Institute for Mathematics Applied to Geosciences IMAGe

The use of WRF-DART analyses for 3 km explicit convective forecasts in support of the 2012 DC3 Field Program

Glen Romine
Morris Weisman
Kevin Manning
Wei Wang
Craig Schwartz
Chris Snyder
Jeff Anderson

Thanks to NCAR CISL (esp. Si Liu) for realtime computing support!

13th WRF Workshop – Boulder, CO – 25-29 June 2012

Where is Morris?

NESL

Morris is in Salina, KS providing forecast support for DC3 (Deep Convective Clouds and Chemistry) Field Program.
So – no attacks on DART this year!

Motivation

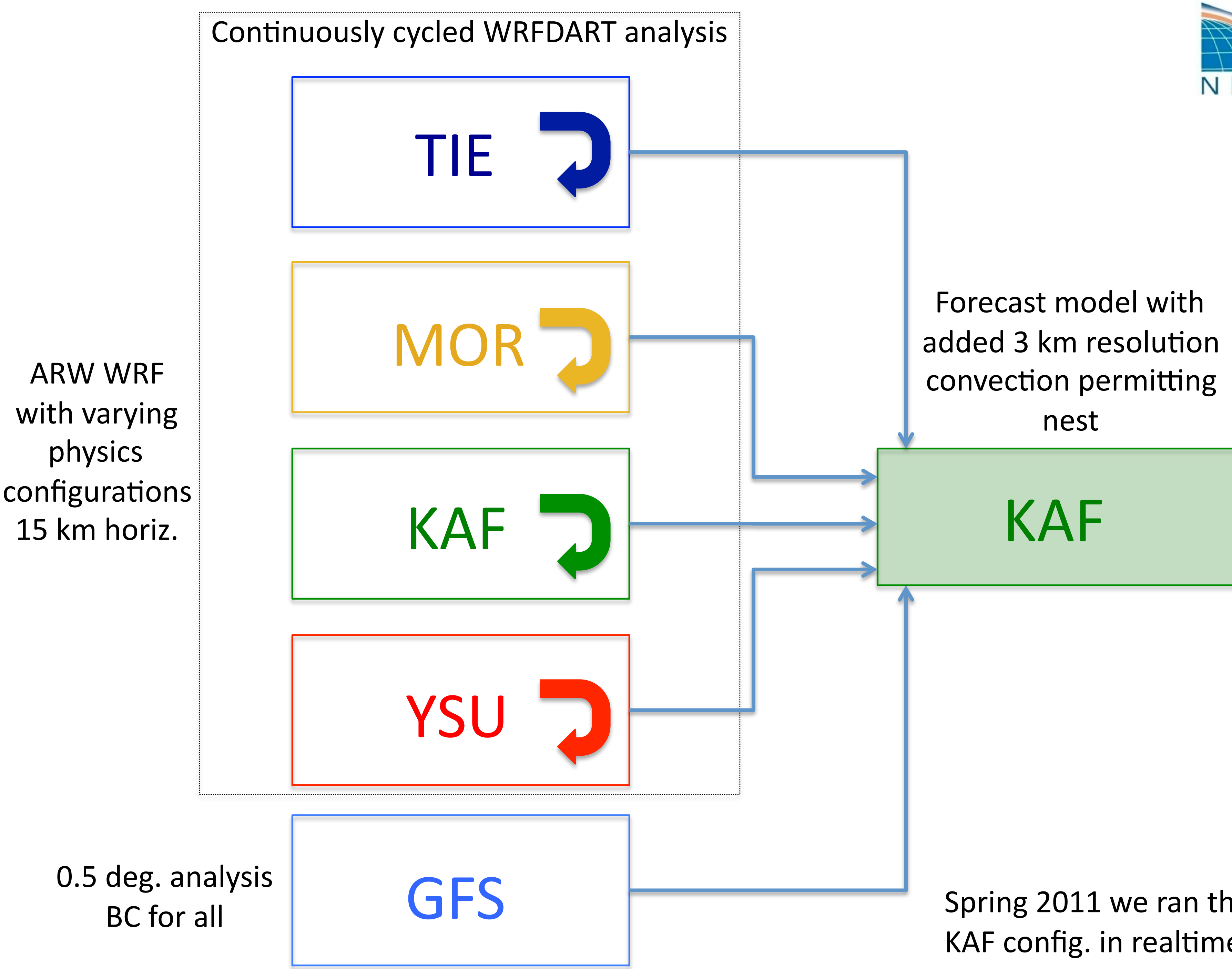
Forecast challenge – Accurate prediction of convective development, character and evolution in the 0-36h time frame, **suspect initial conditions (ICs) play a key role**

Analysis quality metric – Forecasts precipitation systems of the right intensity at approximately the right time and location. Assume better forecast = better analysis

Goal – Use a continuously cycled WRF-DART system (with inferior observation set) and generate an analysis with similar or better forecast skill to external analyses available in realtime (leverage Torn's realtime system for hurricanes to get started)

Various methods for radar assimilation shown to work well in 0-3h time frame, but often fail when mesoscale background is poor. So – get mesoscale accurate first. Inaugural 2011 system left room for improvement!

Sensitivity test – how do physics configurations in the continuously cycled DA system impact analysis quality?



Spring 2011 we ran the KAF config. in realtime

Real-time WRF-DART during Spring 2011

Continuously cycled wrf-dart ensemble from 27 Apr – 13 June 2011

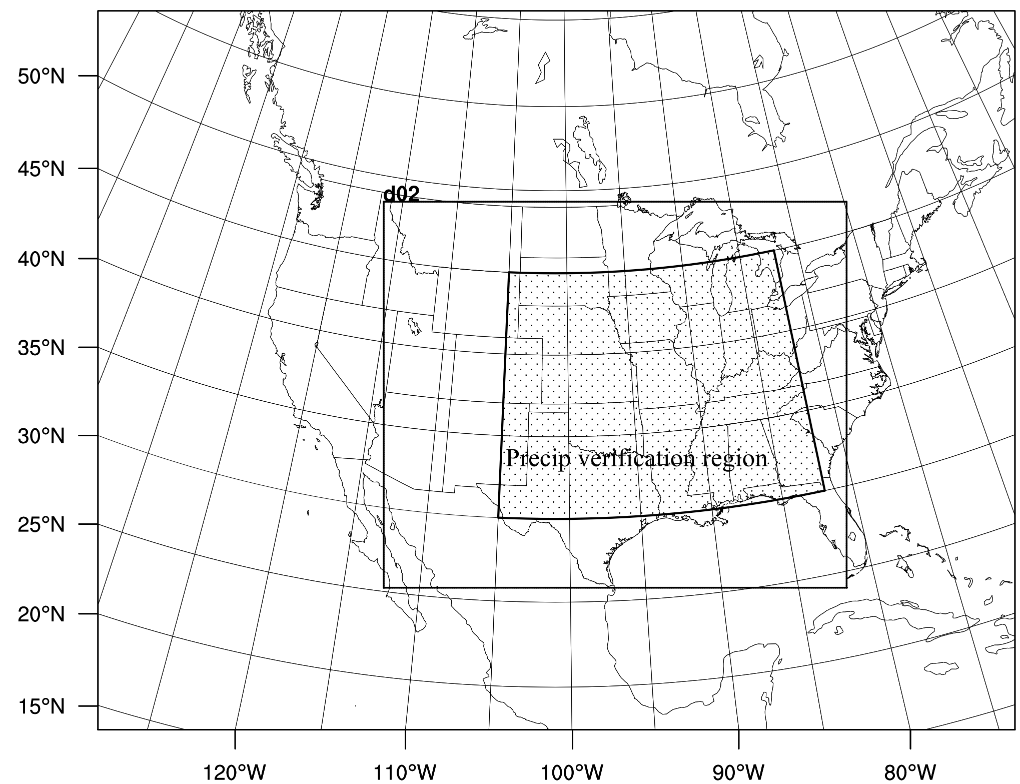
Daily hi-res forecasts from single member analysis 00 UTC

WRF – CONUS 15 km dh, 35 levels
  - Kain-Fritsch (Tiedtke), RRTM LW, Goddard SW, MYJ (YSU) PBL, Thompson (Morrison), Noah LSM

