Towards Multi-Model Ensemble Forecasting of Excessive Heat Events at Subseasonal Lead Times (Week-2 to Week-4)

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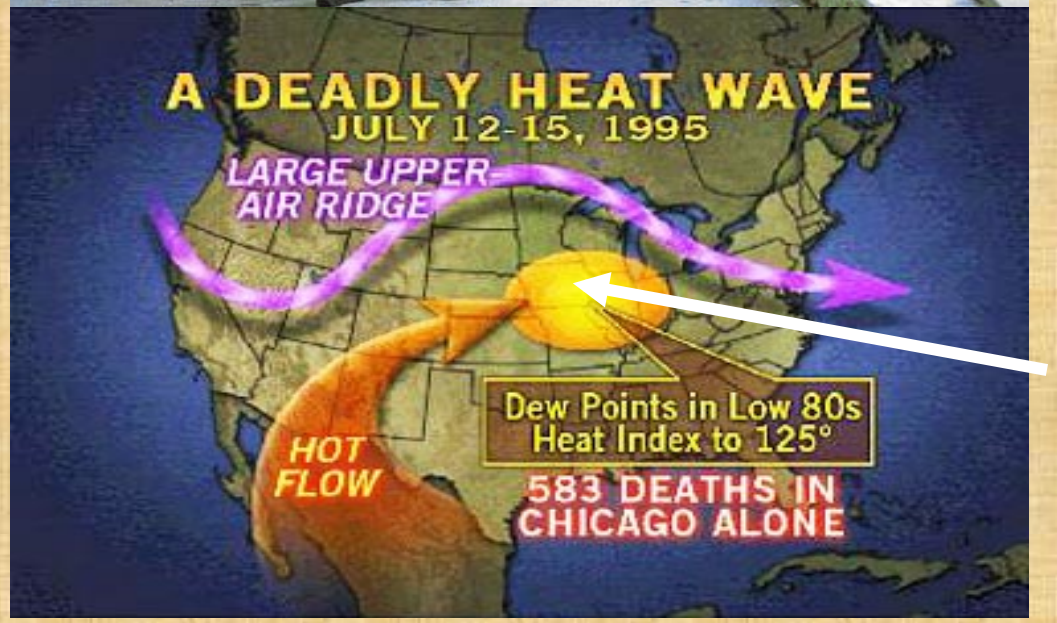
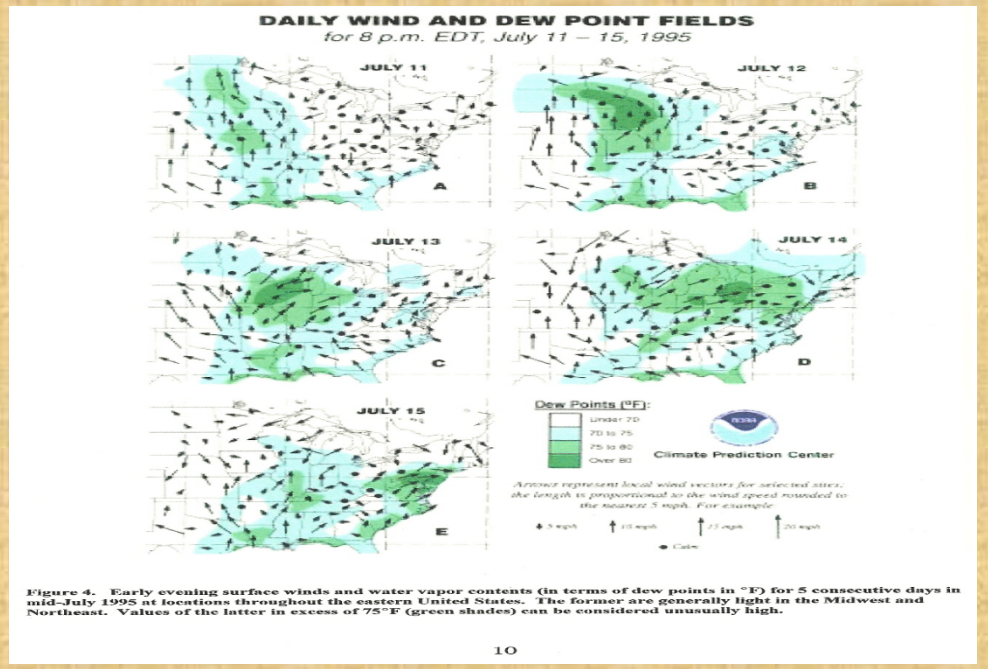
Outline:

- A definition of excessive heat events
- Monitoring heat events
- The baseline forecasting system
- Preliminary forecast verification
- Towards multi-model ensemble forecasting
- Summary and future work

Heat kills: The example of the July 1995 Heat Event




DAILY WIND AND DEW POINT FIELDS
for 8 p.m. EDT, July 11 – 15, 1995

JULY 11 A

JULY 12 B

JULY 13 C

JULY 14 D

JULY 15 E

Dew Points (°F):
Under 70
70 to 75
75 to 80
Over 80

Climate Prediction Center

Arrows represent local wind vectors for selected sites; the length is proportional to the wind speed rounded to the nearest 5 mph. For example:
5 mph
15 mph
25 mph
20 mph
Calm

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.

