The Role of Sawyer-Eliassen Circulations in Sting Jet Formation in European Windstorms

Zachary B. Murphy, Jonathan E. Martin, University of Wisconsin-Madison

Department of Atmospheric and Oceanic Sciences

Introduction & Motivation

A **sting jet** is a stream of damaging winds formed by the descent of drying airstreams in violent extra-tropical cyclones. These winds cause billions of dollars in damage in Europe each year. Schultz and Sienkiewicz (2013) suggested that frontal-scale circulations may be key to their formation. These circulations serve to advect high momentum air from aloft to the surface.

Shapiro (1983), and Lang and Martin (2012) showed that in the presence of temperature advection aloft, the frontal-scale Sawyer-Eliassen (SE) circulations move to allow ascent or descent through the jet (see Fig. 1).

Descent through the jet stream in European cyclones may allow higher momentum air to be transported to lower levels to aid in the sting jet formation process. Thus, the aim of this study is to evaluate the validity of this claim via examination of the SE forcings. This will be done through an analysis of a sting jet case and a non-sting jet case.

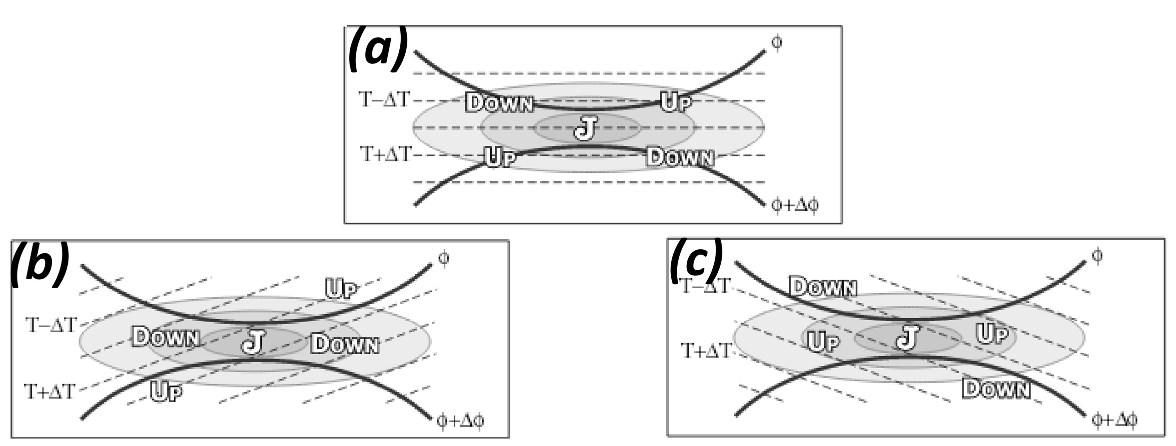

*Fig. 1: Schematic of a straight jet streak in the presence of **(a)** no temperature advection **(b)** cold air advection **(c)** warm air advection. Solid Lines are geopotential heights, Dashed lines are isotherms, and vertical motions indicated by "UP" or "DOWN". From Lang and Martin (2012).*

Methodology

- Data: 1.0 x 1.0 degree GFS data.
- Circulations: The SE circulation ψ is influenced by two main processes, seen below:

$$\left(-\gamma\frac{\partial\theta}{\partial p}\right)\frac{\partial^2\psi}{\partial y^2}+\left(2\frac{\partial M}{\partial p}\right)\frac{\partial^2\psi}{\partial y\partial p}+\left(-\frac{\partial M}{\partial y}\right)\frac{\partial^2\psi}{\partial p^2}=Q_g-\gamma\frac{\partial}{\partial y}\left(\frac{d\theta}{dt}\right)$$

A B

- Where A is the geostrophic forcing, and B is the diabatic forcing. The equation was numerically solved for ψ.
- Cases: From Gray (2011), Cyclone Erwin produced a sting jet around **0400 UTC on 8 January 2005**. Cyclone Tilo produced strong non-sting jet winds around **0100 UTC on 8 December 2007**.

