Heat island effect in an industrial cluster – Identification, Mitigation and Adaptation

Introduction

Higher ambient air temperature (2-5^{0}C) of an area compared to the surroundings classifies the area as an Urban Heat Island (UHI). According to the Indian Meteorological Department (IMD), when the ambient air temperature of an area in the plains crosses 40^{o}C, the area is regarded as the heat wave affected area. However, IMD does not take humidity into account while declaring heat waves. Studies suggest that humidity increases the wet bulb temperature (TW) which reduces the human body's ability to cool itself. Disruption of the body's ability to regulate temperature can immediately impair physical and cognitive functions. **If ambient air TW exceeds 35°C (typical human body skin temperature under warm conditions), metabolic heat can no longer be dissipated.** Human exposure to TW of around 35°C for even a few hours will result in death even for the fittest of humans under shaded, well-ventilated conditions. While TW well below 35°C can pose dangerous conditions for most humans, 35°C can be considered an upper limit on human survivability in a natural (not air-conditioned) environment. **The TW may reach 35°C even when the ambient air temperature do not reach 40^{o}C.**

The International Disaster Database (EM-DAT) reported that the heat waves have claimed more than 2500 lives in India during 2015-16. In the country, third largest mortality related to heat wave was recorded from the state of Odisha. Titlagarh, Angul and Jharsuguda in the state were reported as severe heat wave prone areas. It has been noted that the large positive departure of maximum temperature from the climatology during the heat wave periods largely coincides with the areas (particularly in Uttar Pradesh, Bihar, and Odisha) where climate models predict TW to approach or exceed the survivability threshold. **Scientists who studied India's 2015 heatwave concluded that the region was likely to see intense heatwaves once in every 10 years instead of once in every 100 years.**

The UHI phenomenon may be attributable to climate change, changes in land cover, energy intensive industrial activities, coal mining, congestion in urban pockets, increase in built-up areas, etc. and can significantly affect human health, economic productivity as well as energy demand. It is important to develop mitigation strategies to reduce the effect of UHI, while adaptation strategies are required to cope with the heat stress. The key challenges to implement these strategies are primarily related to **lack of industrial and institutional framework as well as lack of adequate drive, capacity and awareness among the policy makers as well as the affected population.** The Ib-valley region of Jharsuguda is one of the four UHIs (Jharsuguda, Titlagarh-Balangir, Angul-Talcher, Bhubaneswar) in the state of Odisha.

This policy document outlines the UHI mitigation and adaptation strategies based on the study conducted in this region.

Methodology

The following the key methodologies were adopted to establish the UHI phenomenon in Jharsughuda.

1. **Indirect Satellite based measurements:** Development of daily mean temperature contour map averaged over one month for the entire area using MODIS 7 Thermal Infrared (TIR) band data at 1 sq km resolution to identify thermal hotspots based on land surface temperature (Figure 1).

