The development, evaluation and applications of CPC Week 2-4 excessive heat forecast tools and services

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Week 3-4 Seminar Series
December 6, 2021

Outline

- ✔ Project background, overview and objectives
- ✔ Extended-range (Week-2) products, methods and evaluation
- ✔ Subseasonal (Week 3-4) products, methods and evaluation
- ✔ Additional services and applications

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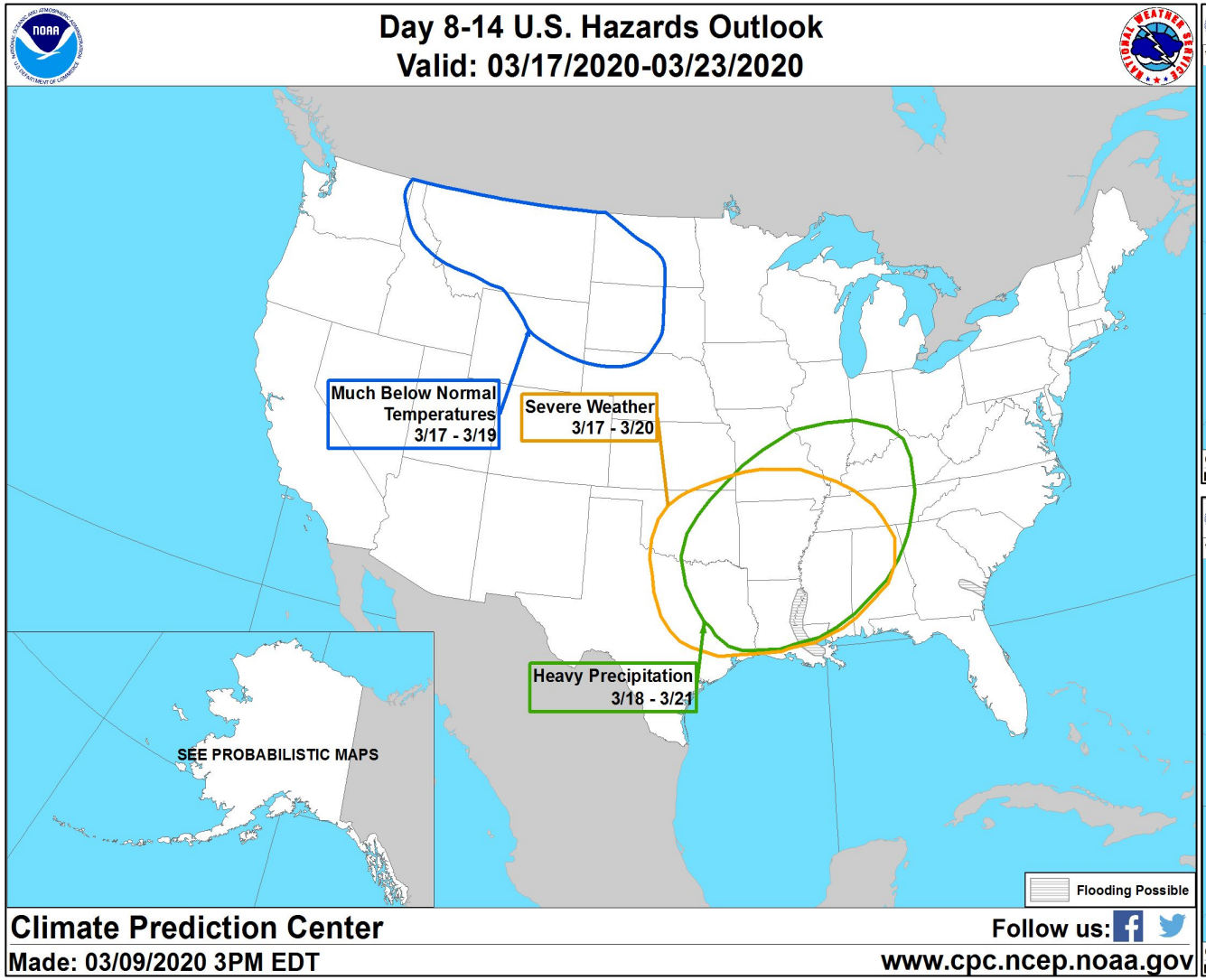
Background

CPC releases a Week 2 U.S. Hazards Outlook that highlights potential hazardous events related to temperature, precipitation and wind – including “excessive or extreme heat” events

The goals of the ongoing project have been to:

- ✔ Develop and operationally implement improved Week 2 dynamical model based forecast guidance products and information to inform extreme heat potential for the Week 2 U.S. Hazards Outlook
- ✔ Utilize Week 2 excessive heat forecasts and information to enhance IDSS at an increased forecast lead consistent with the recently developed U.S. Hazards probabilistic framework, and
- ✔
- ✔ Explore and apply statistical and hybrid methodologies to support the development of experimental Week 3-4 forecast tools targeting extreme heat

