



SAHF IBF WG IMPLEMENTATION PLAN PROJECT

REGIONAL WORKSHOP ON IMPACT-BASED FORECASTING (IBF)

Heat Season Review & Cold Season Planning

29 September - 01 October 2026 | Bangkok, Thailand



FORECAST GENERATION FOR COLD HAZARDS

Potential impacts and early warning considerations

SHIROMANI JAYAWARDENA

Advisor, Climate and Weather Service
SAHF / RIMES

Cold hazards quietly harm people, crops and livestock

Cold waves in Terai region of Nepal and farmer's perception of the effect of fog events and cold waves on agriculture

Shreemat Shrestha¹ · Murray C. Peel¹ · Graham A. Moore¹

Cold stress during winter over North India: Patterns, trends, and mortality risks

K. S. Athira · Raju Attada^{*}, Sulekha Komeravelli

797

people died in cold waves in Nepal, 2000–2013

4,449

cold-wave deaths in Uttar Pradesh, 2000–2020

22,000 ha

of crops damaged by cold waves in Nepal

732

cattle deaths from cold waves in Nepal

~1,800

cattle and goats lost to cold shock, Sri Lanka, Dec 2022 (Cyclone Mandous)

In this session

- 1 Meteorological drivers and why fog matters
- 2 Parameters and thresholds
- 3 Wind chill and UTCI: human thermal stress
- 4 Vulnerability: who is most at risk
- 5 NWP-based forecasting
- 6 Impacts across three sectors
- 7 A plan for cold-season IBF

Sources: Shrestha et al. 2023 (Theor. Appl. Climatol. 151:29–45); DG Dept. of Animal Production & Health, Sri Lanka, as quoted in national media (Dec 2022); Athira, Attada & Komeravelli (2026), PLoS One 21(6): e0351740.

Meteorological Mechanisms & Drivers of Cold Hazards

Western Disturbances

Trailing northwesterly winds after a WD draw dry polar air across the plains, elevating wind-chill stress. WDs also drive cold waves through rear-sector cold-air advection, reduced insolation under cloud cover, and radiative conditions that favour surface frost (Mooley, 1957); composites show a 2–3 K lower-tropospheric cold anomaly.

Persistent fog blanket

WD moisture feeds low-level fog, blocking solar radiation and suppressing daytime warming. Advection fog forms ahead of the WD (moist southwesterly flow over cool ground) and is thicker; radiation fog forms in its rear sector (calm, subsiding air) and is more common overall (Hunt et al., 2025).

Katabatic & valley funneling

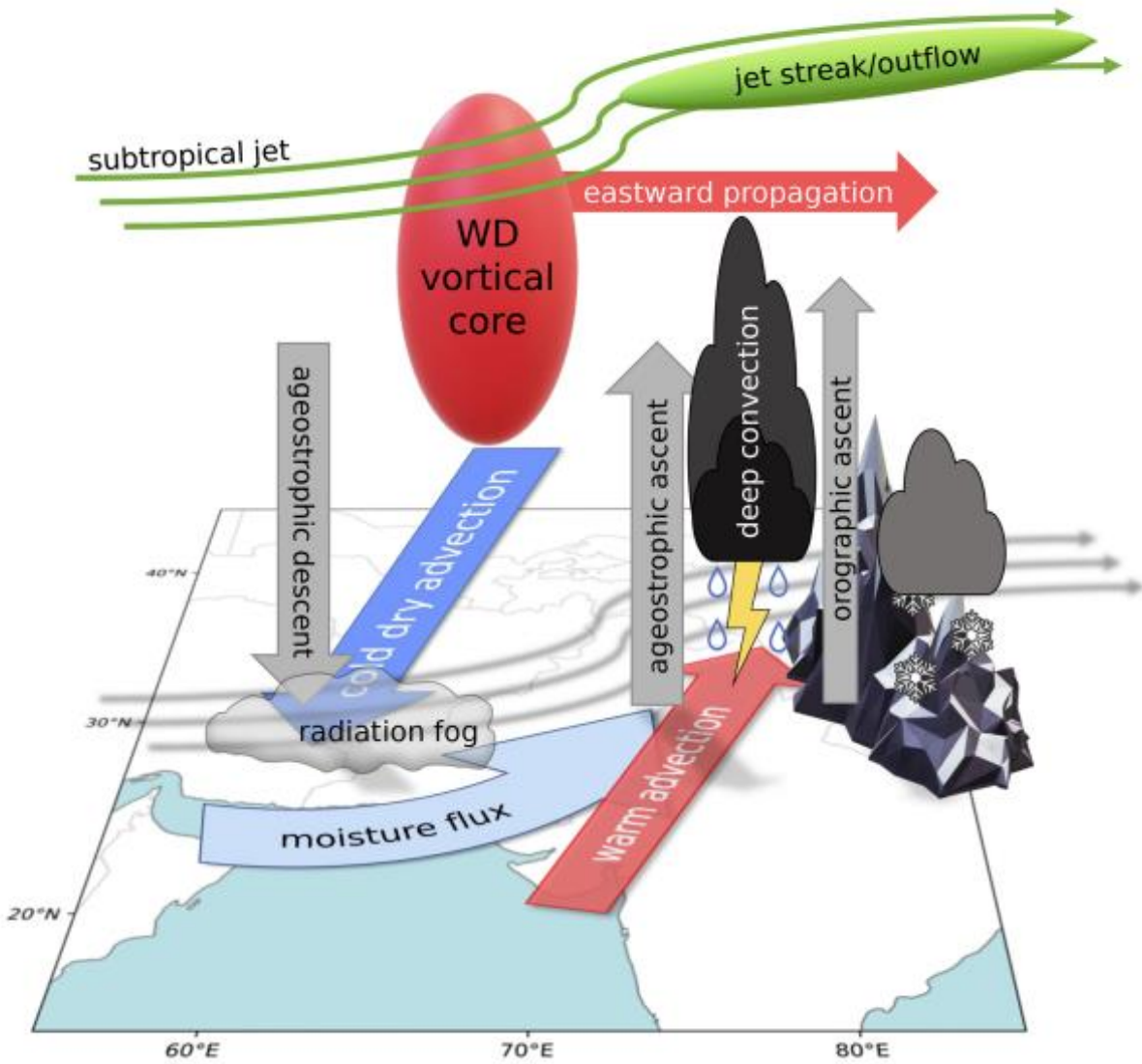
Mountain drainage winds in high-altitude valleys accelerate convective heat loss, compounding frostbite and cold stress risks.

