Environmental Factors Associated with the Anomalous 2007 Arabian Sea Cyclone Season

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Summary

Cyclonic activity in the northern Indian Ocean was exceptionally strong in 2007, as inferred from both storm intensity and frequency. In order to assess the environmental factors that may have influenced the season, the constraints on cyclogenesis are assessed and anomalies during 2007 are identified. Both dynamic and thermodynamic influences are found to actively regulate cyclonic activity over the mean seasonal cycle . However in 2007, environmental conditions suggested a thermodynamic basis for anomalous cyclonic activity as anomalies in PW/CAPE/SST were conducive for cyclonic development while anomalies in shear were generally neutral or detrimental.

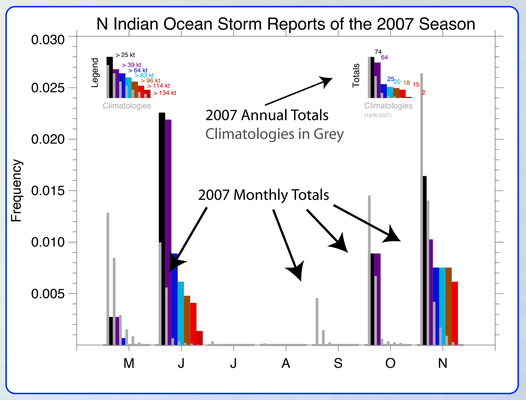
1. Introduction

Storm reports for 2007 (from JTWC advisories) shown by reports exceeding a given category. [Grey lines are climatologies.]

Cyclonic activity is interrupted by monsoon induced shear, with June and Nov peaks in cyclonic activity.

During 2007, approx 30% more storm activity at and above tropical storm intensity occurred - following a quiet month of May.

The proportion of supertyphoons (>Cat 3) was also significantly above the climatological average.

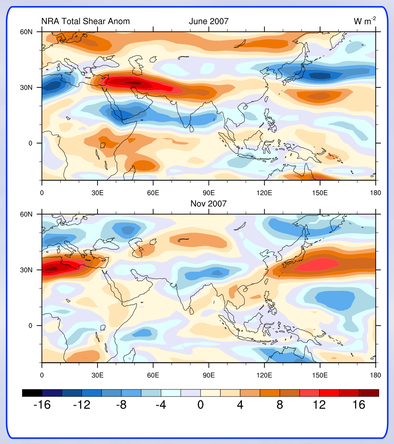


3. Environmental conditions in 2007

Shear (U200-U850)

In Jun 2007, anomalous vertical shear was notable over the Arabian Sea. These anomalies represented stronger than normal shear both north of 20N (where shear is typically positive) and south of 20S (where shear is typically negative). These enhanced shears should act to prohibit the development of strong storms.

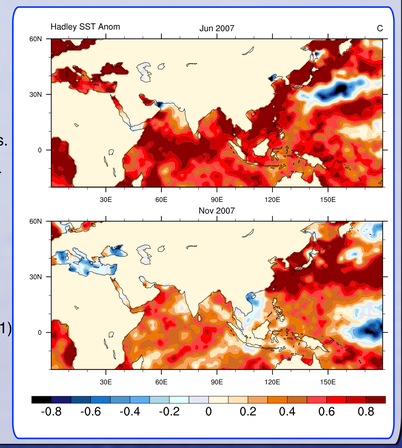
In contrast, during Nov 2007 shear anomalies were largely absent from the Arabian Sea. Thus, shear is unlikely to have contributed significantly to anomalies during 2007.



SST

As our calculations of CAPE and bias-corrected PW are ongoing, SST serves as a useful interim proxy for thermodynamic forcings.

For both Jun and Nov 2007, SST was anomalously warm in the Arabian Sea and northern Indian Ocean overall, suggesting a thermodynamic basis for anomalous cyclonic activity - despite a strong negative feedback from storm activity as evidenced by storm statistics (in 1) and storm wakes (in 5).