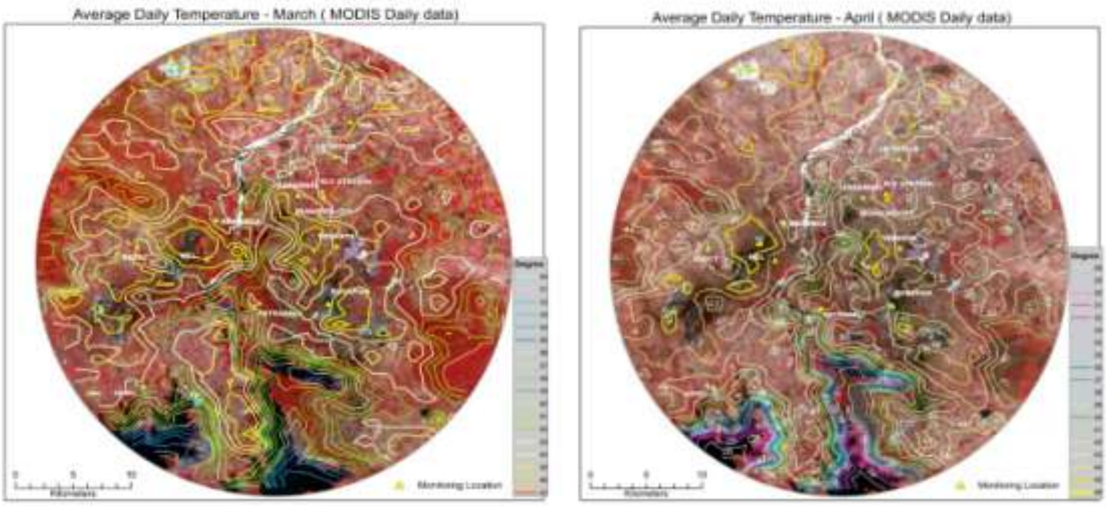

Figure 1: Daily average LST in March and April 2016 using MODIS daily data. Yellow contours indicate hotspot regions. Ambient temperature trend-lines were plotted for the years 2005 to 2010 using IMD data. It was found that T_{max} increased by 0.36 °C, T_{min} increased by 0.55 °C, and the diurnal temperature difference $T_{max} - T_{min}$ decreased by 0.15°C, implying that minimum temperature has increased more than the maximum temperature during this period, at a confidence interval of 99%. This establishes a steady build-up of heat in the study area over time.

2. **Direct monitoring at predetermined locations based on satellite data analysis:** Identification of the thermal hotspots in the area using thermal retentivity and heat index indicators – calculated based on the real-time data recorded in the temperature-humidity data loggers installed at eleven locations [A. Brijraj Nagar, B. Patrapali, C. Bhushan Power and Steel, D. Municipality Office, E. Market Road – Railway Station, F. Krosaki, G. Odisha Power Generation Corporation (OPGC), H. Airport/IMD Station, I. DM office, J. Sarasmal Village, K. Mahanadi Coalfields Ltd.].

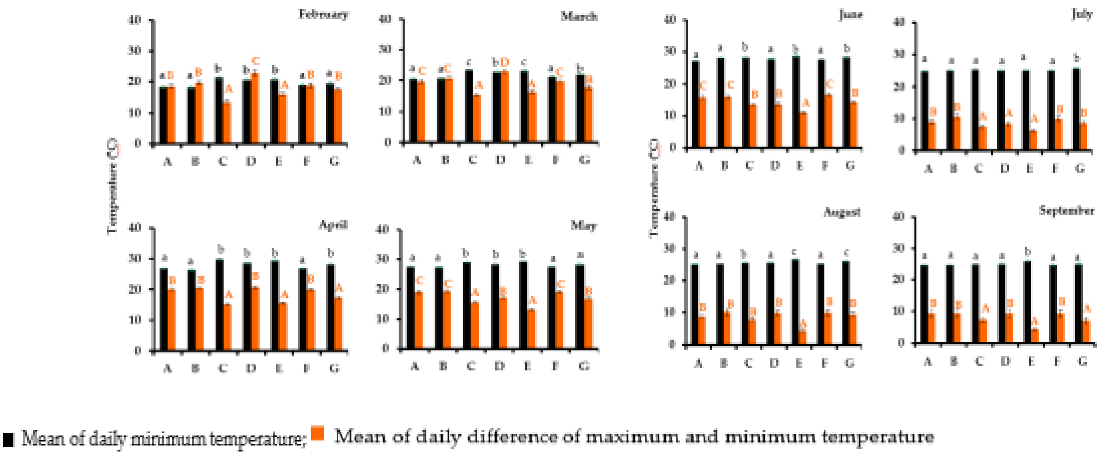

Figure 2 Monthly variation of T_{min} and ($T_{max} - T_{min}$) from February to September at different sampling locations. Higher the T_{min} and lower the T_{max}-T_{min}, higher is the thermal retentivity of the region. Monthly averages of these parameters have been computed for each location and categorized based on Tukey's Honest Significant Difference (HSD) test.

3. **Estimation of heat release from various anthropogenic activities**: Heat release from different industrial activities such as open-cast coal mining (OCP), storage of coal in industry stockyard, etc. based on the surface area under different land use types (quarry area, barren land, de-coaled area, reclaimed area, backfilled area, etc.) and surface temperature (obtained from IR camera readings) of each of the heat sources and sinks. The variation in instantaneous heat release for the five OCPs is given in the figure below.

