Quantitative Precipitation Forecast (QPF) from Weather Prediction Models and Radar Nowcasts, and Atmospheric-Hydrological Modelling for Flood Simulation

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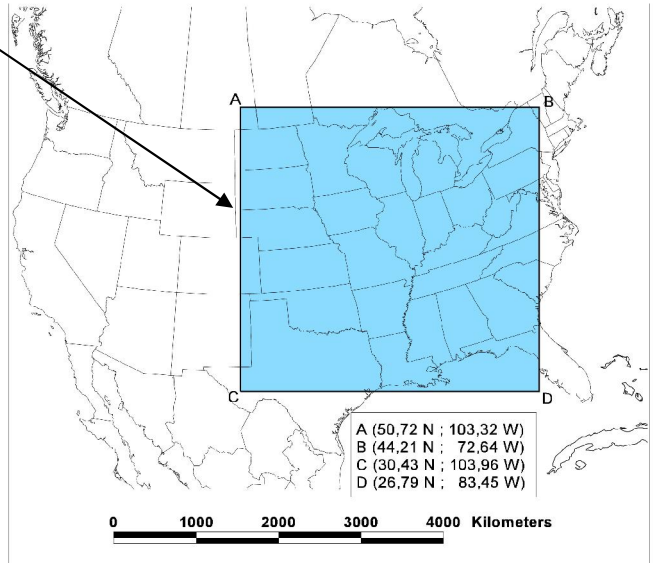
Objectives

- To assess skill of precipitation forecasts from weather prediction models
- To assess skill from radar nowcasts
- To compare skill of model forecasts and radar nowcasts
- To assess quality of simulated hydrograph driven by model precipitation

QPF Methodology

- Conventional skill measures
  - POD, FAR, CSI, CMAE
- Spectral domain
  - Scale decomposition using wavelets
- Frequency domain
  - Frequency distribution

- Domains of analysis
  - Central and eastern US: 2,160 km × 2,160 km
  - Alberta, Canada: 240 km × 240 km
- Weather prediction models
  - 12 km resolution
  - GEM (Canada)
  - ETA (USA)
- Radar data
  - US composite: 5 km resolution
  - Canadian Carvel radar (Alberta, Canada): 1 km resolution

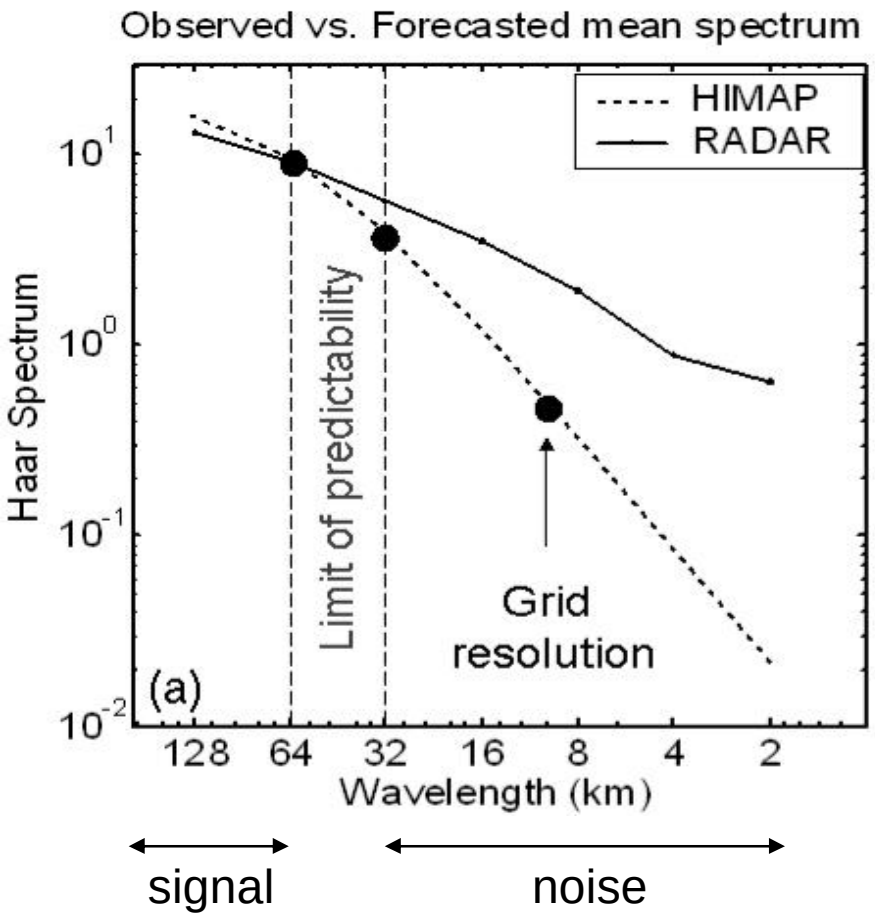


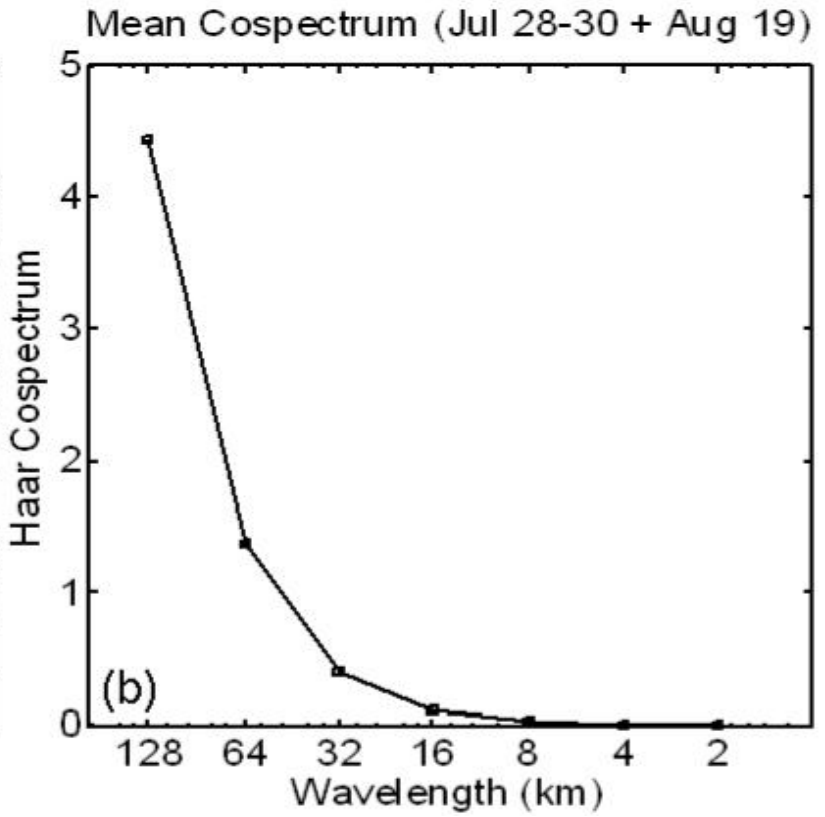
Scale decomposition using wavelet analysis

Canada: July 28-30, August, 2001

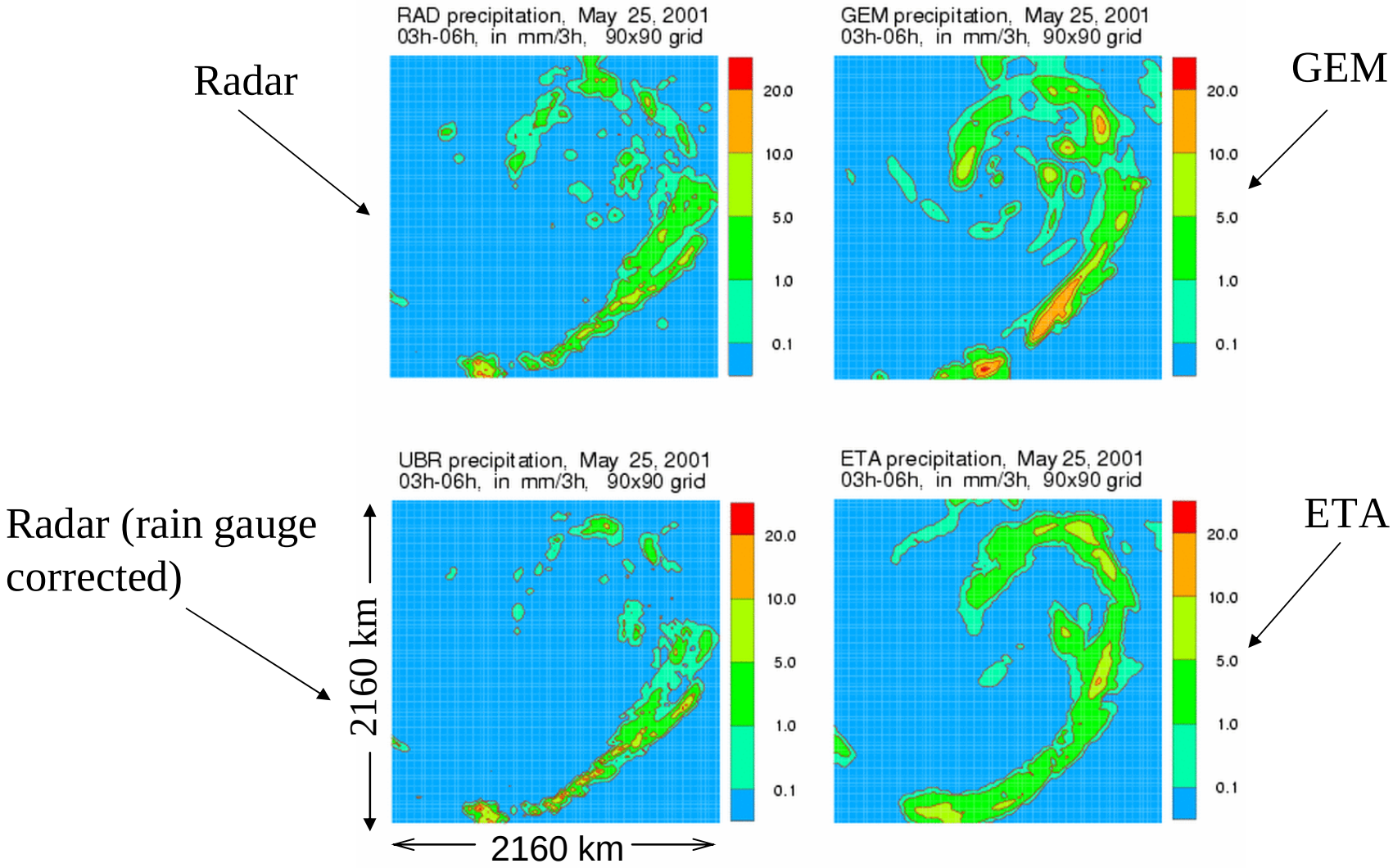
USA: May 24-30, 2001

Average of 28 periods of 6-hour accumulated precipitation from GEM and one Canadian radar (Carvel, Alberta)

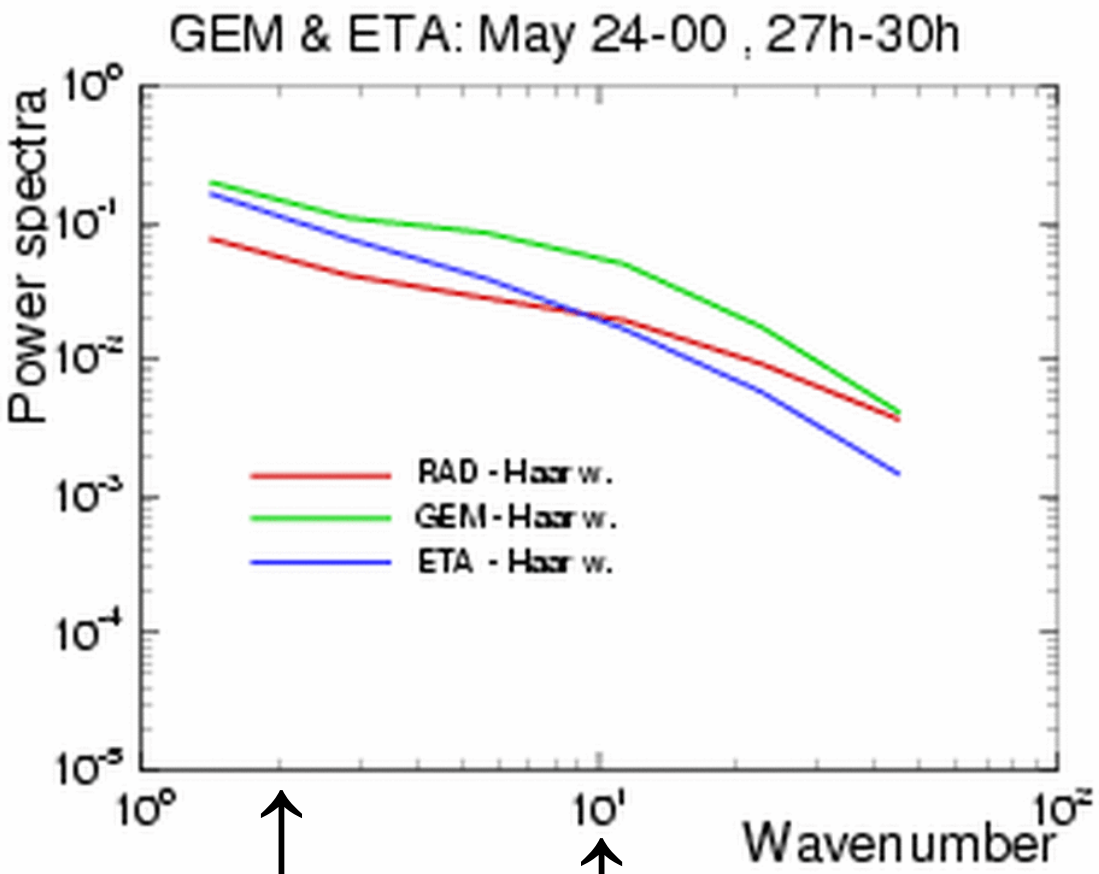




3-hour accumulated precipitation (0600 UTC, May 25, 2001)