Multi-day cumulative impact

The combination of sustained wind chill and fog persistence generates acute agricultural and livestock shock across subtropical Asia.

Avalanche

Heavy WD snowfall (rule of thumb ≥ 30 cm in 24–48 h) rapidly loads 30–45° slopes; wind-drifted snow, buried weak layers, and post-WD warming or rain-on-snow trigger release. WD-driven avalanches, landslides and floods (Dimri et al., 2015)

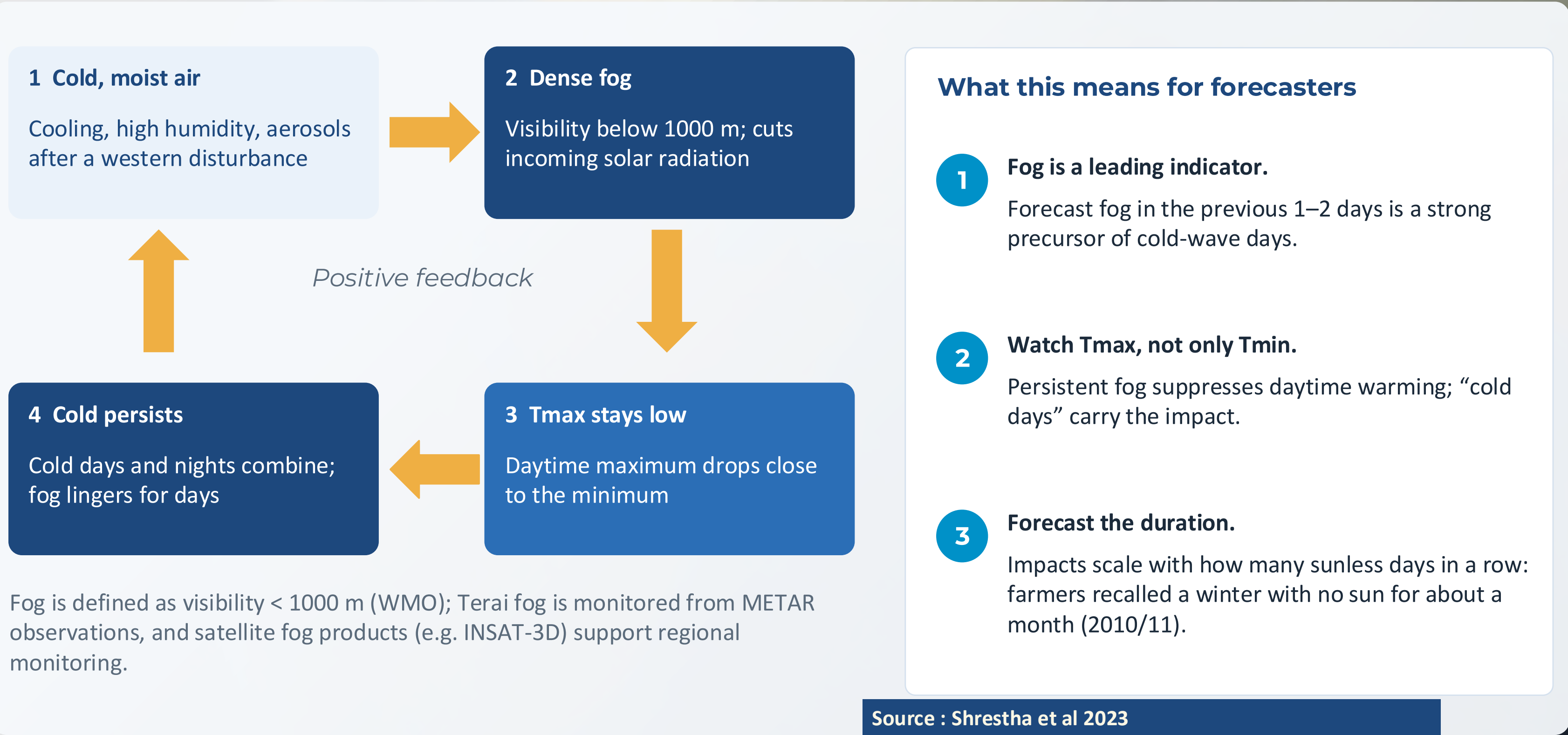


Schematic outlining some of the key meteorological features of western disturbances as they approach the western Himalaya (Source: Hunt et al., 2025).

