Diagnosing an artificial trend in NLDAS-2 afternoon precipitation

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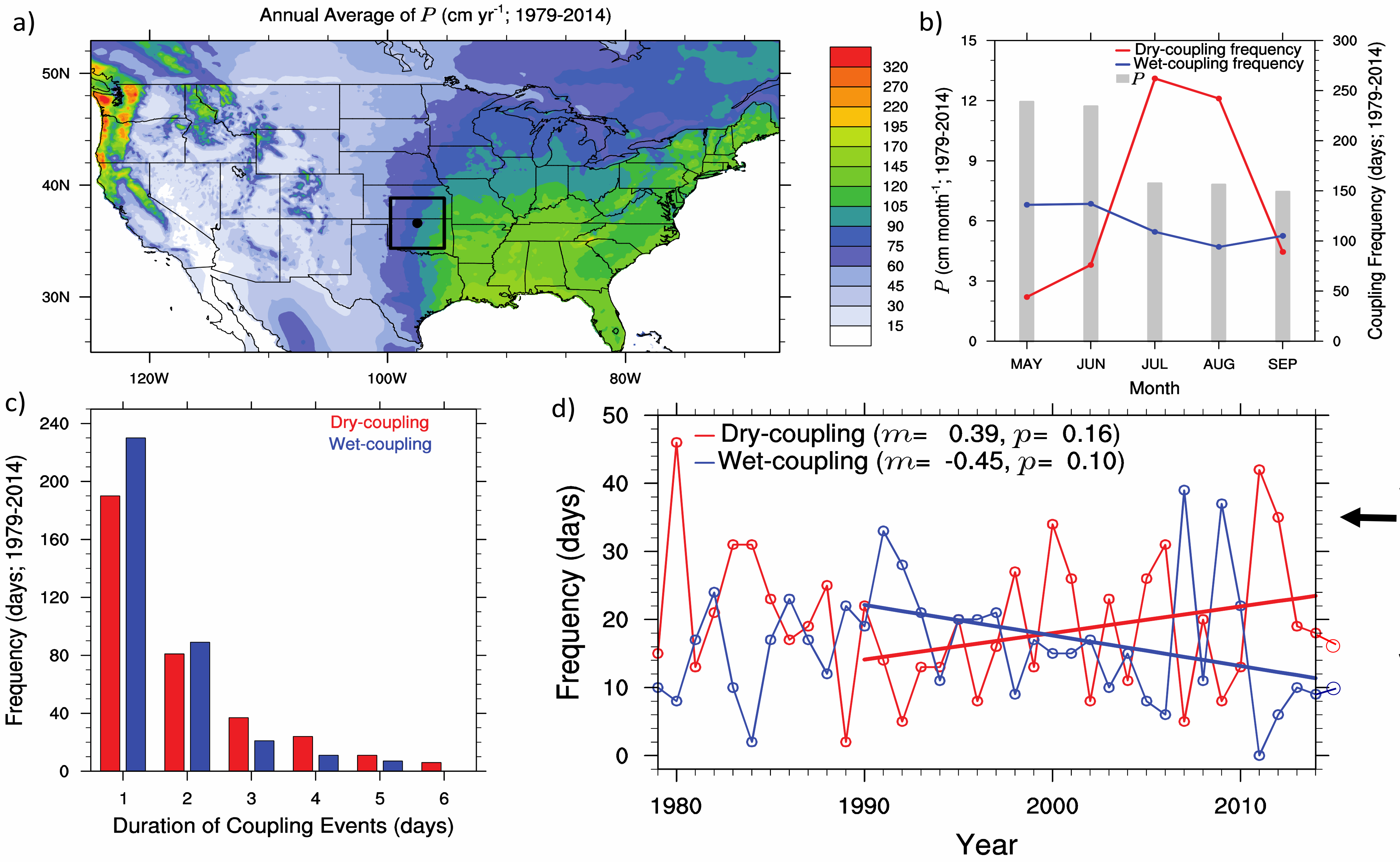
Ferguson, C.R. and D. M. Mocko (2017), Diagnosing an artificial trend in NLDAS-2 afternoon precipitation, *J. Hydrometeor.*, doi:10.1175/JHM-D-16-0251.1, early-online.

Motivation (1/2): Song et al. (2016); Land-atmosphere coupling



Song, H.-J., C.R. Ferguson, and J.K. Roundy (2016), Land-atmosphere coupling at the Southern Great Plains Atmospheric Radiation Measurement (ARM) field site and its role in anomalous afternoon peak precipitation, *J. Hydrometeor.*, doi:10.1175/JHM-D-15-0045.1.

What is the role of precipitation variability?

Motivation (2/2): Research gap

The inter-annual variability of diurnal precipitation cycle over CONUS has only previously been conducted at relatively coarse (i.e., 2.5° x 2.0°) horizontal resolution and for an earlier period from 1963-1993 (Dai 1999; Dai et al. 1999)

Science Question:

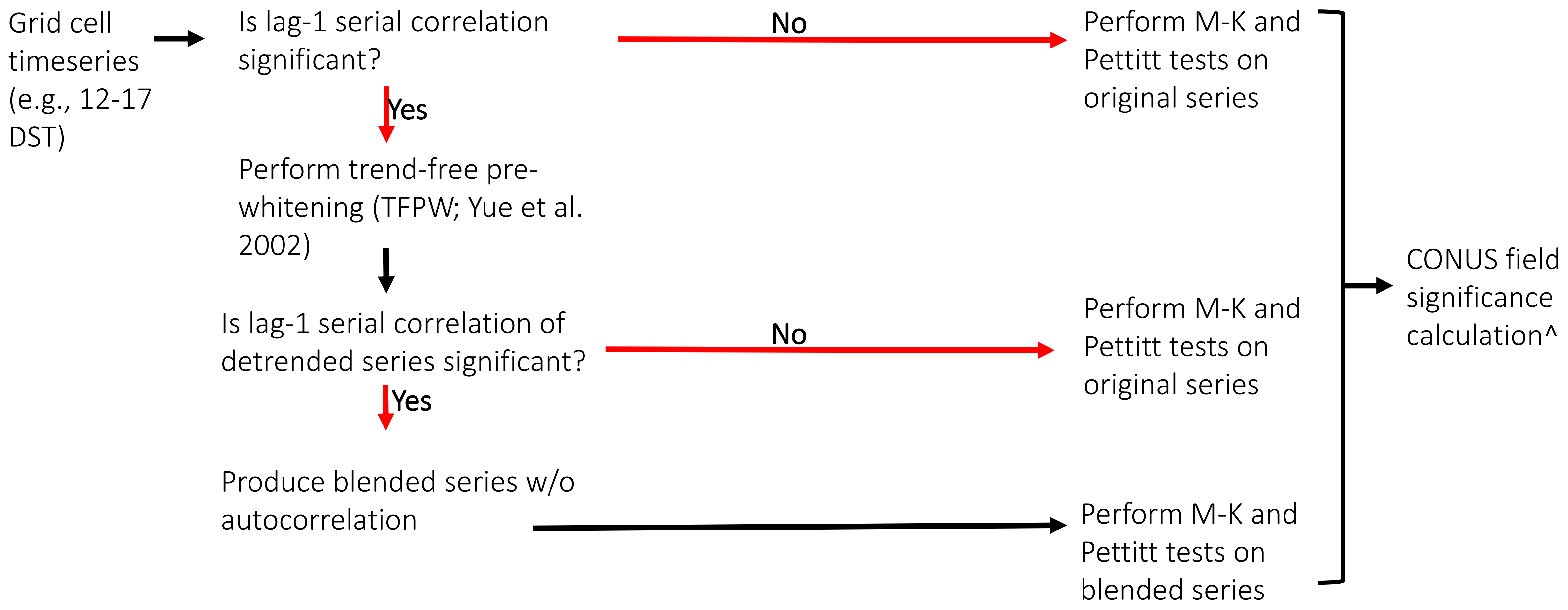
Are there detectable trends in NLDAS-2 sub-daily precipitation characteristics (amount, frequency, and intensity) over the period of record (1979-2015)?

