2018 Kerala Floods

Learnings from the Post-Disaster Damage Survey

July 2020

Contact Information

If you have any questions regarding this document, contact:

AIR Worldwide Corporation
131 Dartmouth Street
Boston, MA 02116-5134
USA

Tel: (617) 267-6645
Fax: (617) 267-8284

Table of Contents

Introduction

In August 2018, Kerala, a southern state of India, was battered with severe floods due to unusually heavy rainfall. Dubbed the worst floods in Kerala since 1924, all 14 districts of the state were placed on red alert. The Government of India declared it a Level 3 Calamity or "Calamity of a severe nature"; the floods affected 5.4 million people, 1.4 million of whom were displaced and more than 400 of whom died. The Post-Disaster Needs Assessment conducted by the UN under the leadership of the Government of Kerala estimated the total disaster effects were around INR 26,720 crore (USD 3.8 billion), exclusive of damage to private buildings, properties, hospitals/educational institutions, and vehicles, as well as Kochi airport. AIR's damage survey investigated the effects of the 2018 Kerala floods on the types of structures that were not included in this estimate.

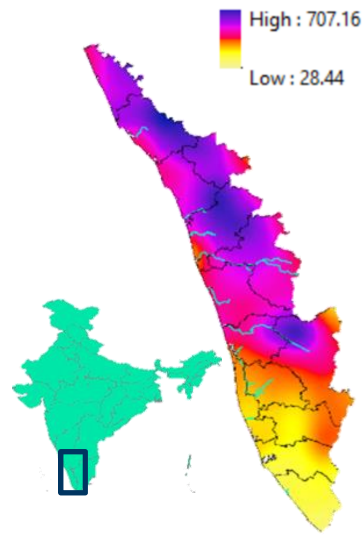

Figure 1. Accumulated rainfall (in mm) 1st to 19th August over the state of Kerala. (Source: TRMM)

The onset of monsoon started normally in the first week of June, followed by the heaviest rainfall in between the 1st and 19th of August; Figure 1 shows the accumulated rainfall for Kerala during this time period. According to the India Meteorological Department (IMD), the state received total rainfall of approximately 2,366 mm (93 inches) between 1st June and 19th August, which is 42% above normal rainfall for this period. The heavy rainfall of about 759 mm observed between 1st and 19th August was 164% above the normal rainfall for that period (Table 1).

Unusually high monsoon precipitation was one of the primary reasons for the large-scale flooding that resulted in severe flooding in 13 out of 14 districts in the State. According to the Central Water Commission (CWC), the rainfall was significantly high during 15-17 August 2018 and this storm event was spread across the entire state of Kerala with its center at Peermade, a hill station located between the Periyar and Pamba river basins (CWC, 2018).

Table 1. Observed rainfall in Kerala in 2018 as compared to normal rainfall (Source: IMD)

Period	Observed Rainfall in 2018 (mm)	Normal Rainfall (mm)	Departure from normal (%)
June	750	650	15
July	857	726	18
1st–19th August	759	288	164
1st June – 19th August	2366	1664	42

Most of the reservoirs in Kerala were at their Full Reservoir Level (FRL)—the highest reservoir level that can be maintained without spillway discharge or without passing water downstream through sluice ways—due to the above normal wet conditions during the months of June and July 2018. Then rains in August forced the release of excess water from these dams across the state, aggravating the flood impact.

Significant and rare events such as this provide opportunities for collecting information, which is valuable for understanding the type and extent of damage and how it can be better prepared for. When we send a damage survey team out to study an event, we aim to have the team on the ground as soon as possible. We are fully aware, however, that the most important consideration after a natural catastrophe is getting the lives of people affected back to normal and showing the proper respect to not only the people who have been impacted but also their property. A team of researchers from AIR in Hyderabad did a comprehensive post-event disaster survey, from 10th to 13th October 2018 across the most affected sites in Kerala to gather information about damage extents, flood depths, and severity. The findings and observations of the team from this damage survey will be discussed in the following sections.

