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

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Introduction

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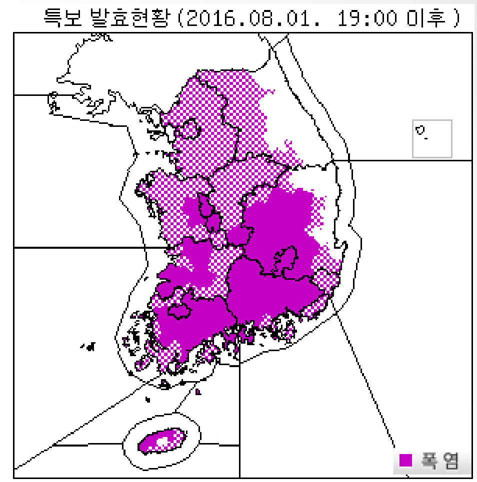
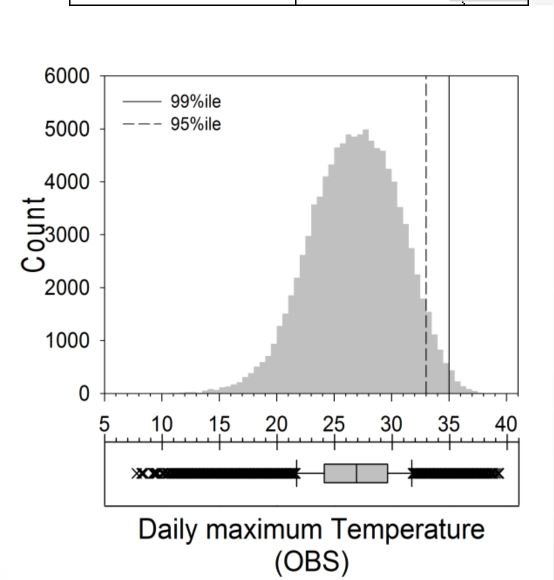
- Currently, heat-wave warnings in Korea are issued by forecasters upon results from RDAPS, MOS etc.

- **Advisory:** daily T_{max} >33°C period > 2days
- **Warnings:** daily T_{max} >35°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)



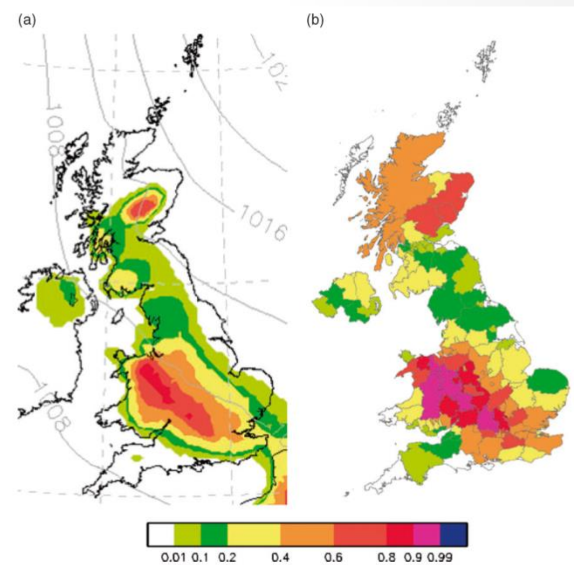


Introduction

- 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)

MOGREPS

Met Office



Source: Neal et al. (2014)

Description of LENS

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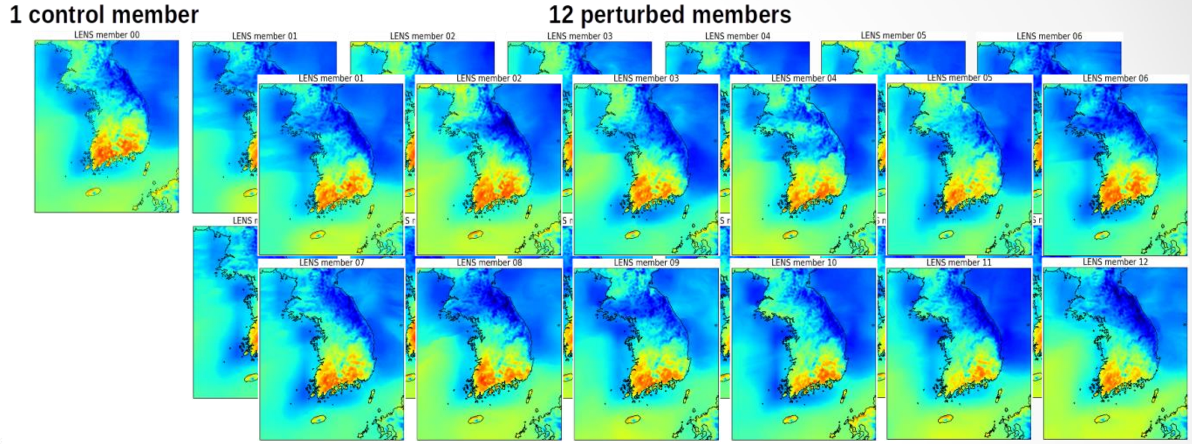
- Unified Model (UM) VN10.1

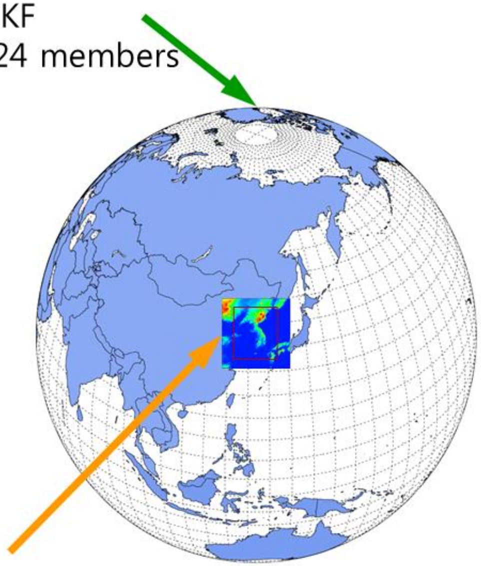
Unified Model
Met Office

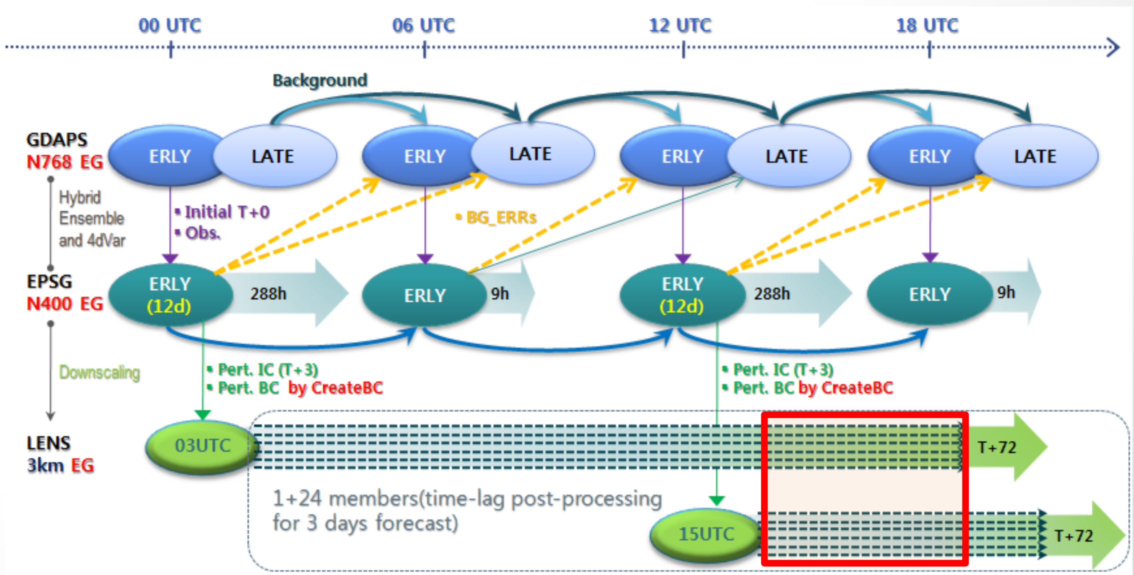
Total: 25 members



Global Ensemble(EPSG)