Methods (1/3)

For each 6-hourly monthly mean time series, Kendall’s tau and Sen’s slope estimators are used to detect and estimate trends, respectively, and the Pettitt test is used to detect breakpoints (BPs). Then, CONUS field significance is computed.

Methods (2/3)

Processing flowchart



Methods (3/3)

^What happens when both a trend and BP are detected?

M-K test applied to each homogenous series segment (i.e., before and after the BP)

If significant trends of same sign are detected for each segment, then BP is dismissed as an artifact of the trend. Otherwise, BP is accepted and the trend is dismissed.

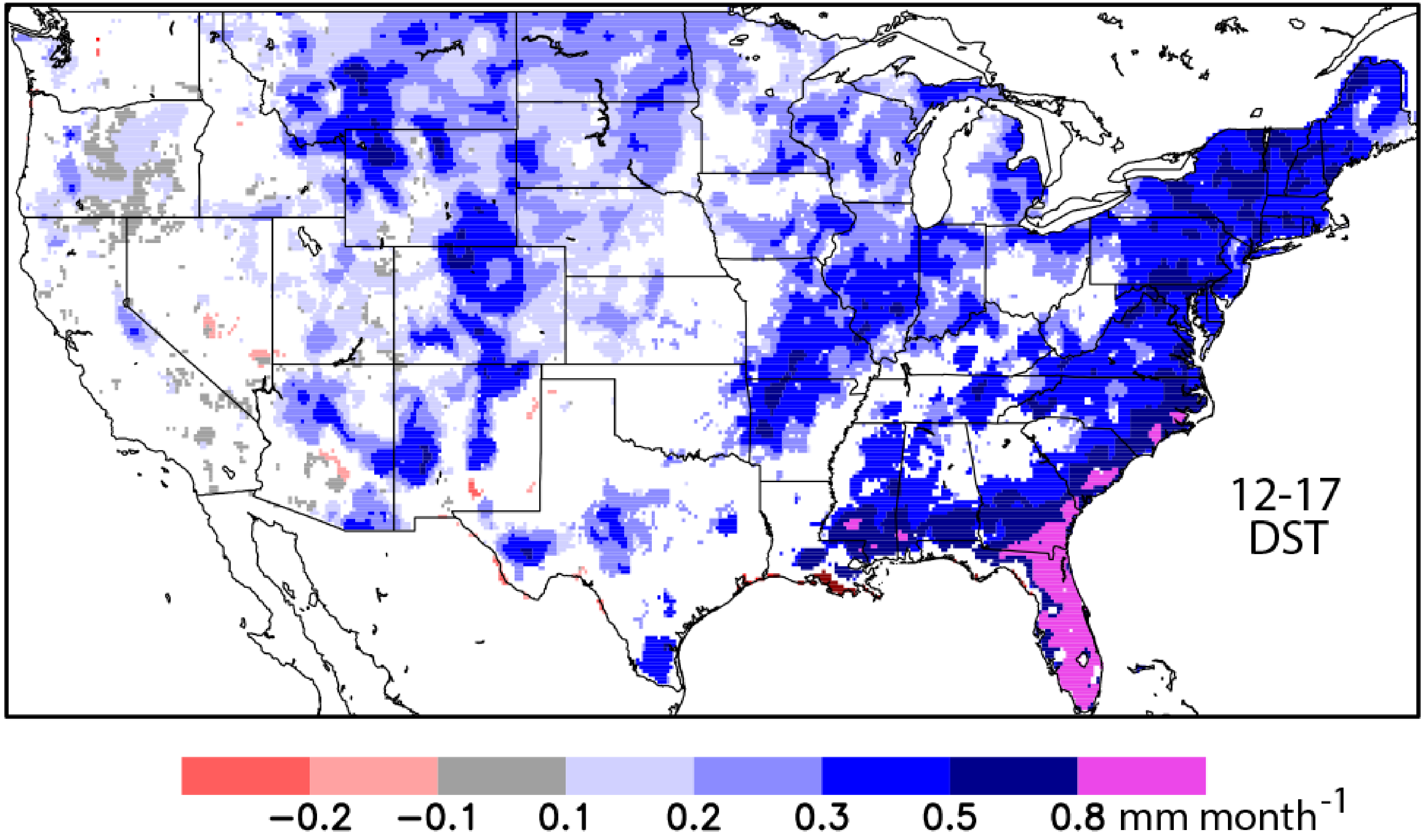
*Simultaneous treatment of trends and breaks, as well as the calculation of field- rather than local-significance advances prior efforts. Such treatment is easier to implement in this NLDAS study because we suspect only 1 BP, whereas we expect several BPs in the 20CR.

Ferguson, C.R. and G. Villarini (2014), An evaluation of the statistical homogeneity of the Twentieth Century Reanalysis, Clim Dyn, 42, 2841-2866, doi: 10.1007/s00382-013-1996-1.

Ferguson, C.R. and G. Villarini (2012), Detecting inhomogeneities in the Twentieth Century Reanalysis over the central United States, J. Geophys. Res. Atmos., 117, D05123, doi:10.1029/2011JD016988.

