). The selections used for this climatology were made with the idea that it was...
better to see as much information as possible and throw out a lot of bad data than to miss features or erroneously blend them into common tracks. We therefore selected 10 m s\(^{-1}\) as the minimum WPA threshold, 20 degrees as the minimum displacement distance, 20 grid points as the minimum object size, and a set of adaptive tracking constraints that were fairly strict (requiring a track to be predictable and smooth to remain continuous).

The main problem with feature-based wave packet tracking is that a single feature sometimes fails to accurately represent the entire structure of a large wave packet. This is particularly an issue when the dynamical support for the wave packet extends over a very large area and/or encounters a barrier to smooth, linear flow. Examples of barriers include wave break events (Polvani and Plumb 1992), large terrain features like the Tibetan High Plateau (Chen and Lin, 2005), and atmospheric blocking (Thorncroft et al. 1993). An example of a terrain induced split in wave packet propagation is shown in Figure 3. Note that the dynamical support (eddy kinetic energy) for the wave packet exists throughout the entire object from the Central Pacific to the Eastern US Coast, yet there are two clearly observable peaks in WPA. This kind of complex internal structure complicates a feature-based tracking algorithm and a method for defining whether two tracks may be related to the same wave packet is therefore necessary.

The merging algorithm constructed for this climatology attempts to correct the largest problem with feature-based tracking – the lack of recognition of the overall shape and size of the object surrounding a local WPA max. This tool attributes all grid points in a gridded analysis with WPA values larger than 10 m s\(^{-1}\) to the nearest local maximum found by TRACK (thus turning a feature into an object), and then merges wave packet tracks by requiring a 50% or greater overlap between the grid points contained in both an existing track object and a potential merge candidate and the potential merge candidate itself (Fig. 4). Merge candidates are found by defining a search box within reasonable geographic proximity to a given track point as shown in Figure 5. If a candidate is deemed to be related to the parent track, both the parent and the merge candidate are given the same track family identification.

The tracking and merging algorithms discussed above produce tracks with a range of durations and intensities – some of which are probably real wave packets, some of which are likely not. The goal is to keep as much good data as possible while excluding nearly all of the bad data. Based on single-point correlation work (Lee and Held 1993) and idealized linear modeling studies (Chang 1993), it is reasonable to conclude that a wave packet should propagate for a protracted period of no less than two days, which was used in this study.

A preliminary wave packet climatology has been obtained using the NCEP reanalysis data from 1948-2010. Figure 6 shows the annual climatology of wave packets, found by isolating the grid cells in each time step of the database included within the object boundaries of significant wave packets, adding their WPA values together, and dividing by the total number of time steps in the record (~90,000 in all). As expected, wave packets are largely associated with the mid-latitude storm track belts, with peaks in activity over the Central North Pacific, Western North Atlantic, and Southern Indian Oceans (down wind of Cape Horn in Africa, Japan in the Pacific and the US East Coast in the Atlantic). Topography appears to play a significant role in shaping wave packets, with the Tibetan High Plateau completely inactive, and a weakness over the North American Rockies. Note also that the ocean-dominated Southern Hemisphere storm track
belt has a generally zonal orientation, whereas the Northern Hemisphere has some meridional structure.

The seasonal cycle of wave packets in the Northern Hemisphere also sheds light on the role of topography in the behavior of the wave guide. Figure 7 shows the evolution of wave packet activity (calculated as before for the annual climatology, but this time binned by month) through the late fall to early spring transitions (September to April). As one would expect, the wave packets move further south during the heart of winter and drift poleward in the spring and fall. However, there is a lack of activity during the midwinter months over the central Pacific (and the corresponding split in wave packet activity around Tibet). We hypothesize that during the spring and fall, wave packets are free to pass north of Tibet. However, during the winter months, the wave guide moves equatorward and wave packets split around the terrain barrier, thus dividing their total energy and weakening the Pacific storm track. This is consistent with the modeling work Park et al. (2010) regarding midwinter Pacific cyclone activity. Note that the Atlantic does not experience the same midwinter minimum, instead peaking in December.

The most operationally relevant aspects of this wave packet climatology are the following:

* The U.S. is lies within a wave packet frequency maximum – wave packet “threat” area.
* There is a rapid increase in activity between September and October. Forecasters may be lulled into tranquility by the summer and then all of a sudden one of these high-amplitude patterns sets up quickly in the Fall and they didn’t see it coming.
* Wave packet activity peaks in November – December (early winter).

To demonstrate that wave packets can be modulated by the large scale flow regime and that the climatology can provide useful insight into this phenomenon, wave packet activity was analyzed in the winter period (December, January, February – hereafter “DJF”) during significant El Nino and La Nina events in the Pacific. ENSO+ and ENSO- years were selected by calculating the mean value of the Multivariate ENSO Index (MEI) as defined by Wolter (1987) in the DJF period and choosing seasons with MEI of greater than 1.0 or less than -1.0. There were 12 ENSO+ and 9 ENSO- winters in the reanalysis record. Figure 8 shows a composite of wave packet activity for ENSO+ and ENSO- winters. It is generally known that El Nino is associated with increased activity in the subtropical jet over the Eastern Tropical North Pacific, while La Nina is associated with a stronger polar front jet over North America and the North Pacific. The same signal is apparent in the wave packet activity maps, with somewhat increased wave packet activity east of Hawaii and over the Southwest US, and decreased activity over the North Pacific during El Nino winters and the reverse being true during La Nina. El Nino also appears to favor more meridional flow over the North Atlantic.
Figure 1 – Defining Wave Packet Amplitude (WPA) as in Zimin (2003) – while the meridional wind field $v(x)$ generally has an oscillatory signal (varying between northerly and southerly flows), the amplitude of each oscillation is modulated by an envelope function $A(x)$. This function is called WPA.

Figure 2. Example of the impact of filtering on the wave packet amplitude (WPA – shaded in m/s) for the (a) unfiltered and (b) T-21 Cholesky filtered and 300 hPa geopotential height (contoured every 240 m) for 03 March, 2009 (06 UTC).
Figure 3. Example discontinuity of a wave packet as it crosses North America showing WPA (shaded in m/s) and ageostrophic geopotential fluxes (see top caption).

