Large-amplitude gravity waves as an unclassified type of storm

Observations and inferences from three decades of synoptic data monitoring applying pattern recognition

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Presentation

- Data
- Some major events and associated hazards
- The case for a storm classification scheme
- Numerical prediction
- Real-time detection
- Recommendations

Data

- Case studies from 1983-2016 of large amplitude IGW (>5hPa) identified in real-time using conventional synoptic data
- Other material from published case studies
- Wake-lows trailing mesoscale convective systems are not included, though share many similarities

Some notable US cases

- 11 April 1944 (Brunk 1949) – first scientific study and still largest documented event (-15 hPa, 35 m s^{-1} sustained wind)
- 11 Feb 1983 (Bosart & Sanders, 1986) – Within intense East Coast snowstorm.
- 27 Feb 1984 (Bosart & Seimon 1988) – Carolina piedmont event
- 15 Dec 1987 (R. Schneider, Powers &Reed studies), multiple IGWs in bombing Midwest cyclone, post-event mesoscale modeling success
- 4 Jan 1994 (Bosart et al., 1998) –WSR88D radar paired with mesoscale observation “network”
- 20 Mar 2006 – successful GFS prediction 150 hrs in advance
- 7 Mar 2008 (Ruppert & Bosart 2014) – detailed mesoanalysis
- 13 Dec 2015, explicit predictions by operational mesoscale and global models, evidence for interfering wave trains

THE PRESSURE PULSATION OF 11 APRIL 1944

By Ivan W. Brunk

U. S. Weather Bureau, Chicago

(Manuscript received 17 July 1948)

ABSTRACT

Windstorms of 11 April 1944 were associated with the eastward movement of a large pulsation in pressure and strong easterly surface winds. Barograph and wind records from many stations are used to show the hourly movement of this pulsation. Precipitation records from the hydrologic network of recording rain-gages are used to determine the hourly movement of a sequence of four bursts of rainfall associated with thunderstorms, tornadoes and pressure pulsations. The pressure pulsation is shown to be an exceptional case of a phenomenon which is frequently overlooked, and about which as yet our knowledge of the physical processes involved is very incomplete.

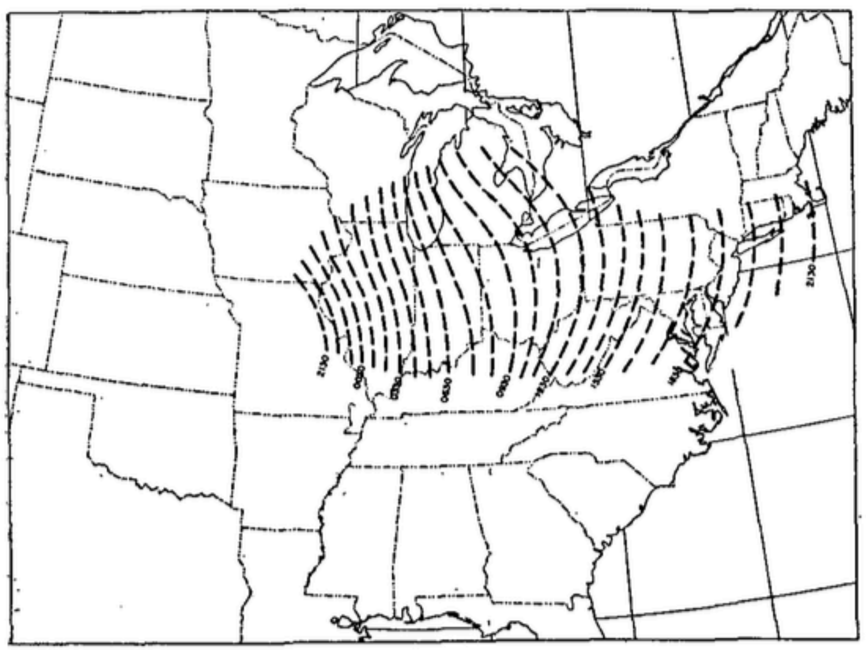
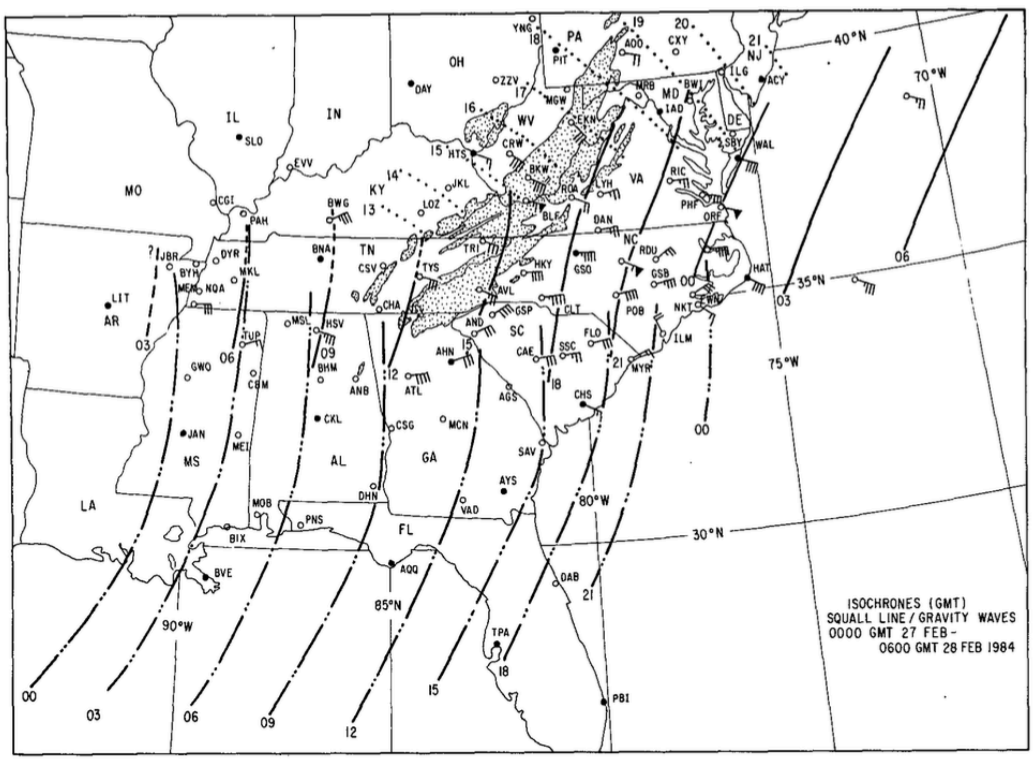
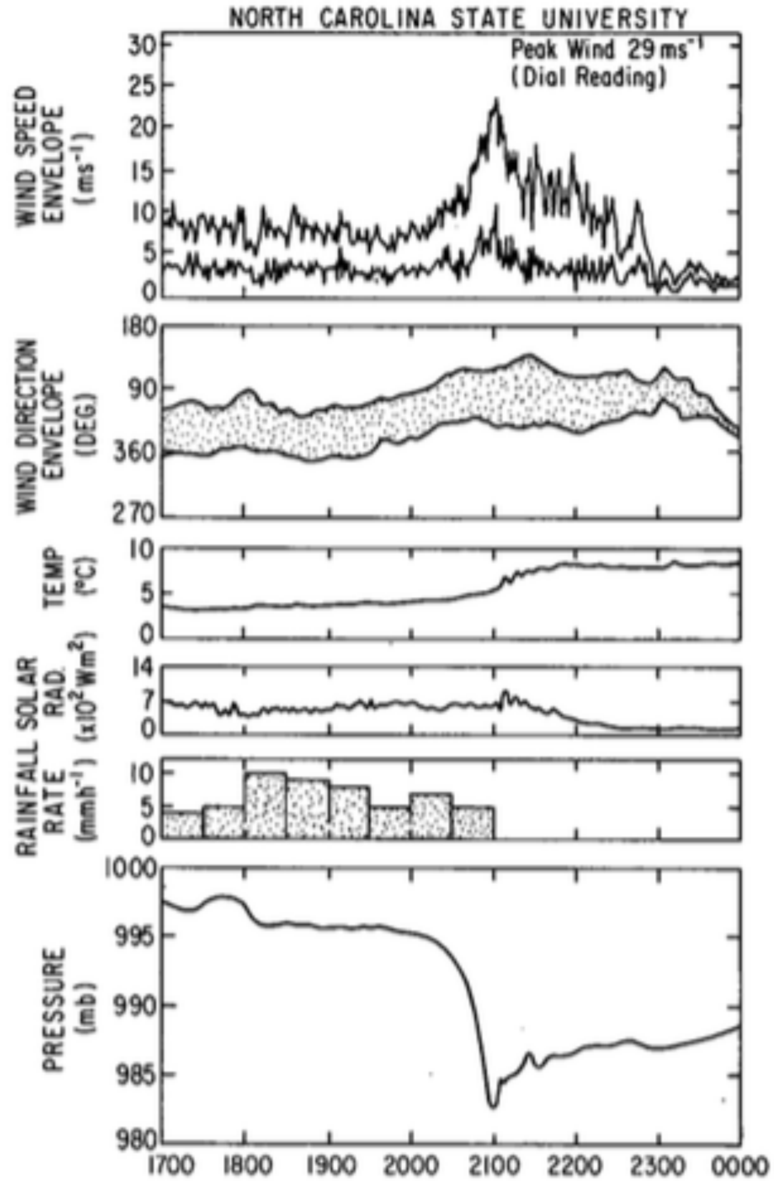


Fig. 5. Hourly movement of pressure pulsation 10–11 April 1944 (CST).

