Excessive Heat Events and Health:
Health-Impact Oriented Subseasonal Excessive Heat Outlook System

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Outlook:

- Motivation for this work.
- Definitions of excessive heat events.
- Physics of heat events
- Is subseasonal forecasting of excessive heat events possible?
- A health-impact oriented excessive heat early warning system.
- Next steps.

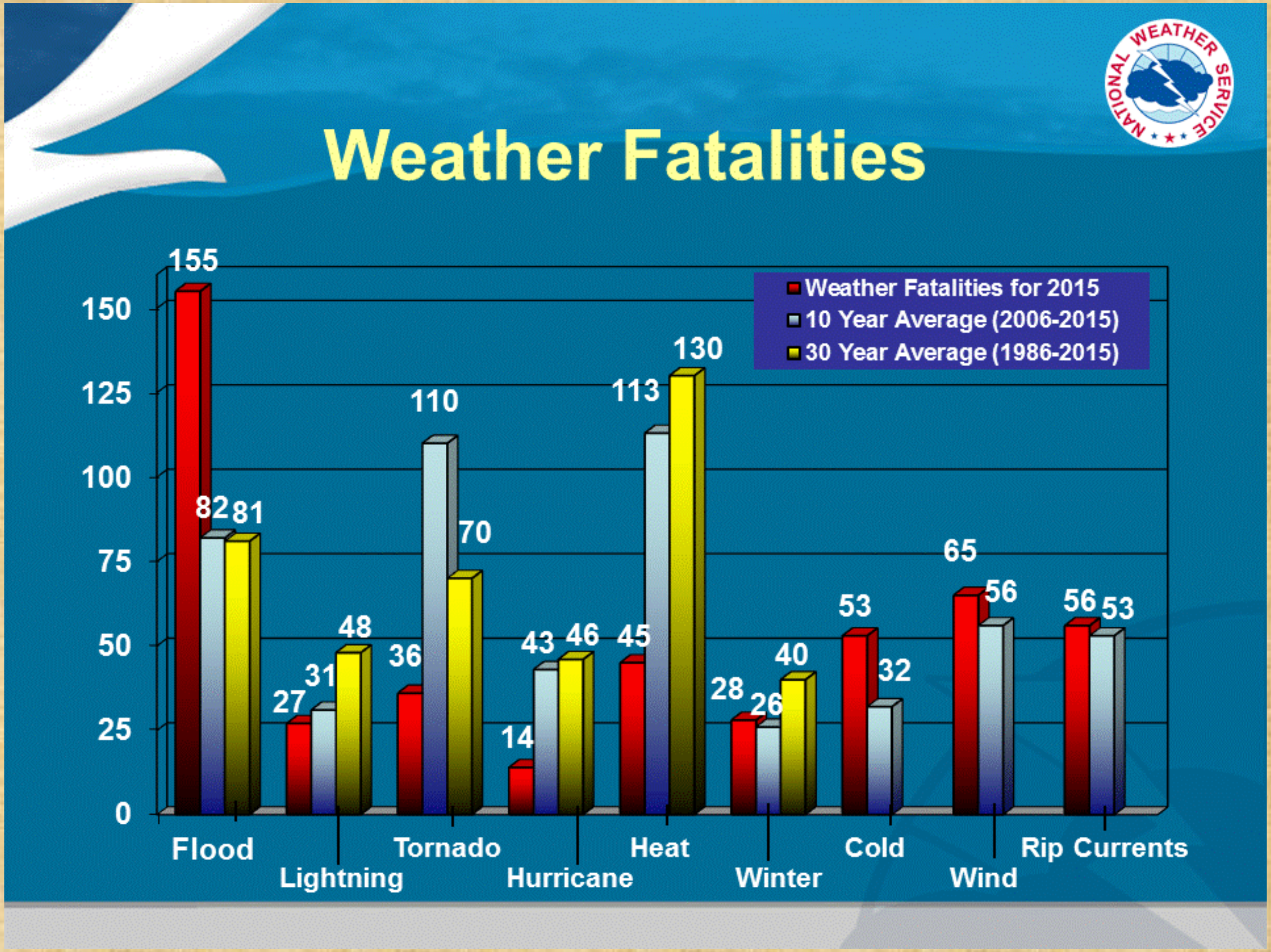
Excessive Heat is a silent killer. It results to more fatalities than any other atmospheric hazards

Currently excessive heat results to more casualties than any other atmospheric extreme. From 1986 to 2015 the annual mean fatalities over the United States:

Heat = 130
Flood = 81
Tornado = 70
Lightning = 48
Hurricane = 46

As the population becomes older and thus more sensitive to heat and excessive heat is projected to be more intense and frequent the number of casualties from excessive heat will increase.

Early warnings to relief agencies will help to build resilience.

