# Optimal Temporal Frequency of NSSL Phased-Array Radar Observations for an Experimental Warn-on-Forecast System

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# Warn-on-Forecast and Phased-Array Radar

- NOAA Warn-on-Forecast (WoF) Program
  - Goal is to support NOAA's *watch-to-warning* operations for high-impact weather by providing probabilistic model guidance
  - Warn-on-Forecast System (WoFS): storm-scale ensemble data-assimilation and prediction system
- *Radar* is the key observing platform for the WoFS
- PAR can scan a full volume every ~1 min (vs. ~5 min for WSR-88Ds)
- Previous OSSE studies show improved analyses and forecasts with more frequent radar DA
- *What about for the WoFS?*


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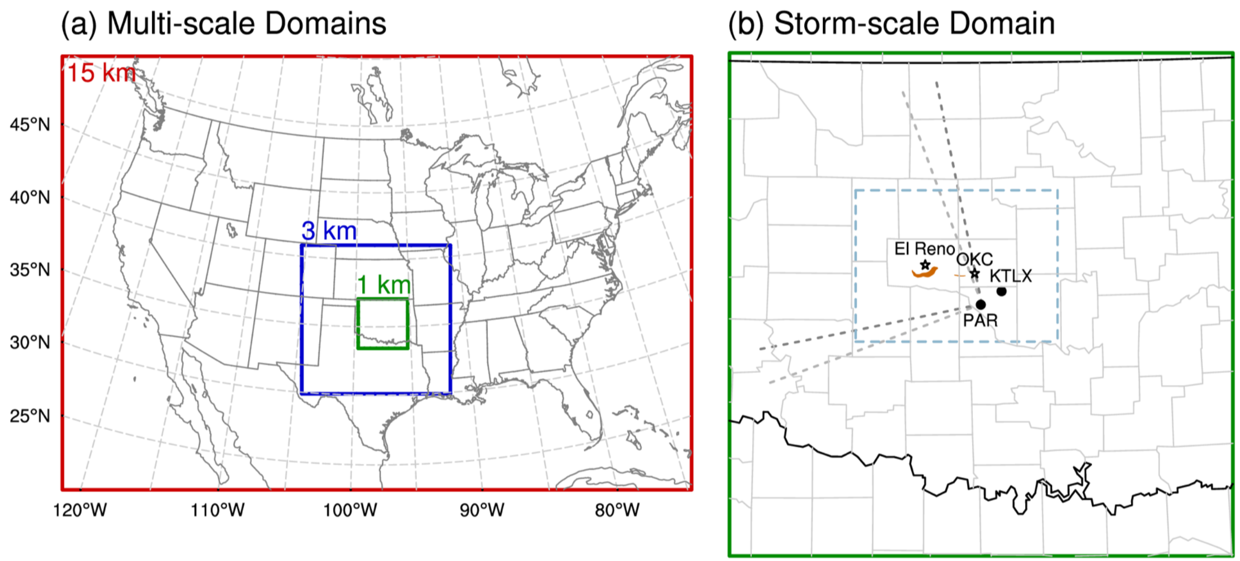
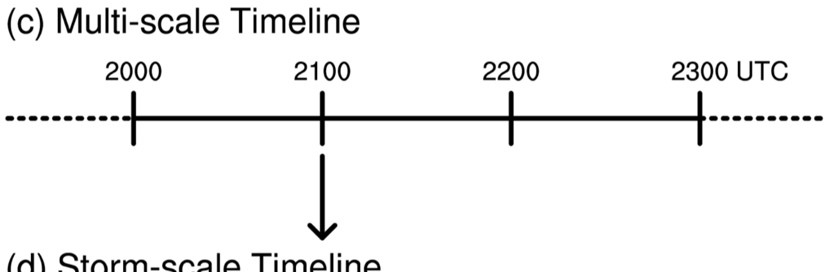
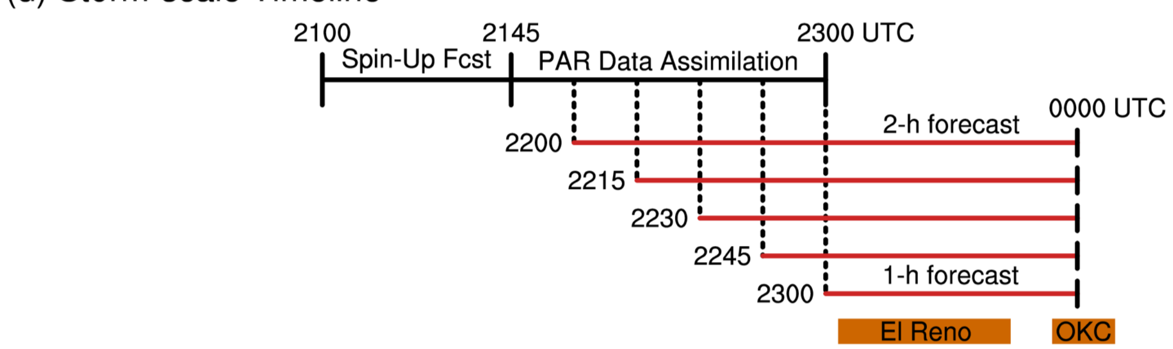
# Experiment Design

- 31 May 2013 "El Reno" EF3 tornado
  - 2303–2344 UTC
- Multiscale data assimilation system
  - GSI-EnKF and WRF
  - 15- and 3-km domains
  - 36 ensemble members
  - *Conventional observations only*
- Storm-scale data assimilation system
  - ARPS-EnKF and WRF
  - ***1-km horizontal grid spacing***
  - 36 ensemble members
  - 3-km ensemble provides IC/BCs
  - ***PAR observations only (Z and Vr)***
- Forecasts launched from five analysis times.