Spectral domain: Haar wavelet Power spectra



wavenumber k =2

wavelength λ = 1500 km

k = 10

λ = 310 km

Frequency analysis

1-hour accumulated precipitation
21 cases in *2003, 2004*

Sept. 2003: 12, 13, 18, 27

Oct. 2003: 14, 17, 25, 26, 28

May 2004: 21, 22, 30, 31

June 2004: 11, 24

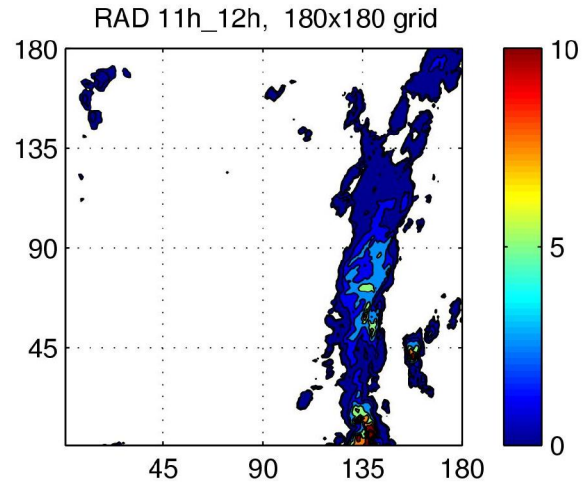
July 2004: 3, 4, 5, 6

Aug. 2004: 19, 20

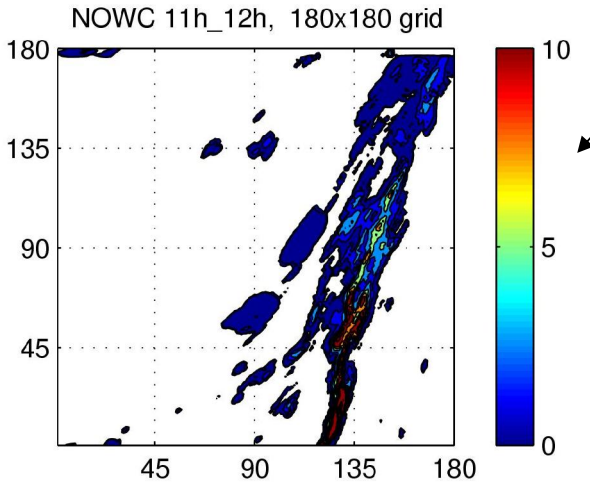
Accumulated precipitation for 11h-12h

- October 26, 2003 -

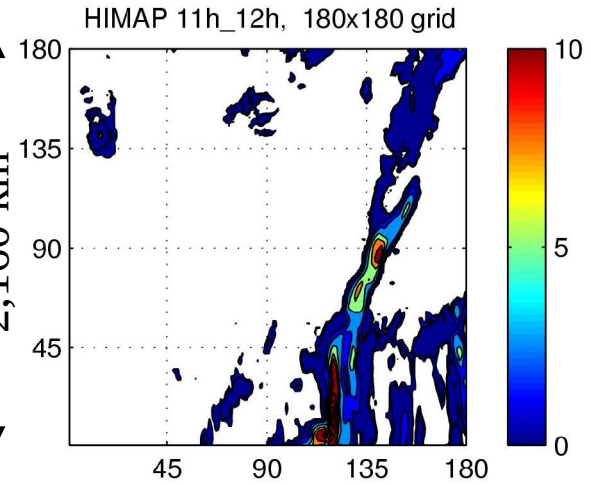
Radar



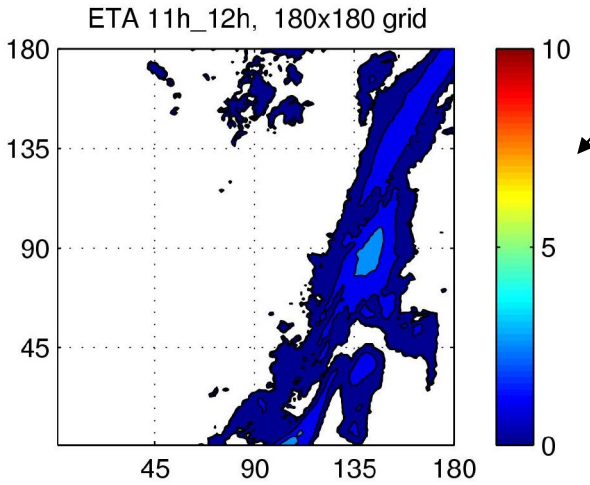
Radar nowcast



GEM/HIMAP



ETA



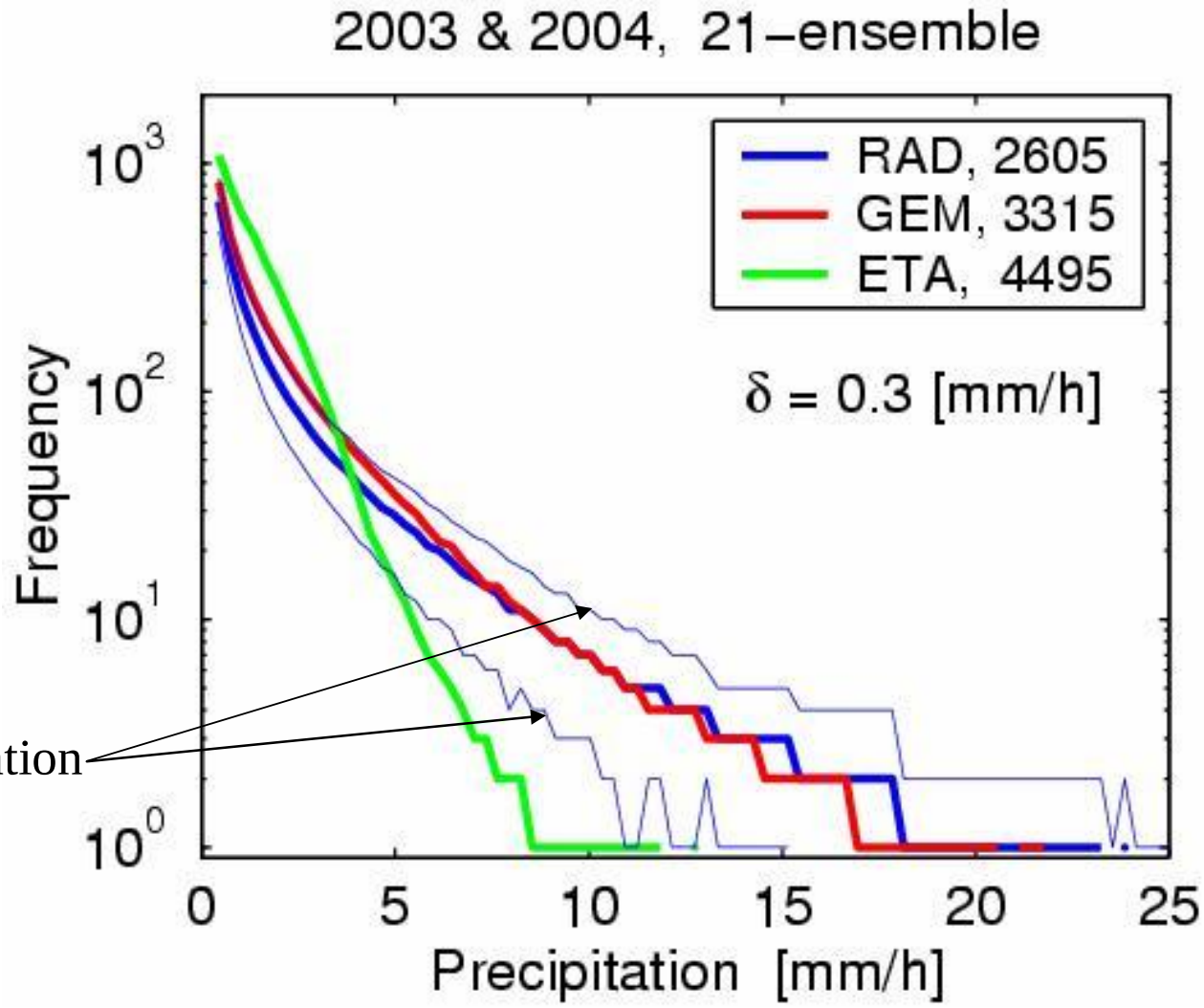
2,160 km

2,160 km

Frequency Distribution Analysis

- 21 days of 24 hourly accumulated precipitation → over 500 cases
- Domain of 2,160 km × 2,160 km at 12 km resolution → Total of 180 × 180 = 32,400 pixels
- Bin hourly precipitation of each pixel, with bin width δ
- Count frequency of precipitation for each bin → histogram

Frequency distribution of precipitation from GEM, ETA and Radar: Power law dependence



Radar: ±1 standard deviation

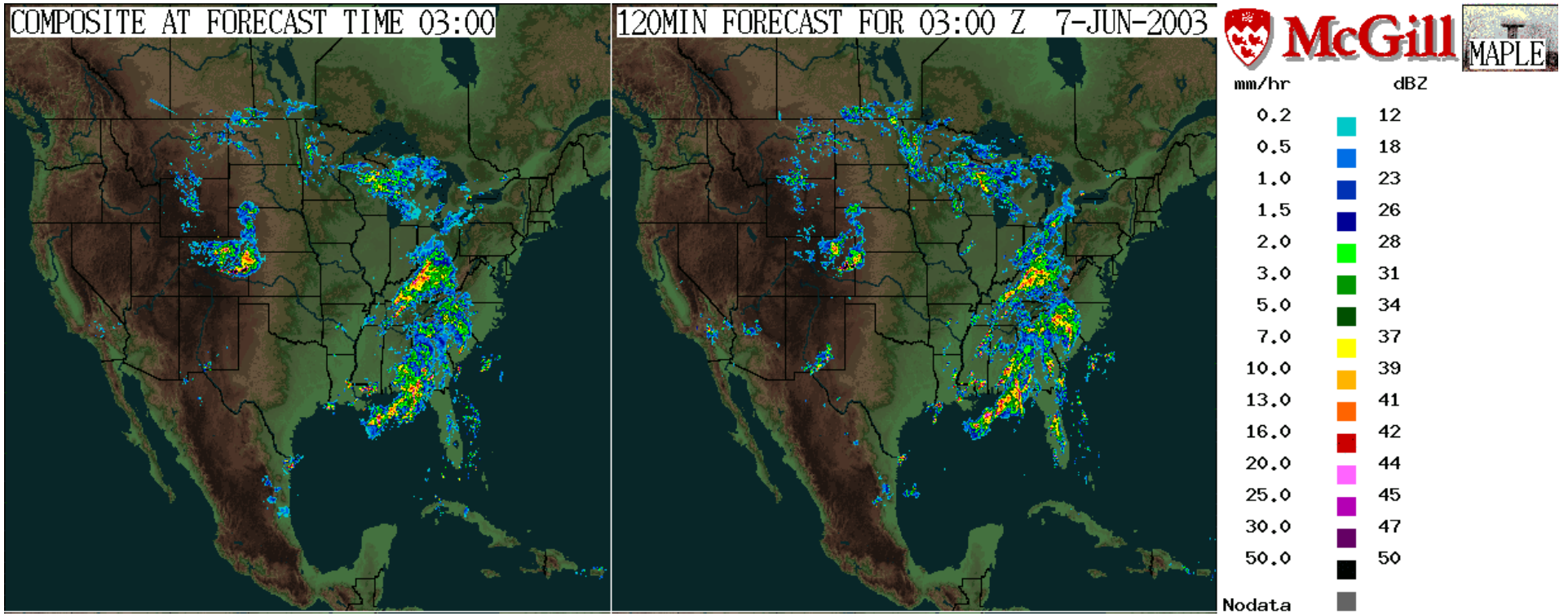
Evaluate skill of precipitation forecasts from radar nowcasts and weather prediction models

Precipitation Forecasts

- **Nowcast methods based on Lagrangian persistence of radar-retrieved precipitation**
  - *MAPLE: M*cGill *A*lgorithm for *P*recipitation forecasting using *L*agragian *E*xtrapolation
  - Germann and Zawadzki (2002), Turner et al. (2003)

- **Operational weather prediction models: Canadian GEM-HIMAP model and US ETA model.**

MAPLE precipitation radar nowcast



Observations: US radar composite

MAPLE (2-hour nowcast)

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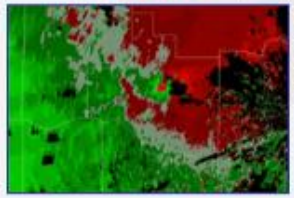
Current News

WDT Gives CONUS a Choice in Lightning Services
A joint venture between WDT and TOA Systems, Inc., a leader in lightning detection technologies, gives America a choice in lightning data. Together we have constructed the United States Precision Lightning Network (USPLN™) which is now operational nationwide. See USPLN.com for more information.

WDT Licenses New Weather Prediction Technology from McGill University
New prediction capability provides accurate precipitation predictions out to 6 hours.



WDT Offers NEXRAD HD™
Weather Decision Technologies, Inc. announces NEXRAD HD™ — the most advanced high-definition radar product commercially available.

Norman, Oklahoma
5:00 PM CDT
Sunny
Temp: 63°F
Wind: NW 17 MPH

Get WDT's WxScope Plugin

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Done Internet

start Inbox - Microsoft ... Latent Heat - Me... cmos_private_se... My Pictures Weather Decision... 6:30 PM

Precipitation skill measures

*(Prec*ipitation t*hresholds: R = 0.1, 0.5, 1.0 mm/h)*

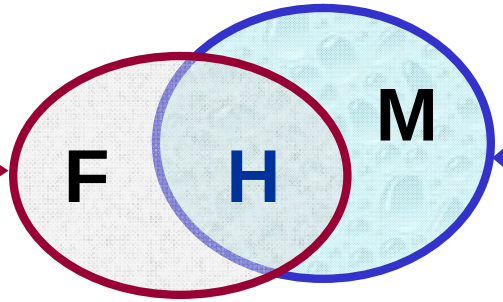
POD = H /(H+M)

probability of detection

FAR = F /(F+H)

false alarm rate

Nowcast / Forecast precip



Radar precip

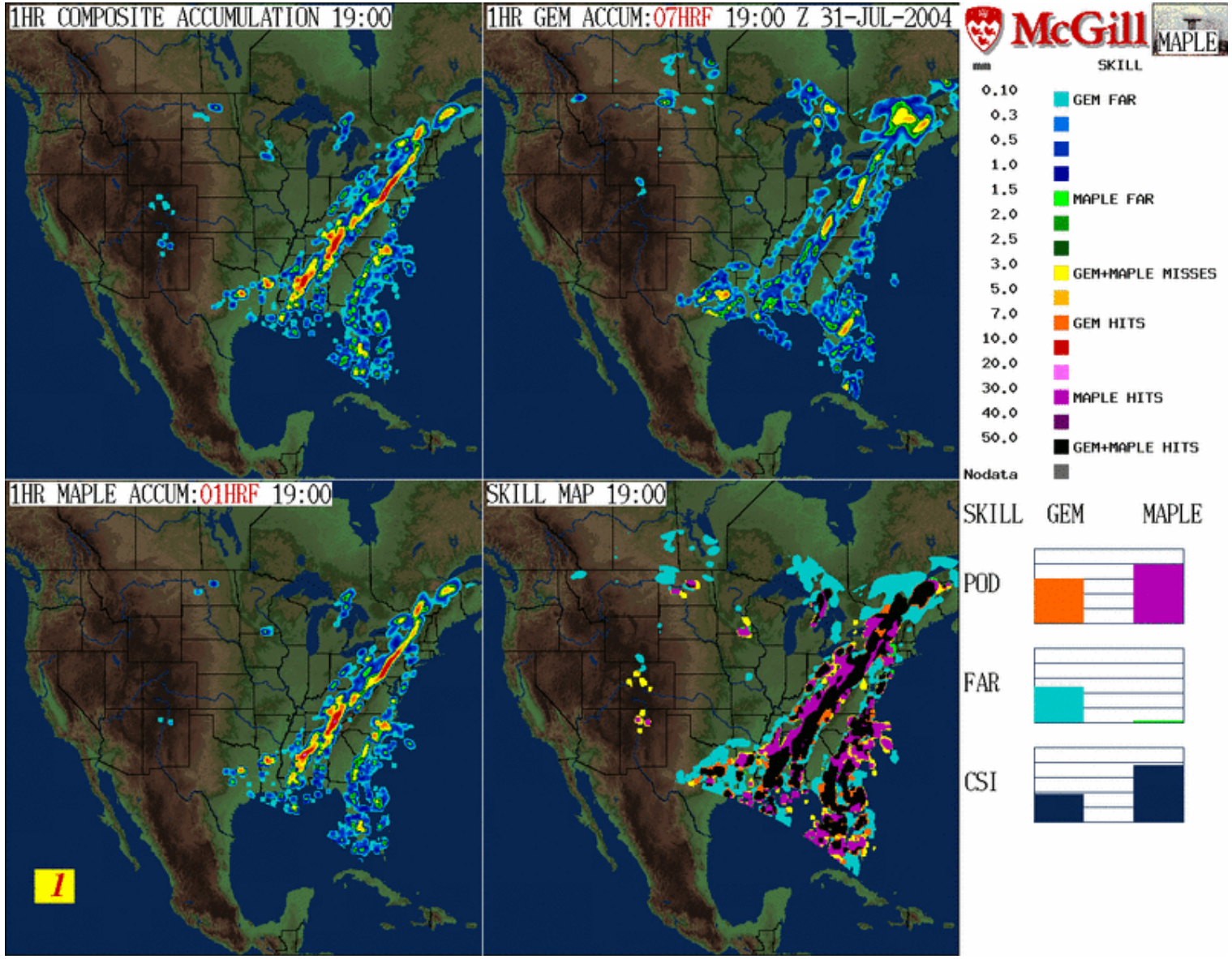
CSI = H/(H+M+F)