Contact: zmurphy@wisc.edu

Sting Jet Case: Erwin

Jet Stream Characteristics

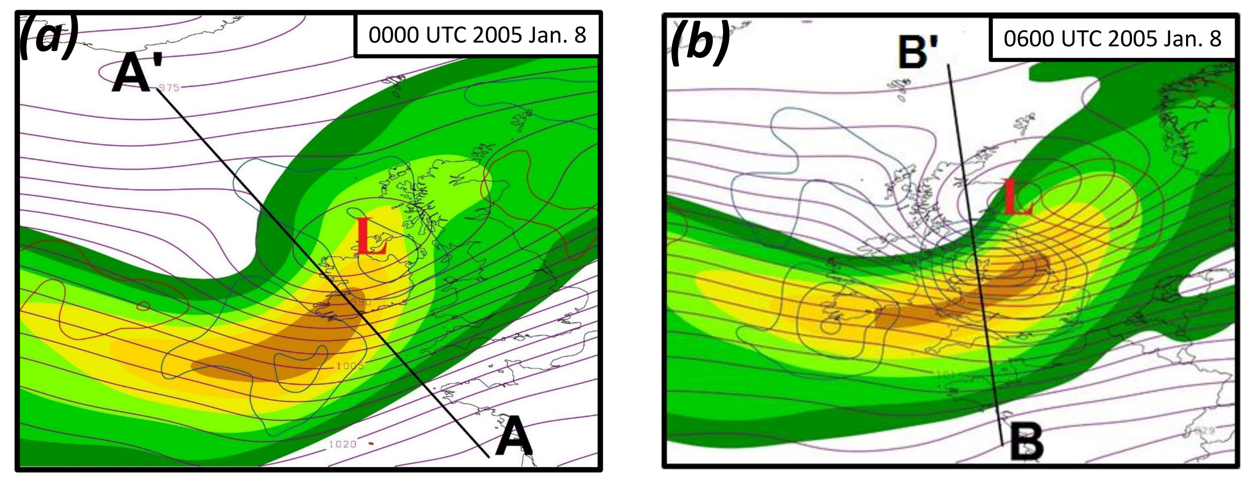

*Fig. 2 **(a)** 300 hPa isotachs (fills), 300 hPa cold-air advection (blue), 300 hPa warm-air advection (red), sea-level isobars (purple)."L" indicates low pressure center. **(b)** As in 2(a).*

Total Sawyer-Eliassen Circulation

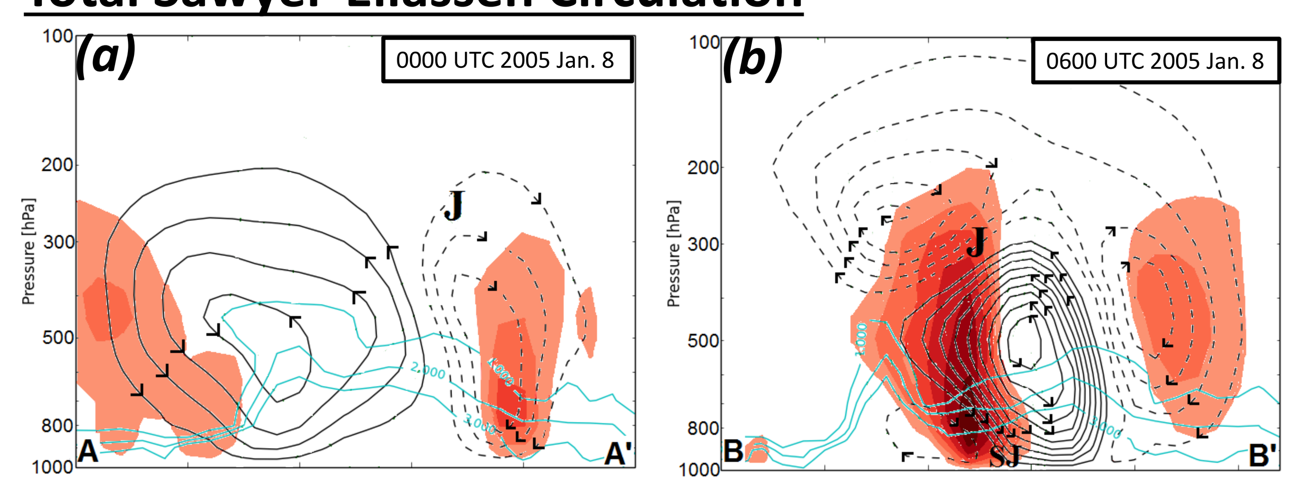

*Fig. 3 **(a)**: Cross-section from A-A' in Fig. 2(a). Black arrows indicate total SE circulation, subsidence (red fill), mixing ratio (blue), "J" indicates jet core. **(b)**: As in 3(a) but along B-B' in Fig. 2 (b). "SJ" indicates sting jet.*

