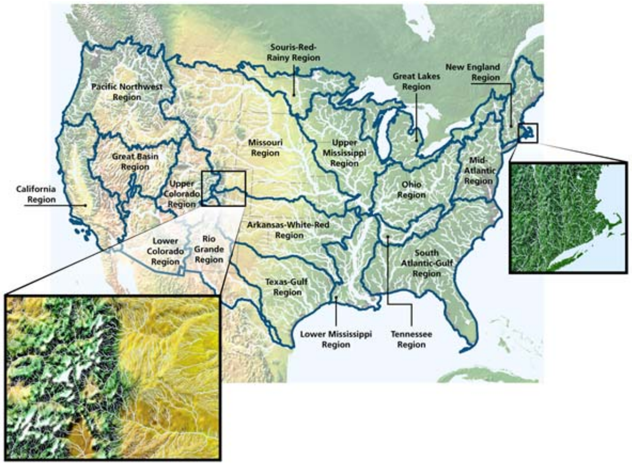
AIR ISSUE BRIEF

THE CHALLENGES OF MODELING INLAND FLOODS IN REAL TIME

As the catastrophe modeling industry has evolved, many clients have come to expect that models should be able to quickly and accurately reproduce natural catastrophes in real time as they are unfolding, anywhere around the world. At AIR Worldwide, we consider it our responsibility to ensure that when we communicate with clients in the aftermath of actual events, the information we provide is robust, defensible, stable, and in agreement with observations.

When catastrophic floods occur, AIR is committed to providing our clients with as much information as possible to help them manage their risk. This process involves a series of communications via the ALERT™ (AIR Loss Estimates in Real Time) website designed to help clients understand the potential impact on their portfolios. Our communications begin with a detailed summary of the event, published as the event is still unfolding, and will generally include maps from the National Weather Service or other similar agencies. Follow-up postings provide additional information along with updated maps, and lists of affected ZIP Codes and Touchstone®-ready shapefiles showing flood inundation extents and depths are then made available.



AIR's model captures inland flood risk for 18 hydrological regions across the contiguous U.S., an area of more than 3 million square miles, with a river network 1.4 million miles long. It includes 335,000 distinct drainage catchments, and all streams with a minimum drainage area of 3.9 square miles are modeled explicitly.

These initial on-floodplain flood footprints, which are based on recorded and estimated river flows and output from the AIR Inland Flood Model for the United States, can be used in Touchstone's Geospatial Analytics Module or other GIS applications to understand the exposure at risk.

Approximately three to four weeks later, once the extent of the damage can be fully assessed, AIR will issue a final summary description of the event along with a set of simulated scenarios formulated using the latest information on precipitation, river gauges, and levee overtopping and failure. These scenarios provide a range of possible realizations of the riverine (on-floodplain) flooding, as well as off-floodplain flooding caused by intense rainfall, flatter terrain, and limited drainage capacity. The range reflects uncertainty in rainfall observations and in probabilistic levee failure.

Developing scenarios that accurately reflect real events is a complex and challenging undertaking that deserves further exploration. In the sections that follow, we discuss the principal challenges of modeling inland floods in real time.

REPRESENTING FLOOD EVENTS IN A PROBABILISTIC MODEL

Certainly, for some natural perils, representing actual events in AIR models can be a fairly straightforward task. Hurricanes, for example, can be defined by a relatively small set of parameters. We rely upon government organizations, such as NOAA (through the NHC), to provide us with these parameters. Then, once we have obtained the standard parameters (i.e., the central pressure, radius of maximum winds, forward speed, angle, and the rest of the forecast track data), a model can faithfully approximate the actual event in question. The same is true for earthquakes, which have their magnitude, location, and depth and fault parameters, such as fault type and rupture length and width, all reported in near real time by the U.S. Geological Survey (USGS).

For some other perils, however, this task remains significantly more challenging. Floods, for example, are generated by a dynamic, highly variable, and constantly evolving precipitation field coupled with the antecedent conditions of soil saturation levels, river flow, water levels in reservoirs and their management, and actual performance of levees and other flood mitigation measures. While floods are typically part of a large-scale meteorological system, they are also highly sensitive to the local settings of the rivers and terrain. Therefore, unlike hurricanes or earthquakes, floods cannot be easily “parameterized” into a handful of variables that can accurately represent flood intensities at a very high resolution, as they vary both spatially and temporally. This makes modeling floods far more complex and challenging, but certainly not impossible.

