# INBO 2016 - 10th World General Assembly
# Merida, Mexico

INBO2016
10th General Assembly
International Network
of Basin Organizations
June 1-4, 2016
Merida, Yucatan, Mexico

## "For Better River Basin Management Over the World"

NANBO
ROBAN
ROCAN

## 1st Topical Roundtable – Adaptation to Climate Change in Basin Management

## Thursday, 2 June 2016


**Bob Pietrowsky, Director**

**USACE Institute for Water Resources**
**& the International Center for Integrated Water Resources Management, *under the auspices of UNESCO***



IWR

UNESCO
United Nations
Educational, Scientific and
Cultural Organization

ICIWaRM
International Center for Integrated
Water Resources Management
under the auspices of UNESCO

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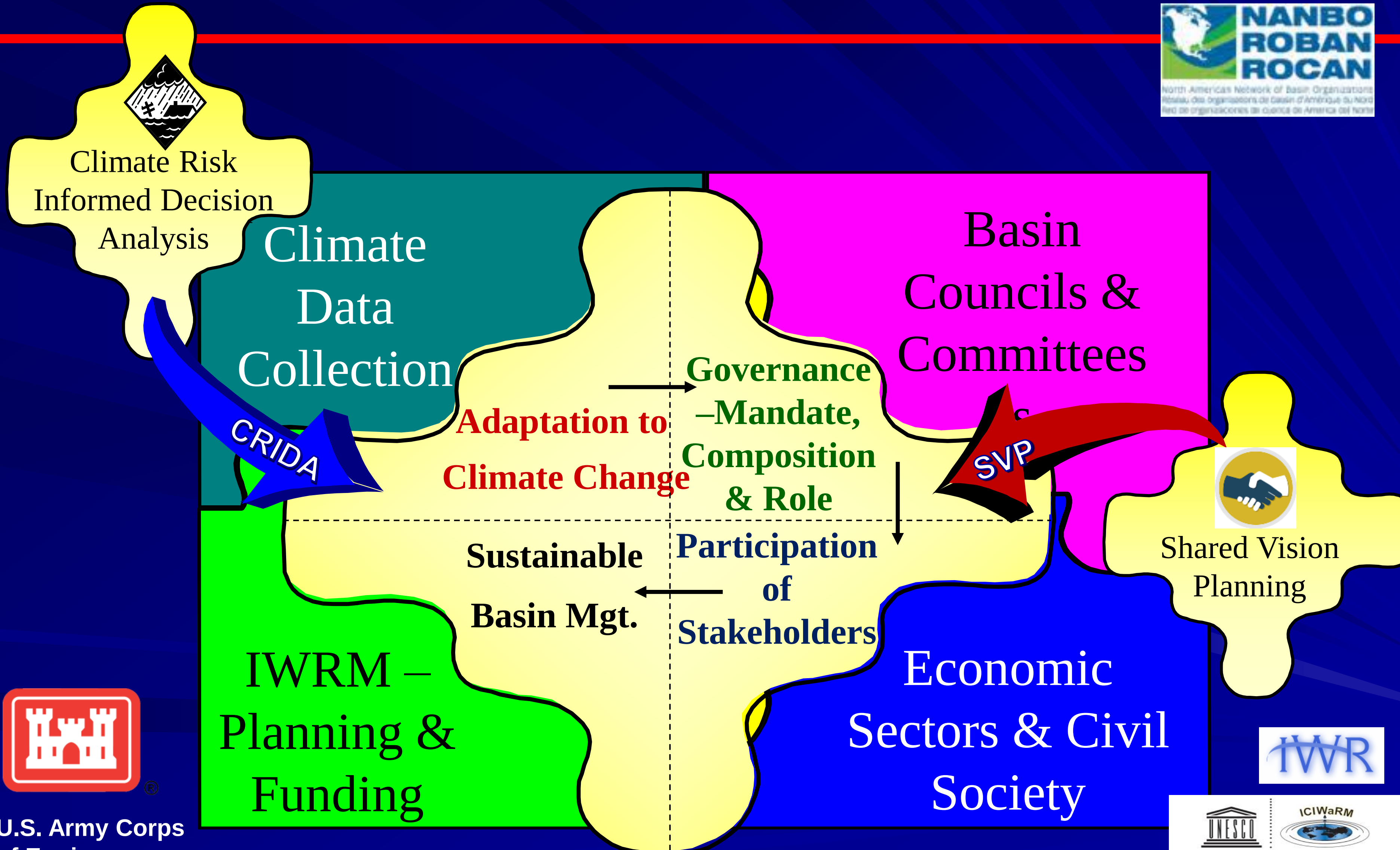
# 1st Topical Roundtable – Adaptation to Climate Change in Basin Management

