

# Improving Probabilistic Short-Term Severe Weather Forecasts Using the Warn-On- Forecast System, ProbSevere, and Random Forests

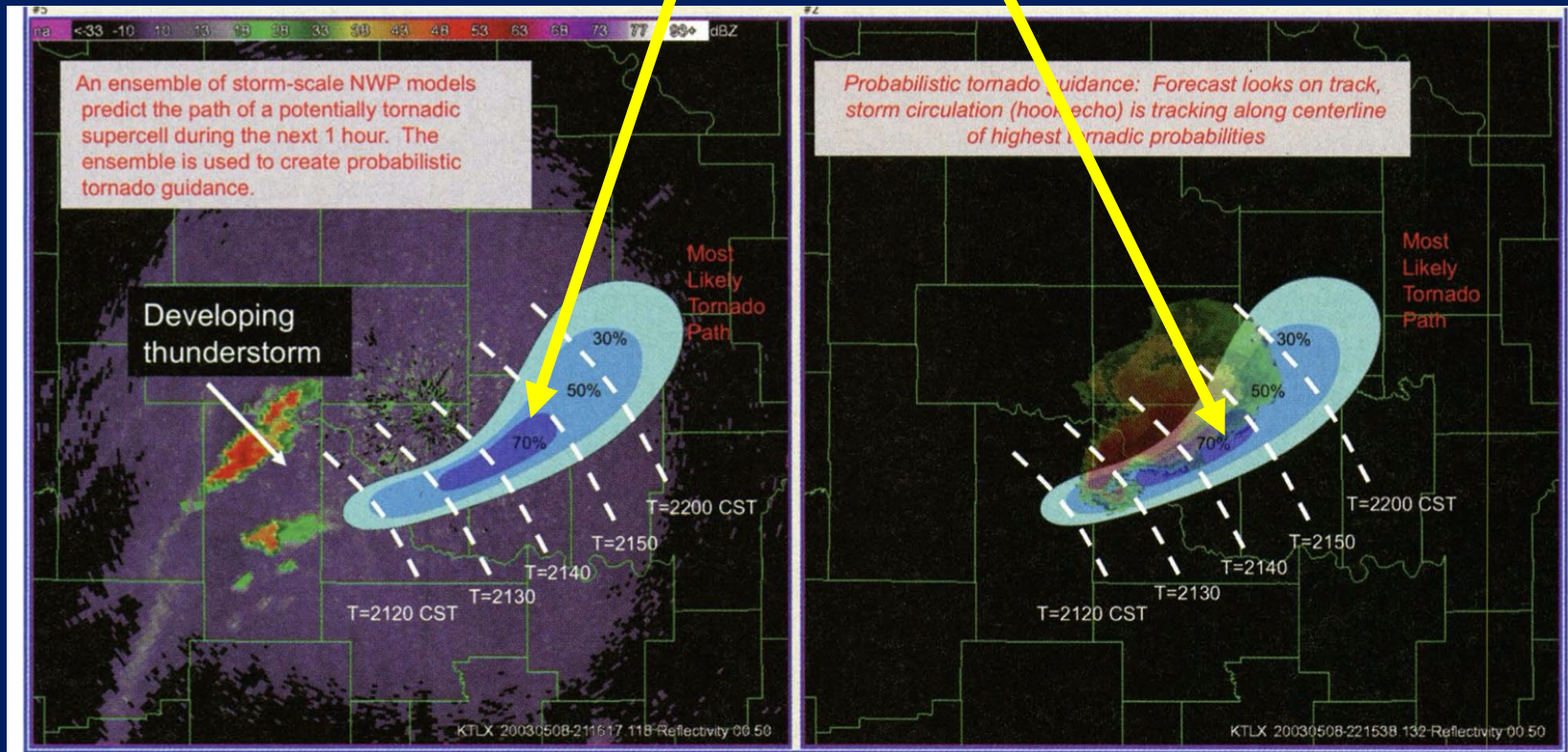
**Eric Loken**<sup>1</sup>, Katie Wilson<sup>1</sup>, Thea Sandmael<sup>1</sup>, Kristin Calhoun<sup>2</sup>, Adam Clark<sup>2</sup>, Anthony Reinhart<sup>2</sup>, Patrick Burke<sup>2</sup>, and Patrick Skinner<sup>1</sup>

<sup>1</sup>University of Oklahoma/Cooperative Institute for Severe and High-Impact Weather Research and Operations

<sup>2</sup>NOAA/OAR/National Severe Storms Laboratory

# Can we make the vision a reality?

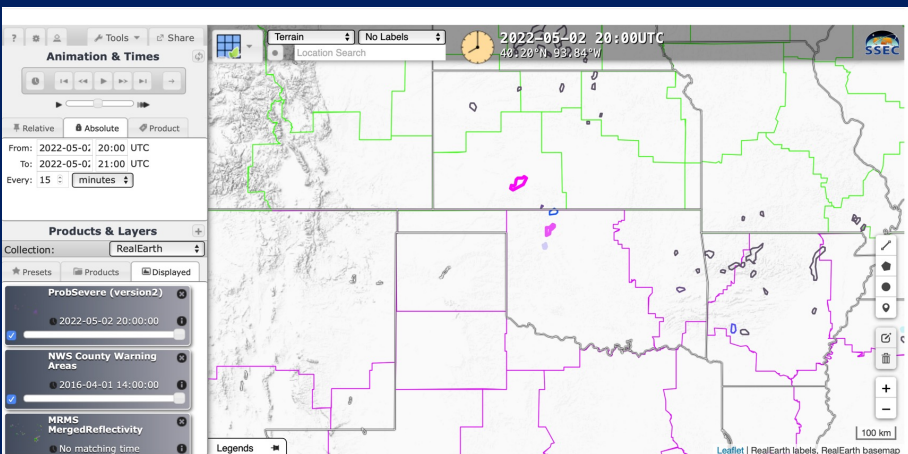
## 90-minute tornado probabilities (rapidly updating)



# Two products with different strengths

## ProbSevere

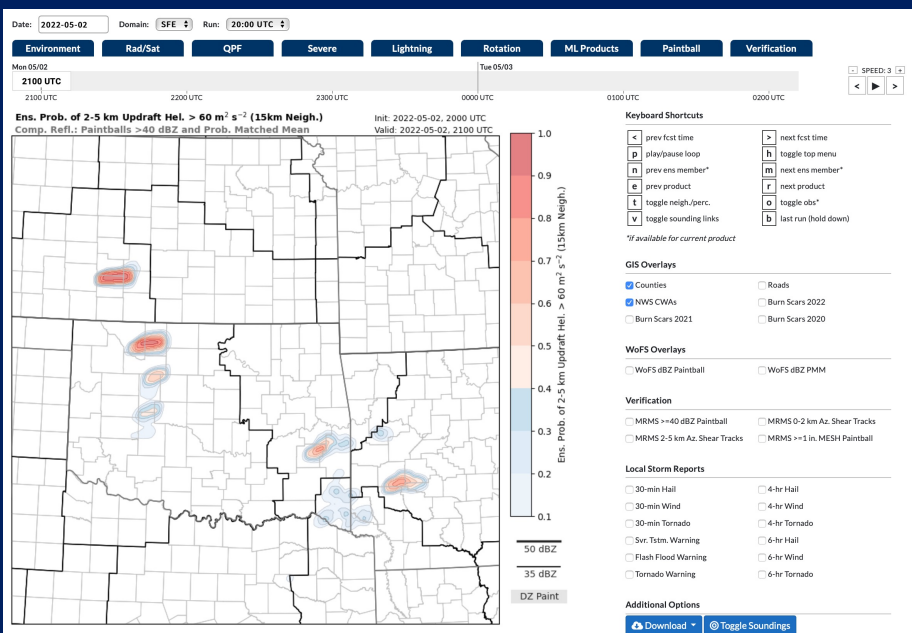
ProbSevere Objects  
Valid 2 May 2022 2000 UTC



[https://cimss.ssec.wisc.edu/severe\\_conv/](https://cimss.ssec.wisc.edu/severe_conv/)

## Warn-on-Forecast System (WoFS)

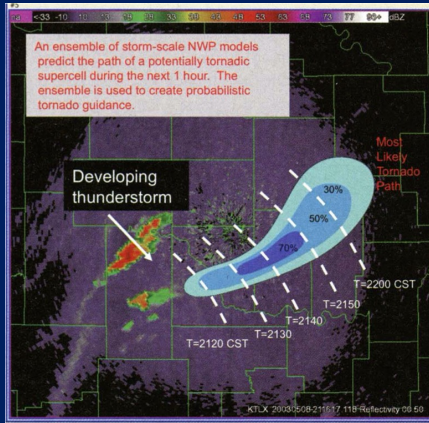
Probability of UH >  $60\text{m}^2\text{s}^{-2}$   
Valid 2 May 2022, 2000-2100 UTC



<https://cbwofs.nssl.noaa.gov/>

Can we combine these to get better short-term severe weather forecasts?

# Combine ProbSevere (PS) and WoFS with Random Forests



NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION

Storm Events Database

The Storm Events Database contains the records used to create the official NOAA Storm Data publication, documenting:

- The occurrence of storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce;
- Rare, unusual, weather phenomena that generate media attention, such as snow flurries in South Florida or the San Diego coastal area; and
- Other significant meteorological events, such as record maximum or minimum temperatures or precipitation that occur in connection with another event.

The database currently contains data from January 1959 to June 2022, as entered by NOAA's National Weather Service (NWS). Due to changes in the data collection and processing procedures over time, there are unique periods of record available depending on the event type. NCEI has performed data reformatting and standardization of event types but has not changed any data values for locations, latitudes, states, damage narratives and any other event specific information. Please refer to the Database Details page for more information.

Register your email address with NCEI to receive future information regarding access system downtime, data issues, new features and general news about the Storm Events Database.

Select State or Area: All States and Areas

Narrative Text Search: [Text Search] [help and examples]

Find all events on this day. List all events from September 28 across all years. Choose 'Any' as the year to search all years of the database for a selected day and month range.

