# 23 Using the Big Weather Web Ensemble to Examine Systemic Biases in WRF Model Parameterizations

**_Russ S. Schumacher[1]_** and _Kevin R. Tyle_

1: Department of Atmospheric Science, Colorado State University; 2: Department of Atmospheric and Earth Sciences, University at Albany/SUNY

ATMOSPHERIC SCIENCE
COLORADO STATE UNIVERSITY

UNIVERSITY AT ALBANY
State University of New York

## What is the Big Weather Web?

- The overall goal of the Big Weather Web (BWW) is to make big data infrastructure affordable and adequate for university members of the Numerical Weather Prediction community by combining the application of three recent technologies: virtualization, cloud computing and storage, and big data management. (**bigweatherweb.org**)
- One major aspect of the project is an NWP ensemble, distributed across many universities, that enables atmospheric research and new cloud/big-data techniques

BIG WEATHER WEB

## The BWW Ensemble

- A total of 47 members, run by 7 different universities, run daily for 2016-2017, with a domain that covers much of North America at 20-km grid spacing

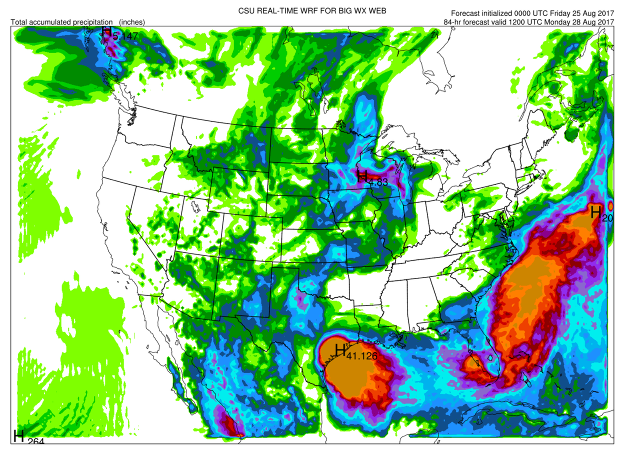


*Fig. 1:* *Example forecast showing BWW model domain (and QPF for Hurricane Harvey in August 2017)*

- Ensemble configuration includes different initial/lateral boundary conditions (from GEFS), physical parameterizations (cumulus, PBL, microphysics), and stochastic perturbations (SKEBS)
- In this work, we will use a subset of the ensemble to focus mainly on biases associated with parameterization choices

| Member | IC/LBC | Cumulus | PBL | Microphysics |
|---|---|---|---|---|
| CSU01 ("control") | GFS 0.5° | Kain-Fritsch | MYJ | Thompson |
| CSU02 | | Grell-Freitas | | |
| ALB01 | | | | |
| ALB02 | GEFSP01 | | | |
| ALB03 | | | YSU (top-down) | |
| ALB04 | | | ACM2 | |
| ALB05 | | New Tiedtke | | |
| ALB06 | | | YSU (no top down) | |
| ALB07 | | | GBM | |
| ALB08 | | New Tiedtke | | |
| TTU01 | | Tiedtke | YSU | Morrison |
| TTU02 | | Tiedtke | MYNN | Morrison |
| TTU03 | | Tiedtke | YSU | |
| TTU04 | | Tiedtke | MYNN | |
| TTU05 | | Tiedtke | YSU | WSM6 |
| TTU06 | | Tiedtke | MYNN | WSM6 |
| PSU08 | | | YSU | Milbrandt-Yau |
| UND02 | | | | WSM6 |
| UND04 | | Grell-Freitas | YSU | Morrison |

- All members have 20-km horizontal grid spacing, 43 vertical levels. RRTMG radiation, 90-second timestep, WRFV3.7.1
- Precipitation forecasts are evaluated using the NCEP Stage IV analysis, regridded to the BWW forecast grid
- Upper-level forecasts are evaluated against radiosonde observations
- Evaluation performed using METV6.0 on the NSF-XSEDE Jetstream Cloud

