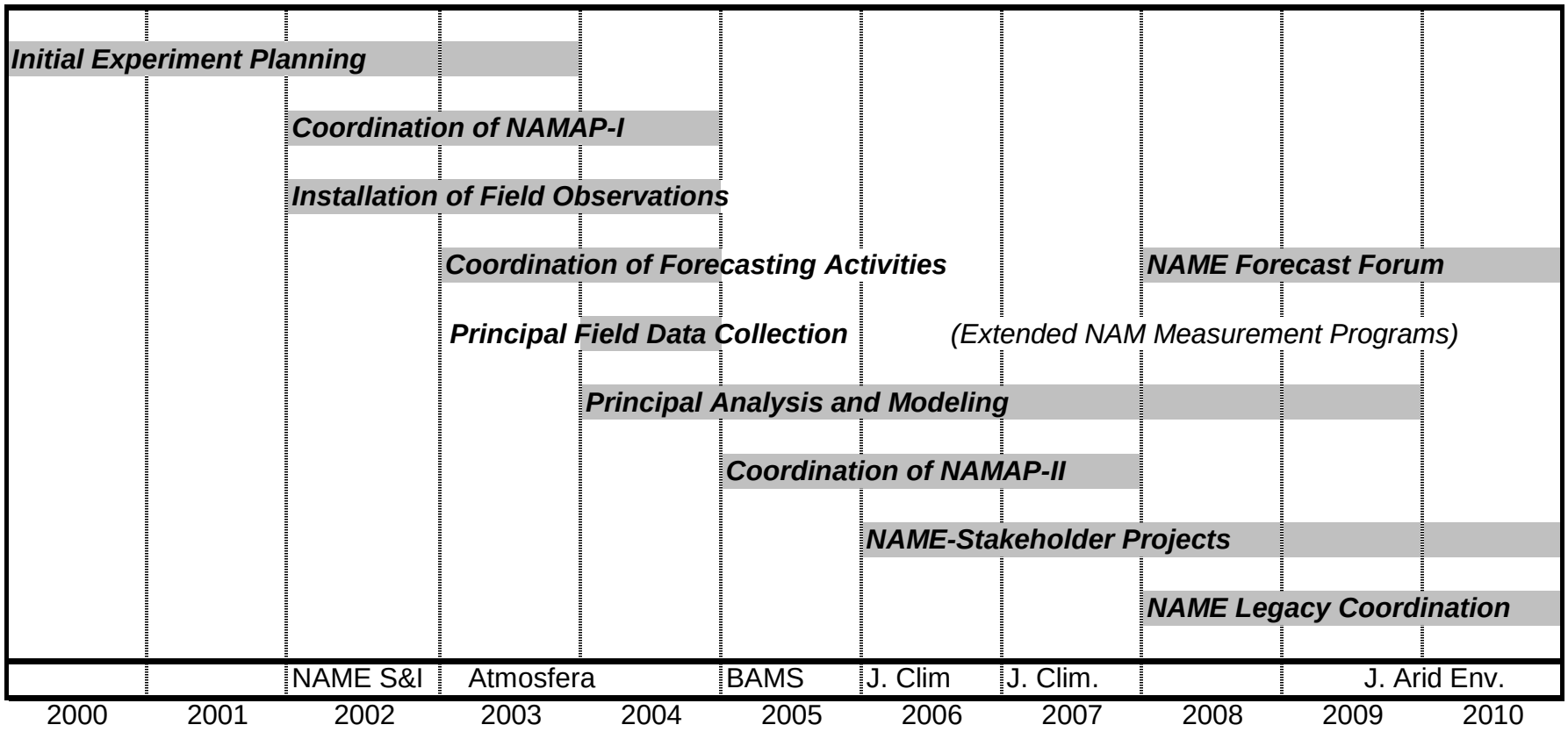
North American Monsoon Research Advances and Future Priorities

David J. Gochis
National Center for Atmospheric Research
Boulder, CO USA

gochis@rap.ucar.edu

Programmatic Review

NAME Program Timeline



- **NAME Data Archive (www.eol.ucar.edu/projects/name)**

Major future plans/activities: NAME

- During sunset: Finalize linkages to ongoing NAME Legacy Programs and other warm season precipitation initiatives:
  - NAME Forecast Forum
  - Intra-America Seas group

- Promote goals of the VAMOS Extremes Panel (CLIVAR Cross-cut, D. Gochis, T. Cavazos) through N. American Monsoon research community
- Integrate NAME climate/climate change assessments with the CLIVAR Anth. Climate Change Panels (CLIVAR Cross-cut, T. Cavazos)
- Submitted inquiry for publishing a N. American Monsoon review article in Reviews of Geophysics (Jan. 2010)