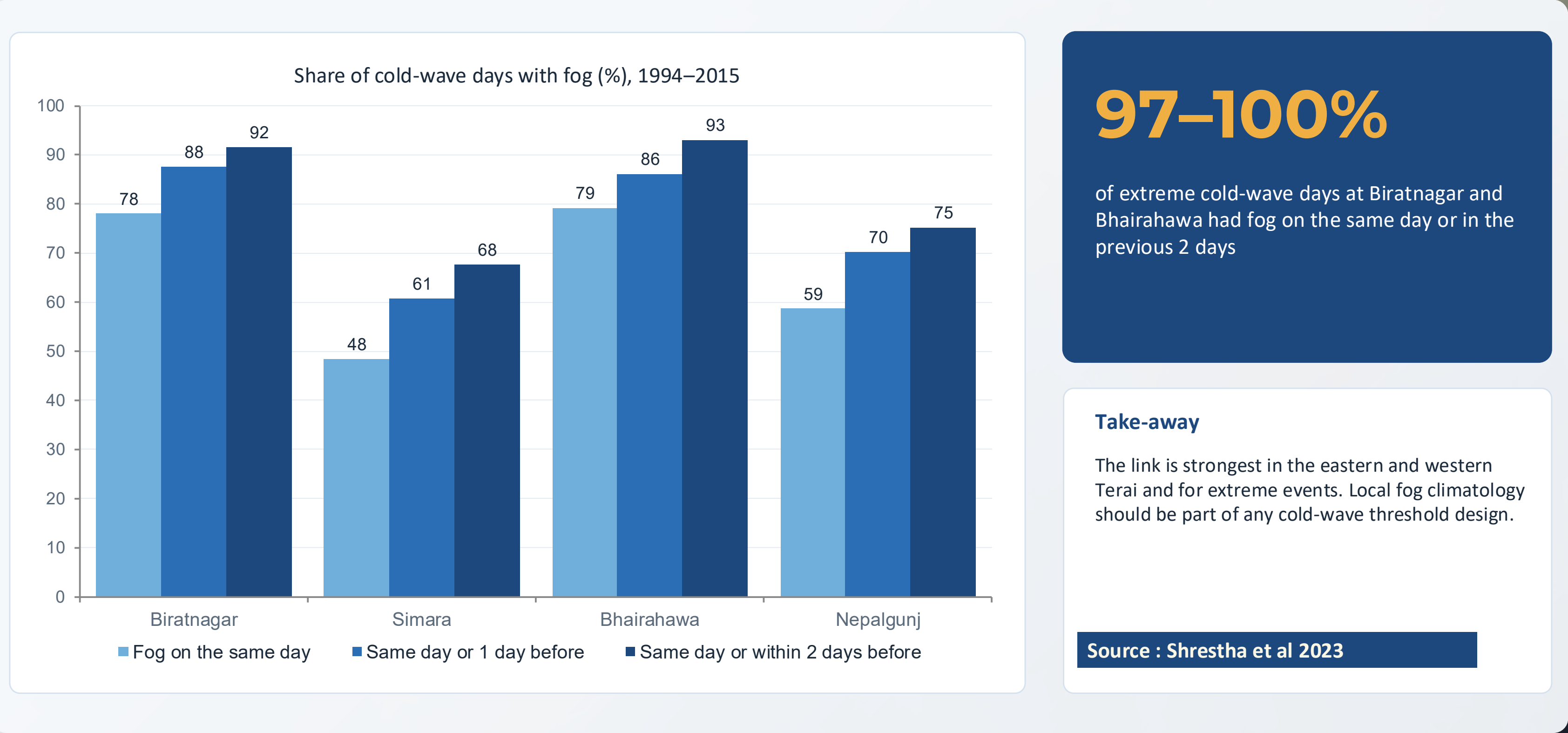
Fog and persistence: a self-reinforcing cold spell

Cold waves in Terai region of Nepal and farmer's perception of the effect of fog events and cold waves on agriculture

Shreemat Shrestha¹ · Murray C. Peel¹ · Graham A. Moore¹



Most cold-wave days are foggy days: evidence from four Terai airports



Parameters and thresholds: cold days matter as much as cold nights

Parameter	Role in the cold-hazard forecast
Minimum temperature (Tmin)	Cold nights; nocturnal cooling, radiative frost, hypothermia risk
Maximum temperature (Tmax)	Cold days; suppressed daytime heating under fog and cloud
Duration (consecutive days)	Separates a cold night from a cold wave; drives cumulative stress
10 m wind speed	Wind chill and UTCI; livestock and outdoor exposure
2 m relative humidity	Fog formation; UTCI input; fungal disease pressure on crops
Visibility / cloud cover	Fog (visibility < 1000 m); reduced insolation; mean radiant temperature
Rainfall	Wet-and-windy cold (e.g. Cyclone Mandous): rapid heat loss

