



**METEOROLOGICAL
SERVICE
SINGAPORE**
Centre for Climate Research Singapore

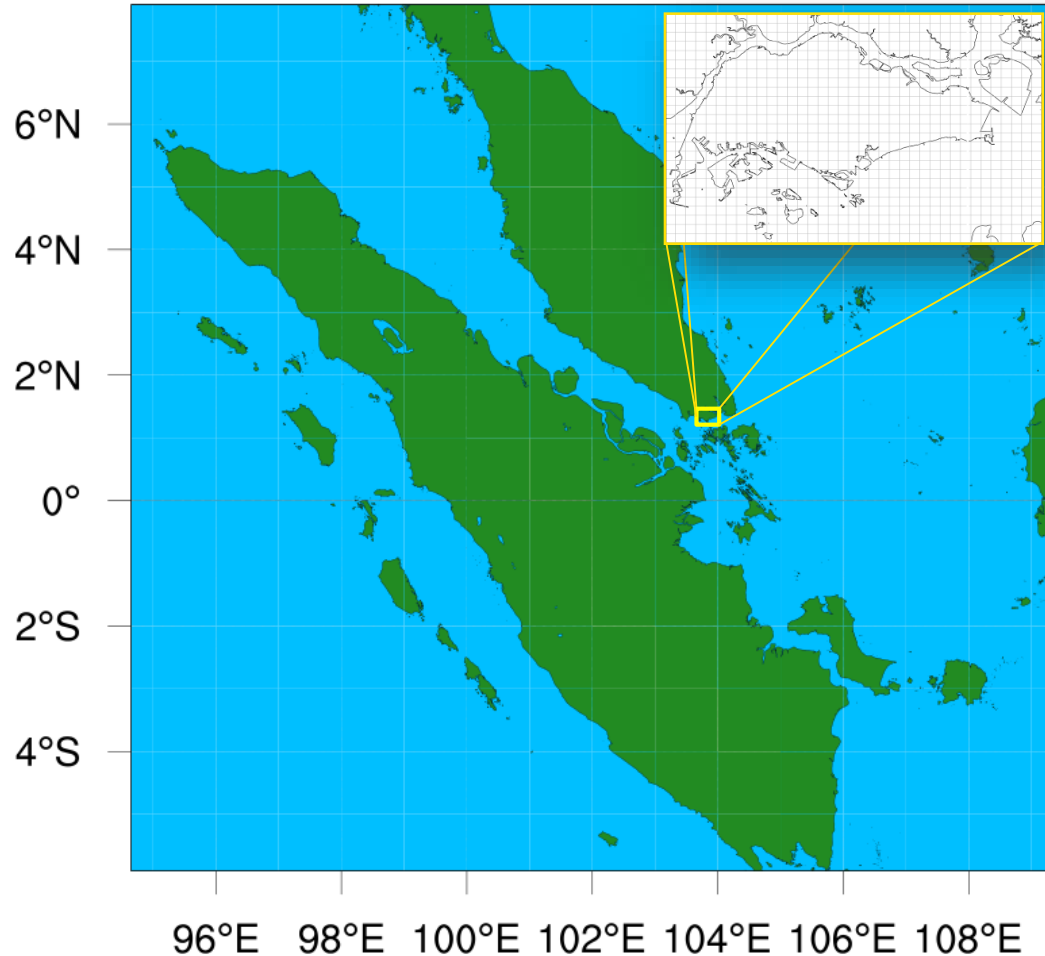
Towards a Nowcasting System for Meteorological Services Singapore

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Research Scientist

Introduction: Meteorological Services Singapore

NWP Domain



Singapore:

- 40/25 km across (1.28° N, 103.85° E)
- Tropics; Rainfall \approx 2500mm; Tmin \approx 24 °C; Tmax \approx 32 °C

Dense Observation Network:

- 60+ AWS; Total Lightning sensors; Lidar systems; Windprofiler; Upper air station; S- and C-band Dual-Pol Weather radars; Himawari-8 receiving station; etc.

NWP:

- Regional Setup of UM with a tropical configuration
- 1.5km Resolution
- DA 8 times a day



