WSN 12
Rio de Janeiro - Brasil

World Meteorological Organization

WMO WWRP WSN12

APPLICATION OF OPTICAL-FLOW TECHNIQUE TO SIGNIFICANT CONVECTION NOWCAST FOR TERMINAL AREAS IN HONG KONG

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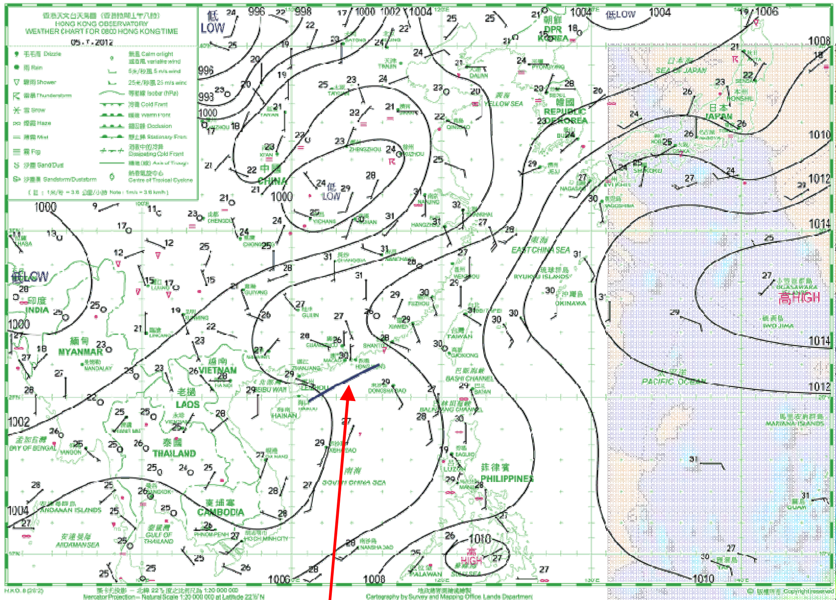
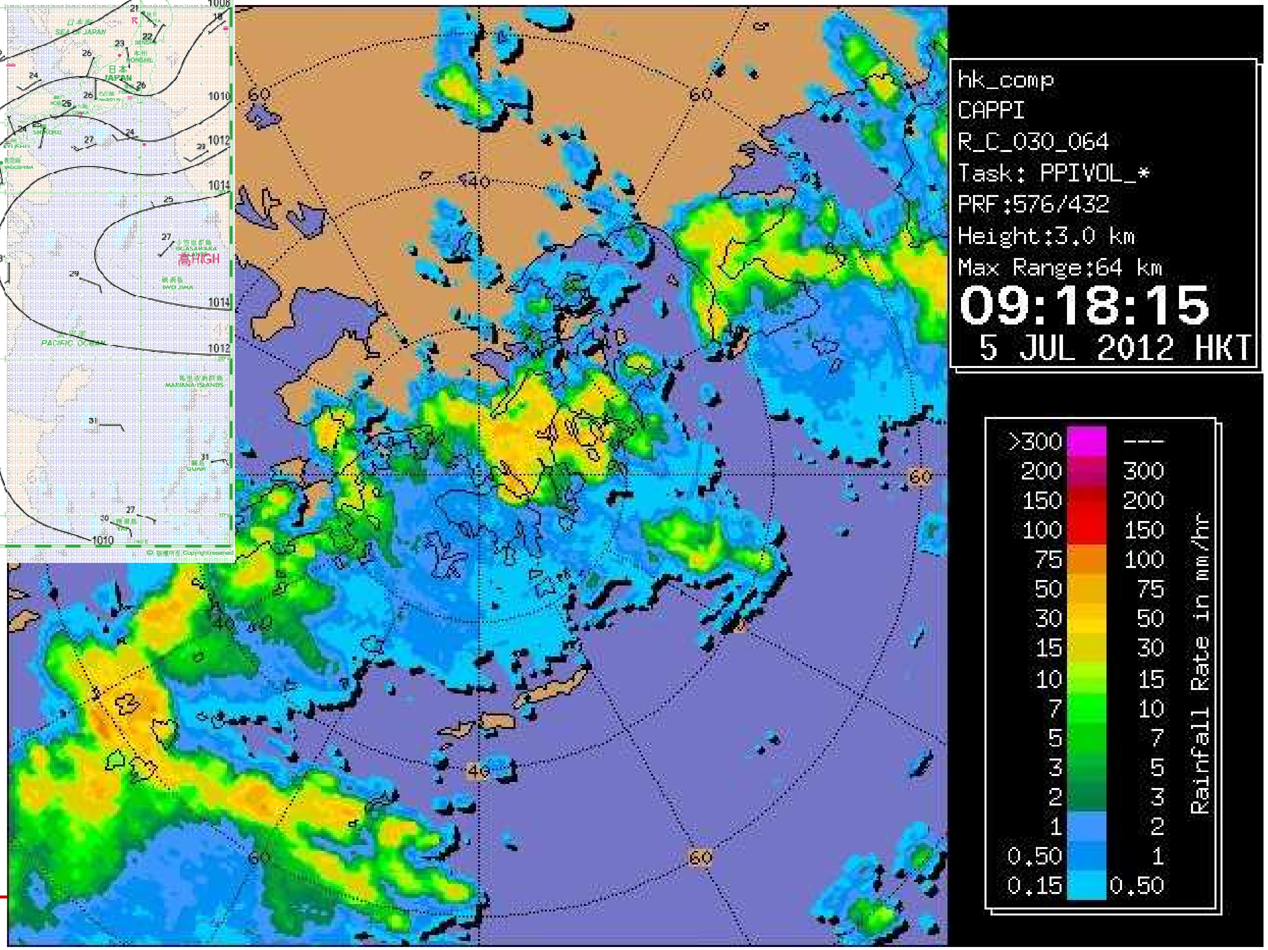
Background

Aviation Havoc

- What causes the chaos in a seemingly "normal" thunerstorm day?