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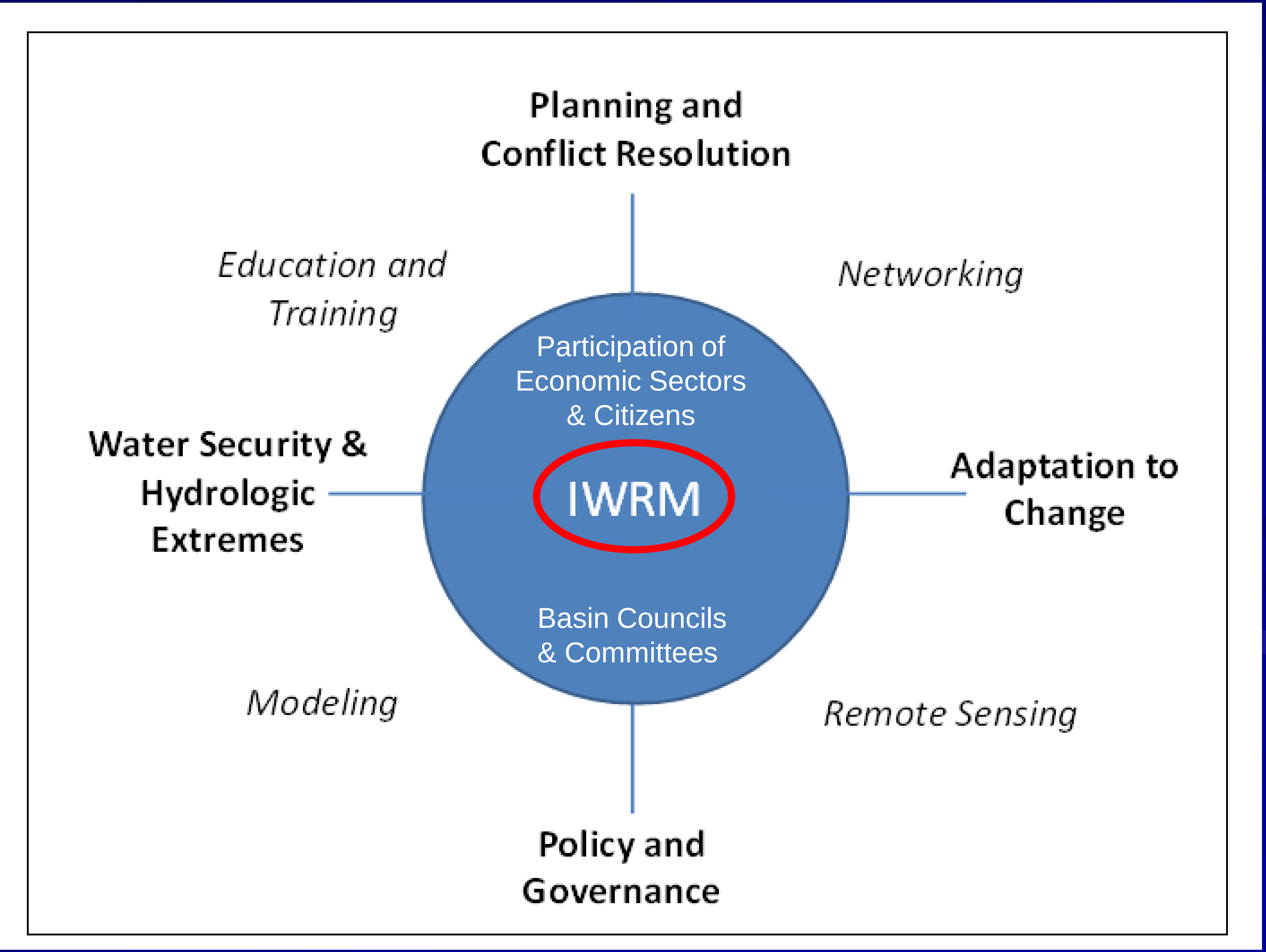
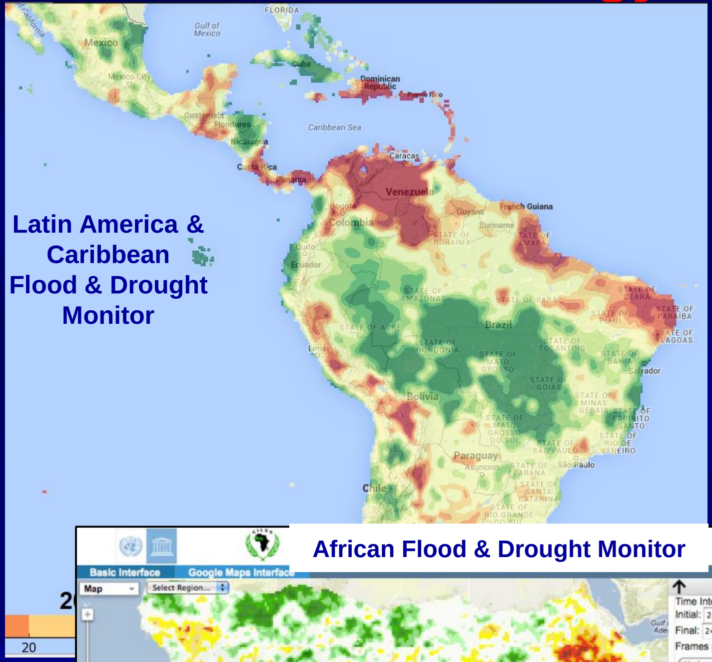
# Sustainable Basin Management – Including Adaptation to Climate Change - is All Tied Together with IWRM…

