How have tropical storms in the Arabian Sea intensified recently?

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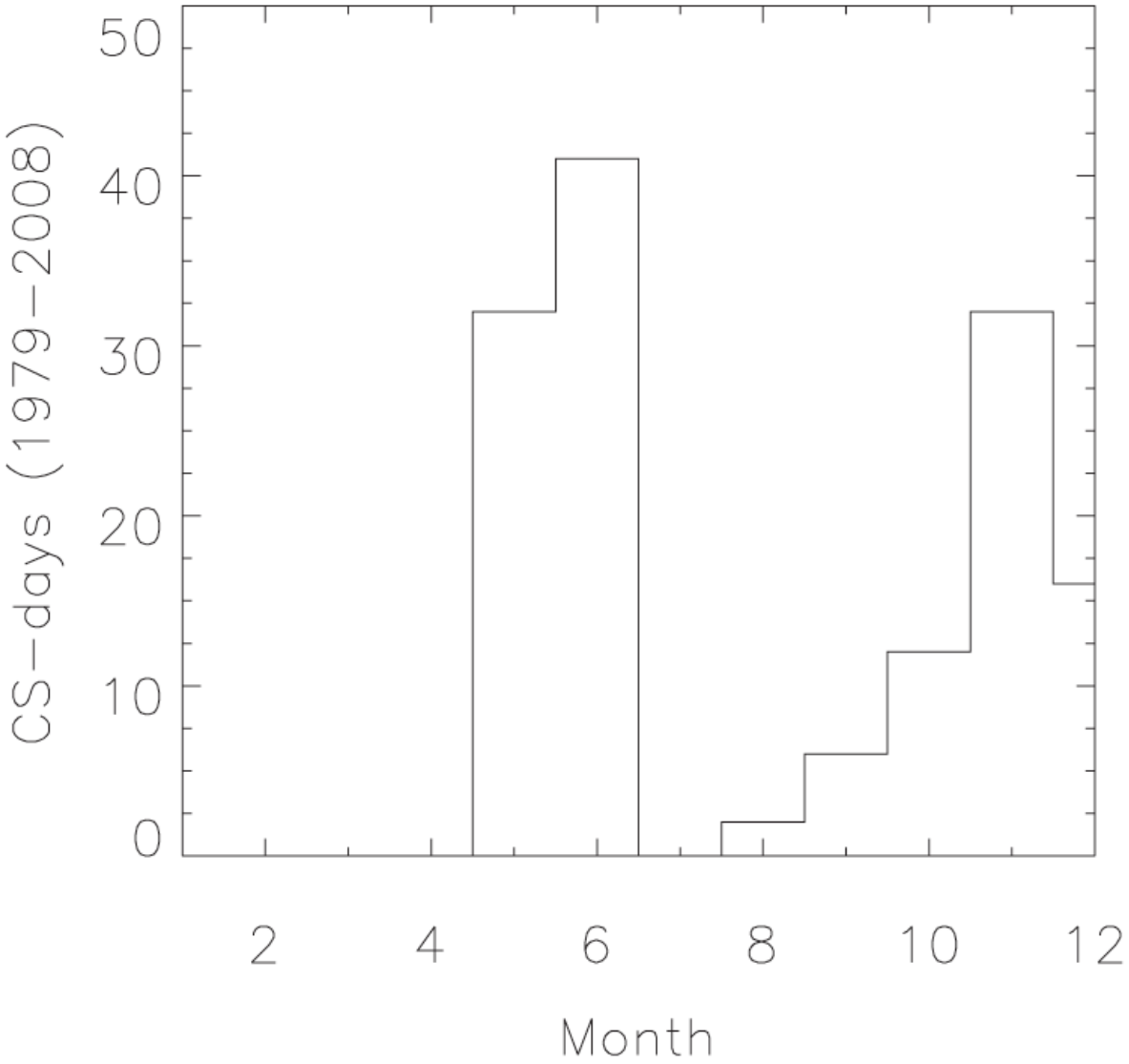
GRIP Science Meeting
May 9-10, 2012
NASA Wallops Flight Facility

Ongoing Research

- Large-scale environmental influences on secondary eyewall radii
- Ensemble experiments to understand genesis and RI processes in Hurricanes Karl and Earl
- RI of Typhoon Nanmadol (2004) under easterly vertical shear
- Arabian Sea TC intensification in recent decade

Background



Histogram showing TC days from 1979-2008 for storms with genesis in the Arabian Sea.

From Evan and Camargo (2010).