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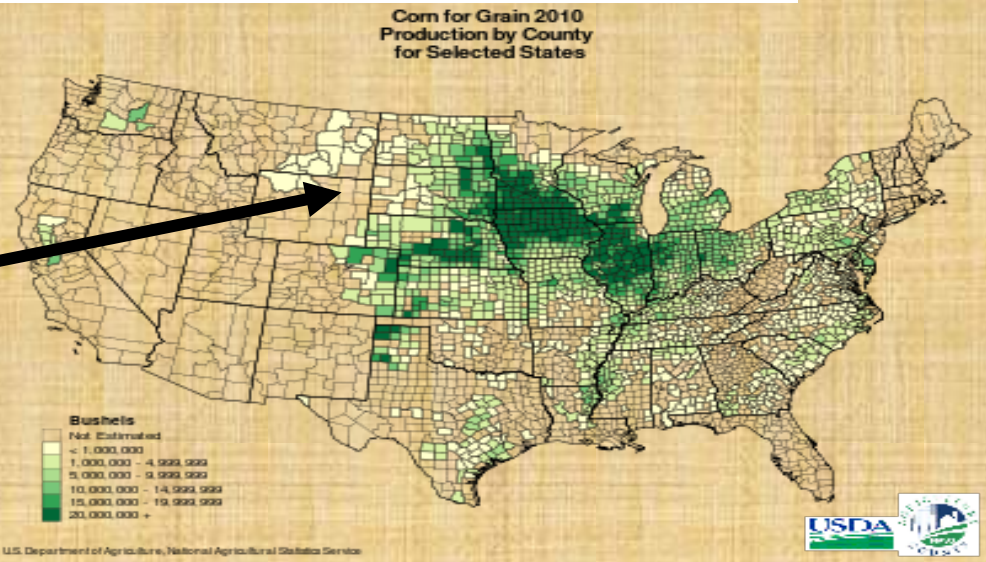
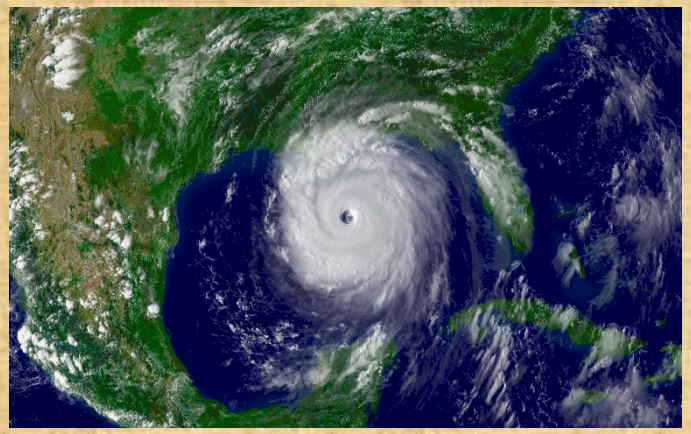
From the NOAA study of the event (published December 1995)

The Corn Belt



Defining excessive heat events (I)

In comparison with other natural disasters heat is a silent (invisible) killer



An extreme heat wave in India May 2015

Defining adequately Heat Events is a necessary step for their monitoring and forecasting:

Defining excessive heat events (II): Ingredients

Impacts of Heat Events:

- **Grow non-linearly as temperature and humidity increase:** Requirement for using apparent temperatures (these 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.

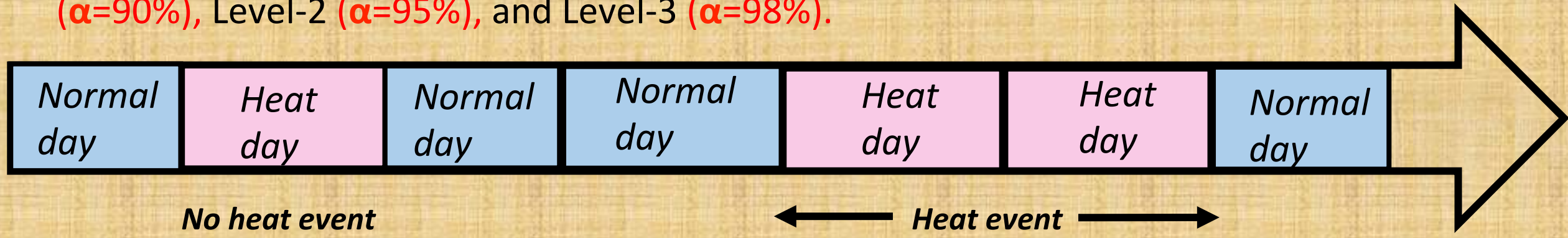
- **Depend on geographical location:** Requirement for a definition of what is high apparent temperature as a function of location.

- **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 timing within the warm season.

Defining excessive heat events (III)

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 forecasts.

Inconveniences of this definition: Based on expensive reforecasts

Monitoring excessive heat events at weekly periods

Based on the above definition we introduce a criterion for 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.

