# Cold-Season Coupled Upper-Level Jet Streaks in the Northeastern United States
# Part 2: Strong Dynamic Cases

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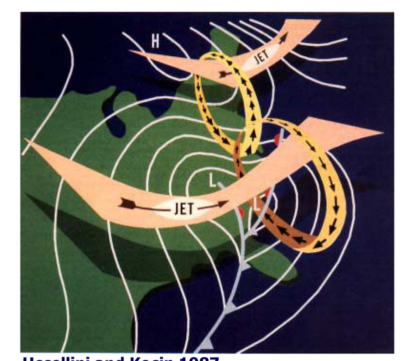
## Introduction

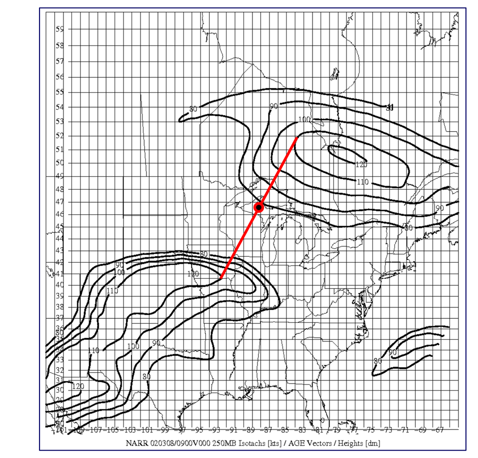
- The interaction of transverse circulations associated with two separate upper-level (UL) jet streaks, along with its effects on sensible weather, have been documented in several studies:
  - East Coast cyclogenesis (e.g., Uccellini and Kocin 1987)
  - Heavy/banded precipitation (e.g., Belville and Stewart 1983; Junker et al. 1990; Hakim and Uccellini 1992; Funk and Moore 1995; Melde 1996)
  - Organized severe thunderstorm complexes (e.g., Hamilton et al. 1998; Ashley et al. 2000; Jamski et al. 2000)
- The term 'coupled jet streaks' refers to the presence of two separate jet streaks juxtaposed in such fashion that the ascending branches of the transverse circulations are collocated with one another, resulting in an enhanced area of upward vertical motion (e.g., Uccellini and Kocin 1987).
- This study will investigate coupled UL jet streak occurrences during the cool season (1 October to 31 March) in the northeastern U.S. over 10 seasons (1993 – 2003).



Uccellini and Kocin 1987

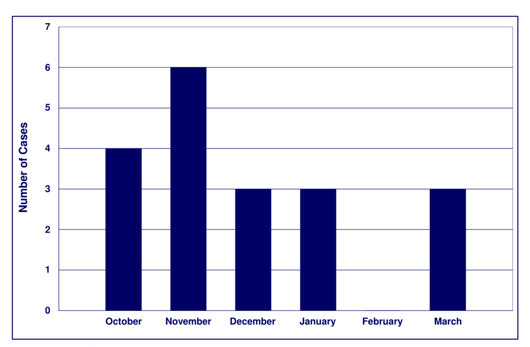
## Methodology

- Preliminary examination of the UL flow regime using the North American Regional Reanalysis (NARR) dataset revealed 79 possible coupled jet streak occurrences during the period.
- Using the General Meteorological Package (GEMPAK) with the NARR dataset, plan-view and cross-sectional analyses of the possible occurrences were analyzed to ensure the interaction of the jet streak circulations.
- This revealed 39 coupled jet streak cases, which were then subdivided into weak dynamic (n=20) and strong dynamic (n=19) scenarios.
- The strong dynamic cases (covered in this presentation) were characterized by strong surface circulations (MSLP < 1000 hPa) and closed mid-tropospheric waves.




- Center points between the jet streaks were then qualitatively determined by finding the midpoint on a line between the strongest common isotach for the initial coupling time, along with the prior 6- and 12-h time periods (see left).
- The NARR data was objectively analyzed to a 31 x 23 grid with 128 km between gridpoints using the Barnes (1973) objective analysis scheme.
- A 27 x 19 grid was then extracted using the center point between the jet streaks.
- Finally, the data was then averaged over the 19 strong cases using the SLUBREW compositing software developed by Moore et al. (1996).

