MPEX data analysis plans: Purdue

MPEX Workshop

11/19/2013

NCAR, Boulder, CO

Purdue plans

- Our plans with the MPEX data
  - calculation of thermodynamic and kinematic parameters (e.g., CAPE, SRH, PV) to assess upscale feedbacks (Woznicki, Trapp)
  - assimilation of all available data to produce a high-resolution analysis at convection-allowing resolutions (Fehnel, Baldwin); and
  - predictability of high-impact events during multi-day periods of activity (Dawson, Trapp, Baldwin)

On the significance of multiple consecutive days of tornado activity

Trapp, MWR, in review

Motivation

- Observations during MPEX
  - 5/20 Moore tornado
  - 5/31 El Reno tornado
  - common thread: occurrence during a multi-day period of tornado activity
    - the period containing the 20 May event consisted of six consecutive days of reported tornadoes within the U.S.
    - the period containing the 31 May event consisted of seven consecutive days
  - 5/22/11 Joplin tornado, and 4/27/11 Tuscaloosa tornadoes and outbreak, also occurred during multi-day periods of tornado activity

Goals

- Examine climatological distribution of tornado-activity periods, and explore a possible relationship between tornado significance and period length.
- Attempt to posit a relationship between period length and frequency characteristics of the atmospheric forcing.

Data and methods

- U.S. historical tornado database maintained by the NOAA Storm Prediction Center
  - The specific data used are the commencement time and date of each (human-) reported tornado, and the damage-based tornado rating (F or EF scale)
  - Time and date are used to determine *tornado days*, which literally are days when at least one (but possibly many more) tornado(es) is reported somewhere in the country.

Data and methods

- Tornado days – which will are referred to here as "days" – are examined over 1983-2012.
  - This coincides with North American Regional Reanalysis (NARR) data availability, and also represents a relatively stable interval of the record
  - The set of all tornado days during 1983-2012 is parsed to identify consecutive tornado days. The unique, *non-overlapping*, *consecutive-day* groupings are referred to as periods, which have length ρ

Data and methods

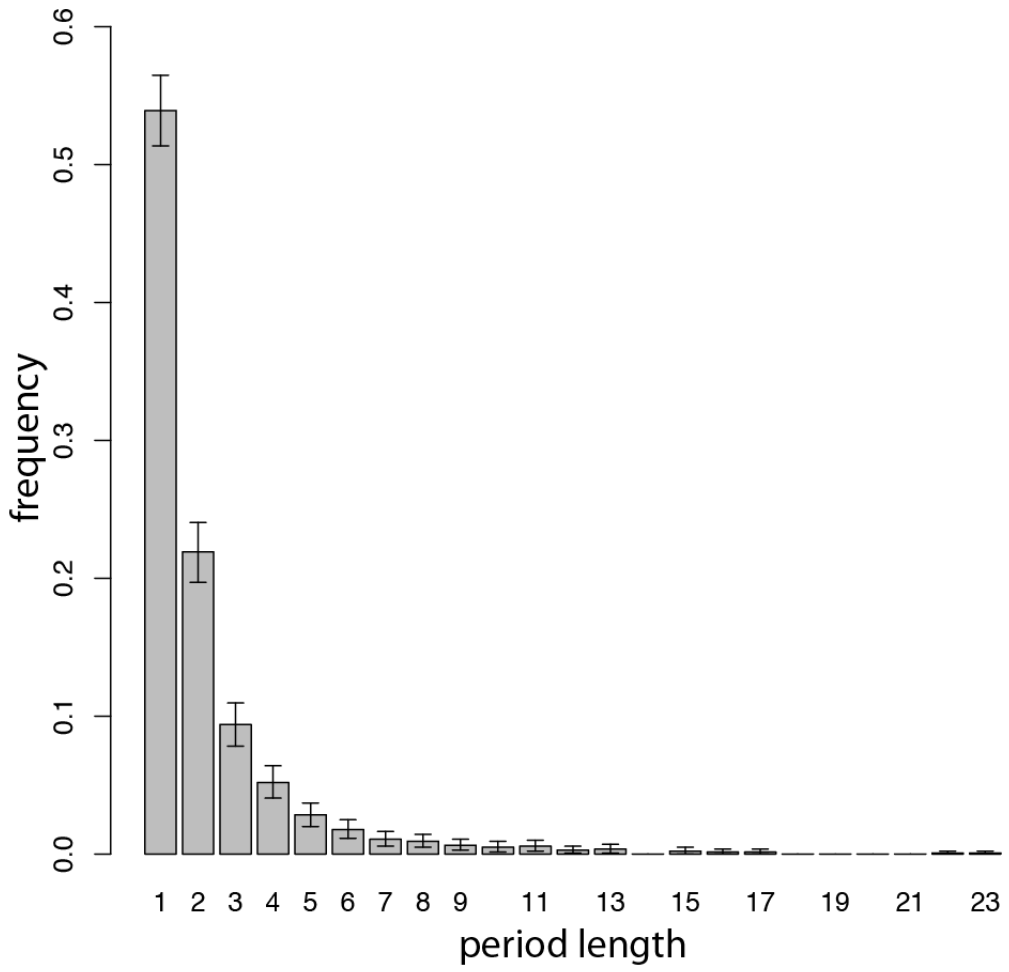
- Tornado days – which will are referred to here as “days” – are examined over 1983-2012.
  - To prevent the influence of possible spurious reports in the tornado day and thence period identifications, a minimum of **three** reports on a given day is required for that day to be considered a tornado day.
  - This is a somewhat arbitrary threshold, and tests of result sensitivity are presented later.