- Horiz. : N400 (~32km)
- Vert. : 70 layers (top ~80km)
- +12days 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

Source: Lee Seungwoo

LENS post-processing

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Source code:

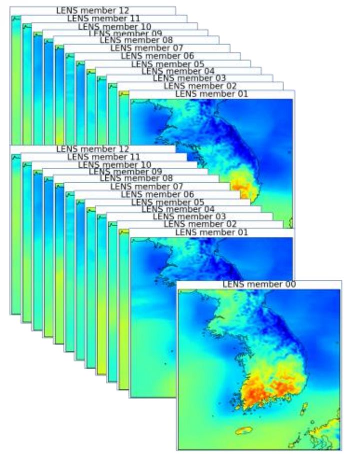
python™

Iris

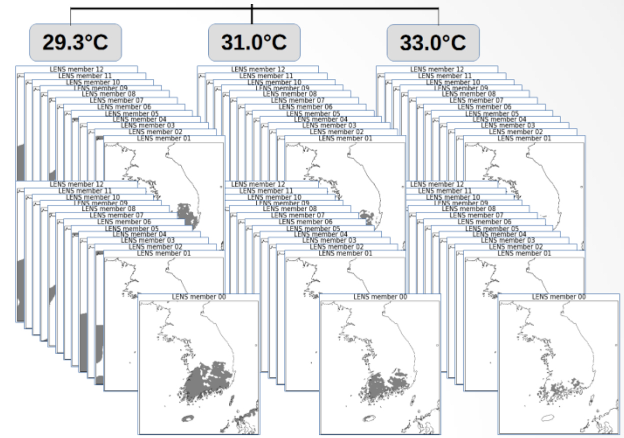
Met Office

matplotlib

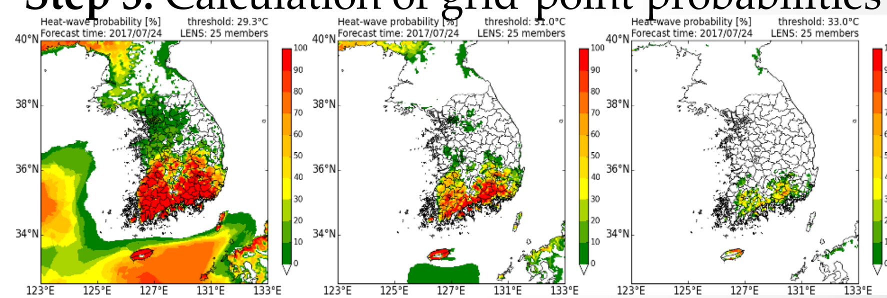
Step 1: Constructing time-lag ensemble and daily T_{max}



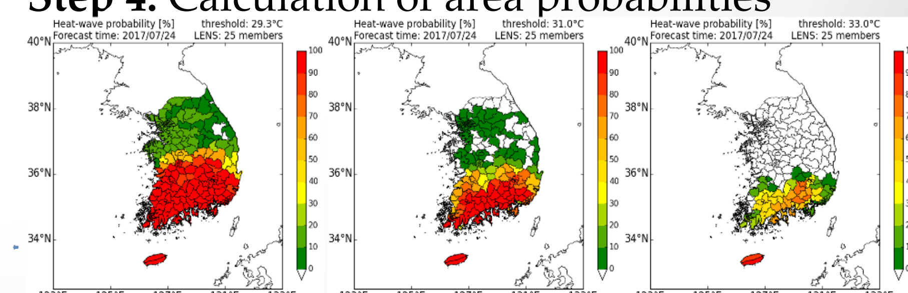
Step 2: Masking by daily T_{max} thresholds



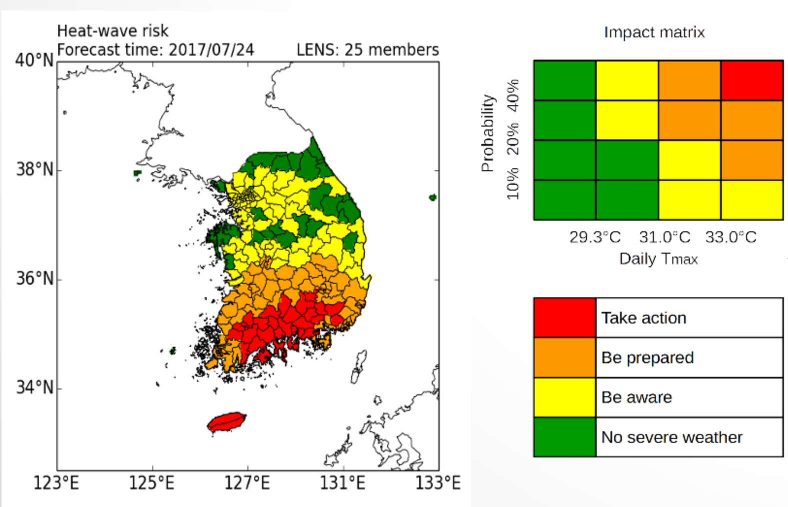
Step 3: Calculation of grid-point probabilities



Step 4: Calculation of area probabilities



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



(red)	Take action
(orange)	Be prepared
(yellow)	Be aware
(green)	No severe weather

Computation of probabilities

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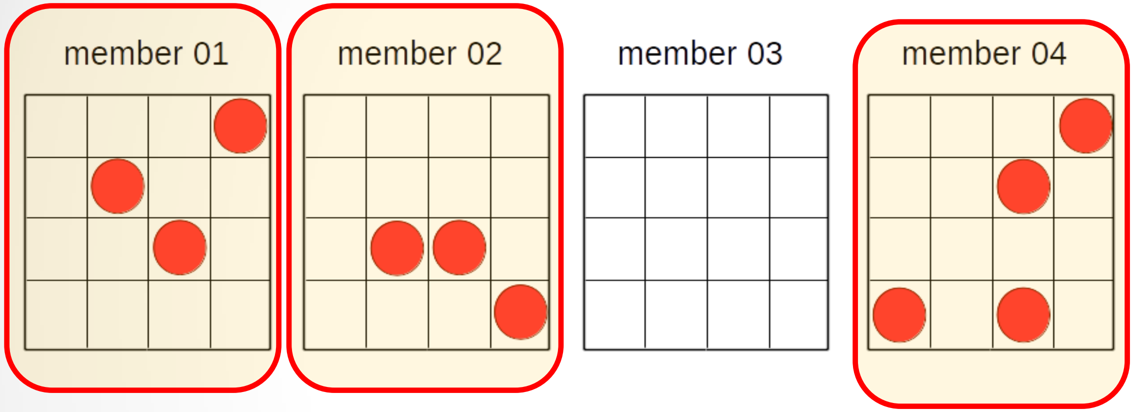
- Grid-point probability (GPP): fraction of members exceeding threshold
- Area probability (AP):
  1. Maximum grid-point probability within the area (MXAP)
  2. Counting members that exceed threshold within the area (MCAP)



Grid-point Probability [%]

0	0	0	50
0	25	25	0
0	25	50	0
25	0	25	25

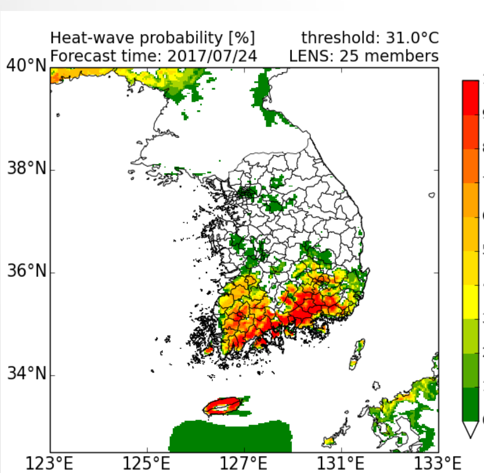
Area probability[%]

