ANNUAL REPORT DATA INDEX CARD

PROJECT TITLE: ECONOMIC BENEFITS OF WEATHER AND CLIMATE FORECASTS TO CALIFORNIA ENERGY PRODUCTION MANAGEMENT

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Keywords: energy production, climate forecasts, economic implications

Task/Theme: Evaluate economic benefits of climate forecasts

NOAA Strategic Goal(s): (2, 3)
Goal 1**: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management;** Goal 2: **Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond;** Goal 3: **Serve Society's Needs for Weather and Water Information;** Goal 4: **Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation.**

1. RESEARCH OBJECTIVES AND SPECIFIC PLANS TO ACHIEVE THEM:

The purpose of this research is to produce weather and climate forecasts tailored to the energy production industry, and to evaluate the economic benefit of those forecasts. We plan to achieve this by assessing the climate related needs of key energy industry decision makers, then producing, evaluating the skill of, and distributing forecasts to address those needs. The results will be given directly to the relevant energy industry personnel in addition to being published in the scientific literature.

2. APPROACH/EVALUATION AND METHODOLOGY: (Describe the nature of your project and how it was carried out. What were the major and planned activities, and who was involved.)

The two objectives were broken down into specific tasks, notably:

Objective 1 (produce and evaluate skill of weather and climate forecast variables important to energy supply and demand):

(1) Assess weather-related issues if importance to energy industry
(2) Identify weather/climate information needed to address these issues
(3) Produce operational 0-7 day weather forecasts for the energy industry
(4) Produce 0-14 day hindcasts for energy industry
(5) Produce seasonal forecasts for the energy industry
(6) Iterate to produce optimal weather/climate forecasts
(7) Evaluate the skill of the climate forecasts

Objective 2 (quantify the economic benefit of weather and climate forecasts)

(1) Identify key weather/energy scenarios
(2) Evaluate climate connections between California and the Pacific Northwest
(3) Calculate the economic benefit of various strategies used during the scenarios
(4) Evaluate the sensitivity of the business forecast to the weather forecast
(5) Evaluate the economic benefits of the weather-enhanced business forecast

Personnel:
From Scripps Institution of Oceanography: Tim P. Barnett, Dan C. Cayan, John R. Roads, David W. Pierce, Alexander Gershunov, Mary Tyree.
From Georgia Institute of Technology: Anne Steinemann
From University of Washington: Dennis P. Lettenmaier

3. RESEARCH ACCOMPLISHMENTS: (500 WORDS)

The California Energy Security Project ("CalEnergy") has resulted in four primary accomplishments. First, we produced weather and climate forecasts tailored to energy agencies and utilities, and evaluated the skill of those forecasts. Second, we established collaborative relationships with energy partners, including utilities and government agencies, and identified the types of decisions and the decision-makers that could potentially benefit from these forecasts. Third, we worked directly with users to integrate those forecasts into decision-making, which involved an iterative process of communicating and refining forecasts products to meet user needs. Fourth, we evaluated the net economic benefits of using that forecast information, relative to existing information.

Examples of the forecast projects we have worked on are:

a) Working with the California Independent System Operator (Cal ISO), we calculated that a reduction of forecast error in the California central valley from the current 3.05^{o}F to 2.7^{o}F would reduce weather-related error costs from $10M to $8M/year. We designed a series of statistical correctors to the weather forecast data that are optimized to reduce the biases in the forecasts that incur the greatest costs for them (and, hence, ratepayers). We designed a forecast for likelihood of the “delta breeze” (which greatly influences their electrical load), which is in the process of going operational.

b) We worked with San Diego Gas & Electric to develop a forecast scheme for calling peak load demand management days (days when electrical load is anticipated to be one of the 12 highest days per summer). This scheme nets 6% greater electrical use on forecast days than average days over the period 1990-2003, compared to the maximum possible (based on temperature forecasts) of 12%. This is better than had previously obtained and obtains half the maximum possible.

c) We worked with PacifiCorp (an large utility in the Pacific Northwest) to forecast the total electrical load expected from irrigation pumps over the summer season. We found some skill using soil moisture and precipitation in the spring to forecast this value. This project is ongoing, but we expect this will help them optimize their operational processes.

d) We have estimated that fluctuations in the North Pacific Oscillation (NPO) climate phenomenon can make a $220M difference in residential and commercial natural gas heating bills over the winter.

e) We have developed an extensive set of forecast products for the California Energy Commission, which should help them in their job of steering California’s electricity utilities towards ways of operation that have the greatest reliability at the least expense.

