METEOROLOGICAL SERVICE SINGAPORE

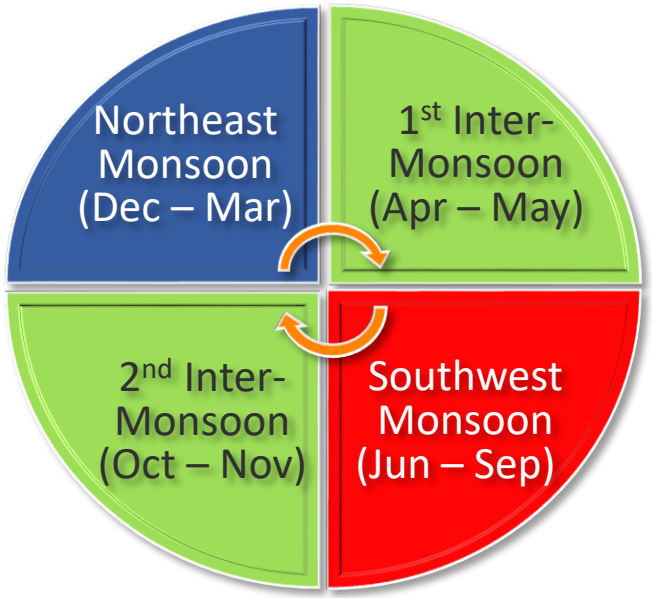
Final Report (Singapore – Changi Airport)

AvRDP Concluding Meeting cum Seminar
19-23 Aug, Pretoria, South Africa

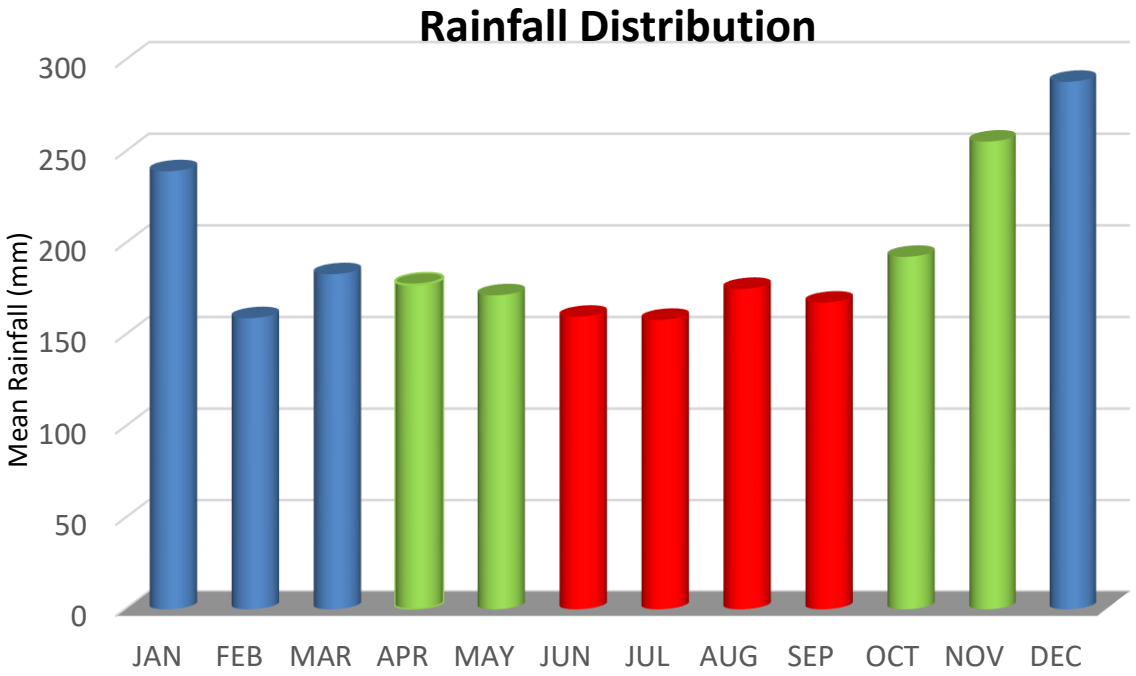
21 Aug 2019

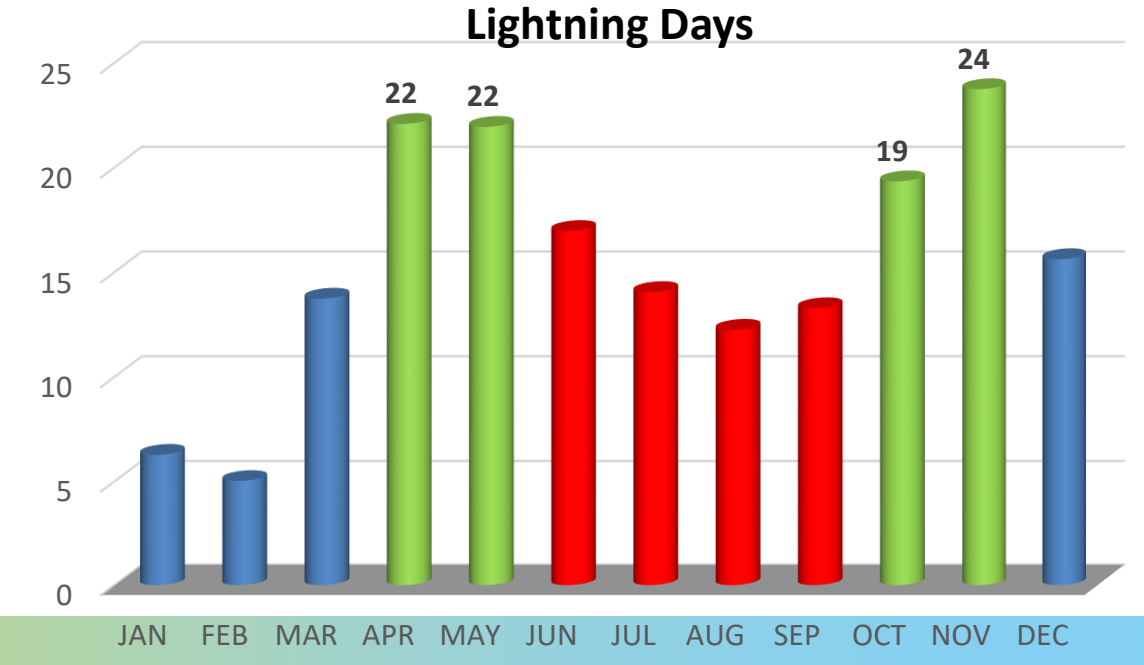
Background

Climate of Singapore



Singapore is lightning-prone: We experience an average of 185 lightning days per year

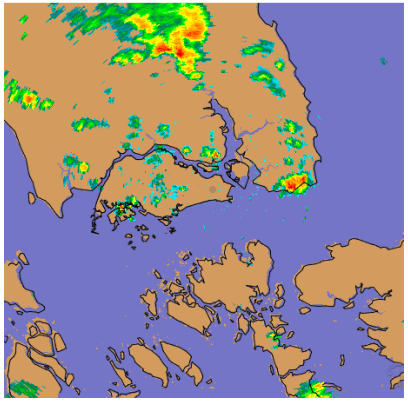




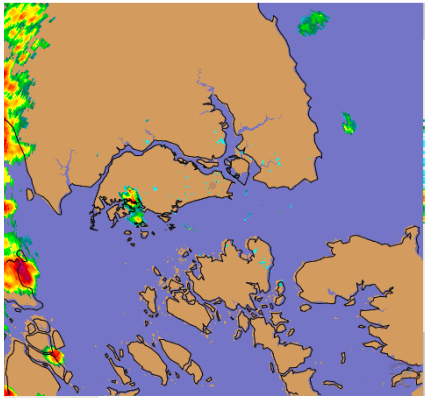
Challenges in Forecasting Thunderstorms

- Rapid development, short lifespan, small scale
- Tropical weather systems largely driven by winds, which tend to be weaker and more variable in direction
  - Difficulty in determining possibility of occurrence, onset, duration, location and intensity
  - Short lead time for warnings (often 15 mins or less)
- Current numerical models have relatively low skill in predicting convective-scale weather systems, such as rain showers and localised thunderstorms

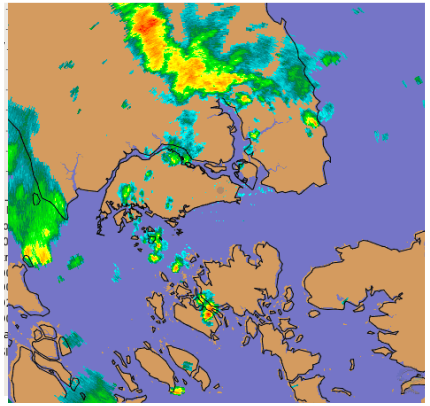
Main weather systems:



Localized convective thunderstorms



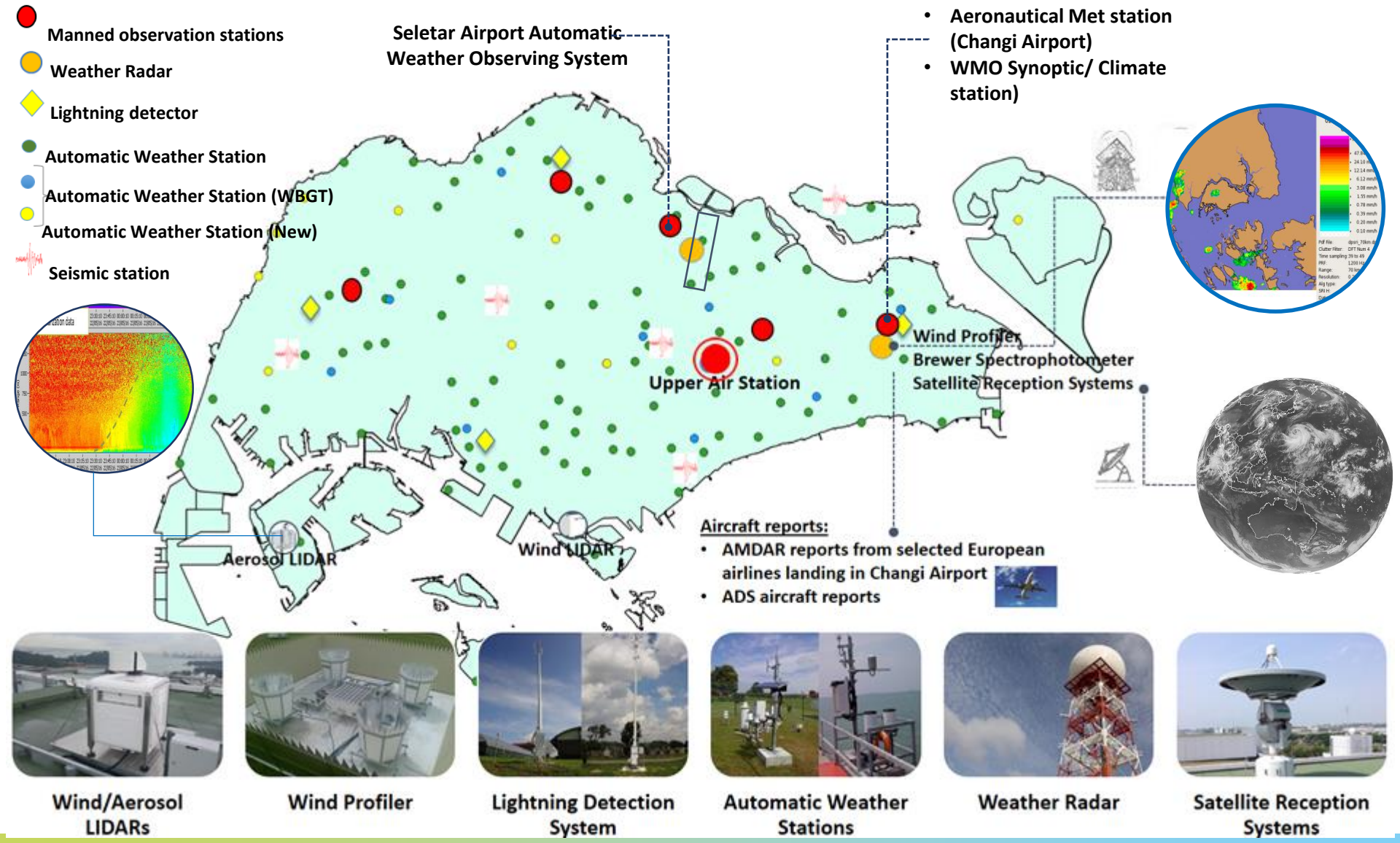
“Sumatra” squalls



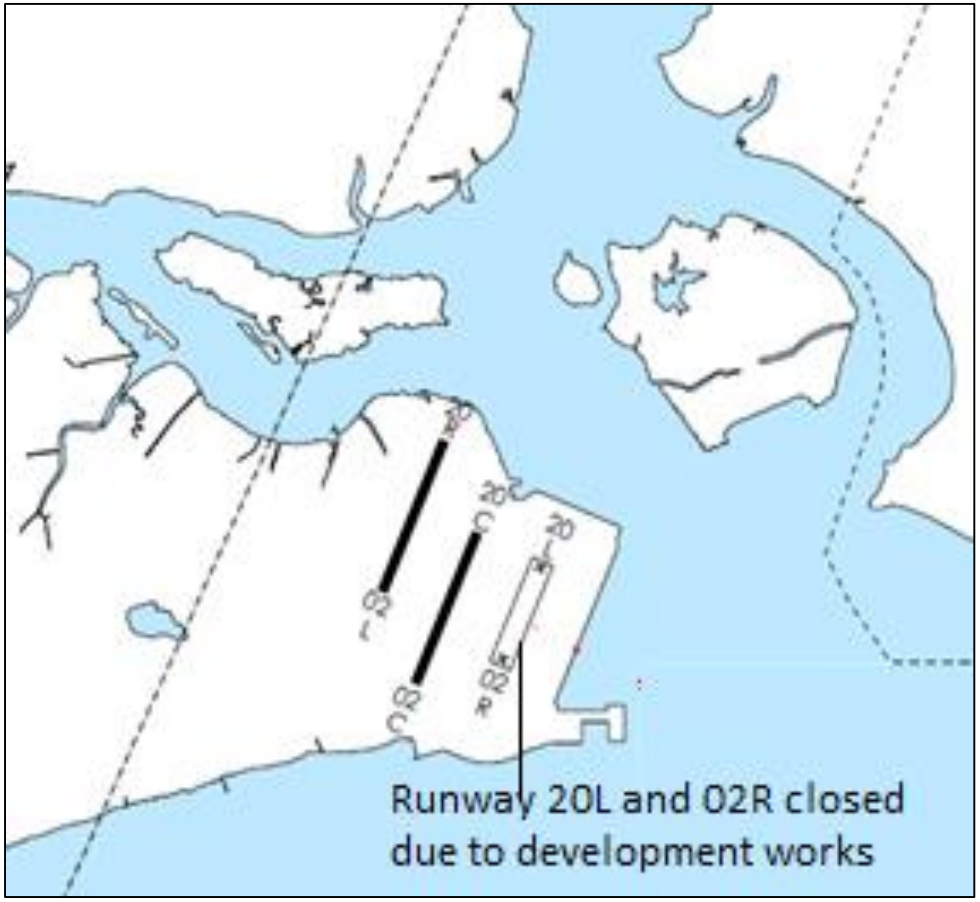
Monsoon surges

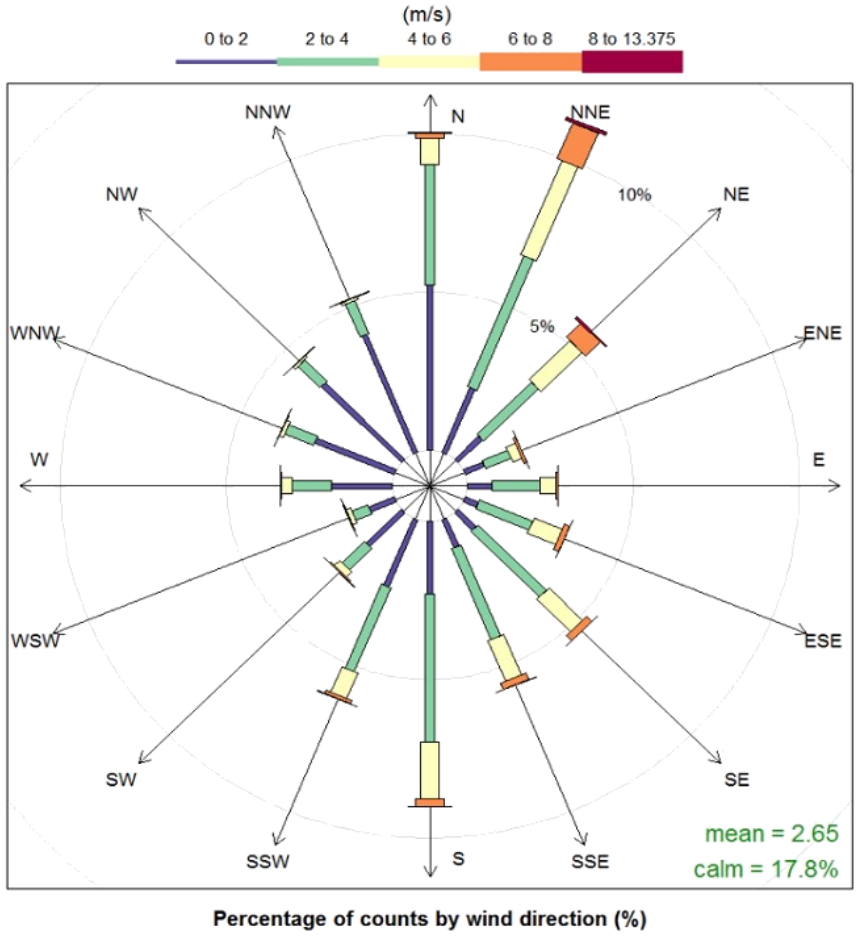
Network of Observation Systems

Observations - Foundation of meteorology and climatology



Aerodrome Characteristics





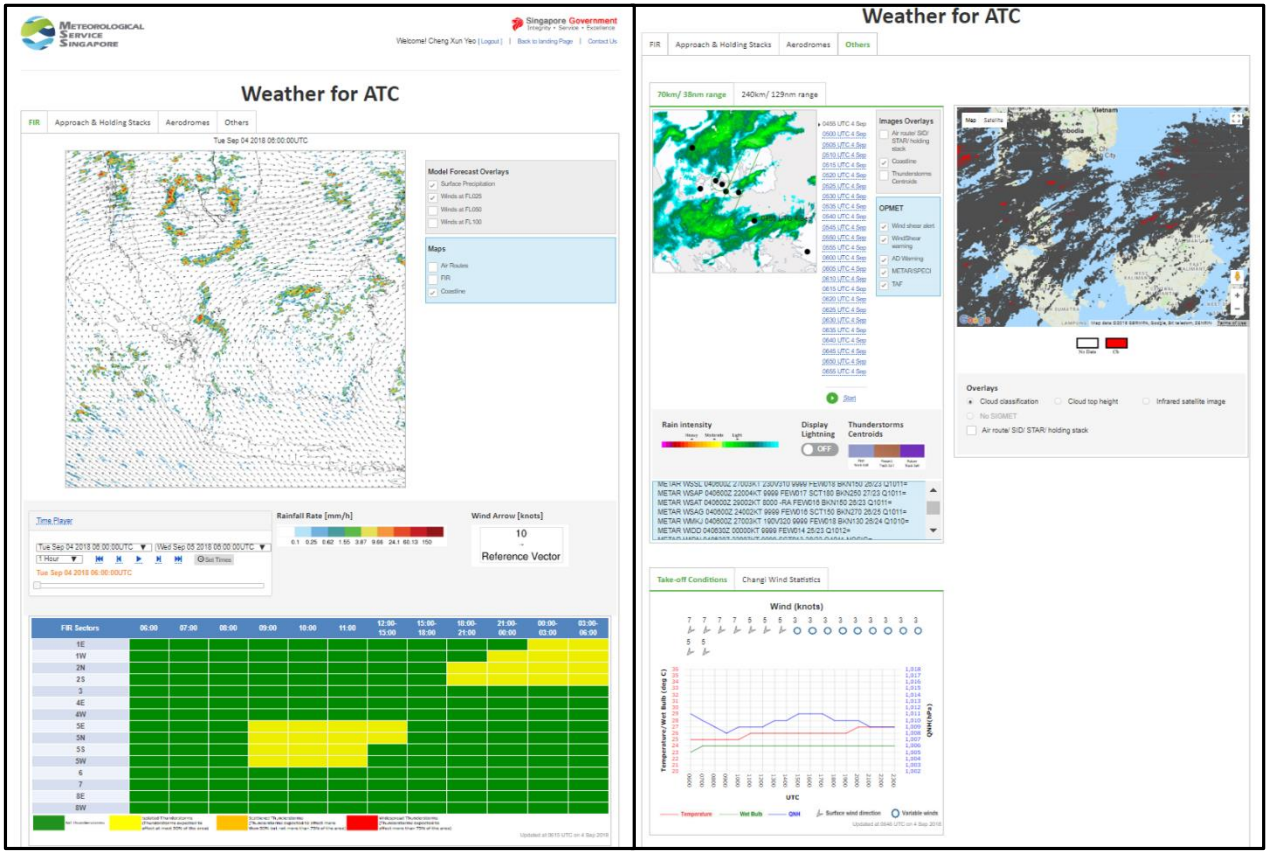
Percentage of counts by wind direction (%)

Tailored Services for ATM

Tailored Services for ATM

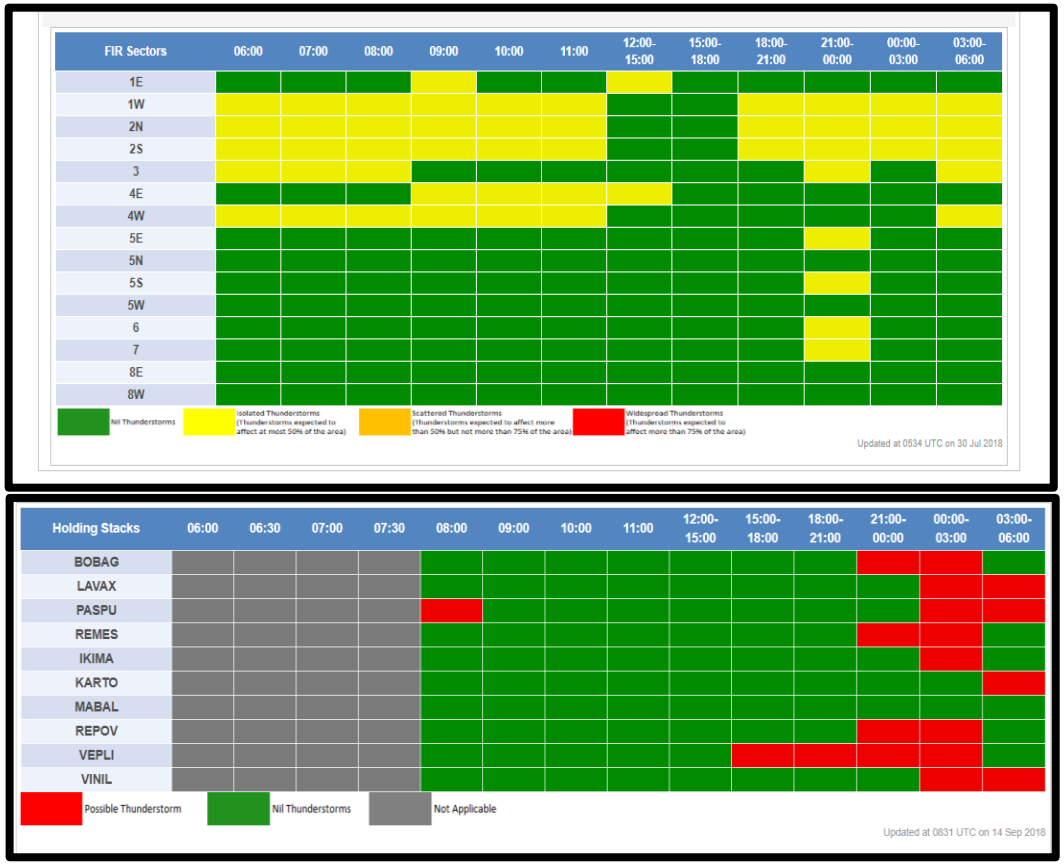
- Daily Weather Briefs (Morning and Afternoon)
- Direct Communication Line
- Dedicated Web Portal (Enhancement released in July 2018)

- Forecast: Weather Window Products
- Real-time Weather Information: OPMET, RADAR/Satellite images, alert banner (for AD warning/SIGMET)