Percentile-based definitions

Cold day / night

Tmax / Tmin ≤ 5th percentile

Extreme cold day / night

Tmax / Tmin ≤ 1st percentile

Cold wave

Tmax and Tmin < 10th percentile for ≥ 2 consecutive days

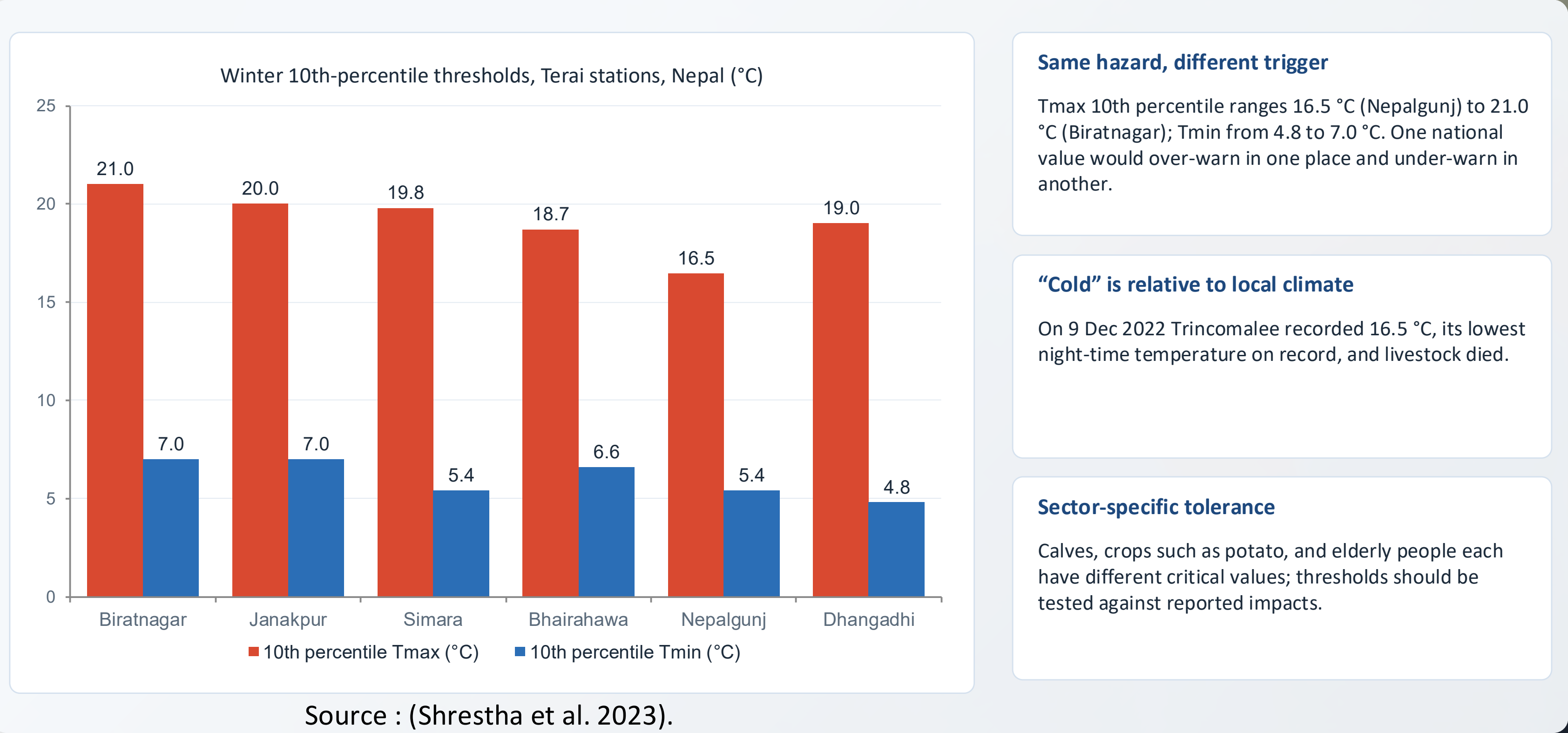
Extreme cold wave

Tmax and Tmin < 5th percentile for ≥ 2 consecutive days

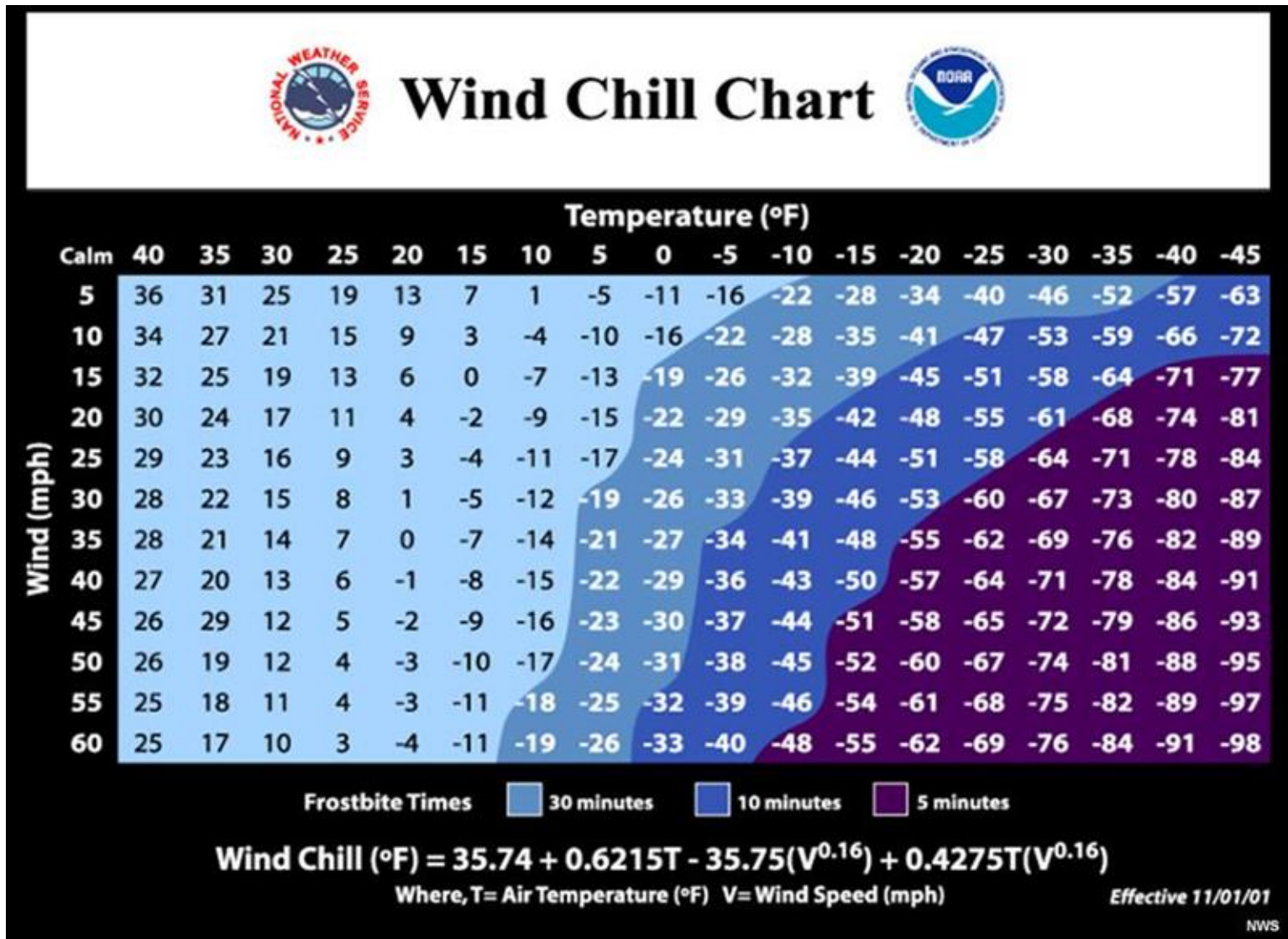
Applied to Terai stations, Nepal, following ETCCDI practice (Shrestha et al. 2023).

Definitions based on Tmin alone can miss cold days when fog or cloud holds Tmax down.

Thresholds must be local: the 10th percentile varies by station



Wind chill: how cold the air feels on exposed skin



NWS wind chill chart (°F, mph), with frostbite-time bands of 30, 10 and 5 minutes.

Thresholds from temperate services must be recalibrated for South Asian climatology.

Wind chill index

$$WC(^{\circ}F) = 35.74 + 0.6215T - 35.75V^{0.16} + 0.4275T \cdot V^{0.16}$$

T = air temperature (°F), V = wind speed (mph).

