A Baseline System for Forecasting Excessive Heat Events at Subseasonal Lead Times

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NOAA/CPC

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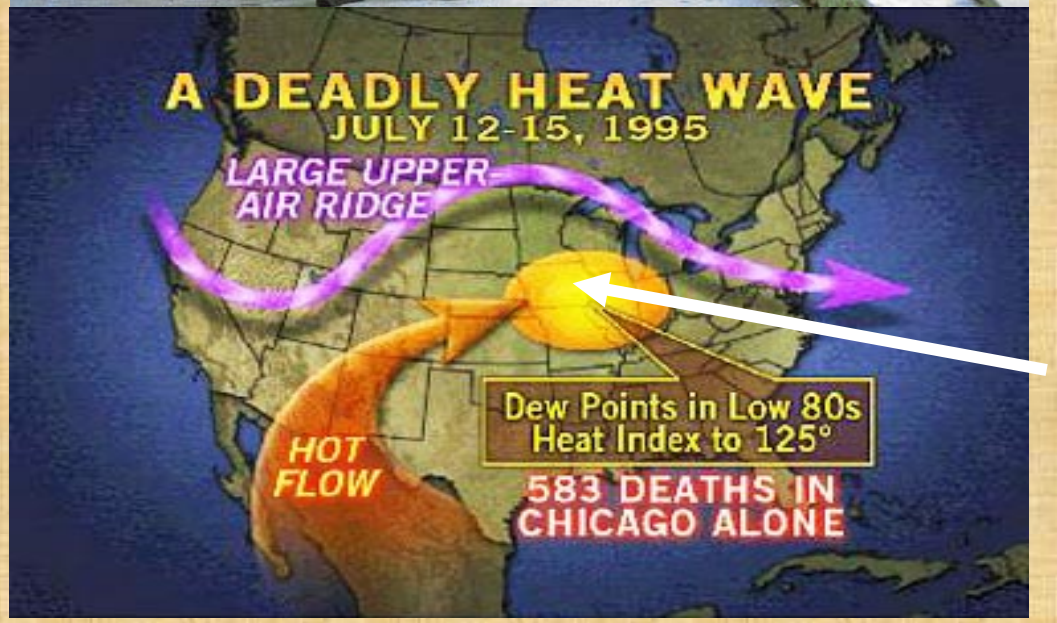
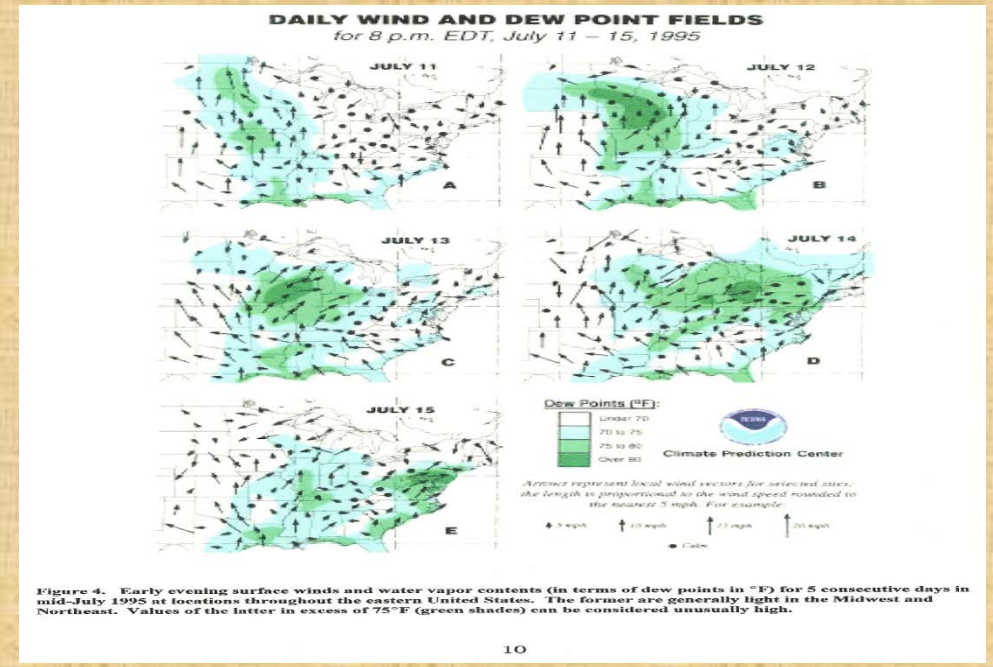
Outline:

- Definition of excessive heat events.
- Description of the monitoring system for heat events.
- The baseline forecasting system.
- Preliminary results from forecast verification.
- Multi-model approaches for improving the system.
- Summary and current/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

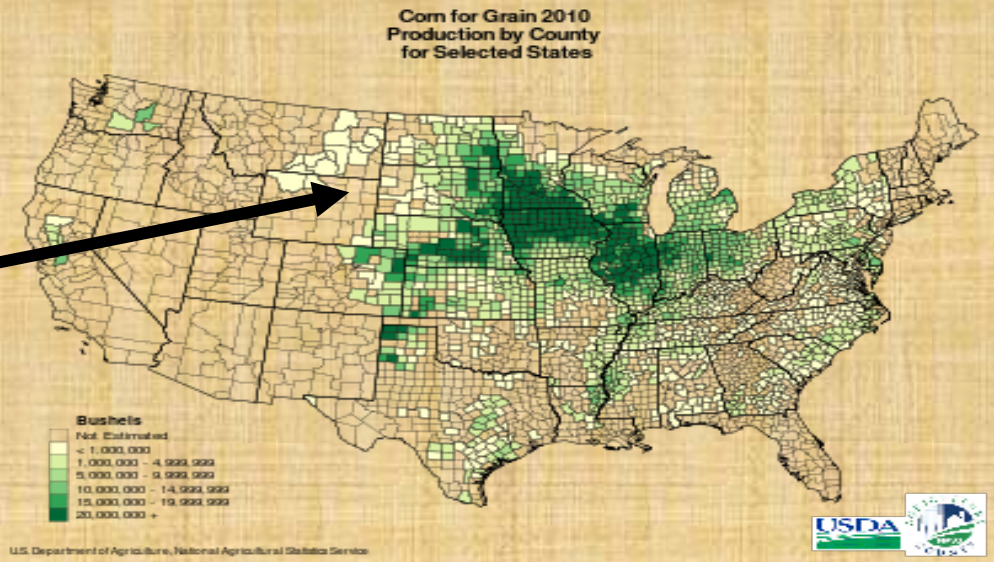
Arrows represent local wind vectors for selected sites; the length is proportional to the wind speed rounded to the nearest 5 mph. For example:

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.

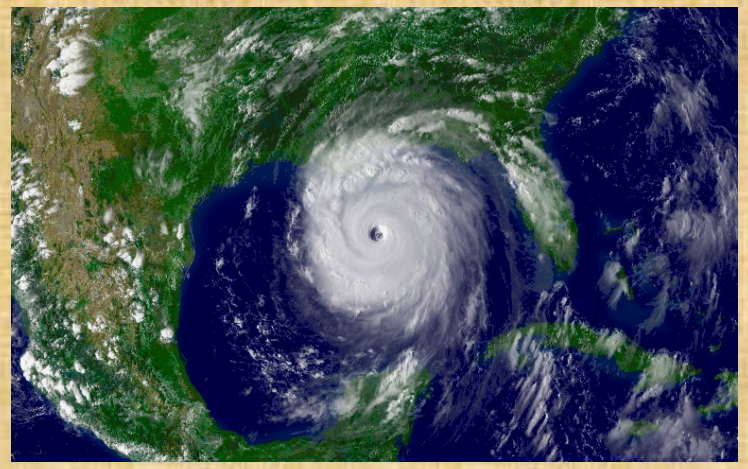
10

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

The Corn Belt



In comparison with other natural disasters, visualization of Heat Events is more complex:



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

Visualizing quantitatively Heat Events is a necessary step before monitoring and forecasting…

Defining excessive heat events (I): Ingredients

Heat event impacts:

- **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.

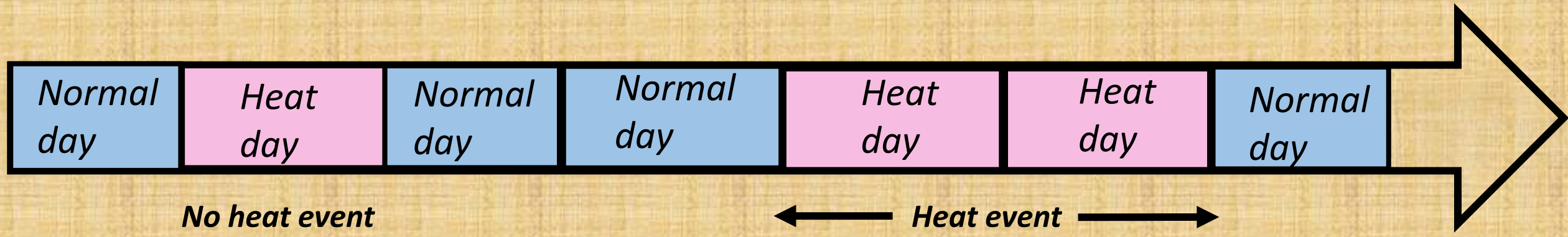
- **Depend on geographical location:** Requirement for a definition of what is high apparent temperature as a function of location.

- **Are a function of time due to acclimatization:** Requirement for definition of what is high apparent temperature as function of timing within the warm season.

Defining excessive heat events (II)

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

- A Heat Day is a day with Maximum Heat Index exceeding a given percentile **α** for the given 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: Needs long historical records (and expensive reforecasts).

Monitoring weekly Heat Events

Heat Week:

- A week is defined as 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 a duration of the heat event within this week.

Monitoring system data source:

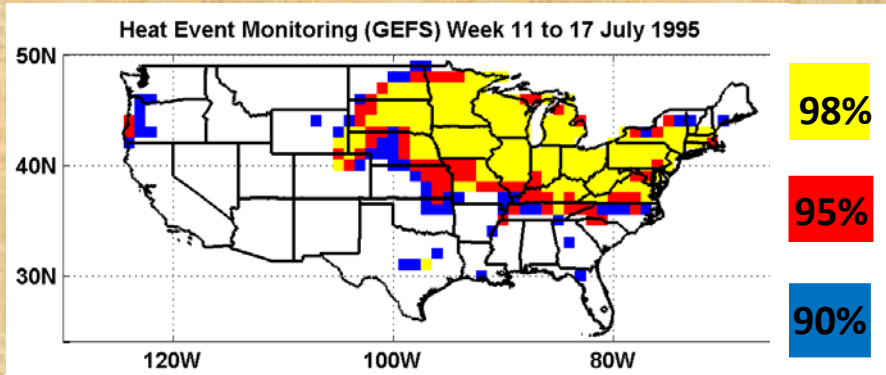
- GEFS Day-1 forecasts.
- NCAR/NCEP Reanalysis (comparison in backup slides)
- Working towards monitoring systems based on direct observations of temperature and humidity

Example (GEFS monitoring): The July 1995 Heat Event

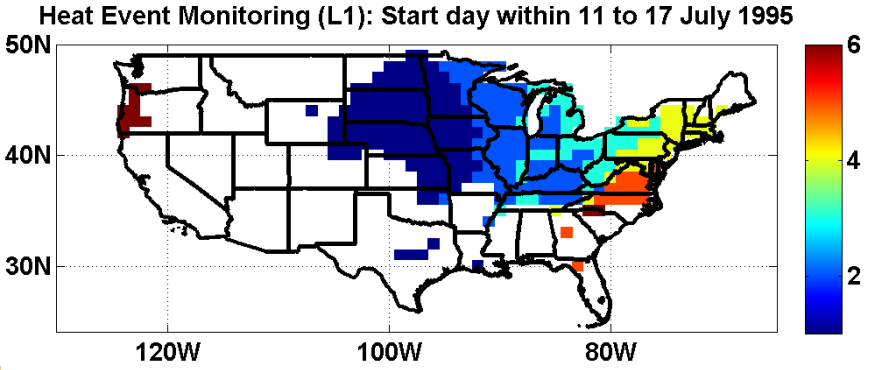
- During the week of 11-17 July 1995 a Level-3 Heat Event (98% - yellow) was covering an extended area from the Upper Midwest to the Northeast and Mid-Atlantic.
- This heat event progressed from west to east during this week.
- The event lasted 5 days (for Level-1 intensity) in the Chicago area.