50

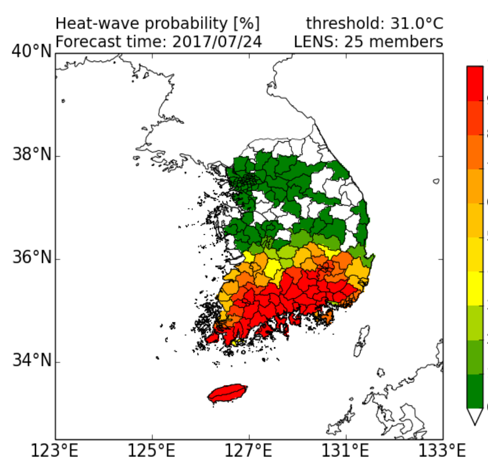
Area probability[%] - member count

75

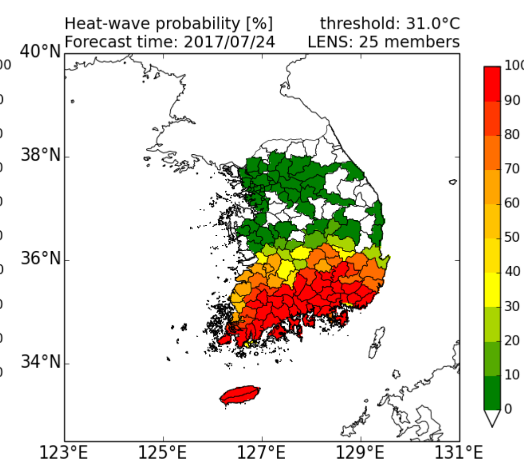
GPP



MXAP



MCAP



Criteria for the impact matrix

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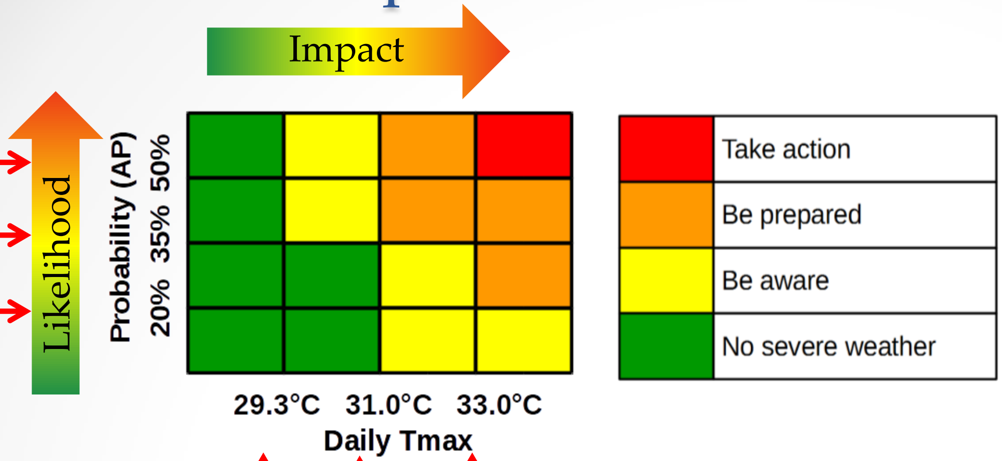
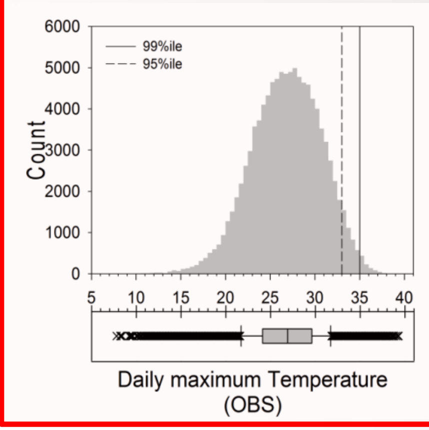
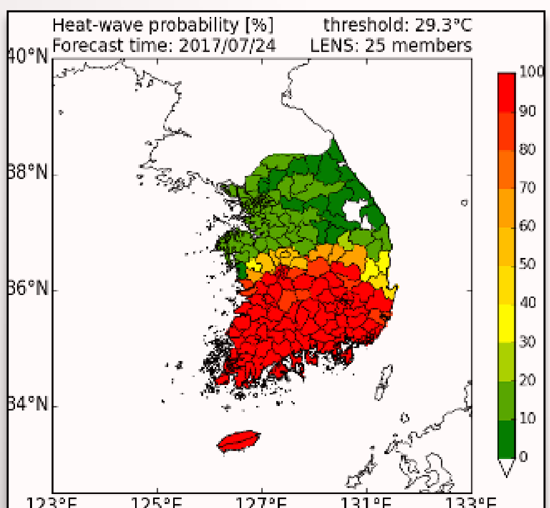


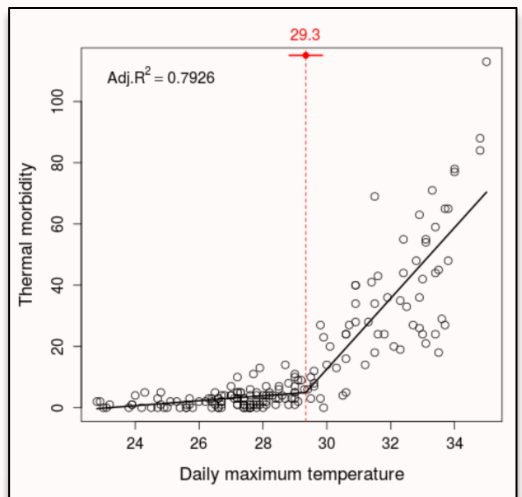
- Climat. character.
- 95 %ile of summer day T_{max}



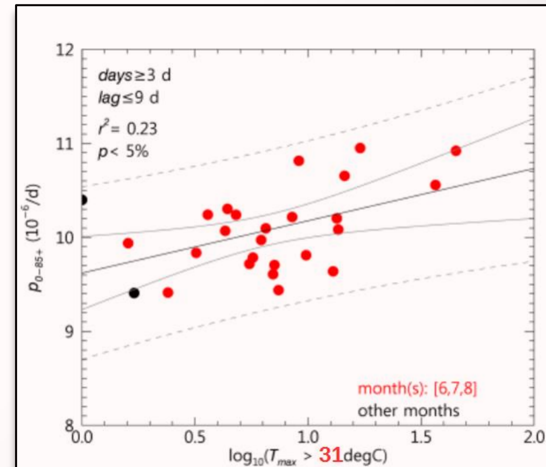
- Probability from LENS:
- Considering LENS bias



- Thermal morbidity :
- Segmented regression



- Thermal mortality
- Event based risk assessment



Source : Jaenicke

LENS evaluation (Time-lag ensemble)

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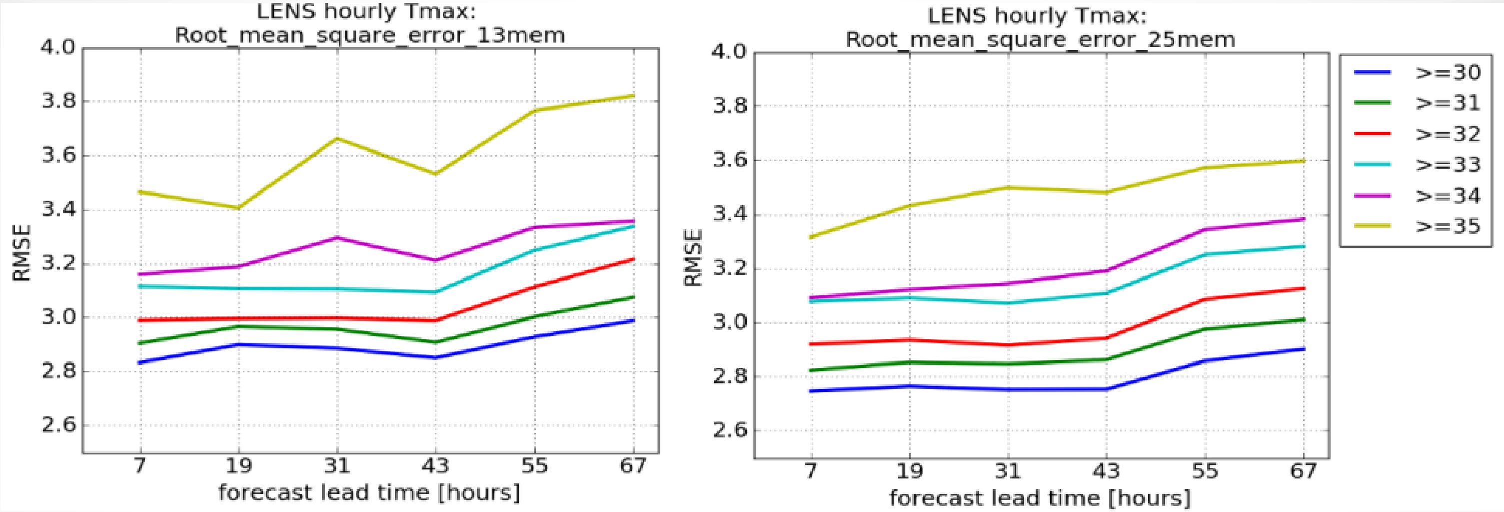