critical success index

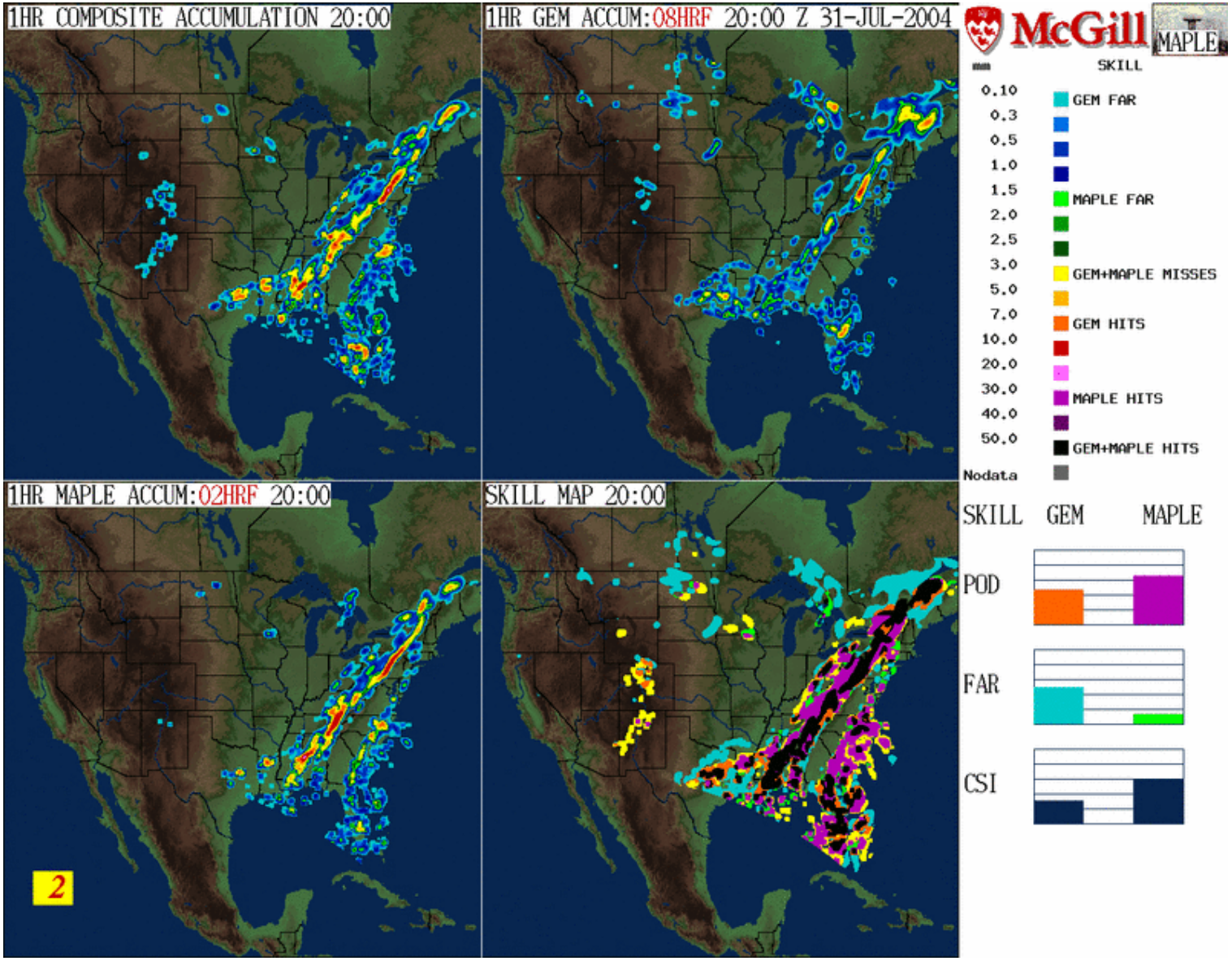
C M A E

conditional mean absolute error

Model Skill vs. Lagrangian Persistence Skill



Model Skill vs. Lagrangian Persistence Skill



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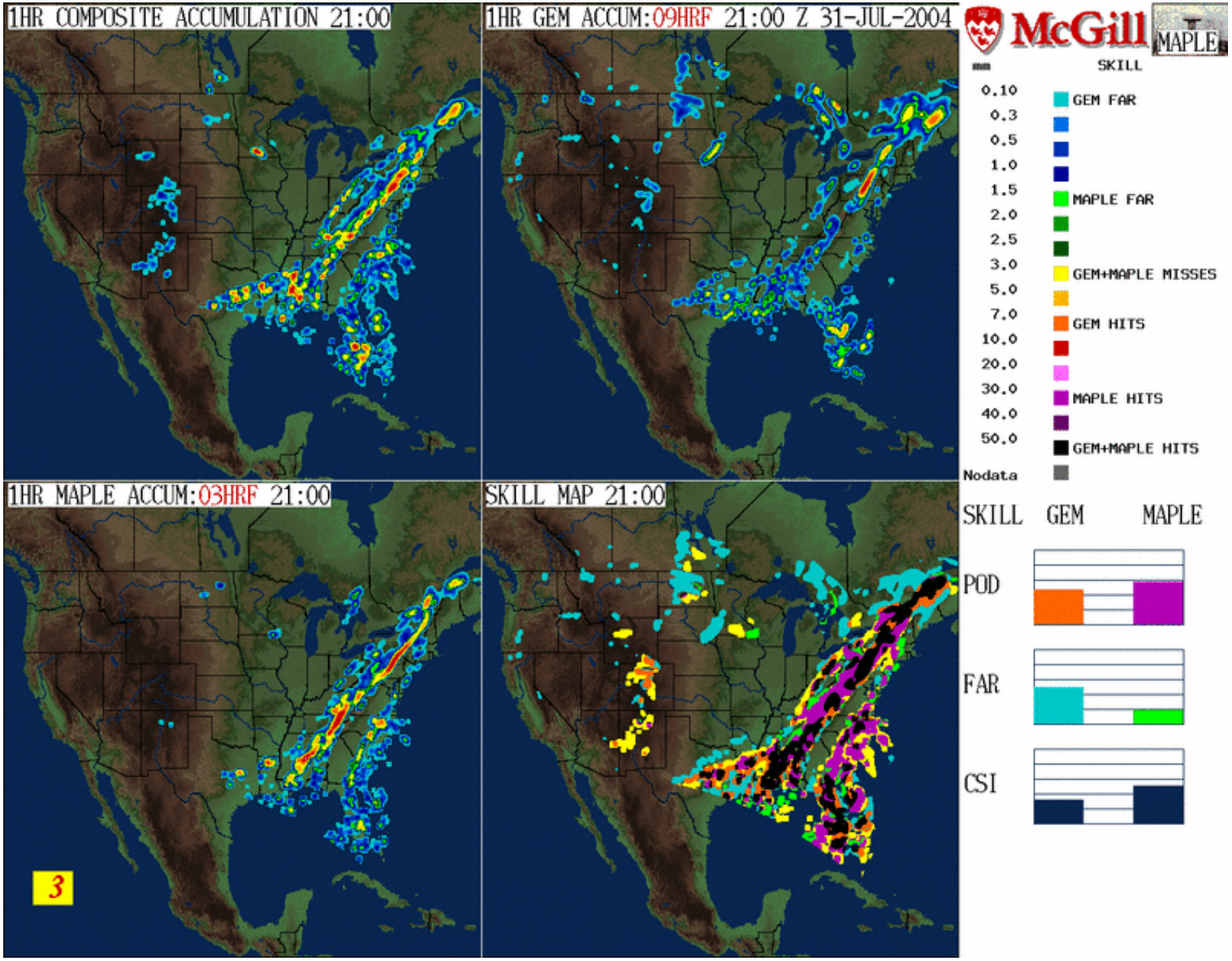
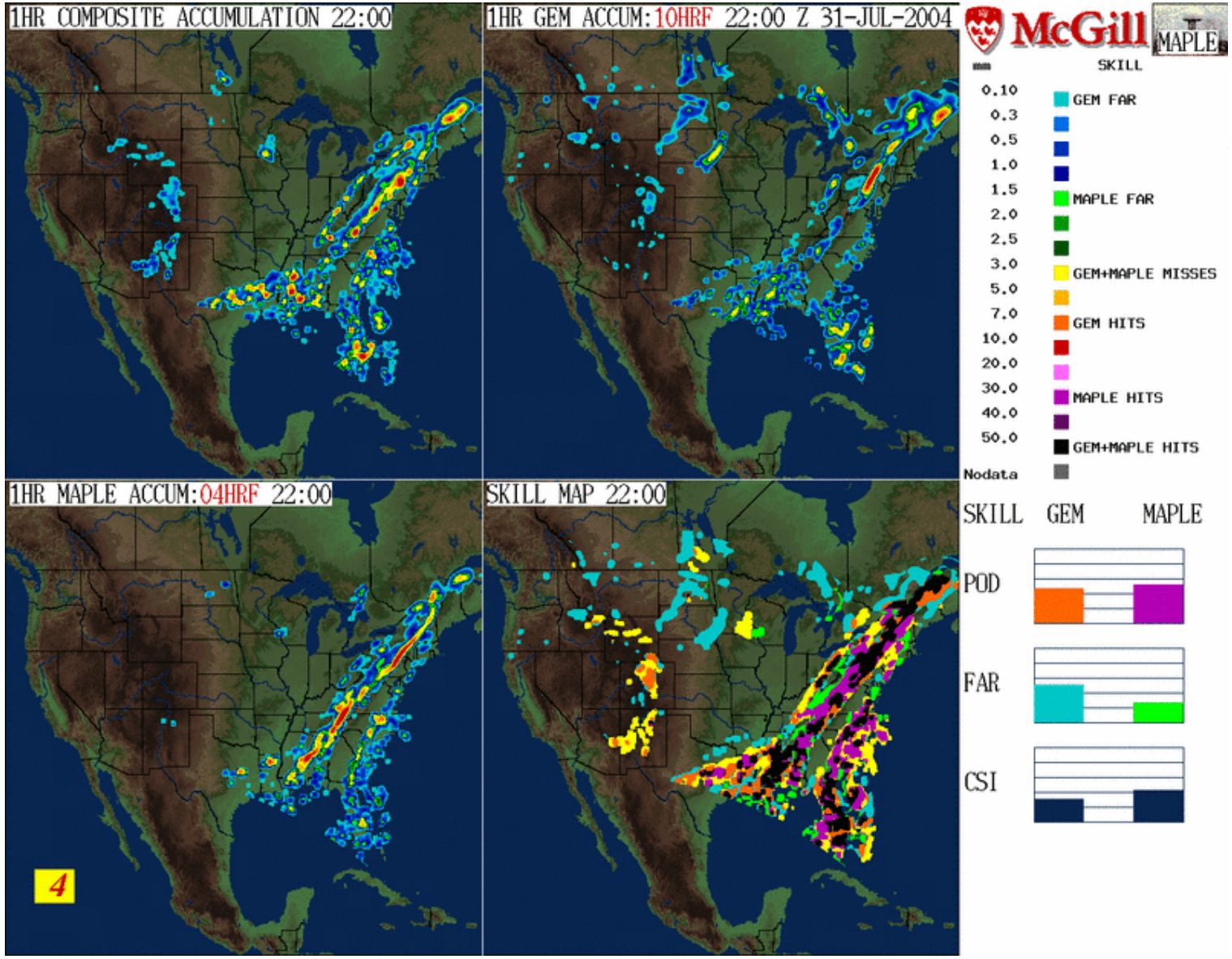
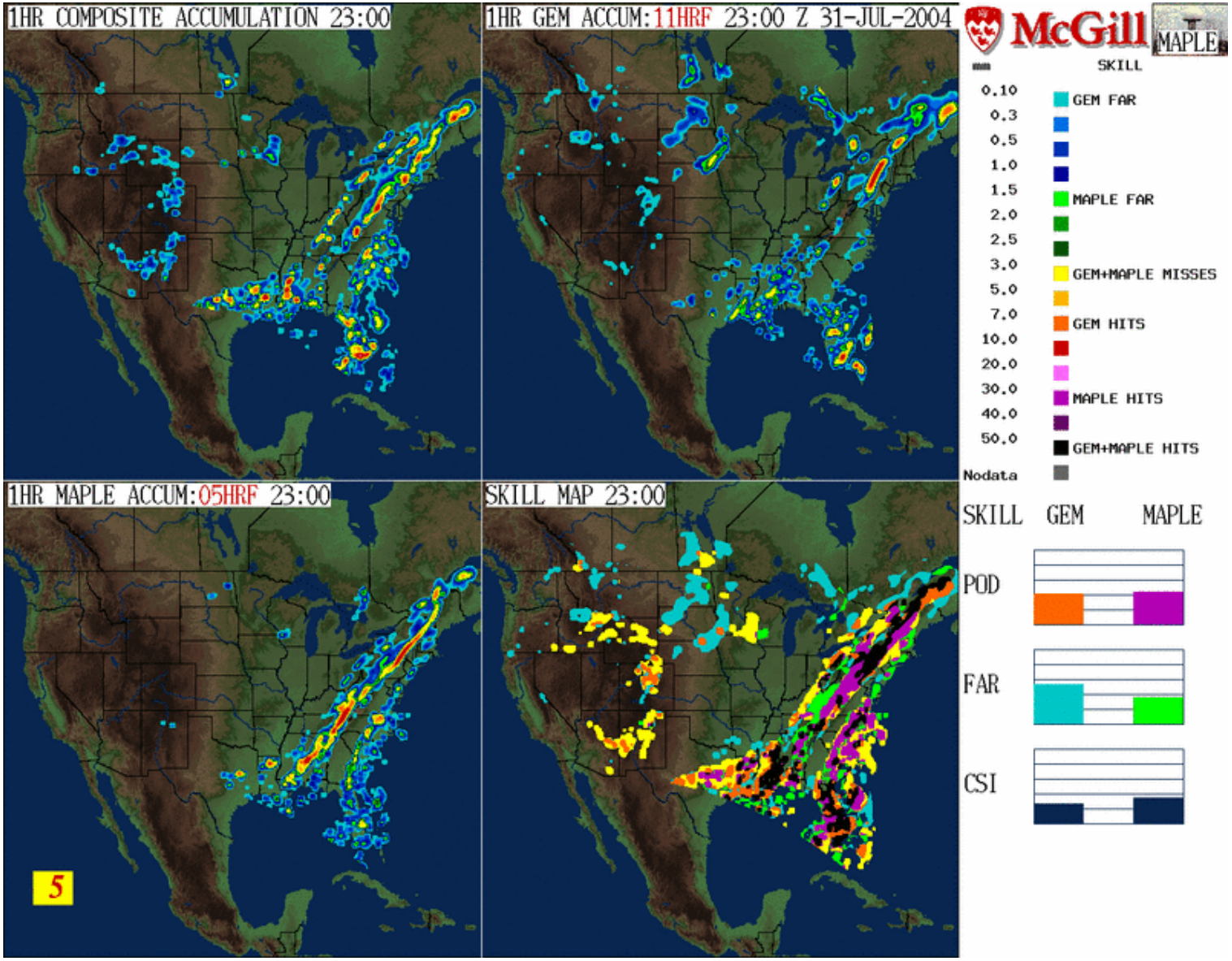


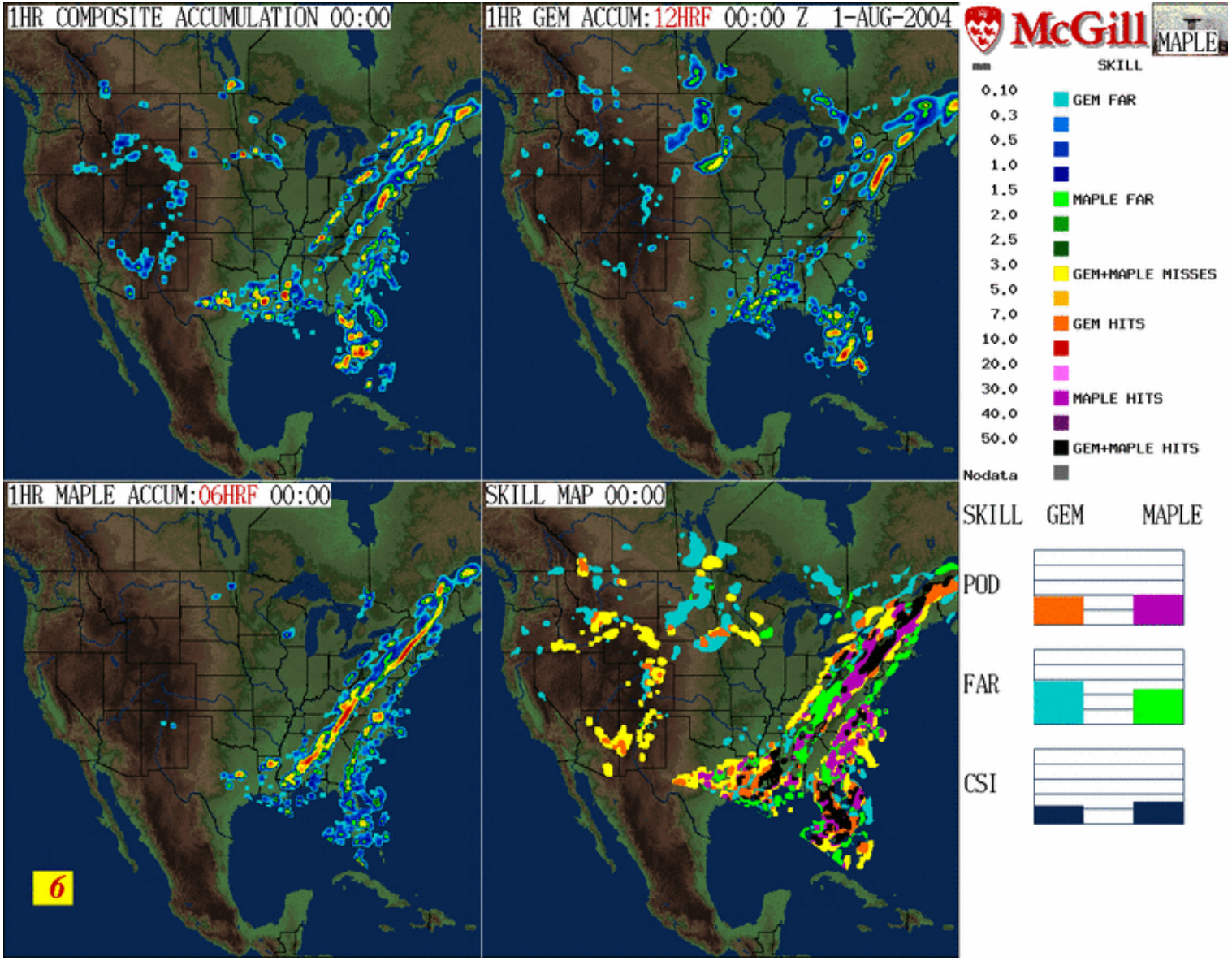
Model Skill vs. Lagrangian Persistence Skill