Background

Arabian Sea tropical cyclones intensified by emissions of black carbon and other aerosols

Amato T. Evan, James P. Kossin,
Chul ‘Eddy’ Chung, and V. Ramanathan

NATURE, 2011 479:94-97

Lifetime Maximum Intensity (LMI)

Vertical Wind Shear (VWS)

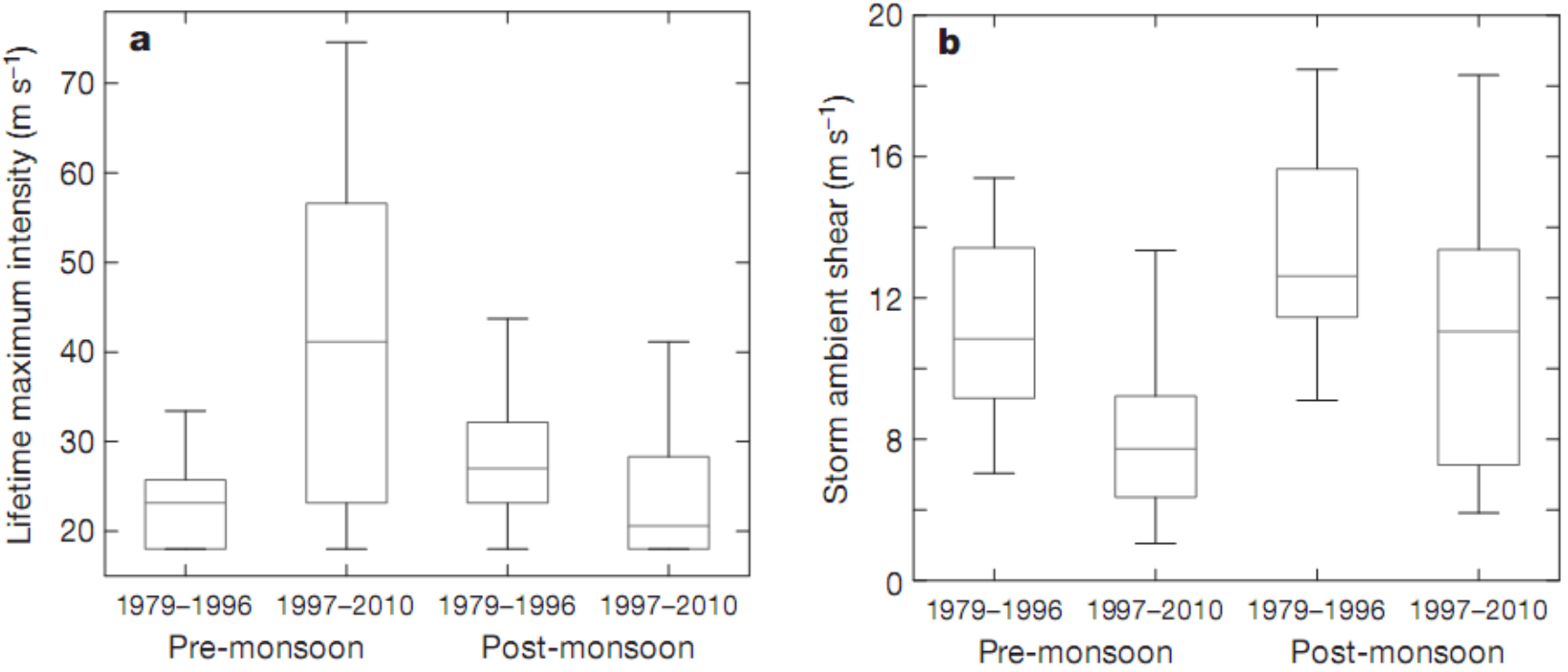


Figure 2 | Distributions of pre-monsoon and post-monsoon LMI and storm-ambient vertical wind shear. Box plots of LMI (a) and storm-ambient vertical wind shear (b) showing the medians (central lines), inner quartile ranges (boxes), and the 25th and 75th centiles minus and plus 1.5 times the inner quartile range, respectively (whiskers). Shear is calculated from the National Center for Environmental Prediction-Department of Energy Reanalysis.

From Evan et al. (2011)