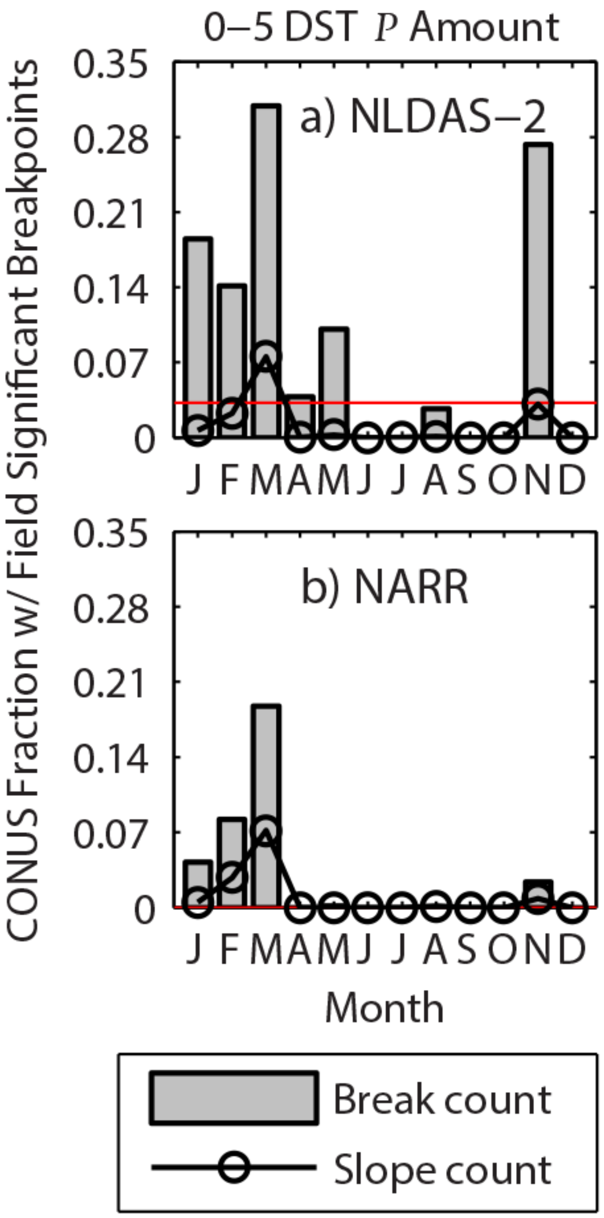
Preliminary Results: Afternoon wetting trends (1979-2015)

*BPs not accounted for, and local-, not field significance

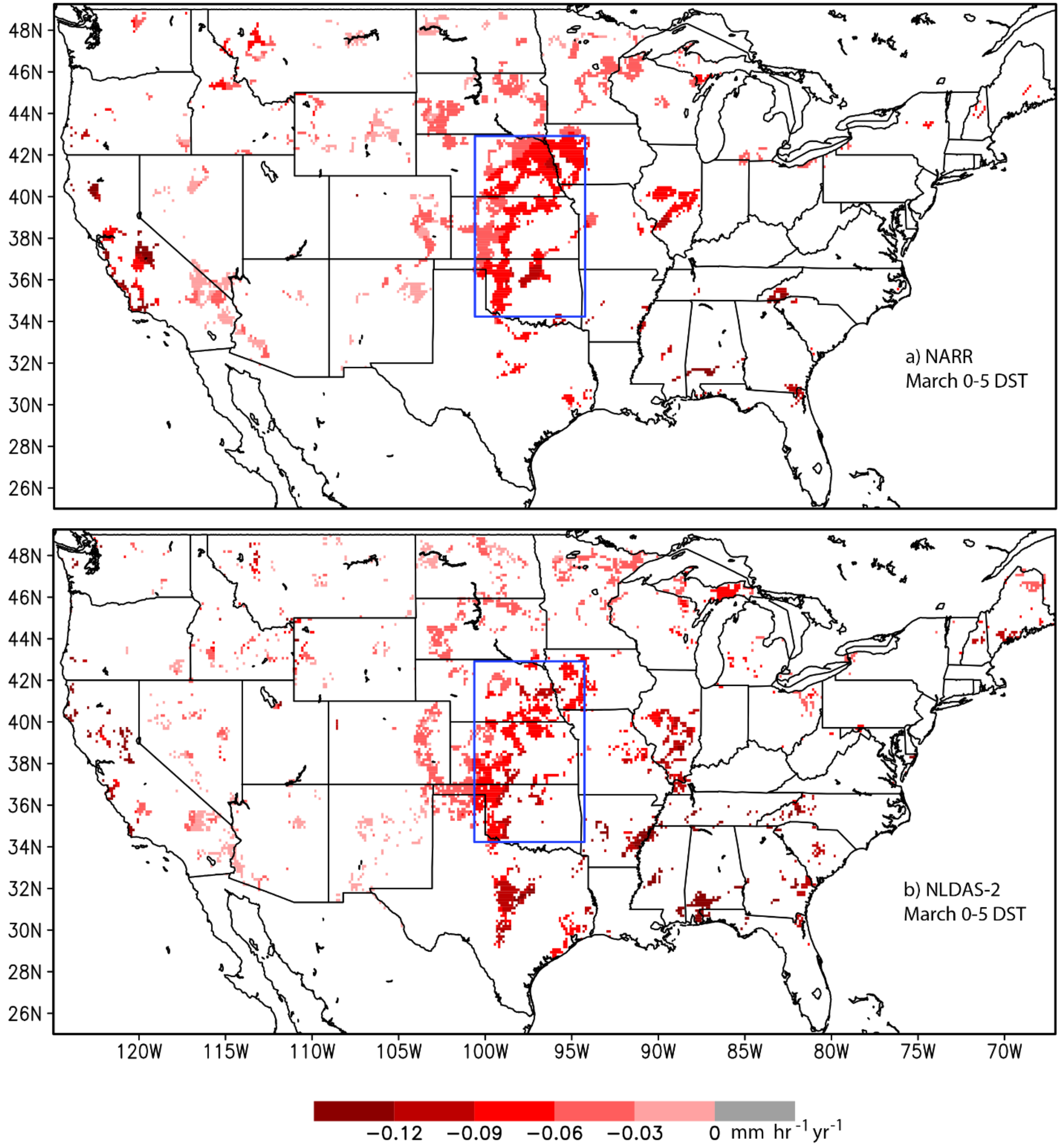


Sen's slopes in NLDAS-2 12-17 (daylight saving time) DST precipitation (*P*) amount between 1979-2015, computed from the 6-month warm-season (April-September) in units of mm month^{-1} (i.e., 0.8 mm month^{-1} x 6 months= 4.8 mm yr^{-1}). All plotted slopes are significant at the 0.05 level, locally.

