

「국가 기후변화 시나리오 워크숍」

# 한반도 상세 기후변화 시나리오 산출 결과

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# 발표순서

## 1. 기후변화시나리오 생산방법 개관

- 상세화 방법 및 특성
- 고해상도 자료 생산 방안

## 2. PRISM

- GIS정보와 Weighting function
- 1km 관측 격자자료 생산
- 1km 관측 격자자료 검증

## 3. PRIDE 모델

- 1km 기후변화 시나리오 생산
- 1km 극한기후지수 생산

# Project Pluvius in 1953 (Tor Bergeron)

- A region of Norway where the largest orographic features were  $\sim 50$  m high.

- A dense network of approximately 200 rain gauges over an area

about 30 km square  $\sim$  almost **2 km** resolution

- Much to Bergeron's surprise he found that

Over these small hills

- precipitation rates could be **twice as high as** adjacent areas

- the differences **persisted** across different storms

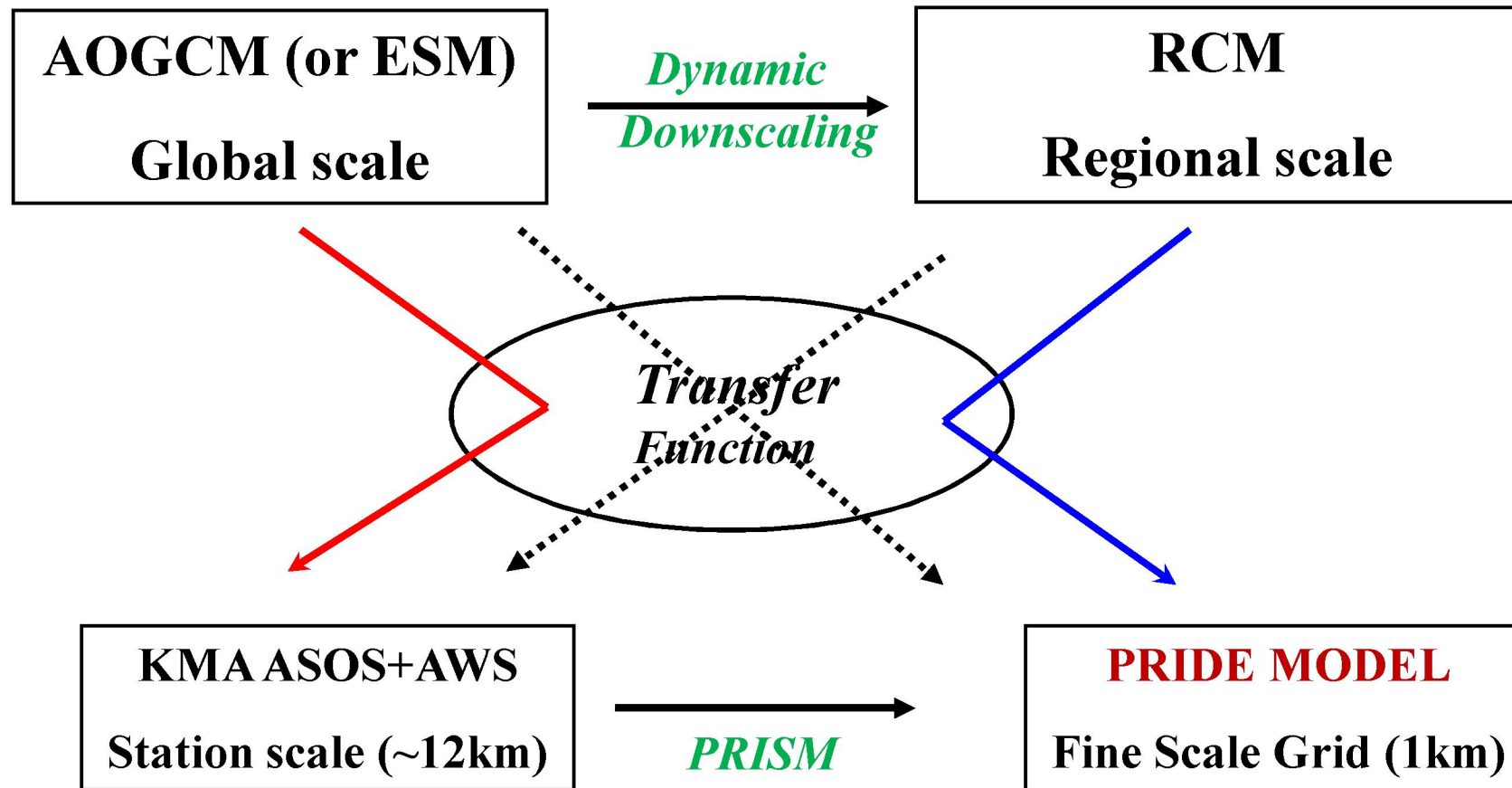
## **Project Pluvius in 1953 (Tor Bergeron)**

**These results led him to write that**

**“I venture to state that in no country is the official network of rainfall stations dense enough to give even just a summary picture of the precipitation conditions” (Bergeron 1961).**



# Climate Change Scenarios



Systematic bias-corrected-high resolution grid data

## Dynamic Downscaling Models (RCM)

- the potential for
  - capturing meso-scale nonlinear effects**
  - providing coherent information among multiple climate variables****
- the main drawbacks are
  - their computational cost**
  - in future climates the parametrization schemes they use to represent sub-grid scale processes may be operating outside the range for which they were designed.****

## Statistical Downscaling Models

- use cross-scale relationships that have been derived from observed data, and apply these to climate model data.
- They require observational data at the desired scale for a long enough period to allow the method to be well trained and validated.
- The advantage of being
  - computationally inexpensive,
  - able to access finer scales than dynamical methods and
  - applicable to parameters that cannot be directly obtained from the RCM outputs.
- The main drawbacks of SD methods are that
  - they assume that the derived cross-scale relationships remain stable when the climate is perturbed,
  - they cannot effectively accommodate regional feedbacks and,
  - in some methods, can lack coherency among multiple climate variables.

# Statistical Downscaling Methods

## 1) Transfer function type

### -Transfer function method

(Kim et al., 1984, Oh et al., 1994)

### -Multiple regression method

(Karl et al., 1990; Wigley et al., 1990; Schubert and Henderson-Sellers, 1997)

### -Empirical Dynamic method

(von Storch et al., 1993, Heyen et al., 1995;

Kim and Kang, 1997; Kim et al., 2004; Oh et al., 2004)

## 2) Weather Generator type

## 3) Analogue methods

### \*Parameter-elevation Regression on Independent Slopes Model (PRISM)

(Daly et al., 2002; 2003; 2008 )

