Enhancing Resilience to Heat Extremes: Forecasting Excessive Heat Events at Subseasonal Lead Times (Week-2 to 4)

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NOAA/NWS/NCEP/CPC

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Outline:

- Defining Heat Events
- Monitoring/Forecasting Heat Events
- Preliminary forecast verification & multi-model approaches
- Realtime forecasting during summer 2016
- Summary and ongoing work

Heat kills: Excessive Heat results to more fatalities than any other atmospheric hazard:

From 1986 to 2015 the annual mean fatalities over the United States:

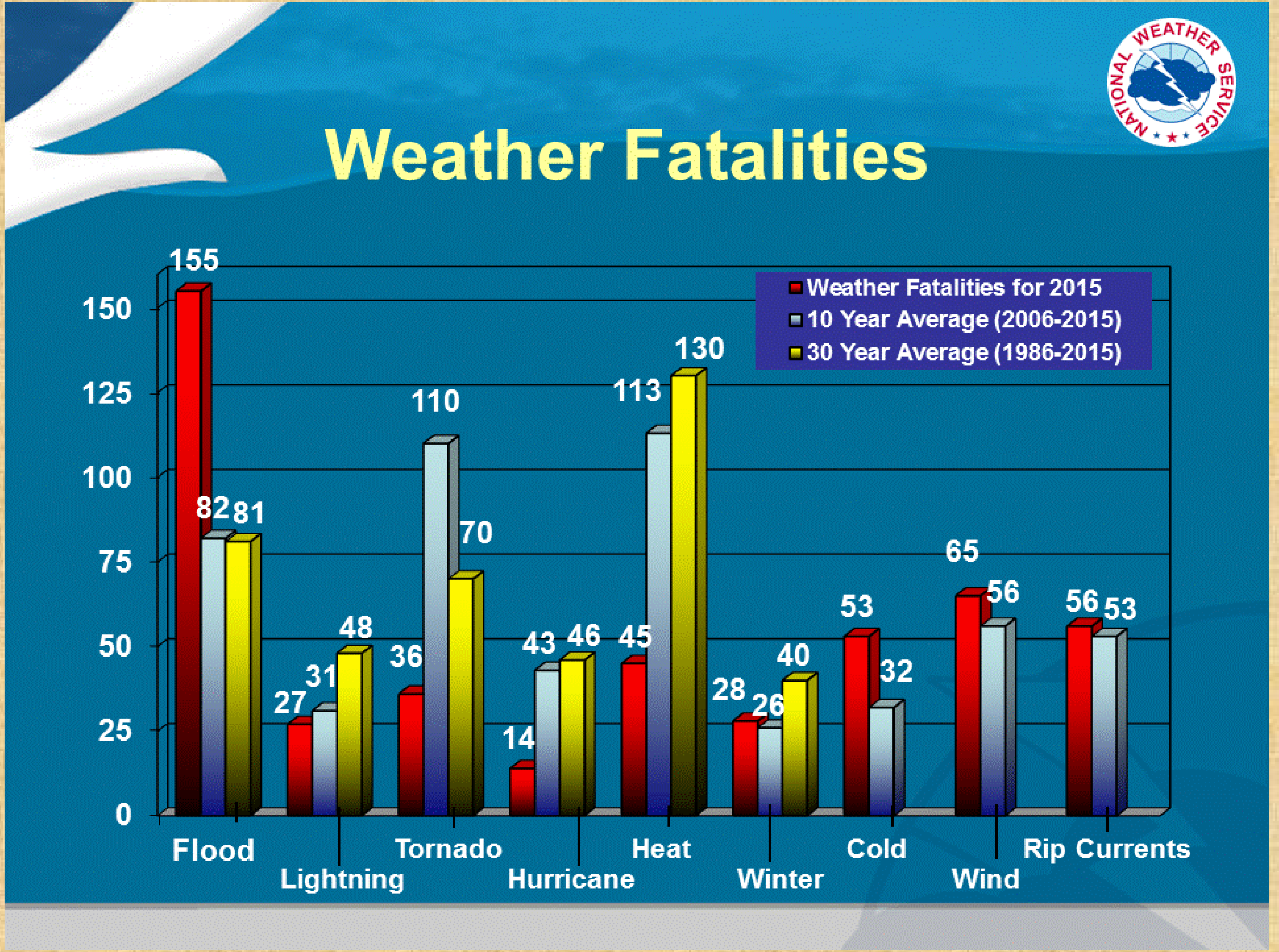
Heat = 130

Flood = 81

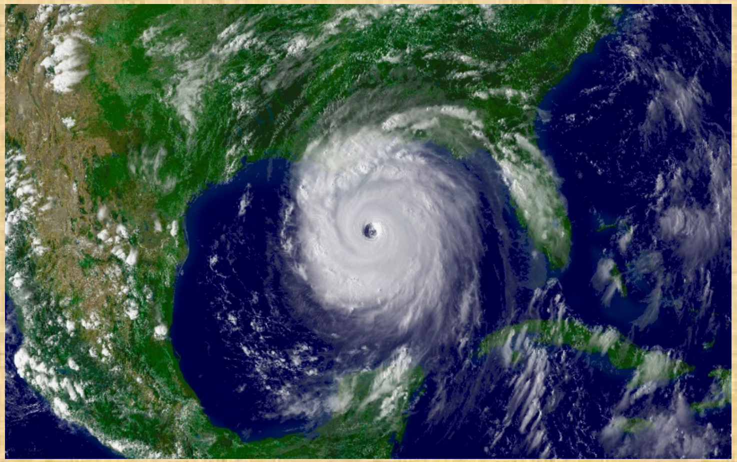
Tornado = 70

Lightning = 48

Hurricane = 46



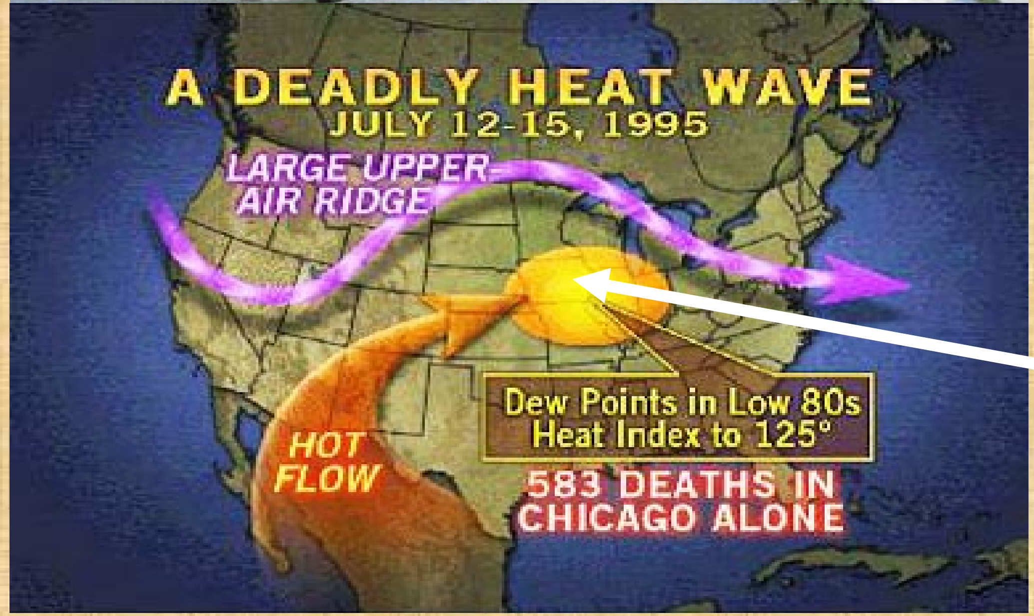
Heat kills: Excessive Heat is an invisible killer



Visualization from an extreme heat wave that occurred in India on May 2015

Quantification of Heat Events is a necessary step before forecasting…

Heat kills: The example of the July 1995 Heat Event



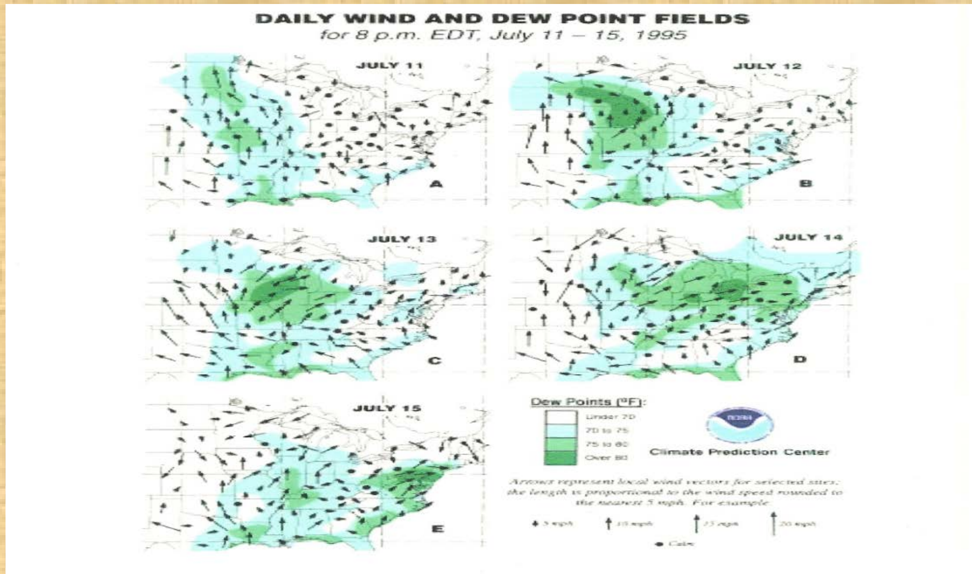
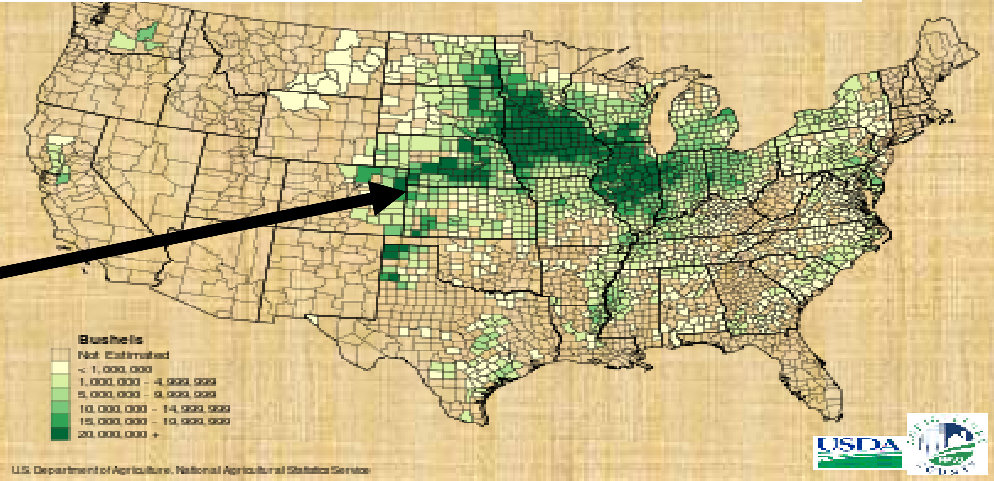


Figure 4. Early evening surface winds and water vapor contents (in terms of dew points in °F) for 5 consecutive days in mid-July 1995 at locations throughout the eastern United States. The former are generally light in the Midwest and Northeast. Values of the latter in excess of 75°F (green shades) can be considered unusually high.

