Delivering Climate Services: Making Believers of a Skeptical User Community

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As in a Jazz Improvisation, a Riff on Two Themes

- Workshop Objectives:
- ***To identify new climate prediction applications research.***
- ***To "build community" by promoting interactions between integrated climate-sensitive research and service communities.***
- To assess impacts of climate forecasts on environmental-societal interactions.
- To provide feedback to producers of climate products on user requirements.

The Limits of an Exclusive Focus on Forecasts

- Experience shows that climate forecasts alone (delta T, delta p) are only utilized by the very technically advanced *unless* forecasts are expressed in terms of impacts on resources

- Also important to provide information about the linkages between climate variability and variations in natural resources

- Every empirical study has shown that climate forecasts aren't used to their full potential. Reasons include:
  - Lack of skill (can be interpreted as lack of transparency in tracking skill on part of forecast provider);
  - Deeply embedded and widespread preference for deterministic forecasts and discomfort with probabilistic forecasts (except in the case of climate change projections);
  - Demands for finer spatial resolution, i.e., down to watershed scale.

  (see Chagnon, Chagnon, and Chagnon, 1995; Pulwarty and Redmond, 1997; Callahan, Miles, and Fluharty, 1999; and Rayner, Lach, and Ingram, 2004, inter alia)

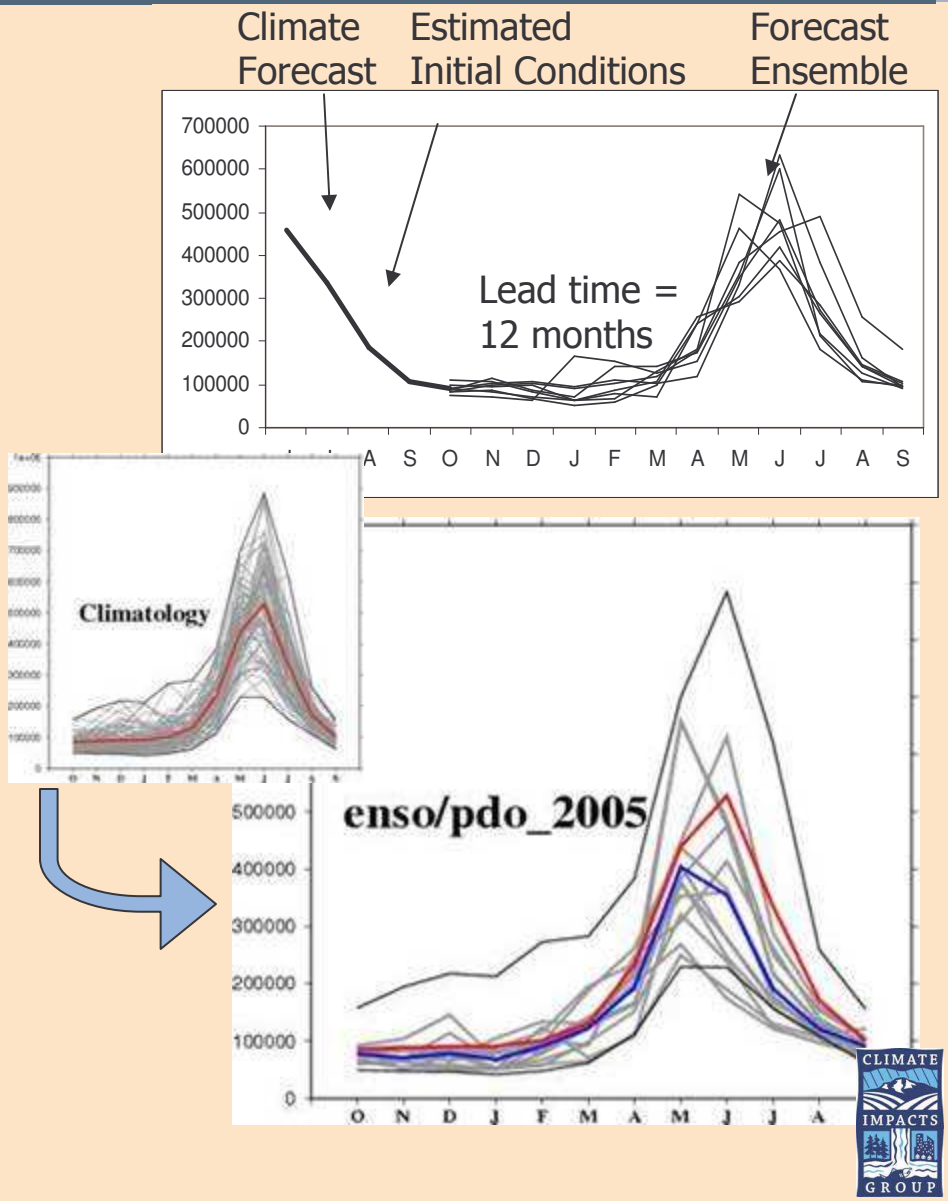
How Does Learning Occur in Majority of User Community?