Figure 1. Comparison of RMSE for various thresholds (hourly data) when using 1+12 members (left) and time-lag ensemble 1+12+12 members (right)

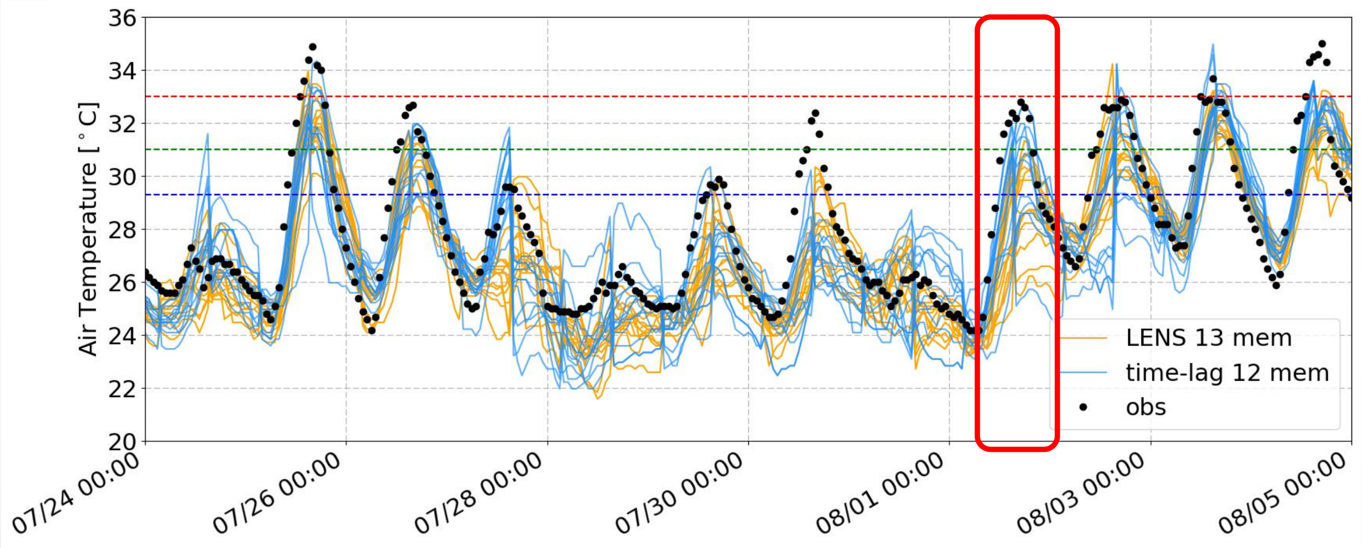

Figure 2. Example of time-series from the most recent forecasts of each member and observation at Seoul 2017/07/24~2017/08/05

LENS evaluation for daily T_{max}

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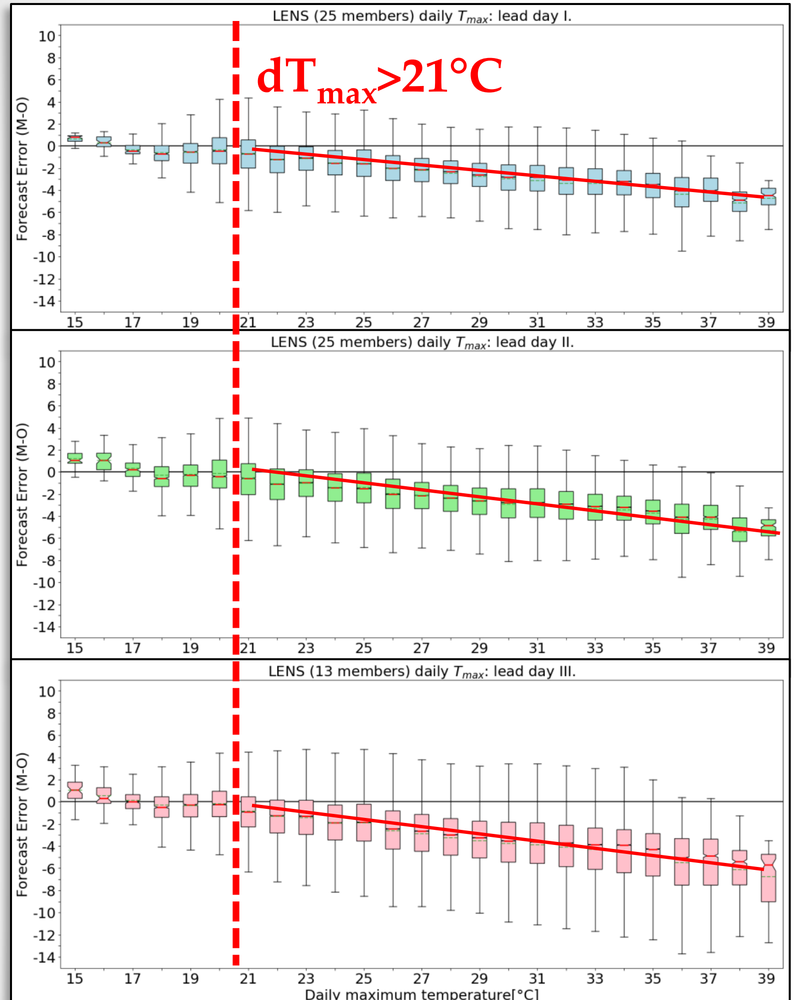

Figure 3. Forecast Errors of daily T_{max} for 3 lead days

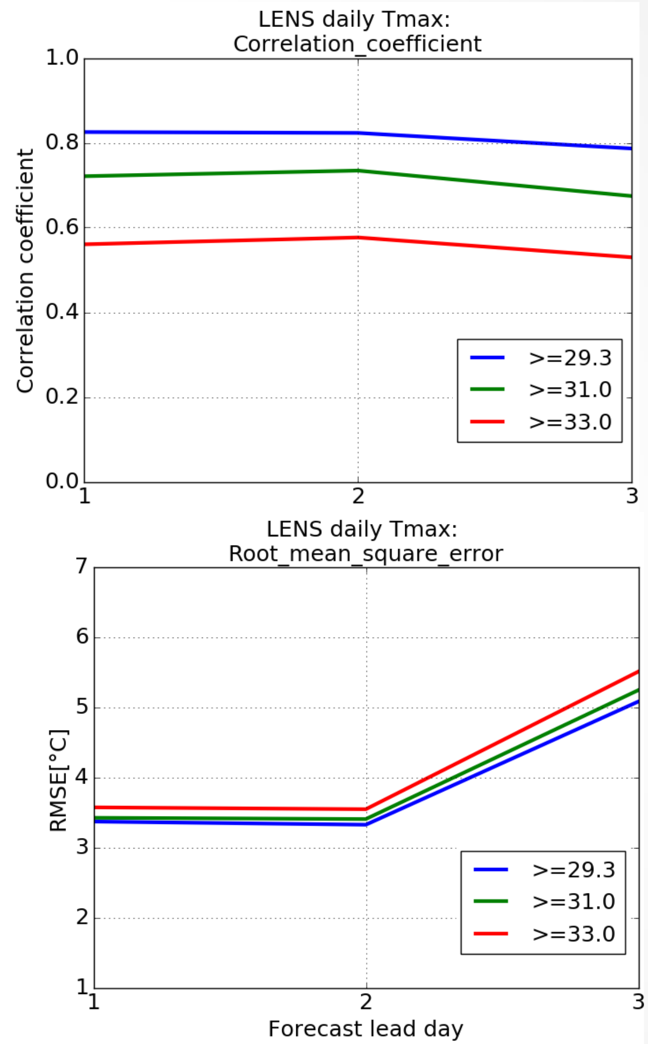

Figure 4. Correlation coefficient (r) of daily T_{max} and Root-mean square error for different thresholds