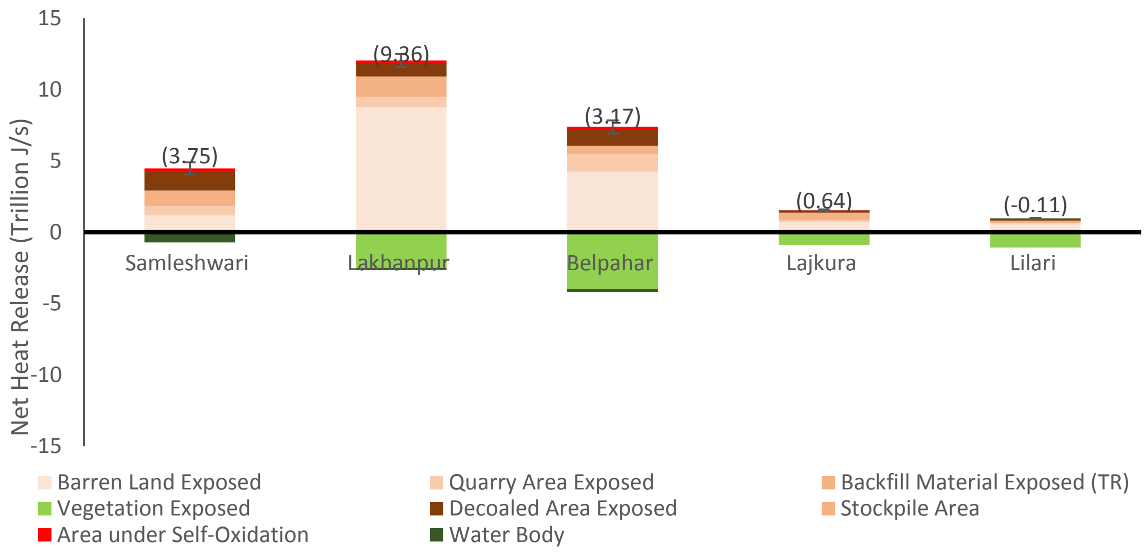

Figure 3: Heat release in 5 OCPs by land use type. Net Heat released is highest for Lakhanpur OCP followed by Belpahar OCP due to large quarry area (area under excavation), and least for Lilari OCP due to the relatively small area within mine boundary. Area under vegetation is largest in case of Belpahar OCP, followed by Lakhanpur OCP.

4. **Assessment of biophysical parameters of land uses to identify thermal sources and sinks:** In this model, the total geographical area is classified in terms of thermal zones (source and sinks)—high, moderate, neutral, and low based on land use practices and function. 40% area out of total geographical area is under thermal sources, 13% area is under neutral category (neither a source nor a sink), and rest 47% are thermal sinks.