- Evolutionary development initially highly interactive & often serendipitous (Miles et al. 2006):
- CIG began with effort to identify & quantify relationships between global climate phenomena & regional hydrologic processes, using historic record. Results used to explain variations on PNW water resources systems.
- Interaction with stakeholders leading to development of general forecasting techniques & specific applications of hydrologic forecasts for PNW water resources mgmt. Work continuing now at much more advanced level (Lettenmeier & Wood). But application of advances not straightforward.
- Successful application requiring integrating understanding of physical dynamics of climate variability with advances in hydrologic forecasting, modeling projected climate change effects, & understanding institutional vulnerabilities to climate variability & change & barriers to use of climate information in comprehensive fashion.

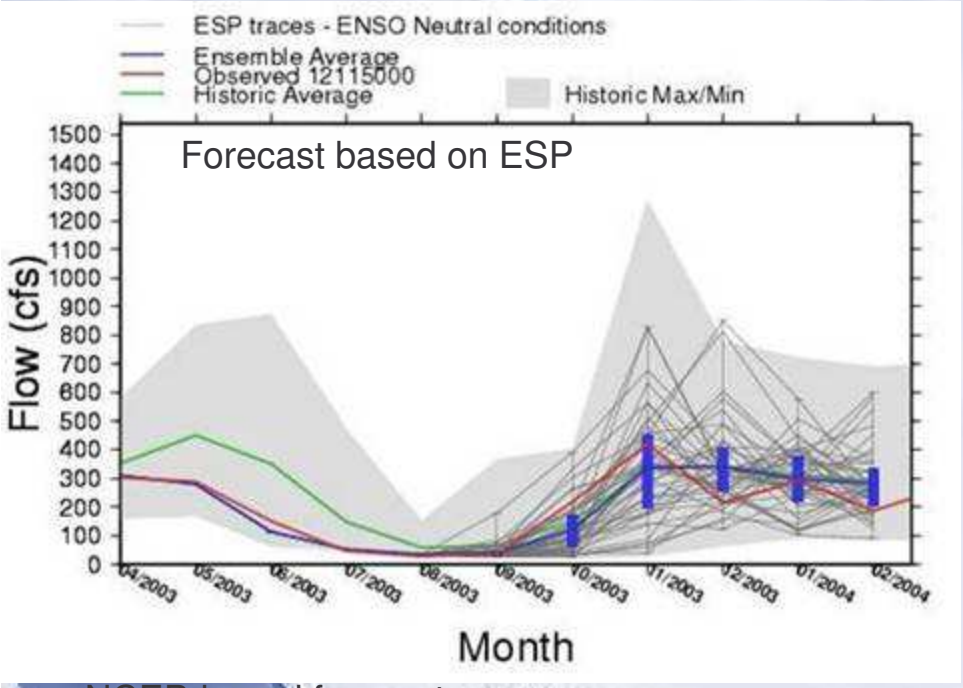
Long-Lead Experimental Streamflow Forecasts for the Columbia R. Basin

