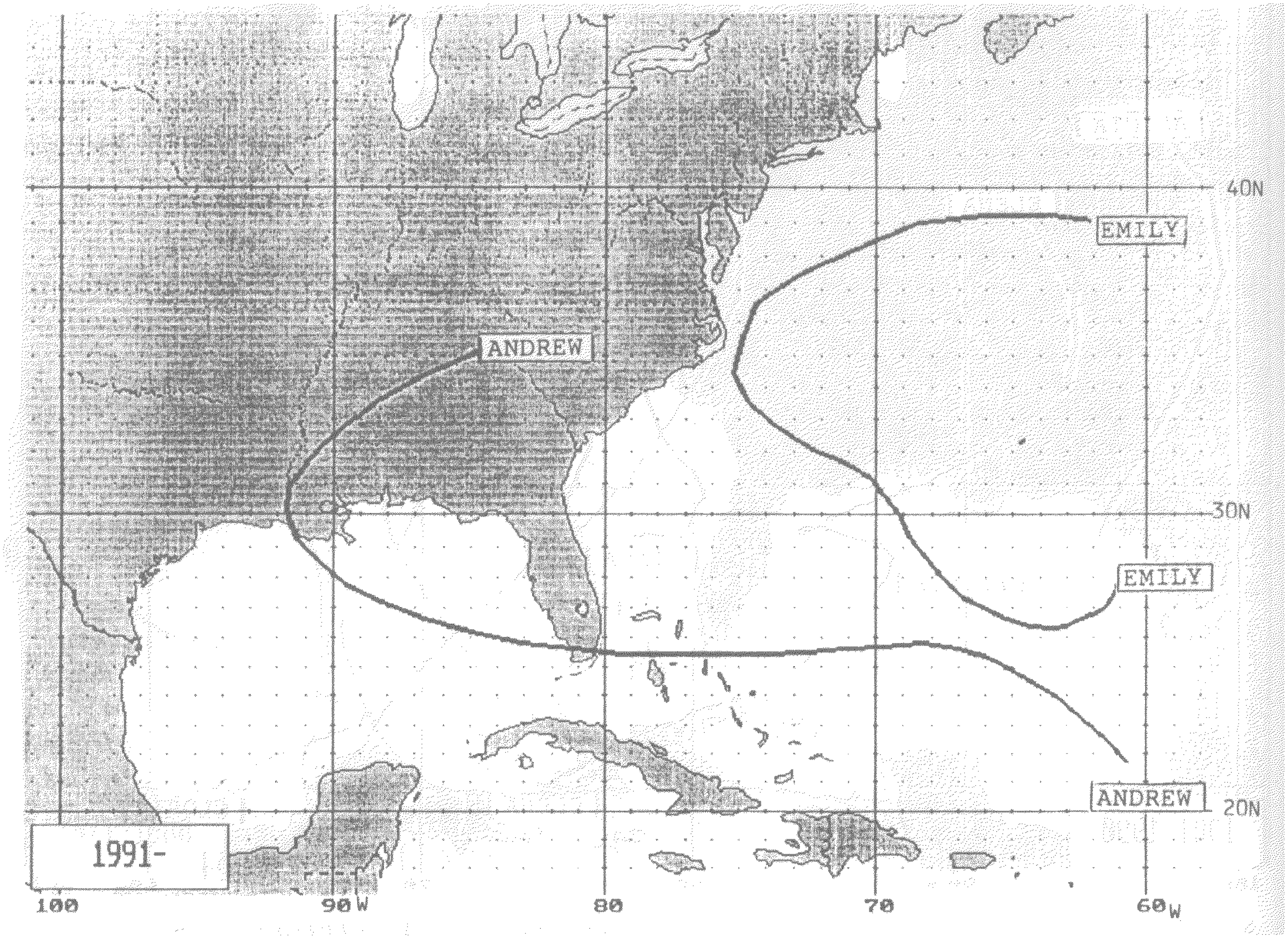
Fig. 4 (f). Major hurricanes striking continental United States. 1991 through 1993.