Tailored Services for ATM (Weather Window Products)

- Categorical forecasts over critical watch areas (En-route sectors, approach, waypoints and aerodromes)
- Valid for 24 hours, with finer temporal resolution for near-term forecast.
- Updated every 3 hours and amended as required.



Observations

- Radar/Satellite/ OPMET/etc

NWP

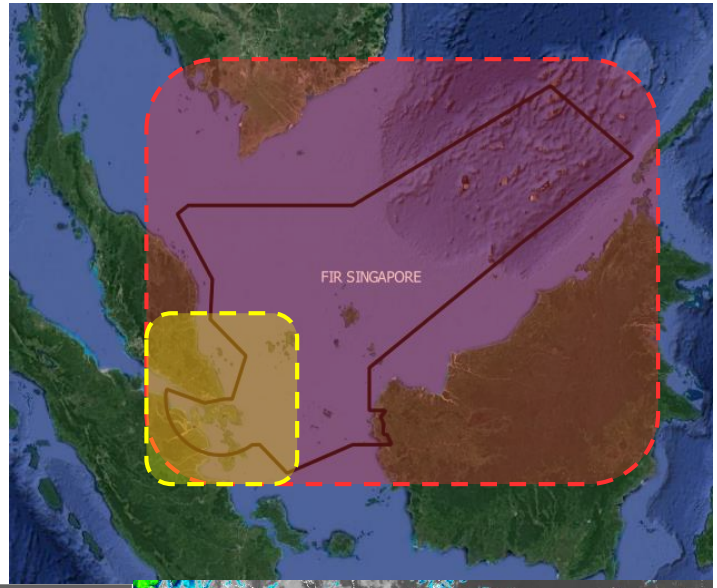
- Global/Mesoscale /Nowcast

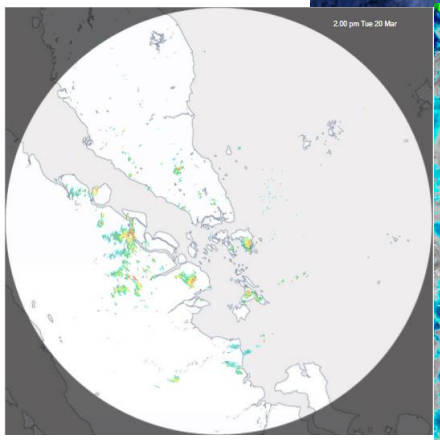
Local Knowledge

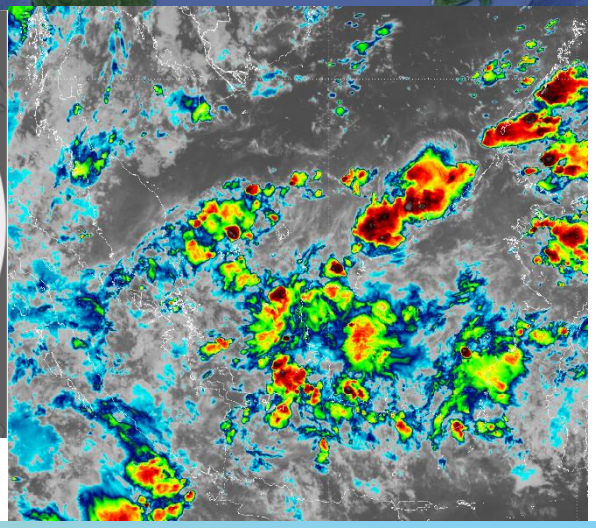
- Climatology
- Local influences

Evaluation

- Ground – Truth Data
  - Satellite
  - RADAR
  - OPMET
  - Lightning Data
- Evaluation Scores
  - Accuracy
  - Probability of Detection (POD)
  - False Alarm Ratio (FAR)
  - Critical Success Index (CSI)
  - Fractional Skill Score (FSS)