- An important factor in moving water managers towards incorporating climate info
- Experimental forecasts made 8-12 months in advance of traditional forecasts
- Forecast based on initial conditions, ENSO forecast, PDO state
- **Benefit: Forecasts guide decisions about reservoir mgmt, hydro production, instream flow mgmt**

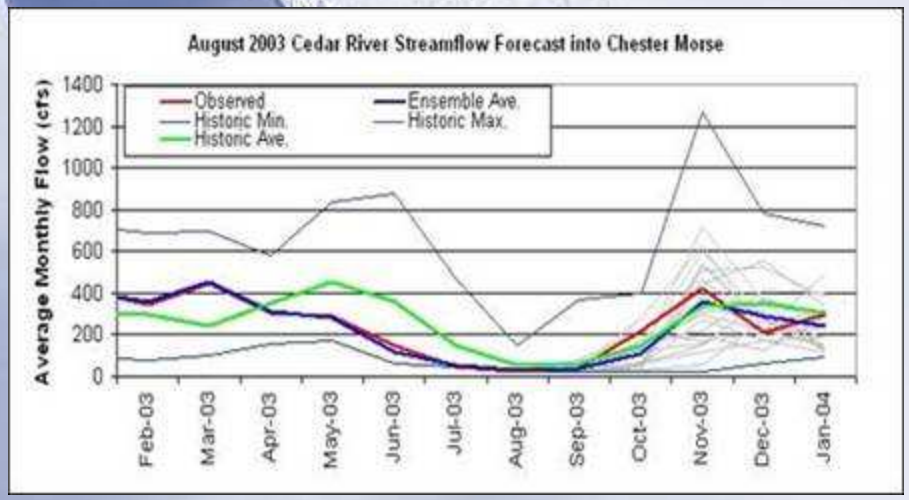
www.cses.washington.edu/cig/fpt/waterfc/oneyearstreamflow.shtml



Municipal Reservoir Forecasts



NCEP-based forecast



- Currently developing 6 month streamflow and reservoir forecasts for municipal water supplies in Puget Sound using NCEP forecasts, ESP
- Product developed at the request of Puget Sound Water Supply Forum
- **Benefit: Forecasts will help reservoir managers balance storage, instream flow requirements at critical time periods**

http://www.cses.washington.edu/cig/res/hwr/muniwaterfc.shtml

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Evolutionary Learning as Punctuated Equilibria

- Evolutionary learning not a continuous function but punctuated either via sharp transitions in response to external events ***or as result of understanding the evolutionary dynamic combined with major internal advances in knowledge in research team of high utility to stakeholders.***
- Sharp transitions = powerful ENSO events; patterns of decadal oscillations in relation to types of impacts of resources of interest.

Evolution within the Research Team as well as within the Community of Stakeholders

- Realization by 1998 within CIG that water central to all four sectors which constituted our focus: regional hydrology/water resources mgmt.; forest ecosystems; aquatic ecosystems [a focus on salmonidae as bridges to marine & terrestrial environment, & 2 climate sensitive spp in Northern California Current System, hake & sardines], & coastal zone.
- Since largest PNW river basins snowmelt driven, winter the crucial period in which principal climate drivers, ENSO & PDO, exert greatest influence on T, P, spring time snowpack, & spring-summer runoff.
- Physical system highly nonlinear, so small changes in drivers produce large changes in climate sensitive resource outcomes.
- One additional, but smaller driver of climate impacts in eustatic SLR, combined with regional isostatic SLR. & transient higher SL during El Niño events $\Rightarrow$ accelerated coastal erosion in winter (Kaminsky et al, 1999).

Evolutionary Learning within the Research Team, cont'd.

- Re climate impacts, enlarged understanding re climate as driver of multiple stresses.
- Environmental changes over last 150 years in PNW result not only from climate, but also [& even more so] from humans. Climate impacts exist in interface between what nature does and what humans do in region.
- But full & instantaneous application of gains in understanding often thwarted by social institutions within which natural resources managed.
- Change not impossible but needs help, either from sharp physical transitions or discoveries that promise large benefits.
- Consider case study of Oregon coho salmon.

