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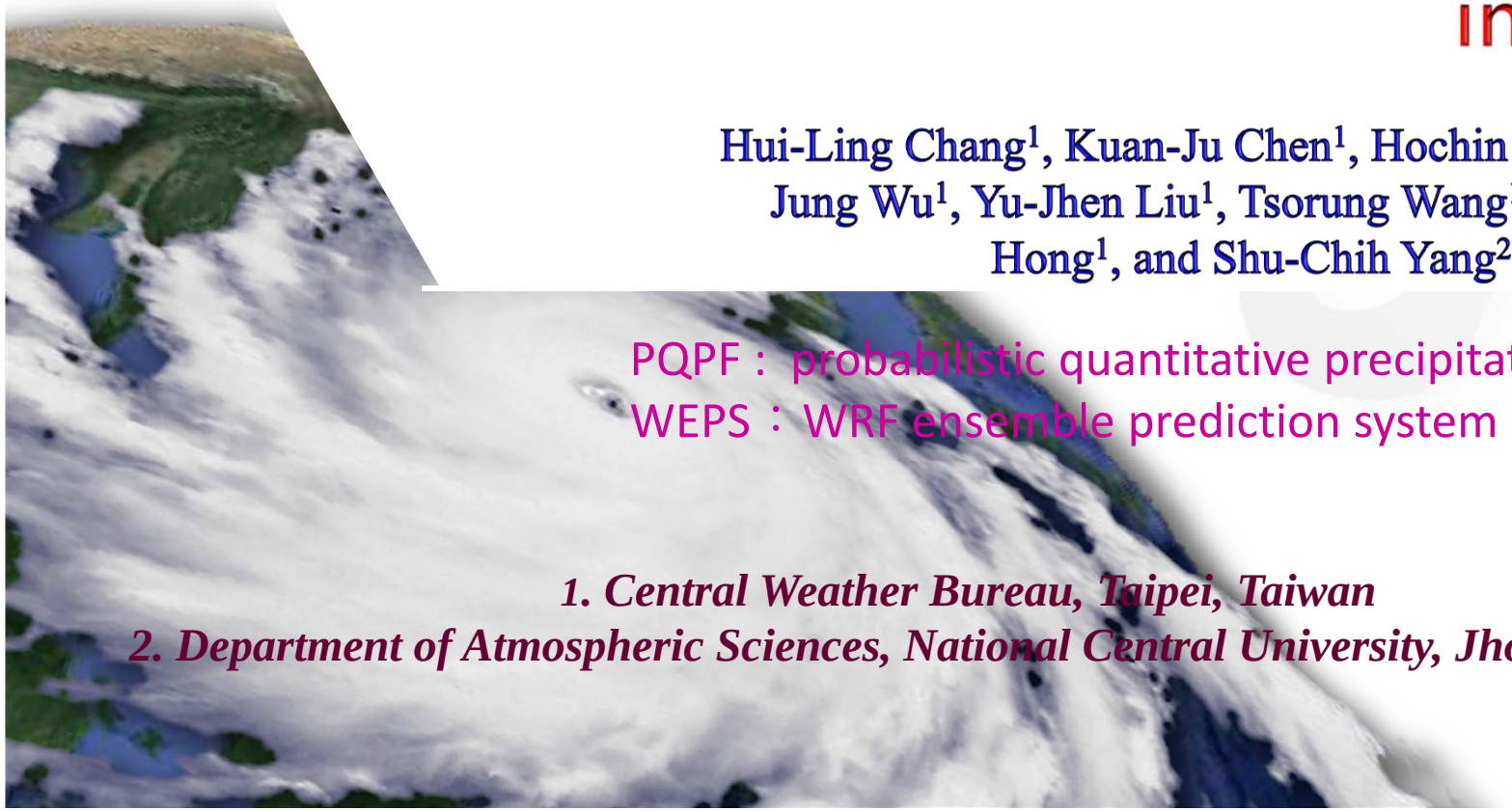
Evaluation, Calibration and Economic Value Analysis of the 0-24h PQPFs from WEPS in Taiwan



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PQPF： probabilistic quantitative precipitation forecasts

WEPS：WRF ensemble prediction system

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Outline

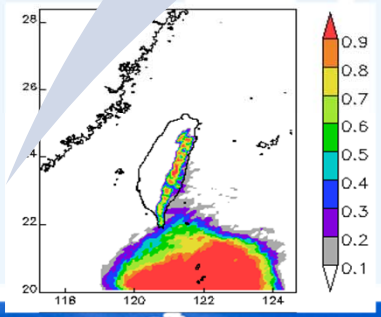
Model, Data, and PQPF Products

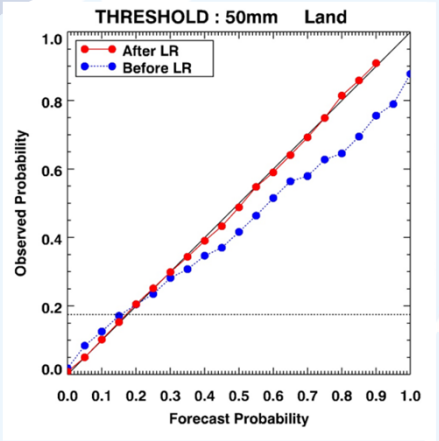
Evaluation and calibration of WEPS PQPF

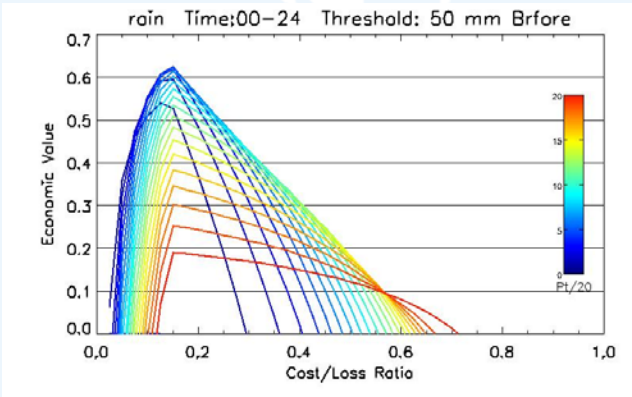
EV analysis of WEPS PQPFs

more reliable and valuable precipitation forecasts for typhoons.

$$EV = \frac{E_{\text{climate}} - E_{\text{forecast}}}{E_{\text{climate}} - E_{\text{perfect}}}$$







Model, Data, and PQPF products

- *Model - WRF ensemble prediction system (WEPS)*

  WEPS has 20 members and is perturbed by different initial states, boundary conditions, and physical parameterizations.