MRMS Operational Product Viewer

2022 May 2 20:00 UTC

Map Center: 96.46, 35.99

Rotation Tracks: Low Level 30 min

05/02/2022 20:00 UTC

1/sec

0.020  
0.015  
0.014  
0.013  
0.012  
0.011  
0.010  
0.009  
0.008  
0.007  
0.006  
0.005  
0.004  
0.003  
0.002  
0.000

Product Type

- Base Reflectivity
- Composite Reflectivity
- Seamless Hybrid Scan
- Fast At Lowest Altitude
- Level Reflectivity
- Echo Top
- Level Threshold
- 3D Mosaic Levels
- ZDR - 3D Mosaic
- RhoHV - 3D Mosaic
- KDP - 3D Mosaic
- Radar Quality Index
- Rotation
- Rotation
- Heavy Lightning
- Charge Influence Index
- FLASH
- Q1 Radar City
- Q1 Multi-Sensor
- Vertically Integrated Water
- Precipitation Frequency Band
- AutoNowCast
- Model

Low Level - Instant  
Low Level - 30 min  
Low Level - 1 hr  
Low Level - 2 hr  
Low Level - 4 hr  
Low Level - 6 hr  
Low Level - 8 hr  
Low Level - 24 hr  
Mid Level - Instant  
Mid Level - 30 min  
Mid Level - 1 hr  
Mid Level - 2 hr  
Mid Level - 4 hr  
Mid Level - 6 hr  
Mid Level - 8 hr  
Mid Level - 24 hr

Opacity 0% 100% [Parallax]

Loop Image [ ] Enable Mouse Wheel [ ]

Product Redout [ ]

Reset Region [ ]

Overlays [ ]

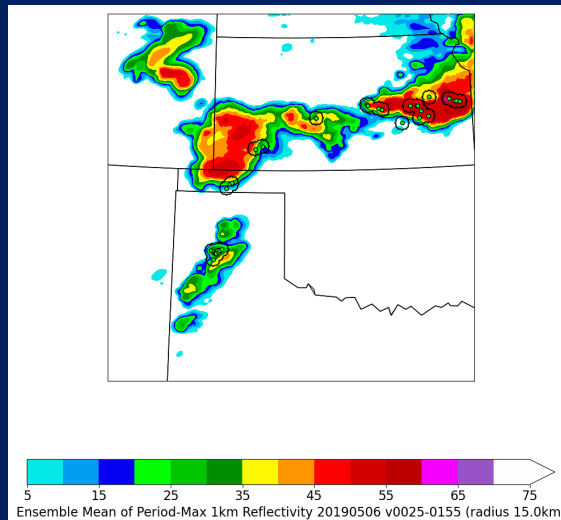
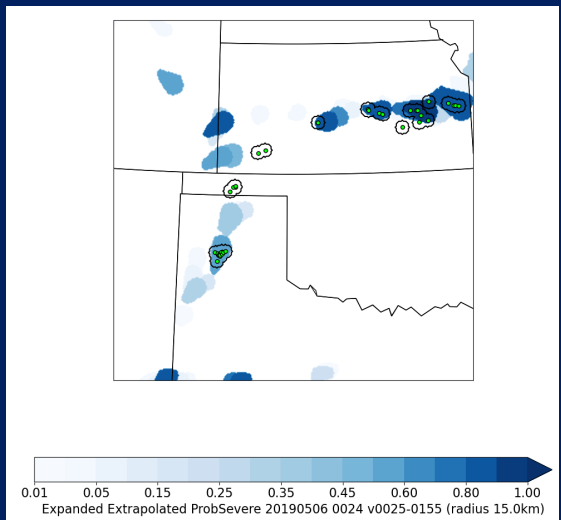
Base Map Layer [ ]

mPING Legend [ ]

Overlay mPING Reports None [ ]

Goal: Spatial hazard probabilities in set time, space

Targets: MRMS-corrected Storm Reports (within a radius)



Predictors: "Representative" PS and WoFS variables

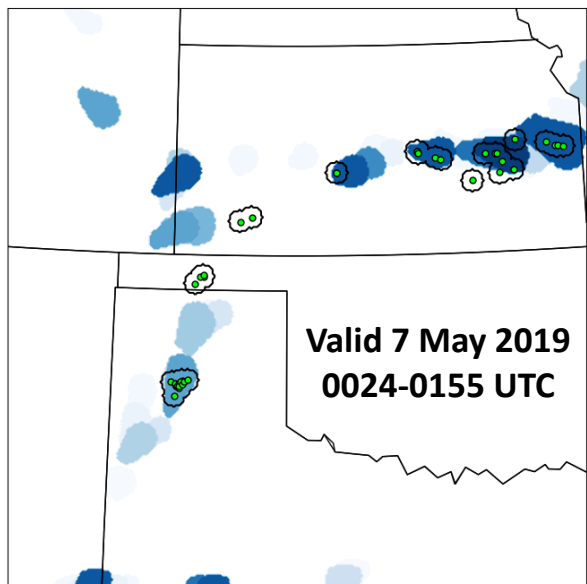
# Predictors: "Representative" PS and WoFS Variables

## ProbSevere

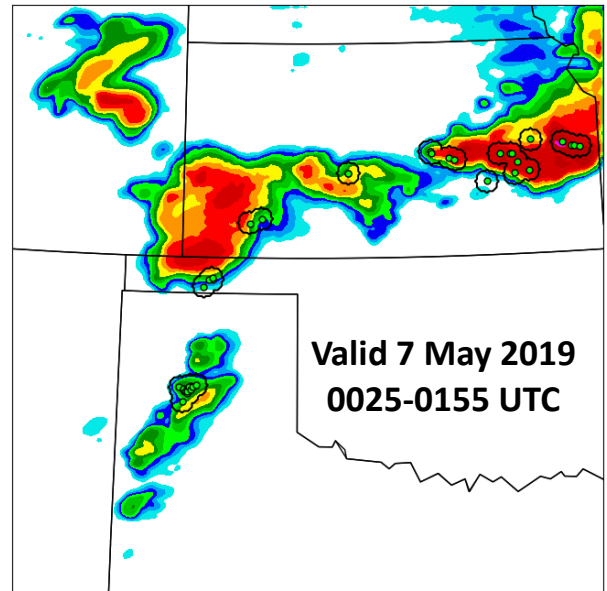
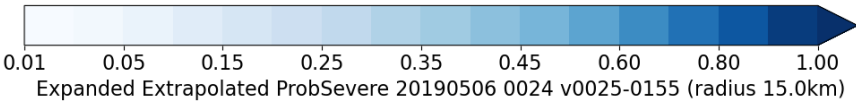
- Map objects to WoFS grid
- Extrapolate in time using storm motion
- Expand using spatial radius

## WoFS

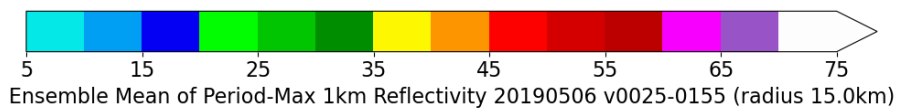
- Aggregate predictors in time
- Take ensemble mean
- Predictors from multiple radii (0- to 45-km)



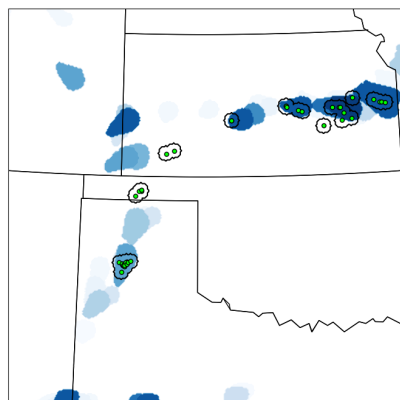
Expanded Extrapolated ProbSevere Hail Probability



Ensemble Mean of 90-min Maximum 1km Reflectivity

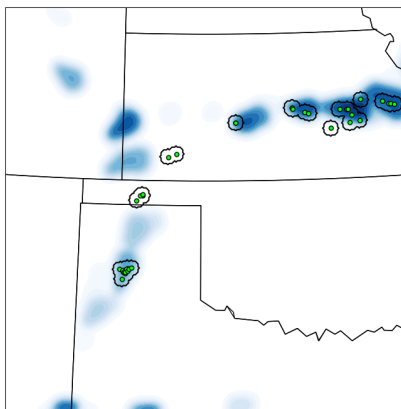


# Six ProbSevere (PS) Predictors Per Hazard



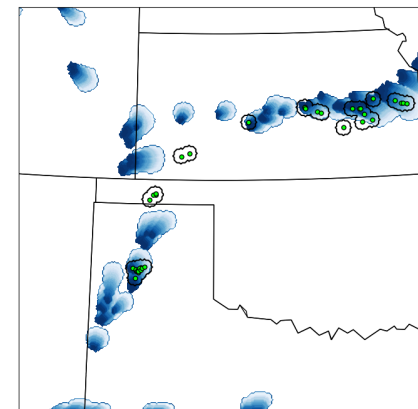
0.01 0.05 0.15 0.25 0.35 0.45 0.60 0.80 1.00  
Expanded Extrapolated ProbSevere 20190506 0024 v0025-0155 (radius 15.0km)

Raw expanded  
extrapolated PS



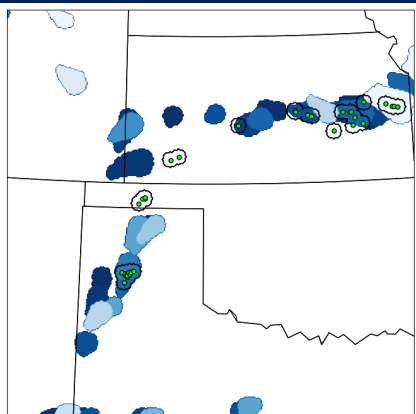
0.01 0.05 0.15 0.25 0.35 0.45 0.60 0.80 1.00  
Expanded Extrapolated ProbSevere 20190506 0024 v0025-0155 (radius 15.0km)

Smoothed expanded  
extrapolated PS



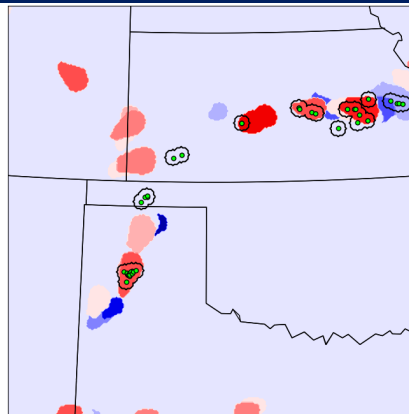
0 15 30 45 60 75 90  
Expanded Extrapolated ProbSevere 20190506 0024 v0025-0155 (radius 15.0km)

Extrapolation lead  
time



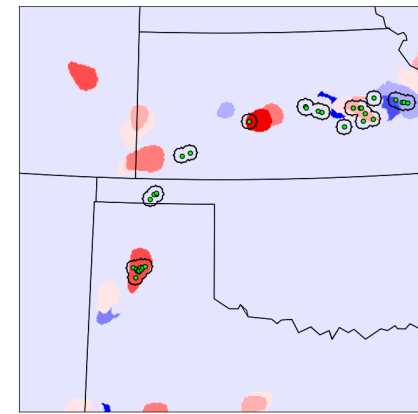
0 10 30 60 90 120 150 180  
Expanded Extrapolated ProbSevere 20190506 0024 v0025-0155 (radius 15.0km)