Overview


Day 8-14 U.S. Hazards Outlook
Valid: 03/17/2020-03/23/2020
Much Below Normal Temperatures 3/17 - 3/19
Severe Weather 3/17 - 3/20
Heavy Precipitation 3/18 - 3/21
SEE PROBABILISTIC MAPS
Flooding Possible
Climate Prediction Center
Made: 03/09/2020 3PM EDT
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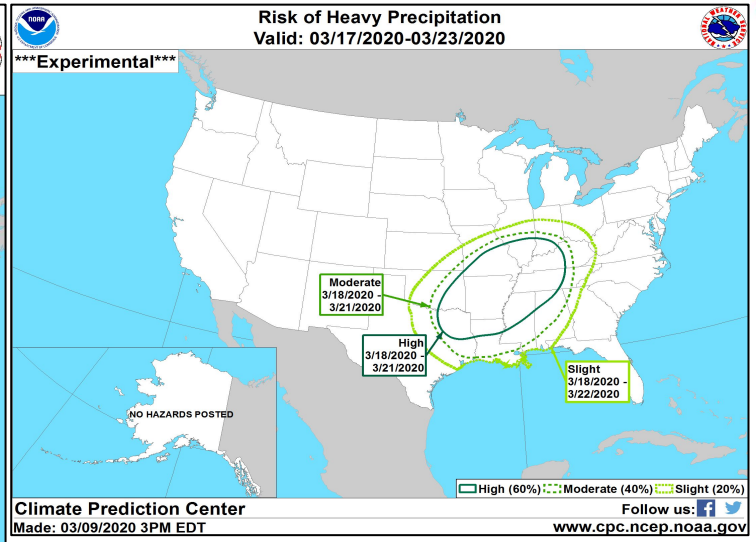
Risk of Heavy Precipitation
Valid: 03/17/2020-03/23/2020
Experimental
Moderate 3/18/2020 - 3/21/2020
High 3/18/2020 - 3/21/2020
Slight 3/18/2020 - 3/22/2020
NO HAZARDS POSTED
High (60%) Moderate (40%) Slight (20%)
Climate Prediction Center
Made: 03/09/2020 3PM EDT
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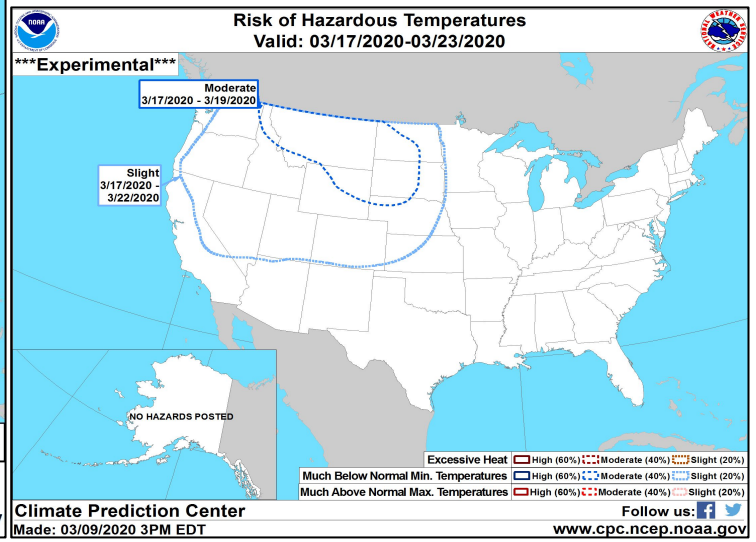
Risk of Hazardous Temperatures
Valid: 03/17/2020-03/23/2020
Experimental
Moderate 3/17/2020 - 3/19/2020
Slight 3/17/2020 - 3/22/2020
NO HAZARDS POSTED
Excessive Heat High (60%) Moderate (40%) Slight (20%)
Much Below Normal Min. Temperatures High (60%) Moderate (40%) Slight (20%)
Much Above Normal Max. Temperatures High (60%) Moderate (40%) Slight (20%)
Climate Prediction Center
Made: 03/09/2020 3PM EDT
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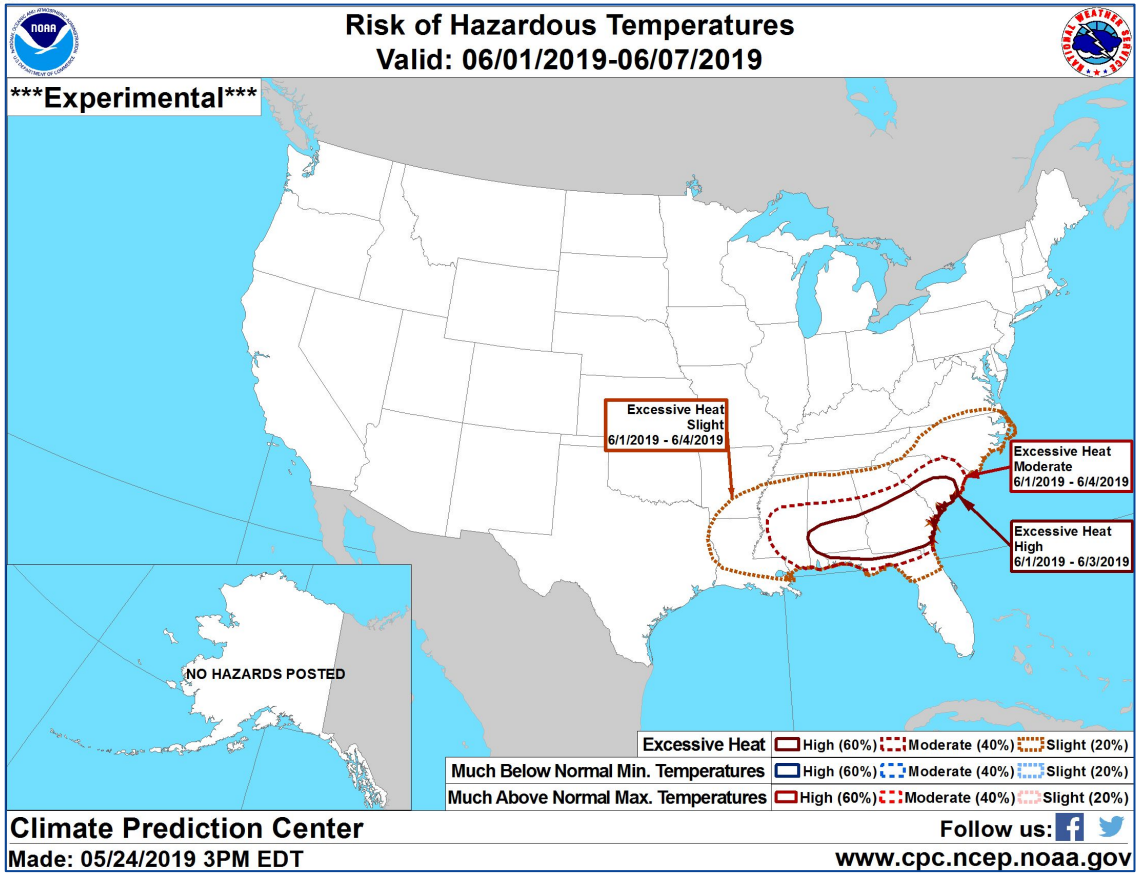
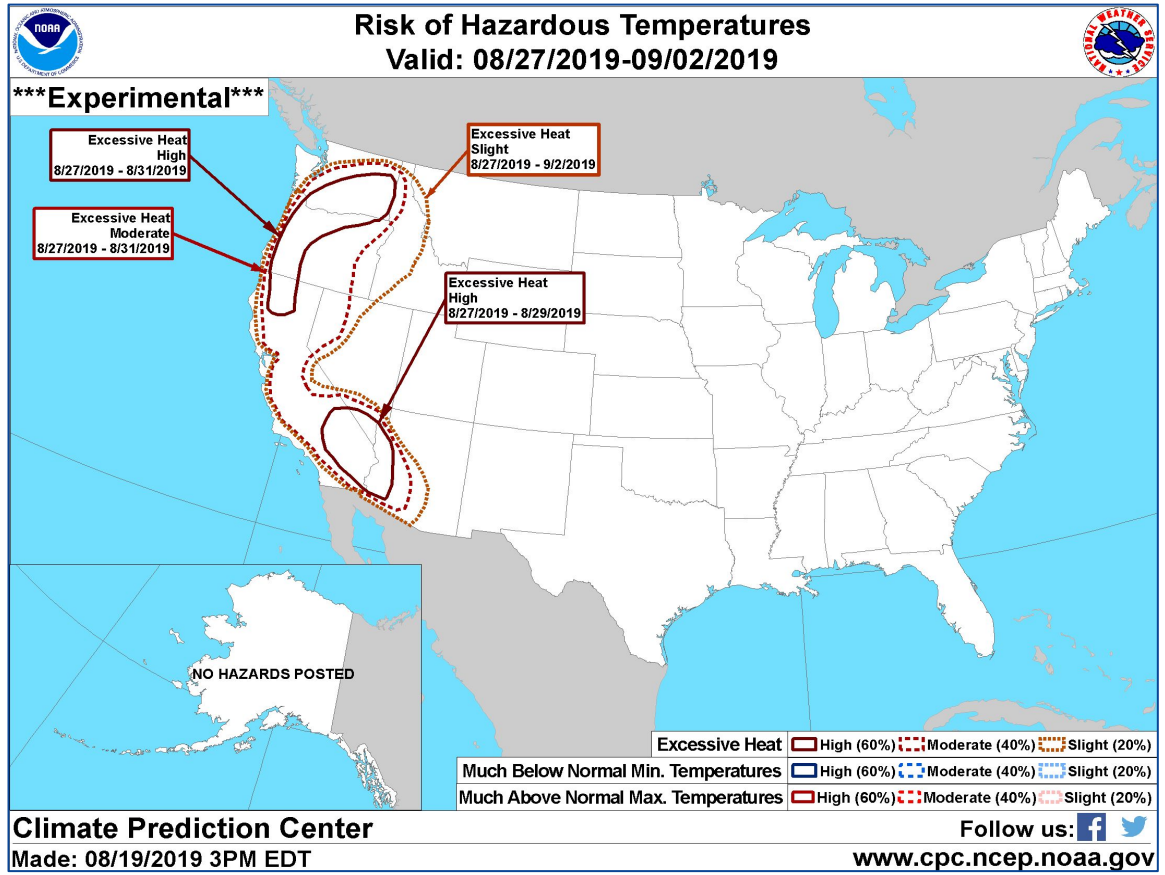
Overview