Description of the July 1995 Heat Event

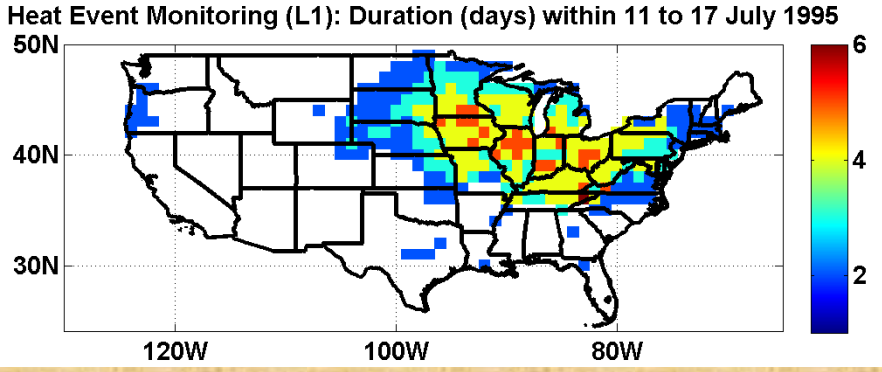
Occurrence



Start day (L1)



Duration (L1)



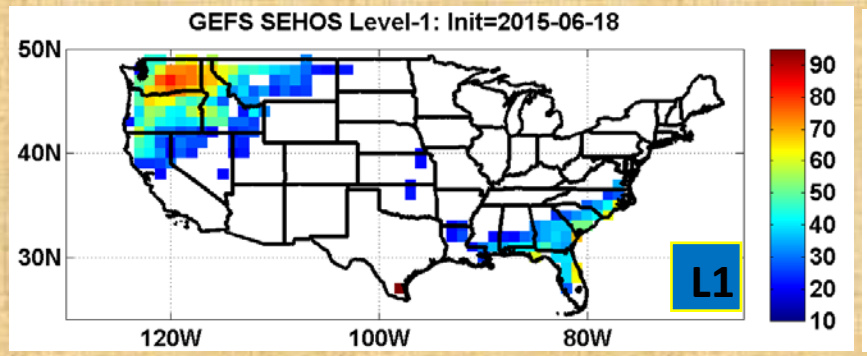
Forecasting excessive heat events (I): Baseline system

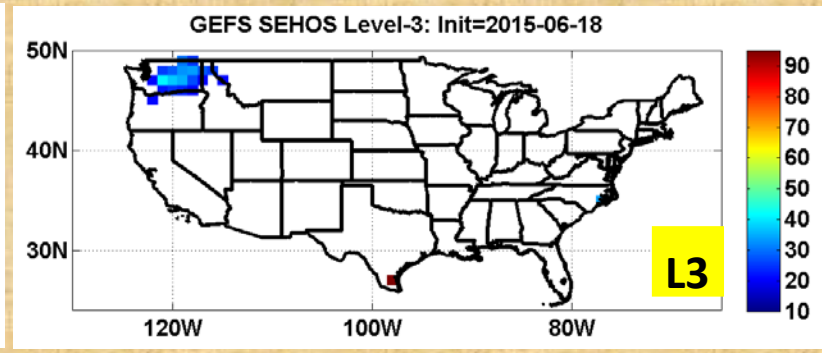
Baseline system: The NCEP GEFS (targeting Week-2)

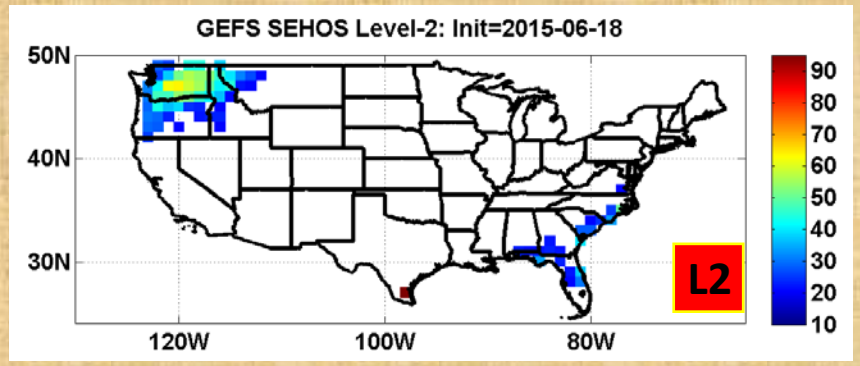
- Initialized daily at 00Z, 06Z, 12Z and 18Z
- 20 perturbed forecasts per cycle resulting to 84-member ensemble per day
- For each ensemble member we compute whether Week-2 is a Heat Week, the starting day and the duration.
- Compute the statistics: Probability of occurrence, mean start day, mean duration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