monsoon trough, quasi-stationary

The Hong Kong Int'l Airport

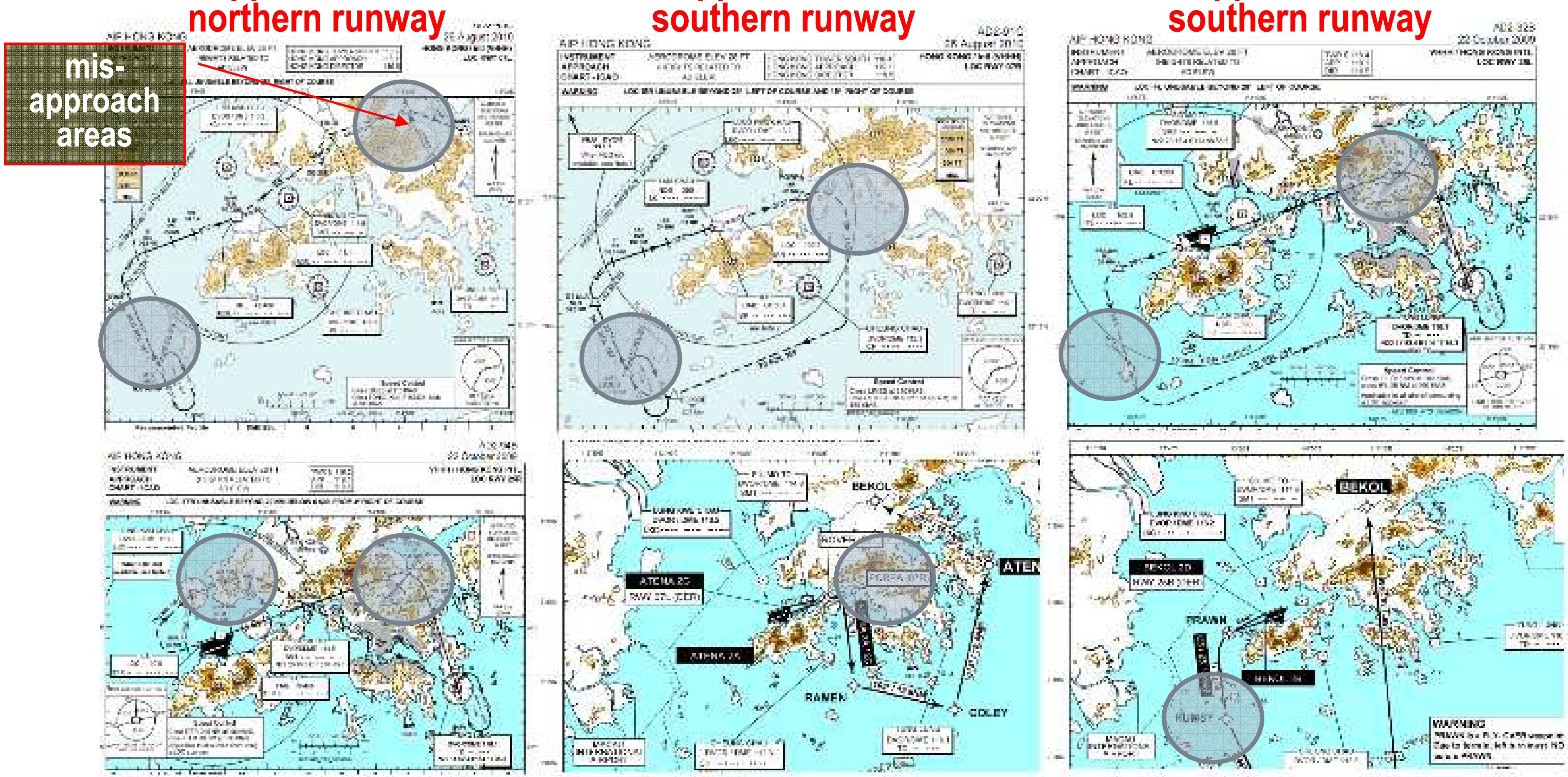
Flying into Hong Kong

- Six different approach/departure flight paths

approach 070 northern runway

approach 070 southern runway

approach 250 southern runway

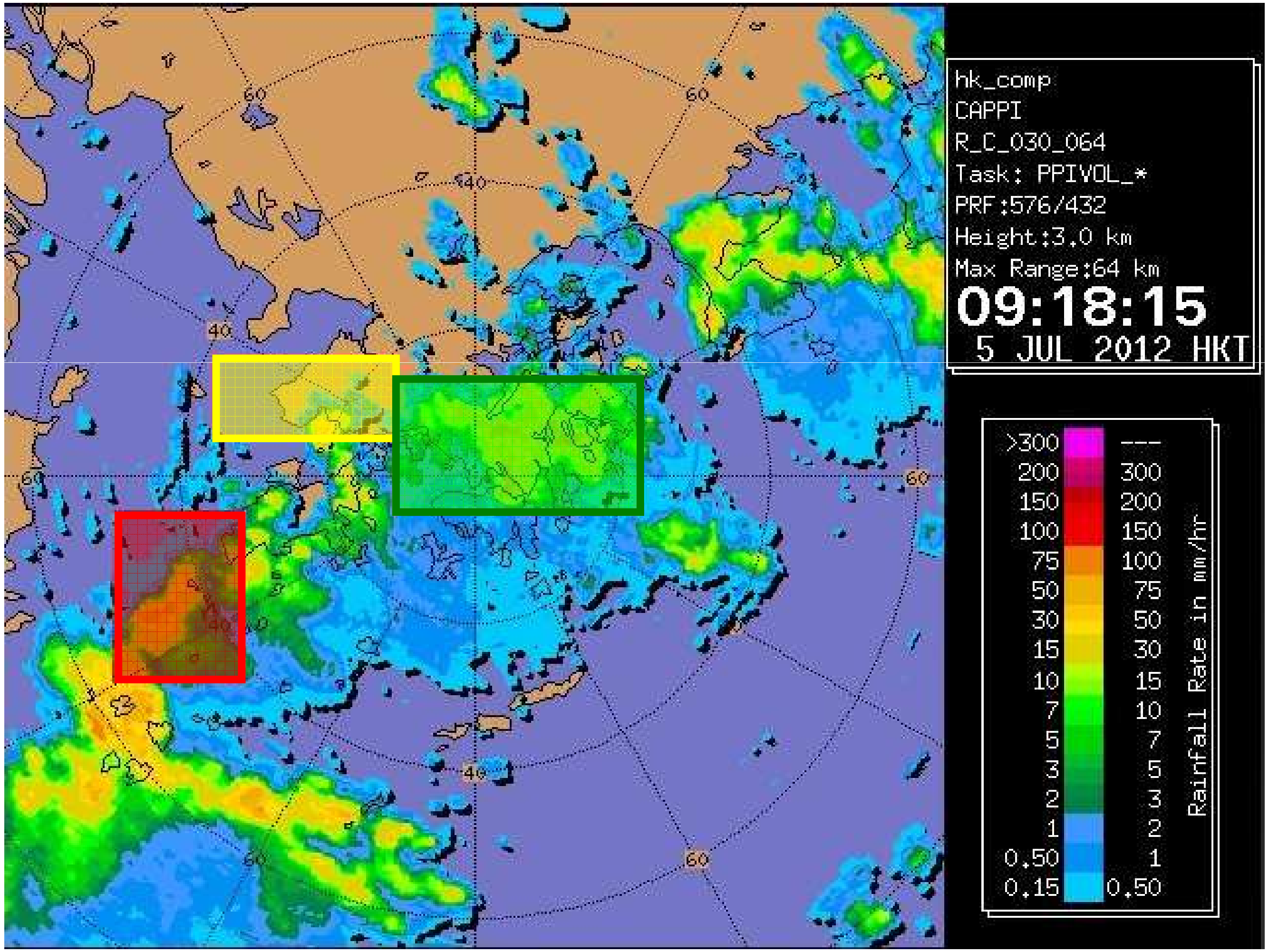


approach 250 northern runway

depart 070

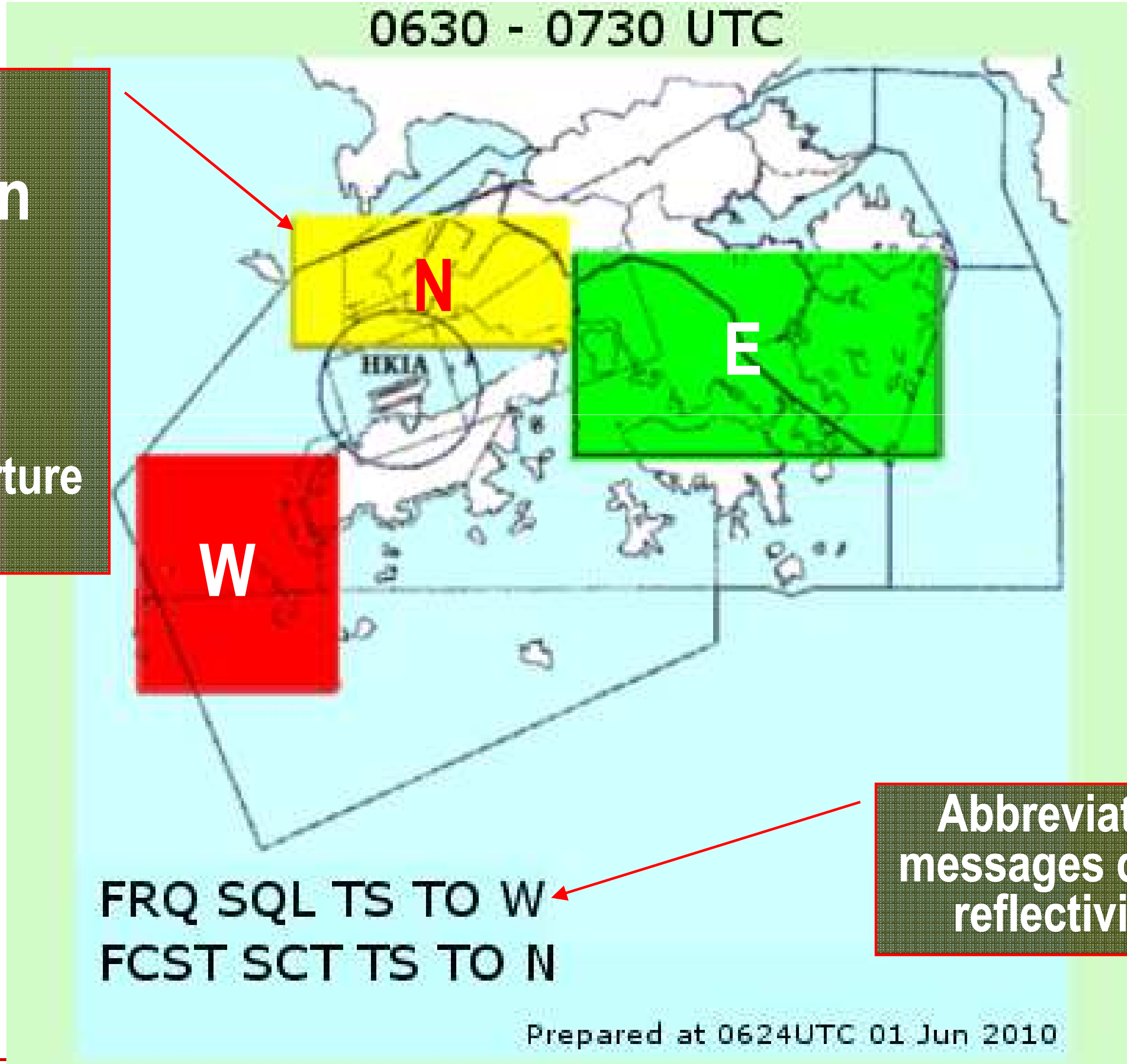
depart 250

Wx. Impact to Aviation Quantified



Products

Sig. Conv. Nowcast Product



Key Convection Sensitive Areas

→ arrival / departure corridors

Abbreviated warning messages deduced from reflectivity forecast

Warning Criteria

Significant convection over a corridor is defined as either:

"yellow" for moderate impact:
at least 50% area with echo intensity ≥ 33 dBZ
AND at least 4% area with echo intensity ≥ 41 dBZ

"red" for severe impact:
at least 10% with echo intensity ≥ 41dBZ

In forecast verification, the Performance Diagram refers to a contingency table of "yes/no" significant convection in 1 hour.

Warning Messages

Currently Observed status	Forecast status	Textual message
GREEN	RED	FCST FRQ TS
YELLOW	RED	SCT TS **INTSF**
RED	RED	FRQ TS
GREEN	YELLOW	FCST SCT TS
YELLOW	YELLOW	SCT TS
RED	YELLOW	FRQ TS **WKN**
GREEN	GREEN	
YELLOW	GREEN	SCT TS **WKN**
RED	GREEN	FRQ TS **WKN**