- ✔ Example Week 2 U.S. Hazards outlook maps highlighting extreme heat events
- ✔ Pathways and evolution of extreme heat episodes vary considerably across the U.S.

Objective

- ✔ The project addresses some of the key target areas outlined in the "Weather Research and Forecasting Innovation Act of 2017"

  (1) Extending outlooks of extreme events further into the subseasonal time scale and,
  (2) Applied research targeting extreme heat events

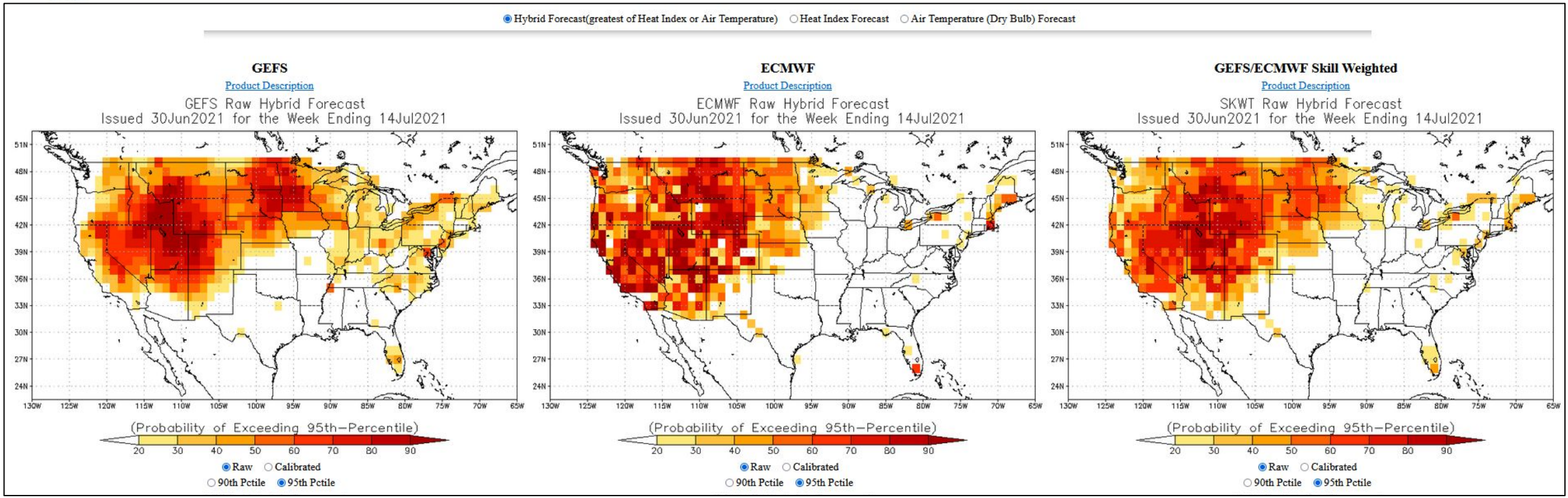
- ✔ Recommendation from the White House Office of Science and Technology Policy (OSTP) for NOAA / NWS / STI to fund a group of Week 2-4 related projects in the late 2010's (including this work)
- ✔ The primary benefit to stakeholders is continued advancement of lead time for decision making ahead of extreme heat episodes that affect nearly all aspects of daily life for many sectors including health, agriculture and energy, among others.

- ✔ Project background, overview and objectives
- ✔ **Extended-range (Week-2) products, methods and evaluation**
- ✔ Subseasonal (Week 3-4) products, methods and evaluation
- ✔ Additional services and applications

