COMPLEMENTING SCIENTIFIC MONSOON DEFINITIONS WITH SOCIAL PERCEPTION IN BANGLADESH

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How the people of Bangladesh perceive the monsoon onset has important implications.

The monsoon onset is a critical event in the Bangladesh calendar. The cool monsoon rains release the country from the scorching premonsoon heat and provide vital moisture for the domestic agricultural sector (Rosenzweig and Binswanger 1993; Gadgil and Kumar 2006). This sector, among others, could benefit from information about the timing and variability of the monsoon onset. But, when does the monsoon start? To produce any information from climate data about monsoon onsets, lengths, and withdrawals, we first need to apply a monsoon definition. Choosing a monsoon definition is not a simple exercise in Bangladesh, because different definitions can lead to different monsoon onsets resulting in potential confusion.

Information generated about the monsoon onset might also be misunderstood if the people with whom we communicate cannot relate to the prescribed definition. Thus, an understanding of the user group's perception must complement the physical climate analysis. However, to gain this understanding, we have to engage with the user group.

In this study we focused on agricultural workers as our potential user group because of the importance of the monsoon onset in Bangladesh to agriculture. We carried out a structured questionnaire in six rural regions around Bangladesh and asked predominantly local farmers how they defined the monsoon and when they thought it started. We then analyzed how these perceptions compared to previously used scientific monsoon definitions, thereby shedding light on how science and social perception compare in Bangladesh.

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Furthermore, we discuss how delicately we should define the monsoon if its onset, withdrawal, and/or length are important elements in a climate application, which aims to inform a specific end user or group. A climate application could entail forecasting at varying time scales or informing about the climate past, present, and future. A climate application could also be aimed at varying user groups, from a single rural community to policy makers or to an entire population.

In Bangladesh, climate applications are often part of larger, adaptation-oriented projects, which are usually financed and managed by international nongovernmental organizations. The project Adaptation for Smallholders is a relevant example and is managed by the International Fund for Agricultural Development (IFAD 2014). Climate information might also be applied to community-based adaptation projects, which primarily target local communities (Ayers and Forsyth 2009). Climate applications may also constitute the major part of an adaptation-oriented project. Webster et al. (2010) designed and implemented a forecasting system to increase the rural community adaptive capacity to the risk of imminent floods. This project was also primarily funded by agencies external to Bangladesh. Whether climate information is a minor or major part of any applied research application, we recognize the need to involve the people or end users in the process (Brooks 2013; American Meteorological Society 2014).

BUT WHY ASK THE LOCALS? The answer to this question depends on the scientific approach of a research project. In a basic research project about the monsoon onset, the resultant information furthers our understanding of the phenomena, with no specific end user in mind. In this case, the people with whom we primarily engage are our fellow scientists. In an applied research approach, the resultant information needs to talk to a certain user group. In this case, we have to engage with these users or local community members in order to ensure that the information is useable (Dilling and Lemos 2011). Through this engagement with the locals, we avoid what Finan (2003) calls a skewed discourse, where science alone dictates the production of information.

In some parts of the world, the monsoon has fallen victim to skewed discourse. In Brazil, the forecasting authorities define the rainy season in a different way to rural communities (Pennesi 2007). It is not surprising that the rural communities feel confused and mistrust the forecasts. We can avoid, or at least reduce, this befuddlement if we actively engage with the end users to understand their perspectives. This engagement can improve important relationships between users and climatologists and enhance the development of advanced forecasting systems (Nyong et al. 2007; Orlove et al. 2010). For example, Webster et al. (2010) generated flood forecasts and communicated them using thresholds that the Bangladeshi users could relate to. The researchers had to gain knowledge of these thresholds and integrate it into the forecasting system at a local level. This process was vital to the success of their forecasting system. However, forecasting is but one climate application.

Climate adaptation projects also need to apply climate knowledge that complements social perception. To create community-based vulnerability assessments and enhance climate adaptation policies, Spinney and Pennesi (2012) showed the importance of incorporating local interpretations of weather events and locally relevant indicators. Similarly, several other social scientists have demonstrated that local definitions, interpretations, and assessments of terms should guide social science research (Nadasdy 1999; Cruikshank 2001; Roncoli et al. 2002; Furgal and Seguin 2006; Crate 2008). Thus, social science research must complement climate science research if the aim is to provide a user group with information about the monsoon onset in Bangladesh. Our aim is to consider and compare the views and perceptions of rural agriculturists in Bangladesh with regard to the monsoon. If we complement and compare this information with physical climate data, then we can make judgments on which scientific monsoon definition might be most appropriate to apply.

