

## Assessment of Climate Information Dissemination Efforts by the Florida Climate Consortium

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The Florida Climate Consortium (FLC)<sup>1</sup>, whose goals are production and application of seasonal to inter-annual climate forecasts, include the Florida State University, the University of Florida, and the University of Miami. The FLC was formed in 1997, primarily with funding from NOAA. In 1999, the FLC shifted its focus from South America to the Southeast USA and started work on understanding the linkages between El Niño Southern Oscillation (ENSO) phenomena and important economic sectors of the Southeast USA, especially agriculture and forestry. In 2003 Auburn University, the University of Alabama in Huntsville, and the University of Georgia joined the consortium. The group was renamed the Southeast Climate Consortium to reflect the new regional emphasis on the southeastern United States. Major products of the FLC for both South America and the Southeast US include:

- Seasonal climate forecasts of temperature and precipitation amounts based on the influence of ENSO phase.
- Analysis of historic crop yields for tomato in South Florida and peanut in the Southeast US relative to different ENSO phases.
- Linking climate and crop models, to forecast regional yields.
- ENSO-based freeze early warnings forecast, wildfire forecast, and turfgrass management recommendations.
- Agricultural and other decision-support tools, including, tailoring options available to management for winter tomato production, ranching, and peanut production, using ENSO-based climate forecasts.
- The FLC has produced reports for general audiences as well as papers for peer-reviewed journals.
- Products targeted at specific user-groups have been produced in collaboration with the Florida Cooperative Extension Service (FCES) and other organizations. These products include a freeze forecast for 2001-2002, an experimental wildfire forecast for January - June 2002, and a bulletin on turfgrass management explaining how to use climate forecasts in agricultural management

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<sup>1</sup> **Abbreviations and Acronyms Used in this Paper:** DOF = Division of Forestry; EDIS = Electronic Data Information System; ENSO = El Niño Southern Oscillation; FAQ = Frequently Asked Questions; FAWN = Florida Automatic Weather Network; FCES = Florida Cooperative Extension Services; FLC = Florida Consortium; IFAS = Institute of Food and Agricultural Sciences; KBDI = Keetch-Byram Drought Index; NOAA = National Oceanic and Atmospheric Administration; RISA = Regional Integrated Sciences Assessment; SMP = State Major Program

The FLC has employed diverse mechanisms to disseminate climate information to FCES Agents and growers. Some of the more important mechanisms include: 1) in-service training organized by the Institute for Food and Agricultural Sciences (IFAS) of the University of Florida; 2) agricultural weather schools conducted by the Florida Automated Weather Network (FAWN); and 3) publications, both general and trade.

The goal of this paper is a first-order assessment of FLC impacts, including assessment of specific climate information products that the FLC introduced from 1999 through 2002. This paper describes the first attempt to review systematically FLC activities during this period. The purpose is to get a rough sense of which activities work and which do not, specifically with respect to user perceptions of FLC products. The approach was to examine the dissemination, application, and user perceptions of specific products, as well as process underlying the gamut of FLC activities. Because the FLC was started in 2000 and has had limited resources and personnel, a significant part of this assessment effort was expended on formulating the conceptual and practical approach with active feedback from partners like FCES, carrying out educational activities, and creating networks with the relevant persons and institutions. The FLC efforts are therefore described, analyzed, and assessed using a general framework that consists of the following broad evaluative criteria:

- Relevance of FLC efforts to the real and perceived needs of users in agriculture, forestry, and related areas.
- Extent and strength of the institutional linkages fostered by the Consortium
- Communication means and quality, accessibility of information, and ease of understanding and use of FLC products.
- Efficacy of FLC educational efforts in terms of increasing awareness and knowledge of ENSO and its impact on climate and agriculture in the Southeast USA.
- Reporting on FLC members and activities in popular media.
- Overall suitability and adaptability of FLC efforts for climate information production, communication, dissemination, and evaluation.

## **Rationale for Climate Services**

The FLC produces and disseminates seasonal to inter-annual forecasts, representing the product of a continuum of activities from basic through applied research. Over the past two decades, the dominant one-direction linear model for transfer of concepts and information from basic research to applied domains has undergone important modification. New concepts of the links between science, policy, and practice use a feedback model, which underscores the linkages and continuous feedback between science and society as changes emerge (Stokes, 1995).

Recognizing the importance of connecting research with its applications, Dutton (2002) calls for better integration between atmospheric data and user decision-models. Fundamentally, the expanded scope for use of climate information derives from parallel scientific advances that have improved prediction of atmospheric conditions on one hand, and have enabled sophisticated risk management for agriculture and other weather-sensitive sectors on the other.

Pielke and Carbone (2002) emphasize comprehensive understanding of the forecast process, including forecast evaluation. A piecemeal approach to forecast production, communication, application, and evaluation leads to neglect of the linkages and feedback among these steps.

The National Research Council (2001) has laid out five “guiding principles” for developing climate services in the country. “Continuing evaluation and assessment, by users and providers, of the use and effectiveness of the services” (p.33) is a cornerstone of climate services. A user-centric integration of climate prediction, communication, and application is best achieved at regional scale, with regions defined to have similar economic, legal, and political characters.

The Regional Integrated Sciences and Assessment (RISA) program, of which the FLC is a part, focuses on linking prediction, impacts, and human dimensions of climate. Different RISAs have focused on various sectors of regional significance, such as water resources, agriculture, and utilities. The FLC is unique in working primarily on agriculture and in forging a close partnership with extension services.

Evaluation of the impact of climate information or forecasts on a sector can be performed in different ways. The conventional approach measures the economic impacts of new research, including forecasts, uses a cost-benefit analysis; in essence the ratio of costs for research inputs to value of outputs. Although useful in providing concrete figures, which presumably estimate the impact of the interventions, a strictly economic approach fails to capture the complexity of the transformative processes that involve a multiplicity of agents and forces that influence any research-to-development trajectory. The problem of tracing impacts of specific research findings can be especially intractable in complex adaptive systems (Ekboir 2003) such as the agriculture sector. A better way to gauge impacts is through a more inclusive and contextual approach that emphasizes institutional learning and innovation. Institutional learning and innovation depend on the smooth flow of information within and across economic, scientific-technical, and social systems (Horton and Mackay 2003). This paper’s approach is to consider efforts of the FLC in conjunction with salient features of the regional agricultural innovation system. Therefore, FLC efforts are evaluated in terms of the degree of fit with:

- Structure of agricultural institutions, especially the parts involved in climate and weather.
- Information flow, both pre-existing and that generated by FLC efforts,
- Connecting agricultural decision-makers with institutional actors.