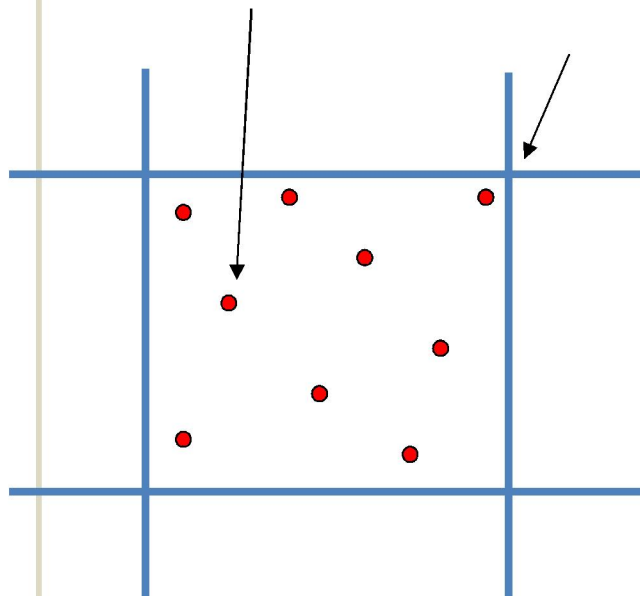
# Transfer Function Type

Station Scale

~ 12km

GCM/RCM Grid

~ 50km



## Climate Inversion (Kim et al., 1984)

Training Period

$$\text{EOFA: } S(s,t) = \sum T_i(t) E_i(s)$$

Transfer Function:  $T_i \sim f(G)$

Projection

$$\text{GCM/RCM } G \rightarrow T_i \rightarrow S(s,t)$$

관측 해상도를 넘는 고해상도 기후변화 시나리오 생산 불가능

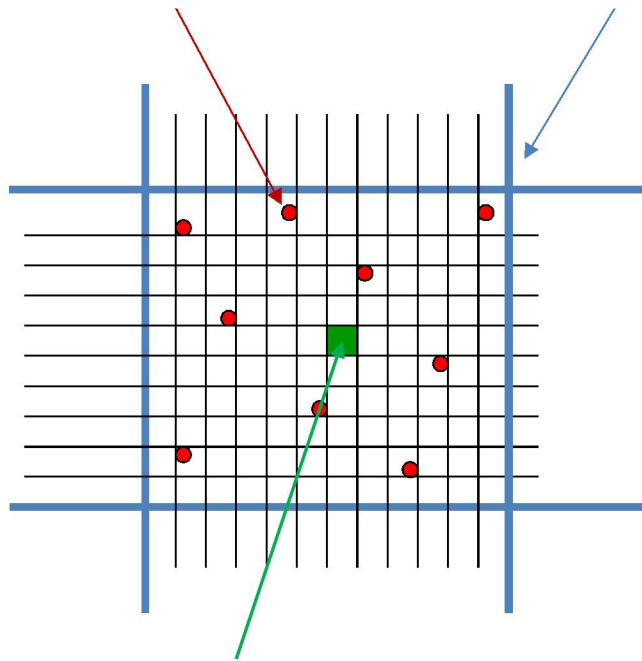
# FINE SCALE GRID

**Station Scale**

**~ 12km**

**GCM/RCM Grid**

**~ 50km**



**Fine scale grid**

**~ less than station scale (1km)**

## Methodology

### 1. Barnes scheme (Object Analysis)

-Distance

### 2. Kriging

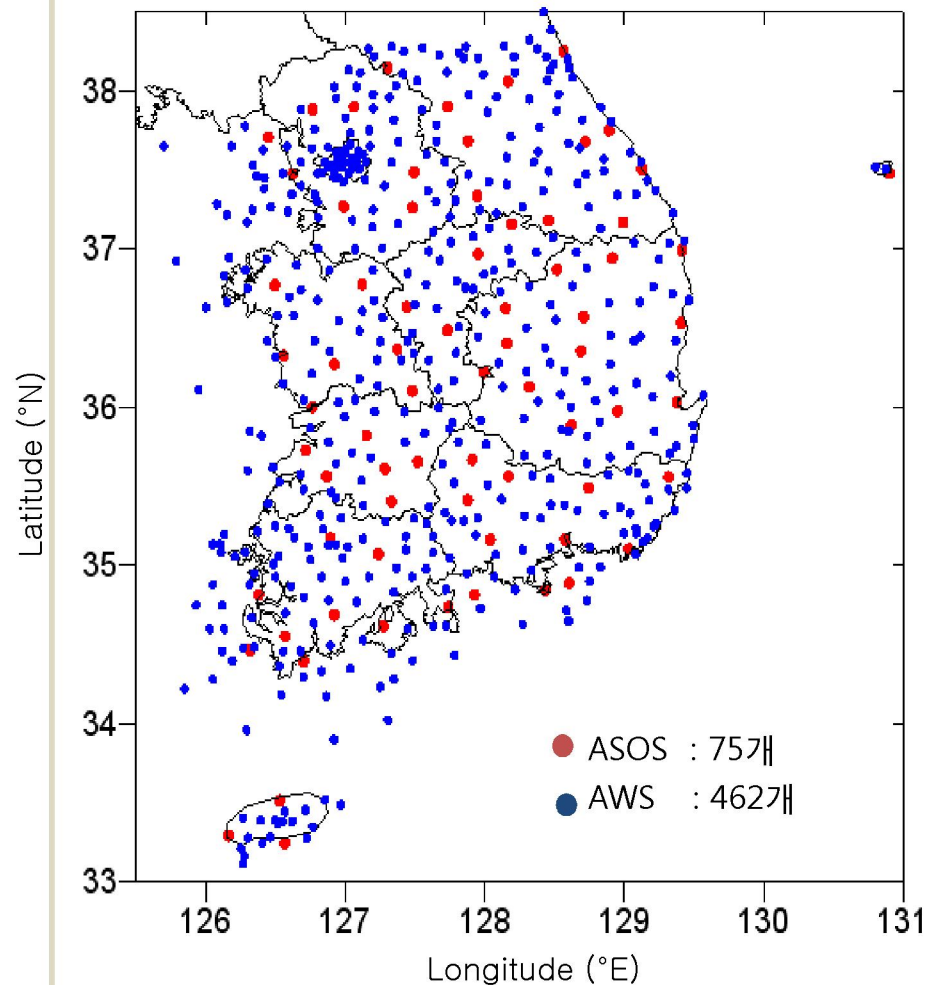
-Distance, BLUE

### 3. PRISM

-GIS Information

# Observation station

관측 자료



관측 지점수 : 537개

**ASOS 75**

(Automatic Synoptic Observation System)

**AWS 462**

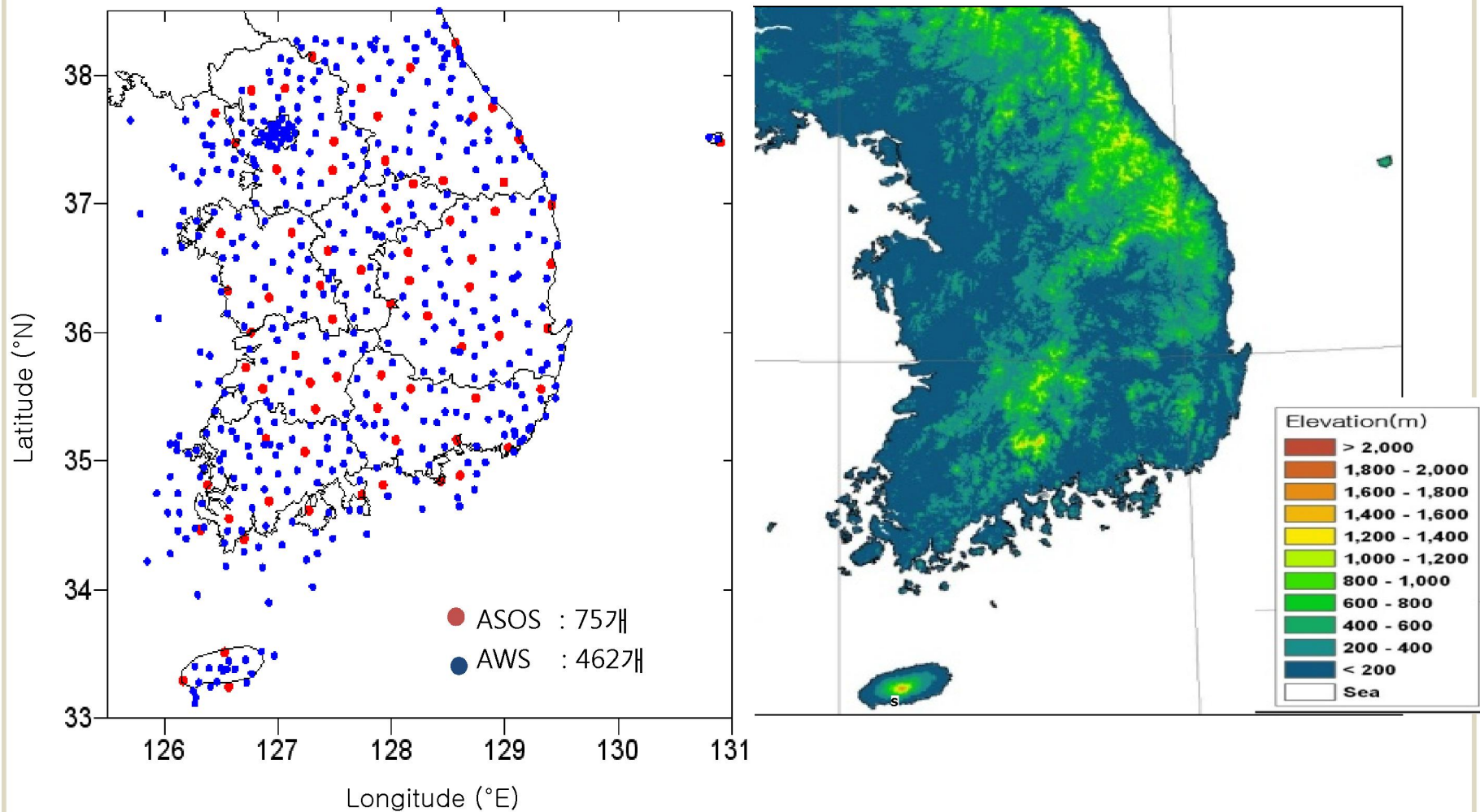
(Automatic Weather System)

