中央氣象署 LETKF對流尺度短期預報系統現況

CWA LETKF Convective-scale Short-range Forecasting System: Current Status

江琇瑛 連國淵 蔡金成
蔡雅婷 沈彥志

CWA RWRF-LETKF systems (1)

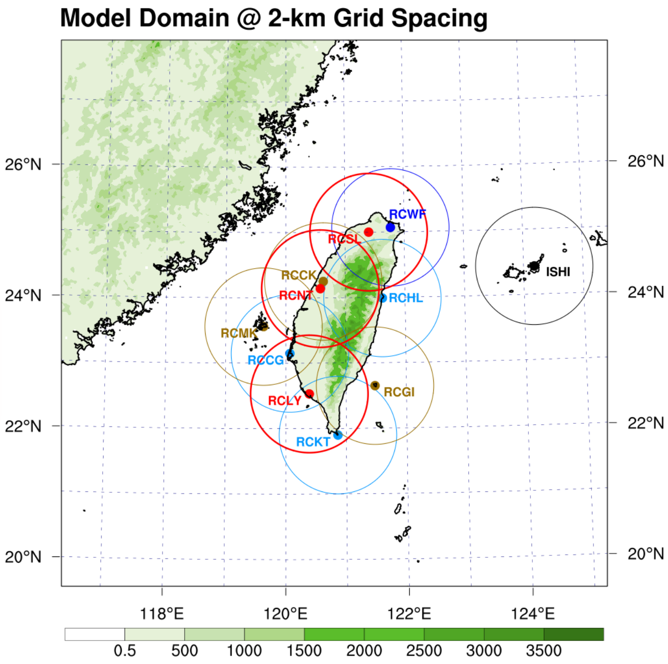
Variational DA — RWRF 2 km

Provide background perturbations for hybrid EnVar

Ensemble DA — RWRF-LETKF 2 Km

Provide initial perturbations for ensemble forecast

Ensemble Forecast — CEPS 2 km developing



Model configuration:

- 2 km model spacing
- Physics:
  - ✓ NOAH land surface model, YSU PBL scheme, RRTMG longwave and shortwave radiation parameterization scheme
  - ✓ **GCE →** **TCWA1 single-moment microphysics scheme** (陳正平教授, 蔡子衿博士)
- **Assimilating surface observations, radar radial velocity, reflectivity, and KDP**

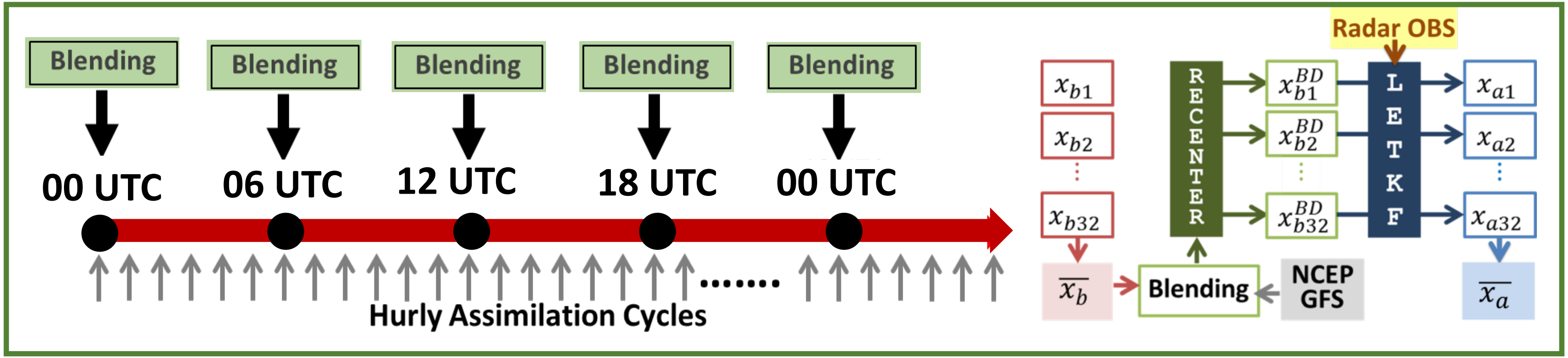
S-band:

- ✓ RCWF, RCHL, RCCG, RCKT (CWA)
- ✓ ISHI (Japan)

C-band:

- ✓ RCSL, RCNT, RCLY (CWA)
- ✓ RCCK, RCMK, RCGI (Air Force)

CWA RWRF-LETKF systems (2)



- **Hourly update strategy**
- **6-hourly blending with the GFS downscaling (Jiang et al. 2021)**

- **Increase the ensemble members from 32 to 40.**
- **Providing 13 hours deterministic forecast hourly from ensemble analysis mean**
  - ✓ In the future, the initial field will be derived from a deterministic analysis.

Roadmap of RWRF-LETKF DA

late 2015 — Start development of the LETKF system (與蔡直謙博士合作)

2017 — Conduct testing for operational deployment

2018 — Transition to operational status

- Developing radar pre-processing. (Tsai et al. 2019)
- Tuning control parameters.
- Deciding on the blending scheme. (Jiang et al. 2021)

2019

2020

- Incorporate the capability to assimilate surface observations into the LETKF program.
- Research and develop the dual-pol radar observation operator.