## **Methods**

To assess operations of the FLC, 13 interviews were conducted with FLC member representatives from all participating institutions: the Florida State University, the University of Florida, and the University of Miami. Members were interviewed in-person about details of FLC activities, partnerships, and products. In order to assess the relationship between the FLC and the Florida Cooperative Extension Services (FCES), which is the principal partner and target

group for FLC dissemination efforts, five additional interviews were conducted with FCES representatives.

To assess dissemination and education efforts, 24 FCES personnel who had undergone in-service training or participated in agriculture weather schools were interviewed. These interviews were conducted with a random sample of FCES personnel, stratified according to area of specialization to ensure balanced representation from different commodity groups, for example, vegetables, field crops, citrus, and livestock. Most of these interviews were conducted by phone, though a few were done in-person. Interviews followed a semi-structured approach, including specific questions about the interviewee's connections with FLC activities, as well as, broad, open-ended questions about climate forecasts, their use in the agent's area of specialization and in Florida agriculture in general. Additional information and clarification of answers in the original interviews was obtained by e-mail.

The goal of the interviews with extension personnel was to measure the impact of FLC efforts through such proxies as:

- Ability to recall the presentation and its contents from in-service training.
- Familiarity with FLC products and how to access them.
- Ability to distinguish between weather and climate forecasts.
- Attitudes towards climate forecasts.
- Knowledge of climate-agriculture linkages in Florida and potential use of climate forecasts.
- Extent that extension agents use FLC products, including forecasts, reports, presentations, and news releases to media.

Finally, an extensive search of Lexis-Nexis was done for reports related to El Niño, Climate and Agriculture in Florida, and the contributions made by FLC members.

## **Communication and Dialogue: Gauging user needs and perceptions**

The distinct contribution of the FLC has been the development of a close partnership with FCES<sup>2</sup> that has enhanced FLC scientists understanding of agricultural systems and information needs of growers within the context of constraints and opportunities existing at both farm and policy levels. The FLC has also collaborated with Florida Division of Forestry (DOF) and other State agencies and institutions to tailor products to specific needs of different groups. One of the most important aspects of this exercise has been the utilization of multiple mechanisms, such as, newsletters, web-based publications, such as the Electronic Data Information Source (EDIS, <http://edis.ifas.ufl.edu/>), and surveys, workshops, and presentations that allow two-way communication, which has helped the FLC learn about target agricultural systems while creating and enhancing interest in seasonal climate forecasts.

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<sup>2</sup> Particularly germane here is Cash's (2002: 450) characterization of extension service as a "boundary organization," which "provides an institutionalized space in which long-term relationships can develop and evolve, two-way communication is fostered, tools for management (such as models) are developed and utilized, and the boundary issue itself is negotiated."

Agricultural weather schools and in-service training for Extension agents have increased agents' understanding of how ENSO shapes Florida's climate as well as eliciting feedback from agents about the usefulness of climate forecasts in a range of existing and potential situations. Approximately 150 agents and growers have participated in these programs, including in-service training courses in Bell Glade, Everglades, and Quincy during 2002 and workshops in Alachua, Milton, and Tavares counties during 2001. In 2001, FLC members also presented climate information in weather schools at Palatka, Lake Alfred, and Marianna. Presentations made at these meetings provided the following principal types of information:

- Explanation of El Niño and La Niña phenomena and their relevance and potential applications to agriculture.
- Distinctions between weather and climate, especially with respect to drawbacks related to spatial resolution needed for agricultural decision-making.
- Displays of precipitation and temperature statistics by ENSO phase, based on data derived from local climate stations, and historical yield analysis for important local crops in relation to ENSO phase.
- Use of climate information in reducing adverse effects and exploiting favorable conditions, simulation results for specific sites and crops, and forestry study results.

Participants at these meetings provided valuable feedback about the potential usefulness of seasonal forecasts in a variety of situations. For example, Extension agents and growers emphasized the utility of a seasonal freeze forecast, and the latter revealed how management of certain light-sensitive varieties of strawberry could potentially benefit from a forecast of ENSO phase, which affects cloudiness. Anecdotes at these meeting often provided unexpected insights into the use of climate information, which reiterated to the FLC the potential usefulness of seasonal forecasts, as well as, specific ways to improve them. For example, an anecdote relating to the better outcomes for the potato growers, who took ameliorative steps (e.g., digging and cleaning drainage ditches to remove excess water) in light of the El Niño forecast for 1982-83, provided evidence of the awareness of the potential utility of climate information.

Several times each year County Extension offices produce newsletters on topics related to agriculture, nutrition, economics, and other matters of local interest. Articles on FLC freeze forecasts and livestock management have been included in five county newsletters. These newsletters contain concise summaries, often in the form of easy-to-follow instructions for a range of issues relevant to growers. Climate forecast information is presented in abbreviated form, often along with weather information from other sources.

The internet provides a powerful communications tool that allows people to get information they need. The FCES hosts EDIS, an internet-based, open-access source for sharing Extension recommendations and relevant research to a cross-section of diverse interests in Florida. The FLC has published several reports on EDIS to increase access to climate information in the agricultural community.

A *Sondeo* refers to a series of open-ended, interactive discussion among specialists from various disciplines and farmers or another target group (Hildebrand, 1981). Four *Sondeo* were conducted during 1999-2001, comprising a total of 41 Extension agents and 38 ranchers.

The *Sondeo* identified a number of decisions involving ranching that can potentially benefit from use of climate forecasts, for example: 1) when and if to plant cool season grasses; 2) rate of seeding; 3) rate and timing of fertilizer applications; 4) quantity of hay needed for winter; 5) purchases of bulk feeds and nutritional supplements; 6) when or if to ship cattle to another region; 7) adjusting stocking levels during winter and spring months; and 8) anticipating market conditions (Breuer et al., 2005). Extension agents interviewed in *Sondeos* indicated that seasonal forecasts could be potentially useful for a range of agricultural decisions, including, planting dates, fertilization, purchasing irrigation, if the information could be placed within a risk-reduction framework. The importance of understanding farmer decision-making within the context of farm management was also underscored.

The FAWN was created in 1997, after the National Weather Service stopped providing weather forecasts to Florida growers, a sequel of the termination of the Congressional funding for the effort. In 1997, freezes struck the citrus industry in northern-central Florida causing an estimated \$300 million in damage (FCES, 1997). Subsequently, FAWN was established as a collaborative effort of citrus industry organizations and the FCES to cater to the weather information needs of growers. A key individual in the efforts was John Jackson, the citrus Extension agent for Lakeland County. Jackson was also instrumental in putting climate information related to ENSO impacts on Florida into the FAWN website, including the freeze forecast for 2001-2002.