SI form: $WC = 13.12 + 0.6215T - 11.37V^{0.16} + 0.3965T \cdot V^{0.16}$ (T in °C, V in km/h).

- 1 Inputs are only temperature and wind.**
Humidity and radiation are ignored; the index is valid for cold, windy conditions (US definition: $T \leq 50^{\circ}F$, $V > 3$ mph).
- 2 Frostbite time makes it actionable.**
Warnings should state wind-chill values and frostbite times so the danger is clear.
- 3 Forecasters use judgement.**
Consider consistency with neighbouring offices, time of year, longevity and areal coverage before issuing a warning.

HUMAN THERMAL STRESS

UTCI: a fuller measure of physiological cold stress

What it is

The air temperature of a reference outdoor environment that would produce the same physiological response as the actual environment, using a physiological model with temperature-adaptive clothing insulation.

Model inputs

- 2 m air temperature
- 2 m relative humidity
- 10 m wind speed
- Mean radiant temperature

UTCI (°C)	Stress category	Typical physiological impact
$0 < UTCI \leq 9$	Slight cold stress	Mild cool sensation and vasoconstriction; comfort kept with warm clothing
$-13 < UTCI \leq 0$	Moderate cold stress	Shivering begins; hands and feet cool; unprotected skin cools significantly
$-27 < UTCI \leq -13$	Strong cold stress	Severe shivering, loss of dexterity; hypothermia risk with prolonged exposure
$-40 < UTCI \leq -27$	Very strong cold stress	Frostbite on exposed skin within 30 minutes; strict protective wear
$UTCI < -40$	Extreme cold stress	Frostbite in under 10 minutes; severe hypothermia danger

Wind chill = temperature + wind. UTCI adds humidity, radiation and clothing. Where events sit in the “slight” to “moderate” bands, local and sector-specific tuning matters most.

Beyond percentiles: impact thresholds from wind chill and UTCI

Class	Description	K (W/m²)
0	Endothermal: very hot discomfort	$K \leq 200$
1	Atonic: hot discomfort	$200 < K \leq 400$
2	Hypotonic: hot sub-comfort	$400 < K \leq 600$
3	Cold: cold comfort	$600 < K \leq 800$
4	Tonic: very cold sub-comfort	$800 < K \leq 1000$
5	Very cold discomfort	$K > 1000$

Siple–Passel index: $K = 1.16 \times [(10.45 + 10vU - U)(33 - Ta)]$; K in W/m², U in m/s, Ta in °C.

This index (W/m²) differs from the NWS wind chill shown later. It is an index, not a temperature, and applies only when air temperature is below 33 °C and wind exceeds 1.34 m/s (Chowdhury & Gore 1988).

Where north India events sit

UTCI, Indo-Gangetic Plain

Slight cold stress (9 to 0 °C); moderate (0 to −13 °C) in parts of Rajasthan in the early morning of cold waves

UTCI, J&K and Ladakh

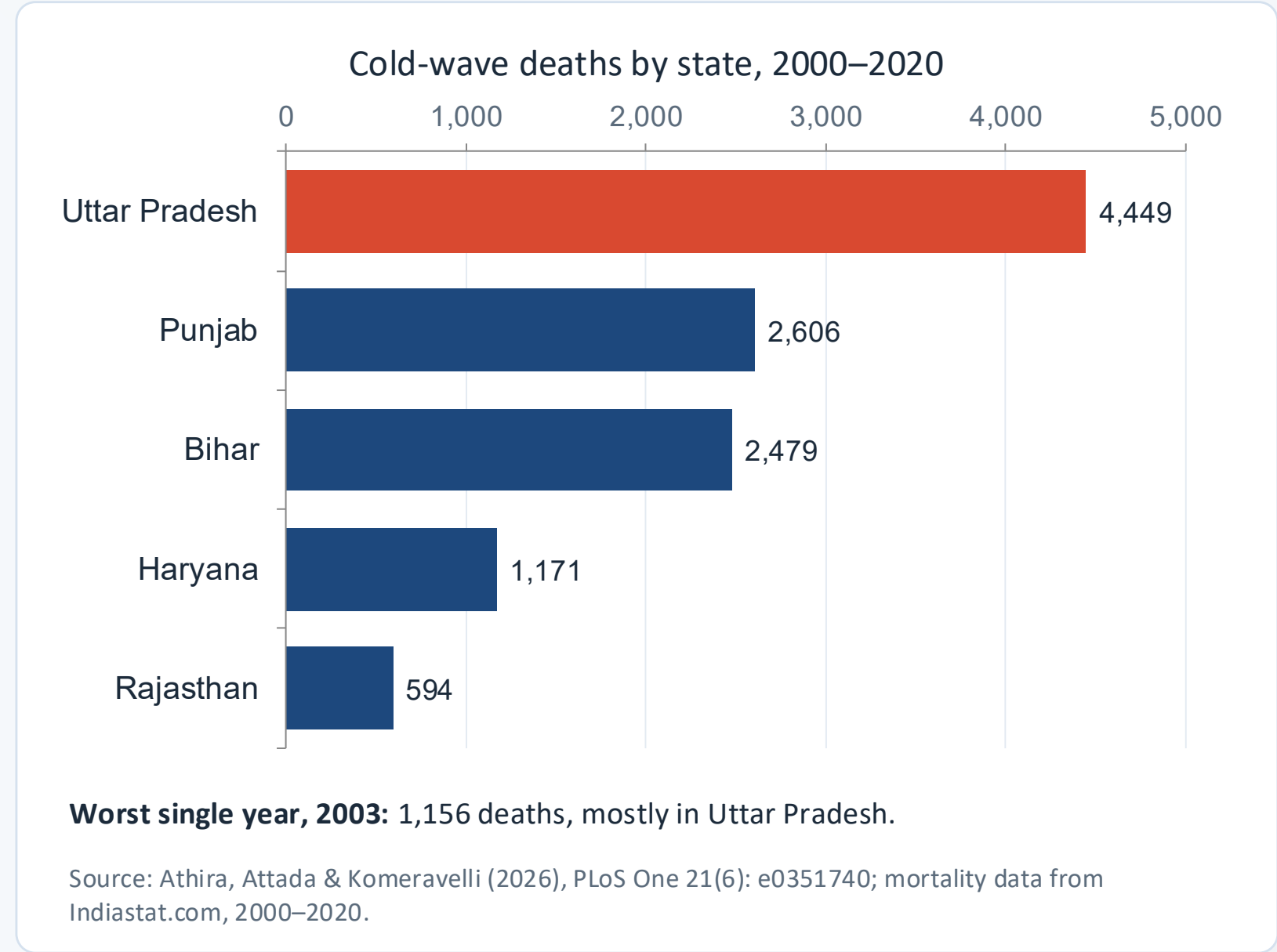
Strong to extreme (below −13 °C) from 18 to 08 IST during cold waves