Model Skill vs. Lagrangian Persistence Skill



Model Skill vs. Lagrangian Persistence Skill



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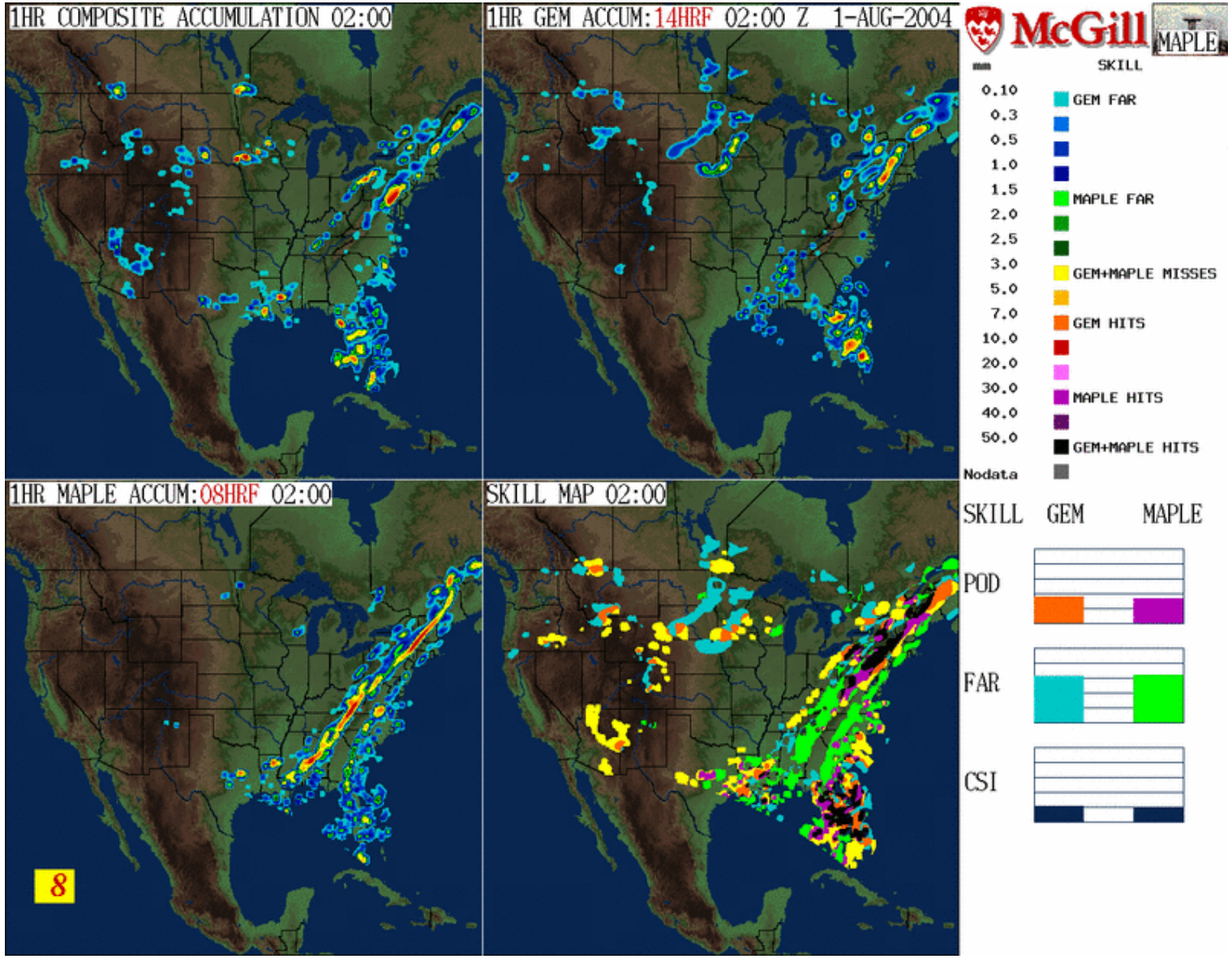
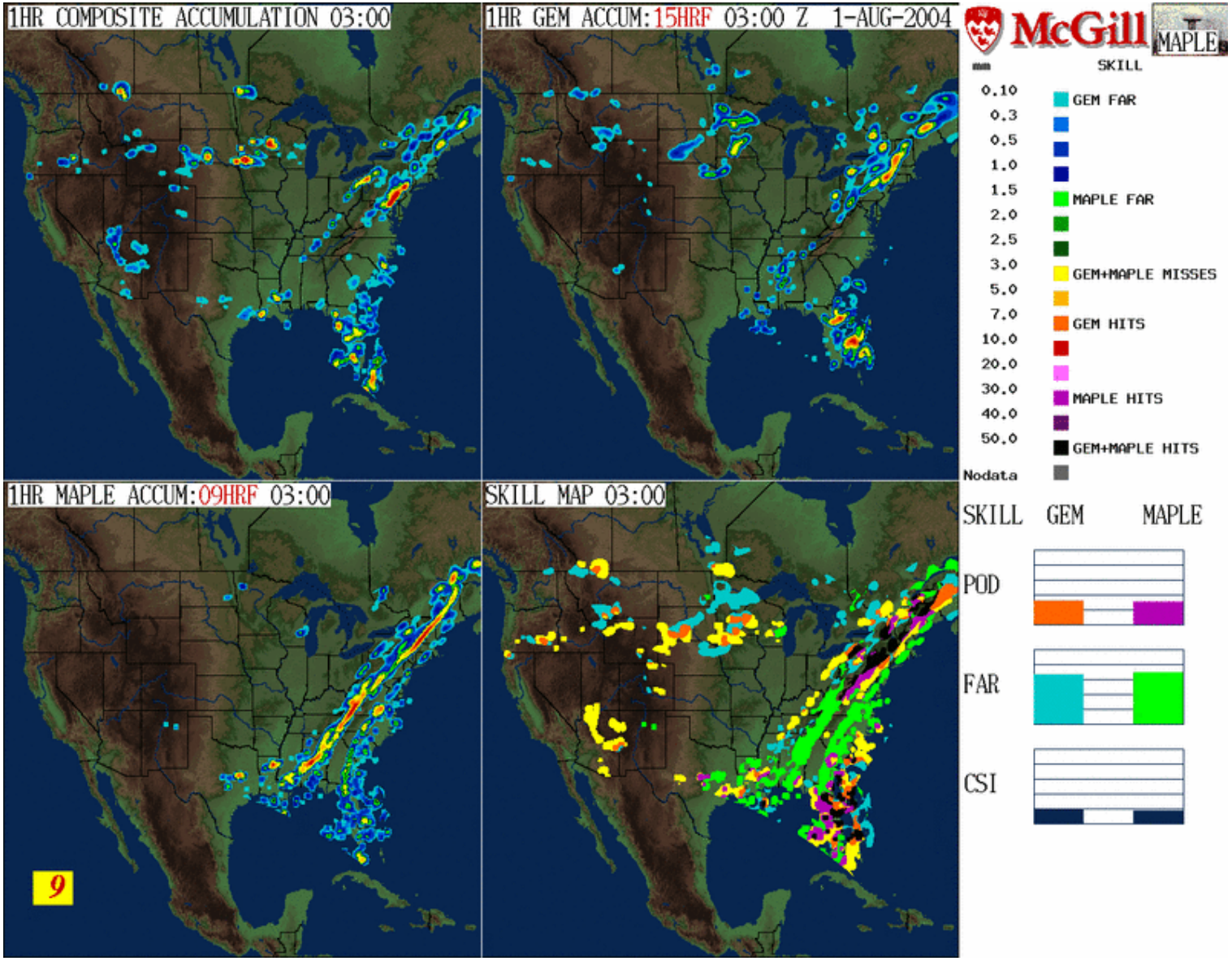
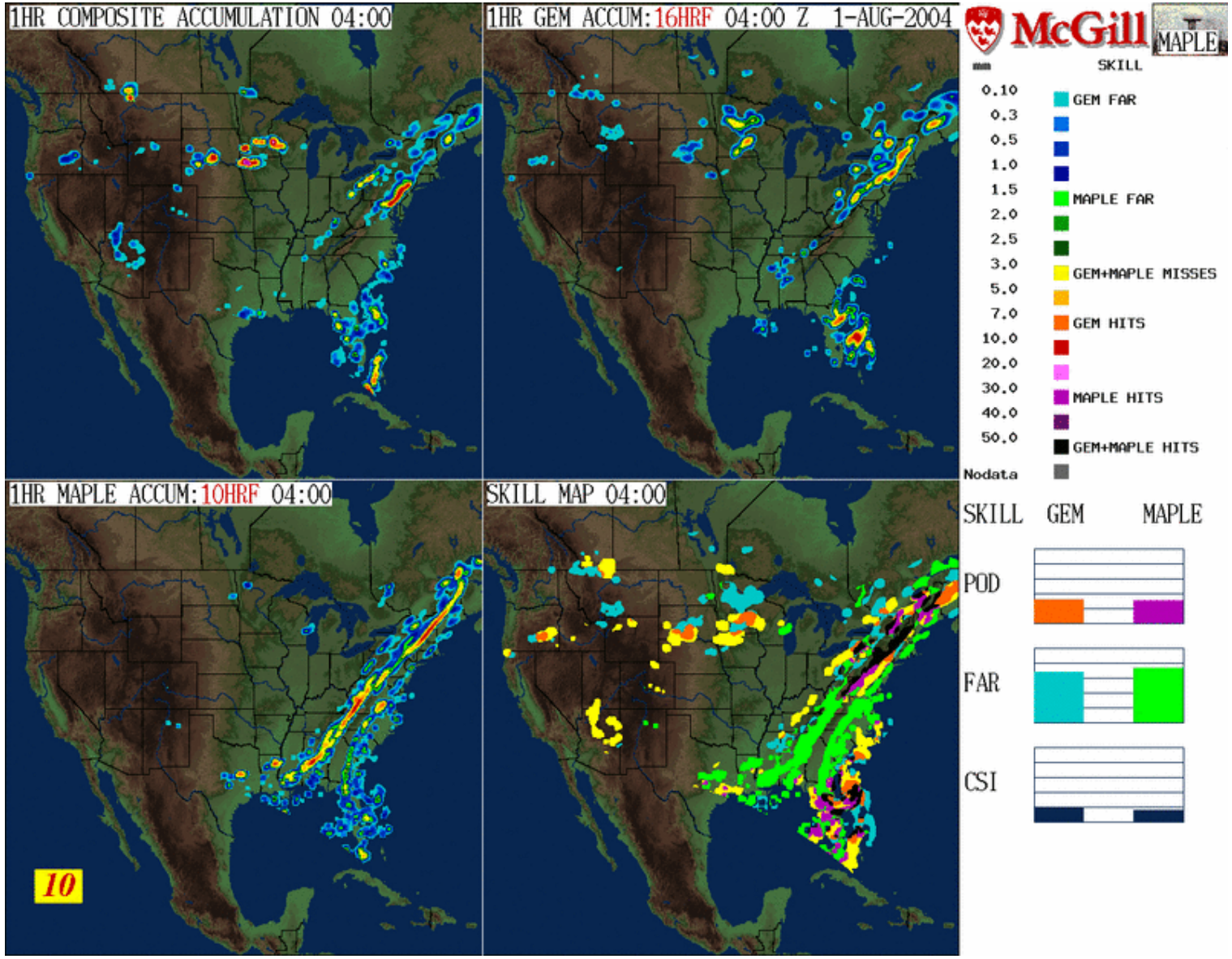


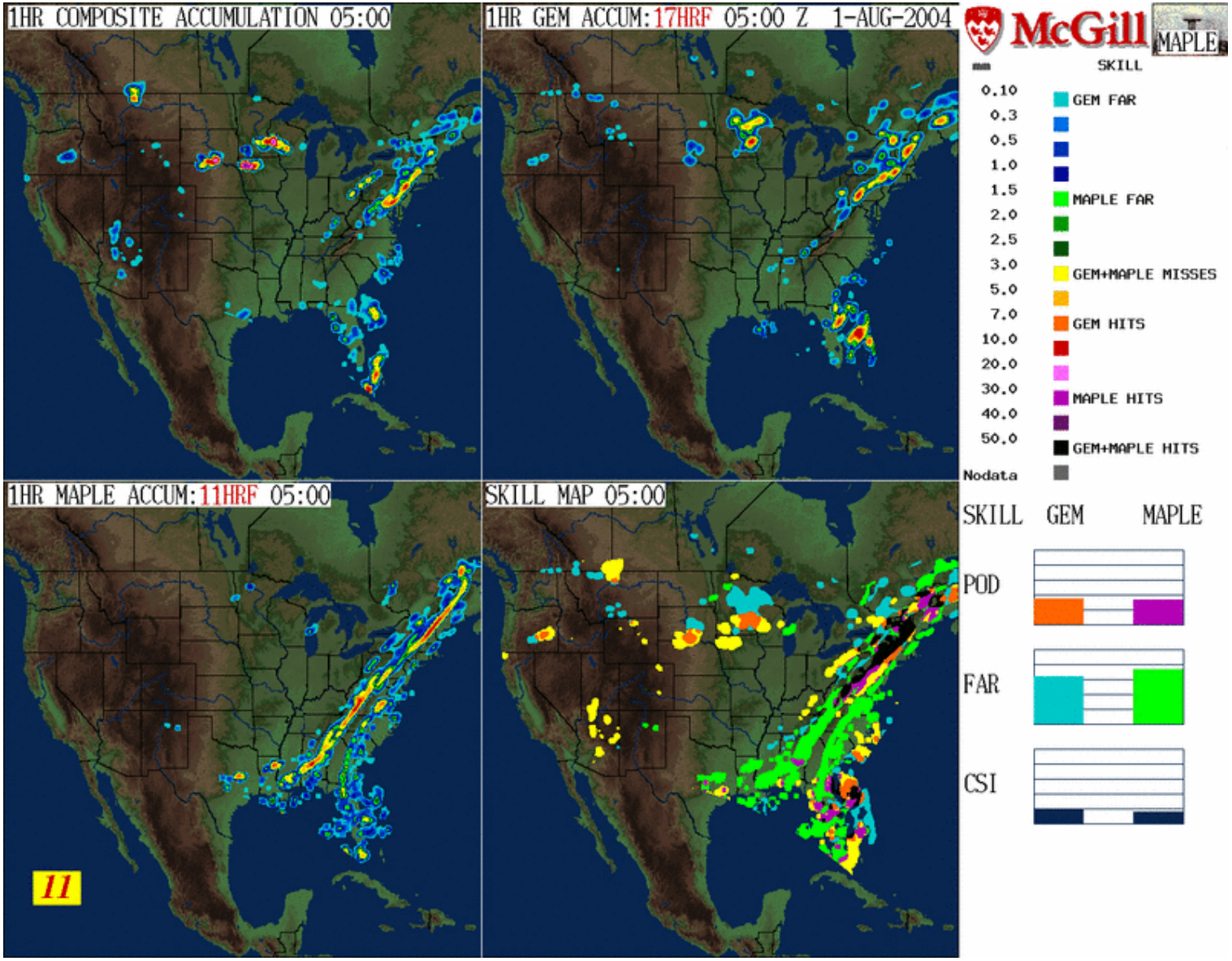
Model Skill vs. Lagrangian Persistence Skill



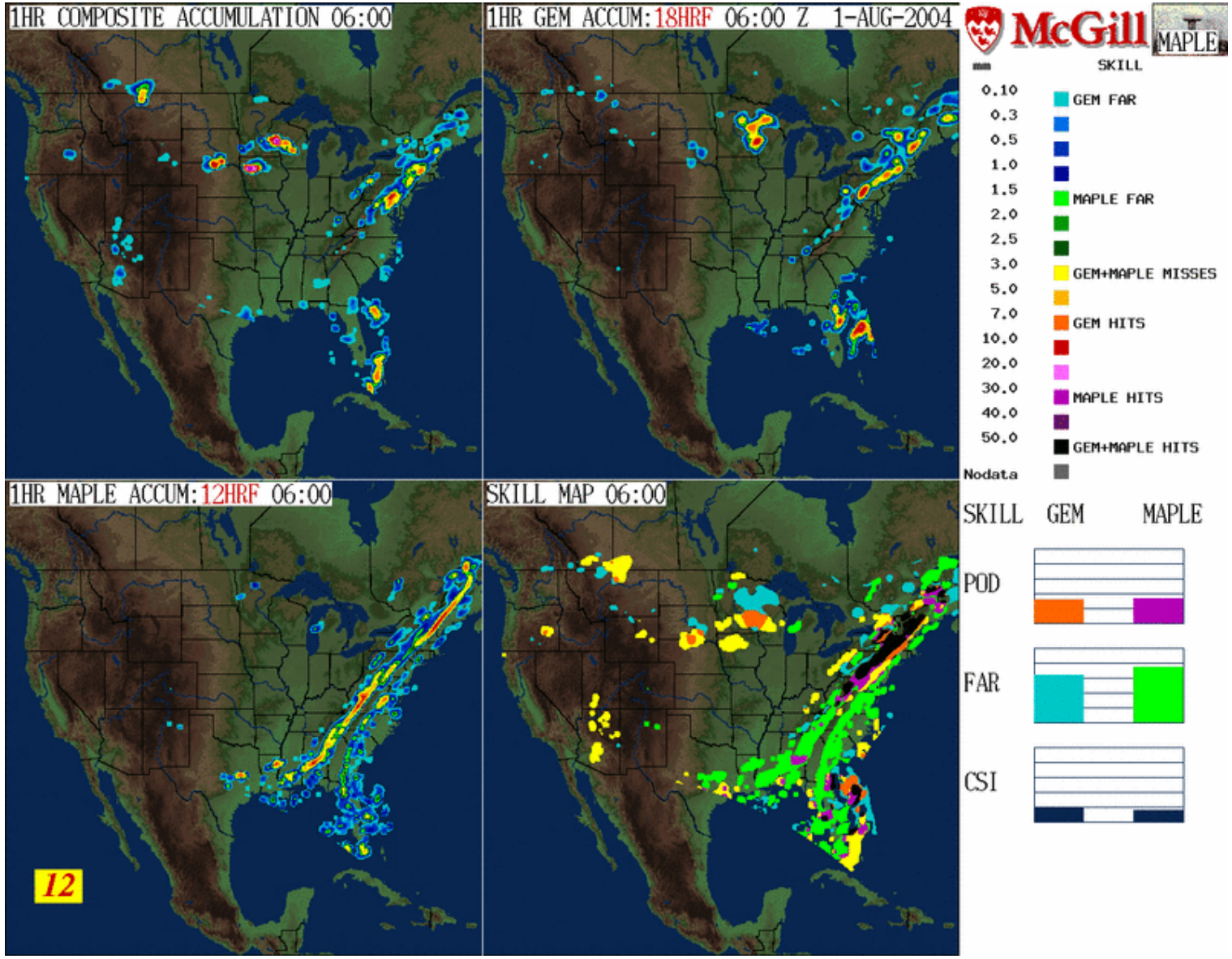
Model Skill vs. Lagrangian Persistence Skill