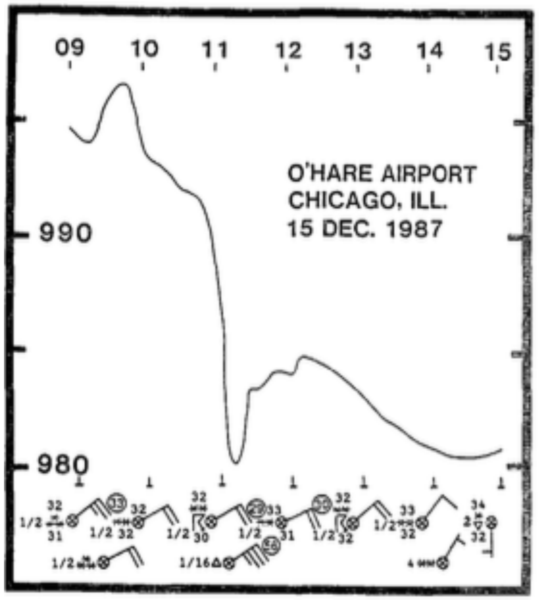
Brunk (1949)

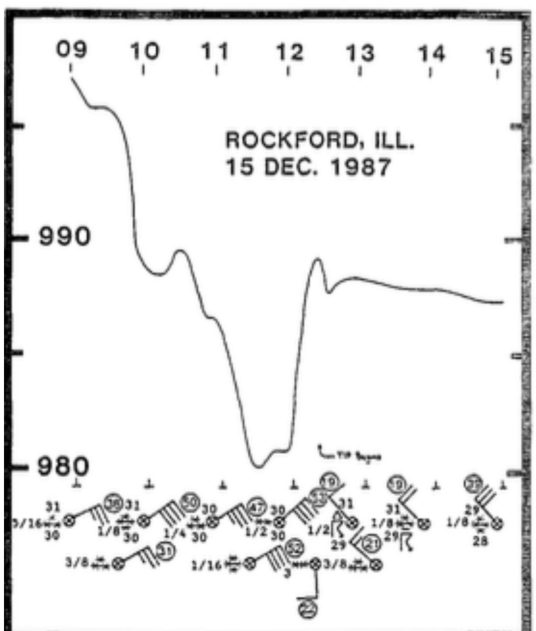
27 Feb 1984 Carolinas case (Bosart and Seimon 1988)