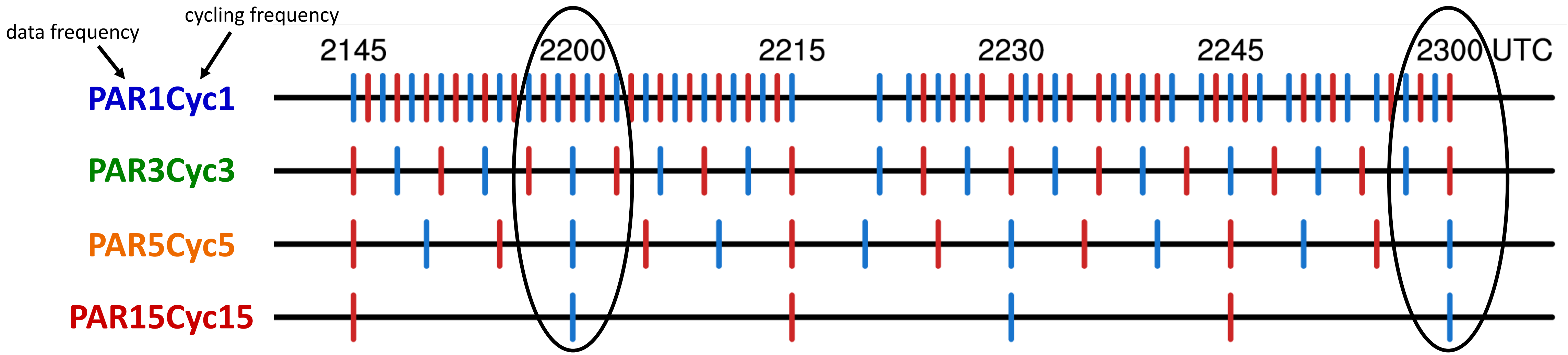


# Data Assimilation Experiments

- Assimilating PAR volumetric scans every 1, 3, 5, and 15 min

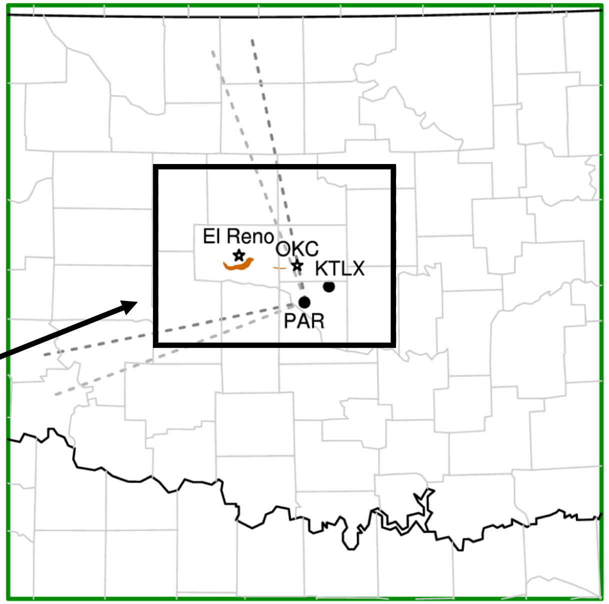


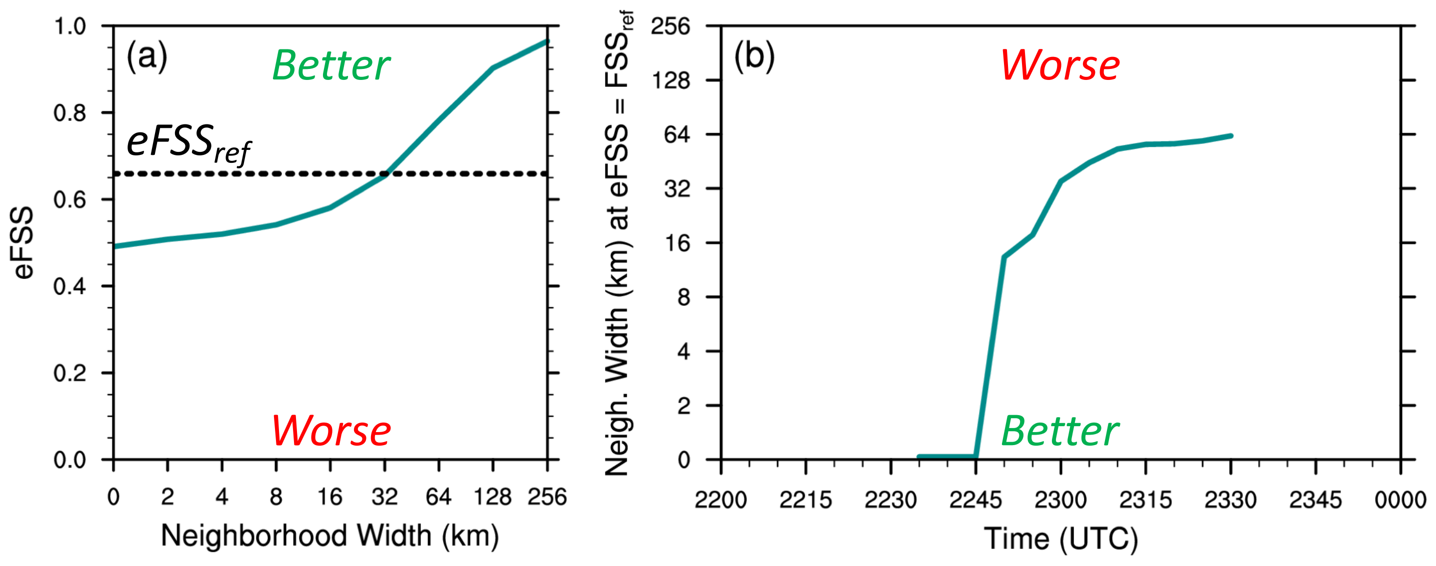

*Current WoFS assimilates one volume of radar data every 15 min, similar to **PAR15Cyc15**.*

# Assessment of Forecasts: 2-km MSL Reflectivity

- Subjective evaluation
  - Probability of reflectivity > 35 dBZ
  - MRMS reflectivity
- Objective verification
  - *ensemble Fractions Skill Score (eFSS)*
  - 35-dBZ threshold