Prepared by: D. Gochis, Chair NAME-SWG

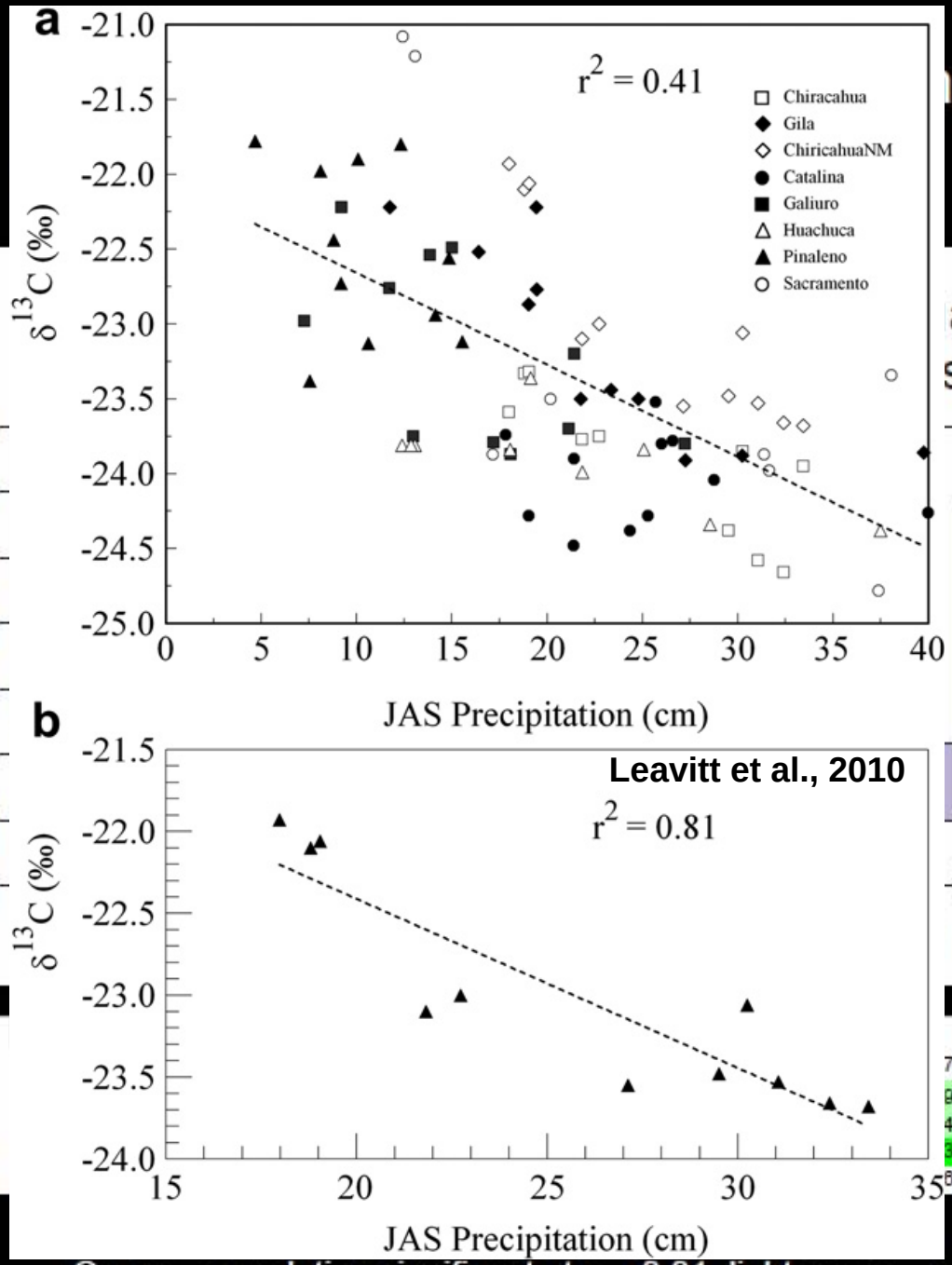
Report on N. American Monsoon Research:

- Report on Integrating Themes:
  - Basic process research
  - Predictions
  - Applications
- Synthesis publications and fora
- Emerging research priorities

The North American Monsoon Research Advances:

- AGU special session on N. American Monsoon climate processes (over 20 submissions)
  - Connie Woodhouse et al. described a new tree ring chronology from Mexico aimed at partitioning warm vs. cool season precipitation variability for the past 300-500 yrs.

Relationship between annual tree growth and monthly precipitation



Leavitt et al., 2010

Chihuahua, Mex Div 5
1921-1992
LATEWOOD WIDTHS

TINlw
TABlw
CIAlw
CBAlw
BSClw

	JUL	AUG	SEP
77	0.233	0.228	0.136
94	0.268	0.042	-0.148
46	0.277	0.053	-0.089
39	0.039	-0.020	-0.008
68	0.141	-0.050	-0.065

Green = correlation significant at $p < 0.01$, light green = $p < 0.05$

The North American Monsoon Research Advances:

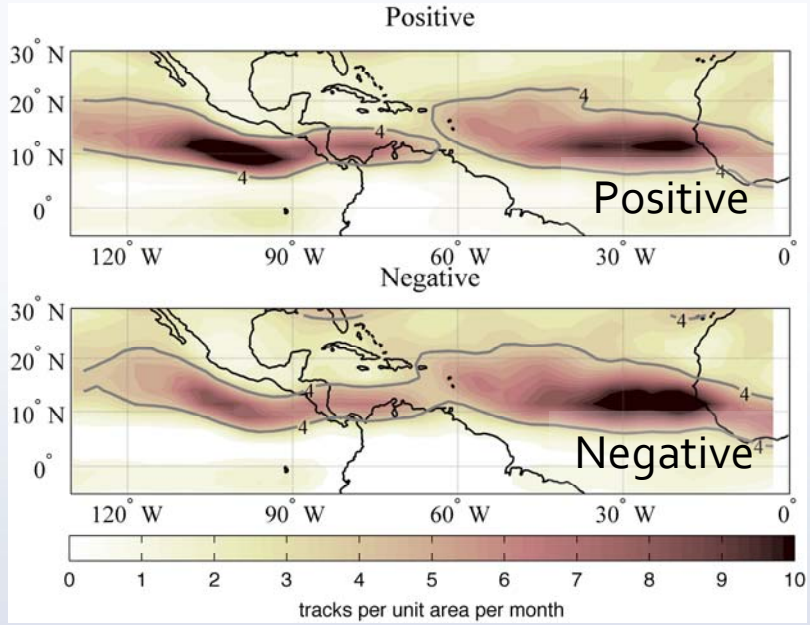
- AGU special session on N. American Monsoon climate processes (over 20 submissions)
  - Connie Woodhouse et al. described a new tree ring chronology from Mexico aimed at partitioning warm vs. cool season precipitation variability for the past 300-500 yrs.
  - E. Vivoni reported on ongoing observational activities in the R. Sonora/R. San Miguel related to land-atmosphere exchange processes
  - Y. Serra summarized new work on intra-seasonal variability in the IAS-NAM region related to EW and tropical storm tracks

