# Determining gulf surge contributions to North American monsoon precipitation using observational and reanalysis data

**Jennifer Stutler**[1*], Christopher L. Castro[1], Hsin-I Chang[1], Michael Leuthold[1], Carlos Carillo[1], and John J. Brost[2]

1 Department of Atmospheric Sciences, University of Arizona, Tucson, Arizona

2 National Weather Service, Tucson, Arizona

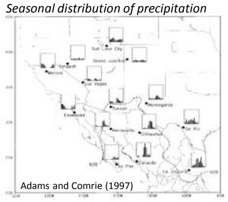
Corresponding Author E-mail: stutler@atmo.arizona.edu

## Overview and Purpose

The North American Monsoon (NAM) contributes nearly half of the annual precipitation in the desert Southwest. Warm season northward surges of low-level, cool, moist air from the Gulf of California, or gulf surges, are an important moisture source for monsoon thunderstorms west of the continental divide. This investigation is designed to examine the relationship between NAM precipitation and the gulf surge. An objective methodology is used for identifying gulf surges in Global Historical Climate Network (GHCN) surface data from the Marine Corps Air Station (MCAS) in Yuma, Arizona, with criteria consistent to National Weather Service operational practice. Surge day wind directions are used to verify the gulf surge related moisture transport for a list of surge onset dates. Surge-associated precipitation is then considered, using the Stage IV combined rain gauge and radar-derived precipitation product. The methodology for characterizing gulf surges will later be applied to dynamically downscaled data, from an atmospheric reanalysis and select IPCC global climate change projection models. The presence of a gulf surge will help define extreme weather event days where the atmospheric environment is favorable for thunderstorms, which will be simulated using very high resolution modeling at a spatial scale sufficient to explicitly resolve convection.

http://www.wrh.noaa.gov/twc/monsoon/monsoon_NA.php

*Seasonal distribution of precipitation*




## Motivation

Gulf surges provide an important source of low level moisture during the monsoon in the Southwest. Identifying gulf surges in observational data and simulating them with a high resolution numerical weather prediction model is essential to reasonably forecast monsoon precipitation. In Arizona, gulf surges facilitate outbreaks of severe, organized monsoon thunderstorms that affect Tucson and Phoenix, as well as the low desert areas south and west of these cities.

*Monthly monsoon precipitation (in) in Yuma, Arizona: 2002-2010*

| Year | June | July | August | September | Total |
|---|---|---|---|---|---|
| 2010 | 0.00" | Trace | 0.61" | Trace | 0.61" |
| 2009 | 0.00" | 0.11" | 0.01" | 1.64" | 1.76" |
| 2008 | 0.00" | 0.74" | 0.59" | 0.16" | 1.49" |
| 2007 | 0.00" | Trace | 0.19" | 1.79" | 1.98" |
| 2006 | 0.04" | Trace | Trace | 0.20" | 0.24" |
| 2005 | 0.00" | 0.68" | 1.82" | Trace | 2.50" |
| 2004 | 0.00" | Trace | 0.00" | 0.00" | Trace |
| 2003 | 0.00" | 0.02" | 0.29" | 0.02" | 0.33" |
| 2002 | 0.00" | 0.00" | Trace | Trace | Trace |
| Average | 0.01" | 0.23" | 0.53" | 0.52" | 1.29" |

http://www.wrh.noaa.gov/twc/monsoon/monsoon_yum.php

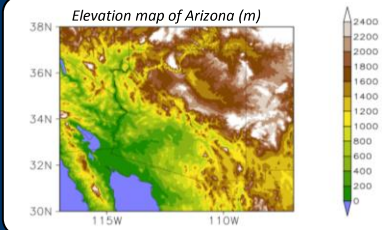
## Data

- Hourly GHCN surface dew point temperature, wind direction, and wind speed recorded at MCAS in Yuma, Arizona, from 1991-2010
- Daily CPC unified gauge-based analysis of daily accumulated precipitation gridded at .25 degrees from 1991-2010 (results not shown)
- Hourly NCEP/EMC Stage IV radar derived surface precipitation gridded at 4km from 2002-2010

## Methodology to Objectively Identify Gulf Surges

Using hourly station data from Yuma MCAS, days with gulf surges are selected using objective criteria consistent with Tucson NWS operational practice. A surge event occurs when the average daily (24 h) dew point temperature is greater than or equal to 18°C and the surface wind direction is between 160° and 180°. 74 surge events between 15 June – 30 September in the period 1991-2010 are identified. Precipitation associated with these surge events is considered in both CPC daily accumulated precipitation and the NCEP/EMC Stage IV product. Only the results from the analysis of Stave IV data are shown here.