10

From the NOAA study of the event (published December 1995)

The Corn Belt

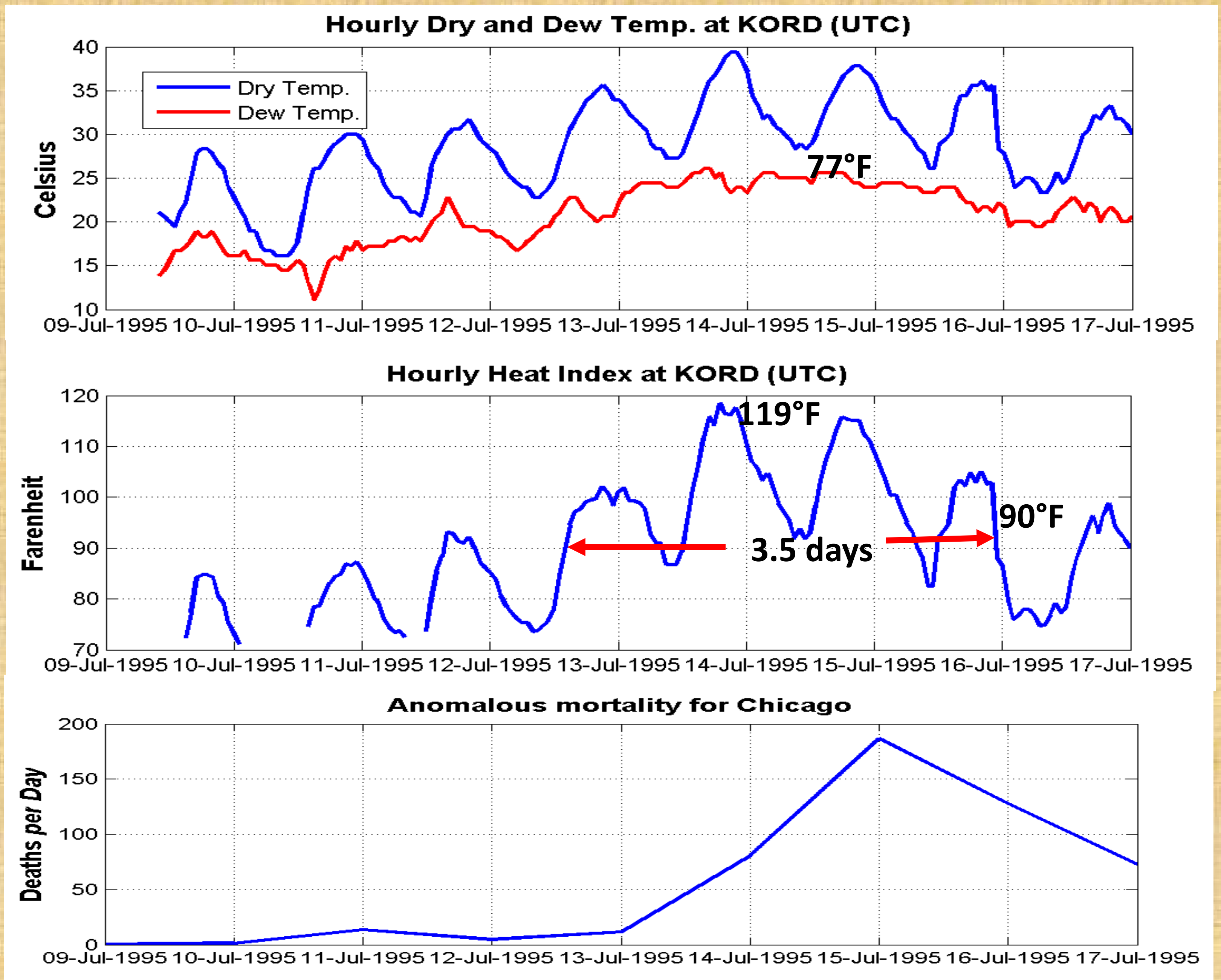


The Chicago July 1995 event (METAR from O'Hare airport; mortality courtesy of Sheridan)

Dry Temperature and Dew point

Heat Index

Abnormal Mortality



Dry temperature anomalies were high but within the 35-40°C range. However the dew point was very elevated

The resulting Heat Index remained over 90°F for over 3 days with maximum reaching 119°F (49°C !!)

Abnormal mortality started increasing at the beginning of the heatwave reaching a maximum 2.5 days after

Heat kills: Heat warnings depend on the geographical location

Las Vegas, Nevada
2 consecutive days
Max: 115F-121F
Min: 75-85

Excessive Heat Warning

URGENT - WEATHER MESSAGE
NATIONAL WEATHER SERVICE LAS VEGAS NV
346 AM PDT WED JUN 1 2016

...EXCESSIVE HEAT WARNING REMAINS IN EFFECT FROM 10 AM PDT /10 AM MST/ FRIDAY TO 8 PM PDT /8 PM MST/ SUNDAY...

* TEMPERATURE...HIGHS WILL BE 105 TO 110 IN LAS VEGAS AND FOR MUCH OF THE MOJAVE DESERT...110 TO 117 IN THE COLORADO RIVER VALLEY... AND 115 TO 121 IN DEATH VALLEY. LOWS WILL GENERALLY BE 75 TO 85.

Portland, Oregon
2 consecutive days
Max: 95F-105F
Min: 55F-65F

Excessive Heat Warning

URGENT - WEATHER MESSAGE
NATIONAL WEATHER SERVICE PORTLAND OR
509 AM PDT THU AUG 18 2016

...EXCESSIVE HEAT WARNING REMAINS IN EFFECT FROM 2 PM THIS AFTERNOON TO 9 PM PDT SATURDAY

- TIMING: THURSDAY AFTERNOON THROUGH SATURDAY EVENING...WITH FRIDAY BEING THE HOTTEST OF THE THREE DAYS.

* HIGH TEMPERATURE: FROM 95 TO 105.
* LOW TEMPERATURE: UPPER 50S TO UPPER 60S.

Defining excessive heat events (I): Synthesis

Impacts of heat:

- **Grow non-linearly as temperature and humidity increase:** Requirement for using indices that are based on models of the physiological effects of heat on the human body. In this work we use NOAA's *Heat Index*.

- **Increase as a function of their duration:** Requirement for consecutive days with high apparent temperature.

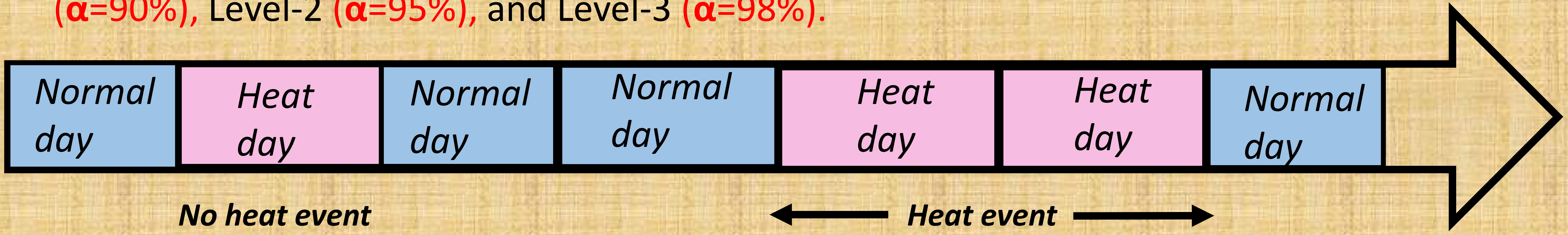
- **Depend on geographical location:** Requirement for a definition of what is high apparent temperature as a function of location.

- **High apparent temperatures are felt differently as a function of time within the warm season due to acclimatization:** Requirement for definition of what is high apparent temperature as function of time within the warm season.

Defining excessive heat events (I)

Based on the above considerations we define heat events using **percentiles of apparent temperature:**

- A Heat Day as a day with Maximum Heat Index exceeding a given percentile **α** of the Cumulative Distribution Function computed from the historical record for the geographical location and time-frame within the warm season.
- A Heat Event as a succession of at least two heat days. We define Heat Events at Level-1 (**α**=90%), Level-2 (**α**=95%), and Level-3 (**α**=98%).



Benefits from this definition: Addressing physiological effects of heat AND challenges of subseasonal ensemble forecasting. Easily extendable to Week-3&4 and seasonal forecasting.

Inconveniences of this definition: Based on expensive reforecasts

Defining excessive heat events based on Reanalysis (CDAS)

Weekly Heat Events. For each grid point:

- A given week is a Heat Week if it contains at least one Heat Event.
- We can define a start day of the heat event within this week
- We can define the duration of this heat event.

Example: The July 1995 Heat Event

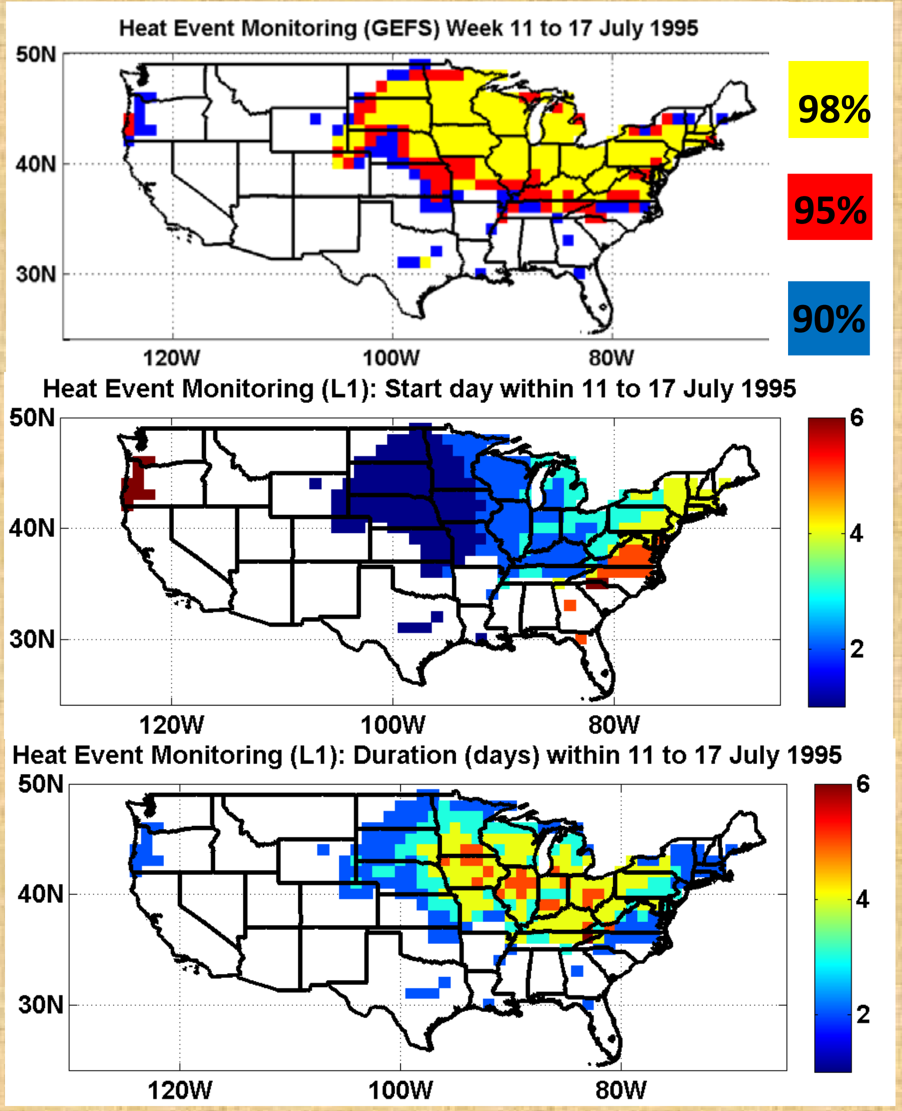
- During the week of 11-17 July 1995 a Level-3 Heat Event (98% - yellow) was covering an extended area from the Upper Midwest to the Northeast and Mid-Atlantic.
- This heat event progressed from west to east during this week.
- The event lasted 5 days (for Level-1 intensity) in the Chicago area.