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

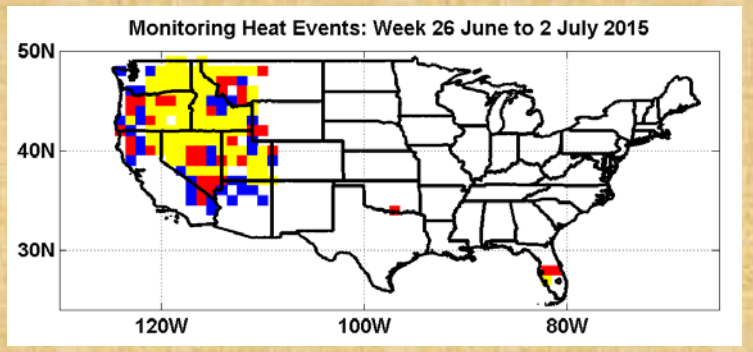
Probability of Occurrence of Heat Event





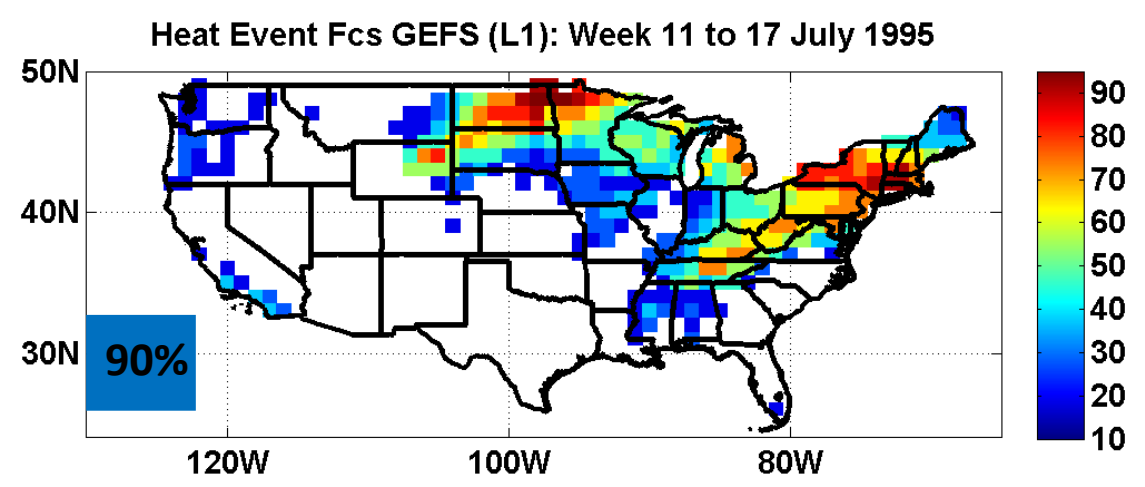


Verification

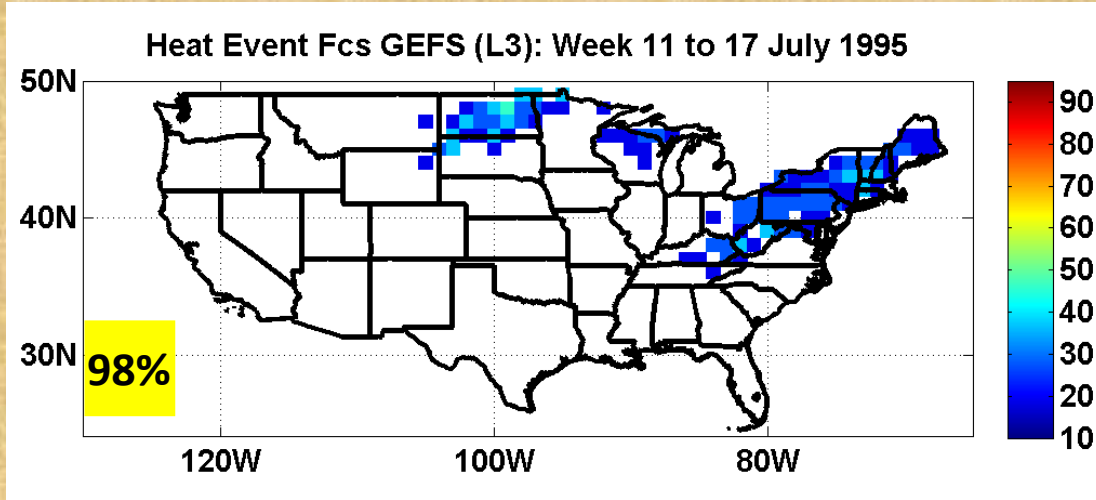


Forecasting excessive heat events (II): July 1995

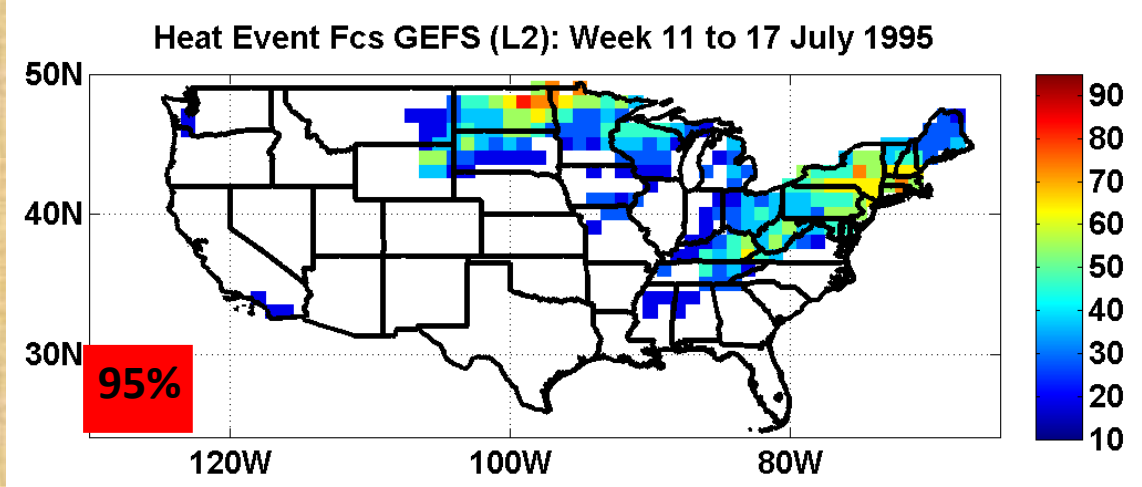
L1



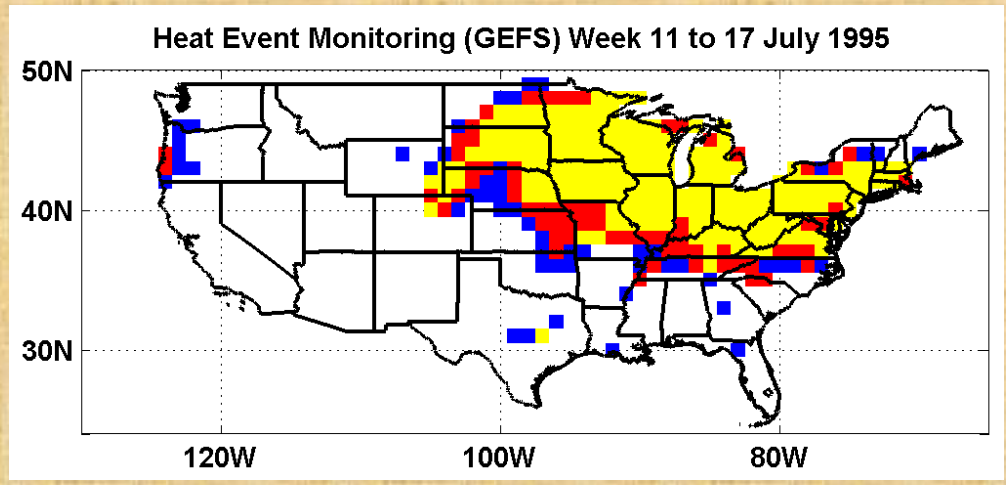
L3



L2



Verification



<u>Caveat:</u> prediction based on the 111ensemble members GEFS reforecast

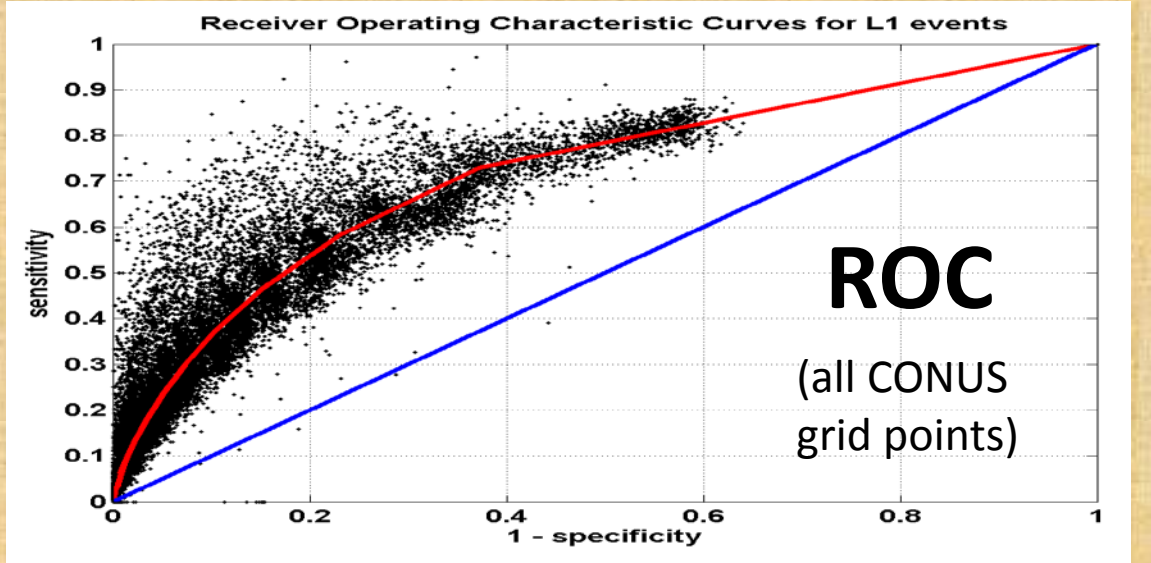
Verification for the 1985-2014 period

Verification of GEFS 1985-2014: Receiver Operating Characteristic (ROC) and Area Under Curve (AUC)

Forecast=**YES** when Probability of occurrence > P

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

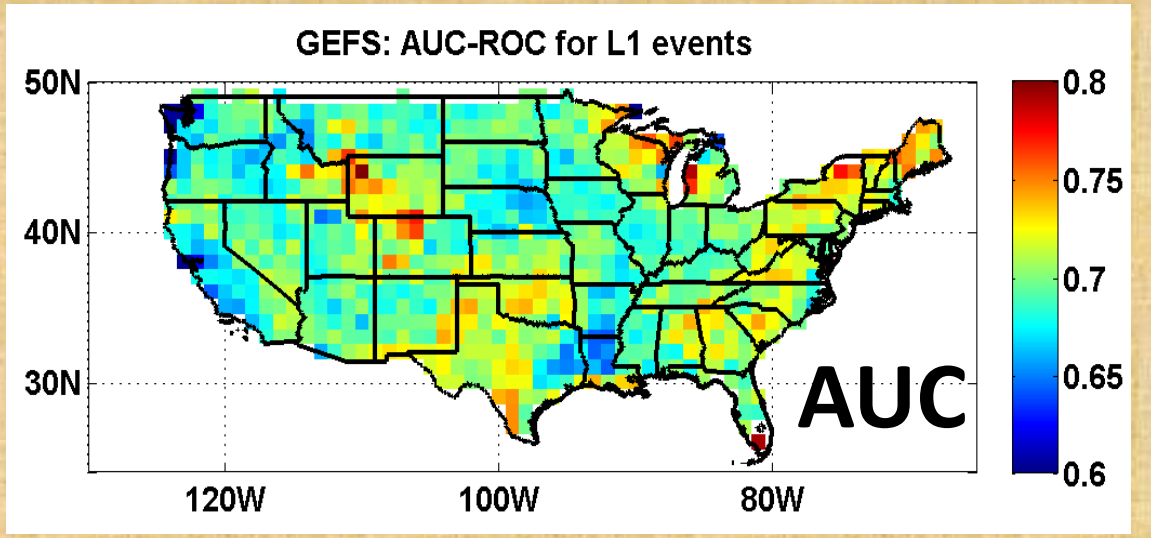
a/(a+c)



b/(b+d)

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

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



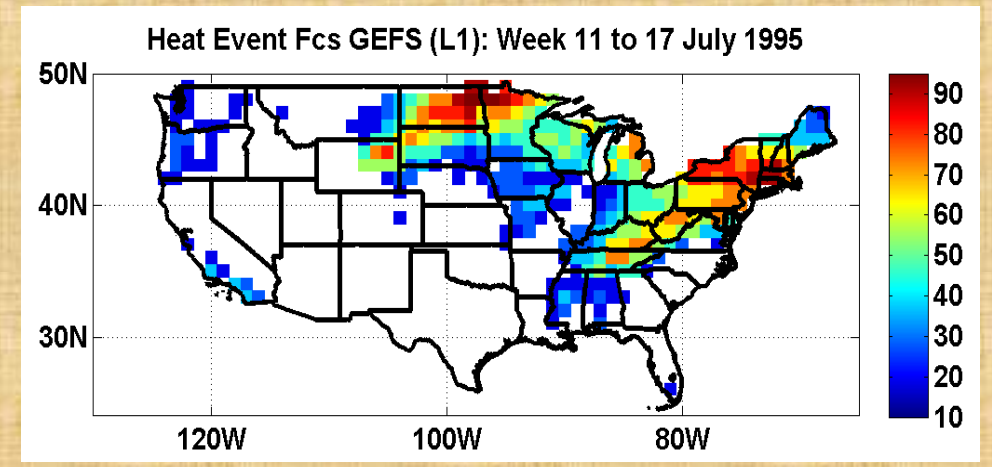
.90-1 = excellent
.80-.90 = good
.70-.80 = fair
.60-.70 = poor
.50-.60 = fail

Ways for improving the system:

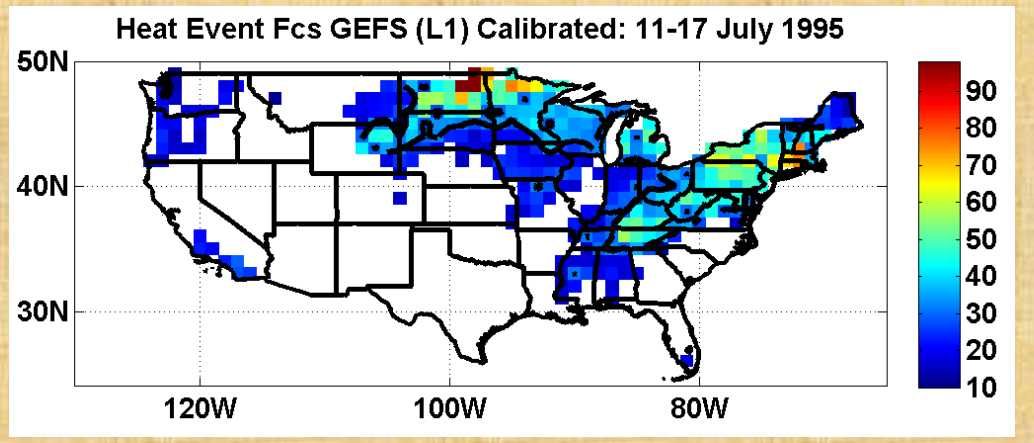
(1) Investigating physical reasons for successes and drawbacks in forecasting specific heat events.

(2) Statistical post-processing (bias correction and calibration) of the probabilistic forecasts (bearing in mind that we are in the realm of rare events).

Example of calibration for L1 events



Reliability mapping

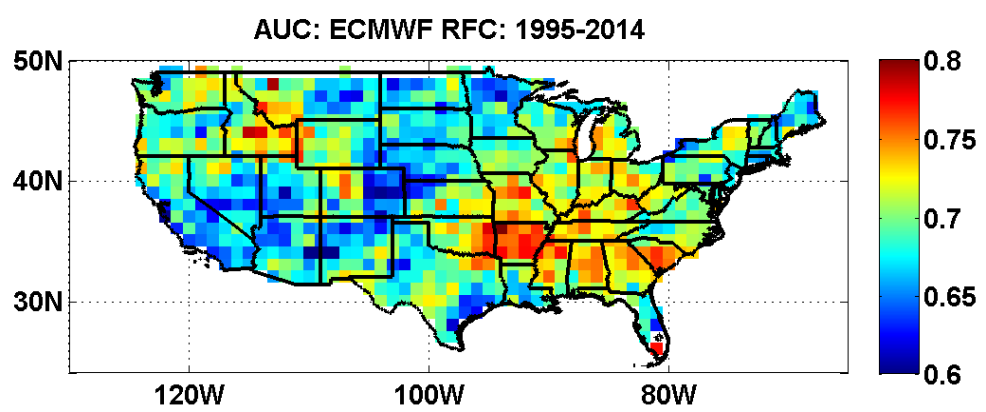


(3) Use multi-model ensemble forecasting approaches

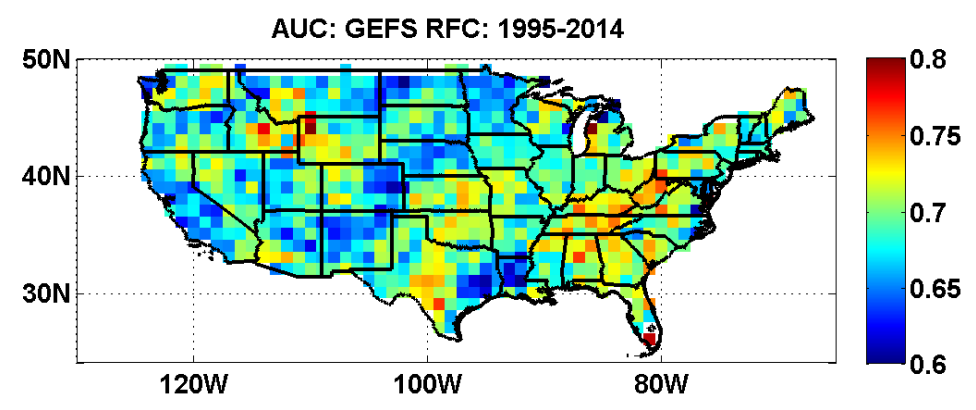
Multi-model forecast skill: Area Under Curve (AUC) for 1995-2014

