METEOROLOGICAL SERVICE SINGAPORE
Centre for Climate Research Singapore

Strengthening Singapore's Resilience to Weather and Climate Change: The Climate Science Research Master Plan (CSRMP)

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Impacts of Weather And Climate Change in Singapore

Atmospheric Turbulence

Icing

Heavy Rainfall

Urban Heat

Thunderstorms

Wind Gusts

Waterspout

Environmental Impacts

Examples of Relevant Sectors and Agencies	Aviation (CAAS)	Flood Warnings (PUB)	Public (NEA)	Energy Supply (EMA)	Maritime (MPA)	Health Alerts (MOH)	Food Resilience (SFA)	Sport & Leisure (Sport SG)	Defence (MINDEF)

Increased WOG demand for **new and better forecasting capabilities** for prediction of **high-impact weather hazards** as well as improved local climate projections **to better prepare Singapore for the impacts of climate change**

Strengthening Singapore's Resilience to Weather and Climate Change

Desired Outcome:

Weather/Climate Research to support a Whole of Nation approach to Climate Resilience

Decision Making	Aviation (CAAS)	Flood Warnings (PUB)	Public (NEA)	Energy Supply (EMA)	Maritime (MPA)	Health Alerts (MOH)	Food Resilience (SFA)	Sport & Leisure (Sport SG)	Defence (MINDEF)

Key hazards for Singapore: heavy rainfall, urban heat, wind gusts, turbulence, icing, lightning, air/water quality, sea-level rise.
Local/regional 'raw' data products: precipitation, air temperature, wind/speed direction, cloud amount, humidity, sea-level, etc.

H-1 Application Areas	Regional Reanalysis (since 1960)	Environmental Monitoring (now)	Nowcasting (next 1-6h)	Regional Environmental Prediction (next 1-48h)	Seasonal Prediction (next 0.5-12m)	Decadal Prediction (next 2-10y)	Regional Climate Projections (next 10-100y)

H-2 Underpinning Research	Tropical Urban Climate	Tropical Processes	Predictability	Climate Variability & Change	Weather & Climate Extremes

Weather/Climate Research Testbed:

Accelerating pull-through of RI/IHL-led research into operational services through the provision/support of core enablers

H-3 Core Enablers	Observations	Modelling & Simulation	AI for Weather/ Climate Science	IT Infrastructure	People & Partnerships

Decision Making: Ensuring Singapore stakeholders can leverage and prepare for the impacts of local weather and climate change

H1: Application Areas: Mechanisms through which research will be translated into data products to underpin operational weather/climate services

H2: Underpinning Weather/Climate Research: Strategic research areas to advance understanding, modelling, and prediction/projection of weather and climate change in Singapore and the SE Asia region

H3: Enablers: National capabilities required to enable relevant underpinning weather/climate research and subsequent delivery of operational weather/climate services

SINGV: A km-scale Regional Weather/Climate Model for Singapore

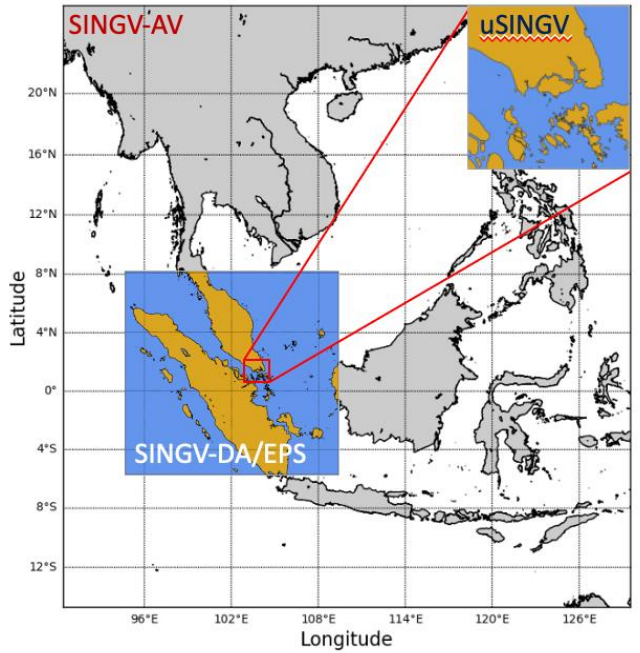
- MSS—UK Met Office collaboration (2013 – 2018).
- SINGV project: Develop a km-scale version of the Unified Model (UM) suitable for use in the deep tropics.
- ‘Seamless’ approach: SINGV used in both numerical weather prediction (NWP) and climate change research.
- SINGV-DA implemented in operational NWP in July 2019.
- Since then, numerous configurations developed:

SINGV-DA	SINGV-AV	SINGV-EPS	cSINGV	uSINGV	SINGV-RCM
		Rachel Koh	Rajesh Kumar	Song Chen	Xin Rong Chua

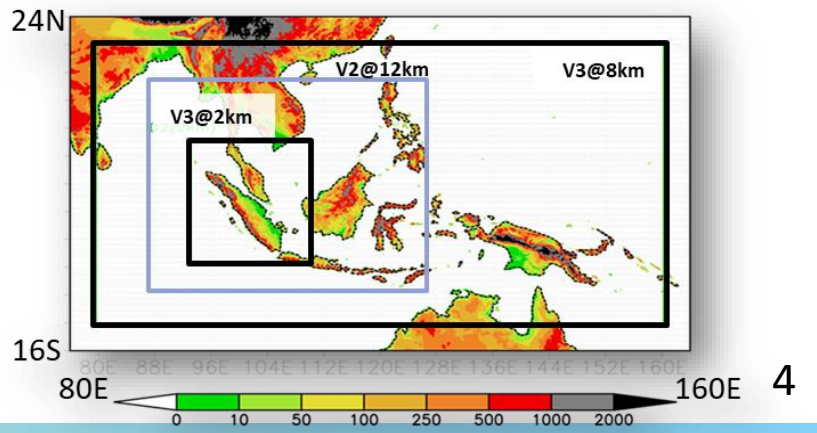
SINGV-DA (operational NWP)

