4

Impacts of Global Warming in India*

Narratives from Below

Nagraj Adve

Climate change can often appear as a distant, abstract issue. Evidence of climate change is often presented in terms of long-term averages, such as the fact that the earth is currently, after accounting for natural fluctuations, 1.1°C warmer than the 1880–1920 average,[1] or that India has warmed by about 0.8°C since 1901.[2] Invaluable as the science has been, and grave as these numbers are, abstract data

* A brief word about the method followed. This chapter is based on multiple sources: interviews and conversations with people in, and from, different states; scientific papers; India Meteorological Department (IMD) and Indian Institute of Tropical Meteorology (IITM) publications; non-governmental organization (NGO) literature; state action plans on climate change; people's testimonies at public hearings; public meetings; and one film. Through this, it seeks to provide narratives of global warming in India from below.

[1] National Aeronautics and Space Administration/Global Surface Temperature Analysis data, quoted in Hansen et al. (2019).

[2] This figure is based on long-term records and current trends. The rise in both maximum and minimum temperatures has accelerated in India

Nagraj Adve, Impacts of Global Warming in India. In: *India in a Warming World*. Edited by: Navroz K. Dubash, Oxford University Press (2019). DOI: 10.1093/oso/9780199498734.003.0004.

often does not adequately communicate the impacts of these changes on people's lives. This chapter seeks to address this issue by using ethnographic and documentary material to look at how people experience and negotiate climate change in parts of India. Using such an approach, it aims to provide a qualitative narrative of some key, current impacts of global warming.

Drawing out this narrative is complicated by the fact that anthropogenic factors other than greenhouse gases (GHGs) also often have a role to play in a changing climate, such as land use changes, increased atmospheric pollutants (Roxy et al. 2017), and urbanization. Over the last few years, climate science has made remarkable strides in a growing literature on attribution (Chapter 3 in this volume), which seeks to examine whether the occurrence of a specific extreme climate event—events of extreme rainfall, drought, or acute heat stress—was made more probable due to anthropogenic warming.

It is also made more challenging by the fact that specific impacts in a particular place or context are mediated by far-reaching social changes, such as a partly changing agrarian reality, gender relations, caste dynamics, the spread and deepening of capitalism in India, and growing inequalities in incomes, housing, and wealth. Basically, two complex systems—the climate and the social—are both changing in myriad ways, while continuing to influence each other. Unpacking the relative effect of all these intersecting drivers is not easily done, nor is it the intention of this chapter, but their relevance is best not forgotten.

This chapter presents some key, current impacts of global warming in India to examine how the lives of people, as well as other species, are likely affected. For want of space, the discussion does not include some other important changes unfolding: for instance, an increase in the frequency and duration of heat stress, which has been causing thousands of deaths in India in recent years (Rohini, Rajeevan, and Srivastava 2016); or the increased variability, particularly in the monsoon, over the last few decades. In fact, in many places, farmers now say that the rains have become very unpredictable: it rains when it should not and does not rain when it should (Public Advocacy Initiatives for Rights and Values in India [PAIRVI] 2010). There has been a tripling of geographically widespread extreme rainfall events

---

since 1981; our average temperature is currently rising by 0.17°C per decade (Srivastava, Kothawale, and Rajeevan 2017: 20).

during 1950–2012 (Roxy et al. 2017). The southwest monsoon, so crucial to Indian agriculture, has been lessening overall in most regions of the country, for which the Indian Ocean warming faster than the Indian landmass has a crucial role to play (Roxy et al. 2015). There has also been a significant increase in the area and intensity of monsoon droughts since the mid-1950s (Pai et al. 2017: 78). The effects of these changes on crucial sectors of the Indian society and economy—say, agriculture and water, to name just two—are discussed in other chapters in this volume.