Monitoring system data source:

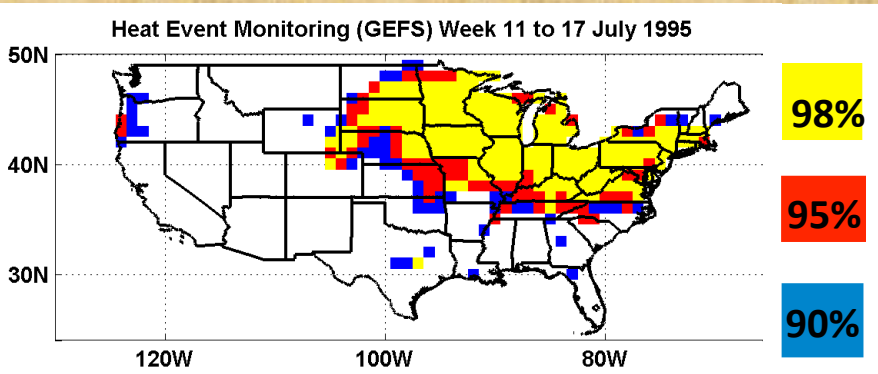
- GEFS Day-1 forecasts.
- NCAR/NCEP Reanalysis (comparison in backup slides)
- Working towards monitoring systems based on direct observations of temperature and humidity

Example: The July 1995 Heat Event

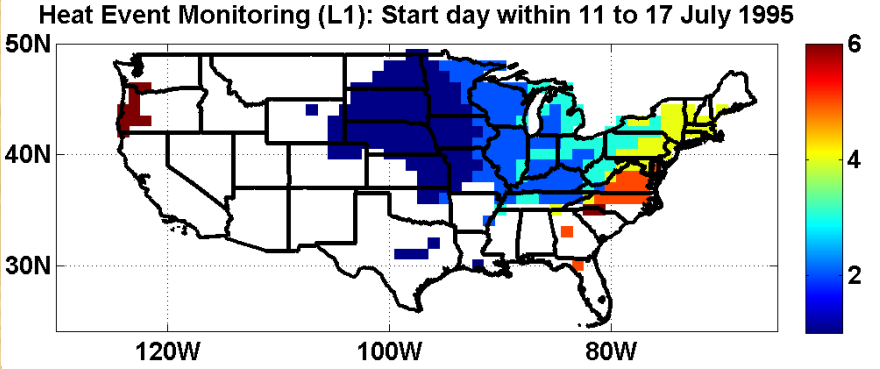
- During the week of 11-17 July 1995 a Level-3 Heat Event (98% - yellow) was covering an extended area from the Upper Midwest to the Northeast and Mid-Atlantic.
- This heat event progressed from west to east during this week.
- The event lasted 5 days (for Level-1 intensity) in the Chicago area.

Description of the July 1995 Heat Event

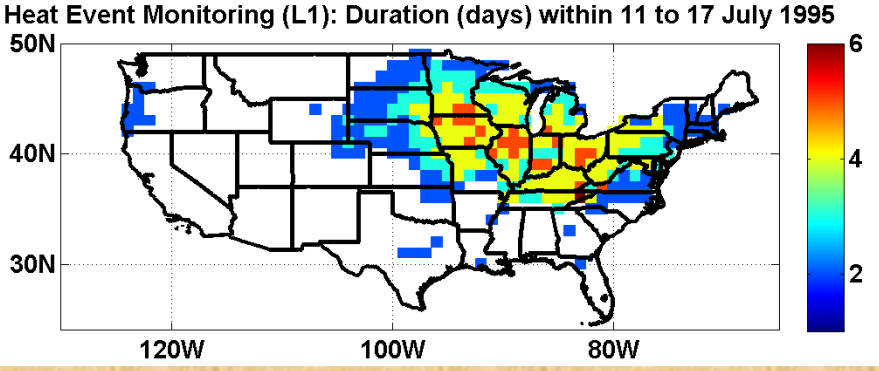
Occurrence



Start day



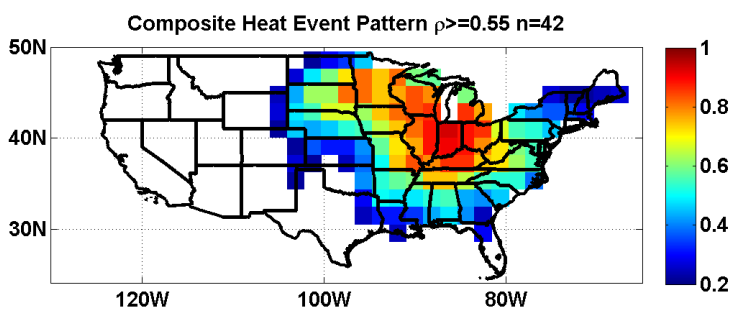
Duration



Investigating sources of subseasonal predictability for Heat Events:

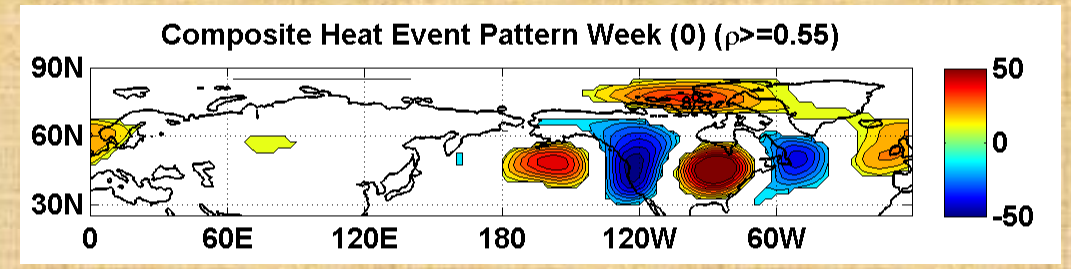
Composites of anomalies of 500mb geopotential for L1 – Heat Events similar to the Chicago 1995 event

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

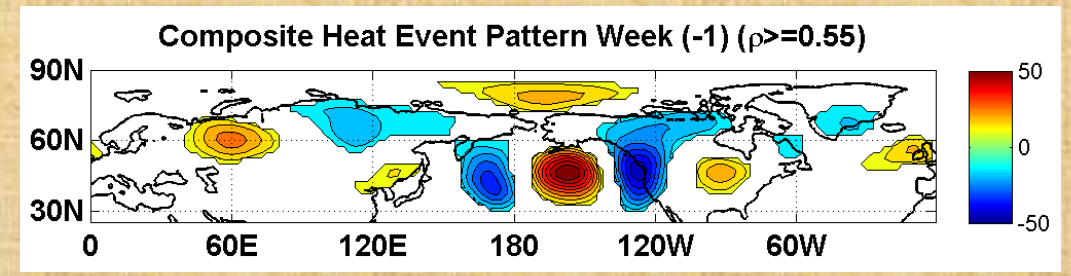


This diagnostic shows a midlatitude high wavenumber structure in 500 hPa geopotential similar to recent reports (Teng et al., 2013; McKinnon et al. 2016)

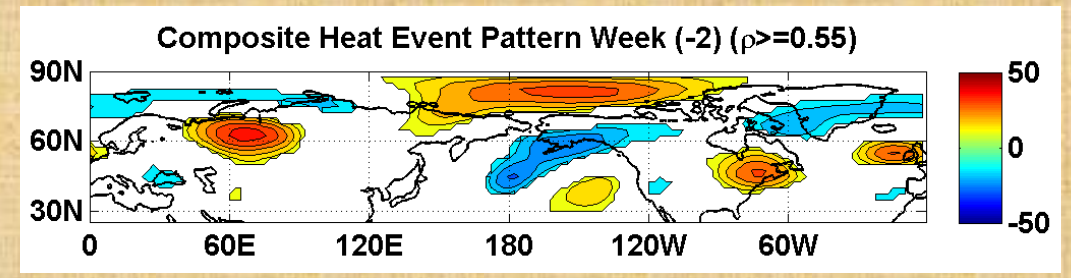
Composite weekly mean geopotential anomalies:



during the week of the Chicago 1995 type of events



during the week prior to Chicago 1995 type of events



two weeks prior to Chicago 1995 type of events

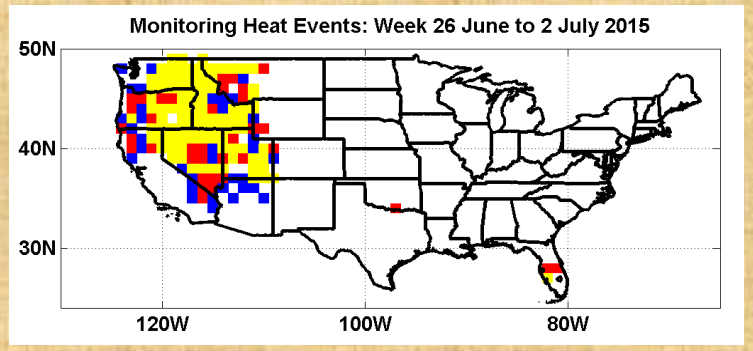
Forecasting excessive heat events (I): Baseline system

Baseline system: The NCEP GEFS.

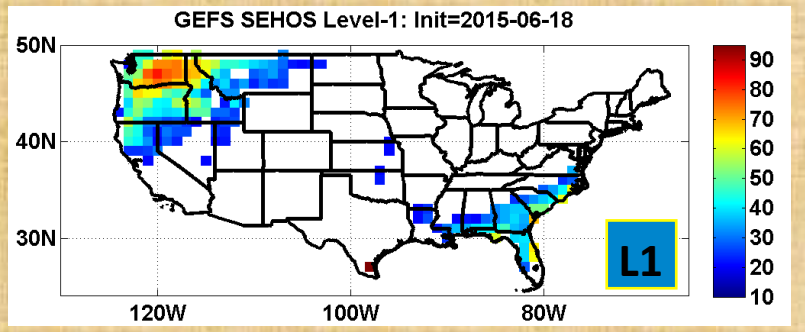
- Initialized daily at 00Z, 06Z, 12Z and 18Z
- 20 perturbed forecasts per cycle resulting to 84-member ensemble per day
- For each ensemble member we compute whether Week-2 is a Heat Week, the starting day and the duration.
- Compute the statistics: Probability of occurrence, mean start day, mean duration (CDFs as a function of lead time)