Personal contacts of FLC members have played an important role in influencing the composition of the FLC itself, as well as, the choice of projects that have been undertaken. The FLC wildfire risk forecast, for instance, was facilitated by Scott Goodrick, a Florida DOF meteorologist who had earlier worked under Professor Jim O' Brien, Florida State University, who is a FLC principal investigator. Professor Jim Jones, University of Florida, who is another FLC principal investigator, has played a pivotal role in initiating and sustaining collaboration with the FCES. The favorable reception accorded the FLC and its various products by its FCES partners and others, is in large part, an outcome of its identification with these individuals who have enormous professional and personal credibility.

Members of the FLC have also been interviewed in mass media about impacts of climate on economic sectors in the region. Extreme weather events, including hurricanes (The Atlanta Journal Constitution, 26 Jun 1997; Tampa Tribune, 12 Mar 2002), freezes, droughts (The Tampa Tribune, 2 Oct 2001, 21 Dec 2001; St. Petersburg Times, 2 Jan 2001), and wildfires (The Tampa Tribune, 3 Feb 2002) are topics of perennial interest. Sources for climate impacts on agriculture are mostly university-based agricultural scientists, trade group representatives, and administrators. The FLC members are cited in 15 of the 155 results produced by a LEXIS-NEXIS search of El Niño, Agriculture, and Florida, in the General News category.

Media coverage of ENSO impacts on Florida offers several lessons. The FLC members already have accumulated significant social capital<sup>3</sup>, which is reflected in the frequency their

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<sup>3</sup> Social capital is the aggregate of actual or potential resources that are linked with a durable network of somewhat institutionalized relationships or group memberships. These resources and linkages provide each member with the backing of the collectively owned capital, a 'credential,' which entitles them to credit within society, whether in terms of trust, goodwill, or other forms of social credit.

views on climate and climatic impacts are elicited. Although, FLC is not specifically identified in most reports (the official affiliation of “state climatologist” is most commonly used), the FLC can use these connections with media that have been made over time to highlight FLC products and activities.<sup>4</sup>

Another important factor is the almost total absence of private organizations as sources for seasonal forecasts<sup>5</sup>. The overwhelming presence of university-based researchers and other publicly-funded research institutions suggests that climate information, including seasonal forecasts, is still considered to be a public good. This reinforces the validity of the research-to-application path using the FCES, which is the preeminent channel for communicating public information related to agriculture<sup>6</sup>.

Finally, the widespread awareness of ENSO and the relatively sophisticated media coverage of its impacts indicate the potential for greater utilization to leverage dissemination of more complex and potentially useful products to users.

## **Specific seasonal climate forecasts and the related FLC products: origins, communication and impact**

The FLC products vary in terms of the extent of their dissemination to users. Some prototype products have been circulated more widely than others and can be considered to be near the application end of the research-application continuum. Other studies are more exploratory in nature, having demonstrated the potential value of climate information but not having bridged the gap between the forecast production and use.

### ***Prototype products***

The FLC has pioneered a forecast system for Florida and some other areas of the southeastern USA based on establishing a baseline of probable precipitation amounts during years with neutral ENSO phases. Seasonal forecasts of temperature and rainfall are presented in terms of shifts in probabilities for El Niño and La Niña years as compared with neutral ENSO phase probabilities. Categories include the middle 60 percent, top 20 and 10 percent, and bottom 20 and 10 percent of the probable precipitation amounts. Such categorization, with a large middle band constituting 60 percent of all observations and the tails comprising 20 and 10 percent of the observations, was adopted in accordance with the interest expressed by users in probabilities of weather extremes and the shifts therein. Historical weather data used for forecasting is derived from individual weather stations rather than climate division aggregates, which enables forecasts of much higher spatial resolution than is possible otherwise.

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4 One instance of this is the reporting of the nation-wide competition for hosting the International Research Institute for Climate Prediction in which the Consortium participated (St Petersburg Times Nov 7, 1995) and which could not possibly have occurred without the initiative of Consortium members.

5 A few larger farms and agri-business firms, however, have been reported to get climate information from subscriber-based services and in-house meteorologists.

6 The public good characteristic of climate information may make attempts to commercialize it premature and is important in light of one of the FLC PI’s observation that “People don’t appreciate a service unless they pay for it.”

### *Experimental Wildfire Forecast*

The FLC issued a wildfire risk forecast for Jan-June 2002 in consultation with the State DOF. The forecast consisted of Keetch-Byram Drought Index (KBDI) values on a monthly and county-by-county basis for the period. The DOF had been a pre-existing program for wildfire management, including both fire suppression and prescribed burns, which was able to incorporate wildfire risk forecasts based on ENSO phase.

In Florida, the active wildfire season starts in January and ends in June with the onset of rainy season. The intensity and frequency of wildfires depends on soil moisture, temperature, and the availability and condition of fuel—the underbrush and dried-out vegetation—among other factors. Wildfire risk increases as the season progresses as a combined result of increasingly dry conditions and the greater likelihood of lightening strikes. For example, during La Niña conditions in 1998, extreme dryness in May-June resulted in 506,000 acres of wildfire, one of the highest levels in the period from 1981 to 2002. In contrast, during El Niño conditions in 2002 only 56,000 acres burned, the lowest acreage lost to wildfire since 1981. The DOF uses the KBDI among other tools to allocate fire-fighting resources to different places in the State. The KBDI ranges from 0, which is extremely dry, to 800, which is extremely wet. Another important use of the KBDI is in prescribing controlled burns through identification of optimum conditions in terms of moisture and temperature to avoid larger potential conflagrations. On average, 2 million acres are burnt in Florida every year as part of the preventive program, more than the total for the Western USA.

The FLC effort provided a bridge between a climate forecast and the KBDI, both of which had been in use at the DOF. The linkage is important because a direct relationship between ENSO phase and wildfire acreage is difficult to establish because anthropogenic factors have dominant effects both on wildfire origins, such as arson or escape, and wildfire mitigation and suppression efforts, vary widely. The KBDI helps into account the influence of climate alone on wildfire risk, without the confounding effects of human activities.