*area used to compute eFSS*

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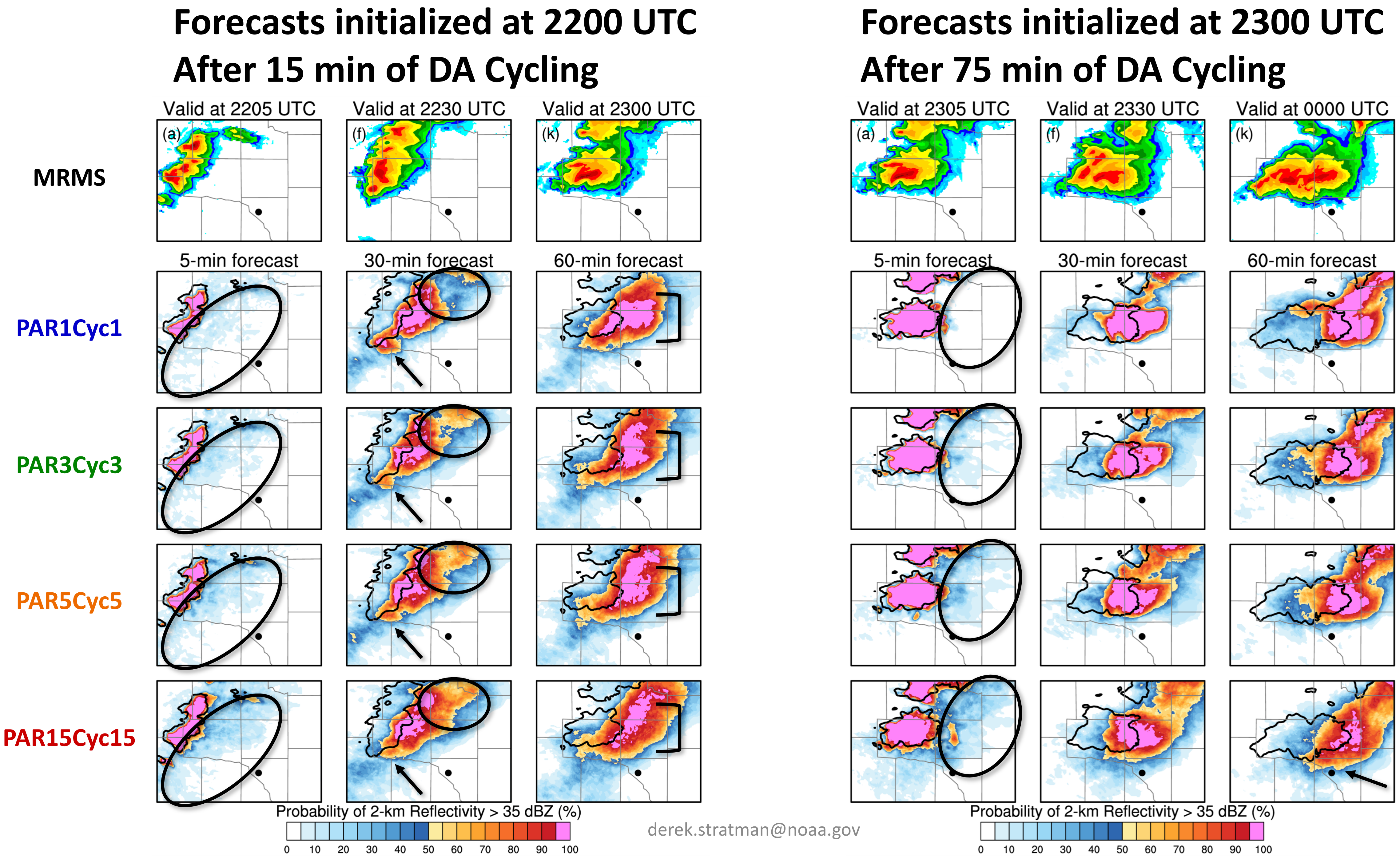


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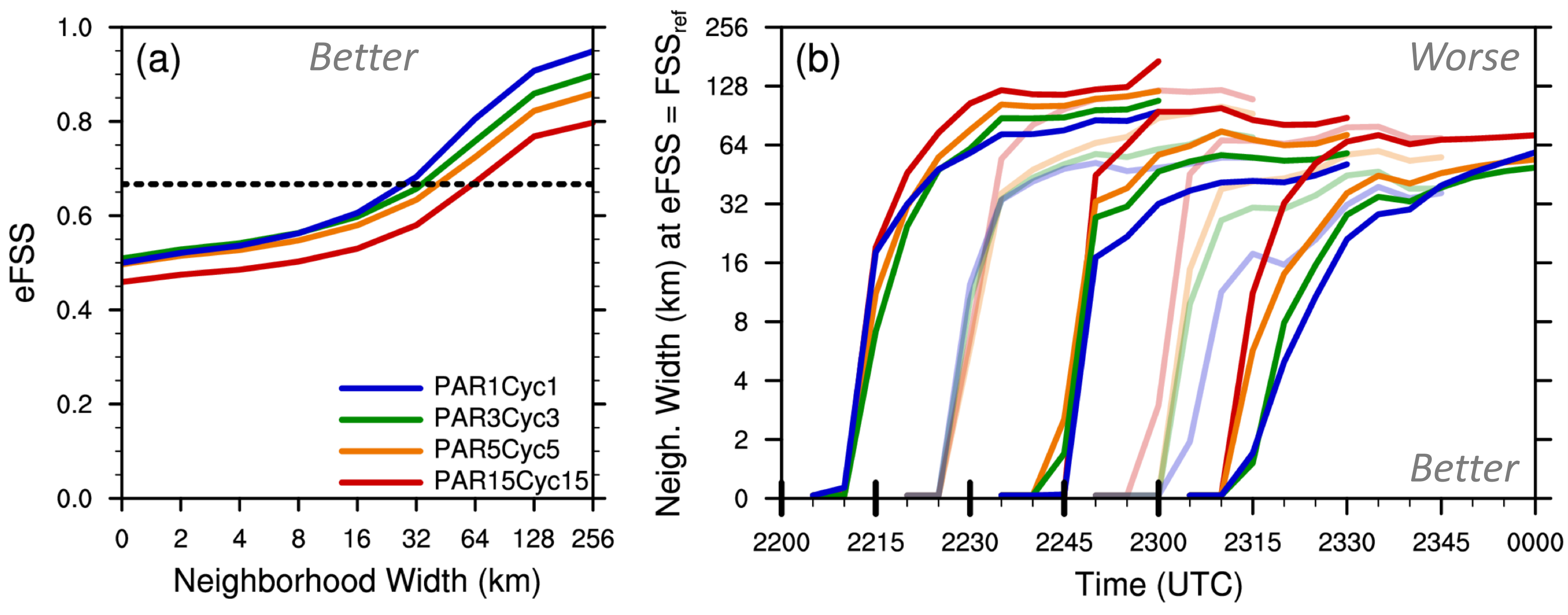
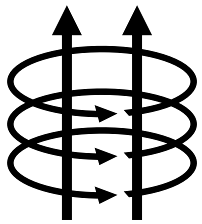
# Ensemble Fractions Skill Score for All Forecasts

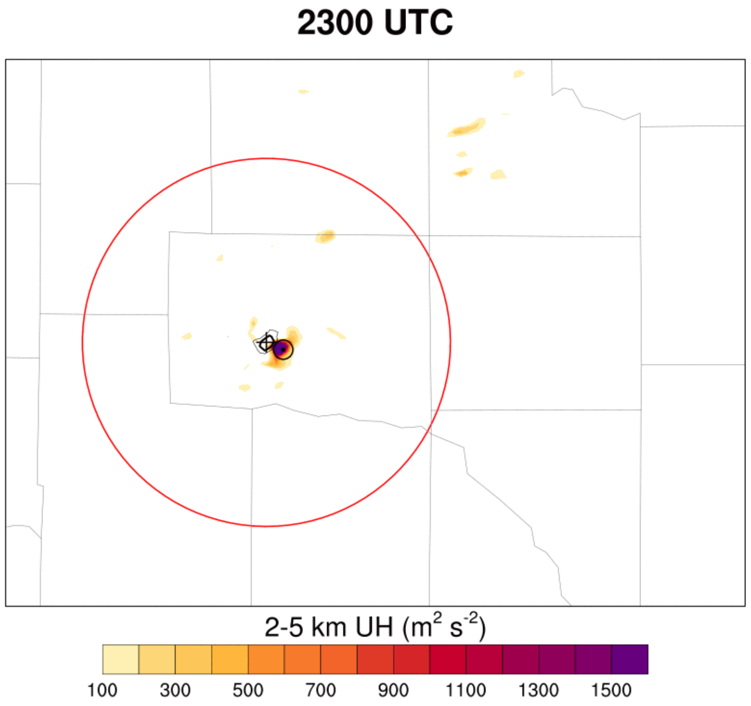



- **PAR1Cyc1** performs the best, followed by **PAR3Cyc3** and **PAR5Cyc5**
- **PAR15Cyc15** performs the worst

