CLIM 796

Scale Interactions in Extratropical Cyclones
(2-credit reading course)
Instructor: James Kinter
Fall 2022

Objective:
Review a series of papers on the topic of extratropical cyclones, particularly relating to scale interactions (frontogenesis, extratropical transition of tropical cyclones, atmospheric rivers). The papers listed provide sufficient background to gain a rudimentary understanding of the general properties and behavior of extratropical cyclones and how the large-scale environment interacts with small-scale dynamical features.

Requirements:

1. Read the papers selected from the peer-reviewed literature listed below.
2. Produce a short summary of each paper (~1 page) that describes
    a. The hypothesis or problem addressed
    b. The data and methods
    c. The major results and conclusions
3. Meet periodically with the instructor to review recent readings and discuss implications.
4. Produce a summary review (~5 pages) that describes the main take-away messages of the group of papers and synthesizes the impact of these papers on the thesis research plan.

Classes:
The class will meet twice per week for one hour (2 credits).

Student learning outcomes:

- Gain an understanding of the life cycle of extratropical cyclones and how interactions between the large-scale environment (pole-equator gradients), the cyclone-scale instabilities, and the mesoscale structures affect their initiation, development and demise.
- Gain an understanding of the predictability of, and current state of the art in predicting, extratropical cyclones, especially limits to predictability created by mesoscale processes.
- Develop an appreciation for how to analyze numerical model output to assess the role of scale interactions in extratropical cyclones.

Potential papers for review:

1. Background reading
    a. https://en.wikipedia.org/wiki/Extratropical_cyclone
    b. https://en.wikipedia.org/wiki/Frontogenesis
    c. Dacre, H. (2020), A review of extratropical cyclones: observations and conceptual models over the past 100 years. Weather, 75: 4-7. https://doi.org/10.1002/wea.3653
    d. Schultz, D. M., Bosart, L. F., Colle, B. A., Davies, H. C., Dearden, C., Keyser, D., Martius, O., Roebber, P. J., Steenburgh, W. J., Volkert, H., & Winters, A. C. (2019). Extratropical Cyclones: A Century of Research on Meteorology's Centerpiece, *Meteorological Monographs*, *59*, 16.1-16.56.

https://journals.ametsoc.org/view/journals/amsm/59/1/amsmonographs-d-18-0015.1.xml

2. Theory
    a. Held, I.M. and Hoskins, B.J., 1985. Large-scale eddies and the general circulation of the troposphere. In *Advances in geophysics* (Vol. 28, pp. 3-31). Elsevier.
3. ETC – Atmospheric Rivers
    a. Gimeno, L., Nieto, R., Vázquez, M. and Lavers, D.A., 2014. Atmospheric rivers: A mini-review. *Frontiers in Earth Science*, *2*, p.2. https://www.frontiersin.org/articles/10.3389/feart.2014.00002/full
    b. Guo, Y., Shinoda, T., Guan, B., Waliser, D. E., & Chang, E. K. M. (2020). Statistical Relationship between Atmospheric Rivers and Extratropical Cyclones and Anticyclones, *Journal of Climate*, *33*(18), 7817-7834. Retrieved Jul 20, 2022, from https://journals.ametsoc.org/view/journals/clim/33/18/jcliD190126.xml
    c. Zhang, Z., & Ralph, F. M. (2021). The Influence of Antecedent Atmospheric River Conditions on Extratropical Cyclogenesis, *Monthly Weather Review*, *149*(5), 1337-1357 https://journals.ametsoc.org/view/journals/mwre/149/5/MWR-D-20-0212.1.xml
4. Frontogenesis
    a. Hoskins, B.J., 1982. The mathematical theory of frontogenesis. *Annual review of fluid mechanics*, *14*(1), pp.131-151.
5. Extratropical Transition of Tropical Cyclones
    a. Evans, C., Wood, K. M., Aberson, S. D., Archambault, H. M., Milrad, S. M., Bosart, L. F., Corbosiero, K. L., Davis, C. A., Dias Pinto, J. R., Doyle, J., Fogarty, C., Galarneau, T. J., Jr., Grams, C. M., Griffin, K. S., Gyakum, J., Hart, R. E., Kitabatake, N., Lentink, H. S., McTaggart-Cowan, R., Perrie, W., Quinting, J. F. D., Reynolds, C. A., Riemer, M., Ritchie, E. A., Sun, Y., & Zhang, F. (2017). The Extratropical Transition of Tropical Cyclones. Part I: Cyclone Evolution and Direct Impacts, *Monthly Weather Review*, *145*(11), 4317-4344. https://journals.ametsoc.org/view/journals/mwre/145/11/mwr-d-17-0027.1.xml
    b. Jones, S. C., Harr, P. A., Abraham, J., Bosart, L. F., Bowyer, P. J., Evans, J. L., Hanley, D. E., Hanstrum, B. N., Hart, R. E., Lalaurette, F., Sinclair, M. R., Smith, R. K., & Thorncroft, C. (2003). The Extratropical Transition of Tropical Cyclones: Forecast Challenges, Current Understanding, and Future Directions, *Weather and Forecasting*, *18*(6), 1052-1092. https://journals.ametsoc.org/view/journals/wefo/18/6/1520-0434_2003_018_1052_tetotc_2_0_co_2.xml
    c. Keller, J. H., Grams, C. M., Riemer, M., Archambault, H. M., Bosart, L., Doyle, J. D., Evans, J. L., Galarneau, T. J., Jr., Griffin, K., Harr, P. A., Kitabatake, N., McTaggart-Cowan, R., Pantillon, F., Quinting, J. F., Reynolds, C. A., Ritchie, E. A., Torn, R. D., & Zhang, F. (2019). The Extratropical Transition of Tropical Cyclones. Part II: Interaction with the Midlatitude Flow, Downstream Impacts, and Implications for Predictability, *Monthly Weather Review*, *147*(4), 1077-1106. https://journals.ametsoc.org/view/journals/mwre/147/4/mwr-d-17-0329.1.xml
    d. Abraham, J., Strapp, J. W., Fogarty, C., & Wolde, M. (2004). Extratropical Transition of Hurricane Michael: An Aircraft Investigation, Bulletin of the