Thus, the two main factors that led to the production and use of wildfire forecast were: 1) strong interpersonal relationship between FLC members and the DOF; and 2) the existence of necessary institutional prerequisites, such as in-house expertise, experience with climate information, and the ability to modify decision-making for the successful utilization of climate information, together which made the partnership possible. Extensive media coverage of the first wildfire risk forecast shows that the forecast fulfilled a pre-existing niche created by the shared expert and public understanding of the ENSO-wildfire linkage, which in turn led to public pressure for better performance from the relevant institutions. It is also important to consider the views of both DOF partners and FLC members in evaluating the forecast. The FLC members involved in the effort described it as “experimental” and successful. The DOF partners expressed overall satisfaction with the forecast, but described it as “not operational” and a “proof of concept” exercise. The wildfire forecast for May 2002 turned out to be poorly perceived because the forecast was for relatively wet conditions, yet the fire danger went to very high levels. The problem was described thus (Scott Goodrick, Personal communication):

The May 2002 forecast was for relatively wet conditions, but we received well below normal rainfall for May. However, despite the dry conditions we had very few ignitions during this period so the fire activity was low. The forecast was not widely distributed outside the Division of Forestry; it was treated as an experimental product. On the prescribed fire side, the May forecast could have resulted in the planning of numerous burns based on the wet forecast that would have been cancelled due to the overly dry conditions.

For 2003, Florida DOF decided not to fund the forecasting and the activity is now being funded directly by the USDA forest service. A possible factor driving this decision could have been the perception of a less-than satisfactory forecast for May, but other factors including the lack of agreement about the usefulness of the product within the DOF may also have contributed. In sum, the forecast closely mirrored actual conditions for the majority of the Jan-June period and this information was acted upon in the sense that “the State did not push to obtain out of state resources and preposition them in anticipation of above normal fire activity” (Scott Goodrick, Personal communication) unlike in 2000 and 2001. It is clear that the strong interpersonal relationship of some of the players on both sides and the trust that was built was used not only to produce the collaborative forecast after ascertaining the needs of the management, but it also prevented the derailment of the effort in the aftermath of a potentially damaging forecast. Currently, efforts are underway to refine the forecast by including information pertaining to history of wildfires, forest types, and improvement of the related KBDI thresholds.

### **Citrus Freeze Forecast**

The citrus industry, a major component of Florida’s economy, is directly vulnerable to climatic extremes, especially, sub-freezing temperatures. The present geographic distribution of citrus in the state has been influenced by massive freezes that ravaged the industry in the 1960s and 1980s, and pushed cultivation limits southwards.

A seasonal freeze forecast for 2001-2002 consisted of Florida maps with contours delineating areas with odds of specific temperature thresholds being reached in a neutral year relative to La Niña and El Niño years. Actual return frequencies associated with different sub-freezing temperature limits were also mapped. The map format was based on a study entitled “Freeze Probabilities in Florida” by James T. Bradley (1975) at the University of Florida. Another factor that contributed to the selection of the map format was its easy-to-understand quality because of visual presentation.

Freezes are classified as mild when temperatures fall below 32 °F for at least one night, moderate if below 28 °F, or strong if below 25 °F. By influencing the strength and location of the polar jet stream and therefore the penetration of Arctic cold front into Florida, ENSO influences in the number and intensity of freezes. All freeze events severe enough to cause relocation of citrus orchards during 1894 through 1997 occurred during neutral ENSO phase years Martsolf (2001). In El Niño and La Niña years, the jet stream circulation remains intact; countering the southward movement of cold fronts and preventing major freezes.

Freeze forecasts for 2001-2002 were disseminated using the FAWN network and a booklet titled “2001/2002 Winter Freeze Forecast for Florida,” which was produced and distributed by the Florida State University team. The FCES uses FAWN to convey weather information, freeze updates, and possible adaptation measures to growers. The seasonal forecast was added FAWN to provide growers with a larger window in which to plan and carry out alleviating steps as compared with traditional weather forecast that growers use to plan measures like water sprays for frost damage prevention. The IFAS extension service newsletter at University of Florida carried the forecast summary about the increased likelihood of freezes (3:1) in Florida in light of 2001 being a neutral year (IFAS 2001). The newsletter also included a general discussion of the relationship between ENSO phase and the freeze risk in Florida, and detailed information about microclimatic modifications including weed control, flooding of irrigation ditches and use of micro-sprinklers to prevent or minimize freeze damage. Some of these ameliorative steps, for example digging ditches, require significant labor and time inputs and could be undertaken specifically in response to a seasonal freeze forecast. *The Florida Grower*, a regional agricultural publication, also carried a categorical version of the forecast along with the possible adaptation measures for citrus growers (Parsons 2002).

The Florida Farm Bureau also took note of the freeze forecast and summarized it on their website thus: “Researchers at the Florida Climate Center have issued a probability estimate for a winter freeze in areas of Florida north of Lake Okeechobee. According to State Climatologist James O’Brien, Florida has a three-to-one greater likelihood of having a severe freeze this winter than during the past three years.”

The freeze forecast for 2001-2002 carried by the *Florida Grower* was also reproduced in a modified form in the publication *Florida Aquaculture* (Issue 12, Nov. 2001), a Florida Division of Agriculture and Consumer Services publication<sup>7</sup>. In keeping with the vulnerability of aquaculture to persistent freezing temperatures, the forecast consisted of a Florida map showing areas with odds of three consecutive nights of 32 °F or lower temperature. Maps also showed areas with higher than even, even, and below-even odds. Possible adaptation measures include covering the ponds with plastic sheets, which need to be purchased in advance<sup>8</sup>, and pumping warmer groundwater into ponds. A discussion of ENSO causes and various phases was also presented in the same issue of *Florida Aquaculture* in a Frequently Asked Questions (FAQ) format. Related information about various sources of weather information including the FAWN was also provided along with the “rule of thumb” popularized by Jim O’Brien, the provider of the forecast. According to this rule of thumb, “If a high pressure center associated with a cold front dips south of Dallas, TX, there is a good chance that Florida will experience freezing temperatures. If the high stays north of Dallas, Florida is probably safe.” Interestingly, the general warning about the potential severity of the 2001-2002 winter was reiterated in *Florida Aquaculture*, alongside a similar assessment of “The Farmer’s Almanac,” a traditional publication that growers use widely.

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<sup>7</sup> Another categorical forecast for 2002-2003 underlining the inverse relationship between El Niño and risk of freezes in Florida was presented in *Florida Aquaculture* (Issue 19, Oct. 2002)

<sup>8</sup> Although figures for plastic sheet sales from the cooperative store were available, it is not possible to attribute the change in sales to the impact of forecast alone as the industry in Florida is in flux with ongoing consolidation and drastic reductions in operations.

The FLC freeze forecast was a result of the in-depth understanding of the citrus and aquaculture industries in the State and the threats that these industries face from freezes. The forecast was produced and disseminated through the strong collaborative relationship of the FLC with the FCES and others, e.g., Florida Division of Agricultural and Consumer Services<sup>9</sup>. More specifically, the FLC was able to earn the trust and support of key Extension personnel having long records of involvement with citrus growers and the industry. Participation of key individuals, such as John Jackson for citrus and Paul Zajicek for Aquaculture, imparted visibility and automatic credibility to the forecast product. Jackson's role in establishing FAWN also helped in getting the forecast posted on the website, which in turn ensured access to growers who use FAWN as a source of weather information. Jackson has been quoted in popular media for his views and information about freezes and their impact on citrus industry (*The Miami Herald*, 28 Dec 2001; 3 Jan 2002; 17 Mar 1997).