Creating the Oregon Coho Marine Survival Forecasts

- Collaboration between CIG (Francis, Mantua, Agostini), NMFS Northwest Fisheries Science Center (Lawson), & NMFS Alaska Fisheries Science Center (Logerwell).
- Methodology based on sequence of four coastal factors which research showed were related to coho marine survival. Three known from observations: winter climate prior to smolt migration from freshwater to ocean; spring transition from winter downwelling to spring/summer upwelling; & the spring upwelling season . Fourth predicted up to 3 seasons in advance based on ENSO forecasts---winter ocean conditions near end of maturing coho first year at sea--will be known from direct observations by April 1 of harvest planning year(Logerwell et al. 2003).
- Four factors distilled into single estimate of coho survival rates which agencies need for planning harvests & allocations.

Oregon Coastal Coho Marine Survival Forecasts

Coastal Ocean Conditions

- Sea surface temperatures
- Sea level
- Nearshore winds

Forecasted Jan-March 2005 SST	Forecasted Return Rate for March 2005
9.33 (1 stand. dev. below mean)	2% (+/- 1%)
10.15 (mean value)	**1% (+/- 1%)**
10.98 (1 stand. dev. above mean)	<1%

- Methodology unique in recognizing the impact of winter conditions on coho marine survival.
- Provides a pathway for incorporating 1 year lead time climate forecasts into seasonal harvest, allocation, and hatchery decisions
- **Benefit: Forecasts available 6 to 8 months in advance of traditional forecast methods (jacks, plankton)**

http://www.cses.washington.edu/cig/fpt/orcohofc.shtml

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Lessons of the Oregon Coho Case

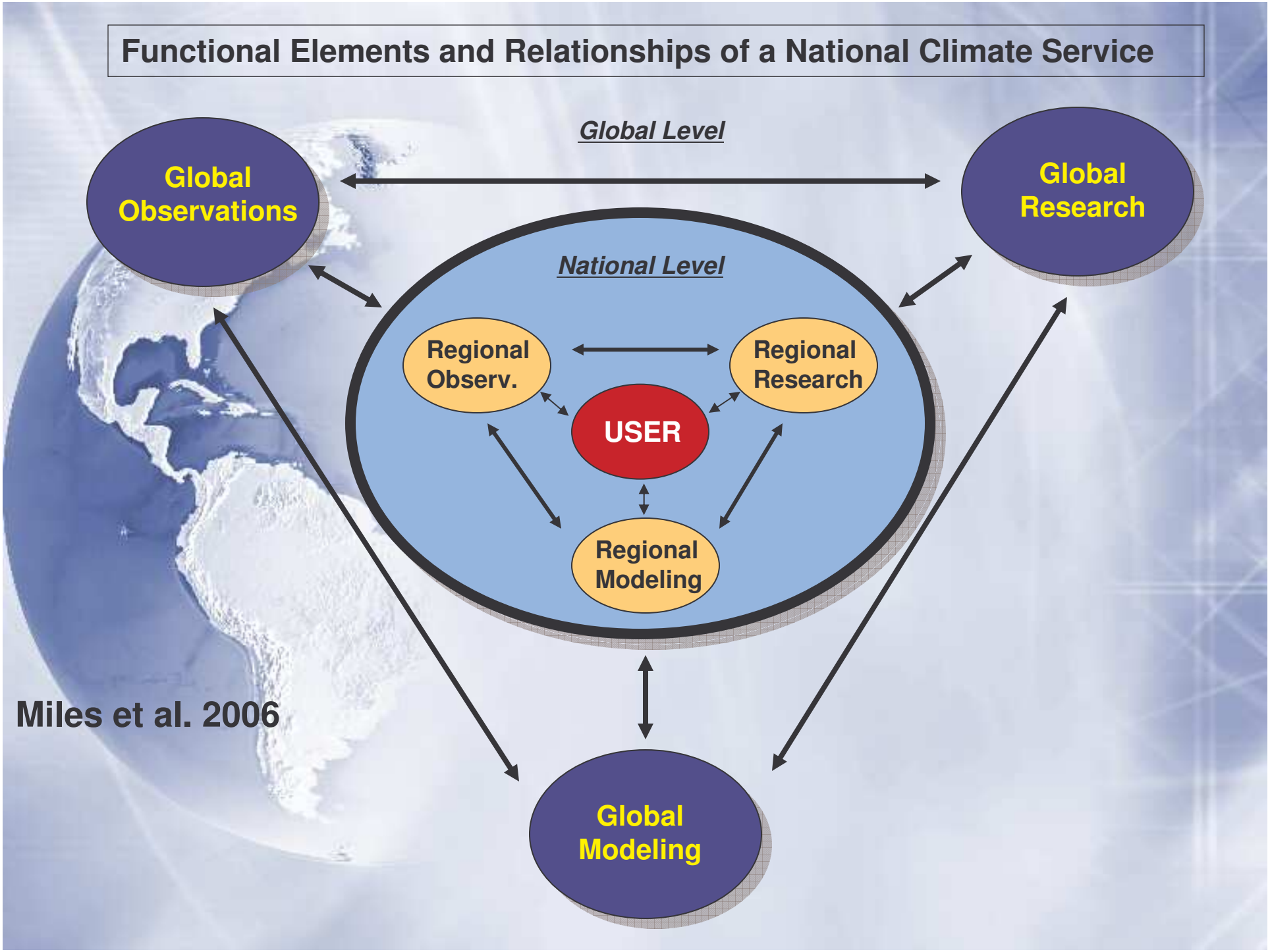
- Research responded to clearly articulated agency need--importance of pre-season abundance forecasts for annual planning.
- Clearly demonstrated link between regional environmental indices & changes in coho marine survival.
- Recognition that changes in regional ocean conditions important for coho survival are influenced by predictable aspects of large-scale climate variations, especially ENSO.
- Collaborative research project created to design custom tailored forecasting tool exploiting links between large-scale climate variations, regional oceanographic variability, & stock specific coho marine survival rates.
- Transitioning results to agency planning teams assured because member of NOAA's coho forecasting team also a member of the research team.

