industrial applications." Gaudry notes that a culture of innovation won't flourish unless there is a sufficiently large pool of talent.

The two reports address both problems. They recommend that 2000 new student places per year be created in the physical sciences, the costs of which should be shared between government and business, and that scholarships be given to students who fill 500 of these places. They recommend that the government invigorate first-rate university research by doubling the number of postdoctoral fellowships from 55 to 110, doubling the $132 million budget of the Australian Research Council (ARC), and providing $275 million for academic infrastructure. At present the council funds only one in five proposals, and individual grants cover only 75% of the research costs.

Most academics believe that the recommendations reinforce the earlier Wills report, which made a convincing case for the value of basic research in fostering productivity. And they welcome the strong support coming from industry. "This is the first time we have had such a united front," says Vicky Sara, chair of the ARC. Still, they caution that years of neglect can't be erased overnight. With her department facing another 20% budget cut, Carter is not alone in wondering whether any boost in government funding may be too little, too late.

–ELIZABETH FINKEL

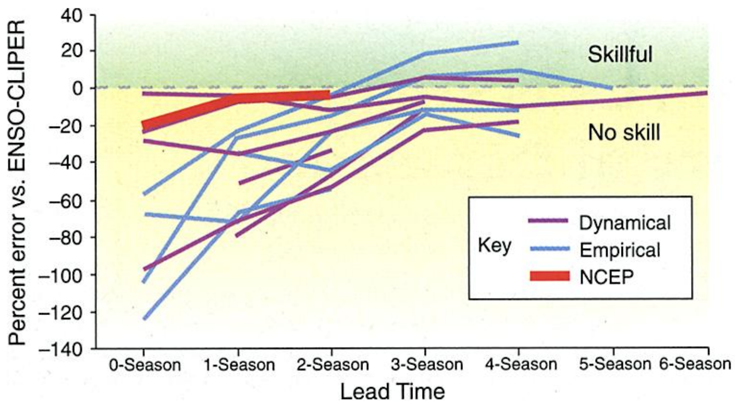
Elizabeth Finkel writes from Melbourne.

CLIMATE PREDICTION

Second Thoughts on Skill Of El Niño Predictions

A few years' perspective on the 1997–98 El Niño and a toughening of standards drops model forecast performance from spectacular to encouraging

What if your high school geometry teacher called you up at grad school to tell you that, on further thought, she was dropping your grade from an A to a C+? That's what researchers are doing to the computer models that forecast a warming of the tropical Pacific early in 1997. Less than a year after the onset of one of the two strongest El Niños of the century, researchers were awarding high marks to models that had anticipated the warming by as much as 6 months, especially the big, computationally expensive models (*Science*, 24 April 1998, p. 522). Now, with the complete rise and fall of El Niño available for grading—and with second thoughts about the standard to which models should be held—researchers have lowered their marks. Some critics have even failed the models.



A cloudy crystal ball. Both cheap and sophisticated El Niño forecast models struggle to exceed a modest standard of skill (dashed line).

SOURCE: C.W. LANDSEA AND J.A. KNAFF, *BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY*

In the September issue of the *Bulletin of the American Meteorological Society*, meteorologists Christopher Landsea of the National Oceanic and Atmospheric Administration's (NOAA's) Hurricane Research Division in Miami and John Knaff of NOAA's Cooperative Institute for Research in the Atmosphere in Fort Collins, Colorado, give the models' performance a failing grade. The sophisticated models, it turns out, did a poor job of predicting the 1997–98 El Niño's full course; in fact, they did no better than a rudimentary model that can run on a desktop. "When you look at the totality of the [El Niño] event, there wasn't much skill, if any," says Landsea. Others won't go that far but agree that the models' reputation needs to be taken down a notch or two. "There's no doubt the models were helpful," says meteorologist Neville Nicholls of the Australian Bureau of Meteorology Research Centre in Melbourne, "but certainly they didn't do as well as a majority of my colleagues had thought. We still can't be certain the models have got the problem solved."

In arriving at their much-reduced forecasting scores, Landsea and Knaff make two changes in the way forecast performance was initially evaluated. Instead of focusing on how well a model predicted the onset of El Niño in the spring of 1997, as early analyses had to do, they gauge success throughout El Niño's onset, peak, and decay and into the beginning of La Niña, the cold phase of the cycle in the tropical Pacific that ended this summer. They found that whereas some models, such as that of NOAA's National Centers for Environmental Prediction (NCEP) in Camp Springs, Maryland, did well in predicting the time of onset, all 12 models they assessed underestimated the size of the actual warming by at least 50% in their 6- to 12-month forecasts. And the models that did well with the timing of onset missed on the decay; although the NCEP model continued to call for a gradual cooling through 1998, the tropical Pacific chilled precipitously in May. "If they do well on the onset," says Landsea, "but then bust on how strong it's going to be and bust badly on the decay," the models aren't doing very well.

