Development of heat-wave impact forecasting system based on Limited Area Ensemble Prediction System (LENS)

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Introduction

- Currently, heat-wave warnings in Korea are issued by forecasters upon results from RDAPS, MOS etc.

- **Advisory:** daily $T_{max} > 33^\circ C$ period > 2days
- **Warnings:** daily $T_{max} > 35^\circ C$ period > 2days

- The thresholds are based on climatological characteristics (95th and 99th percentile of maximum summer temperature (June-September))

- However, an effective warning system should consider also the impact of heat-wave on human health (Lloyd-Sherlock, 2000; Masato et al., 2015)
Introduction

- Numerical models have uncertainties due to unknown initial conditions, unresolved sub-grid scale processes etc.

- Ensemble Prediction Systems (EPS) can deal with these uncertainties by providing several scenarios

- Results from EPS can be then used as base for the probabilistic forecast and warning systems

- Example: MOGREPS-W (Neal et al., 2014; Masato et al., 2015)

- **Main goal:** Development of heat-wave impact warning system for South Korea based on Limited Area Ensemble Prediction System (LENS)

Source: Neal et al. (2014)
Description of LENS

- **Unified Model (UM) VN10.1**

**Global Ensemble (EPSG)**
- Horiz.: N400 (~32km)
- Vert.: 70 layers (top ~80km)
- +12 days Forecast
- ICs: ETKF
- 1+24+24 members

**LENS**
- Horiz.: 3km (460x482)
- Vert.: 70 layers (top ~39km)
- +72 hrs Forecast
- Init Pert.: Downscaling of EPSG
- 1+12 members

Total: 25 members

Source: Lee Seungwoo
LENS post-processing

Source code:

Step 1: Constructing time-lag ensemble and daily $T_{max}$

Step 2: Masking by daily $T_{max}$ thresholds

Step 3: Calculation of grid-point probabilities

Step 4: Calculation of area probabilities

Step 5: Decision on based on impact matrix and visualization of heat-wave impact risk maps
Computation of probabilities

- Grid-point probability (GPP): fraction of members exceeding threshold
- Area probability (AP):
  1. Maximum grid-point probability within the area (MXAP)
  2. Counting members that exceed threshold within the area (MCAP)
Criteria for the impact matrix

- Thermal morbidity:
  - Segmented regression

- Thermal mortality:
  - Event based risk assessment

**Probability from LENS:**
- Considering LENS bias

**Impact**
- Take action
- Be prepared
- Be aware
- No severe weather

**Daily Tmax**
- 29.3°C
- 31.0°C
- 33.0°C

Source: Jaenicke
LENS evaluation (Time-lag ensemble)

Figure 1. Comparison of RMSE for various thresholds (hourly data) when using 1+12 members (left) and time-lag ensemble 1+12+12 members (right)

Figure 2. Example of time-series from the most recent forecasts of each member and observation at Seoul 2017/07/24~2017/08/05
LENS evaluation for daily $T_{\text{max}}$

**Figure 3.** Forecast Errors of daily $T_{\text{max}}$ for 3 lead days

**Figure 4.** Correlation coefficient ($r$) of daily $T_{\text{max}}$ and Root-mean square error for different thresholds

$dT_{\text{max}}>21^\circ\text{C}$
Probabilistic evaluation
Grid-point probability vs Area probability

Figure 5. Brier score of daily $T_{\text{max}}$ (left) and reliability diagram (right) for grid-point and area probability strategies

$$BS_{(t_{\text{res}})} = \frac{1}{n} \sum_{i=1}^{n} \left( \text{Prob} - 1 \left( x \geq t_{\text{res}} \right) \right)^2$$
Figure 5. Brier score of daily $T_{\text{max}}$ (left) and reliability diagram (right) for grid-point and area probability strategies.
Probabilistic evaluation
Grid-point probability vs Area probability

Figure 5. Brier score of daily $T_{\text{max}}$ (left) and reliability diagram (right) for grid-point and area probability strategies.

Example: Date: 2016/08/13, AWS: Chuncheon, $T_{\text{max}}$: 34.7 °C
Heat-wave impact risk maps
Example case study: 2016/07/29 ~ 2016/07/31

Figure 6. Example of heat–wave impact risk maps and distribution of daily $T_{max}$ from AWS stations (interpolated)
Conclusions and Summary

1. Ensemble forecasting systems may underestimate the daily $T_{max}$ which might be critical for heat-wave forecast

2. Considering the cold bias of LENS in predicting the daily $T_{max}$, we utilized the system output to develop a heat-wave impact warning system

3. The lack of ensemble members was solved by using time-lag ensemble strategy, which decreased the RMSE of air temperature

4. Area probabilities are useful strategy to simplify the results, but in our case it also helps to reduce the cold bias of probabilistic forecast.

5. The bias of LENS was also considered in decision making about the impact matrix thresholds.
Future plans

1. Take into account impact of other meteorological variables such as RH, SR, WS etc.:
   - daily $P_{T_{\text{max}}}$ (Perceived temp.) instead of daily $T_{\text{max}}$

Figure 7. Human heat balance.
Source: Human Thermal Environments

Figure 8. Chamber experiments at Seoul National Univ., and Inje Univ.

Figure 9. Flowchart of Perceive Temperature estimation
Future plans

2. Take into account regional variability of vulnerability to heat-stress:
   - set different thresholds for different regions

**Figure 10.** Results of segmented regression of daily $T_{max}$ and thermal morbidity for different regions in South Korea
Future plans

3. bias correction: post-processing

![Impact matrix]

- LENS
- Time-lag Ensemble
- Masking
- Grid-point probabilities
- Bias correction
- Risk maps
- Area probabilities

**Figure 11.** Flowchart of LENS post-processing program

4. upcoming LENS upgrade:
   - spatial resolution 3km -> 2.2 km
   - UM VN 10.1 -> VN 10.4

**Figure 12.** LENS domain with 3x3 km (left) and new domain with 2.2x2.2 km spatial resolution
References

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THANK YOU