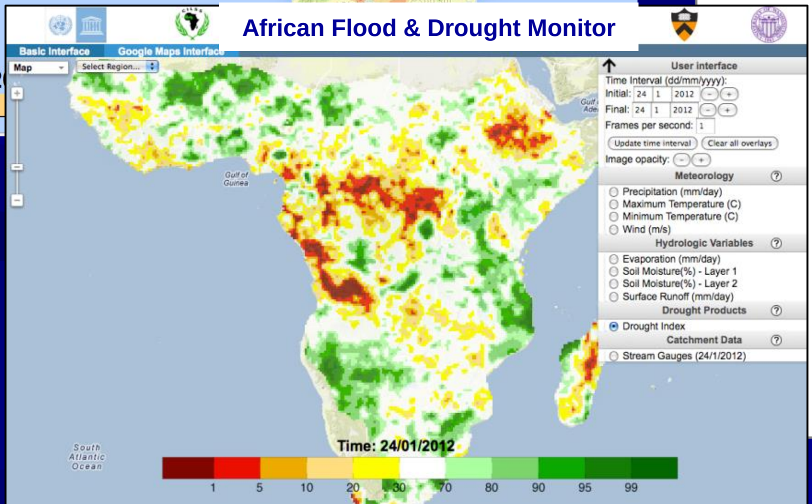


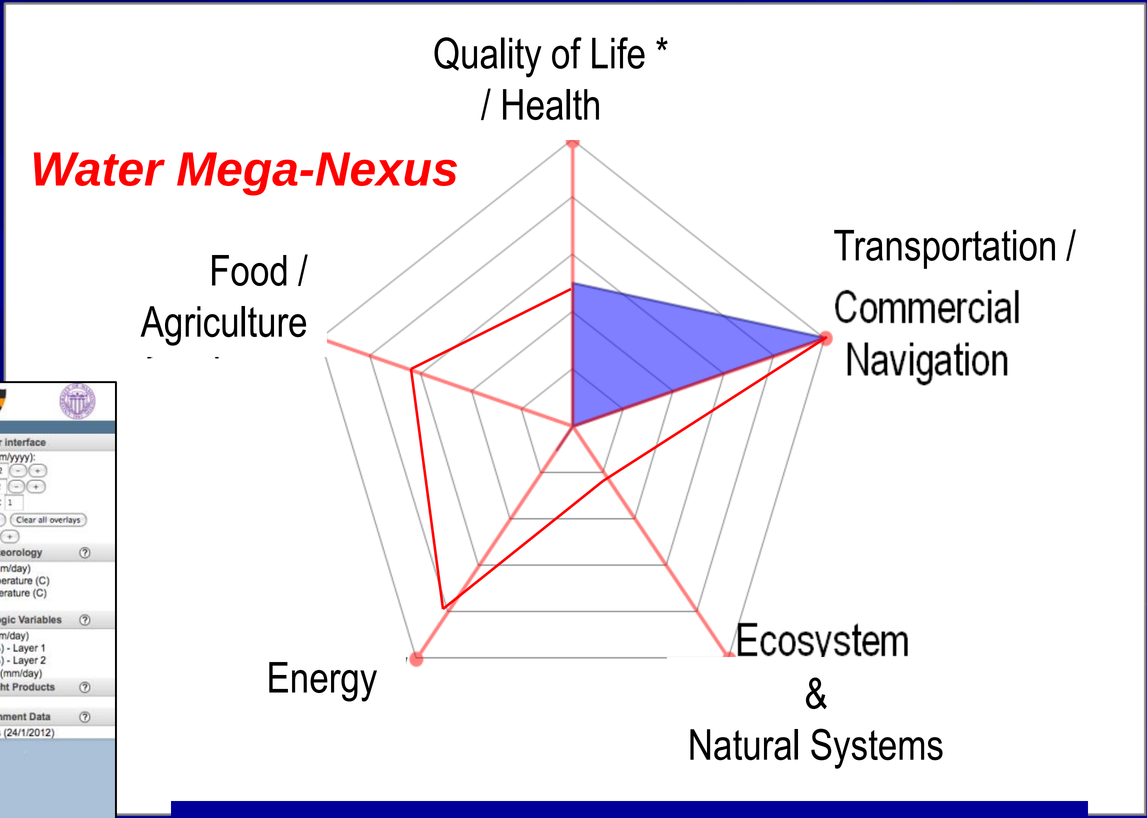
# *Mega-Nexus of Future Water Demand*

**IWRM Context: Importance of approaching societal water problems from the context of the "Mega Nexus" of**

***Water - Food - Energy - Transportation - Ecosystems & Health***




* Includes risk mitigation of extreme events – floods, droughts

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# Evolution of Thinking About Water & Climate

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- Stationarity paradigm – future will look like the past? ***Not Likely!***

- Recognized role of cyclical climate changes:
  - ✓ El Nino
  - ✓ Pacific Decadal Oscillation
  - ✓ Atlantic Multi-Decadal Oscillation

- IWRM is the accepted paradigm / context for dealing with climate adaptation and adaptive management

- Transitional pragmatic evaluation, planning and engineering design tools & sharing best practices are needed in absence of robust information from GCMs and forecasting models

POLICYFORUM

CLIMATE CHANGE

## Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water-resource engineering. It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year–periodic) probability density function (pdf), whose properties can be estimated from the instrument record. Under stationarity, pdf estimation errors are acknowledged, but have been assumed to be reducible by additional observations, more efficient estimators, or regional or paleohydrologic data. The pdfs, in turn, are used to evaluate and manage risks to water supplies, waterworks, and floodplains; annual global investment in water infrastructure exceeds U.S.$500 billion (*1*).