STORM NO. OR NAME	YEAR	DATES	CAT.@	MSLP# (MB)	PRIMARY IMPACT AREA	$ DAMAGE* (THOUSANDS)	U.S.+ DEATHS
ANDREW	1992	8/16-28	4	922	SE FL; LA	$25,000,000	26
EMILY	1993	8/22-9/6	3	961	OUTER B. NC	A	LT 25

TOTAL HURRICANE RELATED DEATHS FOR THE DECADE = 29
TOTAL NUMBER OF MAJOR HURRICANES FOR THE DECADE = 2

@ - Storm catagory based on Saffir/Simpson scale.
# - Minimum sea level pressure at landfall.
* - U.S. damage adjusted to 1990 dollars using U.S. Department of Commerce composite construction index.
+ - Direct deaths only.
A - Less than $400 million. LT - less than. MSLP - mean sea level pressure
MB - hPa

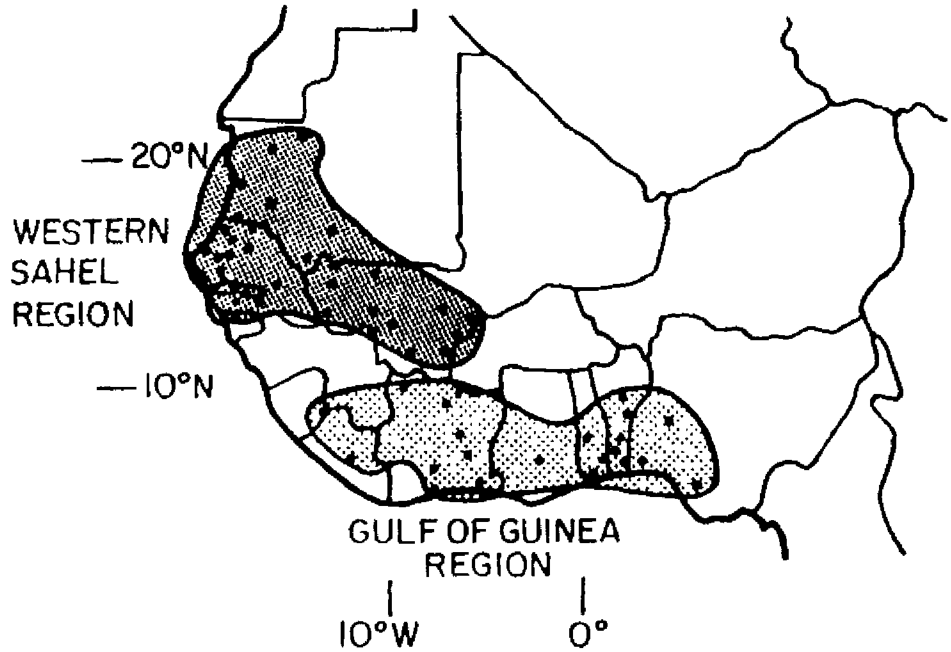


Fig. 5. Locations of rainfall stations used in determination of Western Sahel precipitation index (After Gray, Landsea, et al 1992).