Evaluation Matrix

- Forecasts of convective thunderstorms are evaluated against observations
  - Categorical (Areal coverage) forecast : Evaluated against the extent of thunderstorm observed
  - 'Yes' or 'No' forecast : Evaluated against the occurrence of thunderstorms
- Forecast performance against lead time

Evaluation Matrix (Areal coverage)

Forecast \ Observed	Nil	Isolated	Scattered	Widespread
Nil	Correct Rejection	Miss	Miss	Miss
Isolated	False Alarm	Hit	½ Hit ½ Miss	Miss
Scattered	False Alarm	½ Hit ½ False Alarm	Hit	½ Hit ½ Miss
Widespread	False Alarm	False Alarm	½ Hit ½ False Alarm	Hit

Evaluation Matrix ('Yes' or 'No')

Forecast \ Observed	Nil	Thunderstorms
Nil	Correct Rejection	Miss
Thunderstorms	False Alarm	Hit

Review

Timeline

Deliverable	Planned	Actual
Phase I		
• IOP for ATM-tailored forecast for convective weather	Jun – Aug 2018	Jul 2018 - present
• Review and evaluation	Sep – Oct 2018	On-going
• Phase I results and final report • Preparation for Phase II	Nov – Dec 2018	-
Phase II		
• Operational trial on MET impact translation on air traffic flow management and airside operation	Jan – Mar 2019	
• Review and data analytics	Apr – May 2019	
• Final report	Jun 2019	

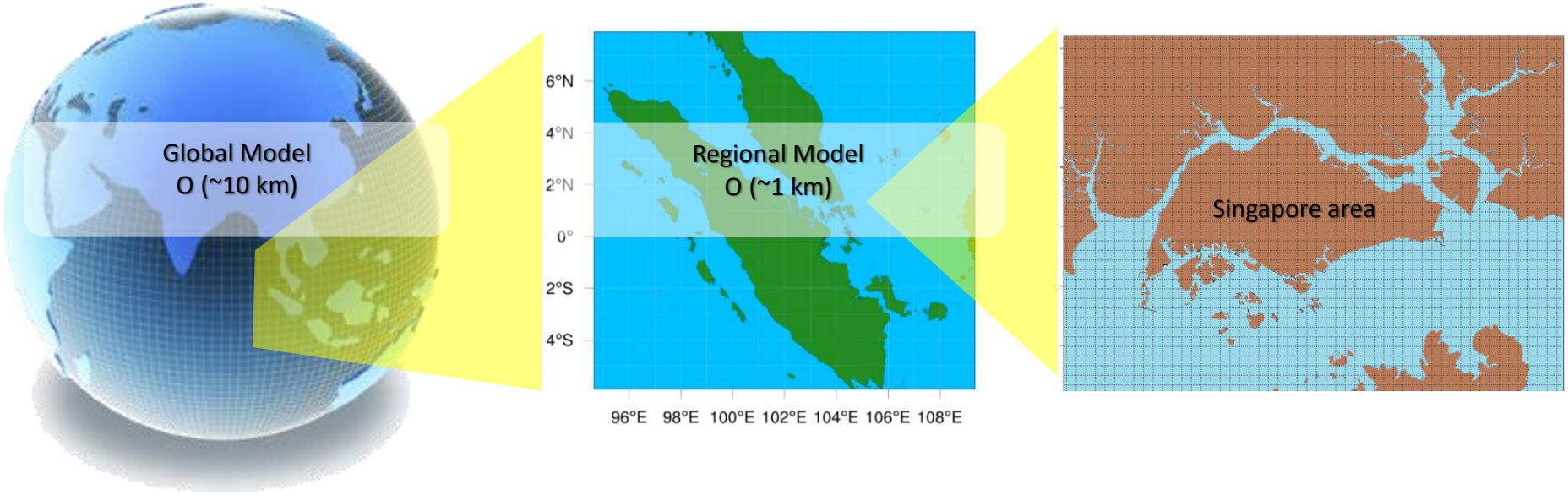
Tropical Numerical Weather Prediction : Very High Resolution Modelling

Requirements

- Resolve convective-scale thunderstorms
- Resolve land-sea contrasts and orography

Challenges

- Computationally expensive
- Convective-scale NWP is cutting-edge research



NWP models used

- Global
  - ECMWF Global (HRES) – ~9km resolution, Medium range (0 – 10 days forecast)
- Mesoscale
  - SINGV (Singapore Variable resolution model) – 1.5km resolution, 36/48-hour forecast output at hourly interval
    - Multi-year collaboration project with UKMO to develop a tropical convective-scale NWP/Nowcasting capability for Southeast Asia region
    - Full non-hydrostatic equations and explicit convection treatment
      - SingV-DS: Downscaler with initial and boundary conditions from ECMWF Global (HRES)
      - SingV-DA: SingV-DS + 3D VAR data assimilation

Types	Sources	Main Variables Assimilated
Satellite	Himawari-8, MODIS, ASCAT	Radiance, Satellite-derived winds
Aircraft	AMDAR, AIREP	Air Temperature Wind Speed and Direction
Radiosondes	Mainly TEMP (weather balloon)	
Surface Observations	SYNOP, METAR, Buoy	

Review of ECMWF Global Model

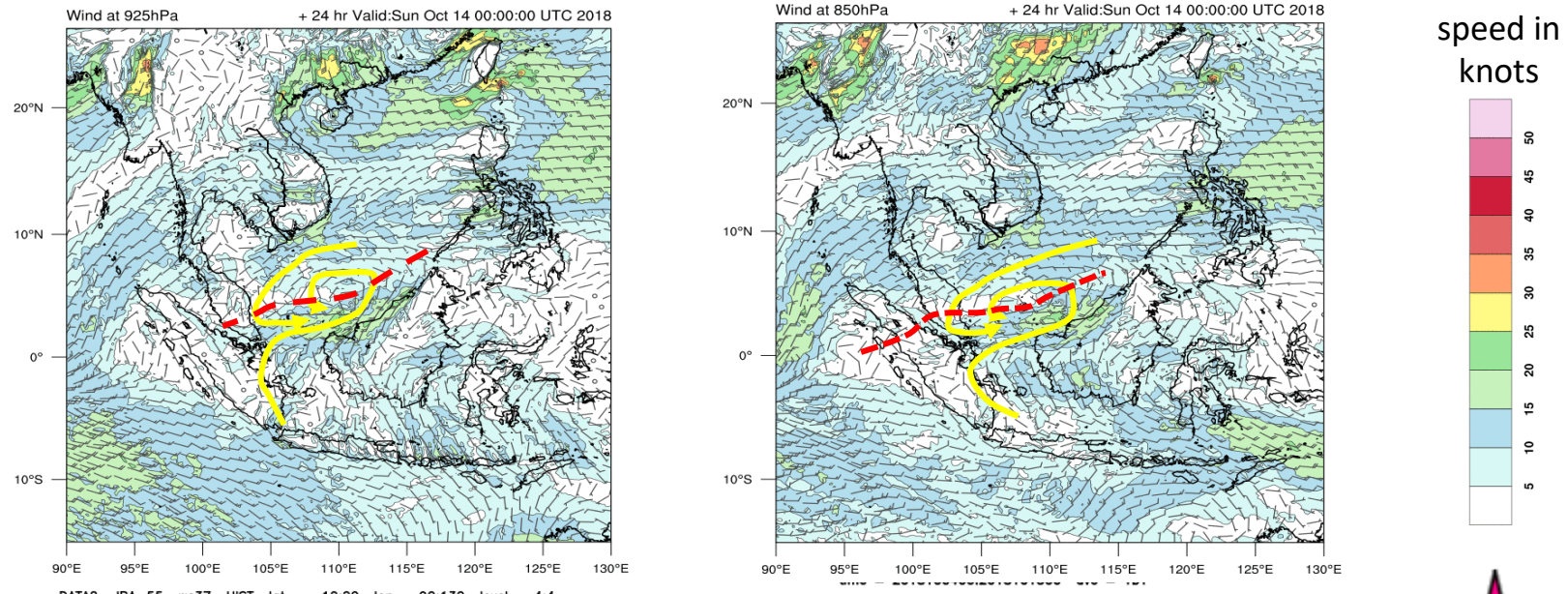
- ECMWF Global Model (precipitation) applied directly to weather window forecast for FIR Sectors
  - No human intervention
- In general, FSS is close to 0.5
  - Performance varies slightly across the monsoon seasons
  - Reasonable skill in capturing synoptic scale weather
  - Able to provide indication of diurnal heating induced convection over land areas
    - Particularly during the inter-monsoon months
  - Less skill in locating convective activities
  - Under-forecast the intensity of convection