Data and methods

- With all caveats of the tornado data in mind:
  - we classify an individual day with more than 20 tornado reports as an outbreak day (OB)
  - we classify a tornado day as significant (SIGTOR) given at least one tornado with a rating of F/EF ≥ 3.

Results

- Comprising the 3130 tornado days (=N) during 1983-2012 are 1406 unique, non-overlapping periods (=R)
  - The period lengths ρ vary from 1-day to **23**-days!
- 0.54 (=M_1/R) of these periods have a single-day length (ρ=1), and an additional 0.22 (=M_2/R) have a length of two days (ρ=2). We are particularly interested in the remaining 0.24, and accordingly claim these for our category of multi-day periods (ρ≥3).

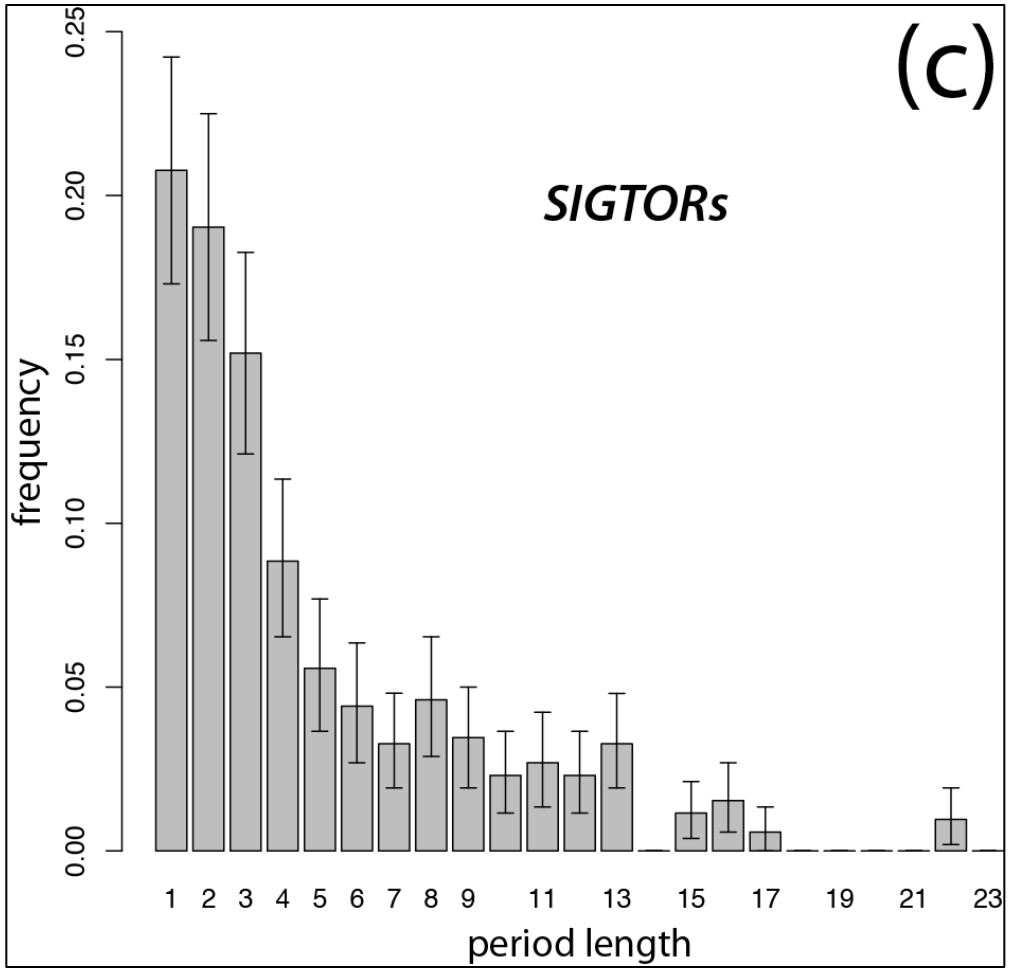


95% Confidence intervals on the frequency of period lengths are determined from 10,000 bootstrap estimates of the frequency of each period, and estimated using the percentile method

Results

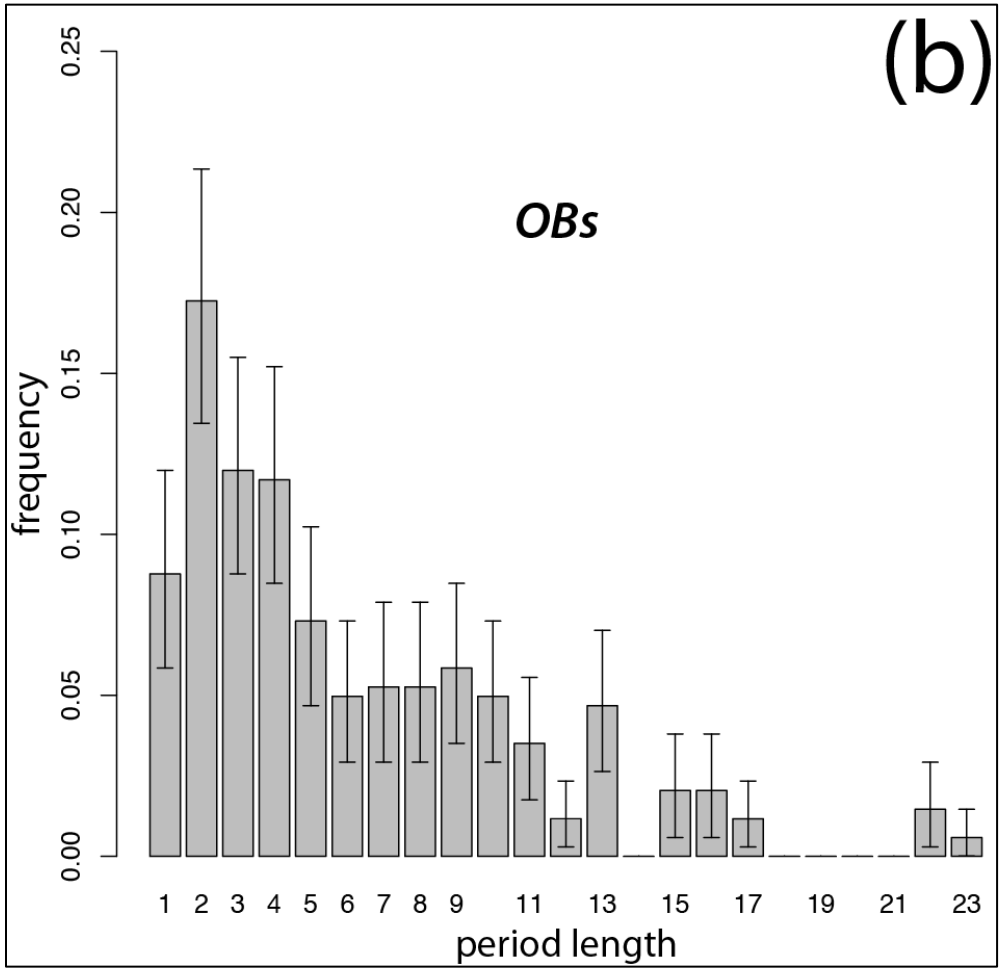
- The significance of the periods can be examined by noting first that during 1983-2012, there were 520 days with SIGTORs (= N_{ST}), and 342 days with OBs (=N_{OB}).
- The working hypothesis is that days with SIGTORs and/or with OBs are more likely to be contained within multi-day periods than within 1-2 day periods.