### ***Exploratory studies***

#### **Pasture management**

Interactions with ranchers and modeling of ranching operations performed by the FLC has revealed that ENSO phase could have significant impact on decisions concerning purchasing hay, growing winter fodder, and fertilizer application (Jagtap et al. 2002). During La Niña seasons, ranchers may need to buy hay because lower winter precipitation increases the likelihood of poor winter ryegrass yields. The impact on price of feed and in turn profitability can influence ranchers' decisions to stock or sell.

#### **Turfgrass management**

The FLC produced a turfgrass management sheet, which was displayed on EDIS to help homeowners and Extension agents use climate forecasts in making decisions about irrigation, fertilization, weeding, and mowing of lawns (Miller et al. 2001). The management sheet was produced in collaboration with the experts in agricultural water management and the FCES, who are familiar with the different elements of decision-making. The information produced despite being placed on EDIS was not widely circulated.

#### **Winter tomato pest management**

Florida produces 95 % of the US winter tomato. The FLC studies have shown that winter tomato productivity differs significantly with ENSO phase. Yields decline of about 20 % during El Niño years and increase 8 % in La Niña years (Hansen et al. 1998). Yield analysis utilizing historical weather data and a tomato crop simulation model showed that planting date modification in accordance with ENSO phase could result in enhanced yields (Messina et al. 2001).

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9 Professor Jim O' Brien's acquaintance with Commissioner Charles Bronson may have facilitated the reception accorded to the climate information he provided, especially to the Commission's officers.

Conclusions on the usefulness of climate forecasts for tomato production are far more uncertain than the above results might suggest. Tomato production in Florida is highly commercialized. Growers produce specific varieties during certain time windows, essentially on contract from large firms. Flexibility of planting dates is further limited by market conditions, which are heavily influenced by the aggregate production. An FLC economic model found that the adoption of climate forecasts universally among tomato growers could depress prices and reduce overall profits. One potential solution would be for growers to coordinate tomato acreage of tomato to avoid a glut, but as yet such coordination seems unlikely.

Preliminary studies with Extension agents and growers have detected a limited interest in seasonal forecasts. Dominant effects of marketing issues and the factors mentioned above dwarf the potential benefit from forecasts. An Extension agent involved in the study also pointed out the difficulty of getting accurate information about how best to apply the forecast because growers are highly secretive about their management for competitive reasons. The tomato industry has very few decision-makers that market to even fewer distributors, effectively forcing all growers to be rivals that jealously guard the secrets of their success.

### **Peanut yields and ENSO phase**

Peanut yields in Florida and other areas of the southeastern US have potentially positive association with modification in planting dates in accordance with the ENSO phase (Mavromatis et al. 2002). Not only did the yields register an increase but inter-annual variability was reduced as well.

The FLC research using crop simulation models has proved that there exists potential for yield increase if the peanut planting dates are altered in keeping with the advanced knowledge of climatic conditions. Farmers normally plant peanut during early April. About half of the peanut acreage in the region is rainfed, thus crop performance depends to a large extent on favorable climatic conditions. Despite the poor predictability of ENSO influence on climate in April-May period, El Niño conditions generally result in lower than normal precipitation. For peanut planted in April, a dry period is likely to coincide with the vulnerable germination phase, thereby reducing yields. During an El Niño year farmers can increase probable yields if they delay planting by two weeks.

The principal constraint on the use of climate forecasts in peanut production has been the US government peanut support program, which leaves little incentive for increasing the efficiency of peanut production. Under the peanut program, growers were encouraged to maintain a constant level of production. They were compensated at the highest rate for the amount of peanut equal to or less than that produced the previous year. In the event that they produced more than they did the previous year, the price offered declined sharply. Production less than the previous year's benchmark led to a decline in the farmer's quota which would be bought by at the highest price during subsequent years. Recently, the quota system has been discontinued, in part to encourage more efficient production. This has predictably led to increase in peanut acreage in certain parts of the state that enjoy some of the highest yields in the country. The impact on use of climate information has not yet been studied but new incentives for more efficient production are likely to increase grower interest in using climate forecasts.

Interviews with Extension agents revealed that in some cases farmers may plant to take advantage of favorable soil moisture conditions even if likelihood of rainfall in the following 30-60 day period is not high. Furthermore, risk of tomato spotted wilt virus attack on peanut plants may constrain farmers' ability to delay planting. Similarly anticipated length of the growing season and probability a wet harvest condition influence farmers' decisions regarding when to plan. It is important for future studies aimed at increasing the use of seasonal climate forecasts in peanut farming that the whole array of practices be considered.

## **Extension, FLC, and Climate Forecasts: Awareness, Attitudes, and Use**

Sixteen of 24 FCES respondents interviewed needed cues to recall FLC presentations at the in-service training or weather schools during 2001-2002. Once the place and date of the presentation was mentioned, most respondents were able to recall in general terms the topics that were covered. These were described as "El Niño impact on Florida," "Description of El Niño," and "Correlation between agriculture and El Niño." Seven respondents were able to recall in detail the content of presentations although this did not always translate into use of the information for making recommendations to end-users. All respondents said they knew El Niño, La Niña, and other and climate forecast terminology before they attended the FLC presentations but acknowledged improvement in their knowledge of these phenomena and their impacts.

Eighteen of 24 FCES respondents had not used climate forecasts or information in the period between the presentation and the interview. Four respondents who were directly involved with the FLC freeze forecast had made specific recommendations based on that information. In three cases, respondents produced qualitative/categorical forecast information using FLC products, and with the help of FLC members. These modified/simplified summaries and analyses were published in newsletters and trade publications (e.g. *Florida Grower*, *Aquaculture*).

Twelve FCES respondents mentioned different potential uses for seasonal climate forecasts. Planting time for peanuts was considered flexible by two weeks, which could enable utilization of favorable soil moisture conditions in the period immediately following planting for establishment of a rain fed crop. Another tool to manage crop risk mentioned was crop insurance, the extent of whose coverage could be varied depending on the forecast and the desired level of protection. From narrations of past experiences with spring and summer precipitation, it is clear that timing of rainfall events can have potentially greater impact than the totals for a particular period. One FCES respondent from southeast Alabama described 2001 as a better year for peanut than 2002 in his area because rainfall occurred shortly after the critical planting period, despite the monthly total for 2001 being lower than that of 2002.