• 평균거리 : 약 12km

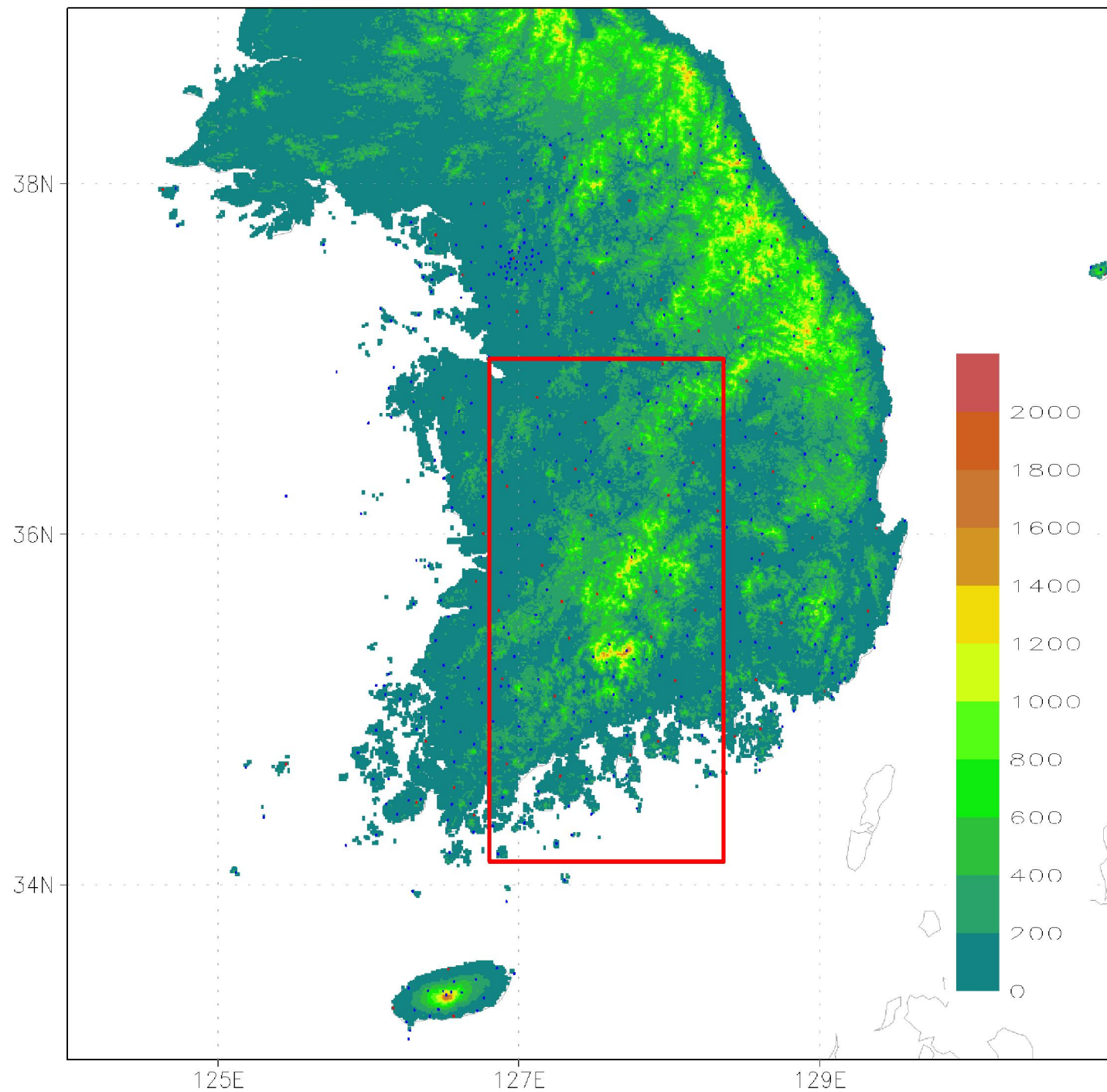
• 기간: 2000-2010



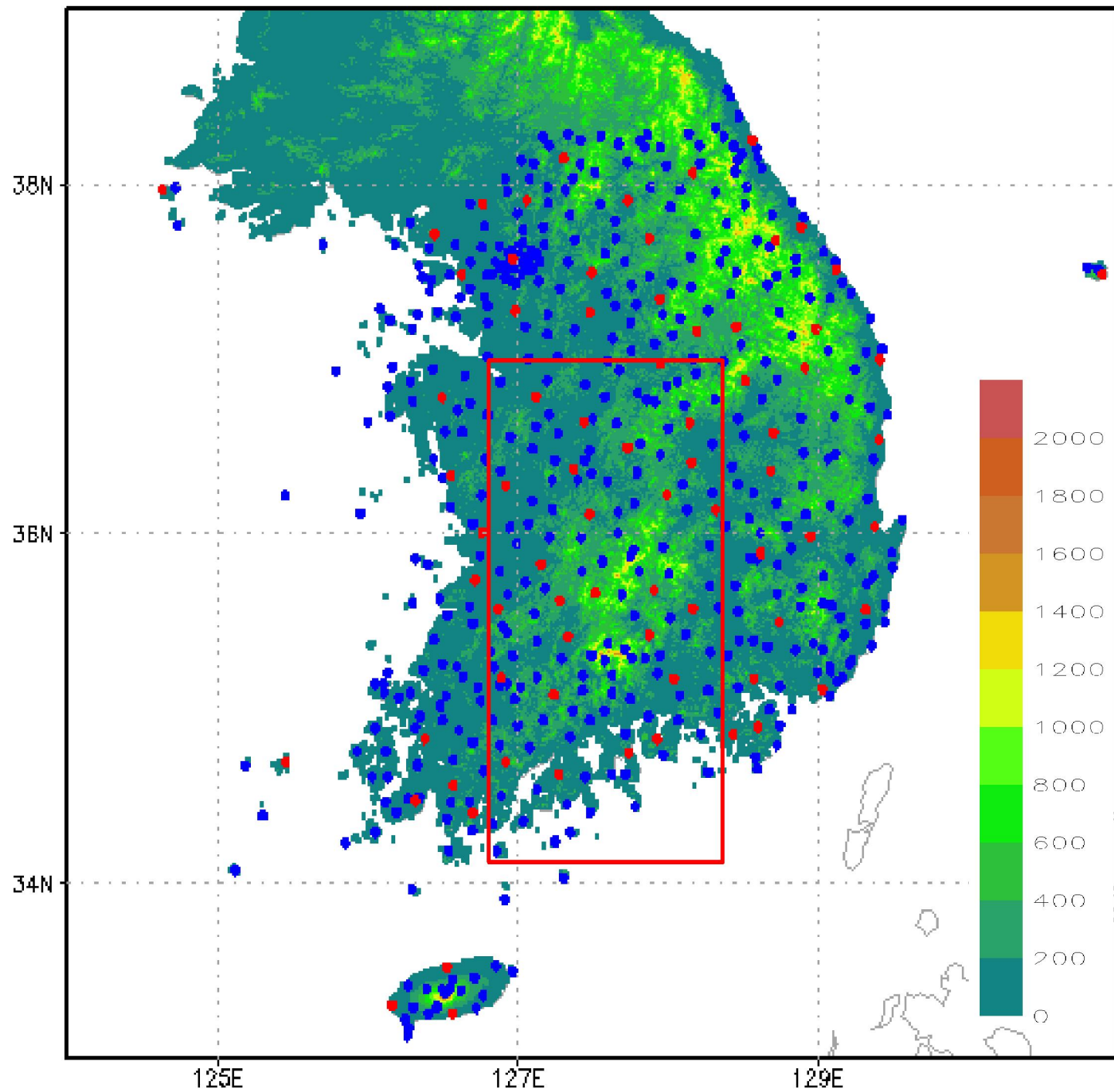
# DEM Elevation (1km resolution)







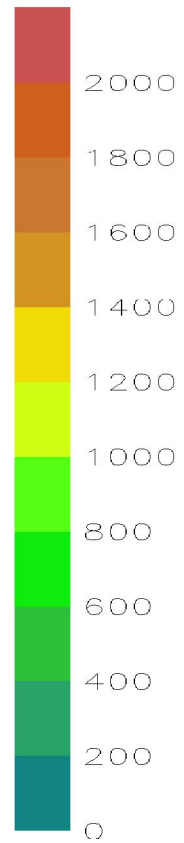
ASOS : 75개  
AWS : 462개



ASOS : 75개  
AWS : 462개



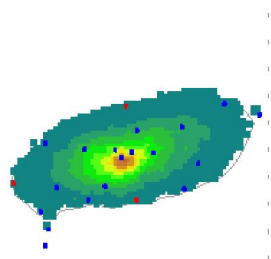
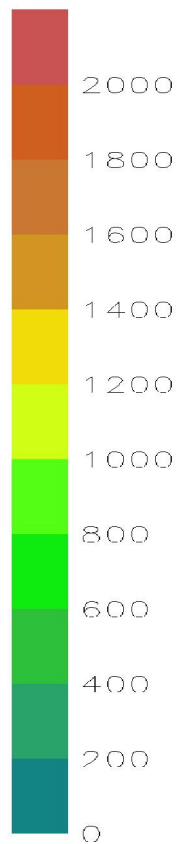
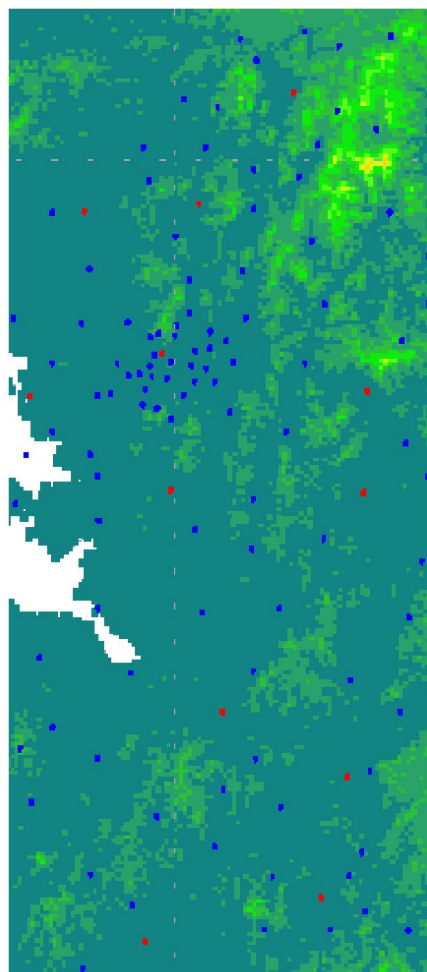
## DEM ELEVATION



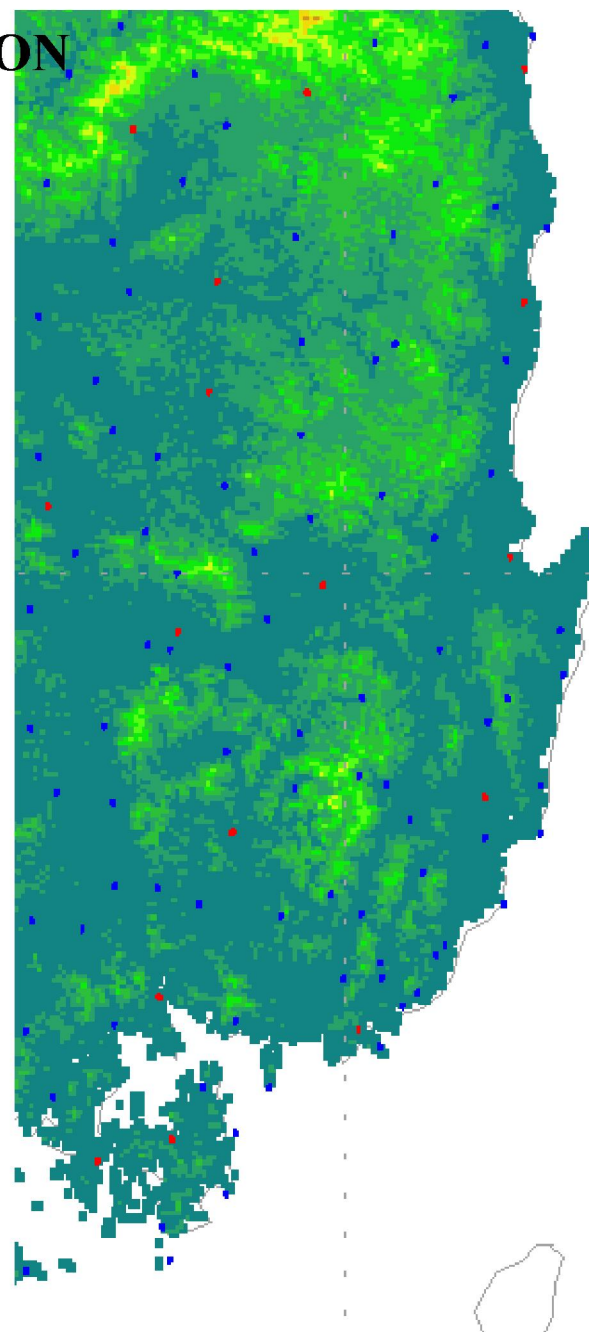
● ASOS : 75개  
● AWS : 462개

S

## DEM ELEVATION



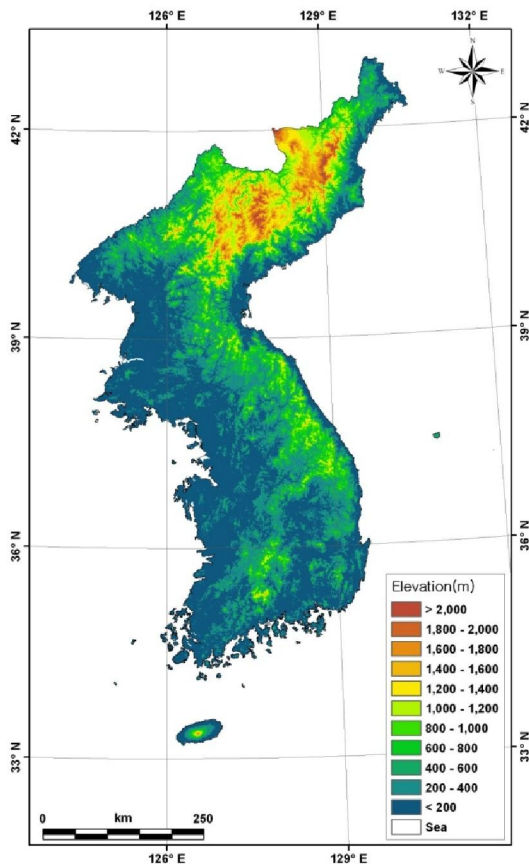
● ASOS : 75개  
● AWS : 462개



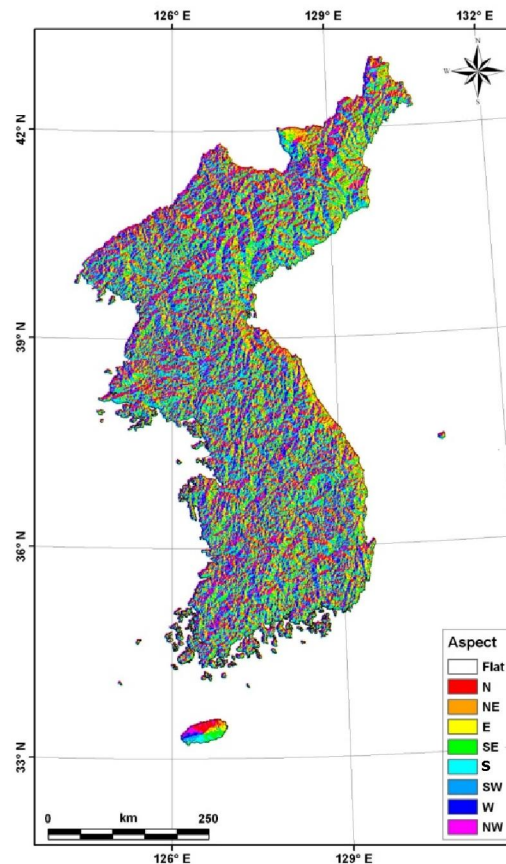


# 1km GIS Information

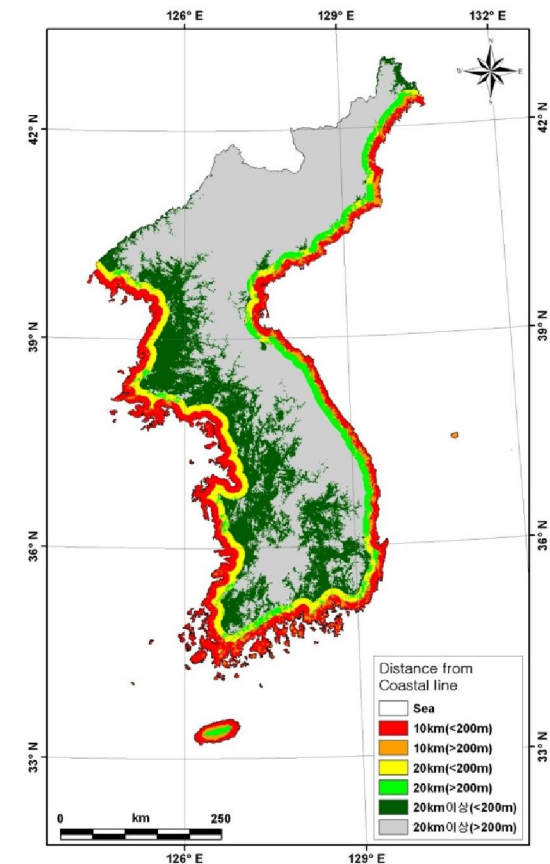
DEM Elevation



Topographic facet



Coastal Proximity



**The PRISM Approach to Mapping Climate in Complex Regions**

# PRISM

## Parameter-elevation Regression on Independent Slopes Model

(Daly et al., 2002; 2003; 2008 ; 홍기옥 등, 2007; 신성철 등, 2008; 김맹기 등, 2011)