Figure 4. Merging related wave packet tracks. Left: Object as it exists prior to potential merge. Right: Old object shown again in pink, new object shown in black, now featuring more than one local maximum in WPA. In green, the overlap region between the old object and the merge candidate object. If this region covers greater than 50% of the merge candidate object, the merge is considered valid.

Figure 5. Search box used to identify potential WPA merge candidates.
Figure 6 – Wave packet activity index (annual average) showing the average WPA value observed in significant wave packets (grid points not in a significant wave packet receive a value of zero) using the NCAR reanalysis period (1948-2010).
Figure 7 – Seasonal variability in Northern Hemisphere wave packet activity.
2.2. Mesoscale Banding Predictability

The Stony Brook ensemble results presented at a previous AMS conference in Novak and Colle (2007) for three snow banding events has been submitted to Wea. Forecasting. The forecast uncertainty for mesoscale snowband formation and evolution is compared using predictions from a 16 member multi-model ensemble at 12-km grid-spacing for the 25 December 2002, 12 February 2006, and 14 February 2007 northeast U.S. snowstorms. The case-to-case variability in the predictability of band formation and evolution is emphasized to highlight the wide range of ensemble uncertainties for snowband events. Feature-based uncertainty information is also presented as examples of what may be operationally feasible from post-processing information from future short range ensemble forecast systems. Additionally, the meteorological context associated with the error growth in each case is explored by contrasting the forecast evolutions of representative members with opposing location solutions.

Considerable uncertainty in the occurrence, and especially timing and location of band formation and subsequent evolution was found, even at forecast projections of < 24 h. The ensemble can provided quantitative information on mesoscale band uncertainty, and helped differentiate between a case with high predictability (14 February 2007) and another event with much lower predictability (12 February 2006). Among the three cases, large (small) initial differences in the upper-level PV distribution and surface mean sea level pressure of the incipient storm were associated with large (small) differences in forecast snowband locations, suggesting a direct link to the quality of the initial conditions. This has implications for targeted observing. Nonlinear upscale error growth was evident in each case, consistent with previous mesoscale predictability research, but predictability differences were not correlated to the degree of convection associated with each case.
2.3. Ensemble Sensitivity Analysis

Prior to this project, ensemble sensitivity analyses (ESA) have only been developed and applied to assess how short range (2-3 days) forecasts depend on changes in initial conditions. In this project, the co-PI (Edmund Chang) and one of the graduate research assistants (Minghua Zheng) implemented ensemble sensitivity analyses for medium range (5 days or longer) forecasts. In short, given an ensemble of forecasts made using an ensemble of initial conditions, how the forecast outcome depend on changes in the initial conditions can be derived statistically based on linear correlation or regression analyses to relate forecast anomalies to initial condition anomalies within the ensemble. Making use of an Ensemble Kalman Filter (EnKF) data assimilation and forecasting system developed by the co-PI (E. Chang), the methodology has been tested and validated for a number of historical explosive extratropical cyclogenesis cases that occurred over the western Pacific.

In this system, an ensemble of 80 randomly selected state vectors taken from a long model run is used to assimilate observations archived for the NCEP-NCAR reanalysis project, using the EnKF data assimilation system developed at NCAR by the Data Assimilation Research Testbed (DART) project. The initial spread of the ensemble is close to climatological standard deviation in each field, but after assimilating observations for several days, the ensemble spread decreases substantially and the spread in the ensemble of analyses at each time represents an estimate of the uncertainty in the analysis consistent with the constraint given by available observations. This ensemble of analyses is then used as initial conditions for an ensemble forecast, and ESA is then conducted on the outputs from this forecast ensemble. Our results suggest that using the appropriate forecast metric, even for medium range forecasts (out to at least 7.5 days), coherent sensitivity signals can be seen spreading upstream from the forecast validation time to the initial time, frequently in the form of downstream developing wave packets (see Fig. 9). Fig. 1, taken from a West Pacific explosive cyclogenesis case from December 1981, shows how the leading EOFs of MSLP variability associated with cyclogenesis near the date line on day 0 are sensitive to 300 hPa height perturbations prior to the event. For this case, EOF 1 (Fig. 10) corresponds to deepening and slight northward shift of the forecast cyclone, and EOF 2 to westward shift of the cyclone location. In figure 9, we can see coherent sensitivity signal spreading westward from the cyclogenesis location upstream towards Eurasia, with highly significant signal found even on day -6, especially for the sensitivity pattern derived based on EOF 2.
Figure. 9. Sensitivity of forecast MSLP EOF 1 (left, corresponds to deepening of forecast cyclone) and EOF2 (right, corresponds to westward shift of forecast cyclone) at day 0 to 300 hPa geopotential height (Z, shades) based on an ensemble of 7.5-day forecasts with 80 members. All shaded regions are statistically significant at the 95% confidence level. Contours represent forecast ensemble mean 300 hPa Z.
In order to validate that these sensitivity signals are indeed causally related with the cyclogenesis events, initial perturbation experiments have been conducted to add (or subtract) perturbations derived based on the sensitivity analyses to the ensemble initial conditions and the perturbed ensemble integrated to validate that the initial perturbations do actually evolve into structures that modify the cyclogenesis event. Our results show that while initial perturbations derived directly based on forecast cyclone parameters, such as cyclone MSLP, latitude, or longitude, are only effective out to 4-5 days, initial perturbations derived based on EOFs of MSLP distribution around the cyclone center are more effective out to 7.5 days or beyond. This represents the first attempt to implement and validate ensemble sensitivity analyses out to the medium range. These results are currently being written up for publication.

With the implementation and validation that the ensemble sensitivity analyses (ESA) technique is applicable in assessing medium range forecasts of extratropical cyclone evolution, currently the technique is being applied to study coastal US cyclogenesis cases, including interesting cases that occurred during the past winter season that our CSTAR partners have shown great interests in through our CSTAR related email exchanges. The ultimate goal is to implement ESA as an alternative tool alongside Ensemble Transform Kalman Filter (ETKF) guidance that NCEP forecasters can make use of in assessing how to deploy targeted observations during annual NOAA Winter Storm Reconnaissance (WSR) missions, as well as to allow forecasters in local weather forecast offices to assess where important forecast uncertainties arise from during high impact weather situations.