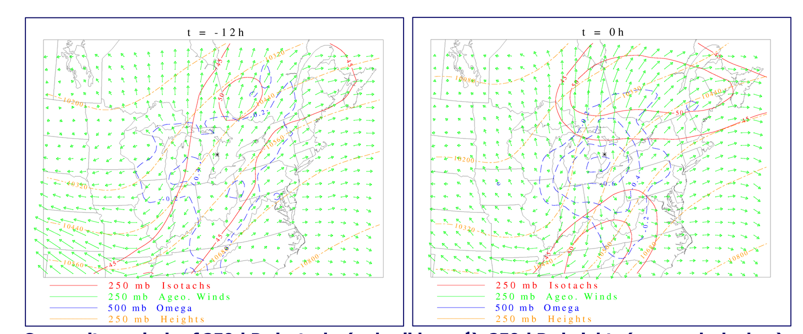
## Composites



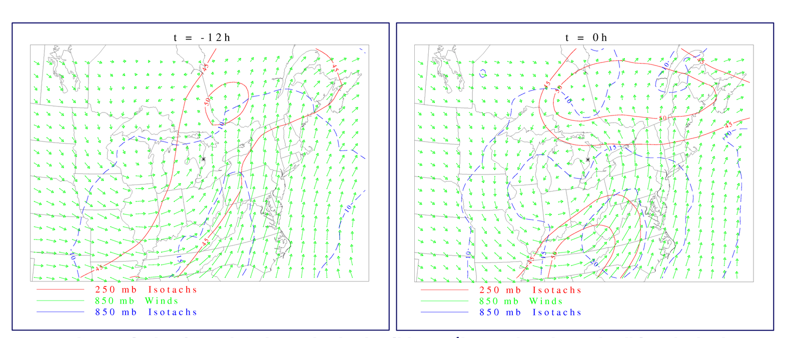
Monthly distribution of the 19 strong dynamic coupled jet streak events.

| Case | Date/Time (HHHH/MMDDYYYY) | Location of Jet Streak Interaction | Center Lat/Lon | Distance Exit/Entrance Regions (km) | Distance Jet Cores (km) |
|---|---|---|---|---|---|
| 1 | 1200/12051993 | Mid-Atlantic | 39.0°N/77.0°W | 872 | 1936 |
| 2 | 1800/03021994 | Mid-Atlantic | 40.0°N/74.0°W | 925 | 2040 |
| 3 | 1800/11271994 | Great Lakes | 43.0°N/86.0°W | 1000 | 2061 |
| 4 | 0600/11271995 | Upper Mississippi Valley | 44.5°N/89.0°W | 864 | 1904 |
| 5 | 1800/01181996 | Middle Mississippi Valley | 42.0°N/91.0°W | 1023 | 1951 |
| 6 | 0000/03251996 | Central Plains | 41.0°N/95.0°W | 893 | 1853 |
| 7 | 1200/10171996 | Upper Mississippi Valley | 45.0°N/96.0°W | 1122 | 2056 |
| 8 | 1800/10291996 | Upper Mississippi Valley | 47.0°N/92.0°W | 1232 | 2020 |
| 9 | 1800/11251996 | Ohio Valley | 40.0°N/86.0°W | 1014 | 1718 |
| 10 | 0000/10261997 | Middle Mississippi Valley | 39.0°N/93.5°W | 778 | 2065 |
| 11 | 0600/11141997 | Mid-Atlantic | 43.0°N/79.0°W | 893 | 1930 |
| 12 | 0600/12241997 | Middle Mississippi Valley | 38.0°N/89.0°W | 927 | 2364 |
| 13 | 0000/03181999 | Great Lakes | 46.5°N/83.0°W | 760 | 1832 |
| 14 | 0000/11031999 | Mid-Atlantic | 42.0°N/82.0°W | 1000 | 2484 |
| 15 | 1800/12141999 | Mid-Atlantic | 42.0°N/76.0°W | 1031 | 1648 |
| 16 | 1800/01102000 | Mid-Atlantic | 39.0°N/78.0°W | 582 | 1508 |
| 17 | 0600/11062000 | Lower Mississippi Valley | 33.0°N/96.0°W | 789 | 1905 |
| 18 | 0600/01302001 | Great Lakes | 46.0°N/81.0°W | 1336 | 2512 |
| 19 | 1800/10162002 | Mid-Atlantic | 42.0°N/77.0°W | 866 | 2007 |