- *Data*

  12 typhoon cases during 2013-2015 (total 134 0-24h PQPFs)

- *Calibration*

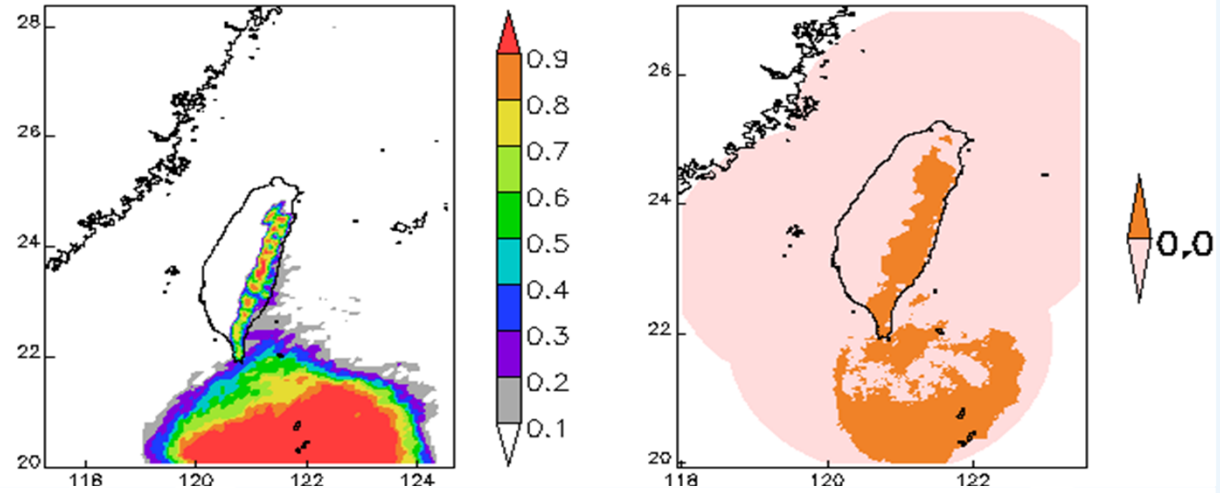
  - ✓ *Linear regression (LR) method (Yuan et al. 2008)*
  - ✓ *Artificial Neural Network (ANN) techniques (Yuan et al. 2007) to calibrate the PQPFs*

PQPF products

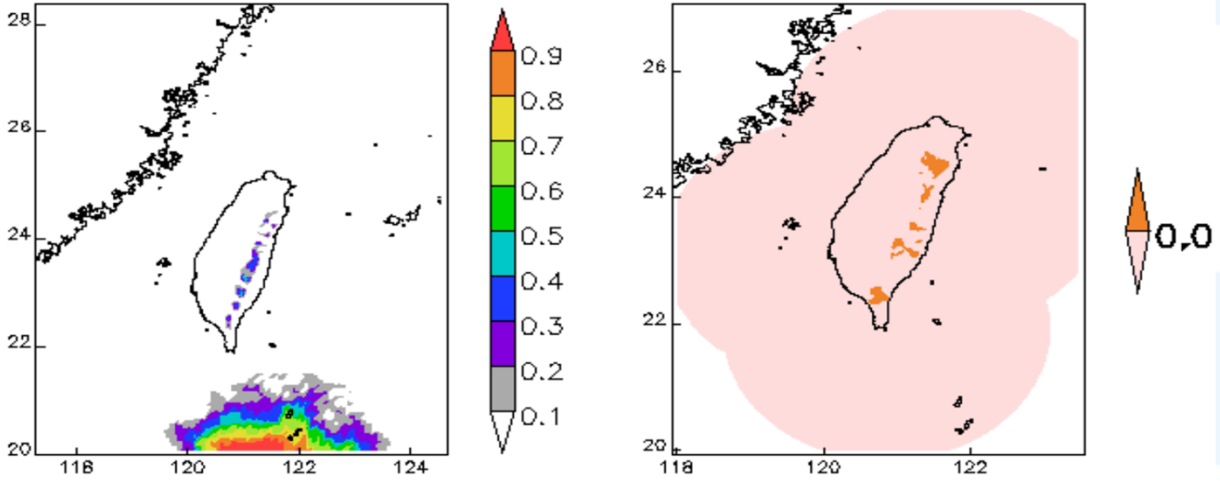
- Typhoon Usage (0-24h PQPFs ending at 0600 UTC 21 sep 2013)