To this end, in year 2 of this project, we will employ TIGGE data to develop and assess ESA guidance related to US significant weather events. To compare ESA guidance to ETKF guidance, we have obtained the ETKF code from Sharanya Majumdar and we will implement ETKF and compare its results to the ESA results. We will use TIGGE data to develop and assess the use of multi-model ensemble forecasts for ESA and ETKF guidance. Initial efforts will be focused on using ensemble data from NCEP, CMC, and ECMWF, which are currently available to NCEP forecasters. However, we will also start to develop tools using ensembles from other forecast centers available from the TIGGE.
grand ensemble to assess whether including data from more forecasting centers can lead to reduction in spurious signals and help in uncertainty assessment.

Research will also continue to develop guidance to assess how to differentiate ESA and ETKF signals that are really causally related to forecast significant weather events from those that may be spurious. This will require further use of the EnKF data assimilation and forecast system mentioned above to conduct initial perturbation experiments for selected cases to assess which of the various ESA/ETKF signals are causal or spurious. As an example, based on continuity of signal propagation, we hypothesize that the negative (blue) signal found on day -4 for EOF 1 (6th panel from top on LHS in Fig. 9) over the North Sea may be spurious – but initial condition perturbation experiments have to be conducted to validate such a hypothesis.

After these assessment efforts, codes will be developed to enable NCEP forecasters to compute ESA based on the available multi-model ensemble and use as a tool alongside ETKF guidance. (Efforts will also be made to retrieve ensemble data locally to compute ESA and ETKF guidance to be posted on our CSTAR web page so that our CSTAR partner forecasters from other local forecasting offices can access these guidance tools to help them assess uncertainties in the ensemble forecasts during significant weather events.)

3. Interaction with Operational Forecasters During High Impact Weather

The predictability of several mesoscale phenomena within extratropical cyclones has been investigated objectively and through extensive discussion with the NWS collaborators during some major events (see appendix).

Forecasters and researchers interacted extensively during and after the 26-27 December 2010 NYC blizzard. This event was poorly forecast a few days in advance in the models likely because of some Rossby wave packet error propagation. Several of the example emails in the appendix are related to this event. A web page was constructed for this event: http://dendrite.somas.stonybrook.edu/CSTAR/2627Dec2010.html. Several NWS offices contributed to graphics illustrating the cyclone tracks, model differences, ensemble sensitivity plots, and other event summary links.

The CSTAR discussions of the 26-27 December event served as a focus for an internal NWS report on the event. Also, EMC diagnosed several different data quality and assimilation issues for this event.

Rich Grumm summarized this event and acknowledges the CSTAR discussions: http://cms.met.psu.edu/sref/severe/2010/26Dec2010.pdf

The CSTAR tutorial on Ensemble Sensitivity was supplemented with real-time examples from the operational NCEP Winter Storms Reconnaissance Program. During the 2010-11 season there was vigorous email exchanges for 10 east coast cyclones (listed below). Discussions were focused on the real-time interpretation of the NCEP Ensemble Sensitivity results (http://www.emc.ncep.noaa.gov/gmb/targobs/wsr2011/). Notice of
flights and associated drop sondes were also shared among the group in real-time. There was ensemble sensitivity discussions among the list participants for the following events:

Nov 4, Dec 8, Dec 12, Dec 19, Dec 25-27, Jan 6, Jan 11-12, Jan 20-21, Jan 26-27, April 1-2

4. Products and Presentations

4.1 Products

A CSTAR web page has been made for this project:
http://dendrite.somas.stonybrook.edu/CSTAR/cstar.html
This page provides background information, as well as links the Partners in the project, models (ensembles) available, presentations, tutorials, papers, and the latest news or events.

A CSTAR email group has also been implemented for this project:
sbucstar@noaa.gov . There are currently 44 forecasters, students, and researchers on the email list.

Over 150 emails have been exchanged in the past six months, including 50+ emails for the 26-27 December 2010 blizzard. Some of these email exchanges are highlighted below in the Appendix.

The university is maintaining the web page showing the real-time wave packet diagnostics.

http://xs1.somas.stonybrook.edu/~chang/personal/Wave/main.htm
This wave packet web page has been used by forecasters. For example, below is a sample area forecast discussion from the New York City office. We also plan to extend this page to the some of the global ensembles (e.g., NAEFS).

FXUS61 KOKX 292304
AFDOKX

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE NEW YORK NY
704 PM EDT TUE MAR 29 2011

.FOLLOWING THE APRIL 1ST DAY STORM...THE PATTERN BECOMES PROGRESSIVE WITH THE ARCTIC OSCILLATION BECOMING EXTREMELY POSITIVE (+6) AS THE NAO REBOUNDS TO NEUTRAL TO SLIGHTLY POSITIVE. STONY BROOK UNIVERSITY COLLABORATIVE RESEARCH ANALYSIS OF ROSSBY WAVE PACKET ENERGY SHOWS A VERY ACTIVE FIRST WEEK OF APRIL FOR THE WESTERN HEMISPHERE (0-180 WEST). THIS COINCIDES WITH A POTENTIAL INCREASE IN MJO ACTIVITY IN THE WESTERN PACIFIC THOUGH THIS MAY NOT BE A TELECONNECTION.
The wave packet identification code at Stony Brook has been shared with our forecast partners, and HPC has now implemented it in their office, with the goal to provide wave packet information on their NAWIPS display system for the forecasters, especially on the medium-range desk.

![Wave Packet Identification Code](image1.png)

**Figure 11.** Sample tutorial slides developed Mike Bodner at the Hydrometeorological Prediction Center highlighting the new capabilities to display wave packet envelopes in their NTRANS display system.

HPC now is archiving the multi-ensemble (over 100 members from the ECMWF ensemble, GEFS, CMCE, and deterministic runs) 500 mb height spaghetti plots with verification overlaid. This is now a CSTAR resource.