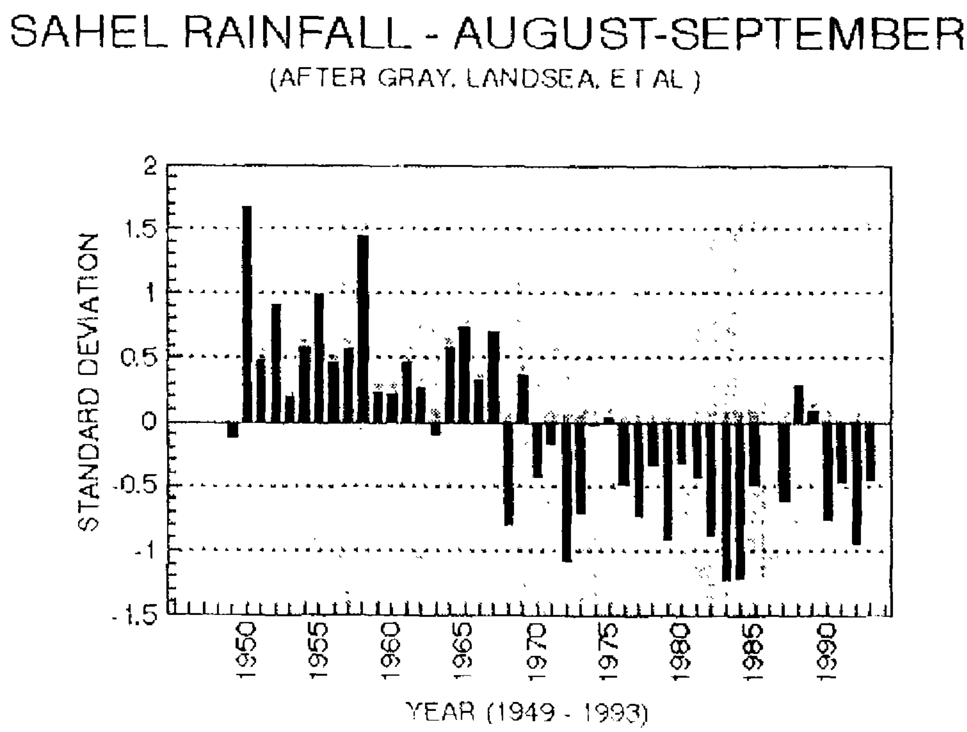


Fig. 6. Mean standardized deviations of rainfall for the 38-station August-September Western Sahel rainfall index (After Gray, Landsea, et al 1992).