Week 2 Forecast Products

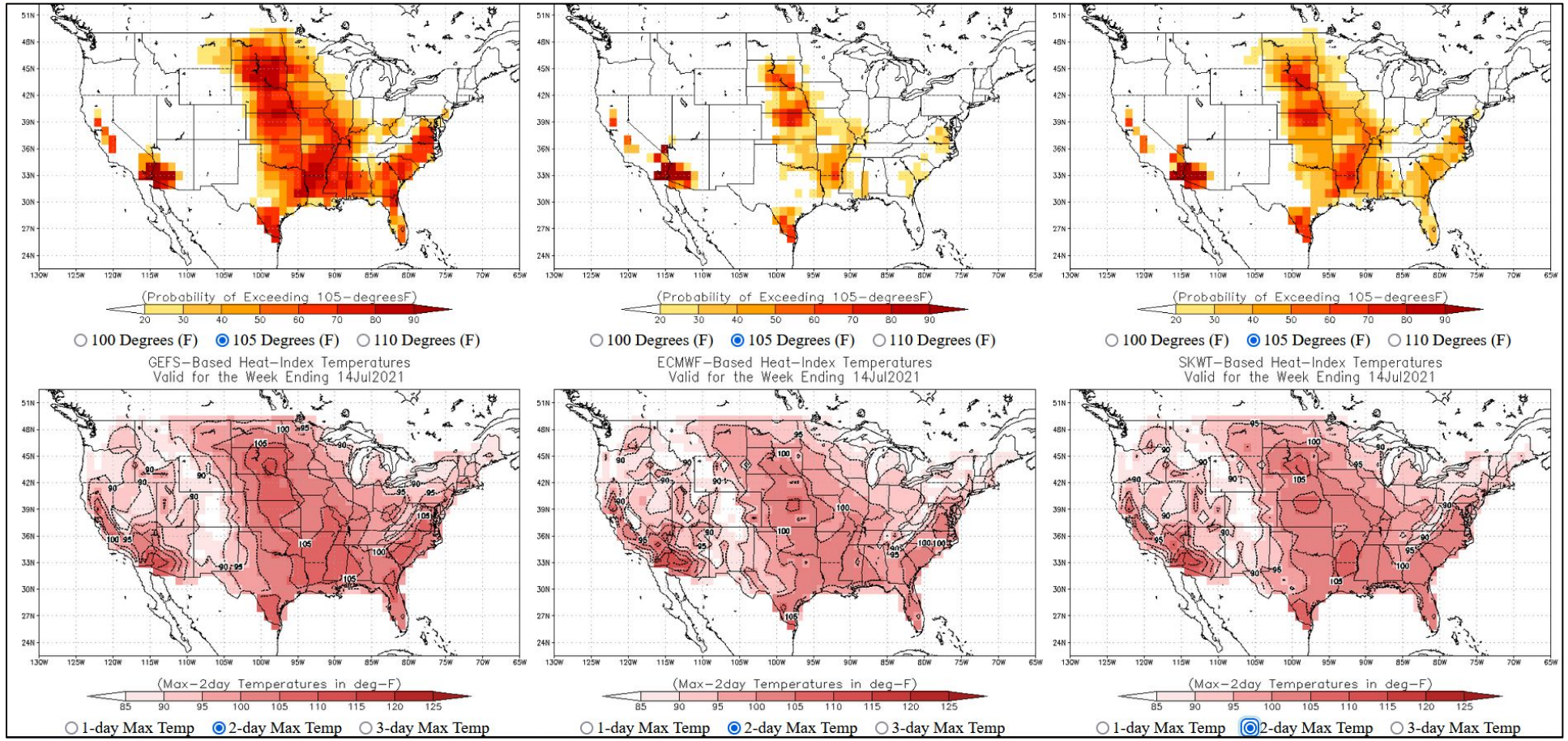
- ✔ Extreme heat event is defined as a period of 2 or more consecutive days in the Week 2 period (Days 8-14) with an extreme heat day represented by the criteria listed below:
  - ✔ **90th percentile of daily maximum air temperature or heat index (first intensity level)**
  - ✔ **95th percentile of daily maximum air temperature or heat index (second intensity level)**
- ✔ Systematic error removed through standard bias correction utilizing available dynamical model reforecasts. Bias correction is a function of time of year and geography.
- ✔ Additional calibration is conducted based on historical reforecast skill which is also dynamic in space and time.
- ✔ Pooling of data spatially and temporally to improve statistical robustness is part of both systematic bias correction and calibration steps.

Week 2 Forecast Products



- ✔ Dynamical model guidance products from the GEFS (**left**) and ECMWF (**center**) ensemble prediction systems
- ✔ Objective, historical skill weighted consolidation of both the GEFS and ECMWF forecasts (**right**)
- ✔ Raw and reforecast calibrated probabilities for the 90th and 95th percentiles available

Week 2 Forecast Products



- ✔ Probabilities of exceeding various heat index thresholds (100F, 105F and 110F) for the GEFS, ECMWF and skill weighted combination (**top row**)
- ✔ Maximum heat index temperatures for 1-day, 2-day and 3-day periods for the GEFS, ECMWF and skill weighted combination (**bottom row**)

Week 2 Forecast Products

Model	AUC-ROC		Max SEDI	
	Reforecast	Summer 2020	Reforecast	Summer 2020
GEFS Only	0.64	0.58	0.30	0.21
ECMWF Only	0.67	0.59	0.34	0.21
ECMWF-GEFS (Equal Weighted)	0.67	0.59	0.31	0.21
ECMWF-GEFS (Skill Weighted)	0.68	0.63	0.38	0.27

AUC-ROC: Area Under Curve - Receiver Operating Characteristic (ranges from 0 to 1)
Max SEDI: Maximum Symmetrical Extremal Dependence Index (ranges from -1 to +1)

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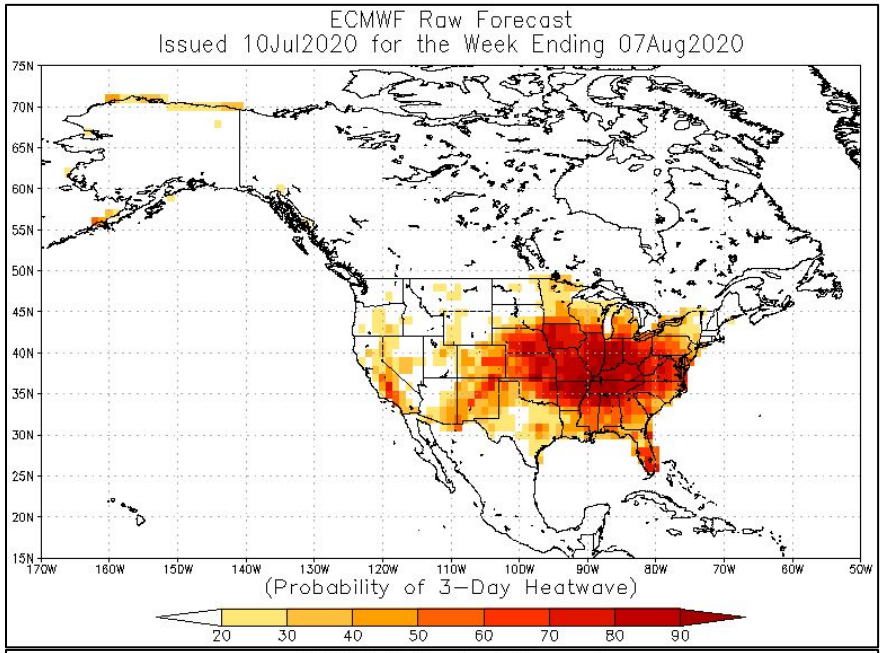
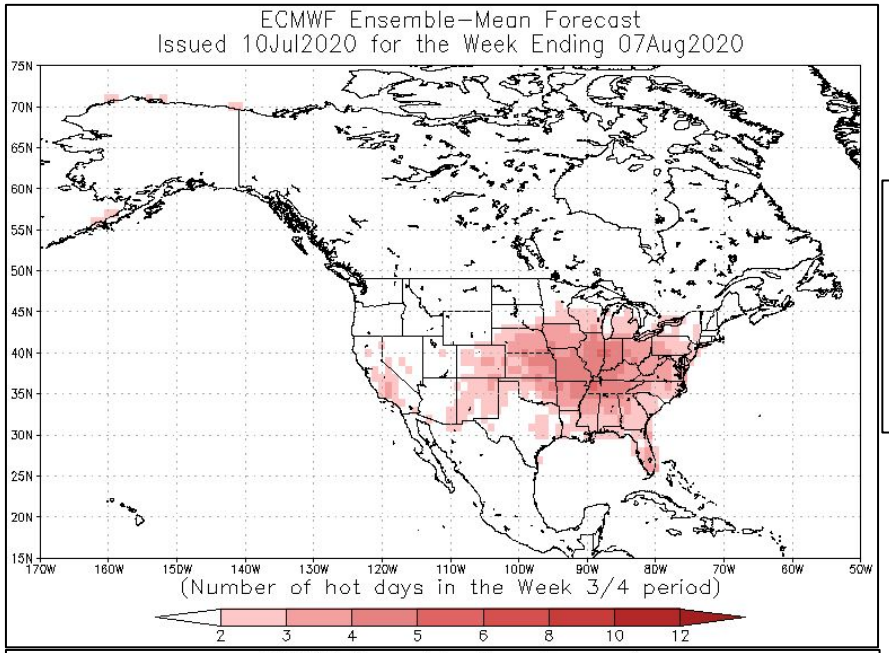
Week 3-4 Forecast Products