Stony Brook is still maintaining the 13-member 36/12-km WRF/MM5 ensemble for the Northeast U.S.: [http://chaos.msrc.sunysb.edu/NEUS/nwp_graphics.html](http://chaos.msrc.sunysb.edu/NEUS/nwp_graphics.html)

Stony Brook University has installed the NWS Weather Event Simulator ([http://wdtb.noaa.gov/tools/wes/index.htm](http://wdtb.noaa.gov/tools/wes/index.htm)) on all 11 computers in the synoptic laboratory, so they can view the same data as the forecast partners for the major storm events.
4.2 CSTAR Tutorials

The following three online tutorials have been given, which are available online: http://dendrite.somas.stonybrook.edu/CSTAR/Tutorials.html. As a result, there are now 2-3 hours of training material developed and available for forecasters.

On 30 June 2010, Dr. Brian Colle and Edmund Chang offered a 45 minute tutorial on Rossby wave packets. About 5 forecast offices participated in this tutorial.

On 4 August 2010, Dr. Paul Schultz at NOAA-ERSL gave a 45 minute tutorial on the Advanced Linux Prototype System (ALPS) for ensemble graphical display. About 5 forecast offices participated in this tutorial.

On 26 October 2010, Drs. Yucheng Song, Sharan Majumdar, and David Novak led a tutorial (webinar) on ensemble sensitivity. About 15 forecast offices participated in this tutorial.

4.3 Papers and Presentations

The following paper has been published or accepted as a result of this CSTAR effort and support:


The following presentations have been given in the past 6 months:

Two graduate student presentations were given at the 3rd Tri-State Weather Conference in Danbury, CT on 9 October 2010:

Three graduate students, the PI (Colle), and the NYC NWS presented CSTAR results at the 12th Northeast Operational Weather Workshop in Albany, NY 3-5 November 2010.

* Matt Souders: "An Automated Rossby Wave Packet Tracking Program: Preliminary Climatological and Model Verification Results"

* David Stark: "Microphysical Evolution Within Winter Snow Storms over Long Island, New York"

* Michael Erickson: "Ensemble Post-Processing and Its Potential Benefits for the Operational Forecaster"

* Brian Colle: "Predictability of High Impact Weather during the Cool Season over the Eastern U.S.: CSTAR Scientific Objectives"

* Jeffrey Tongue (NYC NWS): "Predictability of High Impact Weather during the Cool Season over the Eastern U.S.: CSTAR Operational Aspects"

Four graduate student presentations and a PI presentation related to this CSTAR are planned for the WAF-NWP meeting at the 91st annual AMS meeting in Seattle, WA in January 2011.

* David Stark: "Microphysical Evolution Within Winter Snowbands Over Long Island, NY"

* Michael Erickson: "Impact of Spatial Bias Correction and Conditional Training on Bayesian Model Averaging Over the Northeast United States"

* Matthew Souders: "Spatial and Temporal Climatology of Atmospheric Wave Packets"

* Kelly Lombardo: "Relationship Between Organized Convective Structures and Severe Weather Type Over the Northeast U.S." Kelly Lombardo won the best student oral presentation at this conference.

4.4 CSTAR Group Meetings

There was a teleconference (Go-To meeting) led by PI Colle on 13 January 2011 that had all CSTAR partners online to discuss the 26-27 December event. A recording of the event can be found at: http://www.nws.bnl.org/CSTAR/Dec26th/Dec26th.html
5. Forecast Partner Accomplishments

ALPS is an important ensemble visualization tool available to the forecast offices. It allows forecasters to calculate ensemble statistics (see the pdf) and they can choose what member groupings they want to use. Following the ALPS tutorial in early August, the NWS partners (led by Jeff Tongue and Matthew Sardi in the NYC office) collaborated to get ALPS working on their operational machines using the SREF ensemble data.

Figure 12. Sample spaghetti output from ALPS at the NYC-WFO using the GEFS data for 300-hPa (in dm).

A set of instructions were written for installing ALPS, which are on our CSTAR web page: http://dendrite.somas.stonybrook.edu/CSTAR/Tutorials.html#Alpsinstall

The ALPS software has also been implemented at the Mt. Holly, NJ office (SOO- Al Cope). There is already interest from some other CSTAR groups implementing ALPS (Dr. Gary Lackmann—NC-State Univ CSTAR, personal communication 2010).

Mike Bodner at HPC has implemented the Stony Brook Rossby wave packet software (Fig. 11 above). This required using MATLAB, and writing other software to convert to GEMPACK data for the operational NAWIPS display system. They are currently testing before it is released to the forecasters at HPC.

Rich Grumm (State College) has written up ensemble storm summaries for some of the major events: http://nws.met.psu.edu/severe/ For example, the 30 September flooding event and the NCEP SREF performance is at: http://nws.met.psu.edu/severe/2010/30Sep2010Flood.pdf

After years of delay, EMC started bias correcting the SREF QPF as a result of a strong push from this project. Namely, the PI (Colle) visited HPC in the summer of 2010 and gave a seminar highlighting the benefits of post-processing ensemble QPF.
6. Problems and Difficulties

The biggest problem is the bandwidth at the NWS WFOs. The WFOs have installed the ALPS system, but many do not have the bandwidth to download the NCEP SREF members in a timely way. Thus, they have not been able to use the ALPS they installed to its full potential. We are investigating ways to perhaps reduce the file sizes. Another issue has been the AWIPS and other software upgrades, which has breaks the ingestion of SREF data and ALPS capabilities.

References:

Appendix – Sample of Collaborative Email Exchanges.

Below are some sample CSTAR emails, which highlight the interactions in this project. To provide some continuity below, most of the emails are from the 26-27 December blizzard event.

From: Stephen Jascourt <Stephen.Jascourt@noaa.gov>
To: Sharan Majumdar <smajumdar@rsmas.miami.edu>
Date: Fri, 29 Oct 2010 14:02:51 -0400
Subject: Re: Uncertainties with Eastern US Trough Next Week

Fascinating discussion!
Is anyone examining the source of the wave packets? It seems to me that the wave packets identify long-wave amplification and are associated with uncertainty because a shift in the amplifying pattern leads to a large difference in the forecast. Then, the uncertainty later downstream is tied to uncertainty in the driving source of the wave packets and uncertainty in the environment which affects the subsequent wave propagation.