0-24 h PQPFs *QPESUMS QPE probability*

Heavy rainfall
Ra> 80 mm/24h



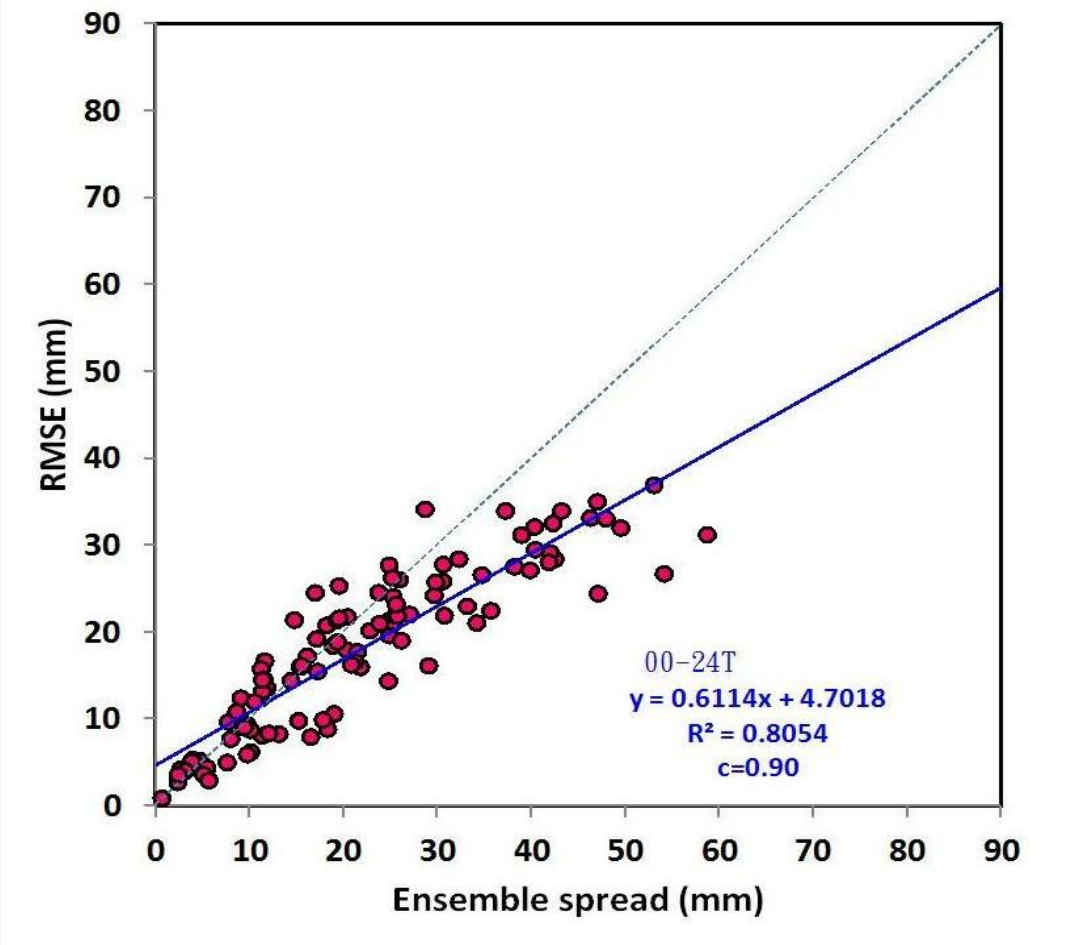
Extremely heavy rainfall
Ra > 200 mm/24h



The precipitation regions of the forecasts and observations have good correspondence.

Evaluation of WEPS 0-24h PQPFs

- Spread-skill relationship



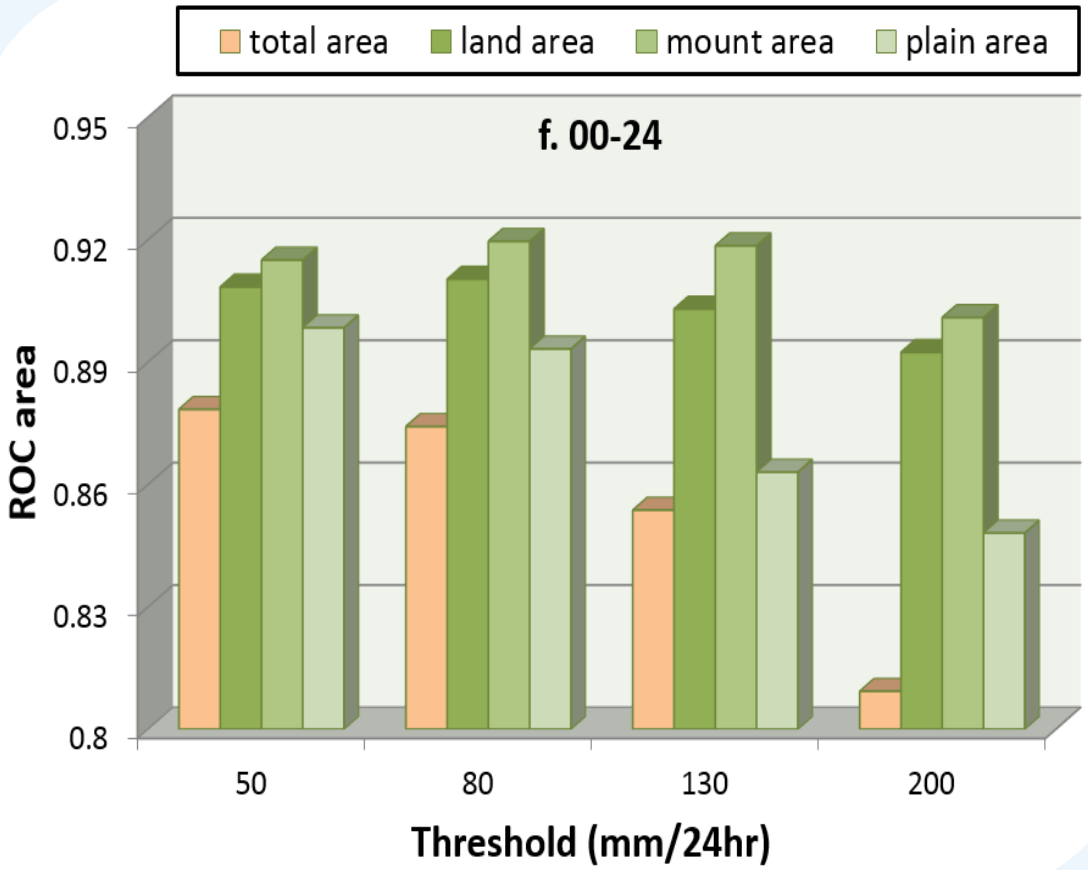
Spread measure :
ensemble spread

Skill measure :
RMS Error of ensemble mean

The ensemble spread can well represent the forecast uncertainties.

Evaluation of WEPS 0-24h PQPFs

- Discrimination/potential usefulness

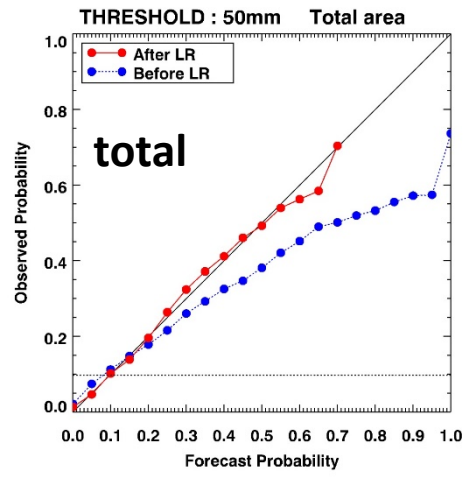


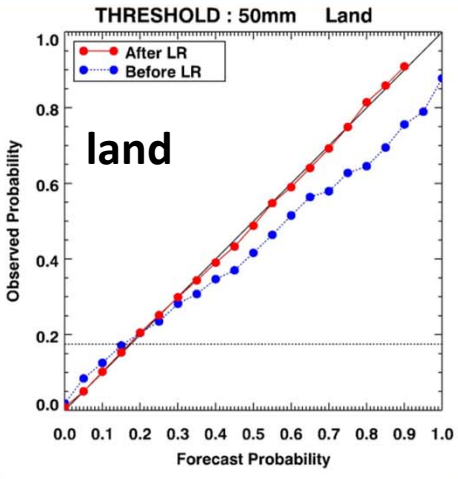
Mountain area: h > 500 m
Plain area: h ≦ 500 m