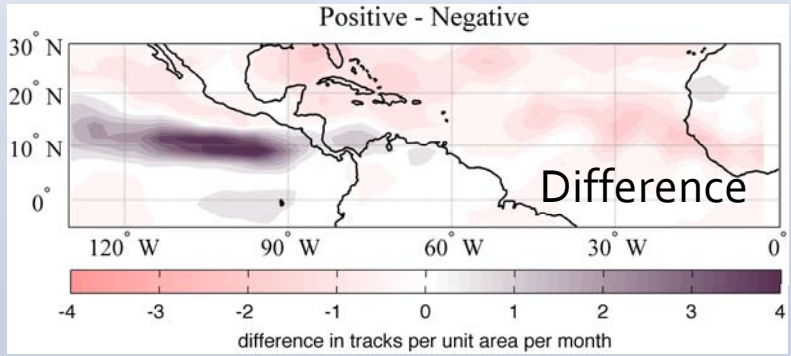
Easterly Wave Activity and the CLLJ

More tracks in the west Caribbean and tropical northeast Pacific when CLLJ is strong.

Affect extends far off the coast, suggesting Papagayo Jet is also important and acts as an extension of the CLLJ in the East Pacific as suggested by Amador et al. (2006).

700 hPa Track Density May-Nov 89-07

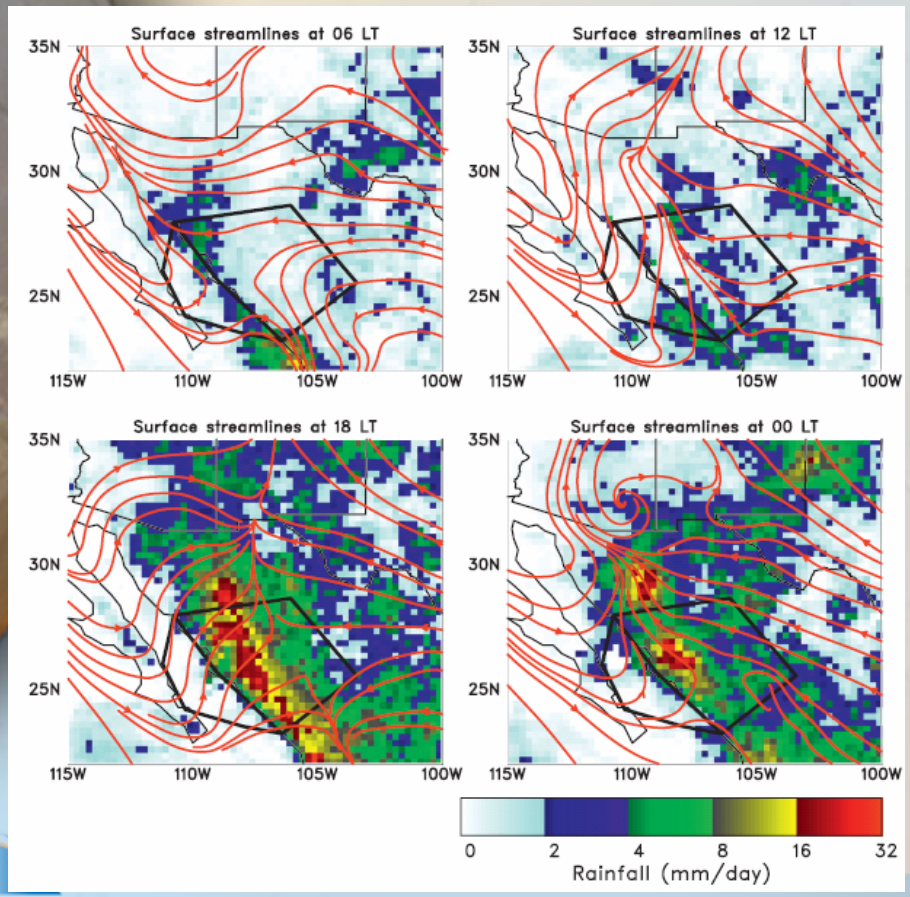




Serra et al. (2009, submitted to J Clim.)

The North American Monsoon Research Advances:

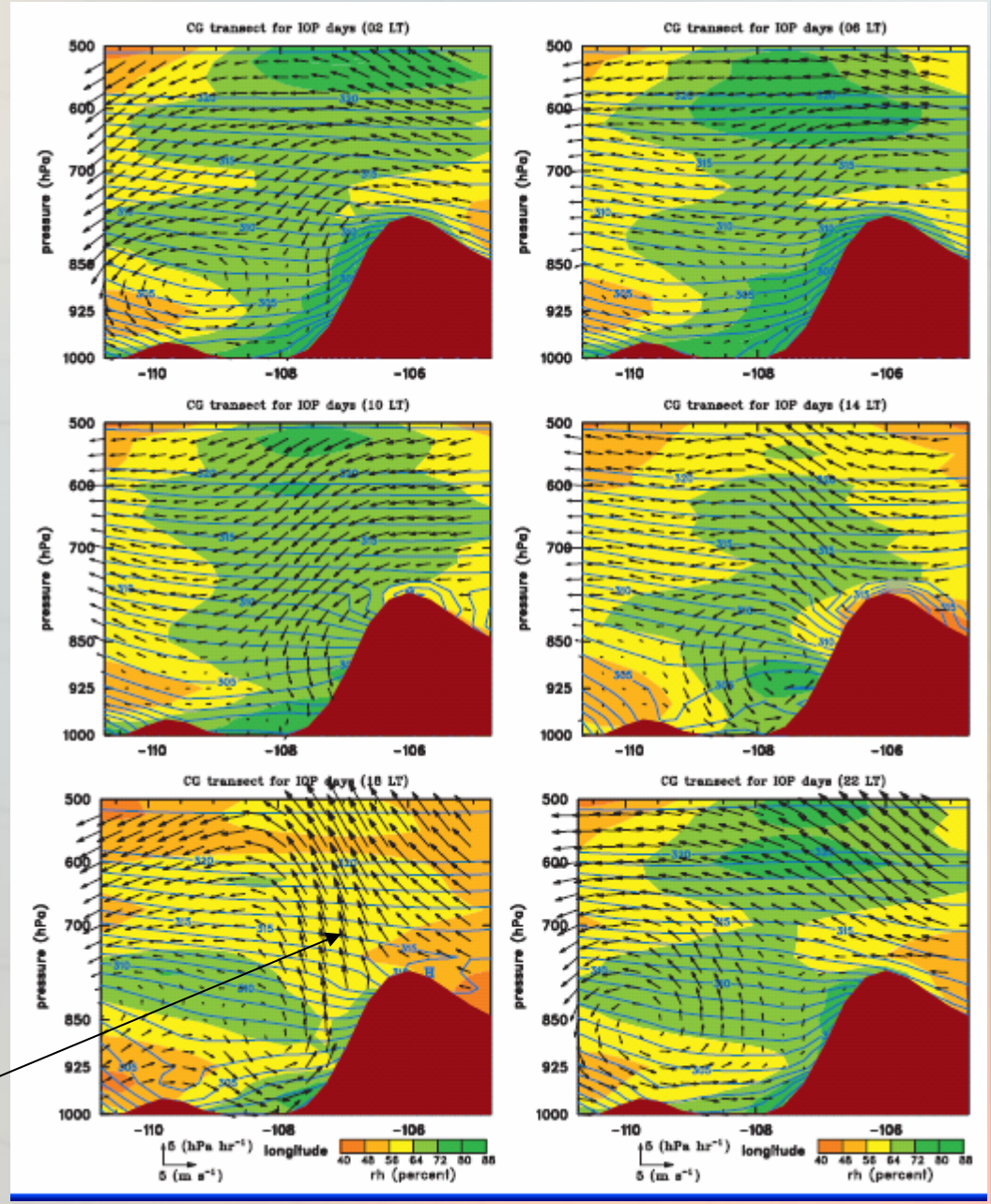
- Johnson et al. (2010) J. Climate Special Issue on 'TRMM Diabatic Heating'



• Diurnal cycle of surface streamlines highlighting evolution of pattern with respect to terrain fields and precipitation patterns
• Enhancement of convergence line along peak topography (12LT)
• Max. TRMM precip. east of high topography (18LT)
• Coastal development with northward/northwestward component near/after sunset (00LT/06LT)…open questions?

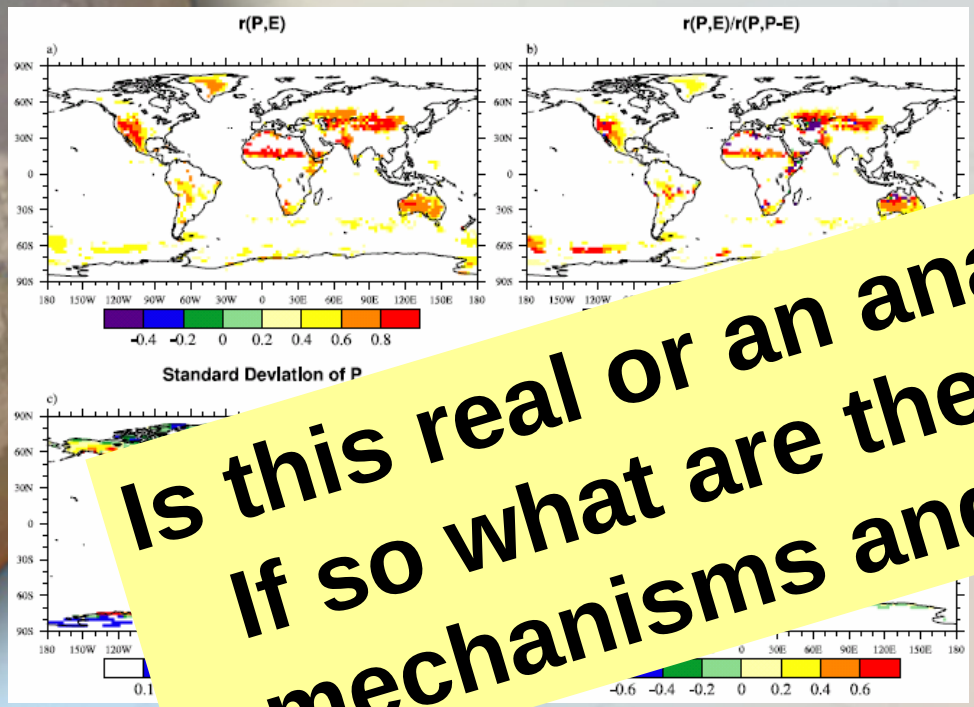
The North American Monsoon Research Advances:

- Johnson et al. (2010) J. Climate Special Issue on 'TRMM Diabatic Heating':
  - Main periods of SMO ascent 14-22LT
  - Interesting lee-side, convective-shear rotor at 14LT
  - Nocturnal/morning descent over western SMO
  - Weak, broad nocturnal ascent over GoC
  - !!!Major issue with afternoon humidity profile over SMO!!!