Sea-Level Rise, Displacement, and Livelihoods

The Sunderbans, the vast deltaic ecosystem straddling India and Bangladesh, is home to 4.3 million people in India, 1.5 million of them below the poverty line. The level of displacement people face here is staggering. 'My earliest home was way over there,' said a 60-year-old farmer, Bishnu Majhi, pointing to the sea. 'There were houses owned by other families even farther. They have all moved inland.'[3]

This conversation took place in front of his third home, located at one edge of Sagar Island. The land in front of the house was barren, the small water body on it rendered saline; all along that stretch of coast were abandoned homes, former agricultural land, and broken trunks of dead coconut trees jutting into the sky, creating a surreal landscape. Packed sandbags were piled up to one side of his front door, used as a barricade when the tide came in during the monsoon months. 'When that happens, where we are now standing, there is water up to our knees,' he said. 'Despite the sandbags, some water seeps into the house,' his wife Jyotsna added. For tens of thousands of people here, encroaching waters is a fact of life. Now, for many, all their childhood memories are under water.

There are multiple factors, natural and anthropogenic, causing waters to encroach on lands in the Sunderbans. The Ganga–Brahmaputra–Meghna delta is subsiding at 2.5 millimetres (mm) a year, a combination of geology, soil compaction, groundwater

[3] Personal interviews conducted during a field visit to the Sunderbans in January 2014. All translations from Bengali courtesy Partha Kayal, whose engagement with the Sunderbans has been long-standing, and Amitabha Kar.

extraction, and sediment supply (Payo et al. 2016). There is also erosion and accretion caused by riverine ebbs and flows, but it is likely that a growing factor is absolute sea-level rise, caused by global warming.[4]

Climate change-induced sea-level rise occurs for two key reasons: one, over 90 per cent of the excess heat trapped by GHGs since 1971 has gone into oceans worldwide, causing the warmer waters to expand; two, melting ice from glaciers and the fact that the great ice sheets on Greenland and West Antarctica 'are losing mass at an accelerating rate' (National Snow and Ice Data Center 2018).

These various factors combined contribute to a relative sea-level rise in the Sunderbans that seems to be accelerating: one study put the rate at 3.14 mm/year at Sagar Island between 1985 and 1998 (Hazra et al. 2002). However, a more recent, authoritative analysis of data from the same observatory at Sagar over the past 25 years stated, 'The rate of relative sea-level rise comes close to 8 mm/year' (Ghosh et al. 2016: 9).

The physical effects of this sea-level rise here are greater coastal erosion, increased saltwater intrusion, and more inundation. Its social effects are severe, more so in a context of serious deprivation: five out of every six homes in the Sunderbans do not have grid-based electricity; and one in three has no access to health care. In a detailed survey of income levels, landholding size, and asset ownership, 18 out of 19 blocks across the Sunderbans were found to be moderately or highly economically vulnerable, with large overlaps between vulnerability and the proportion of Scheduled Caste households (Hazra et al. 2014). About 78 per cent of households surveyed engage in agriculture—rice being the chief crop—in addition to fishing. Though there are a few large landowners—some of the better-off ones grow the more lucrative betel crop—most households have small landholdings, or are landless.

The erosion or salination of agricultural land intensifies this vulnerability. 'We used to have 12 *bigha*s,' said a farmer, Himanshu Jena. 'Six have been swallowed by the water.' As a consequence, forced migration is a constant feature as people join the labouring poor in Kolkata and farther afield to find work. This results in the frequent fracturing of families and communities.

[4] Absolute sea-level rise refers to the rise in sea-levels alone; relative sea-level rise includes natural processes like land subsidence.

Many households have been displaced multiple times. In Gobardhanpur village in South 24 Parganas district—a village of about 300 households, over a hundred of whom had lost land to encroaching waters—Shankar Das, a small farmer, said he had to shift his home three times. 'Land is much more difficult to find now,' said one old couple who had moved even more often. Numerous people had shifted home no less than three times. In every case, the land they owned was significantly less than they had earlier.