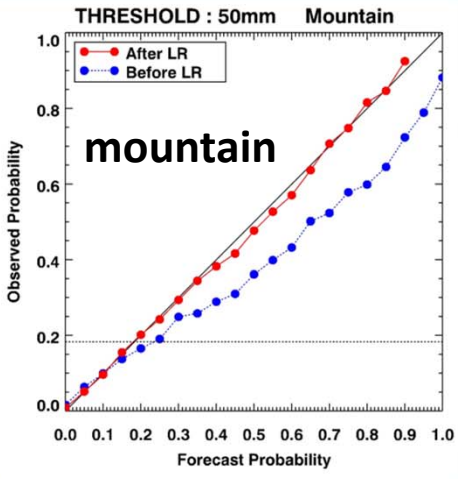
ROC areas are all greater than 0.7 at different thresholds for different areas, which indicates skillful potential usefulness.

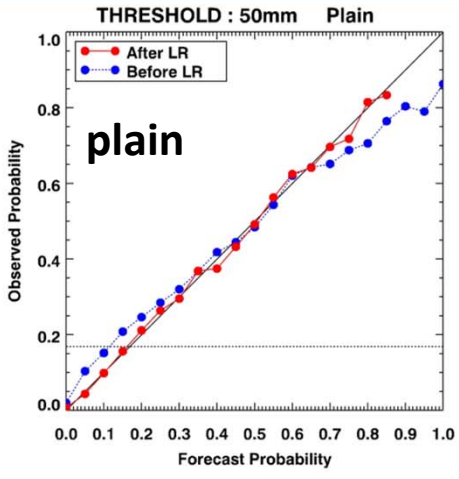
Evaluation and Calibration of WEPS 0-24h PQPFs

