

# HKO Nowcasting System Community SWIRLS (Com-SWIRLS)

Wang-chun WOO

WMO VCP Workshop on MET-ATM Integration under the Joint  
CAS/CAeM Aviation Research Demonstration Project (AvRDP)

10 Oct 2018, Hong Kong Observatory

# SWIRLS – HKO Rainstorm Nowcasting System

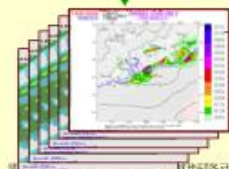
## 電腦模擬大氣物理過程 Computer Simulation of Physical Processes in the Atmosphere



遙感及常規天氣觀測資料  
Remote-sensing and  
conventional weather  
observation data

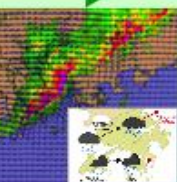


高分辨率風暴模式，直接模擬未來  
15小時雨雲的演變過程  
High-resolution storm model to  
directly simulate the evolution of  
precipitating clouds up to 15 hours  
ahead

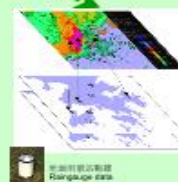


電腦生成未來15小時模擬降雨預測圖  
Computer-generated forecast rainfall  
maps for the next 15 hours based on  
simulation

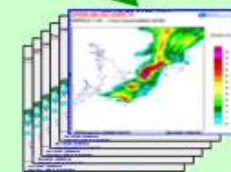
## 雷達追蹤、分析及預測 Radar Tracking, Analysis and Forecast



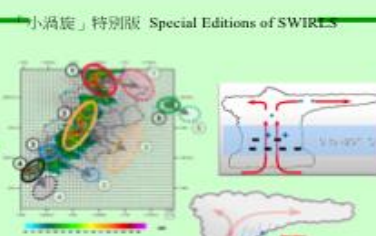
利用雷達自動追蹤及估計雨帶的移動路徑  
Automatic tracking and  
prediction of  
rainband movement  
from radar



利用密集的雨量站數據，  
實時訂正雷達探測降雨率  
Real-time calibration of  
radar-detected  
rainfall rate using the  
dense raingauge  
network



電腦製作未來1至6小時的雷達降雨預測圖  
Computer-generated forecast rainfall maps up to  
6 hours ahead based on radar



「小渦旋」特別版 Special Editions of SWIRLS  
強風暴系統識別及雷達特徵分析  
Cell identification and radar  
signature analysis for severe  
storms



電腦製作狂風、閃電、冰雹及大雨  
預測圖  
Computer-generated forecast map of  
squalls, lightning, hail and heavy rain

## 臨近預報產品及服務 Nowcast Products & Services

支援國際盛事  
In support of Important International Events

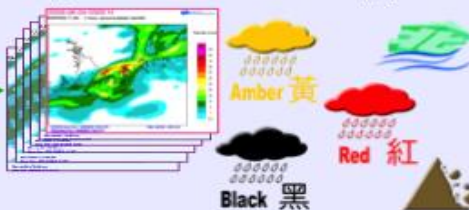


支援雷暴警告系統  
In support of Thunderstorm Warning System

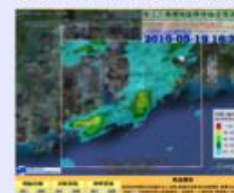


支援暴雨及相關警告系統  
In support of Rainstorm and Related Warning Systems

融合雷達臨近預報及電腦模擬  
結果的未來1至6小時雨量預測圖  
Forecast rainfall maps up to 6  
hours ahead blended from radar  
nowcast and computer simulation  
results



「珠三角」降雨臨近預測圖在天文台網站公開發放  
Public dissemination of nowcast rainfall maps for the Pearl  
River Delta region via HKO Internet website



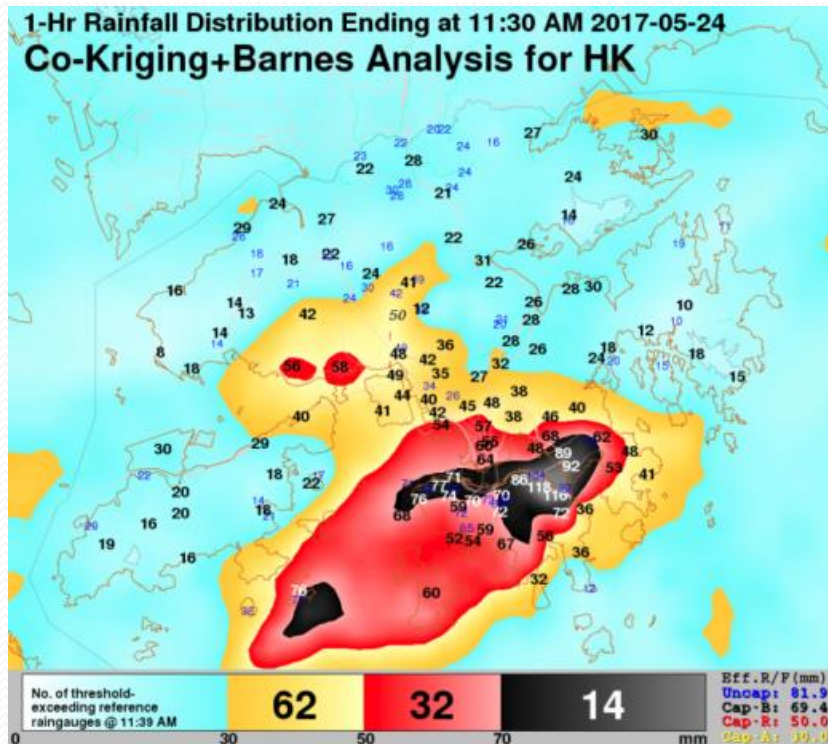
降雨預測資料透過四維立體地圖  
顯示  
Forecast rainfall information  
visualized with 4-dimensional map  
of the globe



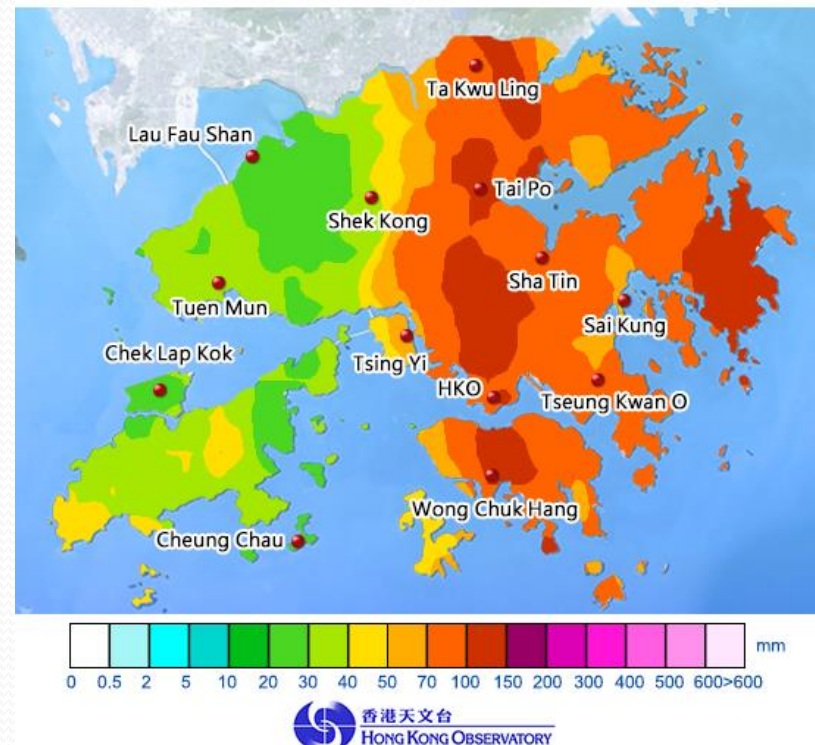
# QPE Products in SWIRLS

For Forecasters

For the Public



Total rainfall on **28-Aug-2017** (based on rain gauges and radar data)



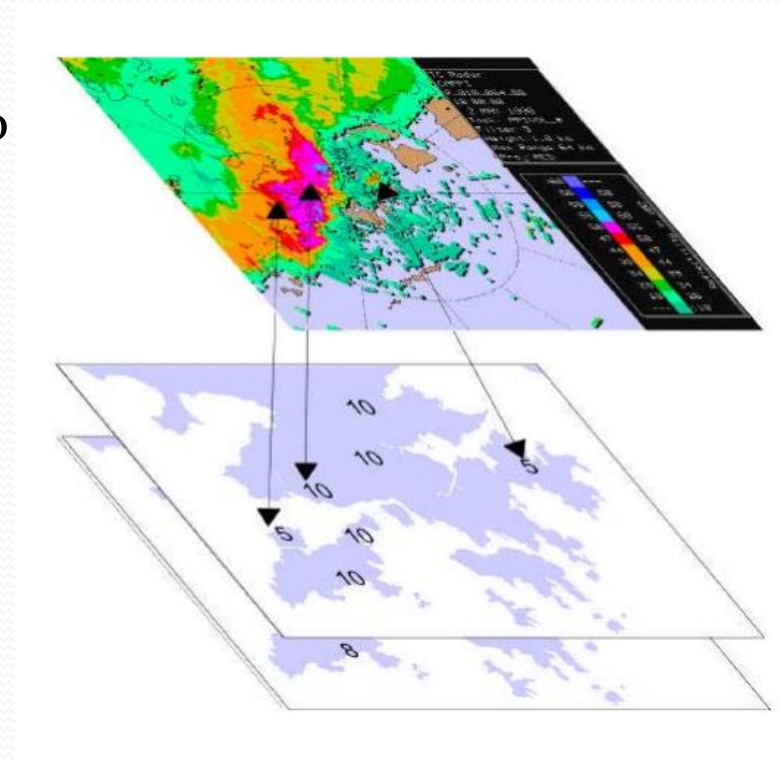
# QPE – Rainfall Calibration Module

- Schematic diagram showing the calibration of radar reflectivity using real-time raingauge measurement.
- Z-R relation for converting reflectivity to rainfall rate

$$Z = aR^b$$

$$dBZ_i = b \text{ } dBG_i + 10\log(a)$$

- Gridded rainfall analysis computed by Barnes successive correction or more advanced co-kriging algorithm