Storm Age



-0.9 -0.6 -0.3 0.0 0.3 0.6 0.9  
Expanded Extrapolated ProbSevere 20190506 0024 v0025-0155 (radius 15.0km)

30-min Change

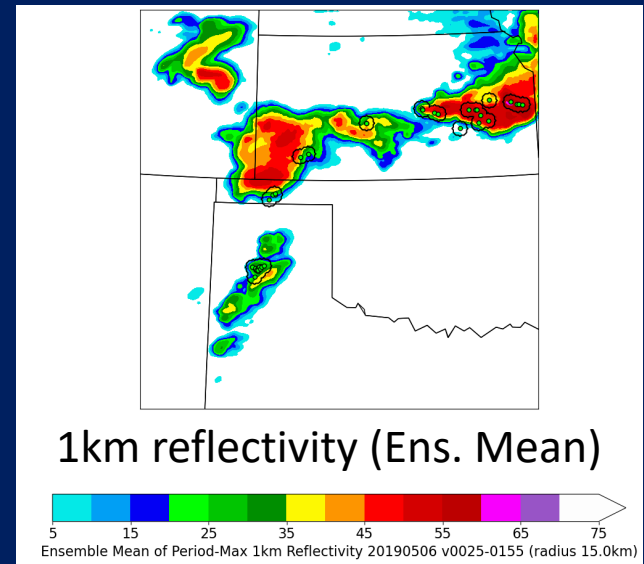
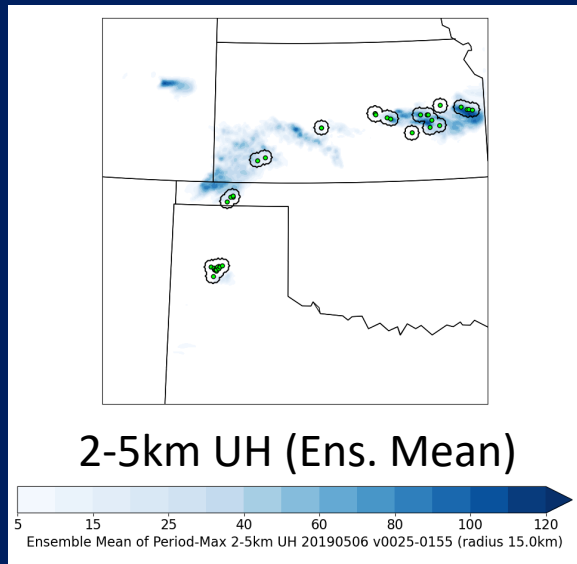


-0.9 -0.6 -0.3 0.0 0.3 0.6 0.9  
Expanded Extrapolated ProbSevere 20190506 0024 v0025-0155 (radius 15.0km)

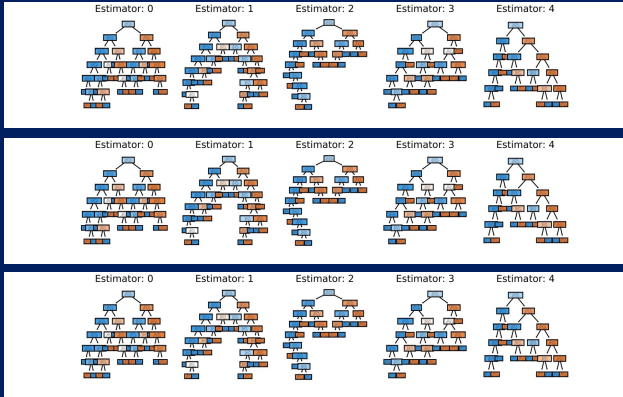
14-min Change

# 53 WoFS Fields as Predictors

- 80m wind speed
- 1km reflectivity
- 0-2 km vertical vorticity
- 0-2, 2-5km UH
- Maximum updraft speed
- 1km updraft
- 10-500m bulk shear
- FED
- 10m wind components
- 2m temp and dewpoint
- Mid and low level lapse rates
- 0-1, 0-3, 0-6km shear components
- 0-500m, 0-1km, 0-3km SRH
- SBCAPE
- STP
- SCP
- Downdraft speed
- Cloud top temperature
- MSLP
- PSFC
- LCL (surface)
- Hail
- Freezing level
- Member 1-18 2-5km UH



# Is there a benefit to combining WoFS and ProbSevere?



RF trained on all predictors

RF trained on only WoFS predictors

RF trained on only ProbSevere predictors

<https://stackoverflow.com/questions/40155128/plot-trees-for-a-random-forest-in-python-with-scikit-learn>

`sklearn.ensemble.RandomForestClassifier` ¶

```
class sklearn.ensemble.RandomForestClassifier(n_estimators=100, *, criterion='gini', max_depth=None, min_samples_split=2, min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='sqrt', max_leaf_nodes=None, min_impurity_decrease=0.0, bootstrap=True, oob_score=False, n_jobs=None, random_state=None, verbose=0, warm_start=False, class_weight=None, ccp_alpha=0.0, max_samples=None)
```

[source]

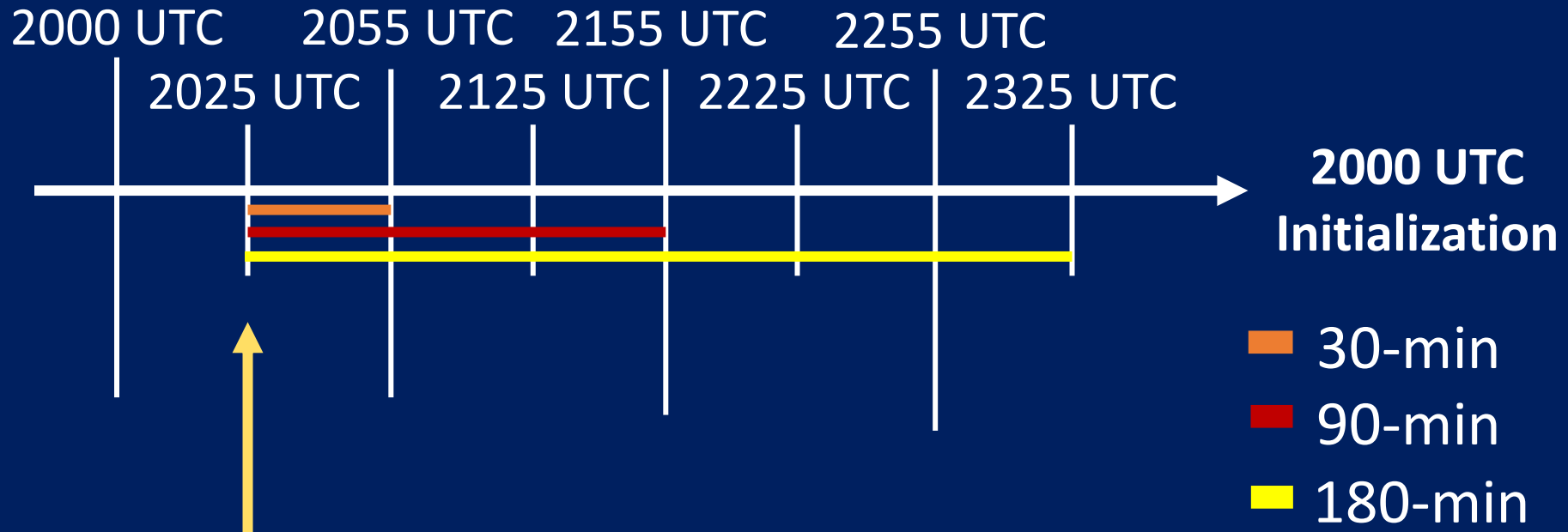
# Trees: 200, Max depth: 15, Min\_samples\_leaf: 20

Max features:  $\sqrt{n}$ , Criterion: minimize entropy

Dataset: 109 days (30 April 2019 – 4 June 2021)



# Look at 30-, 90-, 180-min time windows

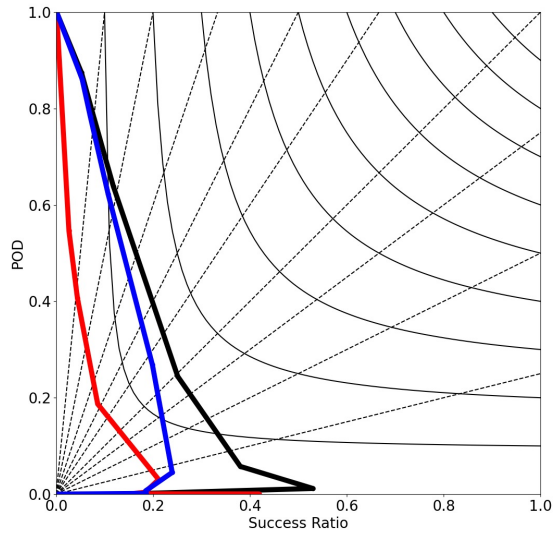


2000 UTC WoFS run  
2024 UTC ProbSevere

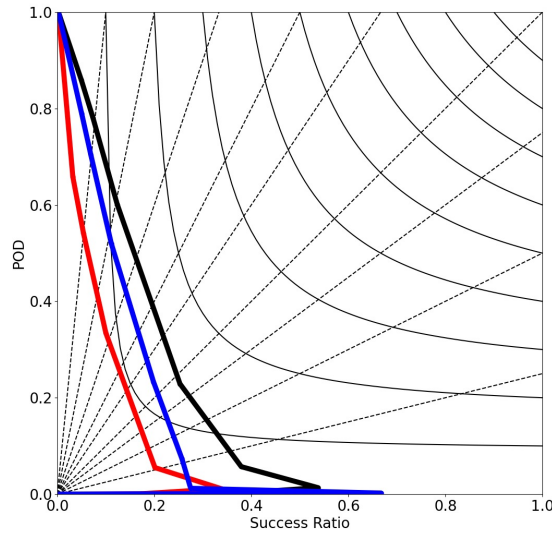
Train using each WoFS  
initialization time