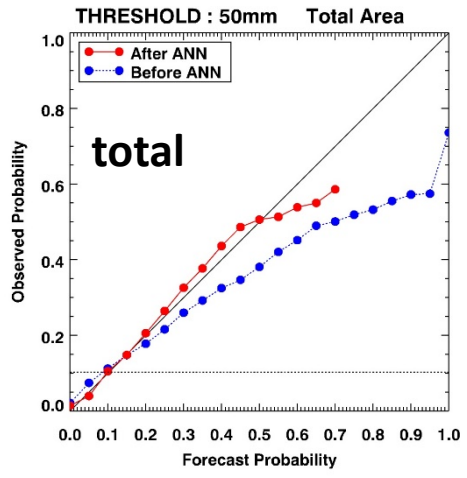
- Reliability







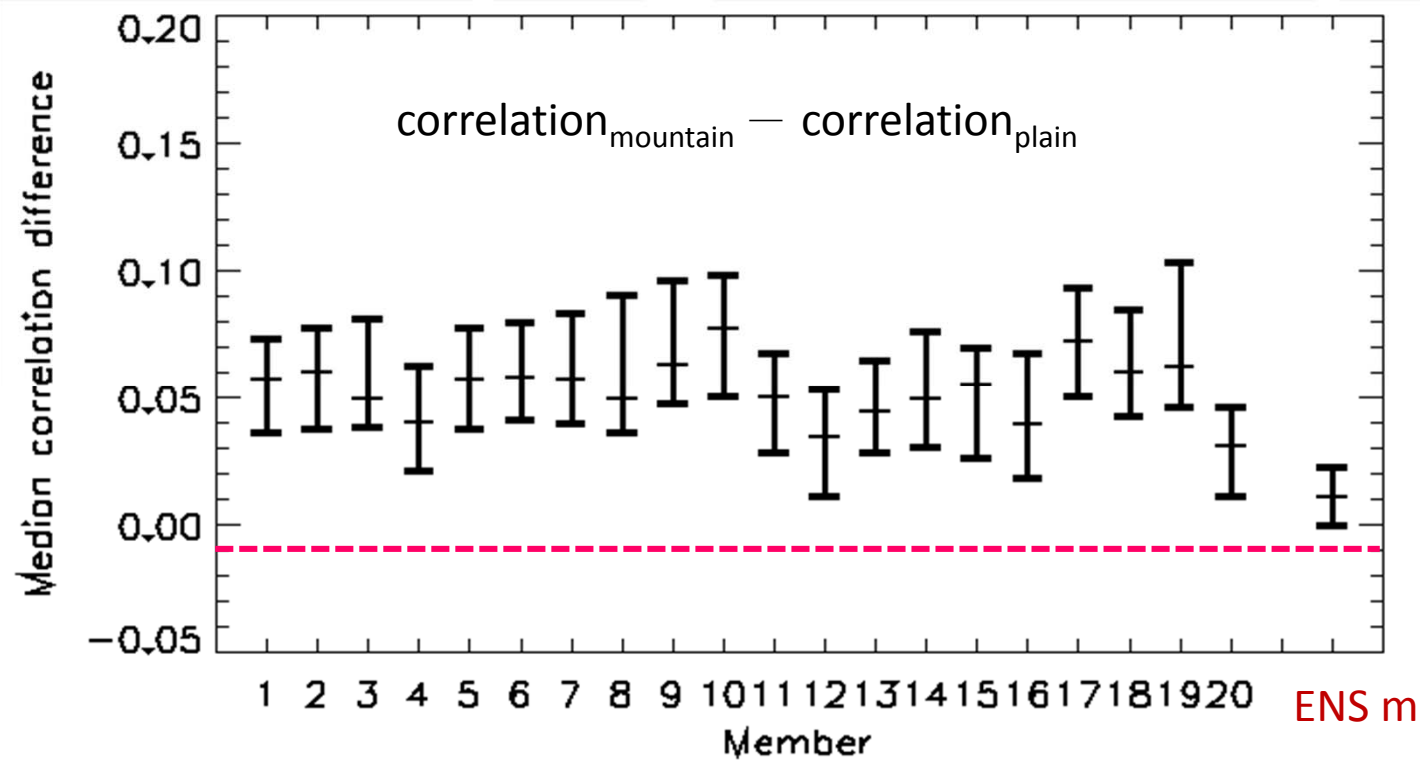


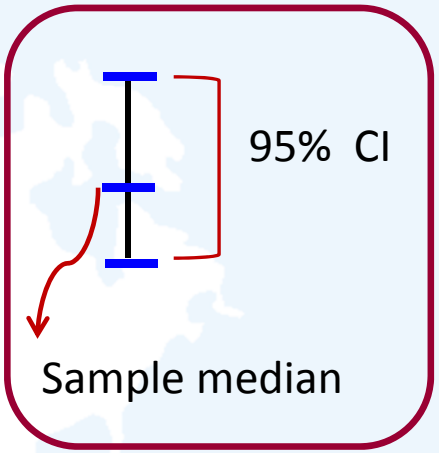


- The PQPFs for different areas display varying degree of wet biases before calibration. The biases were successfully corrected after calibration.
- The calibration effects of LR and ANN are quite similar.

Evaluation of WEPS 0-24h PQPFs

- Comparison of forecast ability over mountain and plain areas





The rainfall pattern of WEPS over mountain area is better than that over plain area.

Evaluation of WEPS 0-24h PQPFs

- Comparison of forecast ability over mountain and plain areas

Non-parametric Mann–Whitney test

H_0 : **median correlation$_1$ = median correlation$_2$**

H_A : **median correlation$_1$ ≠ median correlation$_2$**

Subscript 1: mountain area
Subscript 2: plain area

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95% (=19/20) of members have the p-value < 0.1

→The better rainfall pattern over mountain area than over plain area is statistically significant for 95% of members at the 10% test level.

Methodology

- Analysis of economic value (EV)

➢ *Economic value (EV) for a forecast system (Richardson 2000)*

$$EV = \frac{E_{\text{climate}} - E_{\text{forecast}}}{E_{\text{climate}} - E_{\text{perfect}}}$$

$E_{climate}$: Expected expense (E) using climatological information.

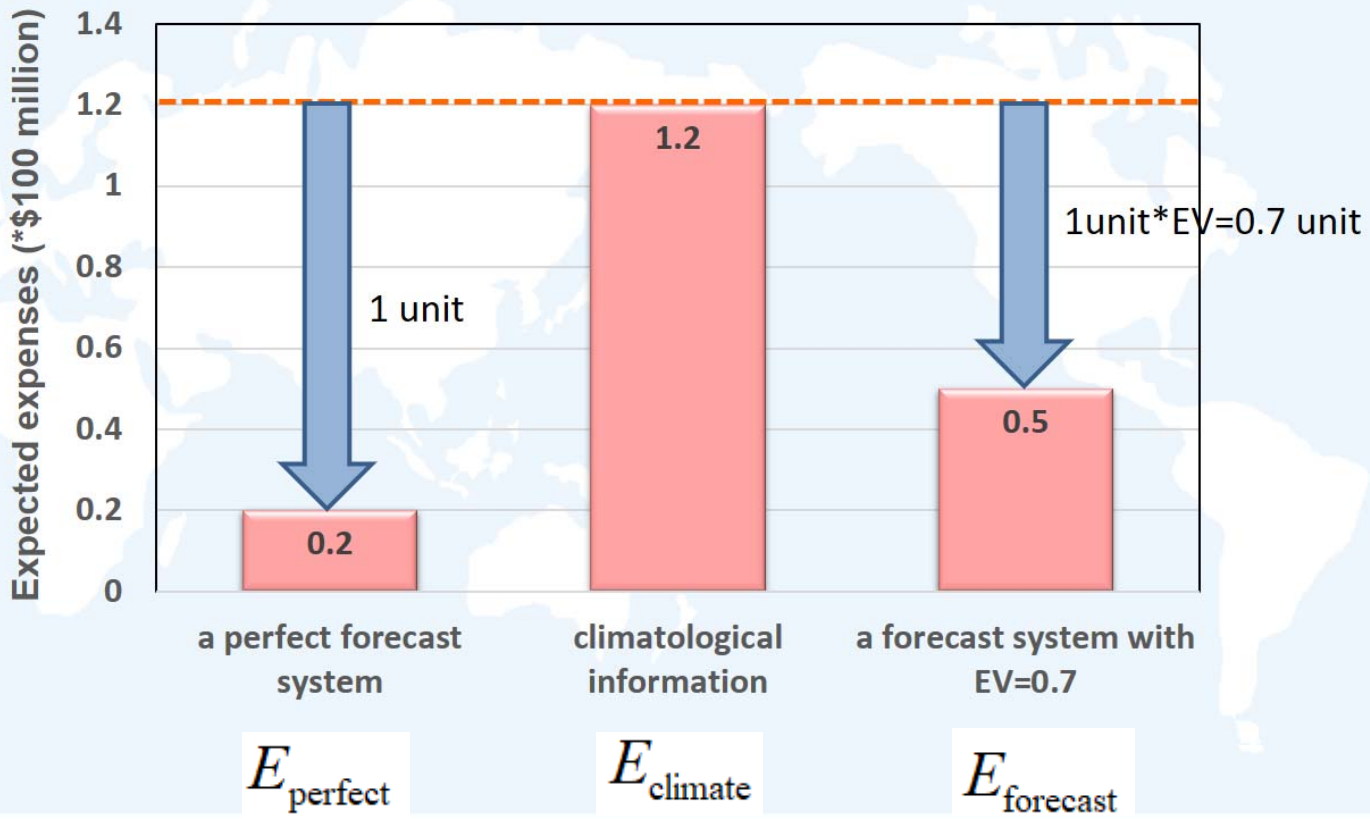
$E_{forecast}$: E using a forecast system.

$E_{perfect}$: E using a perfect forecast system.