- The conditional probability of a period of length $\rho \geq 3$ given a SIGTOR is 0.60.



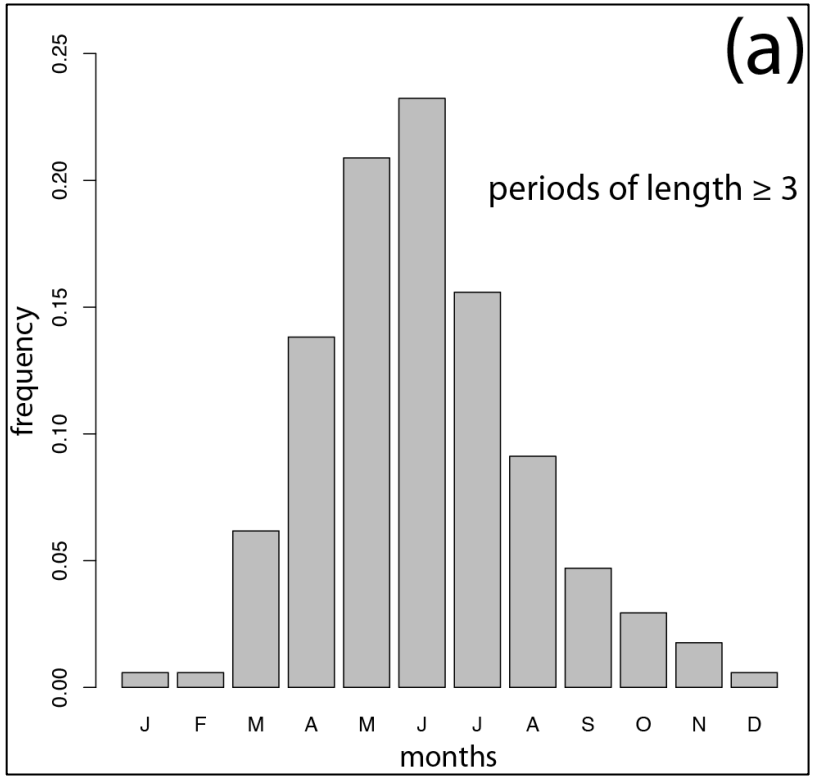
Note that confidence intervals at the 95% level support a distinction between periods $\rho < 3$ and periods $\rho \geq 3$

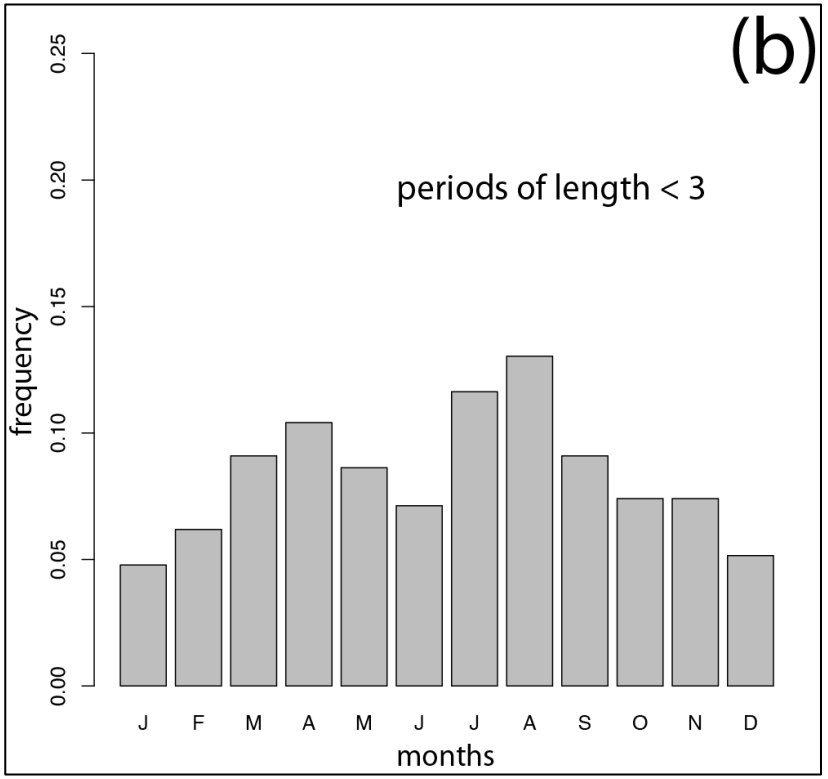
- Similarly, the conditional probability of period length $\rho \geq 3$ given an OB is 0.74.



