**Resent-From:** <jkenyon@ALBANY.EDU>
**From:** "Bosart, Lance F" <lbosart@ALBANY.EDU>
**Subject:** **Synopsis of Friday map discussion for 22 Feb 2013**
**Date:** 25 February 2013 12:00:58 PM EST
**To:** <MAP@listserv.albany.edu>
**Reply-To:** "Bosart, Lance F" <lbosart@ALBANY.EDU>

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Hi Everyone,

Friday map discussion for 22 Feb 2013 was motivated by continuing forecast uncertainty as to whether trough phasing would occur over the eastern U.S. on 23-24 Feb and the possible relationship between the deep trough that crossed the southern U.S. on 20-21 Feb and the forecast downstream trough phasing over the eastern U.S. on 23-24 Feb. Images and links used in the 22 Feb map discussion can be found here: http://www.atmos.albany.edu/student/ppapin/mapdisco/20130222/

Map discussion began with a look at Joe Sienkiewicz's earlier post to the map listserv about possible analysis uncertainties associated with a deep cyclone over the western Atlantic at 1500 UTC 22 Feb 2013. As posted by Joe: "Attached are two images from the western and central North Atlantic from this morning. Visible from 1545 UTC followed by ASCATA and B winds from approximately 1417 (A) and 1330 (B). The vis image speaks for itself. The ASCAT winds give an idea of the complexity of the wind field. The two comma's from right to left have 60 and 50 knots associated with them. Color scale is in knots, upper right, and time of data acquisition is in red (ASCAT-A) and purple (ASCAT-B). Yellow is minimal Gale force, orange strong Gale, brown low Storm force, and reddish brown strong (violent) Storm. For what it is worth the global models have one comma and a single associated wind max."
(http://www.atmos.albany.edu/student/ppapin/mapdisco/20130222/images/sat.gif;
http://www.atmos.albany.edu/student/ppapin/mapdisco/20130222/images/ascat.gif)

The question of how to best determine "sea truth" in oceanic surface analyses is a long-standing issue even in the modern satellite data era. Sanders (1972) analyzed weather observations made by a fleet of sail boats (including his own) over the course of a Newport, RI to Bermuda yacht race in June 1970. Sanders was motivated to construct his analyses after the boats in the race unexpectedly encountered two severe weather episodes that wrought havoc on the fleet and for which the then-operational NMC models had nary a clue and for which the available real-time oceanic forecasts were blissfully ignorant. He used these observations to construct what arguably was the first-ever oceanic surface mesoanalysis using time-to-space mesoscale analysis techniques (Fujita 1955, 1963) and showed the passage of two MCSs that adversely impacted the fleet. Sanders (1990) revisited this oceanic analysis topic again in conjunction with the 1989 ERICA field program. He showed that even with enhanced oceanic observations from a major field program that low-level aircraft traverses were required to capture the true strength of intense oceanic cyclones.

Earlier in the week, deterministic runs of the GFS suggested another trough phasing-related significant snowstorm was likely over parts of the northeastern U.S. this weekend. Subsequent GFS forecasts initialized after 0000 UTC 21 Feb backed off the earlier scenario and suggested that any trough phasing would be weaker or non-existent, reducing the threat of another major snowstorm significantly. To help assess the current situation, we compared: 1) the 0-48 h 500 hPa height/vorticity/wind forecasts from the 1200 UTC 22 Feb deterministic GFS and ECMWF runs (and where available, the most recent ensemble runs), and 2) earlier GFS runs individually and through Kyle Griffin's d(prog)/dt analysis (http://www.atmos.albany.edu/student/kgriffin/maps/). These comparisons and additional information gleaned from these links
(http://www.atmos.albany.edu/student/ppapin/mapdisco/20130222/images/jet.html;
http://www.atmos.albany.edu/student/ppapin/mapdisco/20130222/images/dt_theta.html;
http://www.met.nps.edu/~hmarcham/2012.html) prompted further discussion and suggested that:

a) In today's high-resolution global forecast models trough phasing/merger is not manifest as a "clean" trough/vorticity merger but is manifest instead by complex interactions among multiple elongated vorticity streamers and mesoscale areas of concentrated vorticity ("voracity balls").

b) Trough phasing/merger, and the possibility of a significant snowstorm over parts of the Northeast, first became evident in the 138/144 h GFS 500 hPa height/vorticity/wind forecasts verifying 1200 UTC 24 Feb in conjunction with a stronger and faster southern stream trough and vorticity maximum and a weaker northern stream trough and vorticity maximum over the Great Lakes (http://www.atmos.albany.edu/student/ppapin/mapdisco/20130222/images/500vort.html).