Stamp Maps

→ f/c reflectivity map every 6 minutes → → →

latest run

↓

previous runs

↓

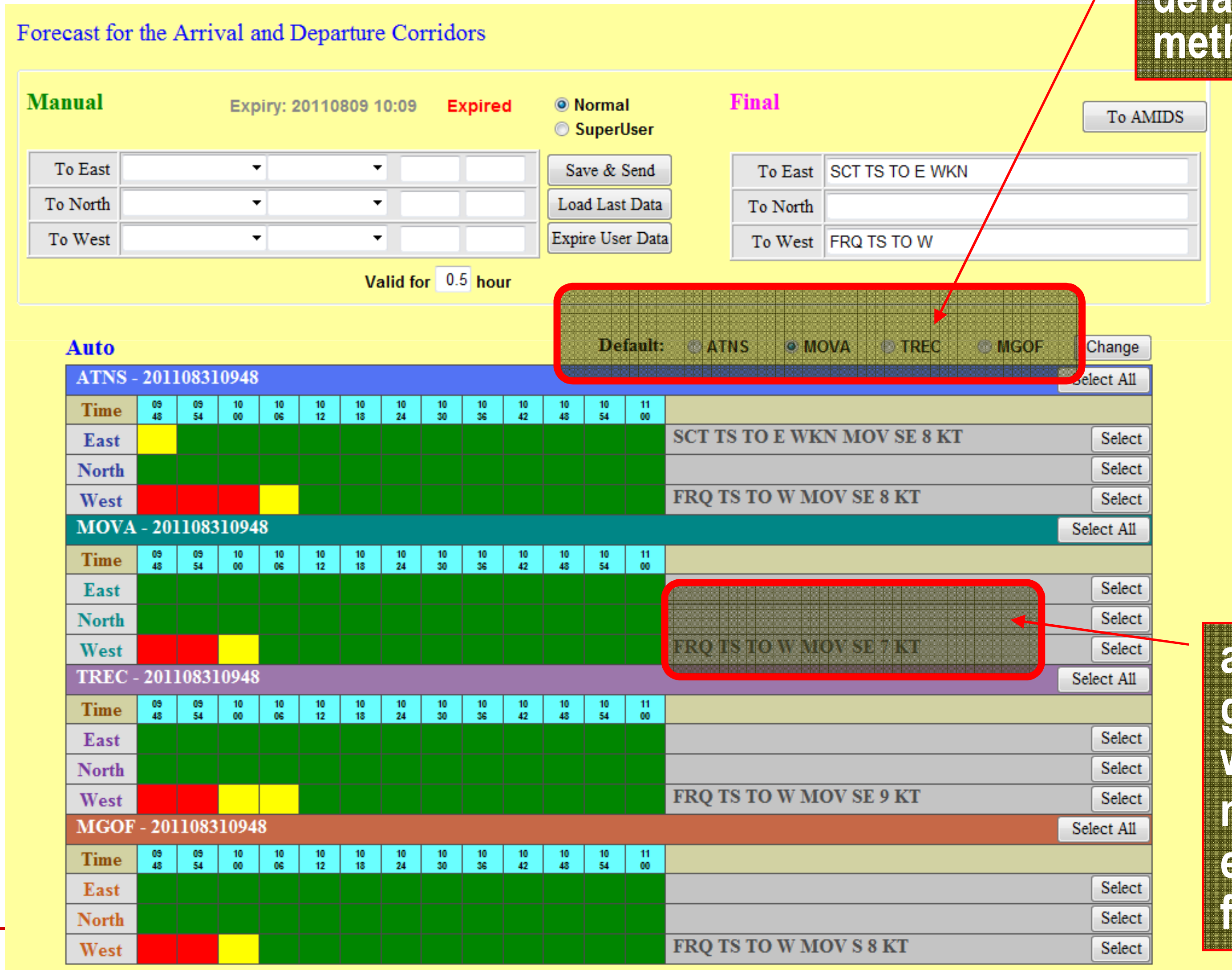
↓

↓

↓

Option to Stagger Stamp Maps

User Interface

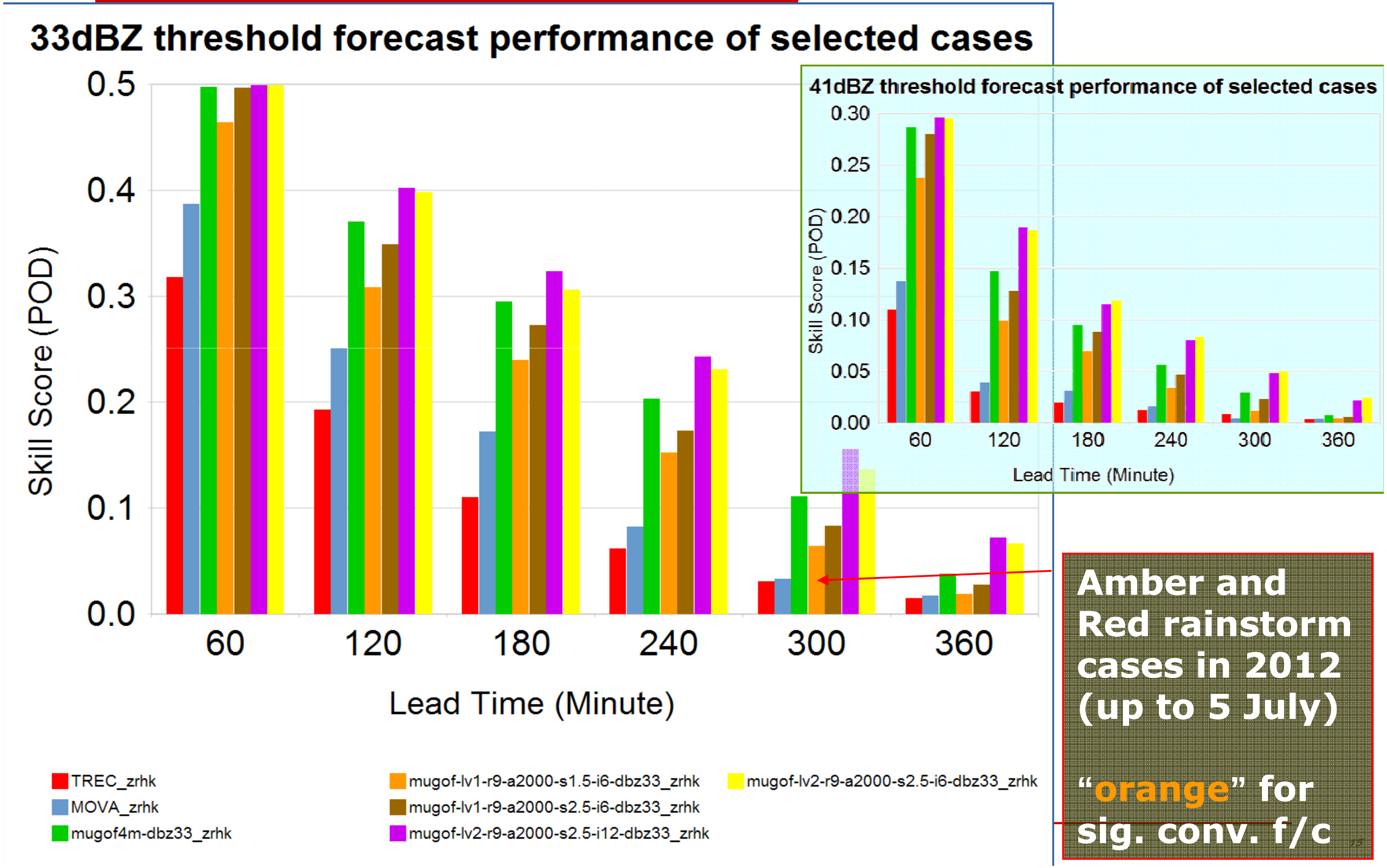


4 choices for default tracking method

automatically generated warning messages, editable by forecasters

Result

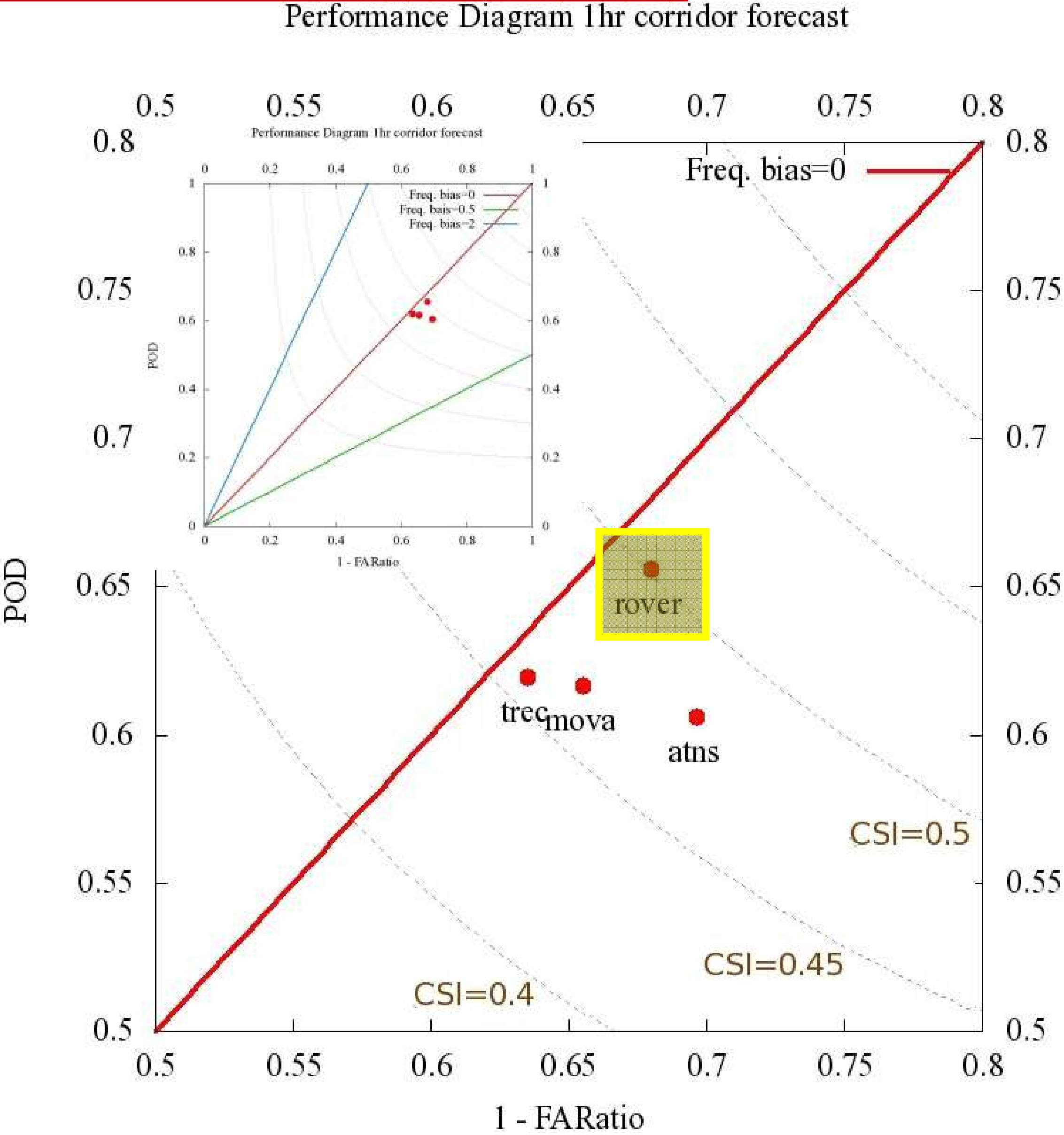
Trial Results – Rainstorms in 2012



Amber and Red rainstorm cases in 2012 (up to 5 July)

"orange" for sig. conv. f/c

Performance Diagram (Jun-Oct 2011)



Techniques

What Does "Optical Flow" Mean?

- "Velocity pattern of the apparent motion of moving objects in a visual scene when projected onto a two-dimensional plane"
  - *after Aubert et al. 1999*
- Originators (in computer vision):
  - *Lucas & Kanade 1981 (local approach)*
  - *Horn & Schunck 1981 (global approach)*
  - *Bruhn et al. 2003 (combined local-global approach)*
    - adapted for use in ROVER of SWIRLS
- In meteorological community:
  - *Germann & Zawadzki 2002 (VET)*
    - from the wind retrieval technique of Laroche & Zawadzki 1994; 1995
  - *Bowler et al. 2006 (Gandolf / STEPS)*
  - *Wong et al. 2009 (MOVA)*

Optical Flow Constraint

- **brightness/intensity constancy assumption:**

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

- **equivalent to the Lagrangian persistence requirement in VET**
- **can be solved by many ways:**
  - *e.g. globally by variational method*
    - HS, VET or MOVA, with different constraints on (u, v) field
  - *e.g. locally by assuming (u, v) constant in a neighbourhood*
    - LK, amongst to solving a 2x2 matrix

