INTERANNUAL VARIATIONS IN WARM SEASON STREAMFLOW IN NORTHWEST MEXICO

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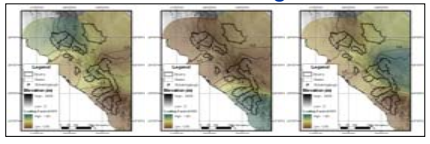
ABSTRACT

Hydroclimatological analysis of the North American Monsoon region of northwest Mexico reveals significant regions of seasonal precipitation and streamflow coherence. In this work, inter-annual variations in regionalized rainfall-runoff relationships are explored. Modulation of precipitation by large-scale forcing mechanisms such as tropical and North Pacific sea surface temperatures seems to have a non-linear effect on runoff generation whose response varies by region. Analyses reveal that the El Nino-Southern Oscillation (ENSO) exerts a modest but statistically significant influence on NAM streamflow. Different ENSO indices exhibit markedly different correlation structures with NAM sub-regions. The occurrence of ENSO also has a significant impact on the partitioning of streamflow between the summer and winter seasons. The summer ENSO influence is explained, in part, by changes in the lower tropospheric pressure and wind fields. These changes result in modest increases in moisture availability (higher PW) fields during La Nina episodes vs El Nino episodes. Based on these results, the effects of ENSO variability need to be accounted for in applying regional downscaling techniques to parent forecast models which have difficulty representing warm season ENSO responses.

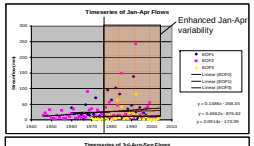
Monsoon Streamflow Regionalization



• VARIMAX rotated EOF analysis of seasonal (JAS) streamflow reveals three distinct regions of coherent streamflow variability (EOF1 – north, EOF2 – south, EOF3 – east: EOFs explain ~ 71% of the JAS variance)

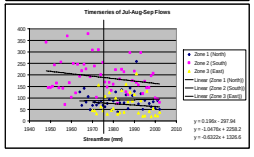
• Nearly identical EOF analysis of JAS precipitation reveals three very similar regions (explain ~ 86% of the JAS variance)

Trends in Seasonal Streamflow



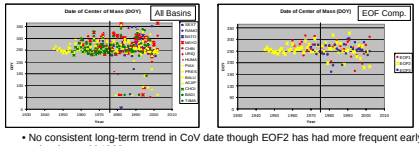
Linear Trend in Flow Volume

Region	Jan-Apr (mm/yr)	Jul-Sep (mm/yr)
EOF1	0.149	0.196
EOF2	**0.456**	**-1.048**
EOF3	0.091	**-0.632**



• Statistically significant (@95%) increasing (decreasing) long term trends cool (warm) season streamflow apparent in EOF region 2 and for decreasing cool season flow in EOF3

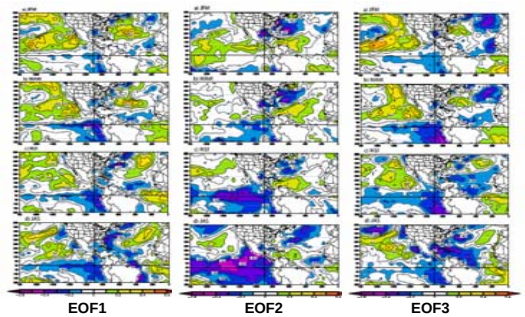
Annual Streamflow Center of Volume Date

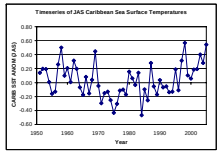


• No consistent long-term trend in CoV date though EOF2 has had more frequent early peaks since mid 1990s

• Marked increase in CoV date variability and early season (< DOY 200) since 1976-1977 climate shift (PDO-shift) most evident in individual basins

Seasonal Evolution of Correlation Between JAS Streamflow and Sea Surface Temperatures





• For each EOF region there is a pronounced seasonal evolution of the correlation structure between JAS streamflow and lead seasons of SST

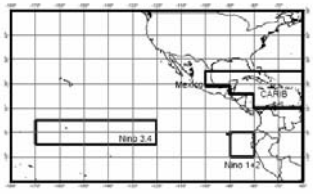
• In EOFs 1 (north) and 3 (east) the warm North Pacific SST at 6 months lead and cool eastern tropical SST (i.e. Nino region 1+2) at 2-4 months lead correlate with above normal JAS streamflow

• EOF2 (south) exhibits a very different pattern where the concurrent, cool JAS SSTs in the tropical Pacific are negatively correlated with JAS streamflow. This suggests that EOF2 JAS streamflow is in phase with La Nina events in the preceeding spring and concurrent JAS period.

• EOF3 (east) also exhibits a modest correlation with SSTs in the Caribbean/Intra-America Seas region during JAS. As shown above SST variability in this region is dominated by a decadal scale cycle.

JAS Streamflow Relation to ENSO

Given the correlation structures above we now explore further the relationship between tropical SST variations and JAS streamflow characteristics in northwest Mexico.