3) GFS indications of trough phasing/merger backed off considerably in the 120, 126, and 132 h forecasts verifying 1200 UTC 24 Feb as the southern stream vorticity maximum was slower and weaker while the northern stream trough and vorticity maximum was faster in comparison to the longer range forecasts verifying this time period.

4) GFS indications of trough phasing/merger returned in the 84-114 h forecasts verifying 1200 UTC 24 Feb as the southern stream trough and vorticity maximum was once again stronger and faster.

5) GFS indications of trough phasing/merger still occurred in the 54-78 h forecasts verifying 1200 UTC 24 Feb. but was slightly weaker and farther offshore, reducing (but not eliminating) the major snow threat to coastal regions of the Northeast in conjunction with a deamplified southern trough and vorticity maximum.

6) GFS indications of trough phasing/merger mostly disappeared in the 24-48 h forecasts verifying 1200 UTC 24 Feb as the southern stream trough and vorticity maximum was weaker/slower again while the northern stream trough and vorticity maximum was a tad faster and a bit farther to the southeast.

7) The northern system in the forecast trough phasing/merger originated with the deep 500 hPa trough that crossed CA/AZ on 20-21 Feb and the Plains/Midwest on 21-22 Feb (http://www.atmos.albany.edu/student/ppapin/mapdisco/20130222/images/500mb.html; was associated with snow/cold in the CA/NV deserts and the Plains/Midwest, respectively, and was the subject of earlier posts to the map listserv (these posts are available on the above URL for this Fri map discussion).

8) The southern system in the forecast trough phasing/merger consisted of two separate 500 hPa troughs. The first 500 hPa trough reached Washington State at 0000 UTC 21 Feb and ripped southeastward, caching southern AZ by 0600 UTC 22 Feb (at which time the leading northern system was over eastern NE and western IA). This AZ 500 hPa trough sheared out and weakened as it raced northeastward, reaching New York and New England by 0000 UTC 24 Feb. This trough briefly flattened the short-wave ridge over the Northeast as it passed and may have acted to increase the zonal component of the flow farther to the south. The second trough, embedded in strong 500 hPa flow, crested the ridge in the northeastern Pacific and reached Washington State by 1800 UTC 21 Feb, moved southeastward, mostly as a shear vorticity maximum, compacted into a curvature vorticity maximum over New Mexico by 0600 UTC 23 Feb, and raced eastward and crossed the mid-Atlantic coast by 1200 UTC 24 Feb along a track slightly farther south than earlier forecasts had indicated (making trough phasing/merger less likely).

A conclusion from this d(prog)/dt analysis was that the phase speed and strength of the southern stream trough and vorticity maximum appeared to be critical as to whether trough phasing/merger would occur. The GFS forecast trough phasing/merger when the southern stream trough and vorticity maximum led the northern stream trough and vorticity maximum so that southerly flow ahead of the northern system could help provide a meridional steering current over the leading southern system, enabling it to slow down and lift northward, making it easier for the northern and southern systems to interact. The southern stream trough and vorticity maximum, a smaller scale feature, didn't enter the North American radiosonde network until 1800 UTC 21 Feb and didn't cross the southern Rockies until 0600 UTC 23 Feb, suggestive of likely uncertainty with the representation of this feature while it was over the northeastern Pacific and while it crossed the Rockies, respectively.

The individual members of the GEFS showed what looked to me to be unusually large within run and between run variability…..a good indication that the forecast of possible trough phasing/merger had relatively high uncertainty (leaves of three leave them be).

**Science Issues**:

We continued the discussion, begun last week, of science issues related to whether or not trough will merge/phase. We discussed the need to create an objective definition of phasing that could be used to create an overall global climatology of trough merger/phasing. The creation of an objective trough merger/phasing climatology would enable an identification of global trough merger/phasing hotspots and whether the occurrence of trough merger/phasing is sensitive to atmospheric flow variability on interannual, intraseasonal and synoptic times scales (ENSO, MJO, PNA, AO/ NAO). Once a trough merger/phasing climatology is constructed the next step would be to prepare trough merger/phasing composite analyses of phasing after which representative case, predictability and modeling studies can be considered.