Wind chill, plains

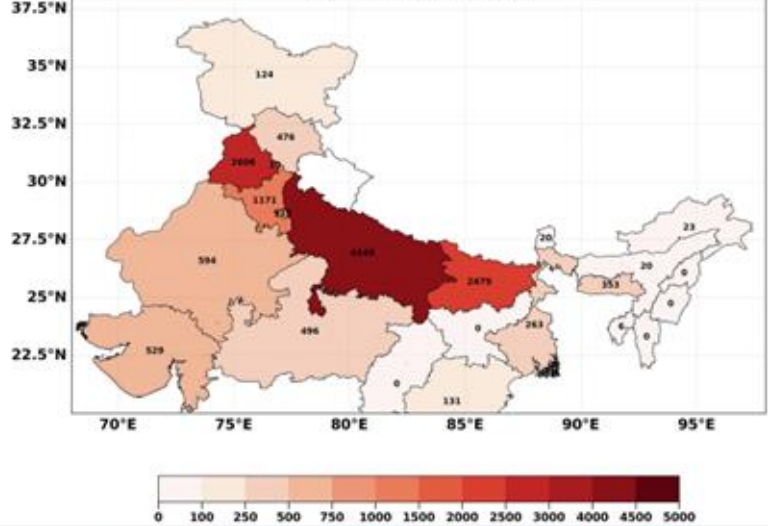
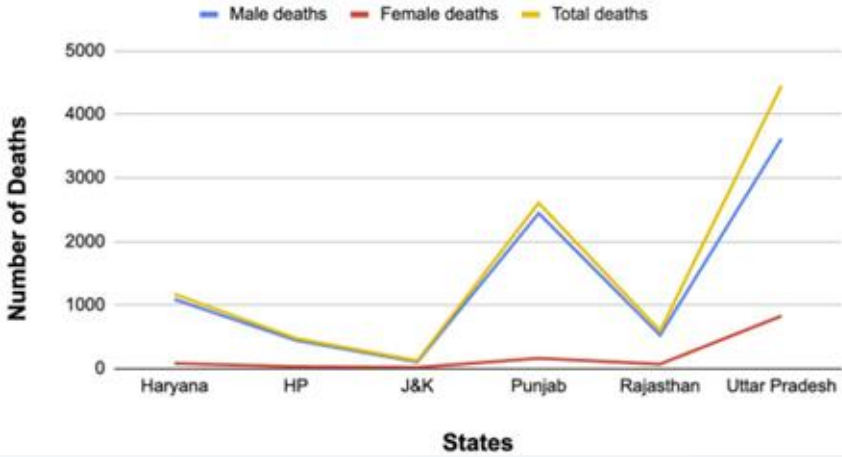
600–800 W/m² from 19 IST, rising to 800–1000 W/m² from 03 to 07 IST, with north-westerlies of 3–5 m/s

POTENTIAL IMPACTS

Even “slight” cold stress kills, and men bear the higher risk



NORTH INDIAN REGION



Cold wave mortality in north India from 2000 to 2020

higher cold-related mortality in men than in women, from an Indian study cited by Athira et al.; deaths are most common at ages 45 to 60

Why the Indo-Gangetic Plain is so exposed

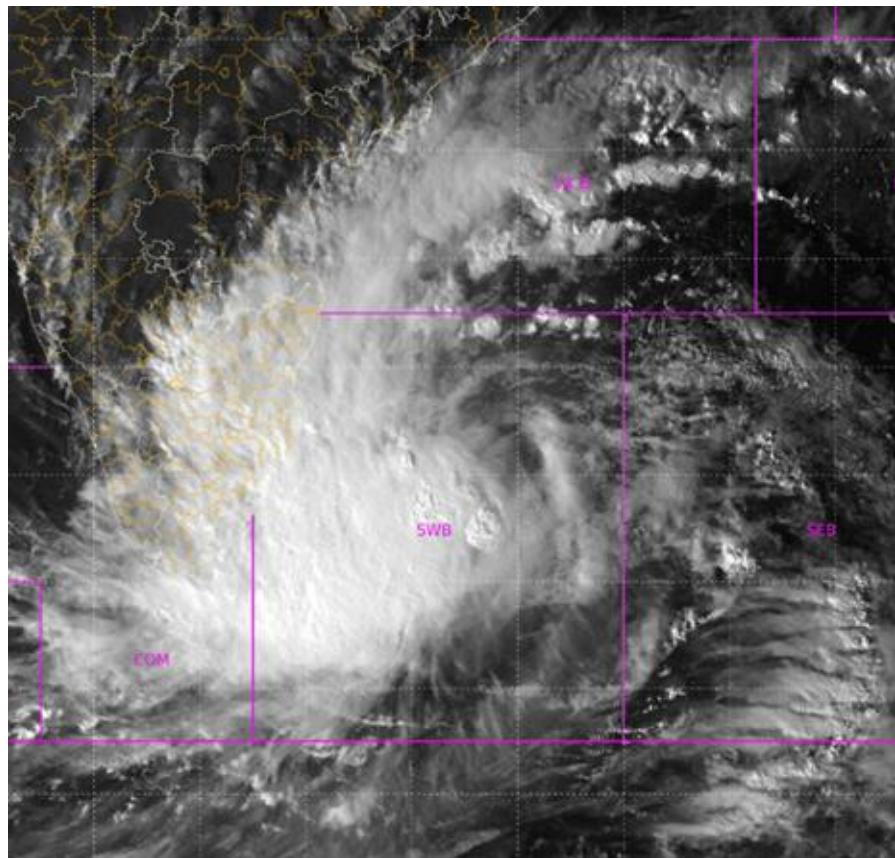
- 1 Men carry most of the risk.**
Male deaths far exceed female deaths in Uttar Pradesh, Punjab and Haryana, likely because more men work outdoors as daily-wage labourers. The gap is much smaller (under 500 deaths) in J&K, Himachal and Rajasthan.
- 2 Wind chill amplifies slight stress.**
Cold, dry north-westerlies (3–5 m/s) lift wind chill to 600–800 W/m² from 19 IST and 800–1000 W/m² from 03 to 07 IST.
- 3 Housing and heating are weak.**
Few homes have central heating; biomass, kerosene or open fires add indoor air pollution and respiratory stress.