Almost 30 years ago, Hoskins and Karoly found wave trains apparently forced by tropical diabatic heating. Is this fundamentally the same as we are seeing in the wave packets discussed here? So probably they are being driven by Typhoon Chaba and their downstream behavior is strongly modulated by the eastern and western Pacific troughs? Then one target would be related to improving the track forecast for Chaba and the total moisture flux into the storm (e.g., something to determine the amount and distribution of diabatic heating). Other targets would be related to features affecting the wave propagation downstream, e.g., probably related to better defining the vorticity distribution (at what level?) along the projected wave packet path. Using ETKF computations (or singular vectors, etc.) to identify sensitive areas bypasses the underlying scientific questions, as those are all buried in the model solutions (to the extent that the model physics and dynamics represent nature), but makes it easy for forecast operations, since the action (where to target) and the resulting forecast can be made without the need to investigate the scientific questions in the situation at hand.

Stephen

Stephen Jascourt, COMET resource on NWP

Hi all,

This is a very interesting case. Thanks for sharing it. My interpretations of Yucheng's ETKF computations are similar to those that Dave and Edmund have given.

First, the continuity in the targets as the hypothetical observing time moves towards the verification time gives us some confidence that the target associated with the Asian trough is genuine. At a lead time of 4.5 days, such a target is very plausible, particularly in the presence of a coherent wave packet. Certainly consistent with what I have seen.
Second, the target associated with Typhoon Chaba may also be plausible. The ETKF likely picks up this target due to a large spread and covariance with features downstream, but it has been demonstrated by Pat Harr and others that some small changes to the position and structure of a typhoon undergoing extratropical transition can substantially modify the longwave pattern downstream. The modification to the warm sector on the NE side of the typhoon amplifies or weakens the ridge, thereby changing the longwave pattern. It may be worth examining this in some of the individual GEFS ensemble members over the Pacific.

Finally, Edmund pointed out that the eastern Pacific trough remains roughly in place. I have noticed this happening in several cases, and it is also a plausible target. So all three targets seem reasonable, although it is not clear how to assign a priority of targets if observational resources are limited.

It would be great if some kind of data denial could be attempted with existing observational data in the GFS/GSI system, to examine whether these areas selected by the ETKF are actually sensitive.

Best Regards,

Sharan

S.J.Majumdar, RSMAS Division of Meteorology and Physical Oceanography, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149-1098. Phone: (305) 421 4779. http://orca.rsmas.miami.edu/~majumdar/

On Thu, 28 Oct 2010, kmchang@notes.cc.sunysb.edu wrote:

Hi Dave and Yucheng,

Thanks a lot for doing the calculations. Very nice illustration of the ideas discussed on Tuesday.

See attached ppt file for discussions below:

I tried putting the sensitive area onto the Hovmoller diagram, and get a slightly different view of the case. It seems to me that out of the main sensitive areas on Oct 29, the one associated with the east Pacific trough stays roughly in place, while the sensitivity center that seems to relate to the emerging east Asian trough move across the Pacific, initially slower than wave packet speed, but as the wave packet develops it moves eastward along the leading edge of the wave packet and caught up with the sensitive area associated with the east Pacific trough and they merged and then move into the verification area. Meanwhile, the sensitive area associated with Chaba seems to move rather slowly eastward and remains east of the date line even by 2 Nov. So based on "continuity", one might argue that if we want to make observations, we should sample the sensitive area.
associated with the emerging east Asian trough and possibly also the sensitive area associated with the eastern Pacific trough. On the other hand, the evolution of Chaba and its associated sensitive area seems to be related to the development of the wave packet itself, so one might want to argue that even though that sensitive area does not bodily move across the Pacific during the forecast period, but its impact might be felt due to the development of the wave packet.

Since Sharan has examined many more of these plots, what do you think of this case?

-- Edmund

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From: David Novak <david.novak@noaa.gov>
To: _NWS ER SBUCSTAR <sbucstar@noaa.gov>
Cc: Sharan Majumdar <smajumdar@rsmas.miami.edu>, Yucheng Song <Yucheng.Song@noaa.gov>
Date: 10/28/2010 04:53 PM
Subject: Uncertainties with Eastern US Trough Next Week

List,

There is a large degree of uncertainty regarding the Eastern U.S. trough next week. Yucheng ran the ETKF procedure on this case, verifying 12 UTC 3 November. He may be able to do a similar series for 12 UTC 4 November. I put together a quick and dirty series of ensemble sensitivity maps and GFS forecasts (attached).

My interpretation of the sensitivity maps is that recurving Typhon Chaba and a trough emerging off the Asian coast later tonight play a big role in Eastern US forecast. These sensitivities move downstream, seemingly along leading edge of the wave train. Really ties these CSTAR ideas together.

Note that the Winter Storms Reconnaissance program is not active at this time of year, so adaptive sampling is not occurring with this case (that I'm aware of).

Dave

Date: Mon, 20 Dec 2010 13:48:57 -0500
From: Jeffrey Tongue <Jeffrey.Tongue@noaa.gov>
To: David Novak <david.novak@noaa.gov>, _NWS ER OKX INTERN HMT <nws.er.okx.intern.hmt@noaa.gov>,
Thanks Dave!

A couple of comments/questions.

Attached is an loop from ALPS with 250 HPA heights. It clearly show the Pacific energy coming across the U.S. and rapidly deepening the trough along the east coast on Saturday. What I find interesting in this projection is how the ridge over Labrador breaks down as the ridge over eastern Russia / Kamchatka builds.

On the sensitivity plots - is there significant sensitivity over the Atlantic (related to the current storm)? (it gets cut off in the plots)

Lastly - looking at the GEFS data in ALPS shows some strange discontinuities in the height fields. See below- I hope that's a function of post processing for AWIPS and not in the model. Stephen - any ideas?

P.S. I've copies this to the OKX Forecast Staff - please include them in any replies (research to operations!).

Thanks.

Jeff

From: Stephen Jascourt <Stephen.Jascourt@noaa.gov>
To: Matthew Souders <matt.souders@gmail.com>
Date: Wed, 22 Dec 2010 15:28:46 -0500
Subject: Re: Latest ensemble sensitivity plots...