### ■ Major weighting factor

$$W = [F_d W(d)^2 + F_z W(z)^2]^{1/2} W(f) W(p)$$

**$F_d$  : Distance weighting importance factor**

**$F_z$  : Elevation weighting importance factor**

**$W(f)$  : Topographic Facet**

**$W(p)$  : Costal Proximity**

$$\bar{x} = \frac{\sum W_i x_i}{\sum W_i}, \bar{y} = \frac{\sum W_i y_i}{\sum W_i}$$

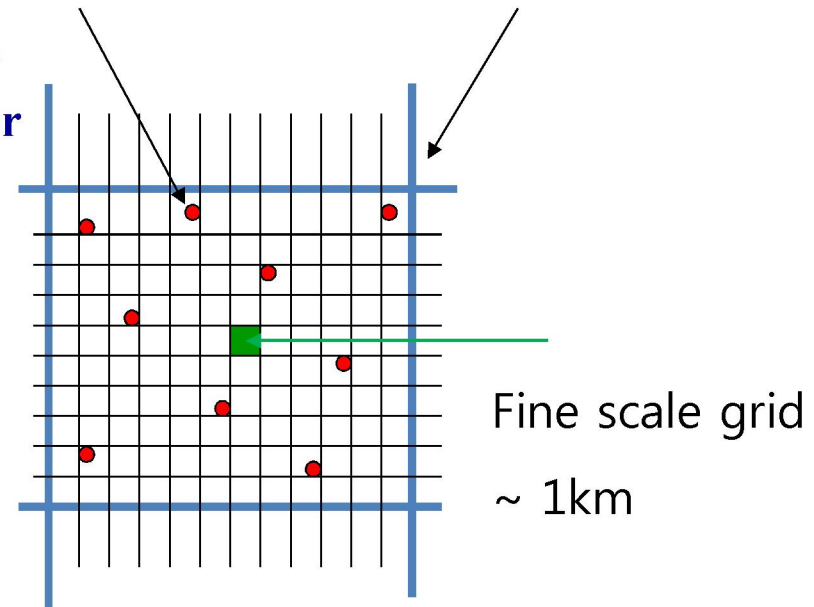
$$\beta_0 = \bar{y} - \beta_1 \bar{x} \quad \beta_1 = \frac{\sum W_i (x_i - \bar{x})(y_i - \bar{y})}{\sum W_i (x_i - \bar{x})^2}$$

Station Scale

~ 12km

GCM/RCM Grid

~ 50km, 12km



Target grid별로 고도, 거리, 지향면, 해양도 등을 고려하여 관측값으로 부터 고 해상도 격자형 관측상당자료를 생산하는 방법

## ◇ Distance weighting:

$$W(d) = \begin{cases} 1; & 1 \geq d \geq 0 \\ \frac{1}{d^a}; & d > 1 \end{cases}$$

**Where  $d$  is the horizontal distance between the station and the target grid cell and  $a$  is the distance weighting exponent.  $a$  typically set to 2, which is equivalent to an inverse-distance-squared weighting function**

## ◇ Elevation weighting

$$W(z) = \begin{cases} \frac{1}{\Delta z_m^b}; \Delta z \leq \Delta z_m \\ \frac{1}{\Delta z^b}; \Delta z_m < \Delta z < \Delta z_x \\ 0; \Delta z \geq \Delta z_x \end{cases}$$

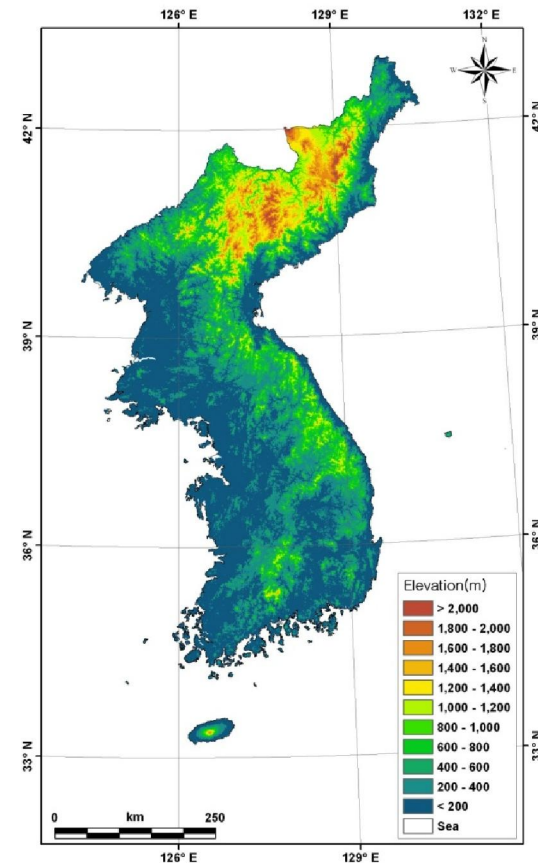
$\Delta z$  : the absolute elevation difference between the station and the target grid cell

$b$  : elevation weighting exponent(1.0)

$\Delta z_m$  : minimum elevation difference (100)

$\Delta z_x$  : maximum elevation difference (500)

## Digital Elevation Model (DEM)





## ◇ Topographic Facet weighting

The rule that best matches the distribution is used to assign an orientation to the target grid cell  
(Gibson et al., 1997)

$$\tan A = \frac{(-\delta Z / \delta Y)}{(\delta Z / \delta X)} (-\pi < A < \pi)$$

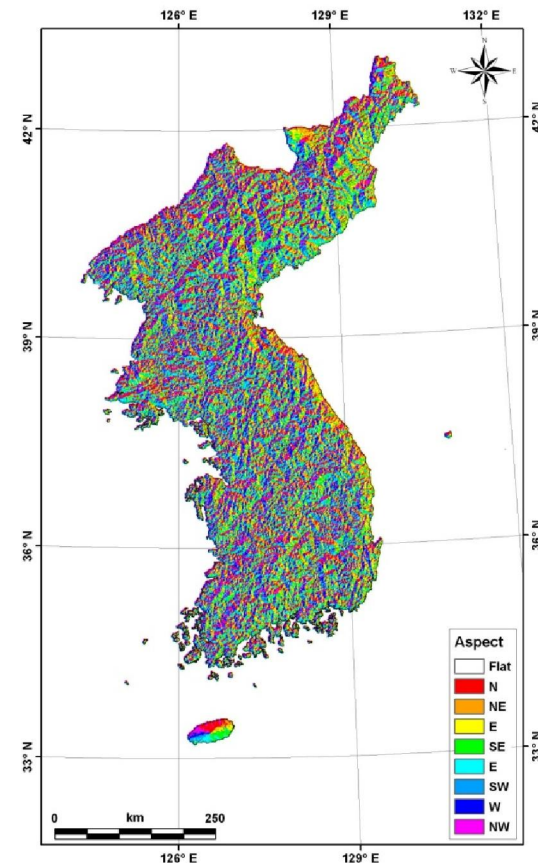
$$W(f) = \left\{ \begin{array}{ll} 1; \Delta f \leq 1 \text{ and } B = 0 \\ \frac{1}{(\Delta f + B)^c}; \Delta f > 1 \text{ or } B > 0 \end{array} \right\}$$

**$\Delta f$** : the absolute orientation difference between the station and the target grid cell ( $\Delta f = 1$  for  $45^\circ$ )

**B**: the number of intervening barrier cells ( $\Delta f > 1$ )

**c**: the Facet weighting exponent( 0.0/**1.5**/2.0 )

Facet direction



## ◇ Coastal Proximity weighting

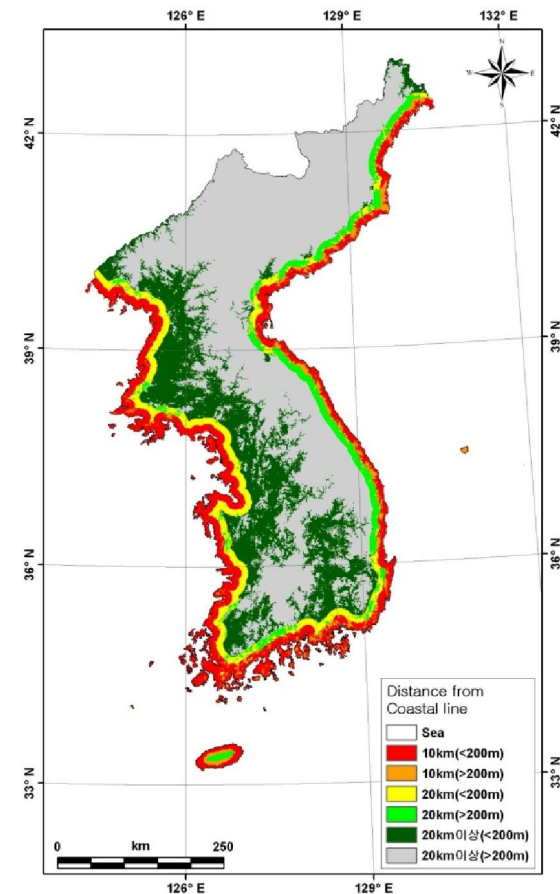
$$W(p) = \left\{ \begin{array}{ll} 1; & \Delta p = 0 \\ 0; & \Delta p > p_x \\ \frac{1}{\Delta p^v}; & 0 < \Delta p \leq p_x \end{array} \right\}$$

$\Delta p$  : the absolute difference between the station and target grid cell coastal proximity index

$p_x$  : the maximum proximity difference

$v$  : coastal proximity weighting exponent  
(0.0/1.0/1.0)

Coastal Proximity



## ◇ Weighted regression

$$W = [F_d W(d)^2 + F_z W(z)^2]^{1/2} W(f) W(p)$$

$$\bar{x} = \frac{\sum W_i x_i}{\sum W_i}, \bar{y} = \frac{\sum W_i y_i}{\sum W_i}$$

**y<sub>i</sub> : Climate elements**

**x<sub>i</sub> : DEM elevation**

$$\beta_1 = \frac{\sum W_i (x_i - \bar{x})(y_i - \bar{y})}{\sum W_i (x_i - \bar{x})^2}$$

$$\beta_0 = \bar{y} - \beta_1 \bar{x}$$



$$Y = \beta_0 + \beta_1 X$$

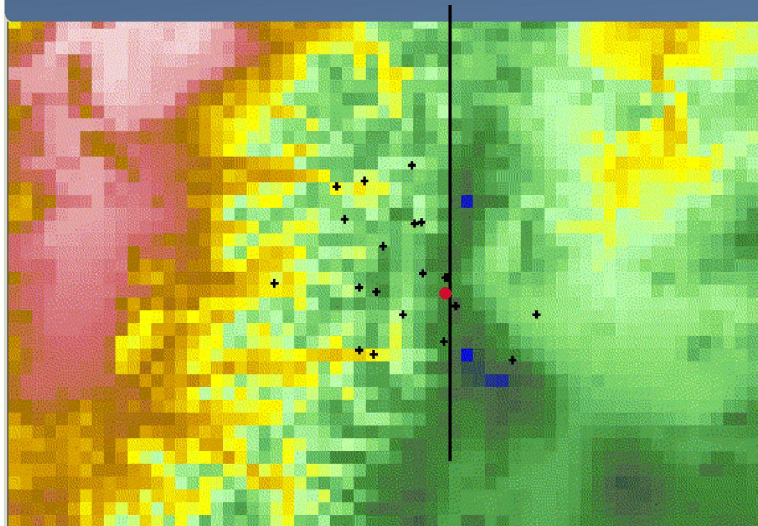
where Y is the predicted climate element,  $\beta_1$  and  $\beta_0$  are the regression slope and intercept, respectively, and X is the DEM elevation at the target grid cell.