Sanders (1988) mapped the locations of 500 hPa trough genesis and lysis locations over the Northern Hemisphere based on a manually created 9-year dataset. He found that trough births significantly exceeded trough deaths downstream of major mountain barriers like the Rockies. He argued that since the primary 500 hPa trough genesis region over the CONUS was located east of the Rockies while the entrance region to the North Atlantic storm track was situated over the Gulf Stream east of the Carolina coast that predecessor upper-level disturbances associated with cyclogenesis in the storm track entrance region likely originated well upstream of where surface cyclogenesis eventually occurred. This synoptic viewpoint differs from the classical baroclinic instability argument in which there is simultaneous growth of coupled surface and upper-level disturbances from infinitesimal perturbations.

Lackmann (1997, 1999) examined the life cycles of these upper tropospheric precursor disturbances and found that shear vorticity tended to be converted to curvature vorticity in conjunction with trough compaction in northwesterly flow downstream of the Rockies. Lackmann showed that the trough compaction and intensification process in the upper troposphere occurred in conjunction with along-flow cold-air advection, cross-flow upper-level frontogenesis, along-flow steeping of the dynamic tropopause, and along-flow increase in the strength of the upper-level jet/front system in northwesterly flow (Gary, if I have misrepresented your work please set me straight). An example of the trough compaction process in northwesterly flow over and downstream of the Rockies can be seen on 22-23 Feb in conjunction with the formation of the southern stream disturbance that originally was to form the southern trough of the two troughs that the GFS forecast to merge/phase when another major snowstorm appeared possible in parts of the Northeast. The role that the Rockies could play in creating conditions favorable for trough merger/phasing in northwesterly flow over and downstream of the mountains needs to be elucidated. Likewise, the sensitivity of the forecast phasing/merger of two separate 500 hPa barotropic vortices in the presence of a large-scale deformation flow as elucidated by Hakim (et al. (1996), remarked upon two weeks ago, needs to be remembered.

Lance

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**References:**

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# The Ohio Valley Wave-Merger Cyclogenesis Event of 25–26 January 1978. Part II: Diagnosis Using Quasigeostrophic Potential Vorticity Inversion

**Gregory J. Hakim, Daniel Keyser, and Lance F. Bosart**

**Abstract**

The dynamical interactions between precursor disturbances during the wave-merger cyclogenesis event of 25–26 January 1978 over eastern North America are diagnosed using quasigeostrophic potential vorticity (QGPV) inversion. This case is characterized by two prominent preexisting upper-level disturbances that induce rapid surface cyclogenesis as they come into close proximity. Static QGPV inversion is used to attribute a particular geopotential height field to the QGPV associated with each precursor disturbance. The full flow is partitioned into the following components: the northern upper precursor, the southern upper precursor, and the background flow. Prognostic QGPV inversion is used to quantify the instantaneous geopotential height tendencies attributable to each of these flow components.

The static-inversion results for the upper precursors exhibit the structure of baroclinic vortices with maximum amplitude near the tropopause. During the 48-h period spanning the period of study of this event, these vortices rotate cyclonically about a point between them with the rate of rotation increasing as the vortices draw closer together. The background flow appears as a synoptic-scale trough, with the meridional tilt of the trough axis positive (negative) prior to (during) rapid surface cyclogenesis. Prior to surface cyclogenesis, the background flow is also confluent in the vicinity of the vortices, acting to bring them closer together. Rapid surface cyclogenesis occurs as the vortices achieve their closest approach (i.e., “merge”). Three interaction signatures are identified and quantified with prognostic QGPV inversion: vortex–vortex (vortex-induced flows advecting the QGPV of other vortices), vortex-retrogression (vortex-induced flows advecting background QGPV), and back-ground-flow advection of vortex QGPV. Solutions for the observed case confirm that the vortex–vortex interactions become more robust as the vortices come closer together. However, the background advections are dominant and act to bring the vortices closer together. Nearly all of the geopotential height falls at the 1000-hPa cyclone center are due to the advection of the upper precursors by the background flow

during the entire cyclogenesis event.

A simple model is proposed that includes the three primary elements of this case: two vortices and a background flow. For a barotropic atmosphere on an *f* plane, the vortices are represented by rigid vortex patches and the background flow by a hyperbolic deformation field that is fixed in time. Solutions representative of observed parameters exhibit many of the properties of the observed case, including "merger." Solutions corresponding to merger are found to be extremely sensitive to small changes in the deformation field for a given set of initial conditions describing vortex position, size, and strength, suggesting limitations to the predictability of the merger phenomenon.