# All-predictor RFs most skillful (15km radius) (30 April 2019 – 29 June 2020)

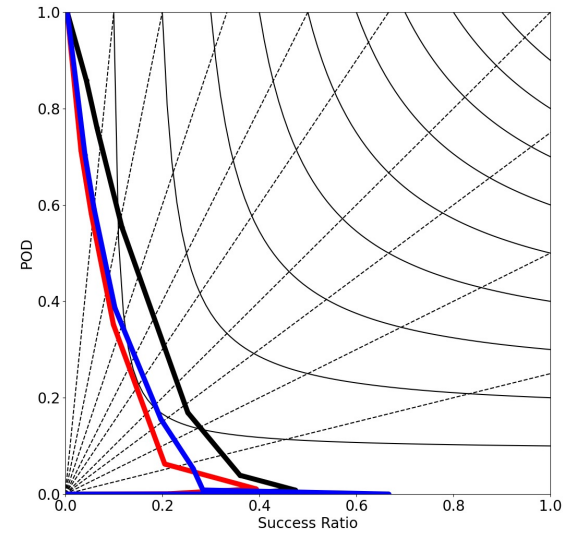
30 min



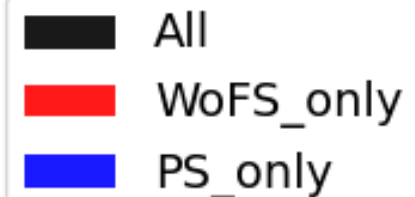
90 min



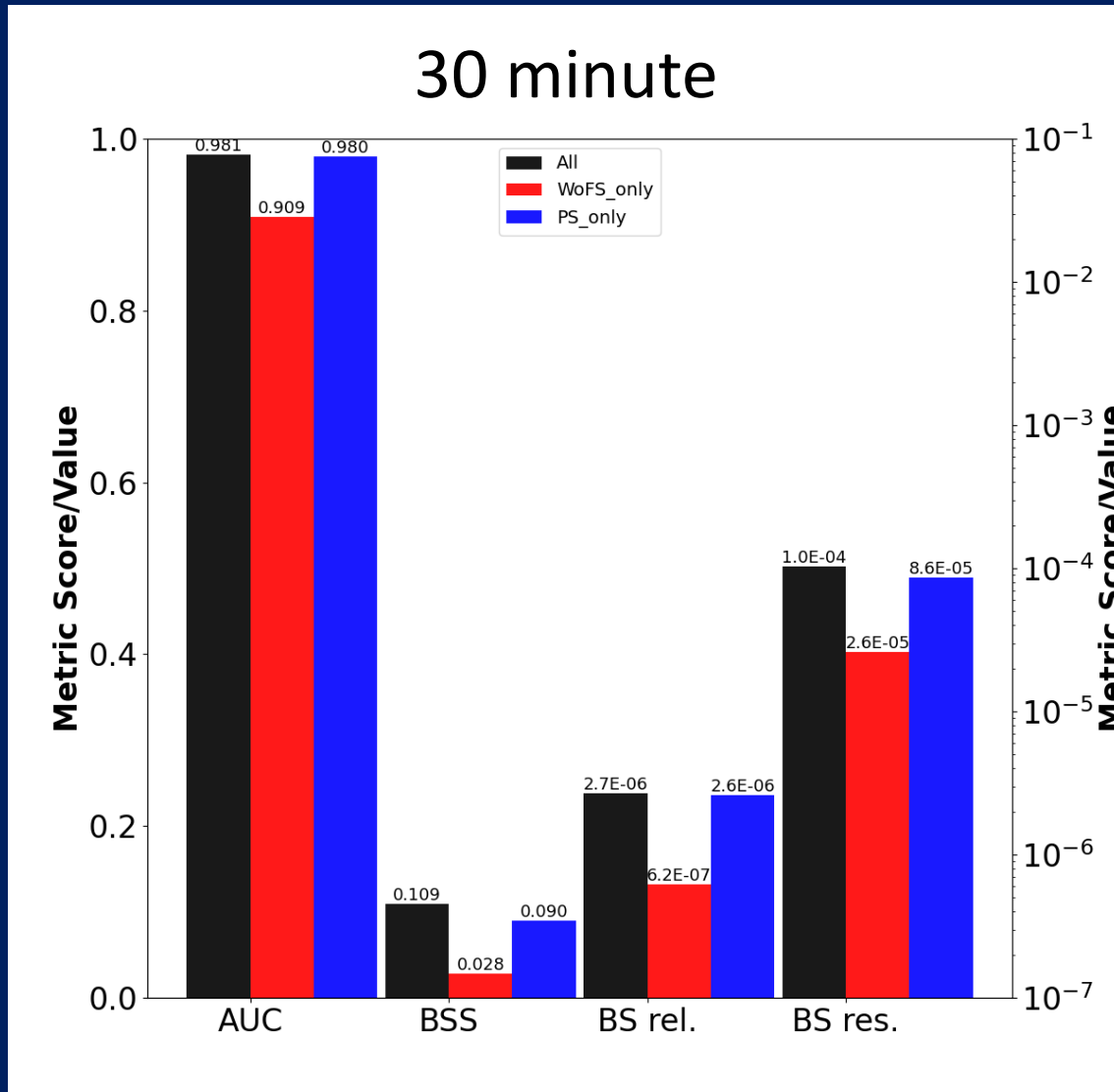
180 min



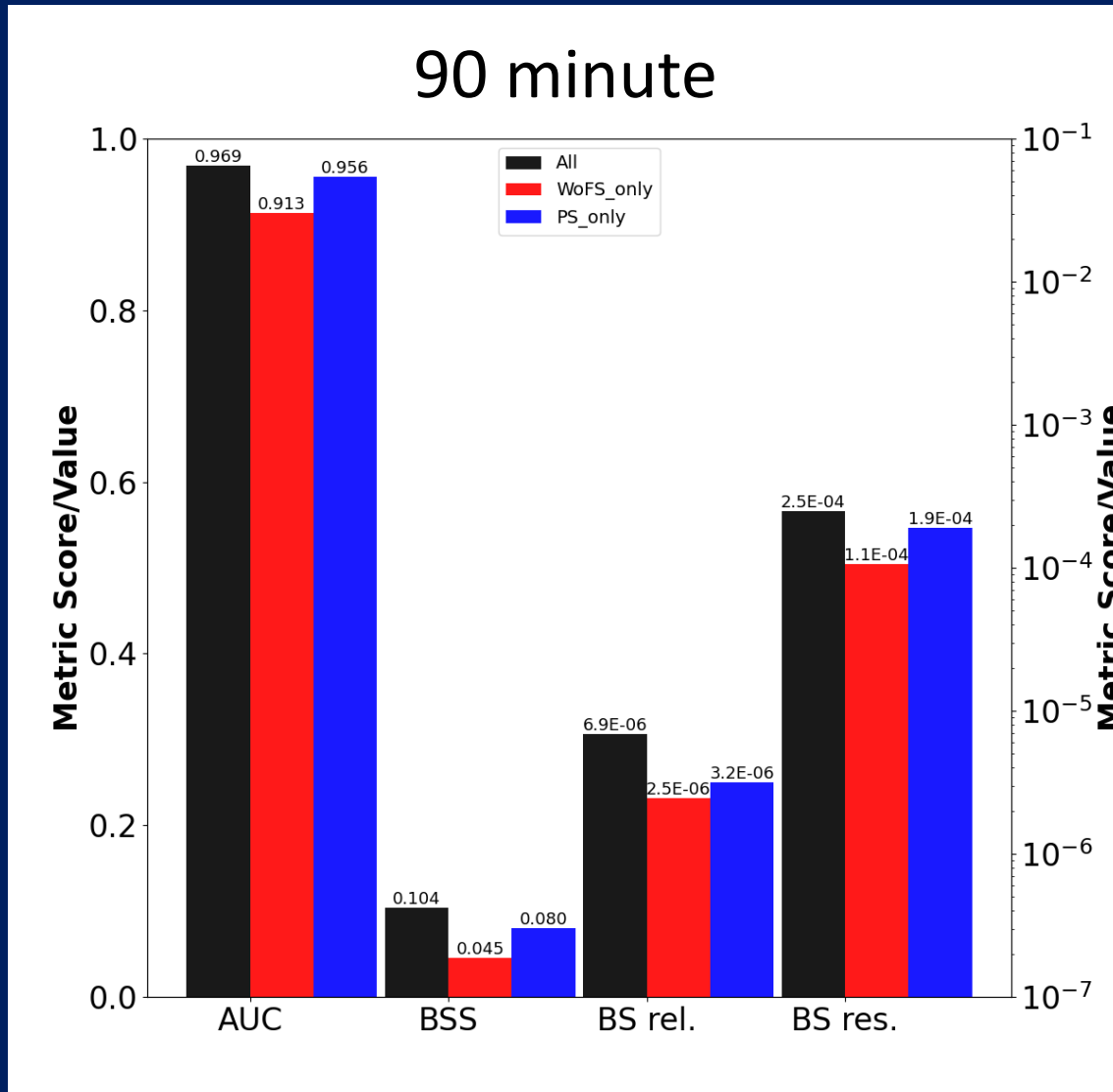
\*For all initialization times combined



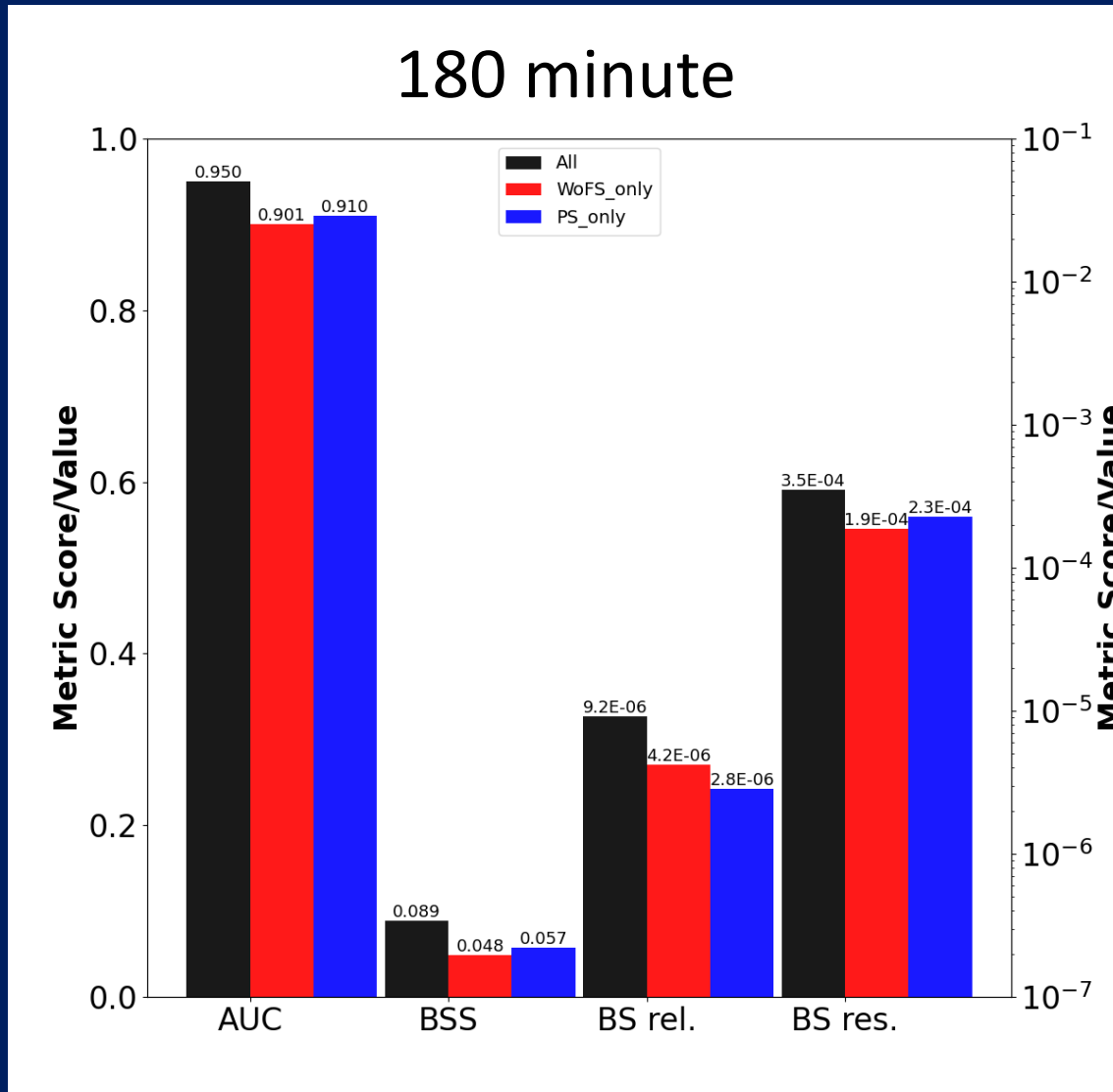
# All-predictor RFs most skillful (15km radius) (30 April 2019 – 29 June 2020)