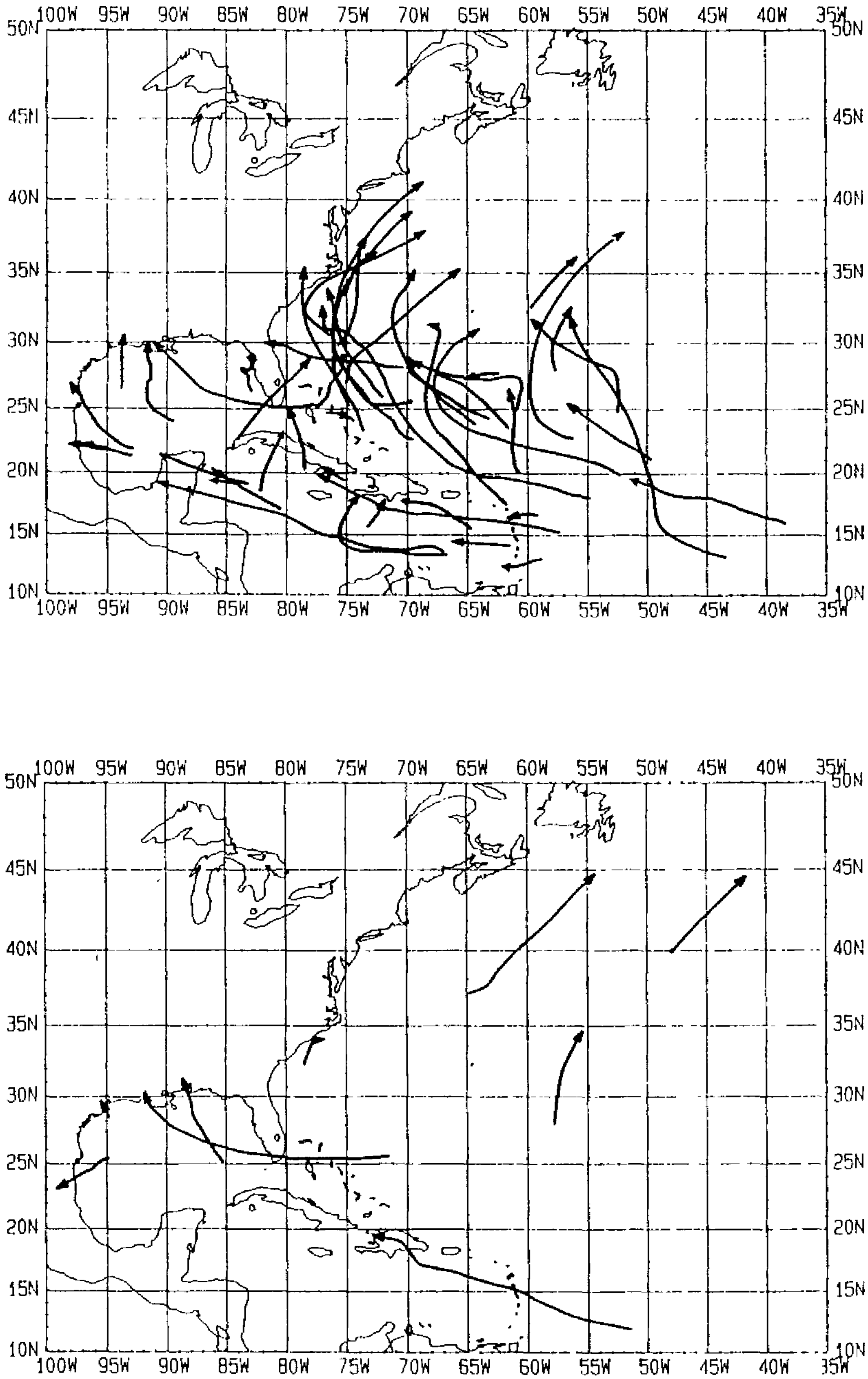


Fig. 7. Tracks of major hurricanes (Saffir/Simpson Category 3 or greater) for (top) the ten "wettest," and (bottom) the ten "driest" years of rainfall in the Sahel region of Africa (see figures 5 and 6) from 1949 through 1993. (After Gray, Landsea et al 1992).

New Orleans, Ocean City, Maryland, etc. Such decisions for protection of life now must be based upon 36-hour or longer range forecasts. The uncertainty in those forecasts, as discussed earlier, is such that relatively large "over-warning" is required in order to minimize the potential for large loss of life. Fortunately, environmental satellite imagery has added to the public's awareness of the existence of hurricanes, in most cases, long before they threaten any major U.S. population centers. The credibility of the warnings is enhanced by the ability to show satellite imagery to the general public. However, even with the use of satellite imagery, coastal radars, etc., there could be an unforeseen meteorological development (rapid change in course (Elena, 1985), rapid change in intensity) which would not permit adequate warning time. Also, there could be some hinderance to the evacuation process (accidents, barge taking out a bridge, slow start of evacuation) which could also result in incomplete evacuations with literally thousands of people trapped on barrier islands and roadway systems as the life threatening elements (rising waters, increasing winds) of the hurricane approach. Clearly, efforts must be made to address these problems.

Some mitigation activities that could be directed toward alleviating these problems are:

1. ***REDUCE REQUIRED EVACUATION TIMES***. This can be accomplished through improved community development and planning including improved roadway systems, limiting growth, minimizing the numbers of people who must be evacuated through use of better building practices including "set backs", building codes and enforcement, providing safe in place sheltering for manufactured and mobile home communities, and local shelters for people who might otherwise attempt to leave the area. That is, optimize the response process by moving people 2 to 10 miles (3 to 16 km) rather than 200 miles (320 km) or more. There needs to be a standard design code for buildings that are to be used for shelters or "last resort" refuges which is adequate for resisting the winds that are reasonably possible for that community. These standards could be used in the selection process for use of existing buildings for refuges or shelters and aid in determining what retrofits might be needed. Also, they would aid in designing new buildings that might be used as shelters in the future.

2. ***PROVIDE LAST RESORT REFUGE***. This would not be publicized so that people would not delay their actions knowing a "last resort" shelter existed, but would provide a means of minimizing potential loss of life when complete evacuations cannot be accomplished for whatever reason. It is always best to get people away from the problem to where services can be provided. That is especially true where hurricanes are prolonged events. However, for the mid-Atlantic states, New York and New England where the hurricane is a short-lived event (Hurricane Bob was a two-hour event in Massachusetts), it may be prudent to provide in place safe refuge rather than go through a lengthy evacuation process with several potential "false alarms". Exceptions would be for regions such as Fire Island, New York where massive destruction from the storm surge might be expected and access cut off for days rather than a few hours.

3. ***IMPROVE FORECAST ACCURACIES***. Forecast accuracies are improving, but unfortunately not nearly fast enough to offset the loss of accuracy for longer-range forecasts required for increased evacuation times resulting from increasing populations at risk. Computer models to predict hurricane paths have improved significantly during the past decade, but further research is needed to develop more accurate models for track,