Difference fields between NAM and the hires window NMM are at http://www.emc.ncep.noaa.gov/mmb/mmbpll/nestpage_4km/ (select east/central US) Aside from having no convective parameterization in the hires window, they are not quite the same model, as hires window is running an old version of WRF code, among other things, though they are fundamentally very similar.

Experimental runs of the new NMM-B with a better advection scheme and some other changes is online at http://www.emc.ncep.noaa.gov/mmb/mmbpll/eric.html scroll down to section 2. Parallel/Experimental Graphics for pages on each of several experiments.
These runs are *not* operational supported and the code can be changing *at any time*, but they are rather reliable and show what is being worked on for the next NAM implementation, planned for next spring or summer. These are not ready for public use - modelers are still sorting out problems and working on the model, but they can be interesting to look at.

The NEMS/NMMB link shows differences from current NAM. The NAMB vs. NAMX is for further experiments, showing differences between experimental versions (labeled NAMB and NAMX).

Most interesting in Matt's context of high-resolution runs is the Nested NEMS-NMMB runs which shows differences between a 4-km CONUS 1-way nest and its 12-km parent out to 60 hours. This is a well-controlled experiment in that the exact same model is being used in the nest and parent other than convective parameterization and some land surface details - more lakes show up in the 4-km nest, now 4-km sea ice data is used directly in the nest instead of up-interpolating to the parent and then down-interpolating to the nest, etc. I should note that presently, these experimental 4-km nests *do* use BMJ convective parameterization but toned down to reduce the tendencies. This mitigates excessive grid-scale response while still letting the grid-scale microphysics generate most of the precipitation, though I have some concerns about using a deep convective parameterization at all in the 4-km run. The high-resolution window runs which Matt pointed to are run without any convective parameterization and that will continue even after these nests in the NAM are implemented - separate hires window runs will continue as they do now (and will be updated with newer versions of WRF using better advection schemes in the spring!).

For today's 12z run out to 60 hours, there is not much difference in large-scale fields between this nested 4-km run and its parent 12-km run except in the core of the southern stream trough, where the 4-km run is not as deep beginning in AZ around 24 h, tracking with the trough, and become more pronounced over a small area over eastern OK by 60 h (see the CONUS4km-NAMX difference loop http://www.emc.ncep.noaa.gov/mmb/mmbpll/nampll_conusnest/diff.conus.500_animate.html ). The 4-km run also has a more pronounced precip shield on the north side of the system over MO, IL, into KY by 60 hours (compare the 2 simulated reflectivities http://www.emc.ncep.noaa.gov/mmb/mmbpll/nampll_conusnest/radarcomp_animate.htm 1 ).

In all of these plots, beware that new plots appear as they are generated, so a loop may contain some new plots and some plots from the previous cycle. The cycle time generally does not indicate the new time until all of the new plots are in.

Stephen

On 12/22/2010 2:28 PM, Matthew Souders wrote:
Just thought I'd point this out...
My office mate and I both think it's fascinating that the hi-res NMM (HRW) at 4 km sees the southern steam shortwave and the upstream height rises much better than does its' 12 km cousin (the 12Z NAM)

http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/namer/nam/12/images/nam_500_048l.gif (NAM)

http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/namer/hiresw/12/images/hiresw_500_048l.gif (HRW NMM)

Both images are for 12 UTC Friday and are 48 hour forecasts.

Apparently, if you run the same model (essentially) with the same physics, and more or less the same ICs (but slightly different LBCs since the hi-res is a smaller grid)...you get very different solutions and they have major downstream implications.

*eyes sideways*

Matt Souders

On Wed, Dec 22, 2010 at 1:03 PM, Mike Erickson <mjaerickson@gmail.com> wrote:

Hi all,

First Dave, thanks for sending the ensemble sensitivity analysis plots. I am curious to see what today has to offer.

For this storm and the previous one I've found the individual SREF members quite handy at figuring out the potential range of solutions. For instance, the SREF still has significant variability in the intensity and position of the subtropical shortwave, especially as it begins to interact with the northern stream energy. In some cases (some NMM members), the subtropical vorticity doesn't phase well and the results will probably be somewhat similar to the 00z NOGAPS. In other cases, the phasing seems better, with a respectable 500 hPa height field (for an east coast storm) by hr 87. I know that the storm is beyond the range intended by the SREF, but real period of interest starts around hr 60. Rather than sending many images you can look at the link below, although you may need a magnifying glass.

http://www.meteo.psu.edu/~gadomski/SREF21500US_9z/srefloop.html

This sensitivity also appears to explain the notable differences between the 06z and 12z GFS. The 06z GFS was weaker with the northern stream 500 hPa vorticity at hr 66:

http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/namer/gfs/06/images/gfs_500_066l.gif
compared to the 12z GFS at hour 60:

http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/namer/gfs/12/images/gfs_500_060l.gif

Mike

On Tue, Dec 21, 2010 at 4:32 PM, Matthew Souders <matt.souders@gmail.com> wrote:

I seem to recall that the EC used to have a bias toward trapping shortwaves from the southern stream against the rockies a bit too long. I note that the EC favors a slower moving southern stream shortwave (especially during lee cyclone formation time over the plains) and thus a bigger storm...is that a model bias that might bite us in the backsides if we lean toward the EC? Or has that bias been rectified by recent EC updates? Anyone know about what I'm referring to here?

Matt

On Tue, Dec 21, 2010 at 3:26 PM, Bill Bua <Bill.Bua@noaa.gov> wrote:

All --

You probably all saw this stuff already, but ...

The medium range ensembles seem to cluster around their respected base model solutions, from what Geoff Manikin showed me (ECMWF lows close to and ON the DelMarVa peninsula, with Canadian ens. and GEFS with greater scatter and farther east). I understand the 12 UTC ECMWF bombs out once again with a 967 low east of Cape May by 12 UTC 27 December. It seems as though the slower the short wave is moving east from the west coast, the more likely and earlier will be the strong amplification. The 12 UTC GFS/GEFS shows the relatively fast, flat, south and east solutions with little more than 0.1-0.25 for the mid-Atlantic/D.C. area. There is one member, though, with an inch of liquid equivalent over 24 hours. Don't see the Canadian ensembles yet.