Twenty-two FCES respondents were aware of the El Niño conditions prevailing in 2002-2003 winter and spring, resulting in above average precipitation for the period. Most of these respondents also exhibited more in depth knowledge of rainfall variability within this period. For instance, December was usually described as having been extraordinarily wet, followed in most areas by a dry January. Almost all respondents commented on the relief experienced from the above normal precipitation, especially as it broke a 3-year drought related to La Niña. Ten

respondents claimed that they would have made different recommendations for planting ryegrass, irrigation of tomatoes, and others if they had known in advance that it would be an El Niño season.

Seven respondents expressed doubts about the reliability of seasonal forecasts using the logic that if short-term weather forecasts are still uncertain, then longer-term climate forecasts cannot be reliable. Three respondents also expressed reluctance to use seasonal climate forecasts because of they were skeptical of the accuracy of predictions. The FLC disseminated a precipitation forecast for May and June 2003 on FAWN, which indicated a slightly increased probability for dryer-than-normal conditions. Those months, however, turned out to have above-normal precipitation for the Southeast USA. One FCES agent from Alabama had mailed out the forecasts in the form of map showing areas of the Southeast with probabilities of rainfall in the bottom 20% and 10% of neutral year amounts. This agent explained that although growers called him about the apparently inaccurate forecasts, there were no complaints as above-normal precipitation was beneficial for crops, especially peanut and cotton, which are planted during the early part of the forecast period.

Four respondents expressed dissatisfaction with one or more aspects of climate information dissemination. Inconsistency in producing forecasts and updates was the most commonly encountered complaint. The absence of a forecast for 2002-2003 was pointed out and the need for timely and reliable climate forecast information was emphasized. A few respondents noted that farming is about the serious business of procuring livelihoods and cannot depend on the vagaries of academic research agendas and funding.

Respondents generally had a poor understanding of the sources of FLC products. For instance, only two respondents knew about the FLC website. In contrast, all respondents were familiar with FAWN and used the information contained therein to varying degrees<sup>10</sup>. Five respondents knew of the links to climate information provided by the FLC on the FAWN website. Other sources of climate forecasts were rarely referred to and seldom used<sup>11</sup>. Three respondents mentioned NOAA but no one had heard of the Climate Prediction Center. Three respondents also expressed a degree of skepticism, sometimes their own views and sometimes on the part of growers, about national sources of weather and climate information, while showing a preference for Florida-based researchers and their work. Respondents worried that “national-level” information may not be specific enough for growers.

Twenty respondents used the terms “climate” and “weather” interchangeably, although this did not necessarily imply lack of understanding of the differences between the two. When seasonal forecasts were mentioned, respondents were able to distinguish them from weather forecasts. Except for two respondents, everyone was aware that the preceding Fall and Winter (2002-2003) had been affected by El Niño. In general, respondents knew that El Niño resulted in

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<sup>10</sup> A principal constraint to FAWN information use relates to its lack of coverage in some areas, especially considering the great spatial variability of weather within Florida.

<sup>11</sup> The issue of trust is vital and was the principal reason the FLC developed a partnership with FCES. The FCES has a record of working with growers to address their problems and have unparalleled understanding of the context, especially farm-level, which is essential to the application of climate information.

higher than normal Fall and Winter precipitation whereas the converse was true of La Niña. However, the ENSO impact on temperature in Florida was poorly known.

The most commonly used means of communicating information to growers are FCES newsletters, trade publications, television, and newspapers. Internet access is improving but still varies widely by region and farm size. The EDIS publications are more widely used by FCES members than by end-users or the general public. One FCES agent said, "People call us and have us search for the required information on EDIS." Four FCES personnel also emphasized the importance of one-on-one, personal interaction with growers. According to them, the importance of inter-personal communication is probably even greater for something as new and untried as seasonal climate forecasts. Such a view agrees with experiences using climate forecasts in Australia, which has led to the observation that, "In general people prefer to get their advice from other people, rather than machines" (Nelson et al. 2002). Still, respondents emphasized the importance of using more than one medium for communication in addition to the internet.

Almost all respondents noted that television continues to be the most commonly used source of information for weather and climate. Some differences exist, for instance, in the case of citrus, where FCES, FAWN, and private providers are important sources of weather information. The expanding FAWN network combined with availability of 15-minute weather updates on their website has led to a rapid increase in numbers of users.

Only six respondents mentioned presentation of climate forecasts although the literature often cites presentation format as a major constraint to dissemination and application of climate forecasts (Callahan et al. 1999)<sup>12</sup>. Climatologists present a seasonal forecast in a probabilistic format, with different probabilities of rainfall being in the upper, middle, or lower third of historical rainfall levels. Farmers and other users often request a deterministic forecast, though once they understand the risks associated with a climate forecast they generally appreciate and request the probabilistic forecast. Respondents said that simplicity and the ease-of-understanding were the most important factors for dissemination and application of climate forecasts. Familiarity with seasonal climate forecasts, although widespread within the group interviewed, remains fairly rudimentary in the general public.

An aspect important to FCES personnel related to presentation of climate forecast is that of supporting information, which may be needed to facilitate its use. Five respondents, mostly those closely involved with the FLC products, emphasized that a forecast alone was not likely to be used unless accompanied with an analysis of impacts on production, prices, and levels of inputs, including fertilizer, herbicides, and irrigation. According to this perspective, recommendations for how to use a seasonal climate forecast specific relative to a crop or sector will help users evaluate the impact on outcomes of interest to them. The need for supporting information will vary with the history of climate information use in a particular activity and with the level of expertise that exists for its successful incorporation in decision-making. For

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<sup>12</sup> Climate forecast use in certain sectors, such as water resources management, occurs in the context of a system that is centralized and almost closed with respect to management goals. These systems rely heavily on mathematical models and highly technical operations. In contrast, agriculture, especially in the case of small and medium growers, has limited capacity and perhaps limited need for highly complex information that would require on-site interpretation and modification.

example, in the case of a freeze forecast, communication of probabilities (or odds) of freezes may be sufficient as the industry as a whole is highly adapted to respond to freeze<sup>13</sup>. Conversely, use of climate forecasts in agronomic crops will probably be successful in proportion to the adequacy of the accompanying recommendations; at a minimum, an understanding of the relationship between climate and planting dates, varieties, and general agronomic practices. Two FCES agents interviewed expressed reservations about making recommendations to the growers. The lack of location specific data for field-level attributes, such as soil type and crop history, can stymie recommendation efforts that do not need considerable modification by the user. In addition, recommendations may have associated liability if users hold FCES agents responsible for deterministic recommendations based on a probabilistic forecast<sup>14</sup>.