COLLECTING, VALIDATING, AND PROCESSING RAINFALL AND RIVER FLOW OBSERVATIONS

Rainfall observations and river flow data lie at the heart of determining the severity of flooding. Accurate, detailed precipitation and river flow data sets provide the foundation on which modelers must construct a realistic simulation of a deterministic flood event.

The 2010 Cumberland River flood, Nashville, Tenessee. (Source: AIR Worldwide)

Rainfall is typically observed using a variety of systems, including river surface gauges, radar, and satellite sensors. These data are made available on a near real-time basis by the National Weather Service (NWS). Observations at hourly intervals for the entire river basin(s) are needed to model and estimate river flows and surface runoff everywhere. However, the availability and quality of hourly rainfall data are not ideally suited for “real-time” modeling purposes, as there are sometimes discrepancies found between hourly and daily rainfall observations. In such situations, modelers have to wait for multiple rainfall data sets to become available so that the necessary adjustments and validation can be performed.

River flow data is typically available through a system of river gauges installed along various river segments. At times, these gauges can malfunction and may get damaged during extreme floods, thereby making it difficult to obtain critical information immediately. Due diligence is required to process such data gaps to fill in the missing data and derive estimates for the missing time periods.

Consequently, some of these rainfall and river flow data sets can contain gaps and errors, even a few days after the event. However, these observations typically improve substantially over time as more comprehensive and consistent data become available and data providers conduct their own due diligence procedures. All of these factors make it difficult to obtain reliable data for modeling a flood (and providing a robust and stable loss estimate) in real time.

ACCURATELY ASSESSING LEVELS OF PROTECTION

Assessing an area’s level of flood protection is a key factor in determining how it will respond during potentially damaging floods. However, this level of protection continually changes as maintenance, repair, mitigation, and protection measures are incrementally put in place all over the country. Obtaining information about the level of flood protection remains challenging, as the U.S. Army Corps of Engineers only has information on 14,000 miles of the more than 100,000 miles of the levee network that protects U.S. cities and towns from riverine flooding. In addition, in some cases, existing structures designed to provide flood protection may be removed in one area to better protect another. For example a levee may be dynamited upstream to allow a river to flood an open field rather than flooding a major population center downstream.

The 2010 Cumberland River flood, Nashville, Tenessee. (Source: FEMA)

ASSESSING HUMAN RESPONSE TO FLOODING

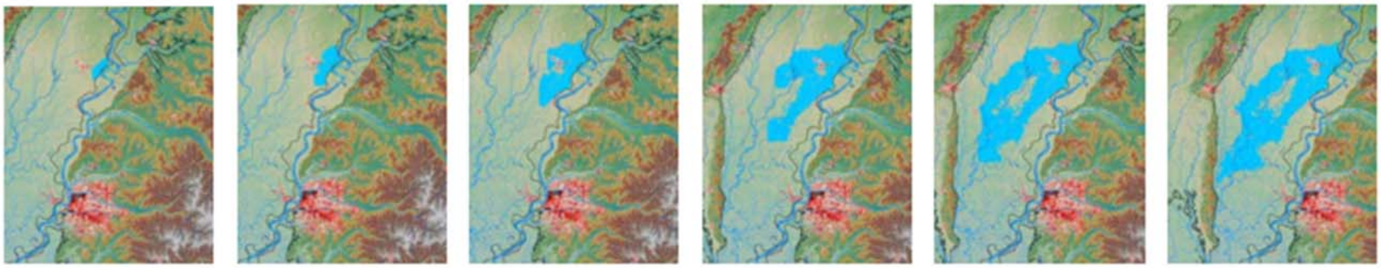
Floods also take place over days or even weeks, giving people far more time to react as the event is unfolding as compared to hurricanes, which occur over a few hours, or earthquakes, which last only minutes. In addition, floods are forecast by governmental agencies with relatively longer lead time and higher accuracy. Therefore, when assessing the impact of a flood in real time, it is critical to develop a full understanding of the event, the information provided to the community in advance, and the human response to that event before the flood can be realistically represented in a model.