Findings from the AIR Damage Survey

Based on the information available from government reports and media articles, our team focused on 15 of the most affected places along the banks of the Pamba and Periyar rivers covering four districts: Ernakulam, Thrissur, Pathanamthitta, and Alappuzha. The team travelled about 680 kilometers along the banks of Pamba, Periyar, Manimala, and Chalakudy rivers (Figure 2) and carried out the following:

1) Measured high water marks at various locations
2) Photographed and documented the types of observed damage
3) Talked with various Kerala government officials, local or Panchayat officials across the villages, and affected residents to understand the prevailing ground conditions and the firsthand experience during the flood

Most local government and Panchayat offices had measured the high-water level markings representing the flood levels, which were then captured by the AIR team and helped to reliably locate and document the observed maximum water levels. Overall 135 high-water level markings along the banks of these rivers in different locations were recorded; latitude and longitude of the observation points were captured using GPS-enabled mobile devices. The damage survey findings are discussed below, by basin.

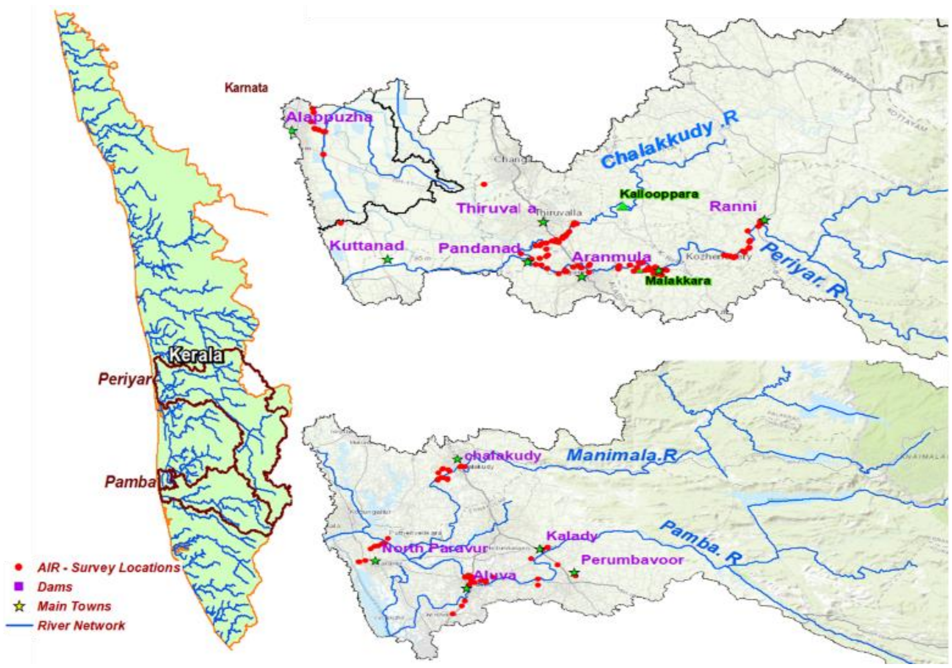

Figure 2. AIR Damage survey locations in Pamba, Periyar, Chalakudy, and Manimala river basins

Periyar River Basin

The Periyar River originates in the Western Ghats before flowing through its 244-km long path entirely through Kerala and joining the Arabian Sea near Ernakulam. The heavy rainfall caused Periyar River to exceed the historically highest observed flood levels called the Highest Flood Levels (HFLs) at Vandiperiyar gauge station downstream of Mullaperiyar Dam, and at the Neeleswaram gauge station downstream to the Periyar Barrage.

The city of Aluva, near Kochi on the banks of Periyar River was flooded when the river crested. The city has a few luxury hotels mostly located on the banks of the river. The AIR team spoke with the management of some of these hotels—Hotel Periyar, Hotel Shirly's Homestay, and Ayurveda Resort—and learned that they experienced high losses because their basements were primarily used for the storage of groceries and the location of laundry facilities, security rooms, firefighting equipment, generators, and the kitchen. The floodwaters deposited a large volume of sediments, which damaged these essential systems and took considerable effort and resources to clean. These hotels remained closed for 10 to15 days, incurring a loss of ₹ 40 to 50 lakhs, on average per hotel, for restoring their services.

The Cochin International Airport Limited (CIAL) located near Aluva town is the fourth busiest airport in India in terms of international traffic and the eight busiest overall. It handled more than 10 million passengers with around 72,000 aircraft movements during 2018-2019 (The New Indian Express, 2019). As the CIAL is located adjacent to the Periyar River, the airport was inundated with 1.5 to 2 meters of water and was closed for operations from August 14 to 26, 2018. The team learned from CIAL's Public

Relationship Officer that the airport's solar power system (CIAL being the world's first solar-powered airport), its 2.5-km long boundary wall, electrical equipment including 800 runway lights, duty-free shops, and other areas of international and domestic terminals suffered significant damage. The income loss for CIAL and Kochi flight operators due to the shutdown of its operations was about ₹ 250 crore (The Financial Express, 2019).