Geostrophic Forcing

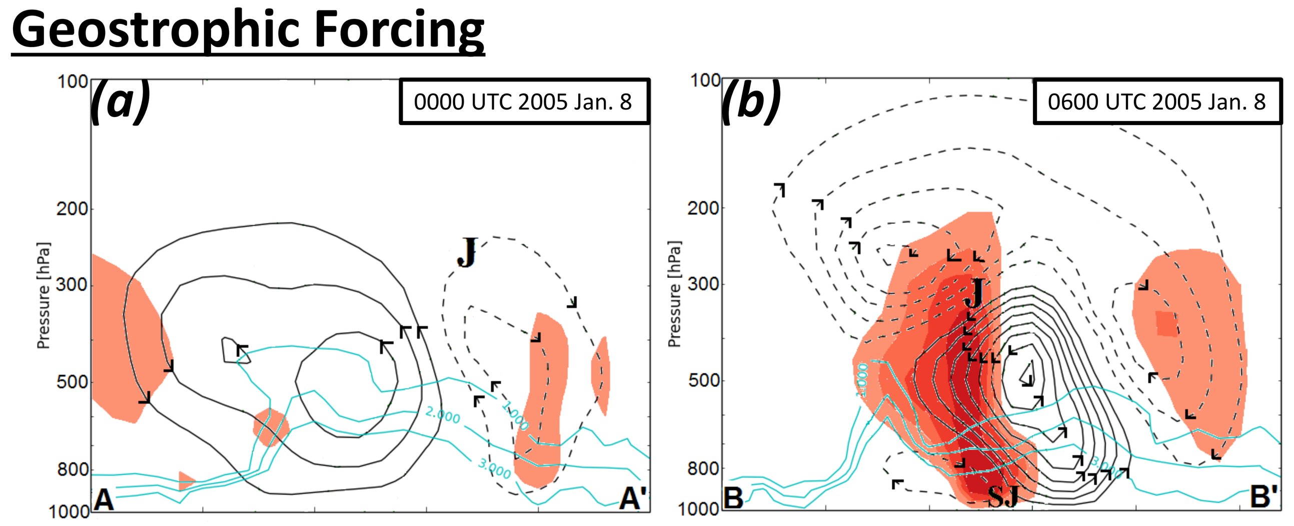

*Fig. 4 **(a)**: Cross-section from A-A' in Fig. 2(a). Black arrows indicate circulation from geostrophic forcing, subsidence (red fill), mixing ratio (blue), "J" indicates jet core. **(b)**: As in 3(a) but along B-B' in Fig. 2 (b). "SJ" indicates sting jet.*