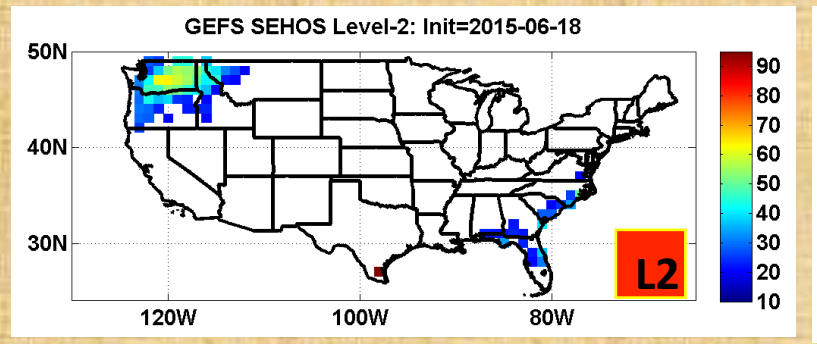
Example of realtime forecast product: GEFS initialized on18 June 2015 for Week-2: 26 June to 2 July 2015.

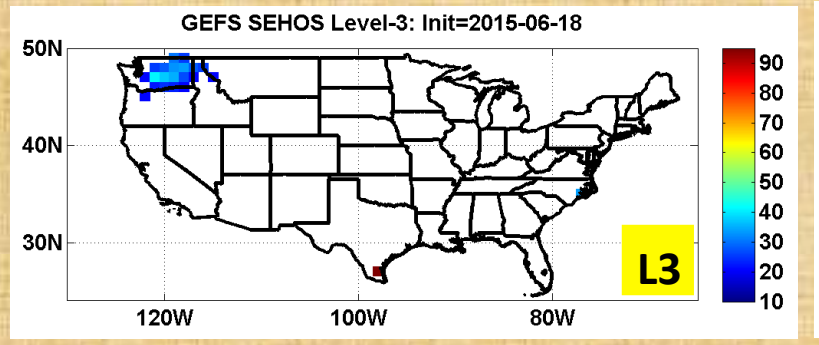
Verification



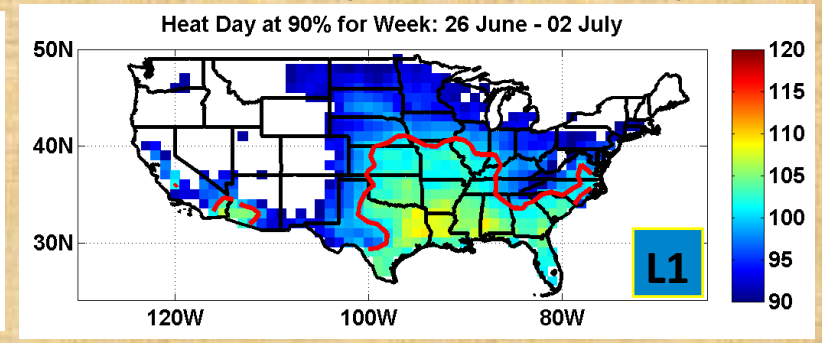
Probability of Occurrence of Heat Event

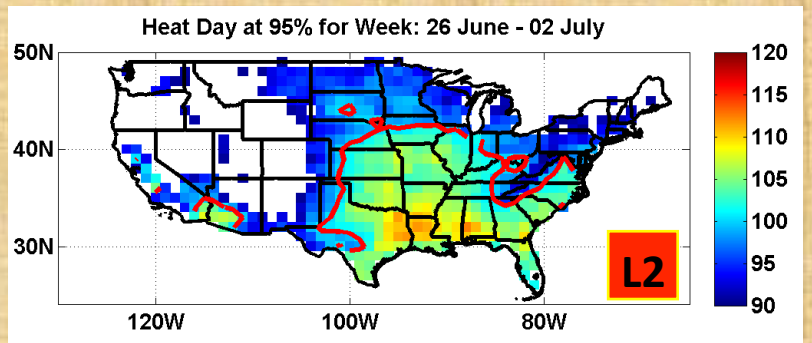


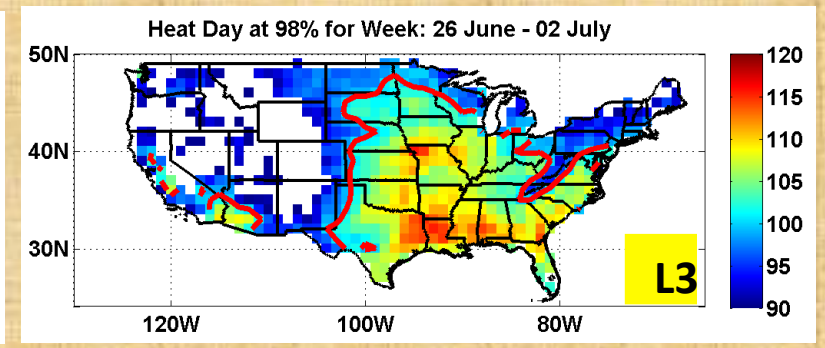




Climatological Heat Day for Week: 06/26 to 07/02 (Red line = 100°F)