DIFFERENT DEFINITIONS, DIFFERENT RESULTS. Some define the monsoon essentially as a rainfall phenomenon (Dang-Quang et al. 2014). Others describe it as a wind phenomenon (Ramage 1995). Others state clearly that we must distinguish between monsoon winds and monsoon rains, as they do not always coincide (Flohn 1968). These different approaches have resulted in multiple monsoon definitions, which do not necessarily agree over Bangladesh.

This diversity of monsoon definitions is understandable, because each one of them is born out of a basic research project with its own scientific questions and objectives. But what if our objective is to inform an end user about the monsoon onset in Bangladesh? To generate this information, we would probably resort to the various scientific monsoon definitions available to us. Thus, an understanding of the differences between these definitions is important.

Figure 1 presents an overview of several of the studies that have shown how the monsoon progresses over Bangladesh according to different definitions. All the definitions are based on varying parameters, thresholds, and methodologies illustrating the well-discussed lack of consensus (Wang and LinHo 2002; Zhang 2010; Zhang et al. 2012). Some of the methods use wind direction as the key parameter, often in combination with other parameters like precipitable water (Zhang 2010) or rainfall, temperature, and humidity (Ahmed and Karmakar 1993). Most of the studies use various rainfall observations or proxy datasets. For example, Matsumoto (1997) only used observations from rain gauges, whereas Lau and Yang (1997) used a global precipitation index based on infrared satellite estimates. Wang and LinHo (2002) used the Climate Prediction Center Merged Analysis of Precipitation (Xie and Arkin 1997), which combines observations, satellite data, and output from numerical weather models. Ashfaq et al. (2009) used the same method as Wang and LinHo (2002) but applied it to climate model data and thereby projected future change.

Not all of the results shown in Fig. 1 were referred to as the *monsoon* progression in their original publications. Some of the authors used the term *rainy season* (e.g., Matsumoto 1997), as its progression across Bangladesh was not necessarily connected with the reversal of the large-scale monsoon circulation. However, all of the results in Fig. 1 have since been called the monsoon in other publications (e.g., Fig. 1 in Ding 2004), leading to potential confusion. We present these results in a condensed format so that it is easier to compare with the locals' perceptions.

Despite the varying definitions presented in Fig. 1, it is evident that most of the figures show a similar pattern of progression across Bangladesh. Figures 1a–i roughly show a uniform progression in a westward or northwestward direction, passing the central districts around 1 June or very soon afterward. A different pattern emerges when we consider Figs. 1j and 1k. Here we see a much earlier onset in the northeastern part of Bangladesh. The early onset (8 April) seen in Fig. 1k is not reflected in Fig. 1j because Ashfaq et al. (2009) used an artificial cutoff date of 21 May (M. Ashfaq 2013, personal communication). Both of these definitions are based on rainfall (Ashfaq et al. 2009; Matsumoto 1997). The early onsets in northeastern Bangladesh signify that the region may receive a considerable amount of rain during this early summer period.

OUT IN THE FIELD. We mapped perceptions by administering a survey and asking roughly 200 people in six locations (total of 1210 respondents) in Bangladesh (Fig. 2). The upazilas (subdistricts) and