Diabatic Forcing

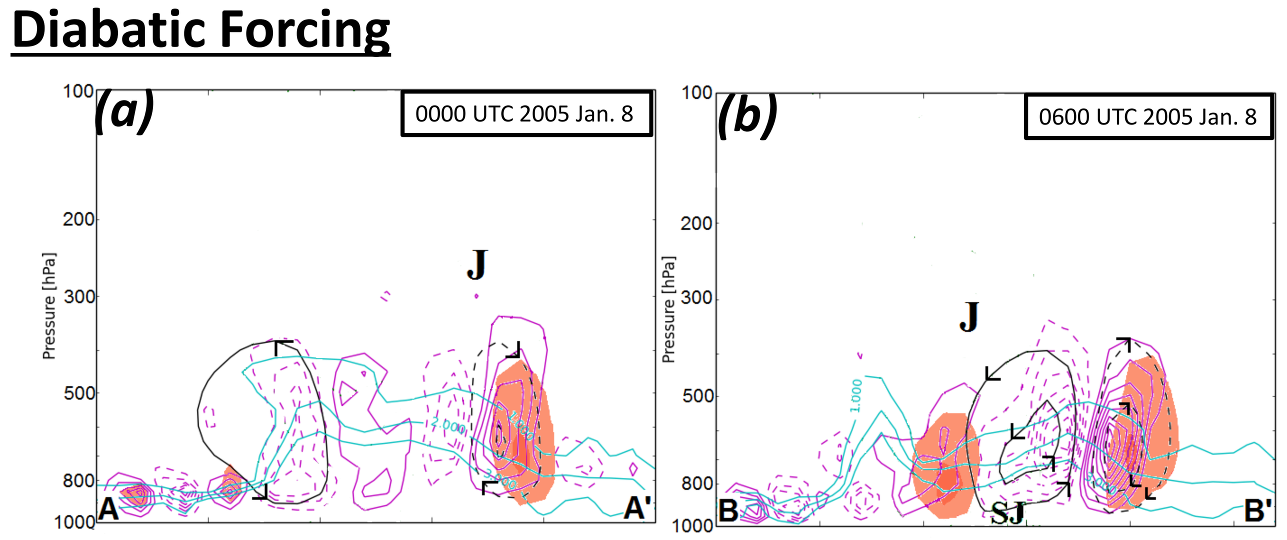

*Fig. 5 **(a)**: Cross-section from A-A' in Fig. 2(a). Black arrows indicate circulation from diabatic forcing, subsidence (red fill), mixing ratio (blue), heating (solid pink), cooling (dashed pink). "J" indicates jet core. **(b)**: As in 5(a) along B-B' in Fig. 2(b). "SJ" indicates sting jet.*

Non-Sting Jet Case: Tilo

Jet Stream Characteristics

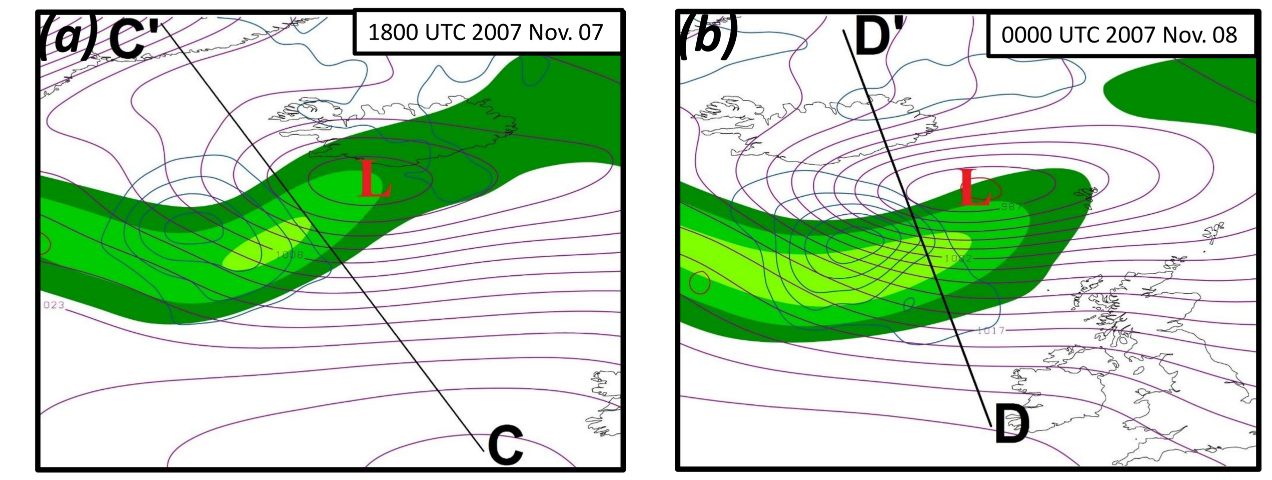

*Fig. 6 **(a)** 300 hPa isotachs (fills) ,300 hPa cold-air advection (blue), 300 hPa warm-air advection (red), sea-level isobars (purple)."L" indicates low pressure center. **(b)** As in 6(a).*