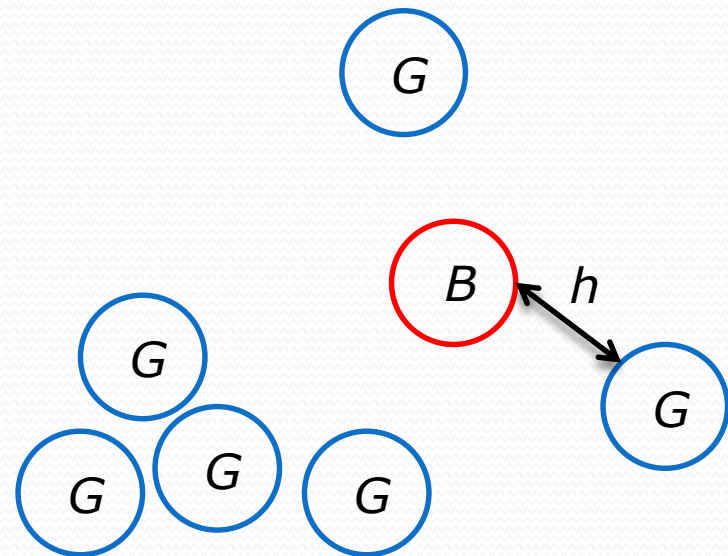
# QPE - Barnes Analysis

- grid-point analysis by Barnes method
  - ➔ interpolation with Gaussian weighting according to distance between data & estimation point
  - ➔ consider correction using residuals and grouping of rainguages

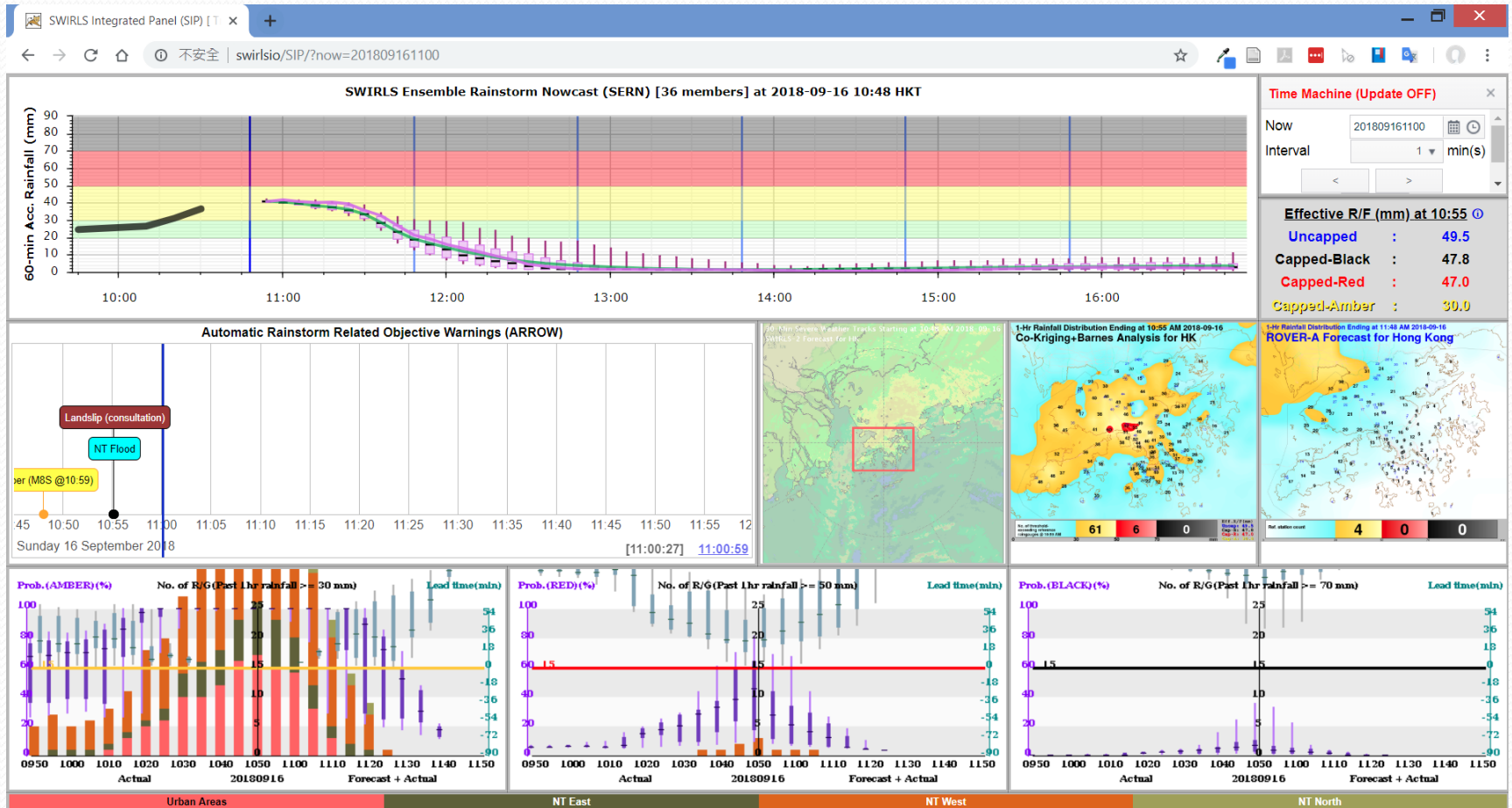
$$B(x_0) = \frac{\sum_{i=1}^{N_0} w_i G_i}{\sum_{i=1}^{N_0} w_i}$$

$$w_i = \exp\left(\frac{-h_i^2}{L^2}\right)$$

$B$  : barnes estimation (mm)  
 $L$  : radius of influence  
 $N_0$  : number of gauge report  
 $G_i$  : i-th gauge report (mm)  
 $w_i$  : weight of i-th gauge  
 $h_i$  : distance between gauge and estimation point