- Evaluate surface data assimilation.
- Evaluate C-band radar data assimilation.

2021 — NEW version of LETKF code module

2022 — Update to the operational system

- Investigate and tune RTPS and additive noise inflation methods. (Tsai et al., in preparation)
- Incorporating the capability to assimilate KDP into the LETKF program.

2023

2024 — Update to the operational system (Upgrade WRF to version 4.4.2 + TCWA1)

Increase the ensemble mems from 32 to 40

- Evaluate perturbation of boundary condition
- Evaluate KDP data assimilation

- Incorporate the capabilities of deterministic analysis members and test for operational deployment. (Expected to be operational by 2025)

Covariance inflation schemes considered for radar assimilation

(Tsai et al., in preparation)

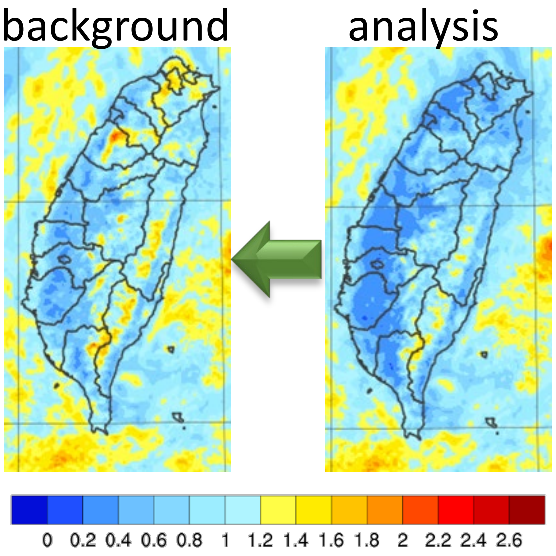
Relaxation to prior ensemble

Relaxation to prior spread (RTPS) (Whitaker and Hamill 2012):

$$\mathbf{X}^a \leftarrow \mathbf{X}^a\left(\alpha\frac{\sigma^f-\sigma^a}{\sigma^a}+1\right)$$

$$\sigma^{f,a}\equiv\sqrt{\frac{1}{K-1}\sum_{k=1}^{K}\left(\mathbf{x}'^{f,a}_{(k)}\right)^2}$$

for each analysis grid



shading: spread

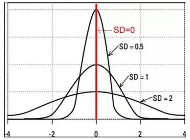
Random additive noise (RAN)

(Dowell and Wicker 2009, Caya et al. 2005)

$$f_i^* = f_i + \sum_{j=1}^{N}(r_j\sigma)e^{\frac{-d_{i-j}}{L}}$$

Where obs dBZ > 25
(Wheatley et al. 2015; Yussouf et al. 2016)

L: Prescribed length scale (km)
di–j : distance between the ith and jth points (km)
fi : value of original field at the ith point
fi* : value of the perturbed (inflated) field at the ith point
N : Number of points within the neighborhood of the ith point
rj : Random number at the jth point
σ : Prescribed standard deviation controlling shape of the Gaussian from which random numbers are drawn



以回波值大於25 dBZ為基準：

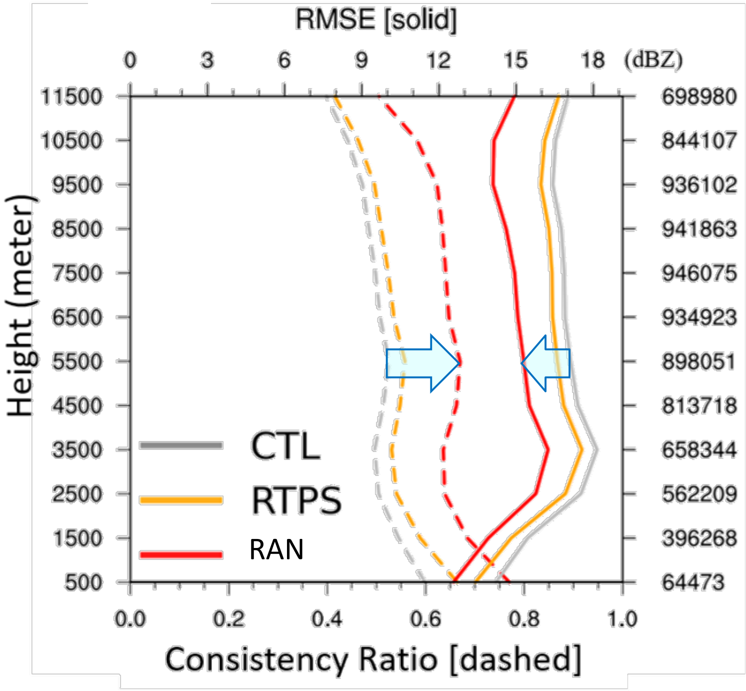
- 該區可能存在劇烈天氣。
- 對模式而言，應具有較高的預報不確定性。
- 對系集預報，應具有較高的系集離散度 。
- 故在初始場中，對溫度、水氣場施加隨機擾動，提升離散度，從而反應預報的不確定性。