- V3 Regional Climate Projections (SINGV-RCM, 2024)
- SINGV-EPS (Ensemble Prediction System – tentative, 2024)

NWP Domains:



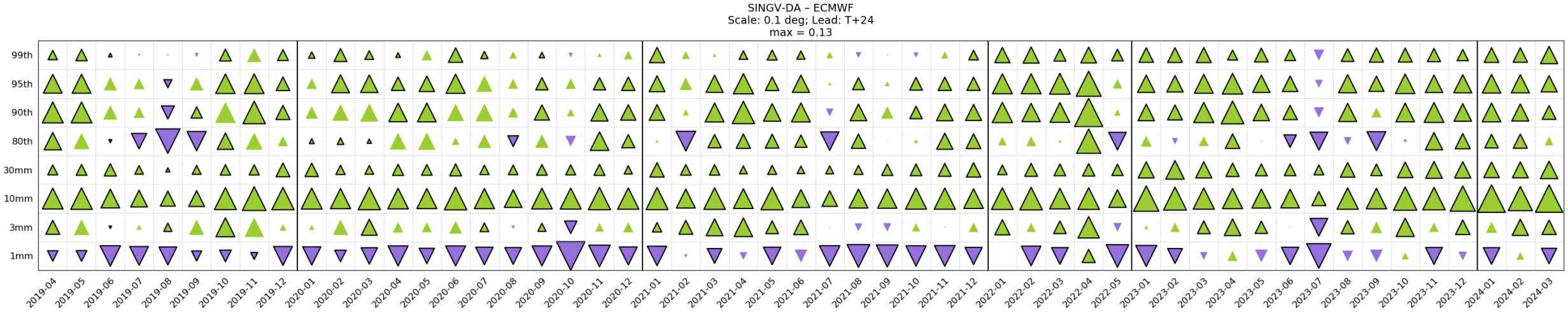
Regional Climate Projections (SINGV_RCM):



NWP Domains

SINGV_DA NWP System

- Major source of value-add for regional NWP is source of driving global NWP data (SINGV uses ECMWF).
- SINGV_DA = Three-hourly 3DVar cycling, using large-scale analysis increment blending for large scales.
- SINGV_DA Hinton diagrams indicate consistent added value of SINGV_DA vs ECMWF



- SINGV_EPS = 4.5km, 12 member downscaling ensemble
- References:

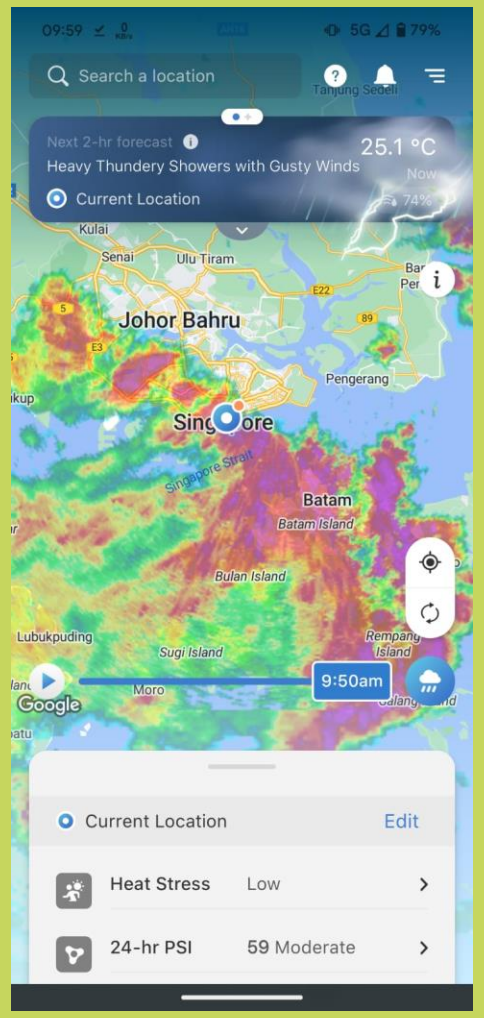
Huang *et al*. SINGV – the Convective-Scale Numerical Weather Prediction System for Singapore. *ASEAN J Sci Technol Dev*. 2019;36:81–90.

Heng *et al*. SINGV-DA: A data assimilation system for convective-scale numerical weather prediction over Singapore. *Q J R Meteorol Soc*. 2020;146:1923–1938.