## Precipitation forecast evaluation

- Consistent with other forecast systems, precipitation forecast skill is:
  - Greater at shorter lead times
  - Greater at lower precipitation thresholds
  - Greater in the cool season, lower in the warm season

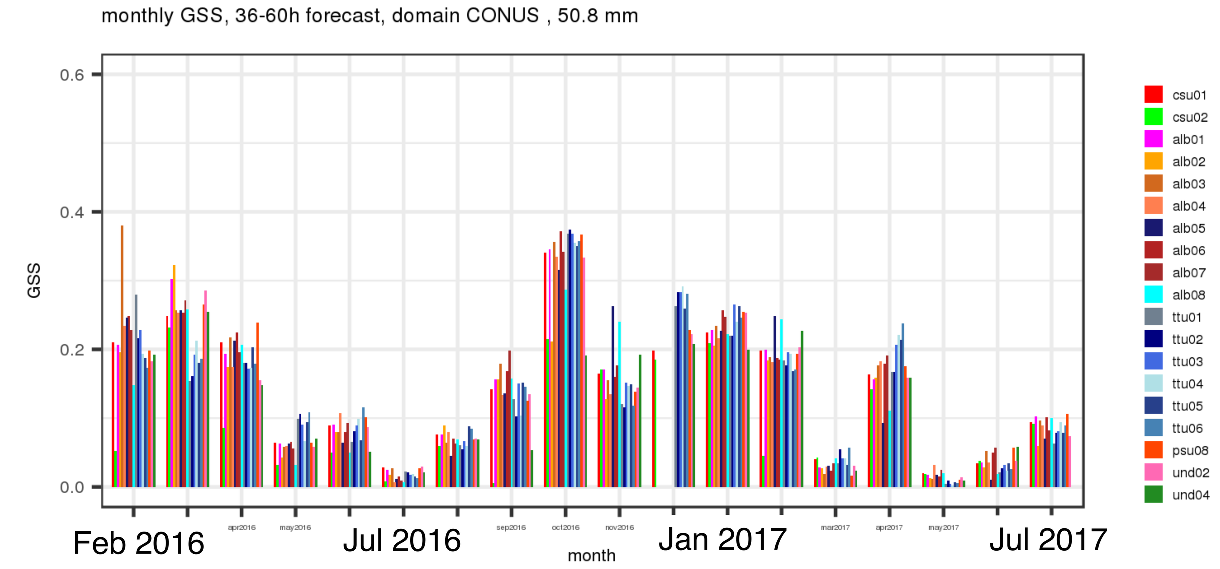
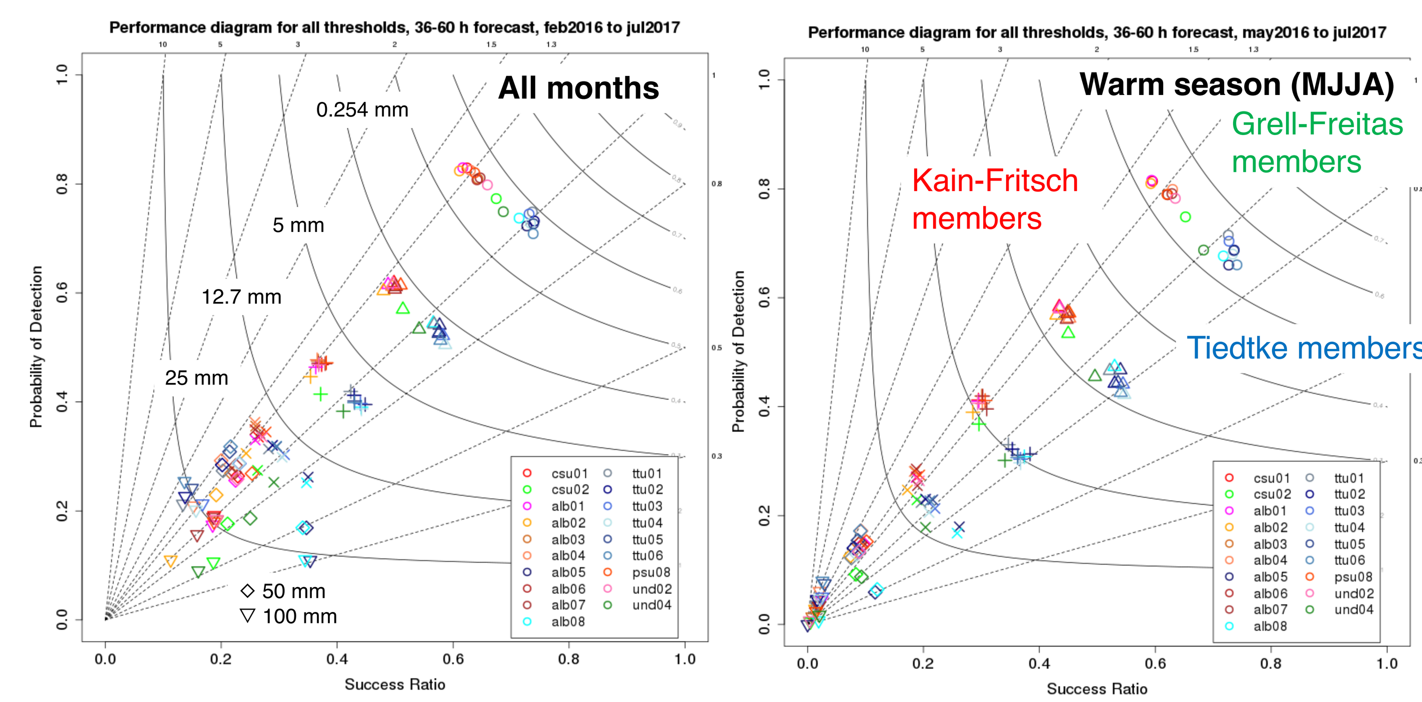