Covariance inflation schemes considered for radar assimilation

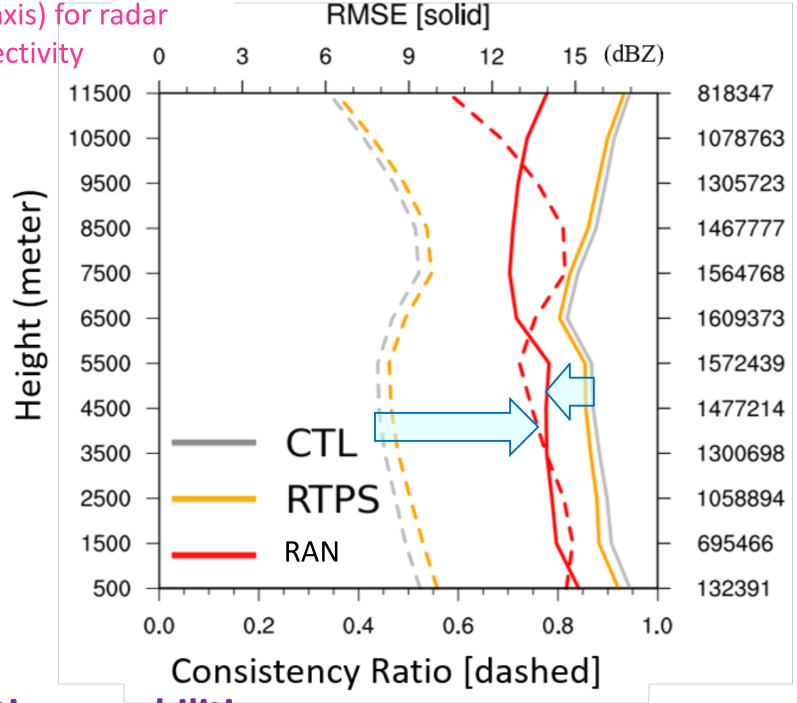
(Tsai et al., in preparation)

Prior ensemble mean RMSE (solid; top x-axis) and consistency ratio (dashed; bottom x-axis) for radar reflectivity

Afternoon thunderstorm case



Mei-yu case

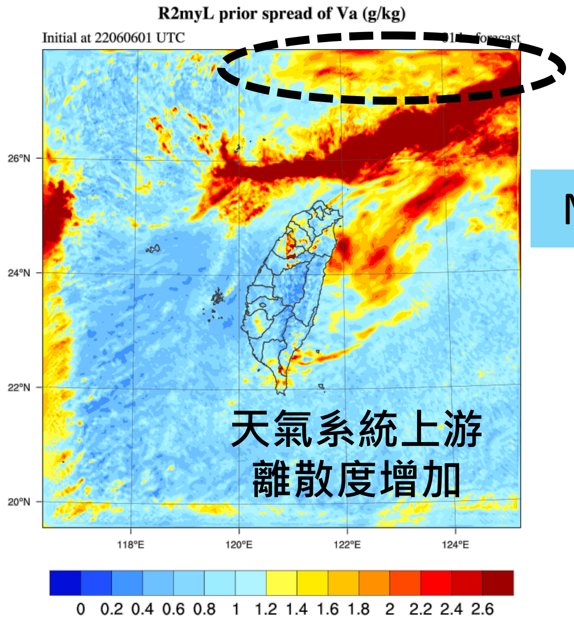


Improved forecasting capabilities

Increased ensemble forecast dispersion

Perturbation of boundary condition (from WEPS)

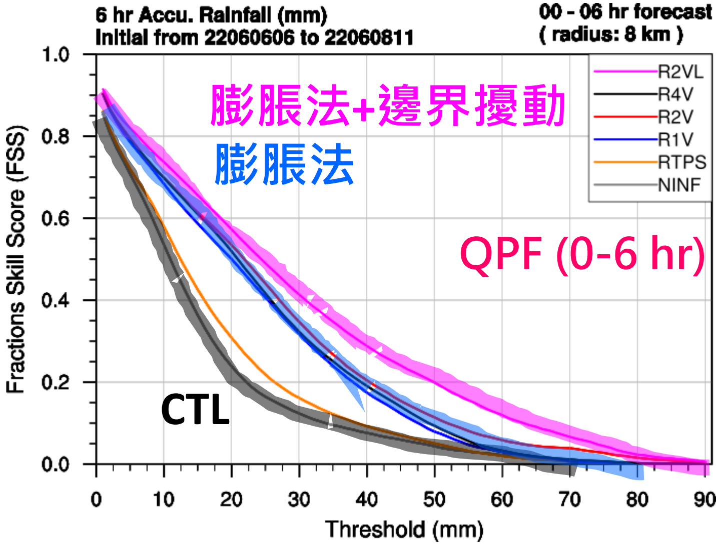
可參考102年天分之
A2-24_評估側邊界擾動在對流尺度系集資料同化系統之影響