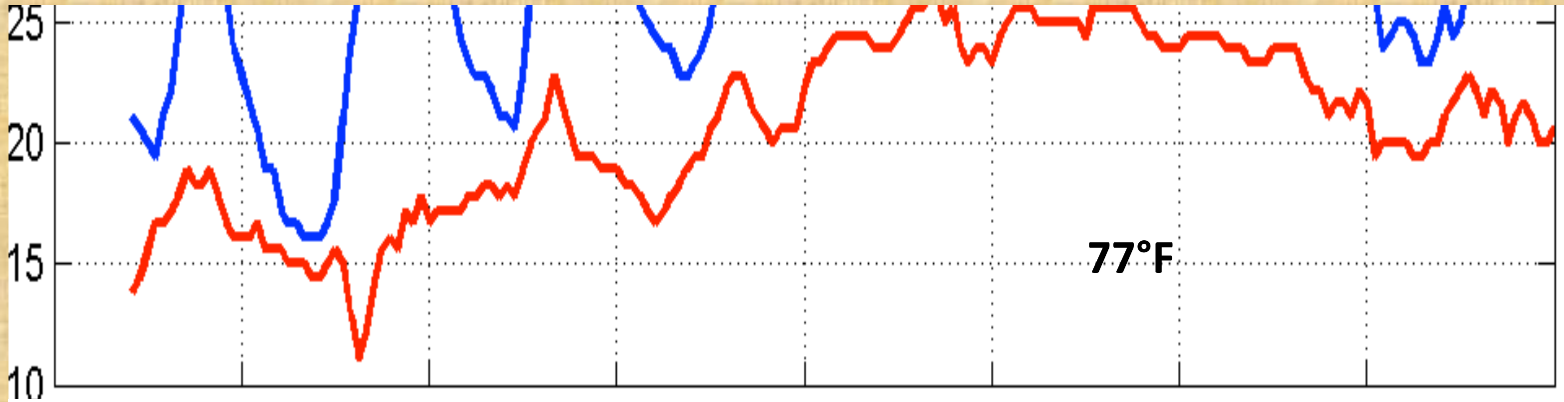


Source: http://www.nws.noaa.gov/om/hazstats.shtml

Anatomy of the Chicago July 1995 event which resulted to more than 700 deaths

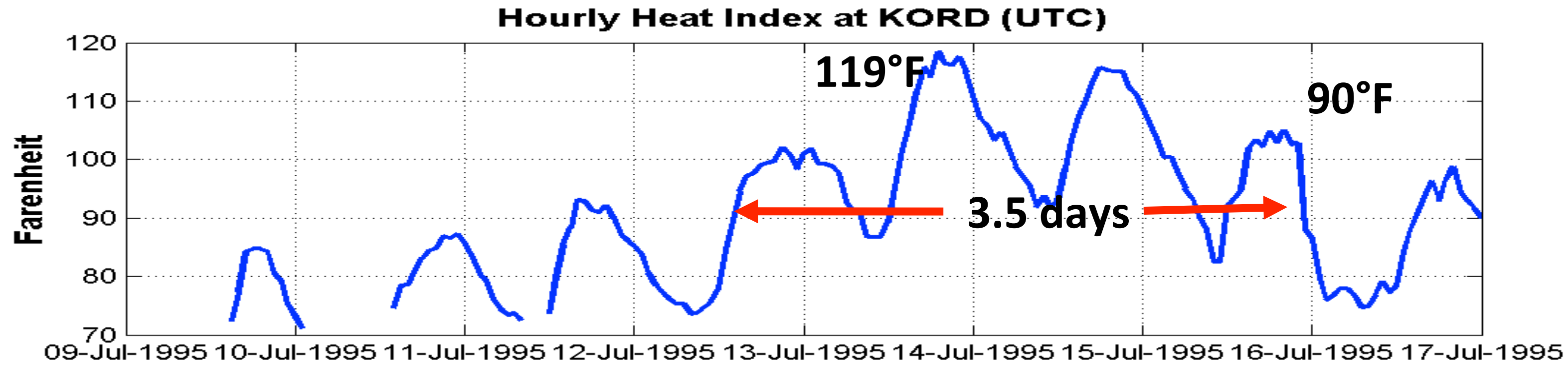
(METAR from O'Hare airport; mortality data courtesy Scott Sheridan)

Dry Temperature and Dew point



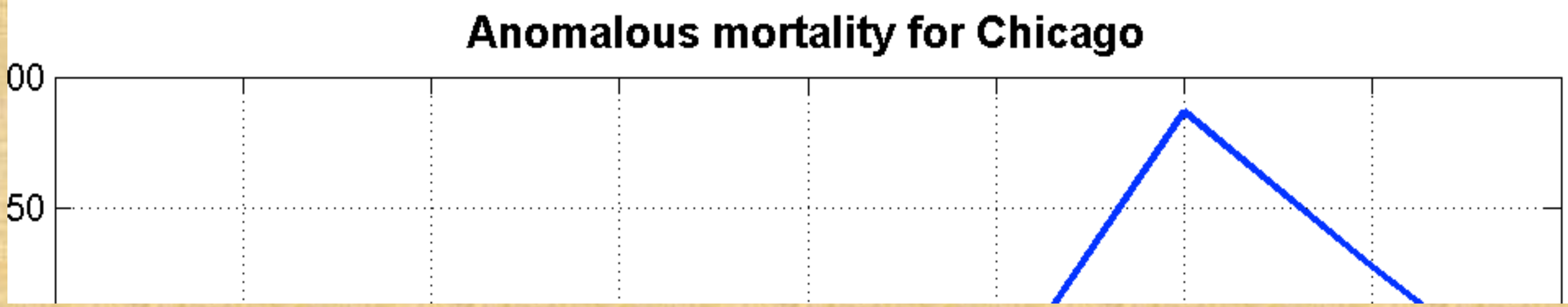
Dry temperature anomalies were high but within the 35-40°C range. However the dew point was elevated

Heat Index



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

Abnormal Mortality



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

Elements of Excessive Heat Events

Impacts of heat:

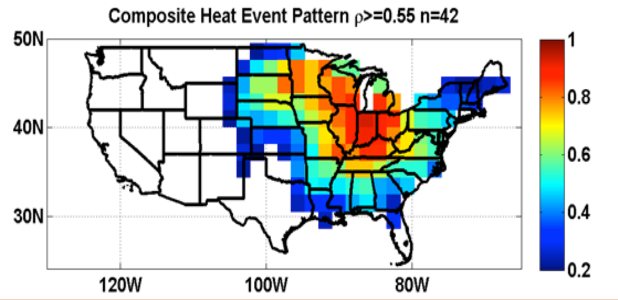
- **Grow non-linearly as temperature and humidity increase.** Therefore we need to use thermal discomfort indices that are based on models of the physiological effects of heat on the human body e.g., the Heat Index, HUMIDEX, WBGT, UTCI, rather than just dry temperature.
- **Increase as a function of their duration.** Therefore we need to consider consecutive days with high thermal discomfort rather than just weekly, monthly, or seasonally averaged temperature.
- **Depend on geographical location.** Therefore we need to consider a definition of heat waves that varies as a function of location. This can be done by considering temperature thresholds (absolute values or quantiles).
- **Depend on earlier periods of colder or warmer than average weather due to acclimatization.** Therefore we need to take in consideration environmental conditions before the heat wave in order to assess possible impacts on health.