Distribution of Automatic Weather Stations across Singapore



Progress overview

Officially launched March 2013



2013

2014

2015

2016

2017

2018

2019

2020

SINGV configuration

Radar DA

SINGV v3.0

SINGV v4.0

SINGV v5.0

UM Partnership

SINGV NWC

**SINGV project
Regional UM**

Data assimilation (DA) capability

SINGV v4.1 Ensemble capability



Start of deep learning based radar nowcasting project

Initial version of the system in real time

Verification package and initial evaluation

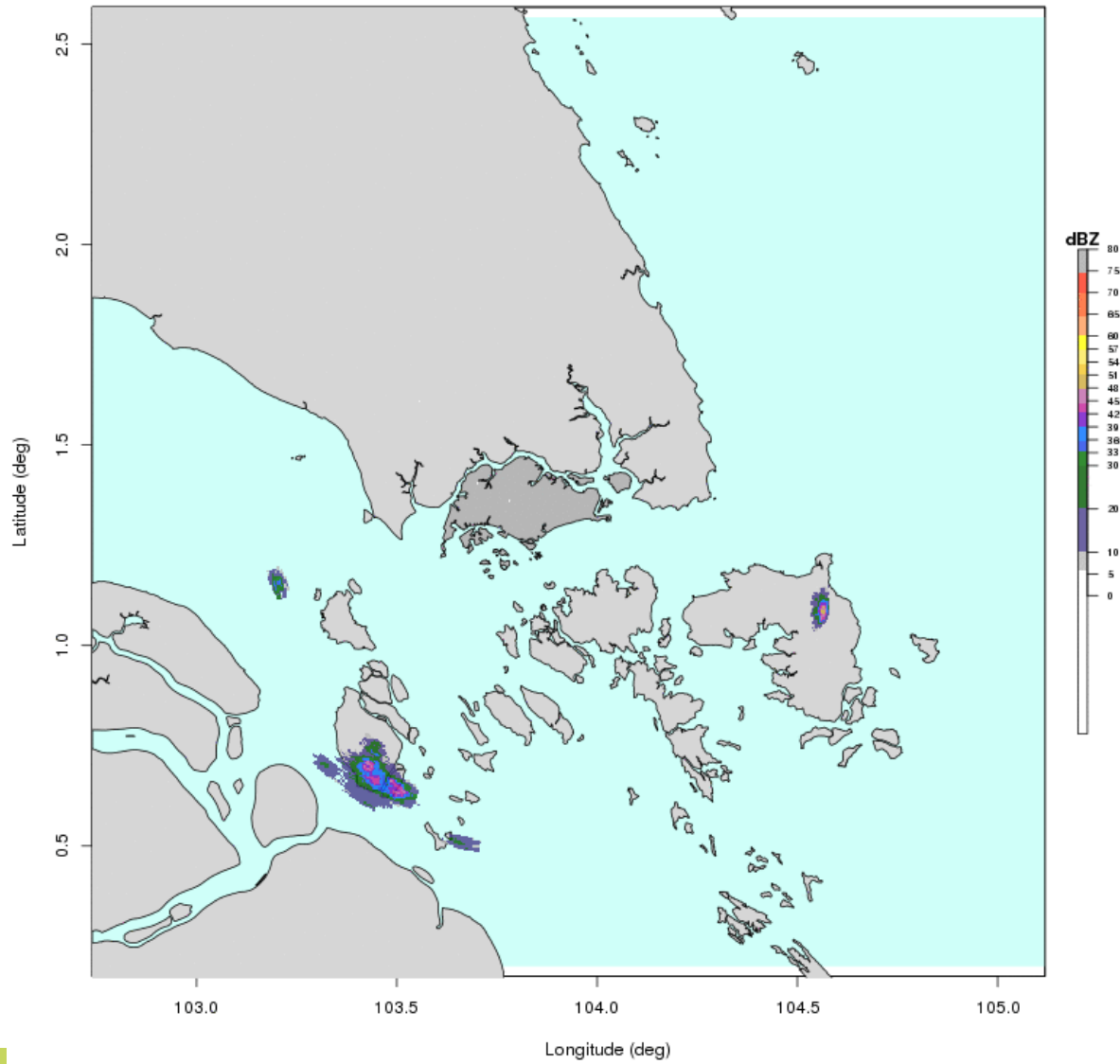
Full System evaluated

Revamp of Radar Processing System and test various techniques

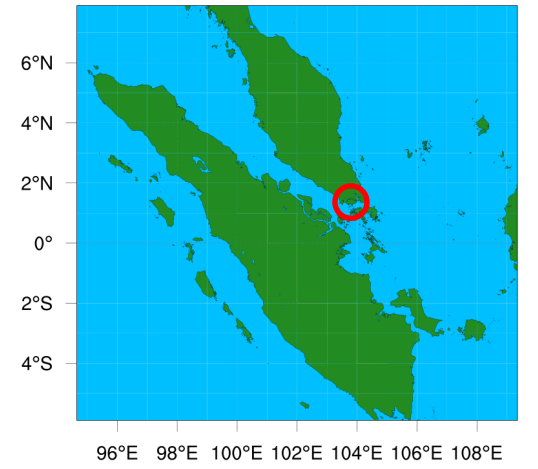
DA
QPE
QPF

Challenges

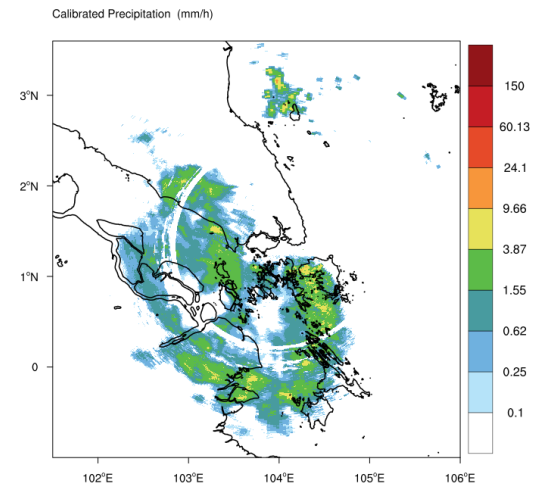
2019-04-10 02:30:00 - CMAX - LT: 2019-04-10 10:30:00



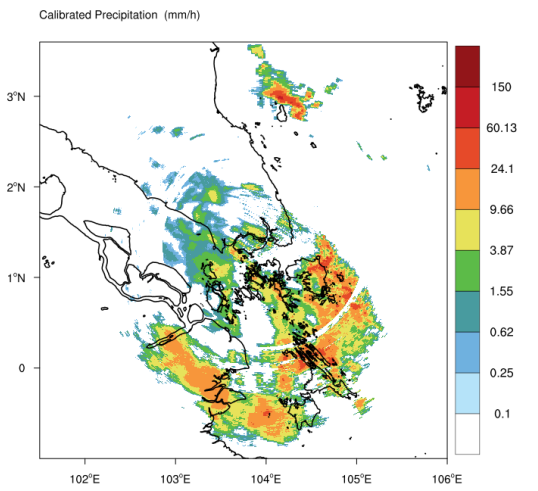
- Small scale and random behaviour of convective thunderstorms
- Limited area of observations



