How do Spectrally Vast AR Thwart Attempts to Skillfully Forecast their Continental Precipitation?

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Outline

• Why do the Largest AR Scales Present a Problem to Limited Area Models?

• Results from Storm-Scale Configuration Tests

• Forecast Vapor Transport Structure Errors

• Why do the Scales Responsible for “Local Precipitation Response” Present an Additional Problem?

• Investigating Simulated Local Response in 2 NWP Systems

• Can Observed Linear Orographic Response Suggest Where to Invest Model Improvement?
AR Storm Scales Present a Problem for LAM

But accumulate here

BC Errors Introduced here

500mb Kinetic Energy control exp. 

\[ BC \Delta x \quad BC \Delta x/3 \]

**Spectral Analysis from Miguez-Macho et al., J. Geophys Res. 2004**
15 Oceanic AR and 10 Landfalling AR were simulated with 2 WRF configurations, both driven by GEFS 9.0.1 CTL member reforecast (GFSRe). Forecasts were run up to 7 days lead time with 24 hr lag.

West-WRF: 9 km / 3 km by 1-way nesting, 60 vertical levels, topographic wind correction.

WRF-ARWS: Identical to West-WRF except outer domain extent is smaller. Nested domains (used for precipitation verification) are identical.

**Selected Physics:**
- YSU BL
- Noah LSM
- MYJ Sfc
- Thomsporn New MP
- Goddard SW
- RRTM LW
- GD 3D Cumulus (9 km only)

*Martin et al., *J. Hydromet.*, In Prep.*
15 Calwater flights completed AR Core transects during CalWater 2014 / 2015.

All transects crossed a moderate strength (IVT $> 500 \text{ kg m}^{-1} \text{s}^{-1}$) core and were more than 1° from model boundaries.

Use these observations to investigate forecast accuracy at storm scales ($\Delta x > 80 \text{ km}$)

**Martin et al., J. Hydromet., In Prep.**
**Martin et al., J. Hydromet., In Prep.**

Performance in Capturing Structure

Left to Right: Partial IVT contours (kg m\(^{-2}\) s\(^{-1}\) - black) and θ\(_e\) (K - blue dashed) from Observations, GFSRe, West-WRF, WRF-ARWS.

In panels showing model Partial IVT, quantity is model – obs. Negative contours are dotted.
AR Precip. at Local Scale a Challenge for LAM and GCM

Δx ~ 1 km necessary to preserve energy density at local topographic scale

**Idealized Wavenumber Spectra from Skamarock, Mon. Wea. Rev., 2004.**
Direct Measurement of the Storm-Local Scale Relationship

- BUF is determined primarily by storm scales (dx > 50 km)
- Rainfall response to BUF (slope, intercept, R^2) is controlled by local dx < 10 km scales.
- Model type determines whether BC, dynamics or physics most influences the error in the response.
- Least Squares can be used to derive a linear model Y = F(X) for observations and forecasts.

Storm-total BUF (IVT Proxy, X Axis) is strong predictor of Storm-total rainfall (Y axis).

**Scatterplot from Ralph et al., J. Hydromet., 2013.**
West-WRF Validation Methods 2

10 “Moderate” or stronger AR that made landfall in the Russian River Watershed are used to build a database for verification.

The NOAA Coastal ARO is used to investigate forcing and precipitation response.

Forecasts are generated for lead times up to 7 days every 24 hr.

West-WRF, WRF-ARWS GFSRe is used for comparison
Which model simulates the forcing-response relationship at local scale?

**Martin et al., J. Hydromet., In Prep.**
Linearizing the Response Relationship

Normalized Error in ST Precip:

\[ e_y = \frac{E\left[ (f(X) - Y_0)^2 \right]}{V[Y_0]} \]

If \( F_o( ) ; F( ) \) derived from linear LS fit obs. and modeled BUF-Prcp at ARO, then

\[ e_{yr} = \frac{E\left[ (F_o(X) - Y_0)^2 \right]}{e_y} \]
\[ e_{yr} = \frac{E\left[ (F(X) - Y_0)^2 \right]}{e_y} \]

are the reduction in forecast ST Precip. by “perfect” local response (pr) and “perfect” storm scale forcing, respectively.

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<tr>
<th>Error Measure</th>
<th>Forecast Lead Time (hr)</th>
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<tr>
<td></td>
<td>12 – 59</td>
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<tr>
<td>( e_y )</td>
<td>West-WRF</td>
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Forecasting AR Requires Special Attention in Constructing LAM Domain.

LAM (West-WRF) are able to forecast AR as accurately as GNWP at large scales up to 7 day lead times.

If Storm-Scale forcing is as accurate, the reduction in dynamics and representativeness errors in high-res LAM offer big improvement in local scale precip. forecasting.

The dominance of local response relationship in driving GFSRe precip. errors was verified by a linearized model.

Linearized model demonstrated that West-WRF can be tuned for better precip. forecasts as well, at both local and storm scales.
NWP Performance at Storm Scales

Only Sondes for which IVT ≥ 250 kg m⁻¹ s⁻¹ used to compute BSS

**Martin et al., *J. Hydromet.*, In Prep.**
NWP Performance at Storm Scales

**Martin et al., J. Hydromet., In Prep.**
QPF Deterministic Skill During Landfalling AR

Validated Against NCEP Stage-IV 24 hr QPE. Models Linearly Interpolated to Stage IV Grid.

**Martin et al., J. Hydromet., In Prep.**