# Assessment of Forecasts: 2–5-km Updraft Helicity

- Subjective evaluation
  - Probability of UH > 400 $m^2\ s^{-2}$
  - 90th percentile of UH
  - MRMS azimuthal wind shear
- Objective verification
  - Match UH objects within *40 km* of azimuthal-wind-shear objects
  - Contingency-table statistics






Observed

| Forecast | Yes | No |
|---|---|---|
| Yes | A(10) | B(1) |
| No | C(2) | D(n/a) |

$$\mathrm{POD} = \frac{\mathrm{A}}{\mathrm{A} + \mathrm{C}} = 0.83$$

$$\mathrm{FAR} = \frac{\mathrm{B}}{\mathrm{A} + \mathrm{B}} = 0.09$$

$$\mathrm{BIAS} = \frac{\mathrm{A} + \mathrm{B}}{\mathrm{A} + \mathrm{C}} = 0.92$$

$$\mathrm{CSI} = \frac{\mathrm{A}}{\mathrm{A} + \mathrm{B} + \mathrm{C}} = 0.77$$

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# Assessment of Forecasts: 2–5-km Updraft Helicity

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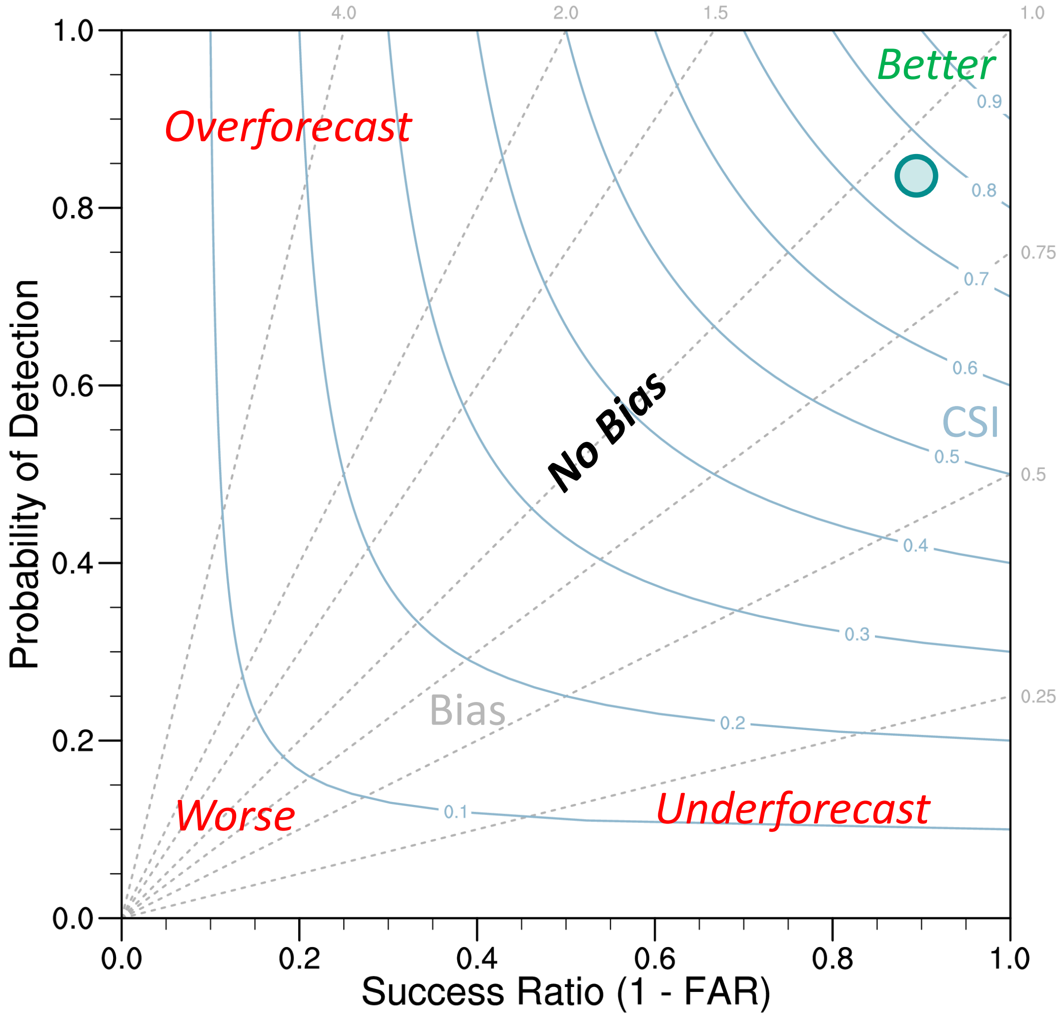
  - *Performance diagram*