- ✔ For the subseasonal timescale, it is necessary to explore statistical and hybrid (statistical-dynamical) approaches as purely dynamical model guidance forecast skill decreases
- ✔ Use dynamical model guidance forecast products as benchmarks for statistical and hybrid methods. Utilize forecast data from the CFS, ECMWF and recent GEFS extended duration model predictions.
- ✔ Bias correction and calibration is similar to that described for Week 2 products

Week 3-4 Forecast Products

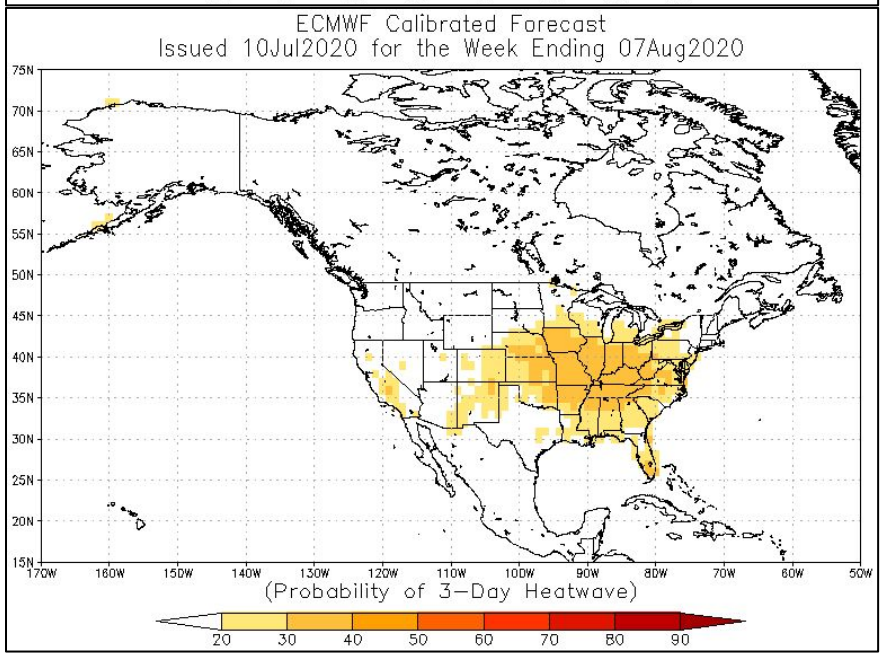
Probability of 3-day heatwave (raw)

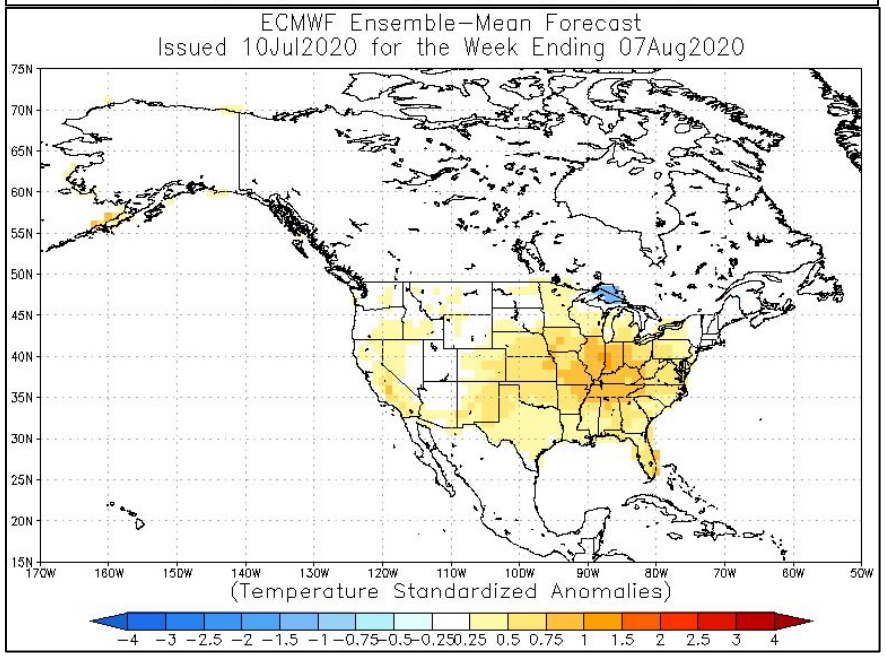




Number of extreme heat days (ensemble mean)

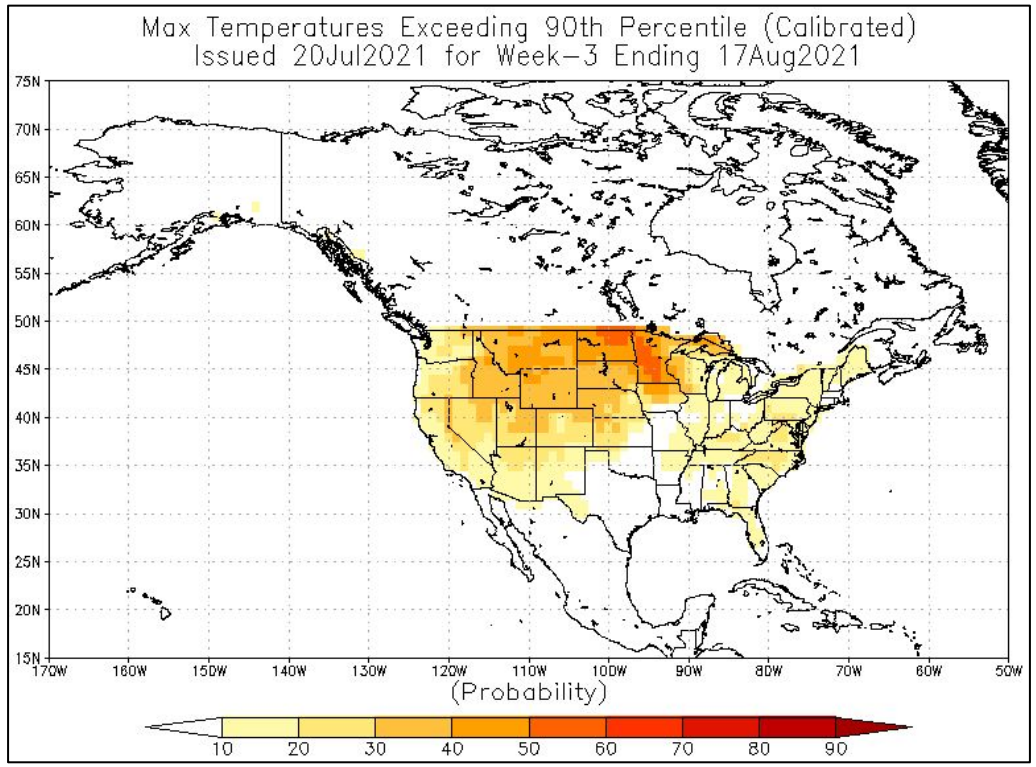
Probability of 3-day heatwave (calibrated)