Methodology

- Analysis of economic value (EV)

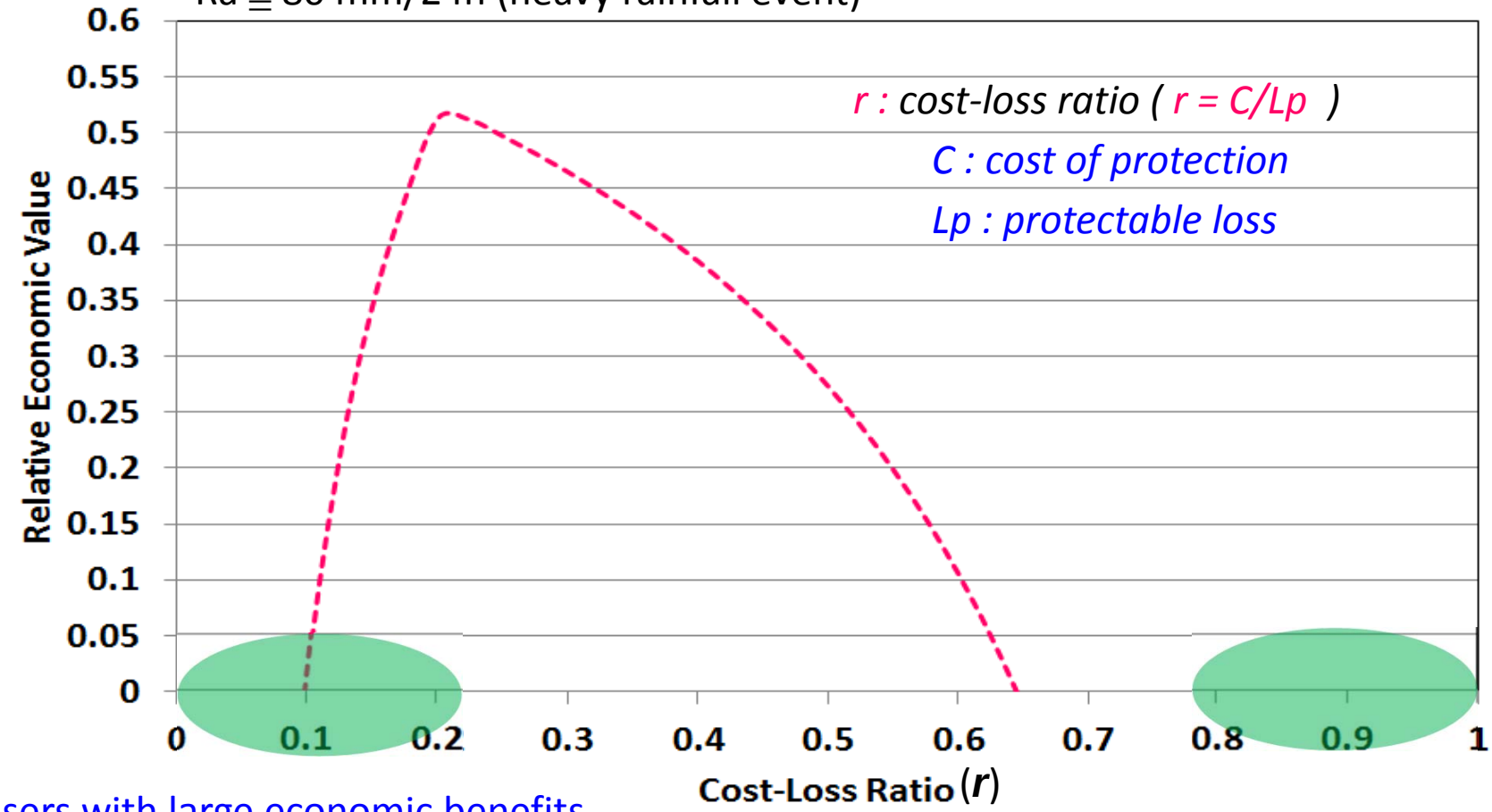
$$EV = \frac{E_{\text{climate}} - E_{\text{forecast}}}{E_{\text{climate}} - E_{\text{perfect}}}$$



Methodology

- Analysis of economic value (EV)

Ra ≧ 80 mm/24h (heavy rainfall event)



Users with large economic benefits

Users with large risk of preventive cost

Analysis of economic value (EV)

- Difficulty in using ensemble probabilistic forecasts

  -The general public have difficulty in making decisions based on probabilistic forecasts.

  -The hydrological people can only use deterministic forecasts as the initial condition for their hydrological models.

- Deterministic forecast products derived from ensembles

  - Ensemble mean

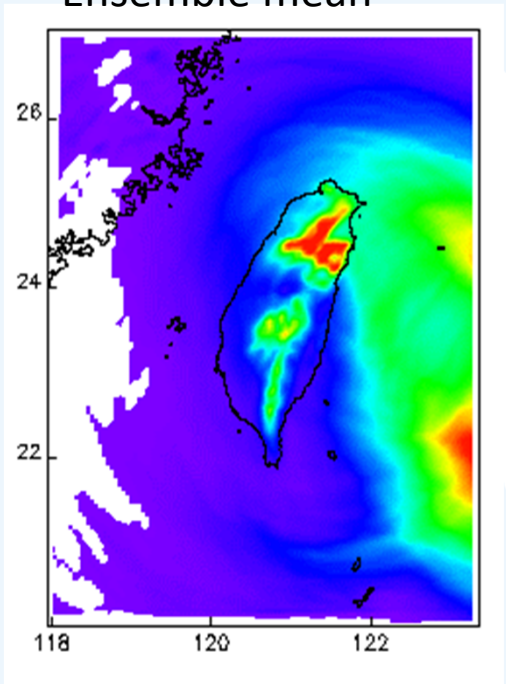
  - Probability Matching (PM)

  - QPF Percentile (QPFP)

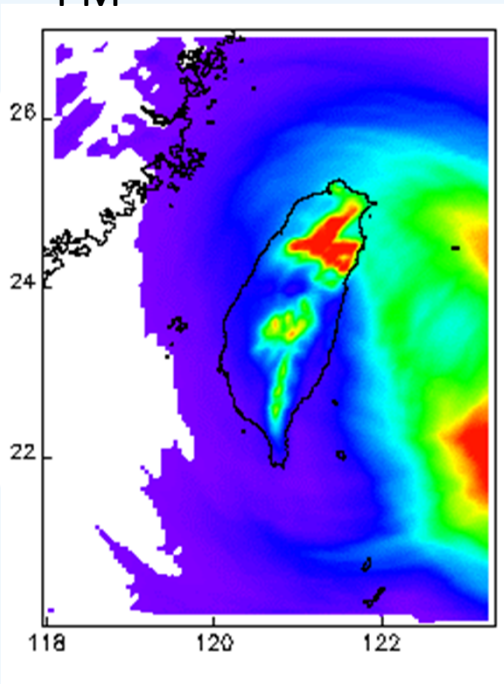
Deterministic forecasts derived from ensembles