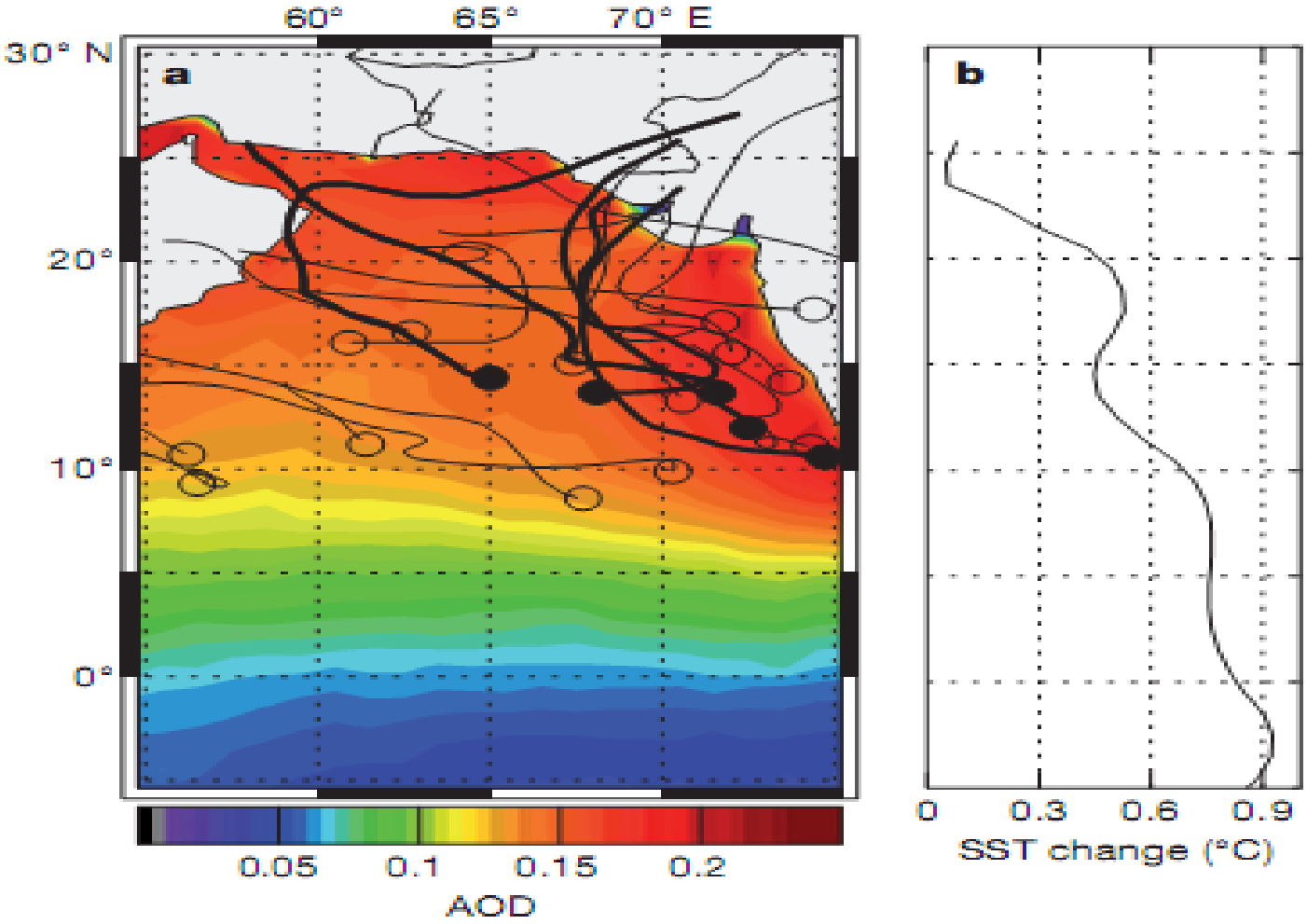


Figure 1 Tropical cyclone tracks, aerosol optical depth and meridional SST trends in the Arabian Sea. (a) Genesis points (circles) and tracks (solid lines) of pre-monsoon tropical cyclones during the period 1979–2010. Storms with an lifetime maximum intensity (LMI) of more than 50ms $^{-1}$ are indicated with a filled circle at the genesis point and thick track lines. Shaded contours represent annual long-term mean fine-mode aerosol optical depth (AOD) from the MODIS Terra and Aqua instruments averaged over 2003–2009. (b) The 50-year change in observed SST, averaged over 55° –75° E. The SST change is defined as the average of the monthly linear trend from 1955–2004, multiplied by 50.

From Evan et al. (2011)