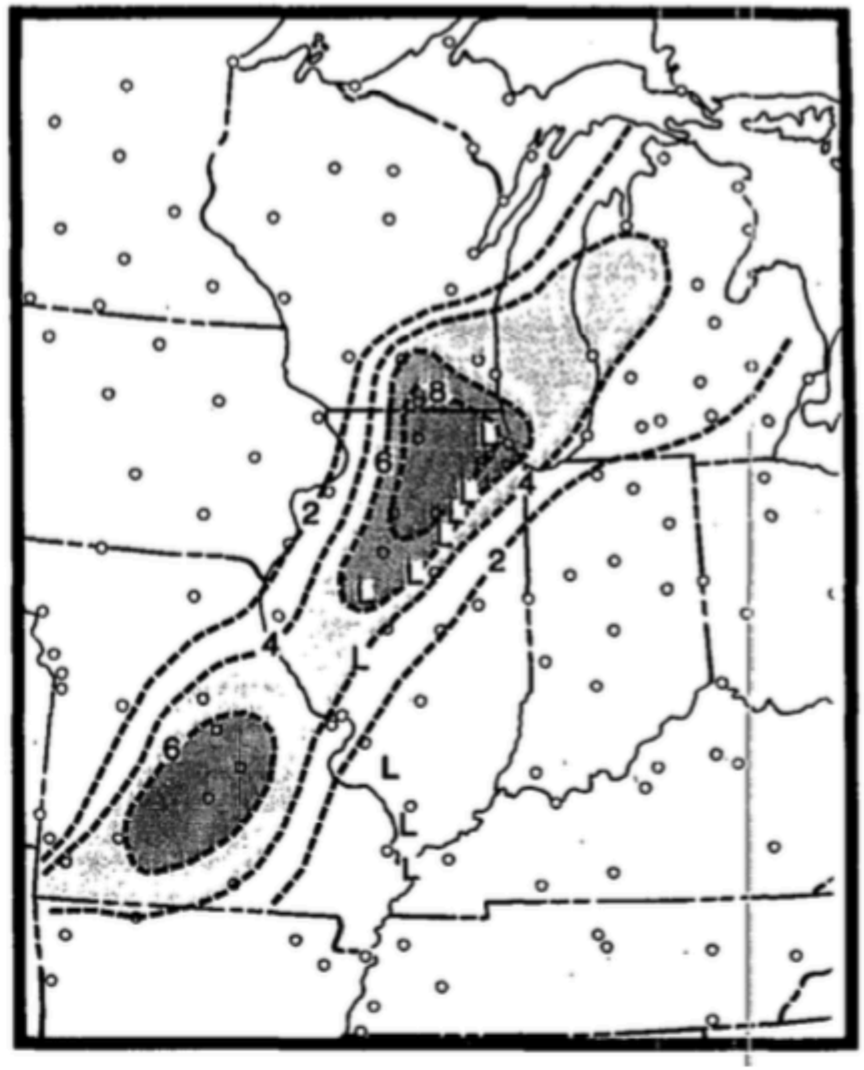




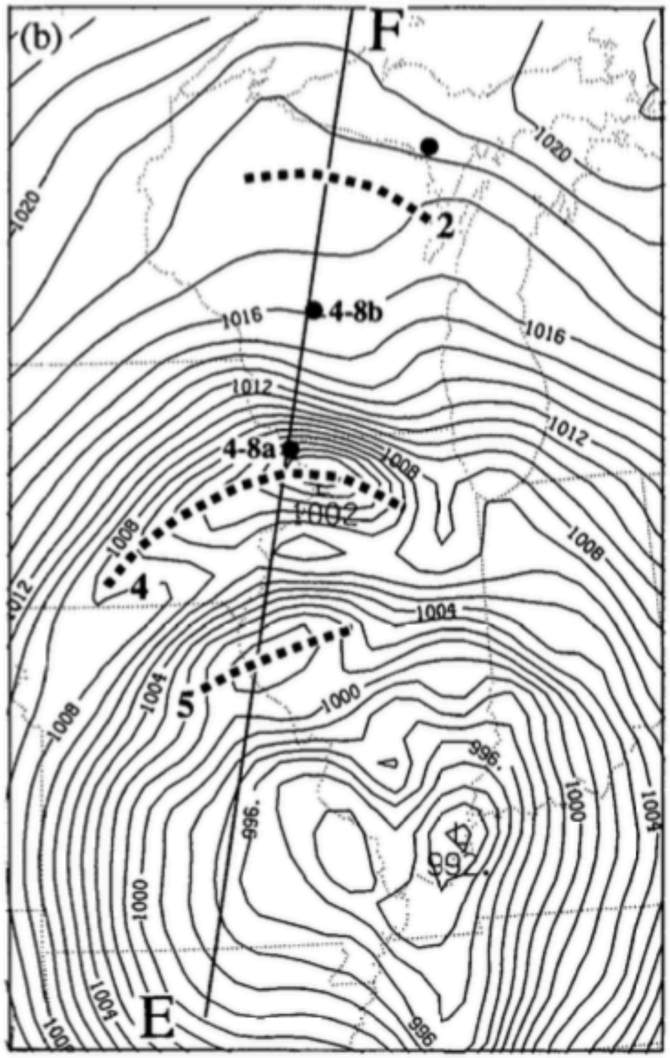
15 Dec 1987 -- Midwest bombing cyclone



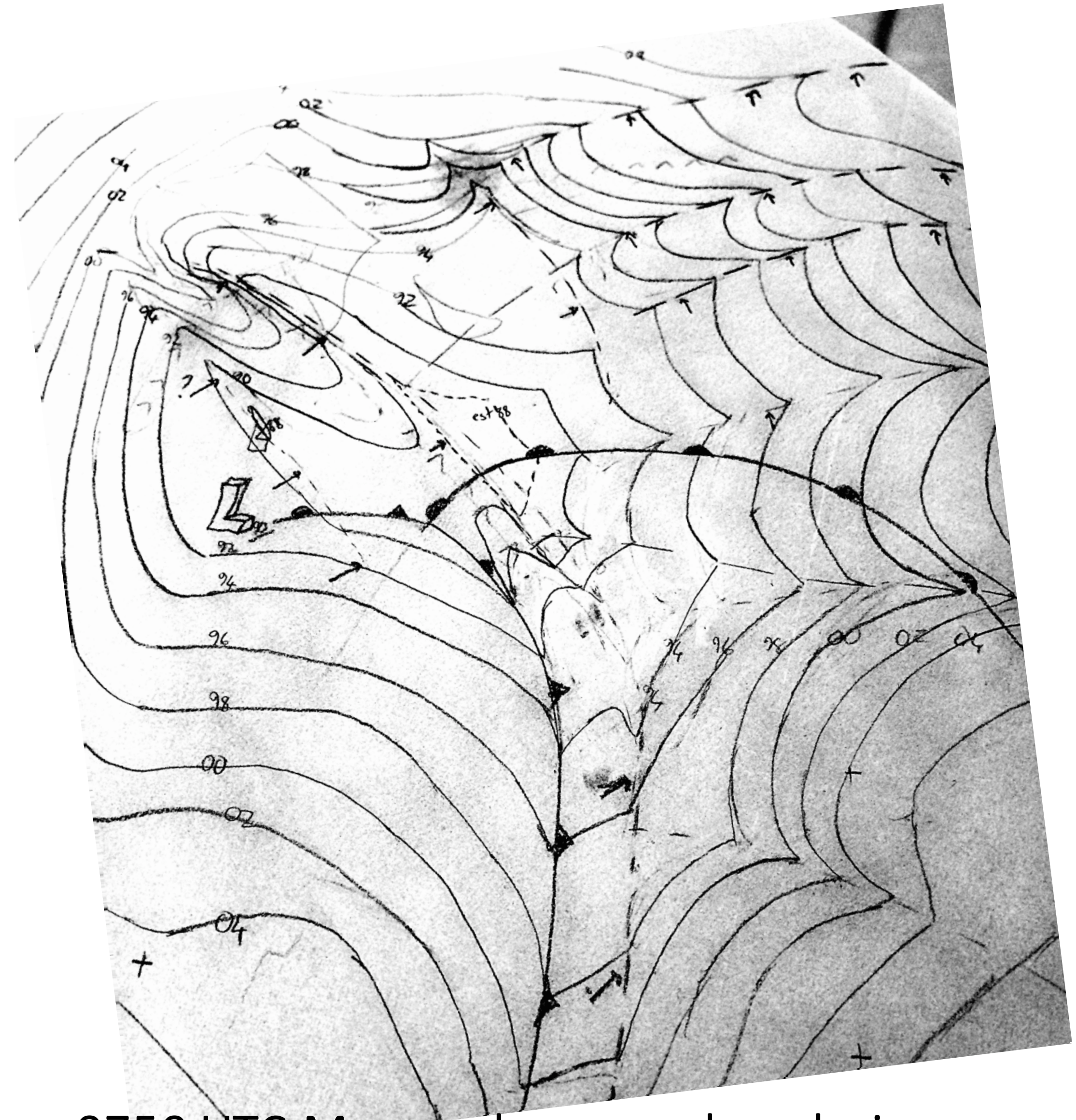




Schneider 1990

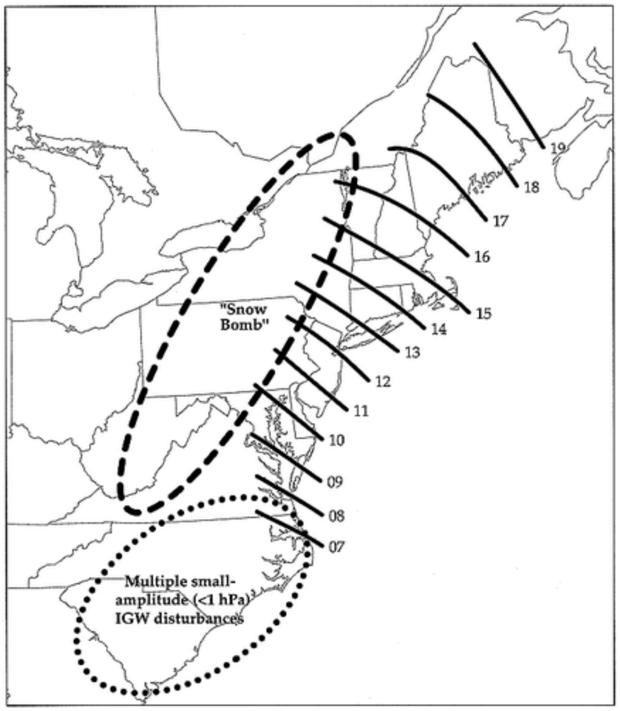


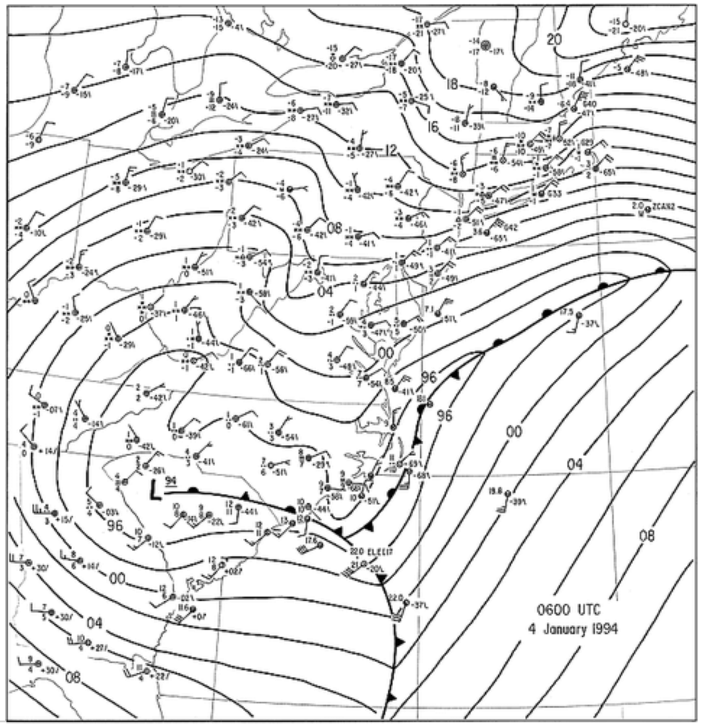
PSU-NCAR MM4model
8 hr SLP simulation
Powers & Reed (1993)

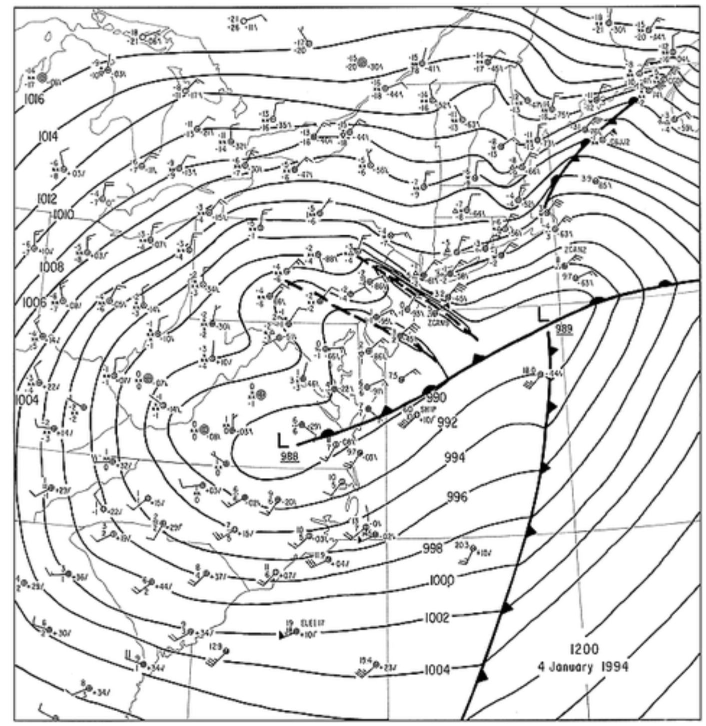


0750 UTC Mesoscale manual analysis
Seimon (unpublished)

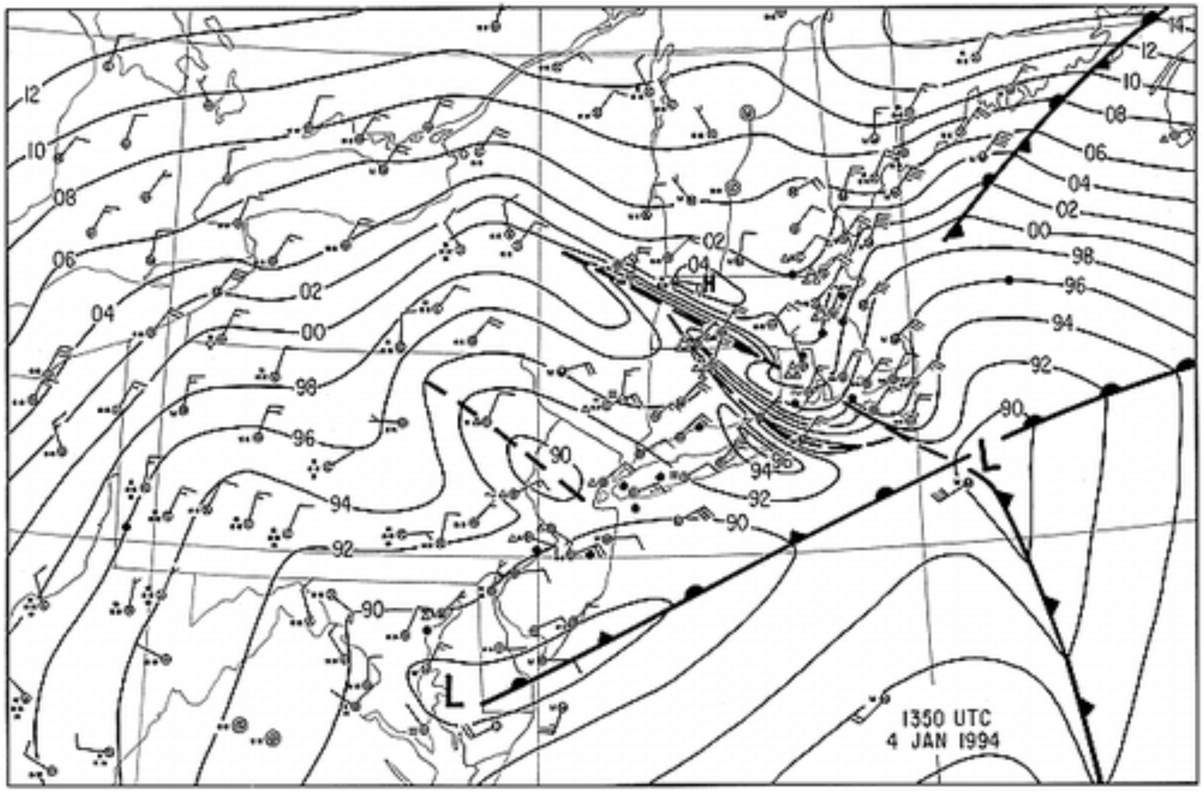
4 Jan 1994 New England snowstorm case







Bosart et al. (1998)



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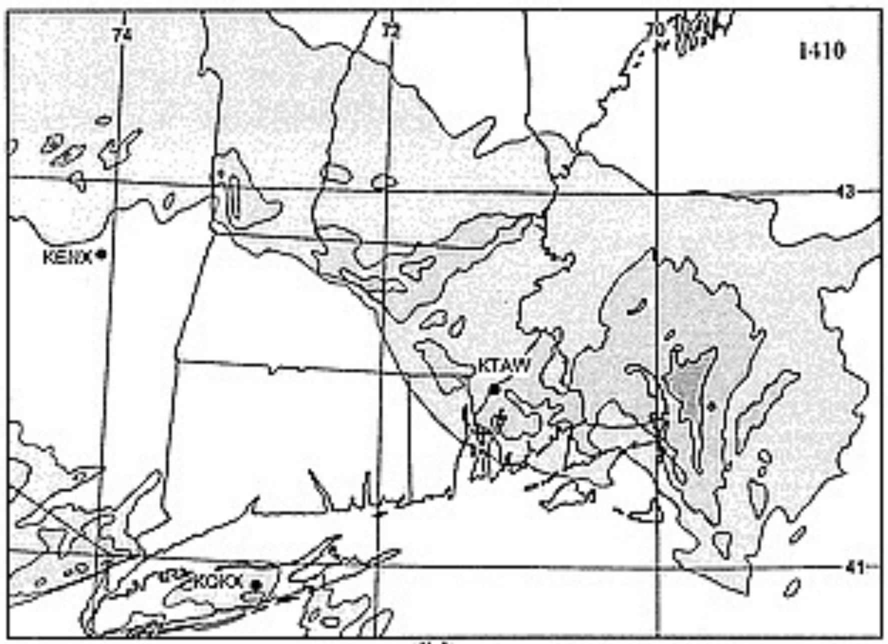