Seasonal cycle

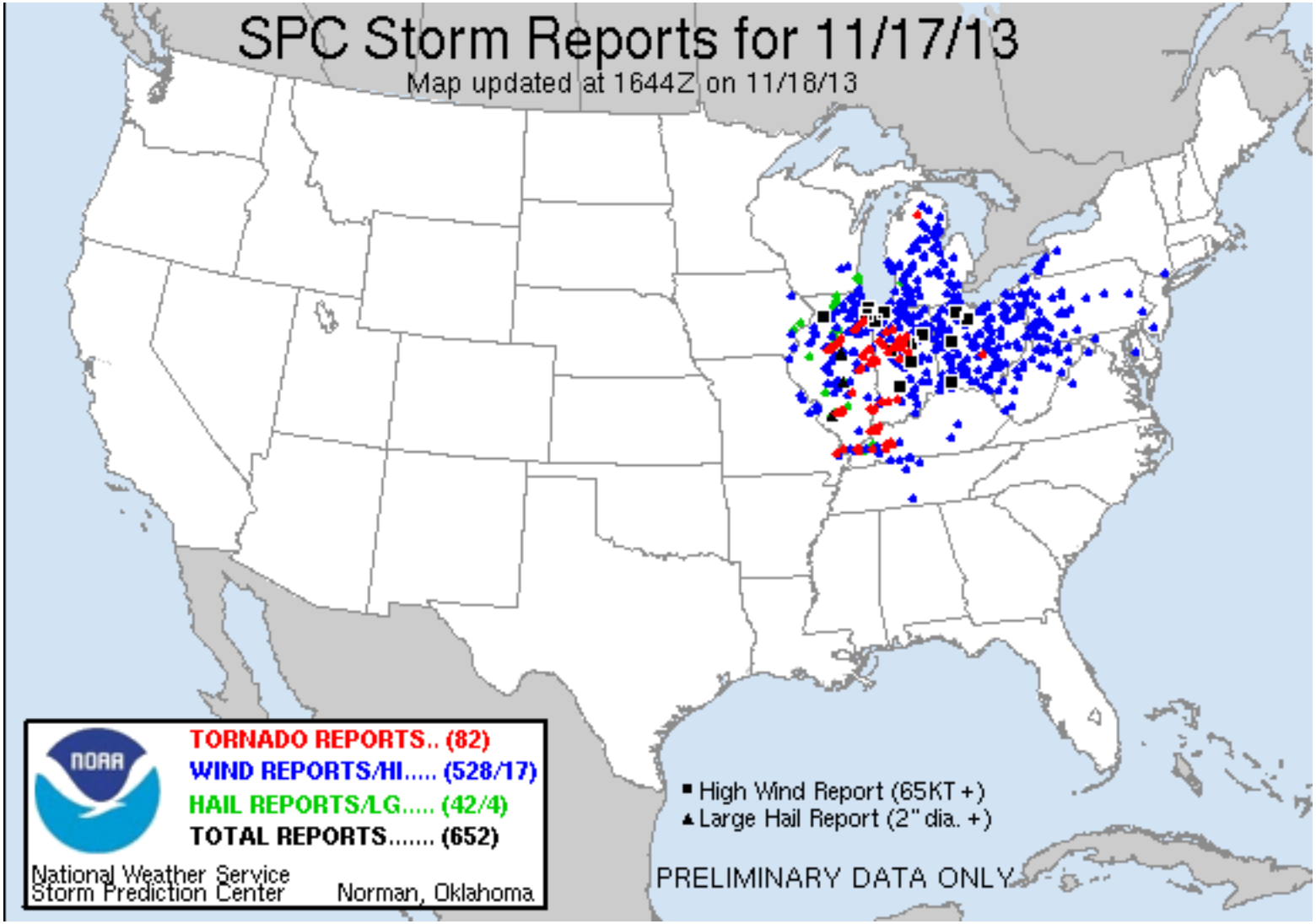
- In the context of a seasonal cycle, these multi-day periods have a heavy bias toward the warm-months of April-July, reflecting well the seasonal cycle of all tornado days.
- The 1-2 day periods, in contrast, are distributed more uniformly over the year, albeit with a noticeable local minima in May-June.