*Fig. 2: Gilbert Skill Score for 36-60-hour QPF for 50.8 mm for the subset of members shown in Table 1.*



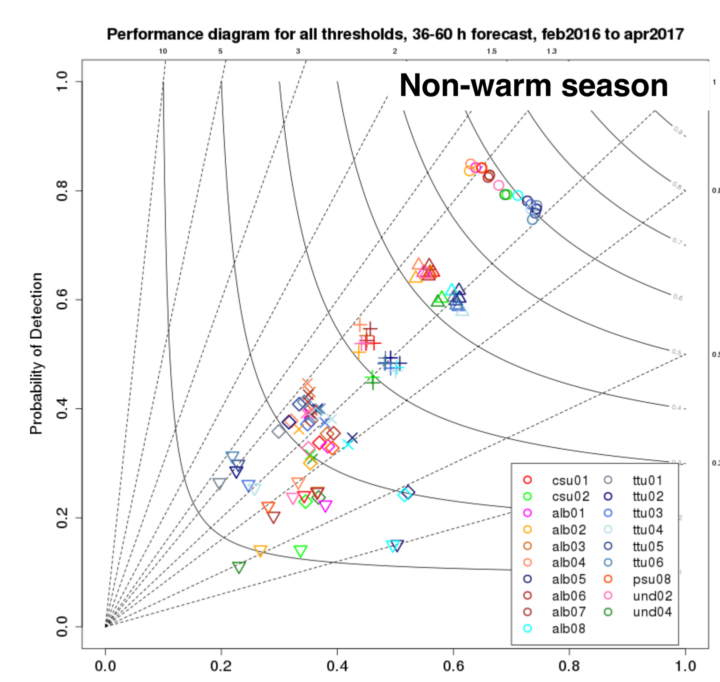
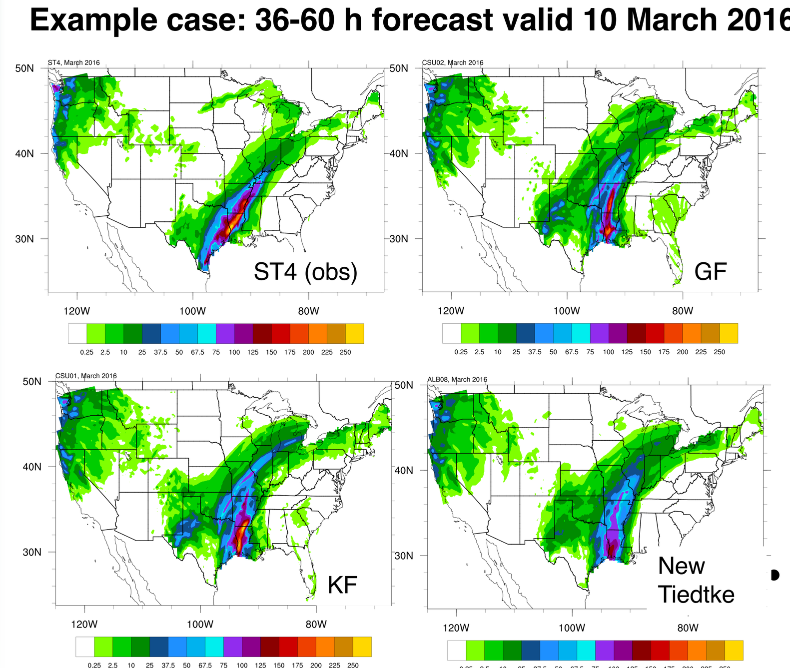




*Fig. 3: Roebber performance diagrams for 36-60-h QPFs over February 2016-July 2017. Colors represent different ensemble members; symbols represent different thresholds, with circles showing 0.254 mm and thresholds increasing toward the lower left (lower skill) part of the diagram.*

- All members using Kain-Fritsch convection have similar aggregate skill and bias, regardless of other perturbations for those runs; members with other cumulus parameterizations are notably different:
  - K-F has a consistent high bias at lower rain amounts, and is nearly unbiased at high amounts
    New Tiedtke is unbiased at lower rain amounts, but has a considerable dry bias at high amounts, mainly in the cool season
  - "Old" Tiedtke does not have this dry bias at high amounts
  - Grell-Freitas lies in between
  - Separation between the members is more apparent in warm season (CP scheme is more active)
- Depending on the application, it might be preferable to be unbiased at high amounts and accept the high bias at low amounts; or alternatively to be unbiased at low amounts that are more frequent

**Example case: 36-60 h forecast valid 10 March 2016**




## Atmospheric forecast evaluation

- Runs with different cumulus parameterizations exhibit different temperature and moisture error characteristics: in the warm season, both the Kain-Fritsch and Grell-Freitas members are cool and moist at low levels relative to observations, and warm and dry in midlevels; biases much smaller in Tiedtke