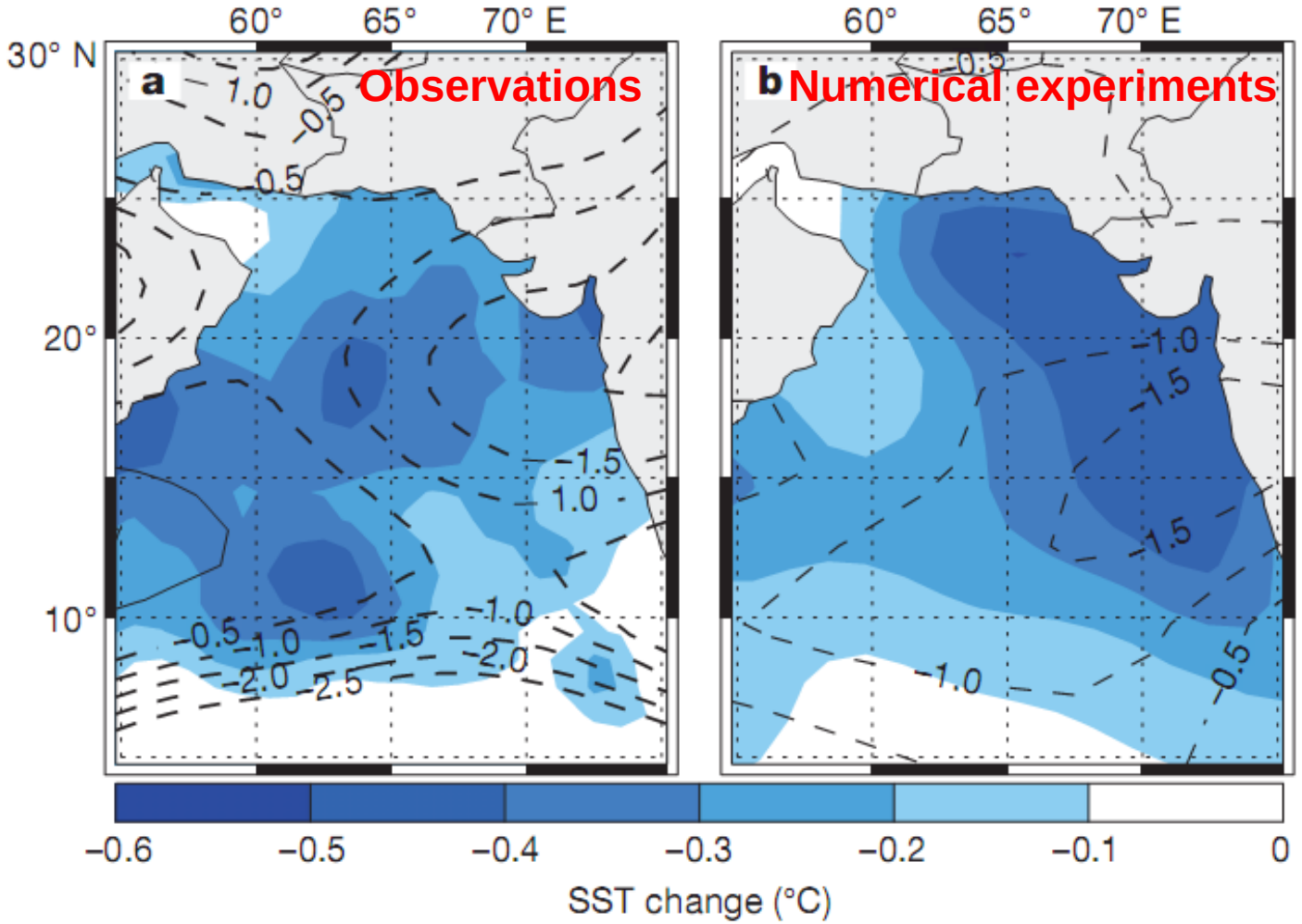
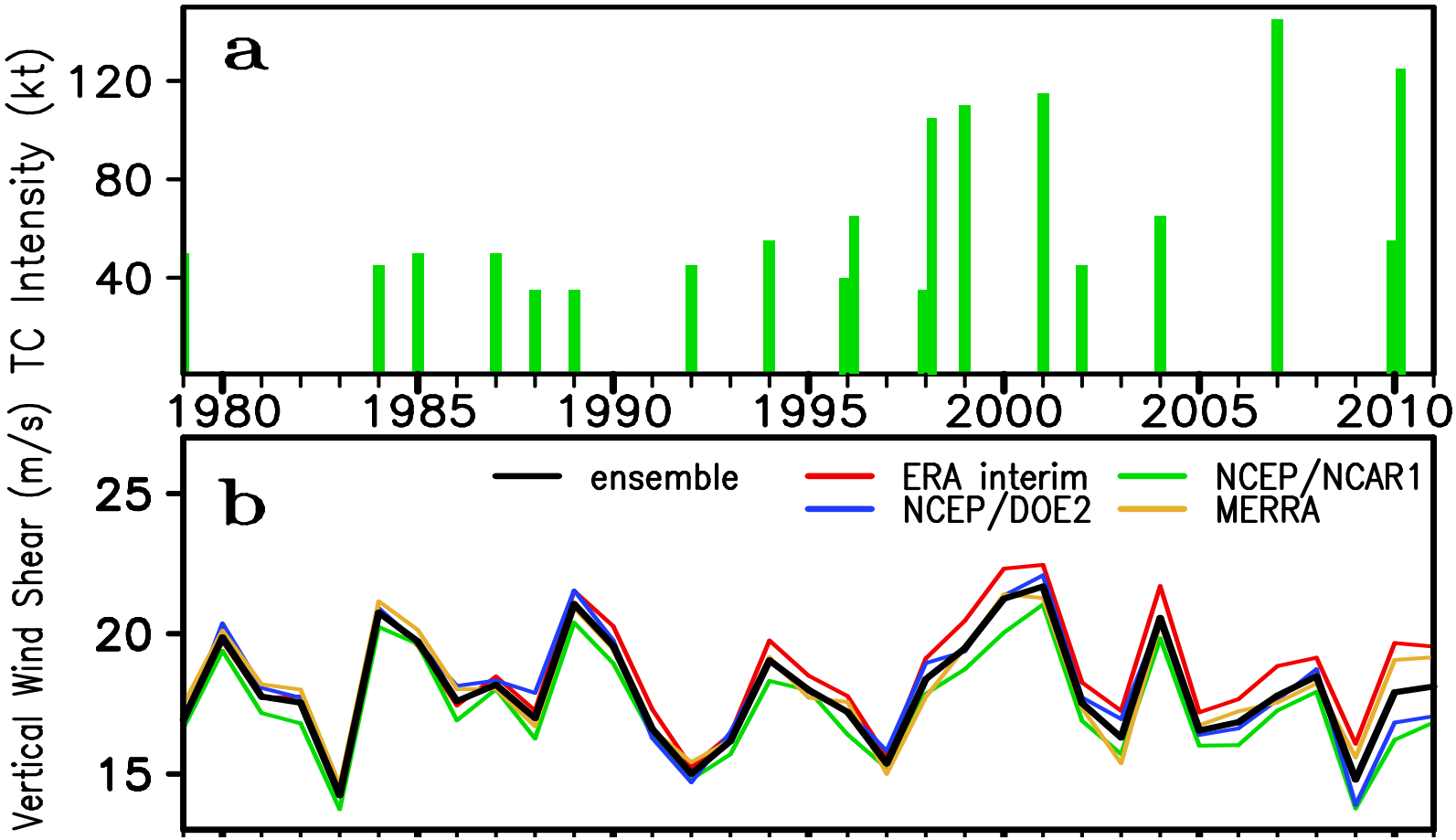


