The Use of Large-Scale Climate Data to Predict Drought, River Flows, and Vegetation Over Central-Southwest Asia

Matthew Barlow
University of Massachusetts - Lowell, Mathew_Barlow@uml.edu

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The use of large-scale climate data to predict drought, river flows, and vegetation over Central-Southwest Asia

Matt Barlow

*University of Massachusetts Lowell*
Where is “Central-Southwest Asia”?

Severe Drought, 1998-2001

Number of consecutive years the precipitation deficit was in the lowest fifth of the record.
Background: Climate of Central-Southwest Asia

Wet in winter, dry in summer

Topography (km)

Cold Season Precipitation (Nov-Apr)
Contour Interval: 15cm

Growing Season Vegetation (NDVI)

Warm Season Precipitation (May-Oct)
Contour Interval: 15cm
Complex Hydrology with Societal Impacts

Primary Rivers

Shrinking Aral Sea

Note that the rivers and watersheds cross all the countries of Central Asia.
Largely Arid, Drought-Sensitive Region

Impacts, 1998-2001 Drought

The severity and spatial extent of the drought—the worst drought in the region for the last 50-100 years—resulted in exceptionally severe impacts across a wide range of sectors. More than 60 million people were affected, with economic losses in the billons of dollars. Several aspects of the drought’s impacts will be felt for decades. A partial list of impacts includes:

Health: Large increases in the incidence of polio, cholera, diphtheria, typhoid, and tuberculosis were reported, particularly in refugee camps.

Agriculture: In 2001, half of Tajikistan’s grain crops failed. In Afghanistan, rain-fed crops failed completely in many regions and irrigated crops were drastically reduced (no water for irrigation). In Pakistan’s Balochistan province, the cropping areas were reduced by 45% from 1999-2003.

Livestock: In Iran, an estimated 100,000 head of livestock died in 2000.

Water resources: National water reserves were down by 45% in Iran by July 2001.

Environment: The internationally-recognized Sistan wetland, home to more than 150 species of waterfowl, including 8 globally-threatened species, was almost completely desiccated. Much of the vegetation died or was collected for fuel, contributing to erosion and significant movement of sand.

Economics: During the first two years of drought in Afghanistan, household debt doubled and assets decreased by half.

Agrawala et al. 2001, Barlow et al. 2006
Regional Drought Linked to Tropical Ocean

Simplified Drought Mechanism

Thermodynamic forcing of vertical motion and changes to moisture transport are both important.

Tropical link is clear but there appear to be multiple dynamical pathways for influence on region.

Proposed in Barlow et al. (2002), related analysis in Tippett et al. (2003), Barlow et al. (2005, 2007), Barlow and Tippett (2008), Barlow (2011), Hoell et al. (draft)
Hypothesis: Two Paths for Pacific Influence

Both areas of tropical convective anomalies in the Pacific appear to affect SW and Central Asia. Relative importance may be related to strength of West Pacific SST anomaly.

Shaman et al. (2004)
How does regional and large-scale flow influence precipitation during winter?

Changes to regional winds have a large impact on moisture transport into the region.

Winter change associated with subsequent river flow variability.
Tropical Ocean Links Give Seasonal Predictability of Precipitation

There are various ways of making use of these links for prediction, including CCA on both observed and forecast fields, and in multi-model contexts. To date, cross-validated skill for seasonal forecasts of precipitation is robust but somewhat modest.

Tippett et al. 2003, 2005
Importance of Snowmelt Gives Even Better Predictability of River Flows, Vegetation

24 River Flow Stations, 36 Years

Local Seasonal Cycle (normalized)

PRECIP (Black), RIVER (BLUE), NDVI (GREEN)
And Large-Scale Climate Data Sufficiently Captures Snow Pack for River Forecasting

Nov-Mar 200hPa U and precipitation

Apr-Aug River Flows

(Using NCEP reanalysis/CDAS wind and model precipitation for ease and consistency in operational use.)

Barlow and Tippett 2008
Amu Dary and Syr Darya Forecasts

Stringent Test: all forecast parameters fixed prior to 1986, then applied to the 1986-2003 period. Forecast of Apr-Aug peak flows made in first week of Apr.