Variational Formulations

$$J = J_o + \alpha \cdot J_v$$

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

$$J_v = \begin{cases} J_{\mathrm{HS}} \\ J_{\mathrm{WW}} \end{cases}$$

where

$$J_{\mathrm{WW}} = \iint \left[\left(\frac{\partial^2 u}{\partial x^2} \right)^2 + \left(\frac{\partial^2 u}{\partial y^2} \right)^2 + 2\left(\frac{\partial^2 u}{\partial x \partial y} \right) + \left(\frac{\partial^2 v}{\partial x^2} \right)^2 + \left(\frac{\partial^2 v}{\partial y^2} \right)^2 + 2\left(\frac{\partial^2 v}{\partial x \partial y} \right) \right] dxdy \quad \text{(WW80)}$$

in MOVA & VET

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

in original HS formulation

Formulation by Bruhn et al 2003

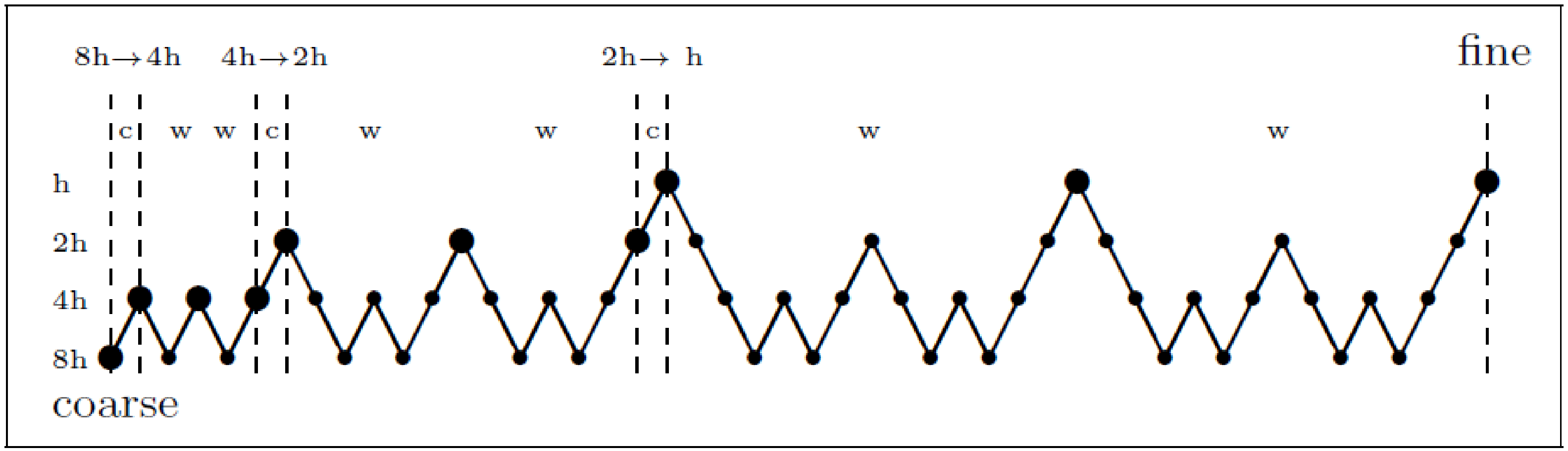
- LK-HS combined – fast

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

$$\begin{pmatrix} u \\ v \end{pmatrix} = \begin{pmatrix} K_\rho * (I_x I_x) & K_\rho * (I_x I_y) \\ K_\rho * (I_y I_x) & K_\rho * (I_y I_y) \end{pmatrix}^{-1} \begin{pmatrix} -K_\rho * (I_x I_t) \\ -K_\rho * (I_y I_t) \end{pmatrix}$$