The climate-elevation regression is developed from x, y pairs of elevation and climate observations supplied by station data in the local area.

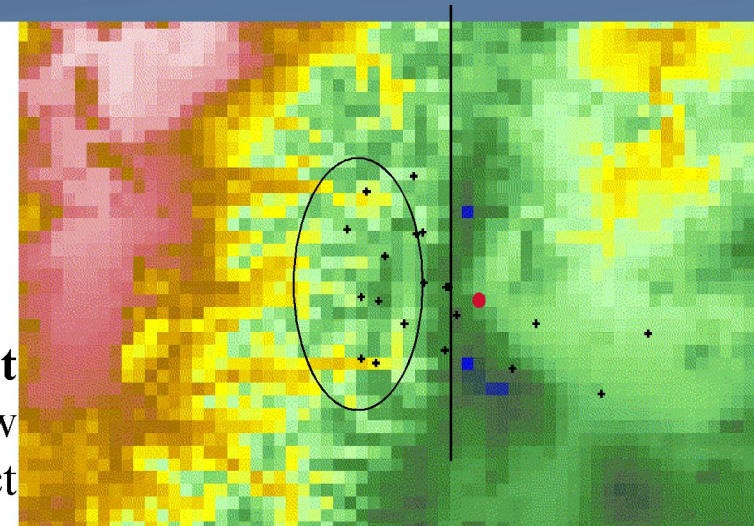
Ridge line

● Target grid

+ Observation station



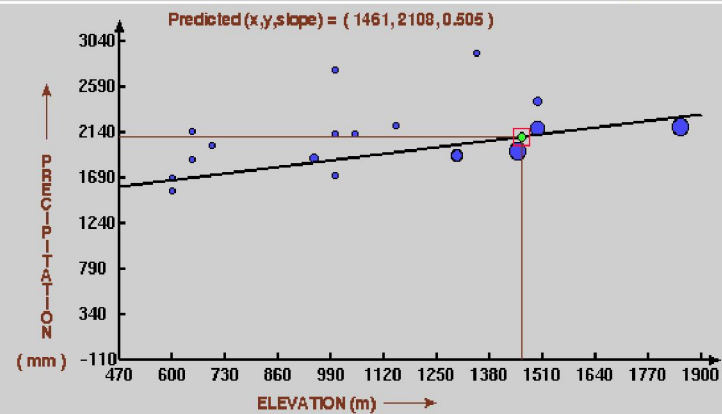
Left  
Topographic  
effect



Right  
Rain shadow  
effect

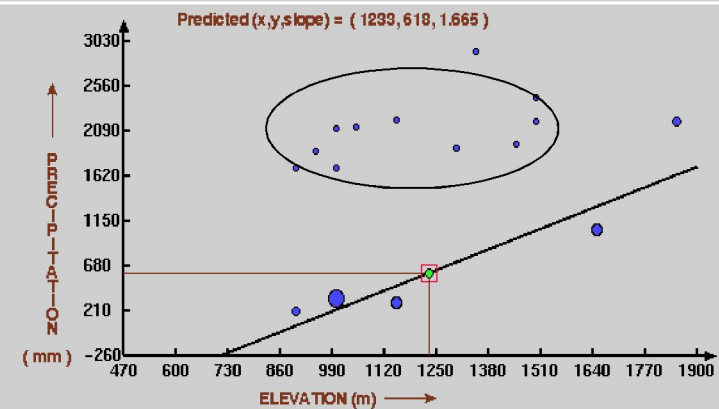
Latitude : 43.874999999999 Longitude : -122.41666666667 X Co-ordinate :

Elevation Vs Parameter Graph



Latitude : 45.333333333333 Longitude : -123.37500000000 X Co-ordinate :

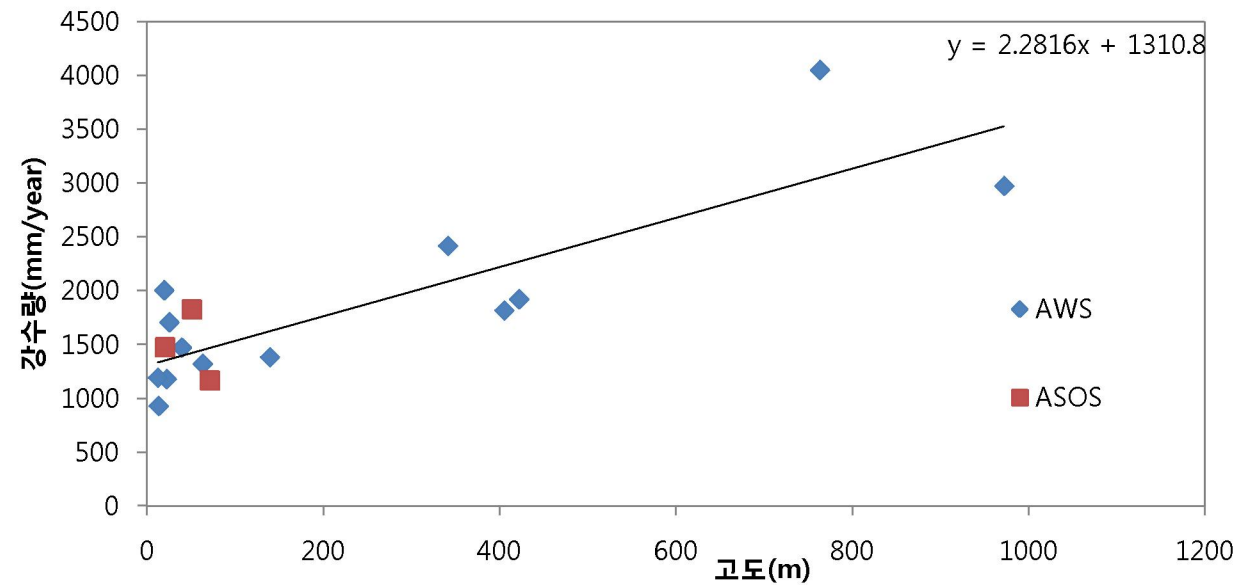
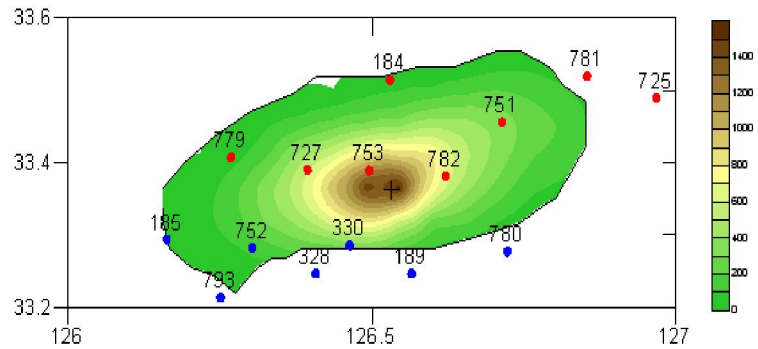
Elevation Vs Parameter Graph



The PRISM Approach to Mapping Climate in Complex Regions



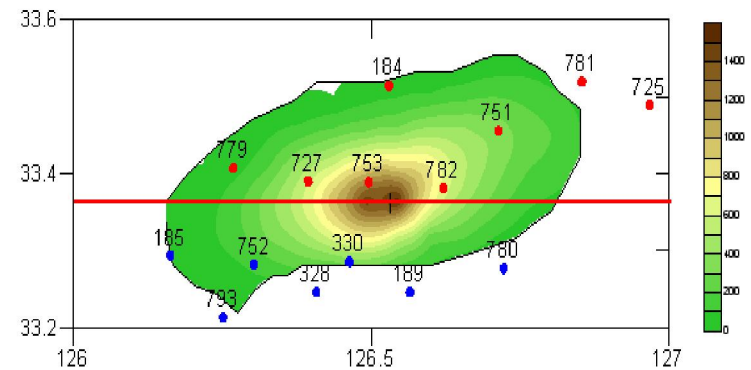
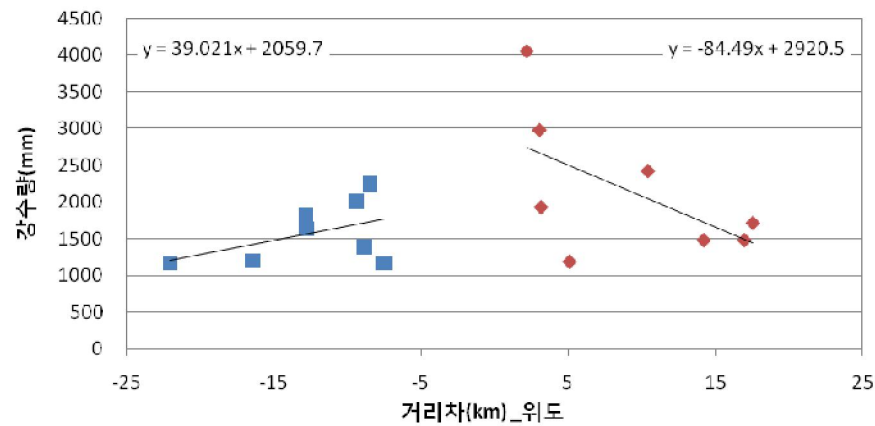
## 고도에 따른 강수량 (제주도)