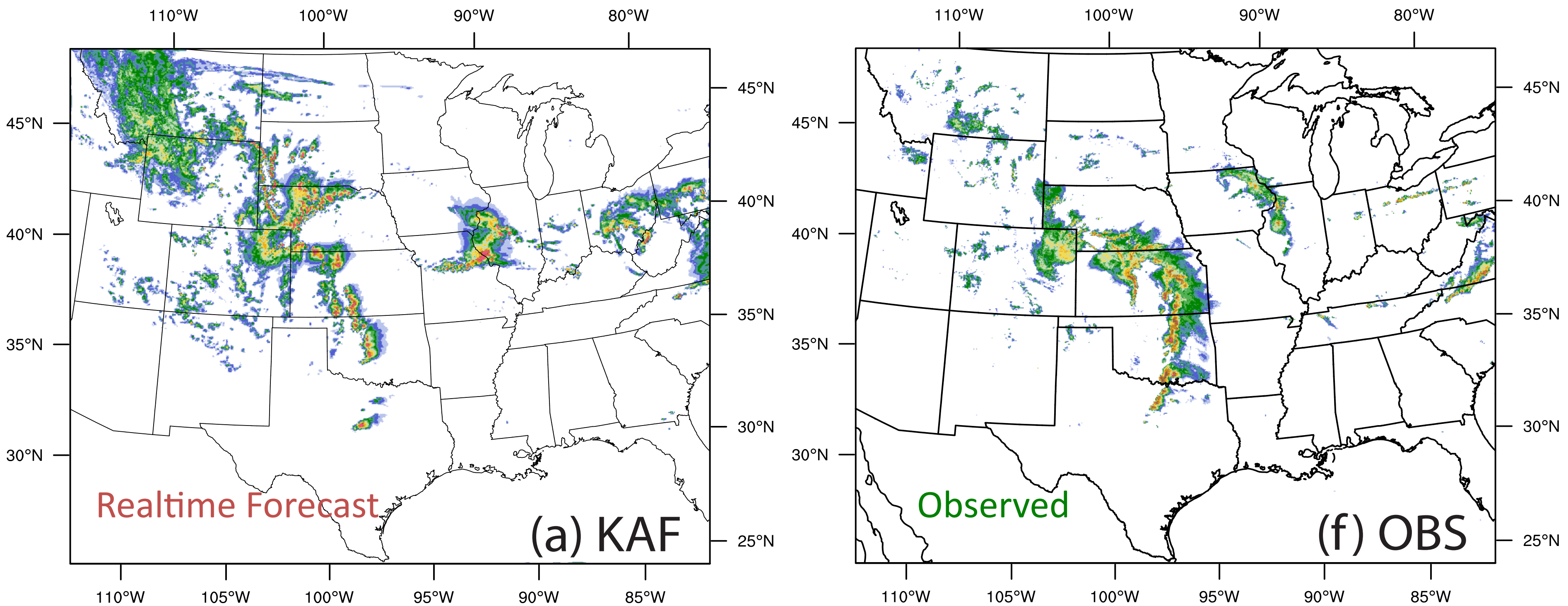
DART – 50 members, 6-hr cycling, adaptive inflation & localization, sampling error correction, ~ 510(6.5) km half-width H(V) localization

Soil states ran free for each member
  - TSLB, SMOIS, SH2O, TSK

Realtime forecasts were noted to have some quality issues, so we looked for clues in the ICs



Example: 24h forecasts from different analyses



The convective system in the Southern Great Plains is too far west, poorly matching observations

'Bonus' convection over Ohio

Example: 24h forecasts from different analyses

Typical 24h realtime forecast errors:

Large scale similarities with observed rainfall patterns where strongly forced – however frequently lagged further west than observed

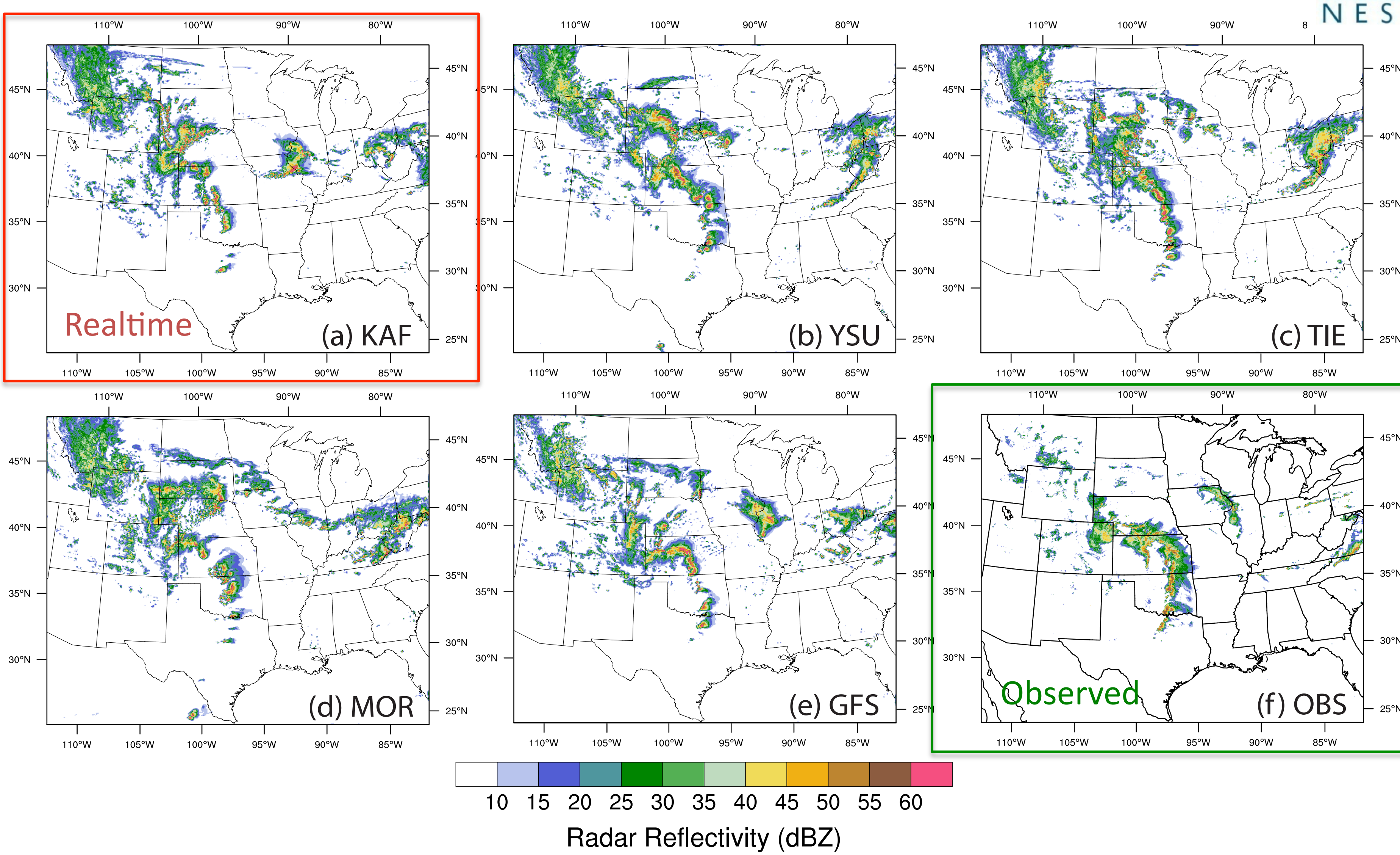
Too much forecast precip NW of low pressure systems

Are these initial condition errors?

If so, could model bias in the ensemble data assimilation system be playing a role?

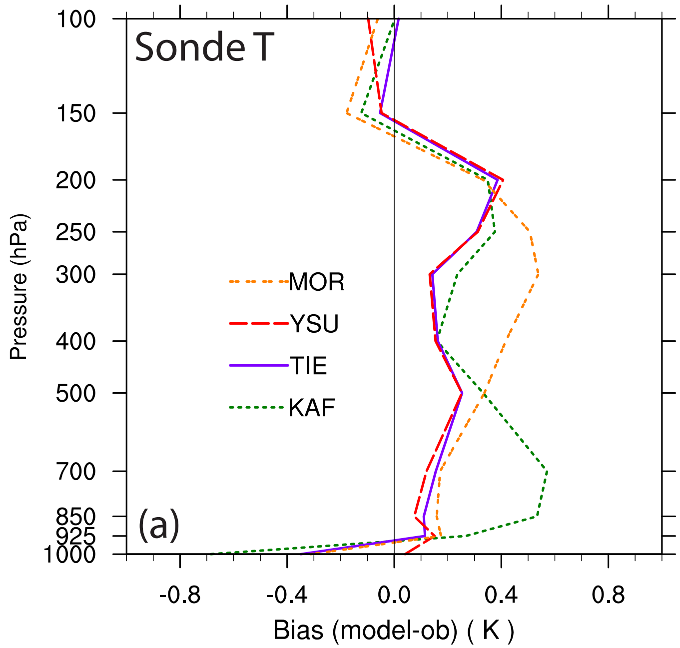
e.g. Torn and Davis 2012 found KF scheme caused storm track bias