Probabilistic evaluation

Grid-point probability vs Area probability

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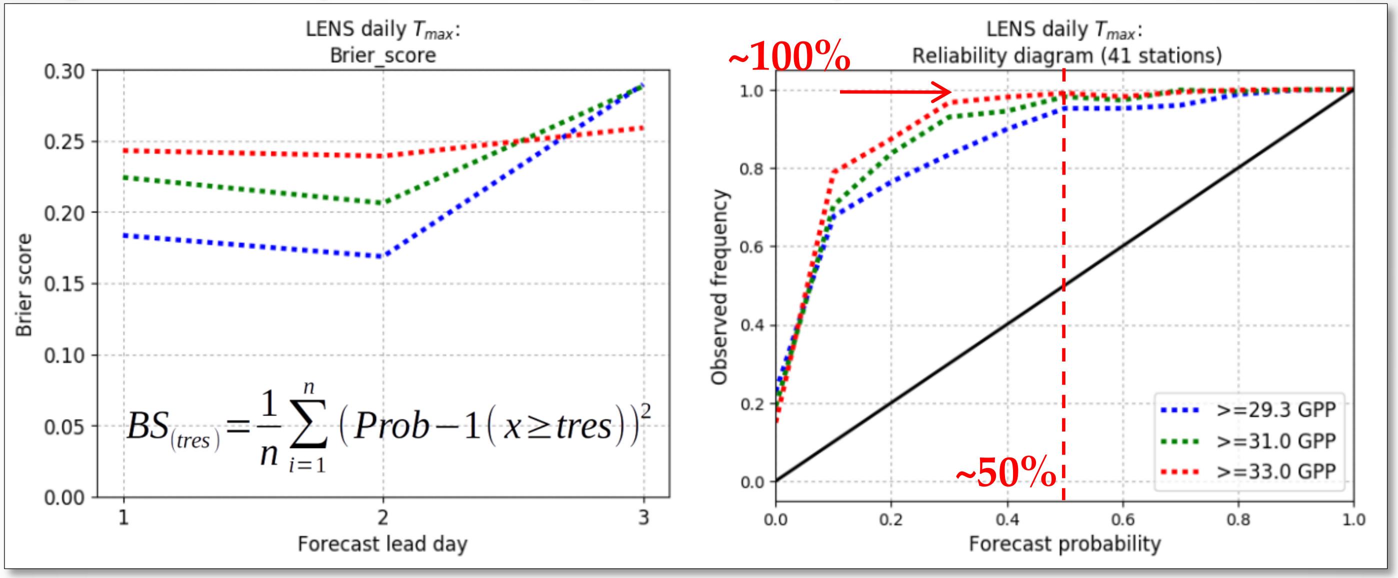

Figure 5. Brier score of daily T_{max} (left) and reliability diagram (right) for grid-point and area probability strategies

Probabilistic evaluation
Grid-point probability vs Area probability

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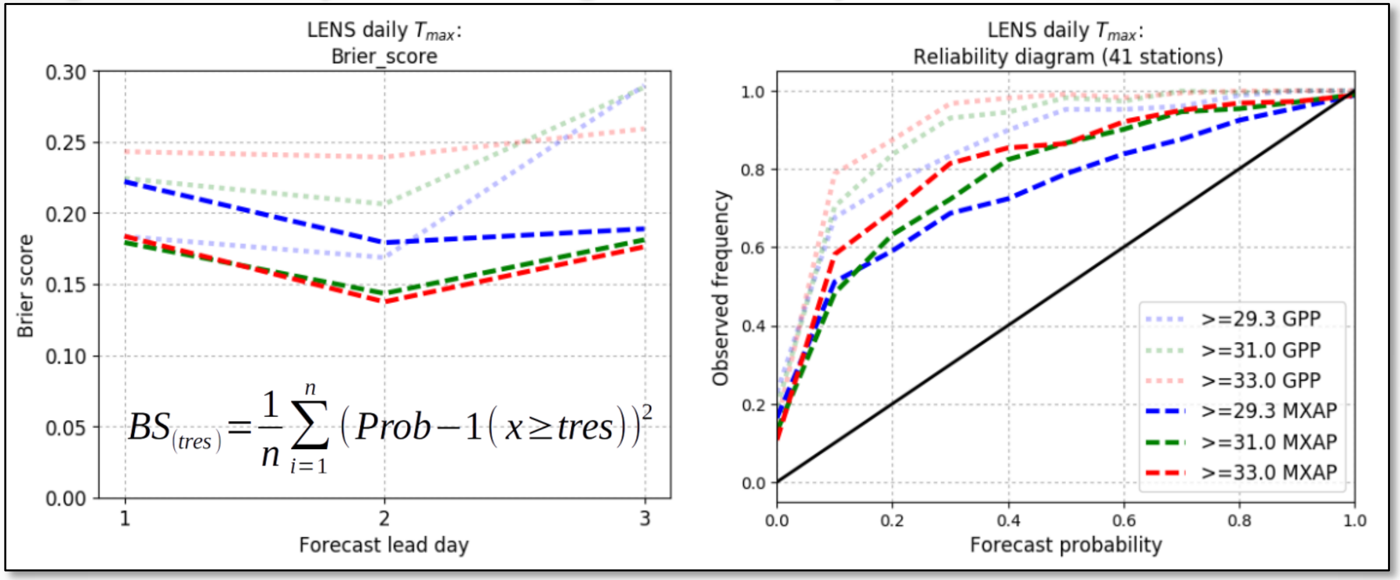

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Probabilistic evaluation
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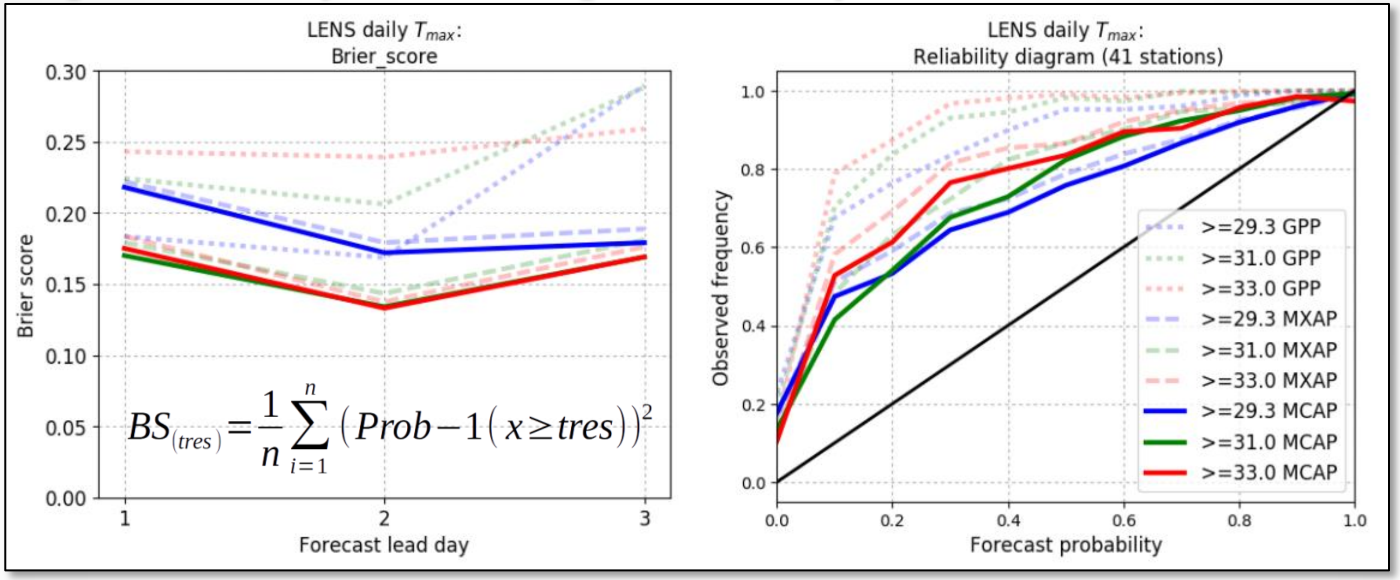