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

- full multi-grid – accurate

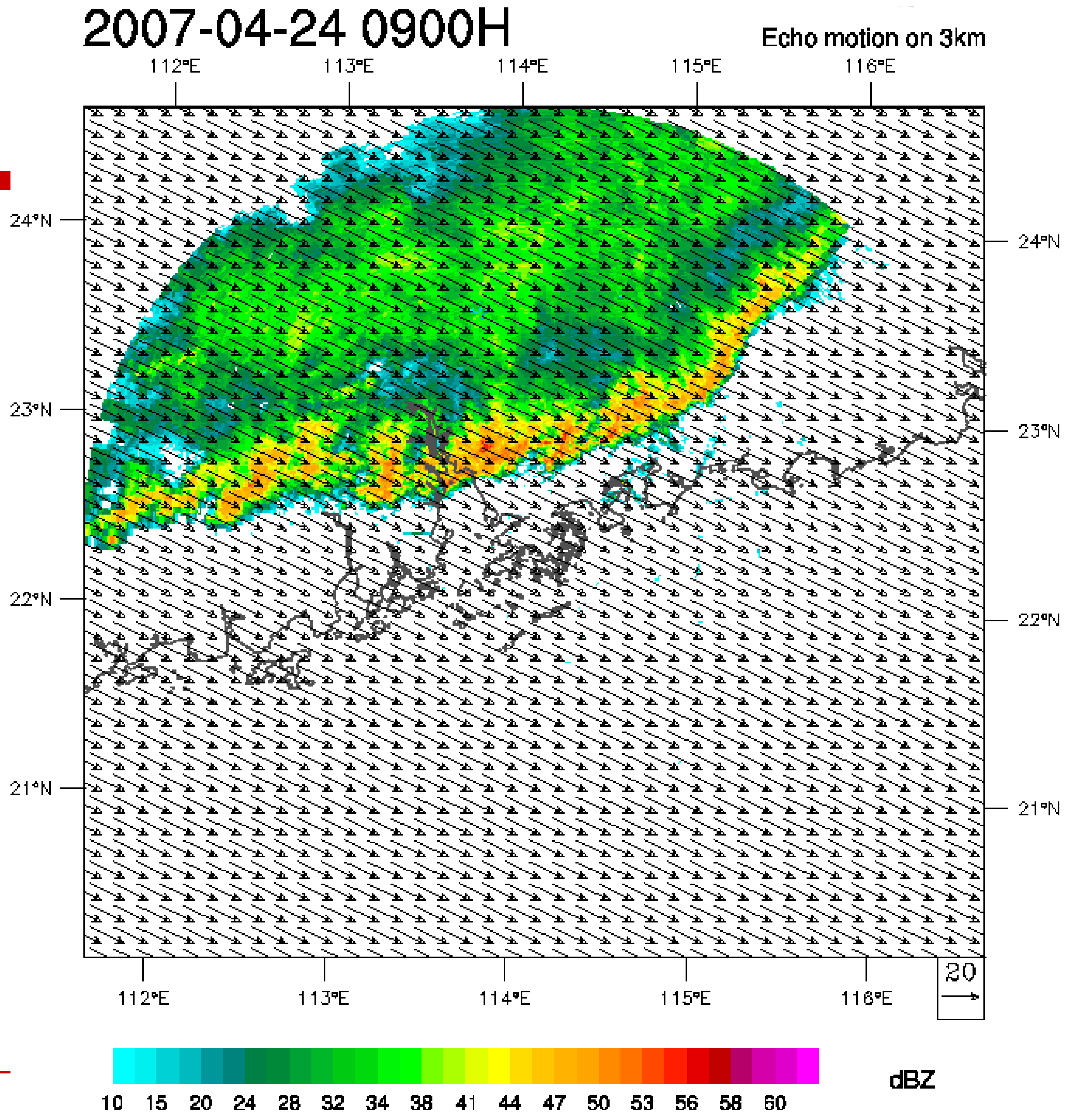


Illustration

$\mathcal{M}=1$

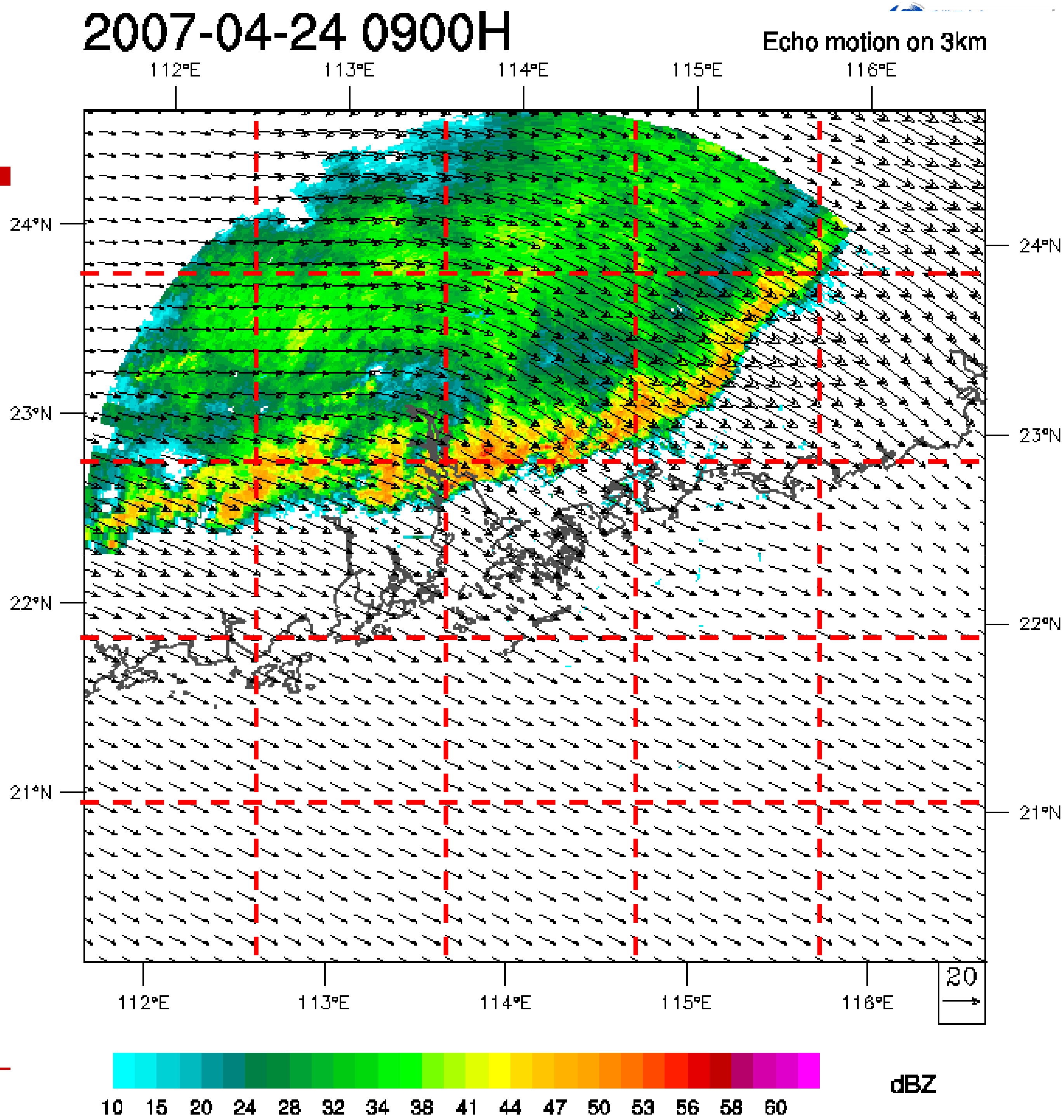
