USE OF TOTAL COLUMN WATER VAPOR MEASUREMENTS FOR FORECASTS OF THE NORTH AMERICAN MONSOON PRECIPITATION

Presented by Yolande Serra
University of Arizona
Collaborators / Support

- Ave Arellano (UA Faculty)
- Chris Castro (UA Faculty)
- James Moker (UA graduate student)
- David Adams (UNAM Faculty)
- Arturo Quintanar (UNAM Faculty)
- Carlos Minjarez-Sosa (UNISON Faculty)

- UA project funding provided by NSF AGS grant 1261226.
- NAM GNSS/GPS Transect Experiment 2013 funding from UNAM PAPIIT grant IA101913 and the Programa de Investigación en Cambio Climatico.
- Ten (10) GPS sensors were provided by the UNAVCO equipment loan program – thanks!
- Help with GPS TPW processing by Chuck DeMets and John Braun – thanks!
Atmospheric Water Vapor (TPW)

Ends 4 March 2014 14Z

Link to Precipitation

4 March 2014  12Z

http://trmm.gsfc.nasa.gov/affinity/affinity_3hrly_rain.html
North American Monsoon Rainfall Climatology

TRMM 3B42
0.25°x0.25°
July – August 1998-2013
North American Monsoon Circulation

June

NCEP/NCAR Reanalysis
500mb Geopotential Height (m) Composite Mean

July

NCEP/NCAR Reanalysis
500mb Geopotential Height (m) Composite Mean

mid-level moisture
Gulf Surge

Strong surges associated with passage of a tropical cyclone or easterly wave near the mouth of the Gulf of California.

Weaker surges can be associated with outflow from MCSs in Mexico.

Adams and Comrie (1997)
GFS Accumulated Rainfall (global forecast at 0.5°x0.5°)

TRMM

8 July 2013 00Z to 10 July 2013 00Z

GFS

8 July 2013 12Z to 10 July 2013 12Z
NAM Accumulated Rainfall (regional forecast at 32 x 32 km)

TRMM

8 July 2013 00Z to 10 July 2013 00Z

NAM

8 July 2013 12Z to 10 July 2013 12Z
Observations in Mexico

Radar Locations

Surface Meteorological Stns
Sonora Example

No Radiosondes!
(standard for vertical profiles of atmosphere and most strongly influence weather forecasting)

http://smn.cna.gob.mx/
Hypothesis

• Water vapor measurements will improve forecasts of severe weather during the North American monsoon season.
• Test this hypothesis using GPS TPW/ZTD observations from 10 sensors placed throughout northwest Mexico during the 2013 monsoon season. Existing Suominet (suominet.ucar.edu) will also be used.
Motivation

• There is still much uncertainty about the role of tropospheric water vapor in the growth of individual diurnally driven orographic convection into organized mesoscale convective systems (MCSs) that produce severe weather and heavy rains across the NAM region.

• Forecasts of severe weather during the monsoon are not very accurate on even short (<24 hour) time scales.

• The lack of observations in Mexico affects monsoon forecasts on both sides of the border.

➢ Surface GPS can provide tropospheric water vapor measurements at high enough time resolution and under all weather conditions to help address these research and operational forecasting issues.
North American Monsoon GPS Transect (2013)

Summer 2013
- 3 month field campaign during summer monsoon.
- 10 GPS Met. stations

Goals:
- Observe MCS development over Sierra Madre at high temporal resolution.
- Assimilate TPW/ZTD into WRF
- Surface flux measurements (green up)
UA Monsoon Discussions 2013

• UA graduate students, led by Jamie Moker, participated in weekly monsoon discussions:
  ➢ http://monsoonwx2013.wordpress.com
Analysis of GPS TPW and Rainfall

Manaus GPS Network

Cuauhtemoc Site, 2013

Images courtesy of Dave Adams
# 2013 Monsoon Synoptic Activity

<table>
<thead>
<tr>
<th></th>
<th>GSs</th>
<th>TCs</th>
<th>EWs</th>
<th>IVs</th>
<th>BDCFs</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSs</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCs</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EWs</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IVs</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>BDCFs</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

GS – gulf surge  
TC – tropical cyclone  
EW – easterly wave  
IV – inverted trough  
BDCF – back door cold front

---

![Graph showing comparison between 2004 and CLIMO monsoon activity](image-url)
2013 Monsoon Rainfall Events (TRMM)

Case study #1: 8-9 July
2013 Transect Precipitation (gauge)

Case study #1: 8-9 July
NWS Tucson graphic issued July 8 at 12Z

More Active Monsoon Pattern This Week

A Surge of Moisture, assisted by Tropical Storm Erick near the tip of Baja will move into Arizona over the next 24 hours and remain through the week.

IMPACTS: More Widespread Showers and Thunderstorms including locally heavy rainfall this week.

Issued Monday, Jul 8, 2013 at 5:35 am MST
National Weather Service - Tucson, AZ
North American Monsoon TPW

Ends 11 July 2013  00Z

Morphed composite: 2013-07-08 00:00:00 UTC

Inverted Trough (IV) on July 9, 2013

500 mb Heights (dm) / Temperature (°C) / Humidity (%)

monsoon ridge

inverted trough

inverted trough convection
TRMM Accumulated Rainfall
GFS Accumulated Rainfall

GFS, 0.5 degree

WRF-GFS, 2.5 km
NAM Accumulated Rainfall

NAM, 32 km

WRF-NAM, 2.5 km
Data Assimilation Activity

• Ensemble Sensitivity Analysis
  • Verify model derived correlation structures

• Observation Simulation System Experiments (OSSEs)
  • Assimilate synthetic data for testing the DA algorithm
  • Find optimal GPS site locations

• Retrospective Assimilation of GPS Obs
  • Explore TPW vs ZTD assimilation

• Model Hindcast Experiments for 2013
  • Test skill of forecasts with updated initial conditions
Jalisco Network Case Study – Hurricane Andres 2009

21-24 June 2009

Data and processing courtesy of Chuck DeMets.
Spatial & Temporal Correlation of GPS ZTD, Hurricane Andres 2009
Summary

• Use 2013 Transect data as a “proof of concept” for the use of surface GPS TPW/ZTD for improving monsoon forecasts of severe weather.

• Similar approach being used by Angelyn Moore and colleagues for southern California monsoon events (see Poster 44).

• Non-homogeneous data assimilation scheme 1) maximizes the benefit of integrated measurements like TPW/ZTD and 2) optimizes placement of GPS sensors through sensitivity studies.

• 2013 was an active season providing a good data set for exploring the fundamental aspects of TPW and deep convection.
Looking Ahead

- TlalocNet offers the infrastructure for GPS TPW measurement installations throughout Mexico providing data in realtime for forecasting and research.
- Suominet, TlalocNet and COCONet together form a continuous network of TPW sensors for Central and North America useful for the study of moisture sources to the region and their variability.
- The all weather capabilities and stability of the TPW measurements from GPS additionally make them useful for climate monitoring.