The physics of Excessive Heat Events

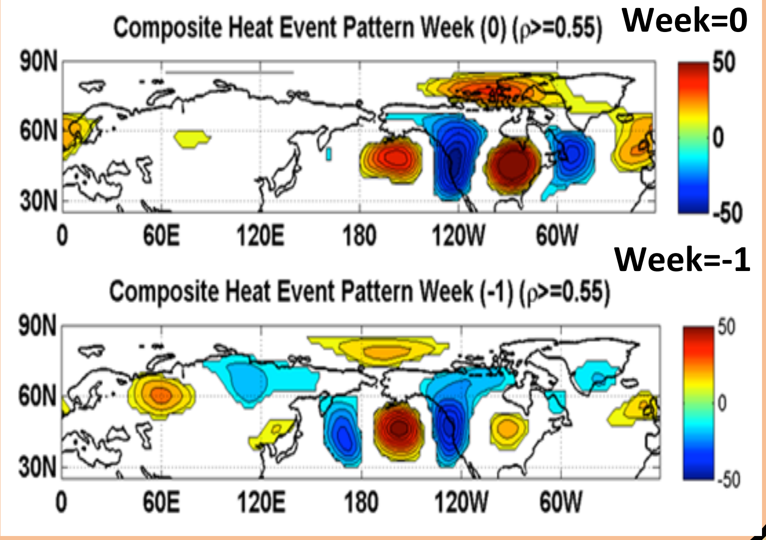
Heat waves result from quasi-stationary wavenumber 5-8 Rossby waves (e.g., Teng et al., 2013; McKinnon et al., 2016; Mann et al., 2017, Frangoulidis et al., 2018). It has been suggested that extra-tropical sea surface temperature forcing has an impact on these Rossby waves and that tropical variability is irrelevant.

To test the impact of high wavenumber Rossby waves on excessive heat we:

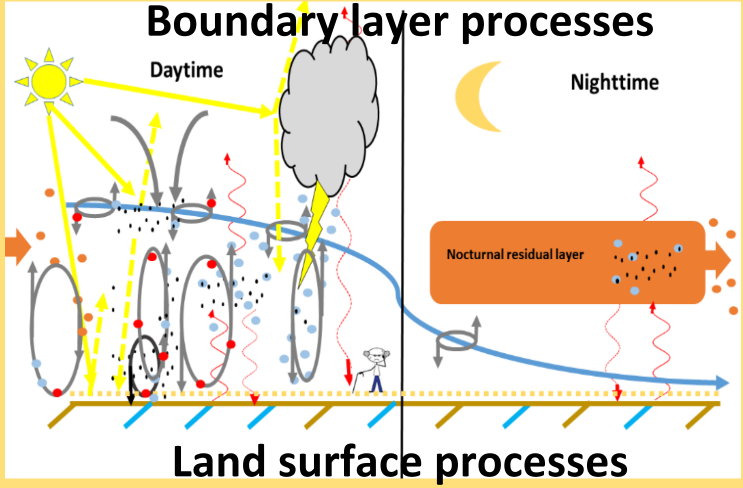
- Choose a baseline definition for heat waves (at least two consecutive days with maximum heat index exceeding the 90th percentile).
- Create a list of heat events similar to the Chicago 1995 event.



We composite weekly anomalies of geopotential at 500 hPa for the week of the events and the week prior to these events. Results show a quasi-stationary wave train indicative of subseasonal (Week-2) predictability.



We need to underline that impacts of the tropospheric forcing to human health will depend on the reaction of the coupled PBL – land-surface system to the individual tropospheric forcing from the cluster of similar events.



Are excessive heat events predictable at subseasonal lead times?

- Use the simplified definition of excessive heat events: At least two consecutive days of maximum heat index exceeding the 90th percentile

- Use reforecasts data from the S2S database to calculate the probability of occurrence of a heat event within a given week

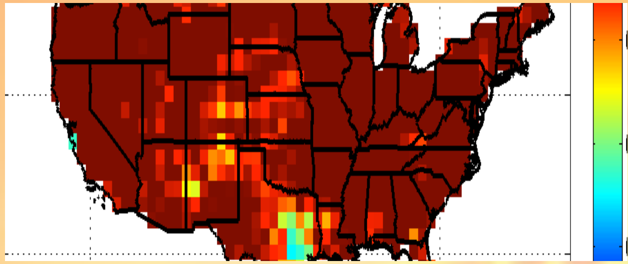
- Verify reforecasts using the Receiver Operating Characteristics (ROC) and Area Under the ROC Curve (AUC):

  - Map probabilistic forecasts to categorical for different thresholds of probability of occurrence
  - For each threshold compare the hit rate to the false alarm rate, generate the ROC curve, and calculate the Area Under the Curve (AUC). A non-useful forecast system has AUC=0.5 (hit rates and false alarms are equal). A perfect forecast system has AUC=1