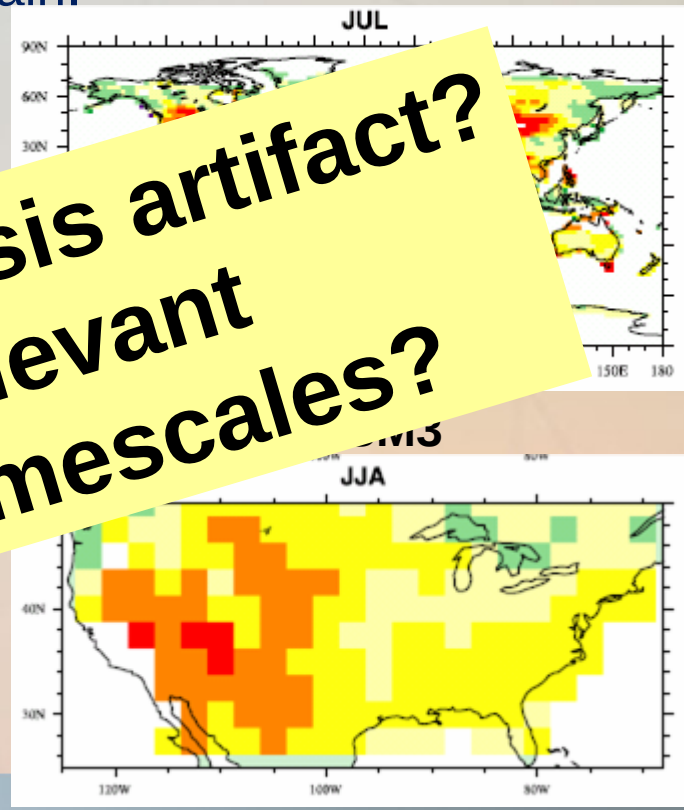


The North American Monsoon Predictions Activities:

- Land-atmosphere coupling diagnostics:
  - Last year reported on veg. green-up effects (Vivoni et al., 2008) and soil depth effects (Gochis et al., 2010)
  - Zeng et al. (2010) show significant 'coupling-strength' (Γ) over much of NAM regional domain.



ECMWF



VIC

Is this real or an analysis artifact?
If so what are the relevant mechanisms and timescales?

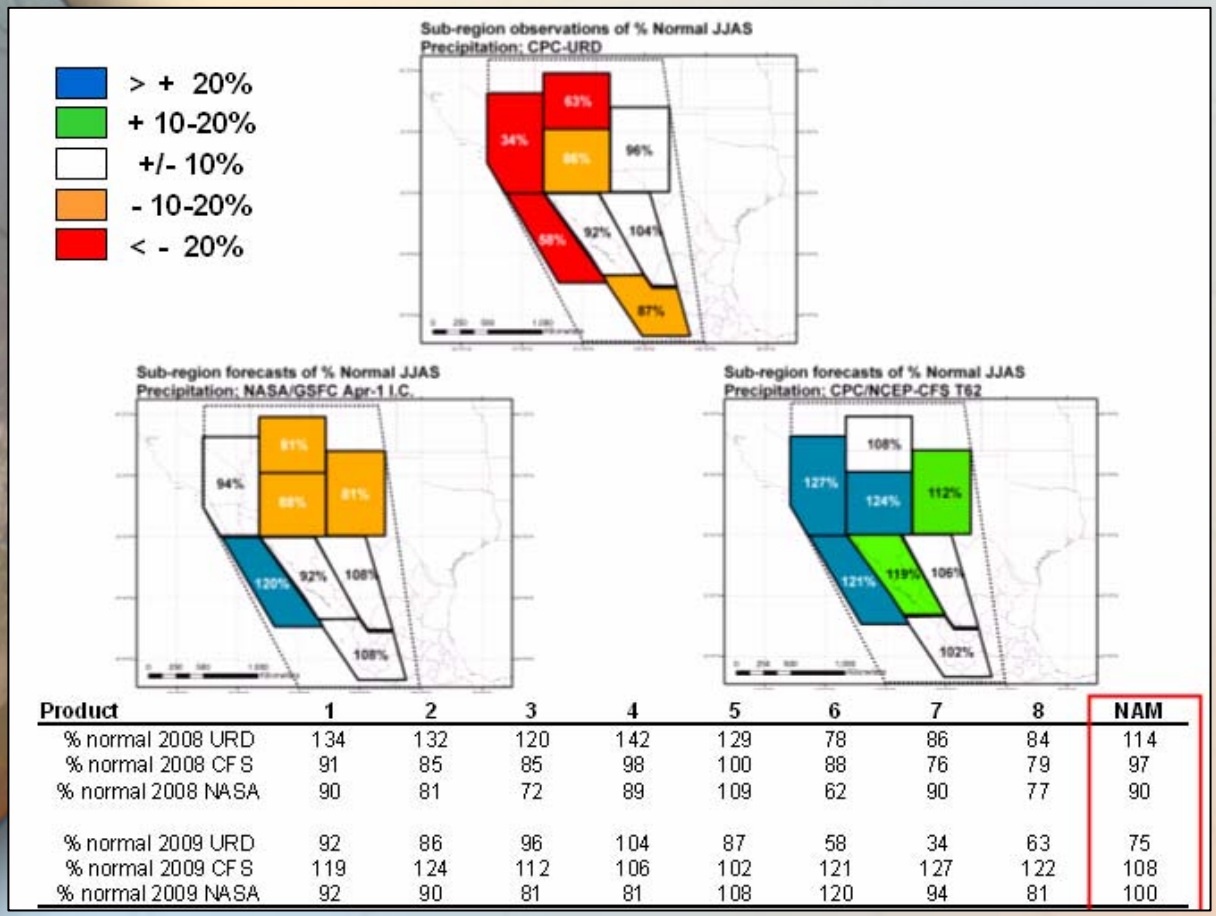
NCAR

The National Center for Atmospheric Research

The North American Monsoon Climate Applications Activities:

- Climate Change downscaling studies: (to be elaborated on by VAMOS CC WG)
  - Yang et al. (2001), Arritt et al. (ca. 2004) and Collier et al. (2007) showed pre-AR4, free-running GCMs having problems getting seasonal cycle of NAM rainfal
  - Lin et al., 2008 analyzed western hemisphere tropical ISV in AR4 models and showed TEWs spectral variance reasonable while westerly modes were universally under-represented.
  - Preliminary works by Dominguez et al. and Cerezo-Mota et al. highlight the need for comprehensive GCM & re-analysis assessment prior to use in climate downscaling

