Meteorological Service Singapore
Centre for Climate Research Singapore

A data assimilation-centred convective-scale ensemble for Singapore and its background error statistics

Rachel Koh, Joshua Lee, Pratiman Patel, HPCB

Centre for Climate Research Singapore

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Session: Convective Scale Data Assimilation

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1. Weather of Singapore
2. Existing forecast systems: SINGV-DA & SINGV-EPS
3. Ensemble verification
4. Background error statistics

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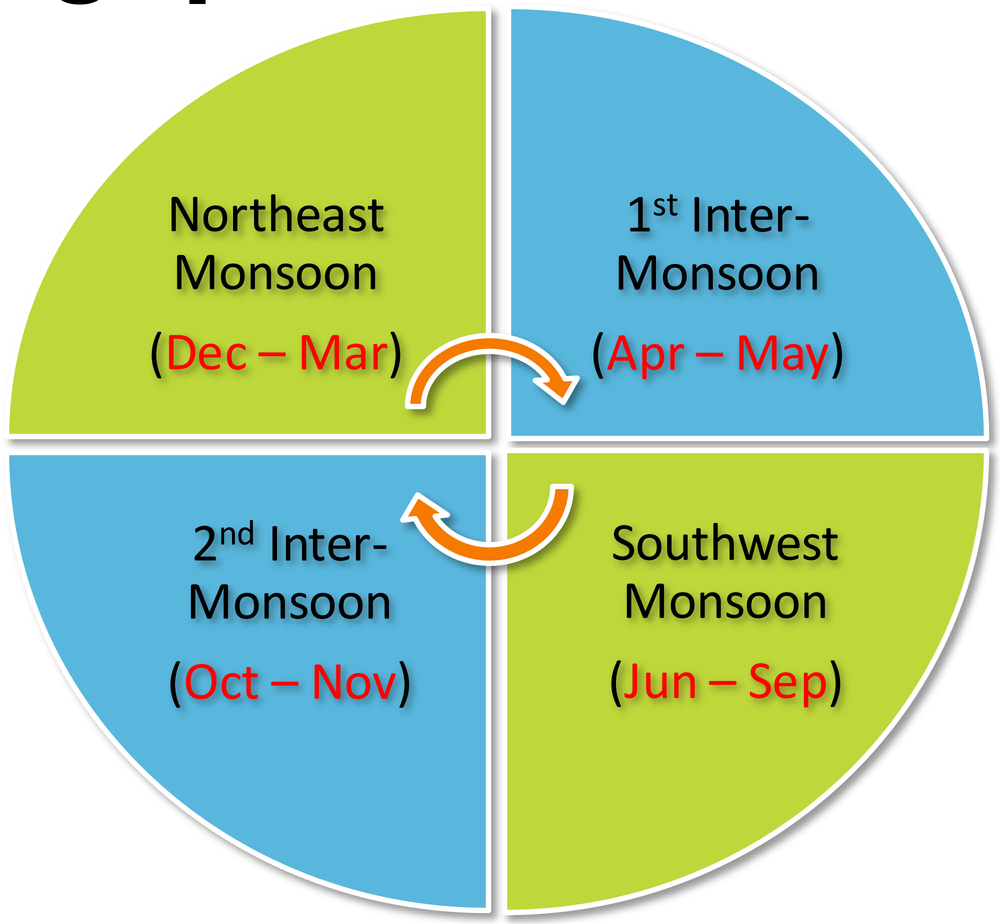
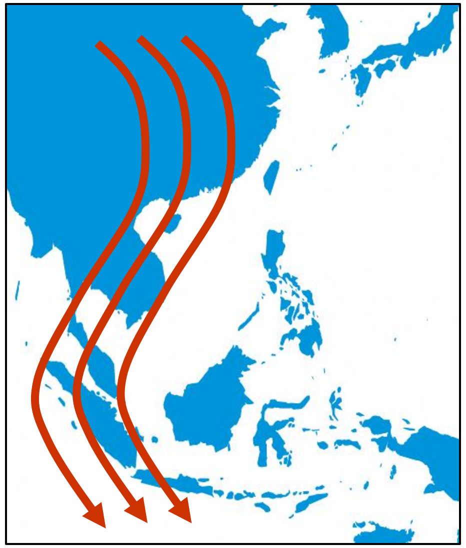
Weather & climate in Singapore