Predictability of Excess Heat Events: Area Under the ROC Curve for 90% – events

Week~1

ECMWF



GEFS

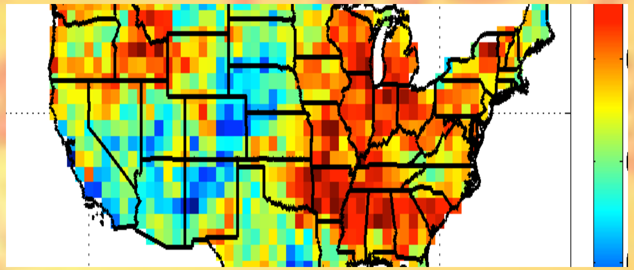
We have not compute AUC for Week-1

CFS

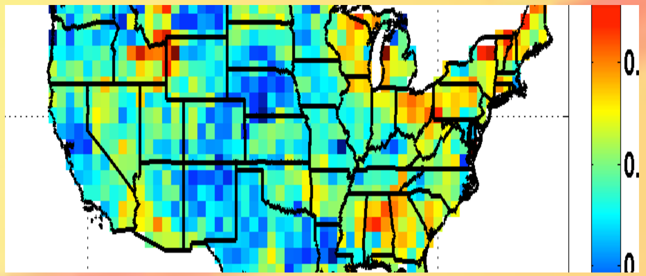
We have not compute AUC for Week-1

Week-2

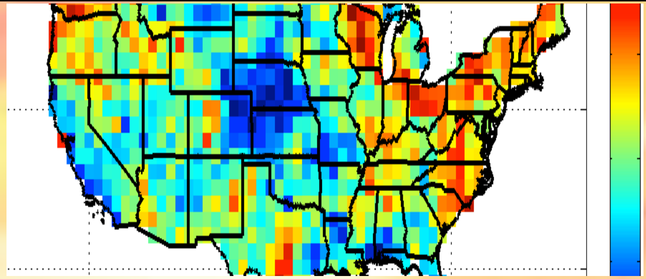
ECMWF



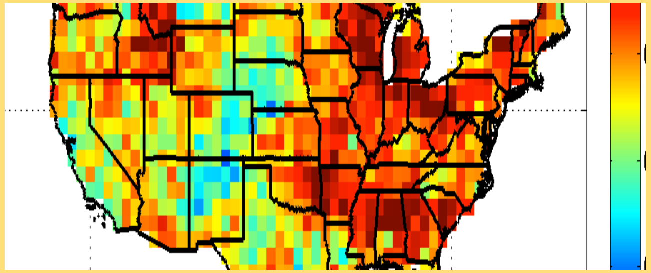
GEFS



CFS

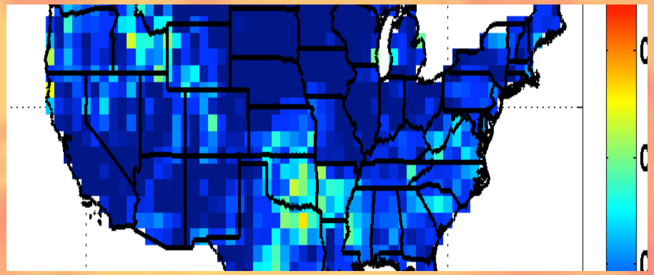


GEFS + ECMWF



Week-3

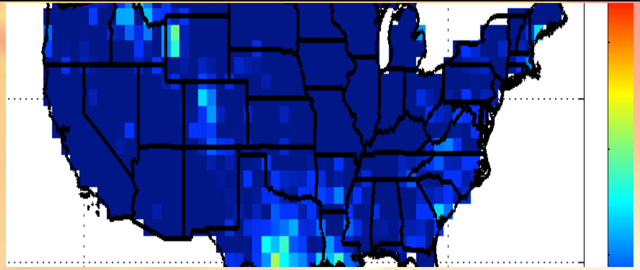
ECMWF



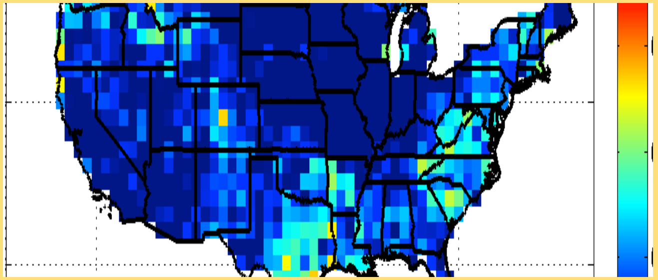
GEFS

No Week-3 GEFS
(for the moment)

CFS



CFS + ECMWF



Multi-Model Ensemble Forecasting of Heat Events

Revisiting the definition of excessive heat

There are two drawbacks in the baseline definition of excessive heat events:

(1) No acclimatization is factored in.
(2) The intensity of heat events is not well defined (extremely important for quantifying possible health impacts).

The Excess Heat Factor (Nairn and Fawcett, 2014) resolves both of these issues.