For warnings: on the plains UTCI shows only slight cold stress, yet mortality is high. Add wind chill and event duration to the triggers, and target outdoor workers (mostly men in daily-wage jobs), the homeless and the elderly.

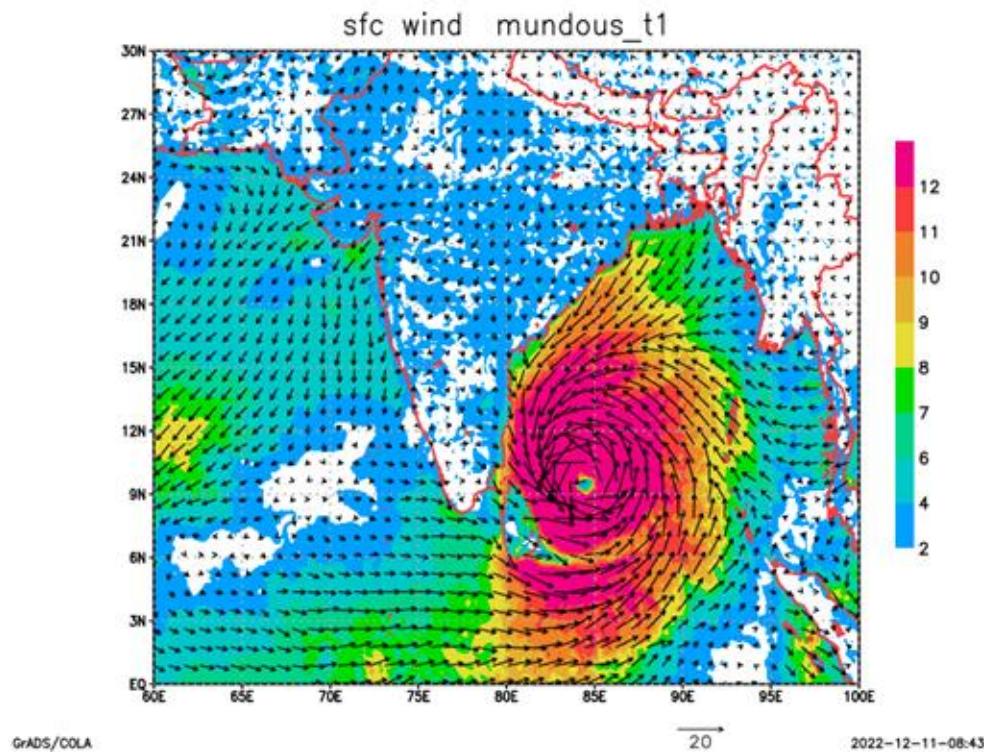
Athira KS, Attada R, Komeravelli S (2026),

CASE STUDY

Case study: Cyclone Mandous and wind chill over northeast Sri Lanka



Cyclone Mandous, satellite view



Surface wind analysis

7–8 °C

negative temperature anomaly

16.5 °C

Trincomalee, lowest night-time temperature on record (9 Dec 2022)