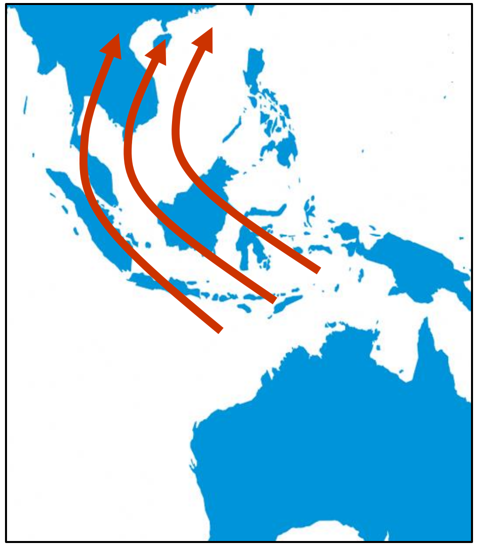
An overview

- Singapore has an equatorial climate
  - Abundant rainfall
  - Moderate and uniform temperatures
  - High humidity
- Weather patterns strongly influenced by monsoon seasons





Northeast Monsoon



Southwest Monsoon

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Convection-permitting models: SINGV-DA, SINGV-EPS & DACE

	SINGV-DA	SINGV-EPS	DACE
Nature	Deterministic	Ensemble	Ensemble
Resolution	1.5 km	4.5 km	4.5 km
Initial conditions	Fixed cycling DA framework	ECMWF-ENS analyses	SINGV-DA analyses
Boundary conditions	ECMWF-ENS analyses	ECMWF-ENS analyses	ECMWF-ENS analyses
Science configuration	RAL3.2 + #504.4	RAL3.2 + #504.4	RAL3.2 + #504.4

DACE

1. Compute ensemble mean

$$\overline{IC\_EC} = \sum_{i=1}^{12} IC\_EC_i$$

2. Calculate perturbations = deviation of each member i from mean

$$pert_i = IC\_EC_i - \overline{IC\_EC}$$

3. Inflate perturbations (x2)

$$pert_i = pert_i * 2$$

To reduce under-dispersiveness

4. Compute initial conditions of each member as a function of forecasts from SINGV-DA

$$IC_i = IC\_DA_0 + pert_i$$

Ensemble centred on best estimate of weather conditions at that time

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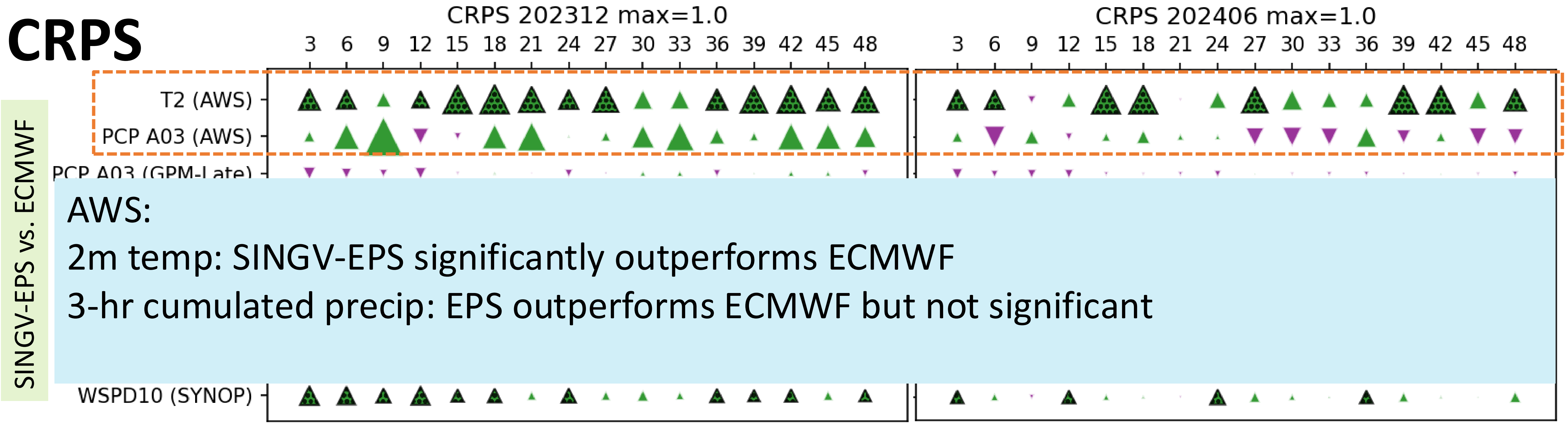
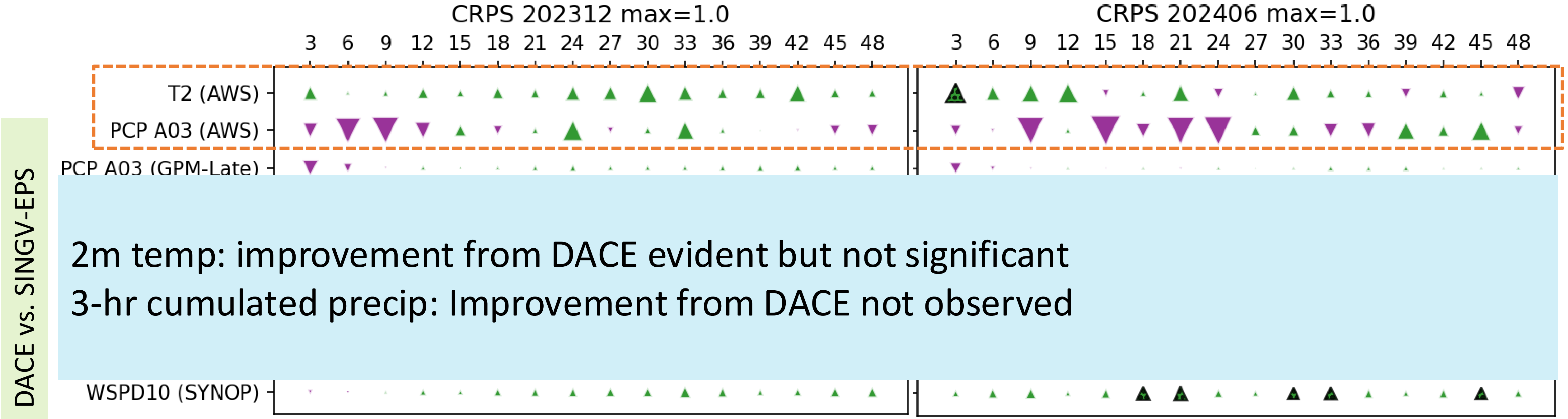
CRPS