Let T_i be the mean temperature of day *i, then*

Significance of the Heat Event

$$EHI_{sig} = \frac{1}{3}\left(T_i + T_{i-1} + T_{i-2}\right) - T_{95\%}$$

Acclimatization factor

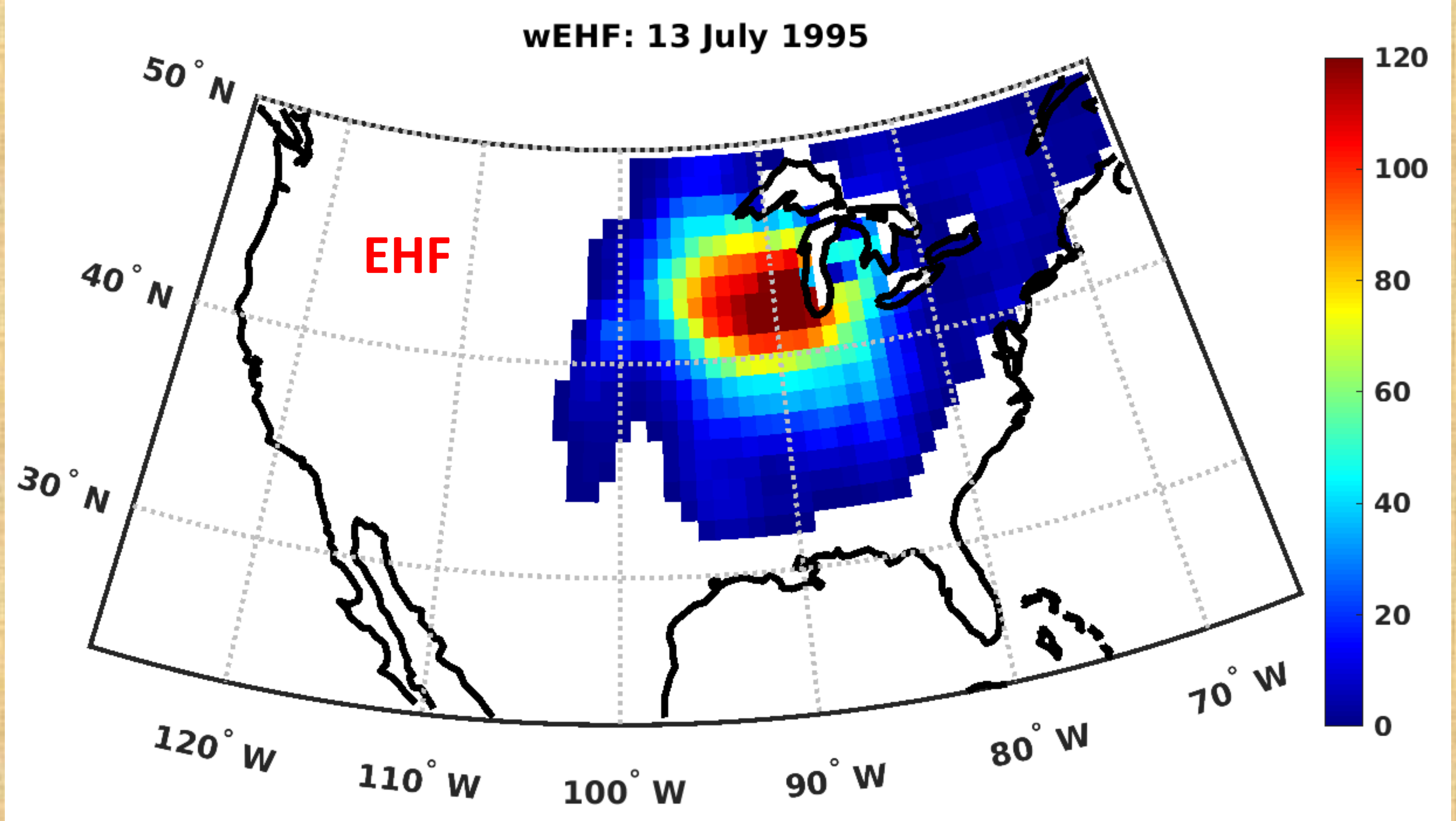
$$EHI_{acclim} = \frac{1}{3}\left(T_i + T_{i-1} + T_{i-2}\right) - \frac{1}{30}\sum_{k=i-32}^{i-3} T_k$$

$$EHF = max(0, EHI_{sig}) \cdot max(1, EHI_{accl})$$

However this Excess Heat Factor considers humidity only indirectly through the use of the minimum temperature of the day and thus events similar to Chicago, 1995 can be misrepresented. To resolve this issue we introduce the wet EHF which uses the maximum between heat index and dry temperature.

Revisiting the definition of excessive heat

Maps of the wet EHF index for 13 July 1995 (during the Chicago, July 1995 event)



Realtime Global Subseasonal Excessive Heat Forecasting System

- We use the Climate Forecast System (CFSv2) forecasts. This choice is based on suggested impacts of SST, real time forecast availability, and previous demonstration of forecast skill of the EHF with the CFS (Ford et al., 2018).
- ECMWF's ERA-Interim which assimilates 2 meter temperature and humidity is used for bias correction **(quantile mapping)** of the CFS-Analysis and the forecasts
- **Experimental real time forecast system:**
  - Forecasts were issued daily and outlooks were sent bi-weekly to an e-mail list from late May 2018 to early September 2018.
  - These forecasts provided the probability of exceedance of the 50th and 85th percentile for each grid point.
- **Experimental excessive heat monitoring system:**
  - For each grid point we calculate the maximum EHF within a given week and plot its quantile.

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Global Subseasonal Excessive Heat Outlook System