Figure 3 | Thirty-year trends in pre-monsoon SST and vertical wind shear. The 30-year trends in vertical wind shear (contours) based on reanalysis data from 1979–2010 (a) and numerical experiments designed to isolate the effect of the ABC on the regional circulation (b). Dashed contours indicate negative trends, and solid contours indicate positive trends; the zero contour is not shown. Positive and negative shear contours are in units of 0.5 ms $^{-1}$. Shading shows the 30-year SST trends over the same period from observations (a), which is relative to the equatorial SST trend, and the aerosol-forced SST change prescribed in the model experiments (b).

From Evan et al. (2011)

Remaining Scientific Issues

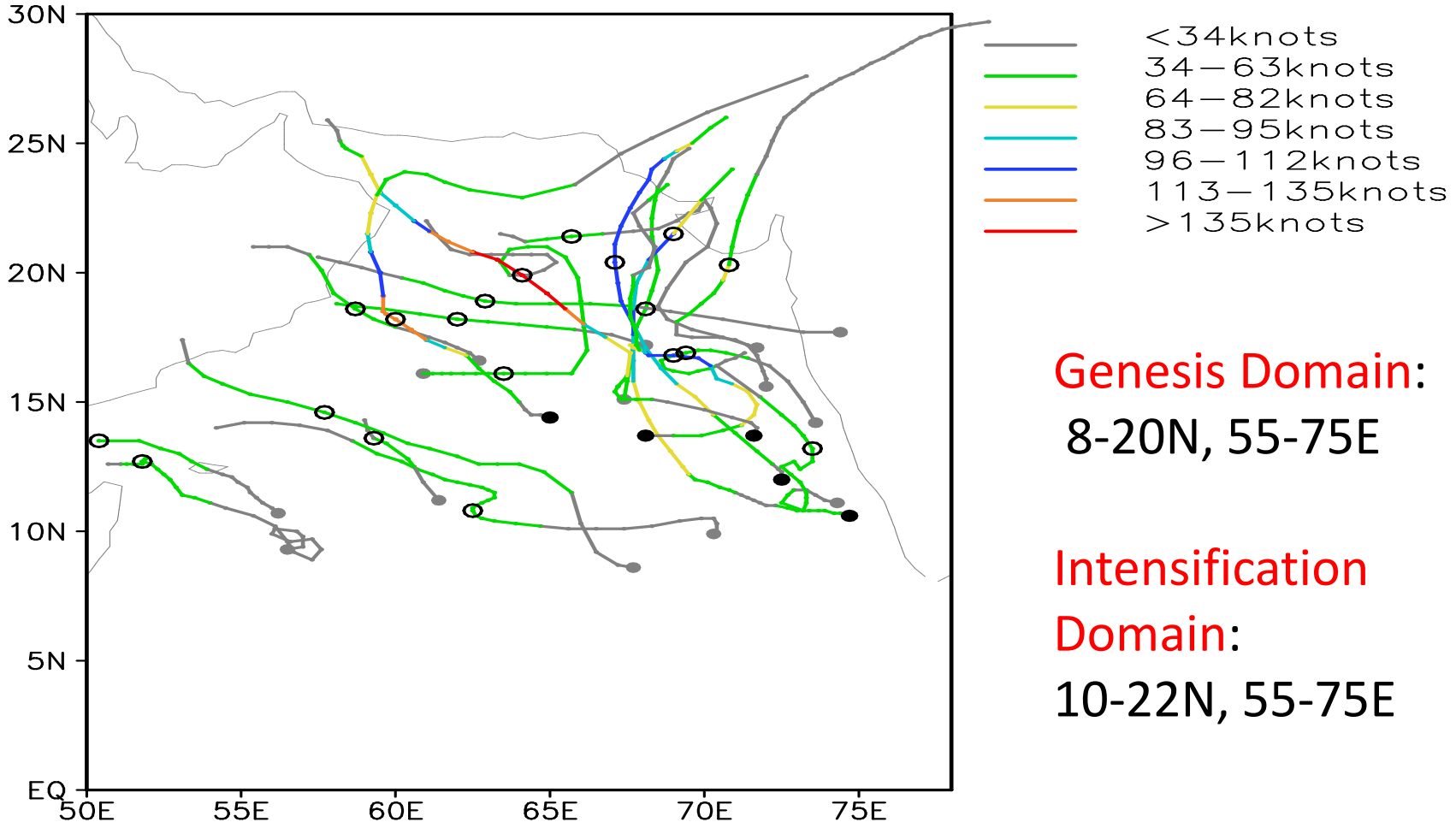
1. Observed storm-ambient VWS reduction is 3 m/s, but the model simulated ABC-induced VWS reduction trend is only ~1 m/s (~0.5 m/s change per epoch).
2. Has the observed long-term mean VWS decreased or increased? The ensemble mean of four reanalysis datasets show no trend over the TC intensification domain (10-22N, 55-75E) during May-June.
3. TC intensity shows a sudden upward shift after 1997, although aerosols have shown only a steady upward trend.