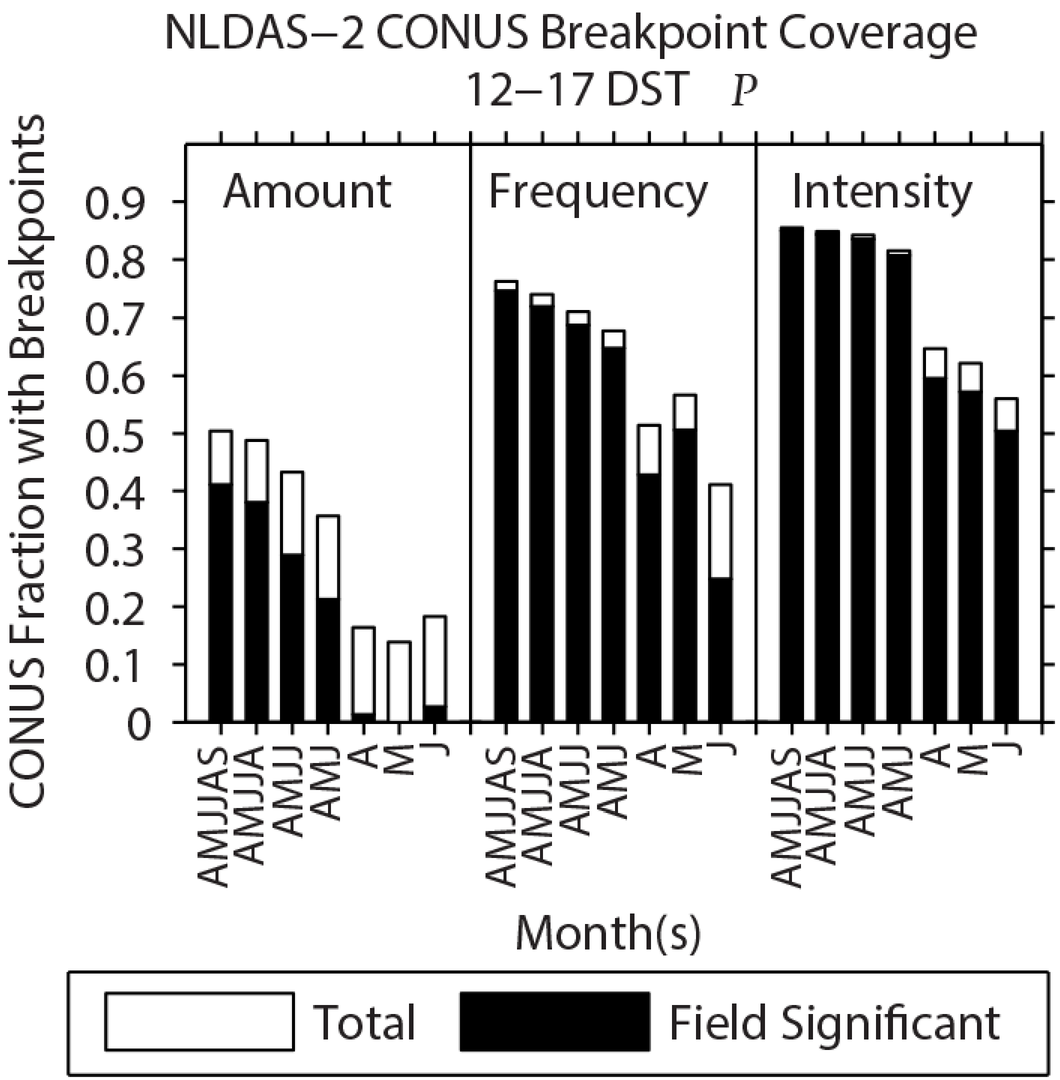
Results: Only trends in 0-5 DST *P* amount remain after accounting for breaks



The fraction (0-1) of CONUS 0.125° grid cells affected by either a Pettitt breakpoint (gray bars) or Sen's slope (line-circle) of field significance at the 0.05 level for (a) NLDAS-2 and (b) NARR 0-5 DST *P* amount during the period from 1979-2015. Horizontal red lines denote monthly median values for breakpoint coverage.



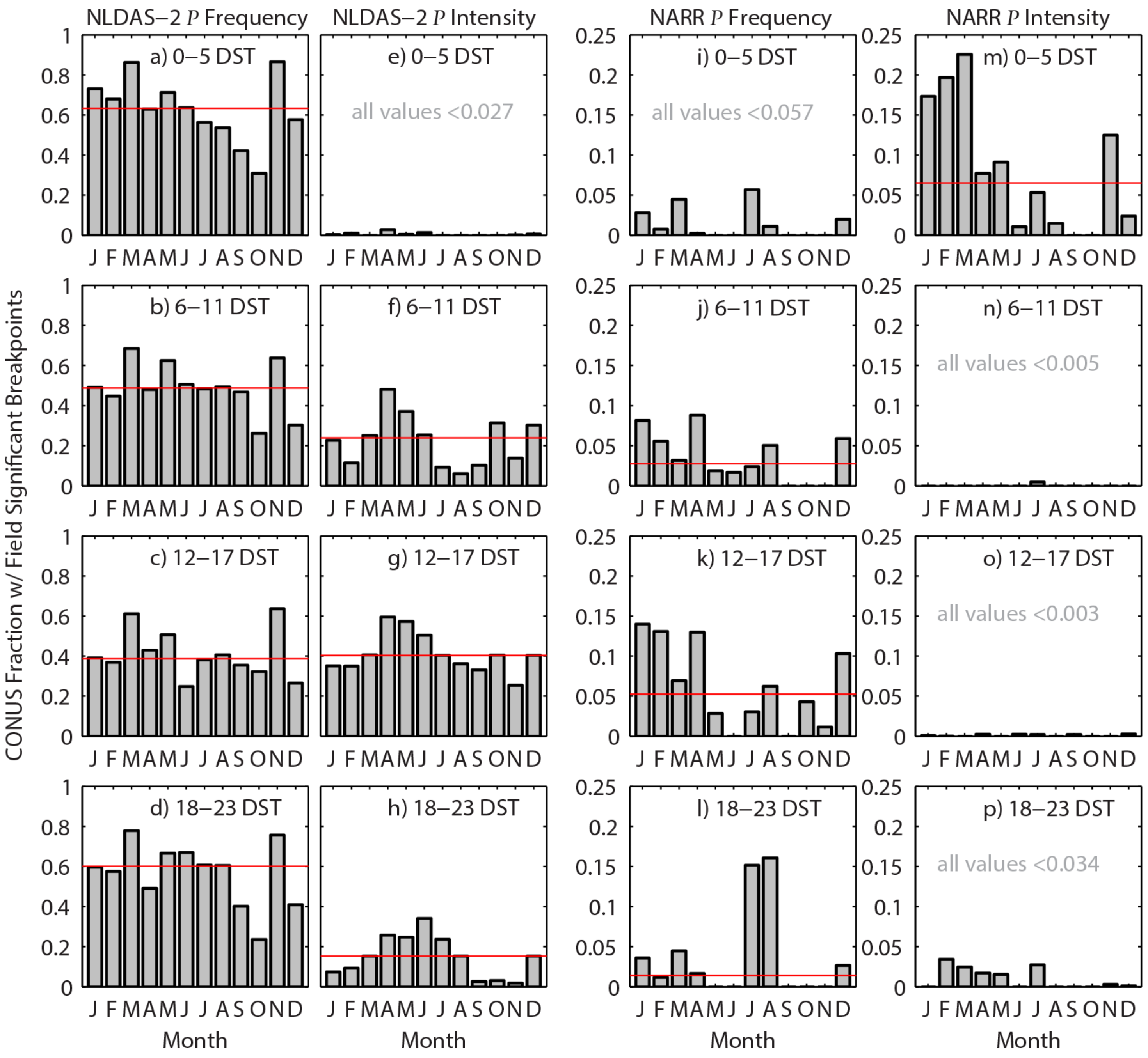
Results: Breakpoints, not trends; frequency and intensity, not amount



For 12-17 DST *P* amount, frequency, and intensity, the CONUS fraction with detected Pettitt breakpoints of local significance at the 0.05 level (hollow bar) as well as of field significance at the 0.05 level (filled bar). Statistics are provided for a cascade of diminishing time periods, including: April-September (AMJJAS), April-August (AMJJA), April-July (AMJJ), April-June (AMJ), April (A), May (M), and June (J).