Case Study (1) - 14 Oct 2018 at 00UTC

Winds at 925 hPa

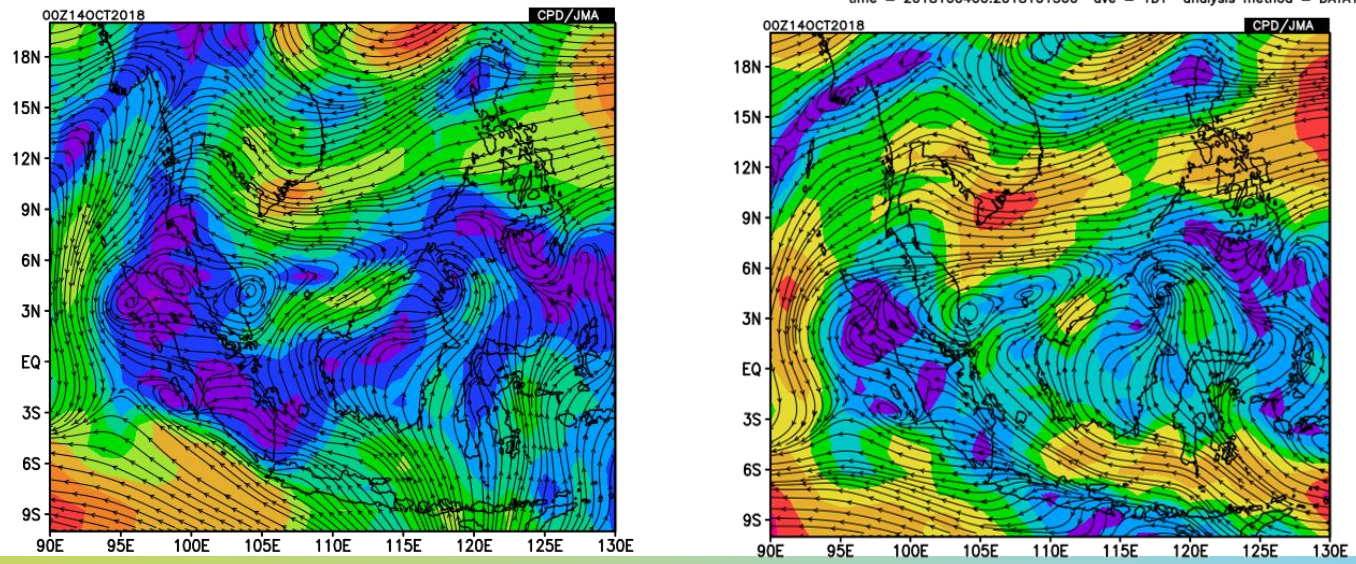
Winds at 850 hPa

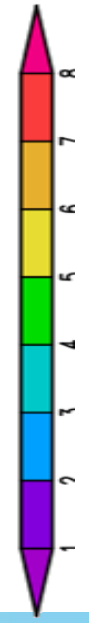
ECMWF Global (0.1 deg)



Wind speed in knots

Analysis Winds





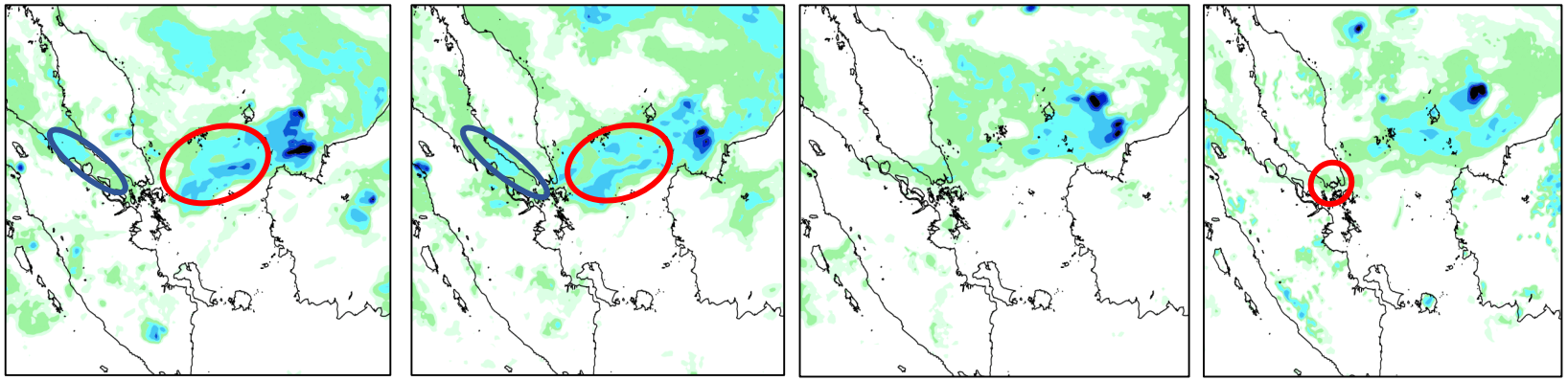
Case Study (1) - 14 Oct 2018 at 00UTC

Total Precipitation

Rainfall
mm/3 hrs

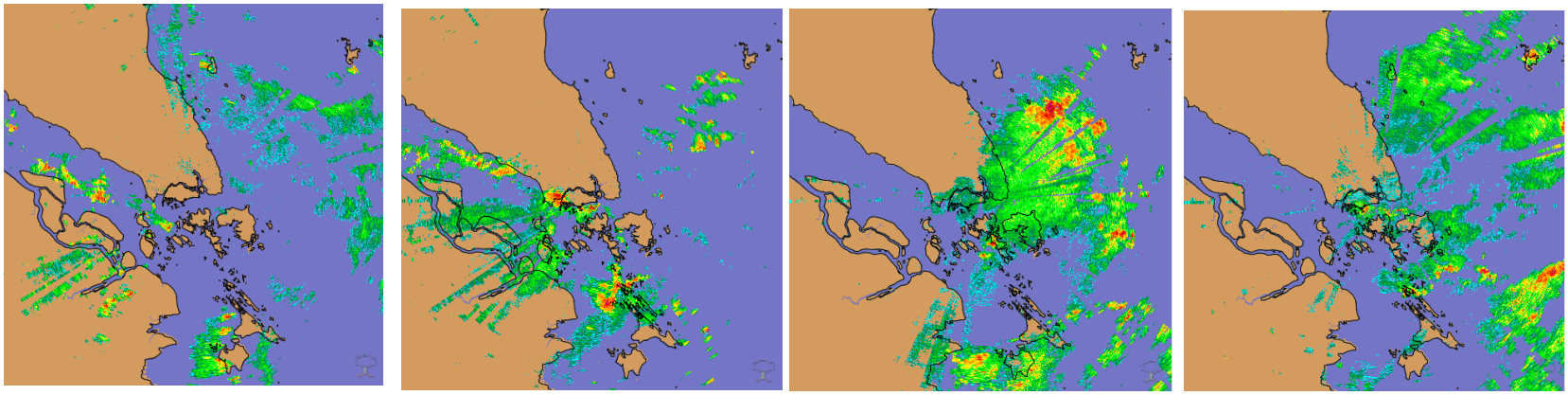
1 2 5 10 20 30 50

ECMWF Global Model (0.1 deg) - Deterministic



18 UTC 21 UTC 03 UTC 06 UTC

Weather Radar

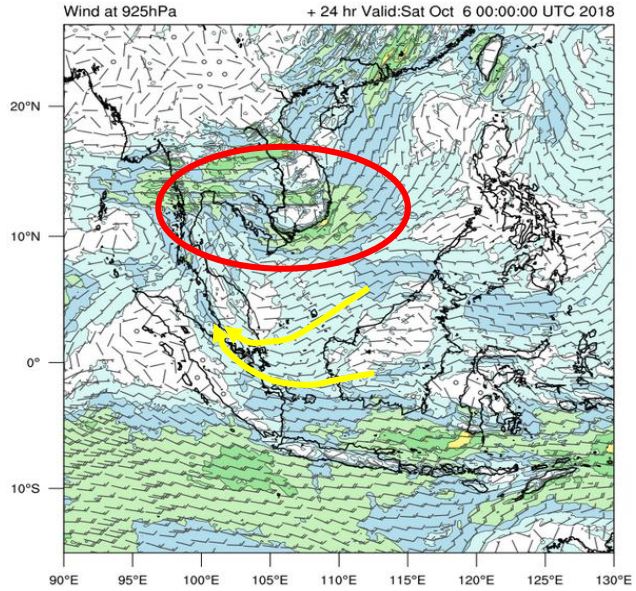


Case Study (2) - 6 Oct 2018 at 00UTC

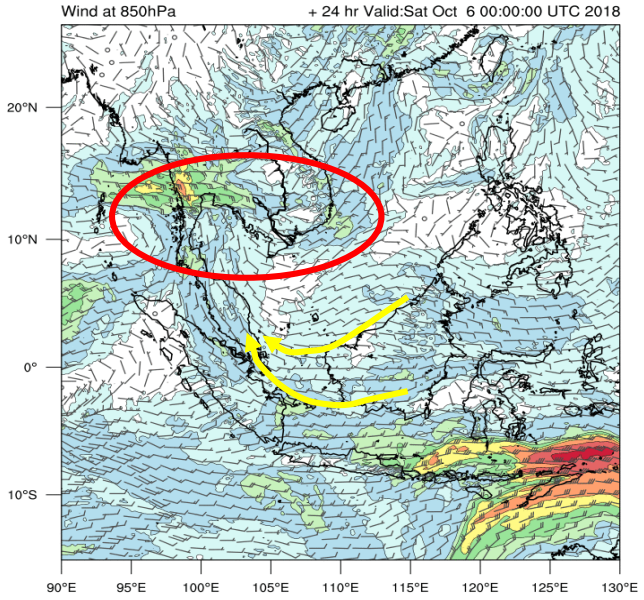
ECMWF Global (0.1 deg)