a. The maximum wind speed of each Arabian Sea TC occurring in each pre-monsoon season derived from IBTrACS[9] data, which confirms the results of Evan et al.[1] that were derived from the JTWC best track data[10]

b. The VWS between 850 and 200 hPa averaged over the TC intensification zone (10˚ -22˚ N, 55˚ -75˚ E) derived from four reanalysis datasets and their ensemble mean: ERA interim[11], NCEP/NCAR1[12], NCEP/DOE2[13], and MERRA[14]. Neither dataset shows significant decreasing trend.

Why has there been a reduction of storm-ambient VWS during the recent epoch?



Genesis Domain:
8-20N, 55-75E

Intensification Domain:
10-22N, 55-75E

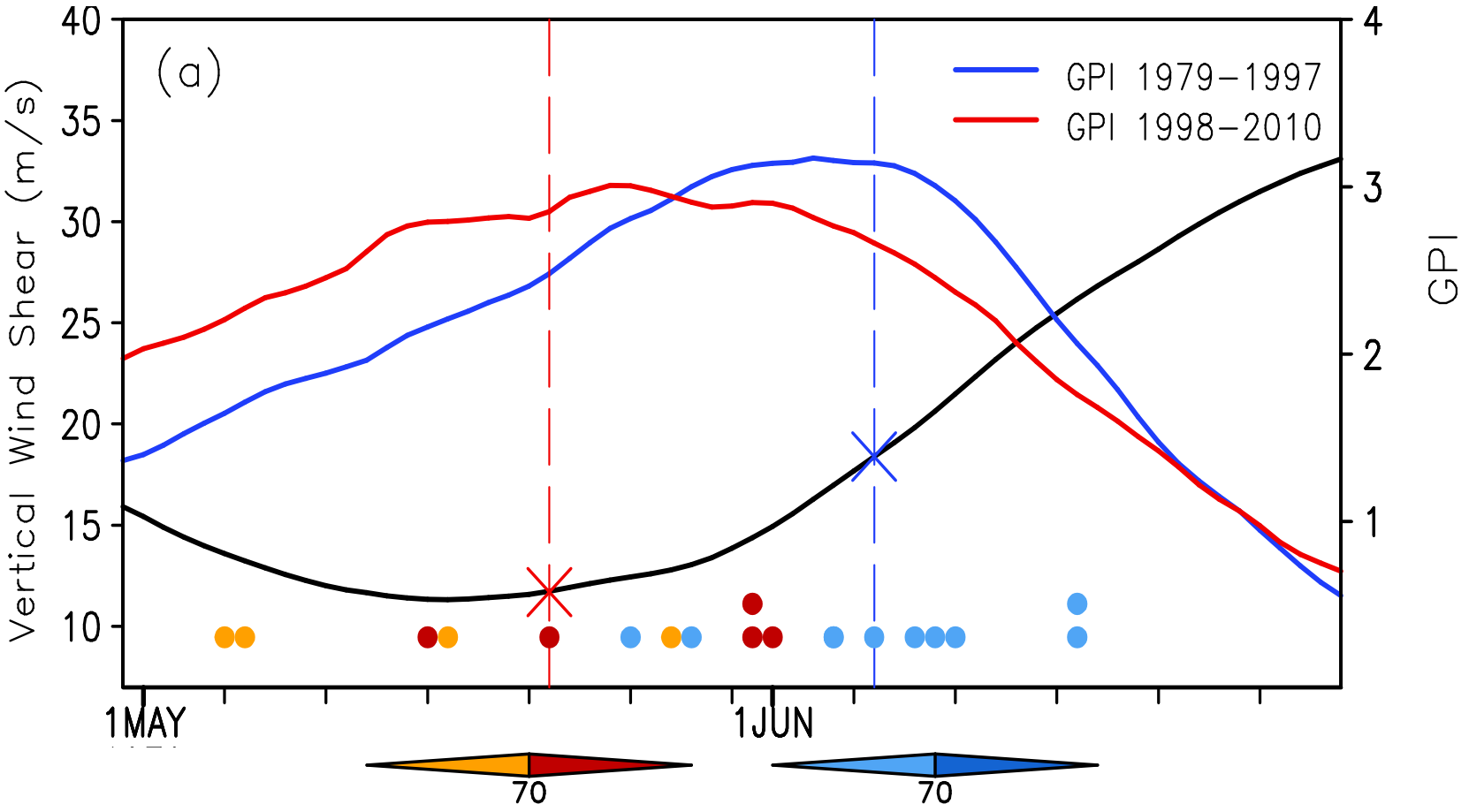
May-Jun TC tracks over Arabian Sea from 1979 to 2010. Dots are locations of TC formation while open circles are TC maximum intensity locations.