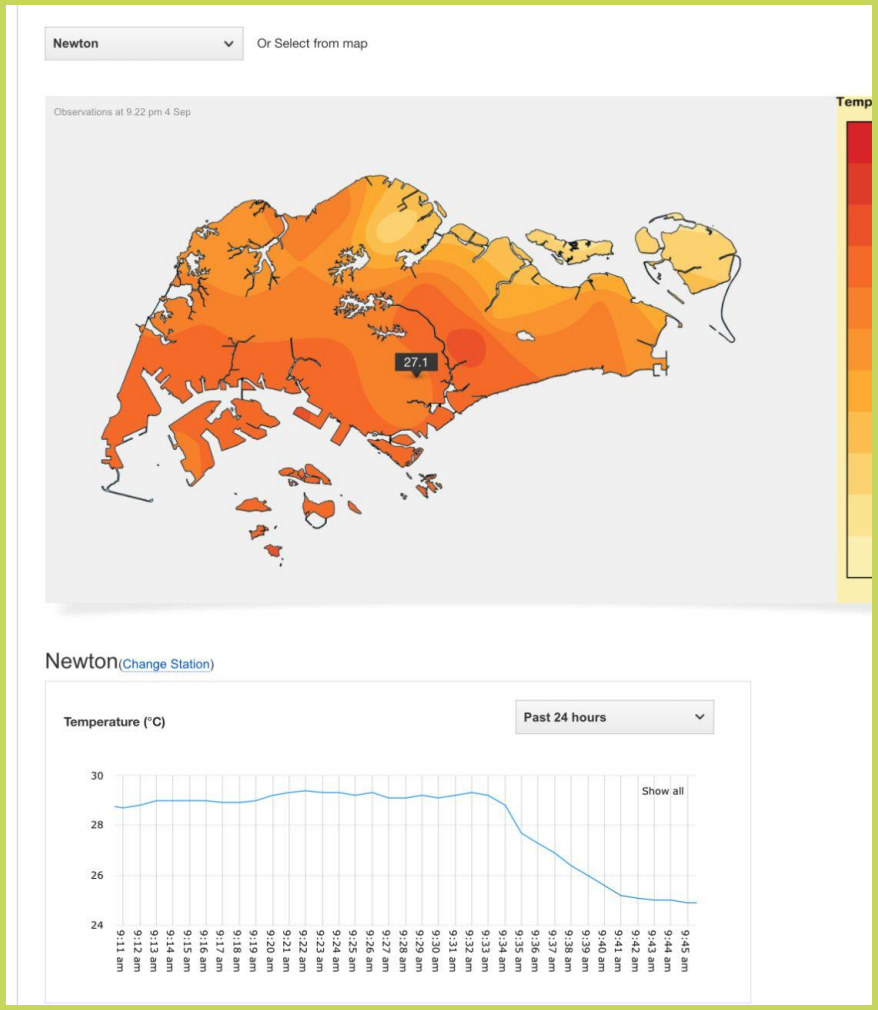
Dipankar *et al*. SINGV: A convective-scale weather forecast model for Singapore. *Q J R Meteorol Soc*. 2020;146:4131–4146.

Sumatra Squall Line Case: 4 September 2024

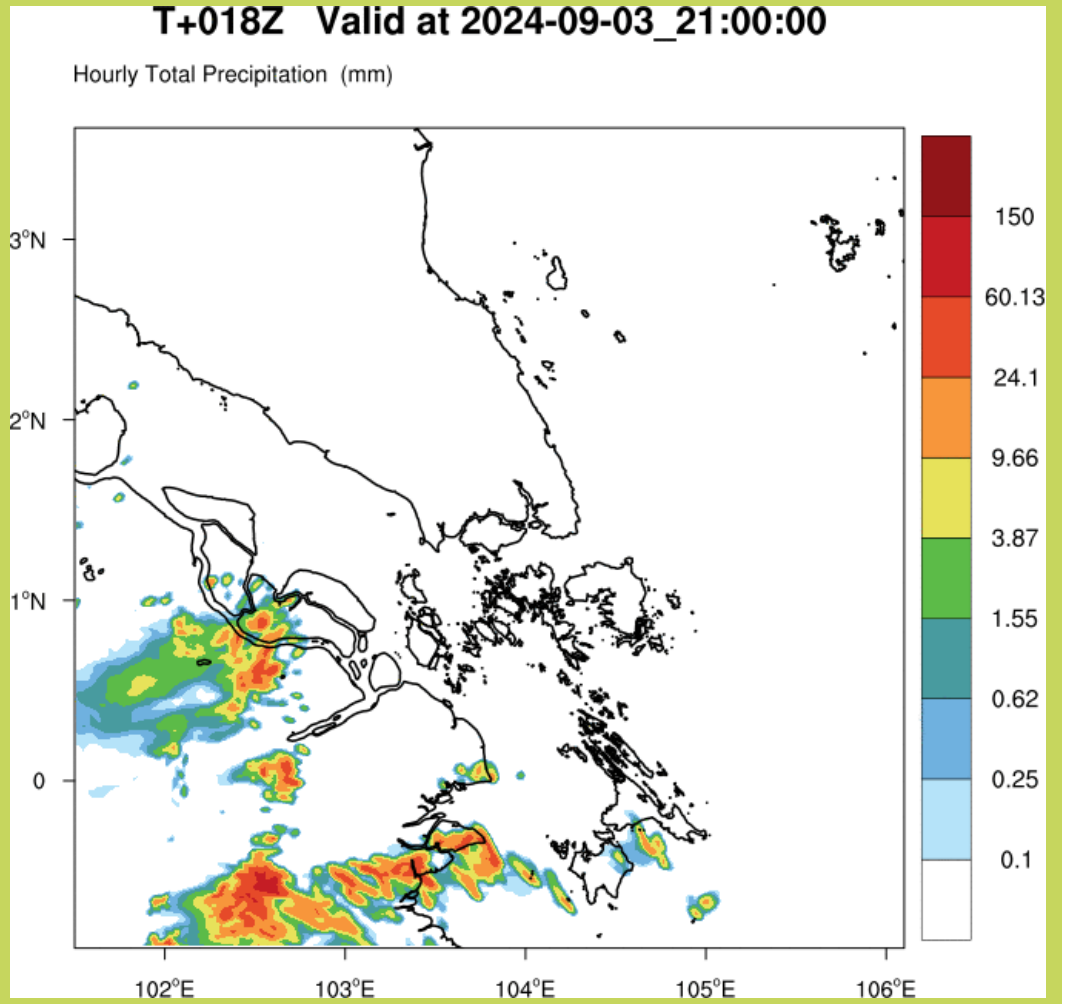
Radar: 09:50am



Surface Temp (Newton)