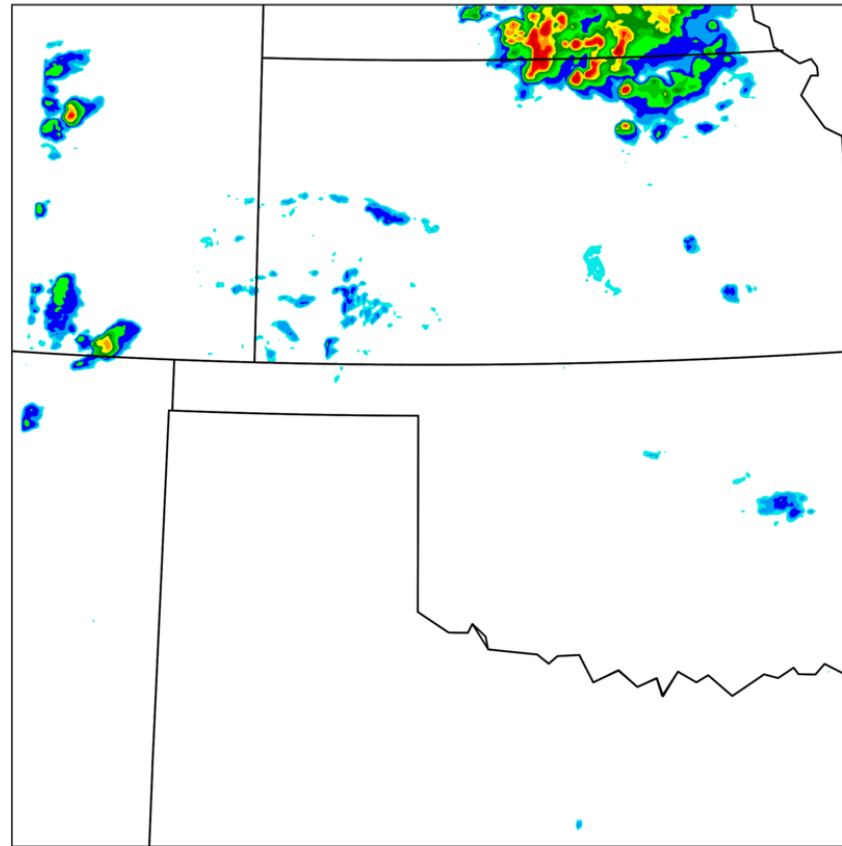
# All-predictor RFs most skillful (15km radius) (30 April 2019 – 29 June 2020)



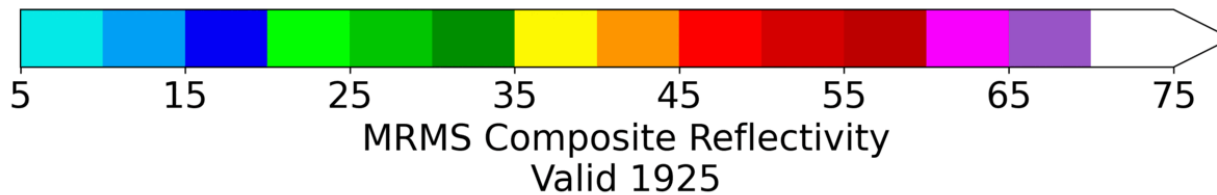
# All-predictor RFs most skillful (15km radius) (30 April 2019 – 29 June 2020)



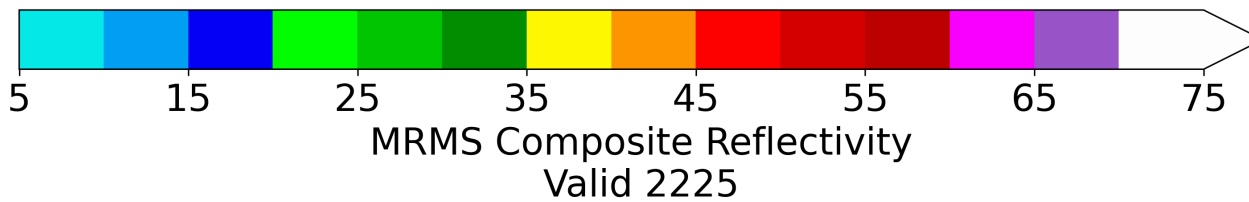
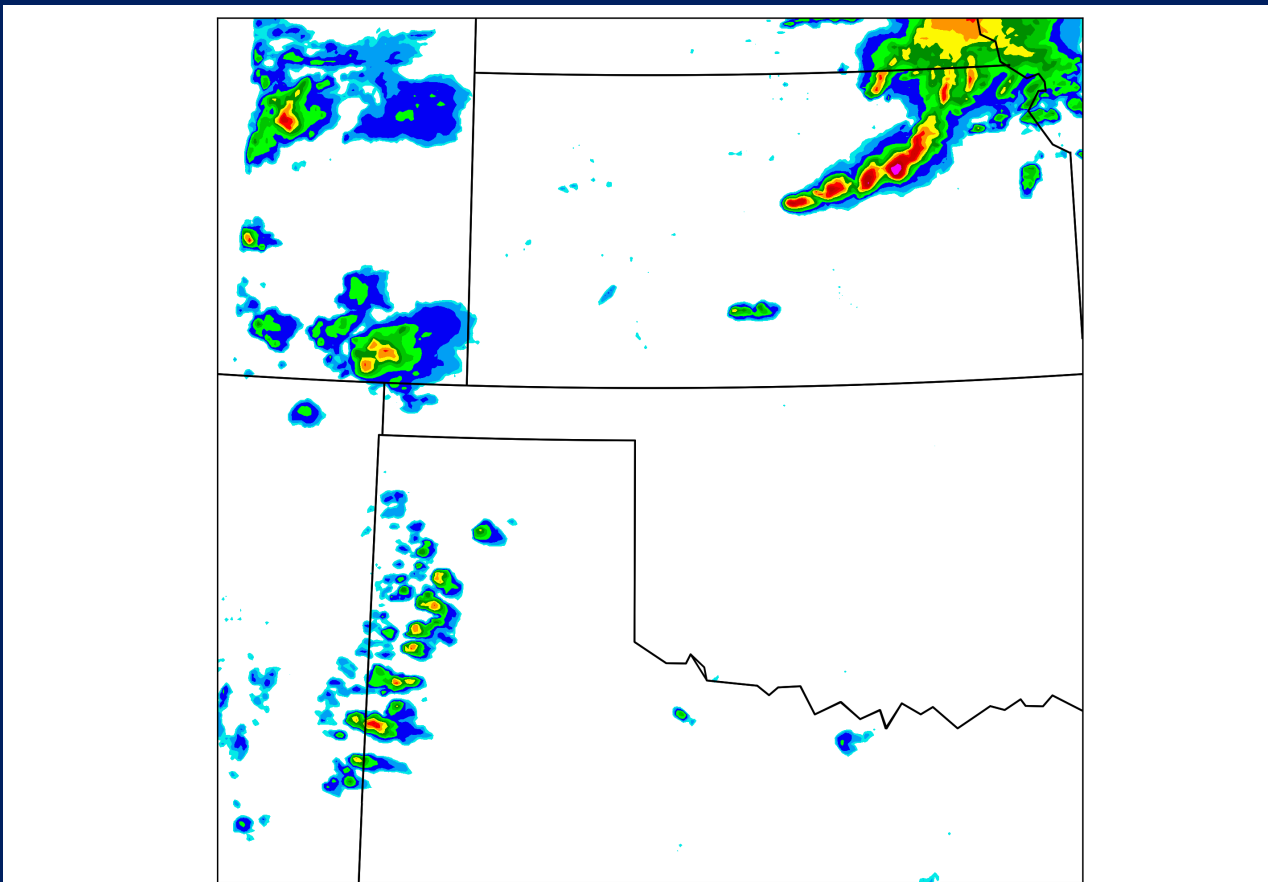
# Case study: 6-7 May 2019



<https://ezgif.com>



# 2225 UTC 6 May 2019



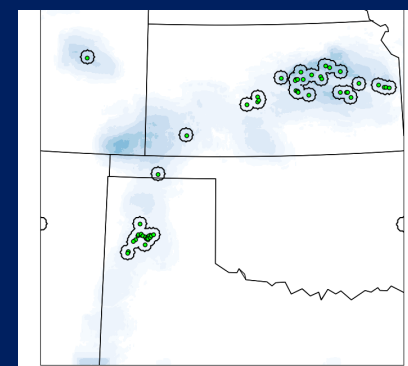
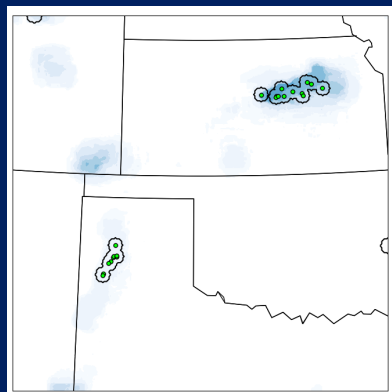
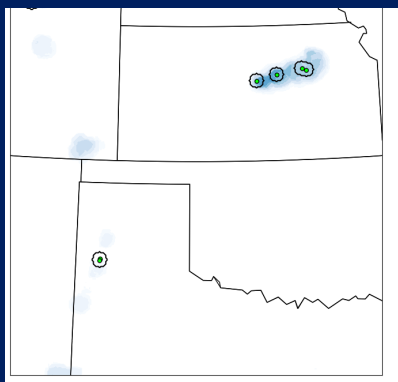
# 2200 UTC Initialization 6 May 2019