Single vector over whole domain

- largest scale resolvable



M=5

5x5 vectors

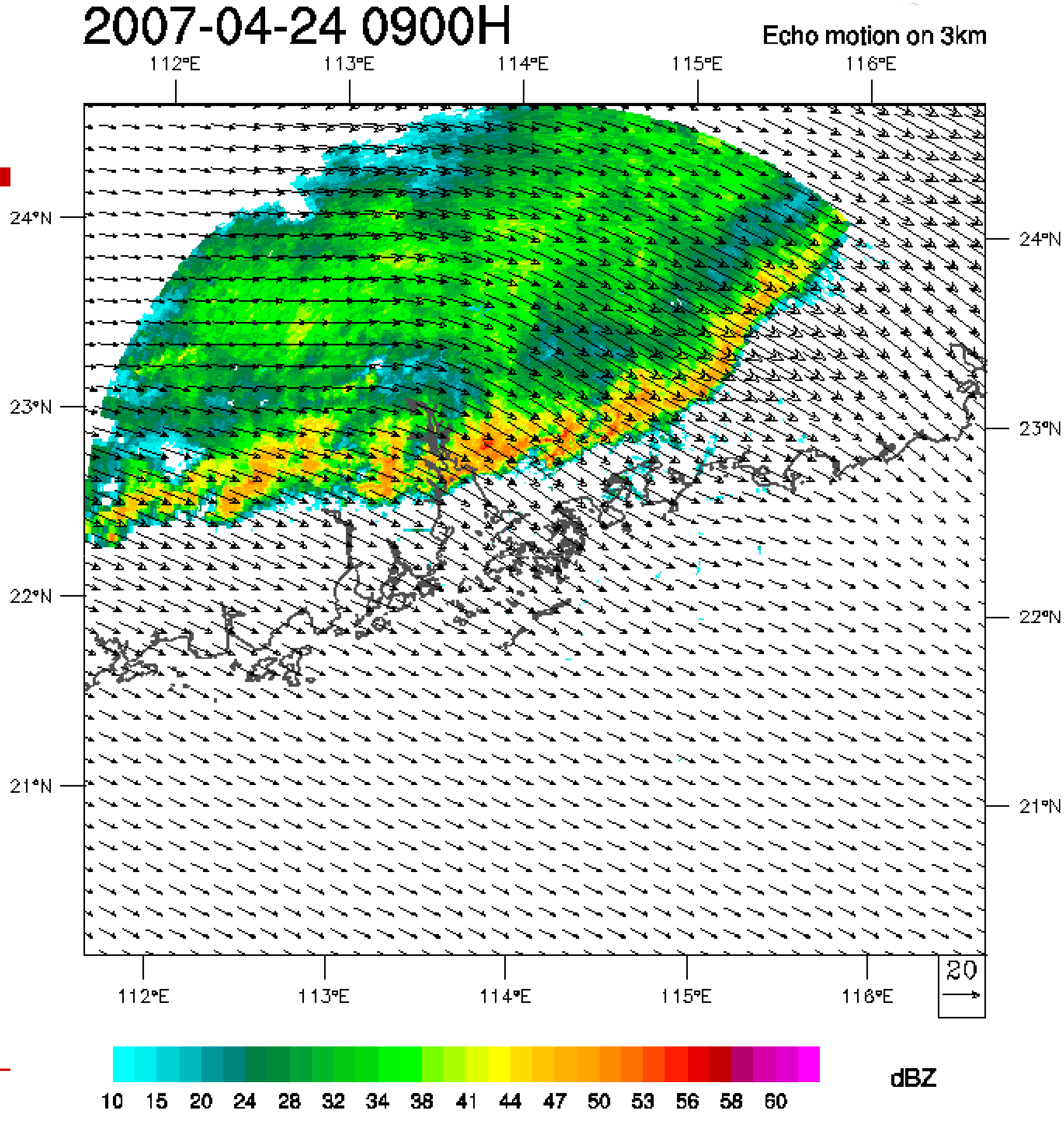


M=10

10x10 vectors

Repeat for

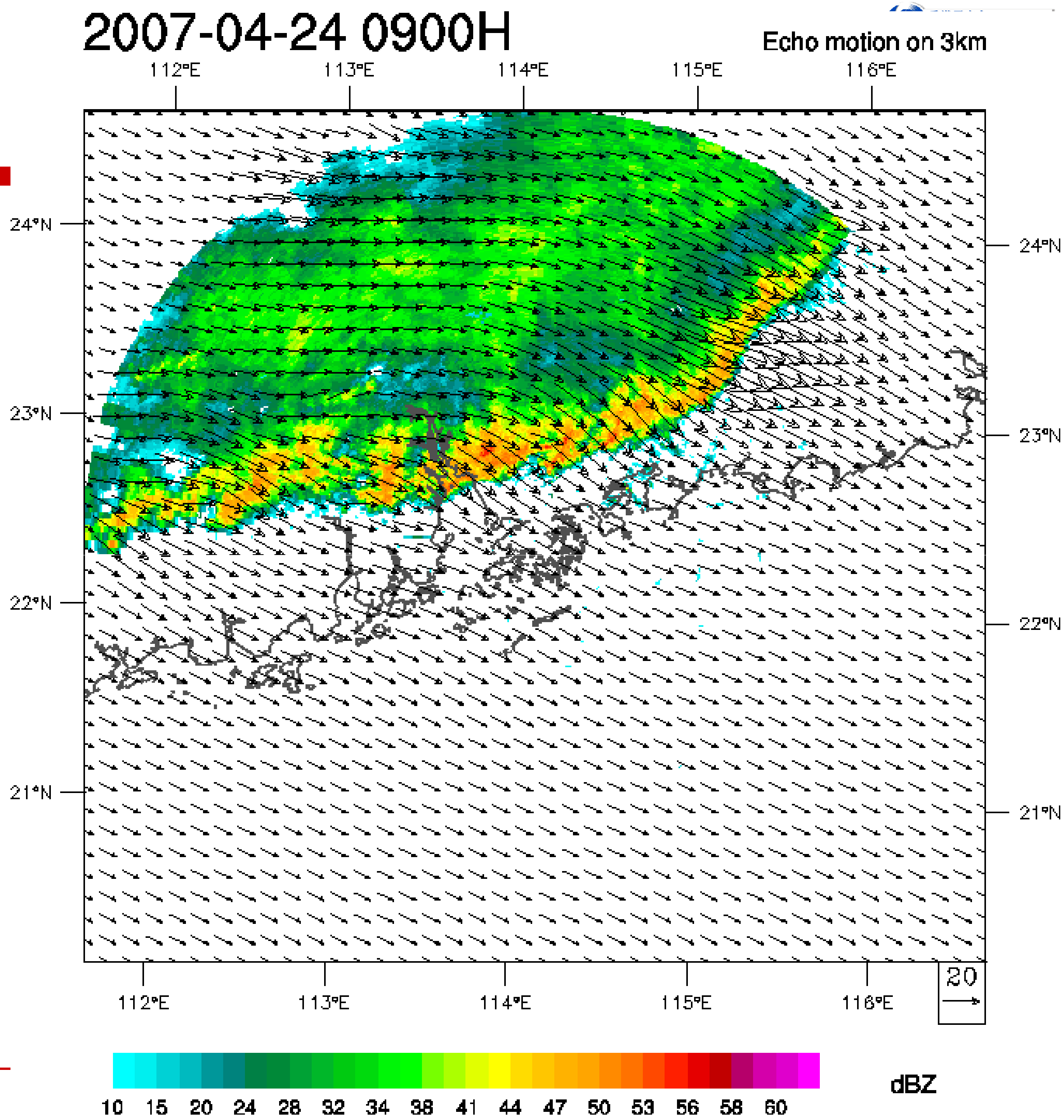
