looked at a silicon support with a gold absorber, while Eurosil experimented with a silicon nitride/gold combination and Valvo tried silicon/tungsten. As it happens, the first two turned out to be good choices, but others have not worked out. Now the entire project is concentrating on these materials. One recent accomplishment is finding a way to minimize distortions in the mask due to the different physical properties of the membrane and the absorber.

Some tasks are contracted to German industry. For example, a critical part of any photolithography process is alignment. Several masks with different patterns are needed in building up a complete circuit pattern, and each mask has to be aligned with the pattern left by its predecessor to an accuracy much better than the minimum feature size in the pattern. The Karl Süss Company near Munich together with a group from Siemens took on the job of constructing a mask alignment system. In tests at BESSY, the apparatus successfully achieved an accuracy (3 standard deviations) of 0.1 micrometer. Unfortunately, the time taken to do the alignment is excessive; it will be shortened.

Development of polymers, also called resists, that combine a high sensitivity to x-rays for rapid exposures and a good contrast, so that low intensities of x-rays leaking through the absorber do not expose the resist, is another example of a project contracted out to the chemical company Hoechst and to other research institutes in this case. Such resists are sensitive subjects as well as sensitive objects and tend to be proprietary, so Heuberger would only say that promising materials are being looked at.

All in all, with about 80 researchers and administrative staff on site, the x-ray lithography project in West Berlin is the largest and most ambitious of any at the moment. In the United States, IBM, which carried out some of the first synchrotron x-ray lithography experiments, has a more modest project under way at the National Synchrotron Light Source at Brookhaven National Laboratory. German electronics companies would no doubt love to be the first to succeed in a frontier area of integrated circuit technology, which is almost totally dominated by American and Japanese firms. If Heuberger is right, they will.

—Arthur L. Robinson

Forecasting the Weather a Bit Better

A new computer model provides a distinct improvement in short-range forecasting, but you may not notice much of a difference by looking out the window

If you don't take your umbrella to the office tomorrow, will it rain on you despite the weather forecaster's reassurances? Will the weekend's picnic be rained out? Sometimes it seems that a look out the window and crossing your fingers is as reliable a guide as the official weather forecast in such situations. Forecasters share your frustration—predicting whether it will rain and how much it will rain has been their most frequent downfall. But now they have a brand new computer model that spins out a sharper and apparently more accurate picture of future weather, especially future precipitation.

Despite their enthusiasm for the new system, forecasters caution that their field is a tough one in which even the greatest efforts yield only modest improvements. An incremental, although significant, improvement such as this one will likely be heralded by meteorologists but go unnoticed by the public, they say.

The new forecasting model is an improvement in many ways, but perhaps the most important difference is its sharper, more detailed view of the atmosphere. A leading forecasting model used during the past 10 years at the National Weather Service's National Meteorological Center (NMC) outside Washington, D.C., is the Limited-area Fine-mesh Model (LFM). Like many computer forecasting models, the LFM can make a forecast using only atmospheric properties at points defined by the intersections of a three-dimensional grid system. All the weather between grid points must be summed up as well as possible at the nearest grid point, so the closer together the grid points the more realistic the model's view of the weather. In its most recent form, the LFM divides the atmosphere horizontally into grid squares about 190 kilometers on a side and vertically into seven layers.

The new system, the Regional Analysis and Forecast System (RAFS), has a grid spacing or horizontal resolution of about 80 kilometers and 16 vertical layers. It was created from scratch in NMC's Development Division, which is headed by John Brown, with particular contributions by Norman Phillips, James Hoke, Geoffrey DiMego, and Joseph Sela. With the improved resolution, weather that occurs on smaller scales, such as the narrow band of rain along a front, is more likely to be clearly defined in the model's initial picture. When the model applies its set of built-in physical laws to compute future weather patterns, the size, shape, and intensity of the forecast rain band should be more realistic as well.

A less fuzzy picture of the atmosphere may be desirable, but it extracts a heavy penalty. Halving the space between grid points over a given area requires increasing the number of calculations by a factor of 8. The burden of the new model's closer grid spacing is carried by the NMC's new CYBER 205 supercomputer, which is up to 50 times faster than the old computer. But even the CYBER could not handle an additional intended improvement—the expansion of the area covered by the model from a box over North America and adjacent oceans to the entire Northern Hemisphere—without special adjustments.

From its beginnings, the old LFM had the problem of determining what weather should be moving across its boundary into its grid from the rest of the hemisphere. A 12-hour-old forecast from another model was the best solution available. But the RAFS extends so far—as far as the equator—that no weather from outside its domain is likely to have much effect over North America during the 48 hours of a forecast period.

In order to handle the increased computational burden of hemispheric coverage, Phillips and Hoke focused the high horizontal resolution on North America where it is most needed. Within a hemispheric grid having 320 kilometers between grid points, they embedded a square having 160 kilometer resolution, and inside that they placed the highest resolution grid (80 kilometers) centered on North America. Weather is free to move back and forth across these grid boundaries. This nesting of three grids, one inside the other, achieves high resolution over North America and reduces the boundary problem while keeping computational demands within limits.

The new model has provided an occasion for the inclusion of a number of other improvements, most of them computationally less demanding. The model's tropopause, the boundary between the weather-generating troposphere and the stratosphere, now allows the passage of air; it had been impenetrable. A procedure was introduced that more accurately calculates the initial state of the atmosphere at each grid point from the observations scattered around it. This improvement, plus the added computer power, also allows a doubling of the number of observations included in the analysis that creates the picture of the present atmosphere, the starting point for the forecast calculations. This is particularly helpful because in the past only a limited number of arbitrarily spaced observations that were reported from balloon-borne instruments could be included. Often the old model had to ignore crucial, sharp variations with altitude of such properties as humidity because the variations fell between the standard reporting levels. Now the crucial observations can be included.