AWS:

2m temp: SINGV-EPS significantly outperforms ECMWF

3-hr cumulated precip: EPS outperforms ECMWF but not significant

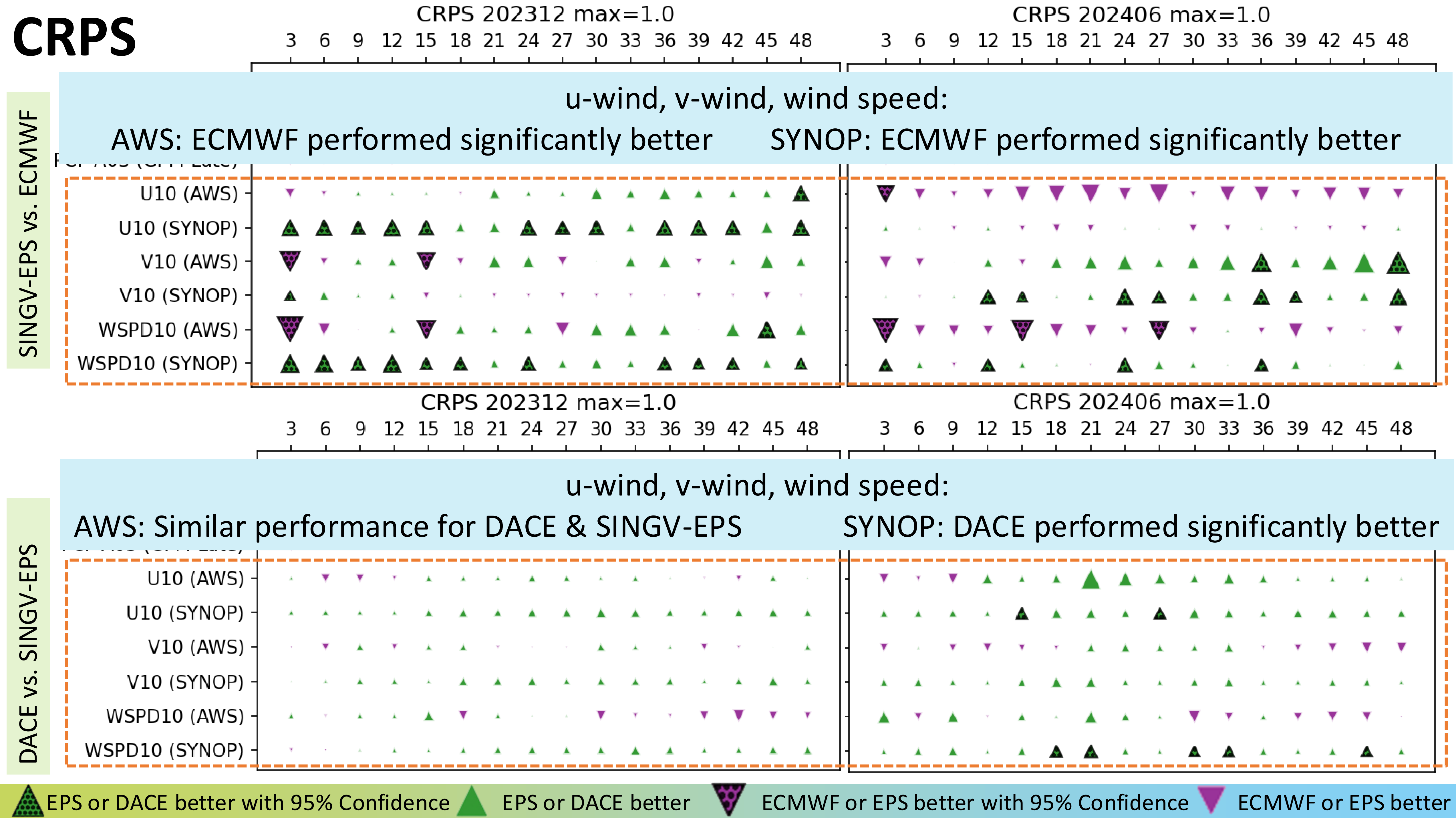


2m temp: improvement from DACE evident but not significant