Total Sawyer-Eliassen Circulation

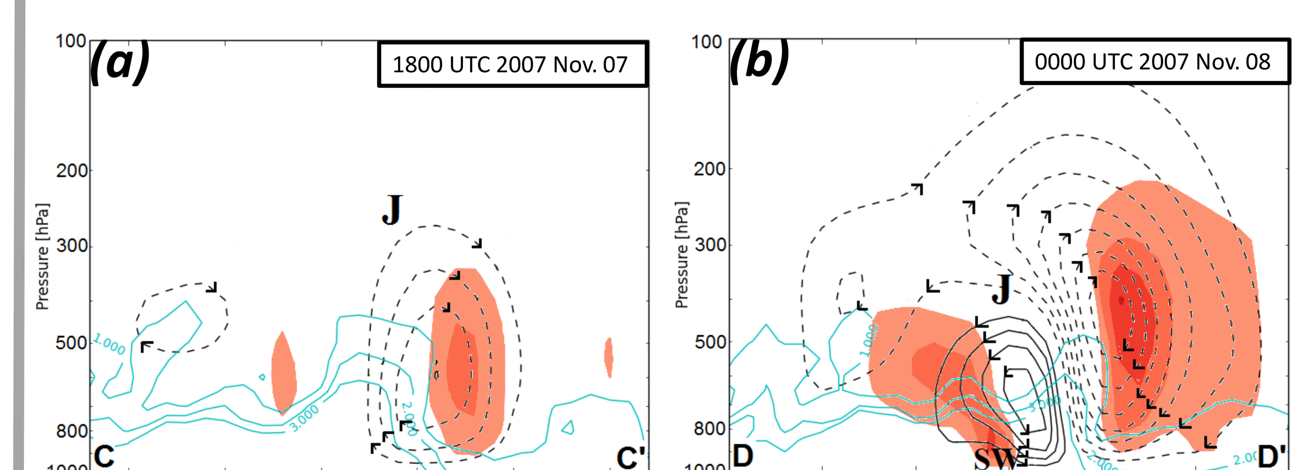

*Fig. 7 **(a)**: Cross-section from C-C' in Fig. 2(a). Black arrows indicate total SE circulation, subsidence (red fill), mixing ratio (blue), "J" indicates jet core. **(b)**: As in 7(a) but along D-D' in Fig. 6 (b). "SW" indicates strong surface winds.*