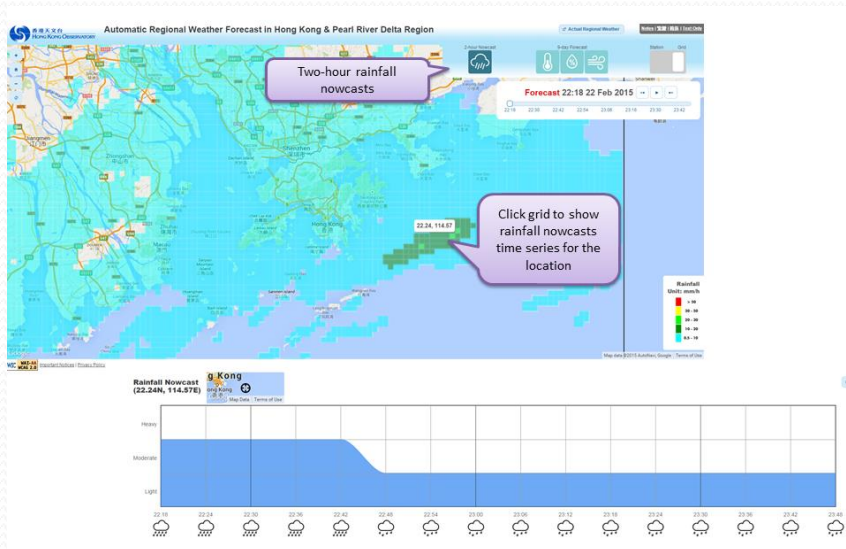


# QPF (Quantitative Precipitation Forecast) For Warning and Forecast Operations

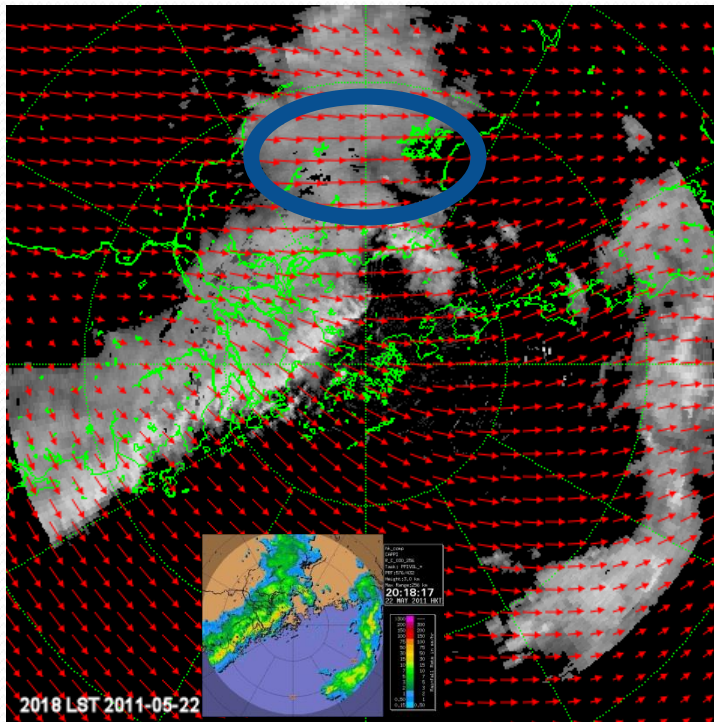




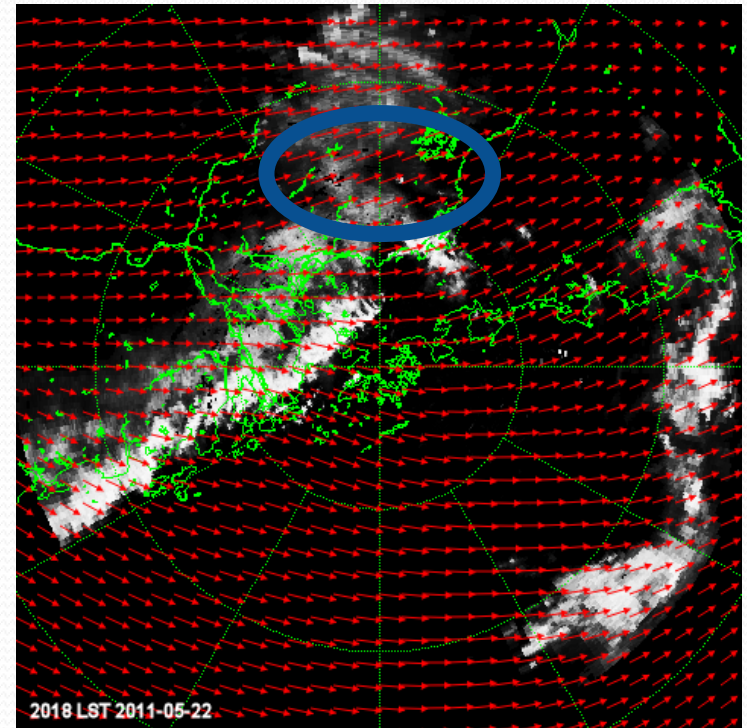
# QPF (Quantitative Precipitation Forecast) For Public Weather Services



# QPF - Pre-processing of Radar Data



Original (linear in dBZ)

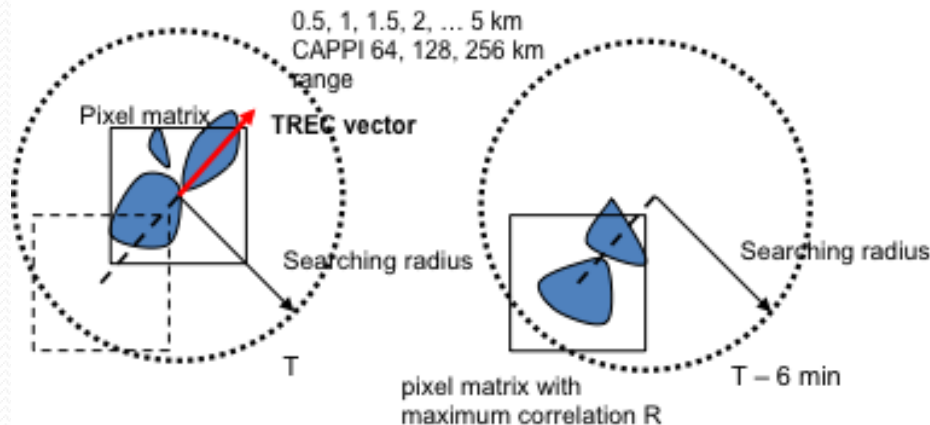


$Z_c = 33$



# QPF – radar echo tracking

## Maximum Correlation (TREC)



where  $Z_1$  and  $Z_2$  are the reflectivity at  $T+0$  and  $T+6\text{min}$  respectively

$$R = \frac{\sum_k Z_1(k) \times Z_2(k) - \frac{1}{N} \sum_k Z_1(k) \sum_k Z_2(k)}{\left[ \left( \sum_k Z_1^2(k) - N \overline{Z_1}^2 \right) \times \left( \sum_k Z_2^2(k) - N \overline{Z_2}^2 \right) \right]^{1/2}}$$

## Optical Flow

Given  $I(x,y,t)$  the image brightness at point  $(x,y)$  at time  $t$  and the brightness is constant when pattern moves, the echo motion components  $u(x,y)$  and  $v(x,y)$  can be retrieved via minimization of the cost function:

$$J = \iint \left[ \frac{\partial I}{\partial t} + u \frac{\partial I}{\partial x} + v \frac{\partial I}{\partial y} \right]^2 dx dy$$

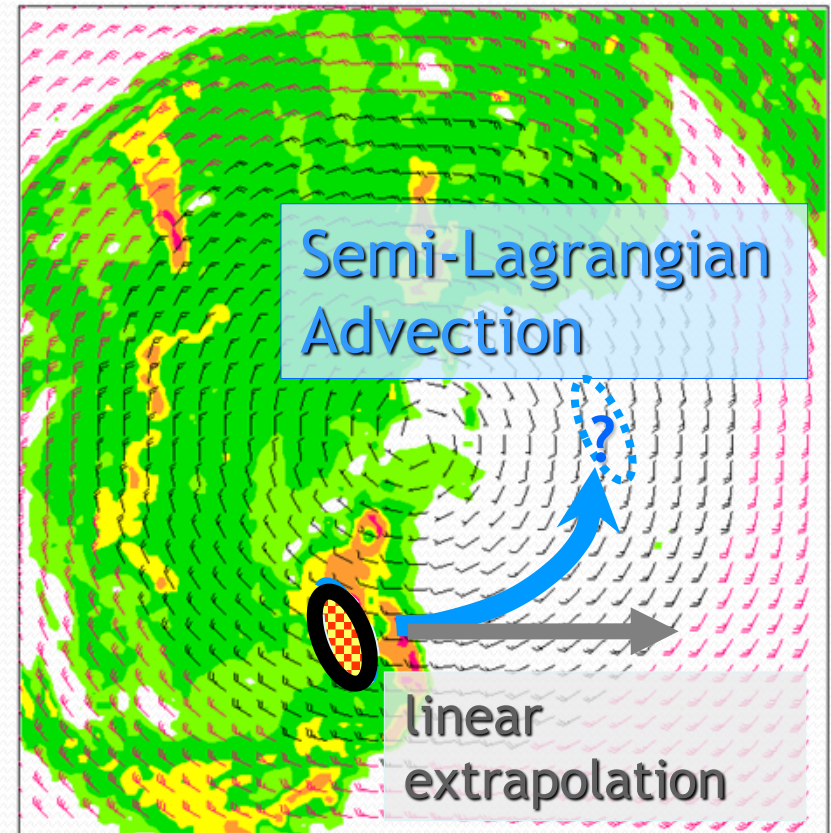
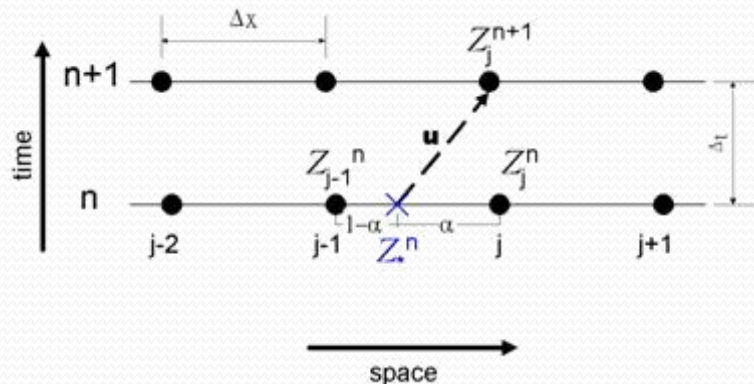
$$\nabla J = 0 \Rightarrow (u, v)$$

# QPF - Forecast by Extrapolation

- Semi-Lagrangian Advection (SLA)

- Robert scheme (3 iterations to find origin point)
- Bi-cubic interpolation
- Flux limiter (local max, min constraint)
- One-way nesting

$$\frac{dZ}{dt} = \frac{\partial Z}{\partial t} + \mathbf{u} \frac{\partial Z}{\partial x} = 0$$



# About Com-SWIRLS

- Freely shared with all **NMHSs**, for:
  - Capacity Building
  - Knowledge Exchange
  - Collaboration
- Features
  - QPE - Quantitative Precipitation Estimate
  - QPF - Quantitative Precipitation Estimate
  - Severe Weathers - hail, gust, thunderstorm



# Code Base of Com-SWIRLS

- Based on HKO's Operational SWIRLS
- Portable code running on common Linux distribution
- Configurable codes for implementation in different forecast domains
- Modular design for easier code changes, and integrate new modules from community users