The stationarity assumption has long been compromised by human disturbances in river basins. Flood risk, water supply, and water quality are affected by water infrastructure, channel modifications, drainage works, and land-cover and land-use change. Two other (sometimes indistinguishable) challenges to stationarity have been externally forced, natural climate changes and low-frequency, internal variability (e.g., the Atlantic multidecadal oscillation) enhanced by the slow dynamics of the oceans and ice sheets (*2*, *3*). Planners have tools to adjust their analyses for known human disturbances within river basins, and justifiably or not, they generally have considered natural change and variability to be sufficiently small to allow stationarity-based design.

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An uncertain future challenges water planners.

In view of the magnitude and ubiquity of the hydroclimatic change apparently now under way, however, we assert that stationarity is dead and should no longer serve as a central, default assumption in water-resource risk assessment and planning. Finding a suitable successor is crucial for human adaptation to changing climate.

*How did stationarity die?* Stationarity is dead because substantial anthropogenic change of Earth's climate is altering the means and extremes of precipitation, evapotranspiration, and rates of discharge of rivers (*4*, *5*) (see figure, above). Warming augments atmospheric humidity and water transport. This increases precipitation, and possibly flood risk, where prevailing atmospheric water-vapor fluxes converge (*6*). Rising sea level induces gradually heightened risk of contamination of coastal freshwater supplies. Glacial meltwater temporarily enhances water availability, but glacier and snow-pack losses diminish natural seasonal and interannual storage (*7*).

Anthropogenic climate warming appears to be driving a poleward expansion of the subtropical dry zone (*8*), thereby reducing runoff in some regions. Together, circulatory and thermodynamic responses largely explain the picture of regional gainers and losers of sustainable freshwater availability that has emerged from climate models (see figure, p. 574).

*Why now?* That anthropogenic climate change affects the water cycle (*9*) and water supply (*10*) is not a new finding. Nevertheless, sensible objections to discarding stationarity have been raised. For a time, hydroclimate had not demonstrably exited the envelope of natural variability and/or the effective range of optimally operated infrastructure (*11*, *12*). Accounting for the substantial uncertainties of climatic parameters estimated from short records (*13*) effectively hedged against small climate changes. Additionally, climate projections were not considered credible (*12*, *14*).

Recent developments have led us to the opinion that the time has come to move beyond the wait-and-see approach. Projections of runoff changes are bolstered by the recently demonstrated retrodictive skill of climate models. The global pattern of observed annual streamflow trends is unlikely to have arisen from unforced variability and is consistent with modeled response to climate forcing (*15*). Paleohydrologic studies suggest that small changes in mean climate might produce large changes in extremes (*16*), although attempts to detect a recent change in global flood frequency have been equivocal (*17*, *18*). Projected changes in runoff during the multidecade lifetime of major water infrastructure projects begun now are large enough to push hydroclimate beyond the range of historical behaviors (*19*). Some regions have little infrastructure to buffer the impacts of change.

Stationarity cannot be revived. Even with aggressive mitigation, continued warming is very likely, given the residence time of atmospheric $CO_2$ and the thermal inertia of the Earth system (*4*, *20*).

*A successor.* We need to find ways to identify nonstationary probabilistic models of relevant environmental variables and to use those models to optimize water systems. The challenge is daunting. Patterns of change are complex; uncertainties are large; and the knowledge base changes rapidly.