Reforecasts of L1 intensity events (1995-2014) initialized twice per week. Statistics for GEFS are computed from the 1985-2014 period. 11 + 11 ensemble members

ECMWF

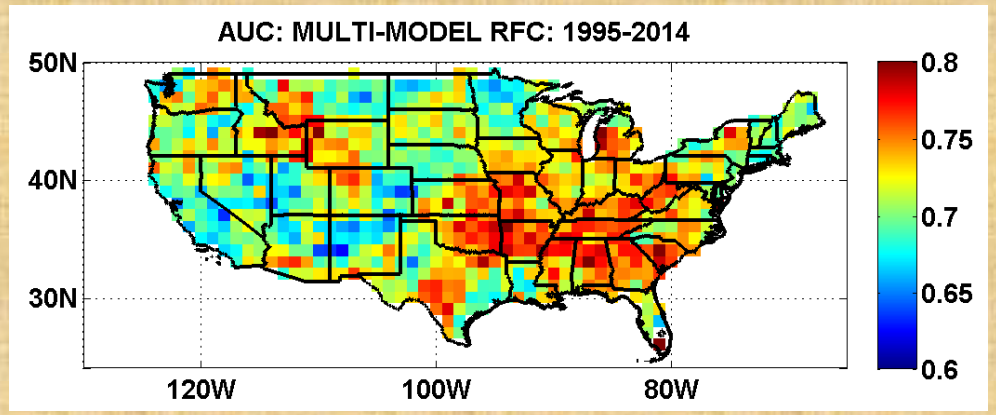


GEFS



Equal weighting of probabilities of occurrence

MULTI-MODEL



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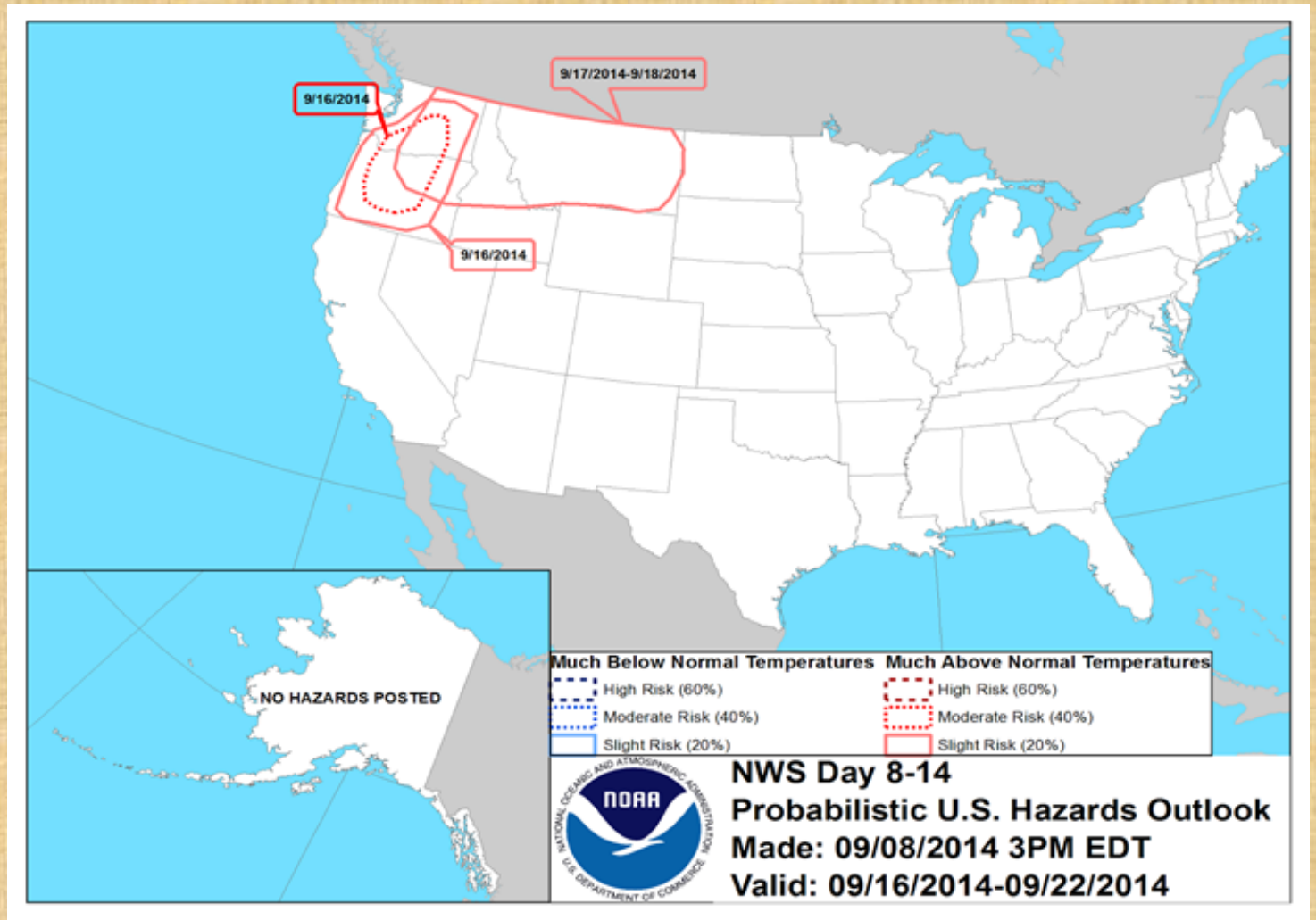
Climate Prediction Center Public Interface:

Human forecasters will be using the model guidance to pinpoint areas of increased probability of occurrence of a heat event and its starting date



Summary

Objective: Develop a subseasonal excessive heat outlook system (SEHOS)

- 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 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).
    - The model tend to miss heat events at higher intensity levels.
- We investigated multi-model approaches:
    - Combining the GEFS and ECMWF models provide better forecasts of heat events (better AUC).

Current/Future Work

- Daily experimental forecasts of Week-2 Heat Events with the 84-member ensemble GEFS will be run during summer 2016.

- These forecasts will be used by Climate Prediction Center forecasters for evaluation.

- In the near future we will be augmenting forecast capacity of the system by including predictions based on the ECMWF and CFS (NMME) forecast systems.

- We will extend the SEHOS to Week3@4 and to the global tropics and subtropics.

Support Slides

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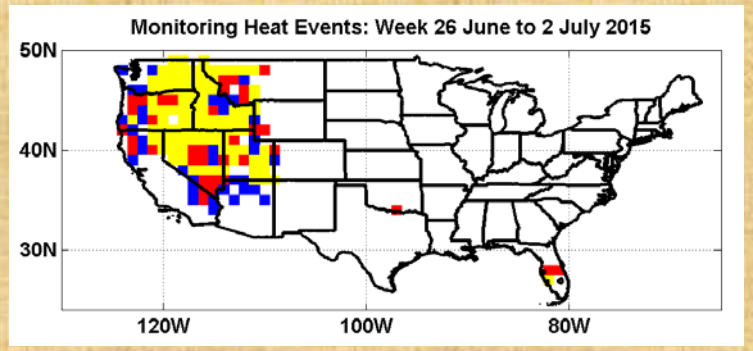
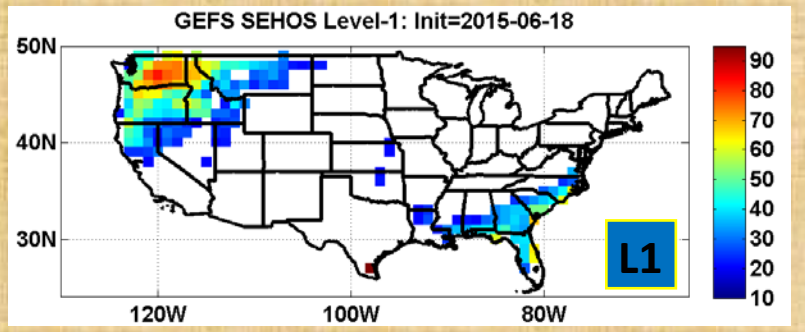
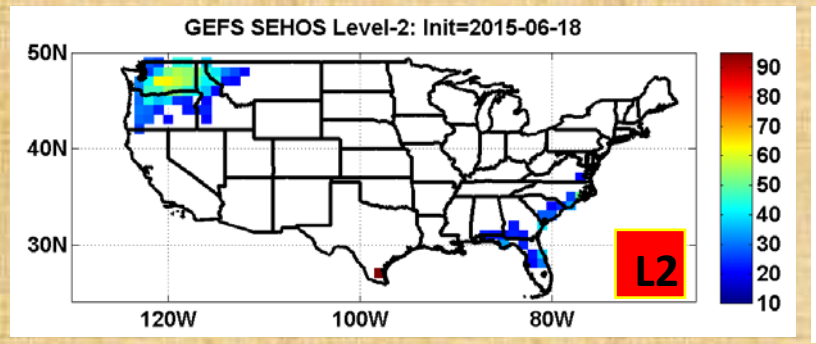
Example of realtime forecast product: GEFS initialized on18 June 2015 for Week-2: 26 June to 2 July 2015.

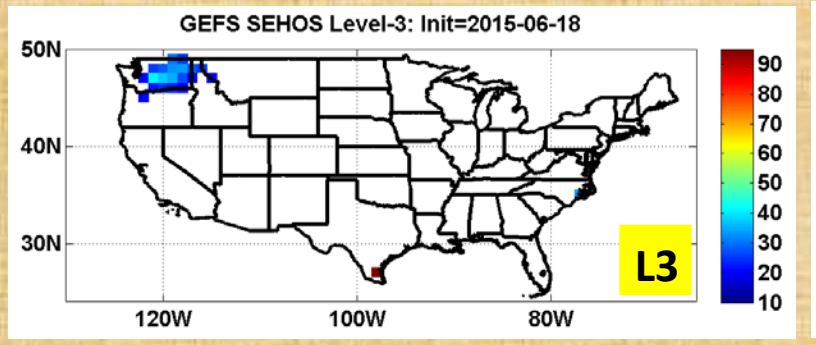
Verification



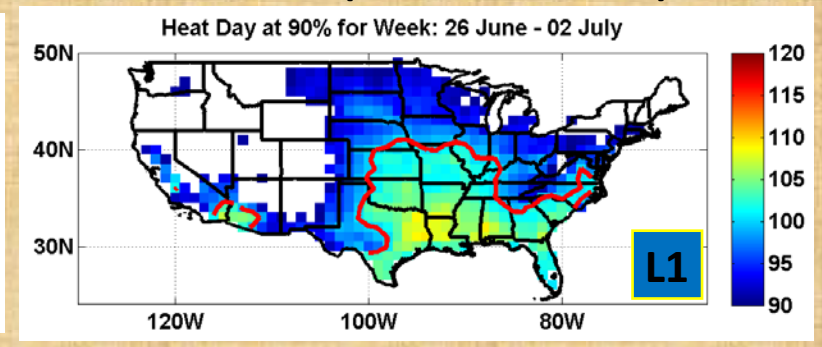
Probability of Occurrence of Heat Event

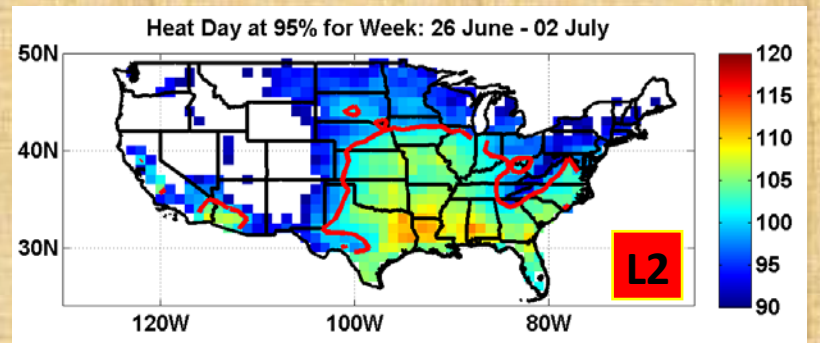


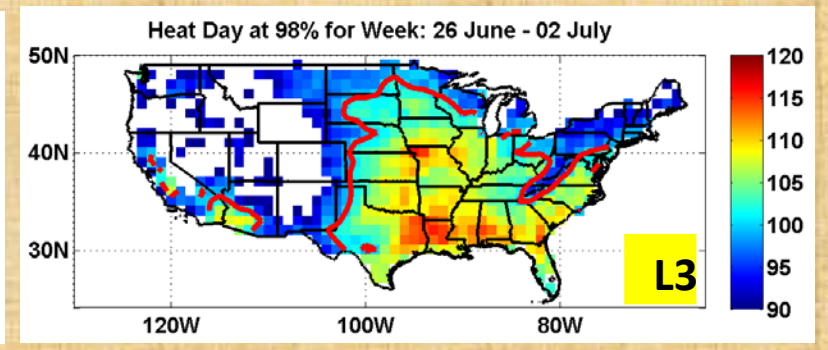




Climatological Heat Day for Week: 06/26 to 07/02 (Red line = 100F)