SINGV_DA Forecast (1.5km resolution)



Numerical Environmental/Weather Prediction (NEWP) Workflow

NEWP

Observations

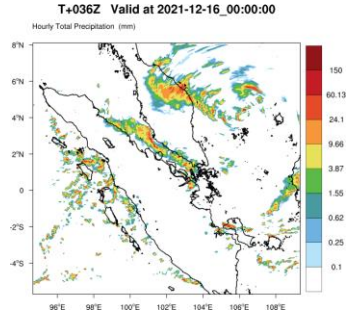
Global Weather Prediction (ECMWF)

Local Model (SINGV, *SINGV_AI)

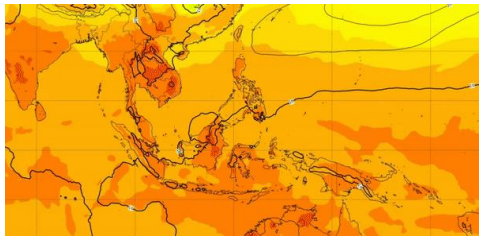
Standard Post-Processing

Local Weather Prediction (MSS)

Physical downscaling



Statistical/AI/ML downscaling



Physical/AI/Hybrid Model simulates earth system

Observations / Reanalysis

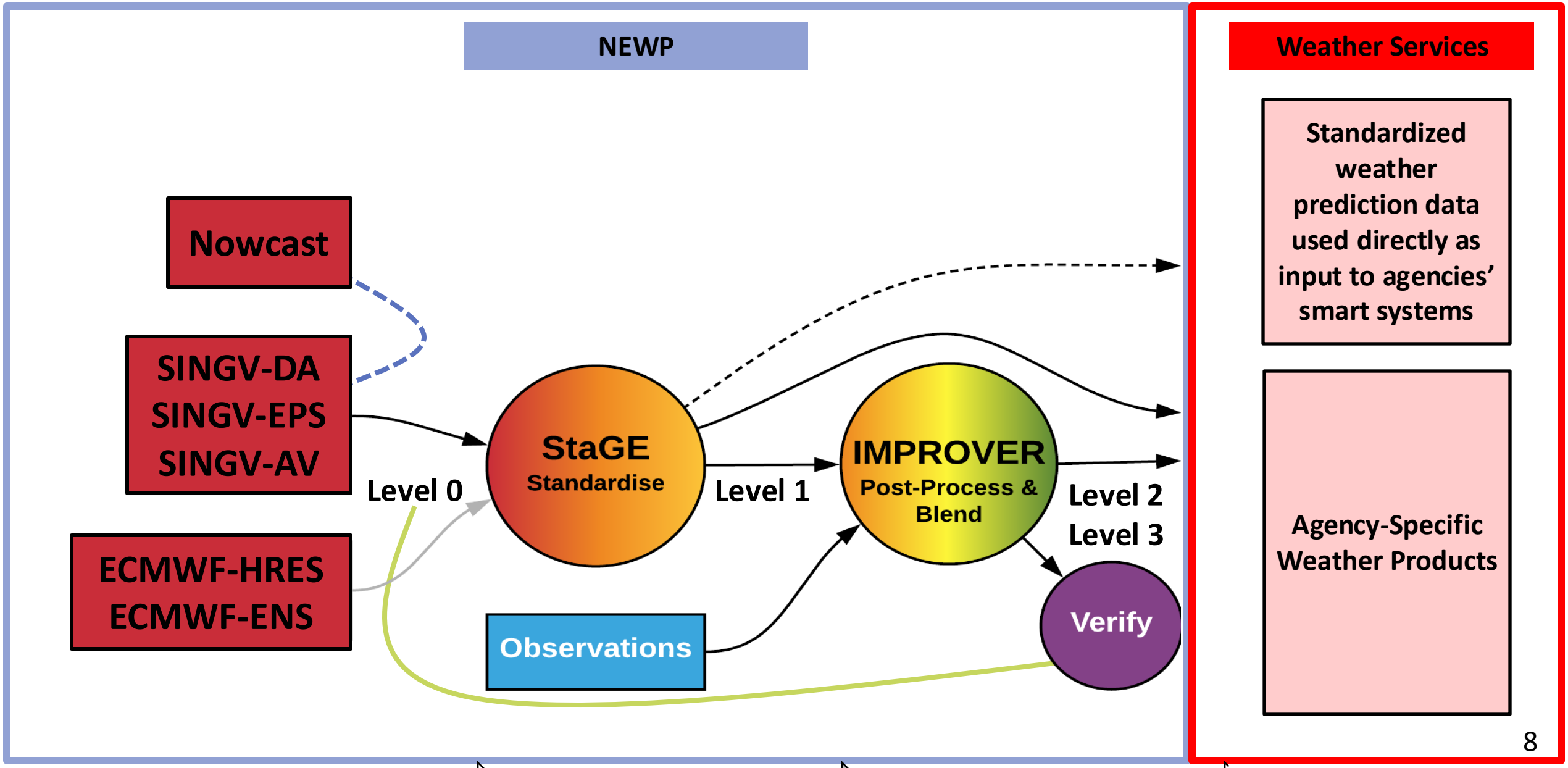
Weather Services

Standardized weather prediction data used directly as input to agencies' smart systems