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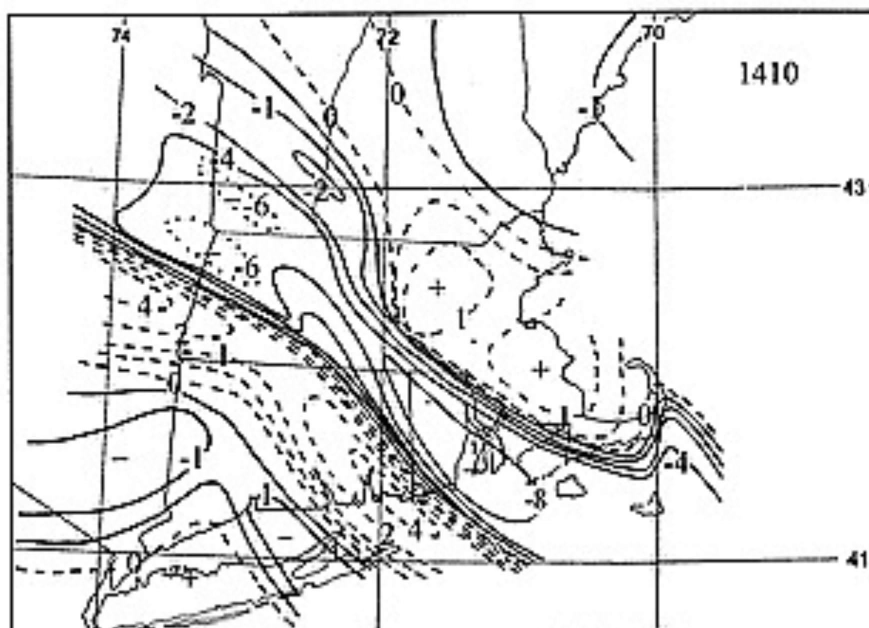


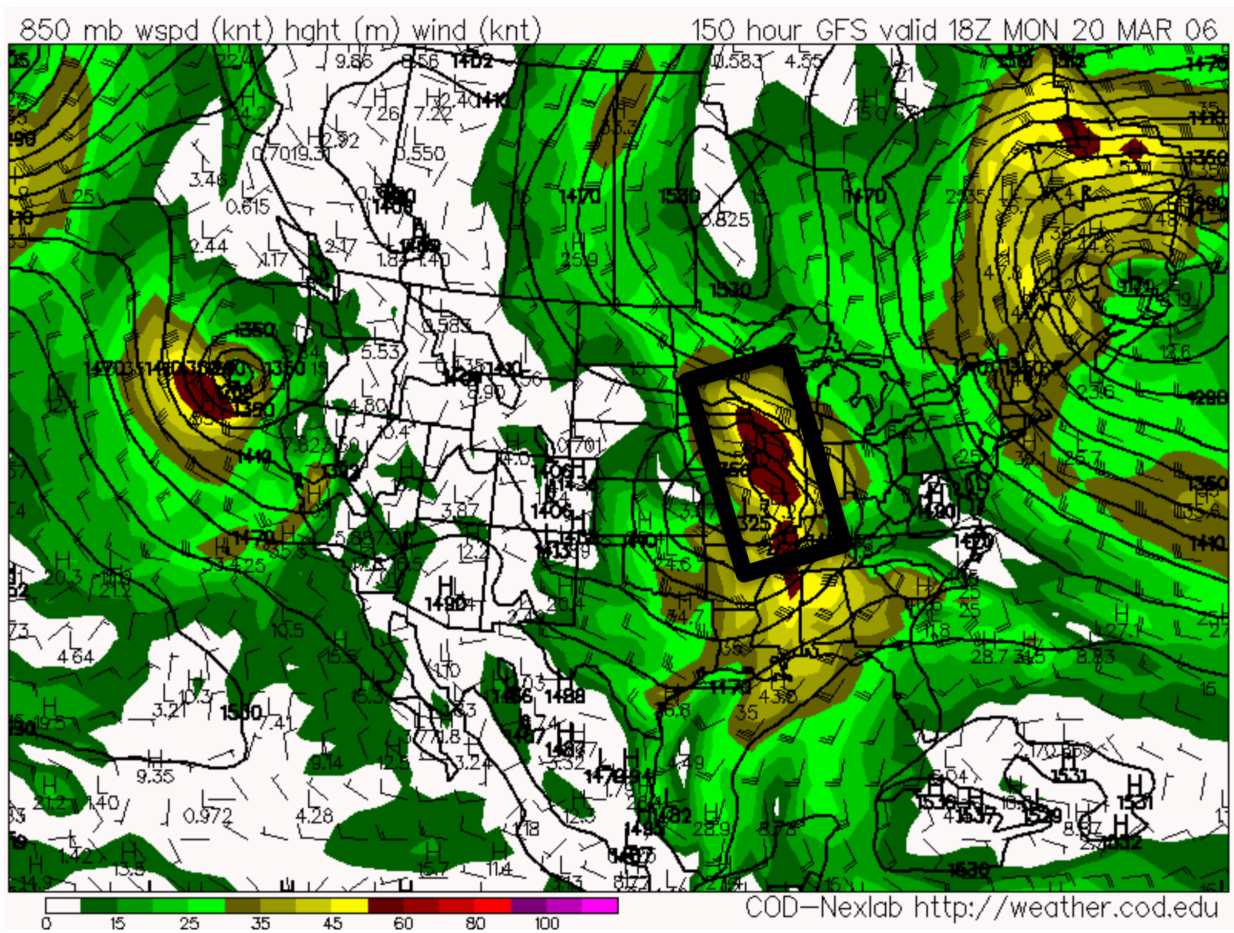
(e)

20 March 2006
IGW prediction by operational GFS

Email to coauthor *6 days* before event:

"…the GFS 00z/14th control run…has a classic synoptic IGW configuration.

…model output actually shows a large-amplitude gravity wave propagating eastward across the IL-IN-OH area between 18z/20th and 00z/21st."

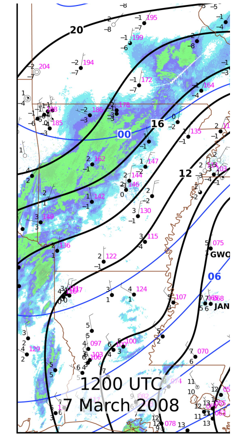


6 days later….

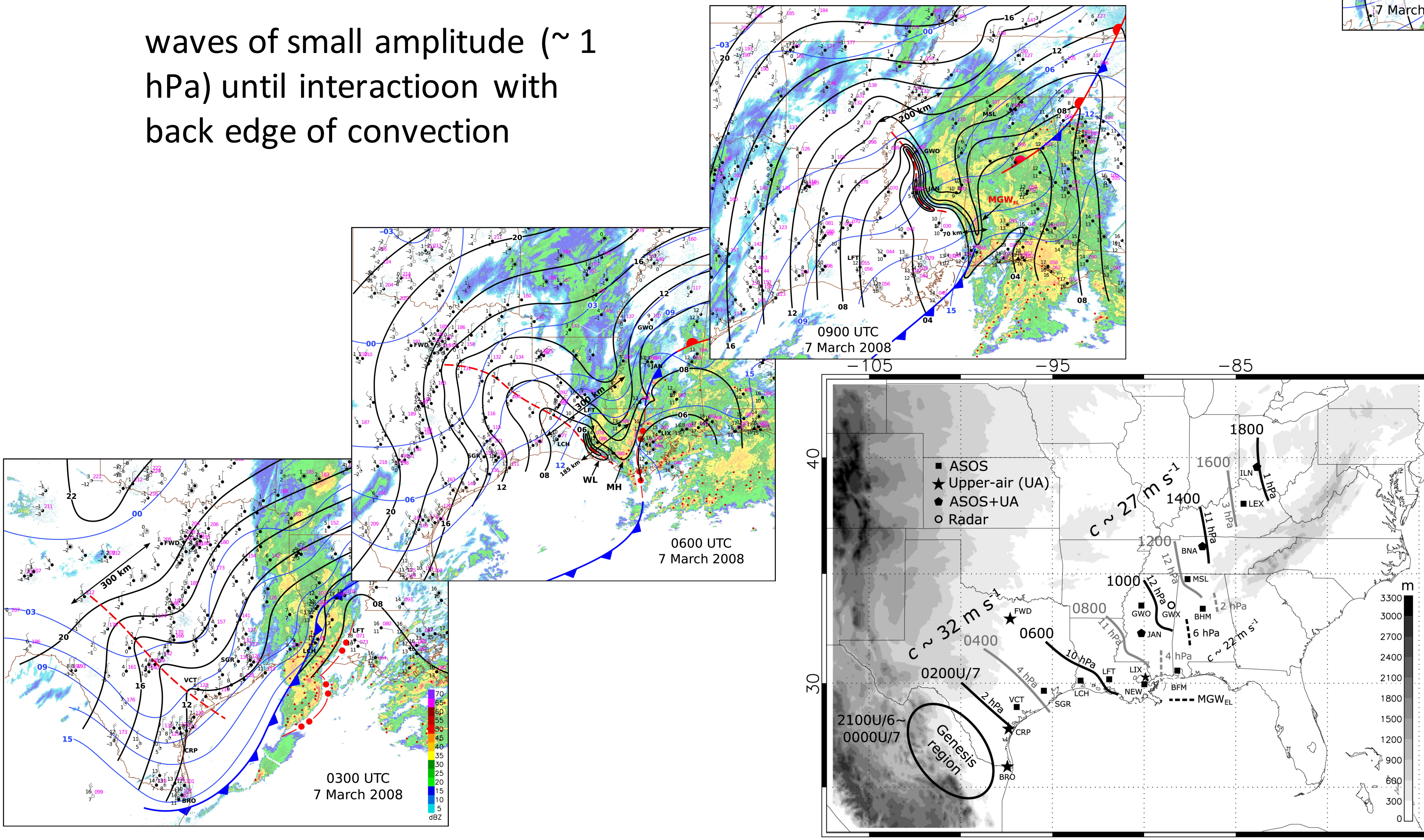
"Not a bad forecast! …The recent obs at North Little Rock (KLRF) show a good wind squall accompanying an ~8 hPa fall in 21 minutes, followed by an almost equal rise over the next 39 minutes."