Description of the July 1995 Heat Event

Occurrence

Start day (90%)

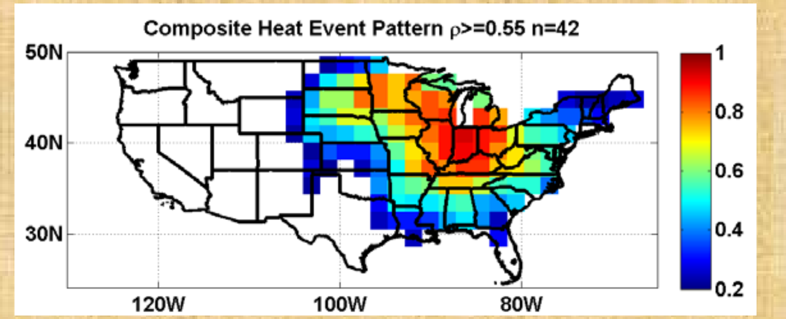
Duration (90%)



Investigating sources of subseasonal predictability for Heat Events:

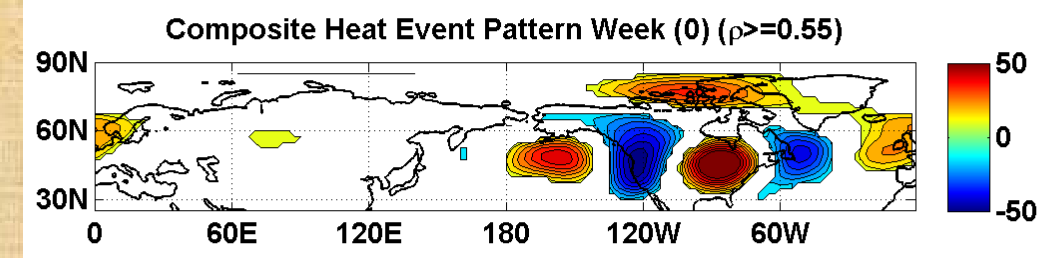
Composites of anomalies of 500mb geopotential for L1 – Heat Events similar to the Chicago 1995 event

Composite heat event of Chicago 1995 type based on 42 cases (1948-2015):

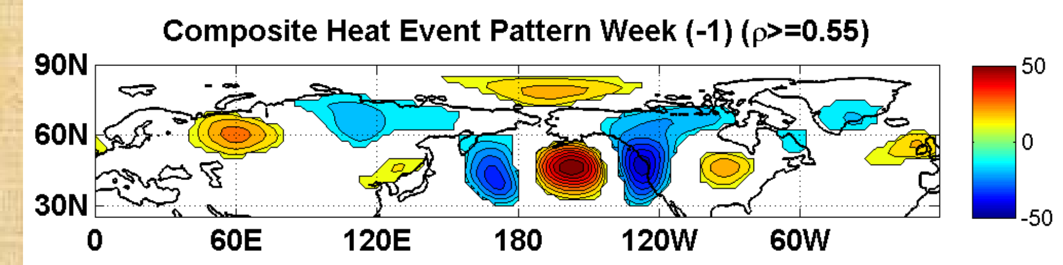


This diagnostic shows a midlatitude high wavenumber structure in 500 hPa geopotential similar to recent reports (Teng et al., 2013; McKinnon et al. 2016)

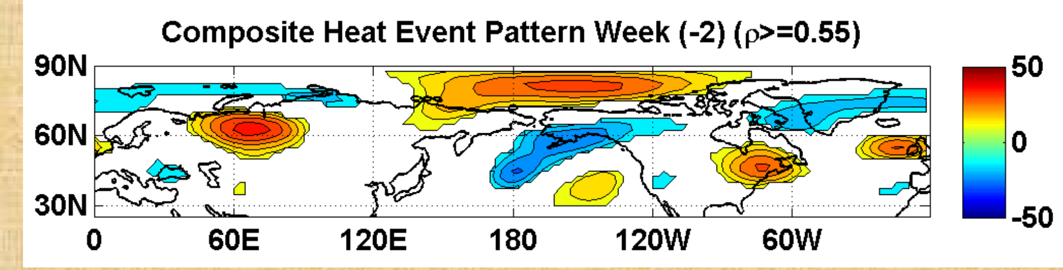
Composite weekly mean geopotential anomalies:



during the week of the Chicago 1995 type of events



during the week prior to Chicago 1995 type of events

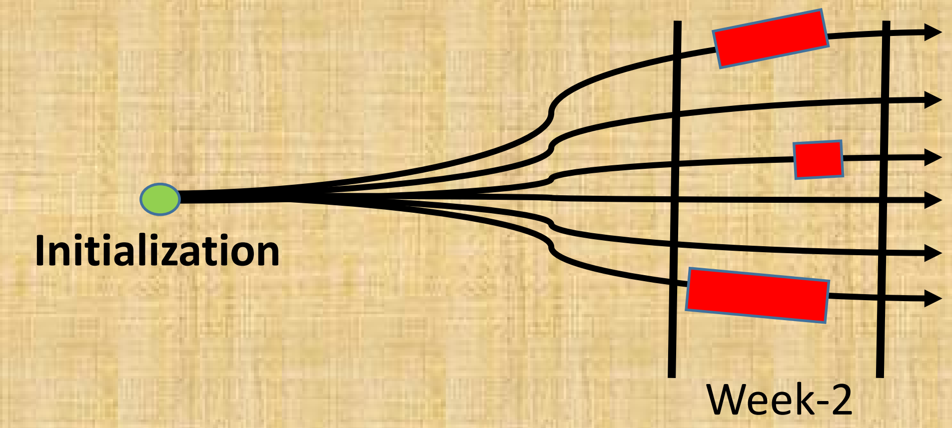


three weeks prior to Chicago 1995 type of events

Forecasting excessive heat events: Baseline system

Baseline system: The NCEP GEFS (reforecast version).

- Initialized daily at 00Z
- 20 perturbed forecasts per cycle resulting to 21-member ensemble per day
- 11 ensemble members per day for the 1985-2014 reforecast
- For each ensemble member we compute whether Week-2 is a Heat Week based on statistics from the reforecast; the starting day and the duration of the heat event.
- Compute the statistics: Probability of occurrence, mean start day, mean duration.

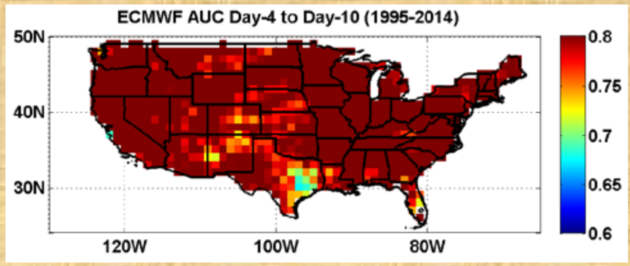


- Validation based on the Receiver Operating Characteristics (ROC) method

Multi-model Ensemble forecasts: ROC Area Under Curve for 90% – events

Week~1

ECMWF



GEFS

We have not compute AUC for Week-1

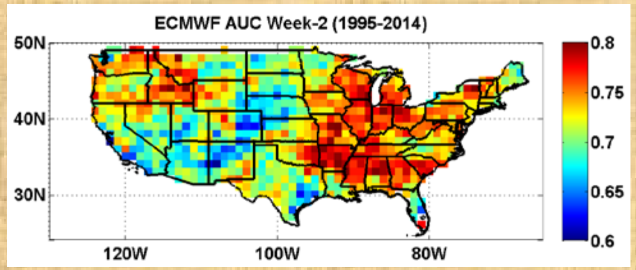
CFS

We have not compute AUC for Week-1

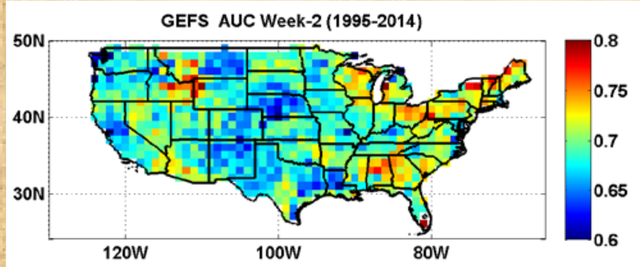
Multi-Model Ensemble Forecasting of Heat Events

Week-2

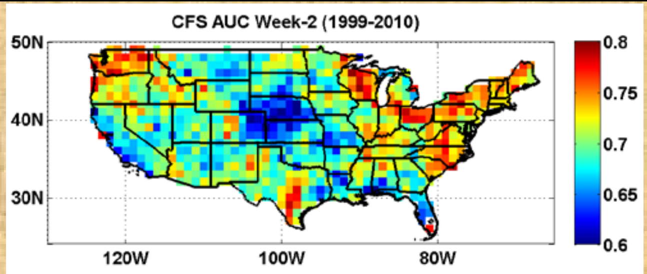
ECMWF



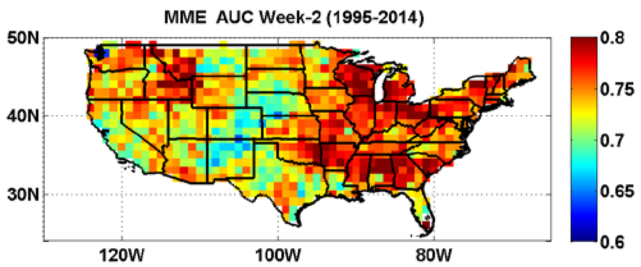
GEFS



CFS

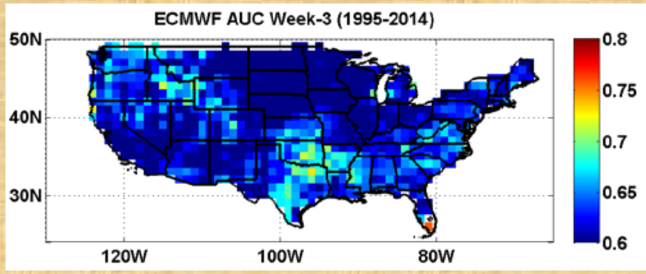


GEFS + ECMWF



Week-3

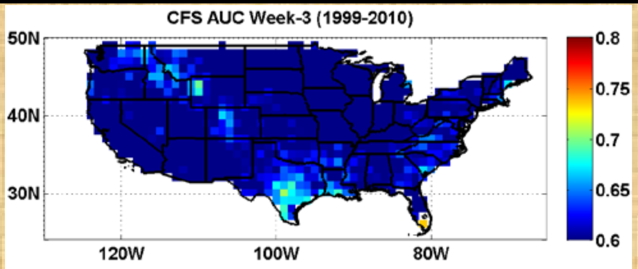
ECMWF



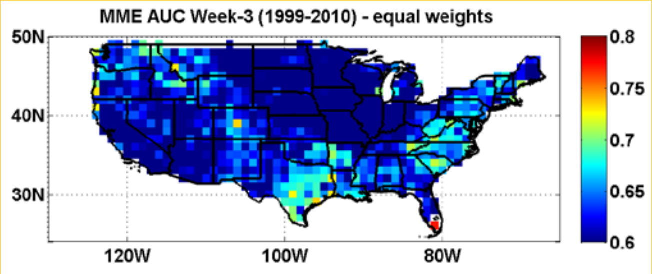
GEFS

No Week-3 GEFS
(for the moment)