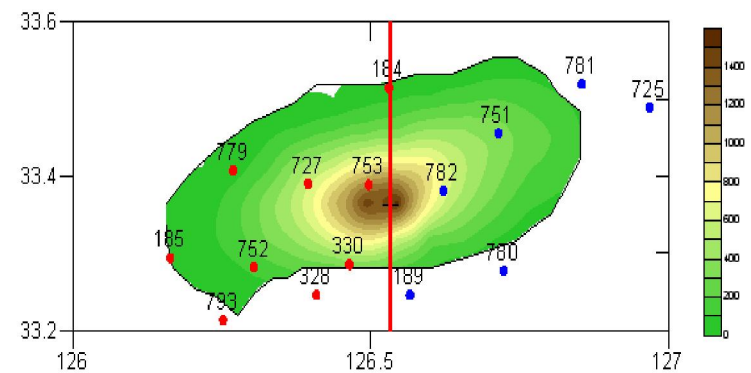
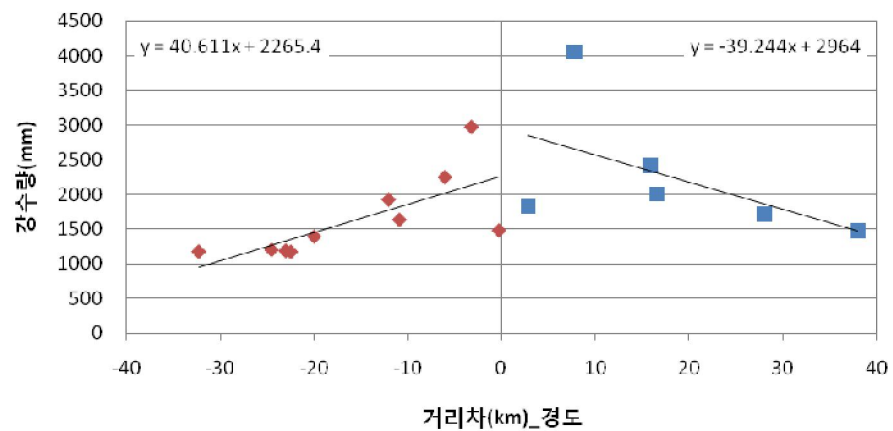
Climate-Elevation Regression

# 거리(지향면+고도)에 따른 강수량 (제주도)

한라산 정상과 관측점 차에 따른 강수량(위도)



한라산 정상과 관측점 차에 따른 강수량(경도)

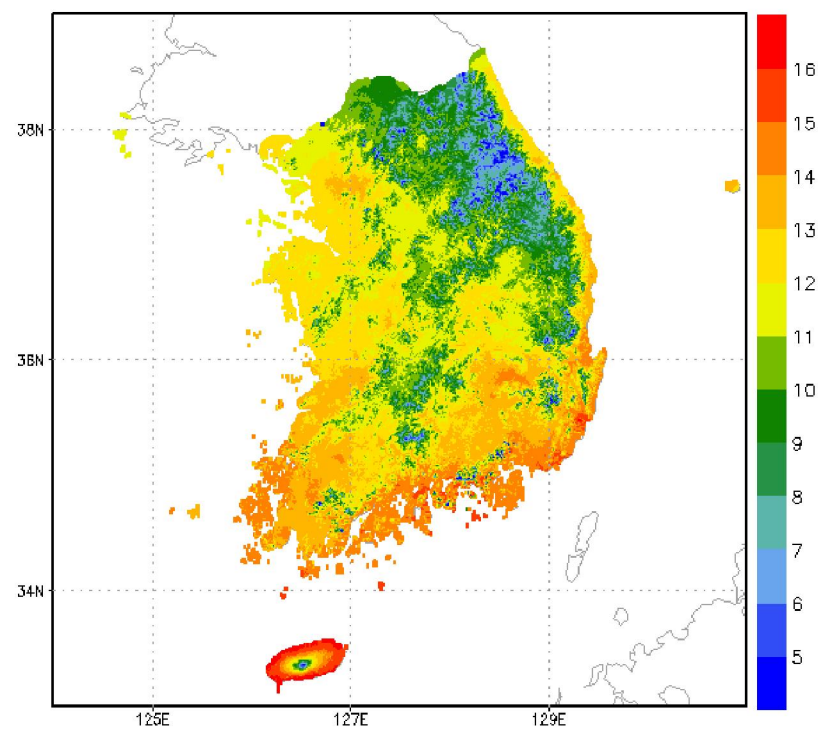
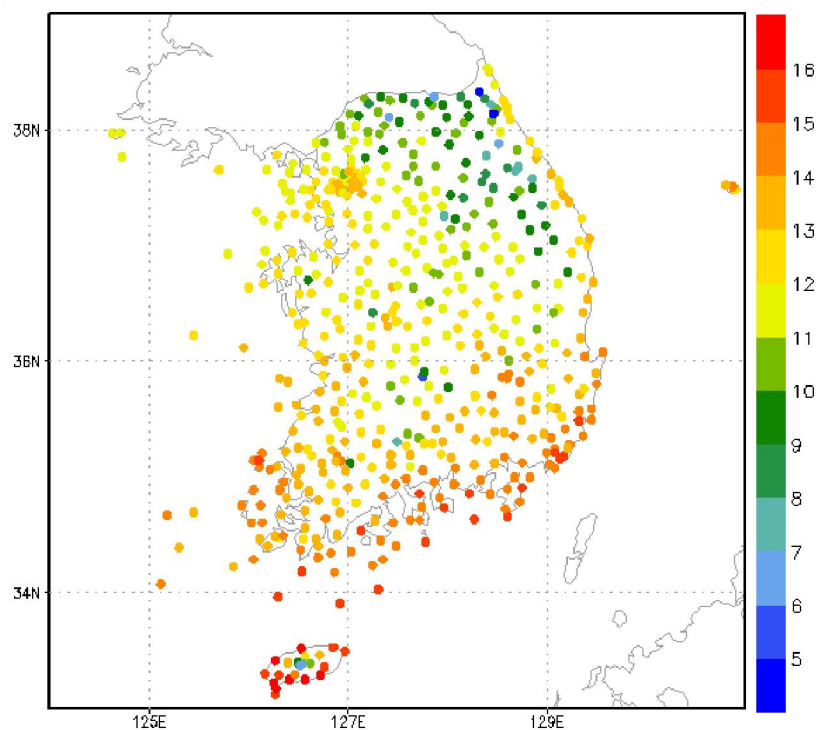


**PRISM 산출 결과 비교**  
**12KM (지점)      vs      1KM (격자)**

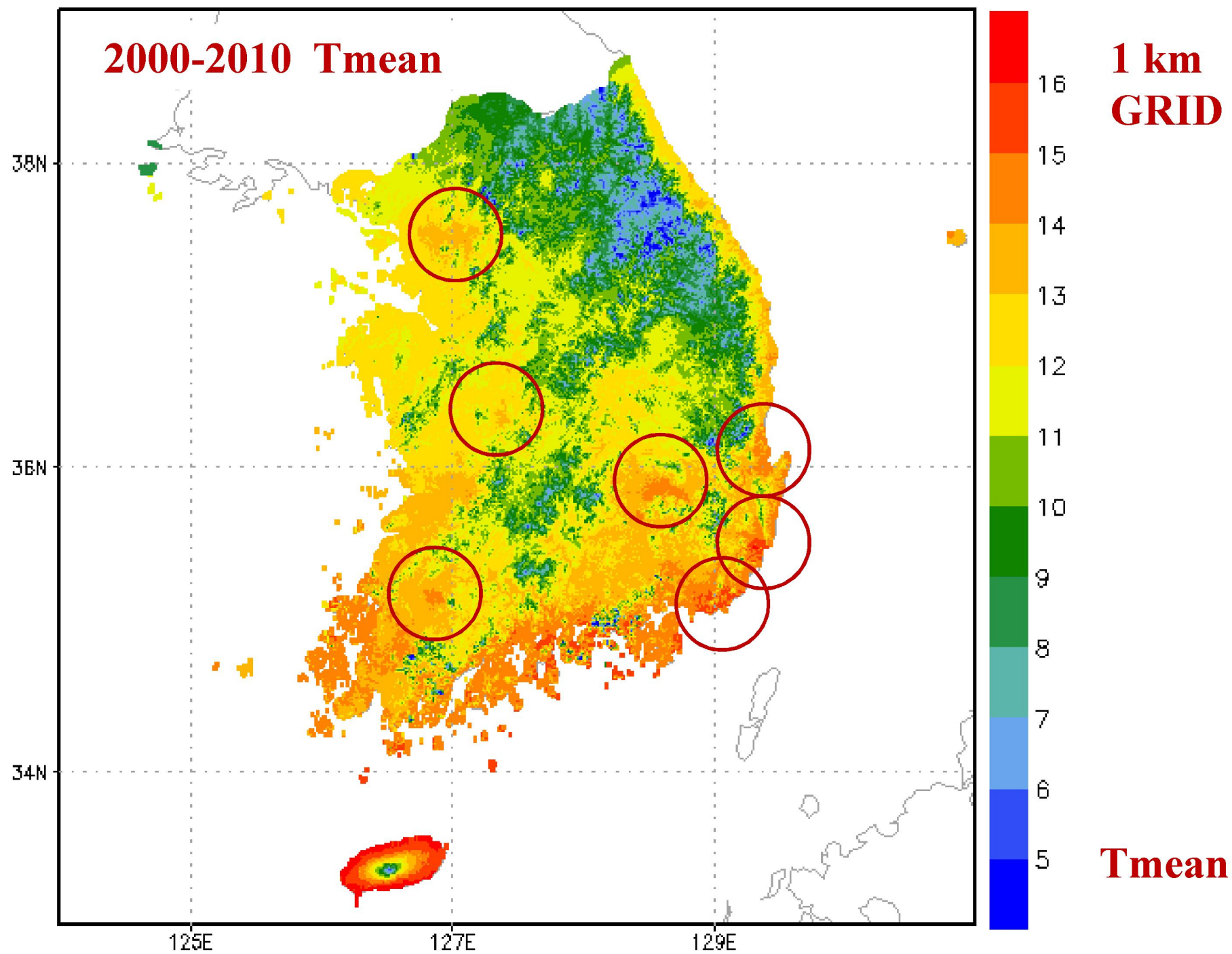
# Observation (12km) vs PRISM (1km)