4. The Seasonal Cycle

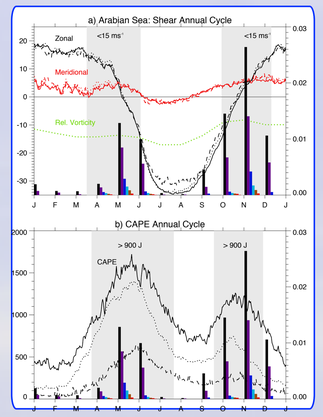
The monsoon plays a key role in interrupting storm activity in the Arabian Sea by inducing strong vertical shear.

A strong seasonal cycle in CAPE is also apparent in the reanalyses - though magnitudes differ considerably between them due to their differing treatments of convection.

The seasonal peaks in cyclone activity (color bars) correspond to periods of both large CAPE and low zonal shear (grey shading).

Explaining the strength of the fall peak (relative to the spring peak) may require additional considerations - such as relative vorticity.

caption: season cycles of **storm activity** (JTWC), **shear** (ncep-solid, era-dot, jra25-dash),and **CAPE** (ncep-solid, era-dot, jra25-dash)



5. A Case Study of Supertyphoon Gonu

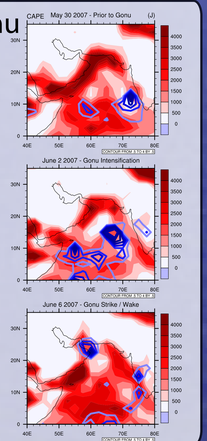
Here the interaction of Supertyphoon Gonu with atmospheric thermodynamic structure remote from the storm environment can be witnessed.

TRMM-retrieved rainfall peaks associated with Gonu (blue contours) can be used to approximate the storm's location while CAPE is shown by the filled contours (mm hr^{-1}).

As Gonu develops into a tropical storm, CAPE values substantially above climatology span the northern Arabian Sea. (upper caption)

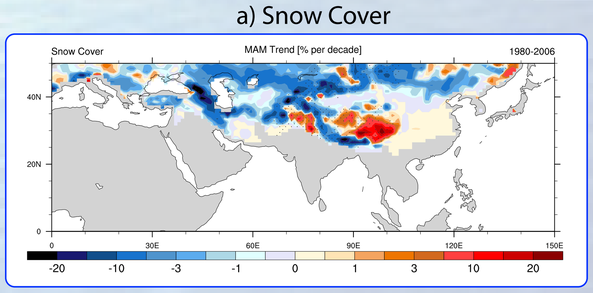
During Gonu's rapid intensification leading up to its peak (2 Jun), the storm appears to feed off of the energy provided by these anomalies. CAPE anomalies in the western equatorial Indian Ocean are also depleted.

As Gonu nears the Omani coast, its wake in the CAPE field is clear and values near 4000 J are reduced to less than 1000 J in a few days. While CAPE near the equator recovers rapidly, the cold wake left in Gonu's path delays the recovery of CAPE.



2. Regional Trends

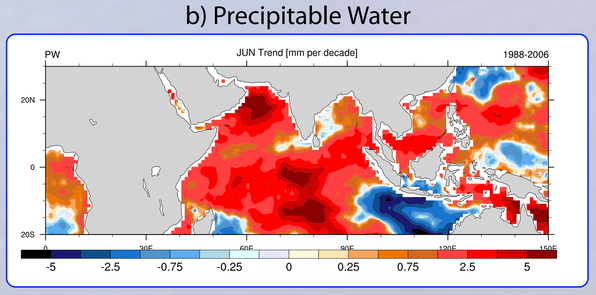
a) Snow Cover



Regional trends have been strong in the past 3 decades and are characterized by a warming Eurasian landmass and an advance of spring snow melt. Here the trend from 1997-2005 shown in Goes et al. 2005 is shown to be representative of the longer data record from 1980-2006.