There is some suggestion that periods lengths ρ =1 to 2 are favored during transition seasons, when baroclinic eddies are relatively more progressive…

example of a single-day (ρ = 1) case!



Relative position of OB/SIGTOR within period

- Another common thread with the tornado events of May 2013 and indeed with other high-impact tornado events is that of their occurrence during the latter part, if not the end, of the multi-day periods.
- The conclusion is that SIGTORs and OBs have a slightly, yet statistically significant higher likelihood of occurrence during the latter half of the multi-day periods
  - supported by 95% confidence intervals on the binomial proportions

MPEX-relevant discussion:

Do convective feedbacks help promote multi-day periods of tornado activity?

- Consider the feedback loop described by Stensrud (1996):
  - The diabatic heating of ongoing deep convection acts to deepen an associated surface cyclone and increase its wind field. Horizontal advection of water vapor and temperature by the enhanced winds help replenish the moisture processed by the convection and otherwise destabilize the proximal environment. The environment is thereafter supportive of subsequent deep convection and diabatic heating, affording another cycle of this feedback loop.

MPEX-relevant discussion:

Do convective feedbacks help promote multi-day periods of tornado activity?

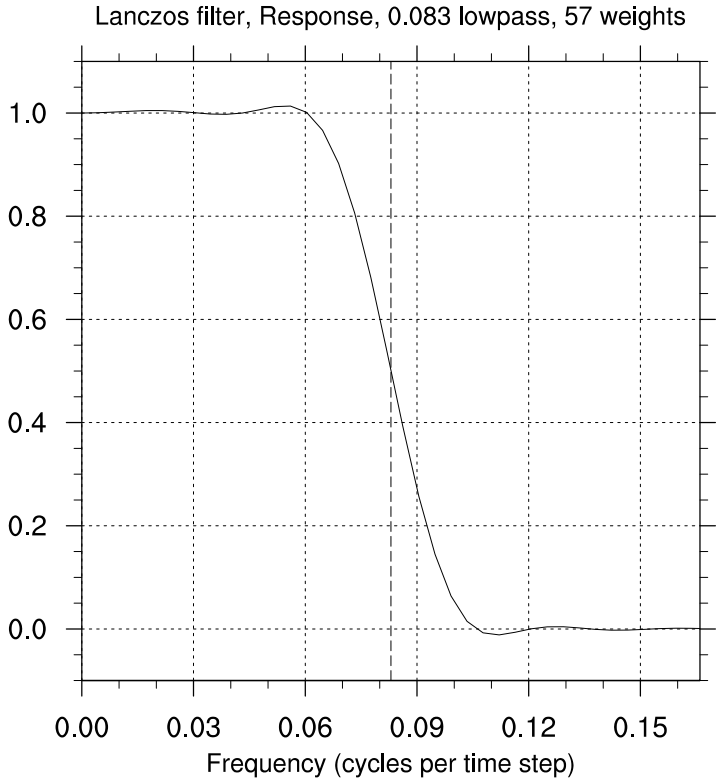
- We speculate that such a feedback helps anchor the synoptic-scale forcing so that CAPE is accumulated over a multi-day period despite a daily convective cloud evolution.
  - The CAPE release near the end of the period then has the potential to result in significantly severe convective storms.

Connection to the meteorological forcing

- We envision that a multi-day period of tornado activity is connected to a relatively slow-moving or even stationary synoptic-scale eddy, with a persistent surface cyclone and persistently strong flow in the lower and middle troposphere.
  - The two May events fit this description
  - But, not all multi-day periods of tornado activity evolve in this way

Analysis of NARR data

- A low-pass *Lanczos filter* is applied to six-hourly NARR data over April-May-June (AMJ) during 2013 as well as for each year during 1983-2012.
  - The spectral response of the 57-weight filter employed is such that 50% of the amplitude of frequencies corresponding to three days is retained, and nearly 100% (0%) of the amplitude of lower (higher) frequencies is retained.