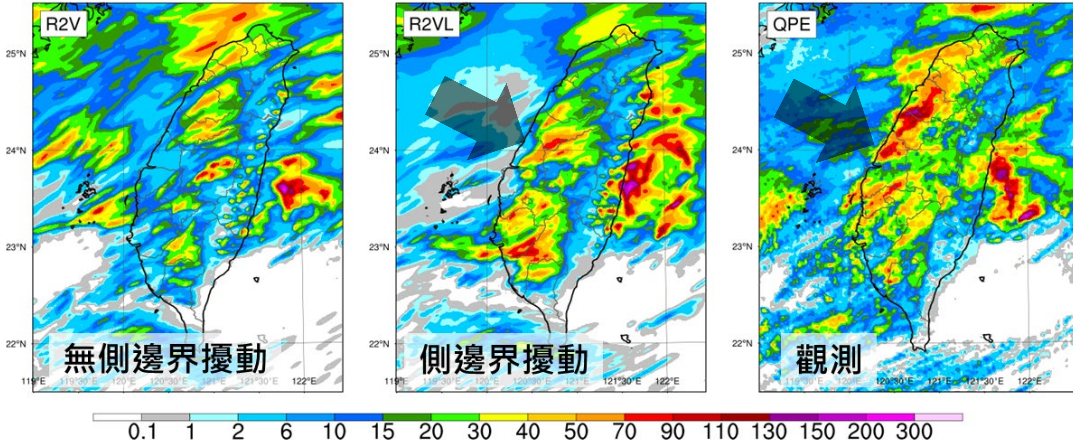


shading: spread

進一步提升邊界的系集離散度

Mei-yu case

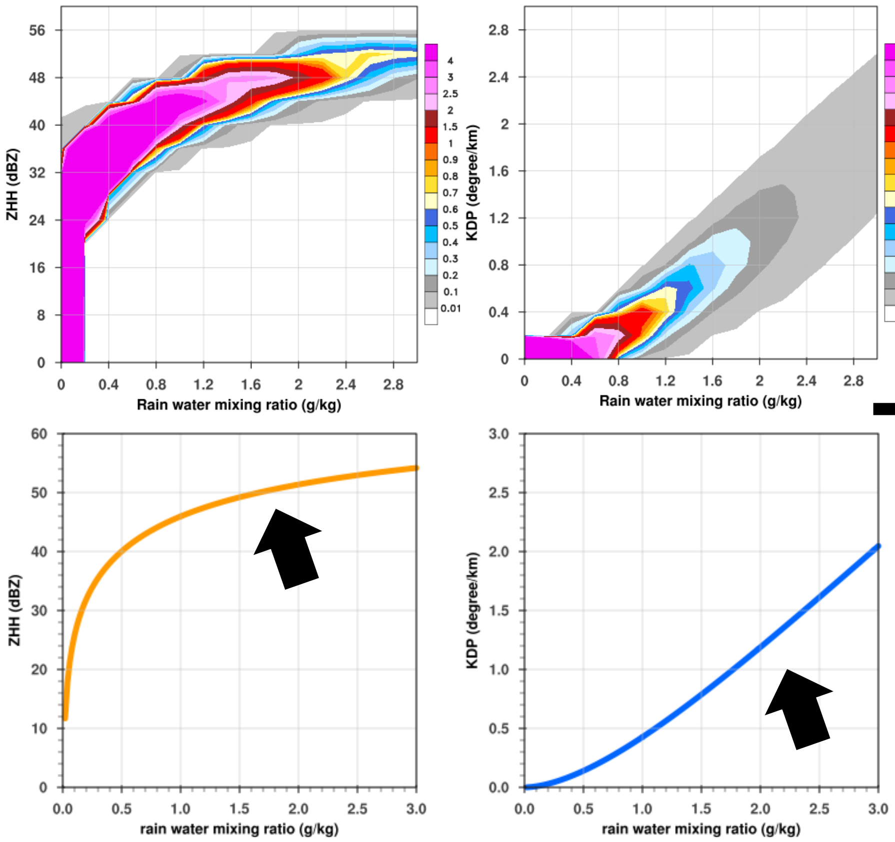




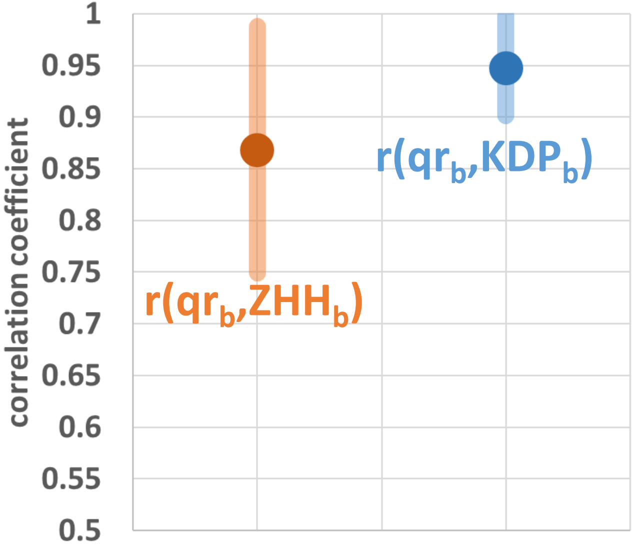
KDP assimilation in LETKF (with TCWA1 single-moment microphysics scheme)