T<sub>mean</sub>

2000년대 일 평균기온



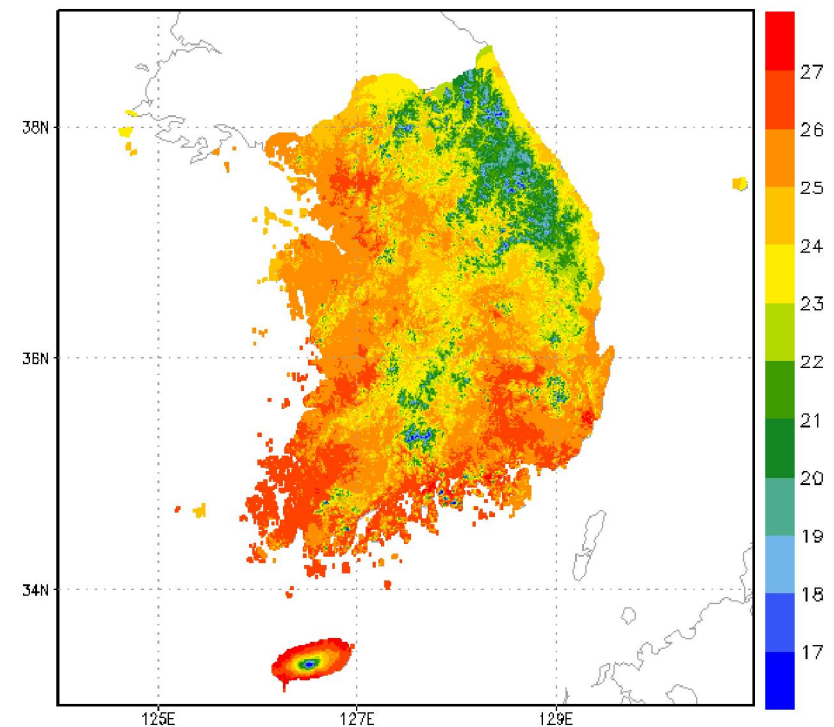
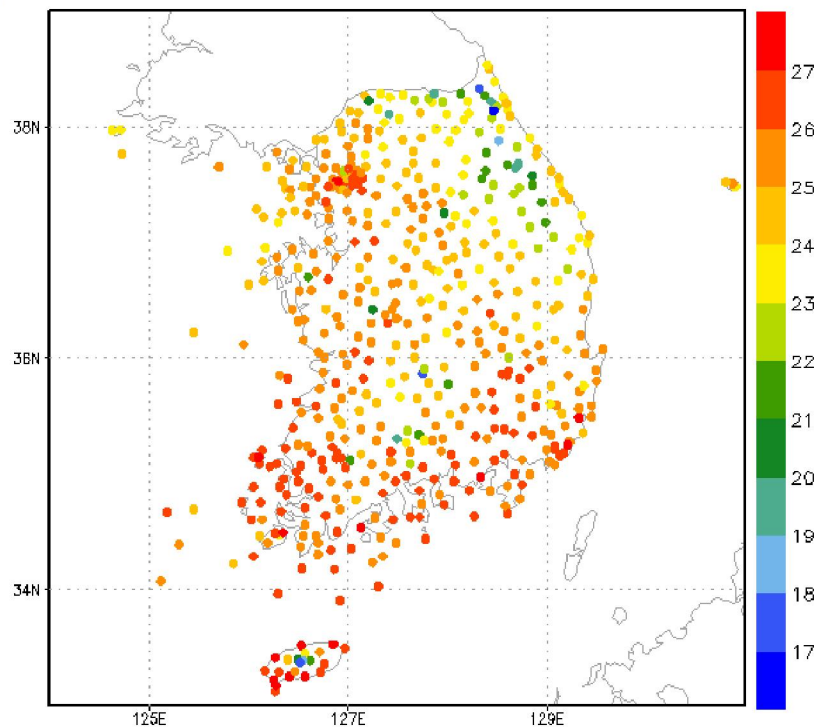




# Observation (12km) vs PRISM (1km)

T<sub>mean</sub>

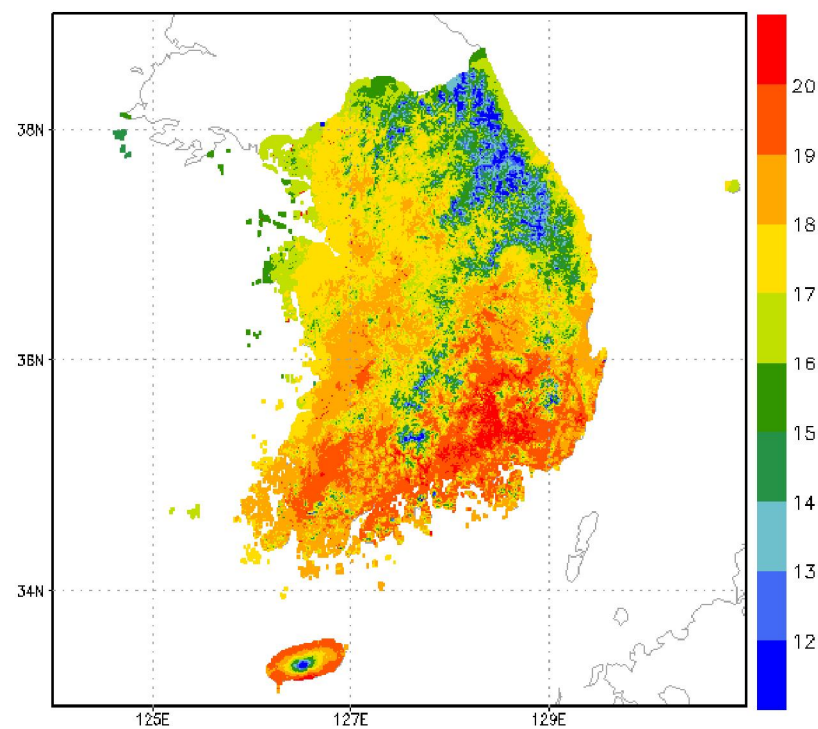
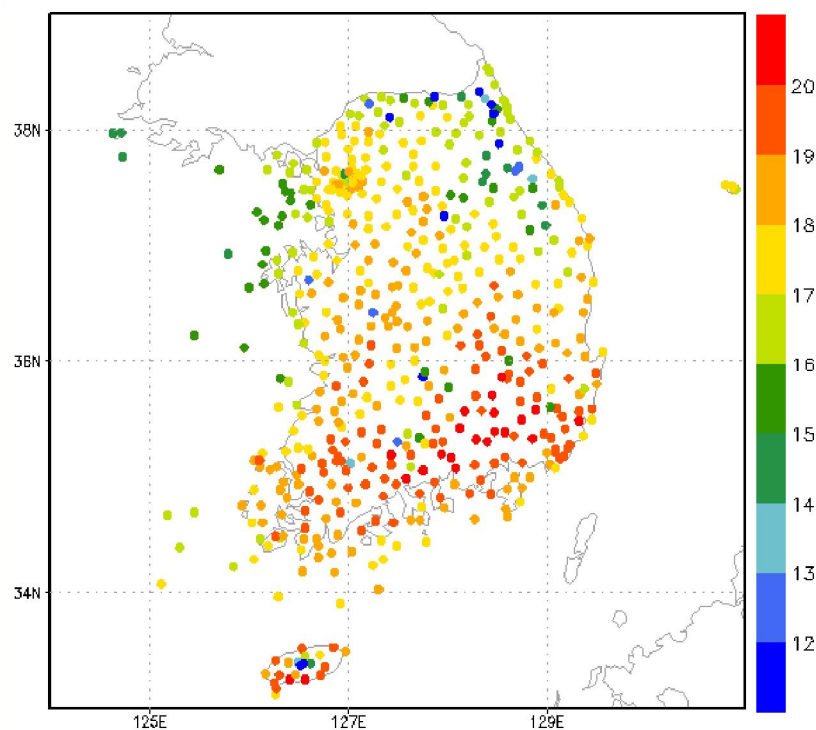
2000년대 일 평균기온 (8월)



# Observation (12km) vs PRISM (1km)

Tmax

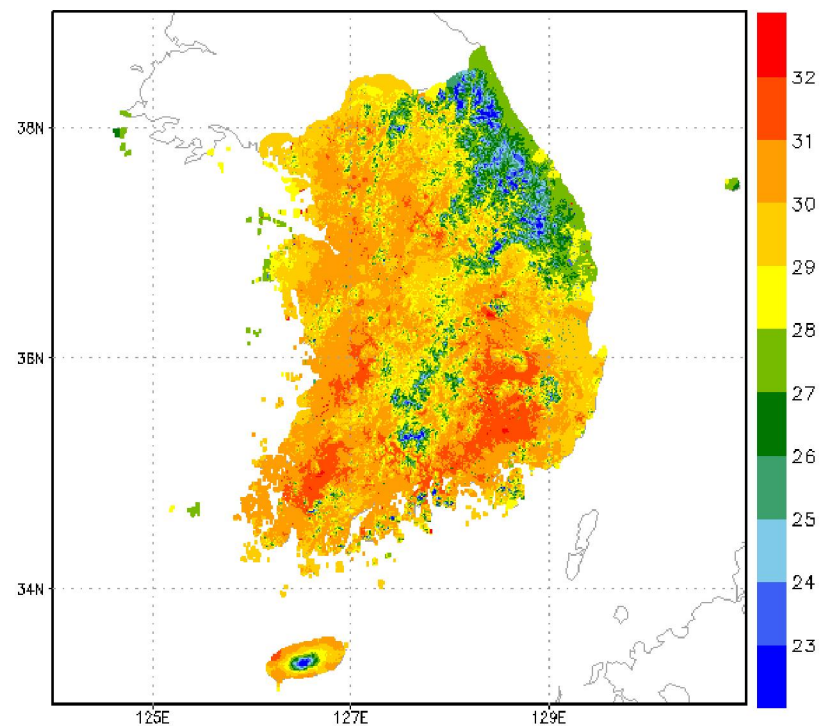
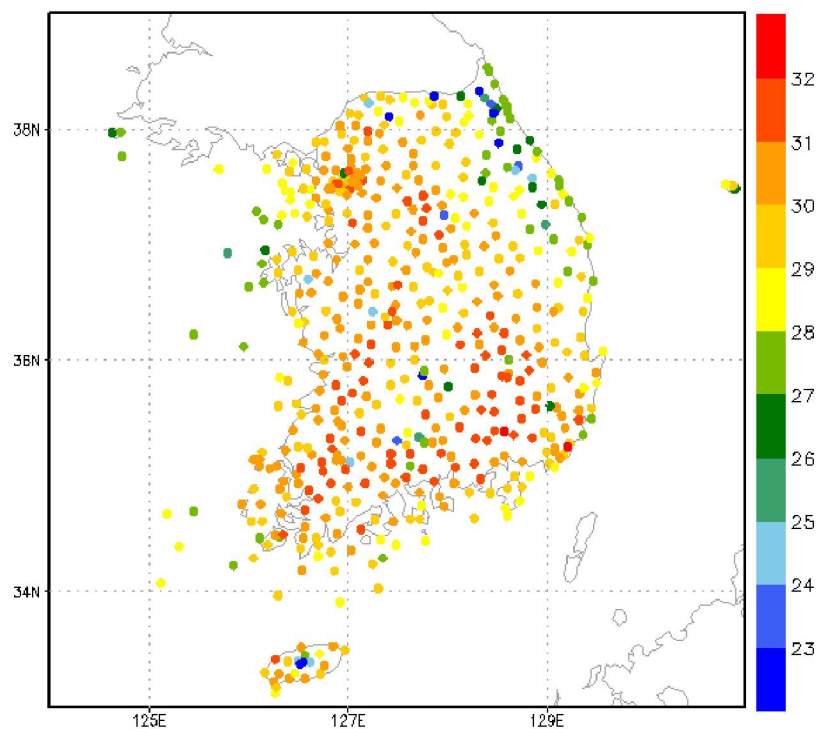
2000년대 일 최고기온



# Observation (12km) vs PRISM (1km)

Tmax

2000년대 일 최고기온 (8월)