Many farmers have switched to growing salt-tolerant indigenous rice varieties, such as Dudeshwar, particularly after Cyclone Aila hit in 2009. The other key attempt at adaptation is collective in nature. 'We wrote to the Block Development Officer with seventy signatures, requesting a proper embankment; little has come of it,' said a group of women who run an NGO. This is an oft-repeated refrain across the Sunderbans—the demand for embankments where they don't exist and for sturdier embankments made of stone where mud embankments do. One Left political party's poster in Patharpratima block reflected this widely-felt demand: 'If you want an embankment,' it stated in Bengali, 'vote for us.'

The effects of sea-level rise extend beyond individual households, to impacts on the community, such as on schools, which are critical for the life trajectories of the young, and for future generations. Boatkhali Kadambini Primary School, at one edge of Sagar Island, which was a flourishing school protected by a mud embankment in 2014, was completely destroyed by the advancing waters in late 2017. As a senior teacher, who shared photographs and a video of the destroyed school building, said, 'The sea water has come in permanently a hundred metres beyond the spot where our school used to be. Last year, we had to move to a makeshift structure 500 metres inland.'[5] The entire stretch, where there were once houses and plots of land, had turned barren.

For India, the Sunderbans is like the proverbial canary in the coal mine; we would do well to pay heed. With accelerating sea-level rise, communities along much of India's 7,500 kilometre (km) coastline will have to cope with Sunderbans' present reality some years from

[5] Utpal Giri, personal conversation, Sagar Island, the Sunderbans, 5 December 2017.

now. Millions of people will likely face coastal erosion, destruction of their agricultural lands, storm surges, forced migration, and potential conflict, on a horrifying scale.

Migration of Species

Global warming also has drastic effects on other species, with implications for different communities. Until about 1985, a key marine species, the oil sardine, used to be found in waters of the Malabar upwelling zone. Over the last 30 years, it has extended its range, from about 14°N to 20°N (Vivekanandan 2011: 25–6). In other words, it has travelled north by about 650 km, well beyond Mumbai, and can now be found along the south Gujarat coast. The Indian mackerel has also extended its range similarly.

A meta-survey of 208 published studies covering 857 marine species found similar phenomena happening across the world's oceans (Poloczanska et al. 2013). Sea surface temperatures have increased worldwide by about 0.4°C on average over the past 40 years (Schiermeier 2017). The Indian Ocean, however, is warming at a much faster rate than other oceans; waters around India's coasts have warmed by about 0.14–0.16°C/decade over 1958–2015 (Gnanaseelan, Roxy, and Deshpande 2017: 169). According to a specialist on marine species in India, there is a 'positive correlation' between rising sea surface temperatures and the extension of these species' ranges northward: 'The warmer tongue (27°C–28.5°C) of the surface waters expanded north of 14°N, enabling the oil sardine and Indian mackerel to extend their distributional boundary' (Vivekanandan, Hermes, and O'Brien 2016).

As a result, according to a Central Marine Fisheries Research Institute (CMFRI) study, the Indian mackerel has become more prominent and extended its range north off India's east coast as well. And oil sardines were not present at all off India's south-east coast until the mid-1970s, but have spread there in a major way since the 1980s (Vivekanandan 2011: 26, 29–30).

These extensions in range have also had a profound impact on the livelihood practices of some fishing communities. In Tamil Nadu, for instance, it catalysed changes in gear and fishing practices. According to a researcher and activist in the area:

> Ring seine nets increasingly made their appearance to catch these new fish arrivals. As these nets are too expensive for any average fishing household, 10–30 households would get together and invest the ₹5 million or more needed to purchase them. It is also a means by which capital is coming from outside the community, either as credit or from shareholders who are not necessarily fishers.[6]

These changes add to the challenges faced by fishers, particularly artisanal fishers, for other, non-climatic reasons, such as resource depletion, smaller size/below maturity of fish being caught, and rising input costs (Food and Agricultural Organization [FAO]/Foundation for Ecological Research, Advocacy and Learning [FERAL] 2008), all of which could adversely affect catch rates and returns, catalysing tensions.