Model Skill vs. Lagrangian Persistence Skill

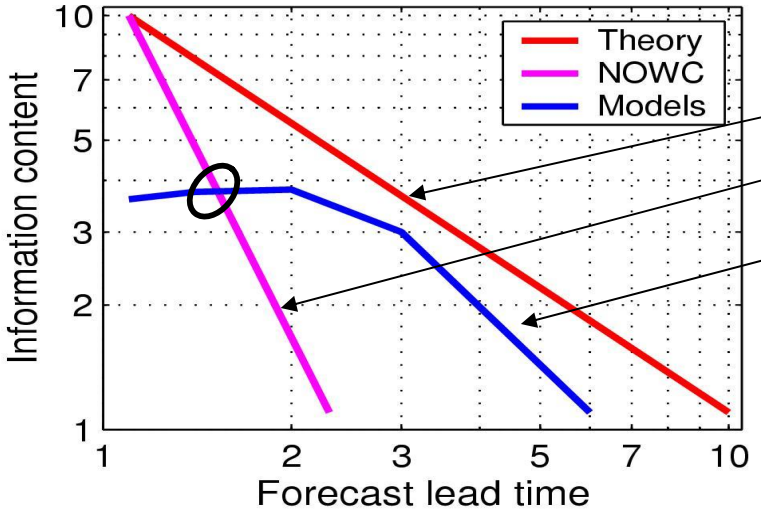


Model Skill vs. Lagrangian Persistence Skill



Compare skill of model forecasts and radar nowcasts

Skill of Precipitation Forecasts from NWP models and Radar Nowcasts



Theoretical limit of predictability

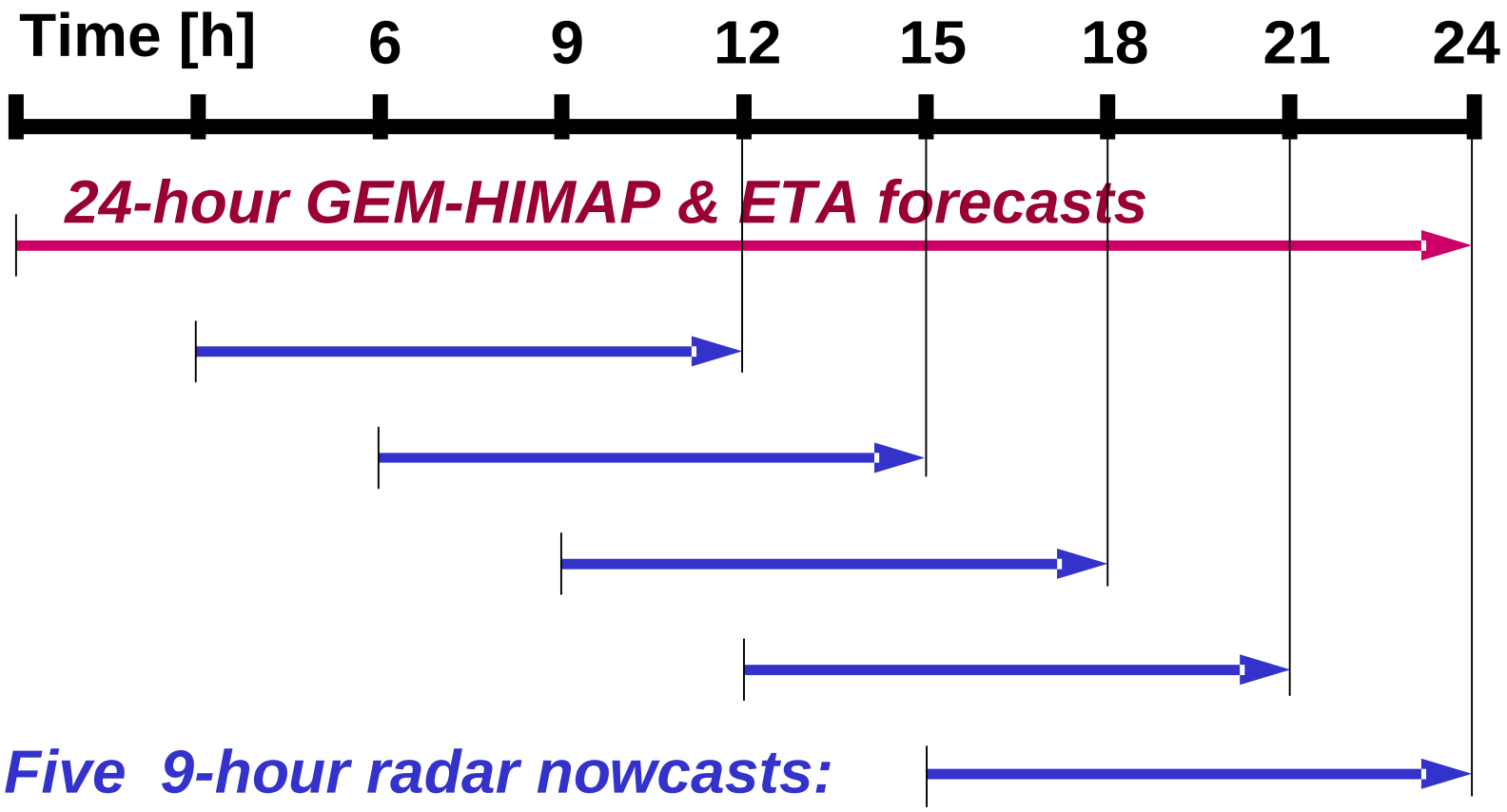
Nowcasting methods

Numerical weather prediction models

[Golding (1998), Austin et al. (1987)]

- **Examine skill**
- **Identify cross-over point**
- **Statistical blending to produce an optimal forecast**

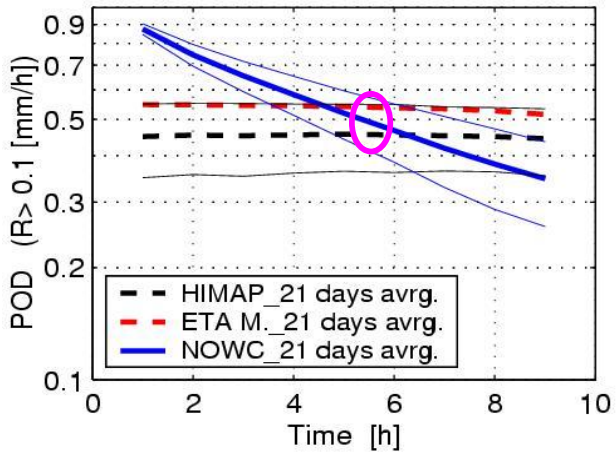
Experimental Design

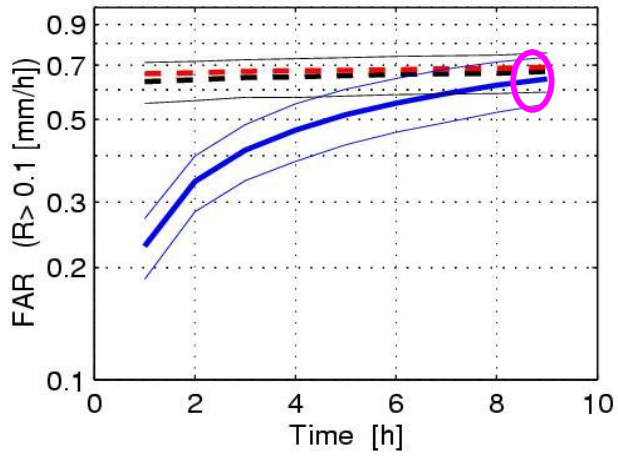


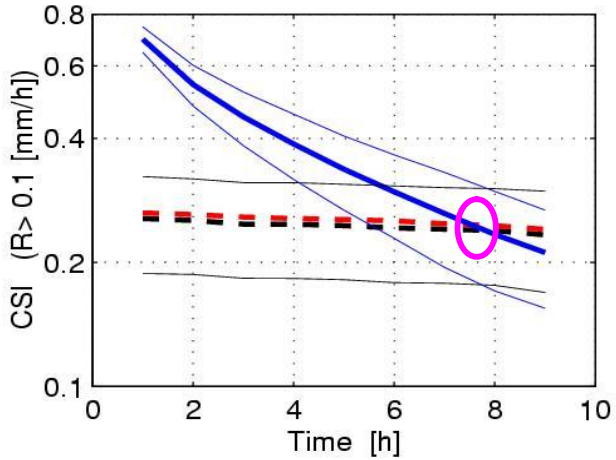
21-day averaged skill scores

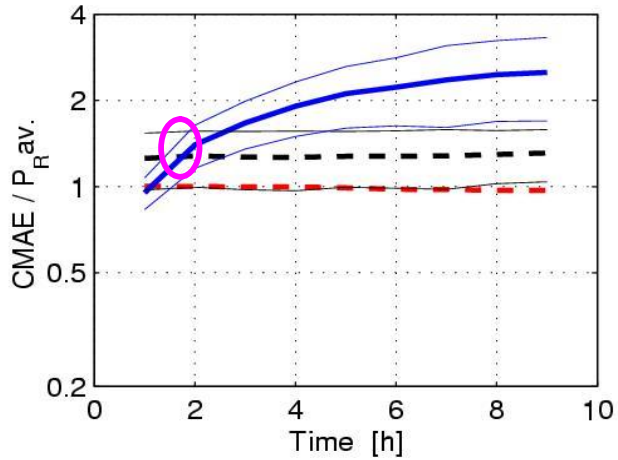
(500 cases of 1-hour accumulated precipitation, 2003-2004)

- Threshold: 0.1 mm/h -





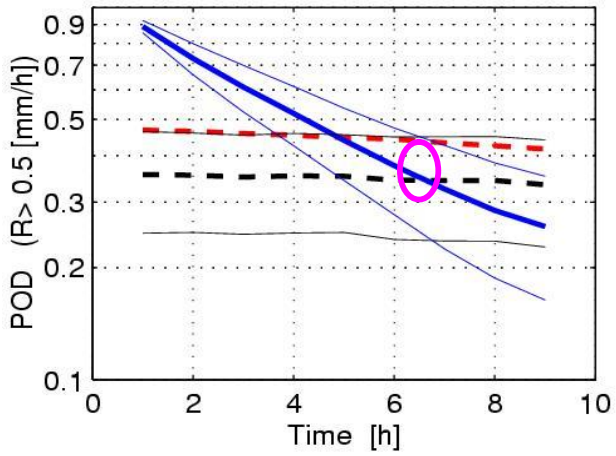


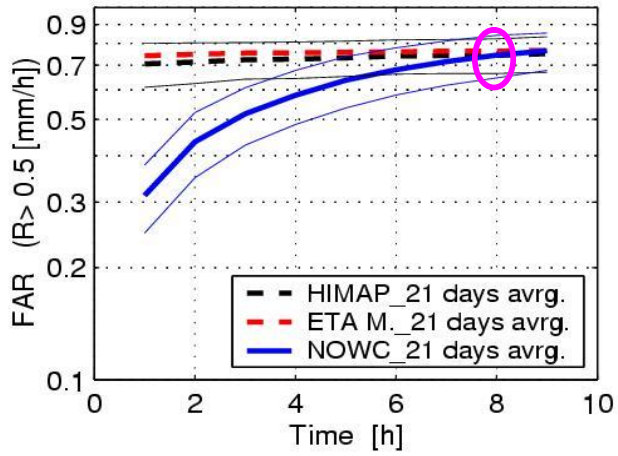


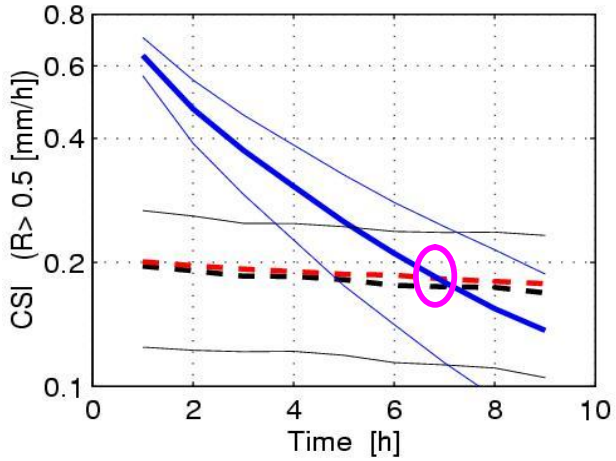
21-day averaged skill scores

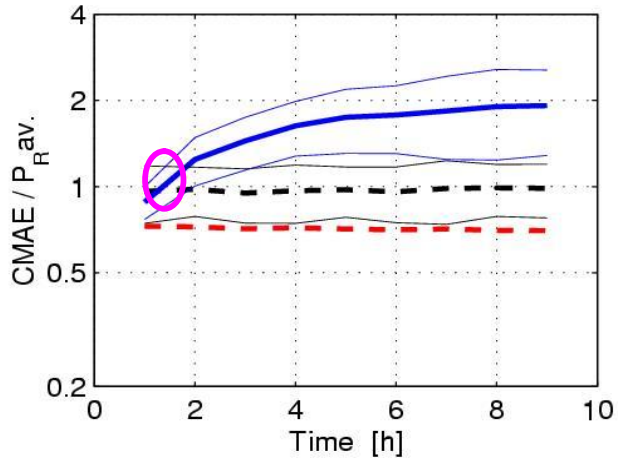
(500 cases of 1-hour accumulated precipitation, 2003-2004)

- Threshold: 0.5 mm/h -





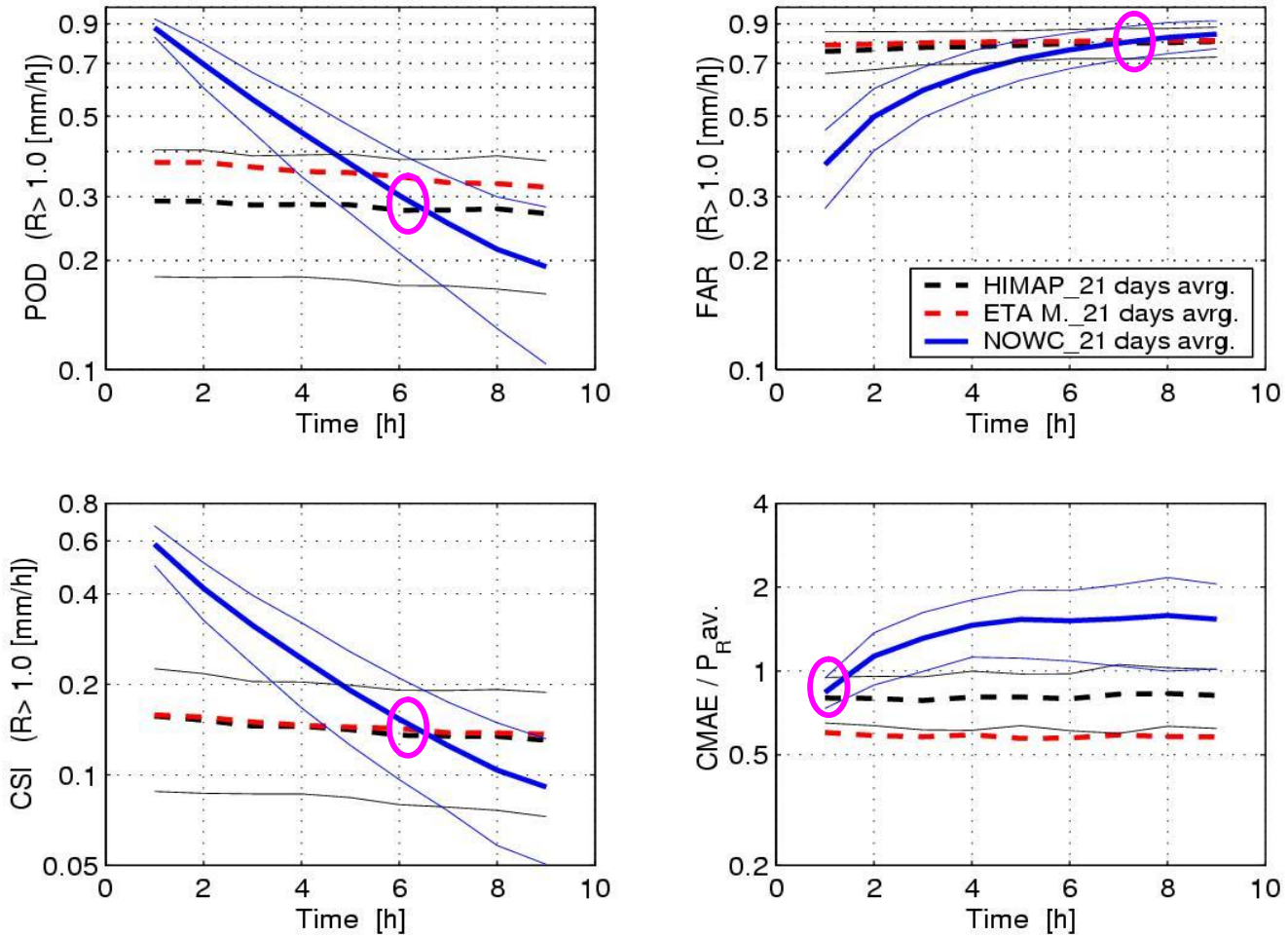




21-day averaged skill scores

(500 cases of 1-hour accumulated precipitation, 2003-2004)