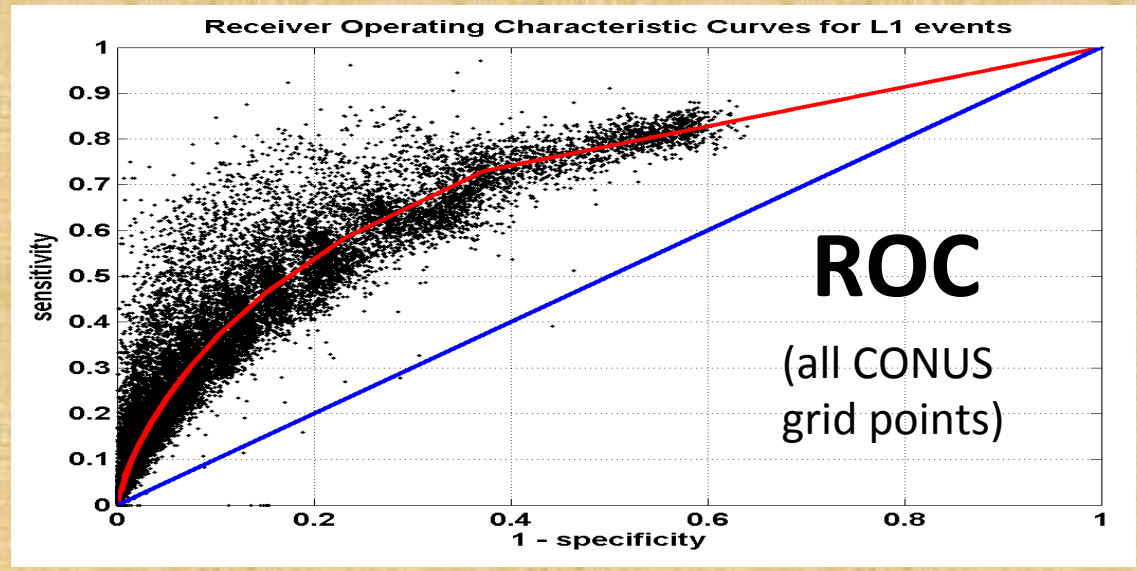




Verification of the baseline forecasting system (1985-2014)

Receiver Operating Characteristic (ROC) and Area Under Curve (AUC)

Contingency table	OBS Yes	OBS No
Forecast Yes	a	b
Forecast No	c	d



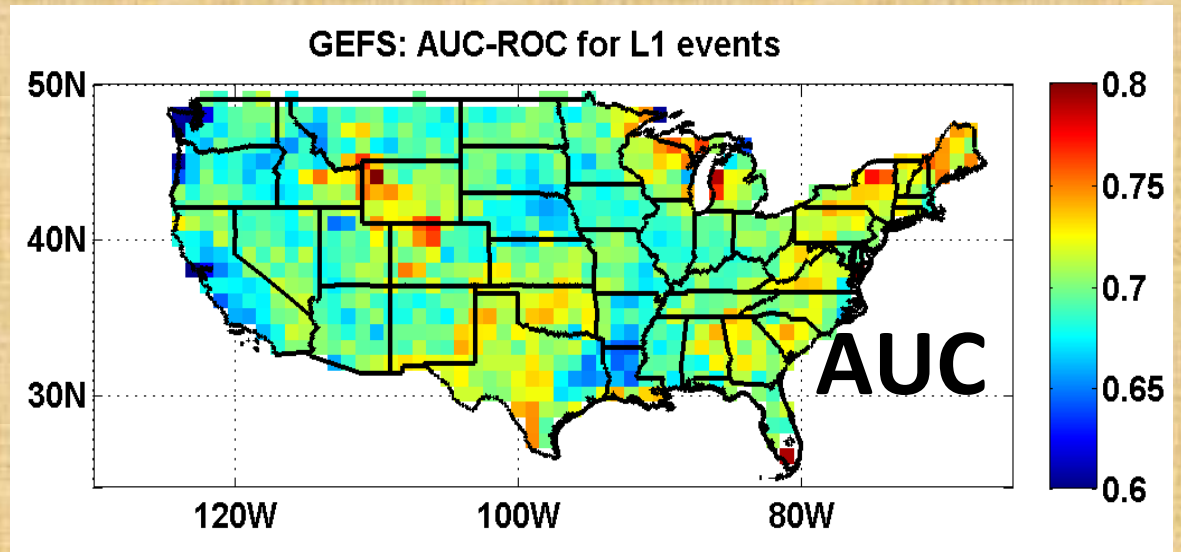
a/(a+c)

b/(b+d)

Forecast **YES** when Probability of Occurrence > P.