Global-SEHOS Monitoring: Northern Hemisphere Summer 2018

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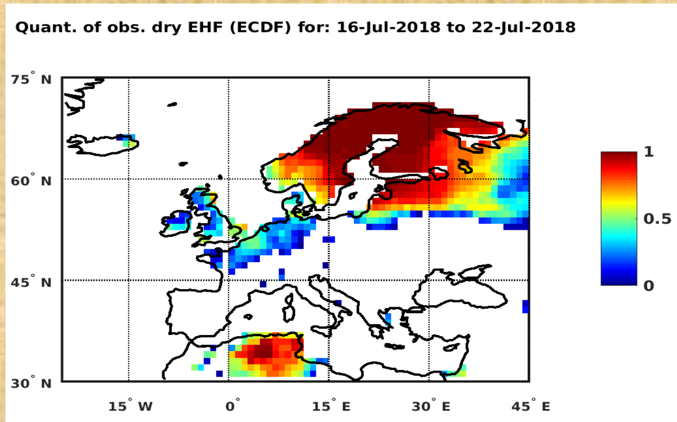
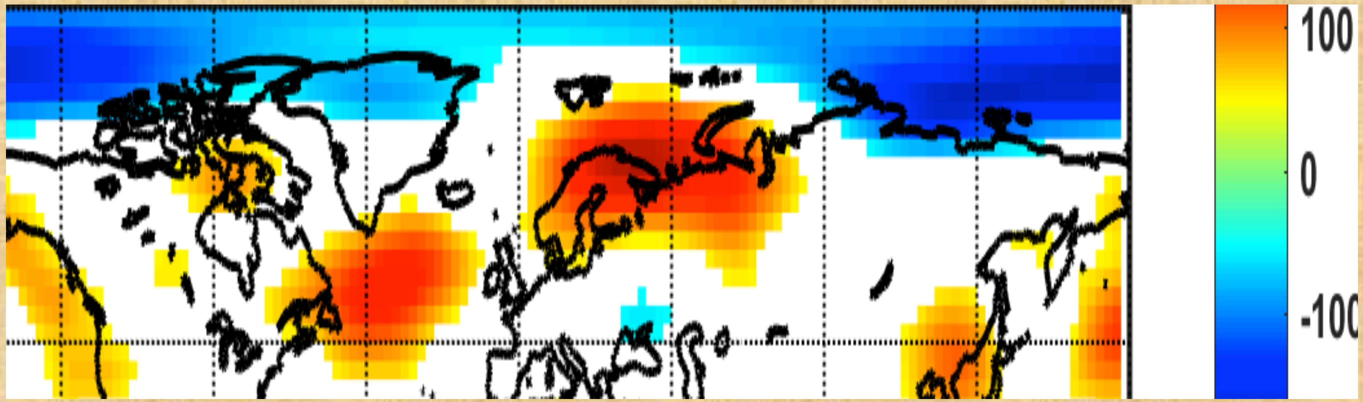
Monitoring the “Scandinavian” Heat Wave

Quantile of the maximum daily EHF within the given week

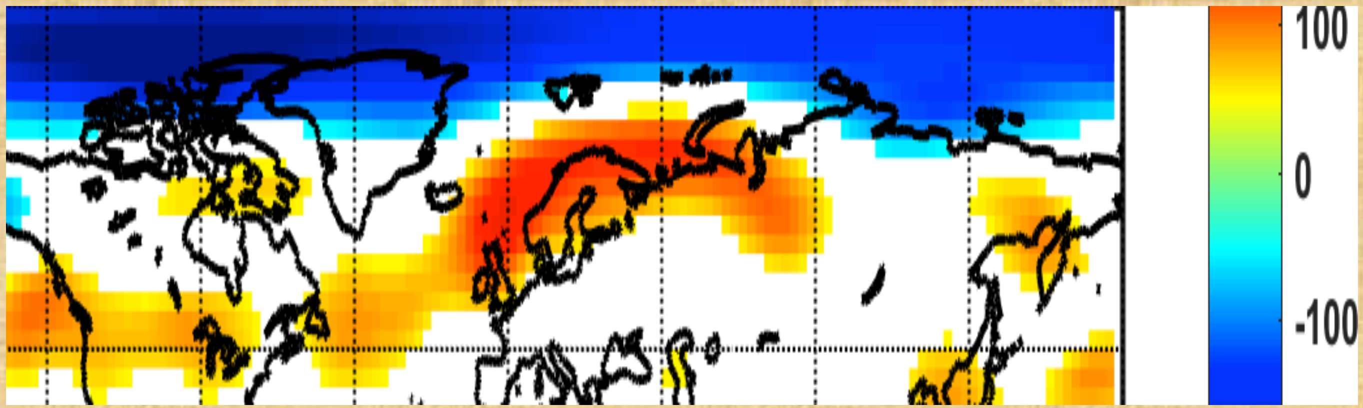


16-Jul-2018 to 22-Jul-2018

Anomalous weekly mean geopotential at 500 hPa



16-Jul-2018 to 22-Jul-2018

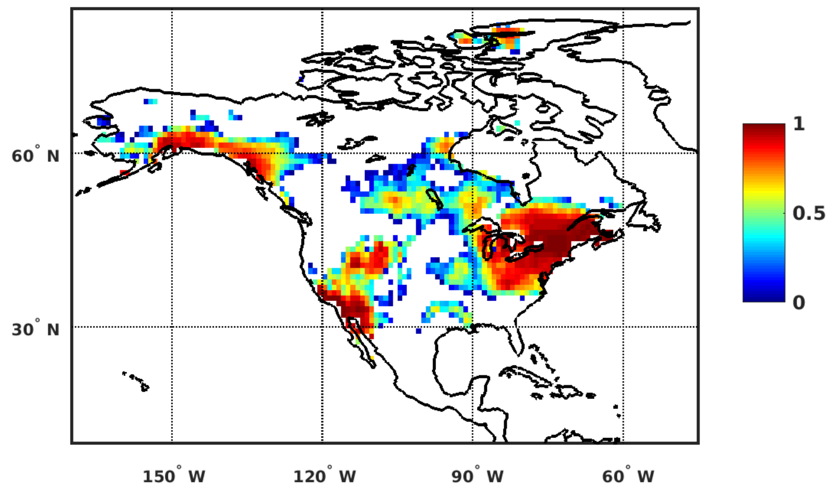


09-Jul-2018 to 15-Jul-2018

Forecast of the Quebec Event (July 2018 >70 casualties)

Observed field

Quant. of obs. wet EHF (ECDF) for: 02-Jul-2018 to 08-Jul-2018

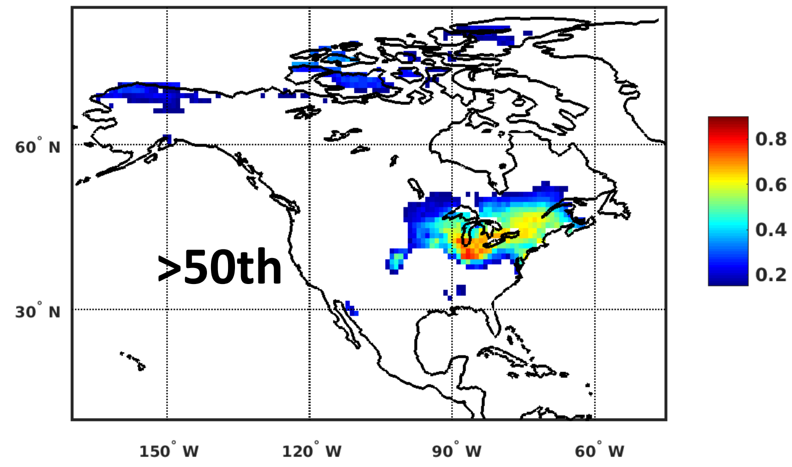


Observations: Quantile of the maximum daily EHF during a given 7-day period at each grid point