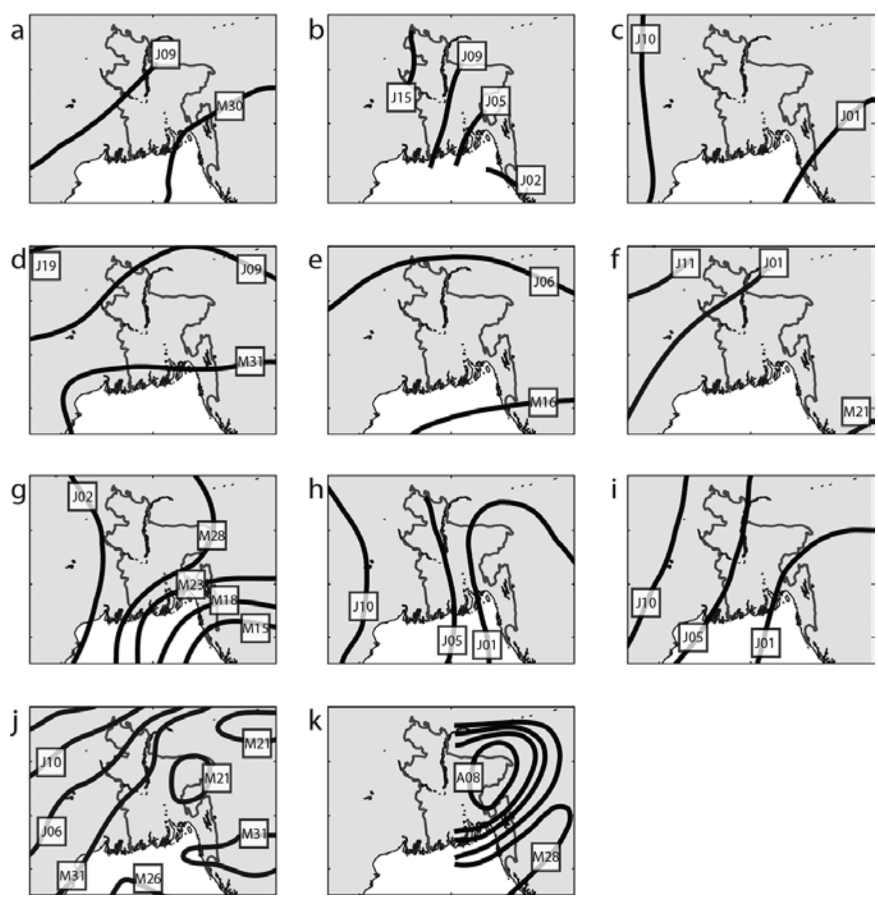

Fig. 1. Previously published monsoon progressions across Bangladesh from (a) Zhang (2010), (b) Ahmed and Karmakar (1993), (c) Tao and Chen (1987), (d) Zeng and Lu (2004), (e) Lau and Yang (1997), (f) Wang and LinHo (2002), (g) Webster et al. (1998), (h) Mooley and Shukla (1987), (i) Tanaka (1992), (j) Ashfaq et al. (2009), and (k) Matsumoto (1997). Months are given as A for Apr, M for May, and J for Jun.

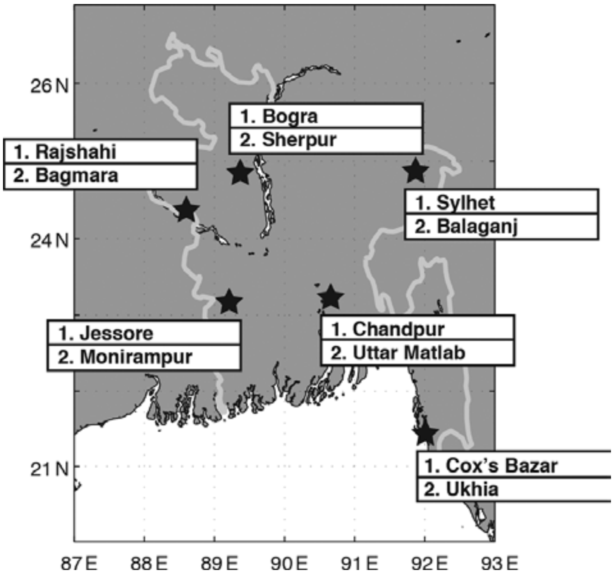

Fig. 2. The locations where the survey was carried out. The number 1 indicates the main region name. Number 2 indicates the name of the subdistricts where three villages were then chosen.

unions (villages) in the survey were chosen carefully through climatological considerations and detailed discussion with local agriculture extension offices.

The field teams traveled to the chosen locations and elected respondents based on simple random sampling. They completed each questionnaire as a face-to-face interview, with no limit on time. Because of questions concerning trends and the fact that we concentrated on the agricultural sector, we stipulated several simple criteria by which the field teams identified possible respondents:

1) over 40 yr old,
2) permanent resident of the settlement concerned, and
3) agricultural worker.