- Ensemble mean and probability matching (PM)

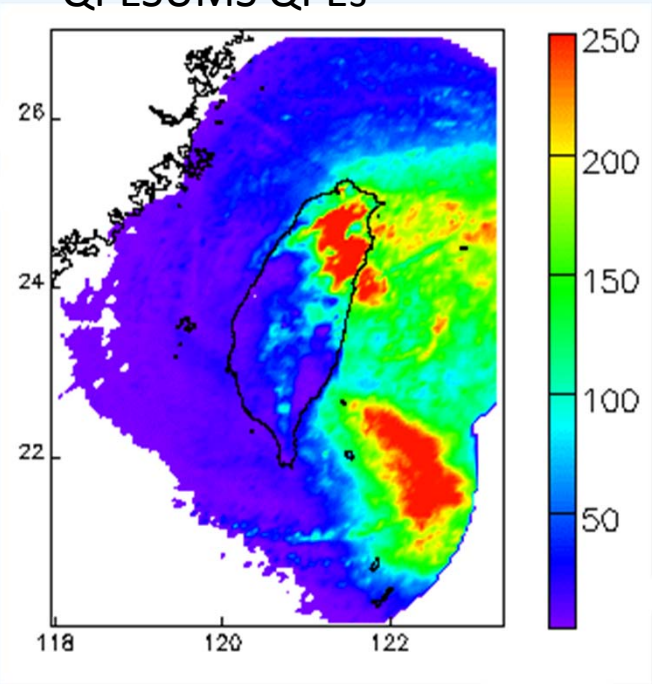
Ensemble mean



PM



QPESUMS QPEs

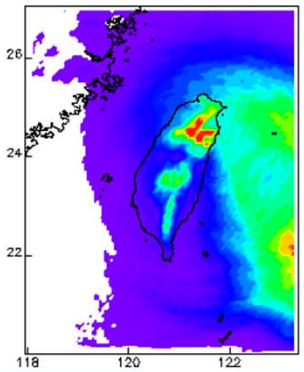


- Ensemble mean tends to smooth out the rainfall extremes due to the averaging process.
- PM has the same rainfall pattern as ensemble mean, but has more realistic rain rate.

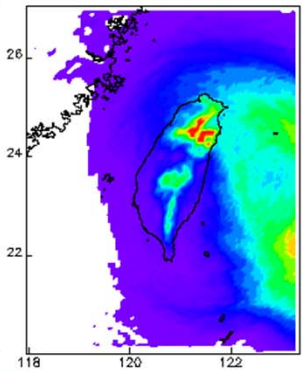
Deterministic forecasts derived from ensembles

- QPF percentile (QPFP)