# Com-SWIRLS Status Update

## Operational

- India
- Malaysia
- South Africa
- Zhuhai, China
- Macao, China

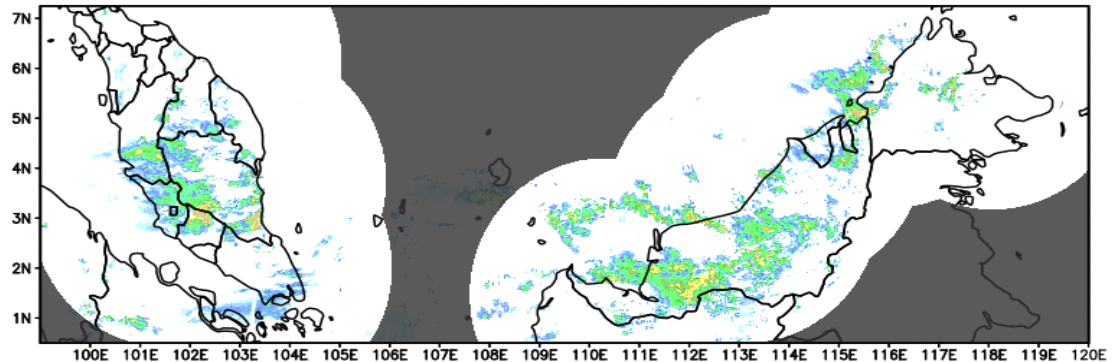
## Under development

- Philippines
- Myanmar
- Vietnam
- Indonesia
- Thailand

# Com-SWIRLS in Malaysia

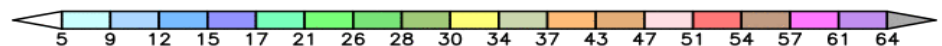
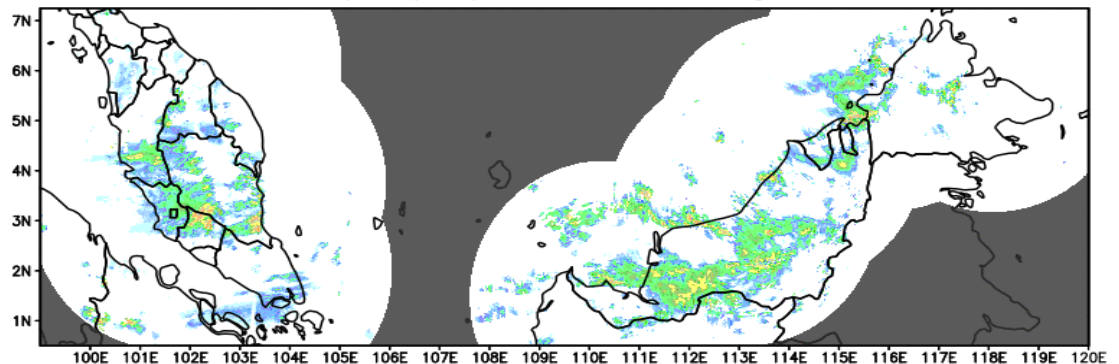
Nowcast

FAST Forecast (mm/hr) at Tue 29 Aug 20:10:00 MYT 2017



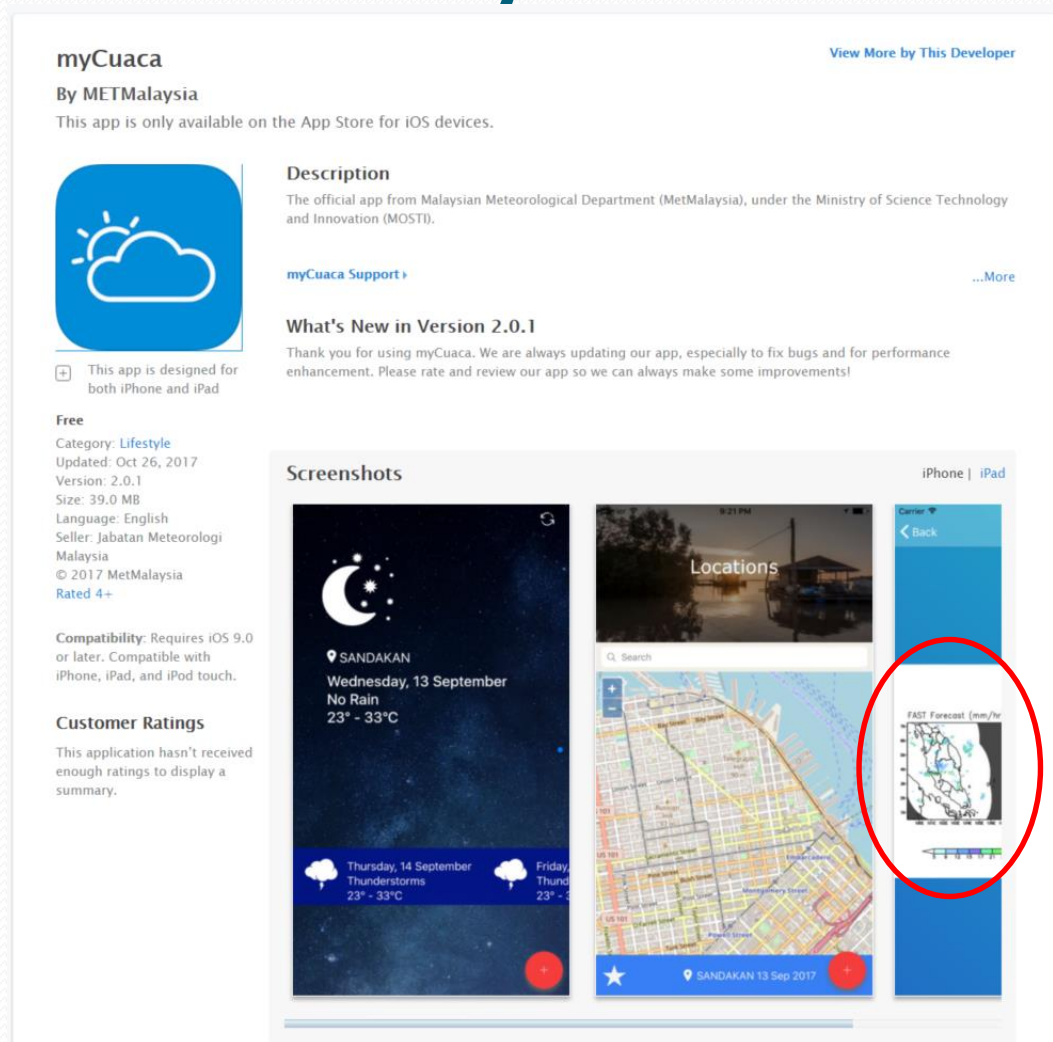
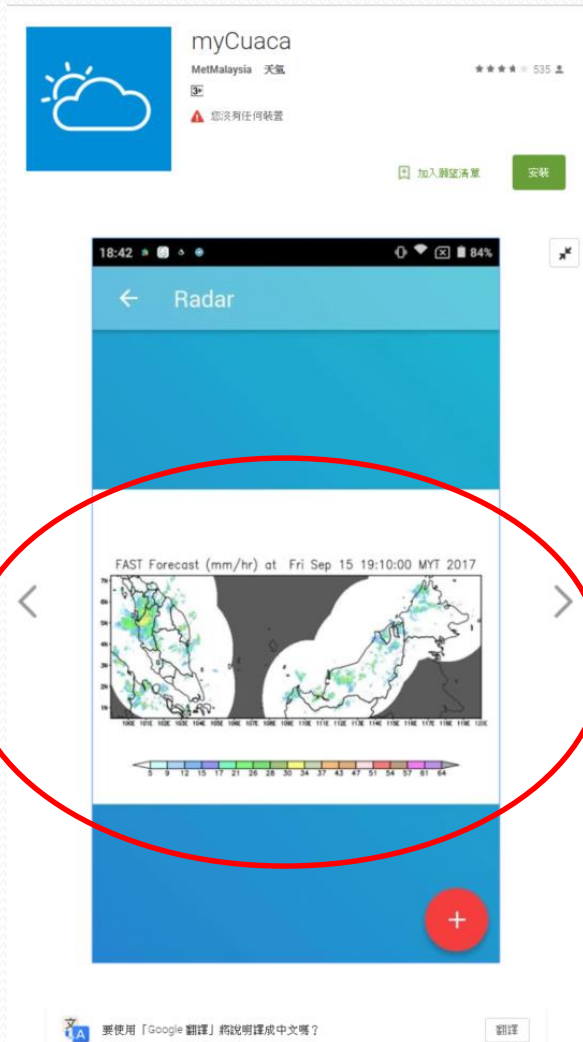
Observation