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Lackmann, Gary M., Daniel Keyser, Lance F. Bosart, 1997: A Characteristic Life Cycle of Upper-Tropospheric Cyclogenetic Precursors during the Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA). *Mon. Wea. Rev.*, **125**, 2729–2758.

# A Characteristic Life Cycle of Upper-Tropospheric Cyclogenetic Precursors during the Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA)

**Gary M. Lackmann,* Daniel Keyser, and Lance F. Bosart**

### Abstract

This paper documents a characteristic life cycle of upper-tropospheric precursors to surface cyclogenesis observed during the field phase of the Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA, December 1988–February 1989). This life cycle begins with the development of an elongated region of lower dynamic tropopause that forms in association with an intensifying midtropospheric jet/front over central North America. The elongated disturbance subsequently compacts into a more circular configuration prior to crossing the east coast of North America and frequently is associated with rapid surface cyclogenesis offshore.

A representative example of the life cycle outlined above is documented through a detailed case study of the upper precursor associated with the second ERICA intensive observation period (IOP 2) cyclone. Emphasis is placed upon (i) description of the tropopause structure and evolution during the upper-precursor life cycle, (ii) diagnosis of mechanisms leading to the development and intensification of a midtropospheric cyclonic vorticity maximum and frontal zone, (iii) analysis of the role of transverse jet–front circulations in deforming the dynamic tropopause, (iv) documentation of the influence of the low- and high-frequency flow components on the upper-precursor life cycle, and (v) isolation of dynamic and thermodynamic factors that render this life cycle especially conducive to rapid surface cyclogenesis. Confluence downstream of the axis of a low-frequency (i.e., periods greater than 120 h), troposphere-deep ridge over western North America facilitates the organization of a midtropospheric jet/front over central North America. As this precursor disturbance approaches the inflection between the western ridge and a downstream trough, tilting, in the presence of cold advection along the midtropospheric frontal zone, becomes an important vorticity generation and frontogenesis mechanism in the upper precursor. Transverse circulations accompanying the jet/front steepen and lower the dynamic tropopause prior to surface cyclogenesis. Compaction of the initially elongated upper precursor is shown to involve deformation in the high-frequency component of the upper-tropospheric flow. The compacted upper-precursor configuration, lowered tropopause, and reduced static stability in the offshore environment lead to strong vertical coupling and vigorous surface cyclogenesis as the upper precursor passes offshore.

The foregoing results suggest that the life cycle of a common class of cyclogenetic precursors is closely related to midtropospheric frontogenesis. A favored location for the development of midtropospheric jet/fronts is over central North America during northwesterly flow episodes. Production of vorticity in the midtropospheric jet/front and subsequent compaction of this vorticity feature suggest a link between midtropospheric frontogenesis and mobile upper-trough genesis. This link may explain the existence of a maximumin the upper-trough-genesis distribution over central North America documented by Sanders.

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# Energetics of an Intensifying Jet Streak during the Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA)

**Gary M. Lackmann[*] Daniel Keyser and Lance F. Bosart**

**Abstract**

A characteristic life cycle of upper-tropospheric cyclogenetic precursors involves the development of an elongated region of lower dynamic tropopause that forms in association with an intensifying midtropospheric jet/front. Transverse divergent circulations associated with the jet/front steepen and depress the dynamic tropopause prior to the onset of lower-tropospheric cyclogenesis. A representative event that occurred during the second intensive observation period (IOP 2) of the Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA, December 1988–February 1989) is analyzed from the perspective of local energetics. The goals of the analysis are (i) to document the evolution of the three-dimensional eddy kinetic energy (EKE) distribution during this event and (ii) to identify the mechanisms leading to EKE growth in the upper-tropospheric jet streak associated with the precursor disturbance prior to cyclogenesis, as well as in the developing lower-tropospheric cyclone.

Computation of the local EKE budget during ERICA IOP 2 indicates that the Reynolds stress plays an important role in jet streak intensification over North America. Analysis of the Reynolds stress reveals that the contribution of this term is determined primarily by the relative orientation of the perturbation horizontal wind velocity and the dilatation axis of the time-mean flow. In regions where the perturbation wind velocity is oriented within 45° of normal to the dilatation axis of the time-mean flow, the contribution of the Reynolds stress to the EKE tendency is positive. The presence of a ridge over western North America favors jet streak intensification through the Reynolds stress as northerly perturbation flow east of the ridge axis possesses a favorable orientation with respect to the dilatation axes of the time-mean flow over central North America. Local EKE increases accompany strengthening transverse divergent circulations, thus facilitating the downward advection of stratospheric potential vorticity and eventually resulting in the development of a mobile upper trough. This sequence is consistent with the preference for mobile upper-trough genesis over central North America in the presence of a northerly flow component, a finding documented previously by Sanders.