- Threshold: 0.1 mm/h -

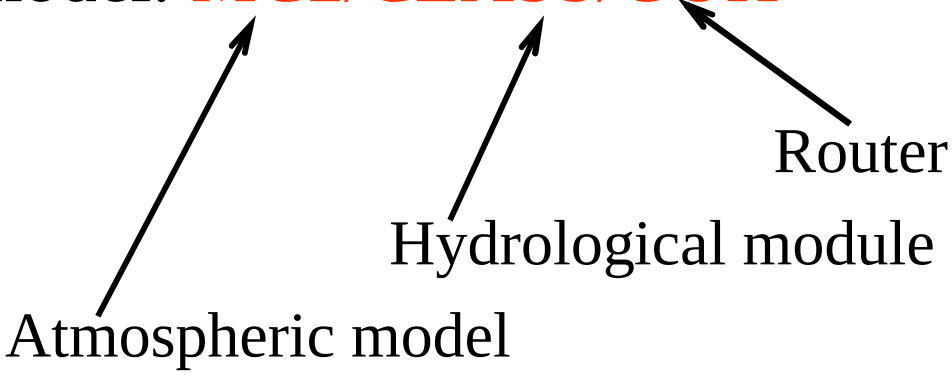


Summary and Future Work

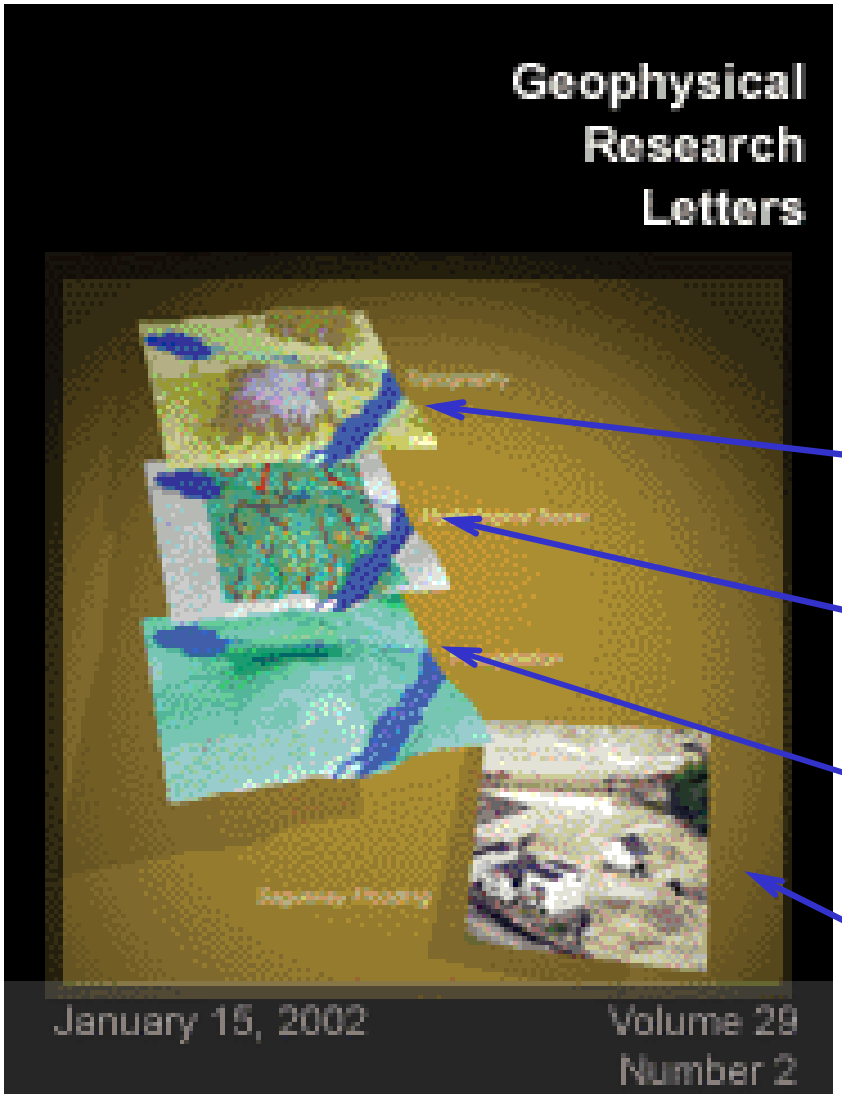
- Skill of radar nowcasts and operational model forecasts is examined using over 500 cases of 1-hour accumulated precipitation and conventional skill measures
- According to POD and CSI skill measures, models start to perform better than radar nowcasts after 6-7 hours, verifying quantitatively conceptual picture
- Continue wavelet scale decomposition analysis
- Blend statistically radar nowcasts and NWP model forecasts to yield an optimal forecast

Application to Saguenay flood

- July 19-21, 1996: 48-hour simulation
- Ha! Ha! River basin
- 1-km GIS database for soil, vegetation, topography
- Coupled model: MC2/CLASS/GUH



Saguenay flood in Canada (July 19-21, 1996): 48-hour simulation with a coupled atmospheric/hydrological model)



Topography of Saguenay region

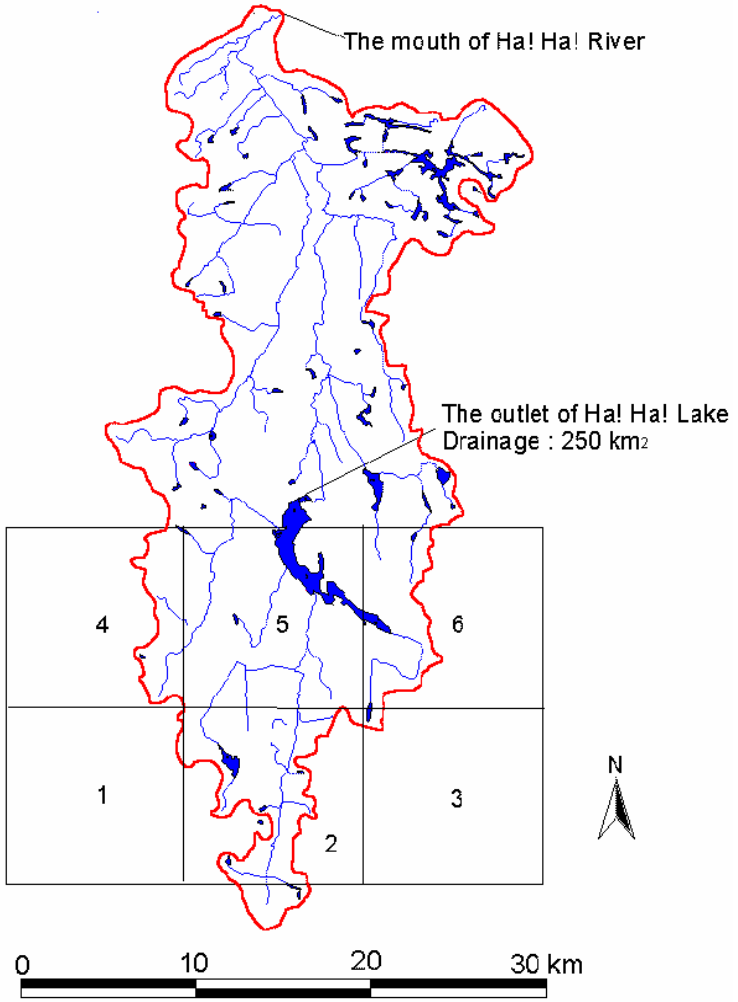
Hydrological basin

Precipitation

Flooding

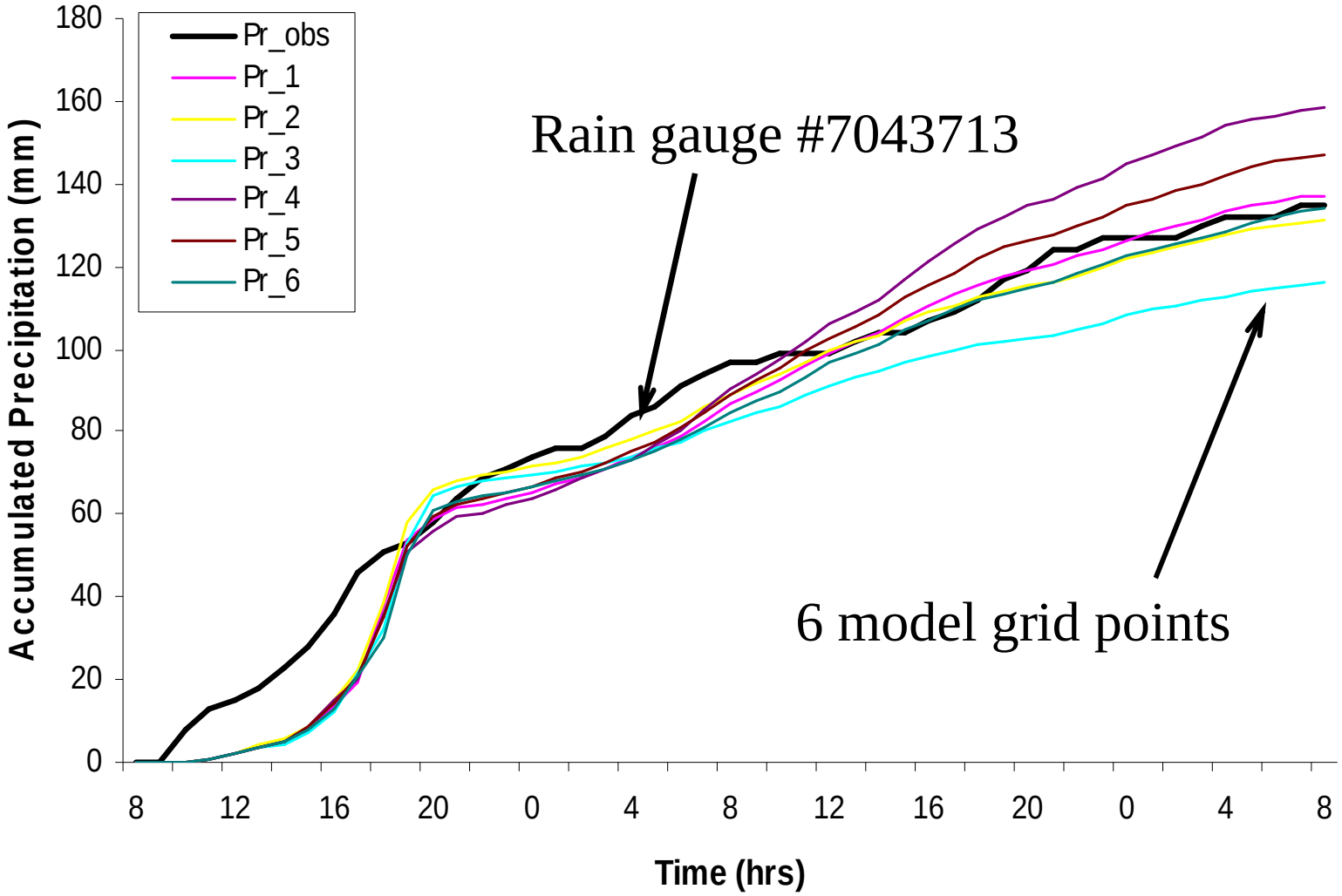
Lin, C.A., L. Wen, M. Béland and D. Chaumont (2002)

Southern Ha!Ha! River basin
covered by 6 model grid points

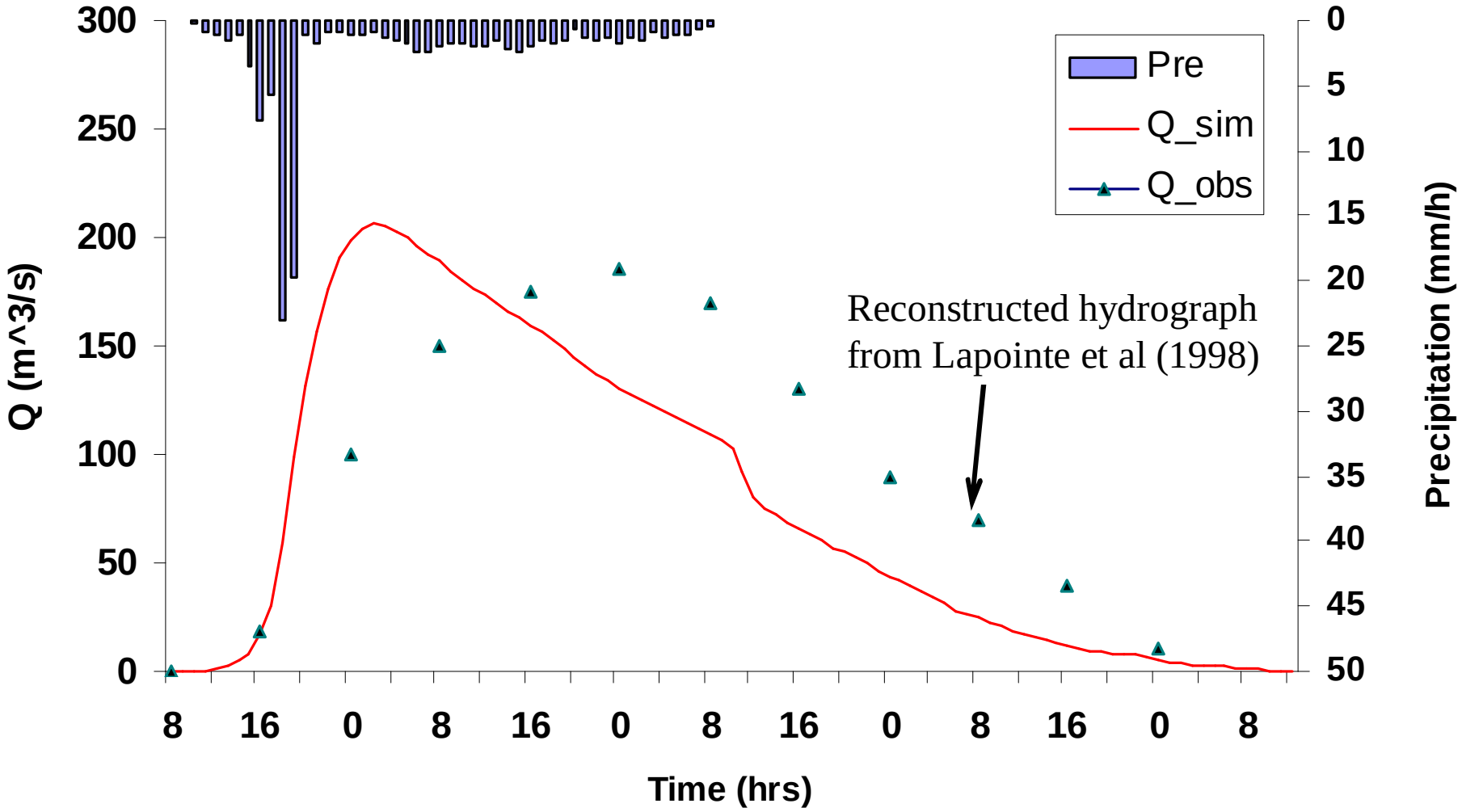


Nearest rain gauge # 7043713

Precipitation over Ha! Ha! River basin



Comparison of two reconstructed hydrographs at outlet of Ha!Ha! Lake (July 19 to 21, 1996)



HUBEX/MAGE Project in China

- China GEWEX project: HUBEX (HUaihe river Basin EXperiment)/MAGE (Monsoon Asian GEWEX Experiment)
- IOP: May 1 to August 31, 1998
- Huaihe River basin: 270,000 km^2
- 213 rain gauges
- HUBEX/MAGE data used for model verification
- Experiments: 6 heavy precipitation cases in summer of 1998 over Huaihe River basin