ROC: POD vs. POFD for different values of P.

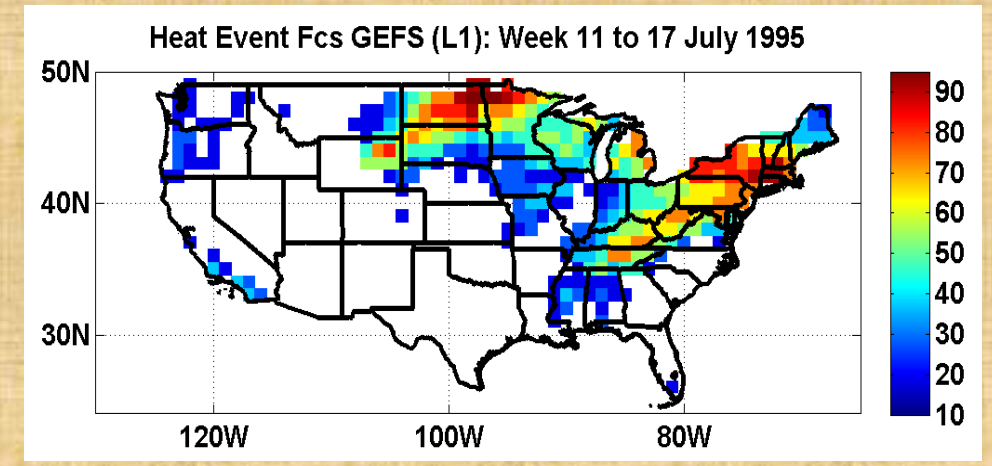
AUC provides a measure of the predictive capacity of the system.



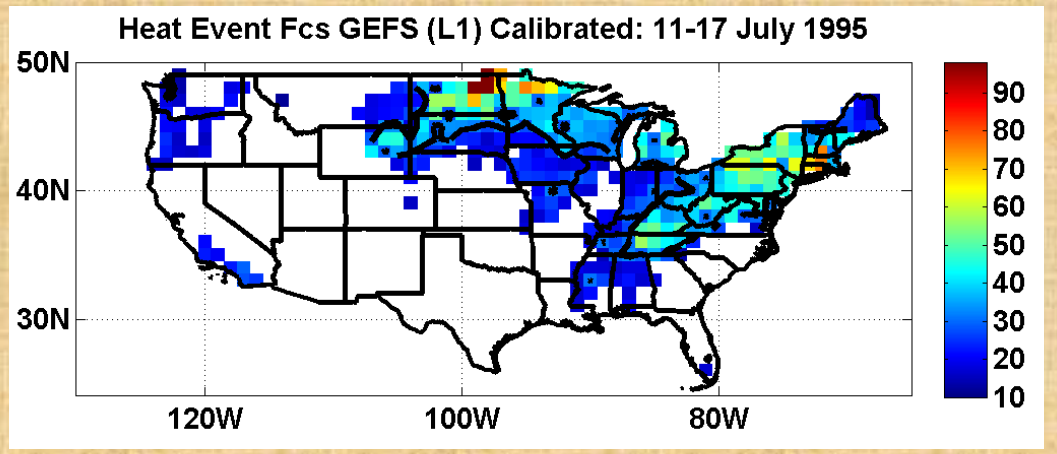
Ways for improving the baseline system:

(1) Investigate physical reasons for successes and drawbacks in forecasting specific heat events.

(2) Use statistical post-processing to bias correct and calibrate the probabilistic forecasts:



Reliability mapping

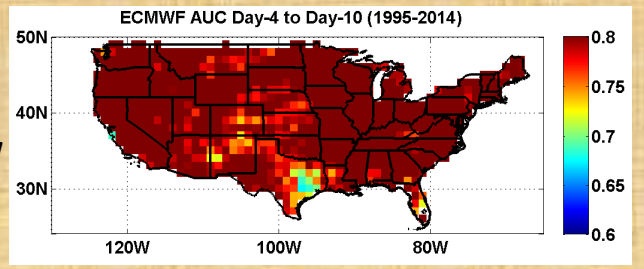


(3) Use multi-model ensemble forecasting approaches:

Multi-model Ensemble forecasts: AUC for L1 – events

Week~1

ECMWF



GEFS

11 ensemble members 1995-2015 twice per week to accommodate the ECMWF reforecast design. Caveat: GEFS is initialized by CFS-R and not GDAS

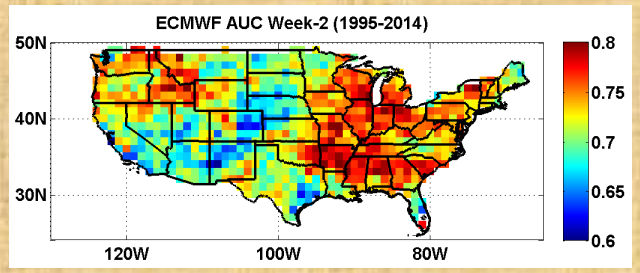
CFS

8 ensemble members constructed by combining forecasts initialized from two consecutive days (1999-2010)