The new Regional Analysis and Forecast System has been run against the old Limited-area Fine-mesh Model since early June 1984. That has been long enough to see that RAFS does most things as well as or distinctly better than its predecessor. So far, the most obvious improvement is in forecasting precipitation. To measure forecast accuracy, meteorologists use threat scores, which balance correct forecasts of rain against unforecasted rain and incorrect forecasts of rain while ignoring correct forecasts of no rain. Threat scores range from 0 to 1, the latter being perfect.

In a test of forecasts of whether it would rain or not during a 24- to 36-hour forecast period, both models had scores of 0.44. But RAFS' forecasts of areas that would receive 1.27 centimeters of rain or more during a 12- to 36-hour forecast period had a score of 0.34 while the LFM had a score of only 0.24, a 36 percent improvement for the RAFS. In the case of 24- to 48-hour forecasts, RAFS maintained a similar advantage in forecasting areas of higher precipitation. RAFS also corrected the LFM's tendency to unduly enlarge forecasted areas of extremely heavy precipitation.

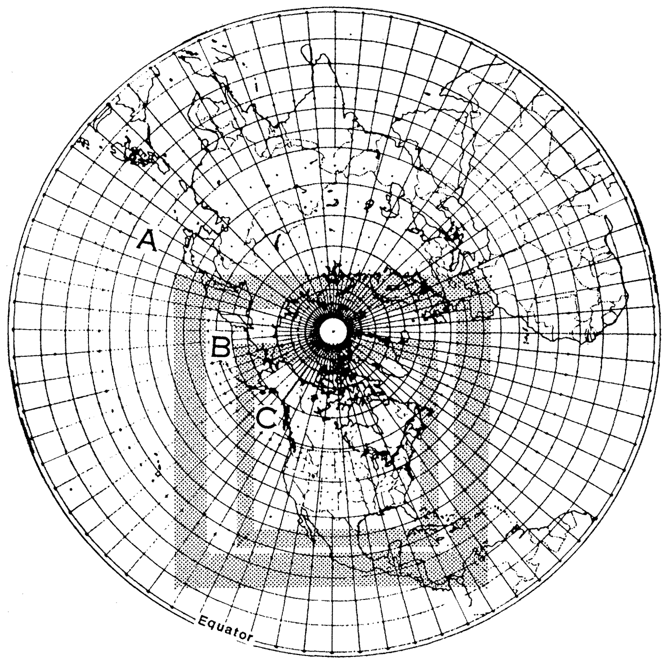
The new forecasting system also does a better job of predicting the shape and location of areas of heavy rain. A particularly striking example of the improvement is the heavy rain that swept across the southeastern United States on 5 and 6 February. The storm dropped 5 to 8 centimeters of rain in a narrow strip running from New Orleans northeastward to Wilmington, North Carolina, on the Atlantic coast. The old model's 24- to 48-hour forecast called for only 2.5 to 5 centimeters of rain in the central southeast and kept the heaviest rain far to the northeast near the Virginia–North Carolina border and beyond. The RAFS forecast placed the heaviest rain more realistically over South Carolina and properly limited the heavier rain to a narrower strip than the LFM did.

Subjective evaluations of model performance also show the new regional system holding a distinct advantage. Harlan Saylor of NMC has summarized the impressions of a group of operational forecasters who compared 31 forecasts made by the two models. He found that the improvement in quantitative forecasts of precipitation using RAFS is three times the improvement managed since 1965. It also does a better job of maintaining ridges of high pressure over the model's west coast, thus keeping storms off the coast as it should.

Joseph Bocchieri and his colleagues at the Weather Service's Washington forecast office have found that the new model does a better job of preserving pockets of cold air that can become trapped east of the Appalachians. On 31 January, for example, the LFM wiped out the cold air that actually persisted over the east coast while RAFS kept it in the forecast, along with the accompanying snow.

The RAFS may have numerous achievements that its developers can point to with pride, but the NMC researchers are the first to note that the improvements are incremental at best and nonexistent in many aspects of the model. They expect little immediate improvement in the forecasting of summer rain, for example, despite the obvious benefits with winter rain. Forecasting of summer rain, because much of it is produced by weaker, less tightly organized low pressure systems, is not likely to respond so positively to the better resolution. Saylor notes that the RAFS is slow to develop and move cyclones that are over and just off the east coast, ones that can explosively develop into damaging wind or snowstorms.

Phillips is planning to attack another problem shortly. The RAFS, it seems, was all too successful at predicting the Florida freeze of 20 January. It moved frigid near-surface Minnesota air to Florida without mixing it with the warmer air above it as actually happens. Other shortcomings of the model will eventually be eliminated. It has no cooling through radiation to space, no night and day, and no evaporation of falling rain, to name but a few of its significant failings. All in all, NMC researchers term their new model a "modest improvement." "It's not going to be a major breakthrough," says Hoke. "It's another important step in the slow process of improvement."—**RICHARD A. KERR**



The nesting of a forecast model

The new computer system forecasting weather at the National Weather Service divides the hemisphere into nested compartments so that its best resolution (80 kilometers) is in box C over North America. Unprecedented in an operational model, the improved resolution has produced a distinct improvement in precipitation forecasts. [*Source: NMC*]

Next: How far short-range forecasting has come and an update on the race to predict next week's weather.