Radar Valid at 2017-01-03_21:00:00

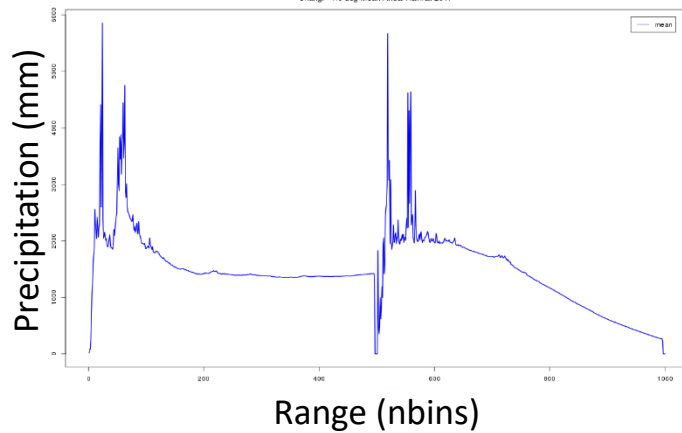


Radar Valid at 2017-01-03_22:00:00



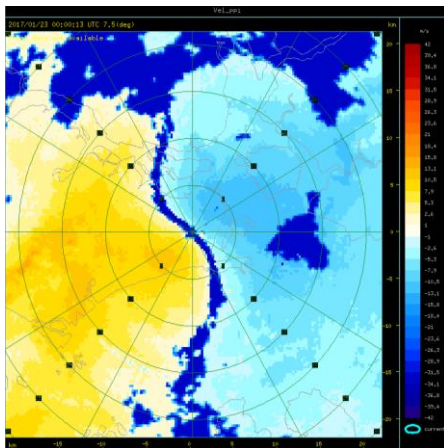
Radar Processing

Changi Annual Rainfall vs Range - 2017

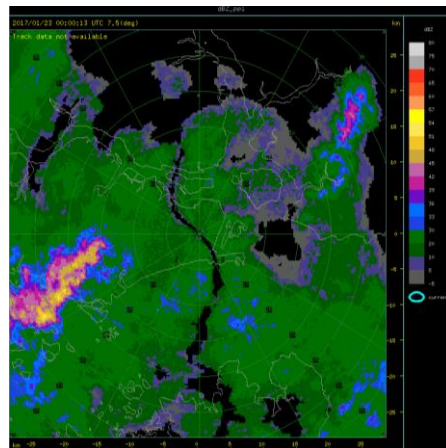


Changi PPI: 7.5°

Velocity



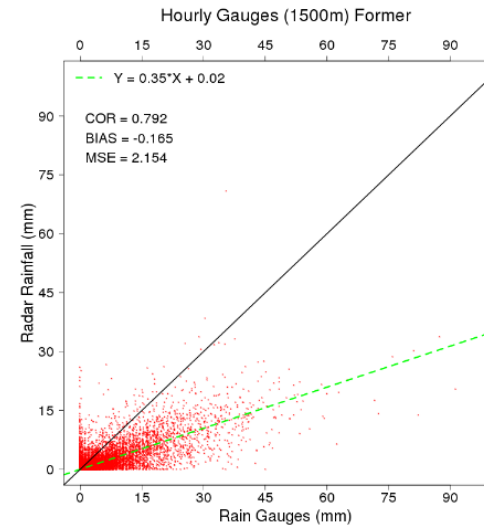
Reflectivity



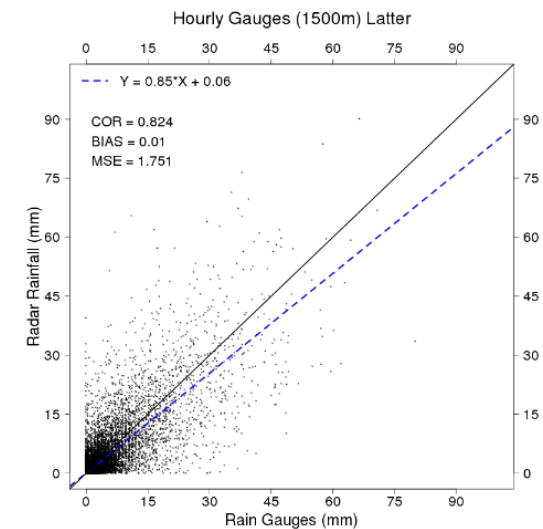
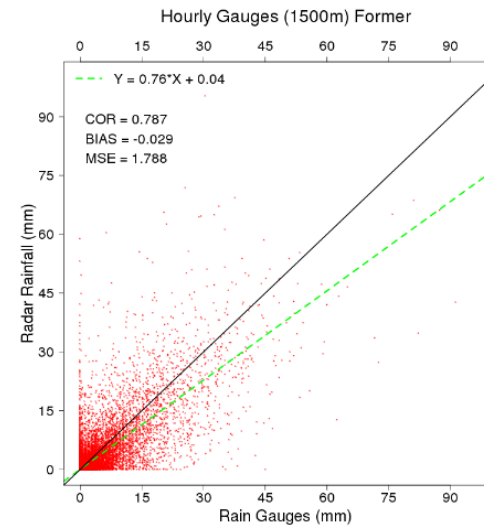
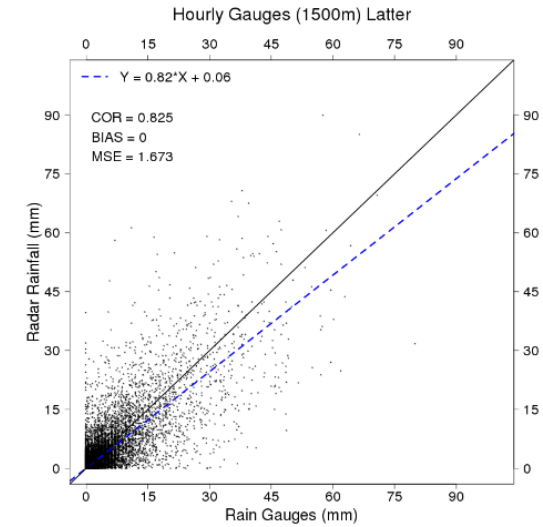
Scan Strategy Setup:

- Radar scan strategy optimized for short range, high resolution scans.
- Data is aggressively filtered on the Signal Processing side.