Vision & Constraints

- Clear that potential market very large for combining new climate prediction applications research with a "building community" strategy in alliance with wide range of stakeholders in large number of sectors of human activity.
- Demand will increase as effects of climate change intensify as means of managing adaptation.
- Constraints imposed by nature re what is knowable will be hard to surmount. But man-made constraints can also be very difficult, especially when they come with the long-standing inertia of institutional barriers


Two Visions with the Same Constraint

Functional Elements and Relationships of a National Climate Service



Miles et al. 2006

The Three-Legged Stool

- The vision of a national climate service as a three-legged stool consisting of observations, modeling, & research, nested in global, national, and regional scales with a user-centric focus of Miles et al.(2006) faces several major hurdles, viz. bureaucratic complexity, inertia, & competition, funding, and severe gaps in the types of data required, spatial coverage, & data quality.

A Multiple Stresses Focus: The NRC Workshop Report (NRC, 2007)

- The Puzzle:
- Both ecosystems & humans often face suites of multiple environmental stresses generated by a combination of external physical forcing & internal forcing. Multiple environmental stresses produce more than additive effects. They create synergies through interaction and produce quantitatively & qualitatively different outcomes from single influences.
- Outcomes are derived from nonlinear processes operating on multiple spatiotemporal scales which lead to critical thresholds or points at which either rates of change shift dramatically and/or the system shifts into a different state.
- However, many (most?) nonlinearities are unknown and gaps in understanding these phenomena lead to gaps in knowing how to respond to them in terms of design of policy & management approaches.

Purpose of NRC Workshop: How to proceed to remedy lack of control generated by gaps in understanding?

- Workshop buying into Barron's formulation that the ability to "anticipate" (i.e., predict) the future is what makes knowledge powerful.
- Decision to focus first on the physical drivers (climate, land use/cover, waste products & streams) & trace interactions in place-based fashion.
- Note that impacts & societal decisions are place-based, but drivers operate on much larger scales.

Remedy for Lack of Control, cont'd.