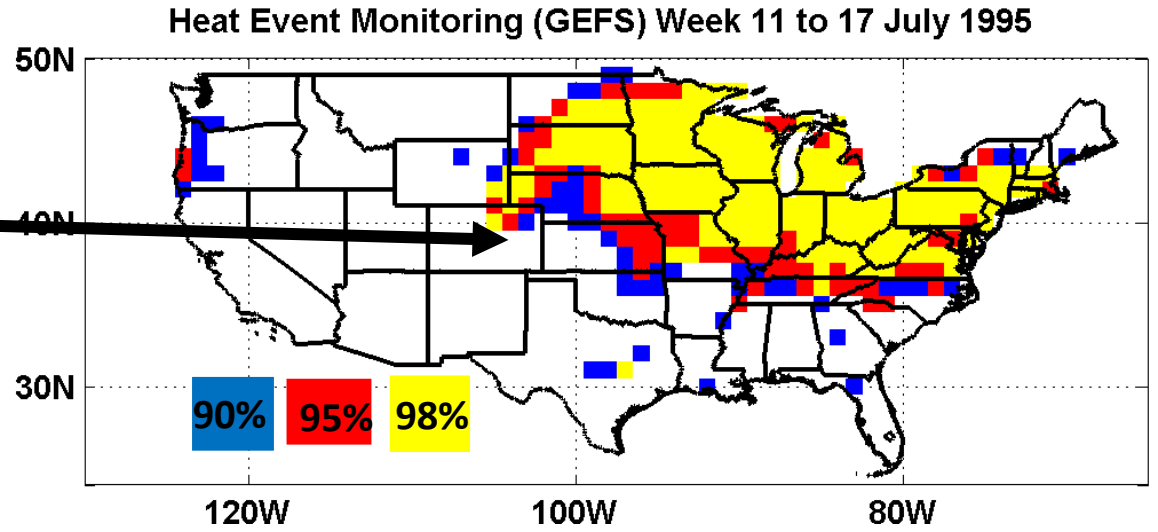
Monitoring excessive heat events (II)

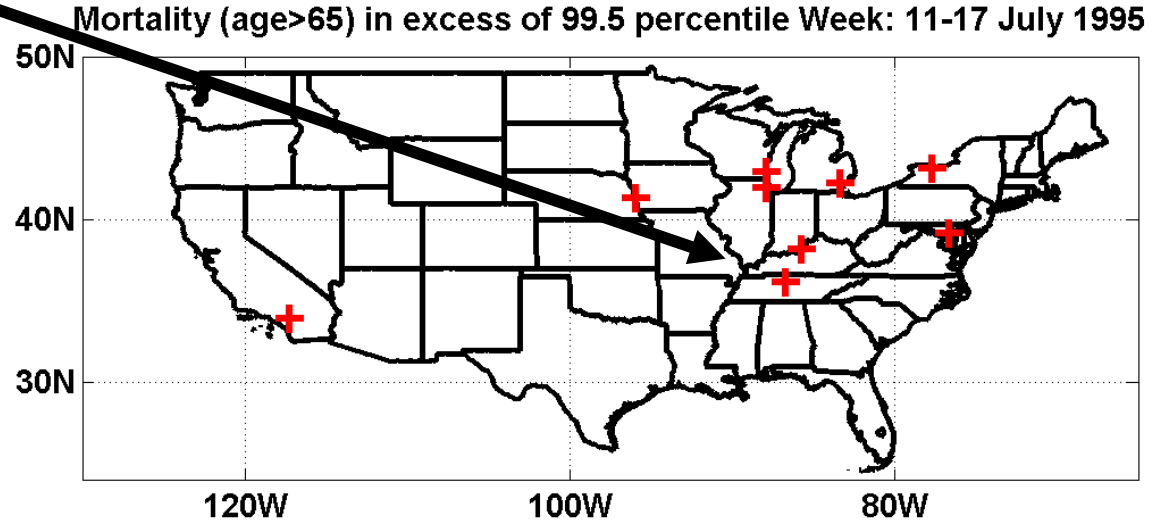
Impacts of the July 1995 Heat Event to human mortality

The Heat Event of 11-17 July 1995 had a significant impact on mortality.

A cluster of excessive mortality is collocated with the area of the heat event.

Locations with at least one day of excessive all-cause mortality for the age 65 or older group during this week. Excessive mortality is defined as exceeding the 99.5 percentile of mortality for the given week. Mortality data courtesy of Scott Sheridan.



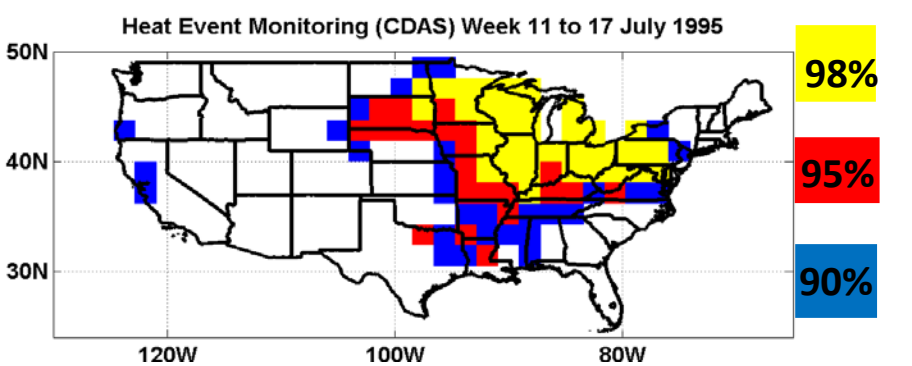


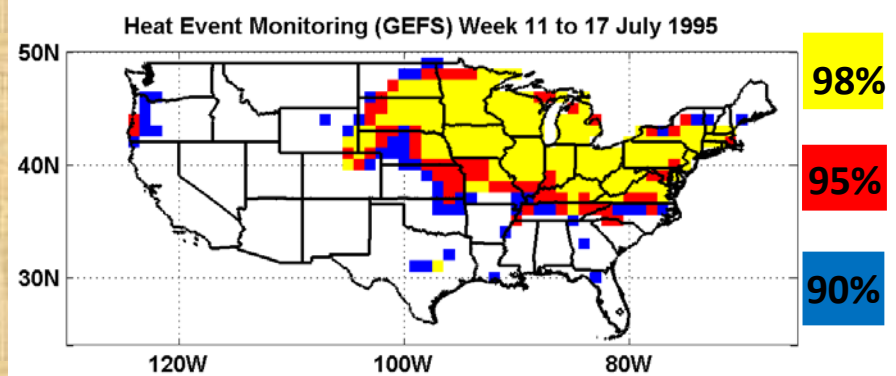
Mortality data not for all cities e.g. Milwaukee, WI