Analysis Winds

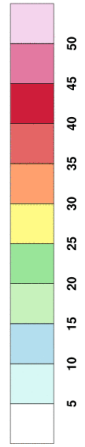
Winds at 925 hPa

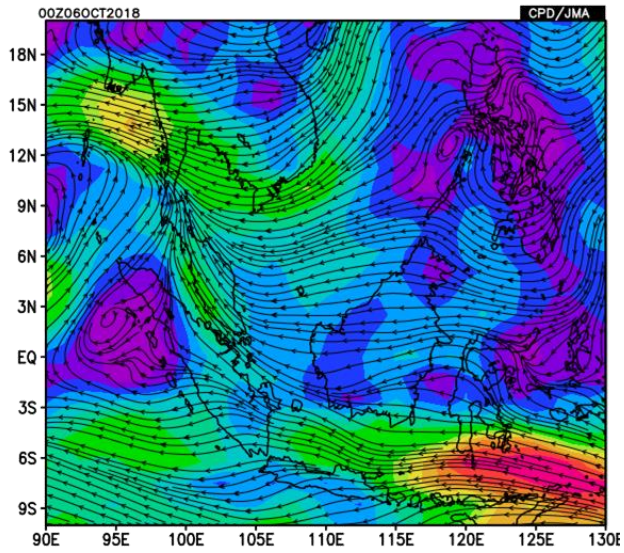


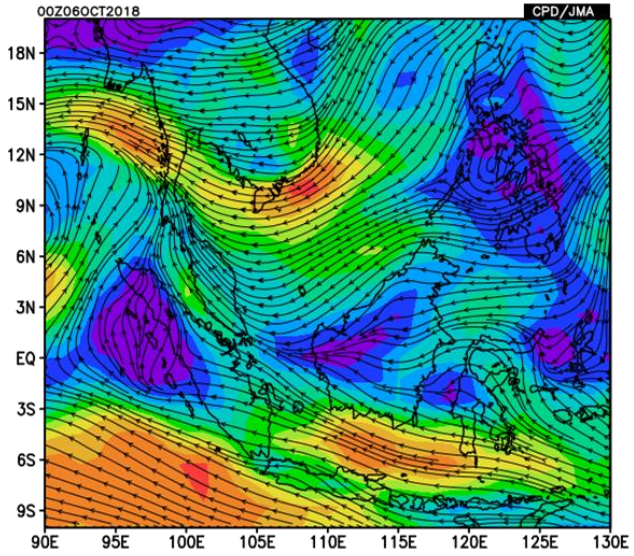
Winds at 850 hPa

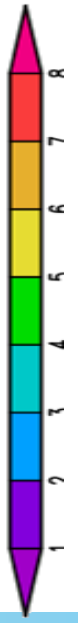


Wind speed in knots







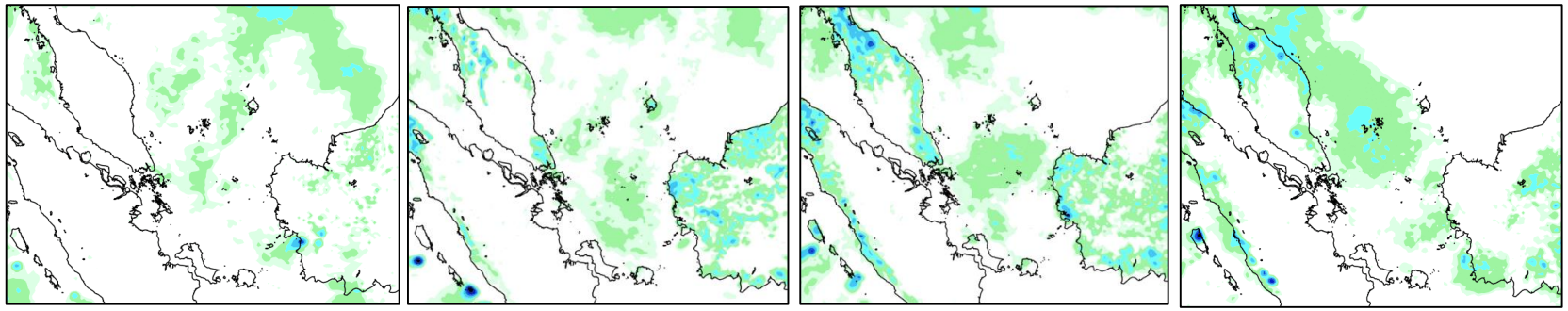


Case Study (2) - 6 Oct 2018

Total Precipitation

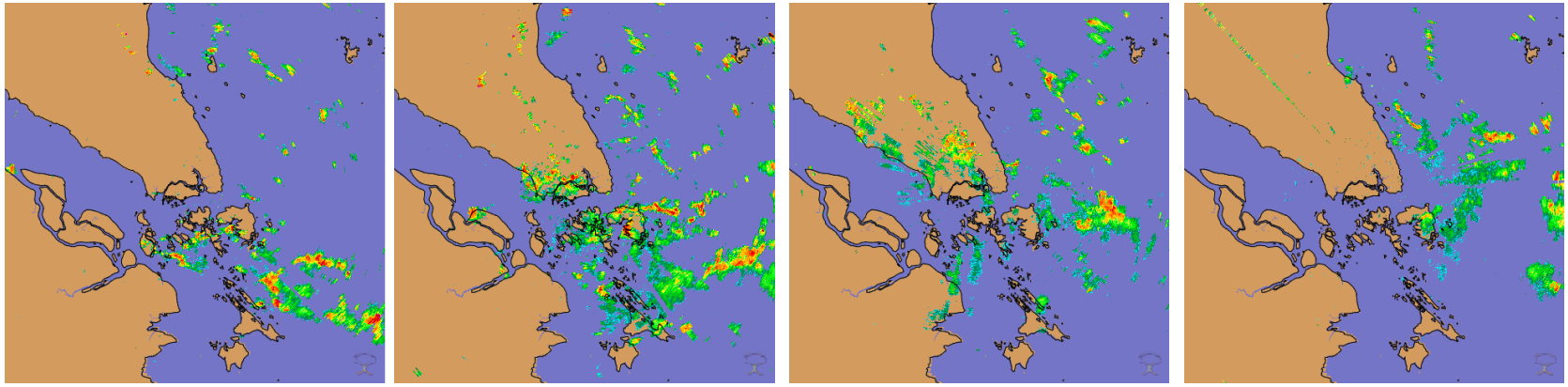
Rainfall
mm/3 hrs

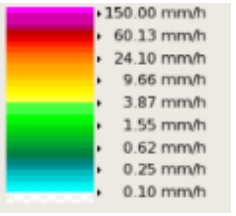
ECMWF Global Model
(0.1 deg) - Deterministic



03 UTC | 06 UTC | 09 UTC | 12 UTC

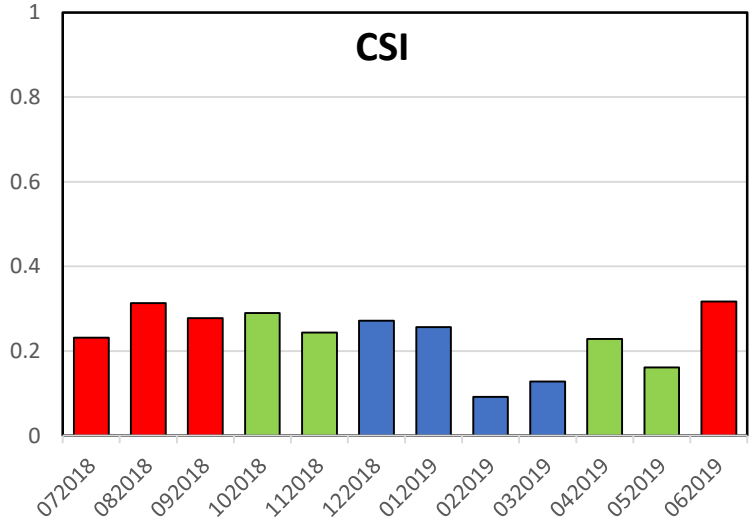
Weather Radar

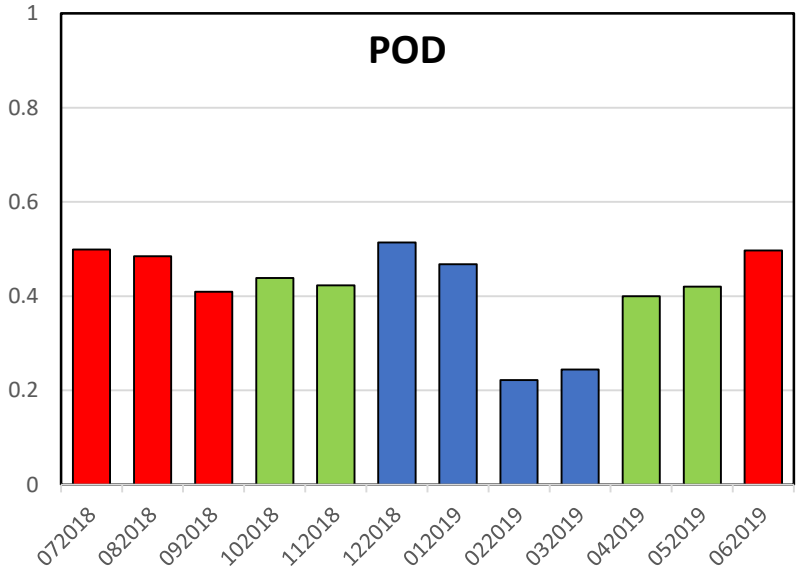


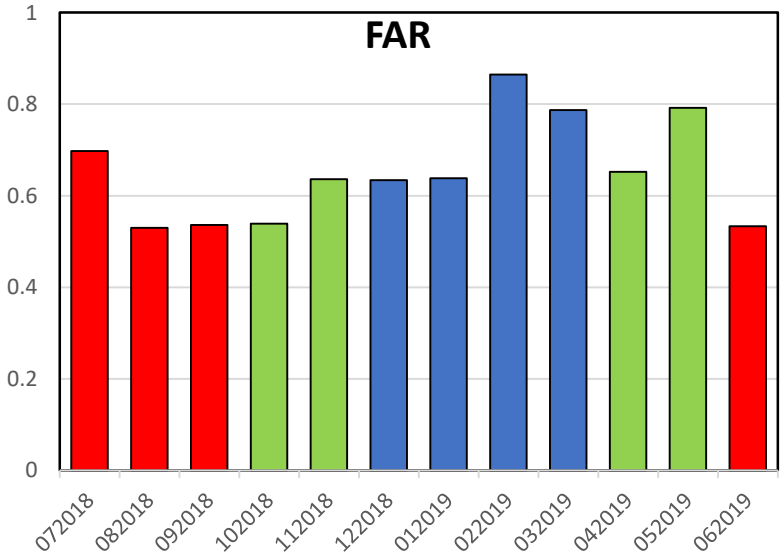


Performance of ECMWF Global Model

- Evaluation of forecast of precipitation for the FIR subsectors
  - Low CSI
  - Low POD and high FAR