American Meteorological Society, 85(9), 1323-1340. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/bams/85/9/bams-85-9-1323.xml

e. Archambault, H. M., Bosart, L. F., Keyser, D., & Cordeira, J. M. (2013). A Climatological Analysis of the Extratropical Flow Response to Recurving Western North Pacific Tropical Cyclones, Monthly Weather Review, 141(7), 2325-2346. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/mwre/141/7/mwr-d-12-00257.1.xml
f. Arnott, J. M., Evans, J. L., & Chiaromonte, F. (2004). Characterization of Extratropical Transition Using Cluster Analysis, Monthly Weather Review, 132(12), 2916-2937. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/mwre/132/12/mwr2836.1.xml
g. Barnes, Elizabeth A, Polvani, Lorenzo M., Sobel, Adam H. "Model projections of atmospheric steering of Sandy-like superstorm" https://www.pnas.org/doi/epdf/10.1073/pnas.1308732110
h. Bruneau, N., Grieser, J., Loridan, T. et al. The impact of extra-tropical transitioning on storm surge and waves in catastrophe risk modelling: application to the Japanese coastline. Nat Hazards 85, 649–667 (2017). https://doi.org/10.1007/s11069-016-2596-2
i. Davis, C. A., Jones, S. C., & Riemer, M. (2008). Hurricane Vortex Dynamics during Atlantic Extratropical Transition, Journal of the Atmospheric Sciences, 65(3), 714-736. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/atsc/65/3/2007jas2488.1.xml
j. Galarneau, T. J., Jr., Bosart, L. F., & Schumacher, R. S. (2010). Predecessor Rain Events ahead of Tropical Cyclones, Monthly Weather Review, 138(8), 3272-3297. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/mwre/138/8/2010mwr3243.1.xml
k. Galarneau, T. J., Jr., Davis, C. A., & Shapiro, M. A. (2013). Intensification of Hurricane Sandy (2012) through Extratropical Warm Core Seclusion, Monthly Weather Review, 141(12), 4296-4321. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/mwre/141/12/mwr-d-13-00181.1.xml
l. Hart, R. E., & Evans, J. L. (2001). A Climatology of the Extratropical Transition of Atlantic Tropical Cyclones, Journal of Climate, 14(4), 546-564. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/clim/14/4/1520-0442_2001_014_0546_acotet_2.0.co_2.xml
m. Hart, R. E., Evans, J. L., & Evans, C. (2006). Synoptic Composites of the Extratropical Transition Life Cycle of North Atlantic Tropical Cyclones: Factors Determining Posttransition Evolution, Monthly Weather Review, 134(2), 553-578. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/mwre/134/2/mwr3082.1.xml
n. Liu, M., Vecchi, G. A., Smith, J. A., & Murakami, H. (2017). The Present-Day Simulation and Twenty-First-Century Projection of the Climatology of Extratropical Transition in the North Atlantic, Journal of Climate, 30(8), 2739-2756. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/clim/30/8/jcli-d-16-0352.1.xml
o. Ritchie, E. A., & Elsberry, R. L. (2001). Simulations of the Transformation Stage of the Extratropical Transition of Tropical Cyclones, Monthly Weather Review,

129(6), 1462-1480. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/mwre/129/6/1520-0493_2001_129_1462_sottso_2.0.co_2.xml

p. Scheck, L., Jones, S. C., & Juckes, M. (2011). The Resonant Interaction of a Tropical Cyclone and a Tropopause Front in a Barotropic Model. Part I: Zonally Oriented Front, Journal of the Atmospheric Sciences, 68(3), 405-419. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/atsc/68/3/2010jas3482.1.xml

q. Shin, J. H., & Zhang, D. (2017). The Impact of Moist Frontogenesis and Tropopause Undulation on the Intensity, Size, and Structural Changes of Hurricane Sandy (2012), Journal of the Atmospheric Sciences, 74(3), 893-913. Retrieved Jul 22, 2022, from https://journals.ametsoc.org/view/journals/atsc/74/3/jas-d-15-0362.1.xml

r. Song, J., Wu, R., Quan, W. et al. Impact of the subtropical high on the extratropical transition of tropical cyclones over the western North Pacific. Acta Meteorol Sin 27, 476–485 (2013). https://doi.org/10.1007/s13351-013-0410-6

6. Tracking
   a. Hodges, K. I. (1995). Feature Tracking on the Unit Sphere, *Mon. Wea. Rev.*, 123, 3458-3465. https://journals.ametsoc.org/view/journals/mwre/123/12/1520-0493_1995_123_3458_ftotus_2_0_co_2.xml
7. Scale Interactions – Predictability
   a. Tribbia, J. J., & Baumhefner, D. P. (2004). Scale Interactions and Atmospheric Predictability: An Updated Perspective, *Monthly Weather Review*, *132*(3), 703-713. https://journals.ametsoc.org/view/journals/mwre/132/3/1520-0493_2004_132_0703_siaapa_2.0.co_2.xml