30 min

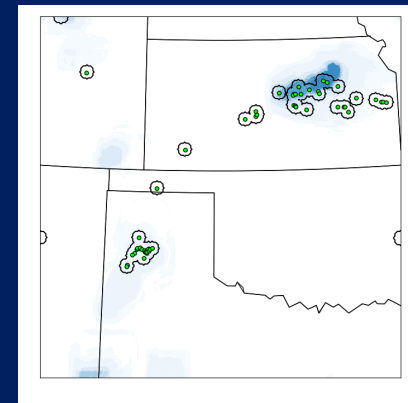
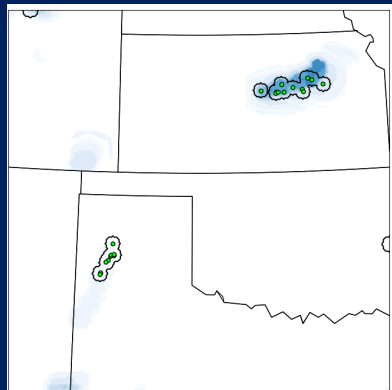
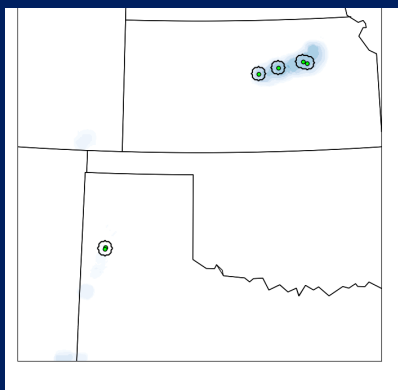
90 min

180 min

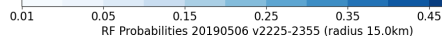
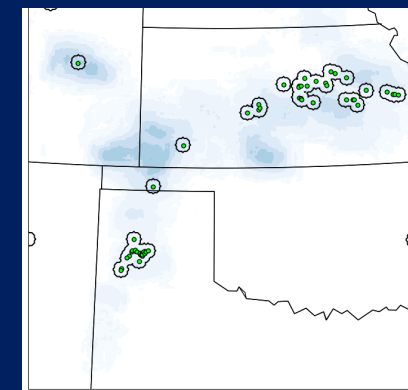
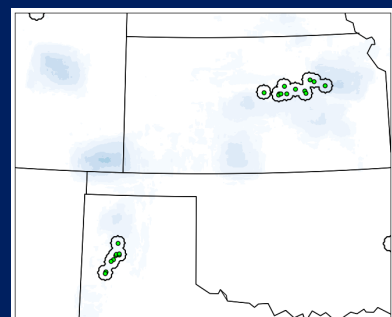
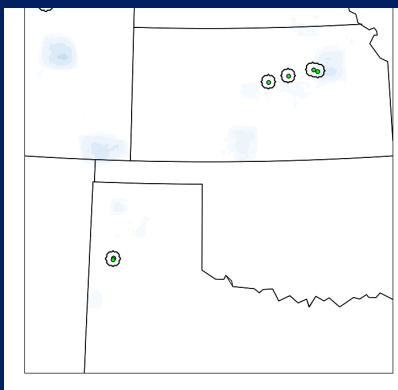
All



PS  
Only

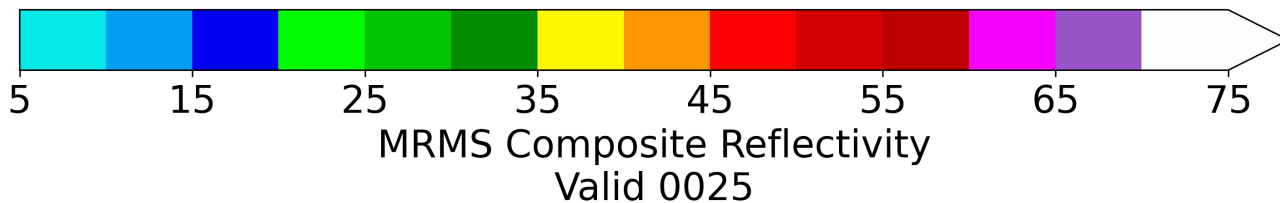
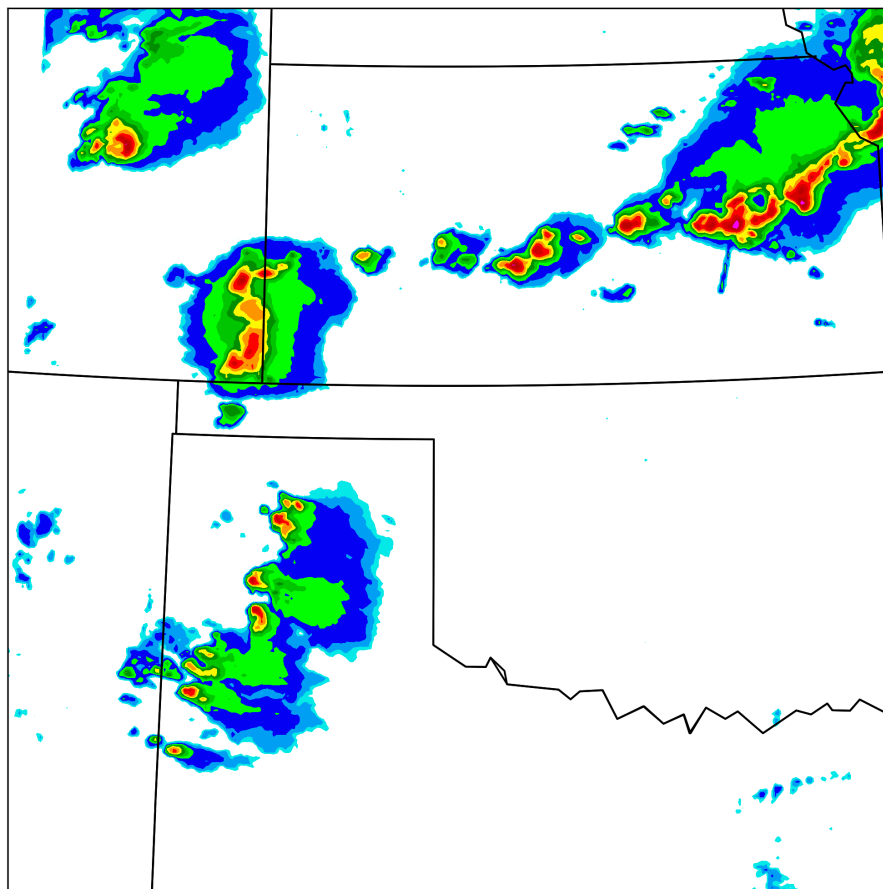


WoFS  
Only





# 0025 UTC 7 May 2019



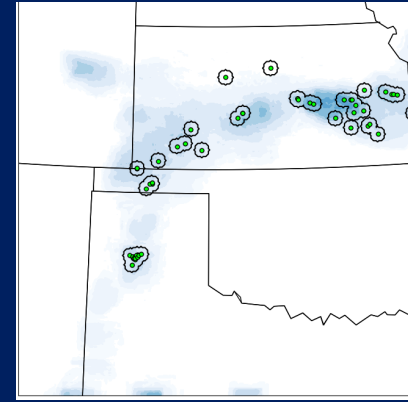
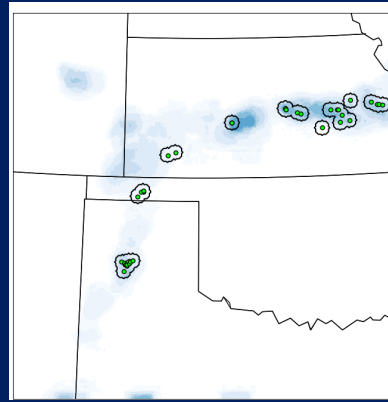
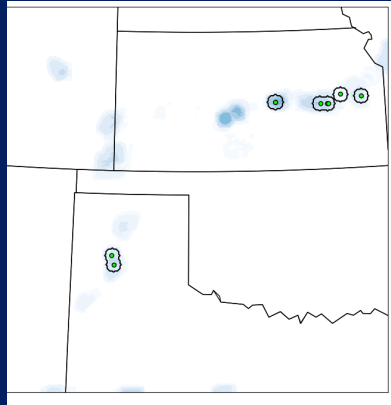
# 0000 UTC Initialization 7 May 2019

30 min

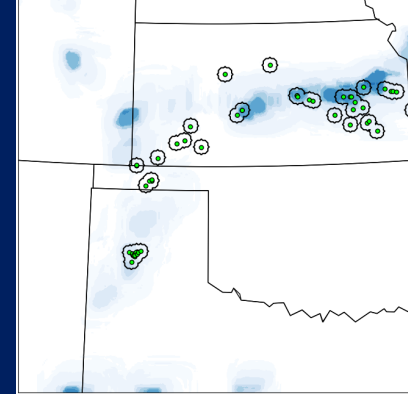
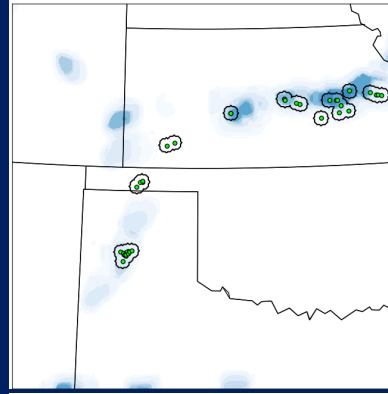
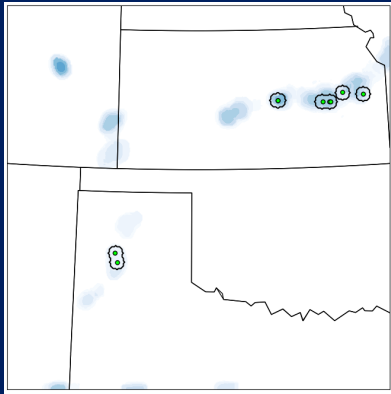
90 min