CFS



CFS + ECMWF

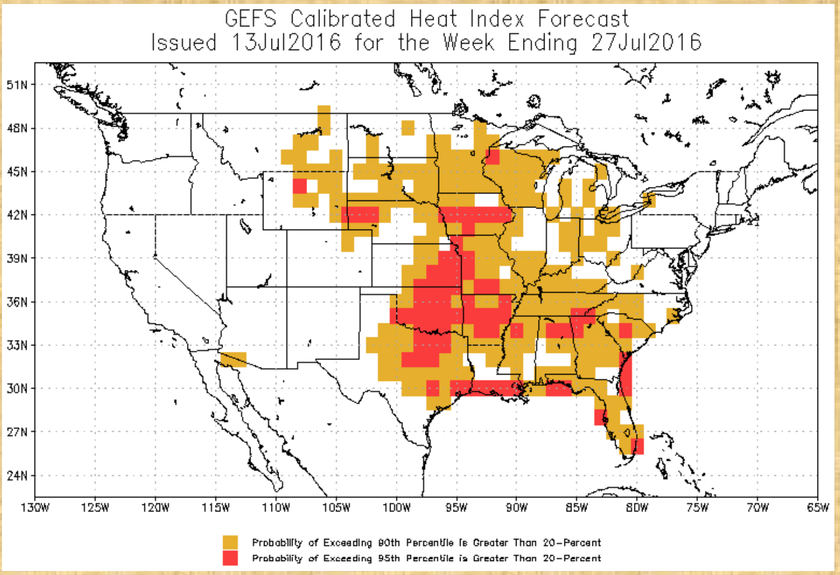


The subseasonal excessive heat outlook (SEHOS) dashboard

During Summer 2016 we were providing daily realtime forecasts to CPC forecasters:

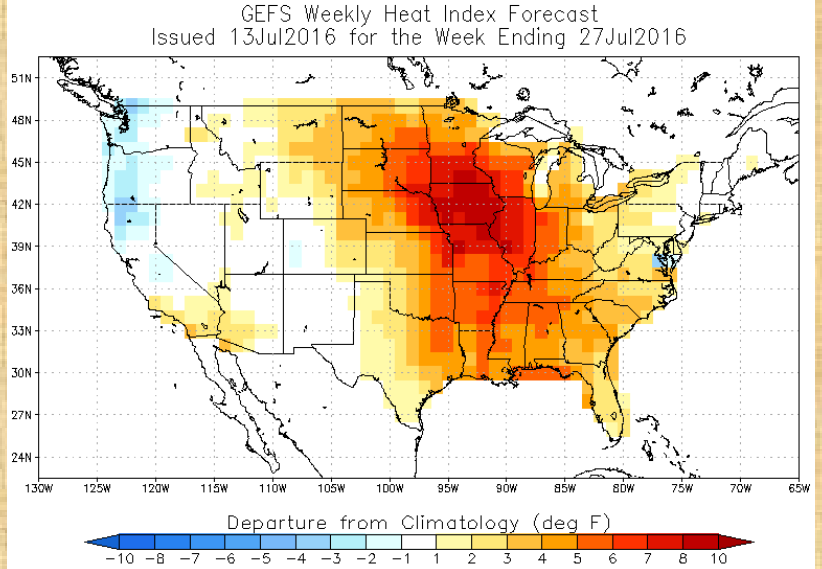
- Anomalous weekly mean maximum heat index
- Controllable projection to categorical forecast for two classes (90% and 95%)
- Probabilities (calibrated and raw) of occurrence of a heat event within a given week
- Climatological value of the heat index for the two classes of heat events during the given week
- Date of initiation of the event
- Duration of the event

Example: Week-2 ending 27 July 2016

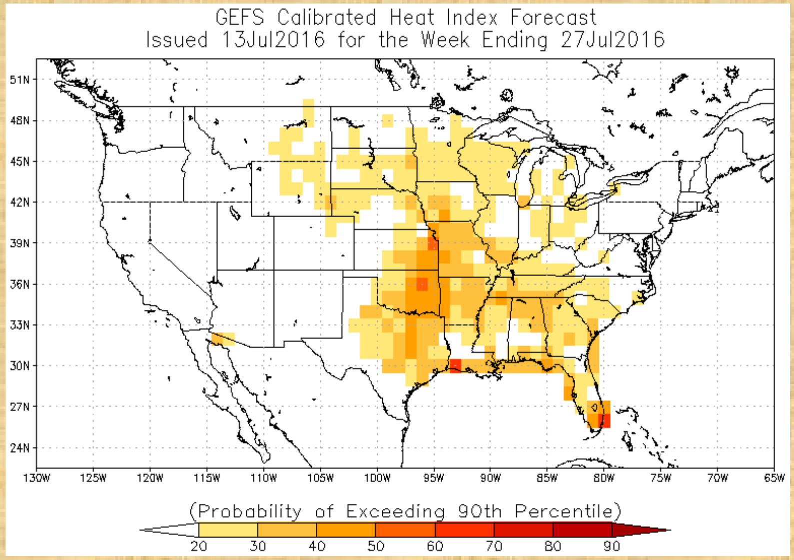


Categorical forecast

Weekly mean heat index anomaly

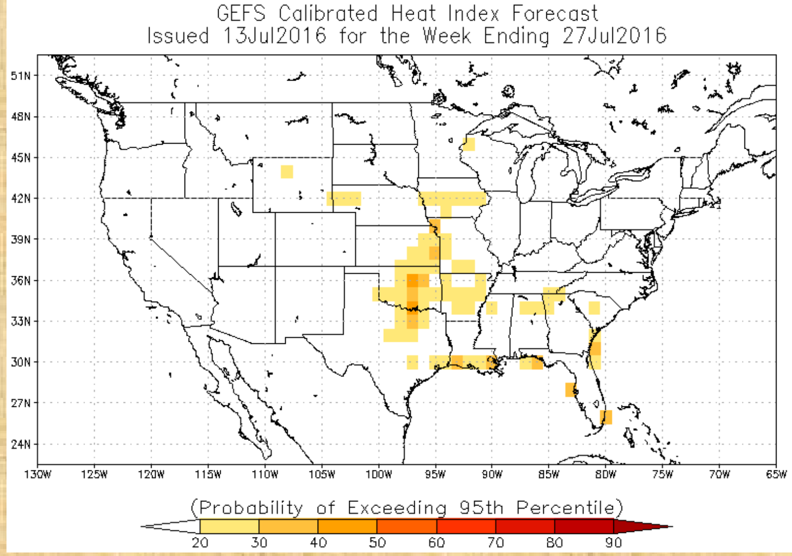


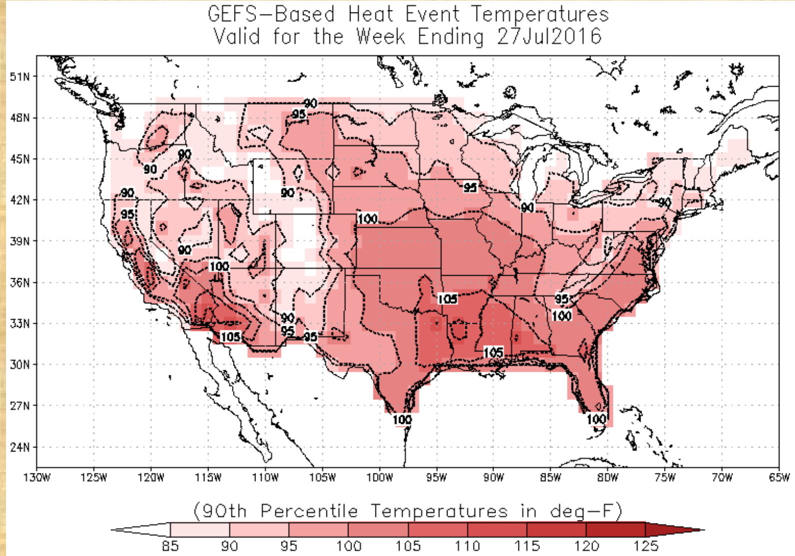
The subseasonal excessive heat outlook (SEHOS) dashboard



Calibrated probability of occurrence of heat event:

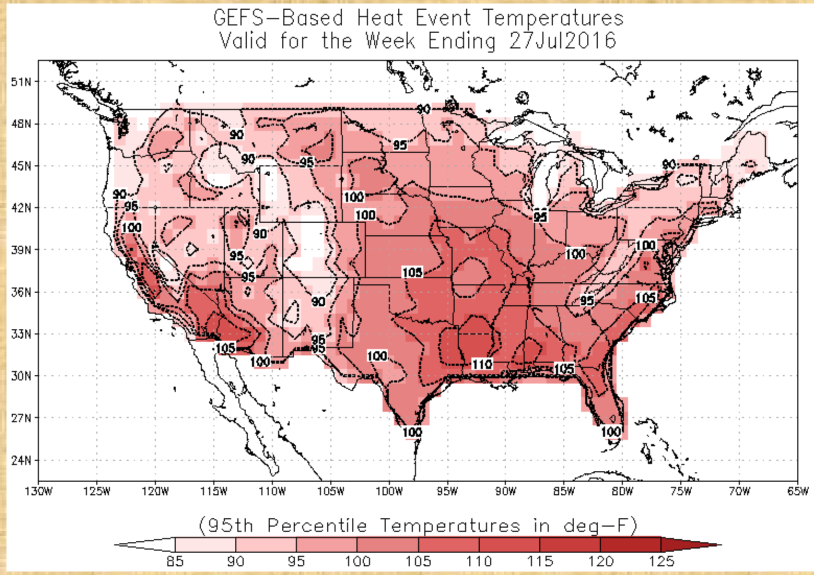
90% **95%**





Climatological value of heat index at:

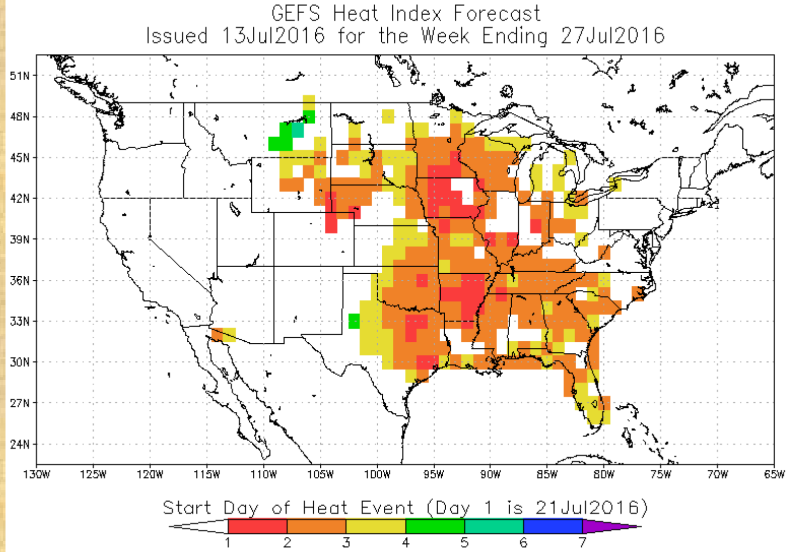
90% **95%**



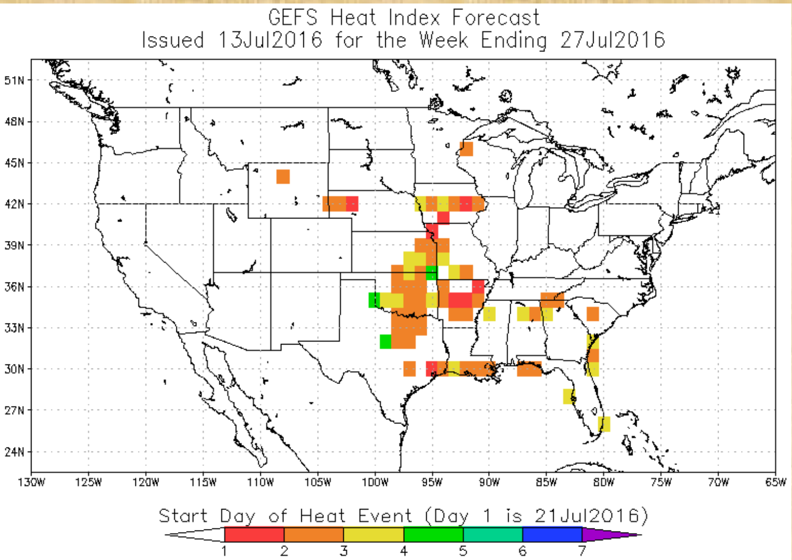
The subseasonal excessive heat outlook (SEHOS) dashboard

Initial day of heat event:

90%

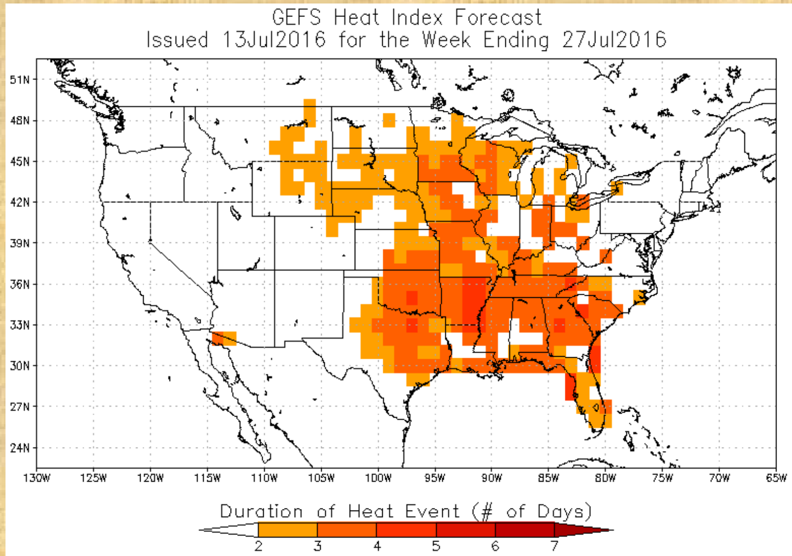


95%

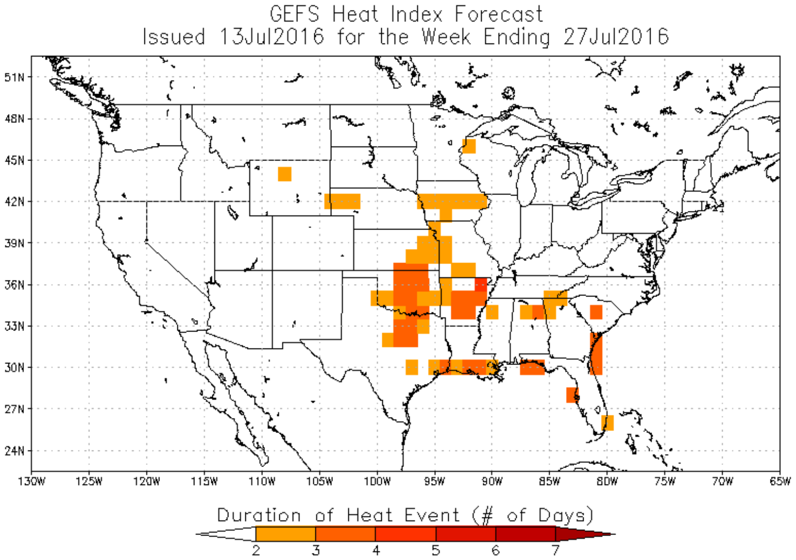


Duration of heat event

90%



95%



Summary and R&D directions

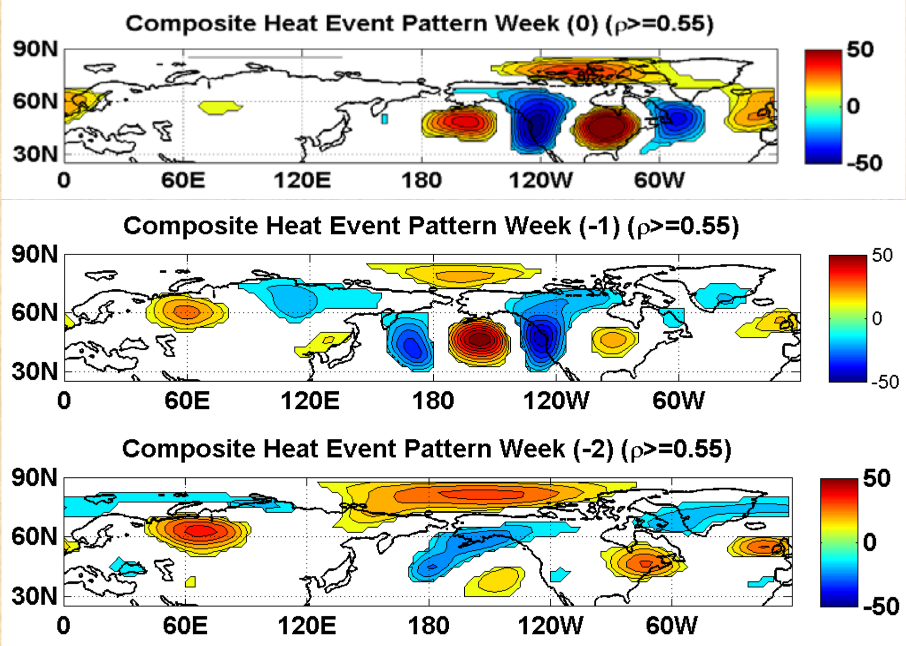
- We defined excessive heat events and used them to describe observed heatwaves e.g., Chicago 1995.
- We computed predictive skill of excessive heat events using retrospective forecasts from the S2S database.
- Excessive heat events are predictable in Week-2 and to a lesser amount in Week-3. Multi-model approaches are promising.
- We conducted daily realtime forecasts accessible to the CPC forecaster during Summer 2016 and currently we are evaluating the forecast skill for each of the observed event.

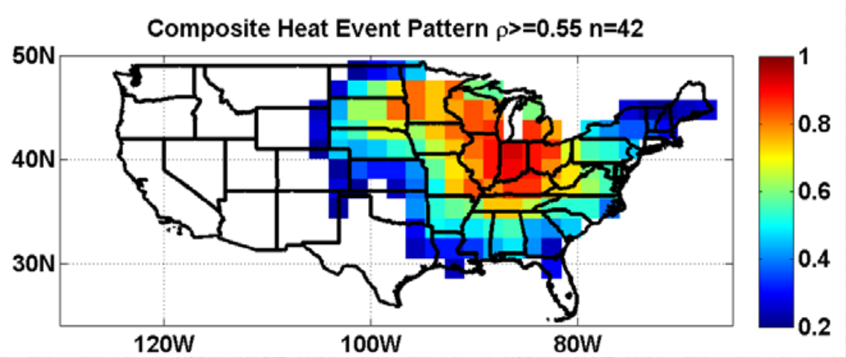
Summary and R&D directions

Understand the physics of heatwaves:

- What are the forcing mechanisms for the high wave-number Rossby waves?
- Under what circumstances these waves become stationary?
- What are the mechanisms that dissipate these waves
- What are pre-existing conditions at the surface that can amplify or damp the atmospheric forcing?

Proposal submitted to the NSF jointly by UMD/ESSIC, GMU/COLA and ODU (leading institution: UMD)

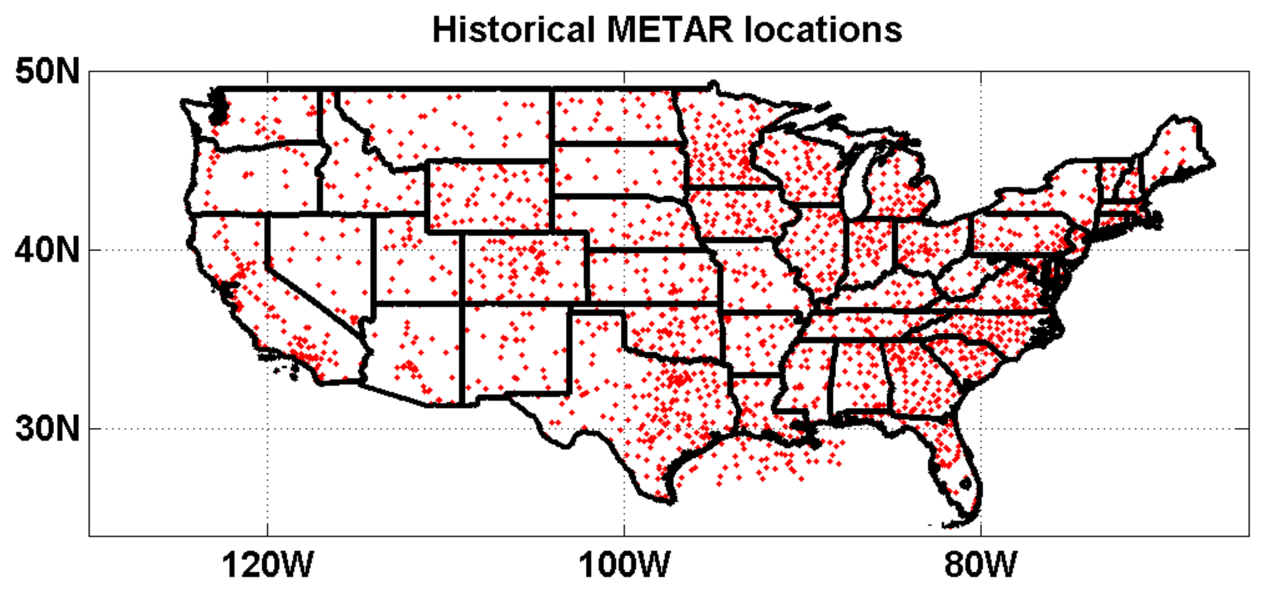




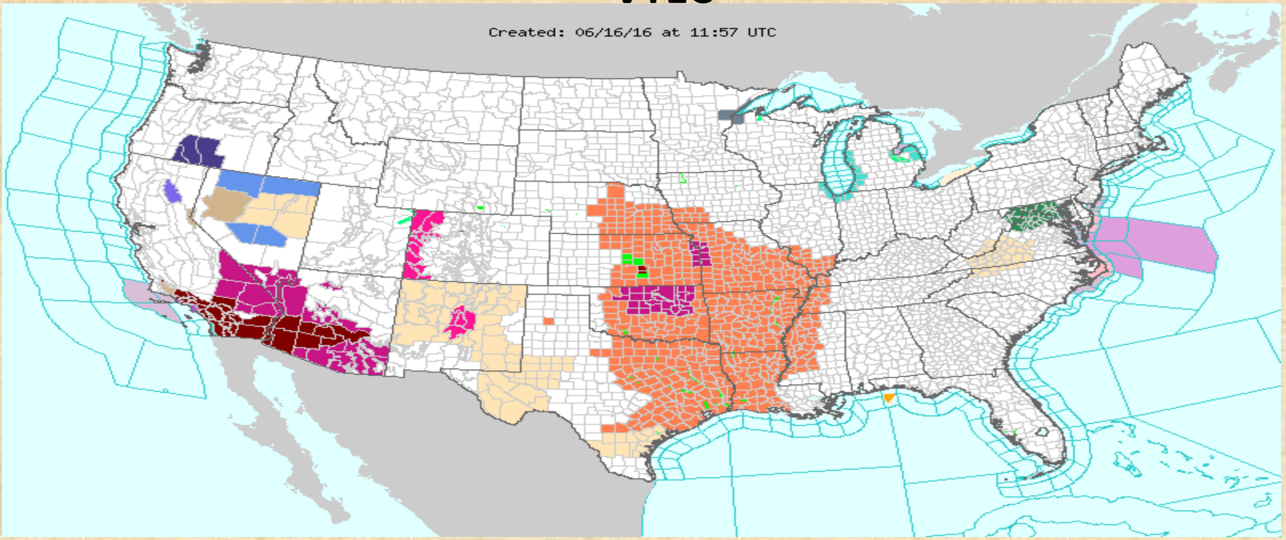
Summary and R&D directions

- Create a comprehensive monitoring system by combining METAR, VTEC warnings/advisories and reanalysis data