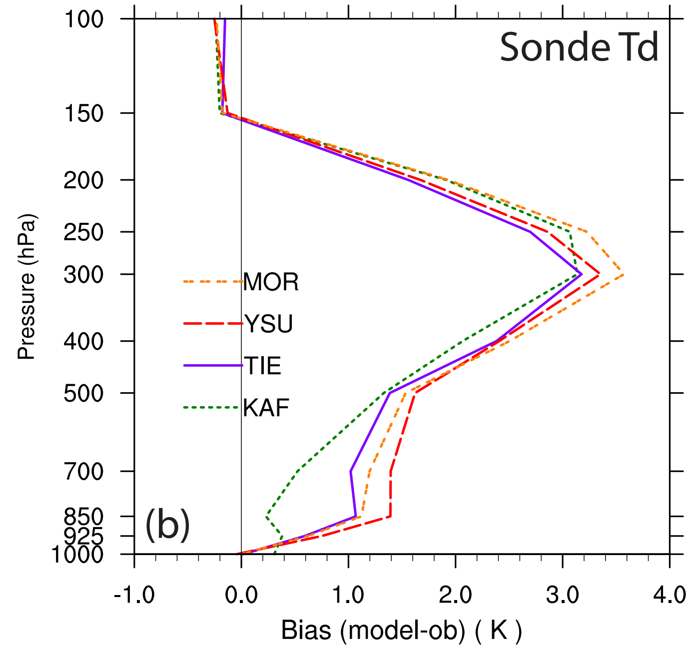
Example: 24h forecasts from different analyses

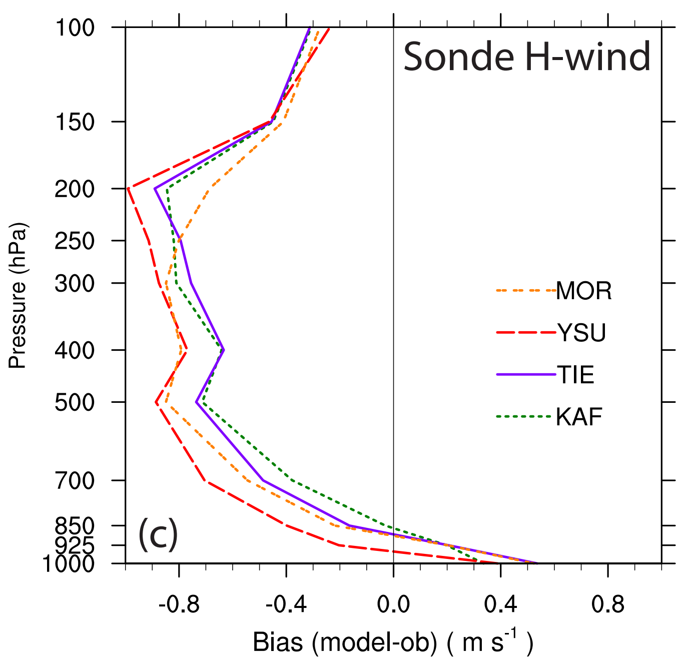


Forecasts use identical forecast model. ICs differ from analysis system physics. More similarity where large scale forcing was strong. All forecasts have + bias (too much rain) and orientation errors with the main precipitation event for this case.

Bias in 6 h forecasts (Priors) against radiosonde obs





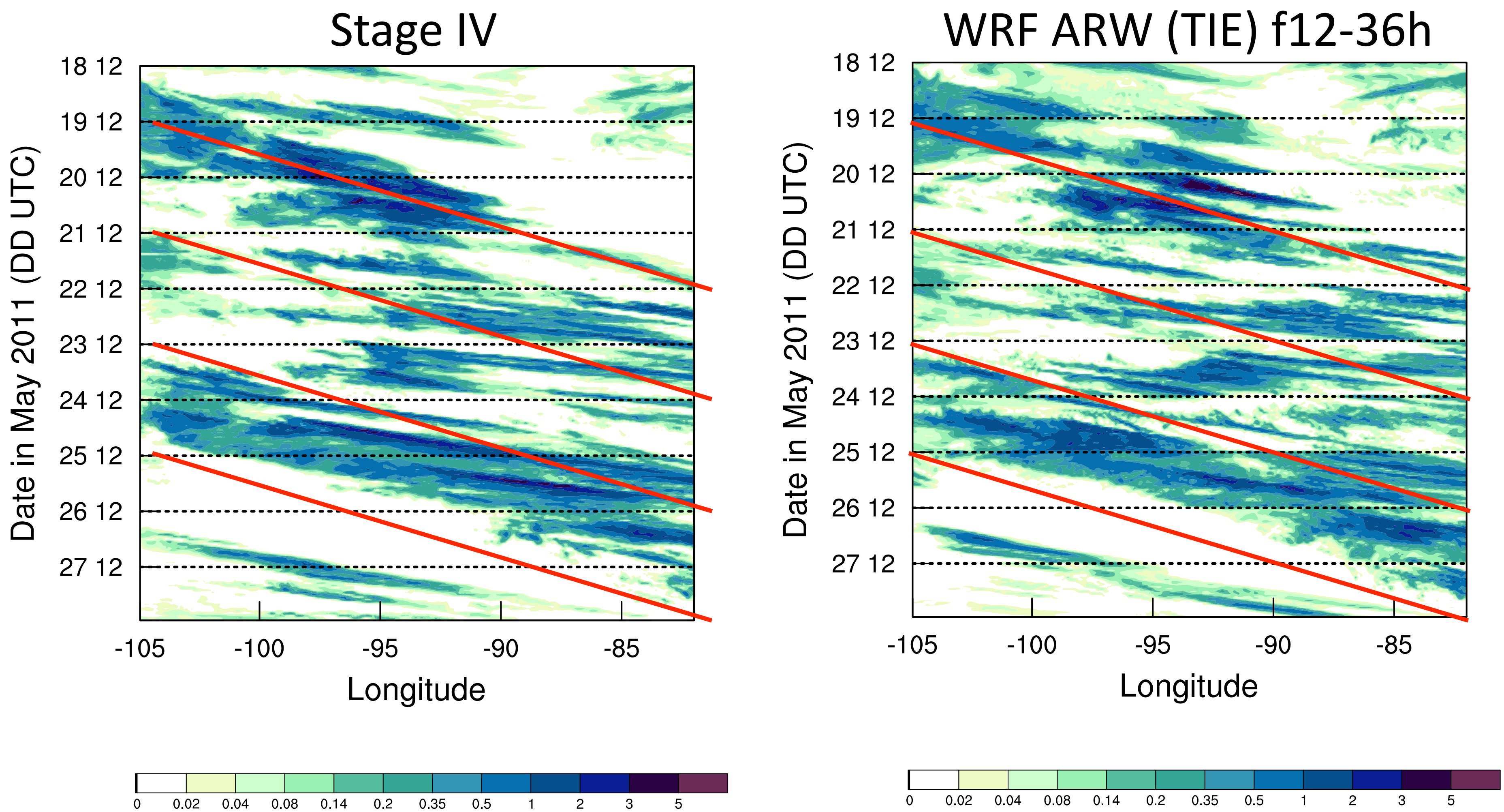


Bias for continuously cycled wrf-dart **priors** – fit to assimilated radiosonde mandatory level observations