## **Views and Perceptions within the FLC**

Interaction among FLC members through meetings, conference calls, interviews, and participant observation, has revealed that there is a consensus about moving towards producing and disseminating operational seasonal forecasts and related products. Several factors have contributed to the focus of the FLC on agriculture and related sectors, such as forestry and aquaculture. First, FLC research has emphasized relationship between climate and agriculture, and other sectors of Florida's economy, filling gaps in knowledge needed before the FLC could be become involved with "on-the-ground" decision-making. Several FLC members also emphasized the limited funding available, which prevented the FLC from expanding its activities. The FLC members also emphasized the balancing of the goals and the resources available; the potential for creating asymmetry between expectations and FLC ability to deliver also acted to limit the scope of activities. The work done so far is seen by FLC members as mostly involving exercises in producing and testing prototypes with limited exposure to selected groups of end users.

Major assets of the FLC have been its principal investigators, who are prominent in their fields of expertise and have close links to policy-makers and administrators in agricultural, the media, and other organizations. Jim O'Brien is much sought after for his expertise, thereby directly and indirectly increasing the visibility of the FLC on climate-related issues because of his position as the State Climatologist for Florida. Jim Jones has been instrumental in forging the partnership with FCES and facilitating the work of the FLC. The principal investigators are often invited to address volunteer groups such as 4-H, Kiwanis, Rotary clubs, and trade groups such as the Florida Fruit and Vegetable Growers Association. These presentations improve the general understanding of climate, its societal impacts, and the role of science in mediating this relationship. Another distinct contribution of these charismatic leaders has been to secure FLC dominance in the field, working together to assure that resources are used efficiently and effectively in order to keep the FLC economically and politically viable. The increasing trend towards the emergence of scientific research with a societal benefit, or at least, demonstration of

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<sup>13</sup> The citrus industry has a long history of using weather forecasts and the consequent microclimatic modification that is often undertaken as an ameliorative measure. Information pertaining to the use of irrigation, micro-sprinklers, etc. is widely available and easy to implement in practice.

<sup>14</sup> One veteran Extension agent mentioned that growers often call him during the growing season to ask what they should do. "Some people would like us to make decisions for them but I always give them the information and tell them that it is their decision to make."

demand from significant client groups, is a prerequisite for funding making the role of these individuals indispensable to the FLC.

A less important factor that has shaped the FLC agenda has been the conviction of some members that research is their primary goal. As Hansen (2002) points out, meteorologists have traditionally considered forecast production and distribution as their mandate, leaving users to determine how they will use the forecast. Some FLC members echoed the reasons that underlie this division of labor, for instance, a lack of expertise in communication and dissemination among researchers.

Related to the dilemma regarding research versus dissemination is the issue of credibility. Some FLC members are concerned that “entering the fray” of end-to-end climate information services might expose those involved to risk of damaged reputations because the potential exists for third party distortion, misuse, or abuse of climate forecasts. Such abuse would be especially difficult to prevent without adequate resources. An example that FLC members mentioned related to the poor public understanding of climate issues in general, even among professionals from other disciplines, and probabilistic forecasting in particular. Farmers, for instance, expect deterministic forecasts and may misinterpret probabilistic information, leading one of the principal investigators to say that unless significant probability shifts are expected, forecasts should not be made<sup>15</sup>. The short-term nature of memory as it pertains to perceptions climatic and poor distinction between weather with climate make much more challenging the task of FLC members that present seasonal forecasts. The decision to produce the freeze forecast in terms of odds of reaching specific temperature thresholds was based on the knowledge of widespread understanding and acceptance of this terminology by growers. Additionally, even an accurate forecast may not have the expected implications. An example cited by one principal investigator relates to the impact of the 1997-1998 El Niño in Australia. Despite the forecast accuracy in predicting rainfall deficit, the expected dire consequences failed to materialize because rains were evenly distributed during the season.

By emphasizing a systems approach to agricultural decision-making, the FLC has avoided many of the pitfalls common to more simplistic approaches, such as those based on maximization of yields or profits. For example, in the study on the application of climate forecasts for tomato production in South Florida, the FLC highlighted the paradoxical impacts for farmers inherent in the adoption of climate information (Messina 2001; FLC 2002). While being potentially advantageous to individual growers, if all growers use climate forecasts they could easily saturate the market with resultant declines in prices and profits. Similarly, FLC research has also revealed that agricultural decision-making must be strategic in an increasingly globalized and inter-connected world. For instance, cow-calf operations in Florida may be less affected by local climate than by the prevailing climate conditions in the Midwest US, which has a strong influence on grain prices. A similar situation for winter tomato prices received by South

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<sup>15</sup> Interestingly, the forecast for 2003 summer monthly precipitation posted on FAWN was based on relatively small, downward probability shifts of 10-15 percent to the likelihood of getting “abnormally dry” and “extremely dry” weather conditions. When Florida, overall, experienced higher-than-expected precipitation for the period, the Consortium member who made the forecast pointed out the limitation inherent in making monthly forecasts, “where climate tends to blur into weather”.

Florida producers, which are strongly influenced by the quality and quantity of the tomato crop in Mexico, which is their main competitor.

## **Conclusions**

### ***Obstacles***

Successful application of seasonal climate forecasts will depend on a number of factors, including user recognition of climatic vulnerability, the value of forecasts in reducing risk, decision-making structure capable of utilizing uncertain information contained in climate forecasts, accuracy, format, lead-time, scale of the forecasts, and the existence of institutions for sustainable provision of forecasts (Hansen 2002). Overall FLC efforts have had limited impact on decision-making so that questions related to use of probabilistic information in forecasts and are in large part premature. Even among FCES personnel, climate and climate forecasts are not sufficiently distinguished from weather and weather forecasts. Some limitations to application of climate forecasts are structural, such as the fact that State agriculture is embedded within the larger national and global economic systems and the resulting inertia, which often leaves growers with little room for modifying management; others limitations relate to frequency and form of climate information to be disseminated.

Another aspect that assumes greater importance in light of the FLC shift towards producing and disseminating the decision-support tools is the willingness and capacity for their application among FCES and end users<sup>16</sup>. This willingness and capacity of application of forecasts must be considered when setting benchmarks for the use of seasonal forecasts and related products, and in devising more accurate measures of climate information value. Where there is limited enthusiasm for well-established crop-models, complex decision-support tools based on coupling crop and climate models may have difficulty finding takers. On the positive side, the utilization of decision-support tools will help in optimal use of seasonal forecasts and reduce the potential for distortions in their interpretation and use. A possible alternative is “discussion support” (Nelson et al. 2002), which is a less directive version of decision support where analytical rigor can be combined artfully with the flexibility offered by a dialogue format. Discussion support would allow recommendations to adapt to the highly dynamic and unpredictable situations that farmers face. The crucial issue is to find a middle ground between disseminating stand-alone forecasts, which generally have limited, serendipitous use, and highly elaborate decision-support systems, which users may find difficult to understand and apply.