ZHH (dBZ)隨qr的變化

KDP隨qr的變化

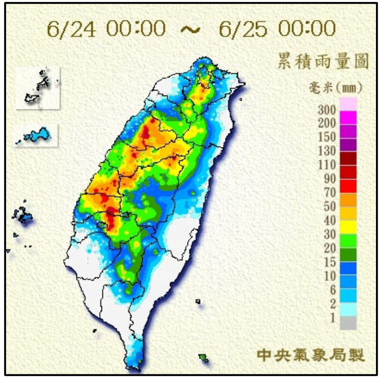


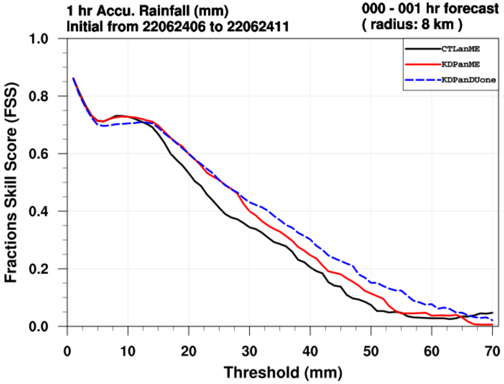
KDP variable is more closely related to qr than to ZHH.

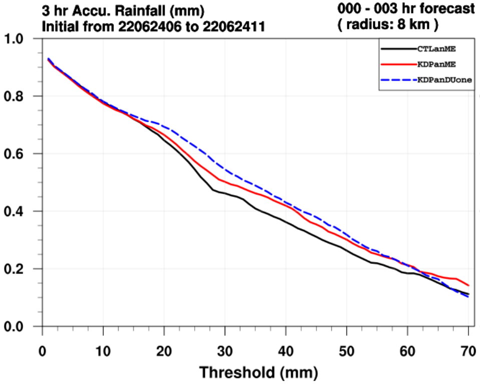


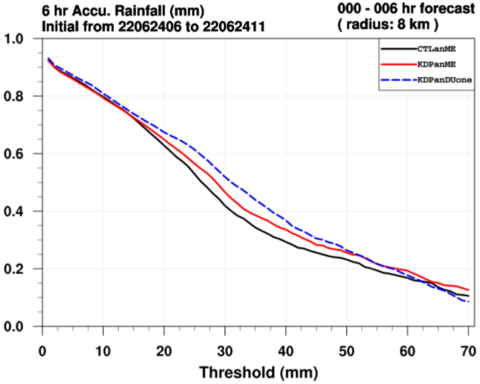
CTL — KDP — KDP + deterministic analysis (Schraff et al. 2016)

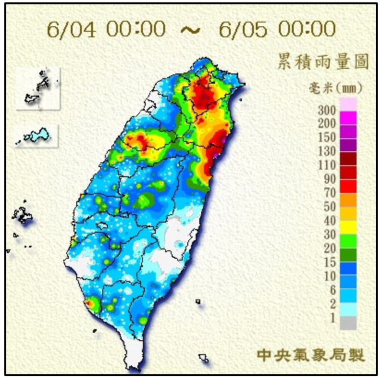
0-1 hr | 0-3 hr | 0-6 hr

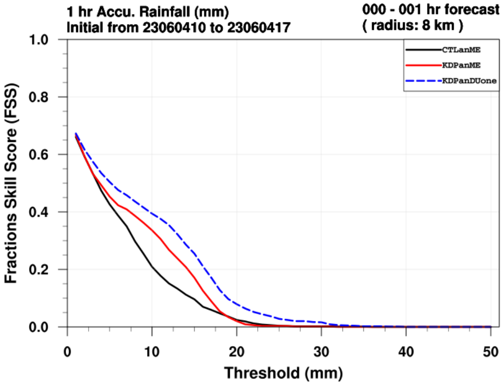


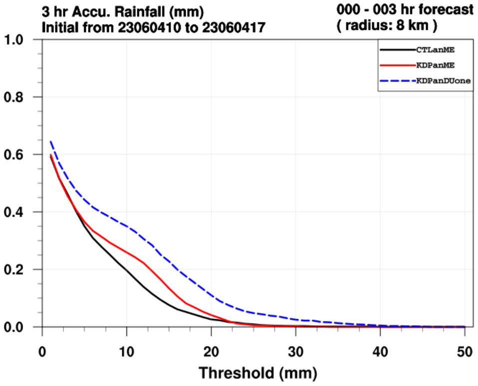


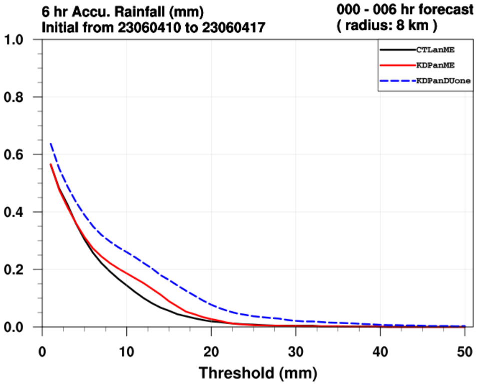












Deterministic analysis in LETKF

Methodology: Schraff et al. (2016)