B

On 12/21/2010 3:09 PM, David Novak wrote:

Hi all,

For the latest ensemble sensitivity plots from last night's 00 UTC ensembles see:
Consider hypothetical observations taken this evening to improve the forecast over the east coast verifying 12 UTC 26 December:
http://www.emc.ncep.noaa.gov/gmb/tparc/special/20101221_NCEP+ECMWF+CMC/Plot9_40N70W_summary_24_132.gif
Like yesterday, the western Atlantic storm, the storm in California, and then two systems NW of Hawaii are key features.

Consider the impact of a hypothetical flight from Japan into the west Pacific sensitive area:
http://www.emc.ncep.noaa.gov/gmb/tparc/special/20101221_NCEP+ECMWF+CMC/sig_var_24_flight76.gif The impact (shading) moves downstream with the system itself, but already by 36 h the impact has "jumped" to the next apparent trough near 150W, and by 48 h the impact has jumped to the shortwave in Texas, which moves into the target region. Other areas light up in a lot of places after 48 h:
http://www.emc.ncep.noaa.gov/gmb/tparc/special/20101221_NCEP+ECMWF+CMC/sig_var_24_flight76_more.gif

Plenty of players causing plenty of uncertainty...

Date: Wed, 22 Dec 2010 15:30:58 -0500
From: David Novak <david.novak@noaa.gov>
To: _NWS ER SBUCSTAR <sbucstar@noaa.gov>
Subject: Latest ensemble sensitivity plots

Hi all,

Here's the latest ensemble sensitivity plots for forecasts verifying 00 UTC 27 Dec:
http://www.nco.ncep.noaa.gov/pmb/sdm_wsr/graphics/20101222/Note the time was significantly adjusted based on the timing change in the models/ensemble.

I'd suggest some of the sensitivity areas have changed, with more emphasis on the western Pacific storm to start:
http://www.nco.ncep.noaa.gov/pmb/sdm_wsr/graphics/20101222/Plot1_38N73W_summary_48_120.gif

and then the wave coming over the ridge in Canada, as well as the further south position of the TX short wave.
http://www.nco.ncep.noaa.gov/pmb/sdm_wsr/graphics/20101222/Plot4_38N73W_summary_84_120.gif

Dave

Date: Tue, 28 Dec 2010 13:09:26 -0500
From: david.novak@noaa.gov
To: map@atmos.albany.edu
Subject: Mesoscale substructure

Map,

In reviewing radar of the northeast blizzard, there are a host of fascinating radar features. Here's a few I saw:

Precip "hole" eastern Long Island and off coast (around 20 UTC 26 Dec), and rapid "fill in" of banded showers behind it:
http://www.rap.ucar.edu/weather/radar/displayRad.php?icao=KOKX&prod=bref1&bkgr=black&endDate=20101226&endTime=22&duration=2

Multibands developing, moving northwest, and merging with primary band (around 00 UTC 27 Dec):
http://www.rap.ucar.edu/weather/radar/displayRad.php?icao=KOKX&prod=bref1&bkgr=black&endDate=20101227&endTime=1&duration=3

Secondary band (west of primary band) sitting over the PHL area ~5 UTC 27 Dec:
http://www.rap.ucar.edu/weather/radar/displayRad.php?icao=KDIGX&prod=bref1&bkgr=black&endDate=20101227&endTime=6&duration=3

And quasi stationary ENE-WSW oriented band of light snow between DC and the Eastern Shore around 6 UTC 27 Dec:
http://www.rap.ucar.edu/weather/radar/displayRad.php?icao=KLWX&prod=bref1&bkgr=black&endDate=20101227&endTime=7&duration=3

Lots to study, including the predictability of such features.
Dave

Date: Thu, 30 Dec 2010 22:25:47 -0500
From: Dan.Petersen@noaa.gov
To: map@atmos.albany.edu
Subject: draft-observed sea level low track and models/ensembles 26-27 dec 2010

Hi Everyone,

In the attached powerpoint file I've compiled the observed sea level cyclone track for the 26-27 Dec 2010 storm and the forecasts from the model/ensemble mean suite.

The observed positions come from the HPC/OPC surface analyses done in real time. The archive is available at http://www.hpc.ncep.noaa.gov/html/sfc_archive.shtml.
Marty Rausch had compiled the series of forecast maps starting on 23 December when he was working the day shift. He showed these during map discussion, and Louis Uccellini asked him to compile the model/ensemble mean tracks for the following days (24-26 Dec). I added the observed positions and the 03z Short Range Ensemble Forecast (SREF)Mean sea level pressure cyclone center starting on 24 December when the SREF covered most or all of the time period of the observed track (the 23rd forecast should be the only one with a SREF Mean track).

The first slide is just the observed low track position/intensity every six hours. The second slide shows the model and ensemble mean sea level cyclone position forecasts from the models/ensemble means on 23 December 2010, except these forecasts are plotted every 12 hours. The third slide shows the same information except for forecasts from 24 December. The fourth slide shows the same information except for forecasts from 25 December. The fifth slide shows the same information except for forecasts from 26 December 2010.

Let me know if you need to see any map or display adjustments.

Dan
Hydrometeorological Prediction Center
Forecast Operations Branch
(301)763-8201

Date: Sun, 02 Jan 2011 09:59:37 -0500
From: Richard.Grumm@noaa.gov
To: Dan.Petersen@noaa.gov
Cc: colle@cyclone.msrc.sunysb.edu, sbucstar@noaa.gov
Subject: Re: Fwd: draft-observed sea level low track and models/ensembles 26-27 dec 2010

Dan,

If I am reading your slides correctly, those 2 84 hour forecasts show a double structured 500 hPa low over the western Atlantic while the GDAS (yellow) shows but one deep low. This implies to me that these forecasts had some difficulty with the merging waves which was critical to cyclogenesis.

There were some subtle errors to the west of this system with the ridge and second trough. I suspect if you showed difference fields, the GFS must have had larger errors on the west side of the trough.

There are other pockets of minor problems in Canada. But the double structure low jumps out of the page at you.

Will attach what little I have accomplished on this event.
Thanks and a great and interesting 2011 to all.

Rich

Date: Sun, 02 Jan 2011 10:13:50 -0500
From: Richard.Grumm@noaa.gov
To: Dan.Petersen@noaa.gov
Cc: sbucstar@noaa.gov
Subject: Re: Fwd: draft-observed sea level low track and models/ensembles 26-27 dec 2010

Dan,

These are really good. I can use them and credit you?