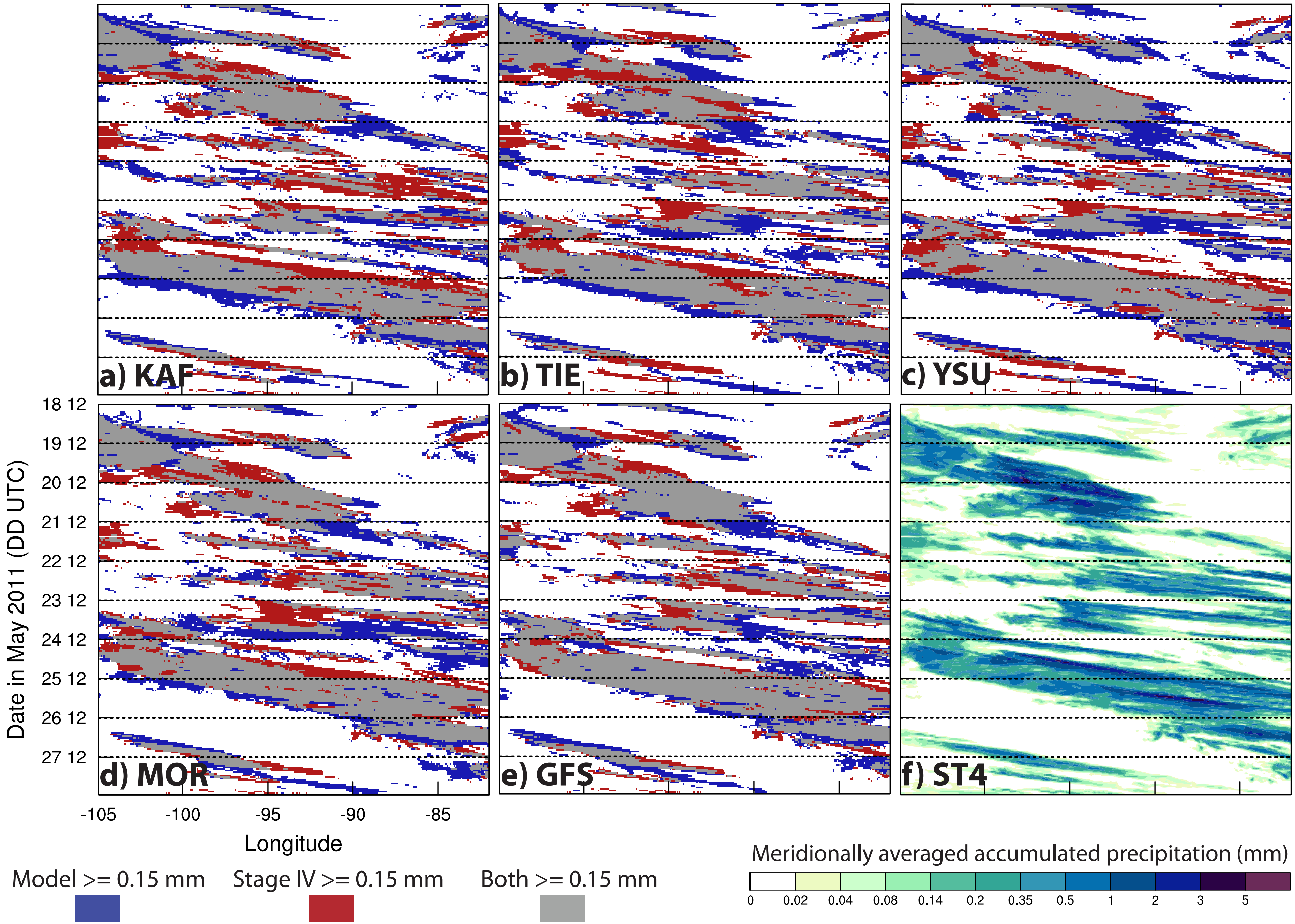
Model state (bkgd) generally too warm, too wet and wind speeds too slow relative to radiosonde obs for all tested physics sets,

Some physics sets appear to have worse fit than others

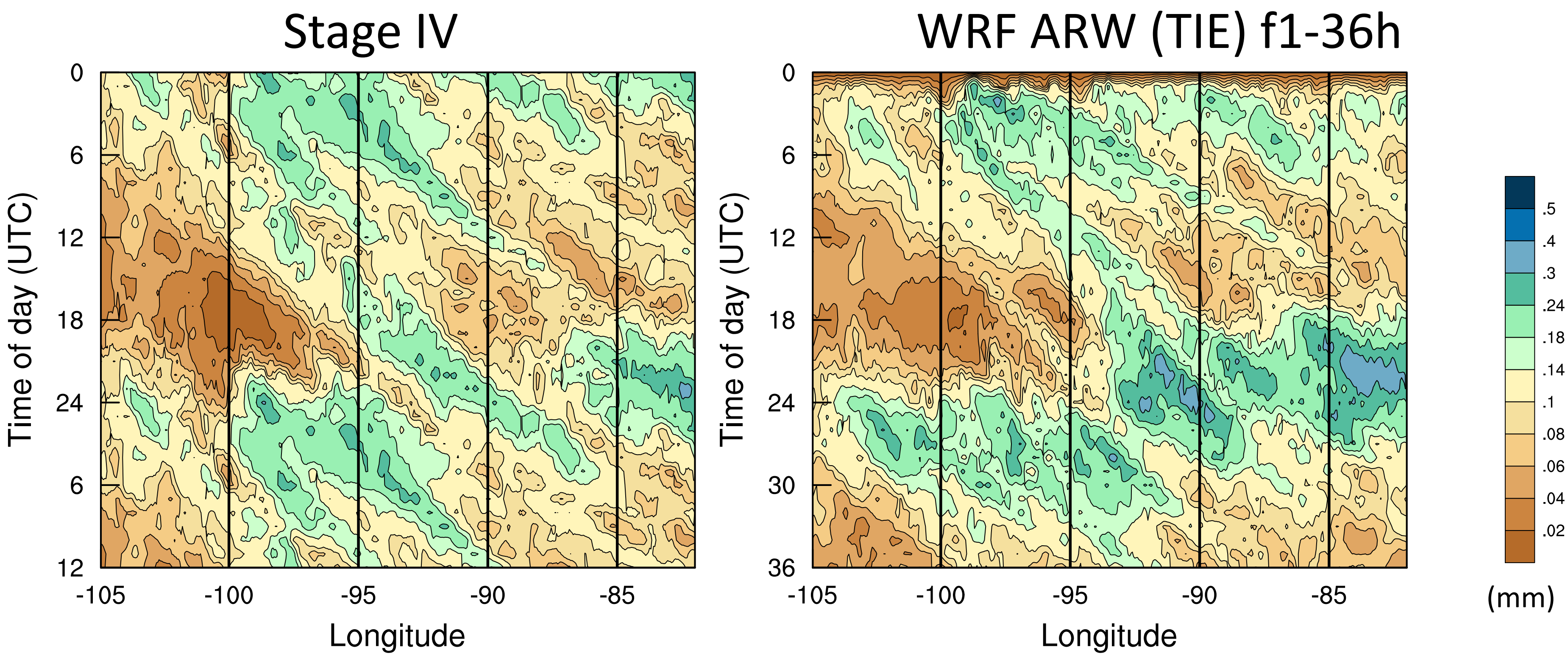
Hovmöller diagrams for period 18-27 May 2011



Discontinuities in sequential WRF 12-36 h forecasts, some displaced missing, or bonus precip