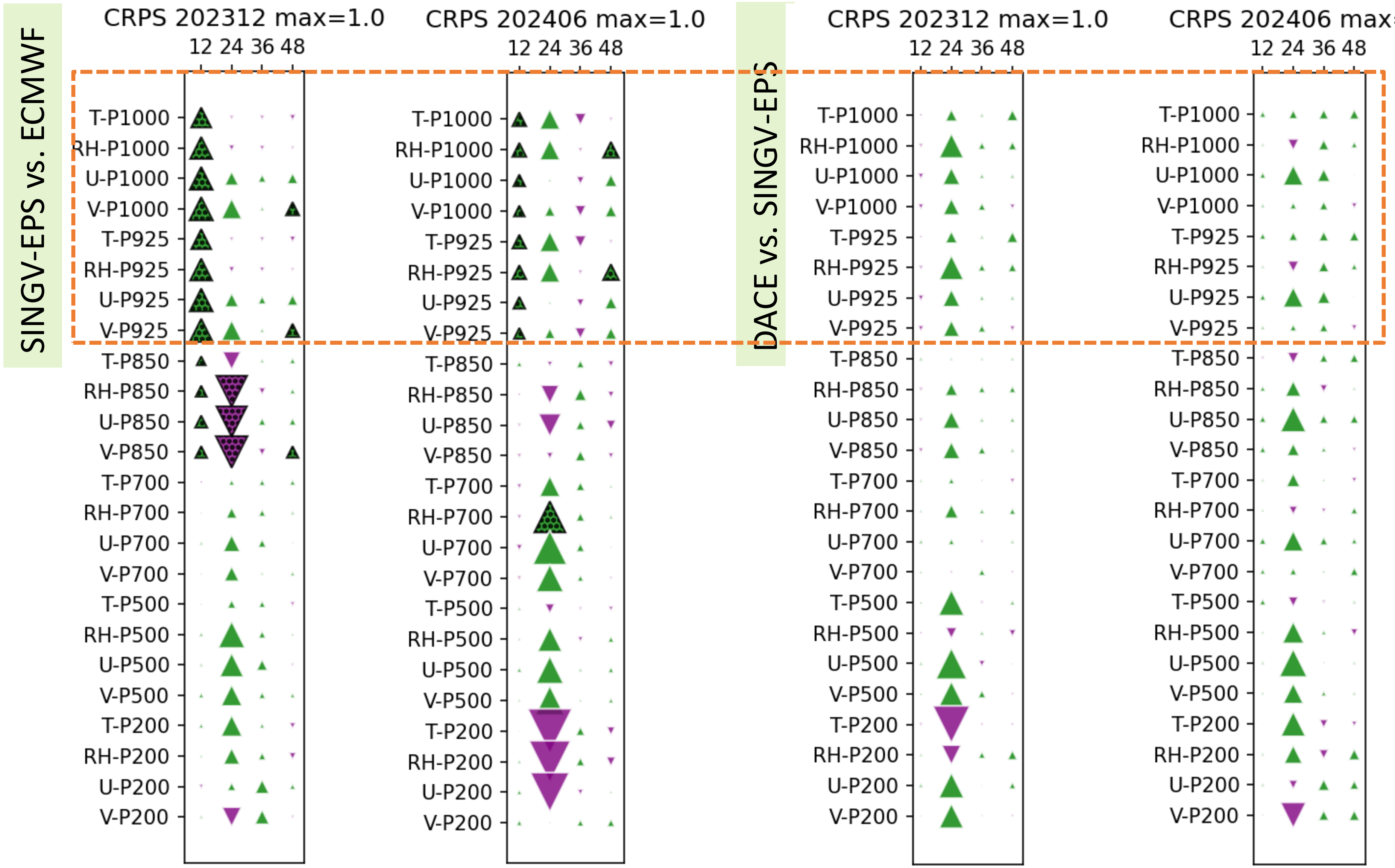
3-hr cumulated precip: Improvement from DACE not observed

EPS or DACE better with 95% Confidence | EPS or DACE better | ECMWF or EPS better with 95% Confidence | ECMWF or EPS better