180 min

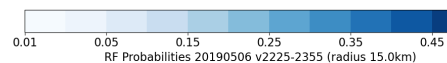
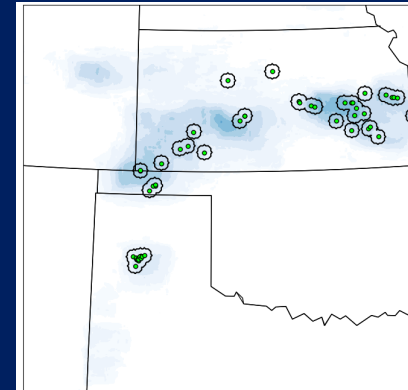
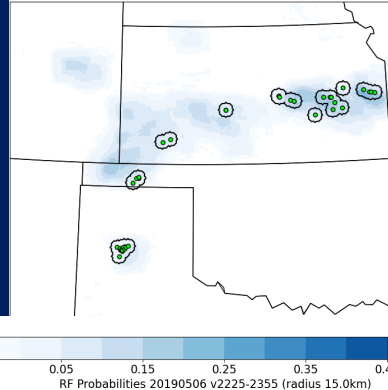
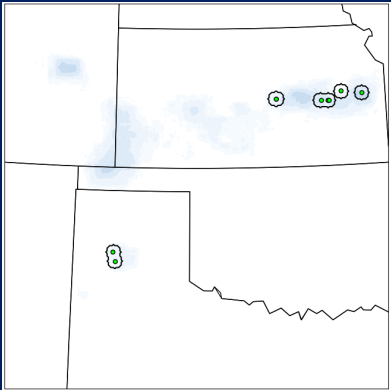
All



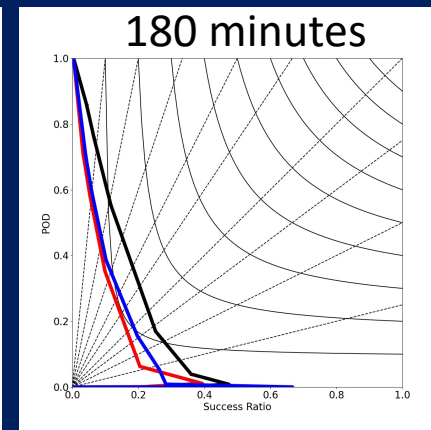
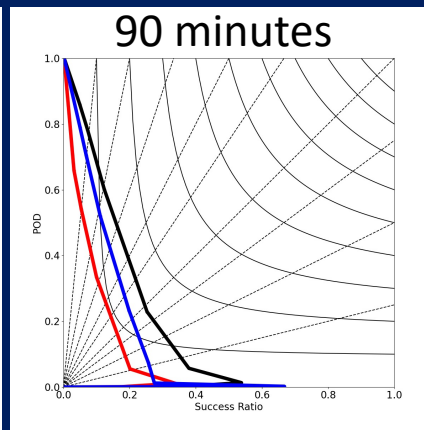
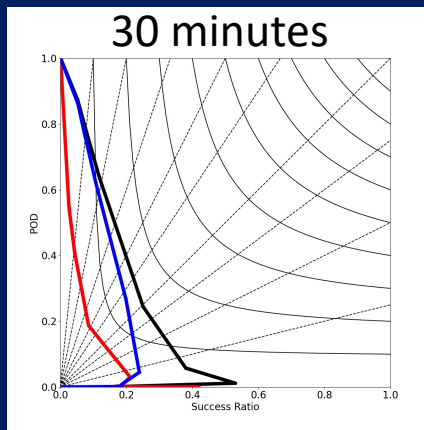
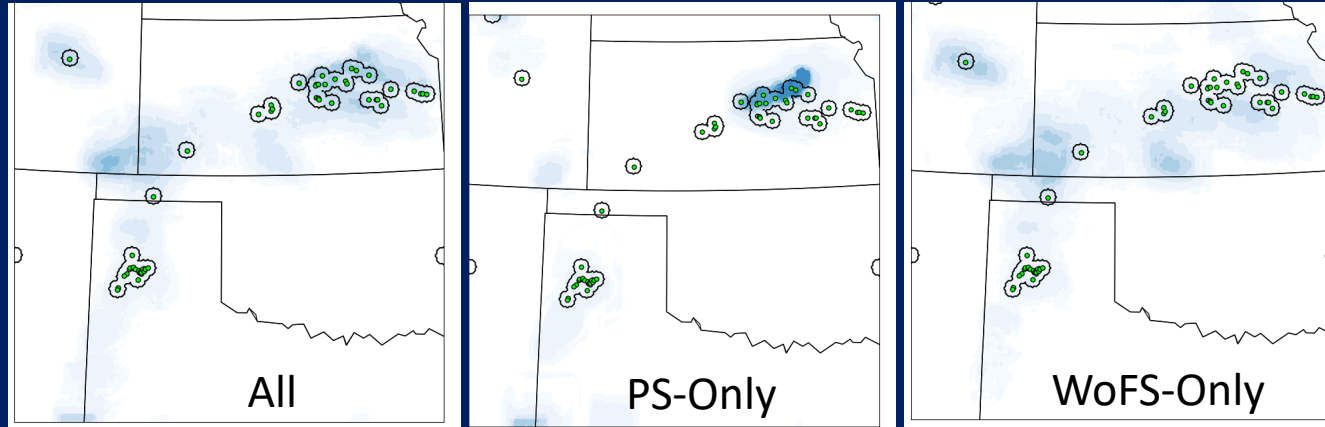
PS  
Only



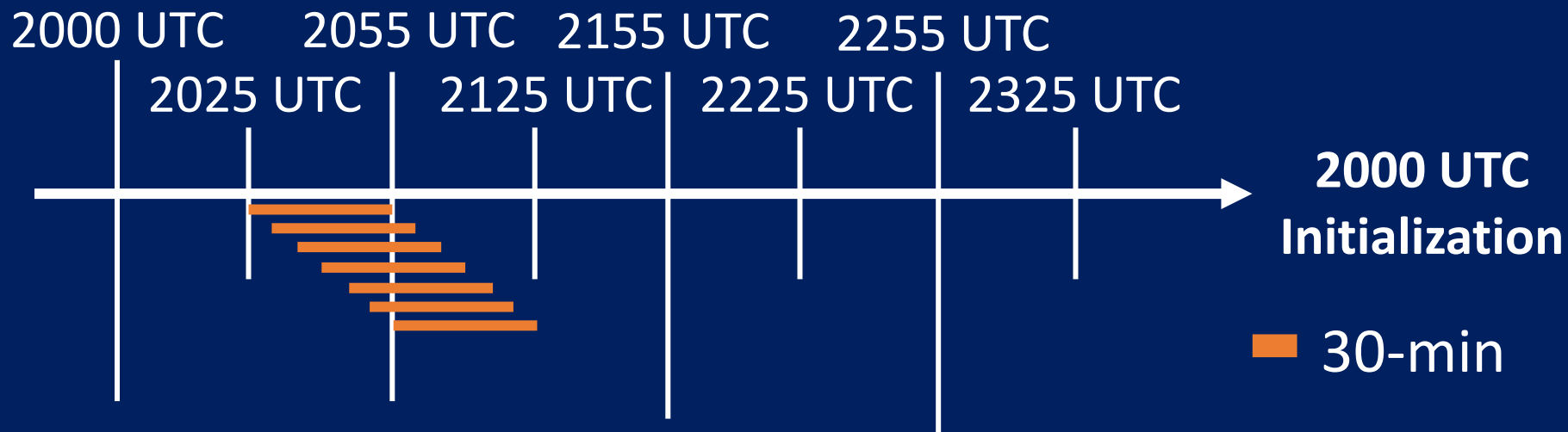
WoFS  
Only



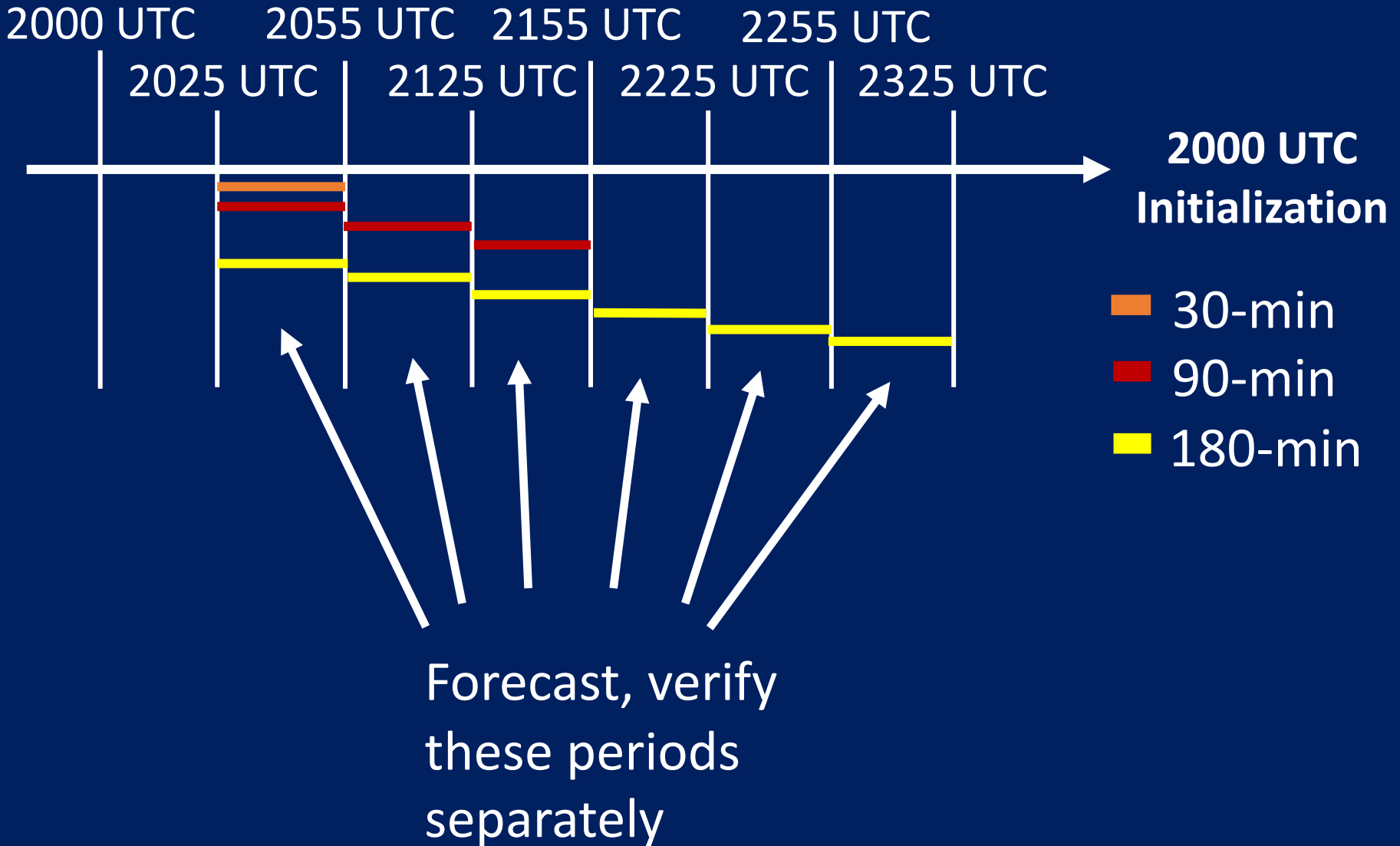
# WoFS + PS combination is best, especially for longer time windows