2017-01-01 → 2017-07-24



2017-08-02 → 2017-12-31

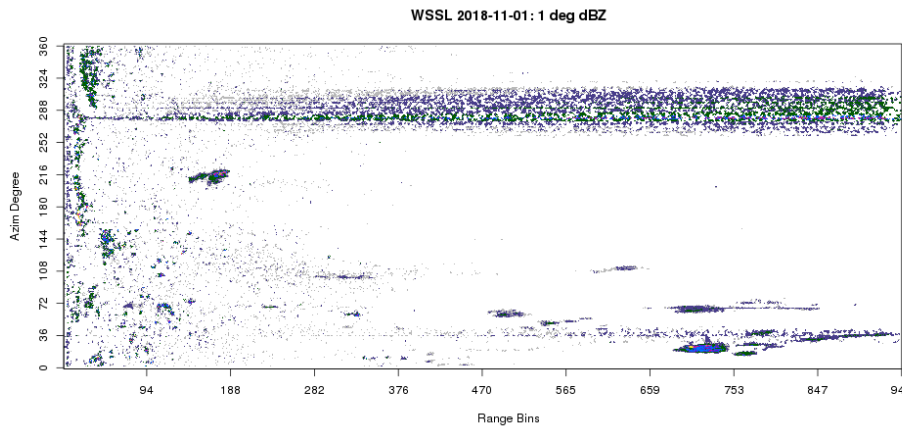


Quality Control

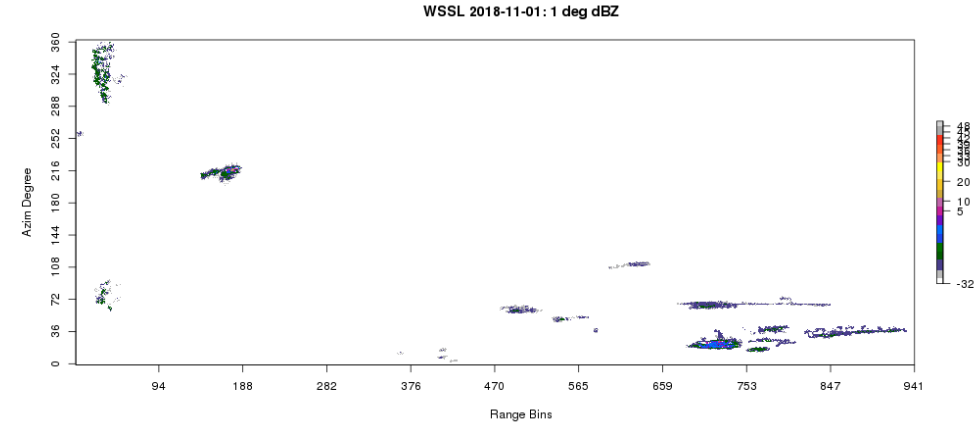
QC Filters Applied:

1. Cut second trip
2. Ships (rack)
3. Non-Met echoes (rack)
4. Speckle (pyart)
5. Threshold extremes
6. Gabella (wradlib)
7. Interpolate Missing Values (wradlib)

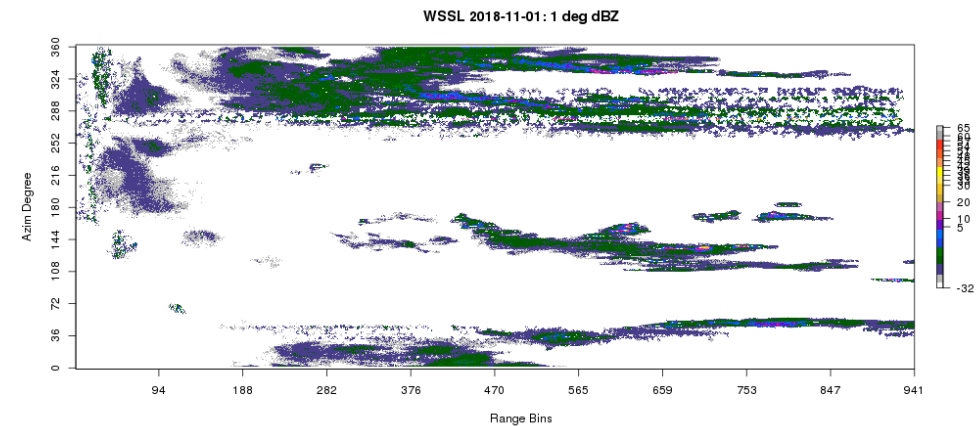
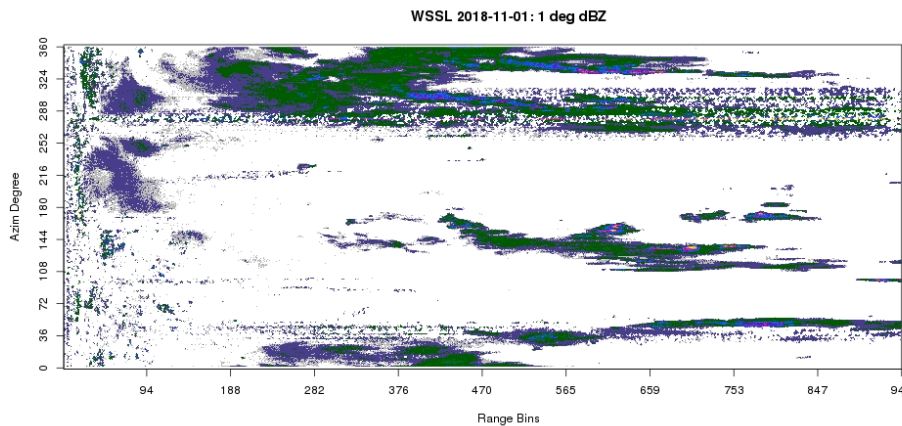
Unfiltered - DBZH