Another important outcome of this project has been scientific outreach: By working directly and continuously with potential users of forecast information, we have been able to provide the forecast products that would be most valuable to decision-making, and in turn, user needs have helped to direct the forecast products that were generated. The research has had far reaching significance because weather and climate forecasts provide broad potential to better anticipate and manage fluctuations in energy supplies and demands.

4. HIGHLIGHTS: (bulleted format only)

- Identified the types of energy problems and decisions that could benefit from forecast information, including operational scheduling, electrical load forecasting, natural gas purchase planning decisions, and hydropower operational strategies.
- Generated and communicated this information to energy partners, including the California Energy Commission, California Independent Systems Operator, San Diego Gas and Electric, and PacifiCorp.
- Integrated forecasts into operational models and other decision processes, for example with “delta breeze” forecasting for CalISO and “tariff day” scheduling with SDG&E.
- Evaluated the net economic benefit of forecast information; the total benefit of just the few projects we

were able to address in the first year is conservatively estimated in the range of $5-$20M/yr. Note that this valuation is that given by the stakeholders themselves of the value of this information.

- Conducted three case studies of the economic valuation of forecast information; the case studies include the delta breeze, using ensemble forecast information, irrigation pump load forecasting, and forecasting peak electricity use days.

- Analyzed effects of the NPO and ENSO on California temperatures. Gave these results to the California Energy Commission, which has charge of incorporating new forecast methods into guidelines for the state energy industry.

- Evaluated climate connections between California and the Pacific Northwest

5. LEVERAGING / PAYOFF: (Relate research accomplishments to public interest. NOAA needs to view as tool for justifying public investment in science initiatives).

The electricity grid in California has been a problem over the past several years, with high prices and rolling blackouts; this has been a problem for the residents. This work gives a way to make the entire system operate more efficiently, by reducing uncertainty in the climate and weather effects on the system through new and improved forecasting tools. This benefits all California ratepayers. (In fact, since the U.S. west operates on an interconnected electrical grid and California is by far the biggest consumer, this affects residents throughout the entire U.S. west, not just in California.)

We established collaborations with utilities and agencies involved with energy planning and decision-making in California and the Western U.S., raising the visibility of the climate forecasting issue in this important industry. We have seen widespread interest in the potential uses and value of climate forecast information in the industry, once we do the legwork of making the products tailored and accessible to the users, and carefully evaluate and document the relevant forecast skill.

6. REPRESENTING JIMO: Research linkages and leveraging of NOAA funded research and spin-off to other agencies (Interagency, Partnerships, Collaborators, Conference Proceedings, Seminars & Workshops)

Interagency: We have been able to leverage our western U.S. regional work on climate variability funded by the DOE to apply those pre-existing climate model runs to this problem, resulting in better use and wider distribution of the DOE work and better data sets and more information for this JIMO project.

Partnerships: California Energy Commission, California Department of Water Resources, California Public Utilities Commission, California Independent System Operator, Sierra Energy, DSI Power, SoCal Gas, Pacific Gas and Electric, PacifiCorp, Sempra Utilities, and San Diego Gas and Electric.

Collaborators: Georgia Institute of Technology; University of Washington

Conference Proceedings & Workshops: (Conference Name, Date and Location) We organized and ran a session at the International Association of Impact Assessor's annual meeting in spring 2004; these are people who consider issues of integrating industrial activity (e.g., electrical generating plants, hydropower facilities) with the environment. Vancouncer, BC, Canada, May 26-30, 2004.