Geostrophic Forcing

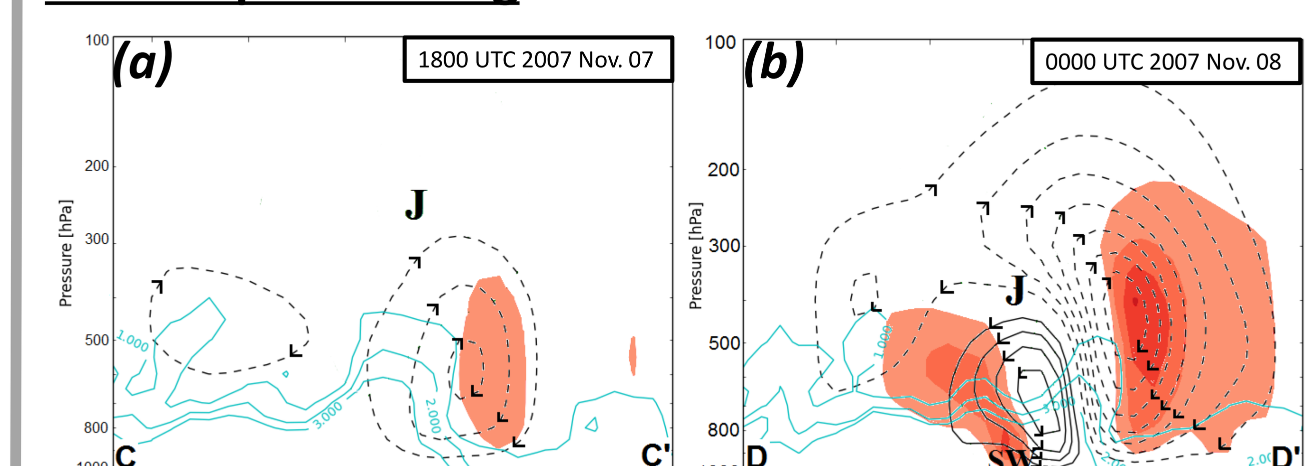

*Fig. 8 **(a)**: Cross-section from C-C' in Fig. 5(a). Black arrows indicate circulation from geostrophic forcing, subsidence (red fill), mixing ratio (blue), "J" indicates jet core, **(b)** As in 8(a) but along D-D' in Fig. 6 (b). "SW" indicates strong surface winds.*

Diabatic Forcing

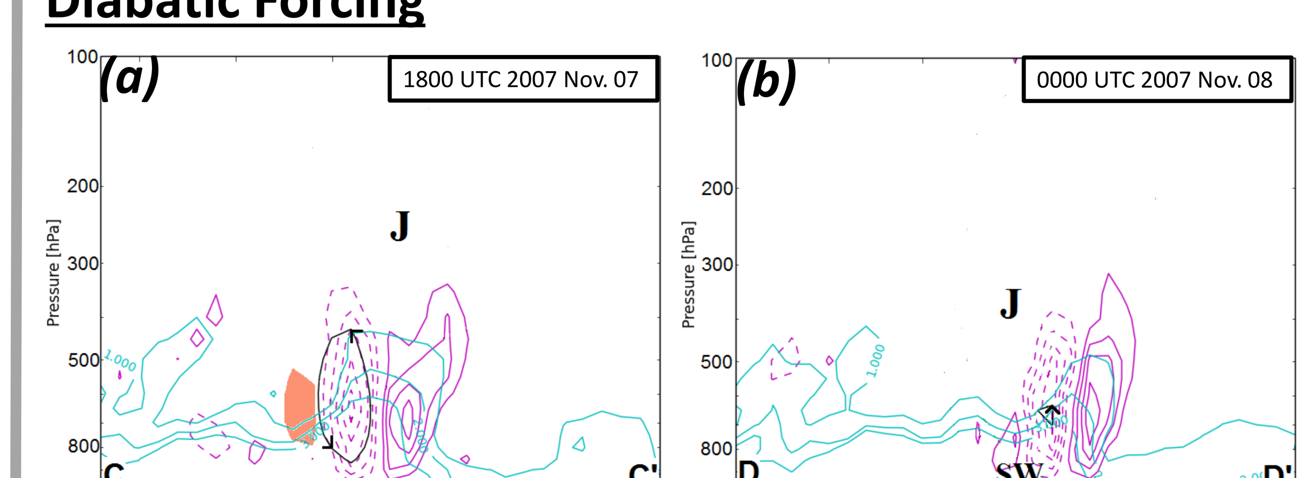

*Fig. 9 **(a)**: Cross-section from C-C' in Fig. 5 (a). Black arrows indicate circulation from diabatic effects, subsidence (red fill), mixing ratio (blue), heating (solid pink), cooling (dashed pink). "J" indicates jet core, **(b)**: As in 9(a) along D-D' in Fig. 6 (b). "SW" indicates strong surface wind.*

Discussion & Conclusions

- The descending branch of the **total circulation** moves close to the jet core by the time of sting jet formation.
- Thus, from a synoptic point of view, **jet-level cold air advection** does appear to play a role in this phenomenon.
- The **geostrophic portion** is dominant in both cases creating subsidence that sends high momentum air downward.
- Though not as strong, the **diabatic forcing** is more noticeable in Erwin than Tilo and is positioned near the surface, with descent occurring in the cool, dry air of the dry slot. It acts to transport this high momentum air to the surface. Thus, the **diabatic forcing in the S-E equation** may be crucial to the sting jet's development and presents an additional perspective of sting jet formation.

Sources of Error

- Data resolution may be too small to accurately capture relatively small sting jets.

Future Work

- Evaluate how the SE circulations act in the presence of conditional symmetric instability (CSI).
- The geostrophic forcing will be partitioned into shearing and stretching pieces.

Acknowledgements

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References

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