Other professions were also represented in the survey, but agricultural workers composed 93.0% of the total.

During the questionnaire survey, the field teams asked several questions about the monsoon onset, withdrawal, and trends. In this paper, we only analyze and discuss how the respondents defined the monsoon and when they perceived it to begin. We originally wrote the questions in English and colleagues at the Bangladesh Center for Advanced Studies (BCAS) translated them into Bengali. We were particularly careful with the survey and question format and designed the questionnaire to be carried out quickly and with little room for misunderstanding. We only used closed-format multiple-choice questions, but respondents could give other answers if desired. A short field test was carried out in Chittagong, Cox's Bazar, and Rajshahi in order to assess practical and rhetorical issues prior to the full-scale survey (Fowler 1995). After the pretest, no changes were deemed necessary.

Despite this pretest and our aim for simplicity, we still discovered errors in final results. For example, some people stated that the latest monsoon onset occurred *before* the average onset date. We took a strict approach on these errors and removed all the answers from the respondents (a total of 5.9% of all respondents) who had answered incoherently.

The respondents gave dates according to the Bengali calendar, which we subsequently translated to the "western" calendar and Julian pentads (5-day periods).

SO WHAT DID THE PEOPLE THINK? FIRST, LET US CONSIDER HOW THE LOCALS DEFINED THE MONSOON. The BCAS field teams presented the respondents with the word monsoon and asked them to choose between one of four predefined options or give a different response. Figure 3 shows the results from the six different regions where perceptions clearly vary geographically. In Bogra and Sylhet, the majority of respondents (33.9%) defined the monsoon as the first period of prolonged rain. The preference of a rain-based monsoon definition prevailed in most regions, with 62.6% of all respondents over the whole country choosing one of the three rain-based definitions. Of all the respondents, 18.5% made the connection between rainfall and wind and defined the monsoon as the first period of prolonged rainfall with southerly winds.

It was not just the rainfall definitions that were popular. In the central and western part of the country (Chandpur, Jessore, and Rajshahi), people preferred a static date definition. In Chandpur for example, 39.8% considered the monsoon onset as the first day of the Bengali month of Ashar (roughly 15 June in the western calendar).

The perceptions of the agricultural communities clearly vary geographically. However, the results certainly draw us toward monsoon definitions based on rainfall and away from definitions solely based on parameters such as wind. Thus, despite being an extremely important factor in large-scale dynamical monsoon studies, the wind direction does not seem to greatly influence local community narrative.

What is the perception of the locals about the timing of the onset? On average, if we initially disregard the Sylhet results, the locals perceive a gradual monsoon progression from Cox's Bazar in the southeast to Rajshahi in the northwest (Fig. 4). This progression seems to agree with most of the previous results shown in Fig. 1, where the results shown in Fig. 1b correspond best with the people's perceptions. In pentad values, Fig. 1b shows that the monsoon begins in southeastern Bangladesh in pentad 31 and finally in the northeast in pentad 34 (Ahmed and Karmakar 1993). The locals in our survey perceive a similar progression between pentad 30 and 33.

However, when we include Sylhet, a different picture emerges because the Sylhet locals perceive a particularly early onset when compared with the remaining locations. How appropriate would scientific information be to locals in the northeast if it depicted a uniform monsoon progression across the country? So far, the results guide us toward rainfall-based definitions that resolve the early summer rainfall in northeastern Bangladesh, which obviously influences local community perceptions and possibly also livelihoods.

Another important quantity with economic consequences is the year-to-year variability of the monsoon onset, as later-than-normal monsoon onsets can strongly impact agricultural profit (Rosenzweig and Binswanger 1993; Gadgil and Kumar 2006). Hence, information about interannual variability has potential benefit to the agriculturists who depend on the monsoonal rains for their livelihood. When we apply a monsoon definition, it also needs to speak to people's understanding of variability. We therefore asked the respondents about their perceptions of interannual variability of the monsoon onset. It is challenging to design questions about variability, as we cannot ask directly about statistical values like variance or standard deviation. We therefore asked locals about the earliest and latest onsets they had experienced over the past 20 yr. These responses indicate by how much the onset can vary interannually. For example, if a respondent says that the earliest and latest onsets are far apart, this will indicate that he/she perceives a large interannual variability. A respondent who says that the earliest and latest onsets are close together perceives a smaller interannual variability.