"Gravity wave is about to propagate across Memphis. **Local NWS doesn't seem aware of this, based on the short term forecast issued an hour ago**. Jonesboro, Arkansas just recorded similar wind conditions experienced 90 minutes earlier in North Little Rock. "

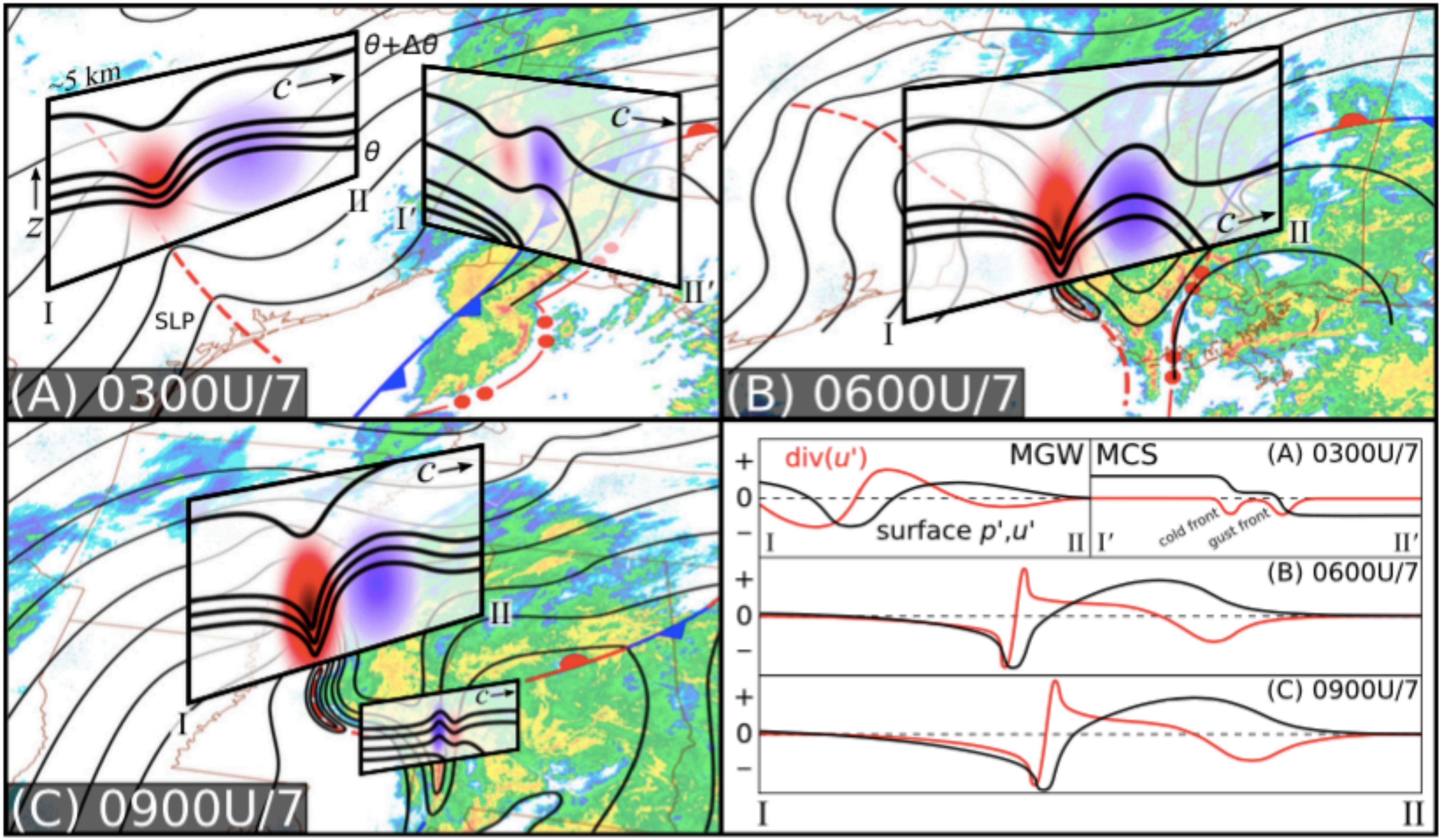
7 March 2008
(Ruppert and Bosart 2014)



waves of small amplitude (~ 1 hPa) until interactioon with back edge of convection



Schematic cross sections

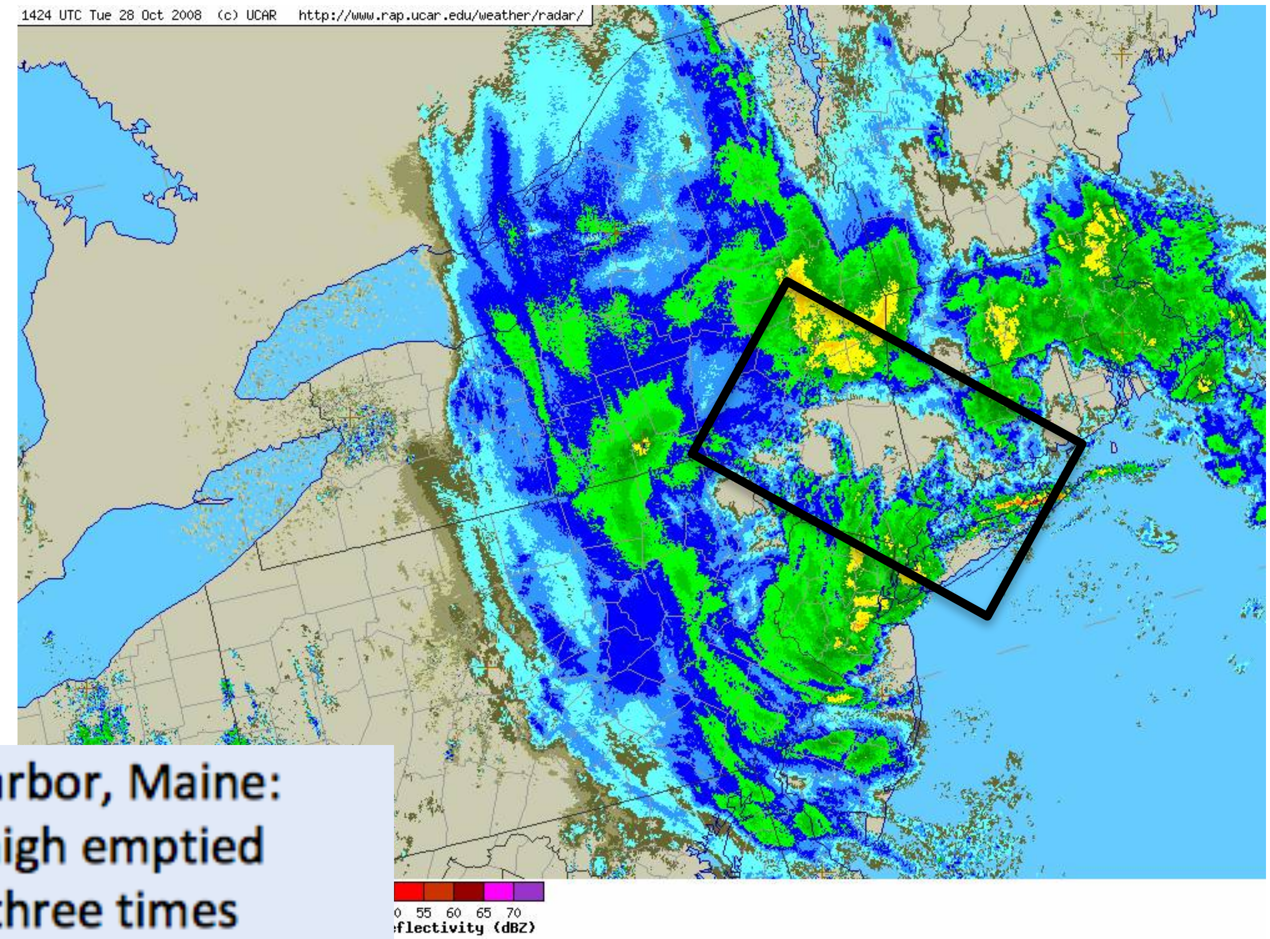


(Ruppert and Bosart 2014)

28 Oct 2008
Hudson Valley-coastal New England

AT 13 UTC, 6-7 hPa IGW over southern NY State moving NE within a cyclonic system

At 19 UTC, multiple sea level oscillations up to 3.5 m affect coastal Maine



News report:

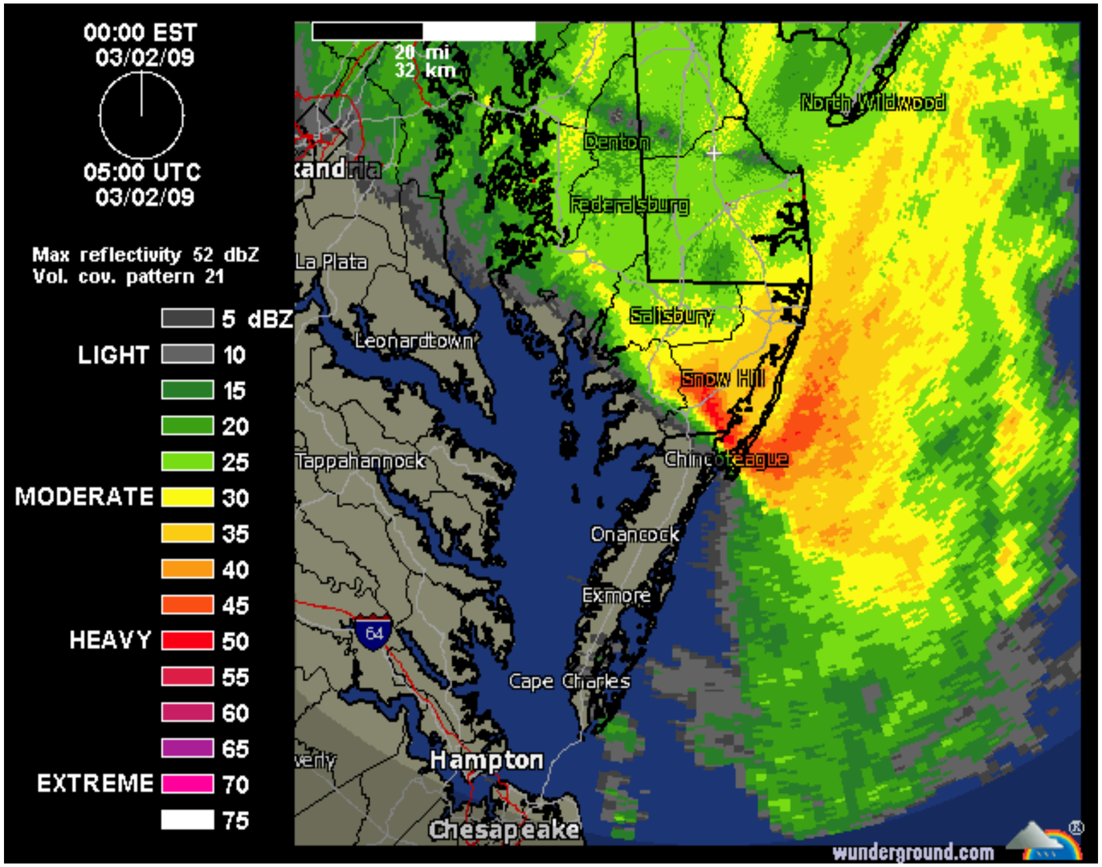
October 28, 2008—Boothbay Harbor, Maine: A series of waves up to 12 feet high emptied and flooded the harbor at least three times over 15 minutes, damaging boats and shoreline infrastructure.

2 March 2009 Explicit model prediction forcoastal winter storm

- Operational WRF model predicts IGW within a high impact winter storm.

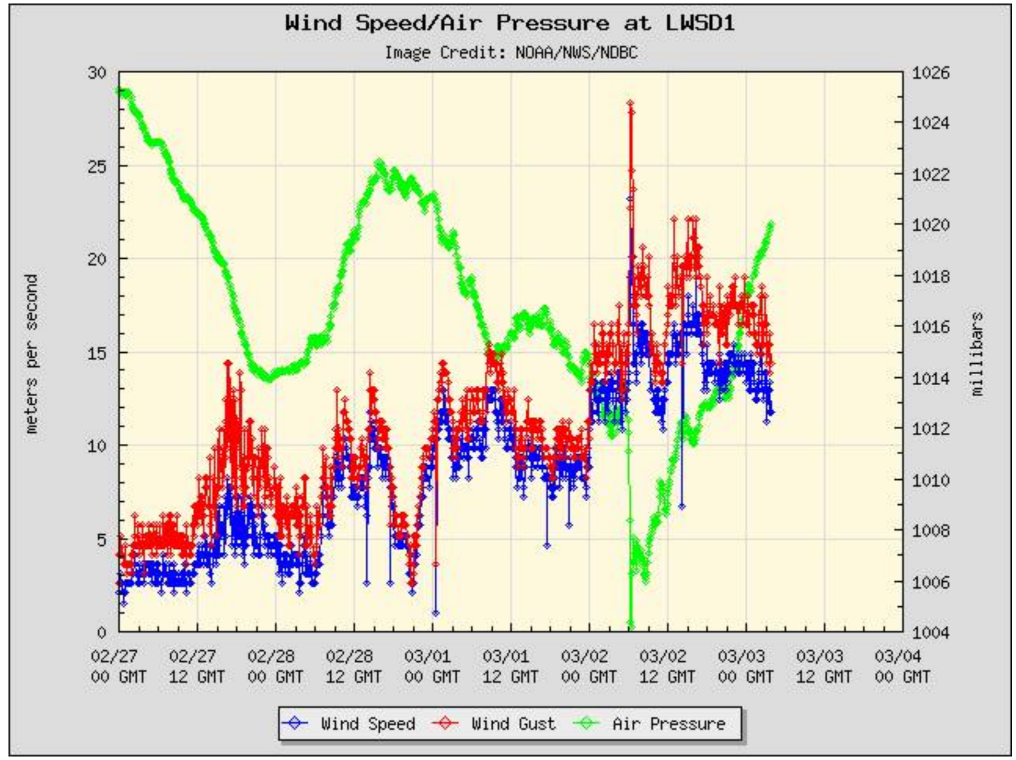
- Forecast verifies, but this is not communicated in public advisories.

- Reports of wind damage.

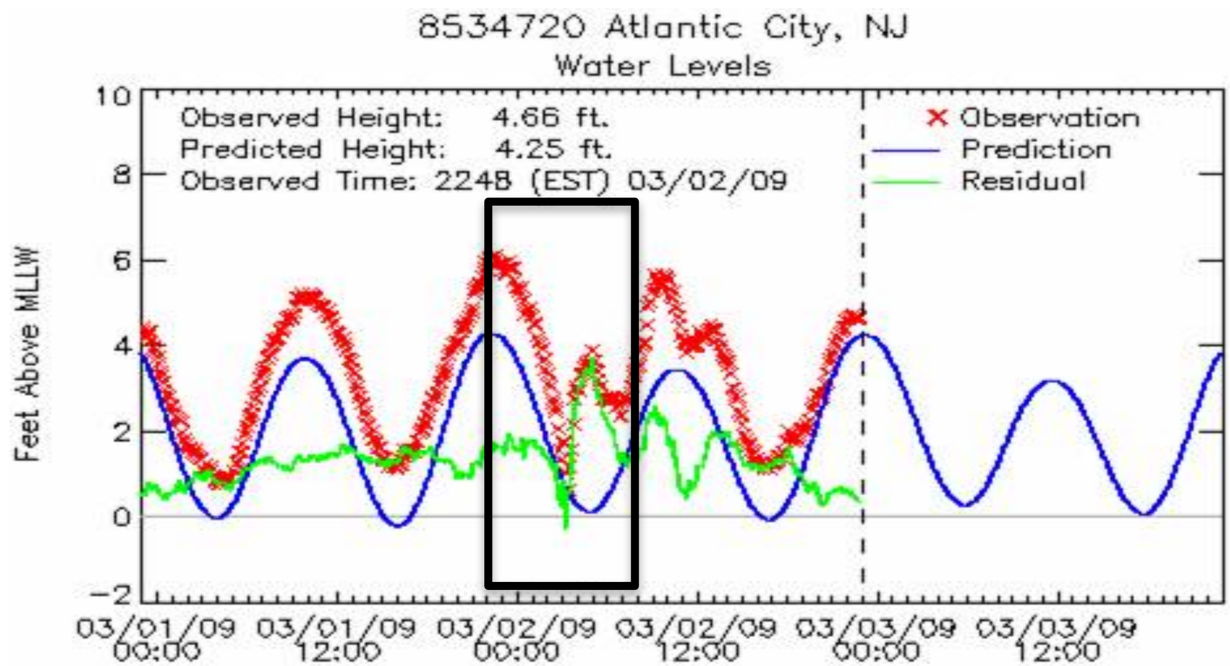


Coastal marine 6-min wind, pressure, sea level

Lewes, Delaware.
Winds reach 23 gusting 28 m s^{-1}.
Pressure -8.1mb/30min;
-4mb/6 min



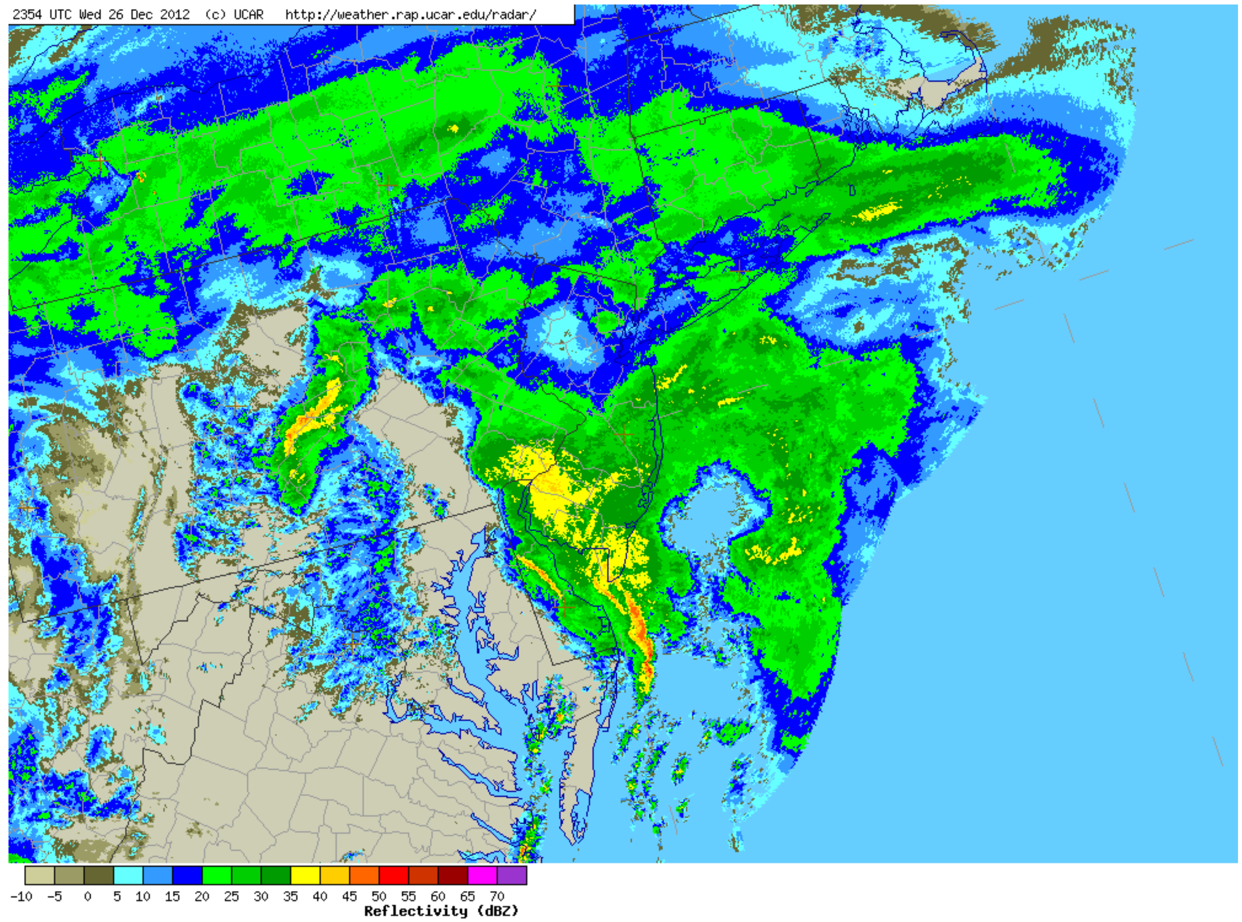
Atlantic City, NJ
Sea level change of 1.3 m coincides with IGW passage (at low tide, fortunately)