Seletar:1° Elevation



Filtered - DBZH

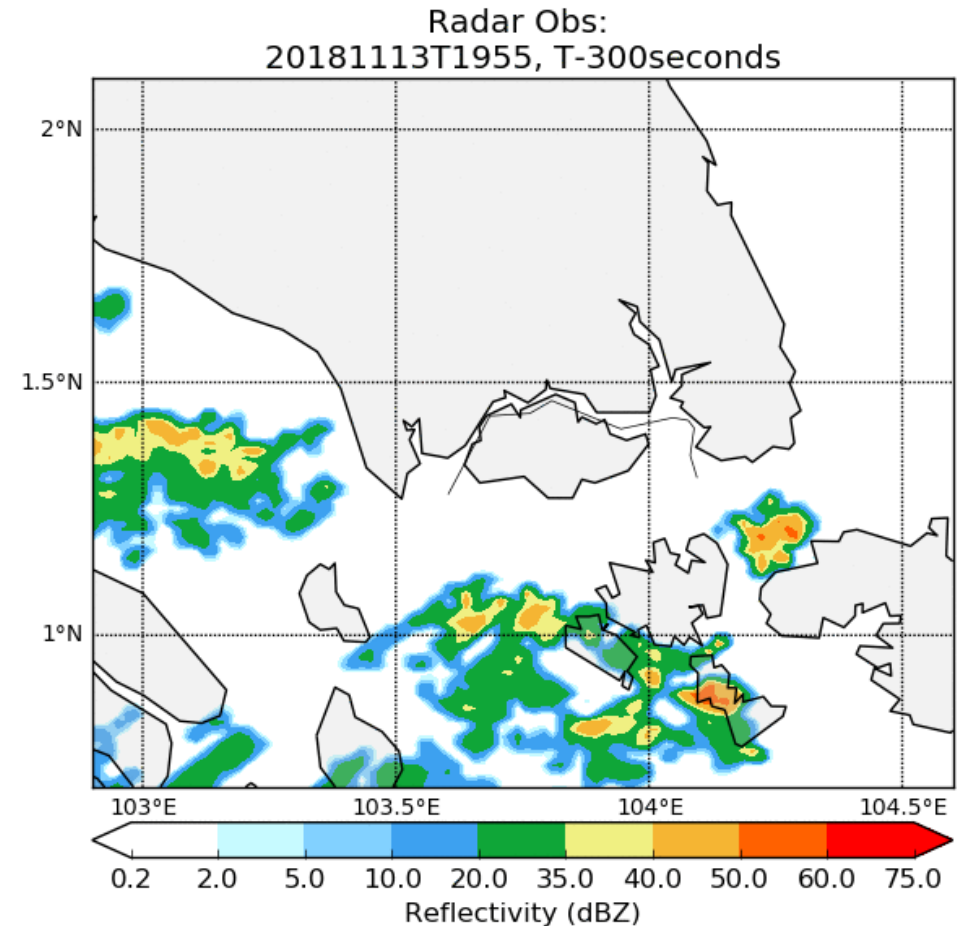


Interference filter active on Signal Processor

rack: baldrad.fmi.fi/software/rack/doc/rack/html/index.html
PyART: arm-doe.github.io/pyart/
wradlib: wradlib.org/tag/python

Artificial Neural Network Nowcaster (ANN-NCST)

- Nowcasting System based on [Artificial Neural Networks](#) (ANN) running in real-time since 2017
- Model Training data consist of the previous **10 radar frames** (i.e. previous 50min)
- Update frequency = 30 minutes
- Grid resolution = 2 km
- Valid forecasts usable at **T+15min** and onwards for forecaster
- Forecasts Range = 60 minutes
- Currently still running in a research mode



Subjective verification (WSD)

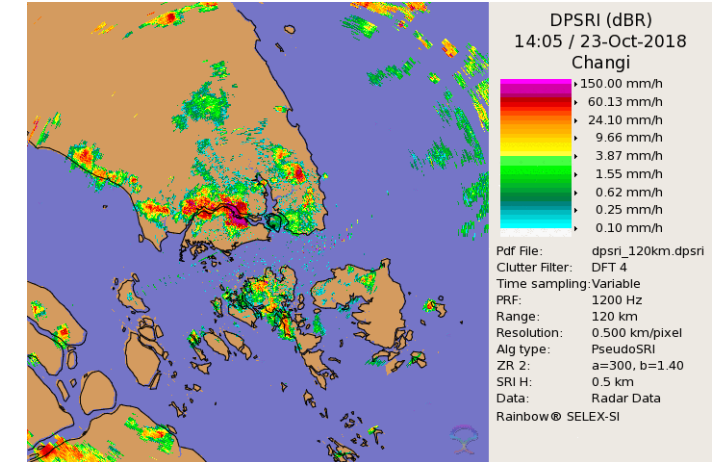
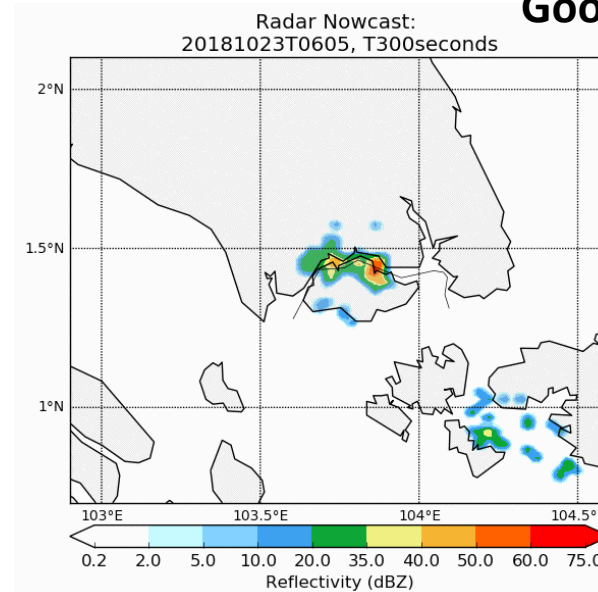
Heavy rain events over Singapore

- Intensity, Movement, Spatial Distribution

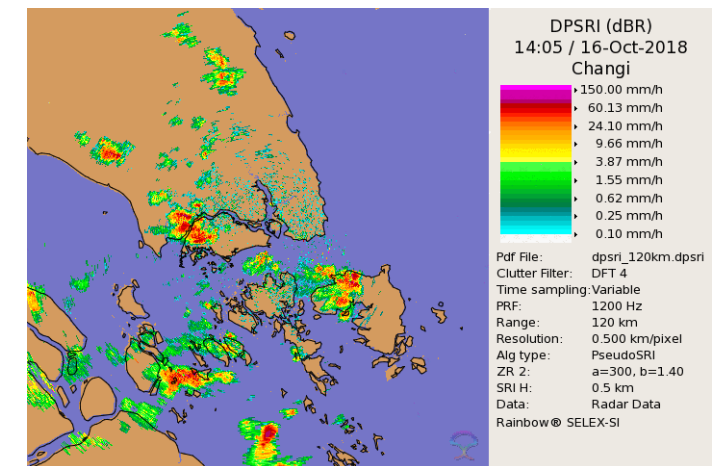
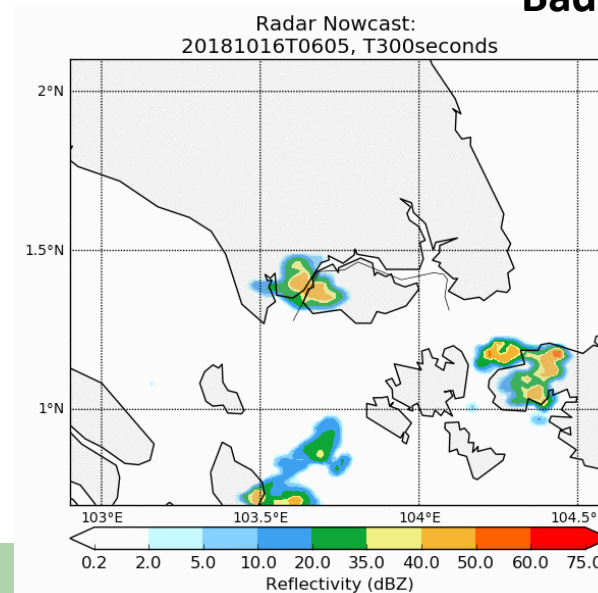
Heavy rain events:

- >35mm/30 mins. >50mm/hour
- Afternoon heavy rain events
- 28 events from October 2018 to January 2019

Good Case



Bad Case



Objective Verification Results

Fractional Skill Score vs lead time

Verification period:

- Six months Nov 2017 to Apr 2018
- Data quality and consistency.