Monitoring Heat Events: The July 1995 Heat Event

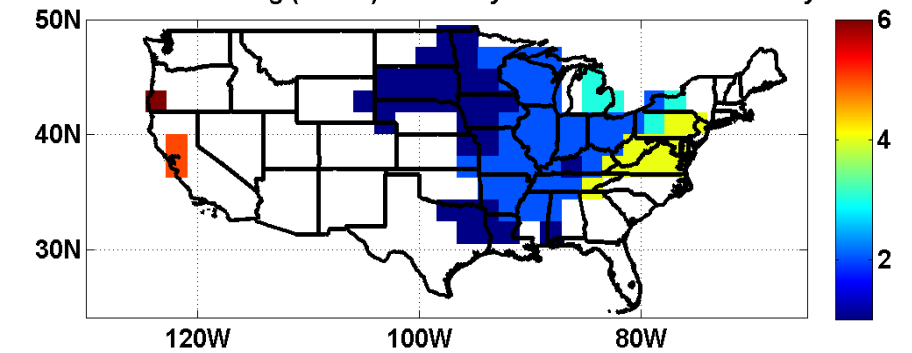
CDAS *vs.* **GEFS DAY-1**

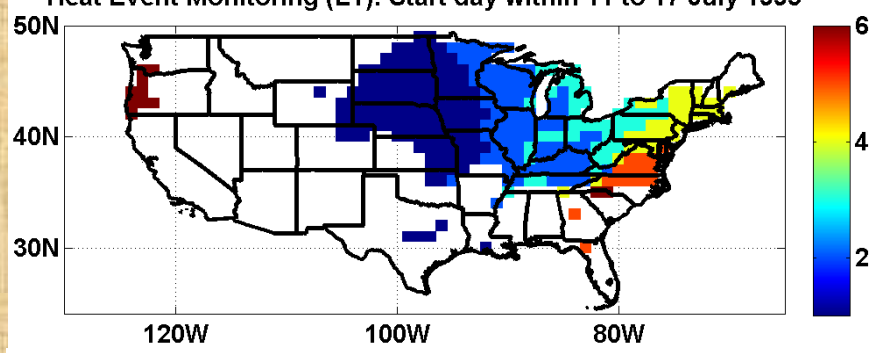
Existence



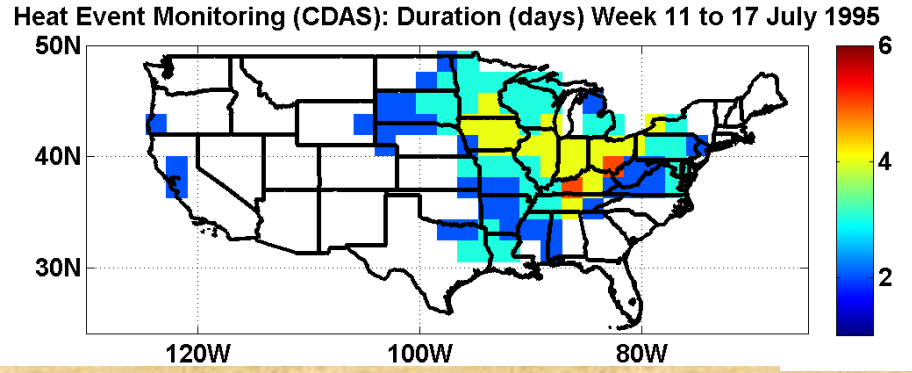


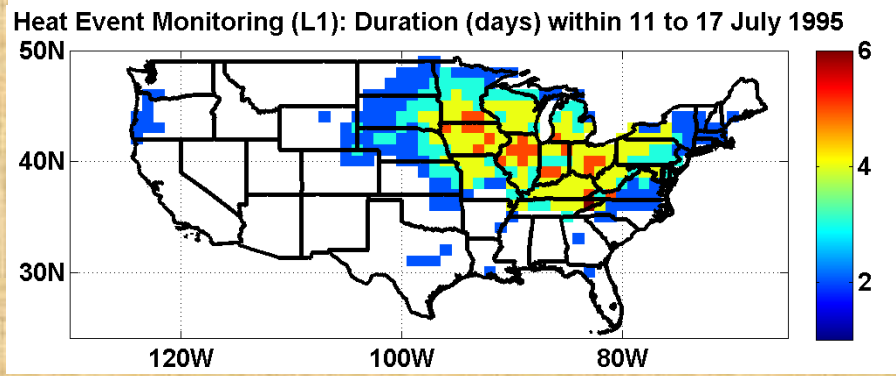
Start





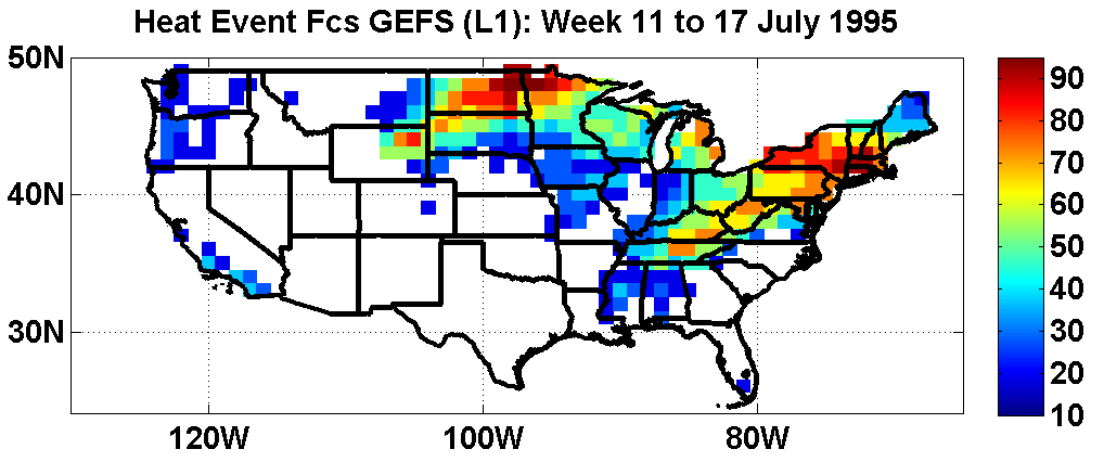
Duration



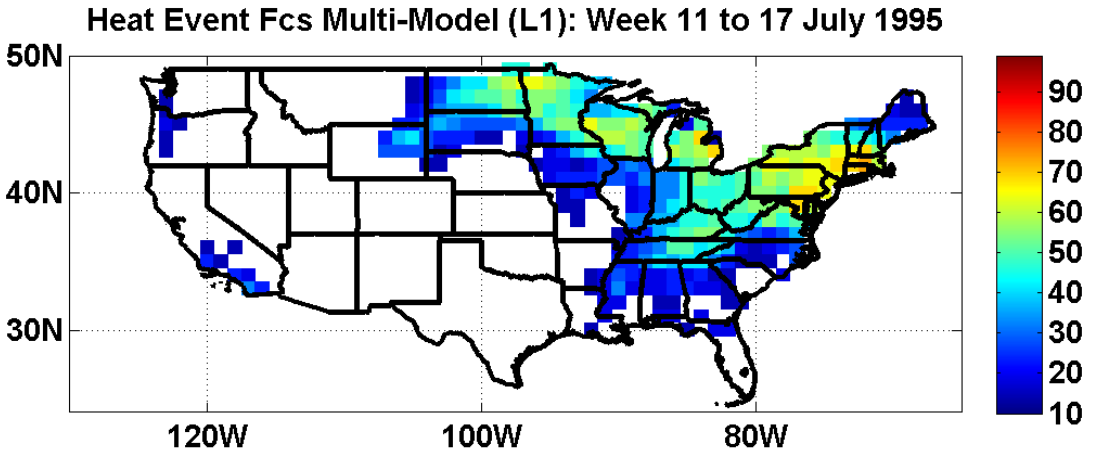


Case study: Week-2 Probability of Occurrence of Heat Event (L1) for GEFS, ECMWF and Multi-Model (equal weights)

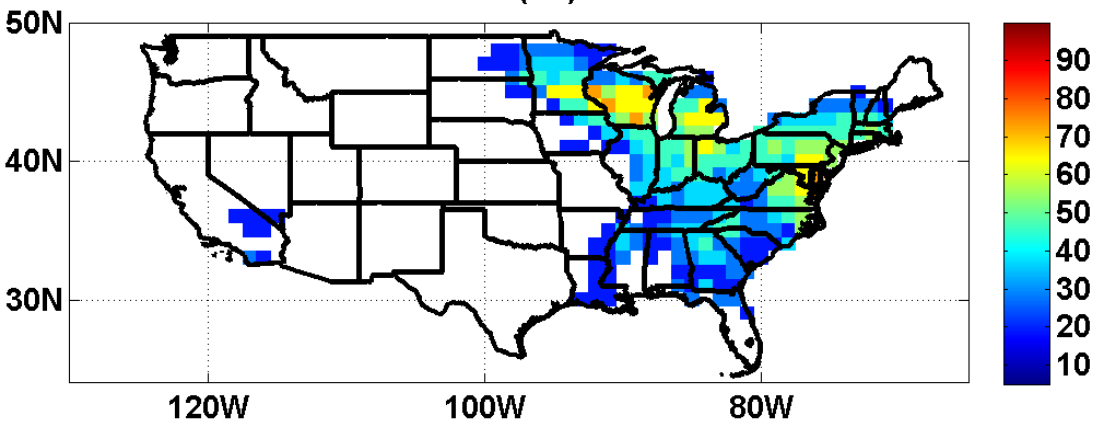
GEFS



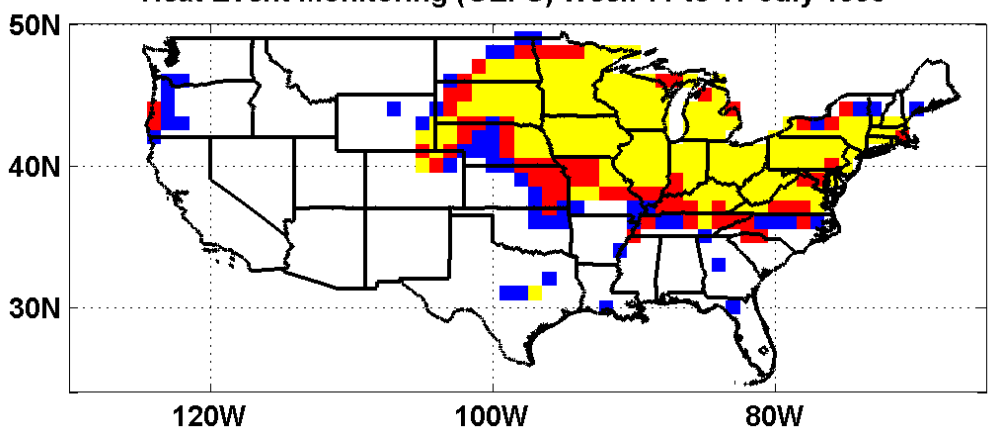
Multi-model



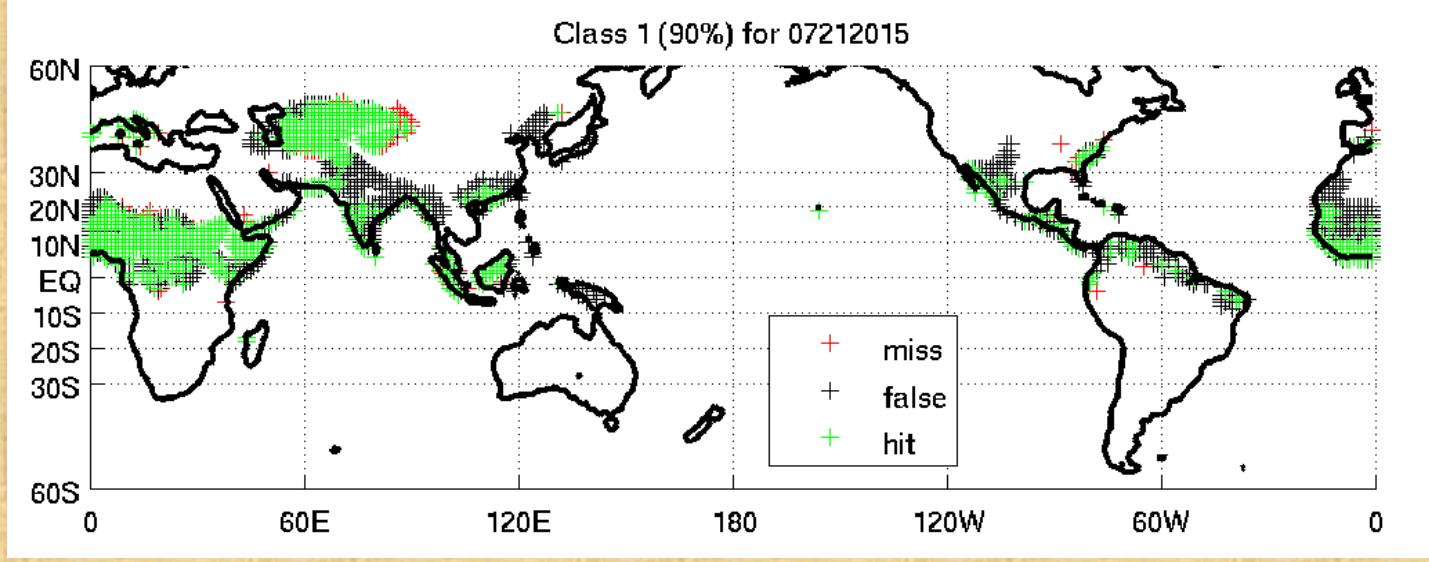
ECMWF

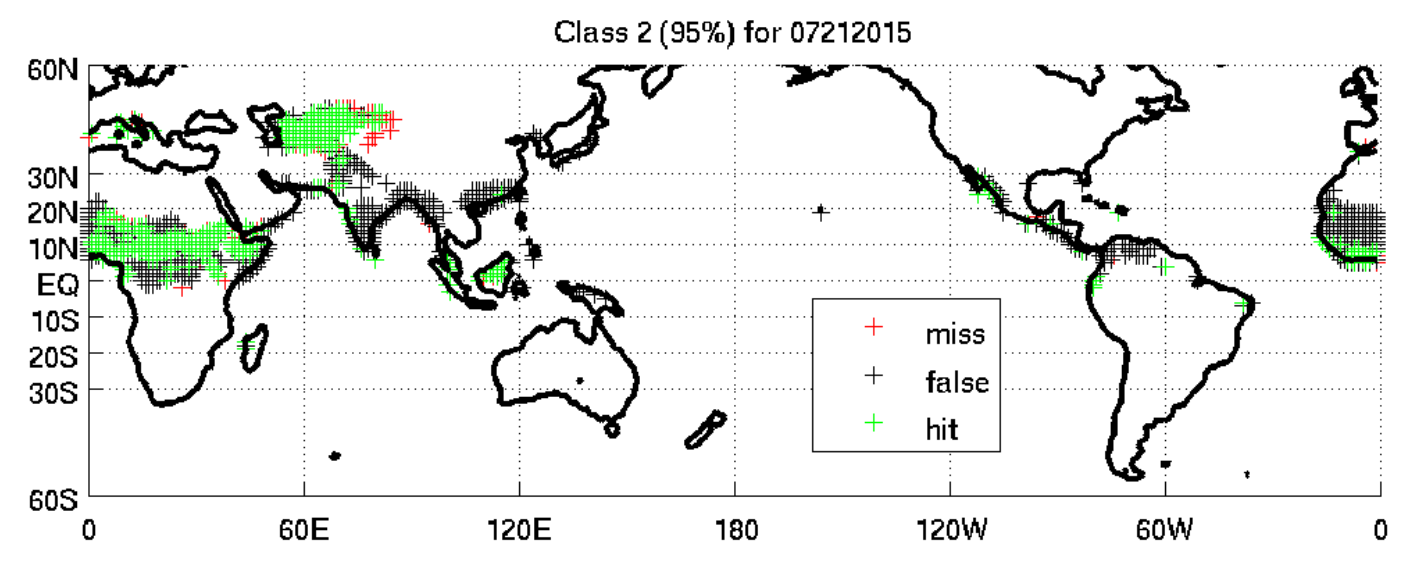


Verification



Week-2 Forecast and verification of L1 and L2 Heat Events with the GEFS in summer 2015