*Elevation map of Arizona (m)*




**Frequency of wind directions for gulf surge event days Yuma, Arizona: 1991-2010 (Total Number of Hours)**

**Frequency of wind directions for all days during the monsoon period JJAS Yuma, Arizona: 1991-2010 (Number of Hours)**

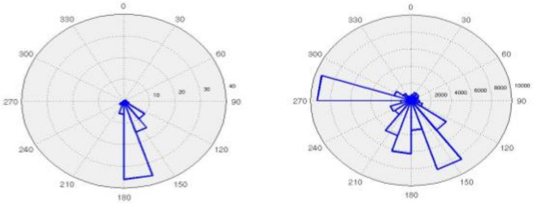


*Figure 1: Wind rose plots for Yuma MCAS considering only days with gulf surges (left) and total monsoon season climatology (right).*

**2003: 1 recorded surge event Dry to average monsoon year**

**2008: 3 recorded surge events Wet monsoon year**

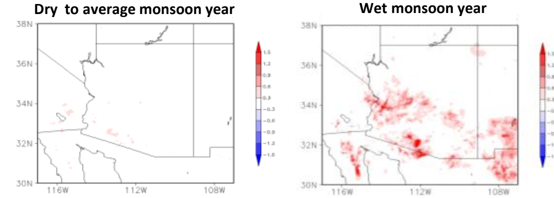


*Figure 2: Average gulf-surge associated precipitation (mm day$^{-1}$) in 2003 vs. 2008, considering Stage IV product. Number of surge events in each year indicated.*

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## Average gulf-surge related precipitation in Arizona

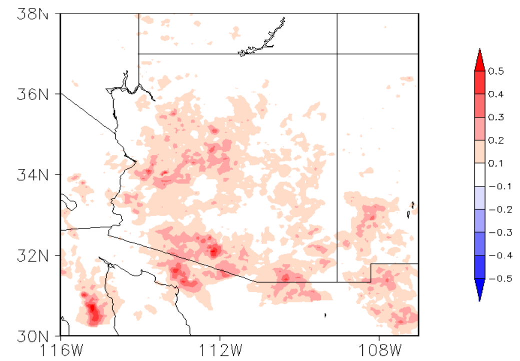


*Figure 3 : Difference in hourly precipitation (mm day$^{-1}$) due to gulf surges and monsoon climatology precipitation for 2002-2010, using Stage IV product.*

## Average gulf surge-related precipitation over a convective diurnal cycle

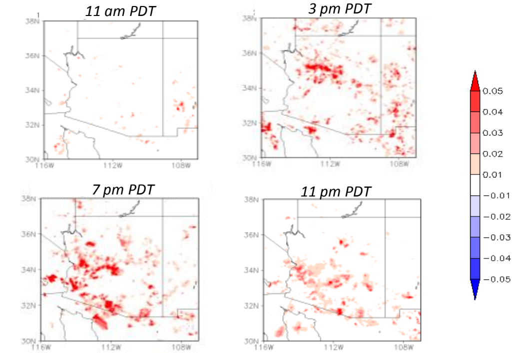


*Figure 4: Differences in gulf surge-related and monsoon climatological precipitation (mm hr$^{-1}$) in Stage IV data, referenced to Pacific Daylight Time (PDT)*

## Conclusions

- Considering NWS-based operational criteria, gulf surges can be very effectively defined using surface meteorological station data from Yuma, Arizona.
- Gulf surges are associated with enhanced monsoon precipitation across Arizona, but particularly in areas to the south and west of the Mogollon Rim, in the urban areas and low deserts.
- During gulf surges in Arizona, there is an intensified diurnal cycle of convection. Thunderstorms organize and generally propagate south and westward from their initiation point along the Mogollon Rim. The relatively lower mountain ranges in southwest Arizona also become favorable spots for local thunderstorm development.