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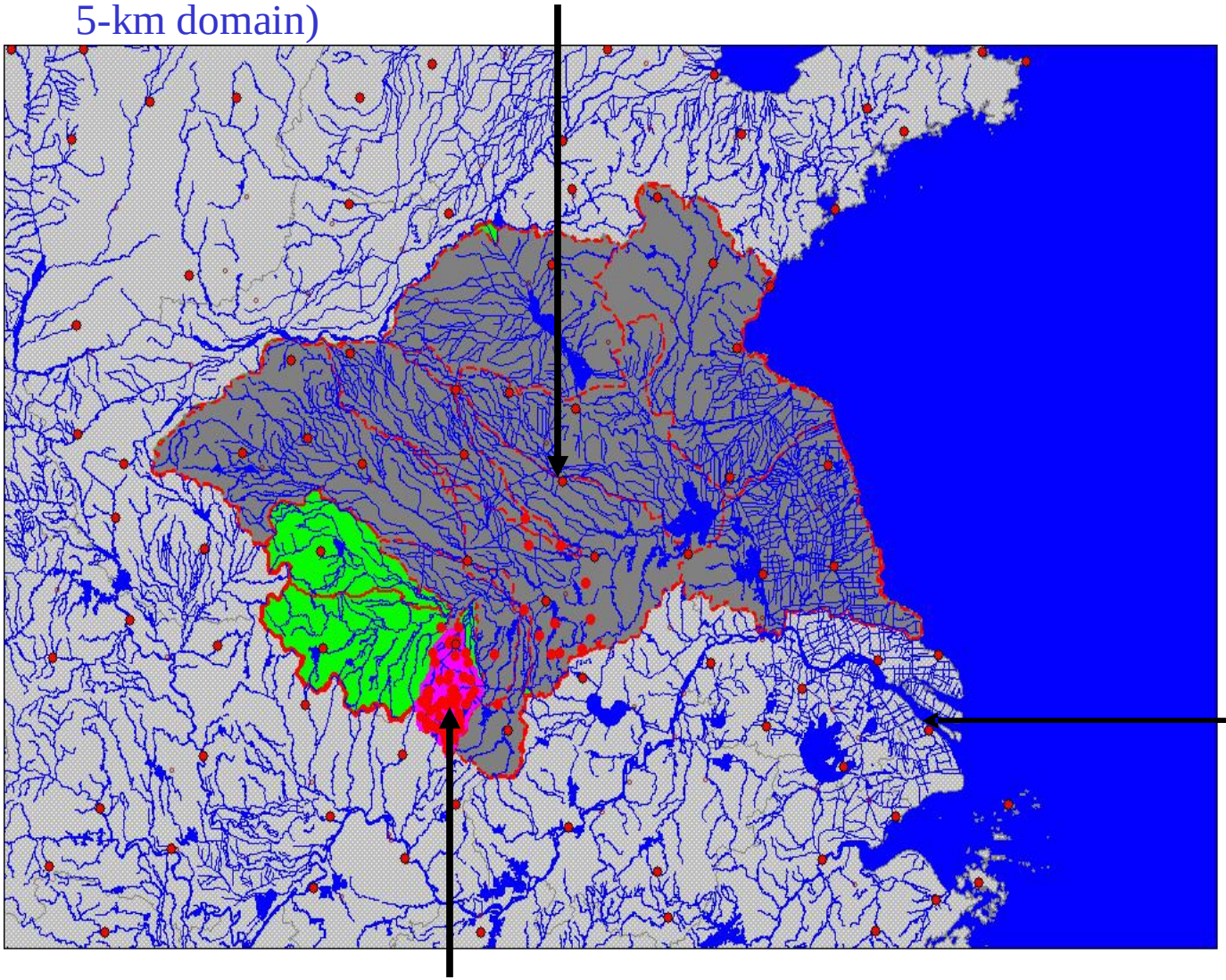
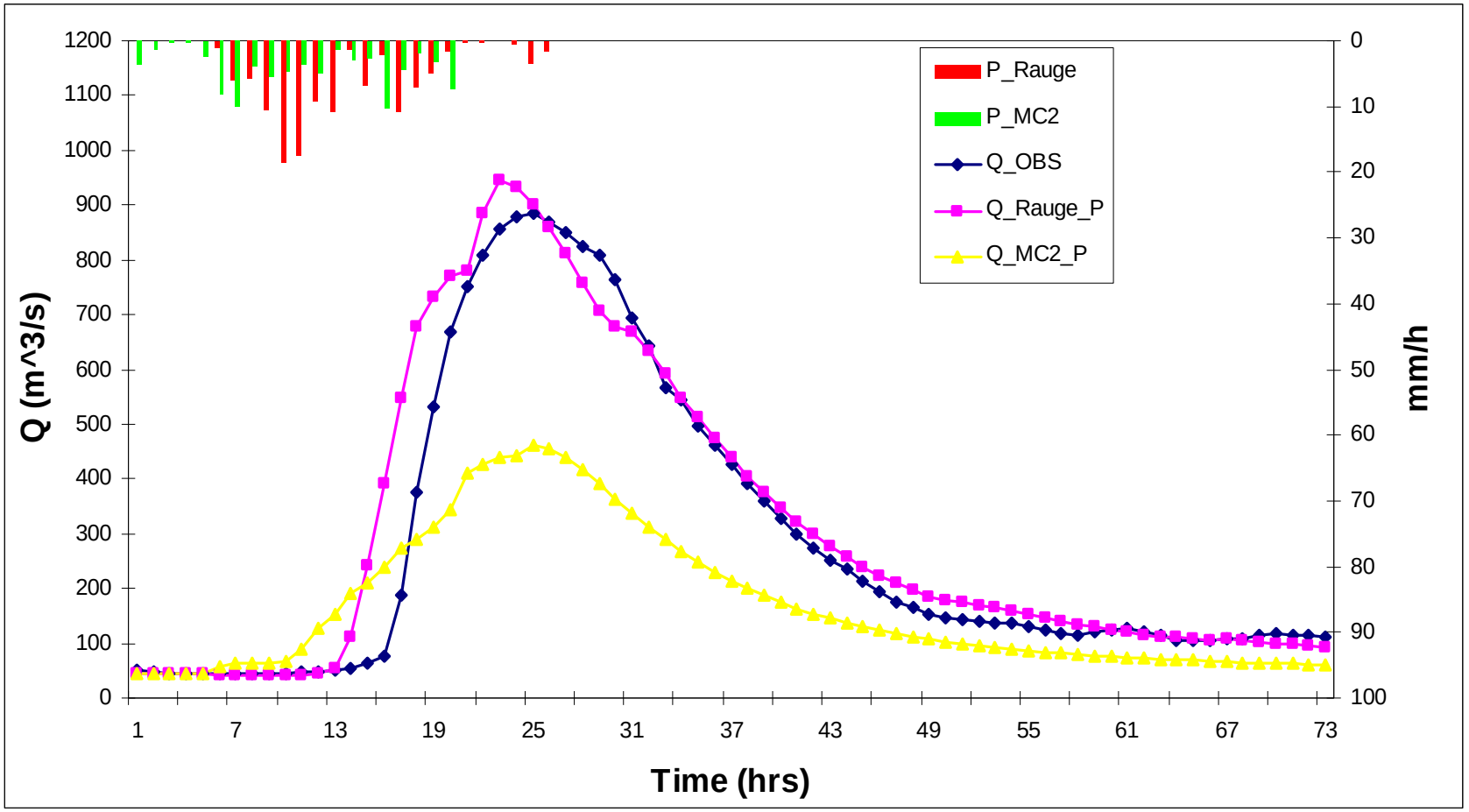
Huaihe River basin (270,000km^2) with 213 rain-gauges (covered by 5-km domain)



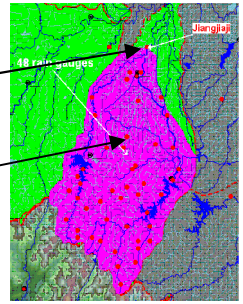
Shiguanhe sub-basin (5,800 km^2) with 48 rain gauges, where Xinanjiang hydrological model is applied

Hydrograph at Jiangjiaji outlet of Shiguanhe sub-basin (August 14 - 16, 1998)



Jiangjiaji outlet

Shiguanhe sub-basin



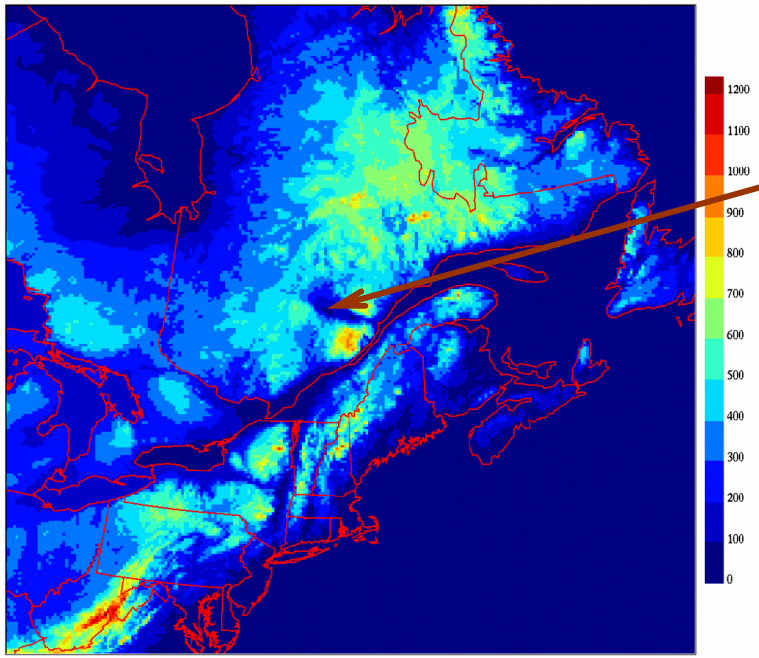
Summary

- Proof-of-concept study: coupled meteorological/hydrological models for flood forecasting
- Encouraging results from Saguenay and Chinese studies
- Continuing collaborative project with Bureau of Hydrology, Ministry of Water Resources, China

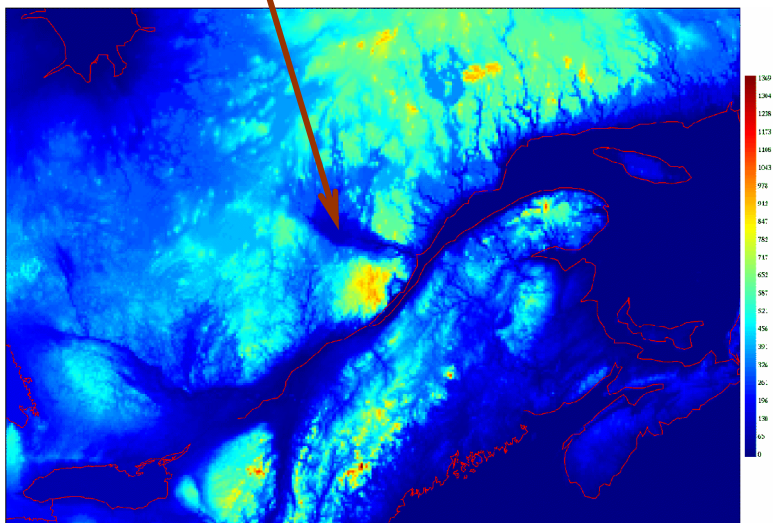
Thank you!