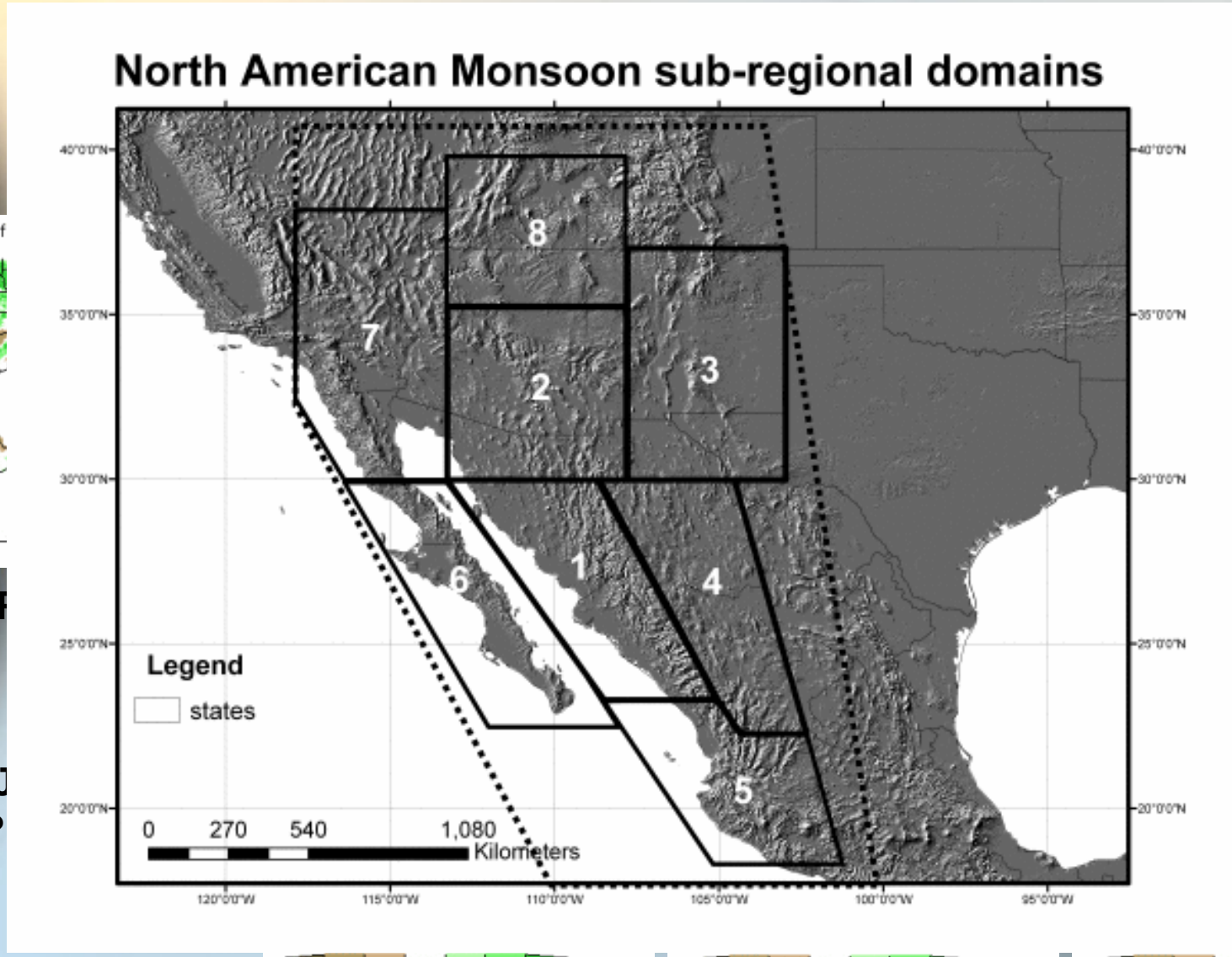
The North American Monsoon Predictions Activities:

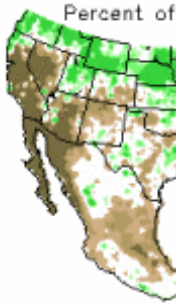


Product	1	2	3	4	5	6	7	8	NAM
% normal 2008 URD	134	132	120	142	129	78	86	84	114
% normal 2008 CFS	91	85	85	98	100	88	76	79	97
% normal 2008 NASA	90	81	72	89	109	62	90	77	90
% normal 2009 URD	92	86	96	104	87	58	34	63	75
% normal 2009 CFS	119	124	112	106	102	121	127	122	108
% normal 2009 NASA	92	90	81	81	108	120	94	81	100

- NAME Forecast Forum:
  - Synthesis from yrs 1 and 2 (Gochis et al. AGU)
  - Global models did a poorer job capturing the mean and intra-seasonal precipitation anomalies during 2009 vs. 2008
  - 2009 Forecast error suggests strong SST evolution limits prediction skill
  - Still need to better analyze ISV in models (TEW, tropical storms/tracks, inverted troughs, westerly modes)
  - Ready for VAMOS! Newsletter report