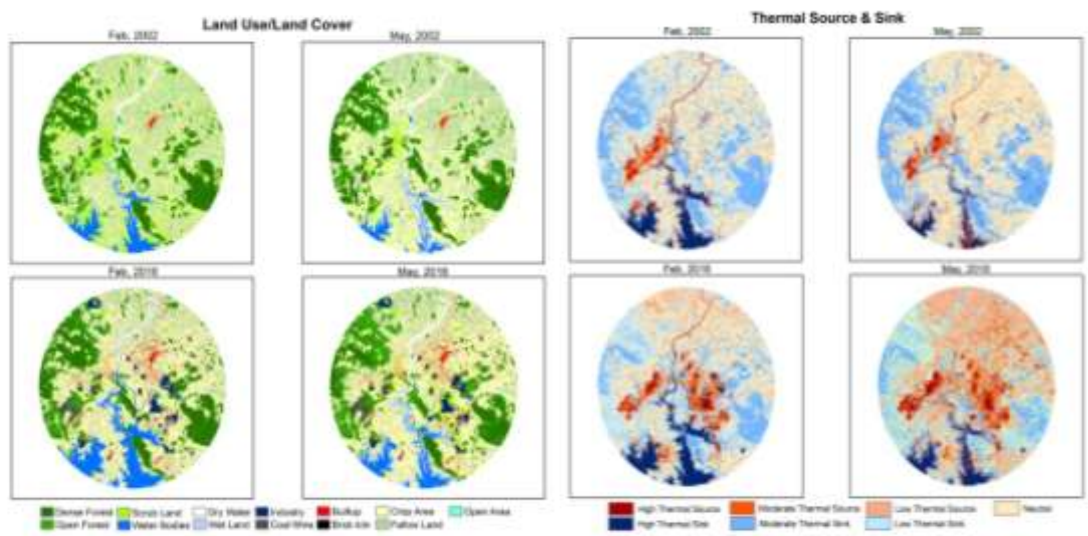

Figure 4 Temporal change in a) land use/land cover and b) thermal sources and sinks in Ib-valley from 2002-2016. Built-up area has increased from 0.30% to 4.14% of total geographical area, which is more than 12 times with respect to the baseline of 2002. Similarly, coal mine area has increased twice and industrial area has increased 10 times than the base

year. It has been observed that dense forest cover has decreased and open forest has increased during this period. Seasonal effects were observed on water bodies and fallow land, while agriculture land shows an increase of 14%.

Key Findings

The key findings are summarized in the table below

Table 1. Key findings of models used in the study.

Model	Key Findings
Remote Sensing – Land Surface Temperature Model	There has been a steady build-up of heat in the region over the years resulting in higher night time temperatures. Coal Mining, Industries, Urban settlements and open non-vegetated surface have come as thermal hotspots
Ambient Air Temperature – Thermal Retentivity Model	'Bhushan Steel' and 'Market Road' are hotspot locations in summer; 'Market Road' is hotspot location in monsoon as well as combined period. This is likely because of the high built-up are on market road
Ambient Air Temperature – Heat Index Model	'Bhushan Steel', 'Municipality', and 'Market Road' are hotspot locations in summer; 'OPGC', 'Market Road', 'Municipality' are hotspot locations in monsoon; 'Bhushan Steel', 'Market Road', 'OPGC' are hotspot locations in the combined period. Higher heat sources, combined with higher built-up as well as more rotating population contributes to the higher heat index
Remote Sensing – Biophysical Model	Coal Mining, Industries and Urban settlements are high thermal sources; forests, vegetation and water bodies are high thermal sinks.
Heat Release Model	For coal Mining areas only – Positive impact of bio-reclamation of de-coaled area (in terms of heat release per unit de-coaled area) highest for Lajkura and Lakhanpur, least for Lilari

Mitigation Measures

The most suitable set of heat mitigation measures have been recommended based on modelling and prioritized based on analysis of information collected from stakeholders' consultation using Multi-Criteria Decision Analysis (MCDA) through Analytic Hierarchy Process (AHP) approach. The sectors covered include coal mining, industries, cropland and urban planning. The recommended interventions along with their description, heat mitigation potential, priority ranking (based on impact to cost ratio), indicative costs and the responsible implementing agencies are provided in the table below.

Table 2. Sectoral Intervention Options for Heat Mitigation

Sector	Description of Intervention	Impact of Intervention
Coal Mining	Improved management of de-coaled areas through increased bio-reclamation as well as creation of water bodies in mine void spaces.	Reduction in net heat release Impact per unit de-coaled area highest in Lajkura, Lakhanpur.
	Introduction of 4 new coal washeries.	Reducing self-oxidation by reducing ash content of coal.
	Complete penetration of surface miner technology.	Reduction in the amount of loose coal susceptible to self-oxidation.
	Speedy and transparent afforestation.	Increase in heat sink potential.
Industry	Management of coal stockpile (reduce inventory in summer months keeping production schedule	Reduction in coal purchase cost as follows: Plant A: Rs. 60 to 190 lakh