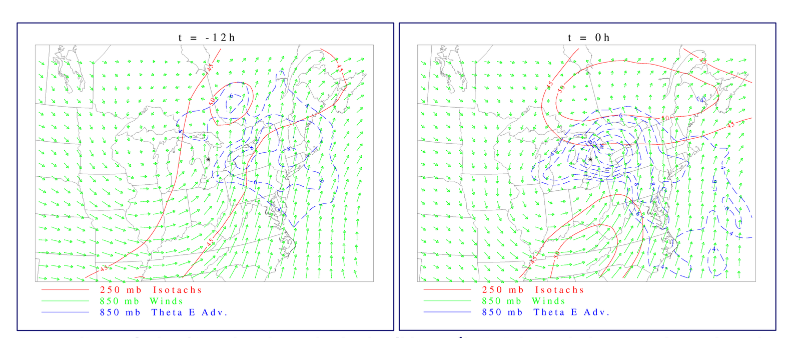
List of strong coupled jet streak cases, including time/date of coupling, area affected, distance between the exit/entrance regions, and distance between jet cores (strong case study in red).



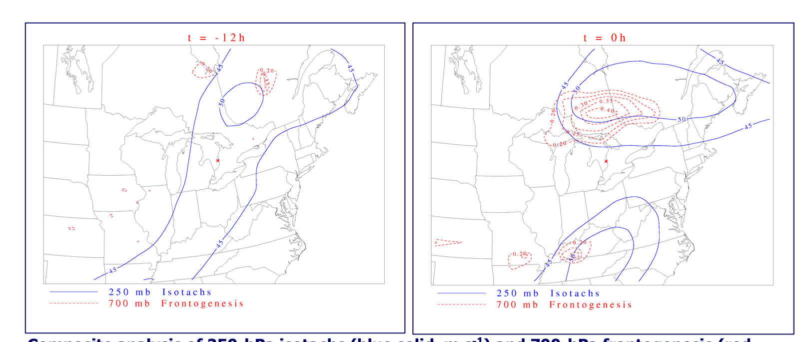
Composite analysis of 250-hPa isotachs (red solid, m s$^{-1}$), 250-hPa heights (orange dashed, m), 250-hPa ageostrophic wind vectors (green, m s$^{-1}$), and 500-hPa omega (blue dashed, 10 μbar s$^{-1}$) at t = -12 h (left) and t = 0 h (right).



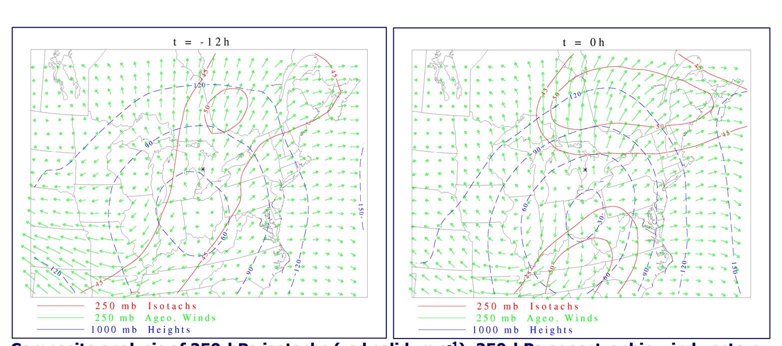
Composite analysis of 250-hPa isotachs (red solid, m s$^{-1}$), 850-hPa isotachs (blue dashed, m s$^{-1}$), and 850-hPa wind vectors (green) at t = -12 h (left) and t = 0 h (right).