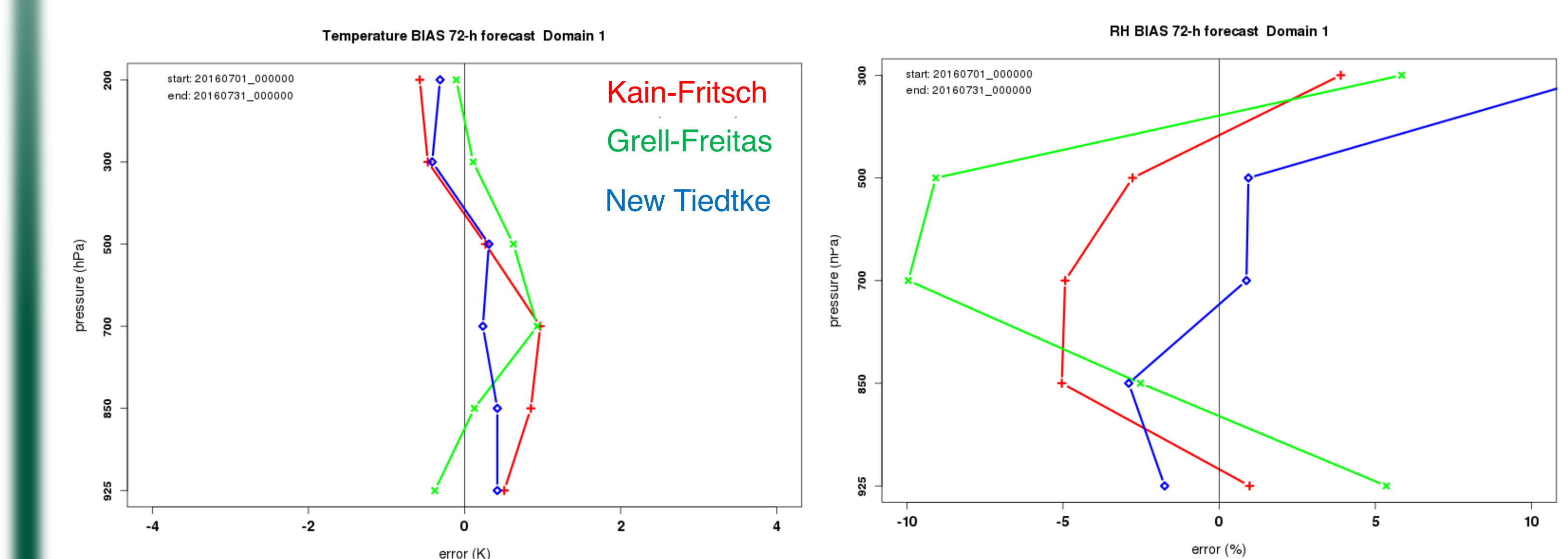



*Fig. 4: (left) Temperature and (right) relative humidity bias for BWW members using Kain-Fritsch vs. Grell-Freitas vs. Tiedtke cumulus parameterizations for 72-h forecasts in July 2016.*

- The RH bias is consistently much larger in the G-F scheme, and most pronounced in the warm season and over the southeast US

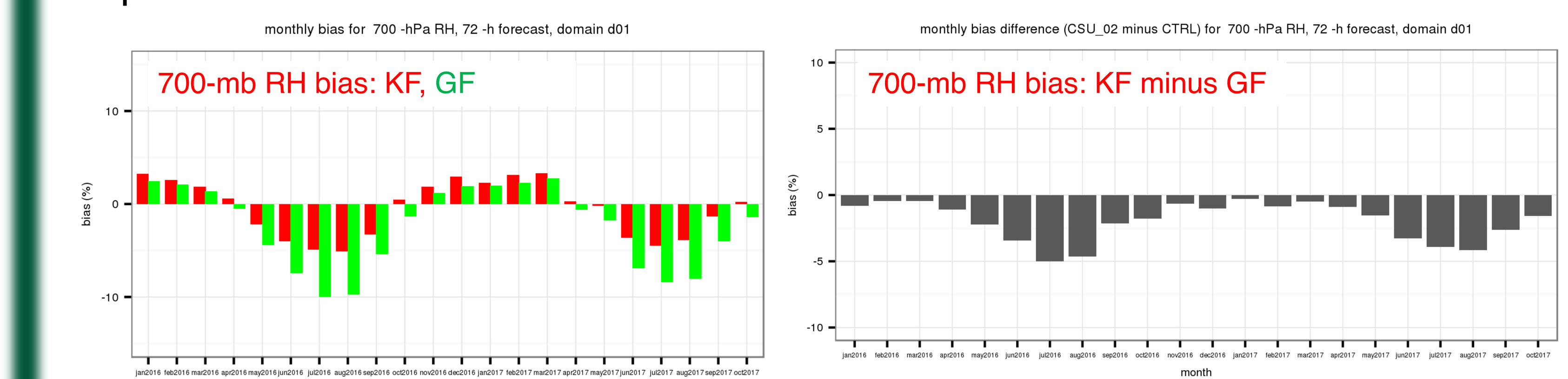



*Fig. 5: (left) 700-hPa relative humidity bias by month. (right) 700-hPa RH bias difference (KF – GF member) by month for the 72-hr forecasts.*