### ***Successes***

The close collaborative relationship between the FLC and FCES, the multidisciplinary composition of the FLC, with members from agricultural, climatology, and social sciences, and the wide range of experience of the FLC members, have helped this research team strike a balance between theoretical innovation and practical application. The relationship has been

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<sup>16</sup> Differences in analytic capacity of end-users can account for differences in their response to information provided by extension and other agencies (Just et al. 2003)

tremendously useful in terms of capitalizing on robust existing networks rooted in trust and personal relationships, thereby externalizing significant part of the cost of transmission and acceptance of information. The FLC goals and action plans are tempered by a healthy dose of realism and activities to date have been informed by a keen sense of the importance of numerous constraints—institutional, cognitive, and technical—in the utilization of seasonal climate forecasts at the farm level.

The FLC has adopted a reflexive evolutionary approach along the lines of Hansen's (2002) conceptualization of climate information dissemination efforts into three stages: exploratory, pilot, and operational. The FLC considers itself as being in the pilot stage with respect to some of its efforts, for example, dissemination of freeze and wildfire risk forecasts, and in the exploratory stage with regard to others, for example, new forecast methods that use global circulation models and regional nested models to improve seasonal forecast accuracy and give greater location specificity as compared with an ENSO-based seasonal forecast.

Creating institutional linkages in addition to inter-personal relationships also represents an informal-to-formal transition. For example, the acceptance of "Climate and Weather" as a State Major Program (SMP) in 2002 fostered the allocation of more resources to this area and systematic accumulation of relevant knowledge, which could otherwise be fragmented and difficult to access<sup>17</sup>. Establishment of a SMP will also allow closer monitoring of the program impacts because the SMP focuses on commodities and problems that are important to a sizable number of people and have significant economic impact. A design team made up of FCES and relevant department experts drawn from University of Florida has been selected to prepare a curriculum and devise ways of monitoring the work done in the program. The ultimate goal envisaged by the FLC is the development of an operational regional climate service. This service will require greater resources and further institutionalization of the relationships that have been established with the user groups.

## References

- Bradley, J.T. 1975. Freeze probabilities in Florida. *Bull. Fla. Agric. Exp. Stn. No. 777*, Inst. Food Agric. Sci., Gainesville, FL.
- Breuer, N.E. V.E. Cabrera, K.T. Ingram, K. Broad, P.E. Hildebrand. 2005. Potential usefulness of seasonal climate forecasts for agriculture and natural resource management. (in preparation)
- Callahan, B., E. Miles, and D. Fluharty. 1999. Policy implications of climate forecasts for water resources management in the Pacific Northwest. *Policy Sciences* 32: 269-293.

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<sup>17</sup> Formalization represents a step in the right direction but its usefulness should not be overestimated. Only 5 of 23 agents interviewed were aware of the new SMP. A few county Extension agents even considered it as typical of what "people in Gainesville" (Extension top-brass) do implying that there is a gap between the needs and perceptions of people at different levels of the Extension hierarchy.

- Cash, D.W. 2002. In order to aid in diffusing useful and practical information Agricultural Extension and Boundary Organizations. *Science, Technology & Human Values* 26(4): 431-453.
- Dutton, J.A. 2002. Opportunities and priorities in a new era for weather and climate services. *Bulletin of American Meteorological Society* 83(9): 1303-1311.
- Ekboir, J. 2003. Why impact analysis should not be used for research evaluation and what the alternatives are. *Agricultural Systems* 78: 166-184.
- FLC. 2002. The Florida Consortium 1996-2001: A critical assessment of research and outreach activities. A white paper. FLC, Gainesville, FL.
- IFAS. 2001. Flatwoods Citrus. Vol. 4 (12). Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.
- Hansen, J.W. 2002. Applying seasonal climate prediction to agricultural production. *Agricultural Systems* 74(3): 309-330.
- Hansen, J.W., A.H. Hodges, and J.W. Jones. 1998. ENSO influences on agriculture in the southeastern United States. *J. Climate* 11: 404-411.
- Hildebrand, P.E. (1981). Combining disciplines in rapid appraisal: the Sondeo approach. *Agricultural Administration* 8:423-432.
- Horton, D. and R. Mackay. 2003. Using evaluation to enhance institutional learning and change: recent experiences with agricultural research and development. *Agricultural Systems* 78: 127-142
- Jagtap, S.S., J.W. Jones, P. Hildebrand, J.J. O'Brien, G. Podesta, D. Zierdan, F. Zazeuta. 2002. Responding to stakeholders' demands for climate information: from research to application in Florida. *Agricultural Systems* 74(3): 415-430.
- Just, D.R., S. Wolf and D. Zilberman. 2003. Principles of risk management service relations in agriculture. *Agricultural Systems* 75: 199-213.
- Martsof, J. David. 2001. Relationship between Florida freeze incidence and sea surface temperature in the tropical Pacific. *Proc. Fla. State Hort. Soc.* 114: 000-000.
- Mavromatis, T., S.S. Jagtap, J.W. Jones. 2002. ENSO Effect on peanut yields and nitrogen leaching. *Climate Research*. 22:115-128.
- Messina, C.D., J.W. Jones, J.W. Hansen. 2001. Understanding ENSO effects on tomato yields in Florida: a modeling approach. pp. 155-156 In: Proc. 2<sup>nd</sup> Int. Symp. Modelling Cropping Systems, Florence, Italy, 16-18 July.
- Miller, Grady L., Sydney Park-Brown, Carol Stiles, Michael Dukes, Fred Royce, Jim W. Jones, Fedro S. Zazueta, and David Zierdan. 2001. Climate based management of lawns. EDIS. <http://edis.ifas.ufl.edu>.
- National Research Council. 2001. A climate services vision: First steps toward the future. National Academy Press, Washington, D.C.
- Nelson, R.A., D.P. Holzworth, G.L. Hammer, P.T. Hayman. 2002. Infusing the use of seasonal climate forecasting into crop management practice in North East Australia using discussion support software. *Agricultural Systems* 74(3): 393-414.
- Parsons, L. 2002. Freeze protection preparations. *Florida Grower* 95(1): 26-28.
- Pielke R., R.E. Carbone. 2002. Weather impacts, forecasts, and policy – An integrated perspective. *Bull. Am. Meteorol. Soc.* 83:393-406.
- Stokes, D.E. 1995. Pasteur's Quadrant: Basic science and technological innovation. Brookings Institute Press.