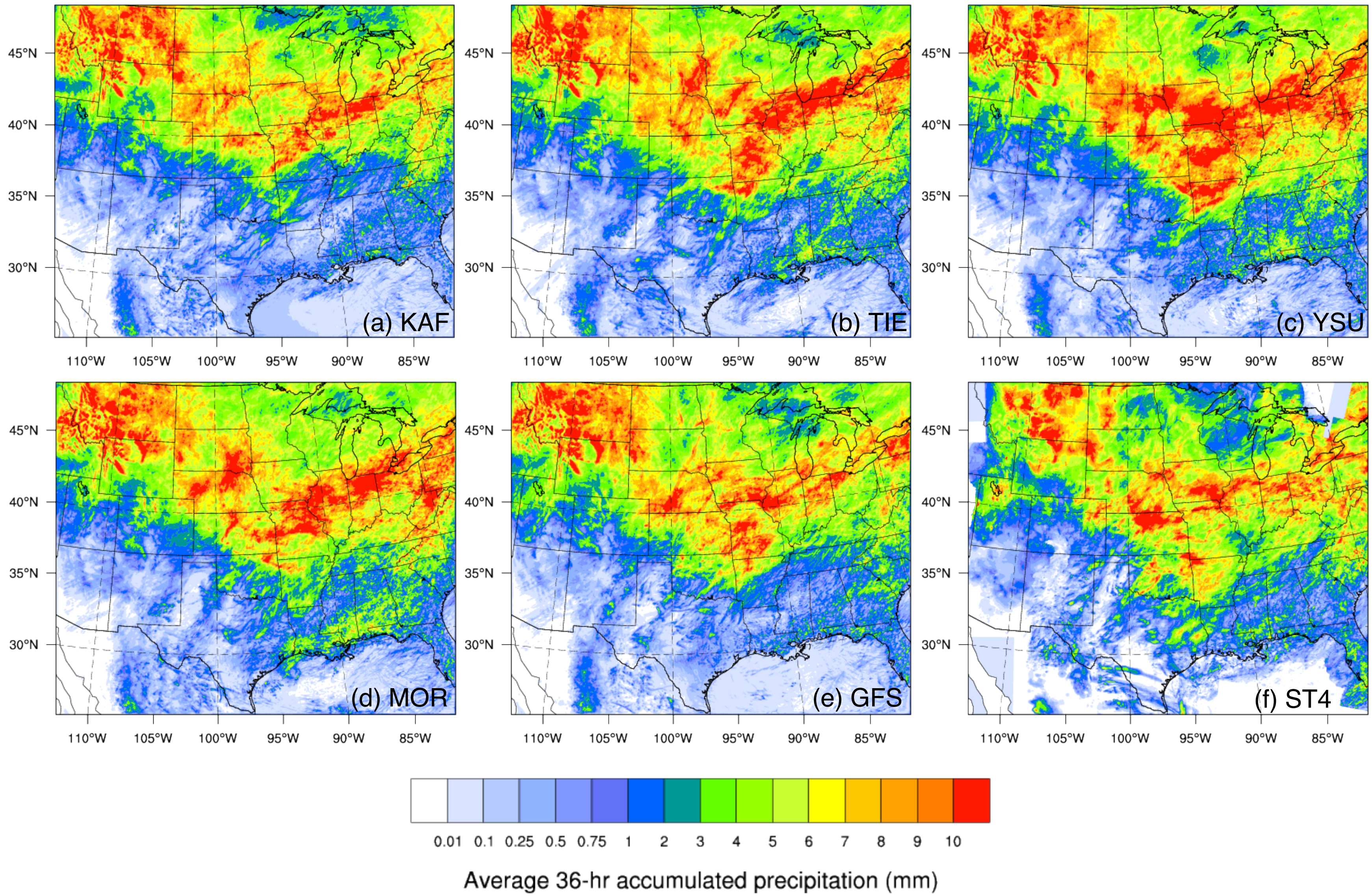

a) KAF
b) TIE
c) YSU
d) MOR
e) GFS
f) ST4
18 12
19 12
20 12
21 12
22 12
23 12
24 12
25 12
26 12
27 12
Date in May 2011 (DD UTC)
-105
-100
-95
-90
-85
Longitude
Model >= 0.15 mm
Stage IV >= 0.15 mm
Both >= 0.15 mm
Meridionally averaged accumulated precipitation (mm)
0
0.02
0.04
0.08
0.14
0.2
0.35
0.5
1
2
3
5

Avg daily Hovmöller f01-36h 14 May – 12 June 2011



- More, shorter, ‘swaths’ than observed in the WRF forecasts (microphysics?)
- Clear wet bias in WRF in 2nd day all longitudes
- Exaggerated diurnal cycle
- Spin-up period 1-3 hrs

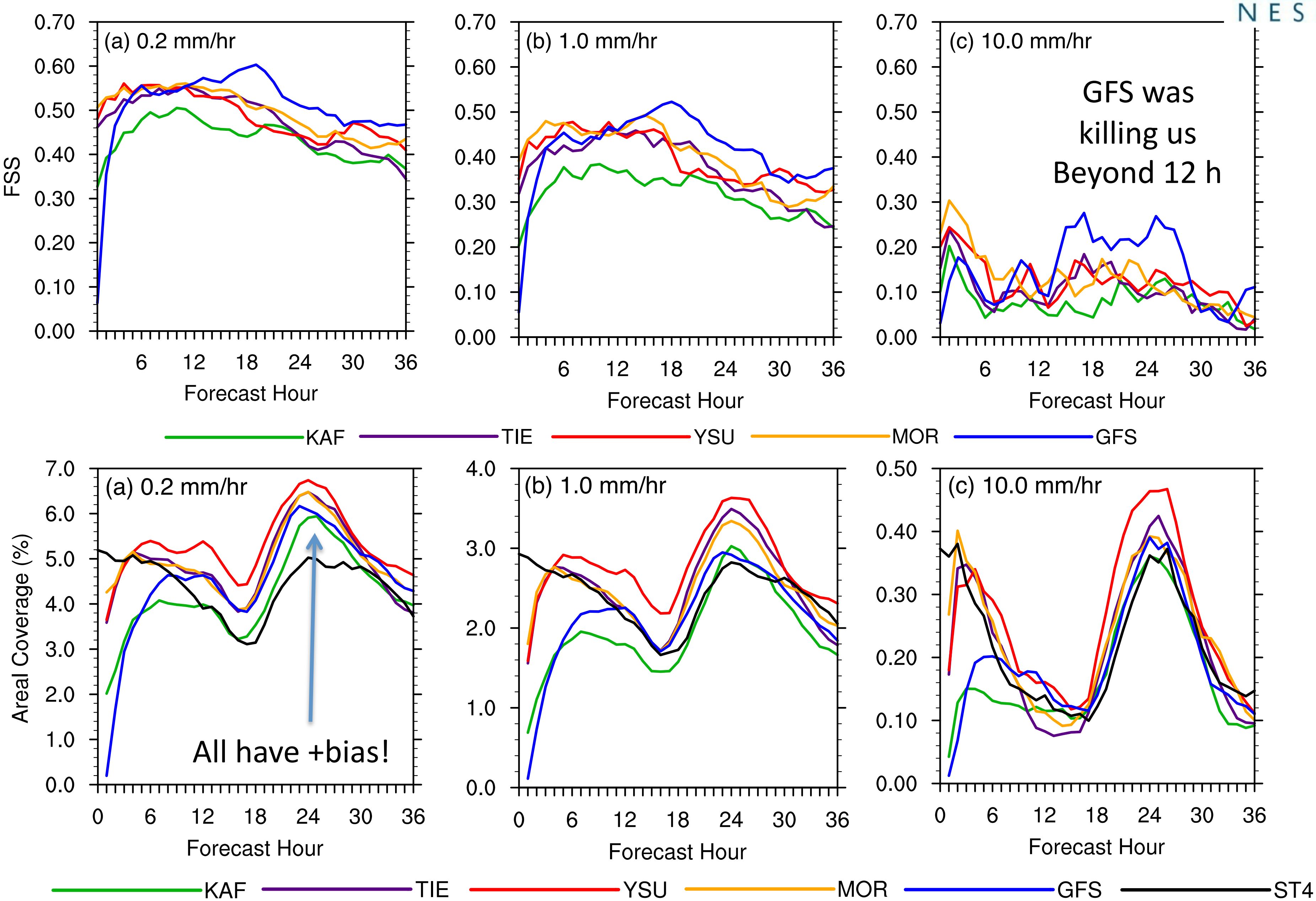
Average 30 day accumulated rainfall for varied ICs



Gross similarities, but differences in details

+precip bias in model forecasts with a wider latitudinal band of heavy precipitation.

Fractions Skill Score and Areal Coverage for varied ICs



Summary of 2011 realtime exercise

Growing our own analysis system for initializing convection permitting forecasts is feasible

Much more work to become competitive with current operational Mesoscale analysis systems (expected, our team has extremely limited resources)

Model, and perhaps even observation bias needs to be minimized or corrected in a continuously cycled analysis system used to generate initial conditions for forecasts:

- only showing for WRF-DART
- small changes in background bias impact forecast skill
- reduced background bias generally leads to better forecasts
- intuitive, but we believe this is first attempt to quantify in LAM

Summary of 2011 realtime exercise

Cont.

Continuously cycled DA system enables identification of model and observation system weaknesses

Some remaining issues:

Forecast model here held fixed – better to have same model in forecast as is used in the cycled analysis system?

Would prefer to be running ensemble forecasts instead of deterministic

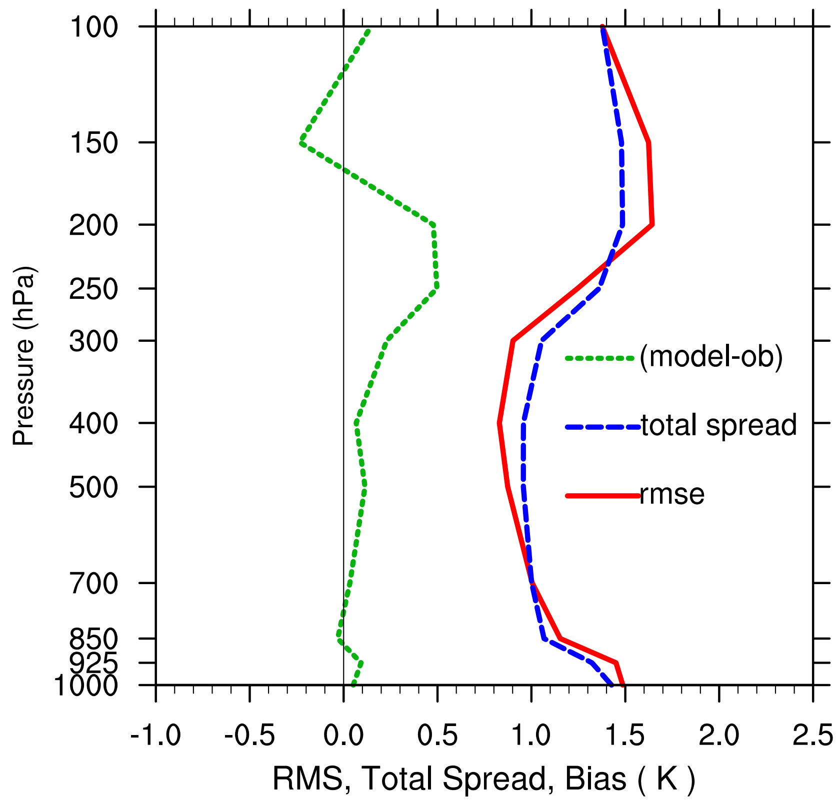
2012 Realtime analysis and forecast exercise