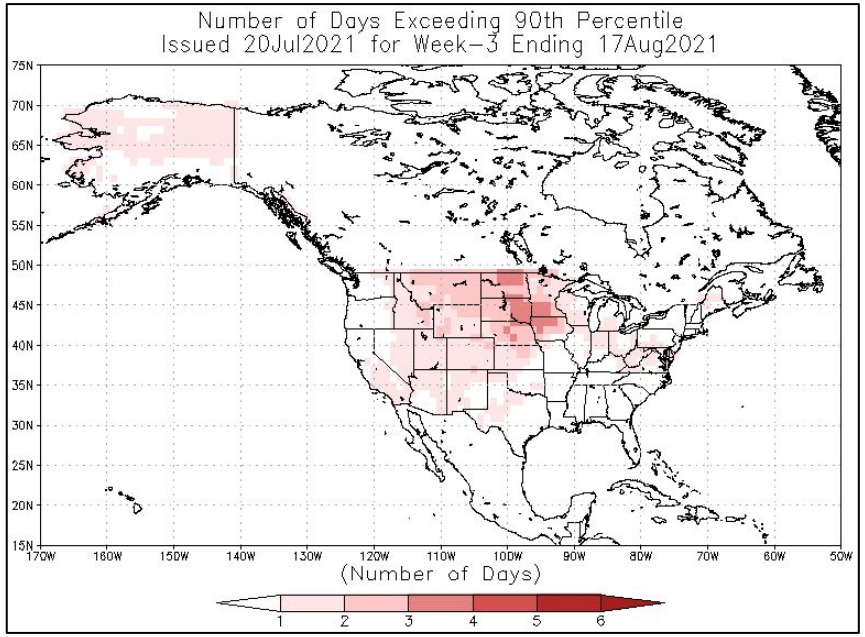


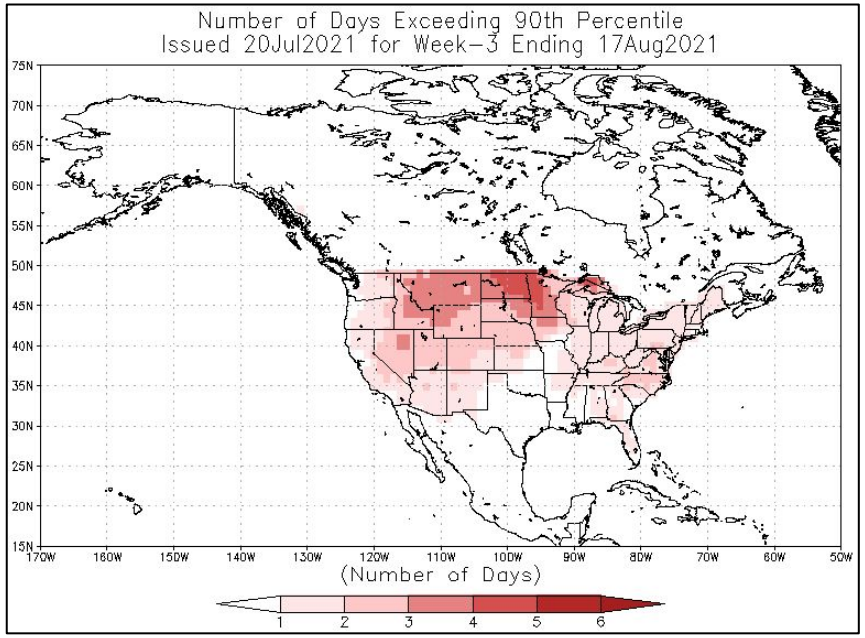


Week 3-4 standardized anomaly (ensemble mean)