7. AWARDS/HONORS:

N/A

8. COMMUNICATIONS, NETWORKING AND OUTREACH:

Activity	Objective	Partners
Communications	These results have been shown in 30 presentations to important stakeholders and lawmakers.	see list at end
Networking	Provide forecast information to decision-makers and energy partners.	see list at end
Outreach/Academic	Educate users, academic collaborators, and the public on climate science and its applications. Evaluate the benefits of this information in decision-making.	see list at end
Graduate/Undergraduate Students (List by name, degree status and continuance after obtaining degree)	Belinda Lu (undergraduate, UCSD)	
K-12 Outreach		see list at end
Presentations/Seminars/ Symposiums	Communicate scientific results to the public; develop and strengthen collaborations with academic, governmental, and industry partners.	see list at end
Fellowship Programs/Internships		see list at end
Public Relations	Bring visibility to NOAA products and enhance interest in weather and climate information and its usefulness.	see list at end

9. PERSONNEL:

Catetory*	Name	Job Title	Brief Biographical Sketch
Lead PI	Tim Barnett	Marine Physicist	Global climate modeling; climate change; El Nino forecasting; statistical and dynamic methodology

PI	Dan Cayan	Research Meteorologist	U.S. west hydrology; societal impacts; snowpack and runoff; drought and streamflow
Affiliated Researcher	Anne Steinemann	Visiting Scientist	Communicating forecast products to decision-makers, coordinating between forecasters and users, conducting economic evaluation
Research Staff	David Pierce	Programmer Analyst	North Pacific climate variability; global climate modeling; numerical modeling techniques; El Nino forecasting
Affiliated Researcher	Dennis Lettenmaier	Professor	Hydrology and water resources; hydropower issues; streamflow forecasting; energy implications of climate variability

*Categories: Leadership team, Research Staff, Affiliated Researchers, Visiting Researchers, Post Doctoral Researchers, Research Assistant, Technical Staff and Graduate/Undergraduate Student

10. PUBLICATIONS: Separate publications by category with full citation (Please indicate in **bold** whether Joint Institute **(JI)** or NOAA Lead Author **(NOAA).** Include Presentations in Section 8 under Outreach.

Journal Articles:

Alfaro, E. J., Alexander Gershunov, Daniel Cayan, Anne Steinemann, David Pierce & Tim Barnett, 2004: A method for prediction of California summer air surface temperature. EOS, v. 85, p. 553-557.

Books/Articles-in-Books:

Reports:

Conference Proceedings/Workshops:

Annual Meeting of the American Meteorological Society, Jan 2005: Seasonal temperature and energy demand predictions for the U.S. West. Oral presentation by D. W. Pierce.

Annual Meeting of the American Meteorological Society, Jan 2005: The California Delta Breeze: Characteristics and Sub-Daily Forecasting. Poster presentation by D. W. Pierce and D. Gaushell.

Ph.D. Dissertations:

Submitted and In Press:

Alfaro, E. J., Pierce, D. W., Steinemann, A. C., and Gershunov, A., 2005: Relationships between irrigation pumping electrical loads and the local climate in climate division 9, Idaho. J. Appl. Meteorol., *in press*.

Alfaro, E. J., Alexander Gershunov, Daniel Cayan, 2005: On the predictability of maximum and minimum temperature over the western USA using CCA. J. Climate, *in press*.

Davis, T. D., D. Gaushell, D. W. Pierce, and M. A. Altalo, 2005: The economic benefits of improving weather and load forecasts for electric utility strategic and operational management. Public Utilities Fortnightly, *in press*.

L.A. Smith, D. Kilminster & M. Altalo, 2005: Probability Density Forecasts or Mere Distribution Forecasts: What Might We Expect from Imperfect Weather Models? Physica D, *submitted*.