The changes are unlikely to end there. As their temperatures continue to rise, Malabar's waters could well get too warm for these species. This has happened with catfish along both coasts: as the temperature of the southern waters rose beyond 29°C over the last decade, they completely shifted north, where the water temperature is still 27°C–28.5°C (Vivekanandan, Hermes, and O'Brien 2016: 50). That the same shift may occur down south with the mackerel and oil sardine, both crucial to the nutrition and incomes of millions, is sobering food for thought.

Himalayan Effects

Shifts in species' range are happening on land as well, particularly in the Himalayas. Average temperatures across the Hindu Kush Himalaya (HKH) have risen by 1.19°C in the period 1901–2014, with 'dramatic warming' after the 1970s (Ren et al. 2017: 150). It has contributed to an upward shift in the ranges of fruits, vegetables, oak trees, reptiles, birds, and other fauna across the Himalayan states, as these species find temperatures to which they are accustomed higher up (Adve 2014).

Krishna Mahant, a 60-year-old apple farmer from Hurla village of Kullu district, at about 4,000 feet, wistfully remembered better

[6] Dr Senthil Babu, personal communication, Puducherry, 12 January 2018.

times: 'I was about ten years old. Our village had lots of apple trees. Apples would get transported to Delhi and Punjab' (Jodha 2005). In Himachal Pradesh, land reforms in the 1950s and, later, state support for horticulture were key to improved livelihoods and standards of living for many. Nonetheless, the average temperature, maximum temperature, and average winter temperatures have all risen in Himachal Pradesh sharply between 1951 and 2010 (Rathore, Attri, and Jaswal 2013). This has resulted in reduced snowfall at many altitudes, including in Mahant's village: 'It needs at least six inches of snow for apples to flourish, which we used to get twenty years ago. Nowadays, even if we get an inch of snow, it's unusual. Today there are no apples in this village' (Jodha 2005).

In contrast, in places that used to be too cold for apple cultivation, farmers have benefited. 'With apples growing here for the past twenty years, people's incomes have suddenly risen,' says Bishan Thakur of Nushala village. At even higher altitudes, such as in Lahaul Valley at 10,500 feet, expanding apple cultivation has boosted farm incomes significantly, even as they have declined in villages lower down, in Palam Valley (Rana et al. 2013). Farmers in the Eastern Himalayas have benefited as well: mandarin oranges and round chillies, a high-value crop, are growing in the Darjeeling Hills at altitudes they could not earlier.[7] However, how long will these windfalls last as these crops continue their climb upward?

Rising temperatures are having other effects across the Himalayan ecosystem. An agricultural scientist from Srinagar told me what it has meant for one of Kashmir's iconic tourism destinations:

> The Dal Lake used to be frozen thick in winters 25–30 years ago. I have played cricket on the lake, driven my motorbike on it; someone I know had driven his car on the Dal Lake. Nowadays it has a thin and unsafe layer of ice. ... Snowfall began lessening about fifteen years ago. The timing and patterns of the snowfall have also changed.[8]

'There's a lot of reporting in Kashmir about global warming when we get less snow or erratic rain,' a professor of political science at

[7] Samuel Thomas, personal communication, Darjeeling, 9 March 2014.
[8] Dr Nayar Kirmani, personal communication, Delhi, 2 March 2015.

the University of Kashmir told me in January 2018. 'Students, and others, are very aware of the problem. They see afforestation as the way forward,' he added.[9]

In Uttarakhand, people's responses during interviews by the People's Science Institute (PSI) pointed to clear perception of rising temperatures, unpredictable seasons, and reduced snowfall, particularly of farmers who face crop failure as a consequence. In the Pindar Valley, where pastoralism is an important livelihood, *bugyal*s (alpine meadows) are being taken over by thorny bushes, and these meadows are moving higher away from villages. This detailed study of climate change and new variability in the Bhagirathi and Pindar valleys emphasizes decreased precipitation and reduced winter rainfall. The 'drastic decrease in snowfall' has reduced the snow cover of the mountains surrounding the Pindar Valley, and consequently adversely affected water availability in streams and rivers in the summer months (PSI 2010).