Week 3-4 Forecast Products





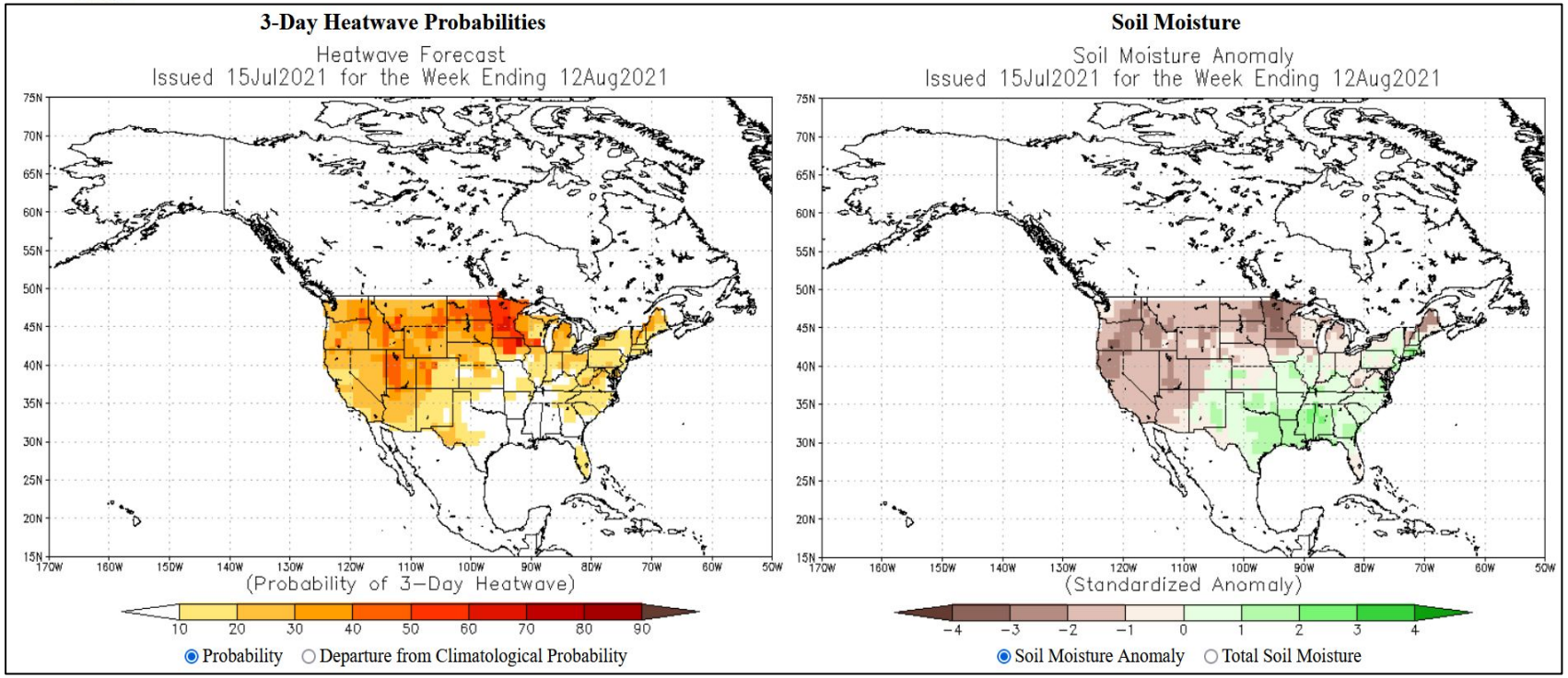


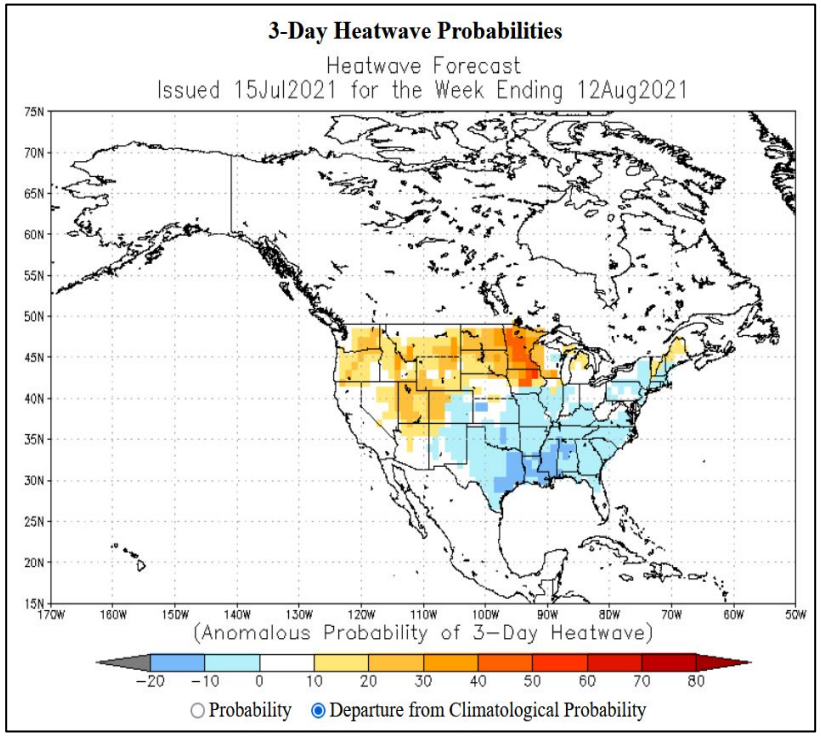
Calibrated probabilities of the 7-day Week 3 average daily air temperature exceeding the 90th percentile from a GEFS forecast (**above**).

The number of extreme heat days during Week 3 only of daily air temperature exceeding the 90th percentile from the ECMWF (**right top**) and the GEFS (**right below**) forecasts.

Week 3-4 Forecast Products

Soil moisture based Week 3-4 forecast tool





- ✔ Substantial deficits in soil moisture have the ability to enhance high temperatures (all other factors being equal)
- ✔ Persistence of soil moisture anomaly (~ 20-23 days for 0.50 autocorrelation)
- ✔ Forecast tool utilizes CPC internal soil moisture data through an historical lag-relationship model as follows:
  - **18-day lag, 2-week period corresponding to the Week 3-4 target period**
  - **3 or more days at or above the 92.5 percentile of daily maximum air temperature**
  - **Goal is to tap potential regional areas of forecast skill (*i.e.*, Plains, Corn Belt, etc.)**

Week 3-4 Forecast Products

- ✔ Realtime forecast skill for the summer of 2021 for the Week 3-4 period
- ✔ Prediction for 3 or more extreme heat days in 2-week period
- ✔ Extreme heat day defined as the 92.5th percentile of daily mean temperature

	AUC-ROC 0 to 1	Max. Sedi -1 to +1
CFS (dynamical)	0.61-0.62 (22-24%)	0.27-0.31 (27-31%)
GEFSv12 (dynamical)	**0.66-0.72 (32-44%)**	**0.32-0.48 (32-48%)**
ECMWF (dynamical)	0.62-0.65 (24-30%)	0.32-0.33 (32-33%)
Soil Moisture (statistical)	0.64-0.66 (28-32%)	0.24-0.28 (24-28%)