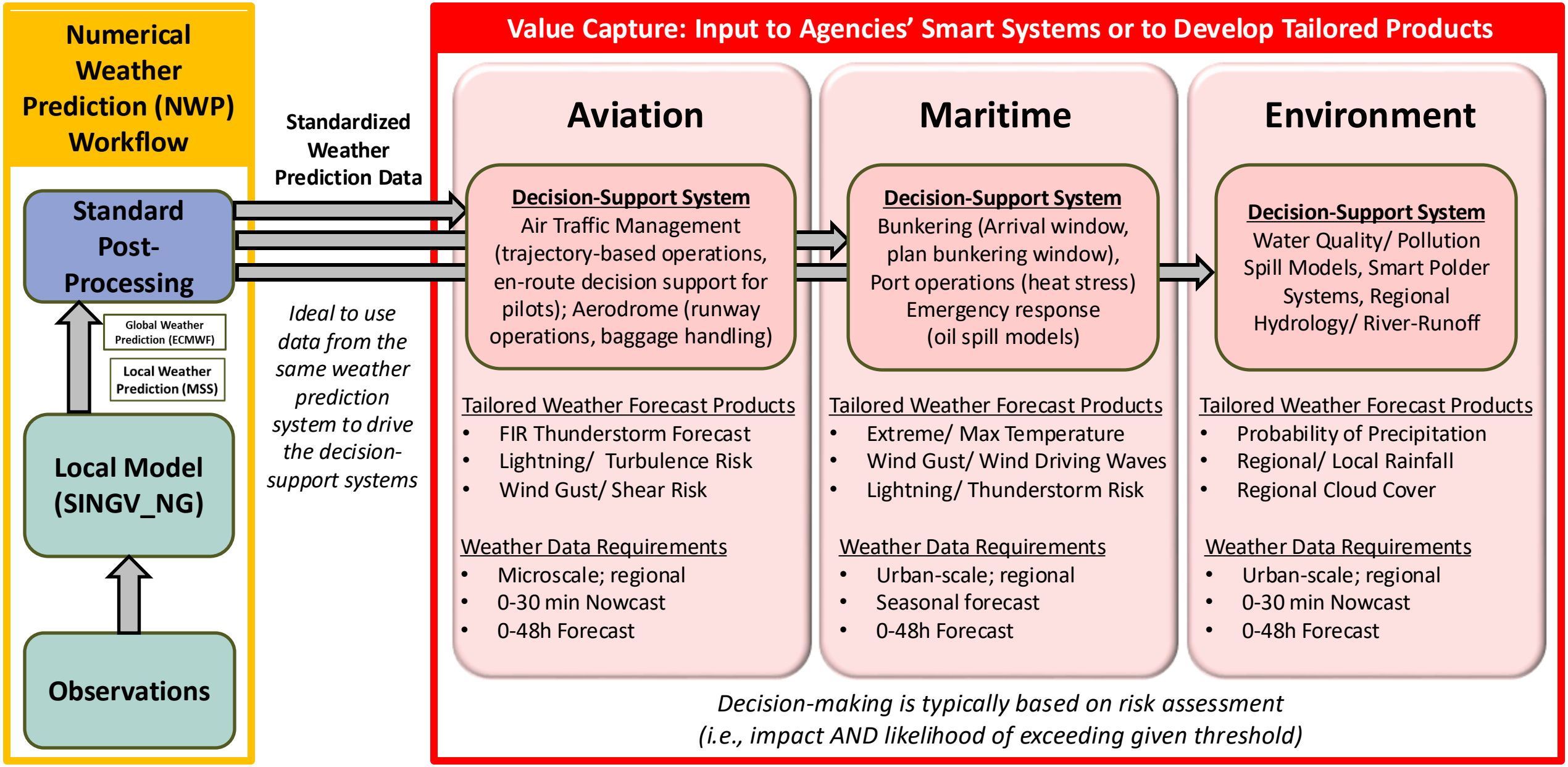
Agency-Specific Weather Products

24/7 Operations (external) | *24 /7 Operations (MSS)* | *Offline Production*

Numerical Environmental/Weather Prediction (NEWP) Workflow

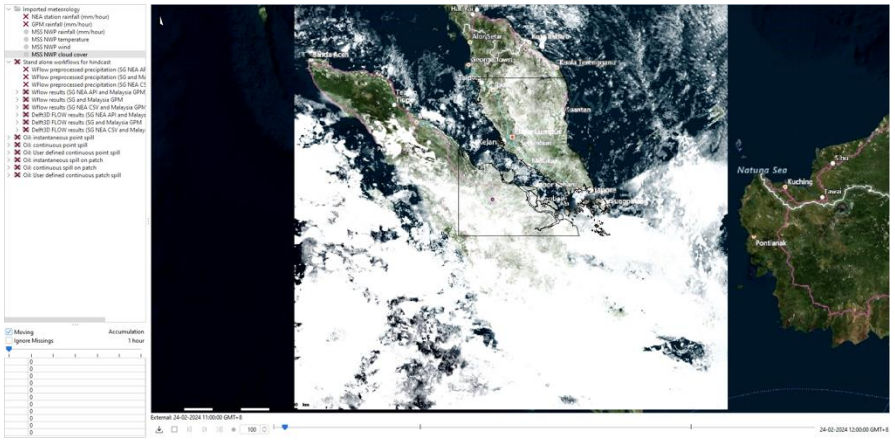


Translating Weather Research to Impact – Use Cases

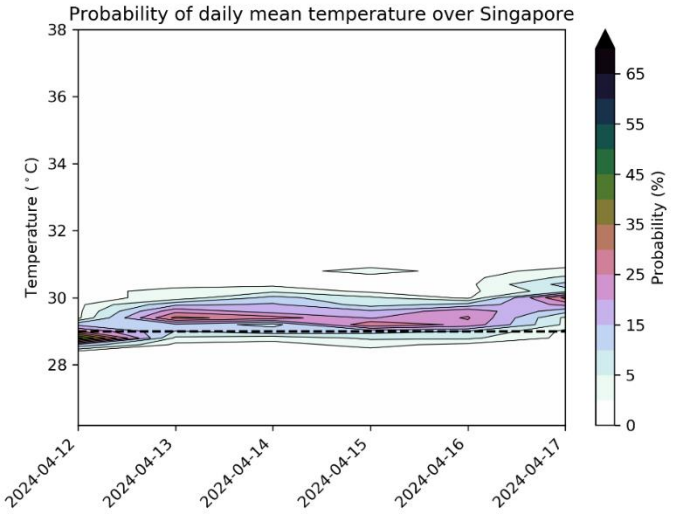


Building Forecast Products to Support Weather Services

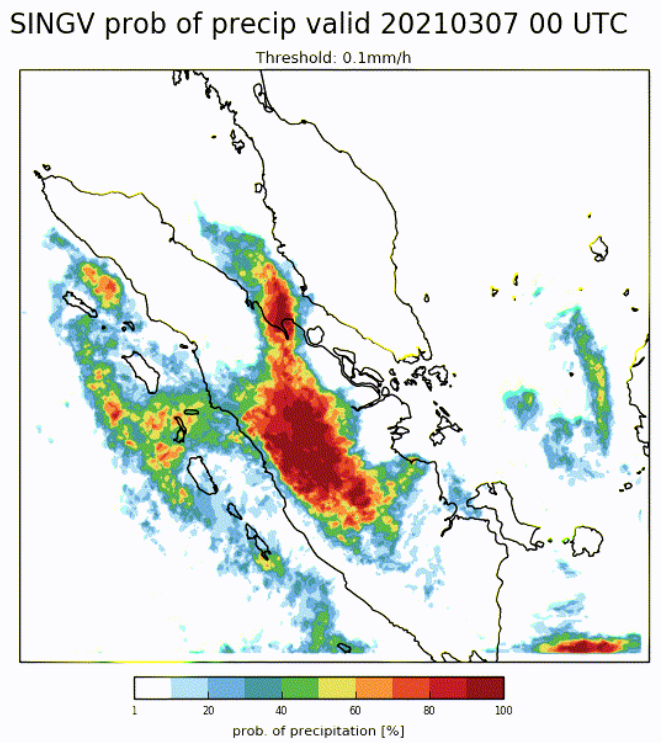
- **Research using weather prediction data required to build new products, tailored for specific applications:**
  - Probabilistic products to support risk assessment (e.g., for heat, aviation, maritime)
  - Data integration into downstream smart systems (e.g., for hydrology, energy management)



Proof-of-concept integration of SINGV cloud forecast data into NEA's environmental monitoring and modelling system