Radar Observation (mm/hr) at Tue 29 Aug 20:10:00 MYT 2017



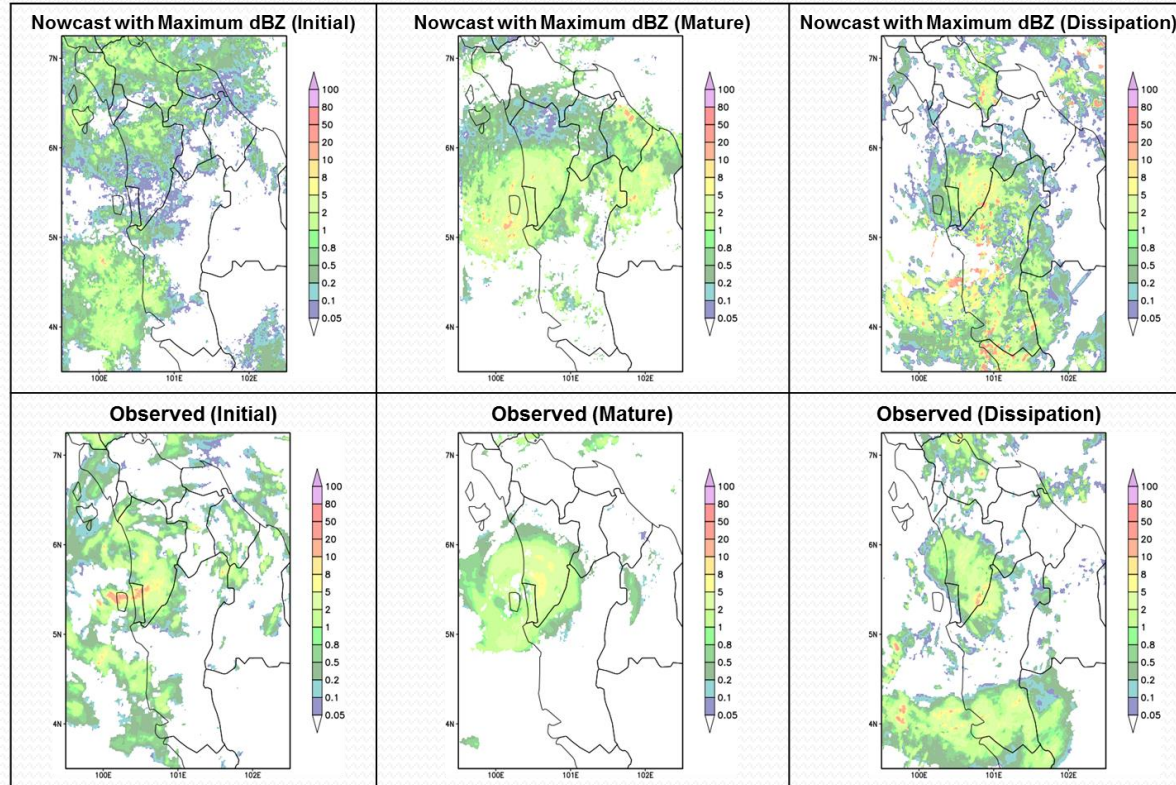


# Com-SWIRLS in Malaysia

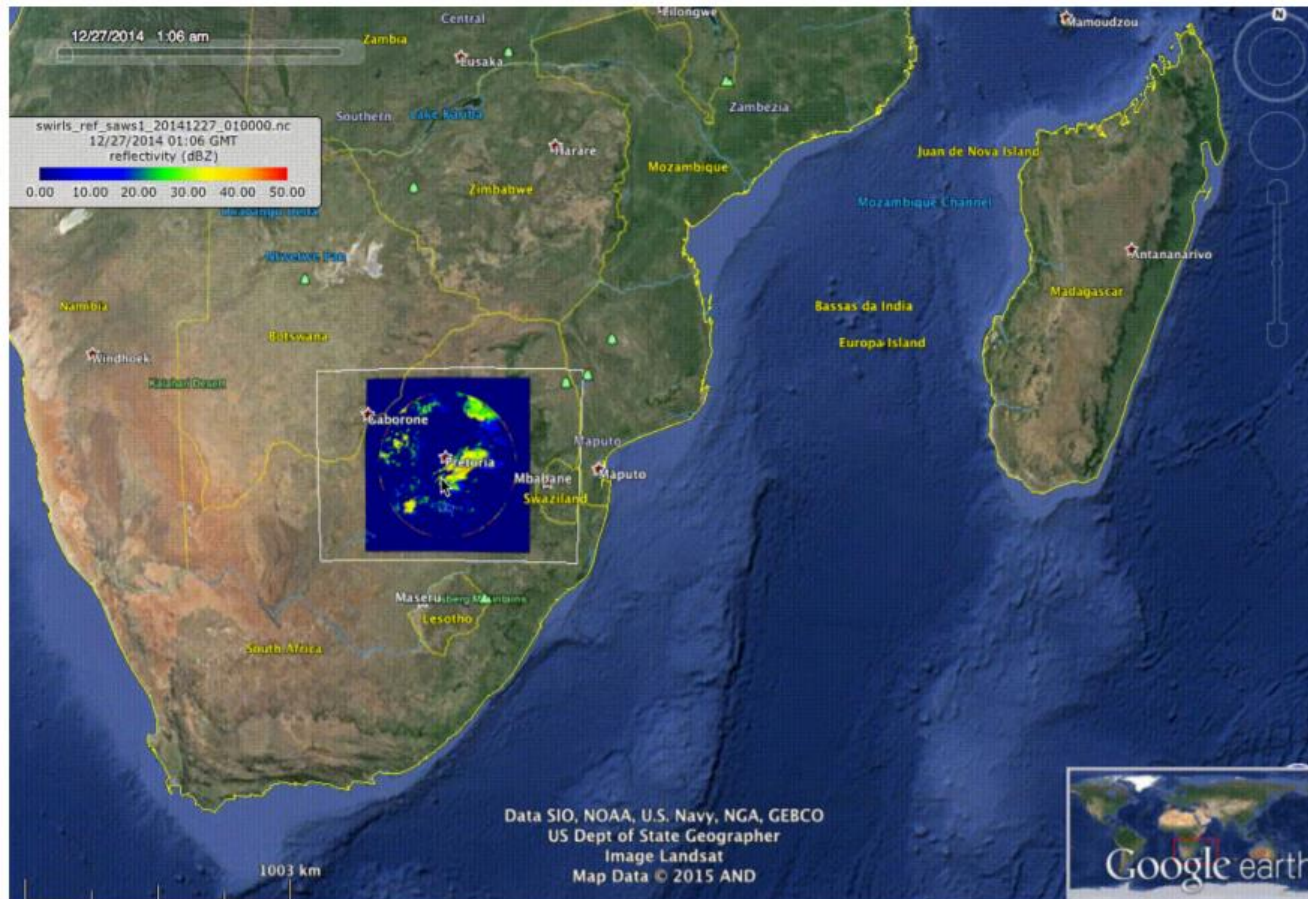


# Com-SWIRLS in Malaysia

TD CASE 05 NOVEMBER 2017 MALAYSIA  
AVERAGE NOWCAST OF 3 HOUR LEAD TIME



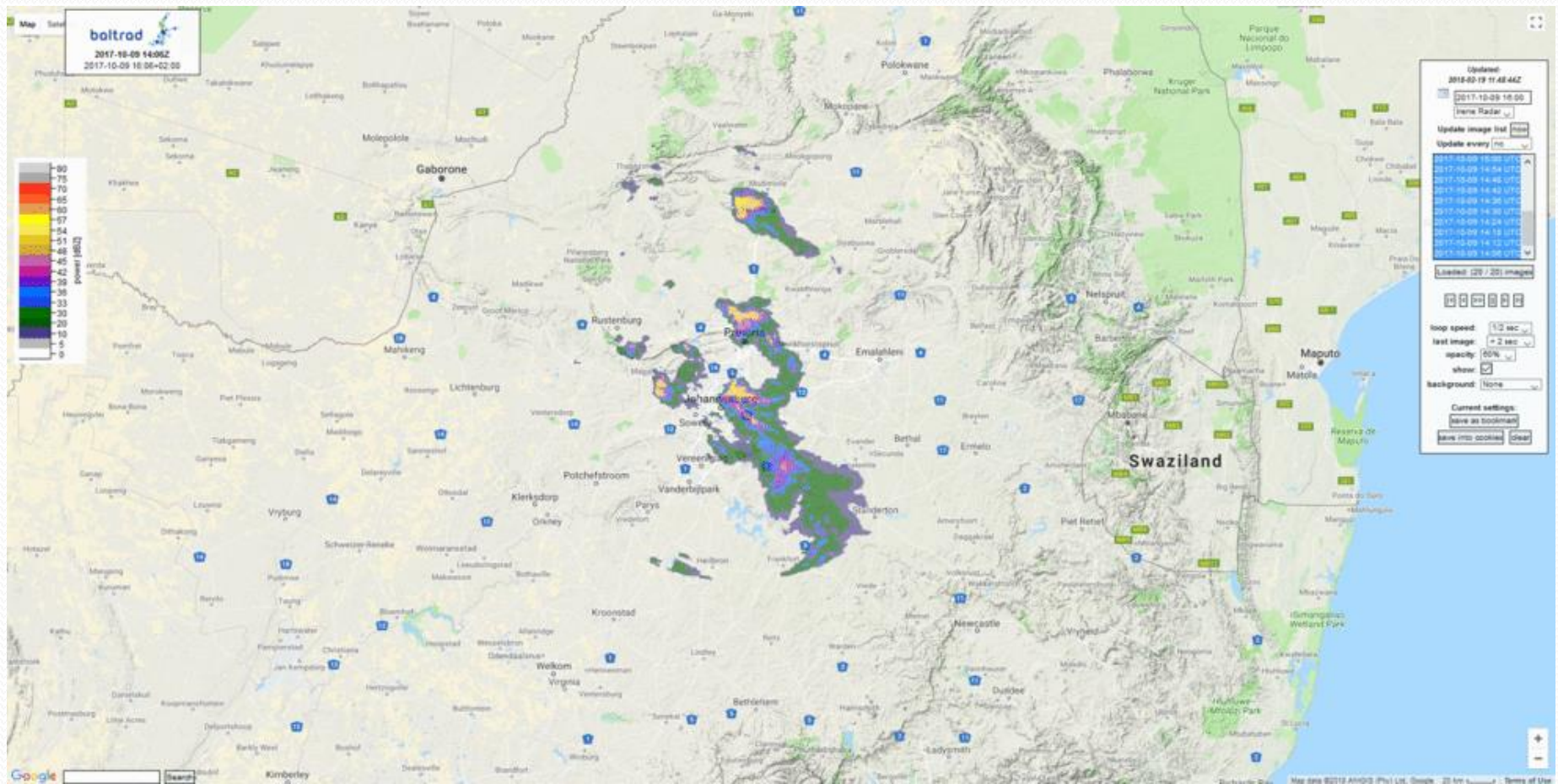
# Com-SWIRLS in South Africa



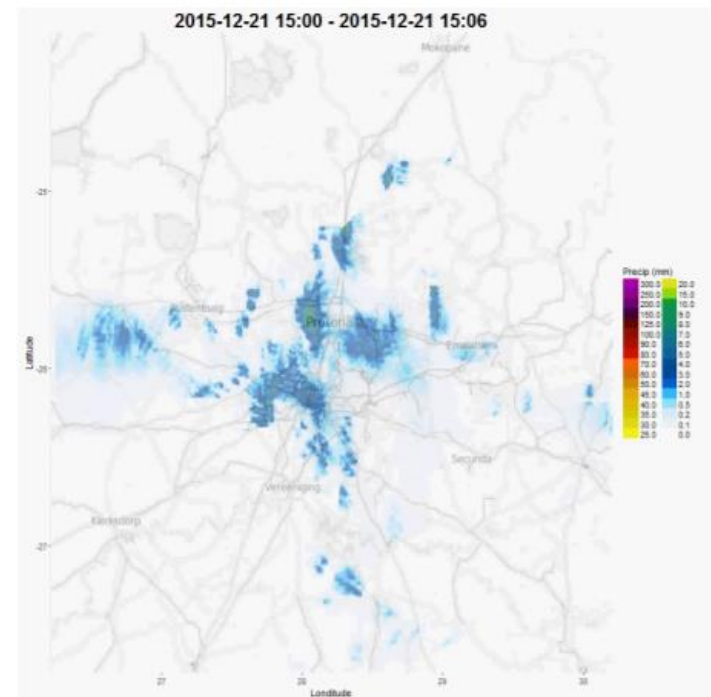
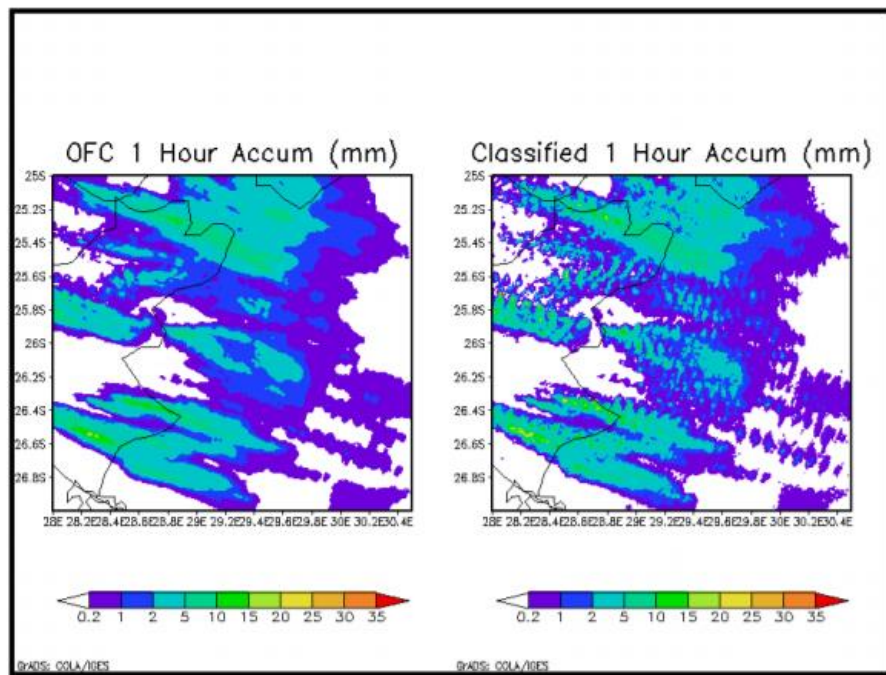
Credit: Eric Becker, SAWS