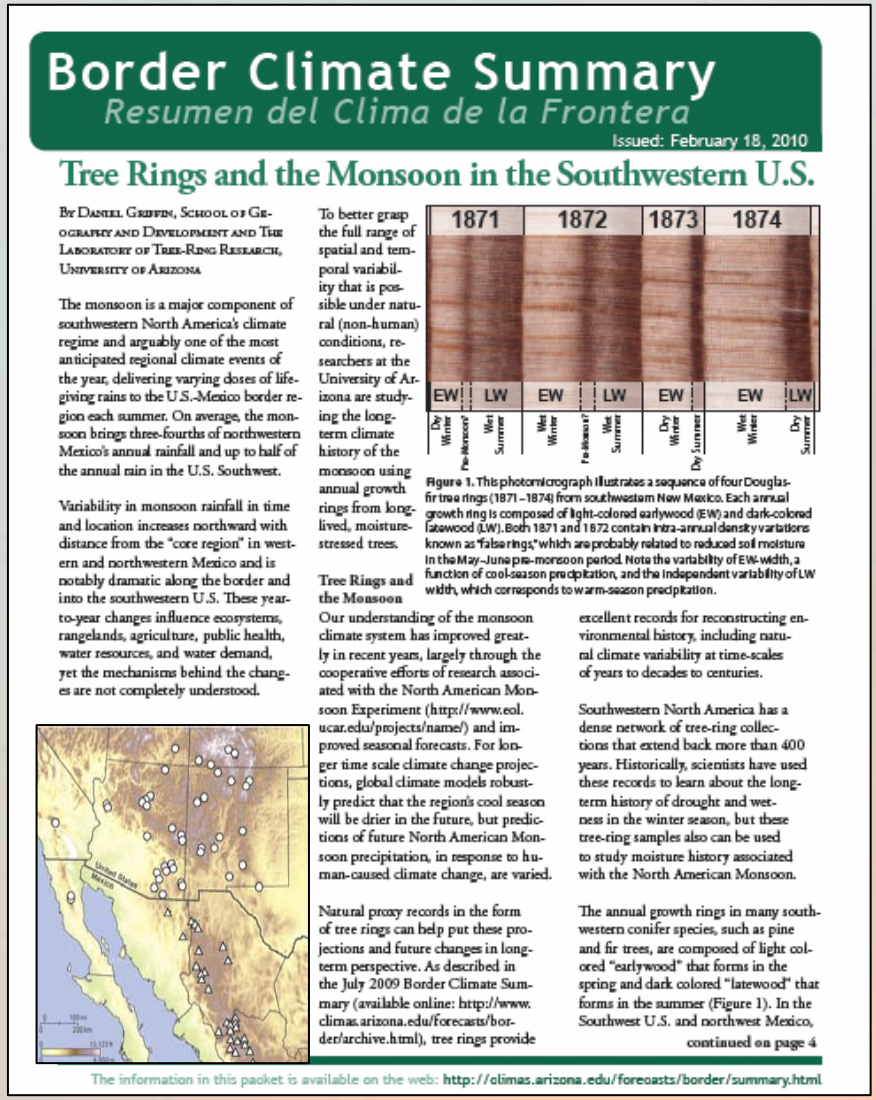
The North American Monsoon Predictions Activities:





The North American Monsoon Climate Applications Activities:

- Monsoon region climate outreach programs:
  - Border Climate Summary:
    - Feb. 2010: recent tree ring work, NFF review
  - Monsoon outlook webcast (2009 and 2010) by G. Garfin (CLIMAS)
  - Host of other regional 'integrated research projects' by CLIMAS/UofA and others, to be reported on by Lisa Goddard



Border Climate Summary
Resumen del Clima de la Frontera
Issued: February 18, 2010

Tree Rings and the Monsoon in the Southwestern U.S.

By Daniel Griffin, School of Geography and Development and The Laboratory of Tree-Ring Research, University of Arizona

The monsoon is a major component of southwestern North America's climate regime and arguably one of the most anticipated regional climate events of the year, delivering varying doses of life-giving rains to the U.S.-Mexico border region each summer. On average, the monsoon brings three-fourths of northwestern Mexico's annual rainfall and up to half of the annual rain in the U.S. Southwest.

Variability in monsoon rainfall in time and location increases northward with distance from the "core region" in western and northwestern Mexico and is notably dramatic along the border and into the southwestern U.S. These year-to-year changes influence ecosystems, rangelands, agriculture, public health, water resources, and water demand, yet the mechanisms behind the changes are not completely understood.

To better grasp the full range of spatial and temporal variability that is possible under natural (non-human) conditions, researchers at the University of Arizona are studying the long-term climate history of the monsoon using annual growth rings from long-lived, moisture-stressed trees.

1871 1872 1873 1874
EW LW EW LW EW EW LW
Dry Winter / Pre-Monsoon? / Wet Summer / Wet Winter / Pre-Monsoon? / Wet Summer / Dry Winter / Dry Summer / Wet Winter / Dry Summer

Figure 1. This photomicrograph illustrates a sequence of four Douglas-fir tree rings (1871–1874) from southwestern New Mexico. Each annual growth ring is composed of light-colored earlywood (EW) and dark-colored latewood (LW). Both 1871 and 1872 contain intra-annual density variations known as "false rings," which are probably related to reduced soil moisture in the May–June pre-monsoon period. Note the variability of EW-width, a function of cool-season precipitation, and the independent variability of LW width, which corresponds to warm-season precipitation.

Tree Rings and the Monsoon

Our understanding of the monsoon climate system has improved greatly in recent years, largely through the cooperative efforts of research associated with the North American Monsoon Experiment (http://www.eol.ucar.edu/projects/name/) and improved seasonal forecasts. For longer time scale climate change projections, global climate models robustly predict that the region's cool season will be drier in the future, but predictions of future North American Monsoon precipitation, in response to human-caused climate change, are varied.

Natural proxy records in the form of tree rings can help put these projections and future changes in long-term perspective. As described in the July 2009 Border Climate Summary (available online: http://www.climas.arizona.edu/forecasts/border/archive.html), tree rings provide excellent records for reconstructing environmental history, including natural climate variability at time-scales of years to decades to centuries.

Southwestern North America has a dense network of tree-ring collections that extend back more than 400 years. Historically, scientists have used these records to learn about the long-term history of drought and wetness in the winter season, but these tree-ring samples also can be used to study moisture history associated with the North American Monsoon.