- Identify more complex yet still predictable definitions of heat discomfort



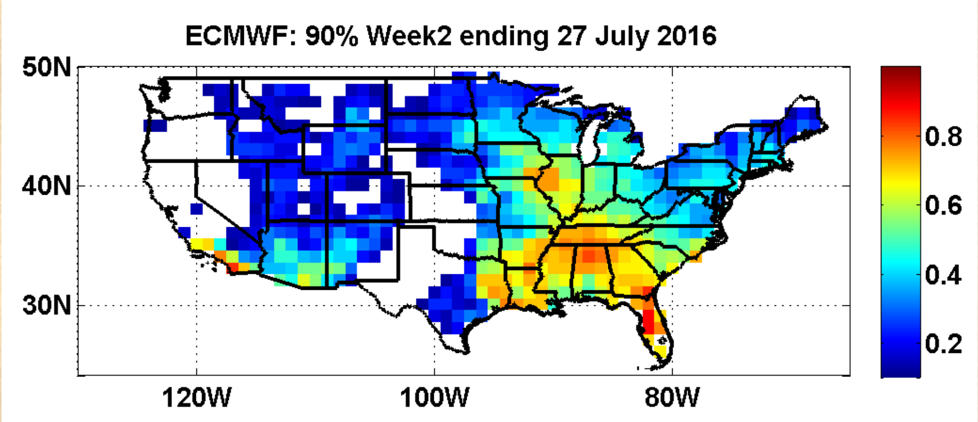
VTEC



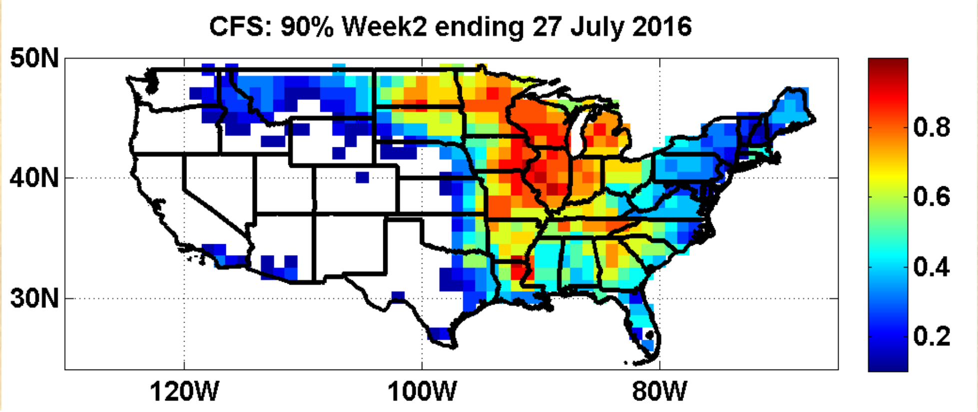
Summary and R&D directions

- Improve the SEHOS dashboard by incorporating feedback from the CPC forecasters
- Develop a multi-model SEHOS for summer 2017 (GEFS, CFS, ECMWF, GEPS) – a R&D direction based on research funded by NOAA/CPO.
- Extend the SEHOS to Week 3&4
- Extend the SEHOS to the tropics and sub-tropics for use by CPC's GTH product (funded by NOAA/CPO)

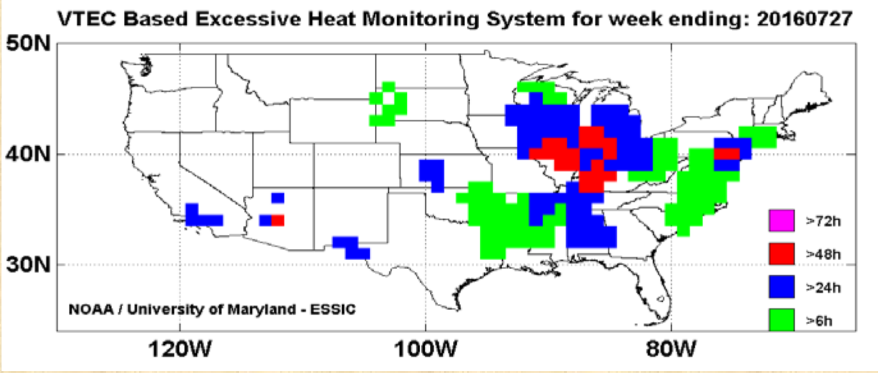
ECMWF forecast



CFS forecast



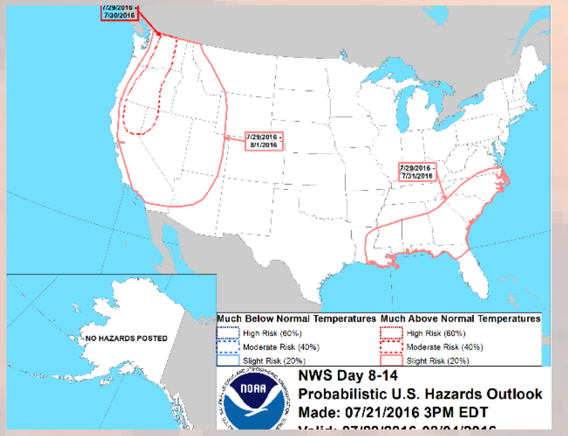
VTEC based verification



Subseasonal Excessive Heat Outlook (SEHOS):

Climate Prediction Center (CPC):

Probabilistic Hazards products Week-2, extending experimentally to Week 3&4



The National Integrated Heat Health Information System (NIHHIS):

a) inform research priorities

b) inform decisions with better climate and health information

Regional and International Pilots cultivate an understanding of decision-making contexts


Questions: Augustin.Vintzileos@noaa.gov

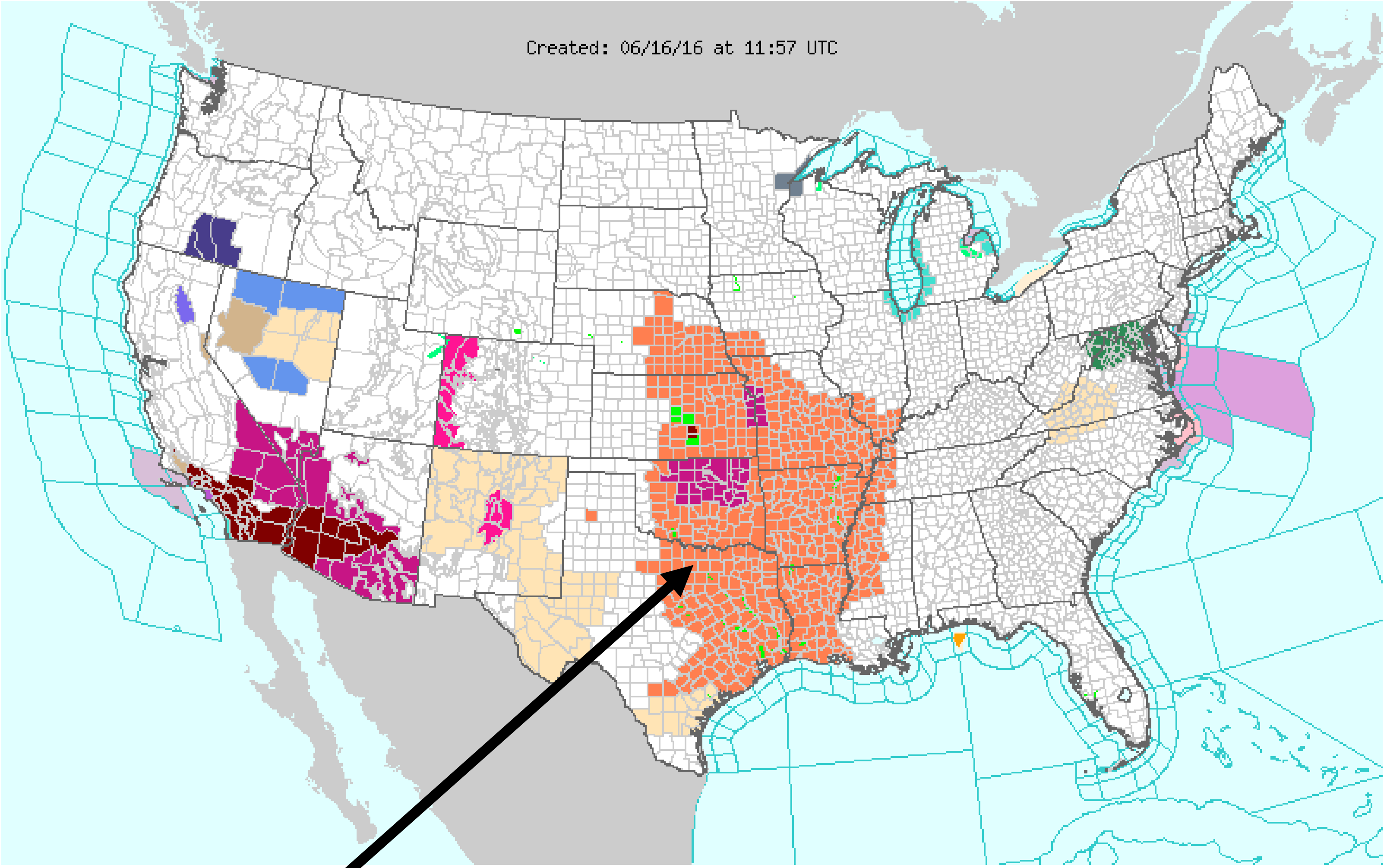
Defining excessive heat events based on WFO messages