At a public hearing, a resident of Chamoli district said, 'Our agriculture, social activities, and entire knowledge system were often determined and regulated by regular climate patterns. But now we are losing all sense of climate … Because of little snowfall, numerous water sources in the region have dried up. This has depleted soil fertility.'[10] Women are affected the most by this crisis of water, having to queue up for water from early morning, and take the help of their children before they go to school. In May–June, when the crisis is most acute, the better-off use ponies and tempos to fetch water from long distances; the relatively poor just walk (Centre for Science and Environment [CSE] 2017: 64–5).

Extreme Rainfall in Uttarakhand

Over four days in June 2013, most of Uttarakhand received 'unprecedented very heavy rainfall', including 482 mm in Dehradun on 16–17 June. Scientists commented on how rapidly and early the monsoon had advanced and how wide an area in the state faced this deluge (Sikka et al. 2015). A landmark study in the *Bulletin of the*

[9] Dr Javid Ahmed, personal communication, Delhi, 4 January 2018.

[10] A speaker at the National People's Tribunal on Climate Change, Delhi, 2010.

American Meteorological Society concluded that 'our analyses of the observed and simulated June precipitation provide evidence that anthropogenic forcing of the climate system has increased the likelihood of such an event' (Singh et al. 2014: S61).

Massive volumes of water suddenly engulfed Kedarnath, following 325 mm of rain in 24 hours around Chaurabari glacier and accumulated water bursting through the moraine of its glacial lake. Thousands of tourists, shop owners, employees, and innumerable workers in the tourism industry were swept away in the deluge or trapped under the huge volume of mud, boulders, and debris. The floods are an indicator of the massive damage that could occur if predictions of a climate change-driven increase in extreme rainfall events come true.

The Uttarakhand government said 580 had died and another 6,453 were missing and presumed dead. Over 3.4 million were affected (Shrestha, Grabs, and Khadgi 2015: 241). The exact number of those who died will never be known and could be much higher, partly because there were so many Nepali and Indian migrant workers there since it was the height of the tourist season. At a public meeting organized by the Uttarakhand Aapda Rahat Manch in August 2013, a team, including doctors who extensively surveyed and set up medical relief camps in Ukhimath tehsil, Rudraprayag, reported that 595 people had died in Ukhimath alone, including 176 students, of which 144 were aged between 9–16 years. 'The women are particularly affected by the deaths of family members; some of them are ill but they do not say anything.'[11]

The loss and damage to livelihoods was also extensive: shops were washed away; and many lost their mules, used commonly for transporting goods and people, as well as their cows and other livestock kept for manure and the sale of milk to tea shops. There was widespread damage to agricultural land from being directly washed away into rivers, or being submerged by debris and silt. Numerous landslides damaged terrace farming, the major method of farming in hilly terrains. The standing crop was washed away (Adusumalli, Dutta, and Jha 2013).

[11] Munish Kumar of the Uttarakhand Aapda Manch, speaking at a public meeting in the Gandhi Peace Foundation, Delhi, 7 August 2013.

While the Uttarakhand disaster cannot as yet conclusively be directly tied to climate change based on current scientific evidence, it does urge us to rethink deeply what may be appropriate development for any place. In the aftermath of the disaster, experts questioned the blasting of tunnels in a fragile mountain ecosystem, 'ill-conceived' hydropower projects, and the 'hotels and land developers [who] have encroached on river banks' (Chopra 2013). The Ravi Chopra Expert Body report recommended that all hydroelectric projects above the winter snowline, and projects that encompass critical wildlife habitats, eco-sensitive zones, and wildlife-protected areas, be rejected. It implicitly calls into question the dominant hydropower energy policy across the Himalayan states. In a likely context of more frequent intense rainfall events, vulnerable regions need more sensible land use and energy policies. The disaster draws attention not just to what we do *after* a disaster strikes, but what we have done or not done *before* it does.

***

This chapter provides glimpses of how people experience and talk about climate change in India. What they say, combined with evidence from the scientific literature, increasingly indicates that its effects are already severely impacting lives and ecosystems. It is concerning that these are based on barely 0.8°C of average warming, since the science suggests we are at the beginning of a very long warming curve. How sharply that curve rises depends on development trajectories, energy choices, climate movements, and the urgency displayed by political elites, in India and elsewhere.