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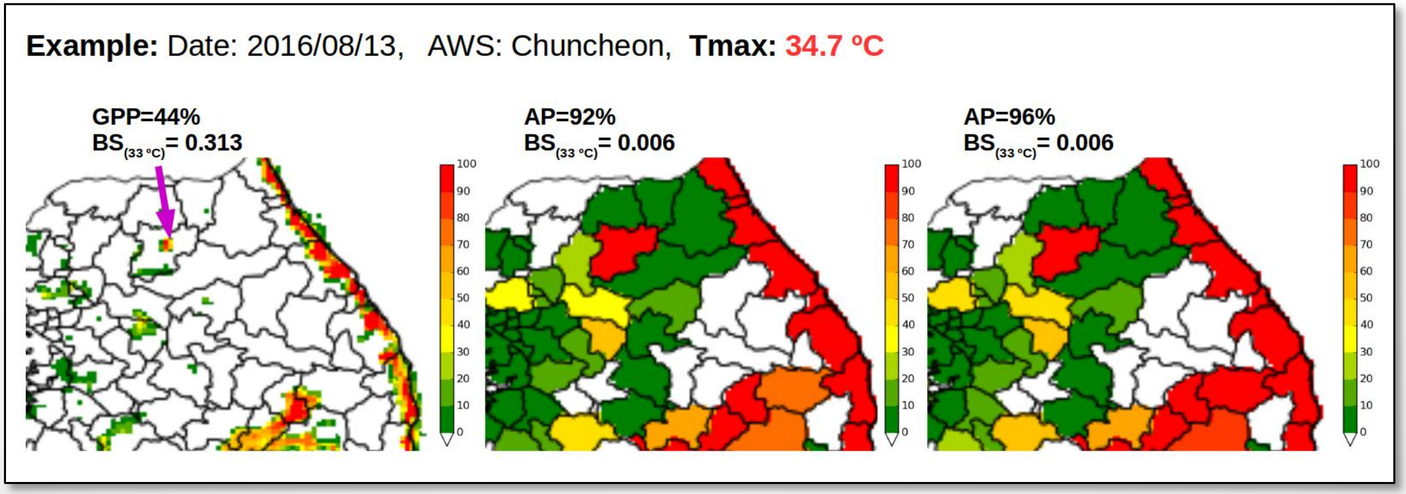

Heat-wave impact risk maps

Example case study: 2016/07/29 ~ 2016/07/31

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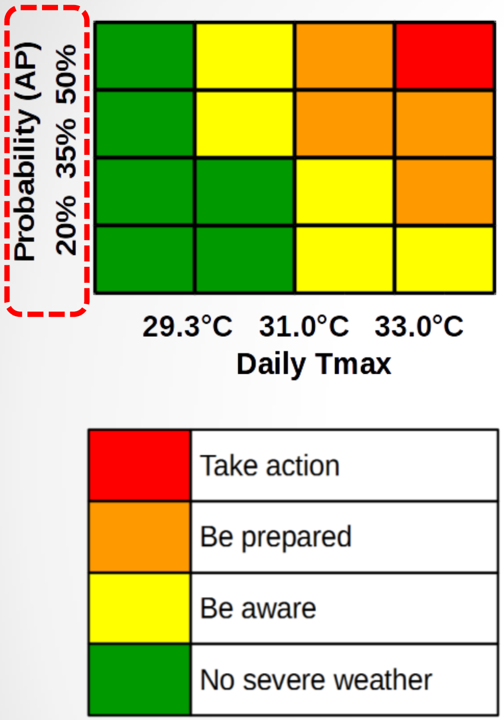


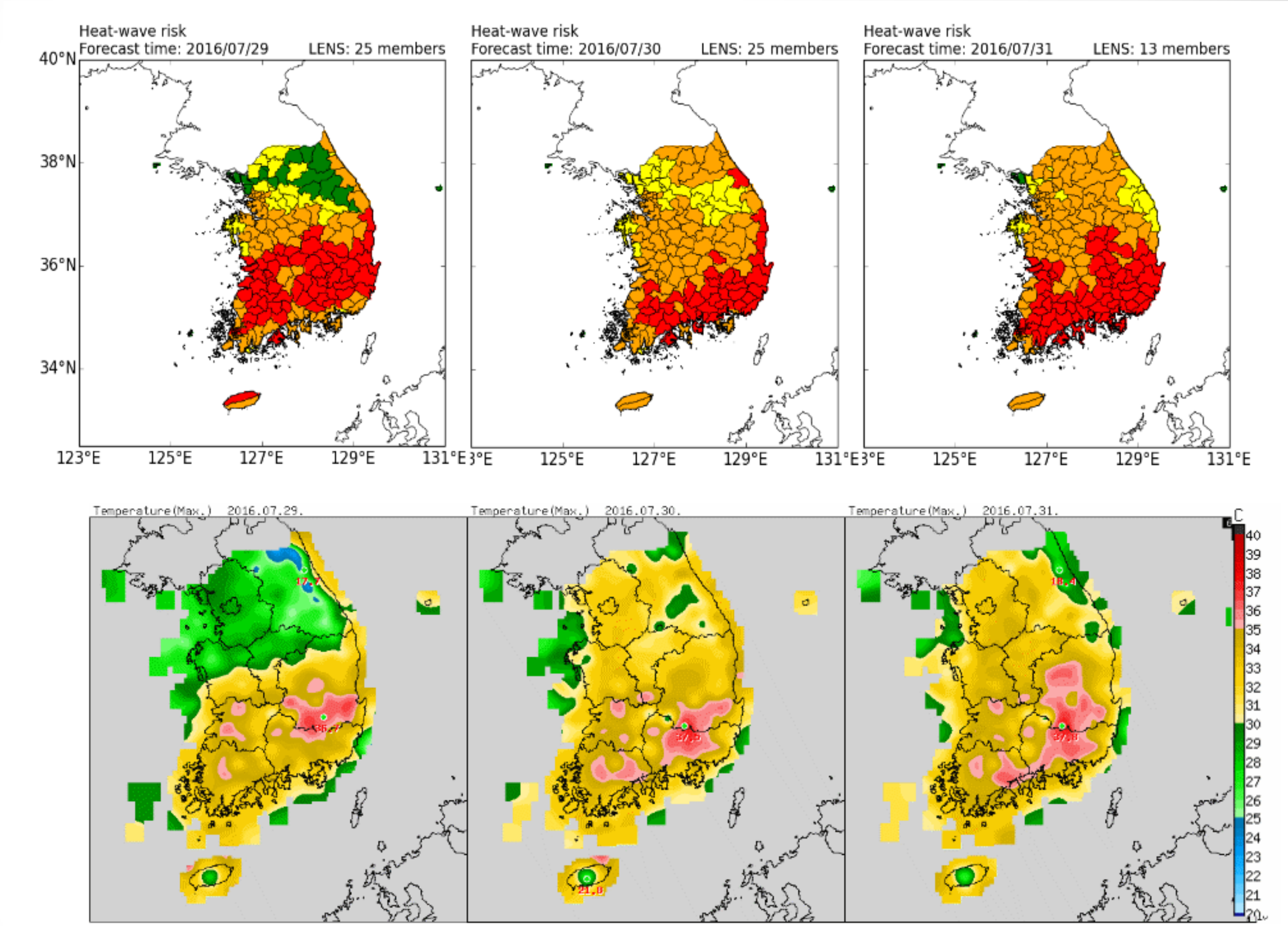
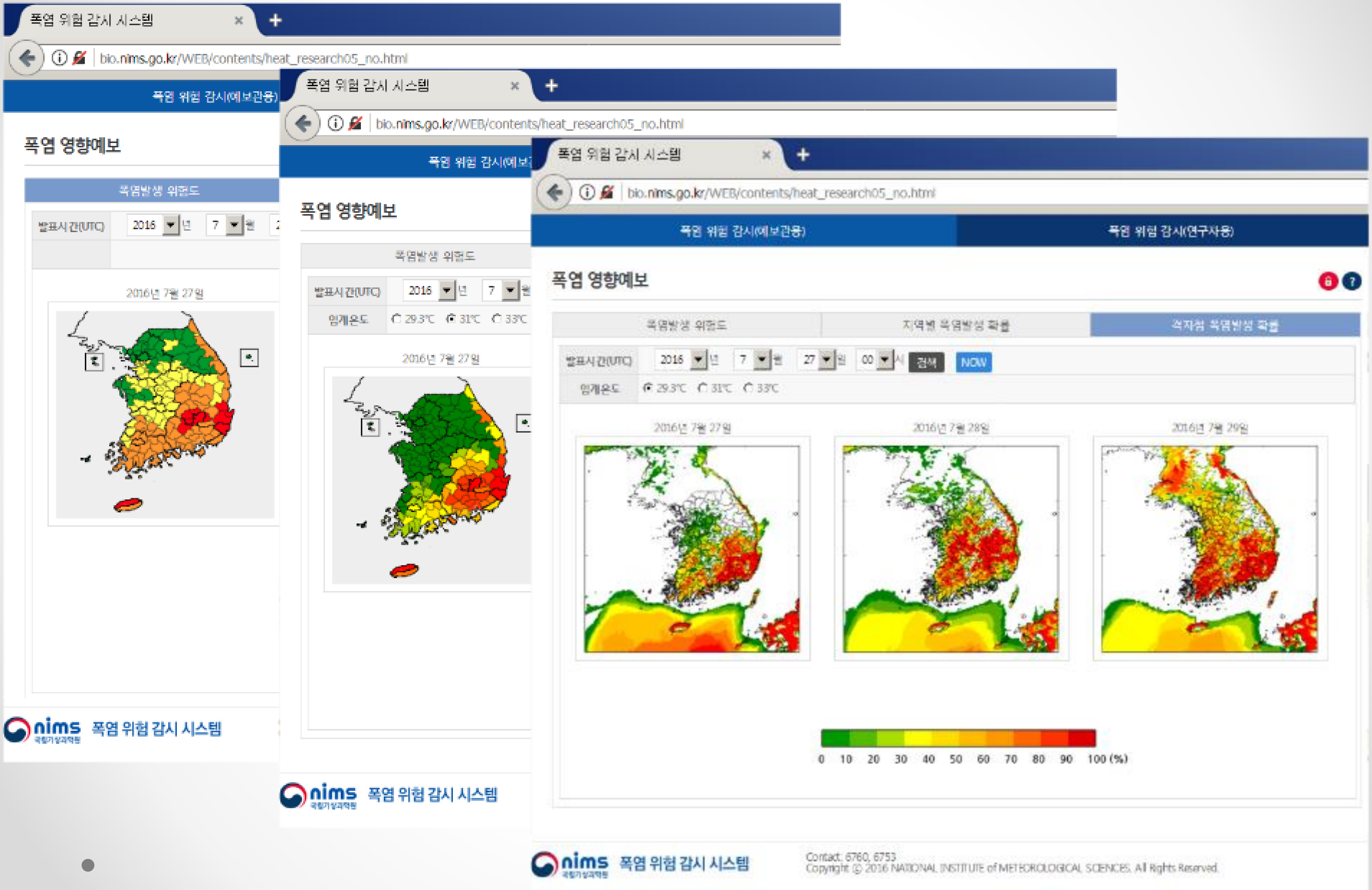