Under the rational planning framework advanced by the Harvard Water Program (*21*, *22*), the assumption of stationarity was

HTTP://ALLIANCE4WATER.ORG

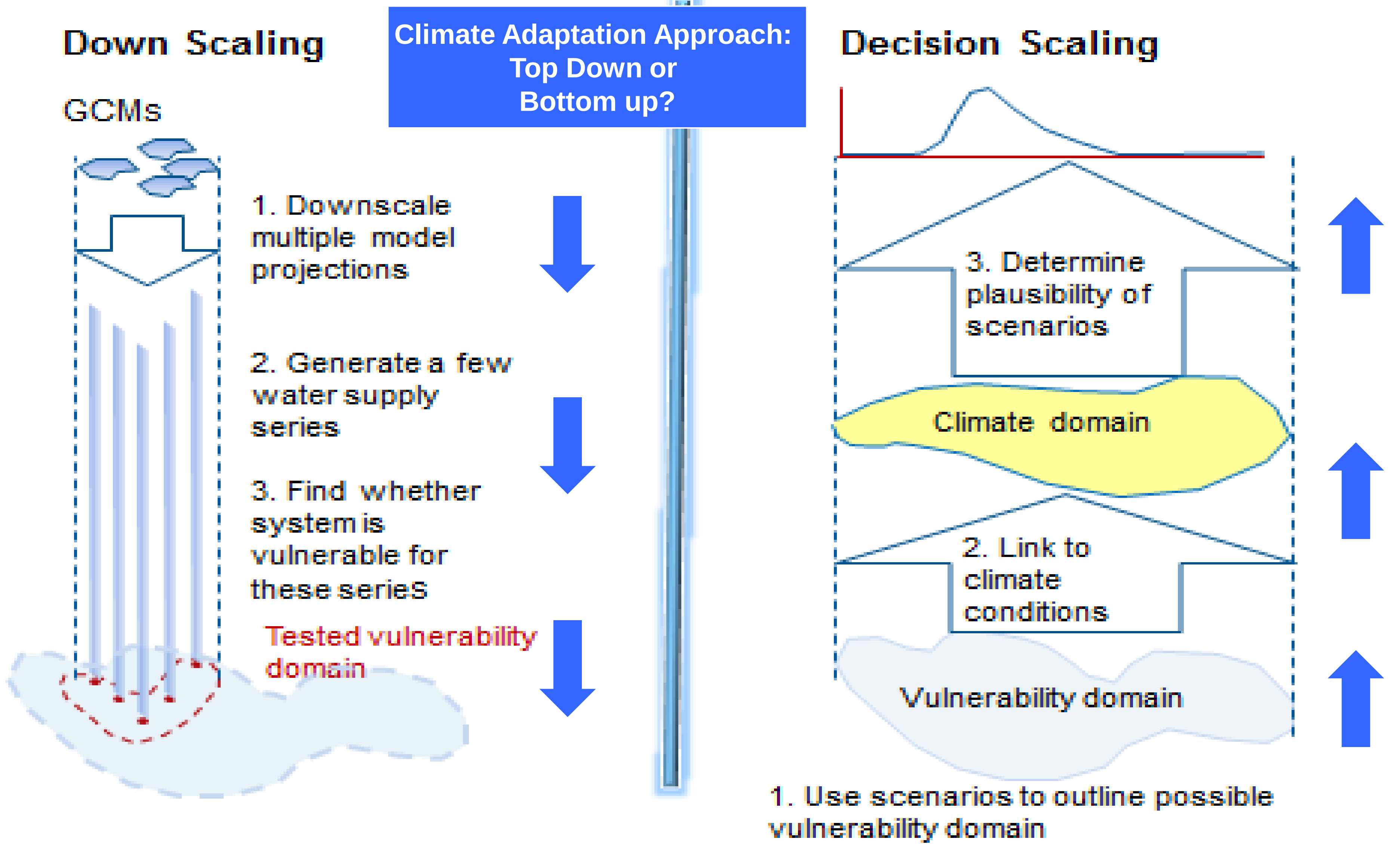
# THE AGWA NETWORK

## ALLIANCE FOR GLOBAL WATER ADAPTATION (AGWA)

- Founded 2010, co-chaired by the Stockholm International Water Institute (SIWI), the World Bank (& also originally, Conservation International
- AGWA Steering Committee members now include:
  - SIWI
  - The World Bank
  - Deltares
  - U.S. Army Corps of Engineers – Institute for Water Resources and its International Center for IWRM (ICIWaRM)
  - Seattle Public Utilities
  - World Business Council of Sustainable Development
- Focused on how to mainstream technical and policy approaches to freshwater climate adaptation
- > 900 members in the network, located globally
- Most members have a technical expertise and serve as an adaptation resource within their own organization
- SIWI hosts the secretariat and also leads the global policy team