Binary verification: (Intensity Thresholds)

- Fractional Skill Score (FSS)
- Performance Diagrams (POD, CSI, etc.)

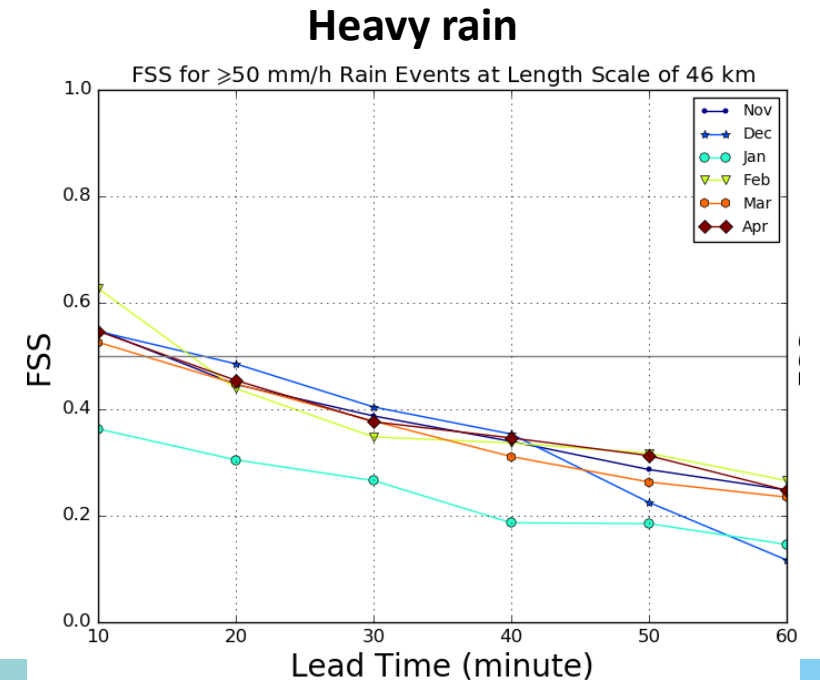
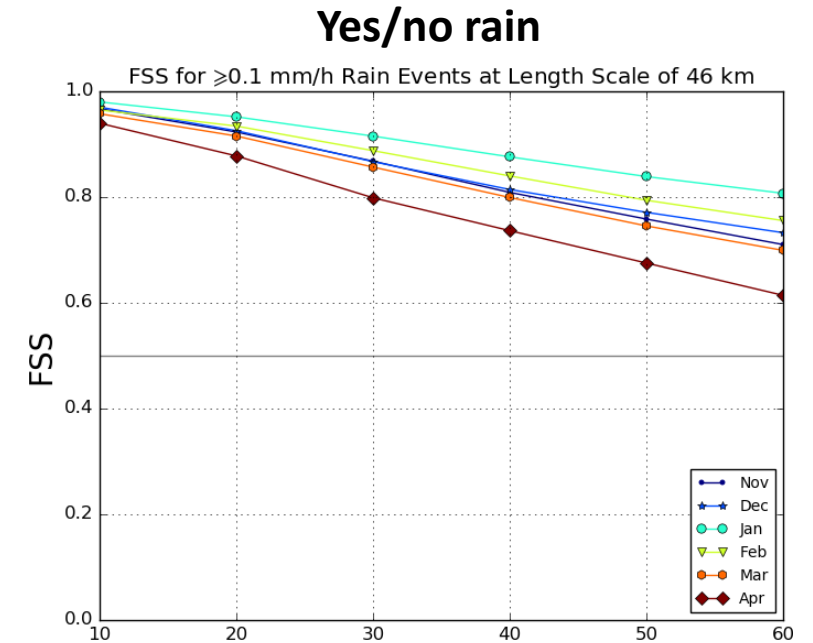
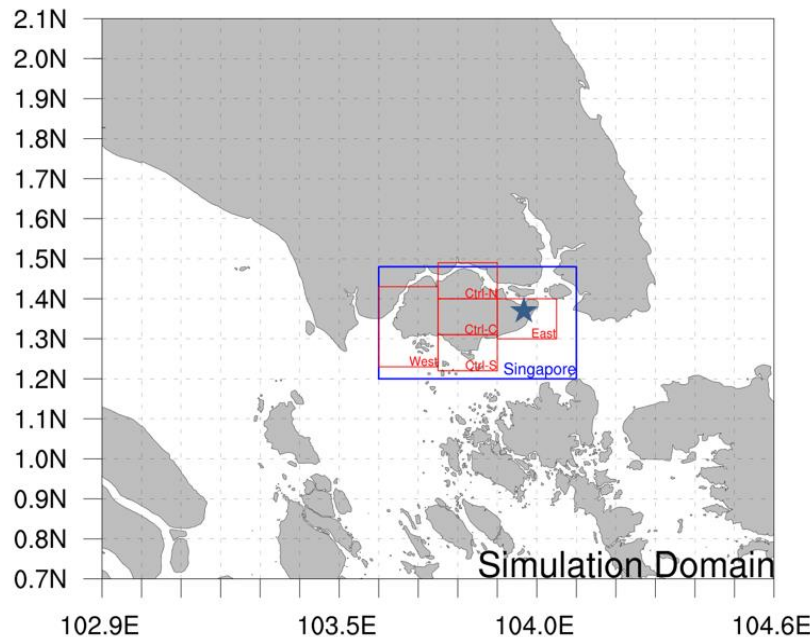
Objective Results (CCRS):

- Difficult to produce useful forecasts for events with rain rate exceeding 50 mm/h.
- However, there is some added value compared to climatology.
- The predictability gain due to large-scale forcing at < 10 mm/h.

Couple of known issues.

How can we Improve?