- ✔ Project background, overview and objectives
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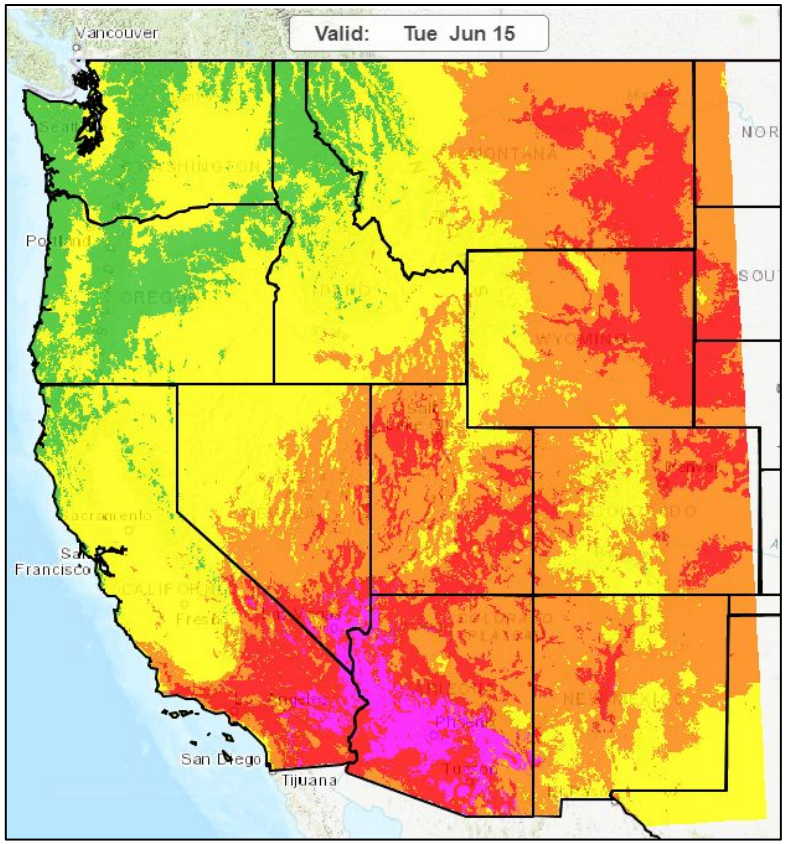
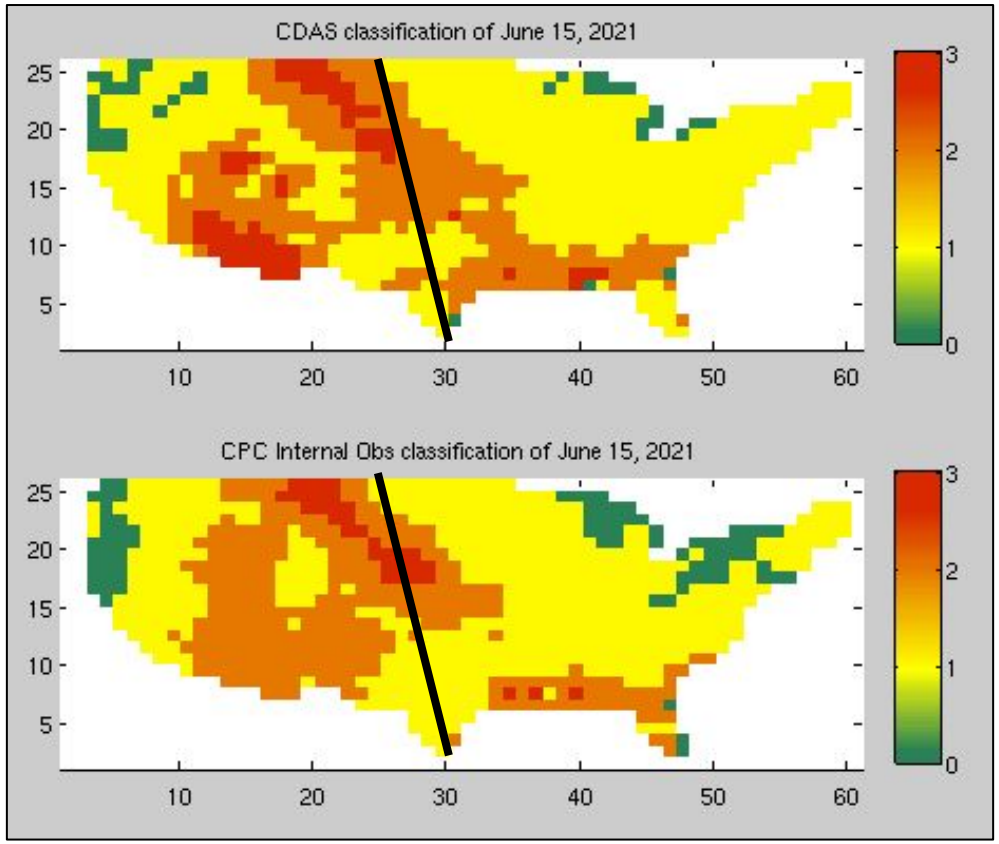
Additional Services and Applications

- ✔ Experimental inclusion of NWS Western Region Heatrisk methodology as part of CPC monitoring and prediction extreme heat product suite
- ✔ Used CPC standard climate observational datasets to develop experimental "analysis" products that highlight HeatRisk categories (*i.e.*, green, yellow, orange, and red)

HeatRisk





CDAS

CPC

Additional Services and Applications

- ✔ Applied HeatRisk system in a prediction framework for the Week 2 period
- ✔ Utilized framework for both GEFS and ECMWF Week 2 model guidance
- ✔ Produced probabilistic forecast products for:
  - **Chance of consecutive orange/red level dates during Week 2 period**
  - **Chance of any red level dates during Week 2 period**
  - **Chance of consecutive red level dates during Week 2 period**

Additional Services and Applications

- ✔ CPC participated in the Urban Heat Island (UHI) mapping campaign during summer 2021
- ✔ Evan Oswald was contributor from CPC as part of this effort which included WPC

Urban Heat Island Forecast Outlook from WPC and CPC

Note: This is a general outlook based primarily on large-scale conditions and data from official forecast products. Please follow up with a local forecast office for more detailed questions and information.

For the Day 3-7 Outlook, temperature forecasts will be highlighted green if they exceed the 90th percentile for that location (1991-2020). The "other" box will be checked and highlighted green if light winds, limited cloud cover, and no or low rain chances are expected. *(Provided by WPC)*

For Week 2-3 Outlooks, the boxes will be checked green for increased chances of hot weather, for increased chances of less rainfall, and for increased chances of weaker winds. *(Provided by CPC)*

UHI Campaign City Location	Forecast Site	90th Pct Temp	SAT Jul 10		SUN Jul 11		MON Jul 12		TUE Jul 13		WED Jul 14		Week 2 Outlook Jul 15 - Jul 21			Week 3 Outlook Jul 22 - Jul 28	
			Temp	Other	Temp	Other	Temp	Other	Temp	Other	Temp	Other	Temp	Less Rain	Less Wind	Temp	Less Rain
Albuquerque, NM	ABQ	93	99	☑	91	☐	91	☐	91	☐	91	☐	☐	☐	☑	☐	☐
Atlanta, GA	ATL	91	87	☐	88	☐	87	☐	88	☐	89	☐	☐	☐	☑	☐	☐
The Bronx and Manhattan, NY	NYC	86	84	☐	82	☐	86	☐	85	☐	87	☐	☑	☐	☑	☐	☐
Brooklyn, NY *Data from the New York Avenue CO-OP site in Brooklyn used as a baseline for 90th percentile; LGA and JFK are situated in Queens*	NY5796	85	83	☐	81	☐	85	☐	84	☐	86	☐	☑	☐	☑	☐	☐
Charleston, SC	CHS	92	91	☐	89	☐	90	☐	90	☐	91	☐	☐	☐	☑	☐	☐
Charlottesville, VA	CHO	89	86	☐	86	☐	88	☐	89	☐	89	☑	☑	☐	☐	☐	☐
Kansas City, MO	MCI	89	82	☐	79	☐	83	☐	88	☑	90	☑	☐	☐	☐	☐	☐
Clarksville, IN *Using Louisville, KY as the forecast location because it is right across the Ohio River and is the closest major observation*	SDF	90	84	☐	84	☐	84	☐	87	☐	89	☑	☐	☐	☐	☐	☐
Richmond, IN *For the 90th percentile used the East-Central Climate Division averages as there was not a close major observation*	INC006	86	80	☐	80	☐	80	☐	83	☐	85	☑	☐	☐	☐	☐	☐

Summary

✔ CPC has developed Week 2 dynamical model forecast guidance products and information targeting extreme heat to inform the CPC operational Week 2 U.S. Hazards Outlook. GEFS and ECMWF based products are available.

✔ For the Week 3-4 forecast period, CPC has developed experimental dynamical, statistical and hybrid based forecast tools to assess the potential for extreme heat periods at this forecast horizon.

✔Considerable work remains to finalize forecast skill conclusions and exploration continues with statistical / hybrid type methods to compare with dynamical model benchmarks.

✔ CPC will continue to include the NWS HeatRisk paradigm into the CPC Week 2 extreme heat experimental product suite.

Thank you for your time and attention

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