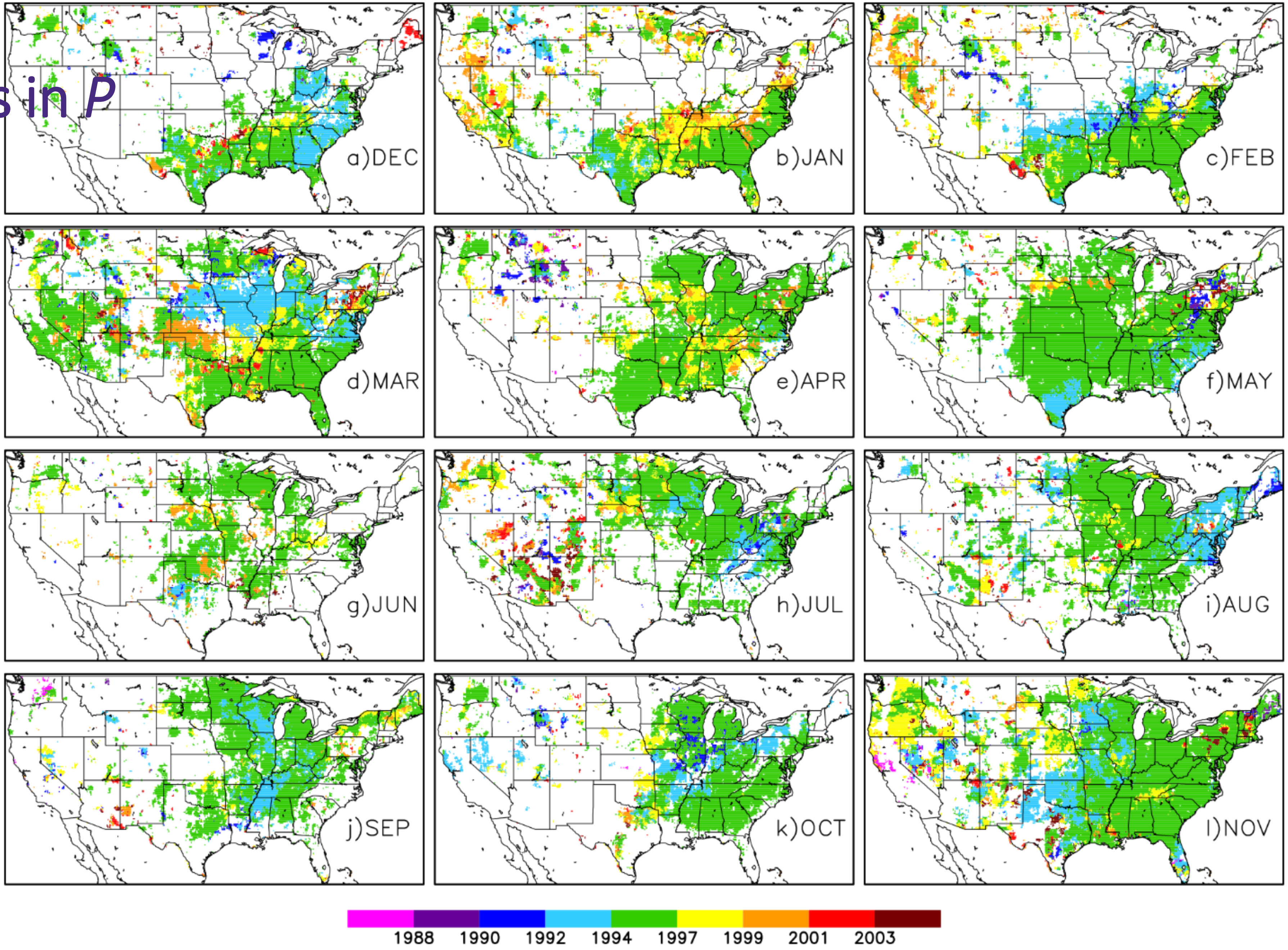
Results:

Breakpoints, not trends; disparity with NARR results



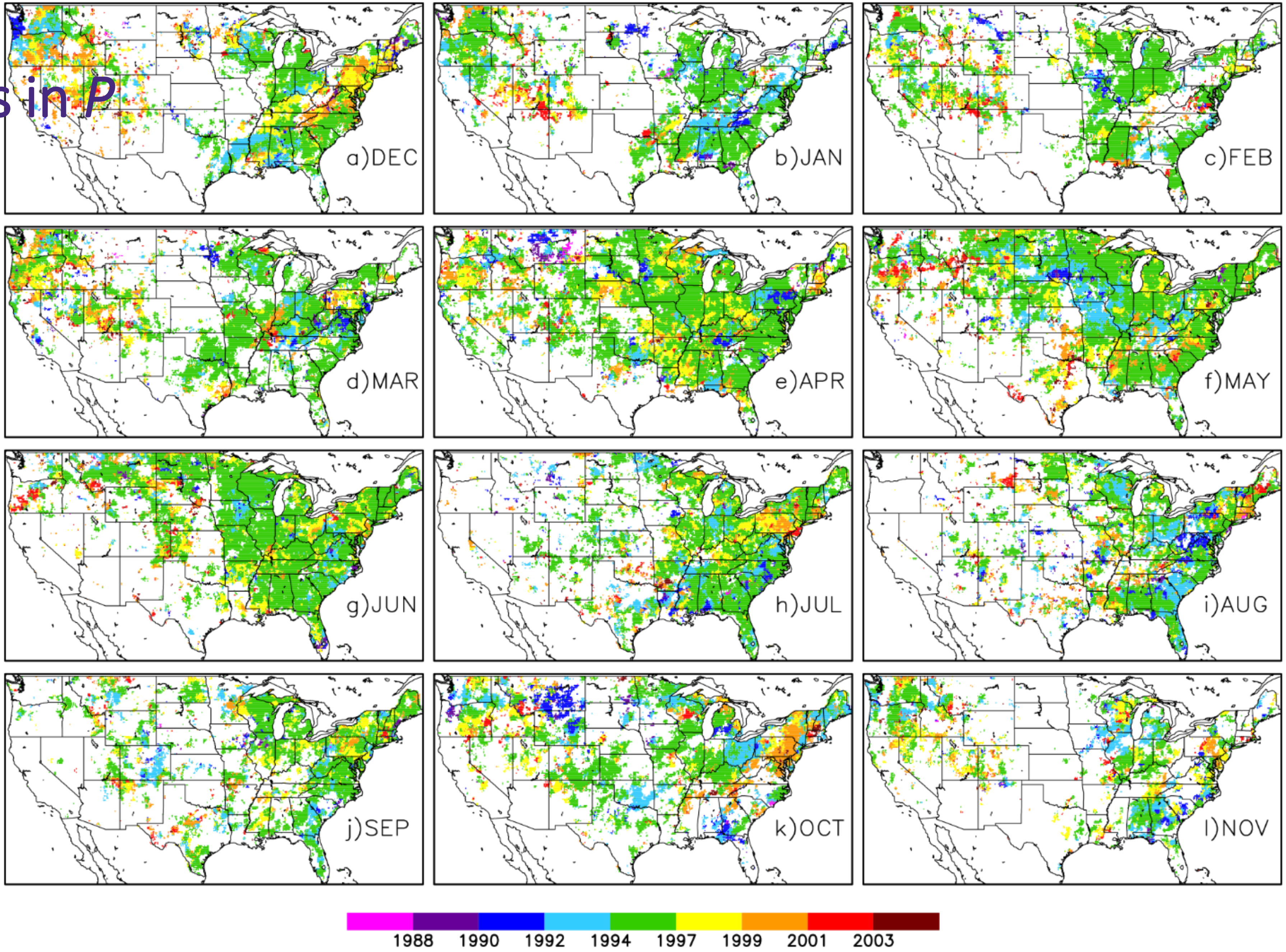
Results:

Breakdates in *P* frequency



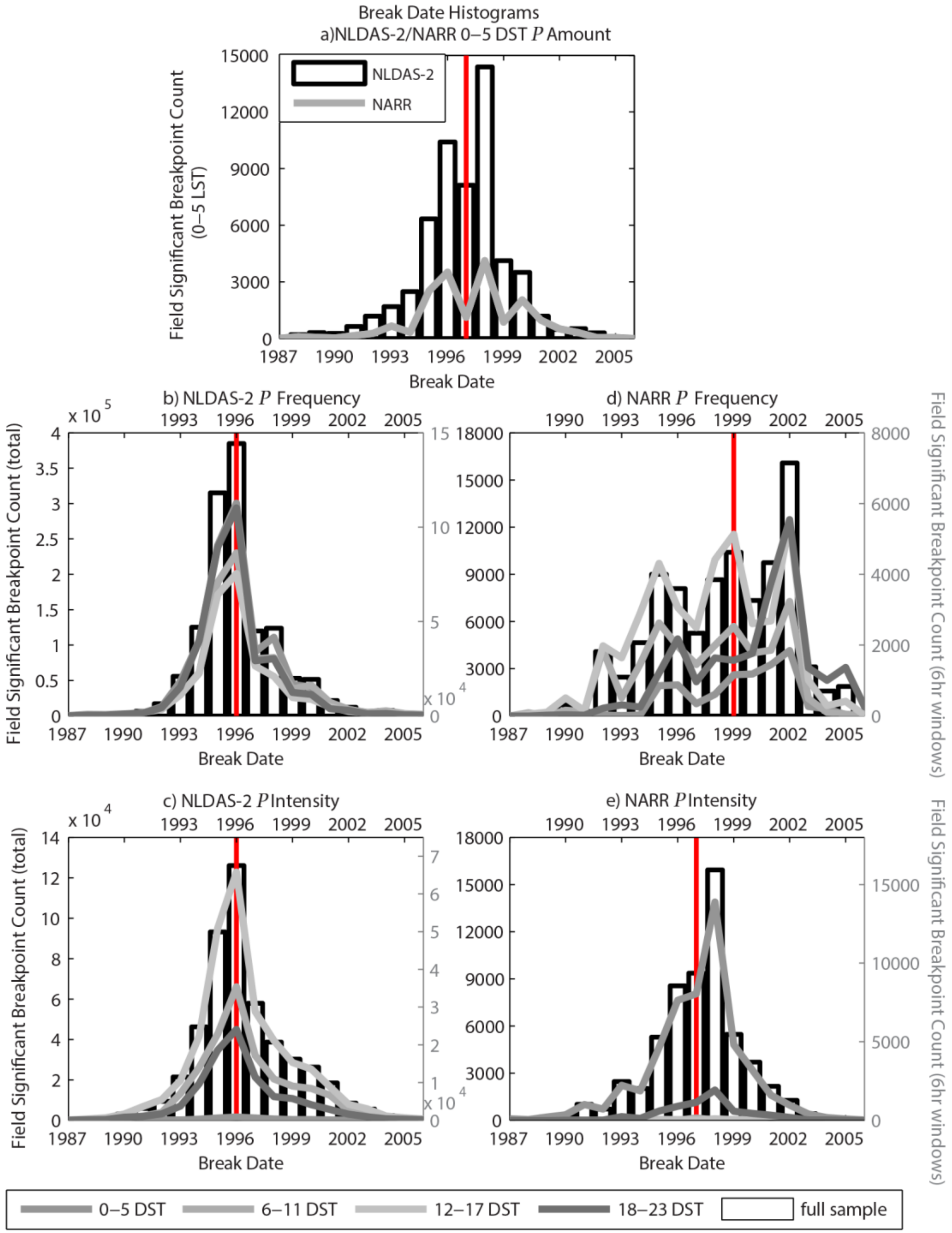
Maps of Pettitt field significant break dates at the 0.05 level for 12-17 DST NLDAS-2 P frequency.

Results: Breakdates in *P* intensity



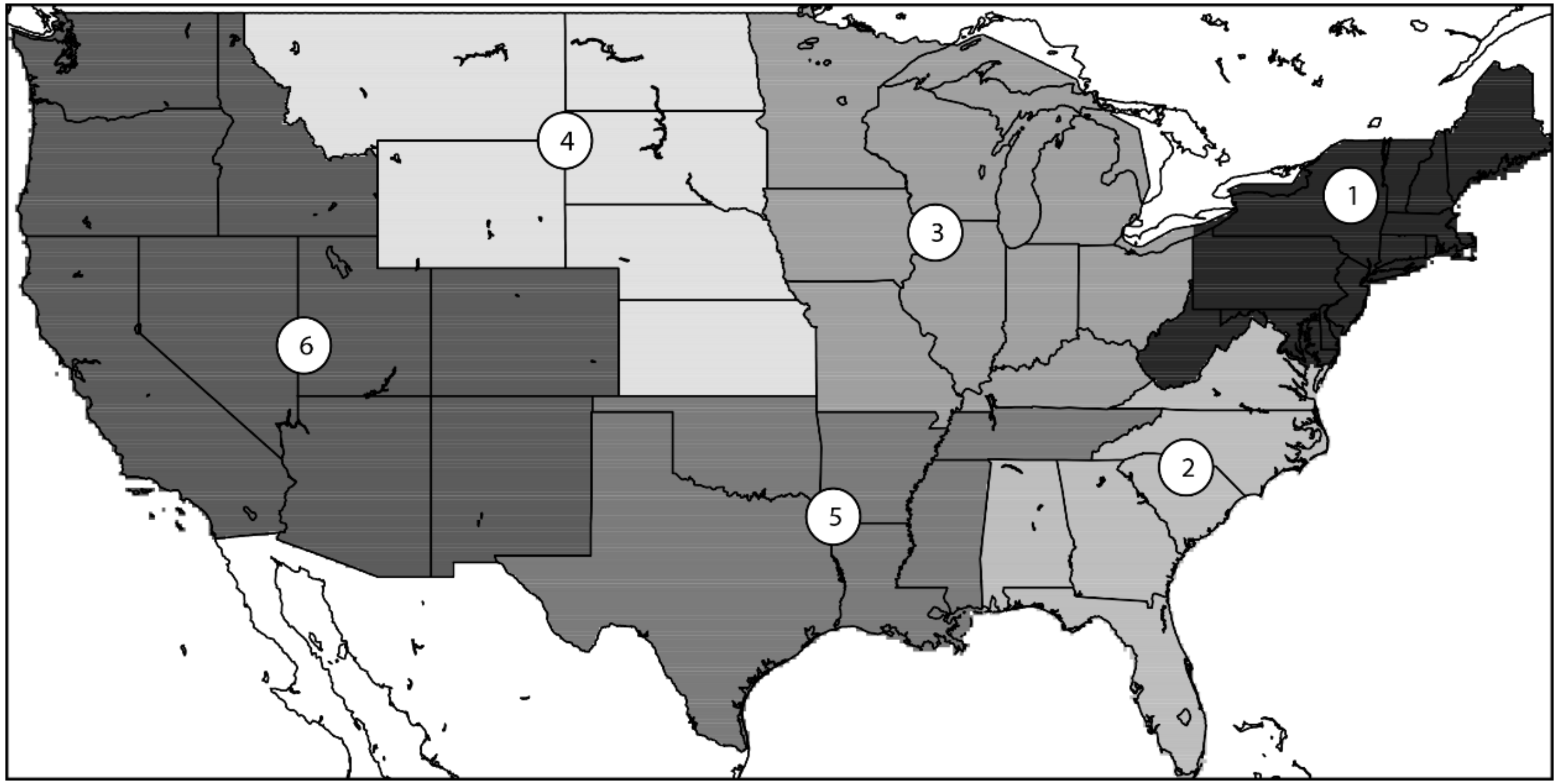
Maps of Pettitt field significant break dates at the 0.05 level for 12-17 DST NLDAS-2 P intensity.