# Com-SWIRLS in South Africa



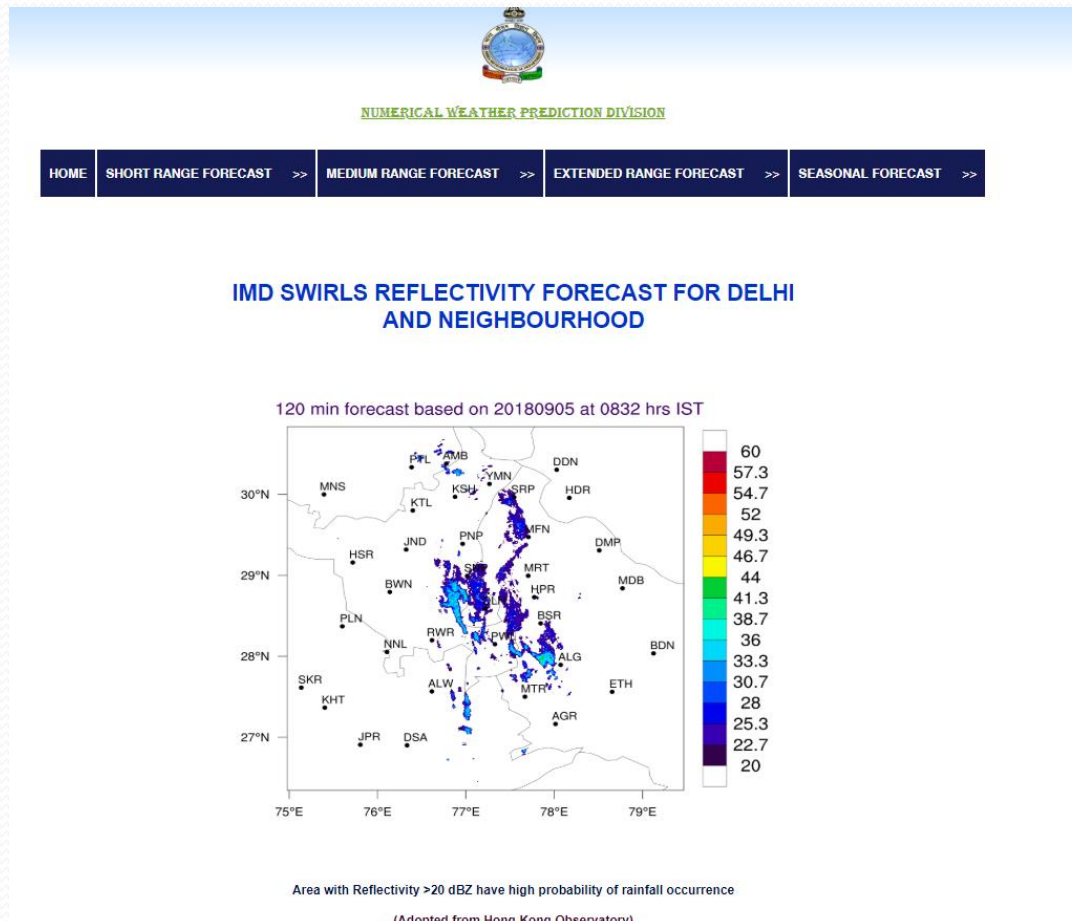
# Com-SWIRLS in South Africa



Credit: Erik Becker

Credit: Eric Becker, SAWS

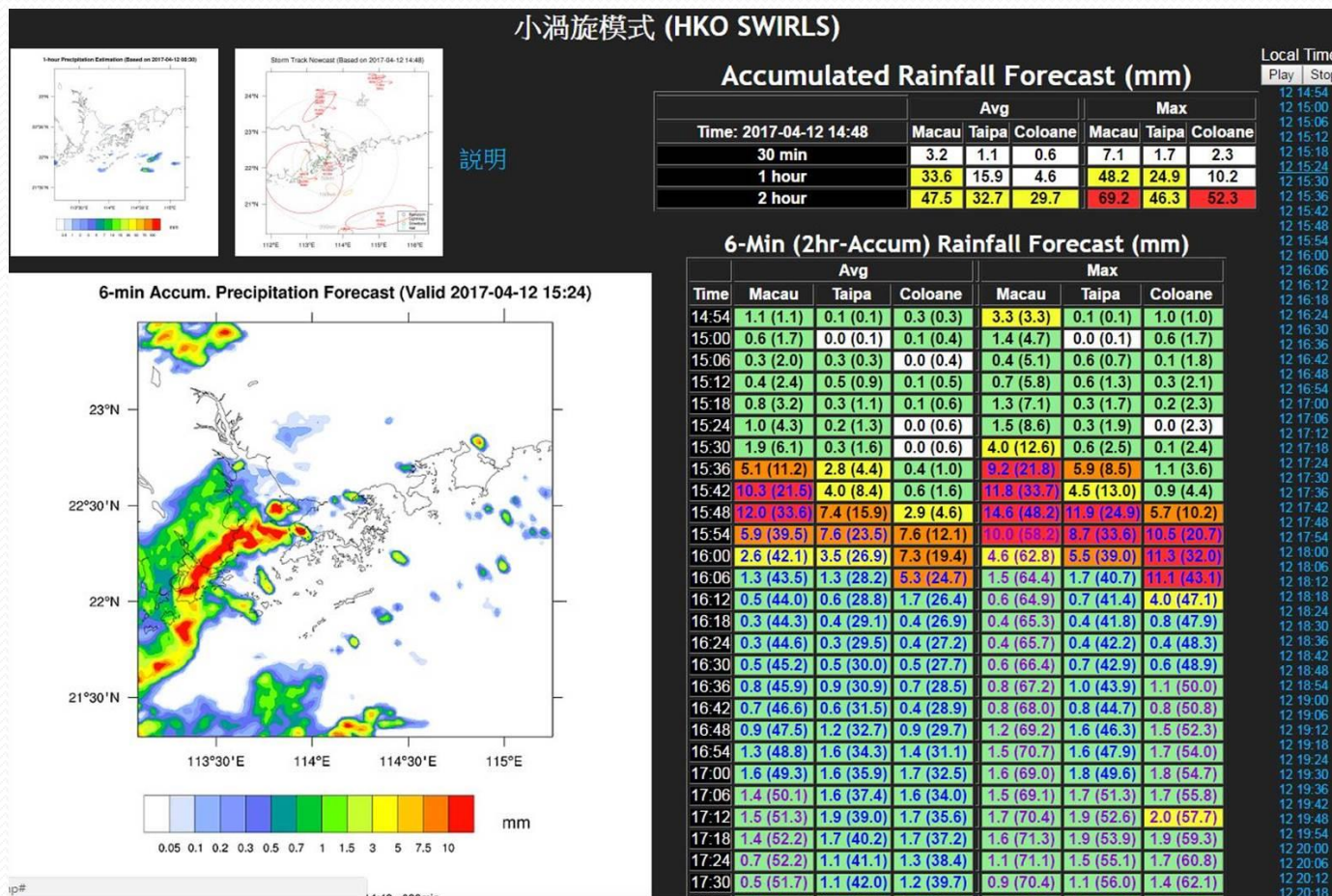
# Com-SWIRLS in India



[http://nwp.imd.gov.in/fdp\\_now/](http://nwp.imd.gov.in/fdp_now/)



# Com-SWIRLS in Macao





# Com-SWIRLS in Zhuhai



# Training

## WMO VCP Workshop on Rainfall Nowcasting 7-11 December 2015

### The Observatory organized the World Meteorological Organization Workshop on Rainfall Nowcasting

Tuesday, 22nd December 2015

[Mobile Version]



The Hong Kong Observatory organized an international workshop on "Rainfall Nowcasting" under the Voluntary Cooperation Programme (VCP) of the World Meteorological Organization (WMO) during 7 – 11 December 2015.

"Rainfall Nowcasting" generally refers to forecasts of rainfall and the associated severe weather such as thunderstorm, hail and wind gusts, for up to 6 hours ahead. It is the pillar for rainstorm warning system and public rainfall nowcast service, both critical to disaster prevention and reduction. The Observatory also took this opportunity to launch the community version of the SWIRLS nowcasting system ("Com-SWIRLS") for use by interested meteorological services around the world.

Experts in rainfall nowcasting were invited as lecturers of the workshop. Dr Jenny Juanzhen Sun of the National Center for Atmospheric Research (NCAR) presented the latest development of rainfall nowcasting based on radar and convection-permitting numerical weather prediction model. Mr Hidehiko Murata of Japan Meteorological Agency introduced the newly available Himawari-8 satellite products and their applications in nowcasting. In addition, Mr Wong Wai-kin, Mr Woo Wang-chun and Mr Cheng Tsz-lo of the Observatory introduced the quantitative precipitation estimation (QPE) system of the SWIRLS.

The workshop was attended by 22 trainees from Fiji, Kazakhstan, Kuwait, Madagascar, Africa, Tajikistan, Thailand, Uganda, Ukraine and the VCP workshop to enable them to learn from the Observatory.

The participants highly appreciated the Com-SWIRLS in their meteorological services. They were most impressed with the learning of the QPE system, a new way to disseminate information of rainfall. They had benefited a lot from the workshop and they would make more effective use of the radar nowcasting system.