To identify the cause of earlier occurrence of Arabian TCs…

GPI (Emanuel and Nolan 2004)

- 850 hPa absolute vorticity
- 700 hPa humidity
- Maximum potential intensity (SST)
- Vertical wind shear

Advanced TC genesis and occurrence over the Arabian Sea



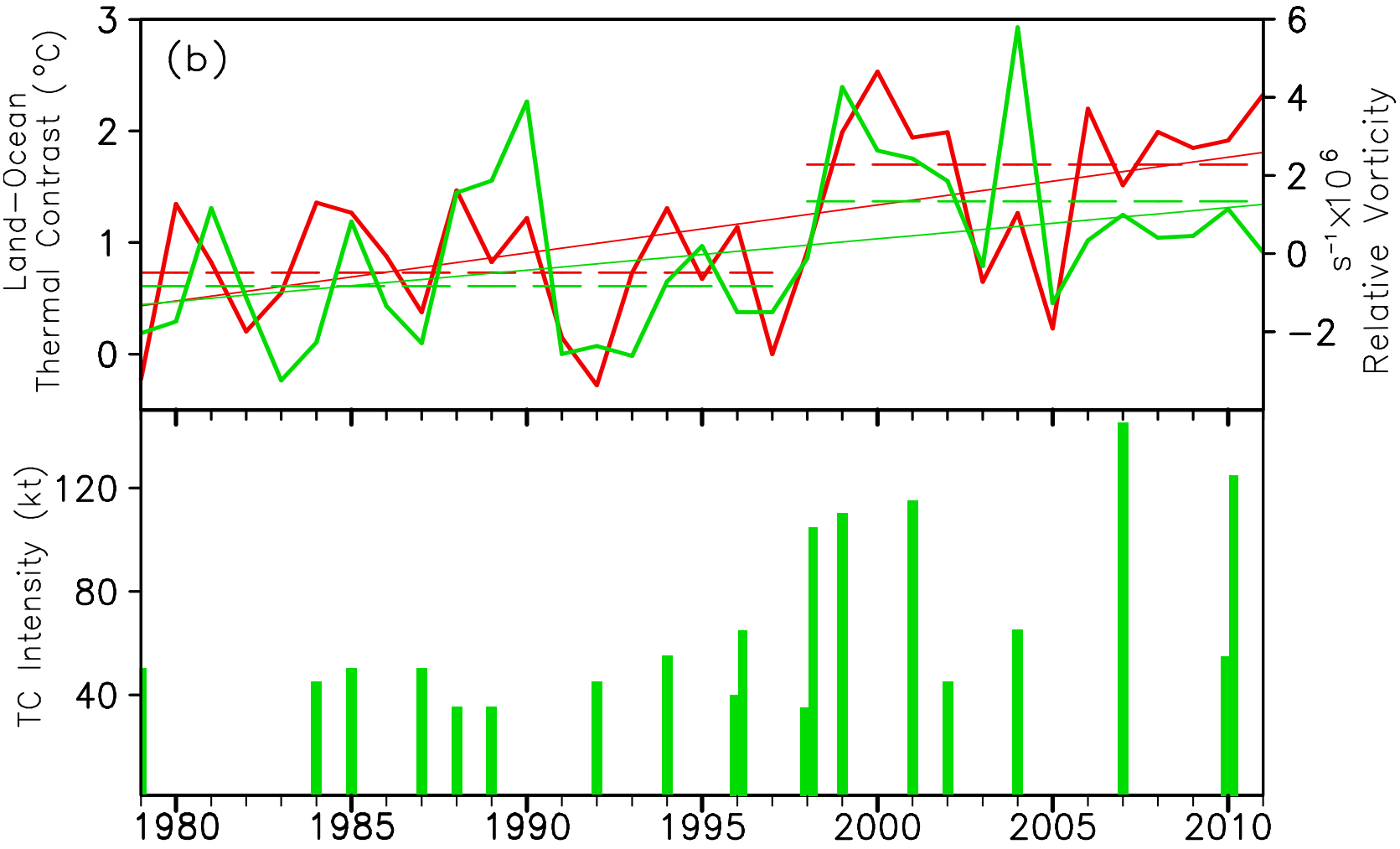
1979-1997: mean genesis date: June 6

1998-2010: mean genesis date May 21

VWS reduced by ~6 m/s due to earlier occurrence

So why is the GPI maximum shifted earlier?