A range of engineering, management, and political decisions as well as actual human actions, in times of extreme floods must also be accounted for, as these can have significant effects on the outcome of a flood. When flood conditions arise, dams—often controlled by skilled operators—play a critical role in controlling and attenuating the flow of water though the river network. The decisions can help manage an ongoing flood disaster, and it is impossible for a model to account for these types of responses when assessing a real-time event.

SIMILAR STOCHASTIC EVENTS

While AIR is able to provide Similar Stochastic Events (SSEs) for many other perils based on the events contained within their respective models' stochastic catalogs, it is virtually impossible to do so for a flood. To locate candidates for SSEs for other perils, AIR uses an event's available parameters to filter through the contents of the stochastic catalog and select appropriate SSEs. In the case of the flood peril, there are no high-level parameters available that can quickly convey a flood's size and intensity, either as part of the real-time event or recorded in the stochastic catalog with which to identify "similar" events. (In other words, with floods, there are no maximum wind speed and R-max observations as there are for hurricanes, nor are there magnitude and depth observations as there are for earthquakes). In the case of floods, the characterization of events typically involves painstakingly recreating the conditions on hundreds or even thousands of river segments and catchments. This number of possible flood outcomes rises very quickly, even for smaller events, so that the number of possible combinations quickly far exceeds the number of events in AIR's stochastic catalog.

Even if we disregard, for a moment, the idea that each river will flood to a certain level and consider each river as a binary system that is either "flooded" or "not flooded," the system can still become hugely complex with just a few rivers. If we consider a system with N rivers, the number of possible combinations of rivers that could be flooded is 2^N. That means that with 10 rivers, there are 1,024 (2^{10}) possible flood combinations to consider, and with just 20 rivers, there are more than 1 million (2^{20}). There are 18 hydrological regions in the United States as defined by the United State Geological Survey (USGS) and these comprise fairly large river basins or regions. One can safely assume that these large regions are relatively independent (i.e., there is little correlation of flooding between regions). So, to get a sense of the scale of the challenge, we can consider just two independent rivers from each region. If we only attempt to model floods as they occur on these 36 rivers nationwide, the number of combinations of flooded rivers would still be more than 68 billion (2^{36}). There are approximately 335,000 river segments or catchments in the U.S. inland flood model's domain (i.e., the continental U.S.), and even after drastically discounting for the high correlation among these river segments and adjoining catchments, the number of possible flood outcomes is phenomenal and presents us with a computationally intractable number of combinations to consider. So, even with more than 685,000 events in the stochastic catalog, we cannot begin to approach all the different combinations of flooded rivers that can occur as the result of a single deterministic event.



As multiple river segments experience a flood, the area affected changes rapidly and modeling the impact of a unique event becomes exponentially more challenging.

CONCLUSION

As we develop a real understanding of a flood, AIR provides our clients with as many resources as we can to help them manage their potential losses. Through AIR’s ALERT website, we provide extensive summaries of the catastrophe as it unfolds. As part of these postings, we also provide additional resources whenever possible to aid in the risk management process, including lists of affected ZIP Codes and shapefiles of flood footprint (covering both flood extents and water depths) as soon as we can validate that this information is as complete and correct as possible given our clients’ need to obtain this information in a timely manner. Then, in the aftermath of the event, AIR collects as much data as possible, validates and augments that data as necessary, and constructs realistic and stable representations of actual floods once the impact of the event can be meaningfully understood and modeled. In this way, we strive to provide our clients with the most stable and realistic assessment of potential losses from these types of devastating floods.

ABOUT AIR WORLDWIDE

AIR Worldwide (AIR) provides catastrophe risk modeling solutions that make individuals, businesses, and society more resilient. AIR founded the catastrophe modeling industry in 1987, and today models the risk from natural catastrophes, terrorism, cyber attacks, and pandemics globally. Insurance, reinsurance, financial, corporate, and government clients rely on AIR’s advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, site-specific engineering analyses, and agricultural risk management. AIR Worldwide, a Verisk Analytics (Nasdaq:VRSK) business, is headquartered in Boston with additional offices in North America, Europe, and Asia. For more information, visit **www.air-worldwide.com.**