Educational facilities also suffered losses due to these floods. For example, SCMS Cochin School of Business located in North Kalamassery was inundated with a water depth of around 3 meters and was closed for seven days. Computers and laboratory equipment and electrical, plumbing, and generator equipment were severely damaged and a total loss of about ₹ 4–5 crores was incurred wherein the content damage itself was about ₹ 2 crores.

Figure 3. High water marks on residential buildings flooded from Periyar river waters

Many commercial shops in the North Kalamassery area and in Salem Kochi highway were inundated with water depths ranging from 0.5 to 1 meter and incurred losses of about ₹ 2 to 5 lakhs each towards removal of debris and cleaning and restoration.

Residential areas in the vicinity of the Ernakulam district and located close to the Periyar River, such as Desam, Kalady, Parambavoor, Kothamangalam, Chendamangalam and Puthenvelikara, were also inundated with water depths of 1.5 to 2 meters (Figure 3). The buildings suffered serious contents damage, consisting mostly of furniture and major appliances.

Chalakudy River Basin

The town of Chalakudy, located on the bank of the Chalakudy River, a tributary of Periyar River, was severely affected due to heavy downpours and huge water releases from upstream dams exceeding HFL on 15th August 2018, at Arangali and remained above HFL until 17th Aug 2018. AIR estimates the return periods of these flood levels to be about 100 years. Many residential and commercial buildings, hospitals, schools, office buildings and other private properties in the panchayats of Annanad, Kottat, Athirappilly, Pariyaram, Kodassery, Meloor, Kadukutty, Annamanada, and Kuzhoor were submerged. In Chalakudy, commercial buildings such as movie theatres experienced severe damage to their generators and electrical and plumbing systems, which cost around Rs. 20 lakhs for

Figure 4. Damaged medical equipment outside a government hospital in Chalakudy. (Source: AIR)

each movie theatre; hospitals were affected in similar way. Figure 4 shows damaged furniture in a government hospital in Chalakudy.

Pamba and Manimala River Basins

The 176-km long Pamba River originates near Pulachimalai hills in the Western Ghats and joins the Arabian Sea flowing entirely through Kerala. AIR estimated the return period of flood level elevation (8.46 meters) in Pamba River at the Malakkar gauge site on 15th August 2018, to be over 100 years.

Figure 5. High water marks at a fuel station in Ranni (left) and at the Pandanad Panchayat Office (right)

In the town of Ranni in Pathanamthitta district, commercial properties such as shops, hospitals, and petrol pump stations were impacted due to the floods during 15th to 17th Aug 2018. The AIR damage survey team learned from the owner of one of the Indian Oil Pump stations in Ranni that their filling station was under 5 meters of water for three days. Floodwaters entered the underground storage tanks and damaged fuel pumps, which could resume operation only after the storage tanks were cleaned. The cleaning process could start only after the floodwaters had receded, thus it took 15 days to restore normal operations. The AIR damage survey team observed the same kind of damage at most of the other fuel filling stations located in the vicinity of Ranni. The College of Engineering, Aranmula, and Sri Vijayananda Vidyapadam school in Aranmula were both submerged under floodwaters with a depth of 4.5 to 5 meters for three days, which damaged furniture, electronic equipment, laboratory equipment and materials, generators, and other contents.

Several residential buildings in the Mundancavu and Kallissery areas in Chengannur town and Pandanad village, located on the banks of Pamba River were inundated also.

Kuttor, Thirumoolapuram and Vallamkulam villages on the banks of Manimala River, a tributary of Pamba River, were submerged under 2 meters of floodwaters. According to the local panchayat office, almost all the commercial and residential buildings were under water for three to five days. The nature of the building damage in this area was also related to electrical, generator, and plumbing systems as well as contents. Figure 5 shows one of the flooded fuel stations in Ranni and a flooded Panchayat building in Pandanad village.