Figure 6. Example of heat –wave impact risk maps an distribution of daily T_{max} from AWS stations (interpolated)

Visualization on the WEB



Conclusions and Summary

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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

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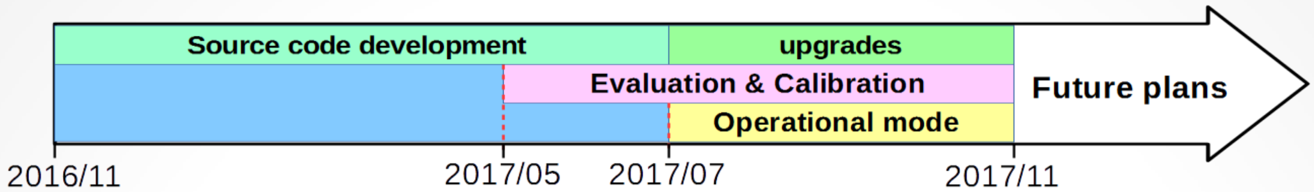

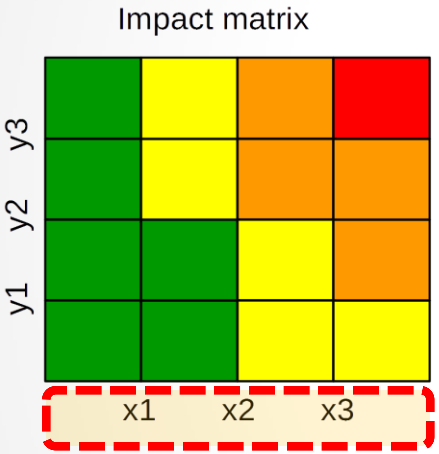

	Take action
	Be prepared
	Be ready
	No severe weather

1. Take into account impact of other meteorological variables such as *RH, SR, WS* etc.:

- daily PT_{max}(Perceived temp.) instead of daily T_{max}

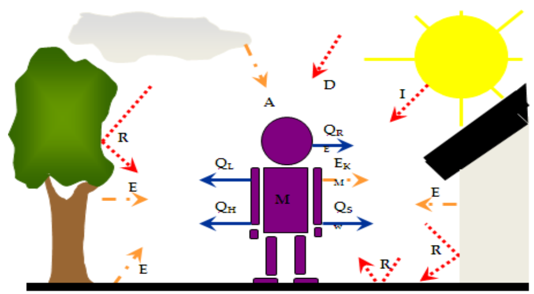

Figure 7. Human heat balance.
Source: Human Thermal Environments

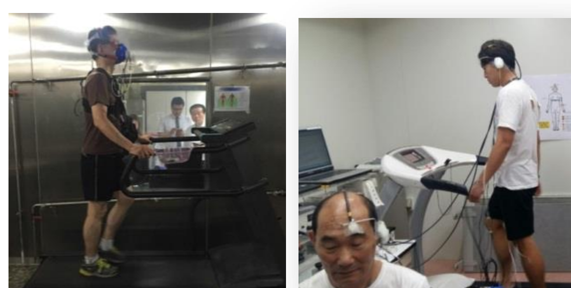

Figure 8. Chamber experiments at Seoul National Univ., and Inje Univ.)

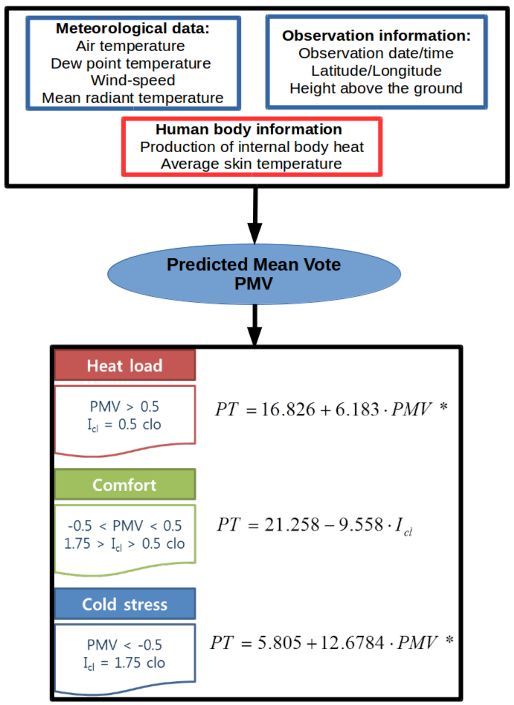

Figure 9. Flowchart of Perceive Temperature estimation

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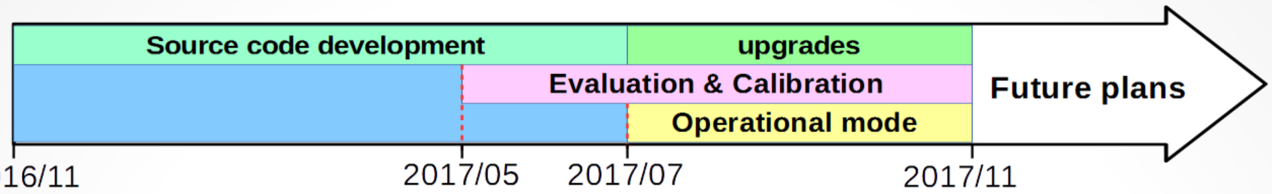
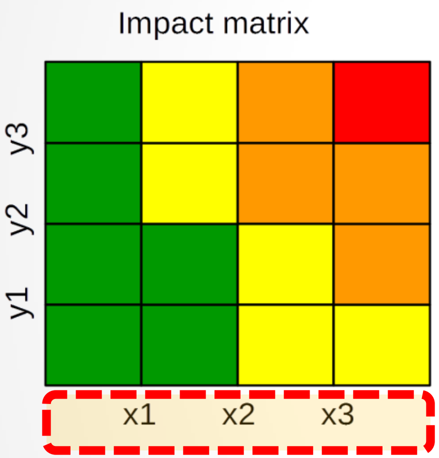
Future plans