11. Figures/Photographs/Illustrations (2) (Please provide figure caption)

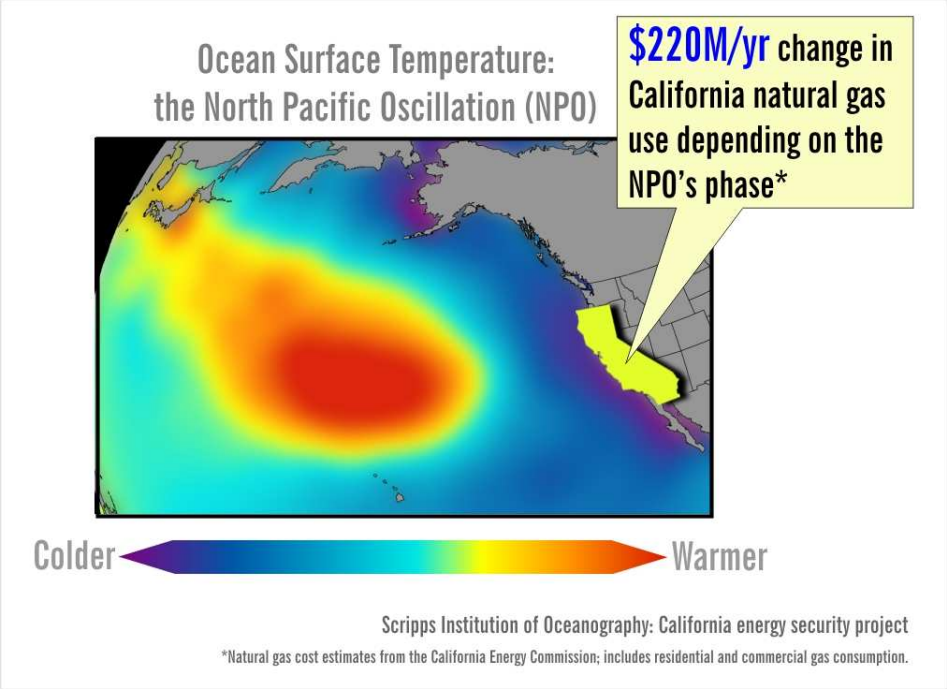

Figure Caption: The large-scale climate fluctuation known as the North Pacific Oscillation (or Pacific Decadal Oscillation) can bring either warm or cold conditions to California in the winter. The difference in natural gas use for space heating between these two phases can be about $220 M/yr.

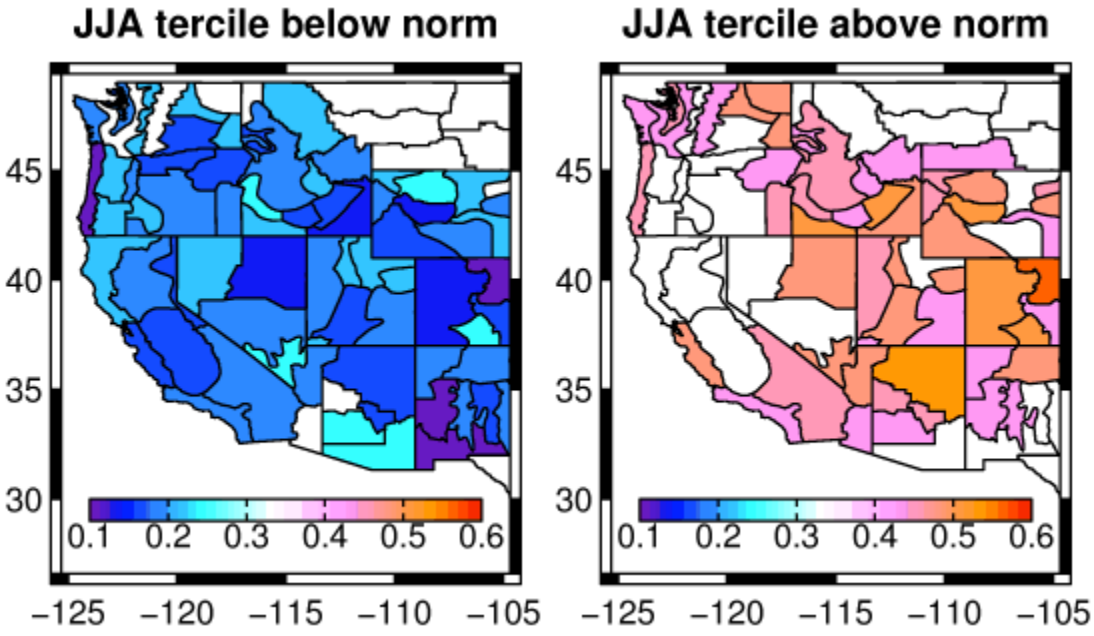

Figure Caption: Given warm temperatures in spring, the figure shows the chance of getting cold (left panel) or warm (right panel) temperatures in summer. Blue colors indicate a low chance, oranges and reds indicate a high chance. This association between spring and summer temperatures forms the basis for predicting summer irrigation pump electrical loads, as described in Alfaro et al., J. Applied Meteorology, 2005.