# Climate Risk Informed Decision Analysis (CRIDA)

## AGWA is addressing the Convergence of Atmospheric & Hydrologic Modeling Capabilities




Source: Brown and Werick (2011): A decision analytic approach to managing climate risks. JAWRA

# Shared Vision Planning (SVP)

## Collaboration, Conflict Resolution & Stakeholder Involvement

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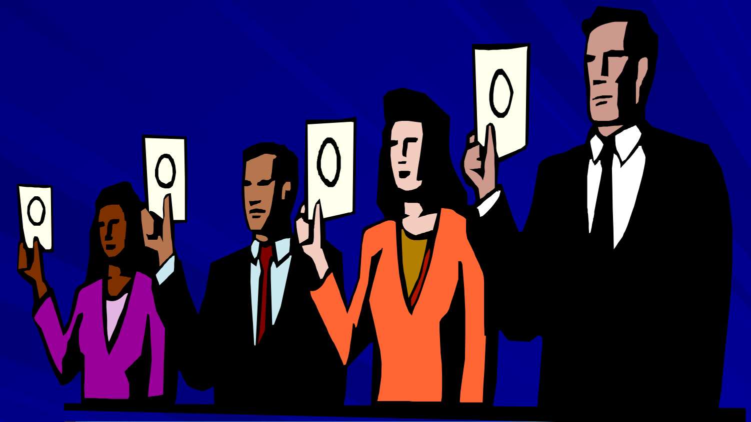
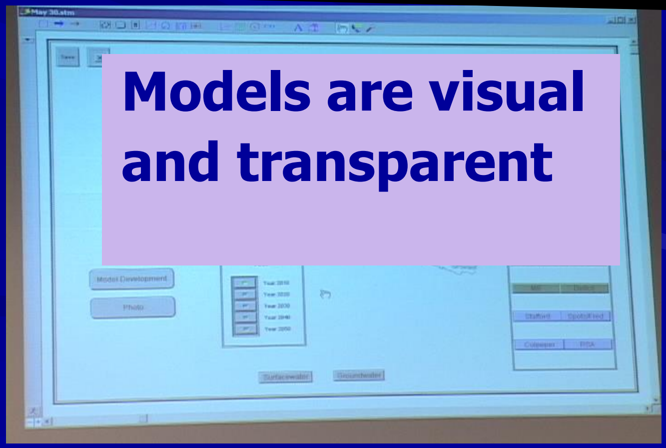
Shared Vision Planning
International Lake Ontario - St. Lawrence River Study

- Process of "technically informed" consensus building.
- Links IWRM Collaboration directly to civil society and the people.
- Information, models are developed collaboratively & accessible to all stakeholders.
- Public and experts work together to build models and supply data.
- Stakeholder concerns are directly incorporated into process.






- Particularly useful in trans-boundary and high-conflict cases

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Red de organizaciones de cuenca de America del Norte

# *Gracias*

# *Merci Beaucoup*

# *Thank You*

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