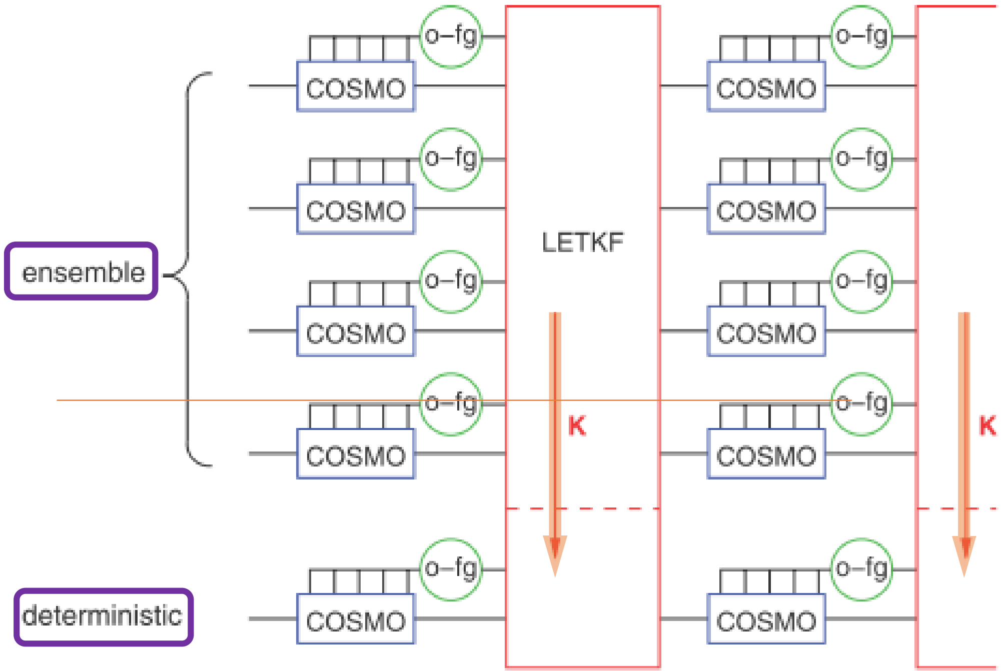


Figure 2. KENDA–LETKF system set-up; 'o–fg' denotes observation minus first guess, 'K' the Kalman gain for the analysis mean.