By taking the difference between the average earliest and latest onset, locals perceive a lower variability in the southern part of Bangladesh. The differences at Cox's Bazar, Chandpur, and Jessore are 9, 10, and 12 pentads, respectively. There is a clear divide in perceptions between north and south. In the north these differences are considerably larger. In Bogra, Sylhet, and Rajshahi the differences between earliest and latest onset are 14, 16, and 17 pentads, respectively. This indicates that locals perceive a less reliable onset date in the north.

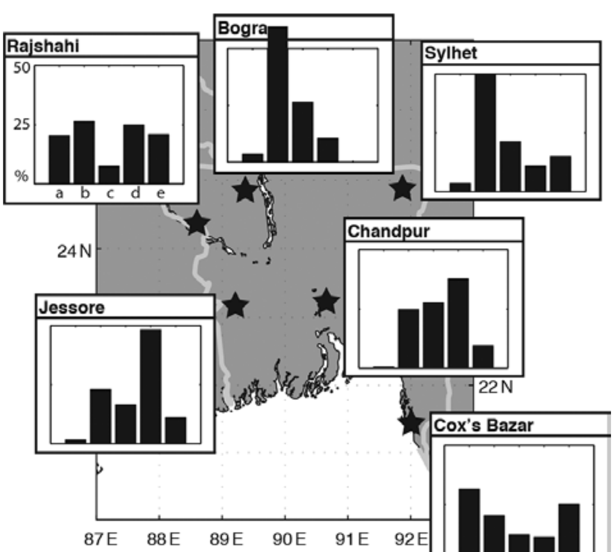

Fig. 3. Results from questions concerning how the respondents define the onset of the period that they called the monsoon. The graphs show the five main responses; from left to right, these responses were first day of heavy rain, first period of prolonged rainfall, first period of prolonged rain as well as southerly winds, first day of Ashar, and other.

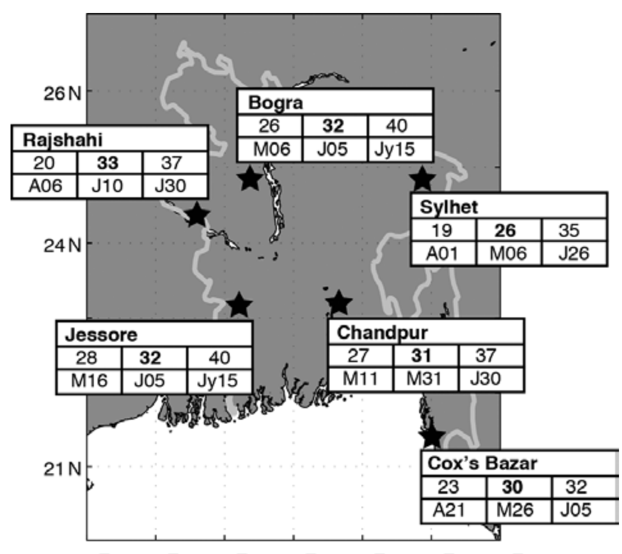

Fig. 4. Results from questions concerning the normal (center value in bold), earliest (left value), and latest (right value) monsoon onset for each location. The values are given as average pentad and date (A for Apr, M for May, J for Jun, Jy for Jul, and digits denote date). The results exclude the respondents who defined the onset as the first day of Ashar, as this is a static date and does not vary from year to year.

Comparing these results with previous publications is challenging because few calculated interannual variability and presented it graphically. It is also difficult to compare the people's perceptions with any statistical values like standard deviation or variance. However, we emphasize the importance of considering the variability and not just the average onset date as it is the variability that affects agricultural profit (Rosenzweig and Binswanger 1993). Our results highlight where large year-to-year variability is perceived in Bangladesh. Scientific analysis should reflect greater variability in northern and northeastern regions due to the early summer rainfall experienced in these regions.

EARLY ONSET IN SYLHET. Why do the local agriculturists in northeastern Bangladesh say that the monsoon starts considerably early? Since they define the monsoon according to rain, it is not surprising that we observe high rainfall amounts (above 6 mm day^{-1}) in this region during the period March–May (Fig. 5).