Model domain with surface topography

St. Jean Lake

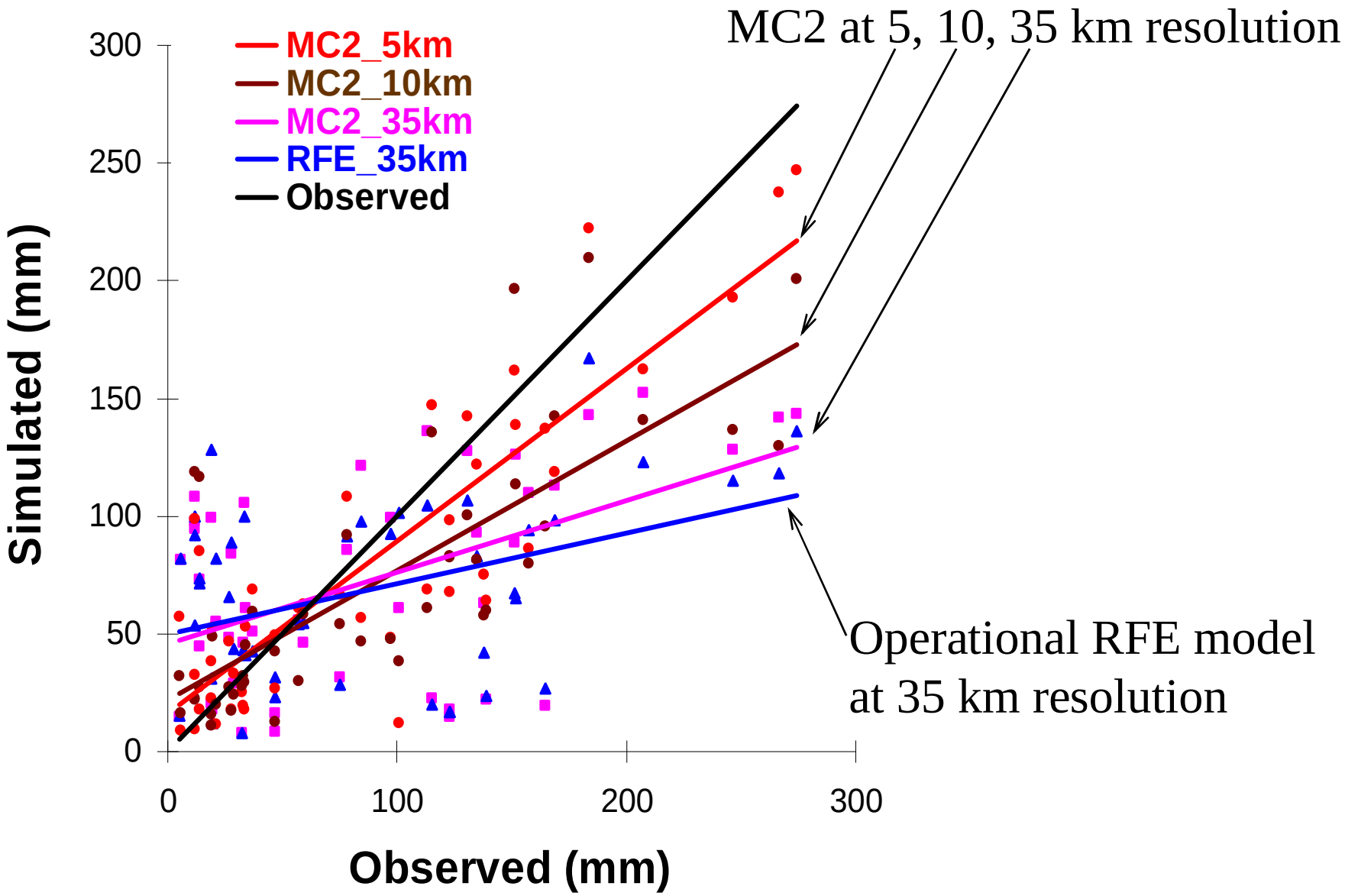


10 km resolution domain

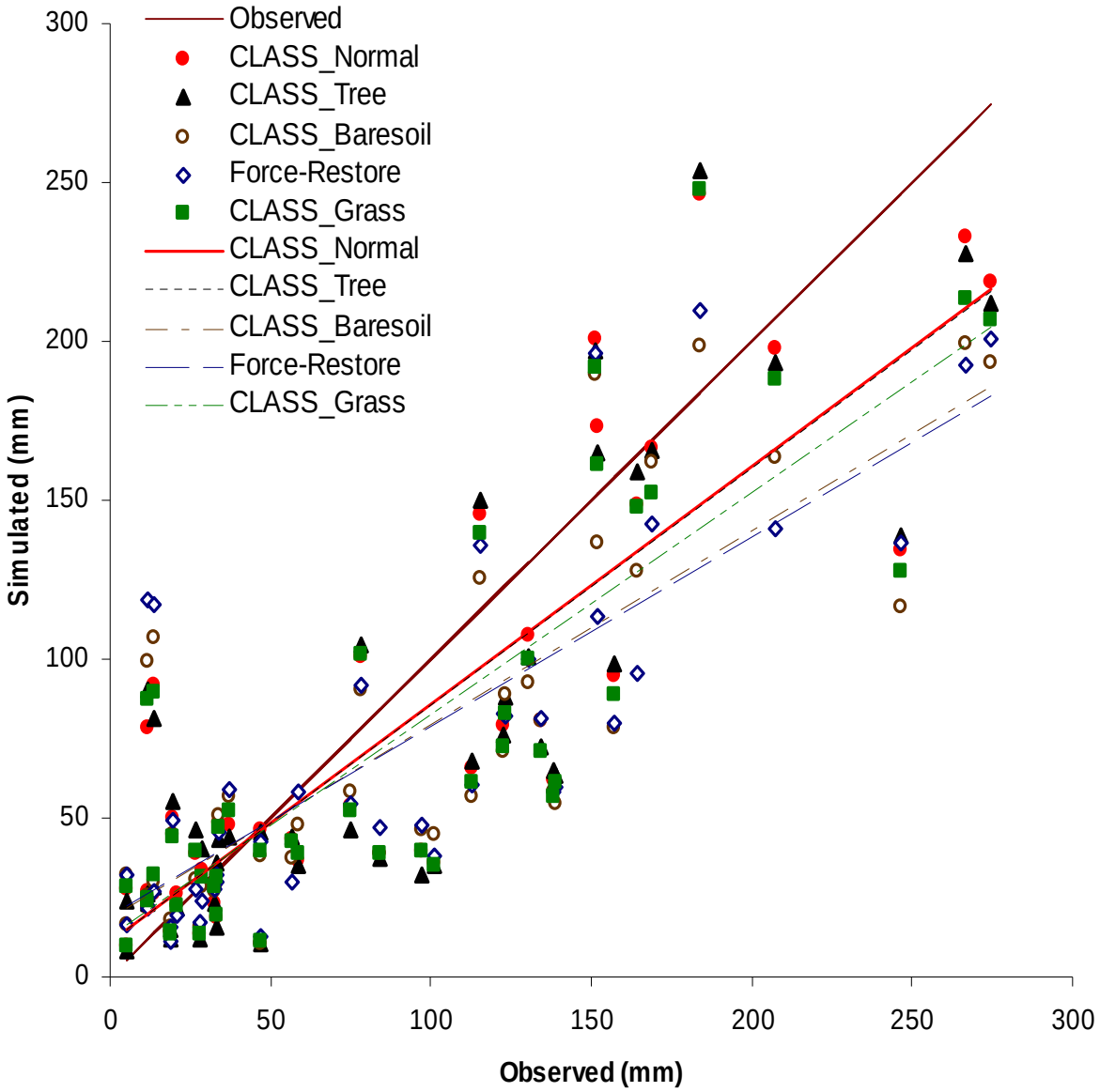


5 km resolution domain

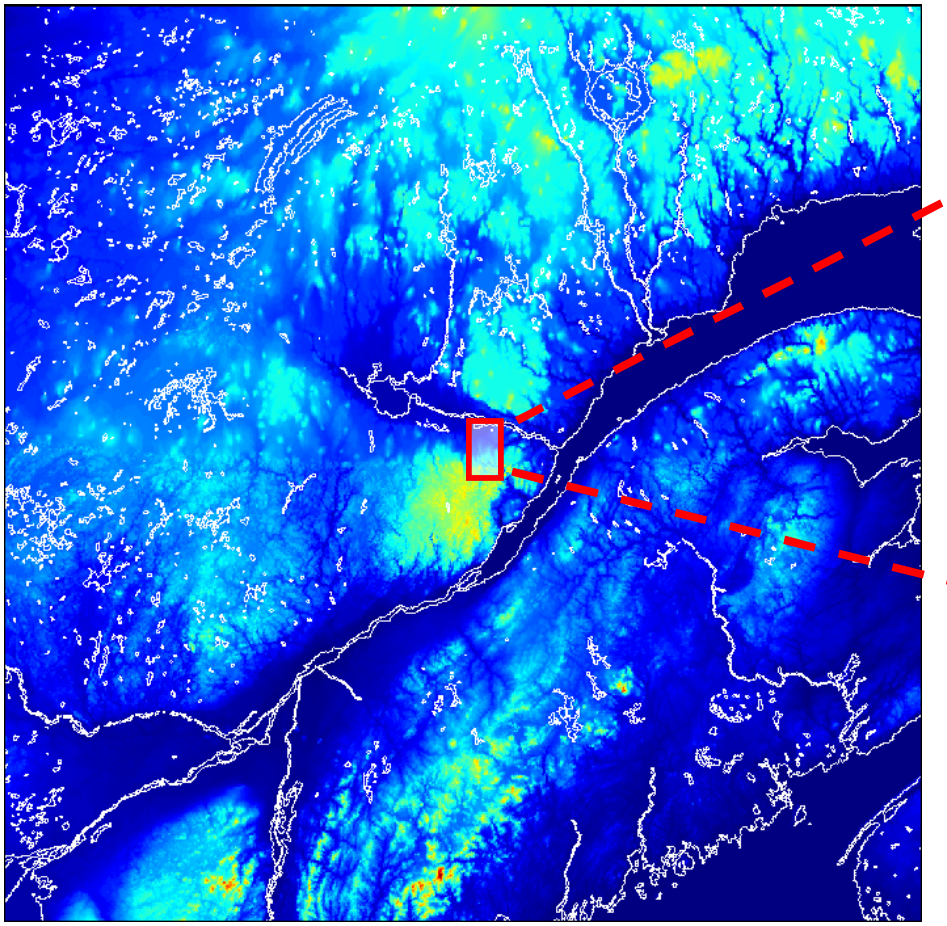
Scatter plot: 48-hour accumulated precipitation (mm)

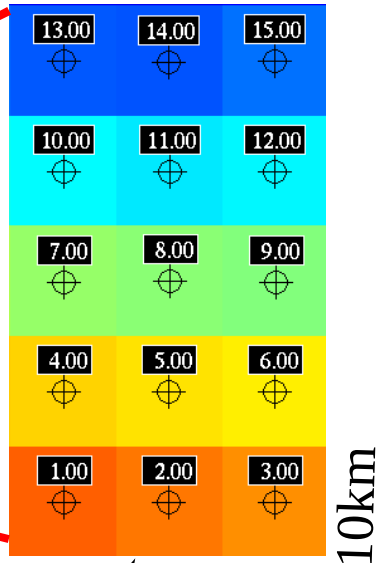


48-h Accumulated Precipitation (mm): Sensitivity to land surface (MC2/CLASS at 10 km)



Ha! Ha! River basin analysis





Ha! Ha! River basin covered by 15 model grid points (10 km × 10 km)

Simulated runoff

- Total runoff
  - Lin et al. (2002) 3.1×10^7 m^3
  - Lapointe et al. (1998) 3.2×10^7 m^3
- Time of peak precipitation is about the same
- Significant difference in time of peak flow

An Assessment of MC2 Precipitation Simulation during the Intensified Observation Period of the HUBEX/MAGE Project in China

Lei Wen[1], Charles A. Lin[1], Guihua Lu[2], Jianyun Zhang[3], Yang Yang[3], Linying Tong[4], Yufei Zhu[1], Zhiyong Wu[2]

1 McGill

2 河海大學 HoHai University

3 中国水利 CHINA WATER

Environnement Canada Centre météorologique canadien

4 Environment Canada Canadian Meteorological Centre

Experimental Design with MC2 and Xinanjiang hydrological model

- MC2: Mesoscale Compressible Community Model
- Initial run

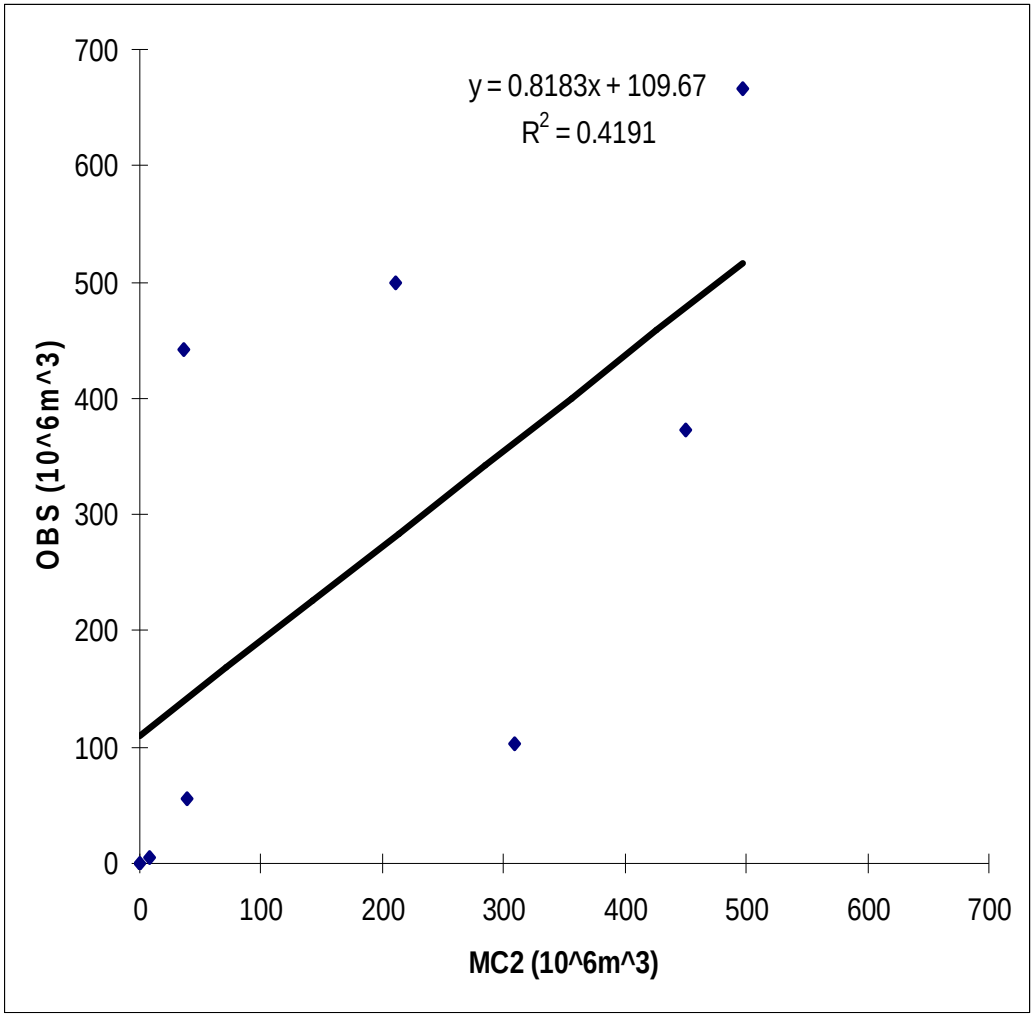
  horizontal resolution: 20 km

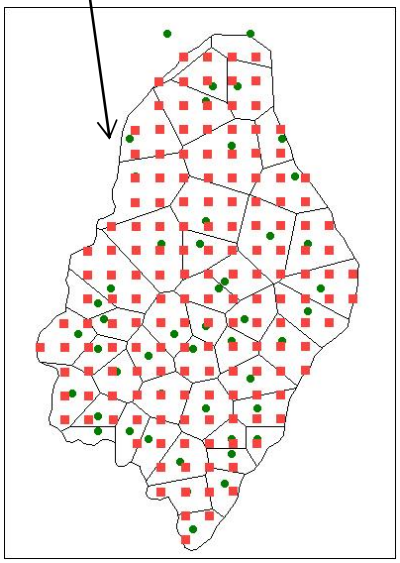
  domain: 409 × 301 × 35 points × 40 levels
- Nested run

  horizontal resolution: 5 km

  domain: 301 x 301 x 35 x 40
- Domains centred at 33 ^{o}N, 116 ^{o}E (Huaihe River basin)
- 78-hour simulation, initialized and driven by CMC global analysis (100 km resolution)
- Xinanjiang hydrological model applied for **Shiguanhe sub-basin**
- Experiments: 6 heavy precipitation cases in summer of 1998 over Huaihe River basin

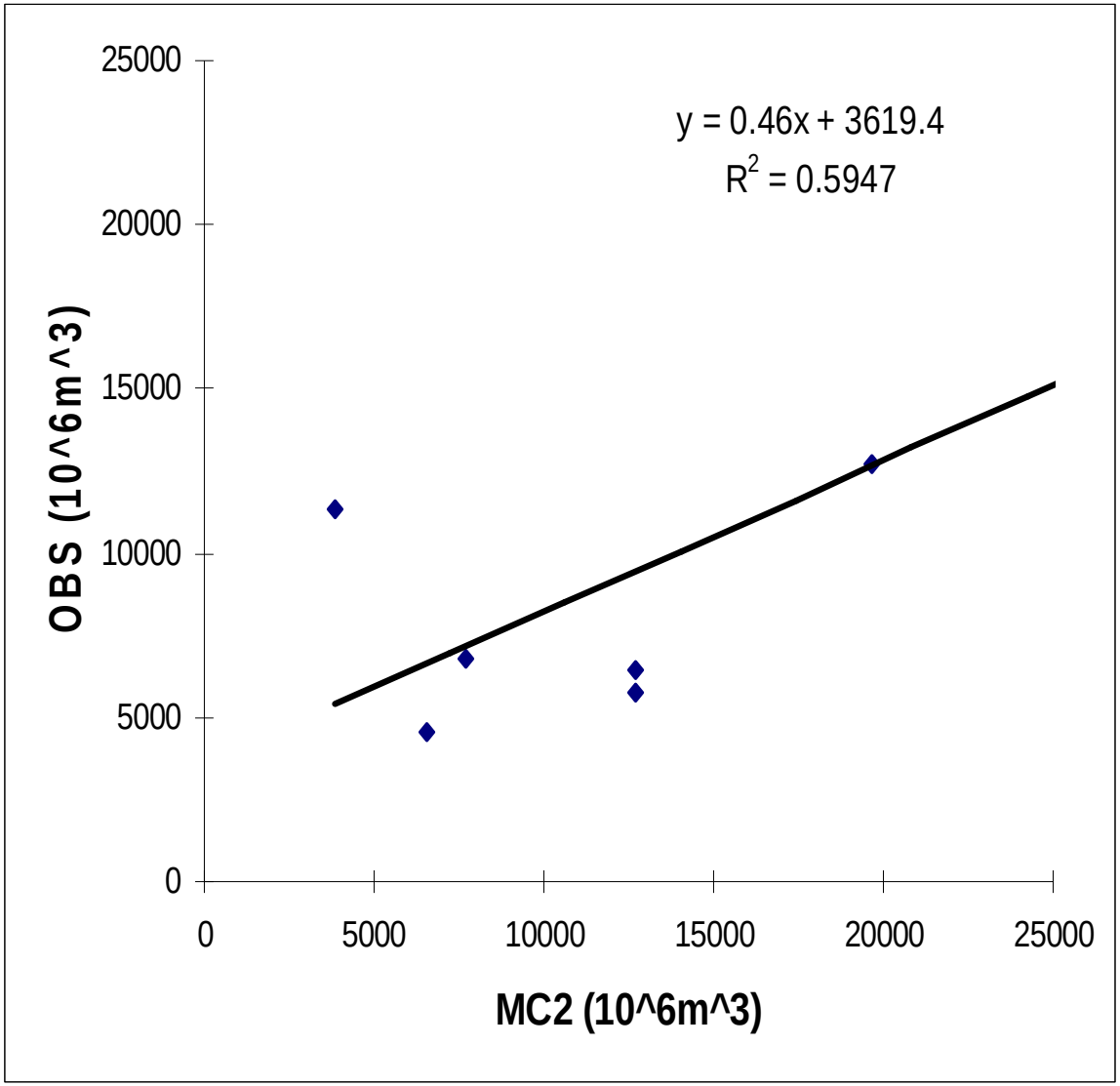
Scatter plot for basin averaged accumulated precipitation over Shiguanhe sub-basin

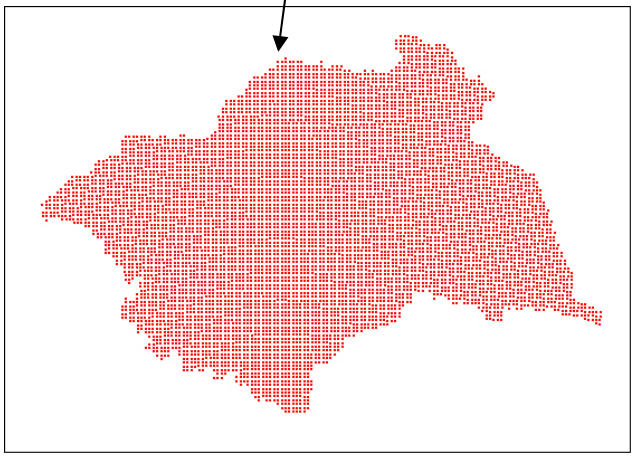




48 rain gauges

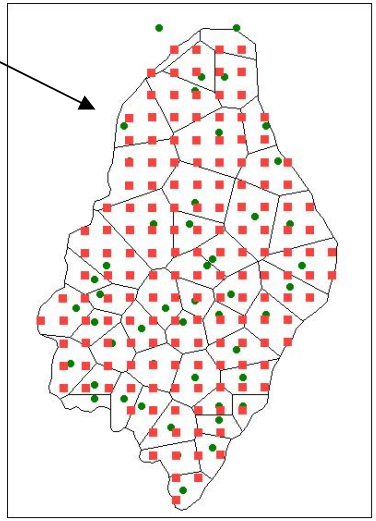
Scatter plot for basin averaged accumulated precipitation over Huaihe River basin





213 rain gauges

Accumulated precipitation over Shiguanhe sub-basin for 6 cases



	MC2	Observed	Error	% Error
1998/06/28	36 (10^6m3)	442 (10^6m3)	-406 (10^6m3)	-91%
1998/07/01	210 (10^6m3)	499 (10^6m3)	-288 (10^6m3)	-57 %
1998/07/27	449 (10^6m3)	372 (10^6m3)	76 (10^6m3)	20 %
1998/08/01	38 (10^6m3)	54 (10^6m3)	-16 (10^6m3)	-29 %
1998/08/05	308 (10^6m3)	103 (10^6m3)	205 (10^6m3)	199 %
1998/08/08	0 (10^6m3)	0.4 (10^6m3)	-0.4 (10^6m3)	No rain
1998/08/10	7 (10^6m3)	5 (10^6m3)	2 (10^6m3)	40 %
1998/08/14	497 (10^6m3)	666 (10^6m3)	-168 (10^6m3)	-25 %

Good agreement

largest case

Conclusions

- Initial simulation of flood events in China using MC2 with Canadian CMC analysis (100 km resolution)

- Simulation of basin averaged accumulated precipitation for 6 cases show reasonable agreement with observations, especially for large rainfall cases

- Simulated timing of peak flow agrees with observed hydrograph over the Shiguanhe basin (5,800 km^2) for only one case

- Error in hydrograph is due to timing of simulated precipitation

Further Work

- Ongoing collaborative project with Hohai university and Bureau of Hydrology, Chinese Ministry of Water Resources

- Plan to use analysis from Chinese Meteorological Agency to drive MC2

- More cases will be examined (up to 20)