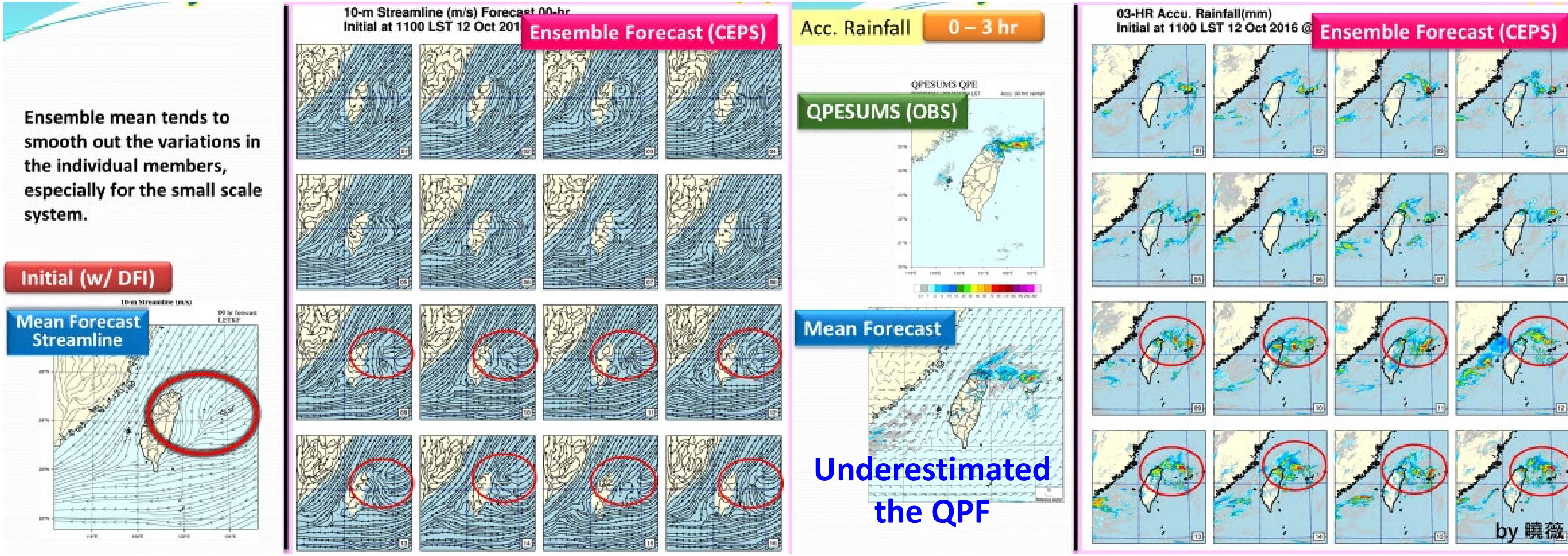
取代系集平均分析場進行決定性預報

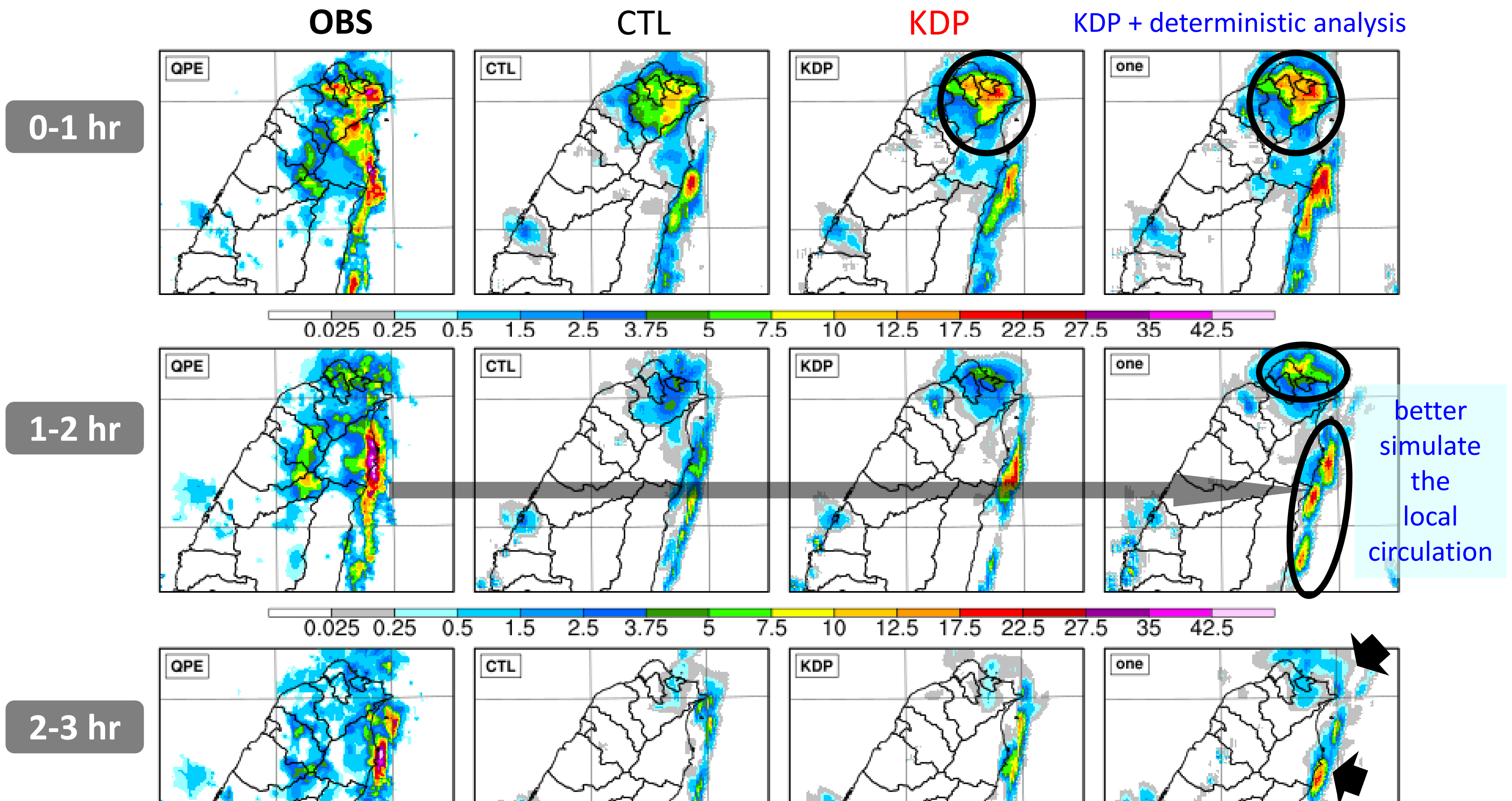
Let the deterministic analysis utilize the flow-dependent ensemble background covariances derived from the Kalman gain.

Deterministic analysis in LETKF

Motivation:

Avoid over-smoothing in the ensemble mean that may obscure high-frequency or small-scale variations.




OBS
CTL
KDP
KDP + deterministic analysis
0-1 hr
1-2 hr
2-3 hr
QPE
CTL
KDP
one
0.025 0.25 0.5 1.5 2.5 3.75 5 7.5 10 12.5 17.5 22.5 27.5 35 42.5
better simulate the local circulation