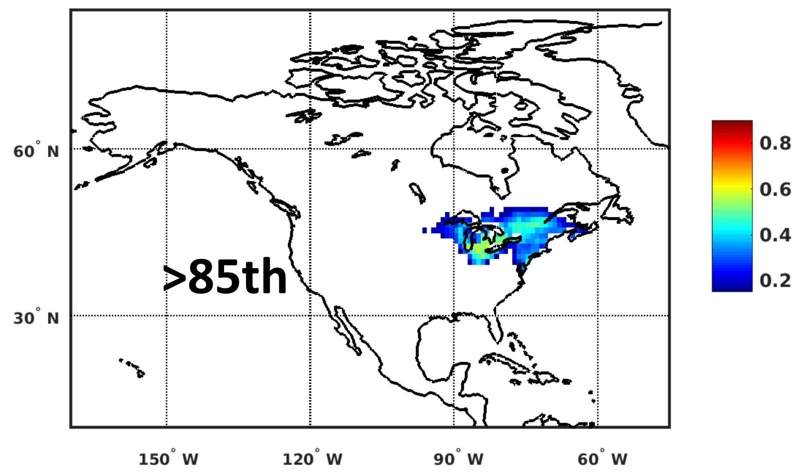
Forecast: Probability of exceeding the 50th or 85th quantile of daily EHF for a given 7-day period

Forecast Week-2

Prob. for wet EHF > 50% perc. Week-2. Valid: 02-Jul-2018 to 08-Jul-2018

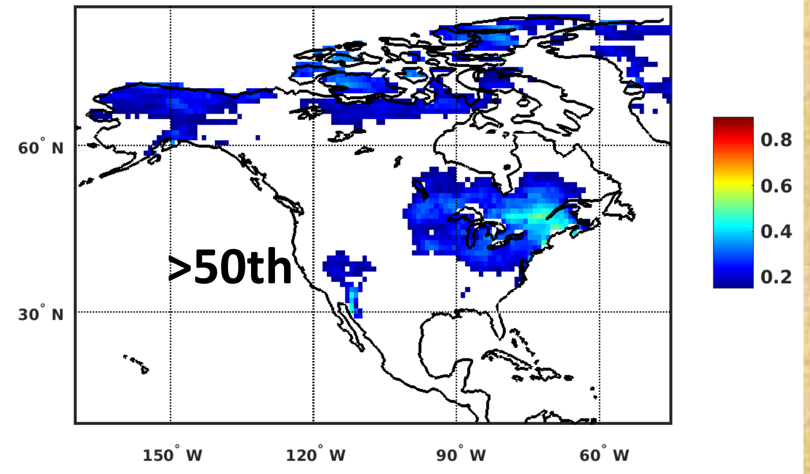


Prob. for wet EHF > 85% perc. Week-2. Valid: 02-Jul-2018 to 08-Jul-2018

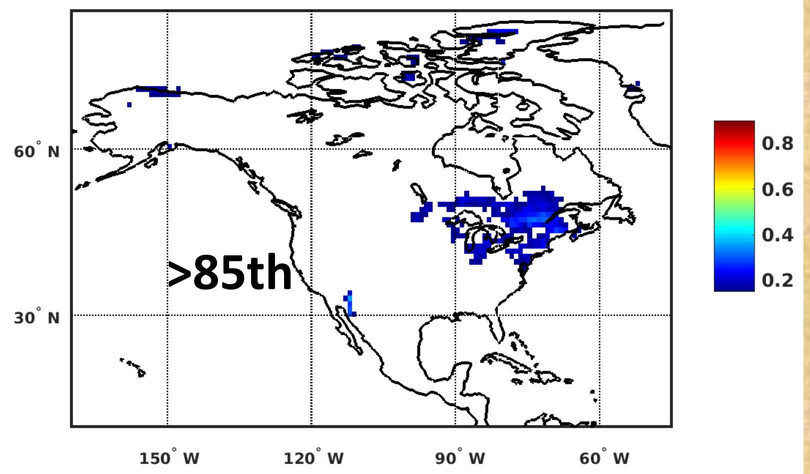


Forecast Week-3

Prob. for wet EHF > 50% perc. Week-3. Valid: 02-Jul-2018 to 08-Jul-2018



Prob. for wet EHF > 85% perc. Week-3. Valid: 02-Jul-2018 to 08-Jul-2018



Summary

- Subseasonal forecasting of excessive heat events is possible.
- We developed a real time forecast system which was used quasi-operationally during the summer of 2018.
- The system continues operating on a daily basis.
- Currently evaluating the skill of this system during summer 2018.