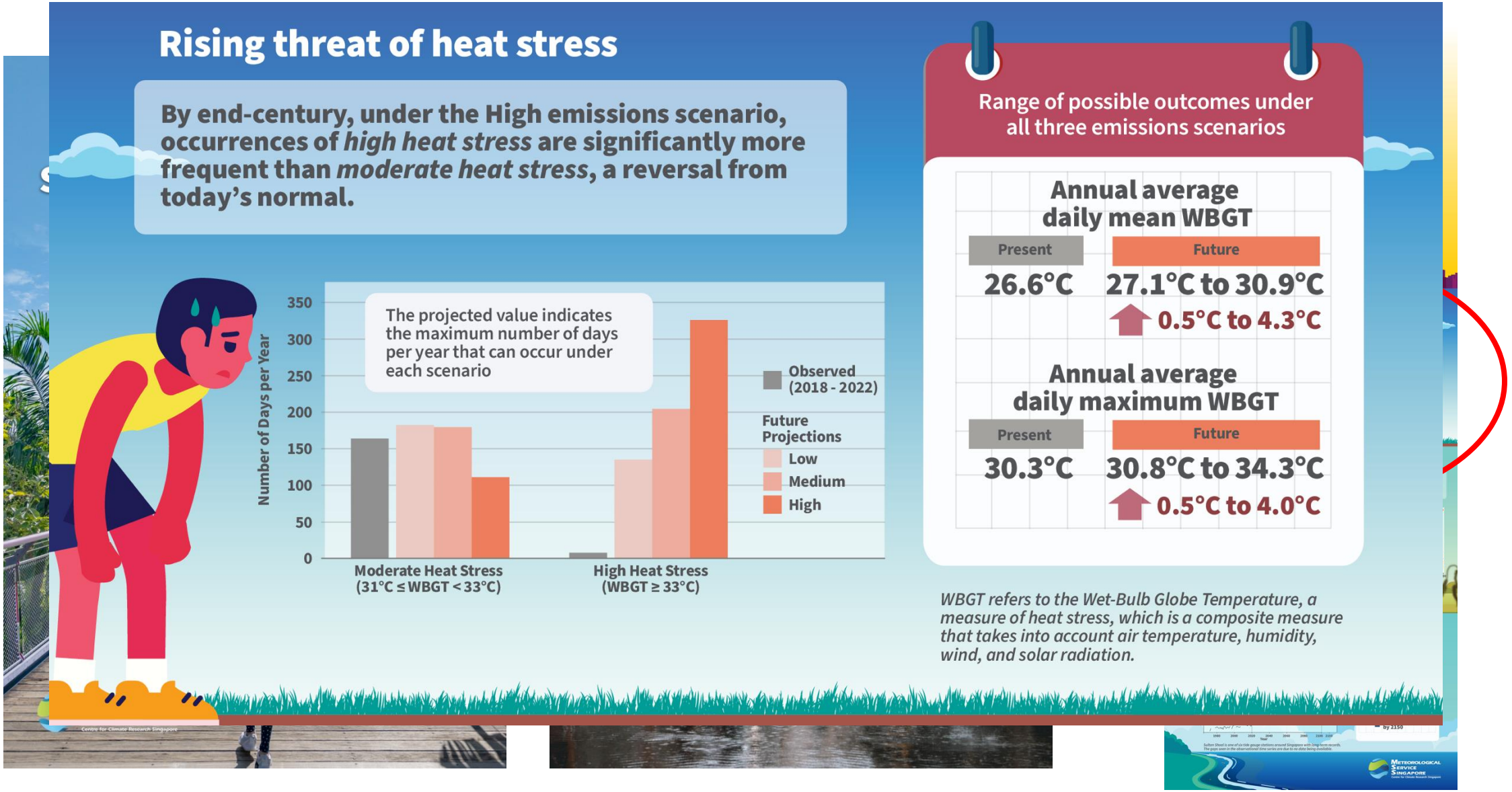


Real-time 5-day heat product supporting operational heat advisories



Probabilistic NWP: Probability of Precipitation

Third National Climate Change Study (V3) – Launched 5 Jan 2024

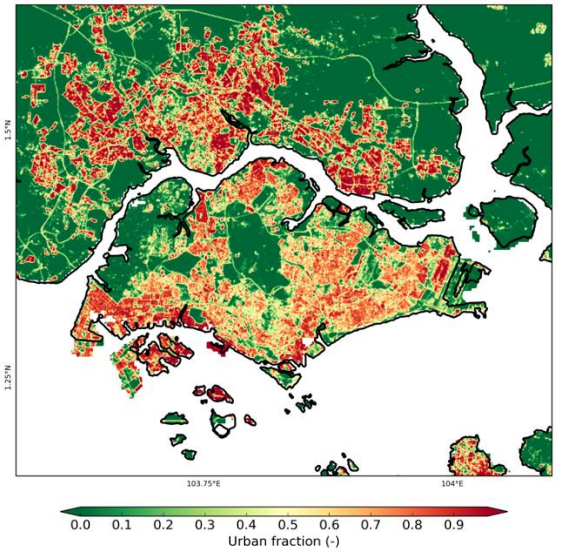


https://www.mss-int.sg/v3-climate-projections

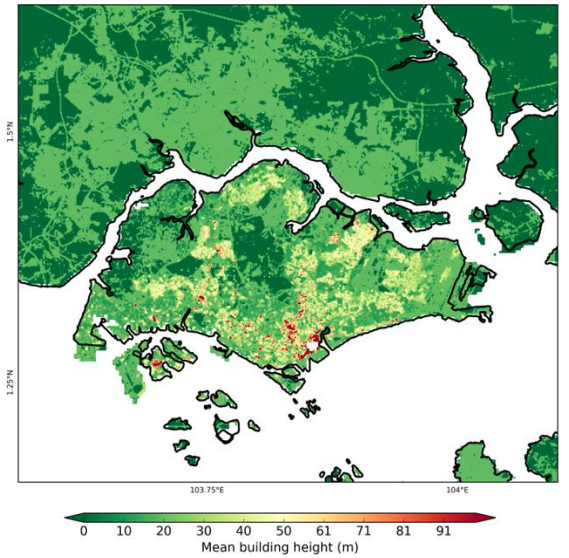
Urban Modelling (uSINGV): Initial Climate Applications

- **Improved understanding/prediction of urban weather/climate is a key science research frontier for Singapore**
- Need to move beyond km-scale modelling/projections e.g. SINGV, V3.
- Target 100-300m resolution initially, to better resolve key meteorological phenomena e.g. localized convection.
- Initial research focus: urban canopy, urban heat island impact on rainfall, high-resolution coupled systems, nowcasting.

100m uSINGV Urban fraction

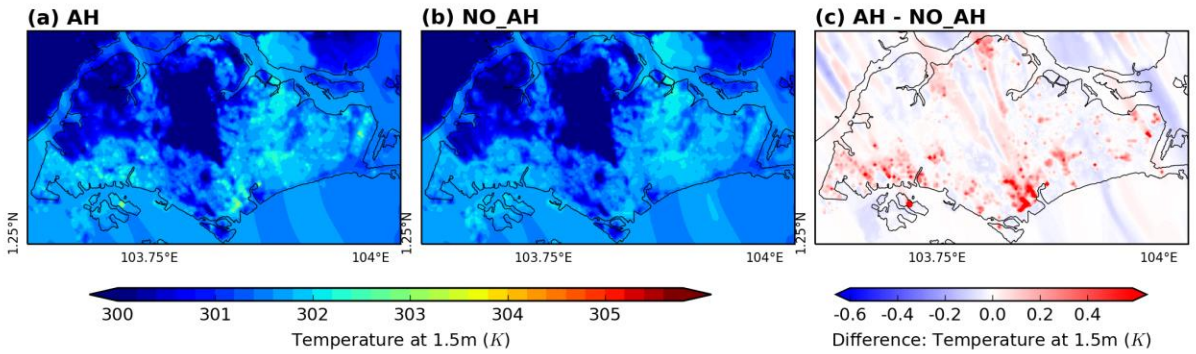


100m uSINGV Mean Building Hgt



Impact of anthropogenic heat on surface temps:

Local time: 21 HR



Climate Impact Science Research (CISR) Programme

The new $23.5M CISR programme aims to understand the long-term impacts of climate change on Singapore, taking into account synergies with CCRS' on-going research and key research focus areas identified to be of priority for government agencies.