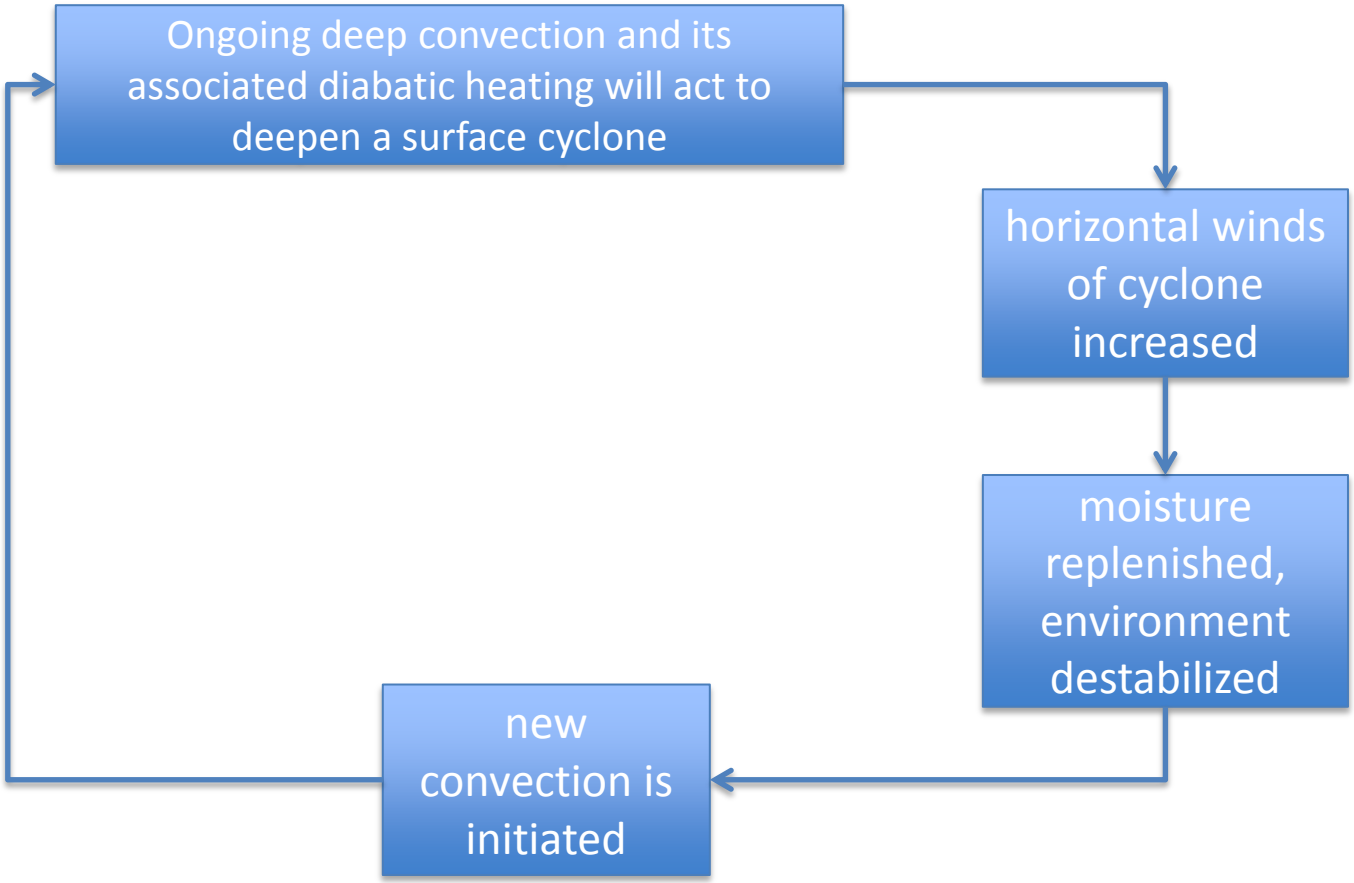


Analysis of NARR data

- The filtered data were then averaged over a 30°-40° latitudinal domain, and then used to construct Hovmöller diagrams over AMJ and a longitudinal domain of 105°- 80° W.
  - For ease of comparison, the unfiltered and unsmoothed AMJ 2013 tornado reports are presented in the same Hovmöller diagram.

Discussion

- *Are they promoted by convective feedbacks?*



The speculation here is that such a feedback helps anchor the synoptic-scale forcing so that CAPE is accumulated over a multi-day period despite daily convective cloud growth.

Discussion

- *Are they predictable?*
- The theoretical limit of deterministic predictability increases with the length scale of the phenomenon (Lorenz 1969), and implicitly with its time scale.
- One implication is that the larger, more slowly evolving/moving synoptic scale systems that often contribute to multi-day tornado periods and hence often to SIGTORs and/or OBs may be relatively more predictable (e.g., Dalcher and Kalnay 1987).