Comparing the Event Flood Extent with AIR Flood Hazard Maps for India

AIR developed probabilistic inland flood hazard maps for all the river basins in India and released them to the market in 2017. They comprise six map layers for 25-, 50-, 100-, 200-, 250-, and 500-year return periods. The maps also provide water depth estimates, with five depth ranges of 0-1m, 1-3m, 3-6m, 6-9m, and over 9m. Available as a geospatial layer for use with AIR's Touchstone® platform, AIR flood hazard maps enable a sophisticated understanding of the threat posed by complex river networks. AIR's India flood hazard maps can be used for (a) managing flood risk accumulations, (b) determining whether a risk meets the underwriting guidelines, and (c) developing effective portfolio management and risk transfer strategies.

Figure 6. Aerial image of Aluva city on the banks of Periyar river (left); flood extents on 15th Aug (center) and AIR 100-yr extents in blue on aerial image (right)

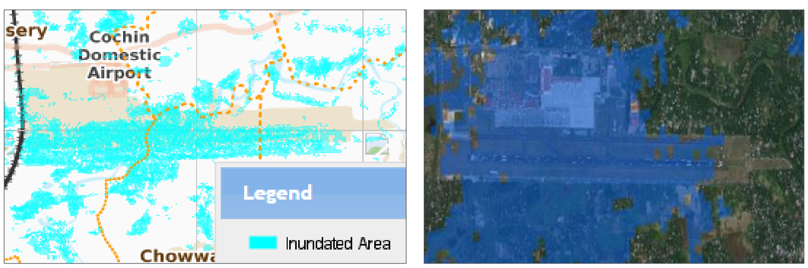

Figure 7. Remotely sensed flood extents in CIAL area as on 20th Aug 2018 as obtained from the Bhuvan web-portal (left) and AIR 100-year return period flood extent in blue overlain on the aerial imagery (right)

The three-day (15-17 August 2018) average rainfall for the event in Kerala was estimated to have exceeded the 100-year return period estimate (Mishra et al. 2018). The Central Water Commission (CWC) measured water levels for 19 stream gauges located in the state of Kerala. These water levels were converted to flows using rating curves developed earlier by AIR; flows for 14 stream gauge stations were found to be around the 100-year return period, or had a 1% chance of happening in any given year. These sites were in the most affected districts of Wayanad, Malappuram, Kozhikode, Ernakulam, Alappuzha, Kottayam, Pathanamthitta and Idukki.

The observed event footprint from remotely sensed and aerial imagery as well as flood depth information collated from the post-event survey were compared against AIR's 100-year flood hazard layer. Figure 6 shows an example: the left-hand panel is an aerial view of flood extents for the city of Aluva located on the banks of Periyar River with the submerged area outlined in red wherein the area inside the red square box is seen to be submerged in both the aerial event extent and the modeled 100-year extent. The right-

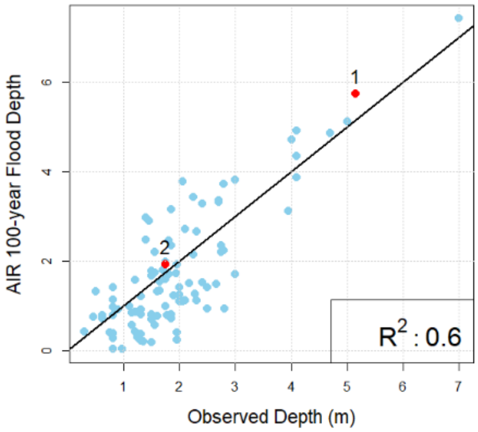

Figure 8. Scatterplot comparing observed depth to the AIR 100-year flood depths. Two observed depth points in the city of Aluva have been marked inset

hand panel also shows two points where flood depths were measured by the survey team. These same two points have been shown on the scatterplot (Figure 8) and both the observed depths are in line with the modeled depths.

In another example, AIR was able to obtain remotely sensed flood extents for the CIAL airport in Cochin from Bhuvan web-portal and compared the same with AIR 100-year flood extents (Figure 7). Measured water depth from our survey at numerous locations was compared to the modeled 100-year flood depths in those locations, and as shown in Figure 8, these matched reasonably well with an R^2 of 0.6. The points shown in this plot lie very close to the 1-1 line which shows that the observed depths match closely with the modeled 100-year depths. It is to be noted that the flood hazard maps are not event footprints and in the absence of the modeled or observed event footprints, this is an alternative method to assess and validate the flood risk. The comparison showed that AIR extents captured the high hazard areas though there were some differences at certain places which can be explained based on (i) unmodeled canals, (ii) water bodies which are not fed by the river such as pond and lakes etc., (iii) urban flooding due to insufficient drainage while AIR's model assumptions consider only riverine flood mapping, not flood defenses, and (iv) the river link may not have experienced the 100-year flow while hazard maps are based on the assumption that every river link experiences 100-year flow.