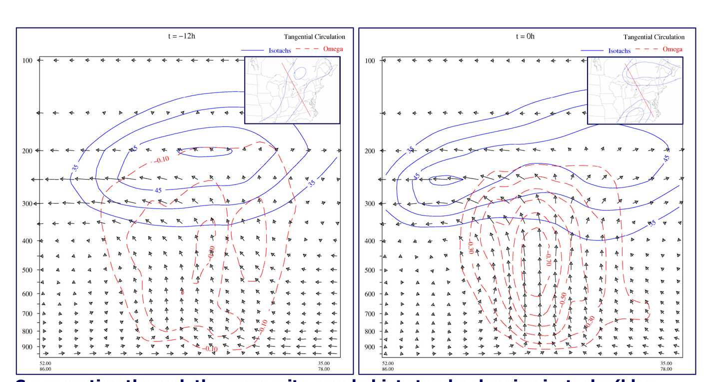
Composite analysis of 250-hPa isotachs (red solid, m s$^{-1}$), 850-hPa wind vectors (green), and $\theta_e$ advection (blue dashed, K hr$^{-1}$) at t = -12 h (left) and t = 0 h (right).



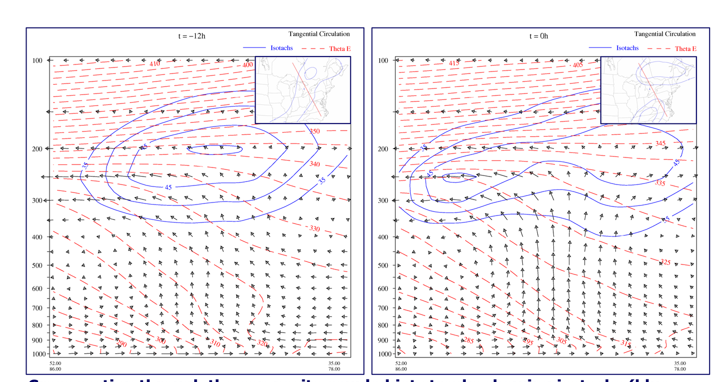
Composite analysis of 250-hPa isotachs (blue solid, m s$^{-1}$) and 700-hPa frontogenesis (red dashed, 10 K [100 km]$^{-1}$ [3 h]$^{-1}$) at t = -12 h (left) and t = 0 h (right).



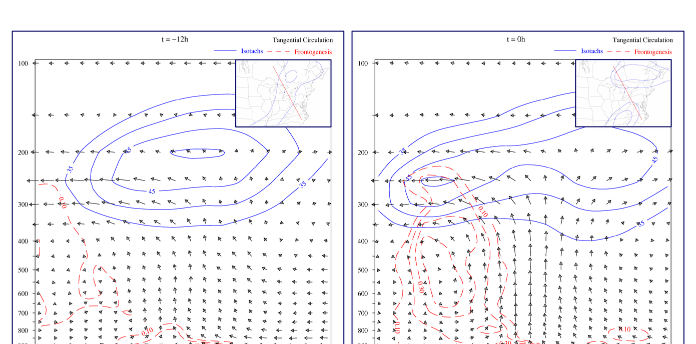
Composite analysis of 250-hPa isotachs (red solid, m s$^{-1}$), 250-hPa ageostrophic wind vectors (green), and 1000-hPa heights (blue dashed, m) at t = -12 h (left) and t = 0 h (right).



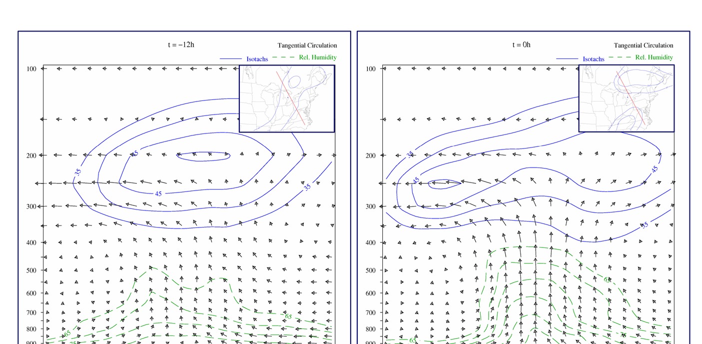
Cross section through the composite coupled jet streaks showing isotachs (blue solid, m s$^{-1}$), ageostrophic circulation (black arrows), and omega (red dashed, 10 μbar s$^{-1}$) at t = -12 h (left) and t = 0 h (right). Inset figures provide the orientation of the cross-section with respect to the isotach field.