未來研發方向規劃

增加同化水氣觀測資訊

- ZTD
- AHI 水氣頻道

增加同化金門/馬祖雷達觀測

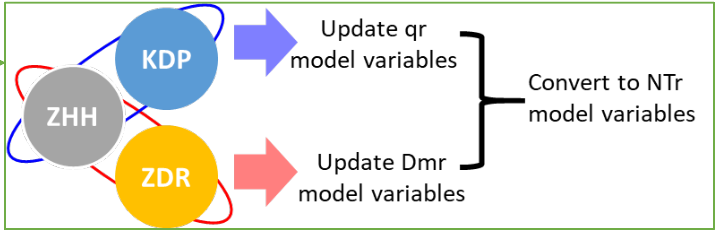
發展X-band / Ka-band 雙偏極化雷達觀測算符

增進模式雲微物理預報

- 發展TCWA2 two-moment microphysics scheme
- 新增同化ZDR與KDP雙偏極化雷達觀測

(Jiang et al., in preparation)

分開更新模式變數的策略方案



Dual-polarimetric radar assimilation in LETKF

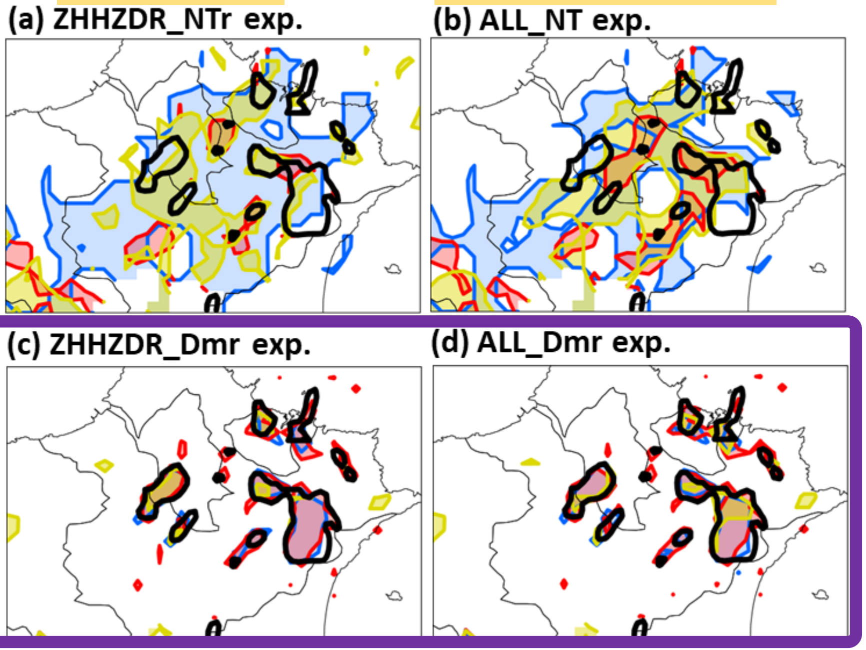
Analysis variable selection & sensitivity to microphysics schemes (Jiang et al., in preparation)

ZHH + ZDR | ZHH + ZDR + KDP

Analysis variables:

qr, NTr

qr, Dmr



Contour: ZDR ≥ 1.8 dB | OBS | NSSL | WDM6 | MORR

- When multiple dual-polarimetric radar observables are **simultaneously** assimilated and with two-moment microphysics schemes, {Dmr} are better analysis variables than {NTr}.
- The use of **{Dmr} analysis variables** can yield less sensitivity of the ZDR assimilation to different two-moment microphysics schemes.

Dual-polarimetric radar assimilation in LETKF

Analysis variable selection & sensitivity to microphysics schemes (Jiang et al., in preparation)

As long as ZDR observations are assimilated, the results of the rainwater analysis are sensitive to the two-moment microphysics scheme.

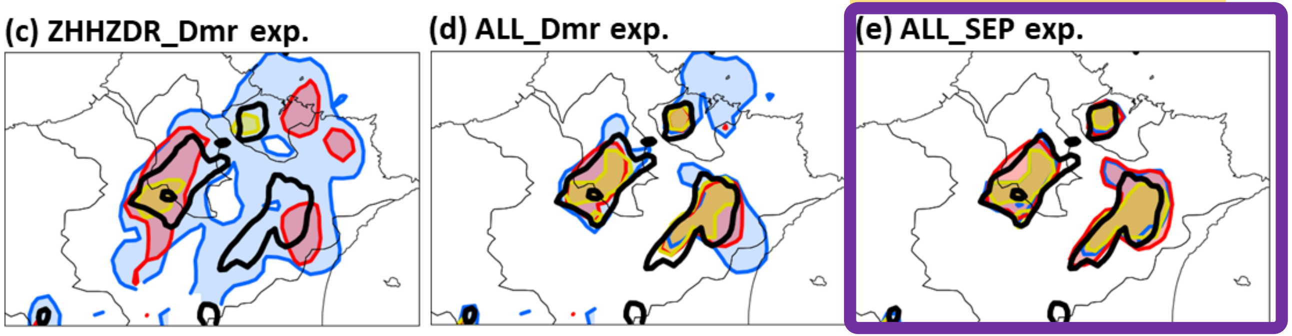
ZHH + ZDR

ZHH + ZDR + KDP

ZHH + KDP → qr
ZHH + ZDR → Dmr

Analysis variables:

qr, Dmr



Contour: KDP ≥ 1.0 °/km

OBS NSSL WDM6 MORR

Separately updating model variables can less sensitivity of the rainwater analysis to different two-moment microphysics schemes.

Thank you for your attention