Some of the examples presented in this chapter interrogate the perception that the effects of climate change in India have been uniformly negative. Farmers in the higher reaches of the Himalayan states have partially benefited. So may have thousands of fishers with the spread of key marine species northwards by hundreds of kilometres, though its effects are complicated by simultaneous social changes, such as expanding capitalist practices in fishing and grave resource depletion. However, given continued climatic shifts, the durability of these gains is questionable.

The examples also suggest that those least responsible for climate change tend to be inordinately affected, such as marginal farmers in the Sunderbans, labourers undergoing greater heat stress, or women facing acute water shortages in Himalayan villages. People who spend years trying to improve their lot are being pulled back down, as the limited gains from development get reversed by the effects of global warming. Any understanding of equity and climate justice needs to take account of the vulnerable within societies, and not only focus on an international, nation-state framework that tends to be divided between North and South.

Women in general, and underprivileged women in particular, constitute perhaps the largest social group in India affected by the combination of increased variability and climate change. It impacts many aspects of their lives and labour that women are made to perform within the home and outside—as construction workers, factory labour, and agricultural workers; in activities such as fetching water, and nurturing; and in terms of access to food and nutrition. A gendered perspective on climate change is sorely needed to be further developed in India.[12]

Also largely missing in India is the urgency which needs to inform human action everywhere if the planet is to avoid crossing thresholds into dangerous levels of average warming beyond 2°C, something that is now being viewed by some scientists as increasingly likely (Raftery et al. 2017).

Finally, the already grave impacts on other species—this chapter touches upon just one—generate a richer and more-nuanced understanding of the problem and underline the need for even greater urgency in tackling it. We humans are part of interconnected ecosystems and serious damage to any of their elements and interactions affects us all.

References

Adusumalli, Malathi, Soumya Dutta, and Ajay Jha. 2013. *Climate Extremes and Loss and Damage: Lessons from the Uttarakhand Disaster, India*. Delhi: Beyond Copenhagen.

Adve, Nagraj. 2014. ‘Moving Home: Global Warming and Shifts in Species’ Range in India’, *Economic & Political Weekly*, 49(39): 34–8.

[12] A recent special issue of the *Economic & Political Weekly* goes some way in filling this gap (see Rao and Hans 2018).

Centre for Science and Environment (CSE). 2017. 'Parched Hills of Uttarakhand', in R. Mahapatra, S.S. Jeevan, and S. Das (eds), *Environment Reader for Universities*, pp. 64–5. New Delhi: CSE.

Chopra, Ravi. 2013. 'The Untold Story from Uttarakhand', *The Hindu*, 25 June. Available at http://www.thehindu.com/opinion/lead/the-untold-story-from-uttarakhand/article4847166.ece; accessed on 15 May 2019.

Food and Agricultural Organization (FAO)/Foundation for Ecological Research, Advocacy and Learning (FERAL). 2008. *Co-management and Livelihood Enhancement Planning in Coastal Artisanal Fisheries.* Puducherry: FERAL.

Ghosh, Nilanjan, Jayanta Bandyopadhyay, Anamitra Anurag Danda, and Sugata Hazra. 2016. *Away from the Devil and the Deep Blue Sea*. Delhi: WWF India.

Gnanaseelan, C., M.K. Roxy, and A. Deshpande. 2017. 'Variability and Trends of Sea Surface Temperature and Circulation in the Indian Ocean', in M.N. Rajeevan and S. Nayak (eds), *Observed Climate Variability and Change over the Indian Region*, pp. 165–79. Singapore: Springer Geology.

Hansen, James, Makiko Sato, Reto Ruedy, Gavin A. Schmidt, Ken Lo, and Avi Persin. 2019. 'Global Temperature in 2018 and Beyond'. Available at http://www.columbia.edu/~jeh1/mailings/2019/20190206_Temperature2018.pdf; accessed on 15 May 2019.