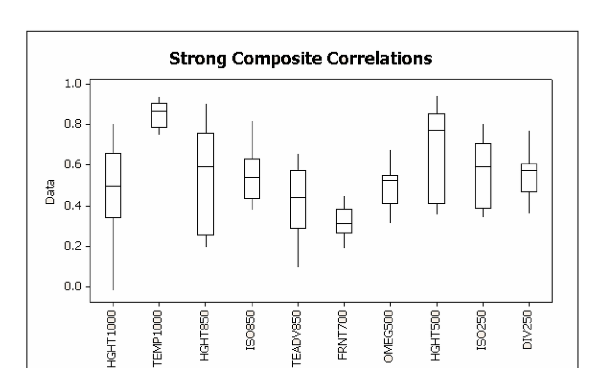
Cross section through the composite coupled jet streaks showing isotachs (blue solid, m s$^{-1}$), ageostrophic circulation (black arrows), and $\theta_e$ (red dashed, K) at t = -12 h (left) and t = 0 h (right). Inset figures provide the orientation of the cross-section with respect to the isotach field.



Cross section through the composite coupled jet streaks showing isotachs (blue solid, m s$^{-1}$), ageostrophic circulation (black arrows), and frontogenesis (red dashed, 10 K [100 km]$^{-1}$ [3 h]$^{-1}$) at t = -12 h (left) and t = 0 h (right). Inset figures provide the orientation of the cross-section with respect to the isotach field.



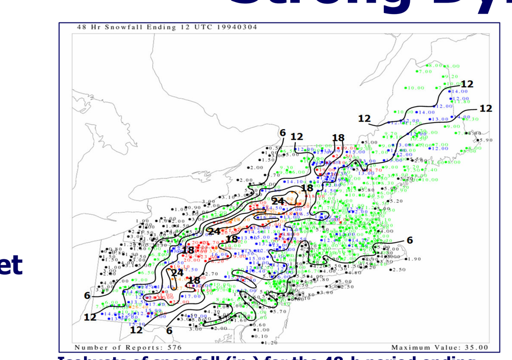
Cross section through the composite coupled jet streaks showing isotachs (blue solid, m s$^{-1}$), ageostrophic circulation (black arrows), and relative humidity ≥ 60% (green dashed, %) at t = -12 h (left) and t = 0 h (right). Inset figures provide the orientation of the cross-section with respect to the isotach field.



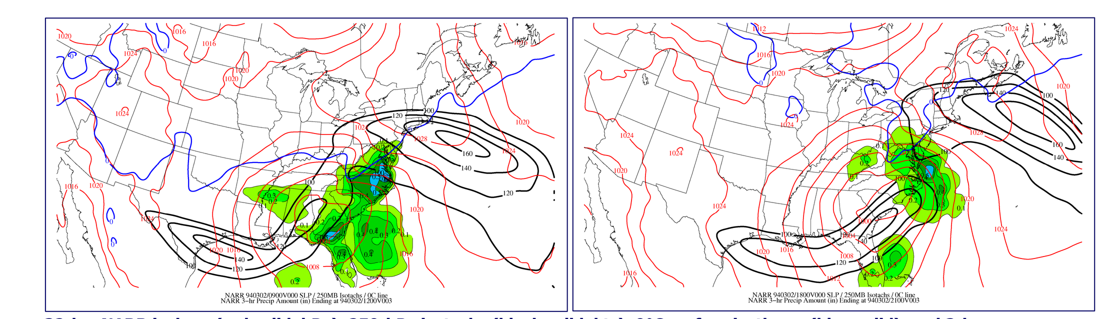
Box-and-whisker plots displaying the range of correlations between the composite fields and the individual strong cases. In each case the horizontal line within each box represents the 50th percentile, the top (bottom) line of the box is the 75th (25th) percentile, and the top (bottom) line outside the box represents the 90th (10th) percentile.