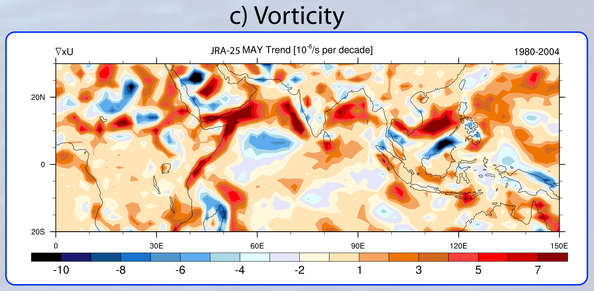
Snow cover at lower elevations, where temperatures are closer to freezing point, exhibits a marked decrease over recent decades while colder regions are more resilient to temperature increases.

b) Precipitable Water



Reliable trends in PW have become available only with the availability of RSS-adjusted SSM/I retrievals. Here, trends for June since 1988 are shown (for ocean only). Increases in PW are pervasive in the Indian Ocean and are particularly strong in the Arabian Sea.

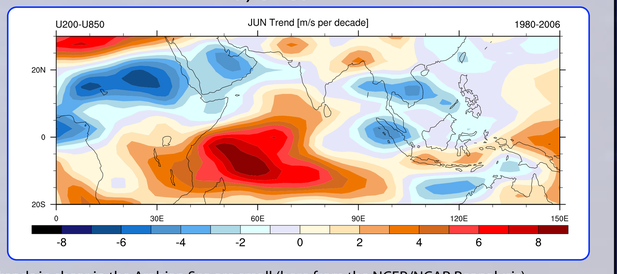
c) Vorticity



Changes in the development of the Eurasian thermal low and the resulting early season surface winds appear to be associated with a redistribution of wind stress curl in the Arabian Sea. The depiction of these vorticity trends is consistent generally across the ERA-40, NCEP/NCAR, and JRA25 reanalyses.

The impact of changes in these forcings on ocean biogeochemistry are investigated further in companion posters in the current session.

d) Shear



Trends in shear in the Arabian Sea are small (here from the NCEP/NCAR Reanalysis) though in neighboring regions, they are not. The accuracy of computed trends remains questionable as they are hindered by the conflation of both climate change and strong natural variability associated with ENSO. Also, the observational gaps in the poorly monitored upper troposphere, particularly over the southern oceans, call the reanalysis fields into question. Further analysis and inter-reanalysis comparison on trends in shear remains ongoing.

6. Discussion and Interpretation

Climate change is inherently linked to the processes that govern cyclonic activity in the Arabian Sea. **These changes are ongoing and are likely to include:**

1) the decline in Eurasian snow cover,
2) the development of the springtime temperature gradient and related vorticity fields, and
3) the moistening and warming of the atmosphere, and especially the lower troposphere, and their roles in elevating CAPE.

Here an initial diagnosis of these influences and their suggested importance during 2007 has been presented. **The results indicate potentially key roles for both dynamics and thermodynamics in constraining the annual cycle. Thermodynamic effects are likely to be dominant for 2007 as anomalies in shear do not indicate a substantial contribution to cyclonic anomalies.**

Uncertainties

Modeling studies are being developed to assist in eliminating uncertainty in interpreting causality that is endemic to diagnostic studies.

Among the key additional uncertainties that preclude an improved understanding of future cyclone trends is the uncertainty associated with the Indian monsoon and its potential climate change response - such as those projected to accompany those in aerosols and the hydrologic cycle.

Ongoing work

Ongoing work includes understanding the impact of variability in monsoon and cyclonic activity related to changes in Eurasia on the biogeochemistry of the Arabian Sea. We are developing the capability to perform a detailed modeling of the relevant interactions and dominant impacts. **This work is supported by NASA GRANT: NNX07AK82G**, *"Climate Change and its Impact on the Ecosystem of the Arabian Sea".*