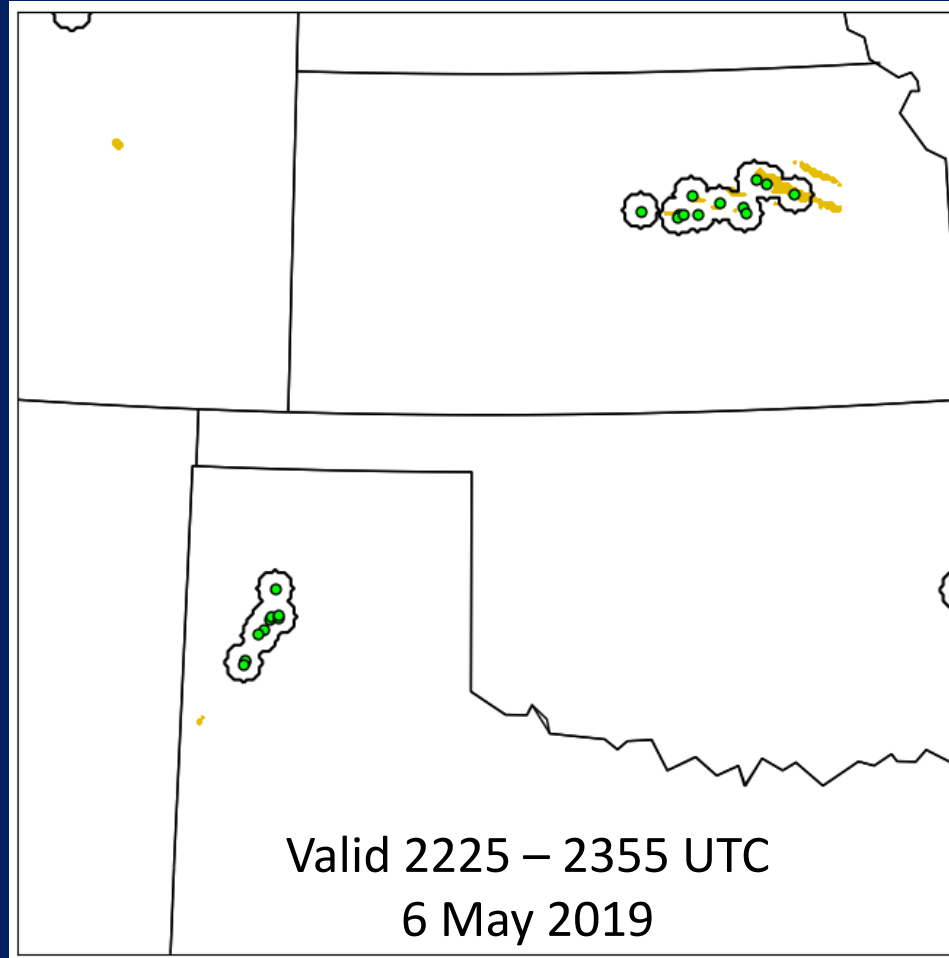
# Future: Sliding 30-min prediction windows



# Future: Segment time windows by lead time

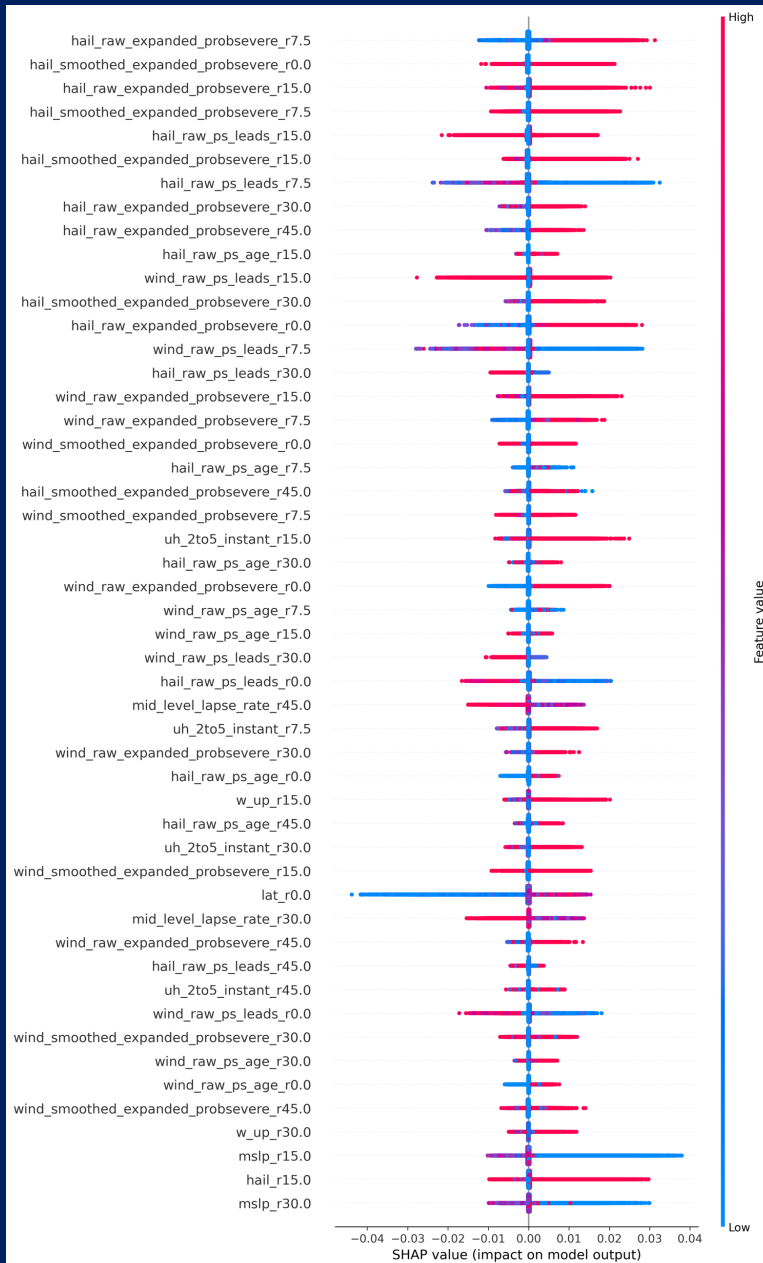


# Future: Test impact of MRMS variables (e.g., MESH) as targets



■ MESH > 1"

# Future: Variable importance



Which variables are most important?

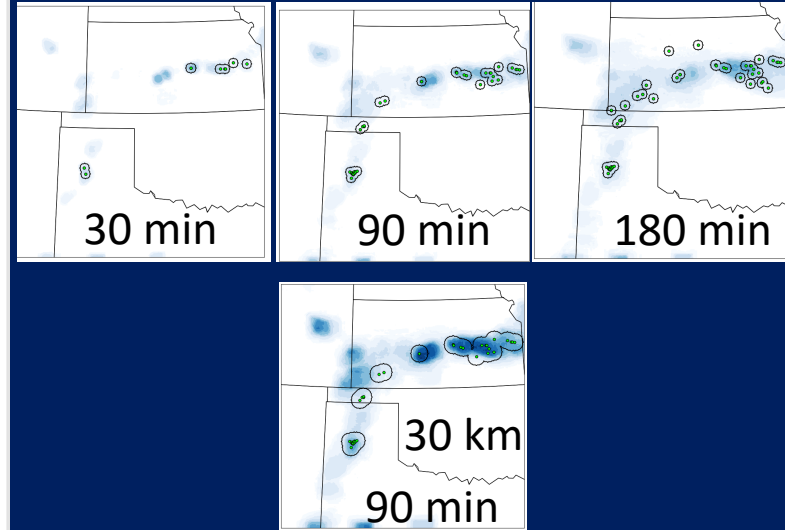
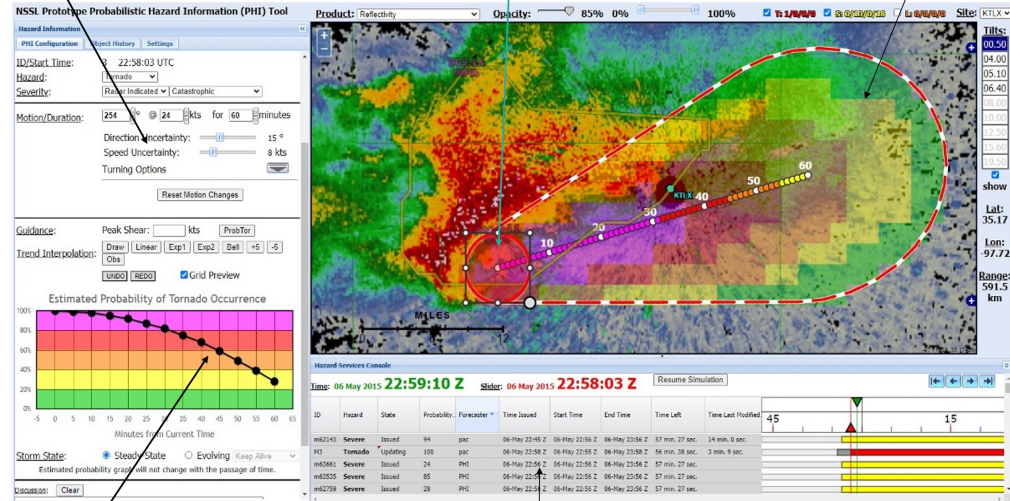
How do variables impact RF probabilities?

# Future: Incorporate into PHI Tool, Test Multiple Versions in HWT

Object characteristics

Hazard-storm object  
(automated or user created)

Hazard Strike Probabilities



Hazard Strike Probabilities

List of all hazards

Environ/radar controls