Hazra, Sugata, Isha Das, Kaberi Samanta, and Tuhin Bhadra. 2014. *Impacts of Climate Change in Sunderban Area of West Bengal, India*. Kolkata: Jadavpur University.

Hazra, Sugata, Tuhin Ghosh, Rajashree DasGupta, and Gautam Sen. 2002. 'Sea-Level and Associated Changes in the Sunderbans', *Science and Culture*, 68(9–12): 309–21. Available at http://www.saconenvis.nic.in/publication%5CSea%20Level%20and%20associated%20changes%20in%20the%20Sundarbans.pdf; accessed on 15 May 2019.

Jodha, Vijay. 2005. *The Weeping Apple Tree*. UK Environment Film Fellowships. Film, at 9 mins 18 secs.

National Snow and Ice Data Center. 2018. 'SOTC: Ice Sheets'. Available at https://nsidc.org/cryosphere/sotc/ice_sheets.html, accessed on 24 May 2018.

Pai, D.S., P. Guhathakurta, A. Kulkarni, and M.N. Rajeevan. 2017. 'Variability of Meteorological Droughts over India', in M.N. Rajeevan and S. Nayak (eds), *Observed Climate Variability and Change over the Indian Region*, pp. 73–87. Singapore: Springer Geology.

Payo, Andres, Anirban Mukhopadhyay, Sugata Hazra, Tuhin Ghosh, Subhajit Ghosh, Sally Brown, Robert J. Nicholls, Lucy Bricheno, Judith Wolf, Susan Kay, Attila N. Lazar, and Anisul Haque. 2016. 'Projected

Changes in Area of the Sunderban Mangrove Forest in Bangladesh due to SLR by 2100', *Climatic Change*, 139(2): 279–91. Available at https://doi.org/10.1007/s10584-016-1769-z.

People's Science Institute (PSI). 2010. *Documenting Climate Change in Uttarakhand*. Dehradun: PSI.

Poloczanska, Elvira S., Christopher J. Brown, William J. Sydeman, Wolfgang Kiessling, David S. Schoeman, Pippa J. Moore, Keith Brander, John F. Bruno, Lauren B. Buckley, Michael T. Burrows et al. 2013. 'Global Imprint of Climate Change on Marine Life', *Nature Climate Change*, 3(August): 919–25. Available at http://dx.doi.org/10.1038/NCLIMATE1958.

Public Advocacy Initiatives for Rights and Values in India (PAIRVI). 2010. *Jalvayu Sankat: Peediton ki Jubani*. Delhi: PAIRVI.

Raftery, Adrian E., Alec Zimmer, Dargan M.W. Frierson, Richard Startz, and Peiran Liu. 2017. 'Less than 2°C of Warming by 2100 Unlikely', *Nature Climate Change*, 7(July): 1–5. Available at http://dx.doi.org/10.1038/nclimate3352.

Rana, R.S., R.M. Bhagat, V. Kalia, H. Lal, and V. Sen. 2013. 'Indigenous Perceptions of Climate Change vis-à-vis Mountain Agricultural Activities in Himachal Pradesh, India', *Indian Journal of Traditional Knowledge*, 12(4): 596–604. Available at http://www.hpccc.gov.in/PDF/Agriculture/Indigeneous%20Perceptions%20of%20Climate%20Change.pdf; accessed on 15 May 2019.

Rao, Nitya and Asha Hans. 2018. 'Review of Women's Studies: Gender and Climate Change', *Economic & Political Weekly*, 53(17). Available at https://www.epw.in/journal/2018/17/review-womens-studies/gender-and-climate-change.html.

Rathore, L.S., S.D. Attri, and A.K. Jaswal. 2013. *State Level Climate Change Trends in India*. Delhi: Indian Meteorological Department. Available at http://www.imd.gov.in/section/climate/StateLevelClimateChangeMonoFinal.pdf; accessed on 10 August 2018.