26 Dec 2012
Coastal Mid-Atlantic

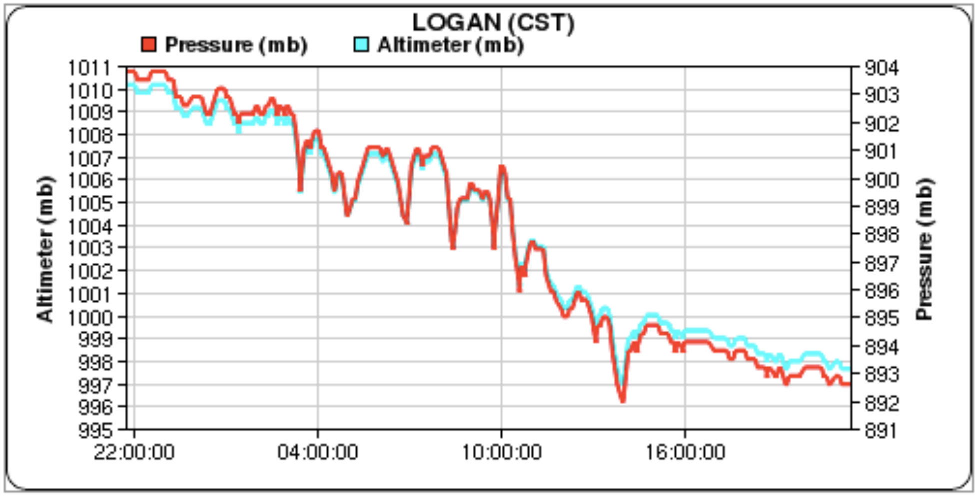
From: "Bosart, Lance F”

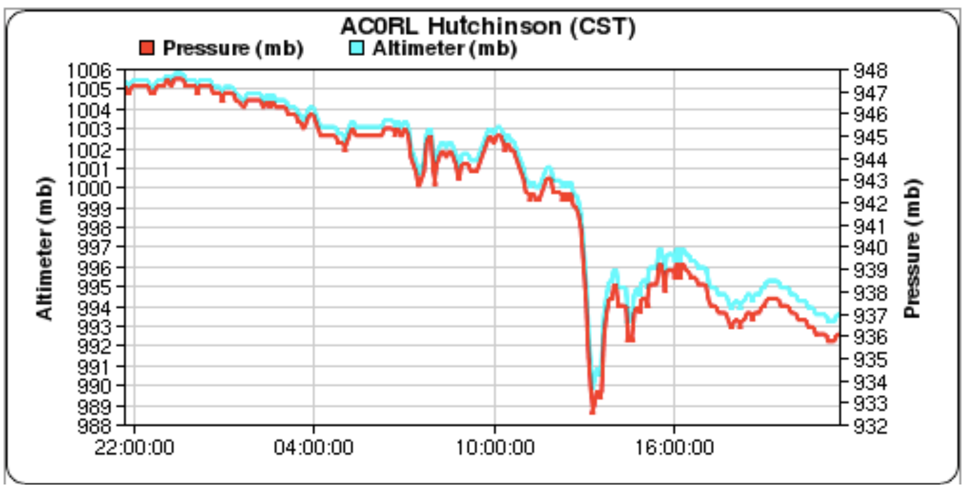
Subject: Re: Inertia gravity wave tracking towards NYC metropolitan area

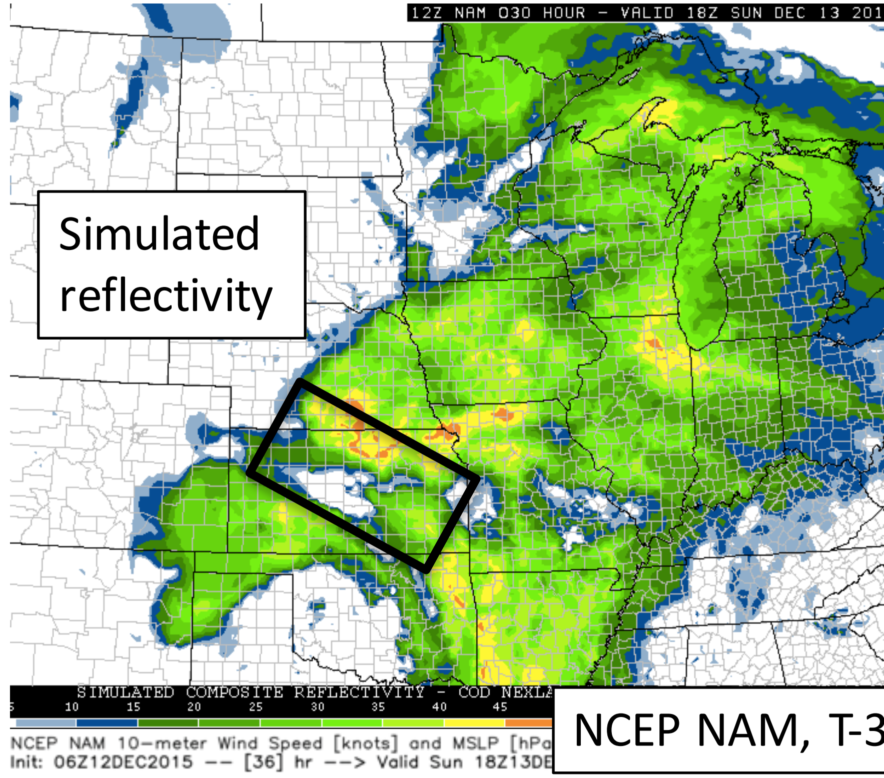


”recent obs from DOV (Dover, DE)……a westerly wind shift at 0000 UTC 27 Dec, westerly winds from 0000-0009 UTC, SSE winds at 0012 UTC, and back to ENE winds at 0015 UTC. At 0026 UTC ENE winds are sustained at 43 kt with gusts to 56 kt.”

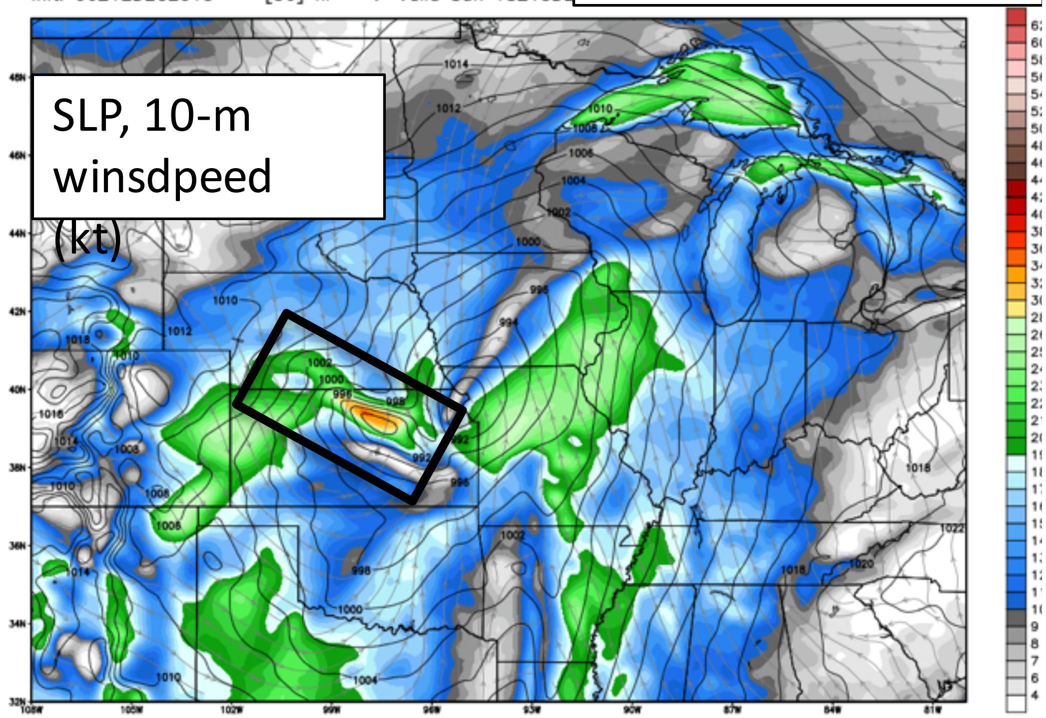
13 December 2015
Kansas – Central plains







NCEP NAM, T-36 hrs



Operational forecasting challenges

Lack of formal designation contributes to IGW phenomenon remaining obscure and poorly understood by most meteorologists and other warning personnel.

- Rarity (est. 1-3 events per year)
- Detection and recognition can be difficult
- Misattribution of IGW parameters to other phenomena
- Lack of conventions for classifying intensity of IGW
- Real-time detection requires high temporal resolution observations, and a means of diagnosing them
- Explicit IGW depictions in numerical predictions go unrecognized without conceptual framework and/or machine algorithms for automated detection

A call for classification

Hazardous weather associated with the passage of large-amplitude , particularly surface winds that may reach 20-40 ms^{-1}, constitute a storm by standard definition yet remain unclassified as such.

AMS Glossary of Meteorology:

In synoptic meteorology, a storm is a complete individual disturbance identified on synoptic charts as a complex of pressure, wind, clouds, precipitation, etc., or identified by such mesometeorological means as radar or sferics.