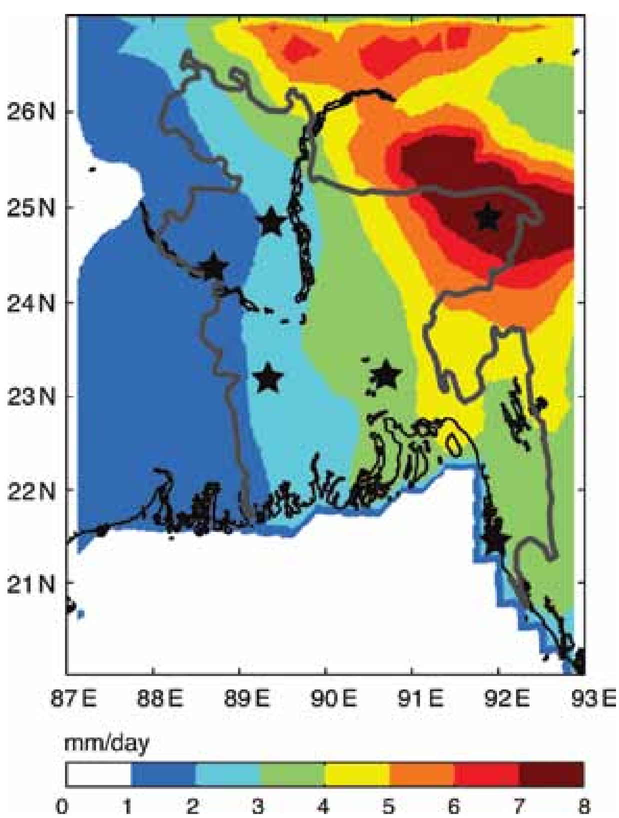

Fig. 5. Average daily rainfall for Mar–May (1981–2010) from the Asian Precipitation–Highly-Resolved Observational Data Integration Toward Evaluation of Water Resources (APHRODITE) rainfall dataset (Yatagai et al. 2012). Extensive regions experience average rainfall of over 6 mm day^{-1}, especially in northeastern Bangladesh.

We visualize this 6 mm day^{-1} rainfall threshold in Fig. 6, which compares the climatological rainfall with the people's perceptions of the monsoon onset date. The figure shows that the people identify the monsoon onset at a similar time to the seasonal increase in rainfall, illustrating a connection between perception and precipitation. Furthermore, the early increase in rainfall in Bangladesh clearly influences the people's perceptions in northeastern Bangladesh.

Climatologists have long recognized this early summer rainfall. Several published theories address the mechanisms behind this rainfall, but none have managed to completely prove the physical processes. This rainfall displays a late night/early morning convective maximum, which occurs during spring and summer, and seems to account for over two-thirds of total rainfall (Ohsawa et al. 2001). The triggering mechanisms could be orographic lifting (Matsumoto 1997), large-scale moist flow convergence with katabatic winds (Ohsawa et al. 2001; Basu 2007), cold pool convergence (Murata et al. 2011), or dryline convection (Weston 1972; Lefort 2013). The convection could deepen by interacting with the midtropospheric India–Myanmar trough, previously known as the Burma trough (Flohn 1968; Yin 1949; Ding and Sikka 2006). Longwave radiative cooling of the cloud tops could also further strengthen the convection (Flohn 1968). In reality, a combination of these mechanisms likely causes this early summer rainfall, making it challenging, yet interesting, to research.

We foresaw that this rainfall could present a challenge in our questionnaire survey, as respondents might not make the distinction between premonsoon and monsoon rainfall. Thus, we included a question to clarify this distinction and 98.4% of the entire sample population made the distinction between the monsoon and the premonsoon rains. Hence, for the people in northeastern Bangladesh, the early summer rainfall *is* the monsoon, whereas the scientific community has consistently called it the premonsoon.

IMPLICATIONS. In this study, we complemented previous scientific knowledge of the monsoon onset with agriculturists' perceptions in Bangladesh. Even though a smooth progression of the monsoon across the country seems like the most robust scientific narrative, it may not be the most appropriate to use in an applied research setting. Overall, our results draw us toward monsoon definitions based on rainfall that show an earlier onset in northeastern Bangladesh.