The NOAA researchers also found that, contrary to initial impressions, the complex computer models, which are similar to ones developed to predict greenhouse warming, fared no better in the longer run than much simpler—and much cheaper—models that are based on statistics. Such so-called empirical models are, in essence, automated rules of thumb that compare sea surface temperature and atmospheric pressure in the tropical Pacific with conditions preceding El Niños of the past 40 years and then issue predictions based on the resemblance. The far more complex dynamical models attempt to simulate, on a global scale, the real-world interplay of winds and currents that leads to an El Niño. "The use of more complex, physically realistic dynamical models does not automatically provide more reliable forecasts," the NOAA researchers write. They don't investigate the reason, but it probably involves the unrealistic way the models simulate the distribution of rain in the tropics. "National meteorological centers may wish to consider carefully their resource priorities. …"

More provocatively, Landsea and Knaff raise the bar high for El Niño predictions. Traditionally in climate work, a forecast would not be considered skillful unless it did better than some simple, barely useful technique. A favorite technique used as a benchmark was just to assume that present conditions would persist through the forecast period. "Persistence is way too easy to beat," says Landsea. "There needs to be a more demanding standard." Everyone seems to concede that point, but there is no agreement on just how demanding a performance standard should be. Landsea and Knaff offer an empirical model of their own—dubbed the El Niño–Southern Oscillation Climatology and Persistence (ENSO-CLIPER) model—as a reasonable benchmark. Developing ENSO-CLIPER took the two of them just a few weeks, Landsea says, and it runs on a workstation in about a microsecond. "If you can't do better than ENSO-CLIPER," he says, "the state of El Niño forecasting is still pretty primitive." Indeed, none of the 12 models tested—six dynamical and six empirical—beat it when forecasting 8 months ahead, and only two empirical models and one dynamical model improved on it out to 11 months and longer, the dynamical model just barely.

The bottom line. An El Niño far stronger than forecast wreaked havoc in Peru.

The reception for the models' regrading is mixed. "I think it's fair," says meteorologist Stefan Hastenrath of the University of Wisconsin, Madison, who forecasts climate in drought-prone northeast Brazil but does not forecast El Niños. "It has to be a little more demanding. I don't think the profession, much less the public, is served by overblown claims." Huug van den Dool, who supervises NCEP's long-range U.S. climate forecasts at the Climate Prediction Center (CPC) in Camp Springs, also thinks "it was an overstated conclusion that the big models were scoring big. [Landsea and Knaff] upped the bar a little, which I sympathize with."

Meteorologist Anthony Barnston of Columbia University's International Research Institute for Climate Prediction in Palisades, New York, (who was until recently at CPC) agrees that "we don't have a whole lot to crow about yet concerning dynamical models," but he thinks comparing them to ENSO-CLIPER "is a little bit too harsh," pointing out that ENSO-CLIPER is relatively sophisticated for an empirical model. Vernon Kousky of CPC, who produces official El Niño advisories, also sees ENSO-CLIPER as too high a standard. The complex dynamical models "are marginally useful," he says. "They help confirm what we're seeing. We hope they will be better in the future."

The future is where modelers are now looking. "Empirical prediction is a dead end," says dynamical modeler J. Shukla of the Center for Ocean-Land-Atmosphere Studies in Calverton, Maryland, whereas "dynamical prediction has a lot of future." Empirical models will get only marginally better as decades of El Niño history accumulate, he says, whereas faster computers, better observations, and more complete models will surely advance dynamical models more rapidly. Adds Nicholls: Dynamical models "will only improve from here."

—RICHARD A. KERR

NEUROSCIENCE

New Brain Cells Prompt New Theory of Depression

Growing evidence from laboratory and animal experiments and brain imaging suggests that a slowdown in brain cell growth may be linked to depression

Depression can be a crippling disease. Its sufferers become trapped in a cycle of exhausting gloom, in which even eating seems like a chore. Drugs such as fluoxetine (Prozac) have helped millions, but patients are notoriously susceptible to relapses, and often the symptoms worsen with each episode. No one knows what causes depression, although many neuroscientists blame an imbalance of brain chemicals, so-called neurotransmitters, especially those that affect the brain's pleasure responses.

Now a few neuroscientists are converging on a radical, but complementary, theory: that depression may be caused by a lack of new cell growth in the brain. Even a few years ago, that notion, now being promoted by neuroscientist Barry Jacobs of Princeton University, among others, would have been met with ridicule. And indeed, it remains highly speculative today. But the recent discovery that the brain keeps producing neurons into adulthood (*Science*, 27 March 1998, p. 2041) has given it at least one leg to stand on.

Work by several neuroscientists over the past 2 years has shown that growth of new cells in the adult human brain occurs in an area called the hippocampus, best known for its role in learning and memory but also a suspect in mood disorders. And a different line of research has recently revealed that the hippocampus is smaller than normal in many depressed patients. What's more, several of the most effective antidepressants seem to increase brain cell growth, according to animal experiments and some preliminary observations in people.

Put those insights together, says Jacobs, and it starts to look as if disruptions in the cycle of new brain cell growth might be a primary cause of depression. Others say that although a lack of new cells may not cause the sleep disturbances, lack of appetite, and feelings of overwhelming sadness that characterize the disease, the evidence is persuasive that the two processes are linked. "There has been no convincing biological theory for depression," says Jacobs. And the idea that waxing and waning patterns of brain cell growth might account for cycles of depression "could explain at least as much of the biological data as anything else out there."

Those biological data come from several sources. Scientists studying depression have been stymied for years because no one could find any obvious changes in the brains of depressed patients. "We don't have the luxury of knowing where we ought to be looking" for damage, says Helen Mayberg, a neurologist at the University of Toronto. "We have no plaque or tangle or Lewey

Secret of a best seller? Prozac-like drugs encourage brain cell growth in animals.

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