Evaluated against observed Radar



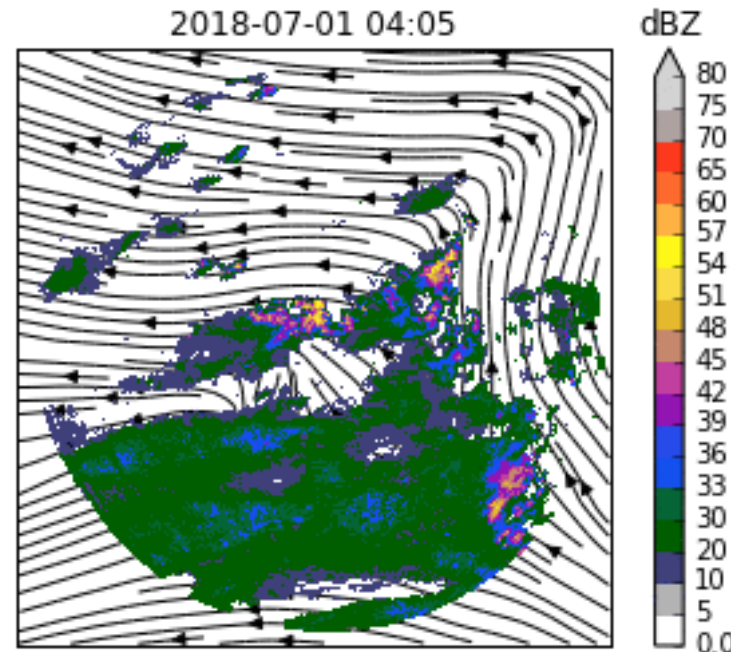
Nowcasting: Extrapolation with Optical Flow

Optical Flow Motion Estimates:

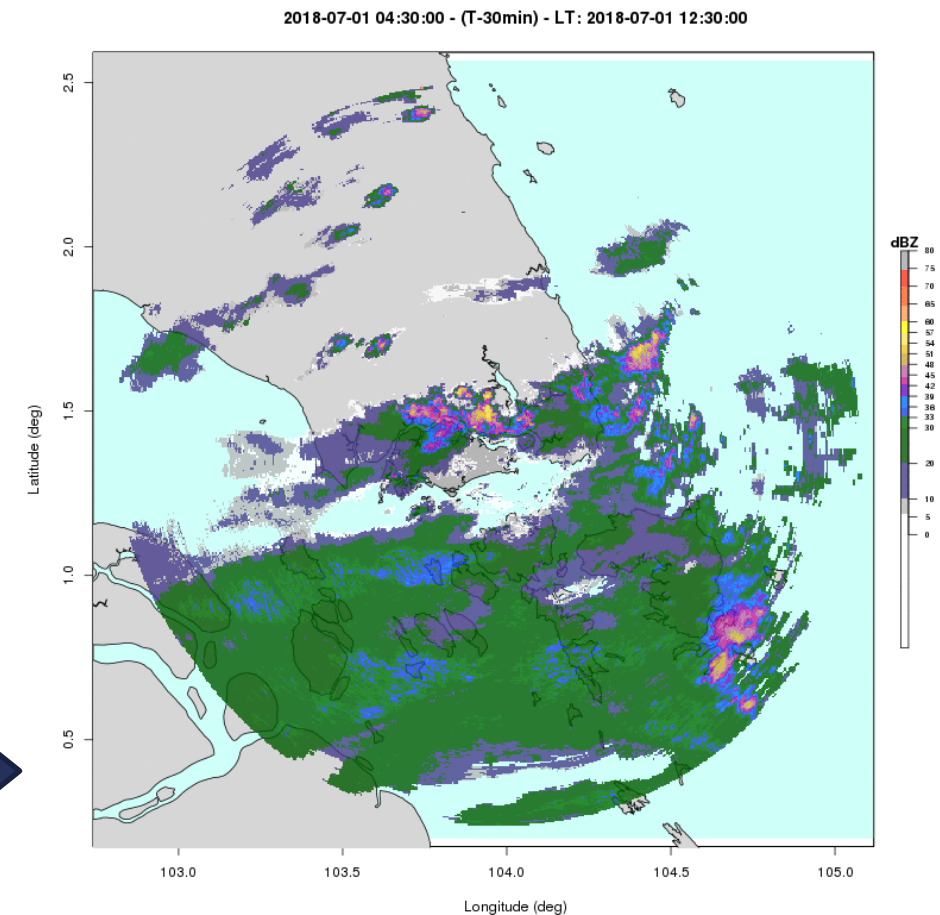
$$D_t Z = u \frac{\delta Z}{\delta x} + v \frac{\delta Z}{\delta y} + \frac{\delta Z}{\delta t}$$

- Valid for single time step:
2018-07-01 04:30
- Calculated using current and previous radar images
- Last 6 images are used to smooth erroneous vectors at storm and domain edges

Motion vectors at 0430 UTC



Extrapolation at 0430 UTC (T-30min – T+120min)