Communications, Outreach, Networking

- Staffer for U.S. Rep. Randy Cunningham **(5/27/03)**
- U.S. Rep Sherwood Boehlert, Chair, House Science Committee **(9/13/03)**
- Eric Massa, House Armed Services Staffer **(9/24/03)**
- House Science Committee members Rep. Vern Ehlers, Chair of the Environment, Technology and Standards Subcommittee; Rep. Nick Smith, Chair of the Research Subcommittee, and Rep. Jerry Costello, who also serves on the House Transportation and Infrastructure Committee. **(10/24/03)**
- SIO director's cabinet meeting (community activists who advise the SIO director) **(12/10/03)**
- Dwight Cates, Staff, House Energy & Commerce Committee; Kathryn Clay, Staff, House Science Committee; Mike Conallen, Chief of Staff, Congressman Curt Weldon; Tina Kaarsberg, Staff, House Science Committee; Chris King, Staff, House Science Committee; Ryan Long, Legislative Director, Congressman Barton; Peder Maarjberg, Appropriations Director, Congressman Visclosky; Shane Perkins, Staff Assistant, Senate Energy Committee; Chris Heggem, Legislative Assistant, Senator Burns; Neil Naraine, Legislative Assistant, Senator Landrieu; Marsha Shasteen, Democratic Counsel, House Science Committee **(1/10/04)**
- Drew Willison and Nancy Olkewitz, Senate Energy and Water Appropriations staff **(1/16/04)**
- Dan Skopec, California state deputy Cabinet Secretary for energy and environment **(1/28/04)**
- SIO director's council, a group of California executive businesspeople and politicians who advise SIO **(2/27/04)**
- Presentation at the International Association of Impact Assessors, people who are involved with planning for the environmental impacts of industry and technology **(4/28/04)**
- Annual meeting of the California Climate Registry, business leaders who are working towards a CO2 credit exchange **(5/7/04)**
- Ryan Broddrick, Director of the California Department of Fish and Game **(5/21/04)**
- Allan Lloyd, Director of California Air Resources Board **(5/21/04)**
- Staff of U.S. Rep. Rohrabacher **(5/27/04)**
- Michael Chrisman, California Resources Secretary, and Jim Branham, CalEPA Undersecretary **(6/3/04)**
- John Wilson, advisor to California Public Utilities Commissioner Rosenthal **(6/11/04)**
- Board of Directors, National Corn Growers Association **(6/14/04)**
- James Paul, Staff, House Committee on Science **(6/29/04)**
- Ed Freeman, Past Director of SIO **(7/14/04)**
- Steven Koonin, Chief Scientist at British Petroleum **(7/15/04)**
- California Energy Commission sponsored public lecture, Sacramento, CA **(8/30/04)**
- Public lecture at the Birch Aquarium, SIO, televised on UCSD TV and the University Channel **(9/13/04)**
- Raymond Orbach, Director of the Office of Science, DOE **(10/7/04)**
- SIO "California Issues" forum: Climate and Energy in California. Public lecture and workshop, La Jolla, CA **(10/22/04)**
- Meeting of the Society for Environmental Journalists, San Diego, CA **(1/28/05)**
- Women's Environmental Council, San Diego Branch, San Diego, CA **(4/27/05)**
- Director and CEO of the Waitt Foundation **(5/13/05)**
- Staff of Sen. Barbara Boxer **(6/13/05)**
- "NOAA Climate Day" on Capitol Hill, Washington, DC. This included a public lecture and visits to the staff of lawmakers Clinton, Boxer, Feinstein, Murry, and Issa, as well as to staff of the commerce and science committees. **(6/16/05)**

- Meeting of the scientific advisory board for British Petroleum, San Diego, CA **(7/1/05)**