Application of Optical Flow Techniques to Rainfall Nowcasting

WOO Wang-chun & WONG Wai-kin, Hong Kong Observatory

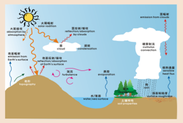
香港天文台 HONG KONG OBSERVATORY

HKO Rainstorm Nowcasting System

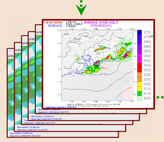
SWIRLS *Short-range Warning of Intense Rainstorms in Localized Systems*

Computer Simulation of Physical Processes in the Atmosphere

Remote-sensing and conventional weather observation data



High-resolution storm model to directly simulate the evolution of precipitating clouds up to 15 hours ahead

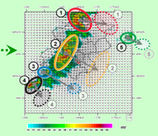


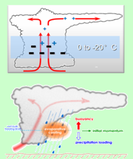
Computer-generated forecast rainfall maps for the next 15 hours based on simulation

Radar Tracking, Analysis and Forecast

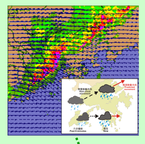
SWIRLS Nowcasting System

Special Editions of SWIRLS

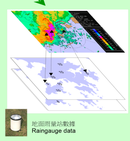




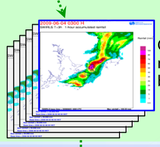
Cell identification and radar signature analysis for severe storms



Automatic tracking and prediction of rainband movement from radar



Real-time calibration of radar-detected rainfall rate using the dense raingauge network



Computer-generated forecast rainfall maps up to 6 hours ahead based on radar

Computer-generated forecast map of squalls, lightning, hail and heavy rain

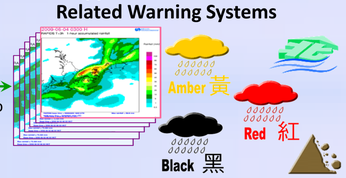
Nowcast Products & Services

In support of Important International Events

In support of Thunderstorm Warning System

雷暴 Thunderstorm

In support of Rainstorm and Related Warning Systems



Forecast rainfall maps up to 6 hours ahead blended from radar nowcast and computer simulation results

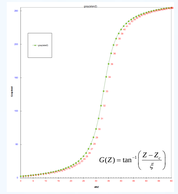
Public dissemination of nowcast rainfall maps for the Pearl River Delta region via HKO Internet website

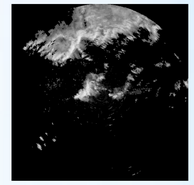
Forecast rainfall information visualized with 4-dimensional map of the globe

Optical Flow

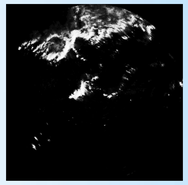
New Radar Echo Tracking Algorithm: **ROVER**

- Enhances radar images to sharpen contrasts in the middle range; &
- Adopts "Real-Time Optical Flow Computation with Variational Methods" Bruhn *et al.* (2003)





before



after

$$\frac{\partial I}{\partial t}+u\frac{\partial I}{\partial x}+v\frac{\partial I}{\partial y}=0$$

$$I_x(q)\cdot u+I_y(q)\cdot v=-I_t(q) \qquad \text{where } q\in\Omega$$

$$\begin{pmatrix}u\\v\end{pmatrix}=\begin{pmatrix}K_\rho*(I_xI_x) & K_\rho*(I_xI_y)\\ K_\rho*(I_yI_x) & K_\rho*(I_yI_y)\end{pmatrix}^{-1}\begin{pmatrix}-K_\rho*(I_xI_t)\\ -K_\rho*(I_yI_t)\end{pmatrix}$$

$$J_{HS}=\iint\left[|\nabla u|^2+|\nabla v|^2\right]dxdy \quad \text{(HS81)}$$

- To compare with other tracking algorithms:
  - **MOVA:** previous optical flow technique
  - **TREC:** tracking by correlation method

References:

- Bruhn A, Weickert J, Feddern C, Kohlberger T, Schnörr C. 2003. Real-time optic flow computation with variational methods. In N. Petkov, M. A. Westenberg (Eds.): Computer Analysis of Images and Patterns. *Lecture Notes in Computer Science*, Vol. **2756**, Springer, Berlin, 222-229.
- Cheung P, Yeung HY. 2012. Application of optical-flow technique to significant convection nowcast for terminal areas in Hong Kong. *The 3rd WMO International Symposium on Nowcasting and Very Short-Range Forecasting (WSN12)*. 6-10 August, Rio de Janeiro.

Case Analysis

5 April 2013
2 hour forecast
Based at 07:00
Valid at 09:00
HKT (UTC+8)
Small charts show 1hr QPF at T+2.5hr

30 March 2014
1 hour forecast
Based at 19:00
Valid at 20:00
HKT (UTC+8)
Small charts show 1hr QPF at T+1.5hr

Verification

Period: June 2012 – May 2014 (2 years)

Data: Grids of 480x480 generated every 6 minutes, i.e. ~2.1 billion data pairs for each algorithm

Forecast \ Observation	Yes	No
Yes	Hit	false alarm
No	Miss	correct negative

$$CSI(TS)=\frac{hit}{hit+miss+\ false.alarm}$$