Results: Breakdate distributions centered on 1996-1999



Histograms of Pettitt field significant break dates at the 0.05 level corresponding to (a) 0-5 DST NLDAS-2 and NARR *P* amount; NLDAS-2 *P* (b) frequency and (c) intensity; NARR *P* (d) frequency and (e) intensity. The hollow black bars denote the histogram of the full sample, whereas the grayscale lines denote the respective histogram for each 6-hour time window (i.e., 0-5, 6-11, 12-17, and 18-23 DST), except in (a) where the gray line denotes the NARR histogram. Vertical red lines denote the median break dates for each full sample histogram.

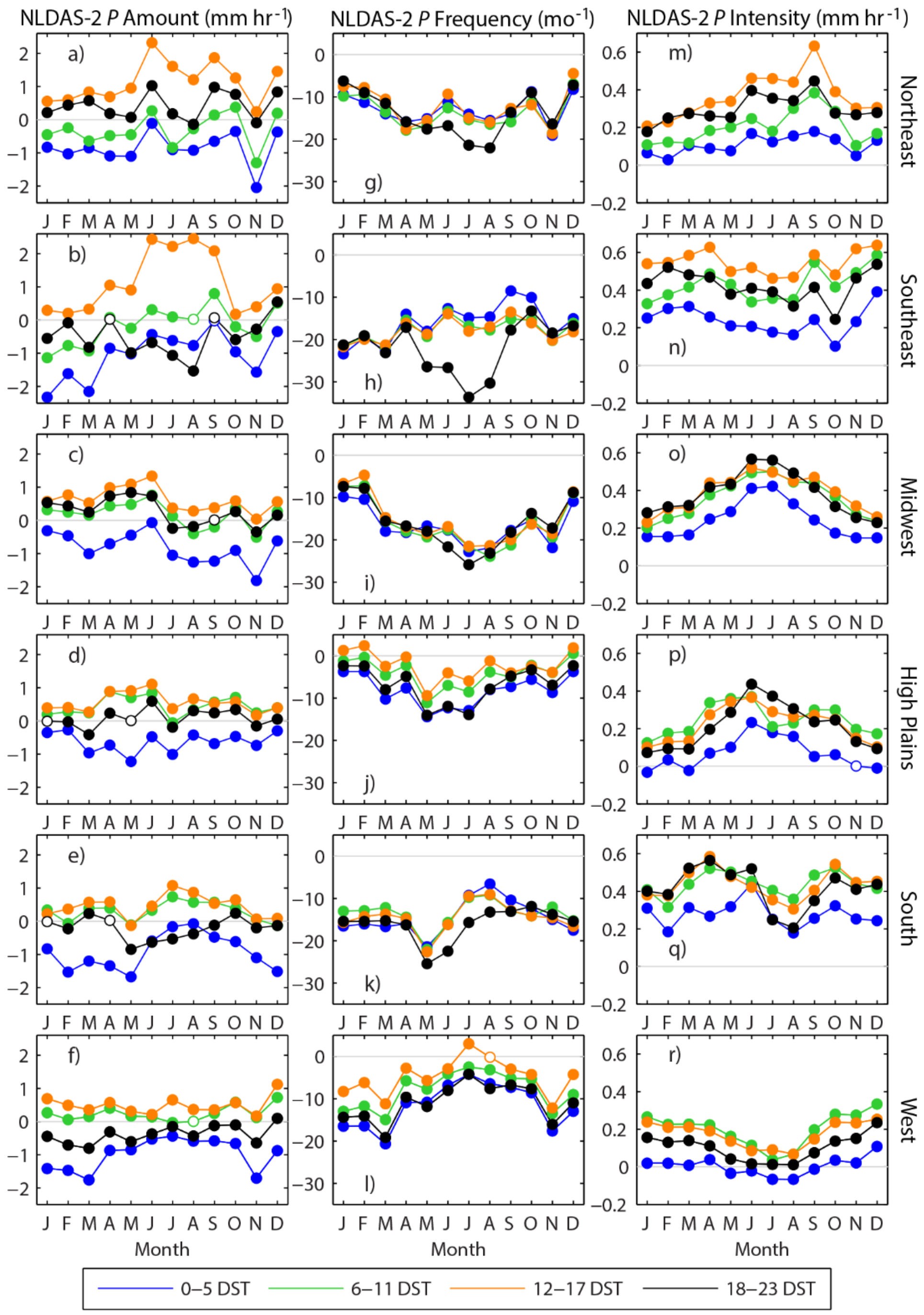
Results: Regional, area-averaged effects



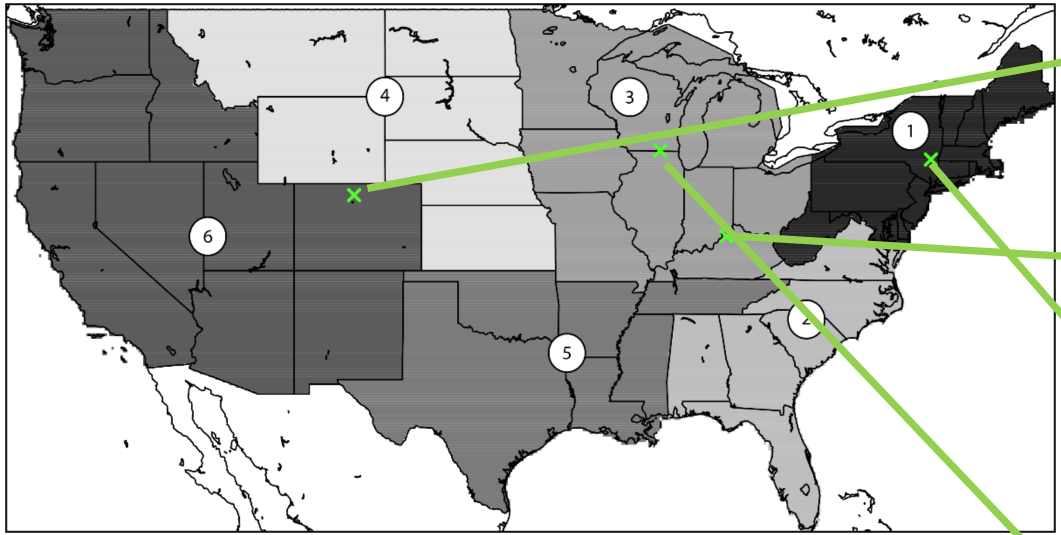
The domains are: 1: Northeast; 2: Southeast; 3: Midwest; 4: High Plains; 5: South; and 6: West.