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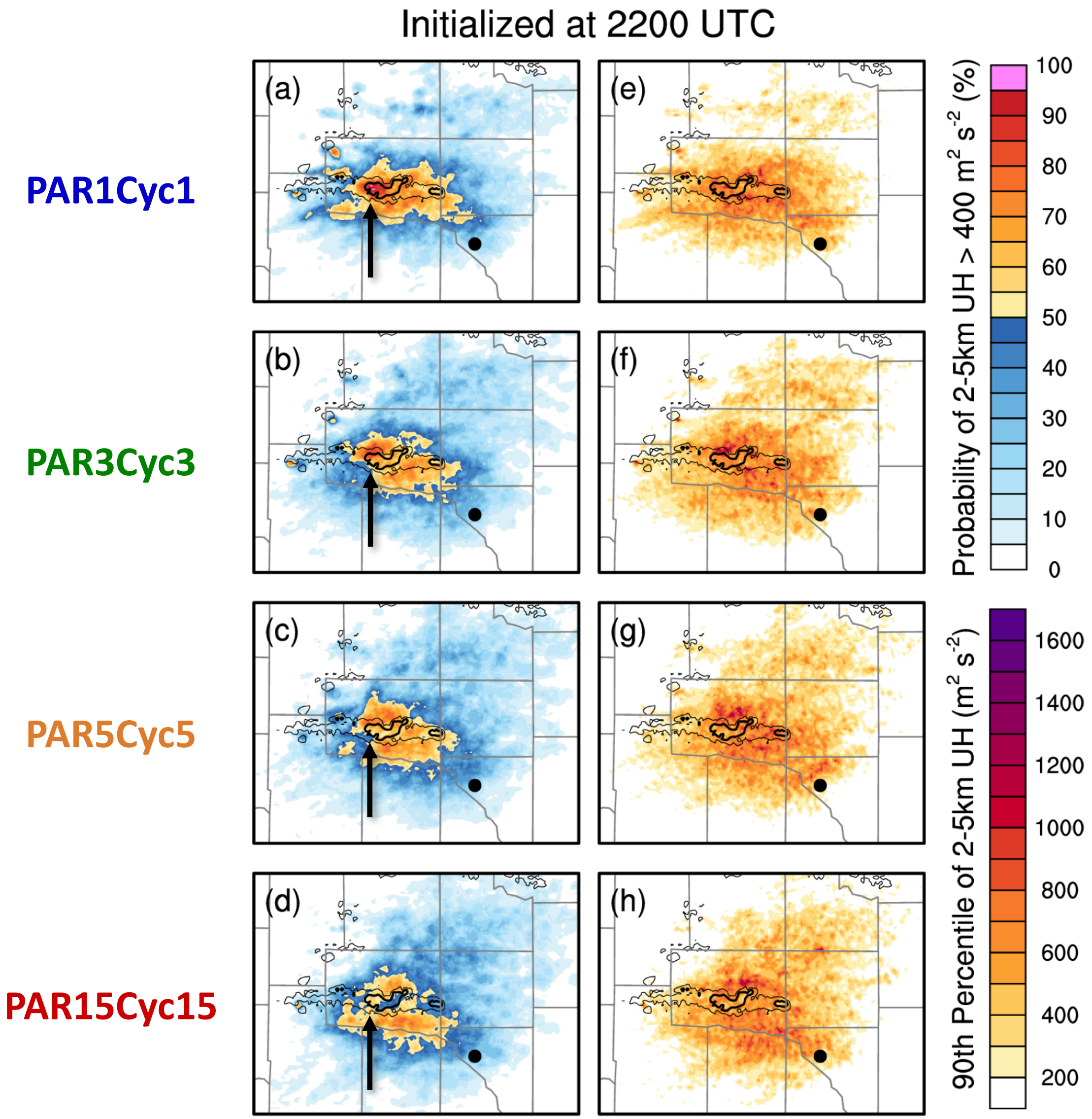
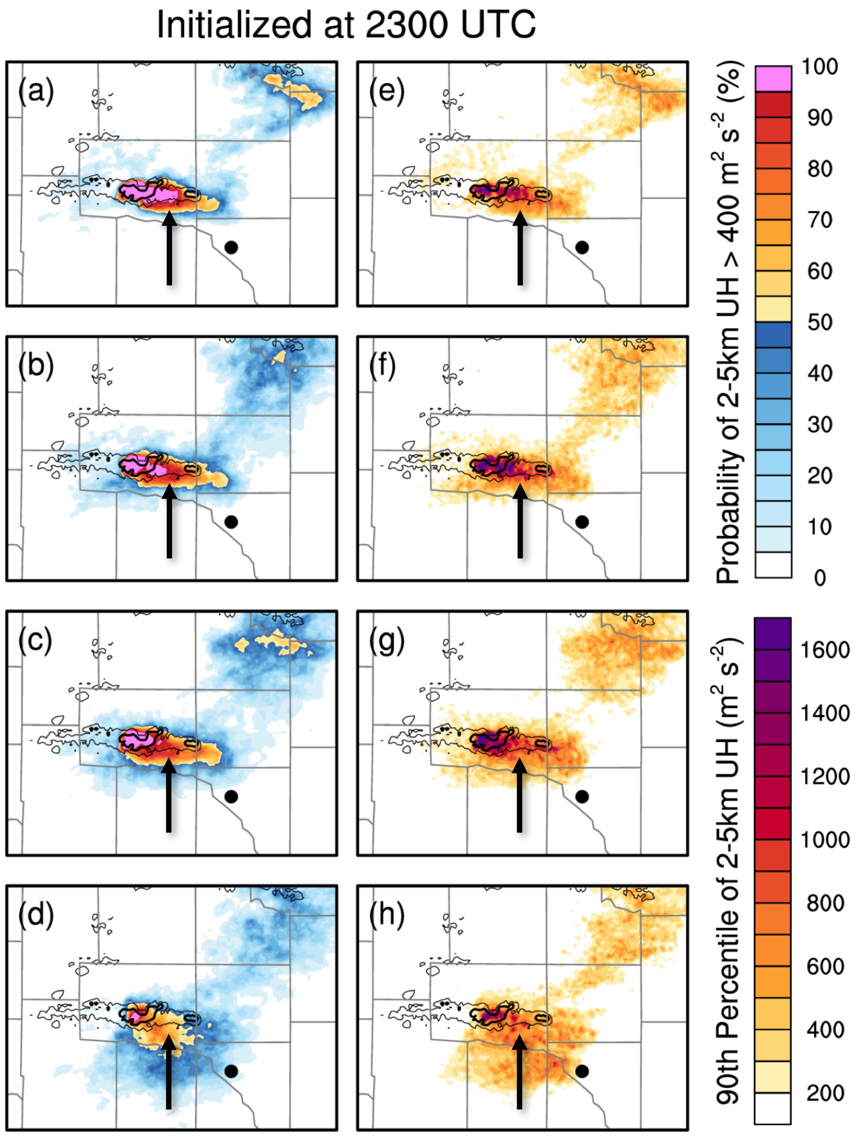
# Forecasts initialized at 2200 UTC
# After 15 min of DA Cycling