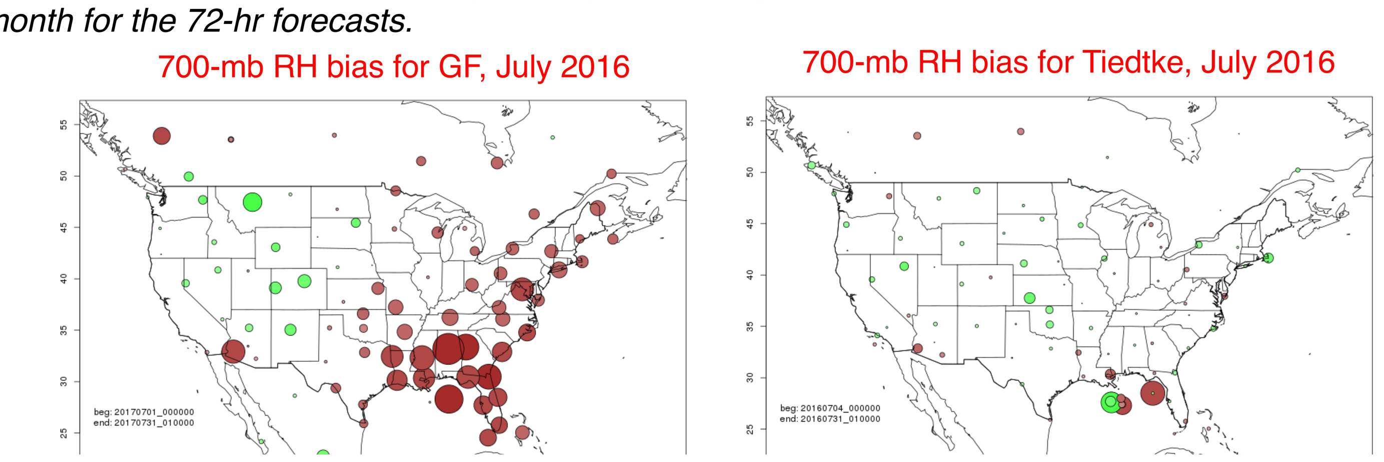



*Fig. 6: Map of monthly 700-hPa relative humidity bias for (left) the G-F member (CSU02) and (right) Tiedtke member (ALB08) for 72-hour forecasts in July 2016. Brown colors reflect a dry bias, green colors a moist bias, size of circle relative to magnitude of bias*

- These biases in G-F differ from those found by Grell and Freitas (2014) for a 15-day period over South America in January, where they found a cool/moist bias at midlevels at 20-km grid spacing

## Conclusions and remaining questions

- In the subset of BWW members analyzed, cumulus parameterization has much larger influence on precipitation forecast than other parameterizations
- There are consistent, repeatable biases in (especially) midlevel moisture related to the choice of cumulus parameterization
- Are the biases in temperature and moisture relevant to the quality of the precipitation forecasts with these different parameterization choices?
- Is an understanding of these bias characteristics in NWP forecasts also relevant to longer-running simulations (e.g., regional climate simulations?)

## Acknowledgments

- Research supported by NSF grant ACI-1450089
- Computing resources provided by the NSF XSEDE Jetstream cloud
- Thanks to Rob Fovell and the entire BWW team for discussions regarding this work
- **For more details, contact russ.schumacher@colostate.edu**