Sensible weather associated with the passage of IGW >5 hPa amplitude:

1) **Pre-storm**. A small positive pressure anomaly of duration ~1 h, accompanied by moderate precipitation and windspeeds 5-10 ms-1

2) **Storm**. Abrupt pressure fall (or sometimes, rise) with delta P rates that can exceed 1 hPa/min, and 14 hPa/40 min. Winds increase steadily in proportion to rate of pressure fall, and reach maxima $\geq$20 m s^{-1} at Pmin. Precipitation decreases during pressure drop, ending around Pmin

3) **Recovery**. Pressure and winds returns to ambient condition, precipitation may resume.

Large-amplitude IGW or Wake Low: does it make a difference?

- Distinctly different phenomena according to generation, evolution and structure
- In terms of sensible weather and hazards to public, both phenomena are largely the same, except in winter storms.
- Neither currently has a classification scheme: opportunity to create a unified intensity scale for use in public advisories

Recommendations

- Seek formal recognition as a storm type
- Denominate with sassier name than "large-amplitude inertia gravity wave"!
- Use objective criteria to classify events, both in predictions and during/after event
- Improve forecaster situational awareness for decision-making and warning issuance
    - Training
    - Online wiki for quick reference
- Develop algorithms to automate IGW detection in numerical output
- Provide plain-language website for public awareness and information access when advisories issued

Pressure-wind relationship provides basis for classification criteria

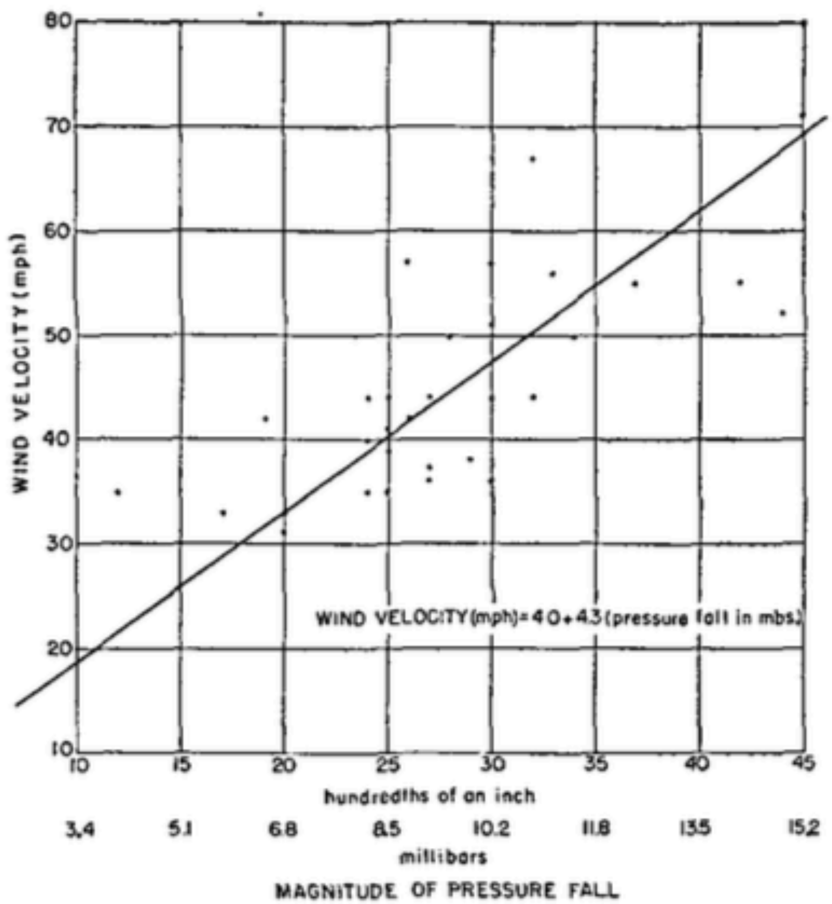
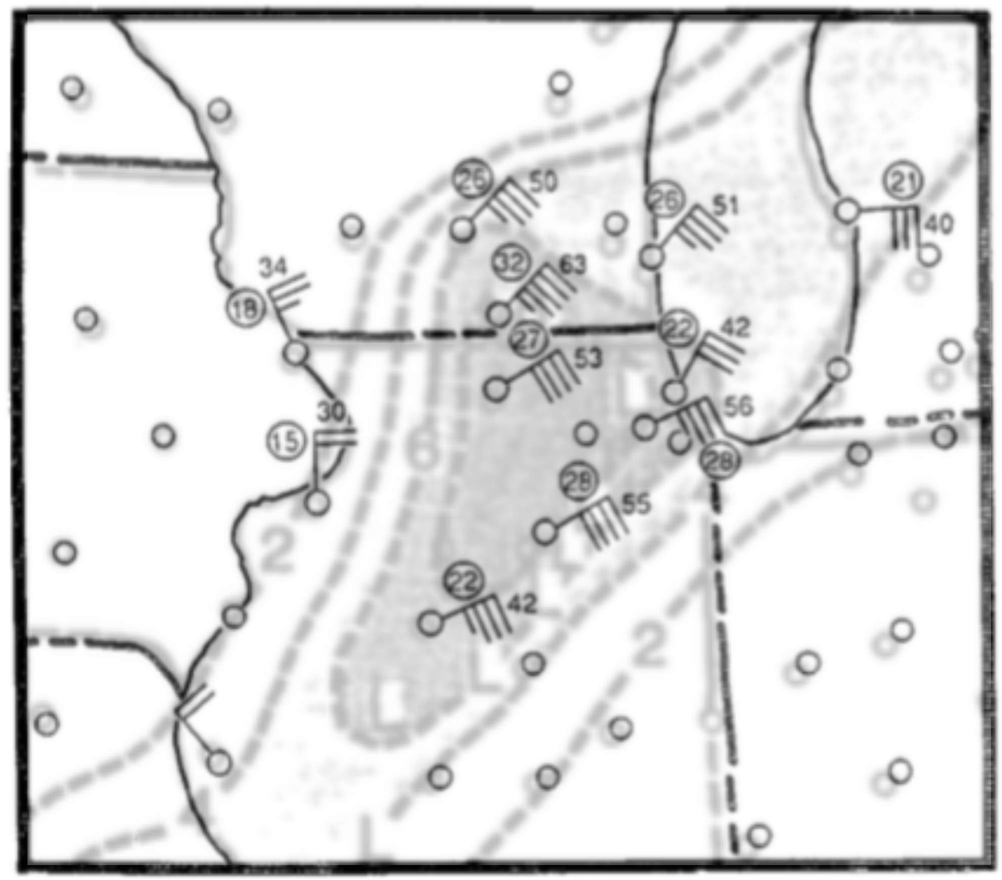


FIG. 6. Magnitude of pressure fall and wind velocity.

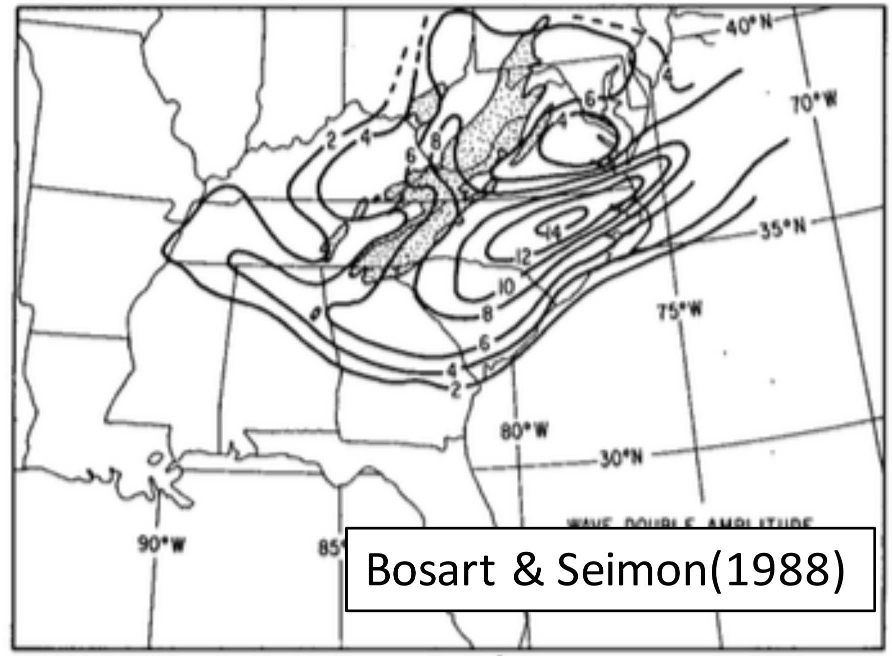


Brunk (1944)

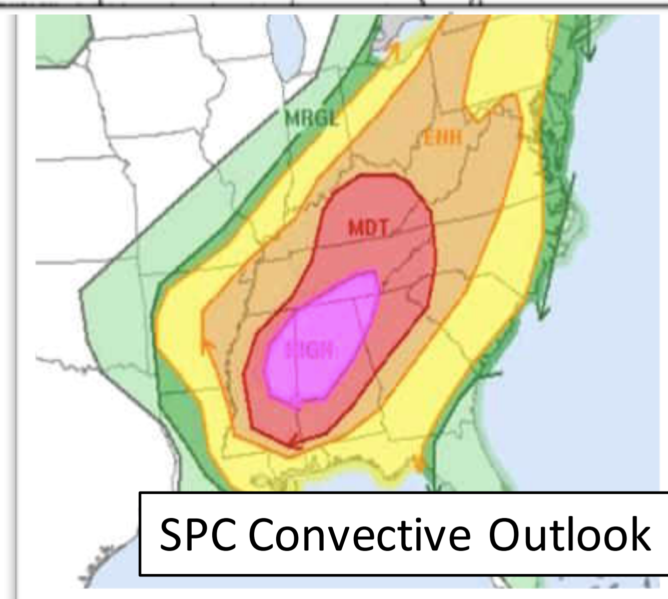
Adapted from Schneider (1990)

Suggested scale and graphical depiction of hazard

Scale	Delta-P/30 min
0	<4.0 hPa
1	5.0-6.9 hPa
2	7.0-8.9 hPa
3	9.0-10.9 hPa
4	11.0-12.9 hPa
5	≥13.0 hPa



Bosart & Seimon(1988)



SPC Convective Outlook