# Forecasts initialized at 2300 UTC
# After 75 min of DA Cycling

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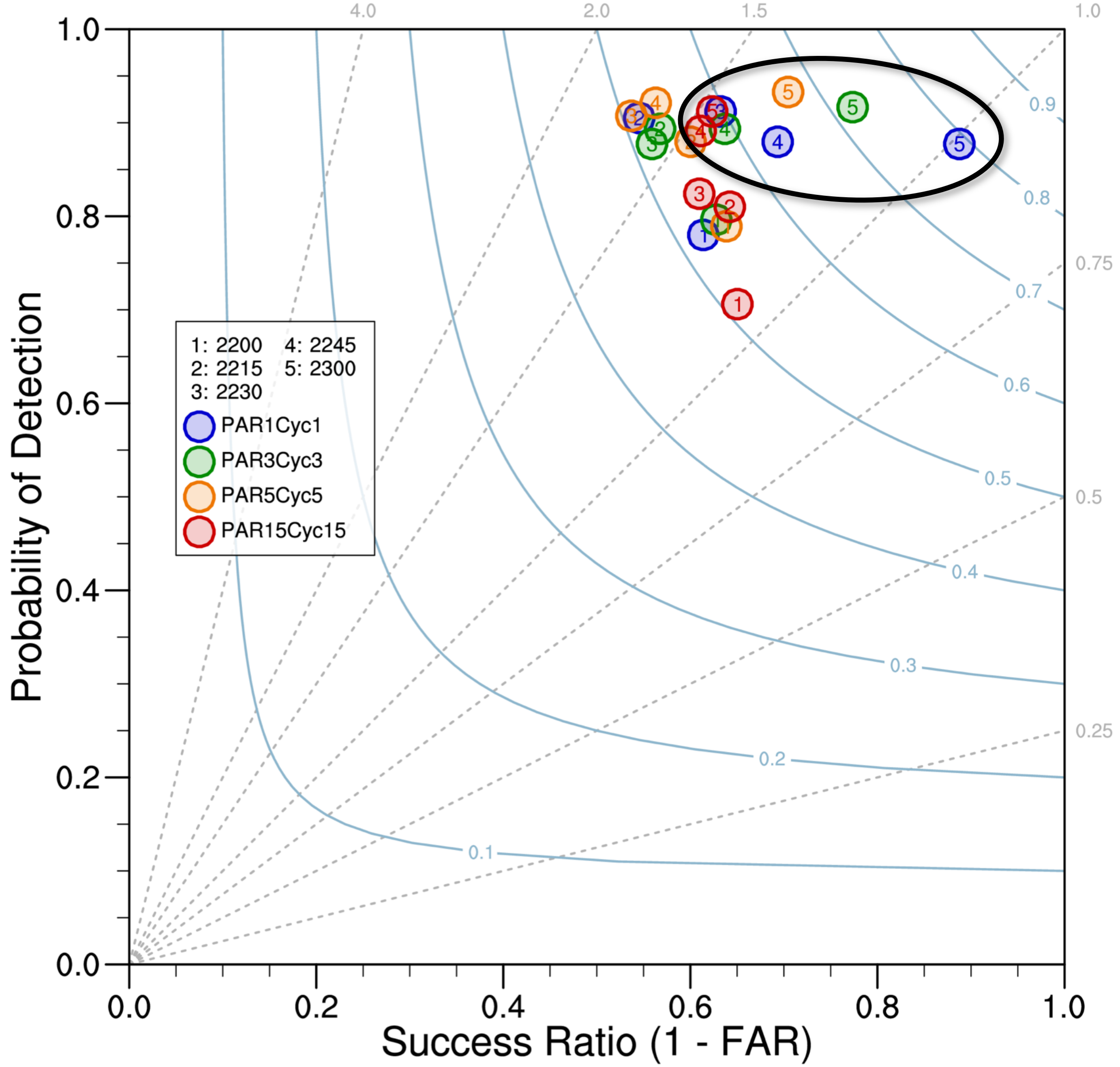
# Performance Diagram for All Forecasts

- **PAR1Cyc1** produces *3 of the top 5* best forecasts, including the best overall forecast

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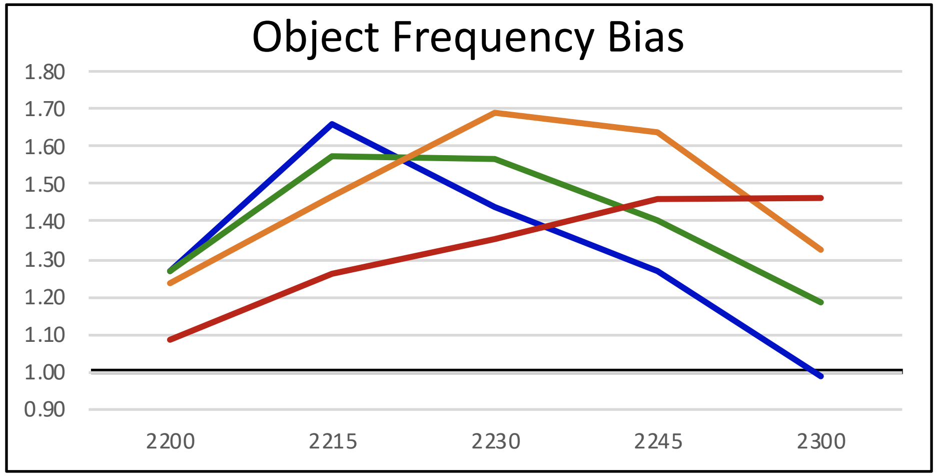
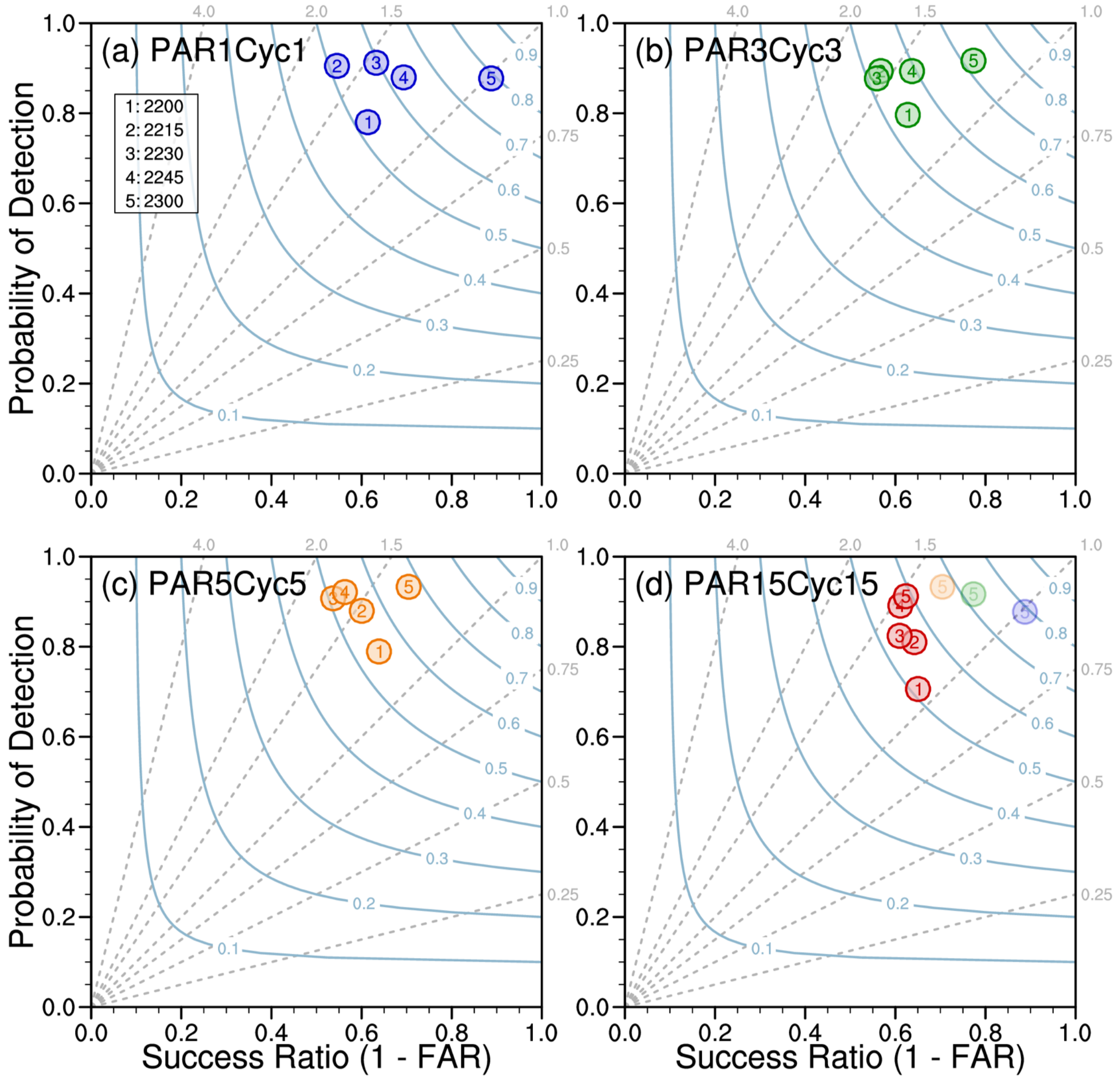
# Performance Diagram for All Forecasts