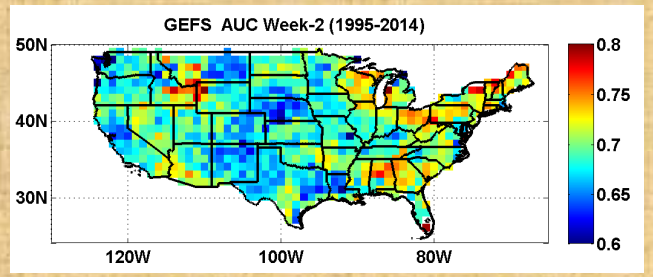
Multi-Model Ensemble Forecasting of Heat Events

Week-2

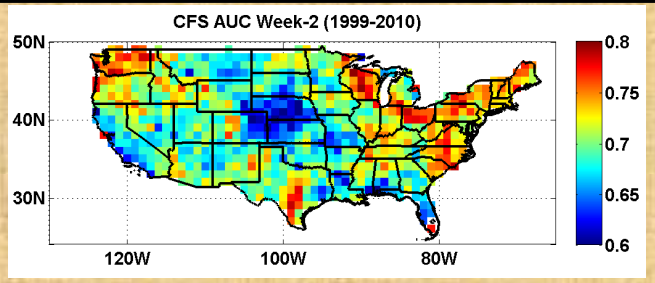
ECMWF



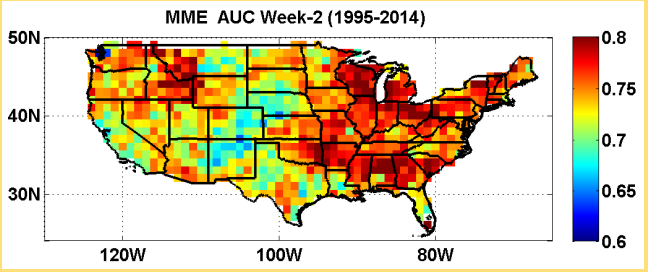
GEFS



CFS

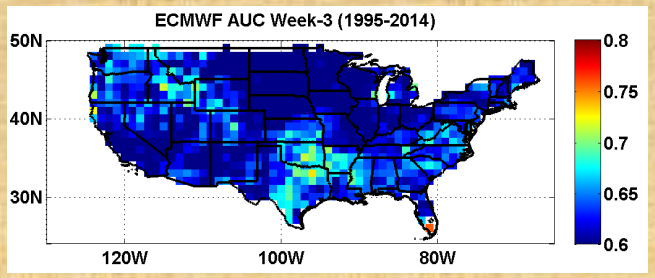


GEFS + ECMWF



Week-3

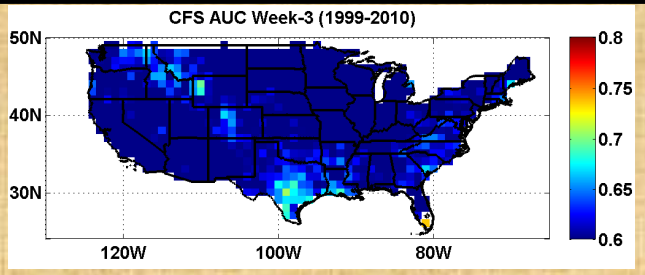
ECMWF



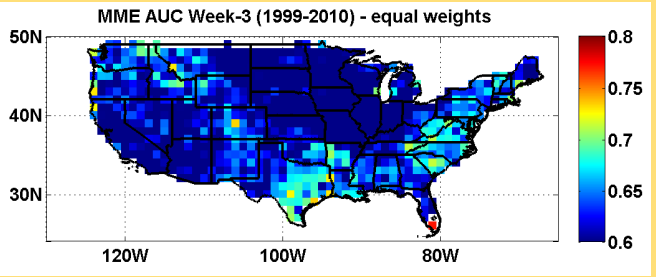
GEFS

No Week-3 GEFS
(for the moment)

CFS



CFS + ECMWF



Summary

- We quantified heat waves using a definition that takes into account human physiology and the constraints of probabilistic subseasonal forecasting (Week-2 to Week-3&4).
- We developed a monitoring systems for excessive heat events.
- We developed a baseline forecast system using the NCEP-GEFS and presented preliminary verification:
    - The system is capable of detecting heat events two weeks in advance (depending on the geographical area).
- We investigated multi-model approaches:
    - Combining the GEFS and ECMWF models provides better forecasts of heat events (better AUC) for forecast Week-2.
    - Combining the CFS and ECMWF models results to better forecasts of heat events along the northeast corridor and the mid-Atlantic for forecast Week-3.

Current/Future Work

- Daily experimental forecasts of Week-2 Heat Events with the GEFS (based on 84 ensemble members) will start during the week 2-6 May 2016.
- These forecasts will be available to Climate Prediction Center forecasters for evaluation which will allow to improve the system.
- Augment forecast capacity of the system by including predictions based on the ECMWF Week-2 forecasts.
- Augment forecast capacity by including CFS and other NMME operational models.
- Extend the system to Week3@4 and to the global subtropics and tropics.