M=20,40 and 80



M=80

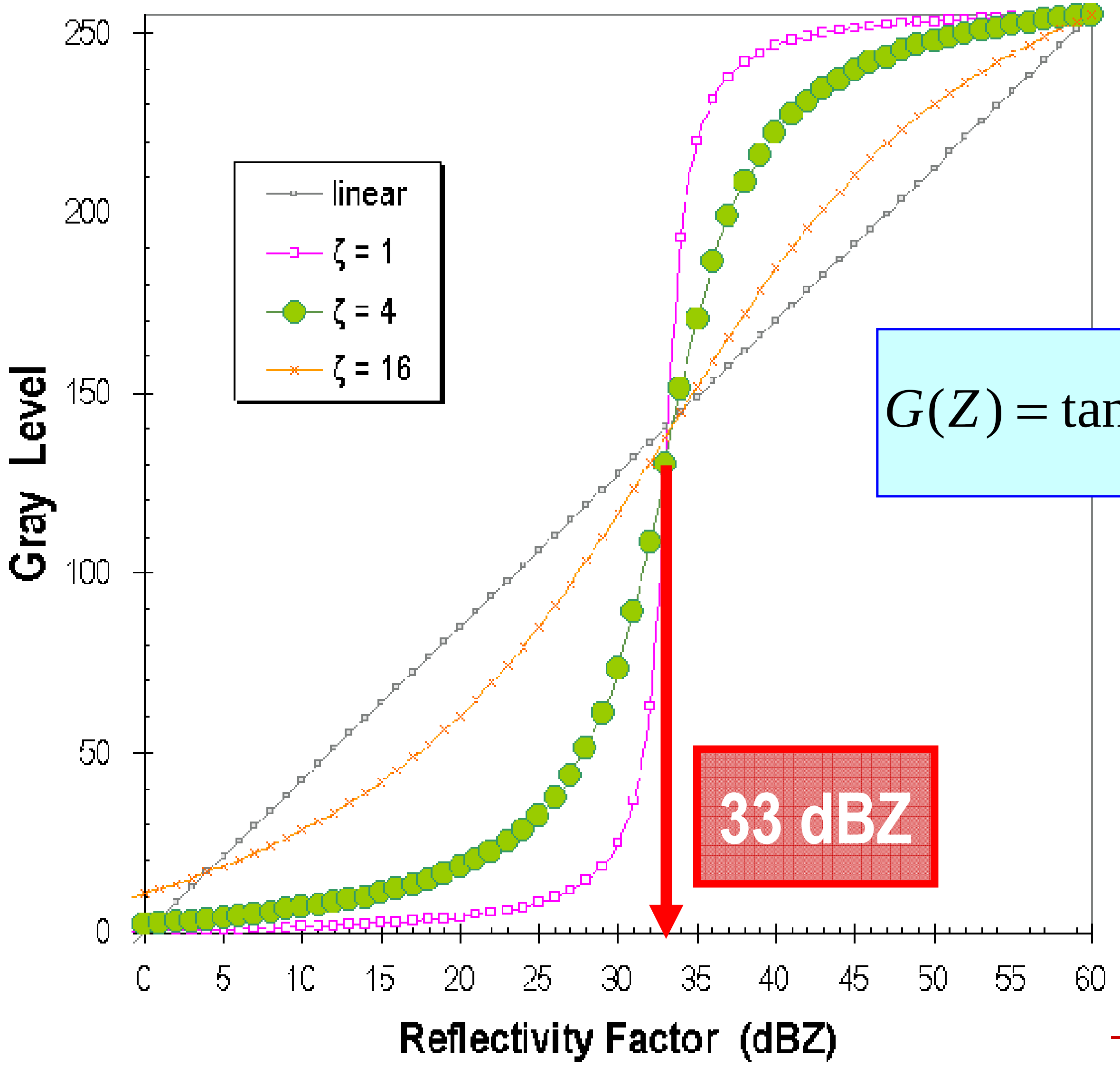
80x80 vectors

(final result)



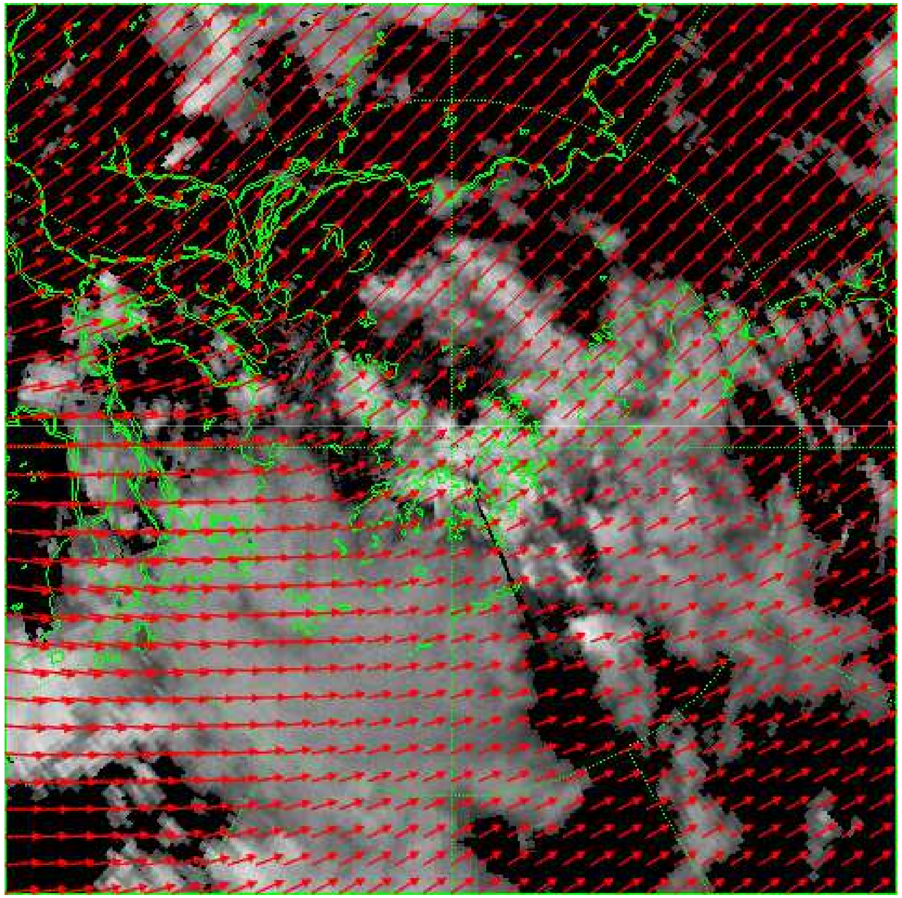
Adaptation

Controlling the "Brightness" of Sig. Conv.