VTEC = Valid Time Event Code

Weather messages for: 16 June 2016

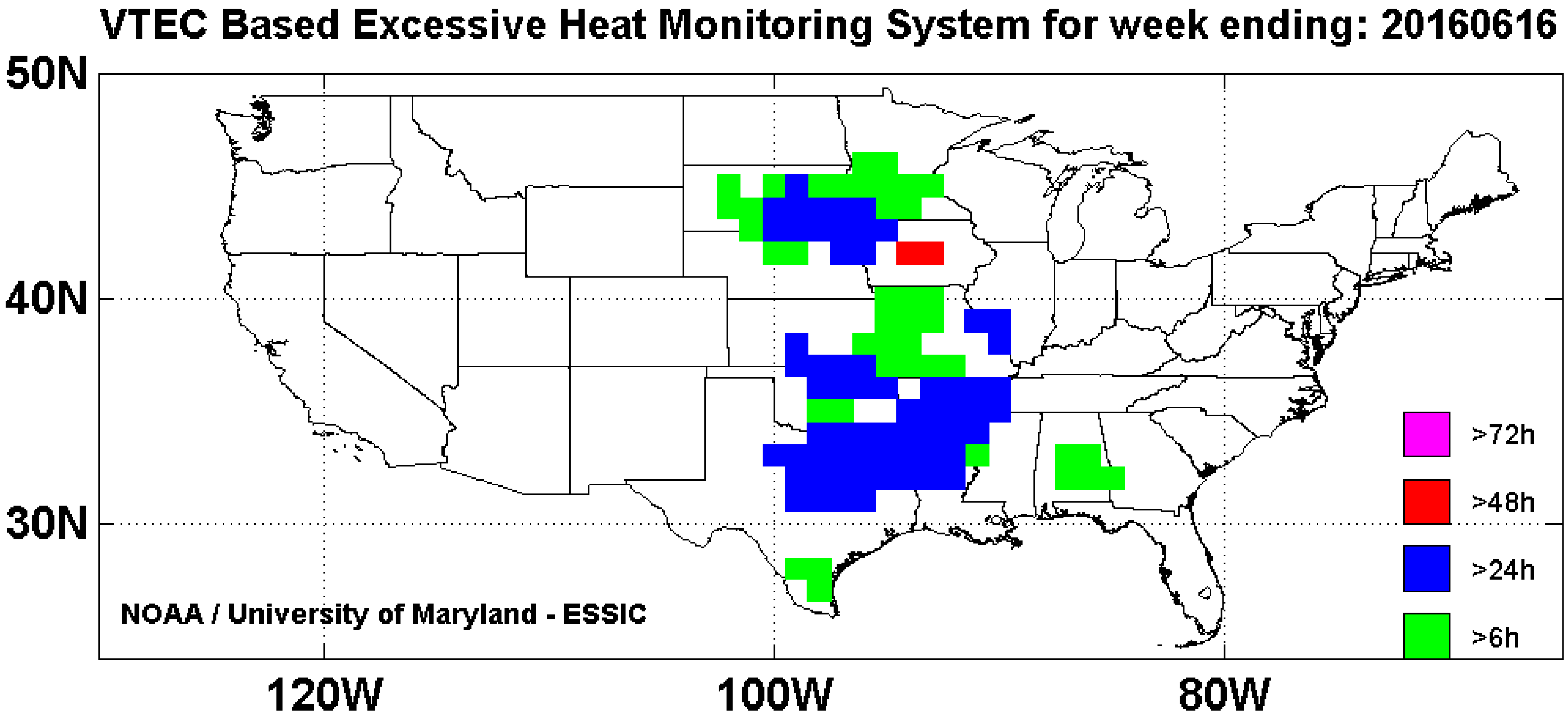
URGENT - WEATHER MESSAGE
NATIONAL WEATHER SERVICE
FORT WORTH TX
531 AM CDT THU JUN 16 2016

TXZ091>095-
100>107-115>123-
129>135-141>148-
156>162-174-175-
162100-
/O.CON.KFWD.HT.Y.0
001.000000T0000Z-
160618T0100Z/



Date, duration and location of event

Monitoring heatwaves based on NOAA's VTEC

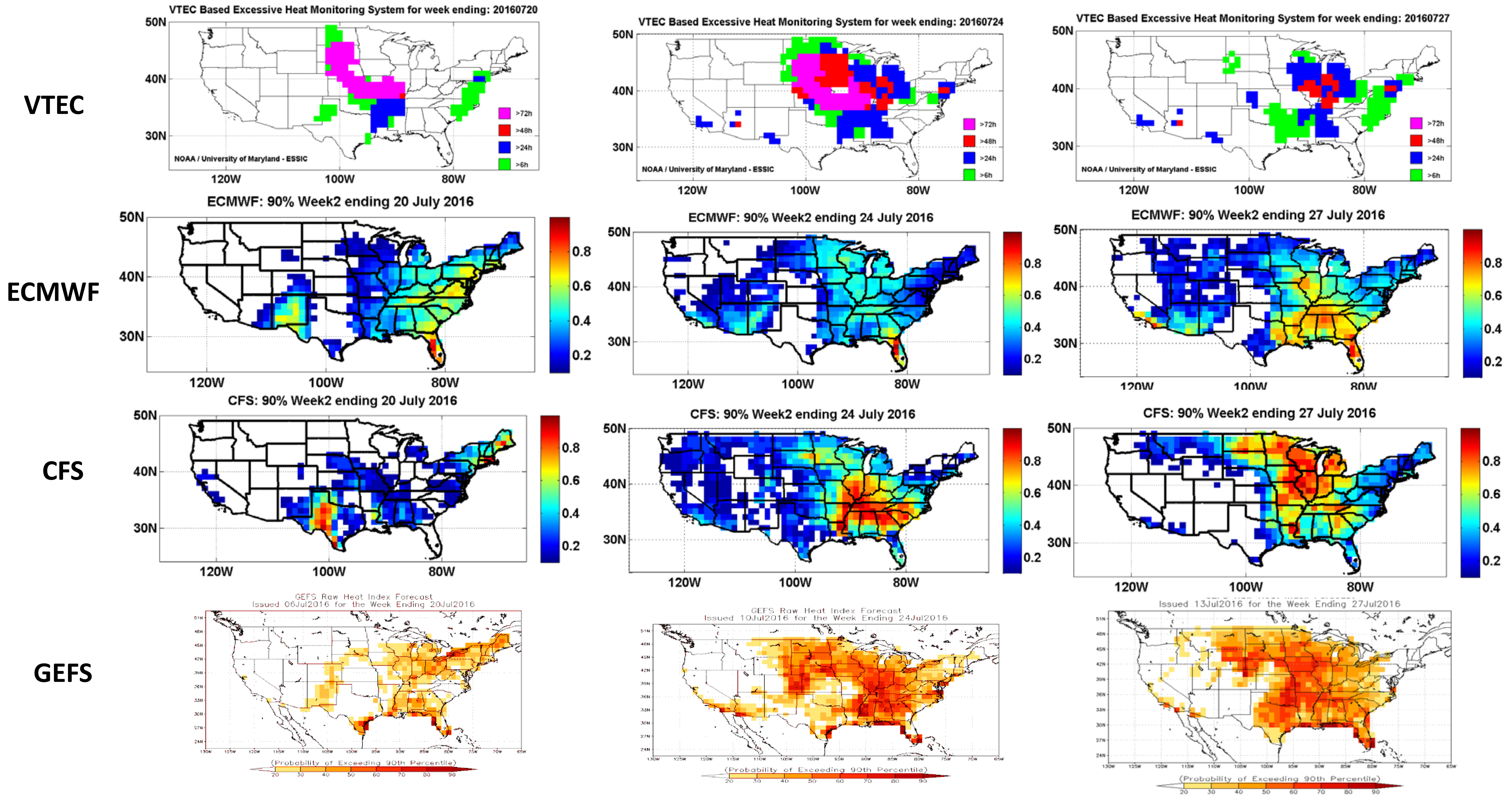


More than 6 hours of Warning/Advisory within the given week

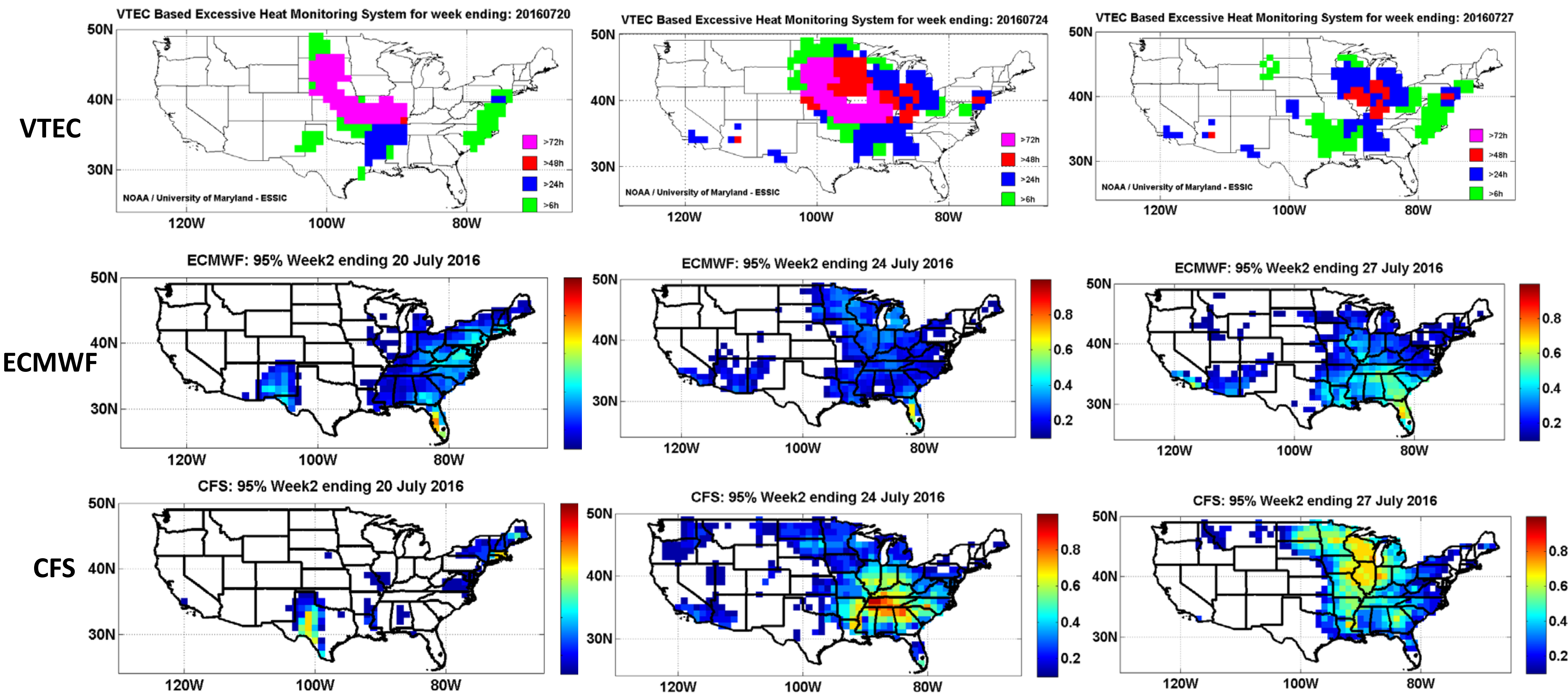
…

More than 72 hours of Warning/Advisory within the given week

Week-2 Probability (uncalibrated) for a 90% heat event



Week-2 Probability (uncalibrated) for a 95% heat event

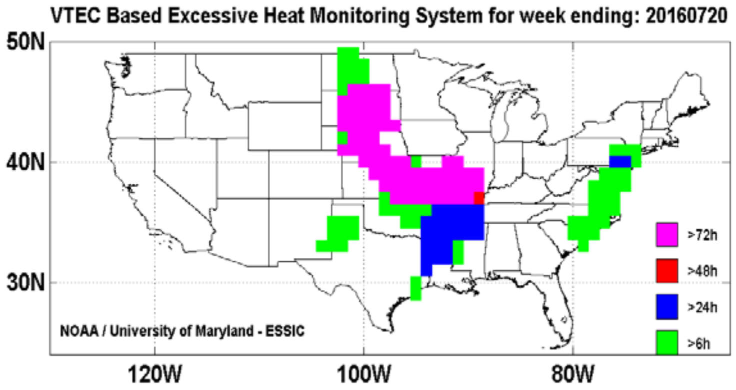


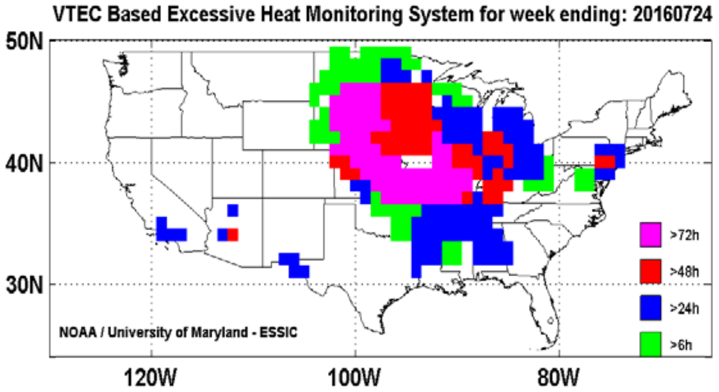
Summer 2016: The late July excessive heat event