- Operations period: 30 April to 30 June 2012
- WRF model changes from 2011:
  - Additional 5 vertical levels, now 40
  - Raise Ptop to 50 mb (from 65 mb)
  - Version 3.3.1 (3.2.1)
  - Tiedtke CP, RRTMG +aerosol and ozone climatology for LW&SW radiation, Morrison microphysics
- DART changes from 2011:
  - Development branch (mainly for obs processing updates)
  - Localization H(V) to 640 (8) km, adaptive localization threshold to 2k
  - Initial inflation SD = 0.80

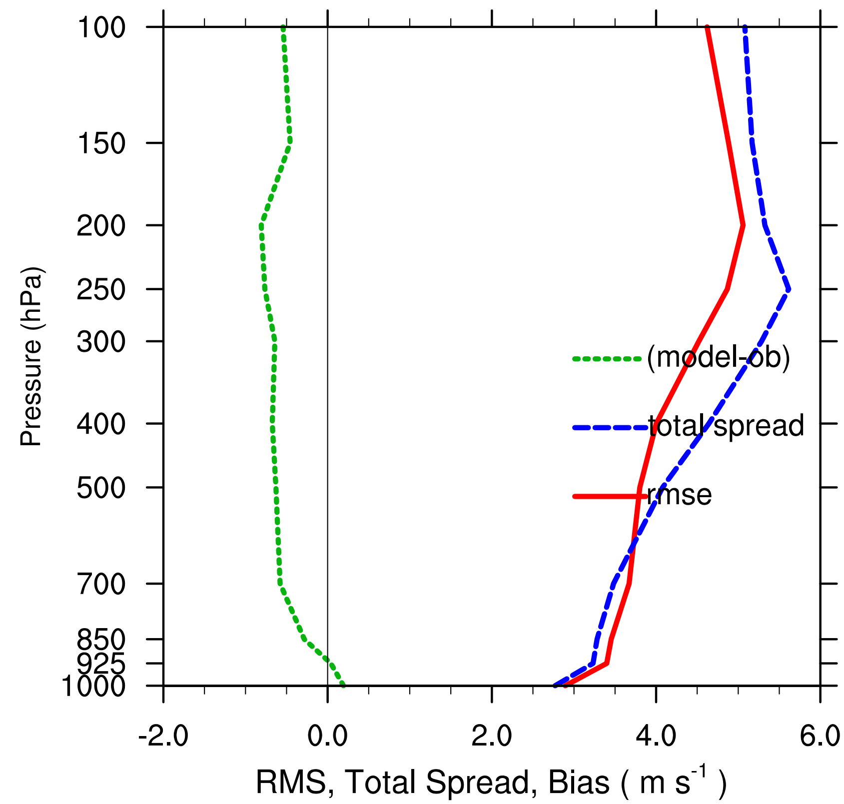
2012 Realtime – observation processing changes

- New:
  - Profiler U, V wind component (MADIS)
  - Significant level radiosonde observations (just T & Td)
- Modified:
  - ACARS superobs larger Horz. kernel (60 km)
  - SAT winds larger Horz. kernel (90 km)
- Ob errors:
  - ACARS temp error increased
  - SAT winds error increased, see related problem in Torn poster
  - Stretched radiosonde error profiles toward lower pressure for 'spring'
  - Tweaked down surface ob errors (T 1.75 K, U/V 1.75 m/s)
  - Dewpoint rh_error 0.05; rh_min = 0.15

2012 Realtime – Aggregate performance 30 Apr-26 Jun



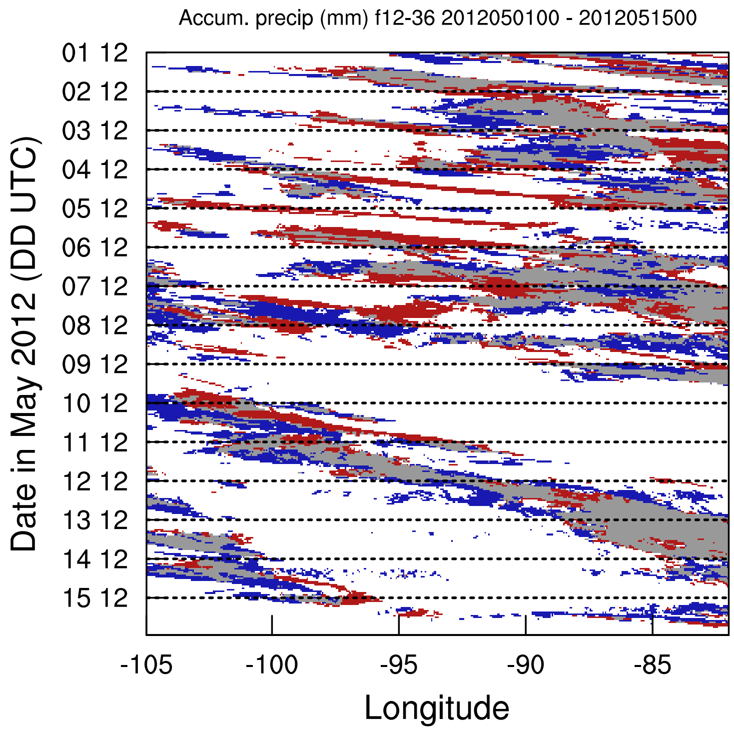
Prior fit to Radiosonde T

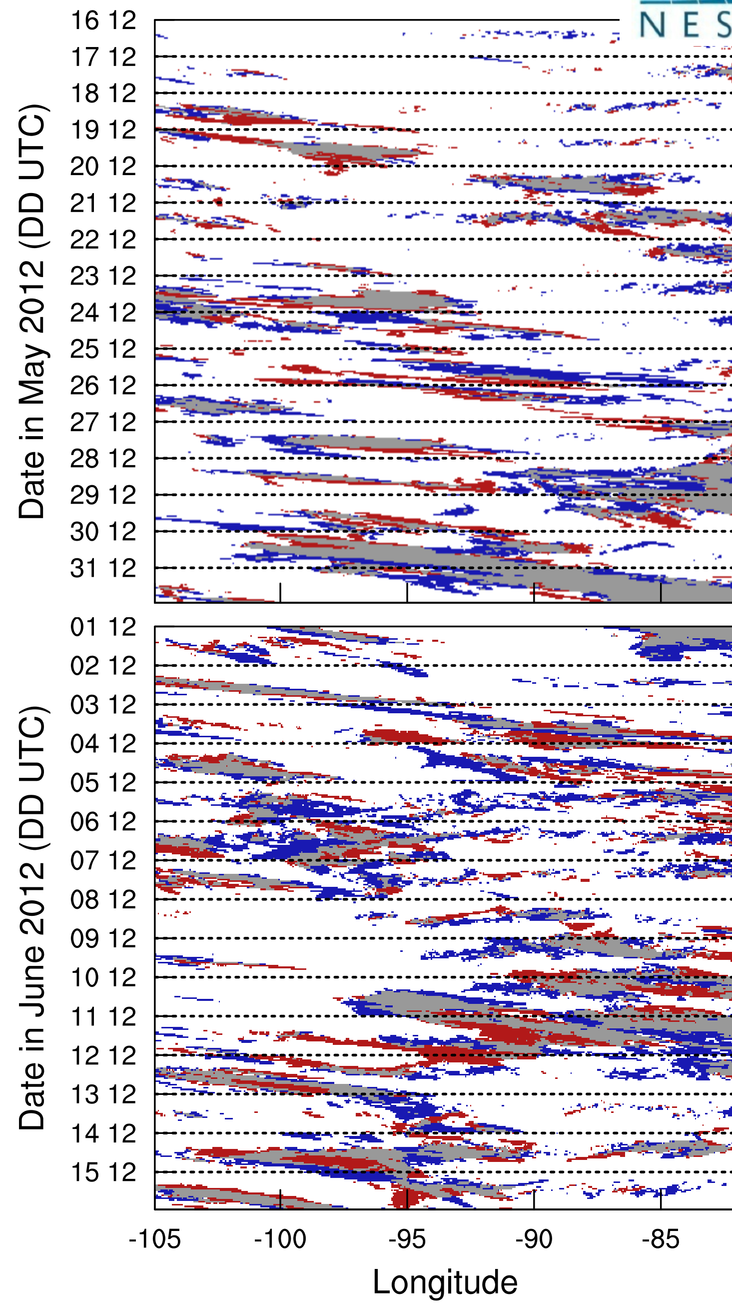


Prior fit to Radiosonde H. wind

- Little evidence of model bias relative to radiosonde temperature obs below 300 mb
- Still a slow wind speed bias