Discussions

The AIR team traveled 680 km and visited some of the most affected places across the four impacted districts and documented the flood extent and depth and damage information at impacted locations in river basins of Periyar, Chalakudy, Pamba and Manimala. The three-day rainfall from 15 to 17 August caused widespread flooding across the state of Kerala. In the absence of the event footprint, either modeled or observed, we compared the observed flood depths with AIR's 100-year recurrence interval flood depths at multiple locations and found that they are in good agreement. We also compared the observed flood extents available from various sources with AIR's 100-year return period flood hazard extents. Areas delineated in a hazard map of a certain recurrence interval have equal probability of flooding and assumes that all rivers experience the same return period flood at the same time, which is not true for actual events. In case an in-depth analysis is required to assess an event intensity, a detailed modelling approach like that of the AIR Inland Flood Model for the United States can be followed. However, this requires a lot of high resolution meteorological, hydrological and

Digital Elevation Model (DTM) and other type of information to validate the model which is not always readily available as was the case for the 2018 Kerala floods. Thus, the AIR 100-year return period flood hazard extents may have differences with the observed footprints but despite that the comparison serves as a qualitative check showing that the AIR hazard maps were able to capture the high hazard zones.

AIR observed that nonstructural components damage such as contents and business interruption were more common. In Kerala, buildings are usually constructed with brick and mortar, which are not directly prone to damage by floodwaters; however, in some cases excess buildup of water on one side of concrete walls as in the case of boundary or flood retaining walls have caused the structure to fail. Contents losses were a common occurrence both in commercial and residential properties. Facilities storing large quantities of goods were particularly vulnerable. This included places such as supermarkets, warehouses, and shops. Articles that were damaged in the floodwaters included electronic equipment, medical equipment, stationery, clothes, food items, and furniture (Figure 9). When water submerged ATM kiosks, it damaged both the internal machinery and the currency stored inside. In addition to such contents losses, costs associated with cleaning after the deluge were also significant. Floodwaters usually are heavily laden with silt and other debris, which gets deposited and needs to be cleaned once the waters recede. Growth of mold and fungus is another phenomenon common in warm humid places where floodwaters stagnate for longer duration. In such cases, mold formed on the walls and wooden structures, affecting aesthetics and health, and structural aspects of the place often needed repairs.

Figure 9. Electronic equipment and vehicles damaged in the floods (left), a couple of damaged ATM kiosks (center), and furniture damaged in a college (right)

Establishments constructed near rivers and natural drainage channels are particularly exposed to flood hazard. Facilities such as airports when built close to or within the floodplain without adequate flood protections have time and again been exposed to floods. Like CIAL in Kochi cited earlier, Chhatrapati Shivaji International Airport in Mumbai and Chennai International Airport were constructed on the floodplains of Mithi River and Adyar River, respectively, and sustained severe damage and service disruption when these rivers rose during the 2005 Mumbai floods and the 2015 Chennai floods. Losses were incurred mainly due to service interruption caused by flooding of the runways and apron, and damage to expensive machinery such as runway lights and solar power equipment. Structural damages like compound wall collapses and damages to the runway and aprons were also reported. As per AIR's flood hazard maps for India, the undefended AIR 100-year flood zone covers at least 70% of the airport premises, whereas at least 50% is within the 25-year flood zone, which indicates that this airport facility is prone to frequent flooding, even in less severe flooding conditions such as 25-year return period events.

Basements and underground structures for buildings are particularly susceptible to floodwaters, often rendering the areas and their contents unusable. The removal of floodwaters and mud deposits add to the cost of cleaning and restoration. Hotels and similar establishments have basements used primarily for the storage of groceries and operations such as laundry facilities, security rooms, firefighting equipment, generators, kitchens, and mechanical, electrical, and plumbing (MEP) systems. Failure of these systems cripple building operations and the resultant business interruption costs are high. Another type of business that heavily relies on underground structures is fuel-filling stations. These places usually have large underground fuel tanks that are often not protected against floods. When floodwaters enter the premises, they seep into these tanks rendering the pumps and fuel stored in these tanks unusable, causing massive losses. Supermarkets have also been severely affected with content damages by floods. These properties usually have large stocks and inventories which are mostly lost when flooded. Educational institutions also experience a similar impact due to flooding. The AIR damage survey team came across numerous schools and other institutions during the survey, whose expensive equipment such as computers and projectors were permanently damaged by the floodwaters, warranting replacement. Pieces of furniture such as chairs and desks were also damaged along with other structural damages. For hospitals and clinics, medical supplies and expensive medical equipment in ICU along with business interruption losses and cleaning costs have mostly been reported.