What on earth happened on 24 December? The entire suite of cyclone forecasts is east of the verifying track. The 23rd forecasts looked better to me in that the western edge of the envelope was near the verification. Wow does that 24th forecast look horrible. Do you have the 12 and 18 UTC data too? I recall using the data and seeing that LI and southern New England were under the gun by later in the day Christmas eve. Your data seem biased toward earlier cycles. I suspect any guidance on the 24th later in the day would have helped responders in NYC!

In the NY Times this AM they had an article about the NYC clean up debacle. The NWS said 3-5 Friday then late Saturday bumped it up to 10-14 or so and only to go to near 20 inches on Sunday. Too late and parked cars created havoc. Had they known they would have put in parking restrictions and better staffed for the storm. Not sure if we could have even provided a range of good probabilities with the implications of slide #3.

Those forecasts early on the 24th directly relate to the NY Times story.

Was this simply a classic Gaza and Bosart trough merger failure or problem in 2010?

When I first saw these I was hopeful of a Poorman's ensemble but the break down on the 24th tells me this too would be of limited value. A considerable amount of predictability studies shall follow this event. Wow.

Regards,
Rich

Date: Mon, 03 Jan 2011 13:15:26 -0500
From: Joseph Sienkiewicz <Joseph.Sienkiewicz@noaa.gov>
To: Richard Grumm <Richard.Grumm@noaa.gov>
Cc: Dan.Petersen@noaa.gov, sbucstar@noaa.gov, Paul J Kocin <Paul.J.Kocin@noaa.gov>
Rich and all:

This is just a simple set of graphics we produce into a VG file for NMAP display of low centers from the ECENS (yellow), GEFS (red), CMCE (blue), SREF (green), and other operational models. This just starts at 00 hour of 0000 UTC 27 Dec and walks back through all forecasts valid at that time to the 84 hour forecast hour in 12 hour time steps. The cusp point appears to be between 60 and 48 hours with smaller trend changes between 48 and 36 hours.

Joe

Date: Mon, 03 Jan 2011 17:18:39 -0500
From: David Novak <david.novak@noaa.gov>
To: _NWS ER SBUCSTAR <sbucstar@noaa.gov>
Subject: GFS run-to-run differences
Parts/Attachments:

List,

Recall the 00 UTC 24 Dec GFS run was out to sea while the 12 UTC 24 Dec GFS run shifted well west. Rich and I worked out the following 500 mb height difference graphics (Thanks Rich!).

Difference of 12 h forecast from the 00 UTC 24 Dec run minus the analysis from the 12 UTC 24 Dec run. http://eyewall.met.psu.edu/rich/cases/BLIZZARD/dave/dave1.png

Difference of 24 h forecast from the 00 UTC run minus the 12 h forecast from the 12 UTC run.
http://eyewall.met.psu.edu/rich/cases/BLIZZARD/dave/dave2.png

If we've got our differencing working, appears to be 5-15 m height differences associated with the short waves over Texas and the Upper Midwest. But also other areas...

Dave

Date: Tue, 04 Jan 2011 15:15:29 -0500
From: Mike Bodner <Mike.Bodner@noaa.gov>
To: Stephen Jascourt <Stephen.Jascourt@noaa.gov>
Cc: colle@cyclone.msrc.sunysb.edu, Richard Grumm <Richard.Grumm@noaa.gov>, sbucstar@noaa.gov, Dan.Petersen@noaa.gov
Subject: Re: relating it all back to wave packets

Colleagues,
A few years ago, I read a paper in the Journal of the Met Society of Japan, "A Diagnostic Study of Different Types of Rossby Wave Breaking Events in the Northern Extratropics" (Gabriel and Peters - 2008 - Vol. 86, No. 5, pp. 613-631). The paper discusses methods to diagnose and identify RWB events and whether they are breaking cyclonically/anticyclonically or poleward/equator-ward. The authors mention standard diagnostic methods such as tracing overturning of PV contours, but they also suggest a meridional wave flux index. This index is derived from the meridional component of the wave activity flux vector found in a quasi-stationary Rossby wave. The authors use the index to separate cyclonically and anticyclonically Rossby wave breaking. Poleward or equator-ward asymmetry was not able to be definitively determined. However using a combination of this index with zonal PV anomalies and diffluent/confluent flow, poleward/equator-ward asymmetry was able to be determined. Attached is a cartoon from the paper illustrating the geometry of 4 types of asymmetric RWB events identified.

I share this with everyone because I think it's important to understand the orientation of the suggested RW development downstream in one of the forecast envelopes. And from my observation of the RWB events that have been occurring since late August/September, and the phase of the GWO that goes along with the strong La Nina regime, it would seem that we have been dealing with P2 or LC1 type events. And the EC has performed somewhat better with the evolution of the amplifying troughs leading to cyclogenesis in the eastern U.S. And this was the case once again on December 21/22 when the big east coast storm was still in the medium range.

With the GWO going back to a more typical La Nina phase (like we saw in September/October) I would not be surprised to see wave breaks further west and thus a slight further west storm track over the CONUS.

Mike

Date: Tue, 04 Jan 2011 16:43:46 -0500
From: Jun Du <Jun.Du@noaa.gov>
To: colle@cyclone.msrc.sunysb.edu, Richard Grumm <Richard.Grumm@noaa.gov>
Cc: sbucstar@noaa.gov
Subject: Re: Fwd: draft-observed sea level low track and models/ensembles 26-27 dec 2010

Brian, Rich and others,

I plotted some individual SREF members for this case and found that even From as early as 03z, Dec. 24, 2010, the SREF envelope seems still encompass the truth although it's on low probability side. Attached is a ppt file I put together about "good" and "bad" SREF members. Anyway, predictability is definitely a part of the issue for this storm and the ensemble did its job for this case (although people were always hesitate to believe low probability events. Keep this in mind that with a better model and better IC, ensemble should perform better with providing sharper solutions with lesser uncertainty). What we
can learn from this event is that please trust all probabilities but not only ensemble mean or high probabilities!

Jun

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