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# Meteorological and Oceanographic Conditions During the 1970 Bermuda Yacht Race

**Frederick Sanders**

**Abstract**

Analysis of conventional data and of information provided by a number of the competing skippers yields an unusually detailed picture of environmental conditions during the Newport, R.I.–Bermuda Yacht Race in June 1970. Sea-surface temperature data indicate the presence of a warm meander of the Gulf Stream just west of the rhumb-line course, a position intermediate between that of a warm meander to the west in May disclosed by bathythermograph observations from the RMS *Franconia* and that of a warm eddy to the east in August found by a Naval Oceanographic Office survey.

The fleet was harassed by two groups of severe thunder-squalls during the night of June 21–22, in the vicinity of the warm meander. Even the anomalously high sea-surface temperatures, however, were cool relative to the air in which the thunderstorms were rooted. The storms originated in the Chesapeake Bay area during the day on June 21, and they appeared, surprisingly, to gain intensity over the ocean after being cut off from their surface source of warmth and moisture. Offshore forecasts for June 21–22 took no specific account of the presence of the severe thunderstorm systems.

On June 25, part of the fleet experienced an unexpected southerly gale just northwest of Bermuda. From the yacht data, it is found that the gale was attributable to a small cyclone that formed in an old frontal cloud band and moved northeastward, remaining undetected by the conventional data network throughout its life history. Analysis of the surface wind field suggests that baroclinic effects played only a minor role in the behavior of this cyclone, which at least in some respects resembled a tropical cyclone. Study of the forecasts available at the time indicate that in neither

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# Life History of Mobile Troughs in the Upper Westerlies

**Frederick Sanders**

**Abstract**

Increasing evidence indicates that surface cyclogenesis is predominantly a response to the approach of a preexisting trough at upper levels. A question then arises about the origin of the upper-level predecessor. As an initial approach to this question, mobile troughs in the major band of westerlies were crudely tracked in daily Northern Hemispheric 500-mb analysis during nine recent cold seasons. These troughs were identified only in the 552-dam height contour. Between 8 and 15 of them were present on a given day. Study of a particular cold season showed a median duration of 12 days and a mode of 5 days. Average zonal phase speed was 13 m $s^{-1}$.

Locations or origin and termination of individual troughs were distributed over all longitudes, but births greatly exceeded deaths over and east of the Rocky Mountains in North America and the highlands of central Asia. Trough terminations dominated over the eastern portions of the oceans. Within the quasi-steady planetary waves, origins and terminations of the smaller mobile troughs occurred preferentially in northwesterly and southwesterly flow, respectively.

More detailed studies of the structure during episodes of origin over North America showed prominent vertical and lateral shear in the time-averaged 500-mb flow, rapid growth of the perturbations through the depth of the troposphere, with a vertical tilt upshear only in the lower half, pronounced maximum amplitude near the tropopause, and a variety of circumstances in which troughs became organized in the belt of major westerlies.

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Sanders, Frederick, 1990: Surface Analysis Over the Oceans—Searching for Sea Truth. *Wea. Forecasting*, **5**, 596–612.

# Surface Analysis Over the Oceans—Searching for Sea Truth

**Frederick Sanders**

**Abstract**

**For the Atlantic storms in ERICA IOP 1–5, NMC operational surface analyses, both manual and automated, were compared with two sets of research analyses prepared later. The positions of cyclone centers agreed within 100 km on average only between the two research sets. Root-mean-square deviations of the automated analysis positions from the research positions were 180 km. Central pressures were not deep enough, especially in the automated analyses. Comparison of reported pressure with the research analyses shows that those from the moored buoys and C-MAN stations were most accurate and reliable. The drifting buoys were nearly as good, as were the best ships.**

**Analyses are shown in detail for the IOP 2 storm, during its evolution from a complex multi-centered system to a single center of great intensity. Careful consideration of low-level aircraft data and of observations from ships (with detection and correction of their errors), was necessary for reconciliation of analyses differences. There were not enough observations to resolve all problems. The final great intensity of the center would not have been known without a low-level aircraft traverse.**

**A small sample of delayed ships' observations received after completion of the research suggested that the root-mean-square error of the pressure analysis was about 1.5 mb.**

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