Sector	Description of Intervention	Impact of Intervention
	constant).	(136878 MTPY sponge iron), Plant B: Rs. 36.7 crore (0.8 million MTPY pig iron), Plant C: Rs. 152 crore (0.5 million MTPY aluminium), Plant D: Rs. 95.5 crore (960 MW), Plant E: Rs. 55 crore (360 MW)
	Change of coal stockpile design	Heat released can be lowered by 11%.
Urban Planning	1) New flyover on the left flank of the existing flyover in the NH-49 after crossing the railway line. 2) Shifting of the entire bus stand from the southern part of the railway line to the northern part. 3) Develop two approach roads – a) From NH-49 and b) SH-10 to the proposed bus stand.	Reduced traffic flow can ease congestion and avoid fugitive and idling vehicular emissions which increase the ambient temperature of the region.
	Plantation of short height trees and trees with higher LAI bordering the pavements of NH, SH and newly proposed roads. **Highway & Road Dividers**: *Capparis grandis, Carissa congesta, carvia callosa, cassia auriculata, woodfordia fructicosa, Bougainvillea, Cascabela thevetia* **Highway sides:** *Ficus religiosa, Ficus recemosa, Syzygium cumini, Ficus benghalensis, Alstonia scholaris, Azadirachta indica, Tamarindus indica* **Municipal Roads:** *Capparis grandis, Carissa congesta, carvia callosa, cassia auriculata, woodfordia fructicosa, Alstonia scholaris, bouganvillea, cascabela sp, oleander plants, etc.*	Reduction of influx of solar radiation and amount of heat absorbed by the asphalt material.
Agriculture	Increased adoption of conservation tillage in the agricultural areas.	Increase in surface albedo by 0.2 over that of the normal tilled crop land, decreasing temperature by 2^0C.

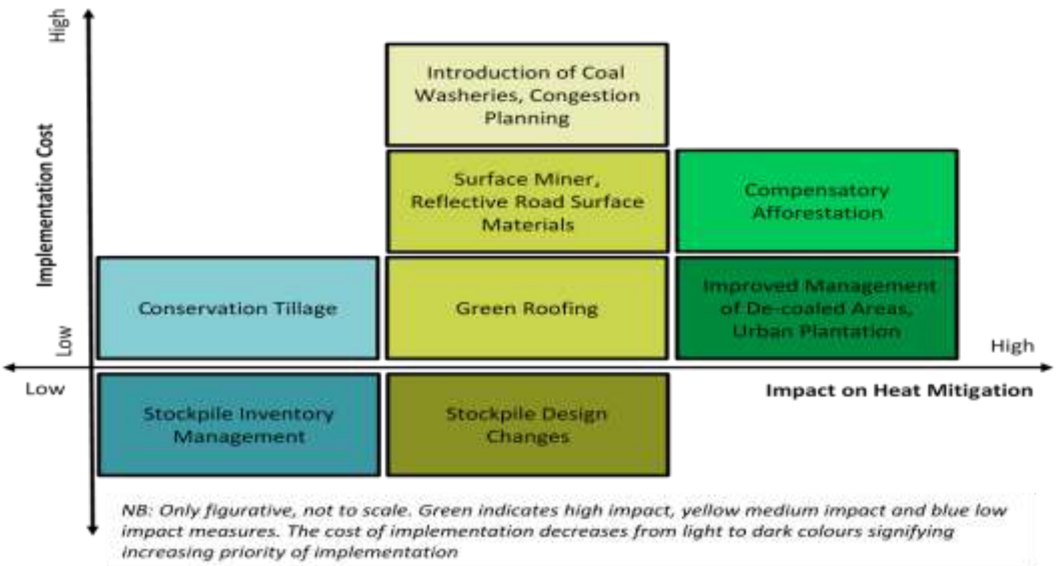

Figure 2. Cost vs. Impact plot of heat mitigation measures

Adaptation Measures

Odisha has been one of the leading states to address the problem of heat wave through a systematic heat wave action plan involving all stakeholders. The state's action plan outlines the responsibilities of the different wings of the state government. Additional roles have been proposed for these agencies over and above their current roles in the heat wave action plan as elaborated in Table 3.

An institutional information flow has also been designed to coordinate the different adaptation response strategies as shown in Figure 3.