Ren, Yu-yu, Guo-yu Ren, Xiu Bao Sun, Arun B. Shrestha, Qing Long You, Yun Jian Zhan, Pan-Feng Zhang, Rupak Rajbhandari, and Kang-Min Wen. 2017. 'Observed Changes in Surface Air Temperature and Precipitation in the Hindu Kush Himalayan Region Over the Last 100-plus Years', *Advances in Climate Change Research*, 8 (3): 148–56. Available at http://dx.doi.org/10.1016/j.accre.2017.08.001.

Rohini, P., M. Rajeevan, and A.K. Srivastava. 2016. 'On the Variability and Increasing Trends of Heat Waves over India', *Nature Scientific Reports*, 6(26153). Available at http://dx.doi.org/10.1038/srep26153.

Roxy, M.K., S. Ghosh, A. Pathak, R. Athulya, M. Mujumdar, R. Murtugudde, Pascal Terray, and M. Rajeevan. 2017. 'A Threefold

Rise in Widespread Extreme Rain Events over Central India', *Nature Communications*, 8(708): 1–11. Available at https://doi.org/10.1038/s41467-017-00744-9; accessed on 15 May 2019.

Roxy, M.K., R. Kapoor, P. Terray, R. Murtugudde, K. Ashok, and B.N. Goswami. 2015. 'Drying of Indian Subcontinent by Rapid Indian Ocean Warming and a Weakening Land–Sea Thermal Gradient', *Nature Communications*, 6(June): 1–10. Available at https://doi.org/10.1038/ncomms8423; accessed on 15 May 2019.

Schiermeier, Quirin. 2017. 'Artificial Warming Trial Reveals Striking Sea-floor Changes', *Nature*, 31 August. Available at https://www.nature.com/news/artificial-warming-trial-reveals-striking-sea-floor-changes-1.22543; accessed 24 May 2018.

Shrestha, Mandira Singh, Wolfgang E. Grabs, and Vijay R. Khadgi. 2015. 'Establishment of a Regional Flood Information System in the Hindu Kush Himalayas: Challenges and Opportunities', *International Journal of Water Resources Development*, 31(2): 238–52. Available at http://dx.doi.org/10.1080/07900627.2015.1023891; accessed on 15 May 2019.

Sikka, D.R., K. Ray, K. Chakravarthy, S.C. Bhan, and A. Tyagi. 2015. 'Heavy Rainfall in the Kedarnath Valley in June 2013', *Current Science*, 108(2): 353–61. Available at https://www.researchgate.net/publication/278021179_Heavy_Rainfall_in_Kedarnath_Valley_during_Advancing_Monsoon_Phase_in_June_2013; accessed on 15 May 2019.

Singh, Deepti, Daniel E. Horton, Michael Tsiang, Matz Haugen, Moetasim Ashfaq, Dui Mei, Diksha Rastogi, Nathaniel C. Johnson, Allison Charland, Bala Rajaratnam et al. 2014. 'Severe Precipitation in Northern India in June 2013: Causes, Historical Context and Changes in Probability', *Bulletin of the American Meteorological Society*, 95(9): S58–61. Available at https://www.researchgate.net/publication/266554791_Severe_precipitation_in_northern_India_in_June_2013_Causes_historical_context_and_changes_in_probability; accessed on 15 May 2019.

Srivastava, A.K., D.R. Kothawale, and M.N. Rajeevan. 2017. 'Variability and Long-Term Changes in Surface Air Temperatures over the Indian Subcontinent', in M.N. Rajeevan and S. Nayak (eds), *Observed Climate Variability and Change over the Indian Region*, pp. 17–35. Singapore: Springer Geology.

Vivekanandan, E. 2011. *Climate Change and Indian Marine Fisheries*. Kochi: Central Marine Fisheries Research Institute.

Vivekanandan, Elayaperumal, Rudolf Hermes, and Chris O'Brien. 2016. 'Climate Change Effects in the Bay of Bengal Large Marine Ecosystem', *Environmental Development*, 17(September): 46–56. Available at http://dx.doi.org/10.1016/j.envdev.2015.09.005.