Sea Level Rise	Water Resource & Flood Management	Biodiversity & Food Security	Impact of Warming Trends on Human Health & Energy Sector	Cross-Cutting Areas
				
1. Coastline and civil infrastructure 2. Impact of Extreme rainfall and storm surge events	1. Impact of heavy rainfall and drought on water supplies 2. Urban runoffs and water resources management	1. *Biodiversity* - urban greenery and vegetation tolerance limits 2. *Food Security* – local and regional food distribution centres and supply chains	1. *Human Health* – e.g. heat stress 2. *Energy Sector* – energy demand	1. Impactful applications of climate change science information in a risk-based assessment

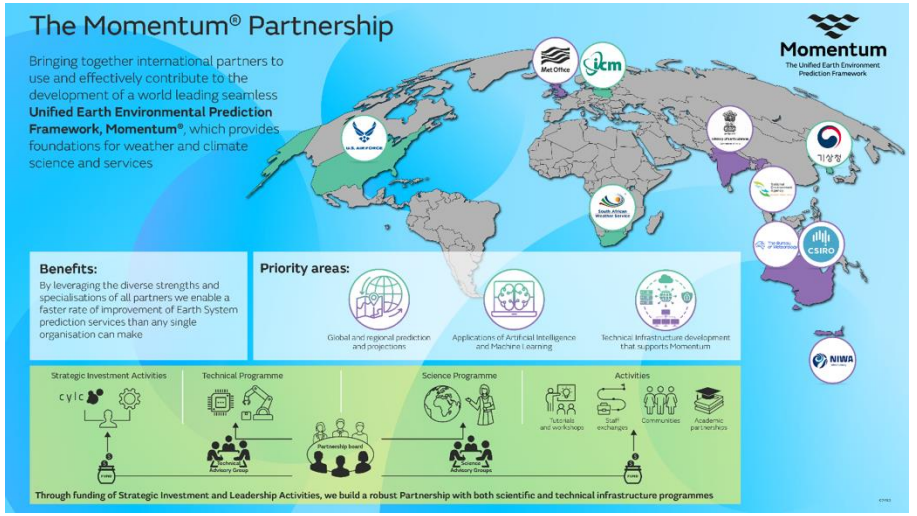
Weather Science Research Programme (WSRP)

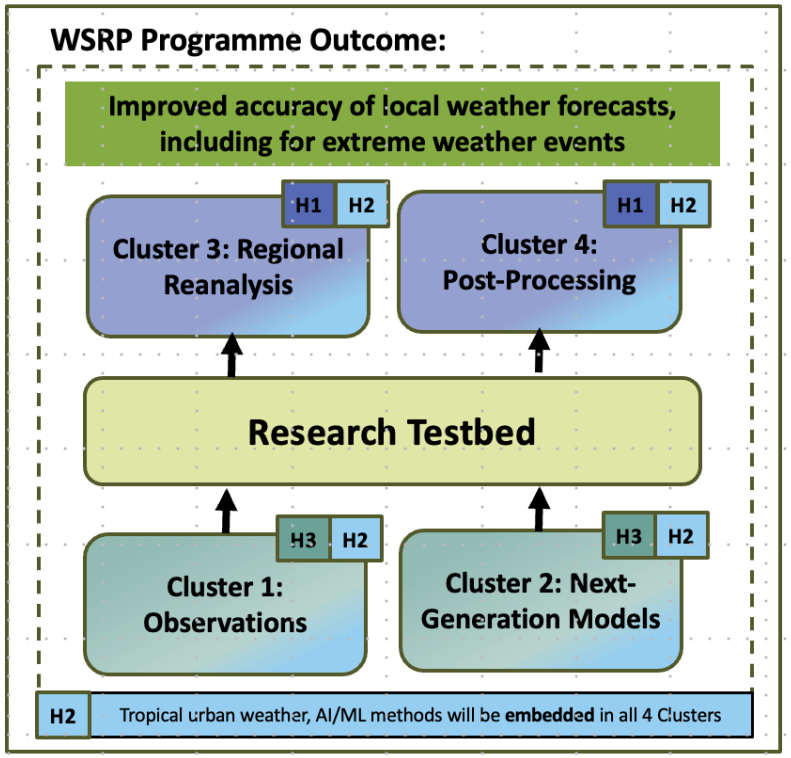
Research Cluster	Cluster 1: Observations (H3)	Cluster 2: Next-Generation Models (H3)	Cluster 3: Regional Reanalysis (H1)	Cluster 4: Post-Processing (H1)
Problem/Gap	Many earth system observations (e.g. satellite, radar) are not optimally used	Existing models will become legacy in next 5 years	Regional high-resolution datasets of past weather and climate (full state) do not exist for SEA	Model forecasts are not optimally used to extract valuable weather information
Solution	New approaches can be explored to make best use of both existing and future observations	Next-generation models tailored for the tropics can replace existing models	Regional reanalysis provides a high-resolution reconstruction of the past weather and climate	New approaches can be explored to make best use of model forecasts to extract valuable weather information
Benefit	Optimal use of current and future observations will enable improved weather prediction	Next-generation models will be faster and scalable to enable improved weather prediction	Supports understanding of historical extreme weather events and training of next-generation AI/ML models	Better usage of model forecasts will enable improved weather prediction
Research Scope	**Retrieval and usage** of earth system observations	**Development** of next-generation models	**Production** of a historical regional reanalysis for past 50 years	**Development** of methods to better use model forecasts

H2 **Underpinning Weather Research**: Tropical urban weather, AI/ML methods etc. will be **embedded** in all 4 Clusters

Summary

- Climate Science Research Master Plan (CSRMP) = strategic framework for whole-of-nation weather/climate science outcomes
- Key strategic research topic: tropical urban climate
- Good progress in recent years to spin up regional weather prediction/climate projection capabilities – much more to do!
- International science collaborations will remain key e.g. Momentum (multilateral); Met Office/Bureau/NCAR (bilaterals)
- Weather Science Research Programme (WSRP):
  - Research targeted on key gaps in local capabilities/products
  - Building up weather/climate capacity in local universities
  - To be expanded later into other areas of CSRMP e.g. S2S.





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