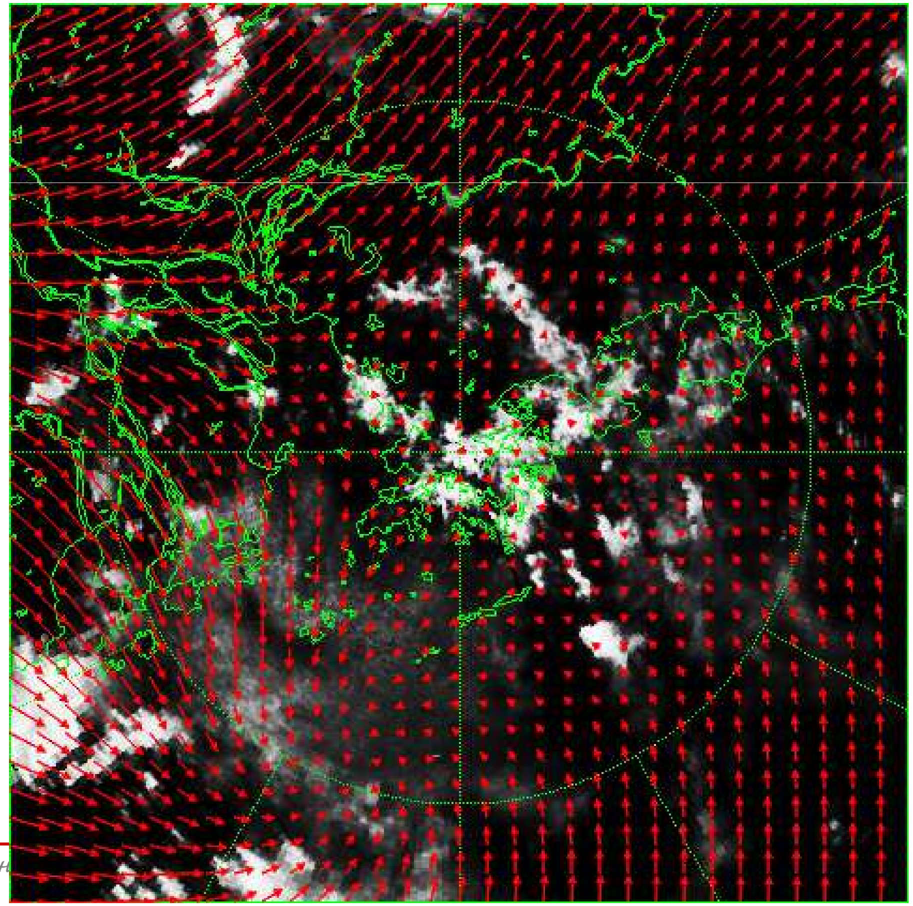
$$G(Z) = \tan^{-1}\left(\frac{Z - Z_c}{\zeta}\right)$$

Effect of Brightness on Tracking



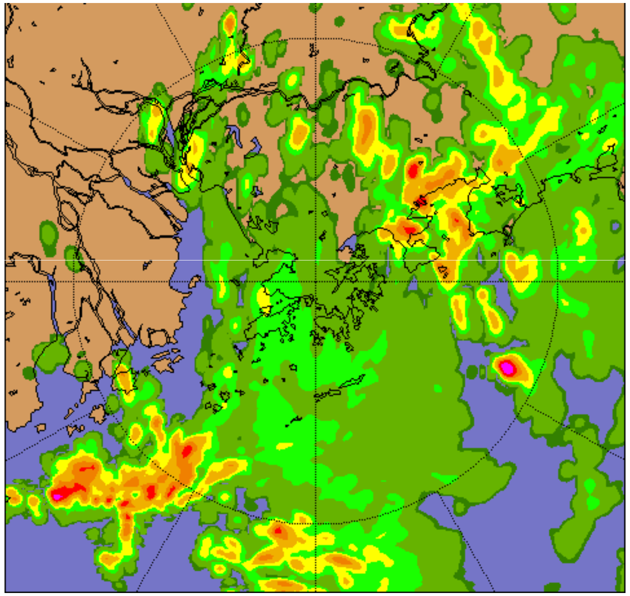
Linear

Non-Linear

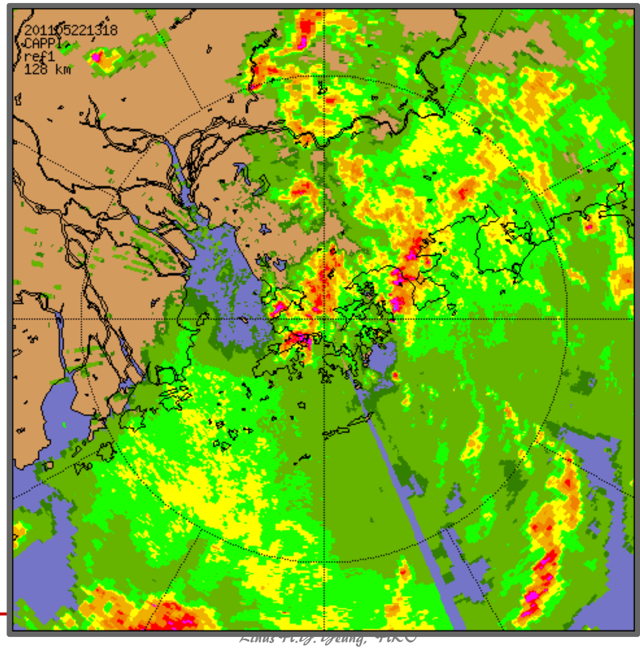


Extrapolation Results (3 horus)

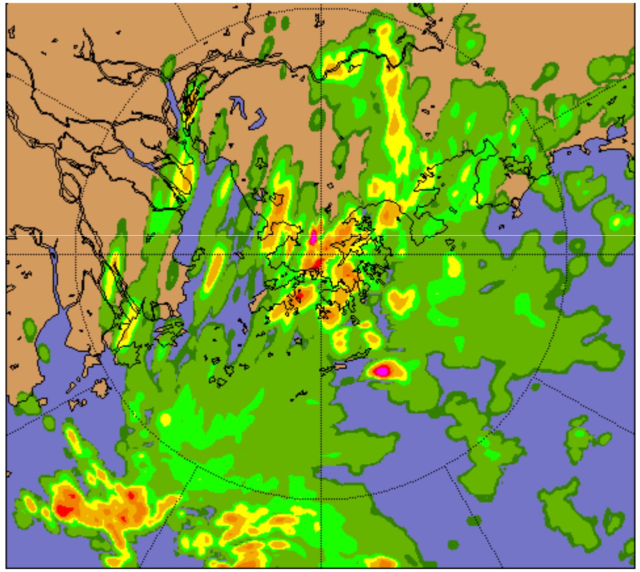
Linear



Actual



Non-Linear



Future Work

- To reduce the jumpiness of the warning messages
  - *by adopting time-lagged ensemble approach*
- To disseminate the significant convection forecasts to pilots
  - *via the ATIS (automatic terminal information system)*
- To further optimize the optical-flow tracker
  - *using a newly developed "Automatic Parameter Tuning Tool"*
    - based on a metahueristic approach using the Cuckoo Search engine
- To enhance the advection scheme
  - *by incorporating large scale motion*

~ End ~

Questions?