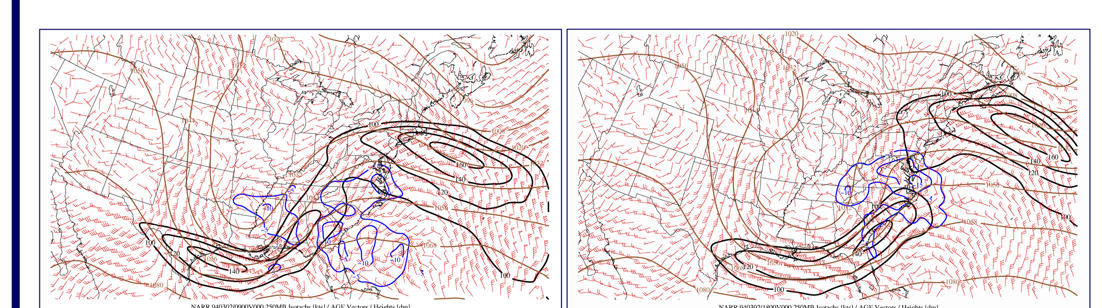
## Strong Dynamic Case Study

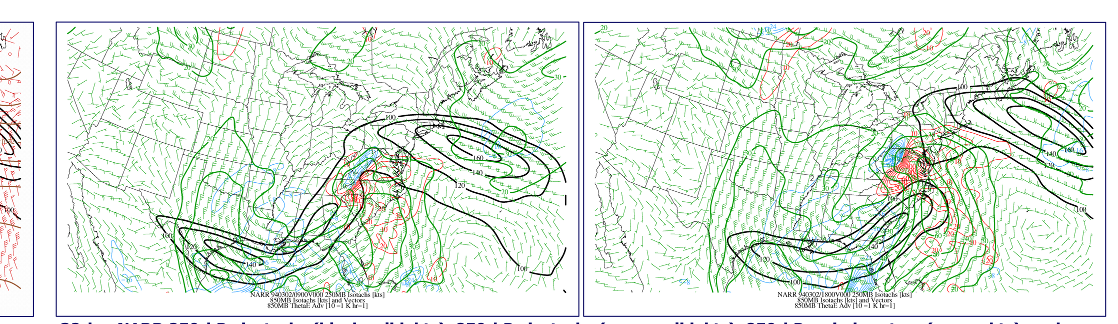
- 4 March 1994
- Regions of 24+ inches of snow
- Wind reports of 80+ kts
- Avalanches reported in PA
- $10M+ damages regionwide
- Significant deepening follows jet streak coupling (8 hPa [6 h]$^{-1}$)

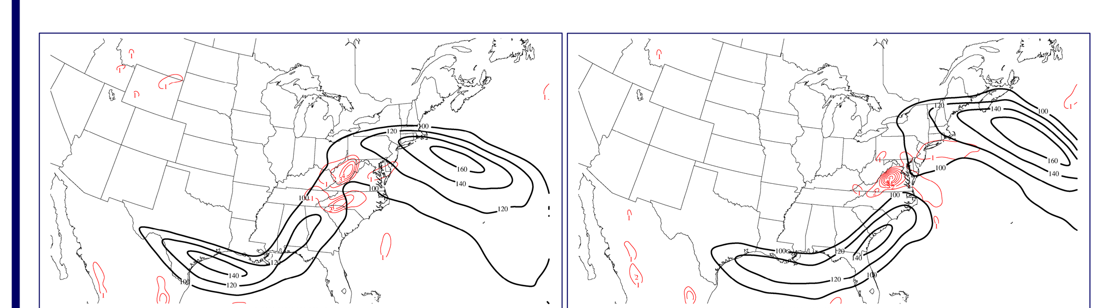


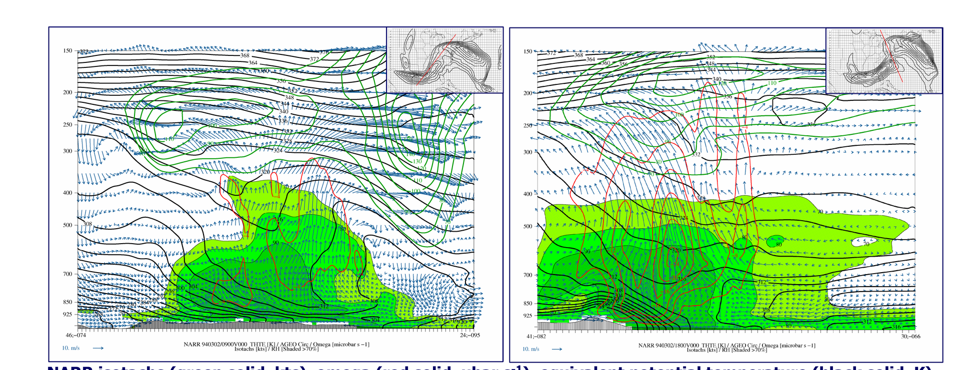
Isohyets of snowfall (in.) for the 48-h period ending 1200 UTC 4 Mar 1994, based upon cooperative station data from NCDC.