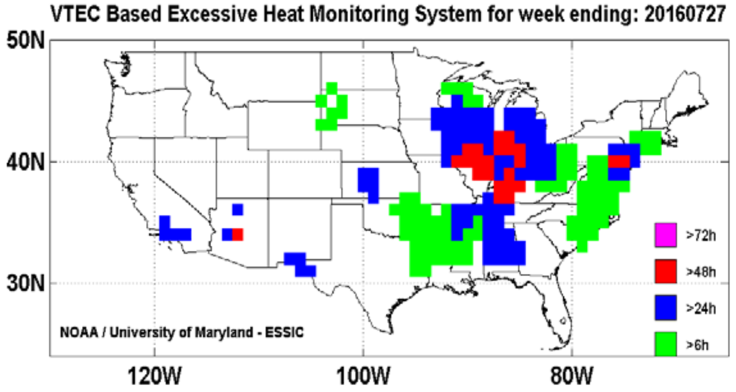
- Started appearing on the VTEC monitoring for week ending 19-July-2016 and disappearing for week ending on28-July- 2016
- Principally a humidity event (no record dry-heat broken)

Ending: 20 July 2016 | **Ending: 24 July 2016** | **Ending: 27 July 2016**

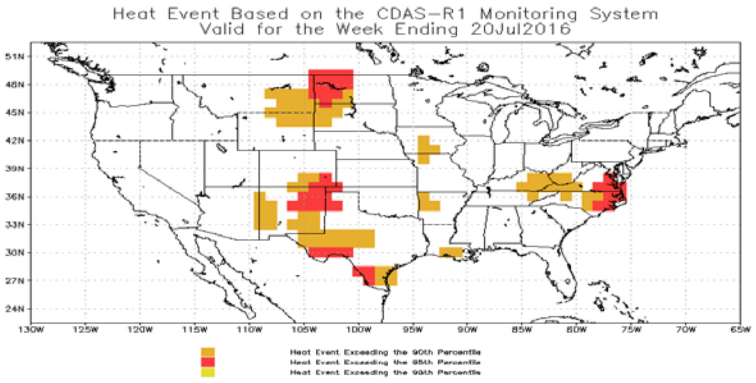
VTEC based Monitoring

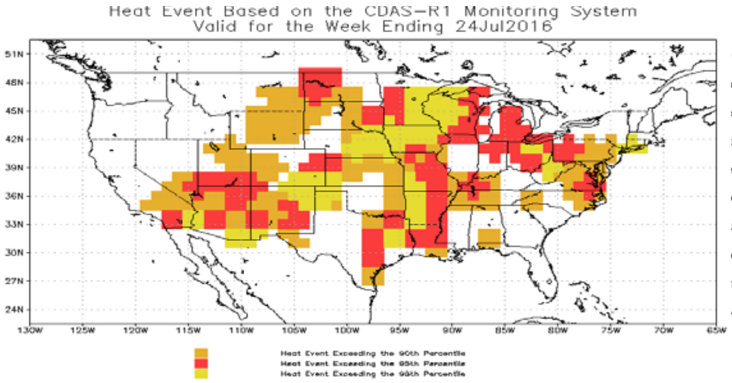


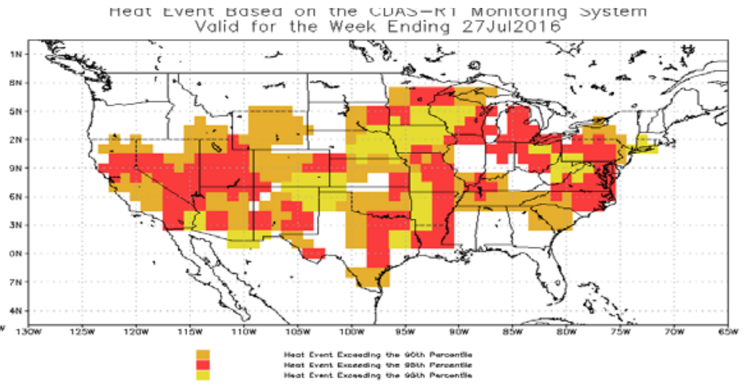


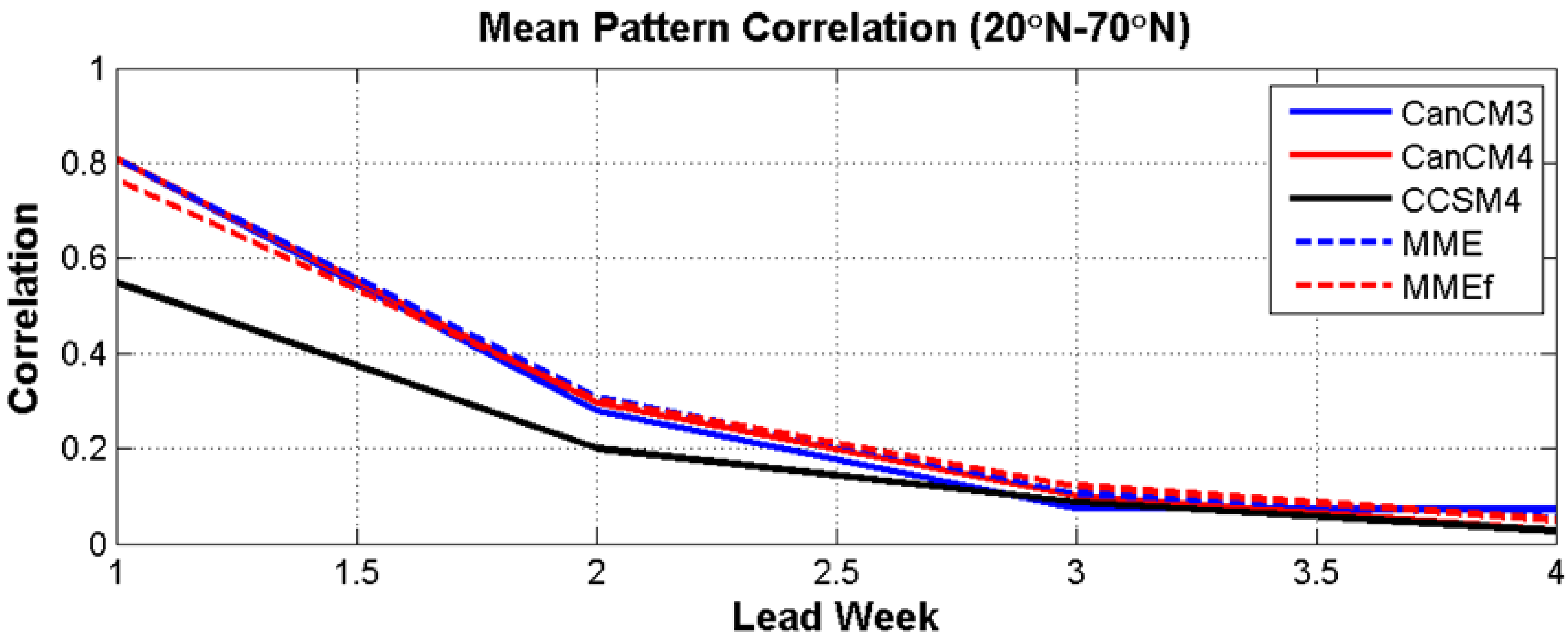


CDAS based Monitoring

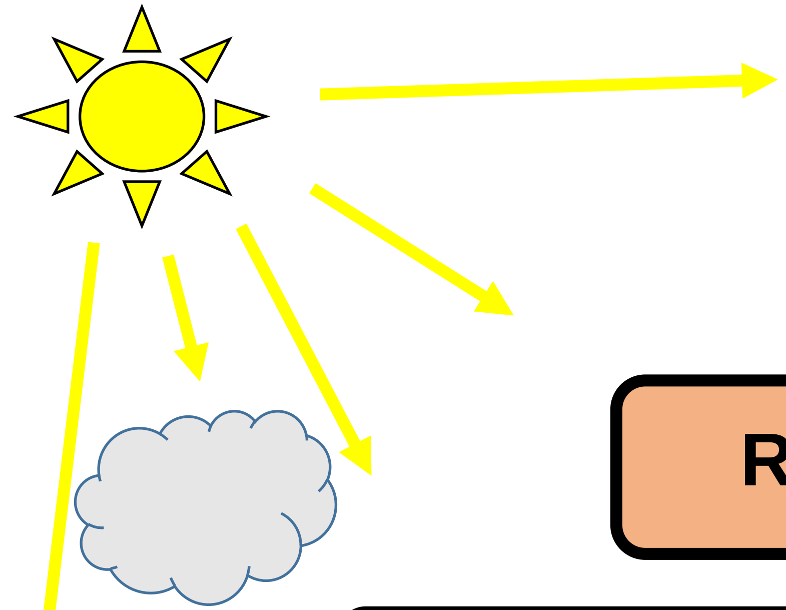







Mean Pattern Correlation (20°N-70°N)
Correlation
Lead Week
1
0.8
0.6
0.4
0.2
0
1
1.5
2
2.5
3
3.5
4
CanCM3
CanCM4
CCSM4
MME
MMEf

Heat kills: Impacts of Excessive Heat to Human Health



Heat Stroke

It occurs when the body becomes unable to control its temperature: the body's temperature rises rapidly, <u>the sweating mechanism fails</u>, and the body is unable to cool down. When heat stroke occurs, the body temperature can rise to 106°F or higher within 10 to 15 minutes. Heat stroke can cause death or permanent disability if emergency treatment is not given.

Heat Exhaustion

Rhabdomyolysis

Heat Syncope

Heat Cramps

Heat Rash

Heat kills: Impacts of Excessive Heat to Human Health

- Human physiology
- Geographical location
- Urban effect
- Preparedness
- Age

Heat Stroke

Heat Exhaustion

Rhabdomyolysis

Heat Syncope

Heat Cramps

Heat Rash

- Health status
- Socio-economic factors
- Cultural factors

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