However, we have to be careful not to make too-far-reaching generalizations. Despite the dominance of rainfall-based definitions, the survey clearly illustrates the variations in perception across the country. For example, in Jessore, a static onset date is also popular, lending weight to the use of a monsoon definition such as June–September, whereas in Bogra, a rain-based definition dominated. These variations in perception emphasize the need to think locally when we aim to inform the communities.

In this study, we have not applied our results directly to a specific climate application. However, by answering how people define the monsoon, we reveal the complexity of this problem, where science and society do not necessarily agree. This does not undermine previous scientific inquiry, but it has implications for climate application design, implementation, and evaluation. In such settings, defining the monsoon is a delicate issue, where social and natural science should complement each other. Engagement with the end users and understanding their perceptions and requirements are vital to the success of a climate application or service (Brooks 2013).

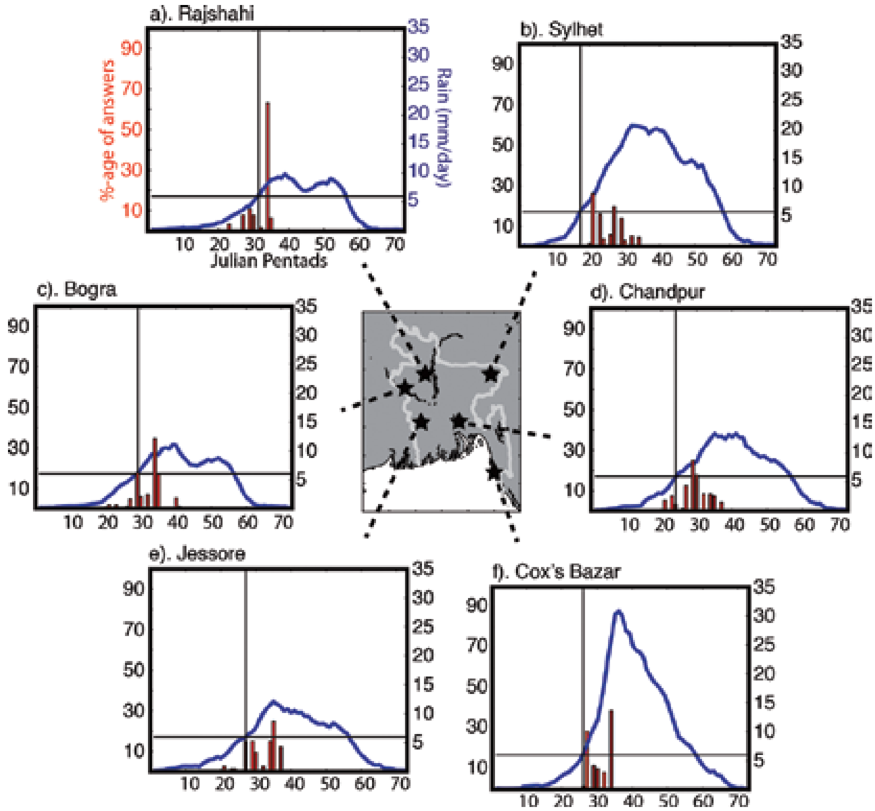

Fig. 6. Social perception of the monsoon onset (percentage; red bars, left axis) plotted against rainfall climatology (mm day^{-1}; blue line, right axis). To make this comparison, we included the results from the people who defined the monsoon as the first period of prolonged rain. The rainfall climatology is calculated from the nearest grid point in the APHRODITE dataset and is smoothed using a five-pentad running mean. The black lines show when the 6 mm day^{-1} threshold is exceeded at each location.

We showed that the people's perceptions are sensitive to location and local climate. Not only do people's monsoon definitions vary, but also their perceptions about the onset date and its variability. In Bangladesh, we showed that the early summer rainfall in the northeast influences the perception. The scientific literature indicates that regional topography might trigger this rainfall. Thus, the early summer rainfall may only affect a relatively small area in relation to the full monsoon region. However, around 10 million people live in this area hence, understanding its effect on climate and perception should not be taken lightly.

Issues like these will present challenges in any country where complex geography influences monsoon circulation or where rainy seasons are bimodal. As the meteorological situation becomes more complex, so increases the need for social and natural science to complement each other in a climate application. Only then can we move away from the risk of skewed discourse and provide climate information that people can act upon.

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