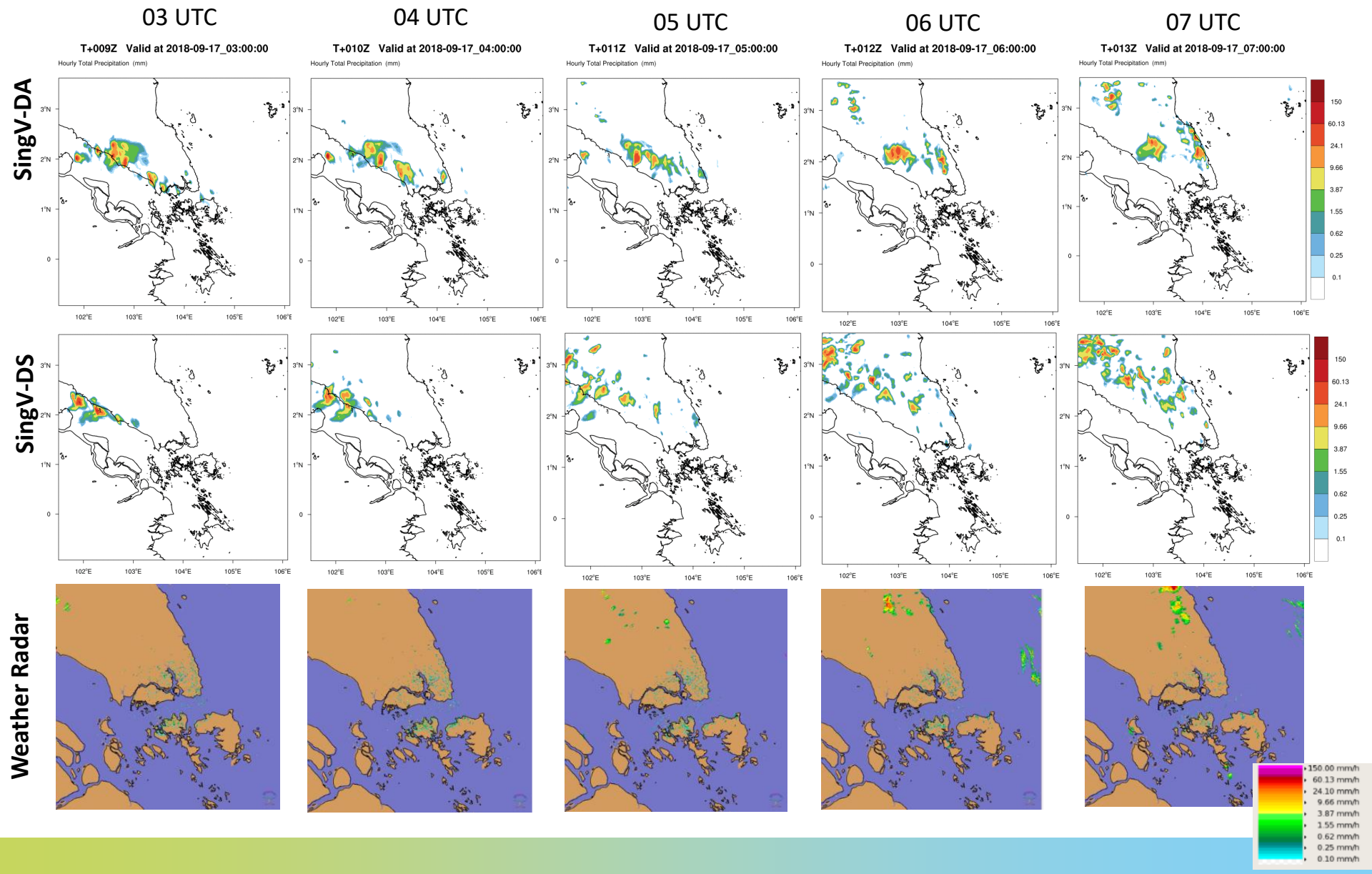


Review of SingV Model

- SingV Models (precipitation) used as forecast guidance for Operational Meteorologists to provide weather window forecast for Approach and Aerodrome
- Evaluation of mesoscale models in predicting precipitation
  - Similar performance for SingV-DS and SingV-DA
  - In general, FSS < 0.5
  - Reasonable skill in modelling diurnal heating influence on convection throughout the year
  - Able to give indications of intense events
  - Low skill in predicting the location and duration of intense convection