intensity, rainfall and storm surge predictions for these longer-range forecasts (24 to 72 hours). Along with improving models, we need to improve the quality and quantity of data going into them. Research studies have shown that given correct quantitative data in the hurricane and its near environment through the depth of the troposphere, substantial improvements in forecasts of track and intensity are possible. Unfortunately, during this same period when computer models have been improving, our conventional observation systems in the tropical and subtropical regions have deteriorated markedly. (The U.S. Data Buoy System is gradually disappearing as the buoys get older and cannot be maintained; the Caribbean Islands Upper-Air Program was cut back from two observations per day to one per day; the old NASA "down range" upper-air systems are no longer in place, etc.). In addition to the need for restoration of the conventional data these improved models need much more sophisticated data in the hurricane and its near environment. Technology exists to provide these data and NOAA is upgrading its operations as fast as the budget and implementation process will allow as part of a long-range modernization program. For example, I was pleased to see appropriation for funds for a mid-size jet aircraft which will be able to provide considerable data in the near environment of the hurricane for use in our numerical models. We are working feverishly to have that aircraft and a basic instrumentation set available for quasi-operational use as soon as practical. We anticipate significant improvements in our forecasts and associated warnings over the next few years as we apply this new technology.

The second item of potential loss mentioned above is the direct destruction of property. Hurricane Andrew again has shown this impact, but as I mentioned earlier, it could have been so much worse with a nearly undetectable change in the meteorological conditions. Clearly, the nation as a whole pays for such losses through insurance premiums, tax subsidized disaster relief funds, charitable contributions, higher prices for goods due to loss of productivity and natural resources, etc. For instance, more lumber was lost in Hurricane Hugo than in the Mt. St. Helen's eruption and Yellowstone National Park fires combined. Other agricultural losses are frequently large. Also, there is usually considerable amounts of under-insured property that results in business failures, individuals not being able to meet their financial obligations, etc., erosion of tax bases for a community that has been devastated and the compounding effects of such losses. Reports have indicated that more than 80,000 jobs were lost in South Dade County alone due to Hurricane Andrew. Also, as mentioned earlier there is an enormous amount of insured property at risk, where major losses could cause the failure of some insurance companies as happened in Hurricane Andrew.

Some mitigation activities that could be directed toward alleviating the problem of direct destruction of property are:

1. *RESTRICT DEVELOPMENT AND REDEVELOPMENT IN HIGH RISK AREAS*

Several programs, including a recent congressional Barrier Island Act have been aimed at accomplishing this goal. One such program implemented by the Department of the Interior under the 1982 Coastal Barrier Resources Act has been successful in deterring development on undeveloped coastal barrier islands through elimination of federal flood insurance and federal financial assistance for public infrastructure. However, experience has shown that whenever massive losses occur in developed coastal areas -- such as in South Carolina after Hurricane Hugo -- policies which limit redevelopment come under enormous public and political pressure, which often force rules and laws to be waived or modified. Unfortunately, this well-intentioned fixation on immediate restoration of damaged areas without consideration of future recurring losses only perpetuates the costly cycle of "wreck and repair."

2. *ESTABLISH AND ENFORCE HURRICANE RESISTANT BUILDING CODES*

There are at least two or three proven codes for resisting damage due to wind and water at minimal increases in cost over conventional construction. People thought that the South-East Florida code was adequate. However, some small changes in the code and interpretation of the code had crept in which caused massive losses and some loss of life. Even with these deficiencies, that code and building practices in Dade County were far superior to most other hurricane prone areas. It often is a problem of education rather than the small increase in cost required to have a good code in place. For example, massive losses occur even in exclusive developments such as Debordieu Beach, South Carolina where the small cost of the application of hurricane resistant codes was not a factor. The developer of that community and others in the South Carolina area expressed surprise at the destruction from Hurricane Hugo and a lack of knowledge of existing hurricane resistant construction codes. Most people vowed to build back using such codes, but were confused about **which** code they should use. Especially, after each major loss, the affected community looks for some improvement in building practices. This frequently consists of developing some new code or selected applications of parts of codes used in other areas. It seems that an adequate experience level exists today, at least from a technical standpoint, where an effective, relatively low cost, uniform code, could be adopted and applied for each type of structure along the coasts. One such code has been produced by the Southern Building Code Congress International (1990). However, the process of uniform adaptation in the past has apparently been hampered by jurisdictional considerations. Unfortunately, such codes and enforcement practices are rare in most coastal areas. Some areas have improved building practices (codes, enforcement, setbacks) in recent years, but with the exception of southeast Florida, almost all other coastal areas remain under government enforced insurance "risk pool" situations for wind damage insurance. Now after Hurricane Andrew, southeast Florida is under a similar situation. Policy holders outside of the "risk pool" areas are probably subsidizing the policy costs for those in the pool situation.