## AvRDP Workshop 20-22 July 2016



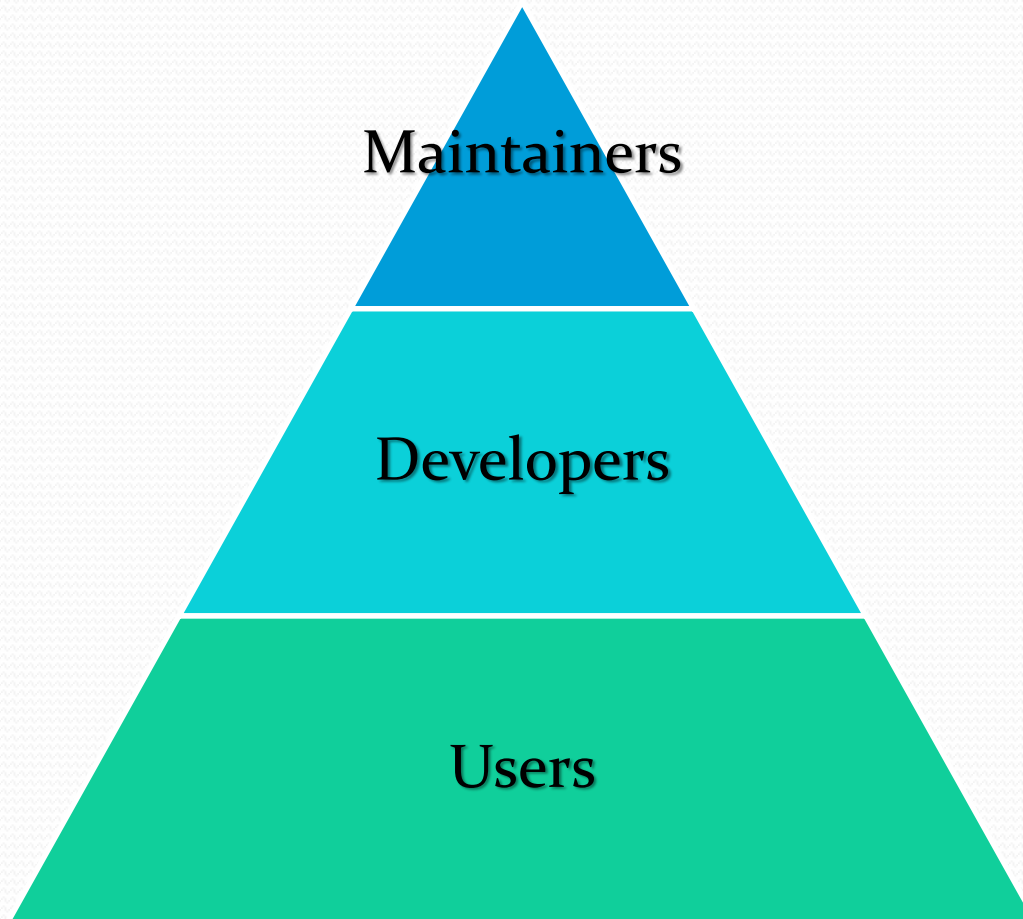
Workshops organised from time to time

# Com-SWIRLS 1.2 (June 2018)

- User-friendly web-based interface for manual mode
- To be distributed as a **virtual appliance** (.ova)
- Installation-**free**\*
- **Cloud** Ready, while also support on-premises uses
- Support **many** radar data formats
- **Documented** APIs

\* Users still need to install an operating system and a virtual machine application on premises or upload the .ova file to a Cloud service.

# Com-SWIRLS 2.0 (early 2019)



```
git merge feature  
conda build .
```

```
git stage .  
git commit -m "feature"  
git push feature master
```

```
conda install http://...  
import ...
```



# Modules Developed (Oct 2018)

Module	Function
<code>rfmap.py</code>	plots a rainfall map based on rain gauge data
<code>cal_ZR.py</code>	Calibrate the $Z=aR^b$ relationship by linear regression
<code>Read_CRaMS.py</code>	Reads in CRaMS Products (MICAPS)
<code>fix_netcdf.py</code>	Fix an encoding issue with NetCDF files by JICA
<code>readnetcdf.py</code>	Reads in and plots out JICA .NETCDF in .PNG format
<code>jmagpv.py</code>	Reads in JMA Radar Grid Point Value Rainfall Rate Product
<code>read_gpm.py</code>	Reads in HDF5 file (NASA GPM)

# Website of Com-SWIRLS

<http://swirls.hko.gov.hk/>

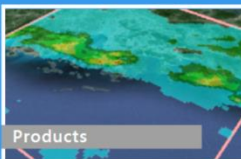
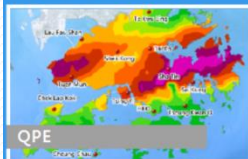
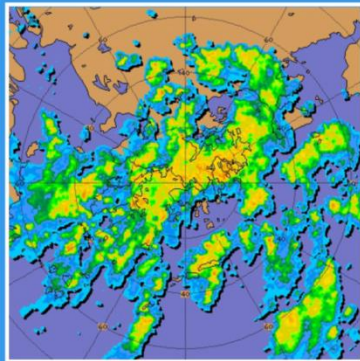


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## SWIRLS

SWIRLS (Short-range Warning of Intense Rainstorms in Localized Systems) is the operational rainstorm nowcasting system of Hong Kong Observatory (HKO). State-of-the-art techniques are implemented in SWIRLS for analysis and prediction of precipitation and convective weather phenomena in the next few hours. SWIRLS has been in operation in HKO since 1999. SWIRLS was also implemented in various meteorological services or participated in international forecasting projects to support the research and development of rainstorm nowcasting techniques.