2012 Realtime – Forecast verification 1 May-15 June

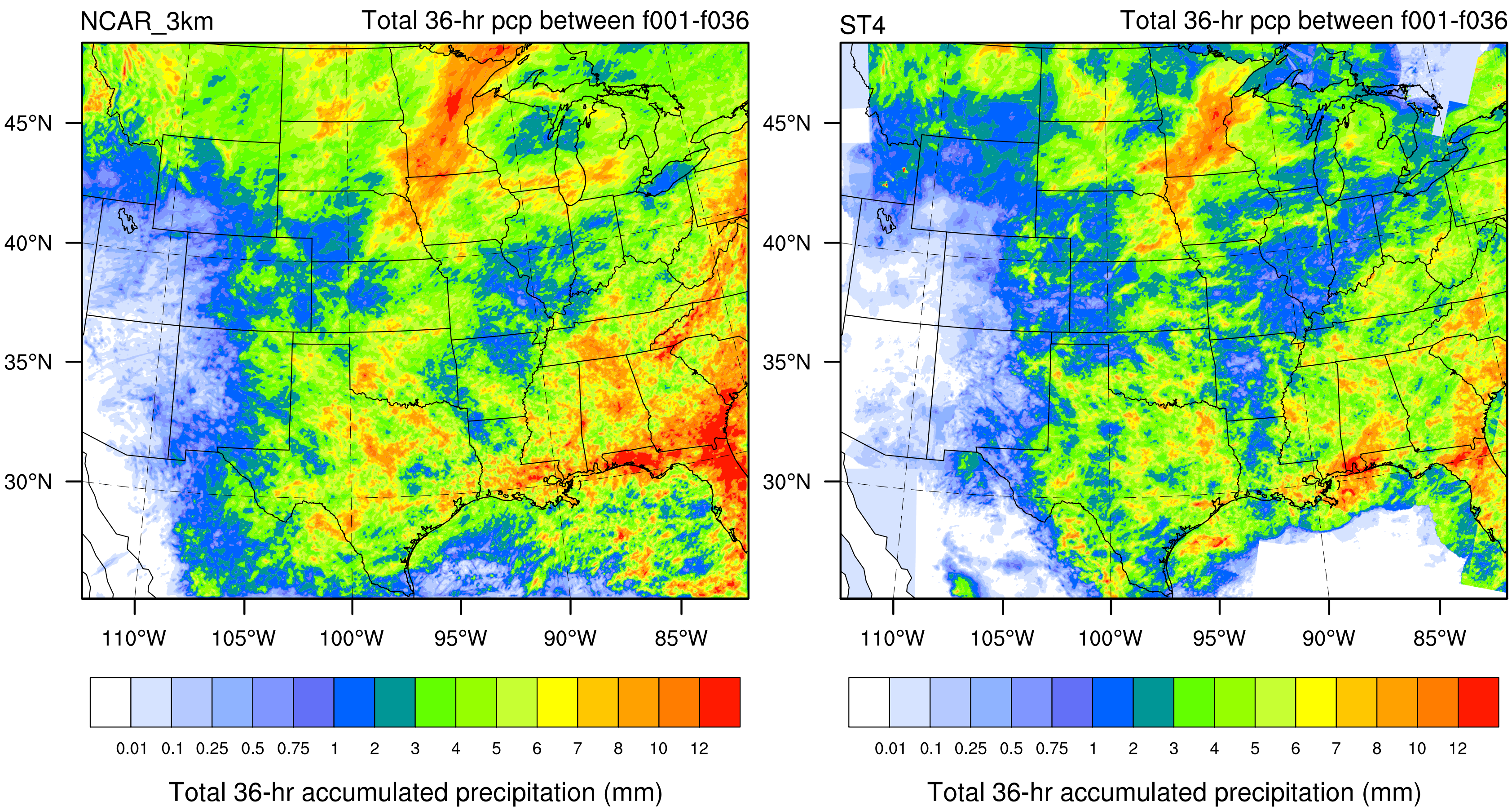




f12-36 h forecast 0.15 mm accumulated precip. against Stage IV from 1 May – 15 June 2012

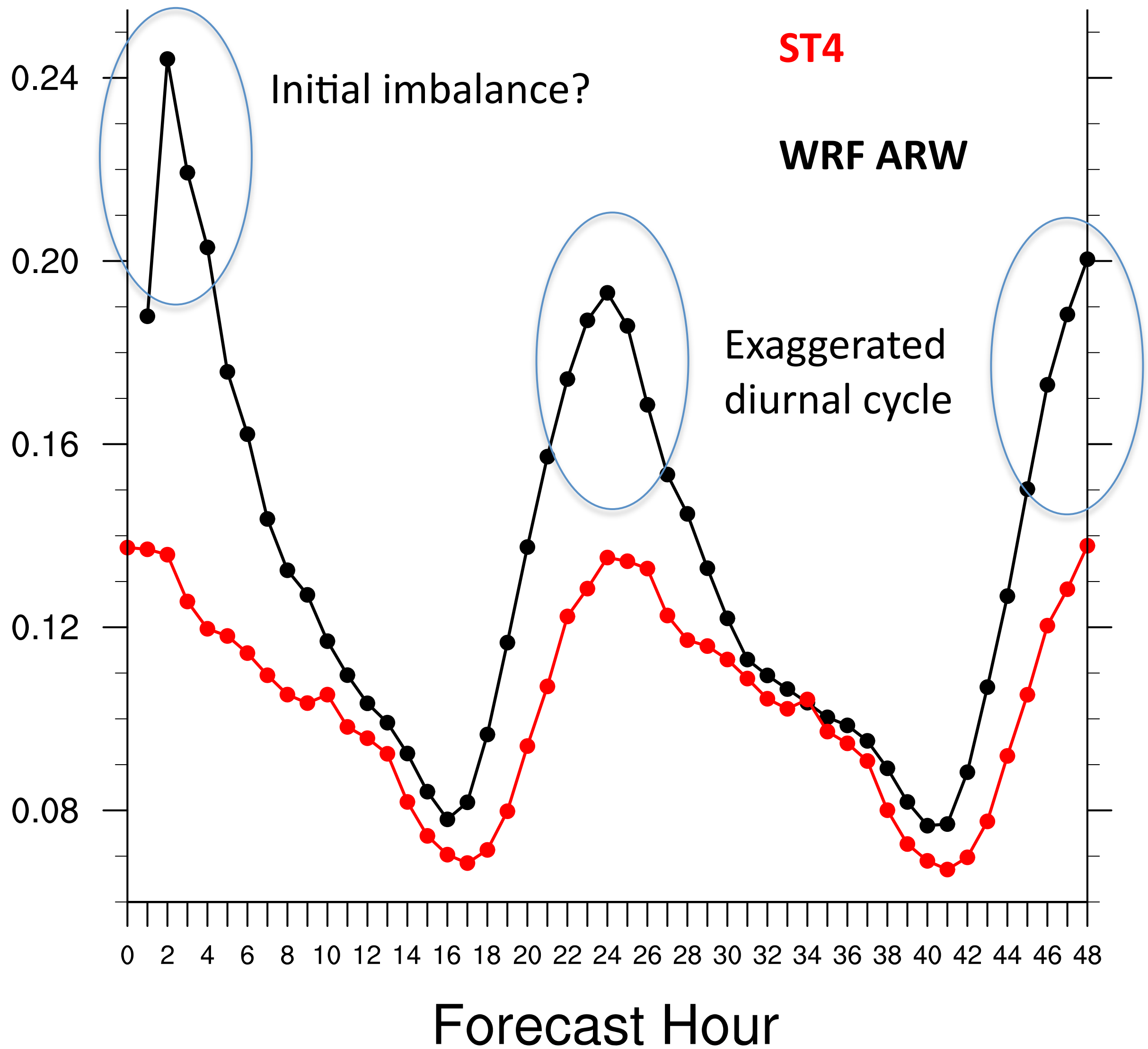
Model >= 0.15 mm   Stage IV >= 0.15 mm   Both >= 0.15 mm