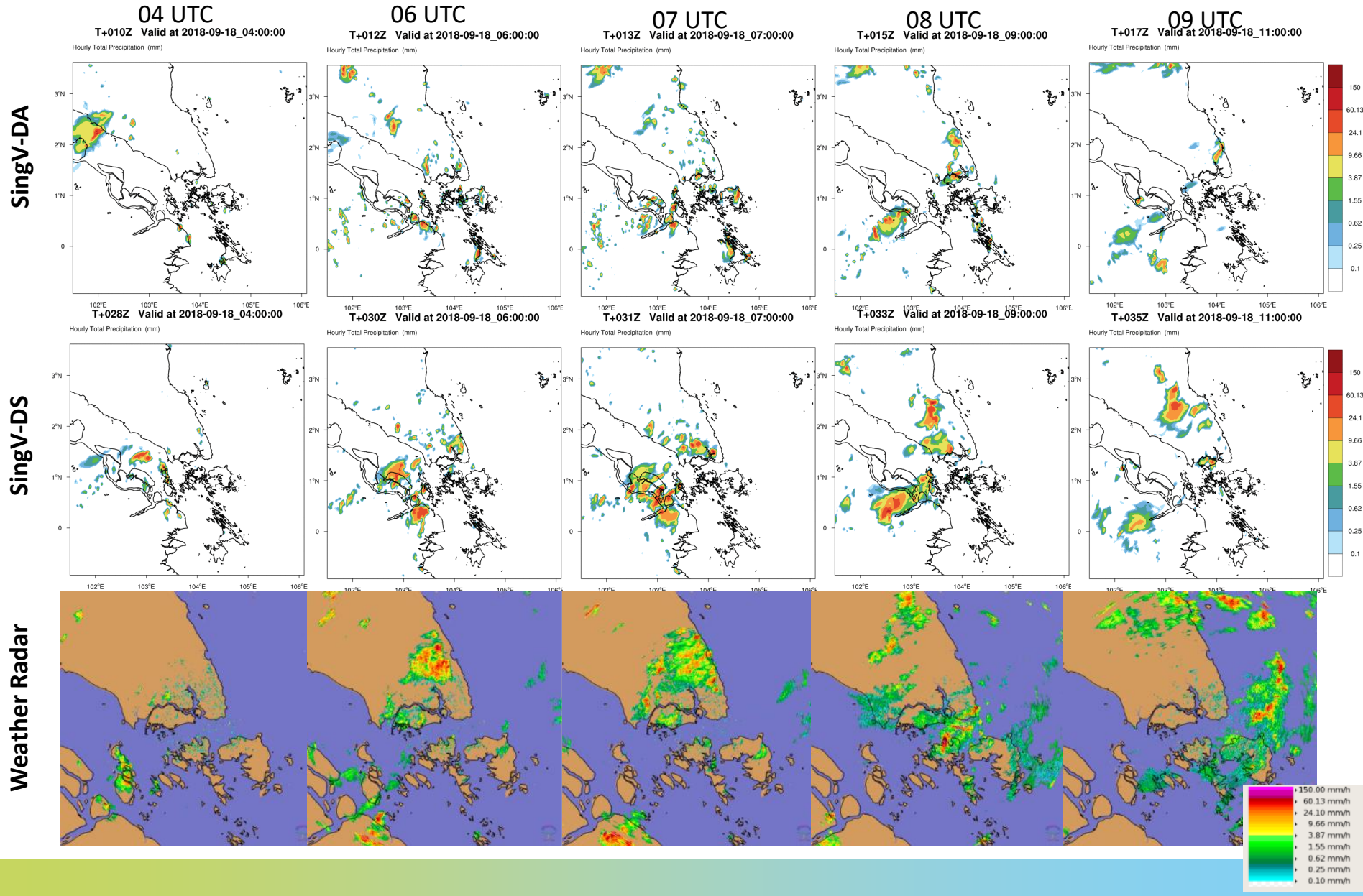
Case Study (3) - 17 Sep 2018

Total Precipitation



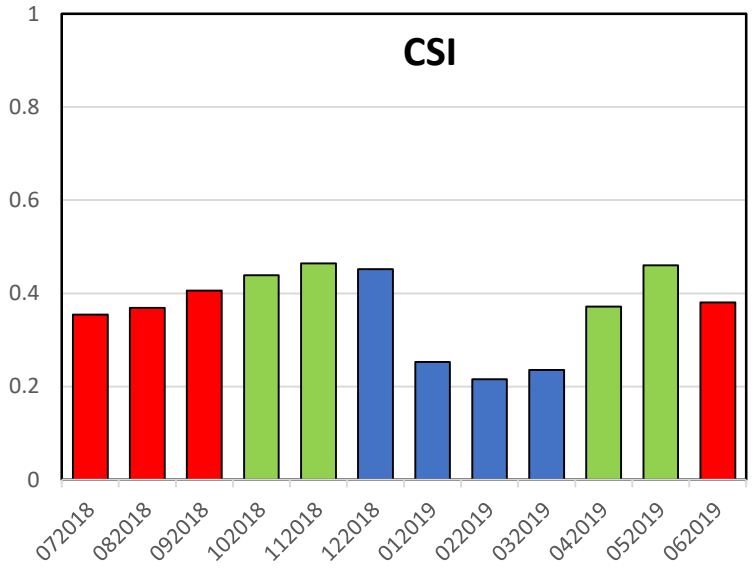
Case Study (4) - 18 Sep 2018

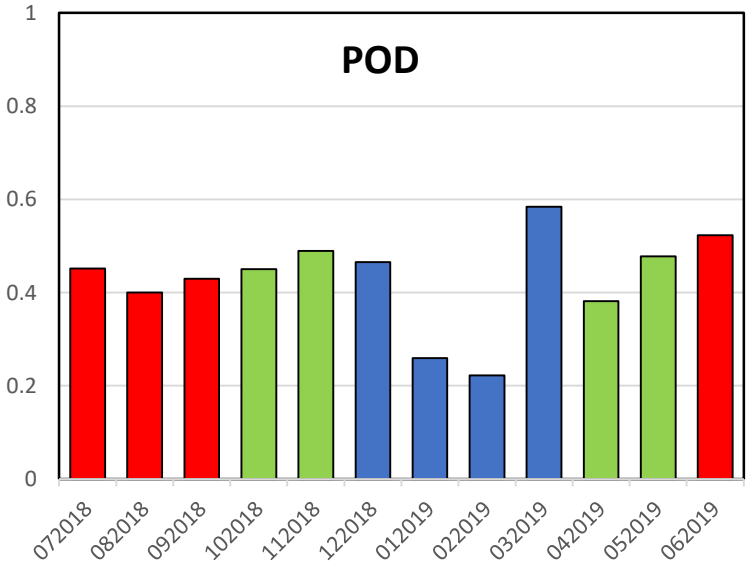
Total Precipitation

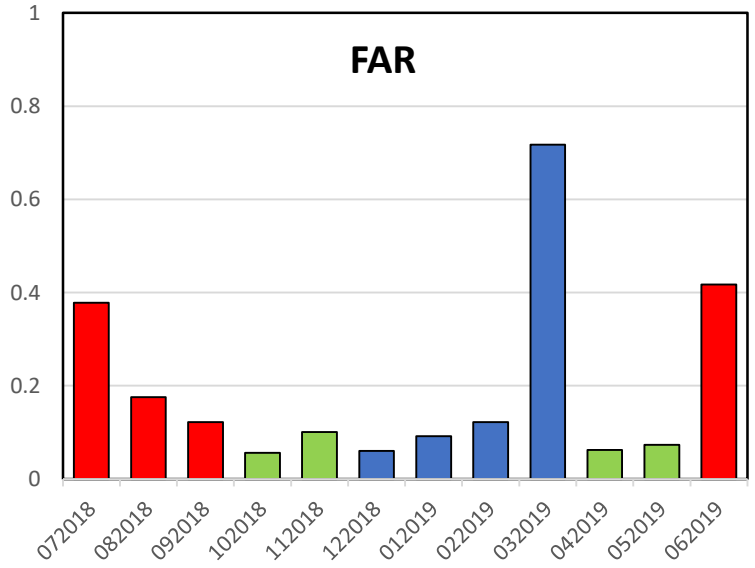


Performance of Mesoscale Models

- Evaluation of using precipitation forecast from SingV-DA and SingV-DS as **model guidance** for approach sector

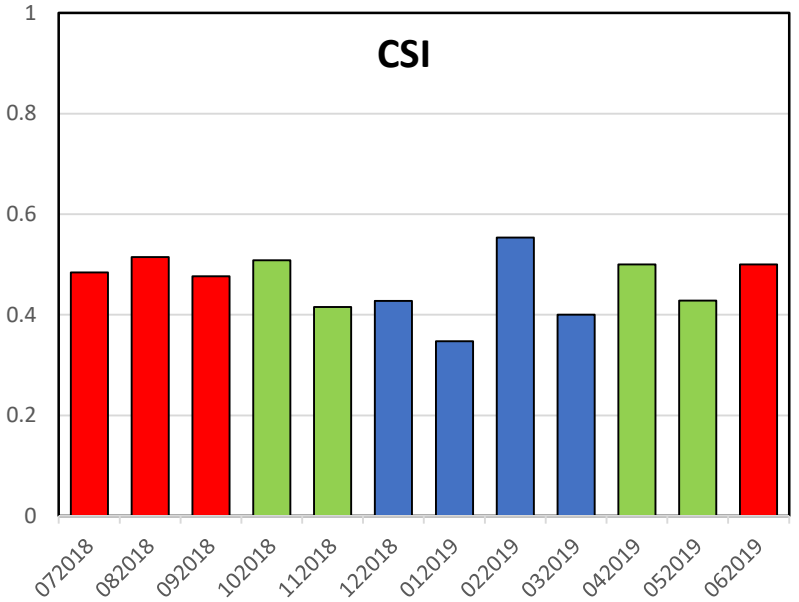


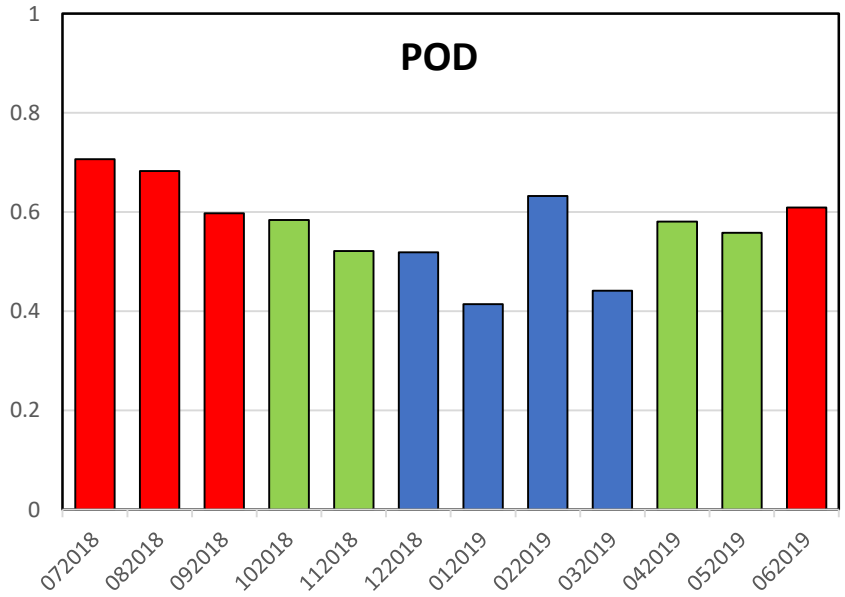


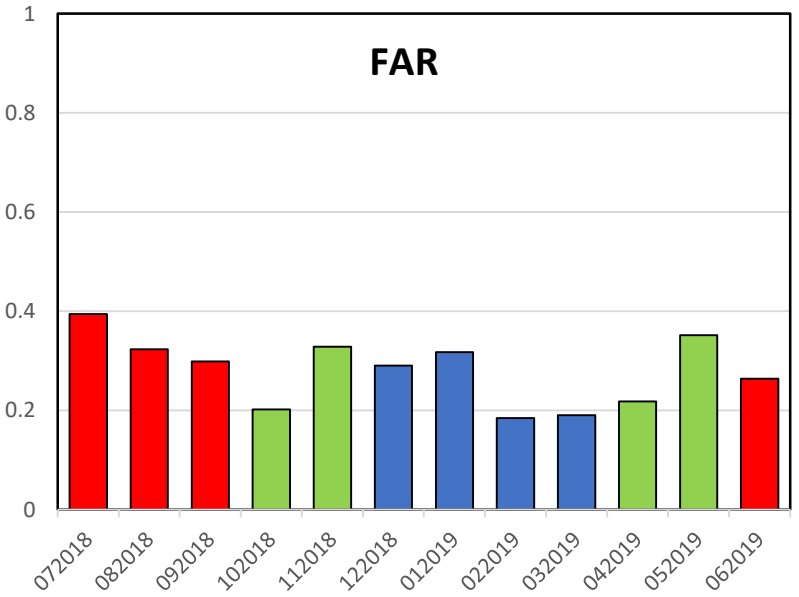


Performance of Mesoscale Models

- Evaluation of using precipitation forecast from SingV-DA and SingV-DS as **model guidance** for warning of TS for aerodrome (lead time of 30 min)







Conclusion

- Forecasting tropical convective thunderstorms is challenging
  - Not tenable to solely rely on NWP models
- Direct model output / auto-generation of forecast based on NWP models is not ideal
  - Presents too much uncertainty for users to plan strategically
- Requires interpretation by trained operational meteorologists
  - Human intervention is necessary in producing better forecast
- On-going research at MSS to improve the model's performance before advancing to Phase II

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