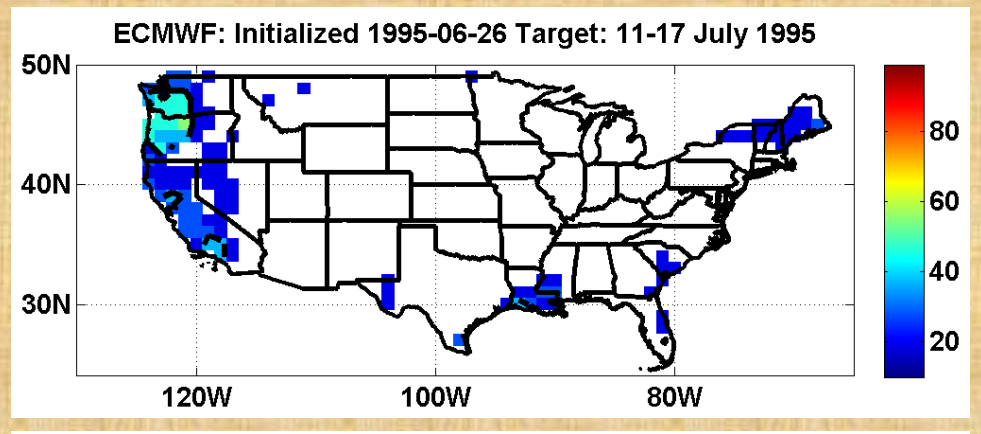


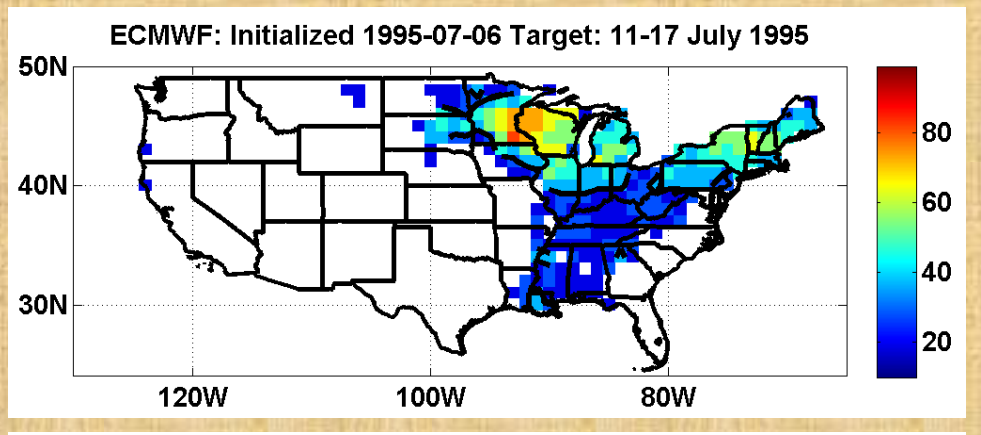


Towards Week 3&4 Forecasts

Beyond Week-2: ECMWF forecast of the July 1995 event (probability of L1 intensity) *vs.* Verification

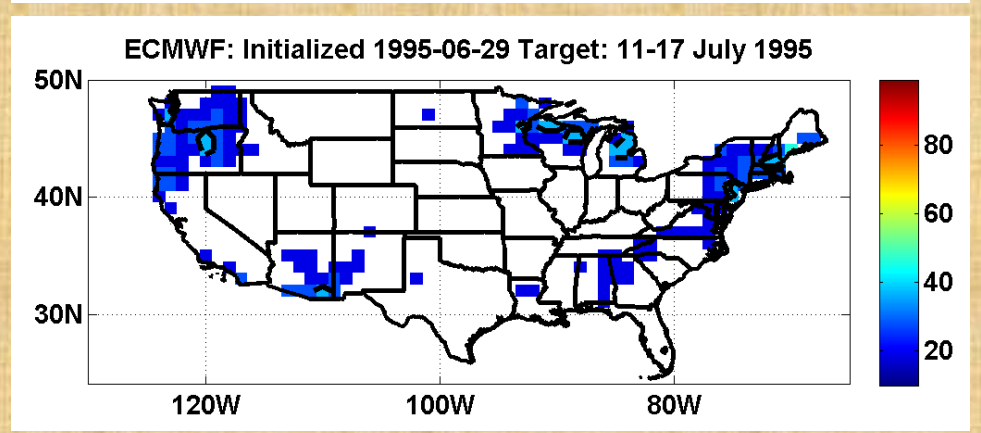
Days: 16-22

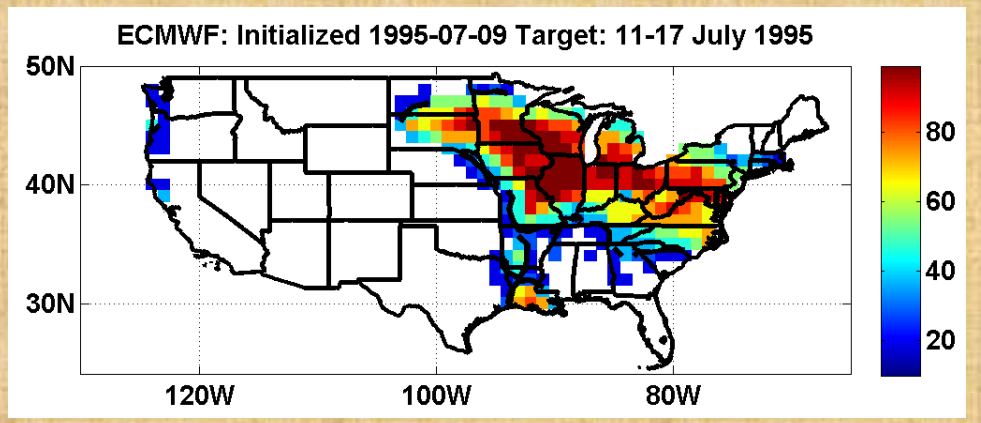




Days: 5-11

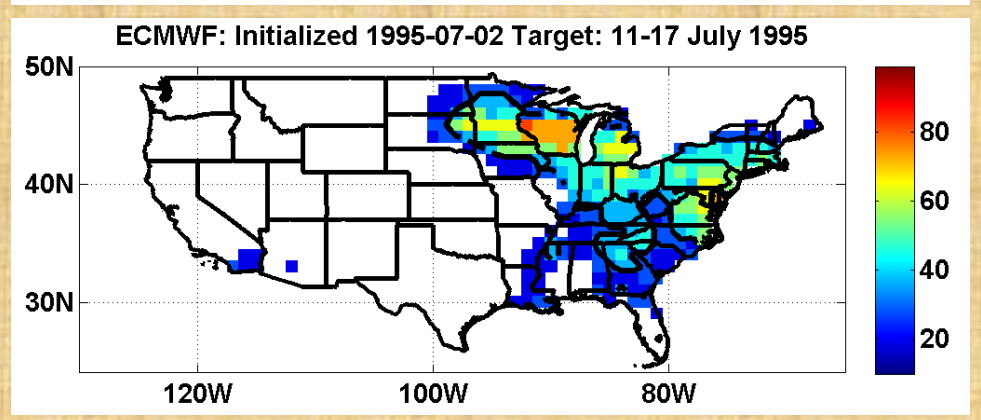
Days: 13-19

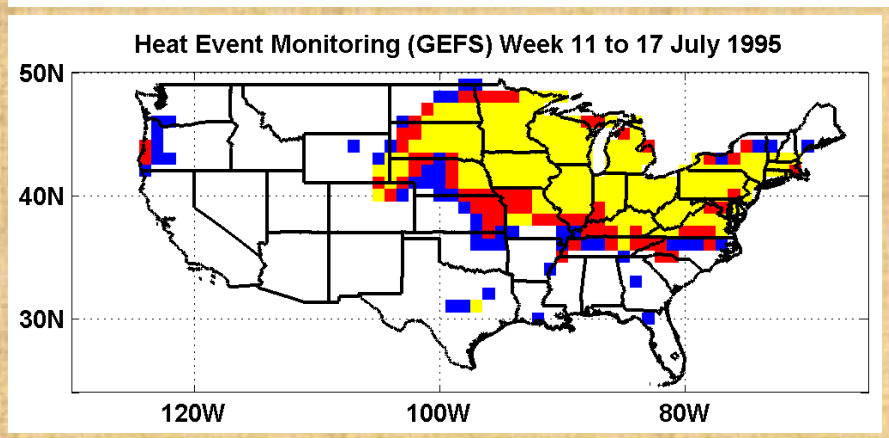




Days: 3-9 (weather forecast)