Table 3. Proposed roles for heat island adaptation for different govt. agencies.

Level	Name of Dept./Agency	Relevant Role
Central	Indian Meteorological Dept.	• Installation of more Automatic Weather Stations (AWS) in heat-wave prone districts • Analyse data from the different AWS to obtain real-time spatial distribution of temperature and heat index in each of the heat-wave prone districts • Provide zone-wise or block-wise early warning forecasts for each of the heat-wave prone districts.
State	Special Relief Commissioner (SRC)	• In addition to disseminating warnings through AIR (All India radio), Doordarshan and other private TV channels, SRC could help create local radio networks in Sambalpuri and organize discussions and other programs for creating public awareness on specific regions in the district which are more vulnerable to heat stress. Information on 'do's and 'do not's during heat stress should be highlighted in several strategic and heat stressed locations as posters, billboards and hoardings in the local language ensuring information is widely accessible amongst different groups of people. • To deploy adequate number of water tankers in water-scarce areas based on a careful analysis of the heat-stress prone regions and the population density of these regions within the district. The Department of Water Resources to be mobilized for release of water in the canals.
	OSDMA	• To arrange for drinking water supply arrangements and access to medical facilities that are equipped to cater to both genders. • To reschedule working hours in educational institutions, for those doing physical labour, veterinary measures, etc. • Distribute leaflets among school children to educate them on heat stress and its prevention • To reschedule timings of public transport, etc. in accordance with early warning forecasts. This should be done only if timings for works, schools and different government and non-government offices are also rescheduled simultaneously in the summer months.
	Dept. of Housing & Urban Development	• Give directives to urban local bodies (ULBs)/Development Authorities to create more public parks and water bodies in hotspot areas for the general public. • Give directives to ULBs to identify temperature hotspots in the built-up areas and incentivize white painted roofs (albedo paint) in these regions.

Level	Name of Dept./Agency	Relevant Role
		• Give directives to ULB/Development Authorities for the use of K-glass, doubly glazed glass in buildings and vehicles which prevent extra entry of heat inside, especially in the built-up areas which are located in hotspot regions.
	Dept. of Labour and Employee Welfare	• Increase awareness among construction workers and factory labourers working in temperature hotspots through lunchtime meetings and labour union meetings.
	Dept. of Woman and Child Development	• Sensitize female agriculture and brick labourers about the health effects of walking long distances to fetch water in the summer months. • Understand the concerns of the women labourers better with regard to working long periods in the heat and design guidelines to optimize such prolonged exposure. • Create awareness among female labourers on the locations of water kiosks in the district
	Dept. of Health	• Setting up of additional health dispensaries in heat stress zones in the district as well as equipping existing dispensaries with additional facilities such as life saver ambulances, available mobile personnel, 24 hour back-up power supplies, air conditioned rooms, availability of cold drinking water, appropriate housing design, etc. • Ensure adequate training and supply of health professionals (doctors, nurses, etc.) to meet the demand of heat stress induced morbidity cases, due to long hours of exposure in heat stress prone areas. • Capacity building of District Medical Officers (DMOs) on their roles and responsibilities towards heat stress and heat islands.
Local Govt.	Urban Local Bodies (Municipalities)	• Conduct Focussed Group Discussions (FGDs) at a block-level to identify vulnerable regions in the municipality to implement immediate coping measures. The FGDs should have representation from all strata of the society and specific representation from women, women with children, aged and daily wage labourers. • Providing public shelter structures in highways and crowded areas such as open markets. • Providing drinking water through jal chhatras (water kiosk) at strategic points. It is to be ensured that more number of kiosks is located at hotspot regions and their maintenance takes place at a healthy frequency. • Alert public transport systems on the heat-stress prone regions, especially in the summer months, to enable them plan alternate routes, if feasible. • Exploring light coloured concrete roads as an option to replace asphalt roads near hotspot regions.
	Panchayats	• Conduct Focussed Group Discussion (FGDs) at village level to identify the heat-stress vulnerable regions to implement immediate coping measures. Similar to the ULBs above, FGDs should have representation from all strata of the society and specific representation from women, women with children, aged and daily wage labourers. • Provision of water kiosks at strategic as well as heat-stress vulnerable points based on the FGDs.