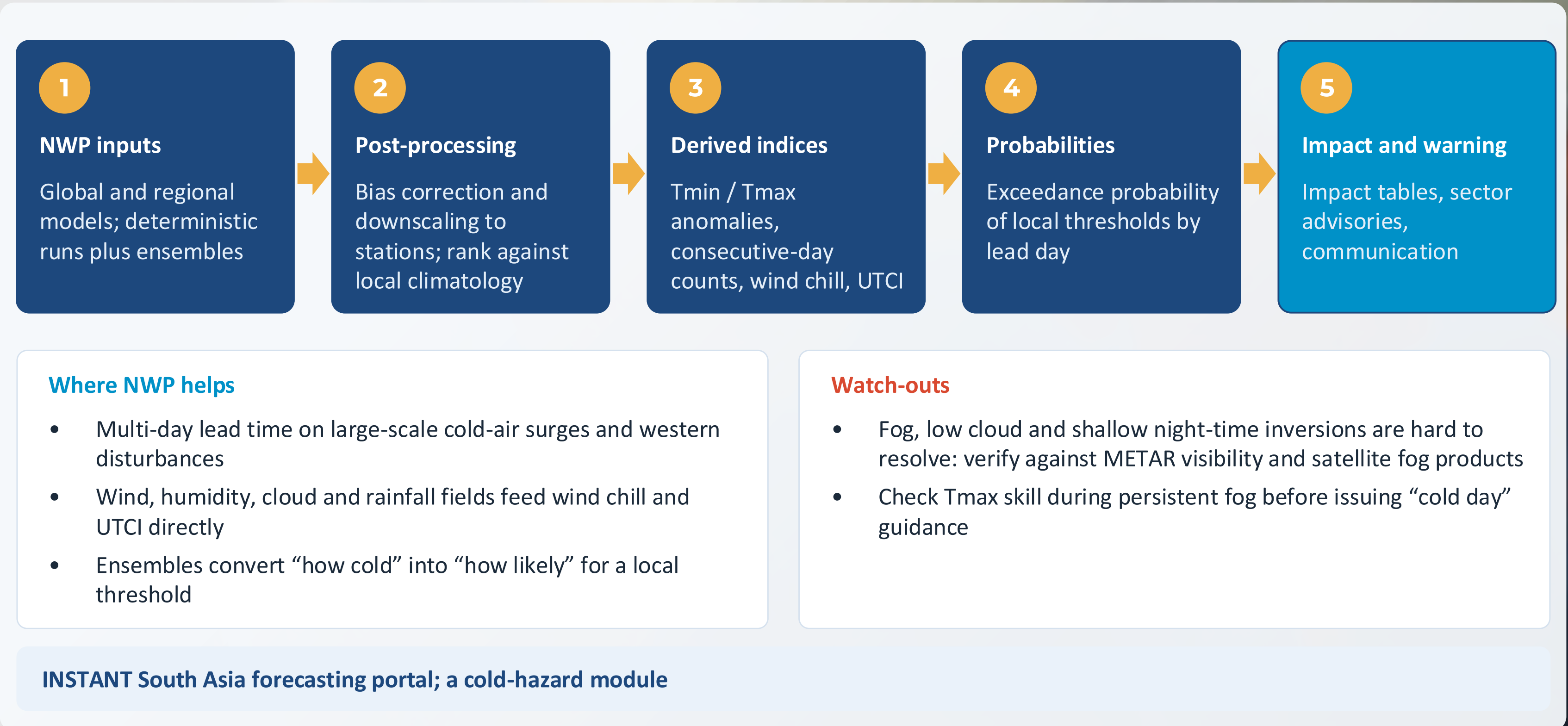
~1,800

cattle and goats died of cold shock

What the event shows

- A thick sheared cloud mass blocked sunlight for three days (7–9 Dec 2022), cutting daytime heating; strong wind, cloud, cool air and continuous rain combined into a rare wind-chill effect.
- Cold hazards are not limited to winter cold waves: threshold design must be location- and sector-specific (livestock here).

NWP-based forecasting: from model grid to hazard-relevant guidance



Potential impacts: one cold spell, three very different sectors

Human health

- Frostbite (nose, cheeks, ears, fingers, toes) and hypothermia
- Most at risk: elderly, infants, children unattended, homeless, outdoor workers
- Schools closed and road accidents in dense fog
- Cardiovascular and respiratory deaths rise, lingering for days to weeks after a cold wave (Athira et al.)
- In India men are at higher risk: outdoor daily-wage work; deaths peak at ages 45 to 60

Agriculture

- Potato, then vegetables, are the crops most affected by fog and cold in the Terai
- Humid fog raises late blight and fungal disease; potato spraying adds about 18% to production cost
- Farm labour productivity fell by more than 50% in the foggy season, per farmer groups

Livestock

- Cattle, goats and buffalo affected; calves most susceptible
- Milk yield down by about 25–33% during fog-induced cold waves (farmer estimates)
- Mass mortality possible: about 1,800 cattle and goats in Sri Lanka, Dec 2022 (a rare single event)

Key messages for cold-season planning

1

Forecast Tmax and Tmin together, with duration: cold days matter as much as cold nights.

2

Thresholds must be local and sector-specific; validate them against reported impacts.

3

Fog drives persistence: monitor visibility and satellite fog products alongside NWP.

4

Use NWP with post-processing and ensembles, and verify against observations.

5

Report wind chill and UTCI with actions, not just numbers.

For discussion

- Which cold hazards matter in your country: cold wave, fog,?
- Which sectors will test thresholds this season?
- What impact data do you have to validate them?
- What do you need from the INSTANT cold-hazard module?

Cold season: broadly November 2026 – February 2027

References

- Athira KS, Attada R, Komeravelli S (2026) Cold stress during winter over North India: Patterns, trends, and mortality risks. PLoS One 21(6): e0351740. <https://doi.org/10.1371/journal.pone.0351740>
- Bhatla, R., Gupta, P., Tripathi, A., & Mall, R. K. (2016). Cold wave/severe cold wave events during post-monsoon and winter season over some stations of Eastern Uttar Pradesh, India. *Journal of Climate Change*, 2(1), 27-34.
- Bhatla, R., Patel, H. S., Singh, R., Sharma, R., & Mandal, B. (2026). Climatological understanding of heat and cold wave variability in Eastern Uttar Pradesh. *Journal of Agrometeorology*, 28(1), 59-64.
- Dimri, A. P., Mohanty, and Mandal. "Simulation of heavy precipitation associated with an intense western disturbance over Western Himalayas." *Natural Hazards* 31.2 (2004): 499-519.
- Dimri, A. P., Niyogi, D., Barros, A. P., Ridley, J., Mohanty, U. C., Yasunari, T., & Sikka, D. R. (2015). Western disturbances: a review. *Reviews of Geophysics*, 53(2), 225-246.
- Hunt, K. M., Baudouin, J. P., Turner, A. G., Dimri, A. P., Jeelani, G., Pooja, ... & Palazzi, E. (2025). Western disturbances and climate variability: a review of recent developments. *Weather and Climate Dynamics*, 6(1), 43-112.
- Mooley, D. A. (1957). The role of western disturbances in the production of weather over India during different seasons. *Indian Journal of Meteorology and Geophysics*, 8, 253–260.
- Rajeevan, M., Rohini. P, Smitha Anil Nair, Snehalata Tirkey, Tanmoy Goswami, Naresh Kumar (2023). Heat and Cold Waves in India- Processes and Predictability. Meteorological Monograph, MoES/IMD/Synoptic Met/01(2023)/28.
- Shrestha, S., Peel, M. C., & Moore, G. A. (2023). Cold waves in Terai region of Nepal and farmer's perception of the effect of fog events and cold waves on agriculture. *Theoretical and Applied Climatology*, 151(1), 29-45.



Heat Season Review & Cold Season Planning

Regional Workshop
29 September - 01 October 2026



THANK YOU

FOR YOUR ATTENTION

Table 2: IMD standards for heat/cold wave for operational purposes (Rajeevan et al., 2023)

S. No.	Heat Wave Conditions	Cold Wave Conditions
1.		
2.		
3.		
4.		



**Heat Season Review &
Cold Season Planning
Regional Workshop**
29 September - 01 October 2026