Days: 9-15

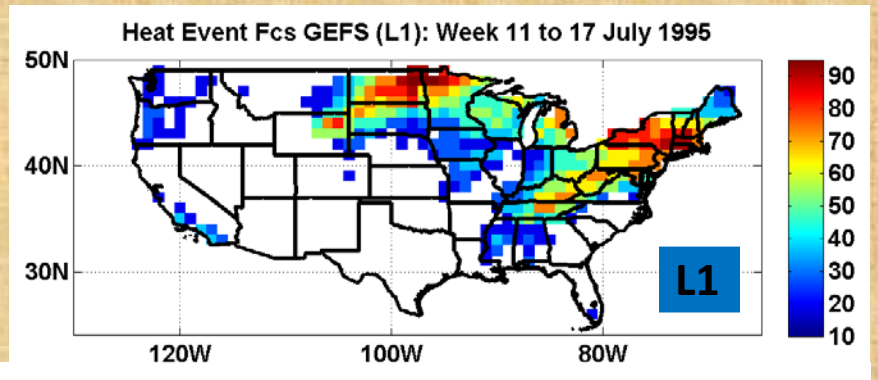


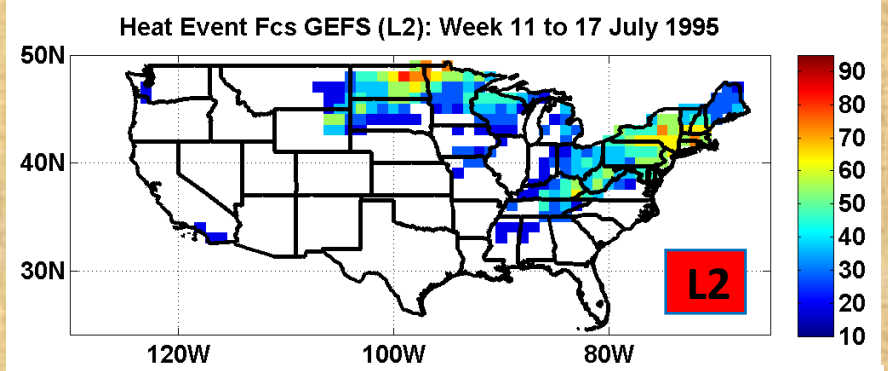


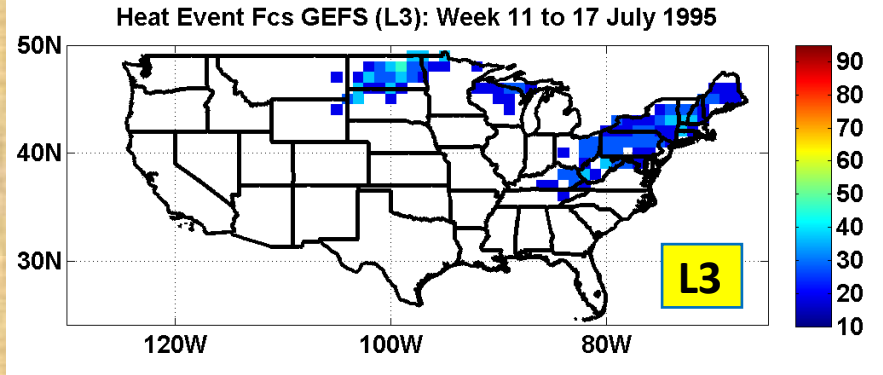
Verification L1/L2/L3

Week-2 forecast of probability of occurrence for L1, L2 and L3 Heat Events

GEFS

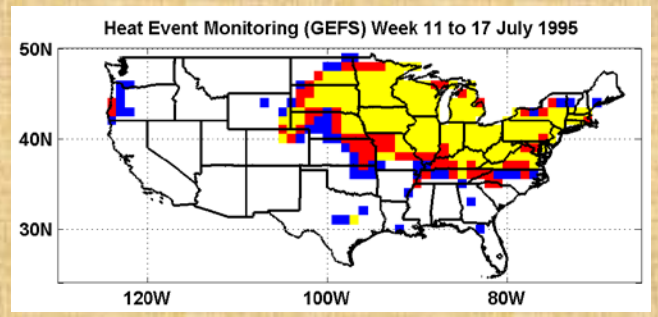






In contrast to the GEFS the ECMWF forecasted L1 heat events in the Chicago area

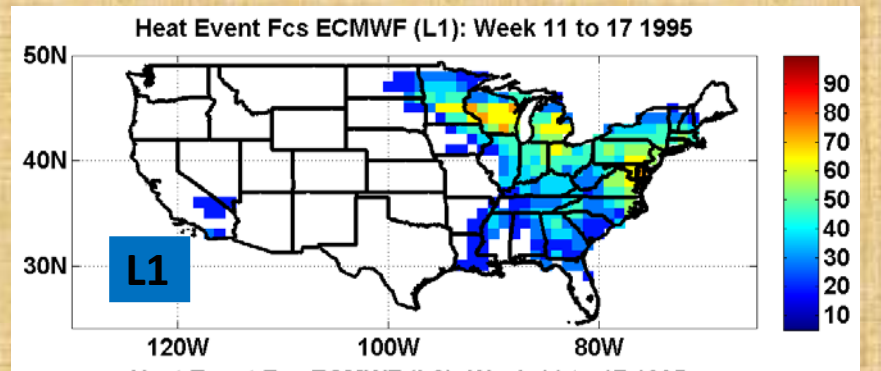
Observations

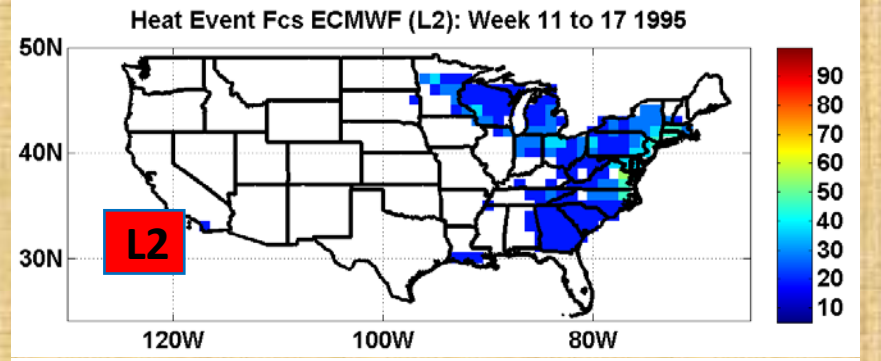


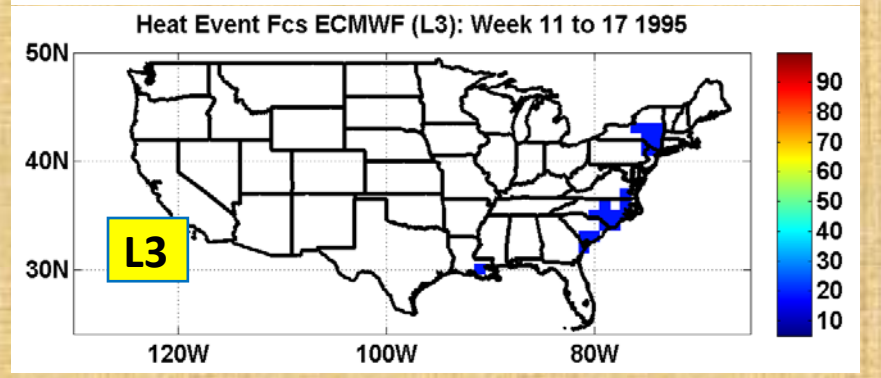
L1 L2 L3

However, forecasted probabilities of occurrence are generally lower for the ECMWF model and decrease rapidly as the intensity class increases

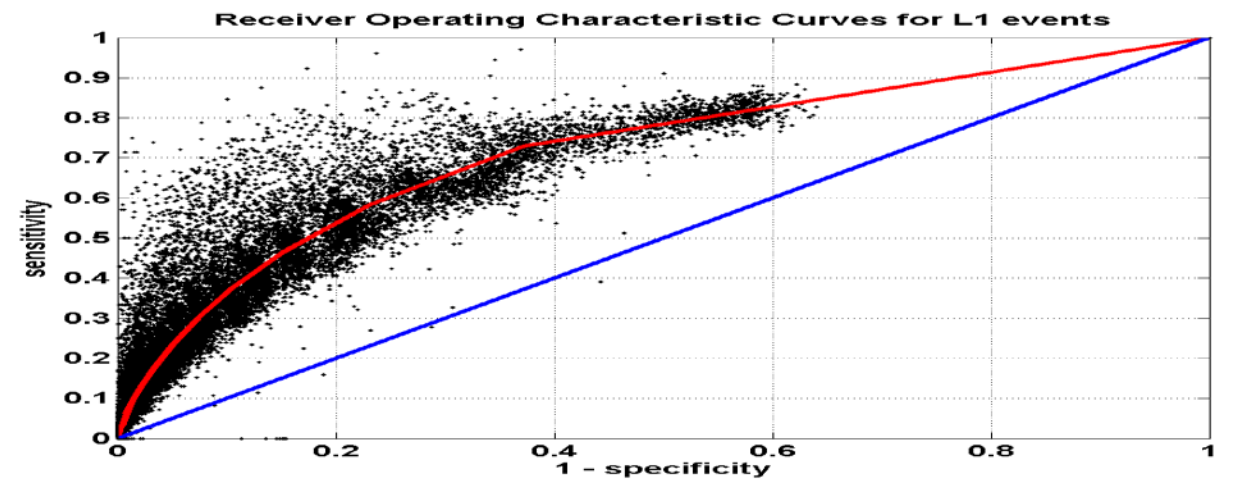
ECMWF

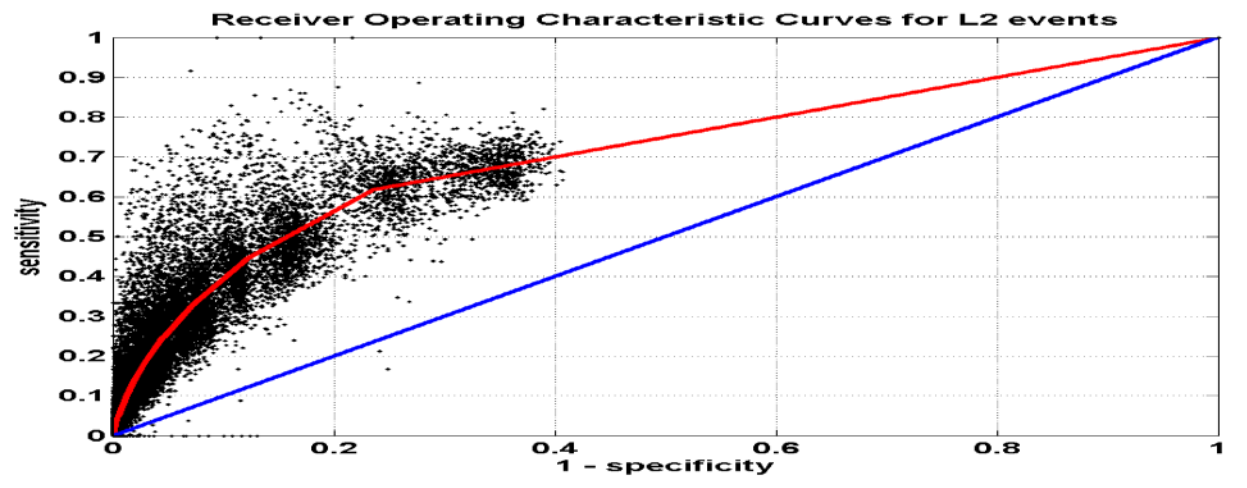


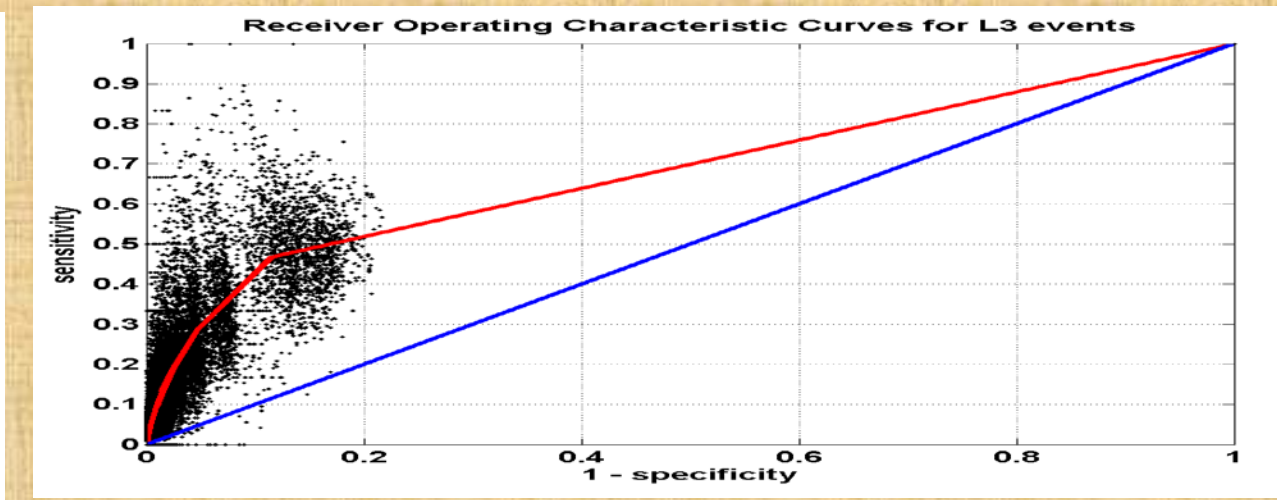




ROC Curves


Receiver Operating Characteristic Curves for L1 events
sensitivity
1 - specificity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1


Receiver Operating Characteristic Curves for L2 events
sensitivity
1 - specificity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1


Receiver Operating Characteristic Curves for L3 events
sensitivity
1 - specificity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1