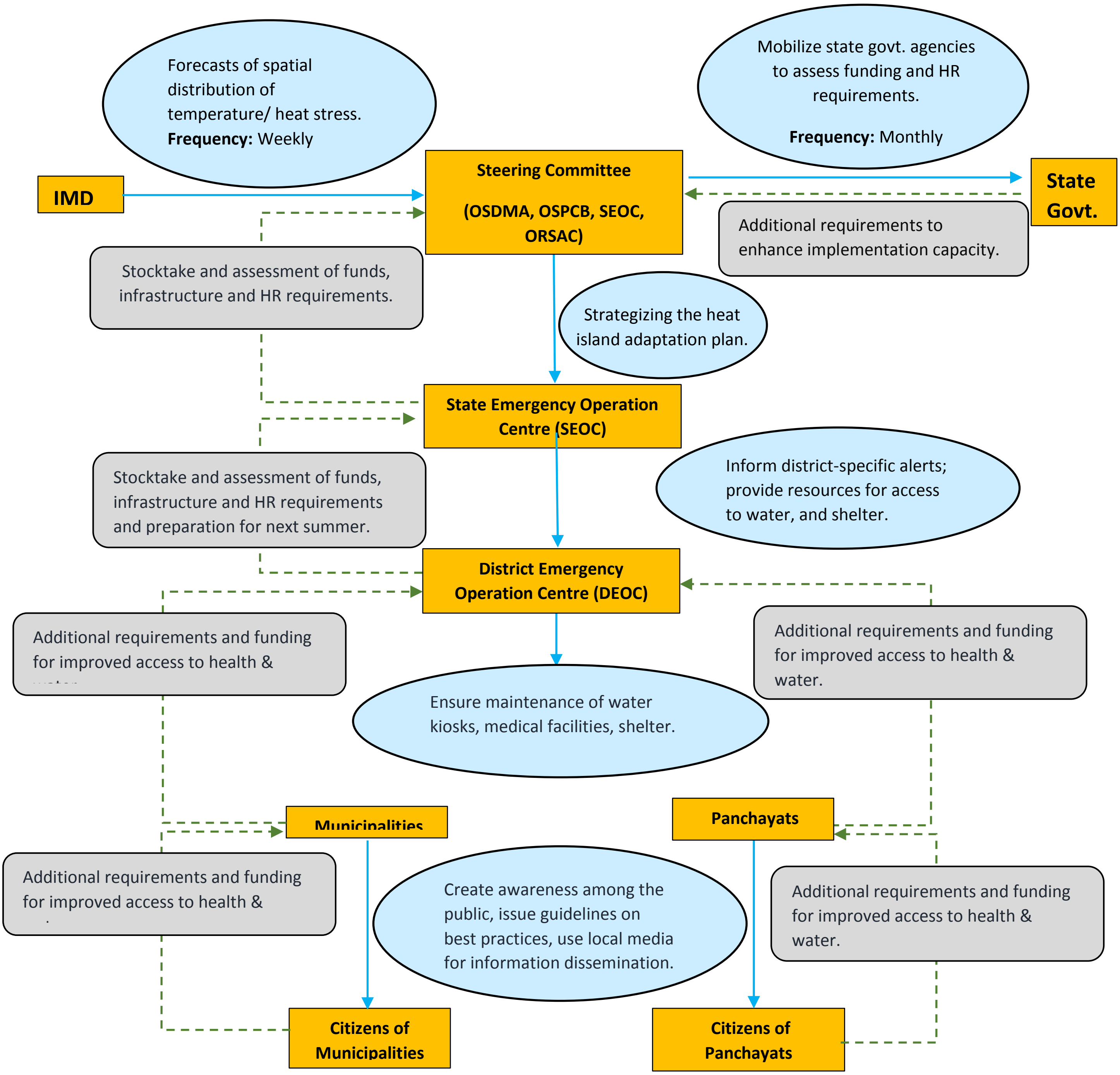

Figure 3. Institutional information flow for coordinated adaptation response