The potential success of the mitigation efforts mentioned above is dependent upon an informed public. Most educational programs to date have rightfully focused on protection of life. Certainly, those programs need to continue and at enhanced levels due to the increased population at risk and the potential for more frequent, strong hurricanes for the next few decades as compared to the past two to three decades as mentioned earlier. However, it is past time to educate the public concerning the catastrophic financial impacts caused by the high winds, storm surge, flooding and erosion associated with hurricanes and how much of that can be prevented with informed actions. It is far better to act decisively now, in advance of the next hurricane or next series of hurricanes, to improve preparedness and reduce financial hardship, than to be in a reactive mode afterwards as was the case for the savings and loan failures.

Such education, of course, will aid in the protection of life as well as possibly leading to mitigation efforts to avert financial disaster as described earlier. Literature needs to be developed for widespread distribution that points out that considerable protection from wind damage can be obtained with minimal increases in construction costs. Simple illustrations of construction elements such as connections have proven quite effective in demonstrating to the lay person that such protection is reasonable and "affordable". The term "affordable housing" has been used by some builders' associations as a reason for opposing implementation of hurricane-resistant construction practices. This literature should demonstrate that such arguments are based upon flawed reasoning. I believe that FEMA is making some progress in this area, but those efforts need to be enhanced. Showing what a hurricane resistant house looks like will hopefully influence buyers which will then influence the construction industry. As we learned from Hurricane Andrew, a lot has to do with the "style" of the home and the types of connections between foundations, walls and roofs, as well as whether or not there were covers for windows and doors.

The final item mentioned earlier for types of direct losses are costs of "over-warning". Those costs can be substantial, averaging many tens of millions of dollars for each warning event. The reasons for such required over warnings are large concentrations of people and property in high risk areas and limitations in our forecasting skills. The forecast and warning problem can be quite complex and is the subject of other extensive papers (Sheets, 1990; Sheets, 1993). The majority of those complexities and constraints are not directly discussed here. However, several of the recommendations enumerated earlier for reductions of potential losses of life and property and improving forecast capabilities would also contribute to reducing losses from "over-warning".

SUMMARY

There are now more than 44 million people living in hurricane-prone coastal counties from Texas to Maine with continued rapid growth rates, particularly in the "sunbelt". The infrastructure of these rapidly growing coastal communities, particularly roadway systems for access to the mainland from many of the barrier island communities has not kept pace with the population growth. The result is that longer and longer warning lead times are required in order to safely evacuate these areas in the event of a hurricane threat. Forecast skills are such that it is unlikely that warnings for all hurricane situations will be sufficient for safe evacuation from the area. This means that residents could be trapped on barrier islands and associated roadway systems while winds and waters are rising around them. Furthermore, only one or two communities have plans in place for "last resort refuge" to deal with this situation, or one created by a failure in the evacuation system due to other reasons such as accidents.

In addition to the threat to life, considerable property is at risk. The value of insured property at risk in the same coastal counties mentioned above (not counting flood insurance) is now approaching **$2 trillion.** A return to continental United States hurricane landfall frequencies of the 1940's through 1960's would mean **frequent multi-billion dollar loses** having national impacts on the economy. At the present time, the "home rule" approach to building codes and construction practices makes it extremely difficult to have effective mitigation programs in any wide spread way. However, because of recent massive losses, insurance is now becoming increasingly difficult to get in many hazard areas such as those that experience hurricanes, earthquakes and floods. Such lack of insurance greatly affects the local, regional and national economy.

A response to this problem has been the introduction of legislation now pending before Congress for establishment of a National All-Hazards Insurance program. Such a program will affect where and how we build (Sheets, 1994). To have a positive impact, the adoption of some type of National all-hazards re-insurance program should include as a condition of availability **reasonable provisions for constraints on development and redevelopment in high risk areas, and requirements for strong building codes and enforcement!** It is imperative that we build in requirements for improved construction practices with respect to whatever hazard we are dealing with. This will not only result in reduced economic losses, but should result in protection of lives as well and make our job for forecasts and warnings for hurricanes a little easier.

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