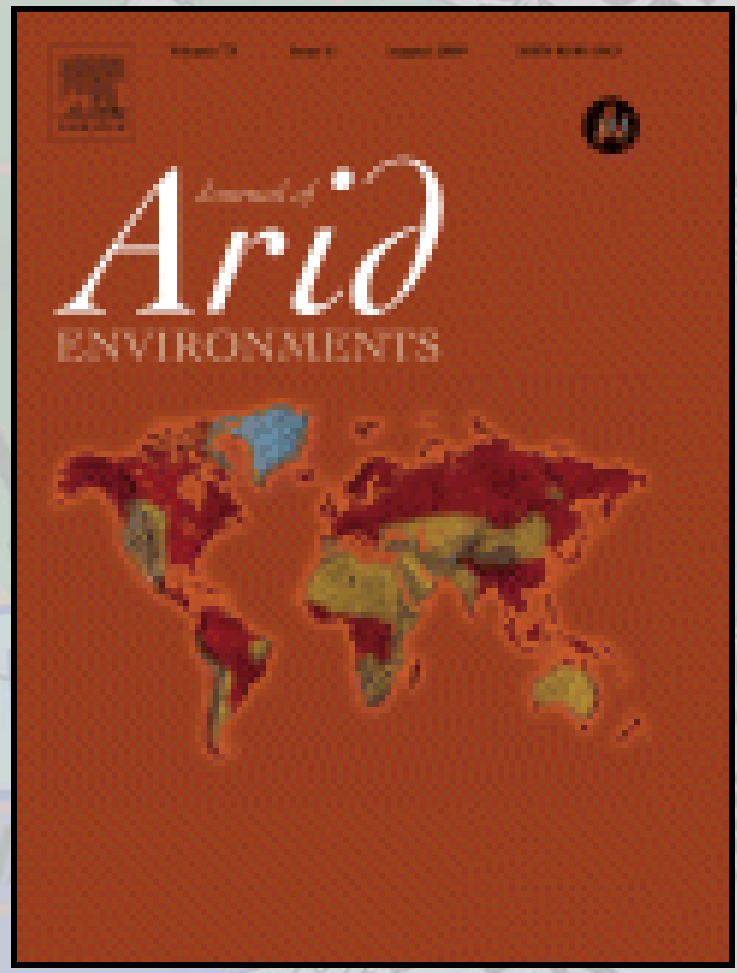
The annual growth rings in many southwestern conifer species, such as pine and fir trees, are composed of light colored "earlywood" that forms in the spring and dark colored "latewood" that forms in the summer (Figure 1). In the Southwest U.S. and northwest Mexico,

continued on page 4

The information in this packet is available on the web: http://climas.arizona.edu/forecasts/border/summary.html

Ongoing NAM Related Synthesis Activities

- Fall AGU session (Gochis, Vivoni, Gutzler)
  - ~20 presentations
- J. Arid Environments Special Issue “Land surface ecohydrology of the North American Monsoon system” (Vivoni, Gochis, Watts)
  - 12 articles



J Arid Env., Vol. 74, May 2010

Ongoing NAM Related Synthesis Activities

• BAMS overview article on the “Year of Tropical Convection” (Gochis and Serra)

– Synopsis of NAM structure during the 2008 and 2009 monsoon seasons

– Explicit emphases on large-scale influences on mean monsoon behavior (mostly precipitation) and on mechanisms of intra-seasonal variability

– Due out later in 2010/early 2011

Ongoing NAM Related Synthesis Activities

- Book chapter for WMO-WCRP (Gochis and Berberry)
  - Synthesis of NAME research and legacy programs largely reported on previously to VAMOS/CLIVAR panel
  - Due out late 2010

- Invited manuscript to Reviews in Geophysics on progress in North American Monsoon research (currently in preparation)

Emerging N. American Monsoon Research Priorities:

- Given all that has been accomplished in NAME:
  - What needs remain?
  - What are the best ways to go about addressing those needs?

Emerging N. American Monsoon Research Priorities:

- Monsoon process studies:

1. Explaining monsoon variability:
   a) How much of the IAV of the NAM can be explained by 'internal' versus 'external' forcing mechanisms? (Probably an ill-posed questions but…)

   b) How does the diabatic heating structure within the NAM region serve to, presumably, enhance the monsoon circulation?
   c) Can we better link NAM variations due to tropical ISV to changes in large-scale drivers such as ENSO, WHWP, PDO, AMO or other drivers?
   d) Can we further refine the role of the land surface in modulating regional climate? (e.g. large-scale antecedent/pre-onset conditions, *memory* of hydrologic inputs)

Emerging N. American Monsoon Research Priorities:

- Monsoon process studies:

2. Paleoclimate studies:
   a) How have the mean and variance structures of monsoon precipitation changed since the mid-holocene (~6000 ybp)?
   b) What are the mechanisms behind past NAM climate extremes, particularly annual and decadal-scale fluctuations and paleoflood events?

3. Climate change processes:
   a) How will differential heating of land and sea evolve?
   b) Will there be significant shift in the monsoon precipitation climatology? (more/less extremes, shifts in elevation or latitude)

Emerging N. American Monsoon Research Priorities:

- Modeling and prediction priorities:

1. Prediction research:
   a) How much value can RCMs and regional NWP models add to parent global forecast models?
   b) How can we improve the use of existing and new observations in making model predictions (data assimilation *and* parameterization development)?

2. Adaptation strategies:
   a) Can we develop pro-active adaptation/resiliency strategies to current and future climate variations and changes?
   b) What levels of forecast certainty are required to motivate societal changes?
   c) What institutional structures need to change?

Emerging N. American Monsoon Research Priorities:

- Recommendations: (based on where NAME has lead us to…)

1. Conduct new OSSE-type experiments to aid in the design of the regional observing system. (particularly for atmospheric profile and radar instrumentation)

2. Expand the generation, collection and consolidation of multi-model forecasts (both atmospheric and hydrological) to create improved estimates of model forecast uncertainty. (Relates to IRI and NFF type efforts)

3. Invest in additional AmeriFlux type research stations that span the NAM climate gradient and include under-represented ecosystems.

4. **More generally, re-engage bi-national research efforts through coordinated meetings, field experiments and new proposals/projects**.

Emerging N. American Monsoon Final Questions:

- What are the best mechanisms for building on NAME program achievements:
  - Austral-Asian monsoon research community has successfully retained programmatic interest for decades, are there lessons to be learned there?
  - How can we further streamline research findings into operational prediction?


EXPERIMENTO DEL MONZÓN DE AMÉRICA DEL NORTE
NAME
WCRP/CLIVAR – VAMOS/GEWEX
NORTH AMERICAN MONSOON EXPERIMENT

End