2012 Realtime – Accumulated precip 2 May-15 June



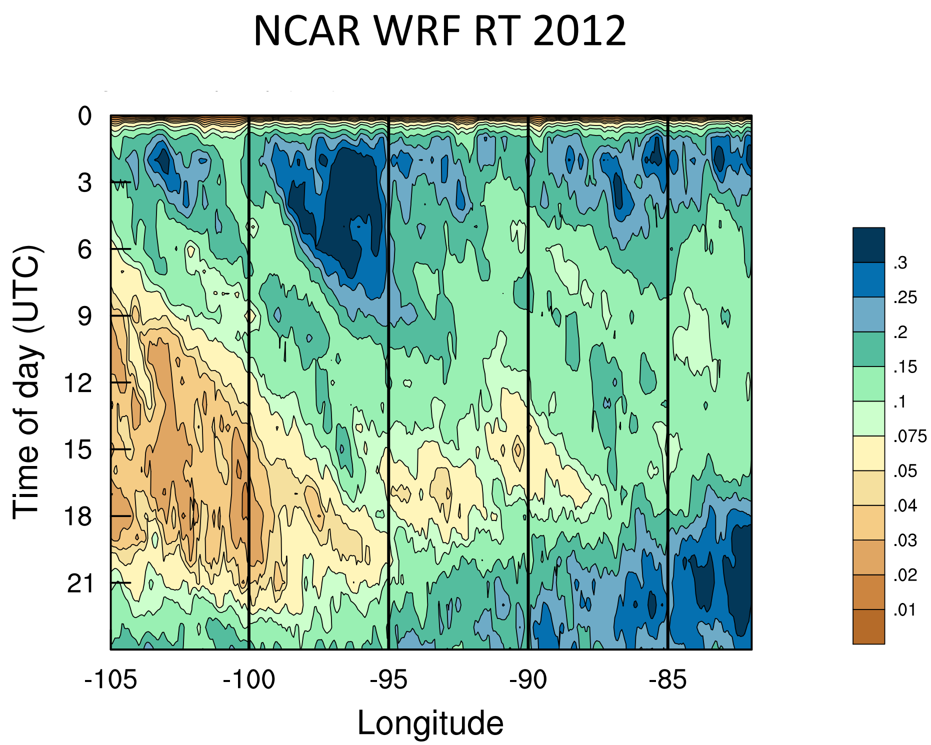
Good spatial agreement in rainfall climatology, but clearly biased

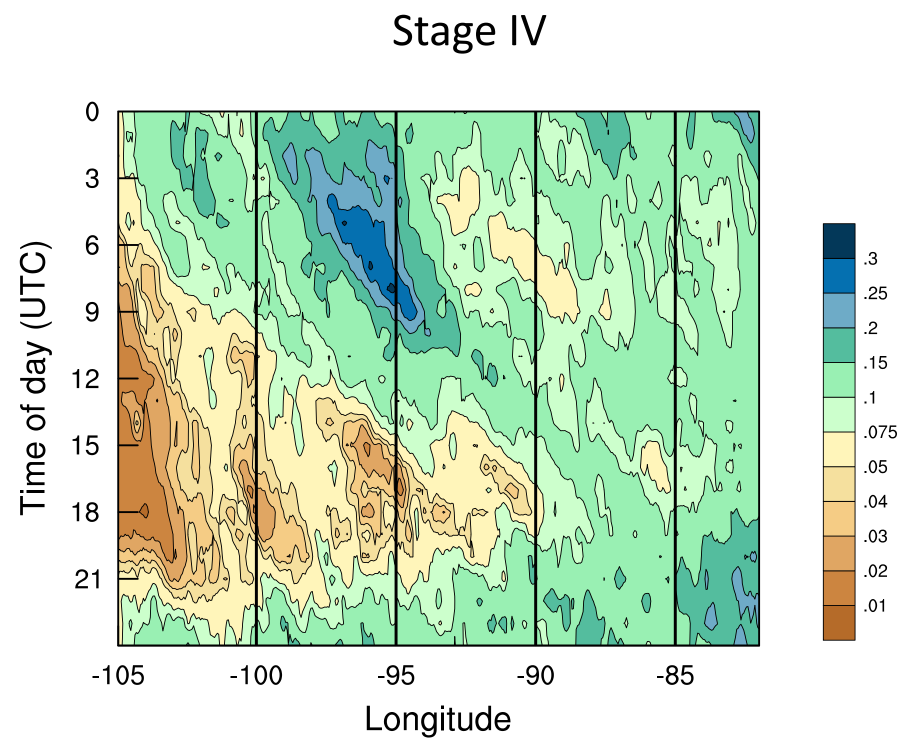
2012 Realtime – Domain total precip 2 May-15 June



The +bias is dominated by excess rainfall at most intense rain rain rates, less so in areal coverage.

2012 Realtime – Avg Daily Hovmöller 1 May-22 June

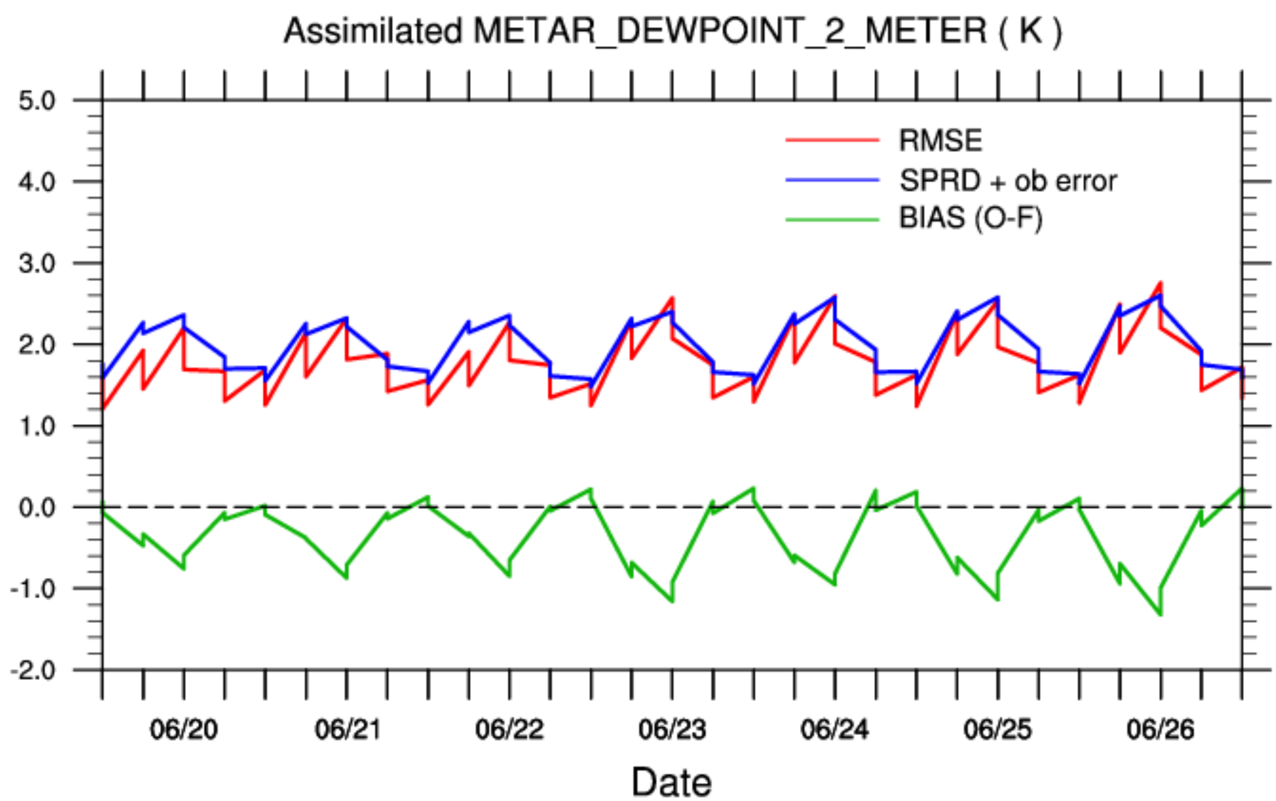




Average daily accumulated precipitation Hovmoller May 1 – June 22 2012

Obvious bias, exaggerated diurnal cycle, spike in development in first 3h (spinup problem?)

2012 Realtime – Surface moisture bias



Diurnal moisture bias (+bias during afternoon and evening) evident against surface METAR stations.

Realtime 2012 – preliminary results

Subjective assessments suggests current analysis and forecast system performing much better than last season (low bar), with greater reliability (less forecast skill variance from day-to-day)

Significant positive bias in 'high end' rain events

Need to examine skill in 12 UTC initialized runs, and compare against control runs and forecasts from other analysis and forecast systems

Have a look for yourself:
Analysis:
http://www.image.ucar.edu/wrfdart/rt2012/index.htm

Deterministic forecasts:
http://wrf-model.org/plots/realtime_3kmconv.php

Next season on our agenda: Ensemble forecasts from the ensemble analysis!!!

Thanks for your attention!