The community version of SWIRLS, or com-SWIRLS, is developed to facilitate knowledge exchange and cooperation on development of rainfall nowcasting technique. Com-SWIRLS can be available from this website for use by the National Meteorological and Hydrological Services (NHMSs) upon request. To request or for any enquiry, please send an e-mail to [swirls@hko.gov.hk](mailto:swirls@hko.gov.hk).



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## SWIRLS User Forum



all categories ▾

Latest

Top

Categories

+ New Topic

Topic

Category

Users

Replies

Views

Activity

Input files for Barnes Analysis and ZR Calibration (QPE)

Installation, Configurati...

3

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Aug 23

Community SWIRLS Updated - Latest Release 1.2

General

0

21

Jun 27

Software for this User Forum Upgraded

General

0

7

Apr 16

Community SWIRLS updated to include severe weather modules

General

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Mar 29

Slides from WMO VCP Training Workshop on Nowcasting in HKO in 2015

Installation, Configurati...

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Mar 14

Presentation on Com-SWIRLS at SWFDP-SeA: RSMT Meeting

General

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Jan 12

Publication: Operational Application of Optical Flow Techniques to Radar-Based Rainfall Nowcasting

General

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Mar '17

Operational SWIRLS : Rapid change in echo direction during squall - lines

Installation, Configurati...

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Oct '16

How to start up swirls for My country

Installation, Configurati...

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Jan '16

SWIRLS installation For Linux

Installation, Configurati...

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Jan '16

UKO Slide Deck on WMO workshop on rainfall nowcasting

General

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06

Dec '16

# Website of Com-SWIRLS



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## Downloads

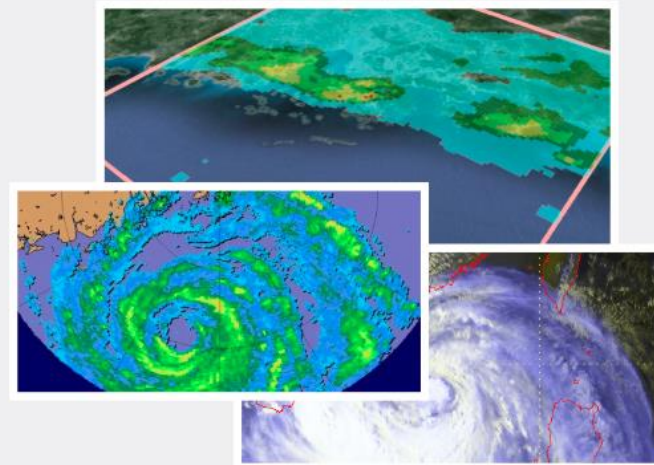
Before download, make sure your environment fulfils system minimum requirement. Also, please install all required packages and dependencies before configure SWIRLS. For more detail, please refer to installation guide and system overview in documentation section.



You will be asked to sign in

### Recommended System Configuration :

- Run on 64-bit machine
- Core i7 2.8 GHz / compatible
- 4 GBytes RAM or above
- Hard disk space of 150 GBytes or above
- 64 bit Red Hat Linux or compatible



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<http://swirls.hko.gov.hk/>

# Website of Com-SWIRLS

The screenshot shows a web browser window with the address bar displaying "swirls.hko.gov.hk/downloadSWIRLS.html". The browser's address bar also shows a list of bookmarks: Handy, 1\_GTS, 2\_Meteo, 3\_NWP\_Portal, 4\_Obs, 5\_Model, 6\_Rain, 7\_TC, 8\_Visibility, 9\_Monsoon, 10\_Cold & Hot, 11\_Marine, and 12\_Earthquake. The website's header features the SWIRLS logo and a navigation menu. A blue overlay box contains the following text:

By downloading SWIRLS, users are required to note that the SWIRLS software is provided for supporting the development of nowcasting techniques and/or operational application under the following terms and conditions and disclaimer:

**Terms and Conditions:**

1. The SWIRLS software (or "Software" ) shall not be partially or totally transferred to a third party;
2. The Software or its derived products shall not be used for commercial purpose; and
3. Due acknowledgement to the HKO shall be given in papers and reports containing results made or derived from the application or use of the Software.

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☐ I accept the above terms and conditions.

[Download](#)

The background of the website shows a "Download" section with a list of requirements: Run on 64-bit, Core i7 2.8 GHz, 4 GBytes RAM, Hard disk space, and 64 bit Red Hat. There is also a "User Forum" link and a "Recommend" section.



# RSMC for Nowcasting

<https://rsmc.hko.gov.hk/nowcast/>

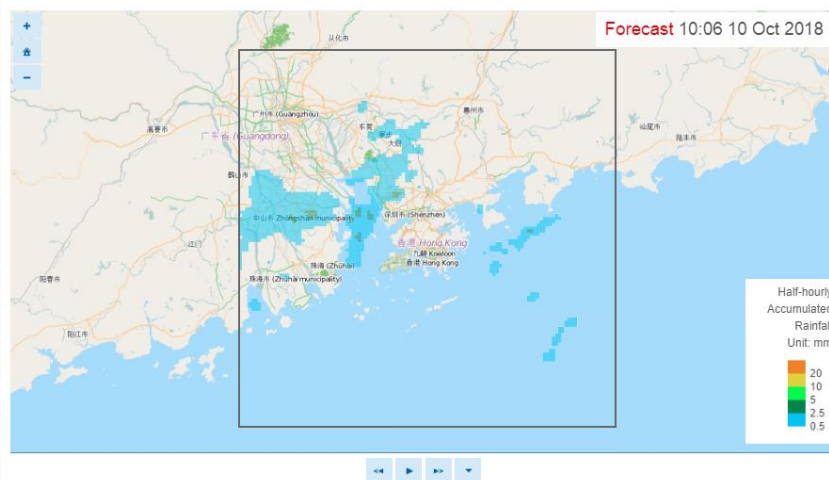


Home Nowcasting Products Com-SWIRLS Research Development Verification Collaborations Training

## Hong Kong Observatory Nowcasting Services

The Hong Kong Observatory (HKO) has been operating its nowcasting services since 1999. In this connection, HKO has developed a suite of nowcasting systems, including the "Short-range Warning of Intense Rainstorms in Localized Systems" (SWIRLS), to aid rainstorm warning operation as well as high-impact weather forecasting for the public and the aviation community. HKO's nowcasting system has been put to use in various WMO Forecast Demonstration Projects and was demonstrated to be among the best performers. In recent years, HKO develops a community version of its nowcasting system (Com-SWIRLS) to promote knowledge exchange in radar nowcasting techniques and for wider application of nowcasting system. HKO is ready to provide nowcasting services to international users in accordance with the standard and requirements for Regional Specialized Meteorological Centre (RSMC) for nowcasting as described in the WMO Manual on the Global Data-Processing and Forecasting System (GDPFS) (WMO-No. 485).

### Location-specific Rainfall Nowcast



## Aviation Nowcasting

Real-time SigConv

Real-time ICI

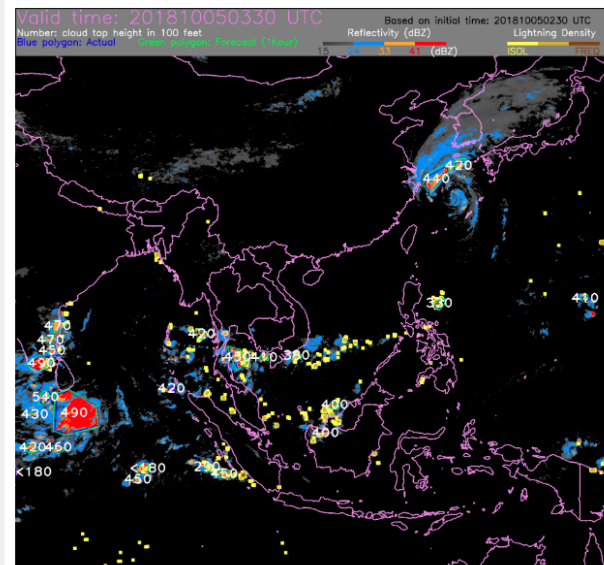
ATNS

ATLAS

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### Real-time SigConv (Significant Convection)

Significant convection presents imminent threats to in-flight aircraft for the associated hazards of lightning, turbulence, icing, rain and hail, etc. Limited by the range and coverage of on-board weather radar, pilots may not have a complete picture of the distribution and short-term evolution of convective systems within their intended flight path. The product shown here uses multiple channels, high resolution meteorological satellite data and real-time global lightning data to automatically identify and nowcast the hazardous areas of significant convection for aircraft's avoidance. More details of the satellite-based algorithm can be found in the paper: [Development of Satellite Reflectivity Retrieval Technique for Tropical Cyclone Rainfall Nowcasting](#).



# How to Start?

- Browse through Com-SWIRLS website to learn more:  
<http://swirls.hko.gov.hk>
- Contact Mr. WOO Wang-chun, at [wcwoo@hko.gov.hk](mailto:wcwoo@hko.gov.hk)  
for Download Password



The End