- **PAR1Cyc1** produces *3 of the top 5* best forecasts, including the best overall forecast
- Forecasts show *increase in FAR and POD* followed by a *decrease in FAR*

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# Key Findings from Experiments

- Rapid assimilation of frequent PAR volumetric data can benefit the WoFS by:
  - more quickly spinning up storms in the analyses
  - more quickly suppressing spurious convection
  - ***leading to better analyses and forecasts at longer lead times***
- However, computational cost is large for **PAR1Cyc1**.
  - Big contributor is WRF I/O (in-core data assimilation?)

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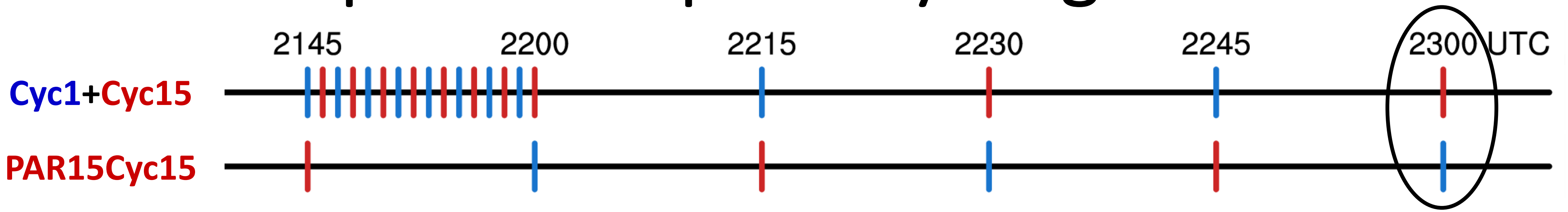
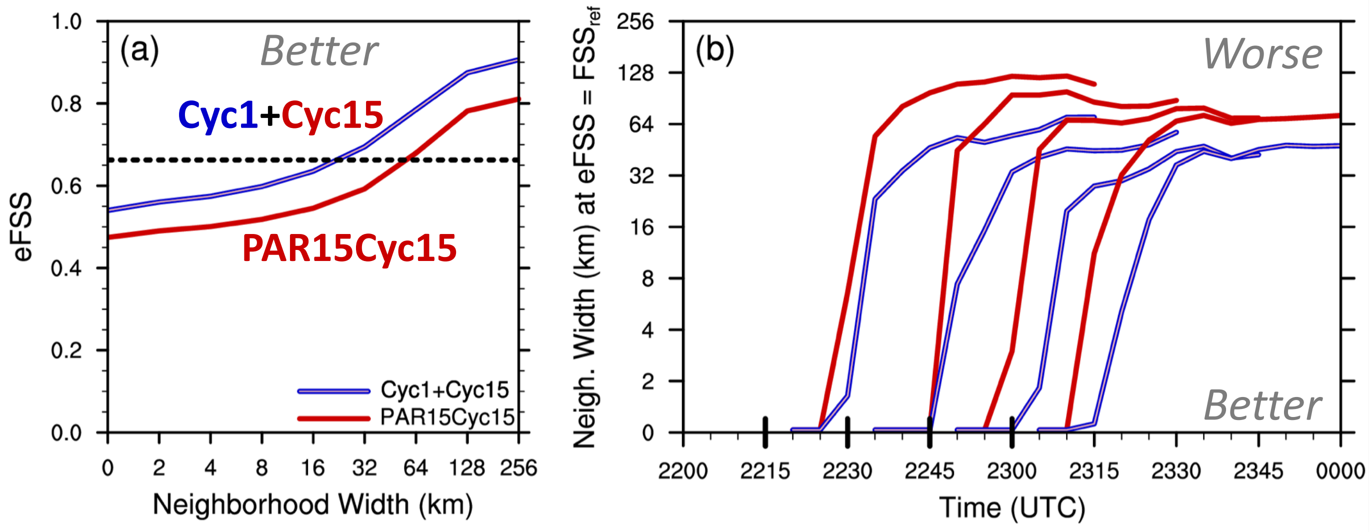
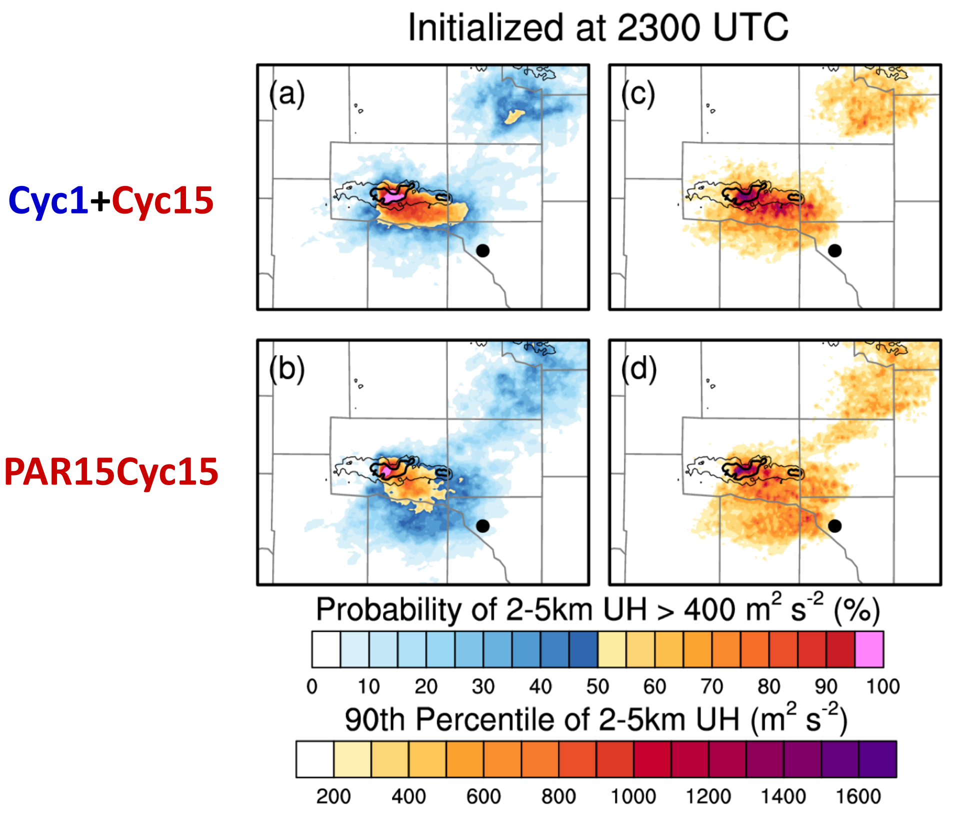
# Example of Adaptive Cycling Intervals