SOI/N3.4 : Clear evolution towards stronger correlations at 'decreasing' lags in all regions

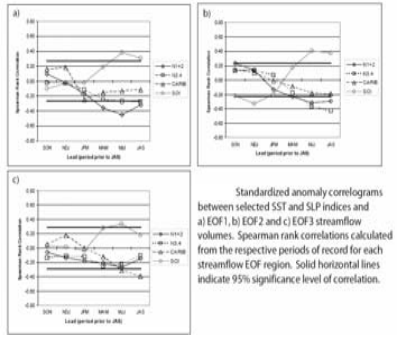
• Peak correlations occur with EOF2 (sig. @ 95% level) during 2 month lead and concurrent period

• Sign of correl. indicates that higher flows occur during La Nina (high SOI) and low flows occur during El Nino (low SOI)

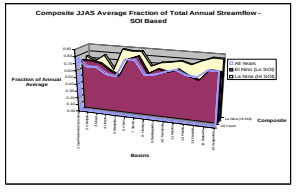
Nino 1+2 : EOF 1(north) exhibits modest neg. correlation with N1+2 at 2 month lead and concurrent periods

• EOF3 (east) also exhibits weak pos. correlation with N1+2 in MJJ

CARIB : Only EOF3 (east) exhibits a sig. correl and 2 month lead and concurrent periods



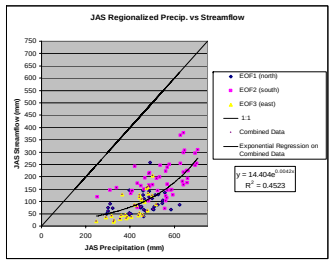
Standardized anomaly correlograms between selected SST and SLP indices and a) EOF1, b) EOF2 and c) EOF3 streamflow volumes. Spearman rank correlations calculated from the respective periods of record for each streamflow EOF region. Solid horizontal lines indicate 95% significance level of correlation.

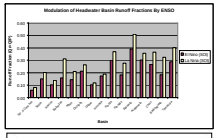


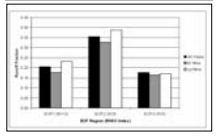
- Composite averages ofJJAS fraction of total annual streamflow also reflect ENSO variability
- High SOI events yield higher warm season fractions of annual streamflow than do low SOI events
- These differences are most expressed in the southernmost basins (EOF2) while most basins in the north (EOF1) show only small changes
- Nino3.4 (not shown based composites show stronger influence in northern (EOF1) and eastern (EOF3) basins

Variability of the JAS Runoff Fraction

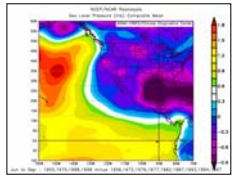
- Relationship between JAS P and Q is somewhat non-linear and the runoff fraction (Qr=Q/P) exhibits substantial interannual variability
- Tendency for Qr to trend towards the 1:1 line (increase in value) with higher precipitation values (most pronounced in EOF2(south) which receives the most rainfall)
- Indication that in-basin abstractions are likely being met so that basins produce runoff with higher efficiency with greater seasonal precipitation
- Compositing EOF Qr values by strongest correlate (SOI-EOF2 and 3, N1+2-EOF1) it is shown that higher JAS runoff fractions occur with La Nina than with El Nino
- Difference in composite means significant @ 90% level in EOFs 1 and 2

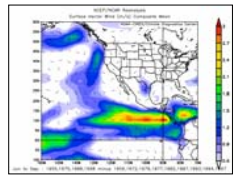




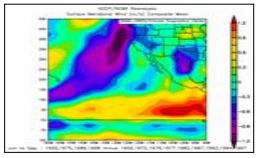


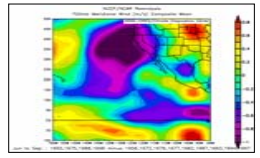
A Mechanism for ENSO-Streamflow Variability





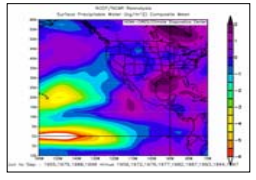
- Subtracting SOI-based El-Nino from La-Nina composite years yields:
  - Enhanced Pacific-North American continent SLP gradient
  - Weaker E. Pac. Trade winds south of Mexico occur during La Nina compared to El Nino along with increased meridional component
  - Increased meridional (inland) winds into Mexico during La Nina present up to mid-levels (though increasingly confined to the coast)

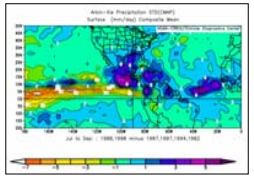




• During high SOI modestly enhanced PW field over much NAM region (except NE Chihuahua) with modestly enhanced differences in southern regions of Mexico

• Precipitation composites also exhibit increased precipitation across Mexico (particularly south) and the southeastern U.S.





Conclusions:

- Analyses reveal that ENSO exerts modest but significant influence on NAM streamflow
- Different ENSO indices exhibit markedly different correlation structures with NAM sub-regions
- The ENSO influence in the southern NAM region is explained, in part, by changes in the lower tropospheric pressure and wind fields. These changes result in modest increases in moisture availability (higher PW) fields during La Nina episodes vs El Nino episodes.
- JAS runoff fractions and the seasonal partitioning of annual flow also appear to be significantly modulated by ENSO variability

References and Publications

Brito-Castillo, L., A. Leyva-Contreras, A.V. Douglas, D. Lluch-Belda, 2002. Pacific decadal oscillation and the filled capacity of dams on the rivers of the Gulf of California continental watershed. *Atmosfera*, **15**, 121-138.

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Acknowledgements

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