2. Take into account regional variability of vulnerability to heat-stress :

- set different thresholds for different regions

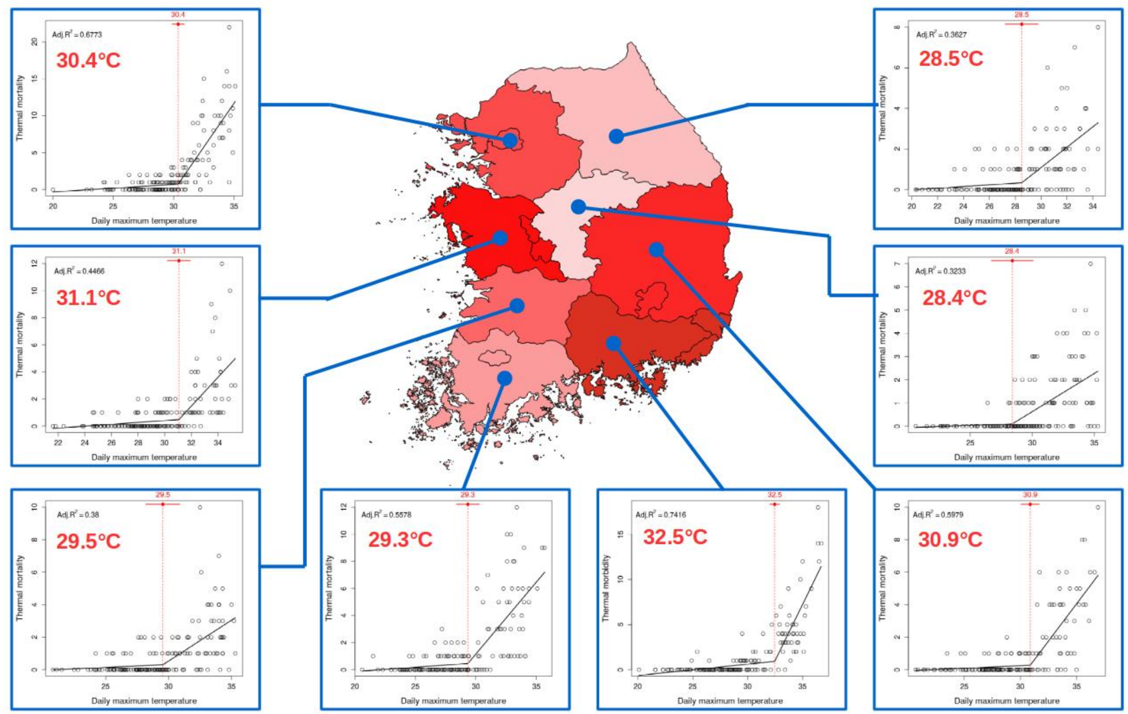


Figure 10. Results of segmented regression of daily T_{max} and thermal morbidity for different regions in South Korea

Future plans

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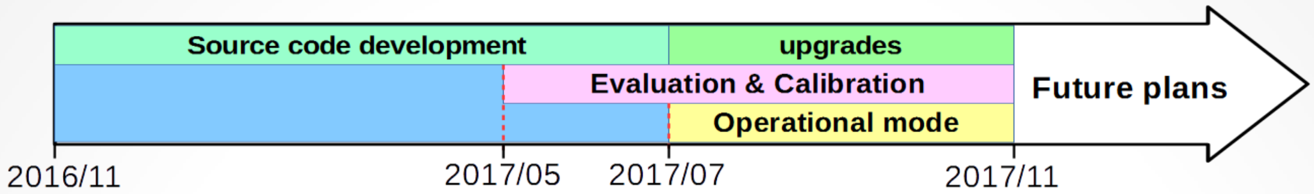

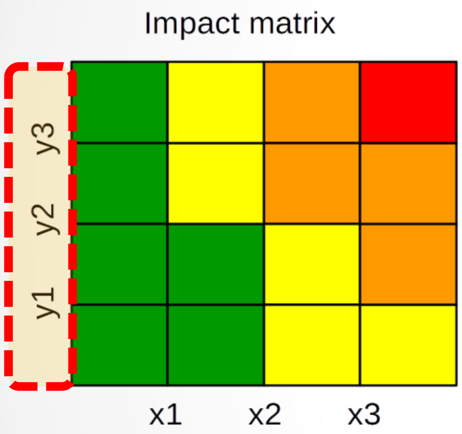

3. bias correction: post-processing

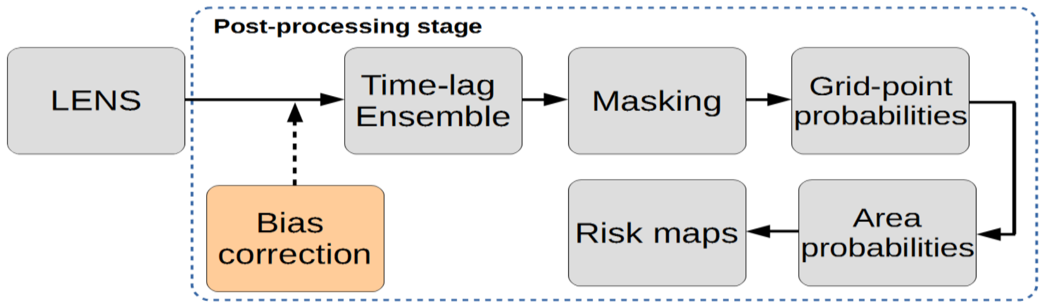

Figure 11. Flowchart of LENS post-processing program

4. upcoming LENS upgrade :

- spatial resolution 3km -> 2.2 km
- UM *VN 10.1 -> VN 10.4*

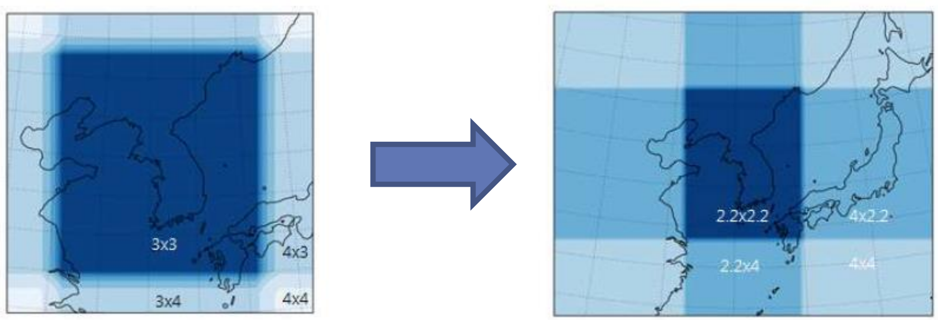

Figure 12. LENS domain with 3x3 km (left) and new domain with 2.2x2.2 km spatial resolution

References

Iris. V1.2. 28-Feb-2013 Met Office. UK. https//github.com/Scitools/iris.git

Lloyd-Sherlock P. 2000, Population ageing in developed and developing regions: implications for health policy *SocSciMed*, 51:887-95

Masato G. et al. 2015, Improving the health forecasting alert system for cold weather and heat-waves in England: A proof-of-Concept using Temperature-Mortality Relationships *PLosONE* 10(10)

Neal A. R. et al., 2014, Ensemble based first guess support towards a risk-based sever weather warning service, *Meteorol. Appl.* 21:563-577

Contact

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