Earlier southwest monsoon development in May



Low-level relative vorticity increase over the genesis region (green curve)

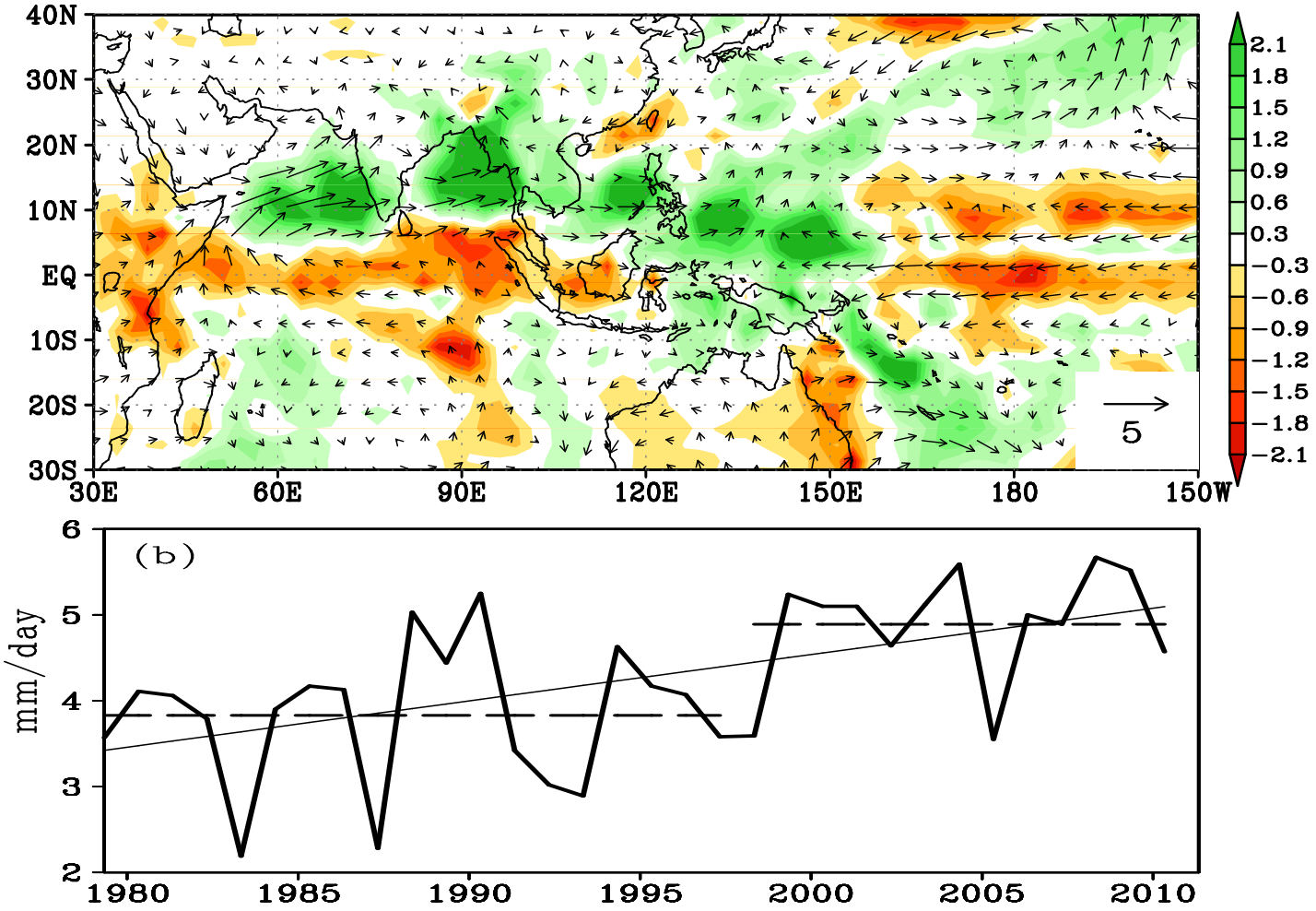


Fig a Epochal differences (1998-2011 minus 1979-1997) in May mean precipitation rate (mm/day) and 850 hPa winds (m/s). **b** The time series (thick soiled line) and the linear trend (thin soiled line)of the May rainfall averaged over the Asian-western Pacific monsoon trough region (5N-20N, 50E-150E). The dashed lines indicate the two epochal mean rainfall rate. The trend in (b) is statistical significant at 95% confidence level by Mann-Kendall test.

Summary

1. The reduction of storm-ambient VWS in the Arabian Sea is associated with an earlier occurrence of TCs by 15 days, which implies a climatological reduction of VWS of 6 m/s.
2. The early occurrence of TCs is a consequence of the change in large scale circulation that advances the maximum GPI markedly.
3. The major contributor to GPI advance is the low-level cyclonic vorticity increase due to early development of Arabian Sea low-level southwesterlies that increases lower tropospheric moisture and precipitation (in May).
4. The earlier development of monsoon SW-ly flow is consistent with the increasing land-ocean thermal contrast in May. This increased thermal contrast mainly increases low-level vorticity, and its impact on VWS is minor.

THANK YOU

Please direct comments/questions to:

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