CRPS


CRPS 202312 max=1.0
CRPS 202406 max=1.0
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48
u-wind, v-wind, wind speed:
AWS: ECMWF performed significantly better
SYNOP: ECMWF performed significantly better
SINGV-EPS vs. ECMWF
U10 (AWS)
U10 (SYNOP)
V10 (AWS)
V10 (SYNOP)
WSPD10 (AWS)
WSPD10 (SYNOP)
CRPS 202312 max=1.0
CRPS 202406 max=1.0
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48
u-wind, v-wind, wind speed:
AWS: Similar performance for DACE & SINGV-EPS
SYNOP: DACE performed significantly better
DACE vs. SINGV-EPS
U10 (AWS)
U10 (SYNOP)
V10 (AWS)
V10 (SYNOP)
WSPD10 (AWS)
WSPD10 (SYNOP)
EPS or DACE better with 95% Confidence
EPS or DACE better
ECMWF or EPS better with 95% Confidence
ECMWF or EPS better

CRPS – Surface to Upper Atmosphere



Near-surface temperature, RH, u-wind, v-wind:
SINGV-EPS significantly outperforms ECMWF, further improved by DACE

Upper atmosphere:
Improvement not significant

EPS or DACE better with 95% Confidence | EPS or DACE better | ECMWF or EPS better with 95% Confidence | ECMWF or EPS better

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Background error statistics estimated using DACE

- 6-hour forecasts from DACE used to compute errors-of-the-day as proxies for background error

$$\mathbf{x}'_k = \frac{\mathbf{1}}{\sqrt{\boldsymbol{N} - \mathbf{1}}}(\mathbf{x}_k - \bar{\mathbf{x}})$$

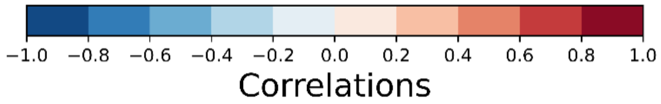
k is the ensemble index
N is the ensemble size
$\mathbf{x}$ *is the ensemble forecast*

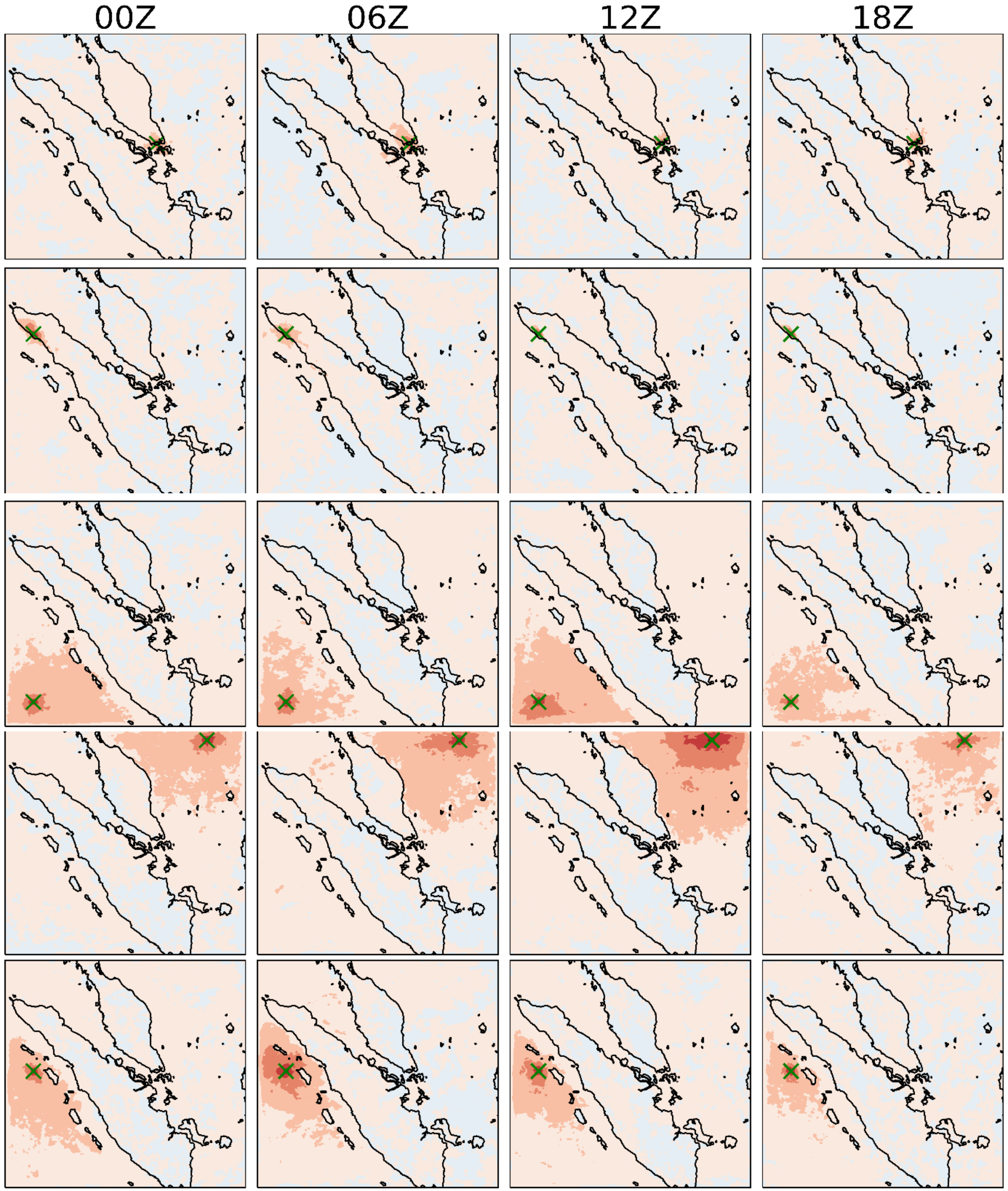
- Samples are accumulated over hindcast trials to compute raw background error autocorrelations