Results: Regional, area-averaged effects

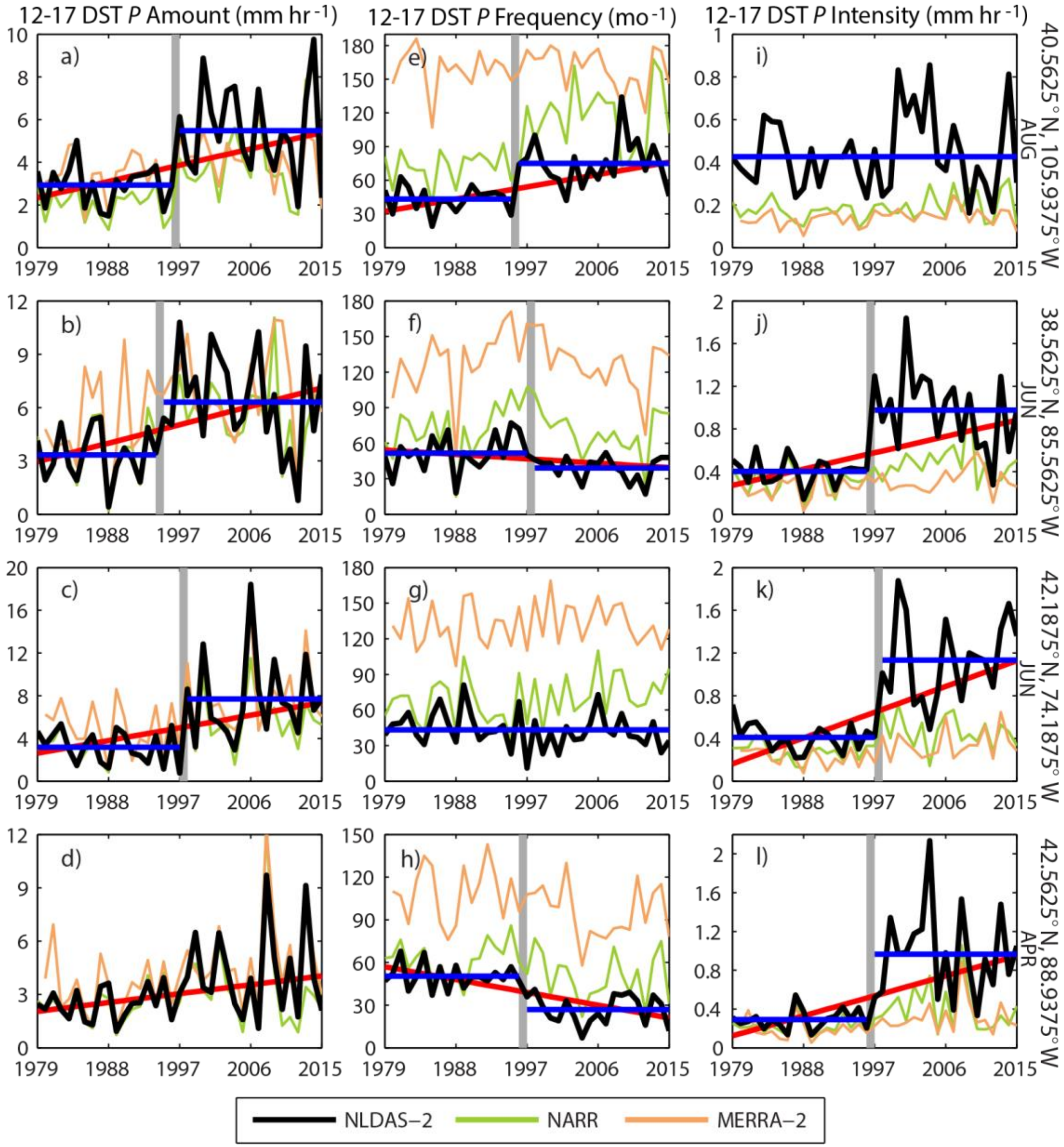
The shift in 0.125° sub-daily NLDAS-2 *P* amount (a-f), frequency (g-l), and intensity (m-r) between pre- (January 1979- July 1996) and post-radar (August 1996- December 2015) period means (i.e., post- minus pre-radar) for the six CONUS sub-regions shown in Fig. 9. The units are: mm hr^{-1}, wet hours mo^{-1}, and mm hr^{-1}, respectively—all for the corresponding 6-hour time window. Filled circles signify that the difference of the period means is statistically significant at the 0.01 level according to a 2-tailed Student's t-test; only 13 (1.5%) differences failed to achieve significance at this level.



Results: grid cell callout review



Detected trends dismissed as BP artifacts



Theil-Sen slope (red) and Pettitt breakpoint (gray) results for the NLDAS-2 (a-d) 12-17 DST *P* amount (mm hr^{-1}), (e-h) frequency (wet hours mo^{-1}), and (i-l) intensity (mm hr^{-1}) time series at four grids (see Fig. 10). From top to bottom row, the time series correspond to the following months: August, June, June, and April. Blue lines denote the mean of statistically homogenous series g) and i), as well as series segments (all other panels, except d)). For context, the NARR *P* and MERRA-2 *prectotcorr* time series are included.

Conclusions:

The July 1996 switch to Stage II radar data for use in temporal disaggregation of daily gauge-based inputs introduced a significant discontinuity in NLDAS-2 sub-daily precipitation frequency and intensity.

Unaccounted for, this discontinuity or breakpoint, leads to the erroneous detection of significant trends in precipitation.

Conclusions (cont.):

When breakpoints are accounted for, less than 2% of CONUS is found to exhibit field significant trends in any aspect of sub-daily precipitation at the monthly scale, with the exception of 0-5 DST precipitation amount over the central U.S.

General takeaways

- Account for linear trends and breakpoints in each other's presence
- Account for the familywise type I error rate (FWER) by computing the field significance
- Carefully consider the domain over which field significance is computed

NLDAS-specific takeaways

- Users should be notified of the July 1996 discontinuity. Impacts will be application-specific. Users can expect direct effects on long-term trends in sub-daily precipitation and indirect effects on trends in modeled soil moisture, surface temperature, surface energy and water fluxes, snow cover, snow water equivalent, and runoff/streamflow.
- Observation feedback archives (OFA) for precipitation are needed. For each hourly forcing file, e.g. How many (and which) stations were used in the daily precipitation analysis? Which dataset was used for temporal disaggregation at each grid point? What are the associated estimates of data quality?, etc.
- Independent of the July 1996 discontinuity, NLDAS-2 likely still provides the most realistic diurnal precipitation cycle over CONUS.

Thanks!

U-Albany’s Whiteface Mountain Field Station, Wilmington, NY