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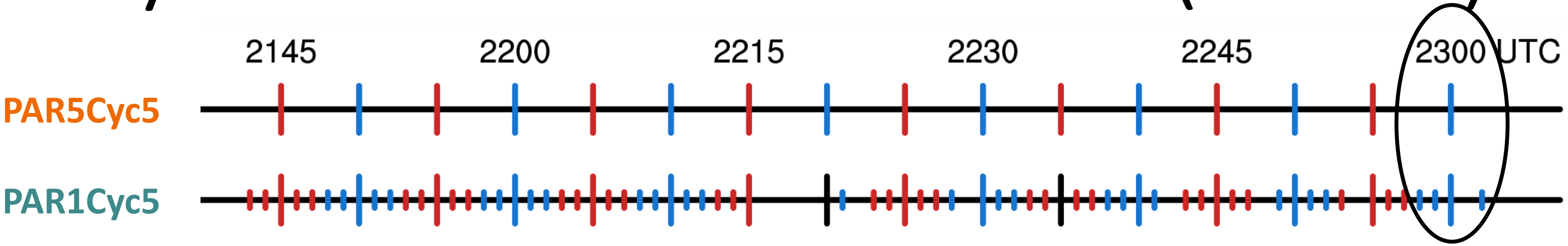
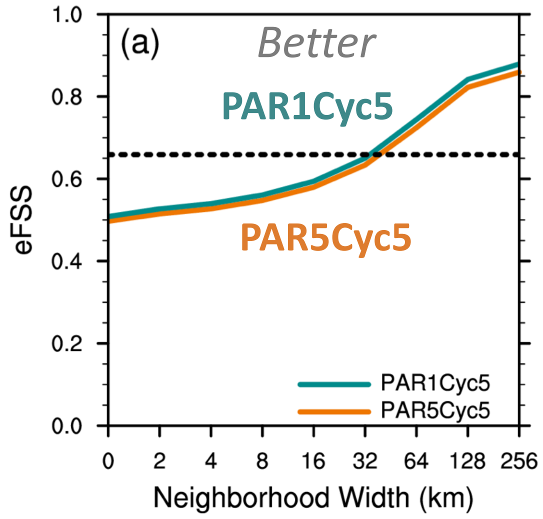
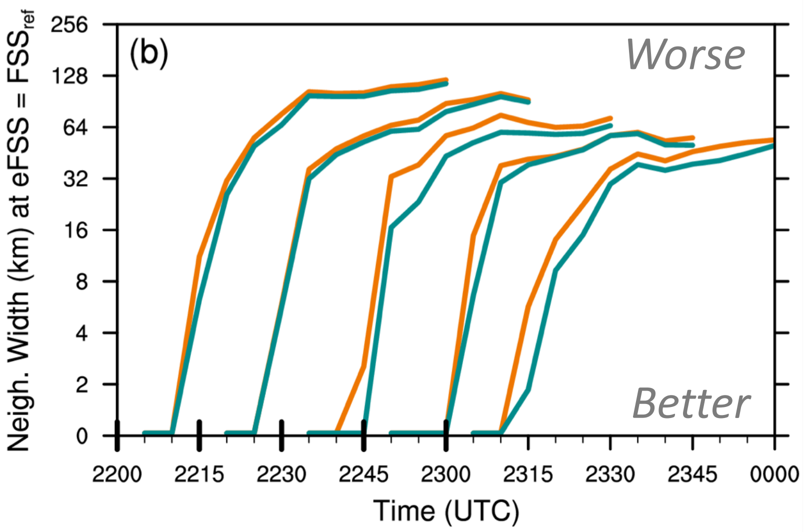
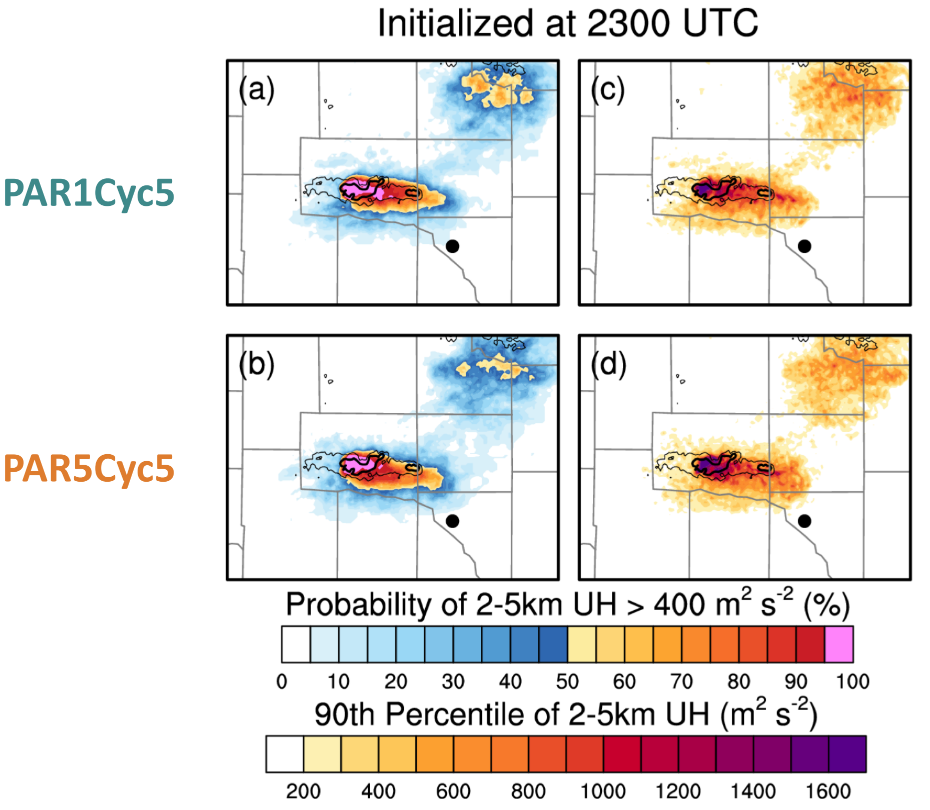
# Asynchronous Data Assimilation (4DEnKF)

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# Summary of WoF-PAR Experiments

- Rapid assimilation of frequent PAR volumetric data can benefit the WoFS by:
    - more quickly spinning up storms in the analyses
    - more quickly suppressing spurious convection
    - ***leading to better analyses and forecasts at longer lead times***
- Adaptive cycling intervals
    - a potential way to *substantially improve* analyses and forecasts
- Asynchronous data assimilation (4DEnKF)
    - only *marginally improved* analyses and forecasts

*Stratman et al. (2020)*
https://doi.org/10.1175/WAF-D-19-0165.1

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