Future plans

Short term:

- Transition ‘ground truth’ from ERA-Interim to ERA-5 which will be delivered in almost real-time.
- Introduce additional forecasts from coupled models that provide freely real-time forecasts.
- Extend the system to seasonal forecasts, future projections

Medium term:

- Better understanding of boundary layer processes during heat-waves
- Better understanding of atmospheric blocking and teleconnections during summer

Longer term:

- Dynamical downscaling (~200m) in ‘hot spots’ using boundary layer parameterizations developed by the better understanding of boundary layer processes during heat events.
- Answer the question: **To tailor model forecasts or tailor forecast models?**

Questions: avintzil@umd.edu

Defining excessive heat events: Apparent Temperature

- Air Temperature at 2meters
- Humidity at 2 meters
- Solar radiation
- Infrared radiation
- Wind velocity at 2 meters

Universal Thermal Climate Index (UTCI)

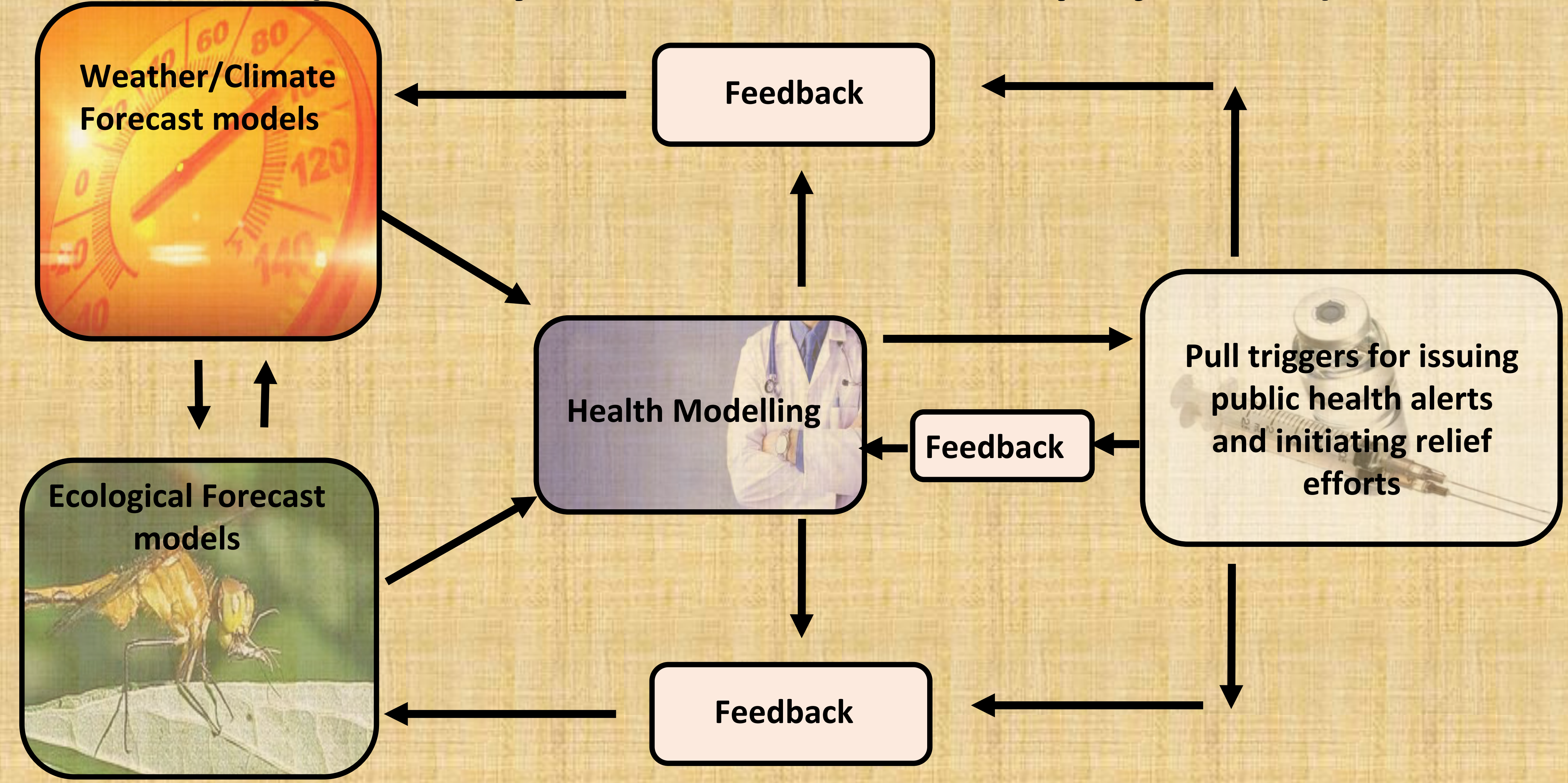
Heat Index (NOAA) and HUMIDEX (Environment Canada)

Maximum and minimum air Temperature e.g. BoM

High | Index complexity | Intermediate | Lower

Days ? | Index predictability | Weeks ? | Seasons ?

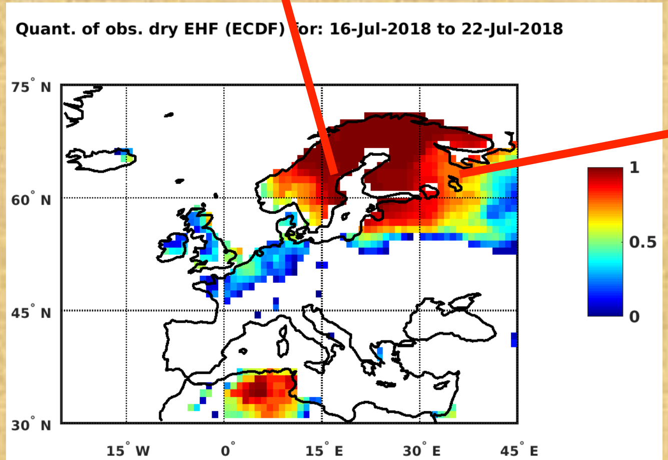
Mission: Develop Health Oriented Early Warning Systems (from days to seasons to future projections)



Excessive Heat Event in Scandinavia

July 17, 2018

Natural-color image acquired by the Moderate Resolution Imaging Spectro-radiometer (MODIS) on NASA's Terra satellite



July 20, 2018