32-km NARR isobars (red solid, hPa), 250-hPa isotachs (black solid, kts), 0°C surface isotherm (blue solid), and 3-h accumulated precipitation (shaded > 0.05 in) at 0900 UTC 3 Mar 2002 (left) and 1800 UTC 3 Mar 2002 (right).


32-km NARR 250-hPa heights (brown solid, dkm), 250-hPa isotachs (black solid, kts), 250-hPa ageostrophic wind barbs (red), and 500-hPa omega (blue solid, μbar s$^{-1}$) at 0900 UTC 3 Mar 2002 (left) and 1800 UTC 3 Mar 2002 (right).


32-km NARR 250-hPa isotachs (black solid, kts), 850-hPa isotachs (green solid, kts), 850-hPa wind vectors (green, kts), and 850-hPa $\theta_e$ advection (red solid [+10$^{-1}$ K hr$^{-1}$], blue solid [-10$^{-1}$ K hr$^{-1}$]) at 0900 UTC 3 Mar 2002 (left) and 1800 UTC 3 Mar 2002 (right).


32-km NARR 250-hPa isotachs (black solid, kts), and 850-hPa frontogenesis (red solid, K [100 km]$^{-1}$ [3 h]$^{-1}$) at 0900 UTC 3 Mar 2002 (left) and 1800 UTC 3 Mar 2002 (right).


NARR isotachs (green solid, kts), omega (red solid, μbar s$^{-1}$), equivalent potential temperature (black solid, K), ageostrophic vertical circulation (blue arrows), and RH ≥ 70% (green shading) at 0900 UTC 3 Mar 2002 (left) and 1800 UTC 3 Mar 2002 (right). Inset figures provide the orientation of the cross-section with respect to the isotach field.

## Conclusions

- No monthly preference for strong dynamic episodes (cf. weak dynamic)
- 942 (1989) km average distance between jets' entrance and exit regions (jet cores) at time of coupling
- Southern jet 'normal' to core of northern jet (cf. weak dynamic)
- Northern jet expands and strengthens significantly during coupling period but maintains core position, while southern jet strengthens as it moves out of trough
- 250-hPa heights fall significantly upwind of jet streaks while trough transitions from neutral to negative tilt
- 250-hPa ageostrophic along-stream flow contributes significantly to upper-level divergence and mid-tropospheric UVM in coupling region (cf. weak dynamic), which doubles and becomes better organized during coupling period
- 850-hPa low-level jet strengthens modestly in coupling region over coupling period, while 850-hPa $\theta_e$ advection becomes stronger and better organized
- 700-hPa frontogenesis region develops rapidly underneath entrance region of northern jet during coupling period (north of max $\theta_e$ advection)
- 'Surface' low deepens modestly over coupling period while maintaining position
- Poleward/upward transport of warm/moist (high $\theta_e$) air (i.e. ageostrophic circulation) becomes better defined over coupling period
- UVM region doubles in strength between jets during coupling period (more 'vertical' than weak dynamic)
- Low-level front strengthens over coupling period
- Mid/upper-tropospheric frontogenetical circulation works in concert with coupled jet circulation as frontogenesis extends upward over coupling period
- Moist layer between jets deepens over coupling period, but maintains width
- Correlations of basic parameters generally better than those of derived parameters, but minimal differences between weak and strong episodes indicate similar properties for both types of interaction

- This project would not have been possible without COMET Partners Project Award S05-52248 and the help of Charles E. Graves (Saint Louis University) who aided the authors in using the SLUBREW compositing software.