- What stands in way of understanding this level of complexity? Need:
- Integrated regional web of sensors linking observations into coherent framework.
- Integrated & comprehensive regional information systems widely accessible to researchers, managers, & stakeholders.
- Directed process studies designed to examine specific phenomena through field investigations.
- Complex coupled system models at appropriate spatiotemporal scales integrating biologic, hydrologic, &socioeconomic systems.
- Strong connections to significant regional issues & stakeholders.
- Progress linked to implementing all 5 principles above.

Critical Data Gaps

- The global scale (GCOS, 2003): "…global terrestrial networks remain to be fully implemented; the ocean networks lack global coverage and commitment to sustained operation; and the atmospheric networks are not operating with the required global coverage and quality".
- At U.S. national scale fragmentation rampant because observational systems created piecemeal, pursuing different mission needs & directives. Whole is less than sum of the parts.
- Until recently, regional needs not the driving force for any of these systems.

Regional Data Gaps: A RISA View in 2006

- In PNW no system for tracking dynamics of PDO variability; nor is there a national program for doing so. Missing data are monthly values of mixed layer depth, location of thermocline, & calibrated heat content of ocean in upper 700m as function of time.
- Re PNW terrestrial environment, important lacunae re hydrological cycle:snow measurements set to facilitate water supply forecasting & not climate monitoring. Only 6 stations in U.S. provide surface measurements of both emitted and long wave solar radiation, none in PNW. Poor coverage of soil moisture in entire West & no long term data base available. Even larger problem exists re groundwater. Coverage spotty & for specific mgmt. purposes, not for climate monitoring.

Critical Data Gaps at Regional Scale, cont'd.

- CALIFORNIA (Cayan, pers. commun., 2006): Great need for historical as well as remotely sensed obs. Regions need data for important societal applications re human health, ecological, & hydrological purposes, *inter alia,* but very difficult to obtain even most basic obs.,like cloud cover in temporal & spatial high definition.
- CA at disadvantage in inability to observe atmosphere in the vertical dimension re inversions, snow/rain, freezing levels & wind. No ready access to historical profiler and radar information.Continuous obs of water chemistry, spp assemblages, & sediment concentrations missing but important for addressing water quality issues as well as source identification & quantification of fluxes in to coastal & other water bodies.
- High elevation obs of meteorological & hydrological variables sparse. This a problem for entire West.

Critical Regional Data Gaps 3

- ARIZONA & SW (Garfin, pers. commun., 2006): Same needs as CA. Critical climate issue is water. Most intense needs re soil moisture, high mountain & mountain-valley paired obs & snow data. Need for remotely sensed obs, particularly re snow, and better coordination between agencies engaged in complemetary obs like USDA/NRCS & NOAA/NWS.
- Given dramatic changes in topography over short distances & relative sparseness of current AZ COOP network, modernization & expansion of network critical to needs of wildland firefighters, emergency managers, land use managers, air quality managers, ranchers, agriculturists, et al.

Critical Regional Data Gaps 4

- PACIFIC (Shea, pers. commun., 2006): Water resources, coastal resources, & hazards mgmt the dominant issues. Critical issue is loss of streamflow information as USGS pulls out or stops maintaining stream gauges throughout U.S. Pacific Is. In addition, need continuous maintenance and upgrades to precipitation measurement systems, particularly in remote areas. Re coastal hazards, need data re sources of flooding--high winds, sea level variations, waves, & heavy precipitation.
- CAROLINAS (Carbone, pers. commun., 2006):Community water system managers, state resource agency personnel, & private sector complain about lack of good evaporation data, lack of groundwater measurements, & systematic water quality measurements. Some are very concerned about declining support for NWS COOP network, & many interested in slowly developing radar/rain gauge hybrid products now being produced by River Forecast Centers. Foresters also want lightning data.

Conclusions

- While promise is great, we are far from where we need to be re observations at global, national, & regional scales.
- Existing systems designed for research & disaggregated management interests of states, not for climate monitoring.
- These limitations will be critical in the face of the impacts generated by changing rates of global climate change.