- Error autocorrelations with respect to various locations in domain, for different variables are shown, to explore:
  - Diurnal variability (effects of time of day)
  - Location-dependence (effects of land, sea, orography)

Variable: 1.5m temperature

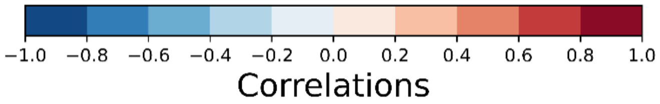
- Forecast error over ocean points has negligible correlation with forecast error over land points
- Correlation length-scales for forecast error over oceans are longer than over land

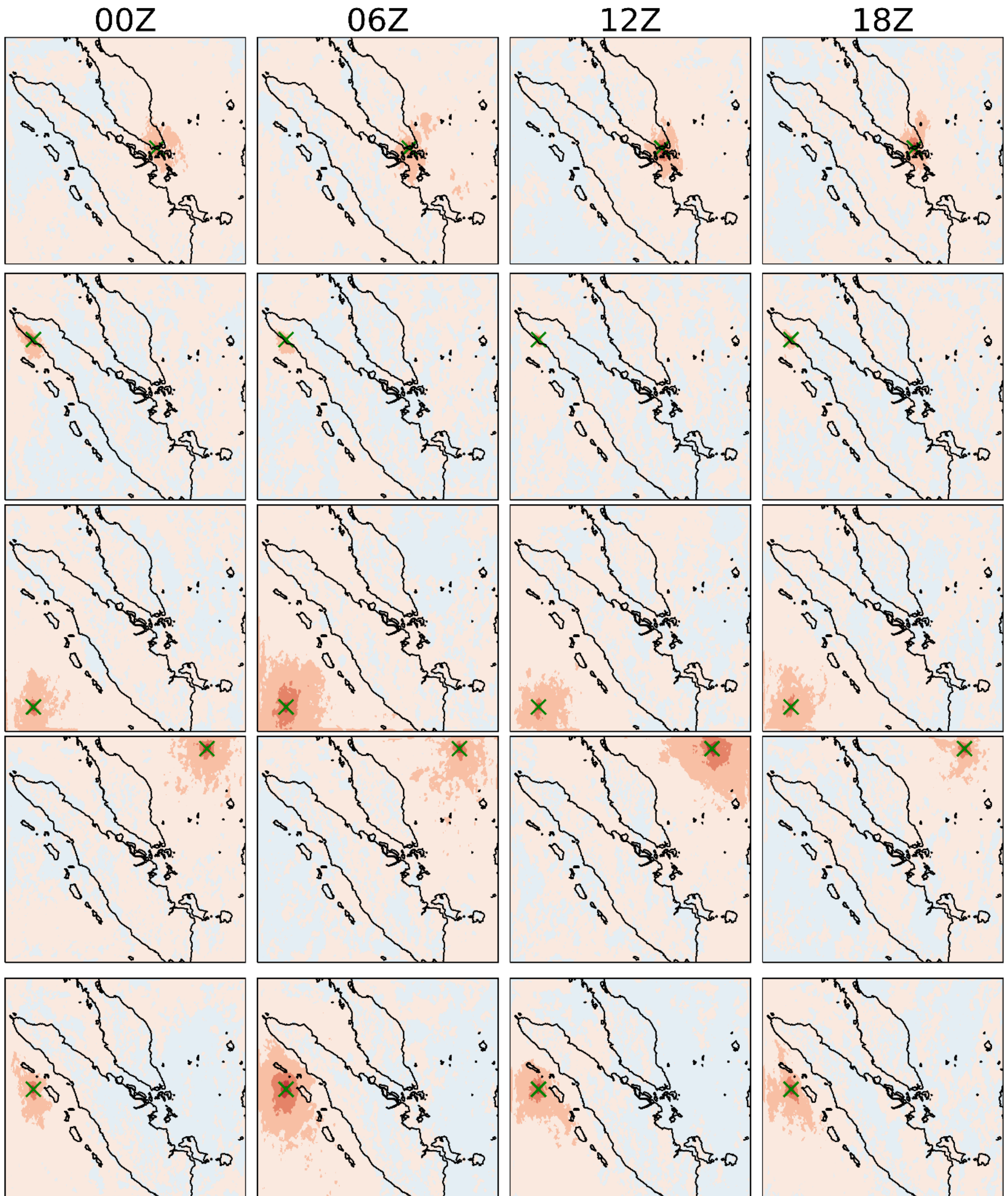




Variable: u-wind

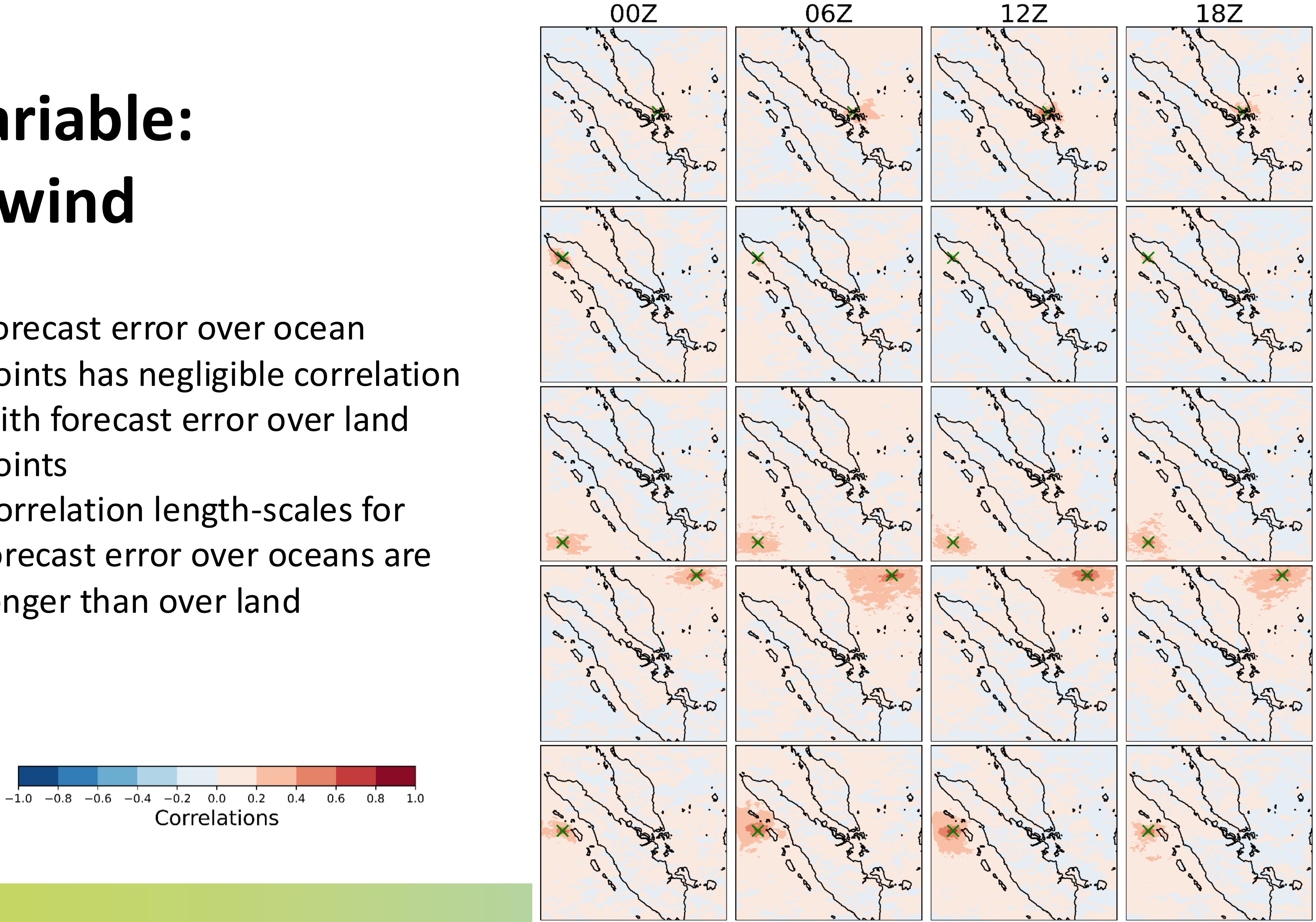
- Forecast error over ocean points has negligible correlation with forecast error over land points
- Correlation length-scales for forecast error over oceans are longer than over land