Forecast (open circles), Observations (filled)

Barlow and Tippett 2008
Growing-Season Vegetation Can be Forecast With the Same Approach

MAY-AUG

8km NDVI Cor

Max. Corr.: 0.94

Currently: breaking skill down by vegetation type, cross-validating
Experimental NDVI Forecast For This Year
At Subseasonal Time-scales, MJO Has Large Influence

In Afghanistan, floods closely linked to MJO phase

MJO circulation well-represented by Gill-Matsuno dynamics only if a mean wind is added

Barlow et al. 2005, 2011
Drought AND Heavy Precipitation
MJO Can Reverse Regional Pattern For Individual Months

Example: 2007-2008 Cold Season

1/5 to 1/2 of Seasonal Mean
2-6 Times Monthly Mean

Season:
• In Iran, power shortages due to lack of hydroelectric production
• Iran buys US wheat for first time in 27 years
• Afghan wheat down 60%
• Etc., etc.

Month:
• Heavy snow and avalanches in Afghanistan: 355 fatalities reported, 60,000 livestock lost (UN OCHA)
• Heaviest snowfall in Iran for more than a decade, double-digit fatalities

Hoell et al. (draft)
Drought Pattern in 1998-01, 2008 and 2010-11

Structure of La Nina was Evident in Nov 2007 and 2010
Summary

• Central-Southwest Asia has severe drought impacts

• Two sources of predictability: (semi) predictable modes of large-scale climate variability at both seasonal and intraseasonal timescales, and the importance of the snow pack to warm season river flows and vegetation.

• Satellite and large-scale climate data can be used to provide a considerable amount of high-resolution local information about the region, including snowpack

• Different aspects of predictability can be combined to provide information at a range of time-scales from seasonal to daily, but communication to the relevant decision-makers in the region has proven difficult.
Orientation and River Data

Study Regions

River Stations

Precipitation  Winds

Rivers
Cross-validated river flow forecast skill

Cross-validation consists of sequentially leaving out a year from the data used to calculate the patterns and then forecasting for that year. This allows an evaluation of the forecasting skill on independent data.

CCA results for river flow station data; cross-validated correlations are shown in the right-most column.

<table>
<thead>
<tr>
<th>Station Name</th>
<th>River Name</th>
<th>Drainage Area (km²)</th>
<th>Elevation (meters)</th>
<th>Apr-Aug fraction of annual river flow</th>
<th>CCA correlation</th>
<th>Cross-validated correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gava</td>
<td>Gvasay</td>
<td>657</td>
<td>1063</td>
<td>0.83</td>
<td>*-0.85</td>
<td>*-0.61</td>
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<td>2. Khujakent</td>
<td>Ugam</td>
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<td>741</td>
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<td>3. Shuchand</td>
<td>Murgab</td>
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<td>90</td>
<td>0.58</td>
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<td>*-0.08</td>
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<td>4. Barchadiv</td>
<td>Murgab</td>
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<td>2510</td>
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<td>-0.26</td>
<td>+0.05</td>
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<td>5. Khorog</td>
<td>Gunt</td>
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<td>2070</td>
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<td>*-0.69</td>
<td>*-0.43</td>
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<td>6. Alibegi</td>
<td>Khanaka</td>
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<td>1004</td>
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<td>*-0.61</td>
<td>*-0.44</td>
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<td>7. Mouth of</td>
<td>Lyangar</td>
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<td>3165</td>
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<td>-0.25</td>
<td>+0.07</td>
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<td>8. Dashnabad</td>
<td>Obizarang</td>
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<td>*-0.38</td>
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<td>9. Pinen</td>
<td>Pashrut</td>
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<td>*-0.54</td>
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<td>1279</td>
<td>0.77</td>
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<td>*-0.40</td>
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<td>11. Mouth</td>
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<td>1041</td>
<td>0.74</td>
<td>*-0.75</td>
<td>*-0.48</td>
</tr>
</tbody>
</table>

Values greater than 0.5 are highlighted in yellow, including 10 of the 25 stations.
Even Something of an MJO Repeat in Jan 2011

Season:
• Reuters: Hungry Afghanistan faces prospect of drought in 2011: “Fresh in the memory of many Afghans is the crisis of 2008, when a surge in global prices combined with local drought to push an additional 5 million people into hunger.”

Month:
• Flooding in Jeddah, Saudia Arabia -- more than 10 fatalities, more than 2000 people temporarily displaced
Afghanistan, 2007-2008 vs. 2006-2007

USDA Foreign Ag Report for Afghanistan

NDVI, Apr 2008 vs. Apr 2007


Central Afghanistan: Winter Snow Pack Comparison

http://www.pcad.fas.usda.gov/highlights/2008/08/Afghanistan%20Drought/