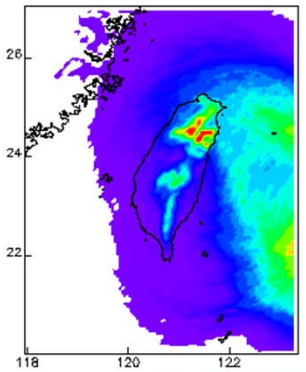
QPFP_50th



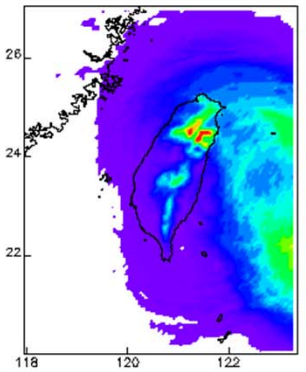
QPFP_40th



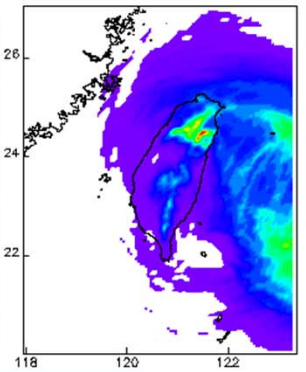
QPFP_ 30th



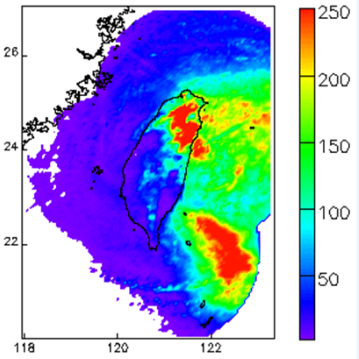
QPFP_20th



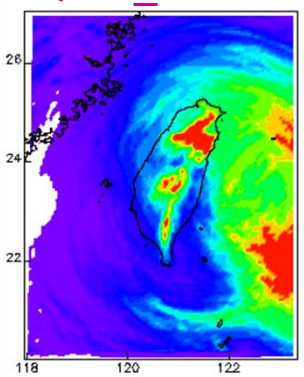
QPFP_10th



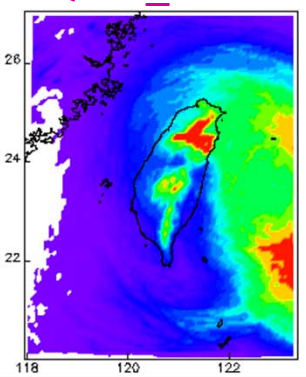
QPESUMS QPEs



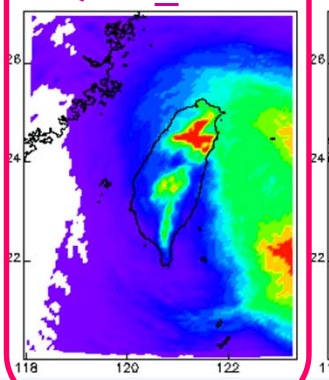
QPFP_100th



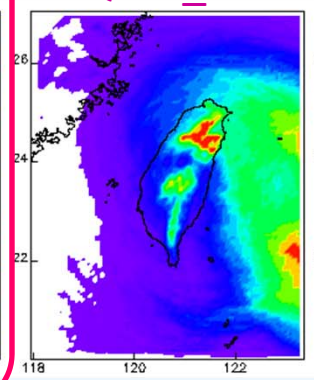
QPFP_90th



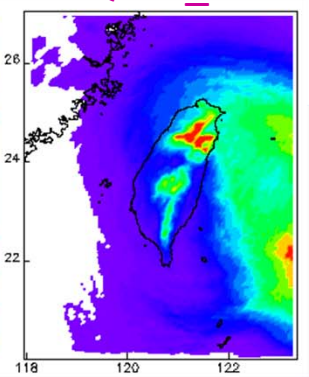
QPFP_ 80th



QPFP_70th



QPFP_60th



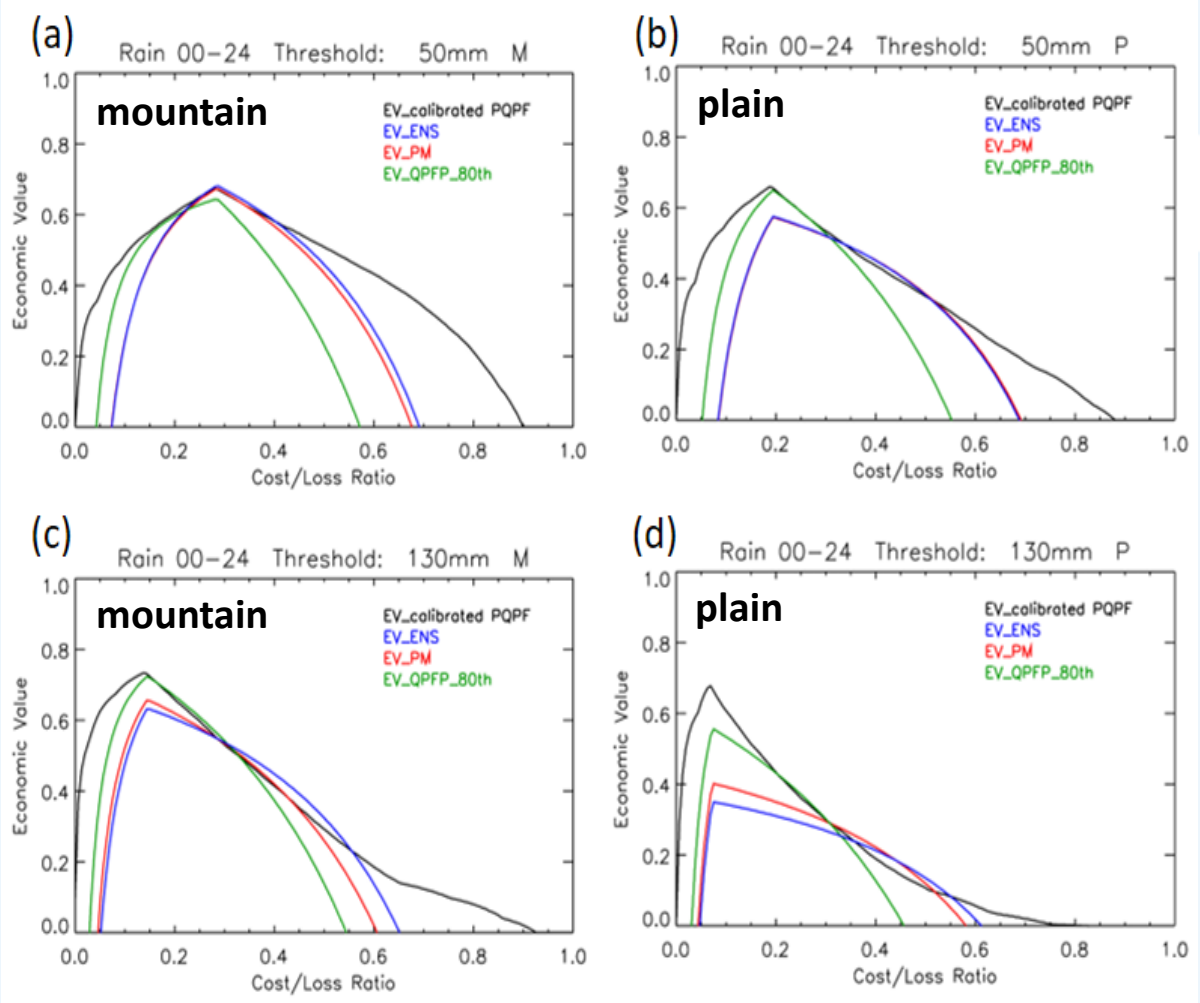
QPFP is the rainfall amount by percentile.

Analysis of economic value (EV)

What benefit can be obtained if users make decisions based on ensemble probabilistic forecasts instead of deterministic forecast products derived from ensembles?

Economic value analysis of WEPS 0-24h PQPF

- Probabilistic forecasts vs. deterministic forecasts



- PQPF can offer more EV to a wider range of users than ensemble mean, PM, and QPFP_80th.
- Users with a very small (< 0.1) or a larger (> 0.7) cost-loss ratio can only benefit from making decisions based on PQPF.

QPFP_80th could be a good guidance with better forecast performance than the other percentiles for Mei-yu cases in Taiwan area. (黃等，2016)

Summary

- The ensemble spread of WEPS can well represent the forecast uncertainties, and the PQPFs have good potential usefulness but also obvious bias.
- Calibration effects of the LR and ANN are quite similar, but the ANN needs more computing time and training samples to establish a stable calibration relationship.
- For WEPS, the better rainfall pattern over mountain area than over plain area is statistically significant at the 10% test level.
- PQPF can offer more EV to a wider range of users than ensemble mean, PM, and QPFP_80th.

Thank You!

張惠玲、陳冠儒、吳佳蓉、汪琮、洪景山、楊舒芝，2018：臺灣地區WRF颱風系集降雨機率預報之評估、校正與經濟價值分析-第一部分：預報評估。大氣科學，46，71－106。

章鶴群、 陳冠儒、劉豫臻、張惠玲、洪景山、楊舒芝，2018：臺灣地區WRF颱風系集降雨機率預報之評估、校正與經濟價值分析-第二部分：校正。大氣科學，46，107－127。

陳冠儒、張惠玲、楊舒芝、洪景山、吳佳蓉、汪琮，2018：臺灣地區WRF颱風系集降雨機率預報之評估、校正與經濟價值分析-第三部分：經濟價值分析。大氣科學（審稿中）。