Towards a new understanding of monsoon depressions

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What is a monsoon low pressure system?

- Vortex embedded in larger scale monsoon
- Diameter ~ 2000 km, moderate winds, abundant precipitation
- Transit and even form over land
- Observed in northern and southern Indian Ocean, western Pacific



Indian monsoon depressions have well-known genesis and propagation characteristics



Boos et al. 2014, QJRMS

Cold-core cyclonic vortices



Why are monsoon low pressure systems important?

- Produce about half the rainfall of much of monsoonal India, Australia
- Precursors for many tropical cyclones
- Create intense floods

Pakistan floods July/August 2010

related to depression from Bay of Bengal

about 2000 dead, \$10-30 billion loss (Aon Benfield disaster report)

NASA MODIS images

Satellite Photos of Indus River Before and After the Flood Event



Satellite image of the Indus River on August 18, 2009 (Source: NASA)



Satellite image of the Indus River on August 17, 2010 (Source: NASA)

Previous theory

- Growth: Like mid-latitude weather systems, monsoon depressions thought to obtain energy from equator-to-pole temperature gradient
 - Shukla 1977 & 1978, Goswami 1980, Mak 1983, Moorthi & Arakawa 1985
- Propagation: westward propagation thought to be controlled by low-level dynamics
 - Rao and Rajamani 1970, Sanders 1984, Chen et al. 2005

Not dry baroclinic instability

composite mean Ertel's Potential Vorticity (colors), potential temperature (contours)



Downshear tilt of PV column in all phases of life cycle is inconsistent with moist baroclinic growth



Cohen & Boos (in prep.)

Monsoon synoptic vortices and TCs have similar genesis statistics

 Poisson regression of observed genesis points on climatological mean variables, after Tippett et al. (2011) for TCs



 $\mu = \exp(\mathbf{b}^{\mathrm{T}}\mathbf{x})$

(Ditchek et al., in prep.)



longitude

vortex moves upstream in mean eastward flow ... why?

Boos et al. 2014, QJRMS

Potential vorticity structure tells a different story

suggests propagation may be governed by nonlinear mid-tropospheric dynamics

Boos et al. 2014, QJRMS

PV (colors) and climatological mean zonal wind (contours)



Propagation by self-advection ("beta drift")



Boos et al. 2014, QJRMS

Propagation by self-advection ("beta drift")



A big story: declining storm count trends in India



Cohen & Boos 2014, GRL

But that record is missing some depressions



Cohen & Boos 2014, GRL

Trend estimates



Cohen & Boos 2014, GRL

Summary

- "Low pressure systems" (e.g. monsoon depressions) are very important, yet are poorly understood and little studied since 1980s
- Steep downward trend reported in number of Indian monsoon depressions



We have shown:

- Indian monsoon depressions propagate westward by beta drift (not by QG lifting in easterly shear)
- PV structure is inconsistent with baroclinic instability/growth
- There are problems with the only dataset that shows downward trend in depression counts

There is great need for community assessments of monsoon synoptic variability in observations and models (both climate & NWP)