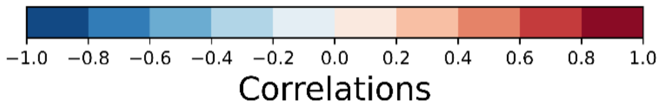
Variable: v-wind

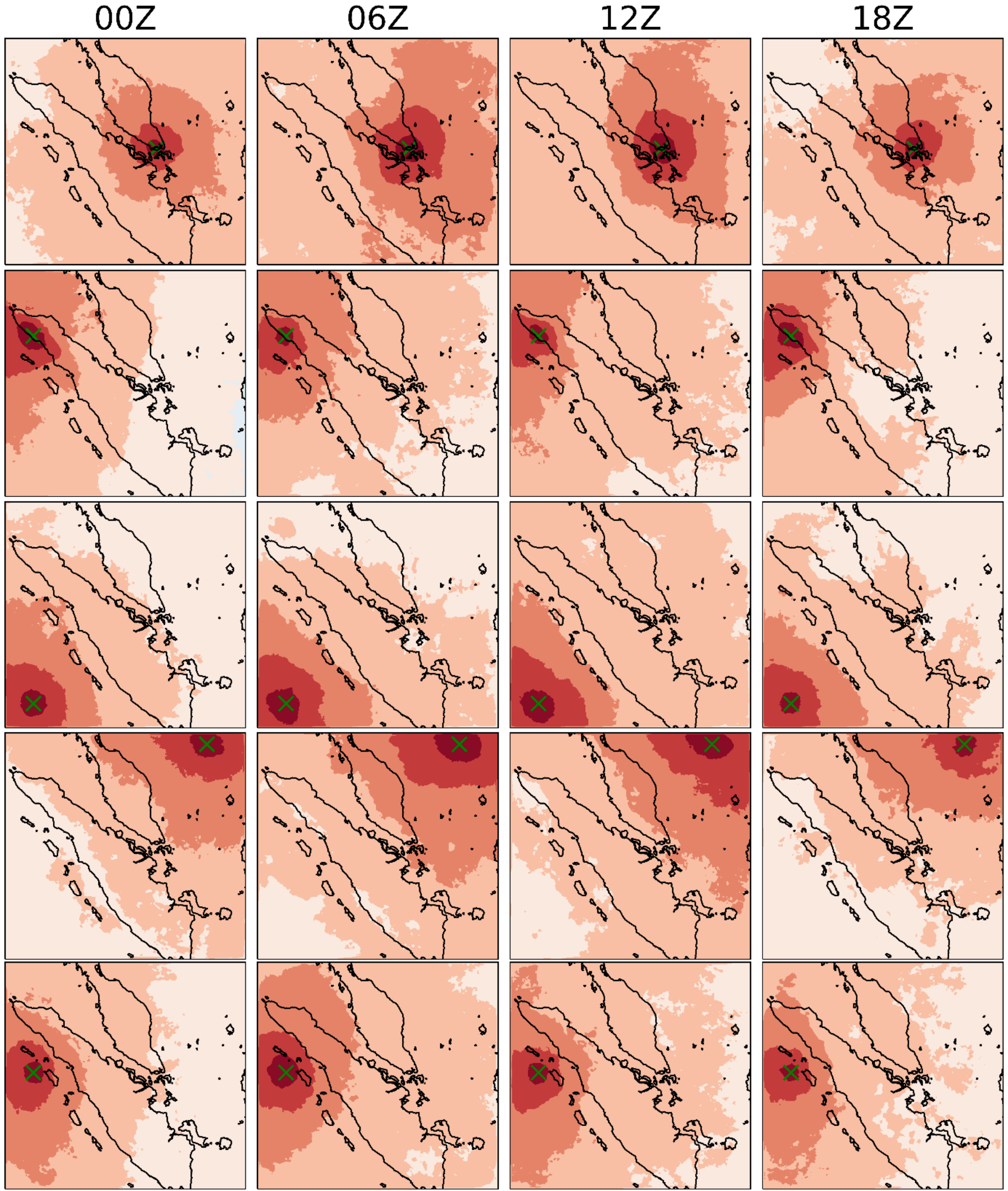
- Forecast error over ocean points has negligible correlation with forecast error over land points
- Correlation length-scales for forecast error over oceans are longer than over land



Variable: Air pressure at sea level

- Relatively homogeneous forecast errors statistics over ocean and land points
- Longer correlation length-scales observed in 06Z & 12Z cycles





Conclusions

- Existing forecast systems: SINGV-DA & SINGV-EPS
  - Latest Regional Atmosphere-Land science configuration (RAL3.2 + #504.4) has been implemented
- DA-centred ensemble (DACE)
  - Addresses spin-up issues, increases forecast spread
  - Verification using METPlus indicates improved performance
- Ensemble time-dependent background error statistics
  - Time-dependent: Diurnal variation of forecast error statistics in the domain
  - Location-dependent
  - Recommended to explore ensemble-based error statistics for DA in the tropics