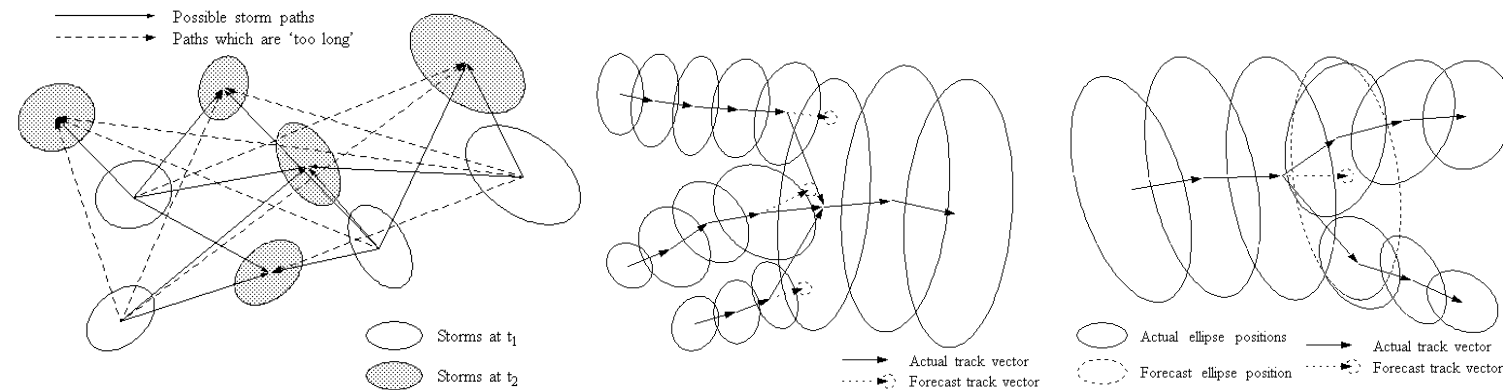
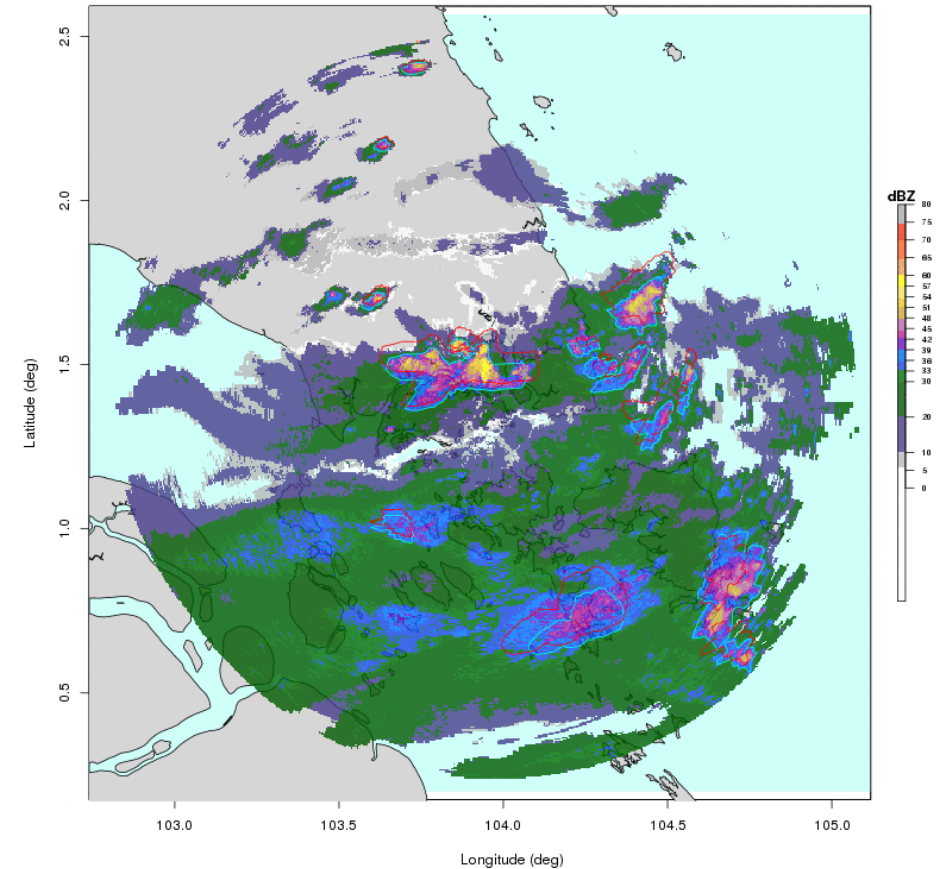
- Semi-Lagrangian persistence
2hr extrapolation
- 0430 UTC Optical Flow Vectors

Nowcasting: Cell Tracking

- TITAN tracking (NCAR).
- Convective storm classification.
- Matching using overlaps and optimization.
- Handles storm merging and splitting.
- Forecasts = Linear Trend
- Cascading for larger features

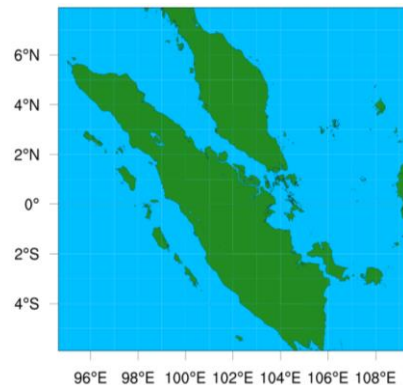
TITAN cell tracking at 0400 UTC – 0500 UTC (30min forecast track)

2018-07-01 04:00:00 - TITAN cell tracking (+30min) - LT: 2018-07-01 12:00:00



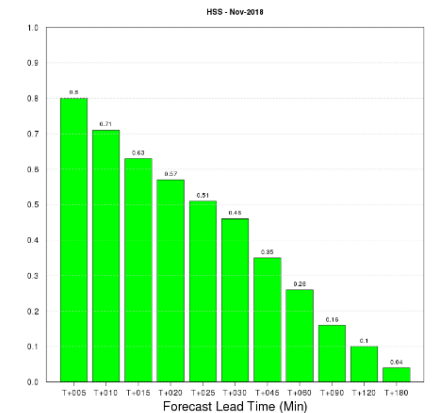
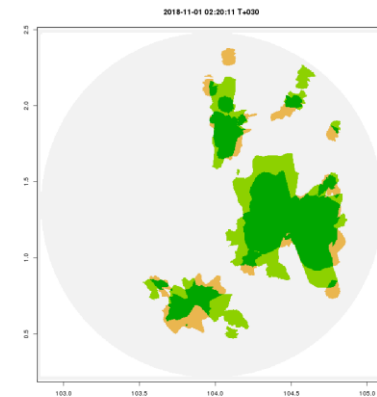
Final Remarks: Nowcasting for 2019 and beyond

- Setup SINGV-DA Nowcasting run:
- Geared more towards a nowcasting setup:
 - 3D-VAR
 - Hourly cycle (Warm start)
 - Data Assimilation:
 - Himawari-8 radiances [AMV's]
 - Radar derived rain-rates [Radial Velocities]
 - Forecast range up to 6 hours



- Explore NWCSAF (Himawari-8)
 - CI
 - RDT

- Test various nowcasting tools and techniques.
 - Setup TITAN, Optical Flow, SWIRLS, pySTEPS.
 - Utilise spatial verification (FSS, MODE, etc.)
 - Categorise by weather regimes (Hassim & Timbal, 2019)
 - Developing storm climatology (collaborating with WSD)



- **Work towards 0 – 6 hour blended product**

Thank You

Questions?



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