The AIR damage survey team also observed that many residential buildings were constructed very close to a riverbank and such buildings were severely affected by floods. Most buildings were damaged up to the first floor and expenses were incurred to clean up the debris, repaint the ground floor and replace/service appliances. In addition, a few buildings were destroyed and needed to be rebuilt. Motor vehicles submerged under water sometimes were repaired and not necessarily a total loss. Increased demand for car repairs after the floods, however, meant that it was more expensive to get such repair work done.

For more information on this study, reference can be made to the HYDRO-2019 conference paper “Utilising Insights from 2018 Kerala floods damage survey in catastrophe Flood Modelling” published by the AIR team (http://www.hydro2019.com/paper-search.php?paperid=&currentpage=5). Due to the unavailability of on-the-ground information of flood depths for events in India through a centralized agency, data collected through such Post-Disaster Damage Surveys are extremely useful to validate and ensure model quality.

Conclusion

The flood of August 2018 in Kerala was perhaps the worst flood in the region in the past 100 years. Intense storms at the end of the monsoon season, exacerbated by saturated soil, triggered massive floods across the state. AIR conducted a post-event damage survey, for which a team visited the affected areas to gather information on flood depths and damage incurred during the event. The team found that commercial as well as residential properties bore the brunt of the high floodwaters, sustaining widespread damage. Shops, businesses, and public services were closed, as most of the buildings were under floodwaters for longer periods. As the floodwaters began to recede in Kerala, the process of recovery started. While much of the flood damage—particularly to residential property—was not covered by insurance, there were substantial losses to property, cargo, and inventory in retail and wholesale shops. Contents damage was significantly more than the structural damage to the buildings. Business interruption losses were also considerable, especially for the area's significant tourism industry; warehouses were forced to shut down for as long as two months and hotels up to four weeks to undertake repairs. AIR's 100-year flood extents and depths have been found to identify the potential hazard areas when compared with the observed flood footprints and depths, implying the product can be utilized by the insurance industry and other interested stakeholders to better understand the associated flood inundation risk to their exposures.

References

1. ADB, World Bank, Govt. of Kerala, 2018. Post Disaster Needs Assessment - Floods and Landslides - August 2018.
2. CWC, 2018. KERALA FLOODS OF AUGUST 2018. Government of India.
3. Indian Meteorological Department, 2018. Rainfall over Kerala during Monsoon Season-2018 and forecast for next 5 days.
4. Mishra, V., Aaadhar, S., Shah, H., Kumar, R., Pattanaik, D.R., Tiwari, A.D., 2018. The Kerala flood of 2018: combined impact of extreme rainfall and reservoir storage. Hydrol. Earth Syst. Sci. Discuss. 1–13. https://doi.org/10.5194/hess-2018-480
5. Sudheer, K.P., Bhallamudi, S.M., Narasimhan, B., Thomas, J., Bindhu, V.M., Vema, V., Kurian, C., 2019. Role of dams on the floods of August 2018 in Periyar River Basin, Kerala. Current Science 116, 15.
6. The Financial Express, 2019. Monsoon rage grounds CIAL's business by Rs 70 crore. The Financial Express.
7. The New Indian Express, 2019. Crore plus transit CIAL in 2018-19; domestic travellers exceed international [WWW Document]. URL http://www.newindianexpress.com/states/kerala/2019/apr/08/crore-plus-transit-cial-in-2018-19-domestic-travellers-exceed-intl-1961513.html (accessed 9.23.19).
8. Srinivas Kondapalli, Raj Kumar Nagamanickam, Samyadeep Ghosh, 2019. Utilizing Insights from 2018 Kerala Floods Damage Survey in Catastrophe Flood Modeling. HYDRO-2019.

About AIR Worldwide

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

AIR
A Verisk Business