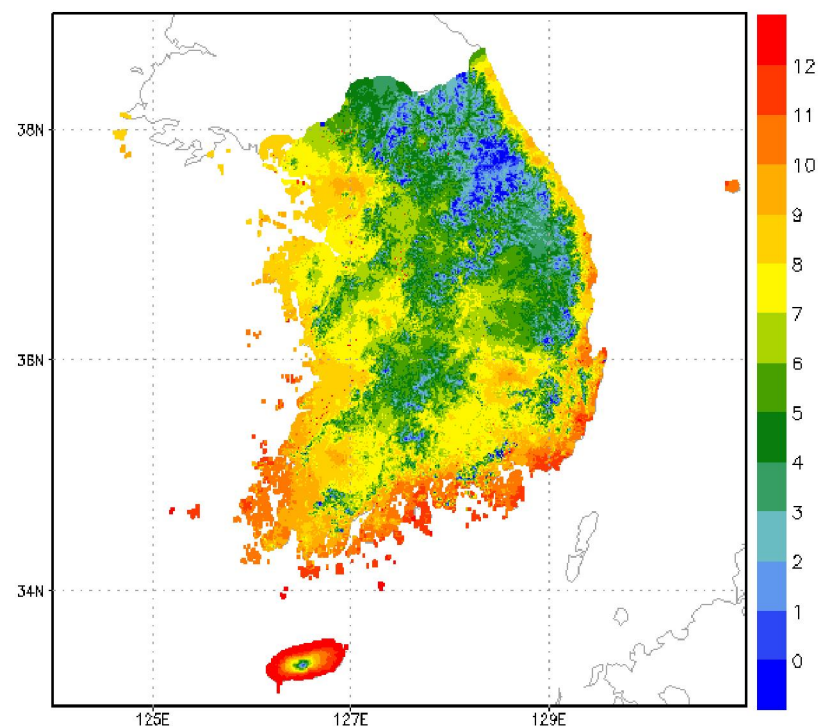
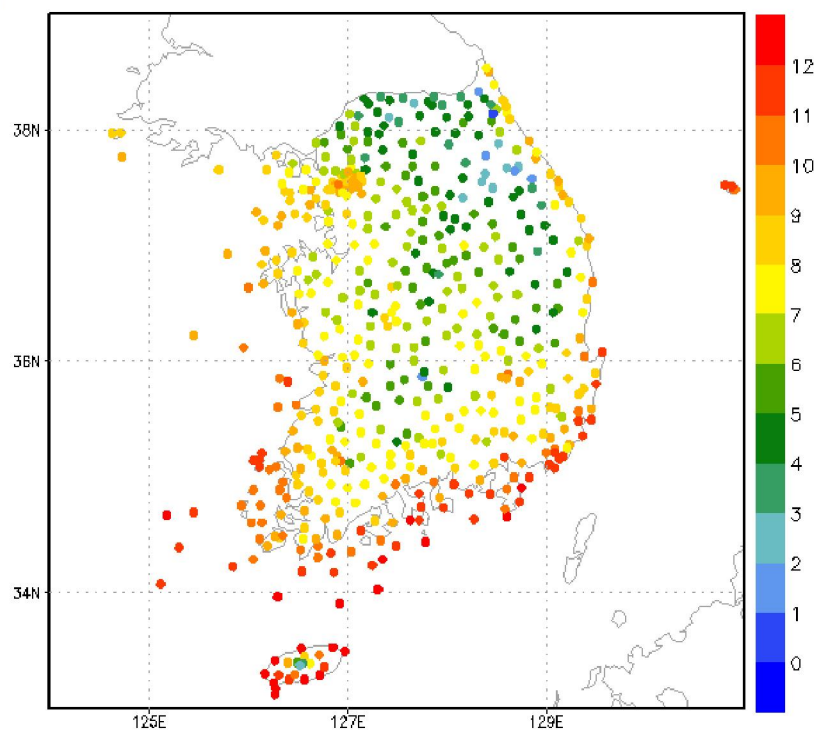




# Observation (12km) vs PRISM (1km)

Tmin

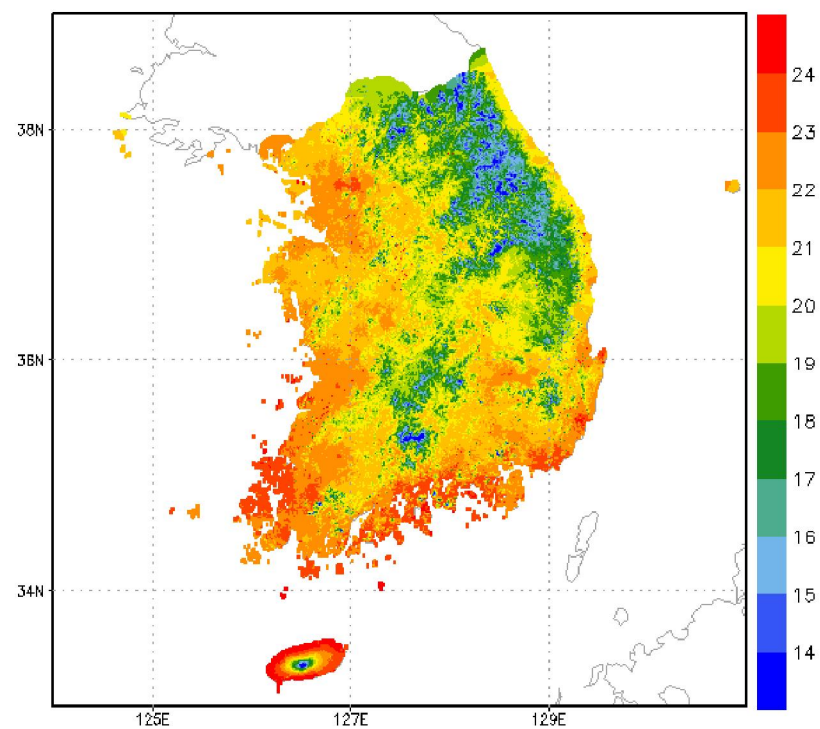
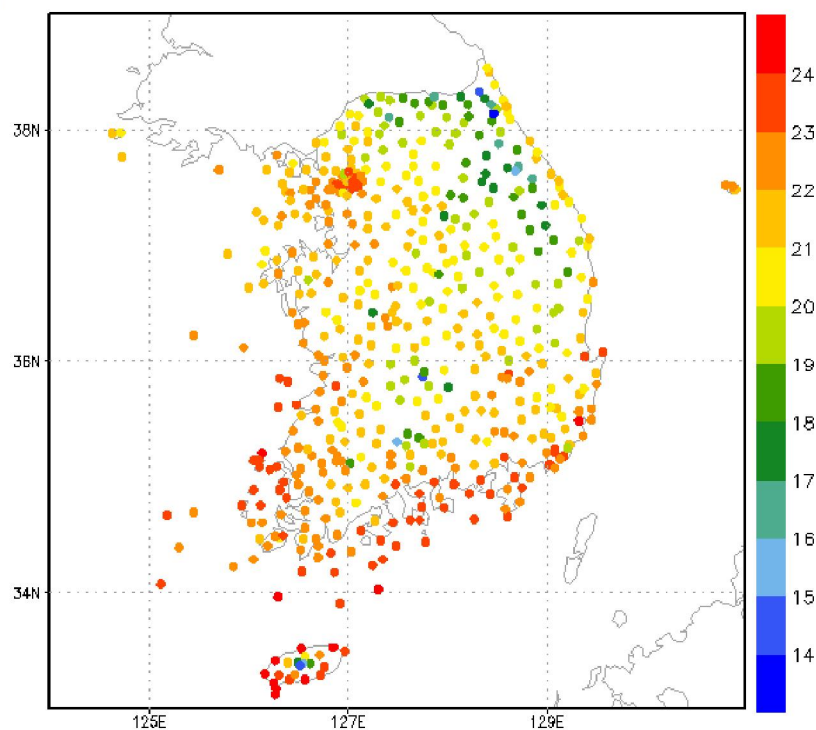
2000년대 일최저기온



# Observation (12km) vs PRISM (1km)

Tmin

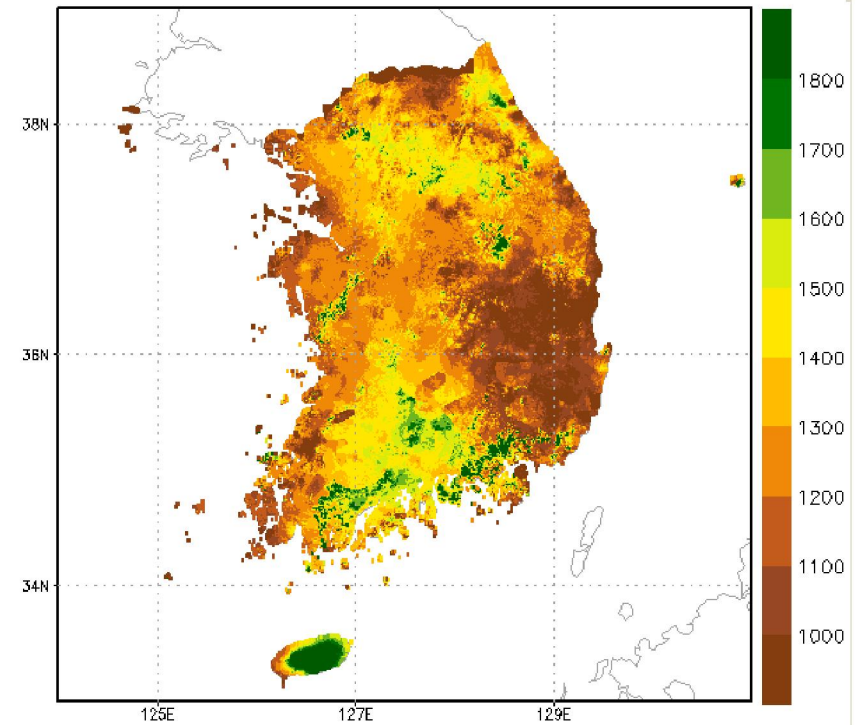
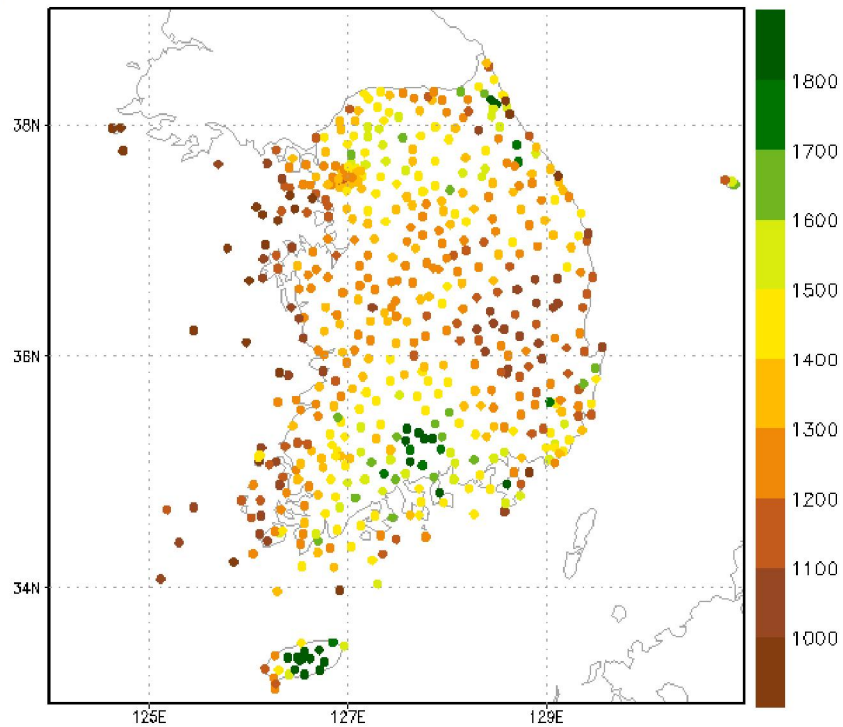
2000년대 일최저기온 (8월)



# Observation (12km) vs PRISM (1km)

PRCP

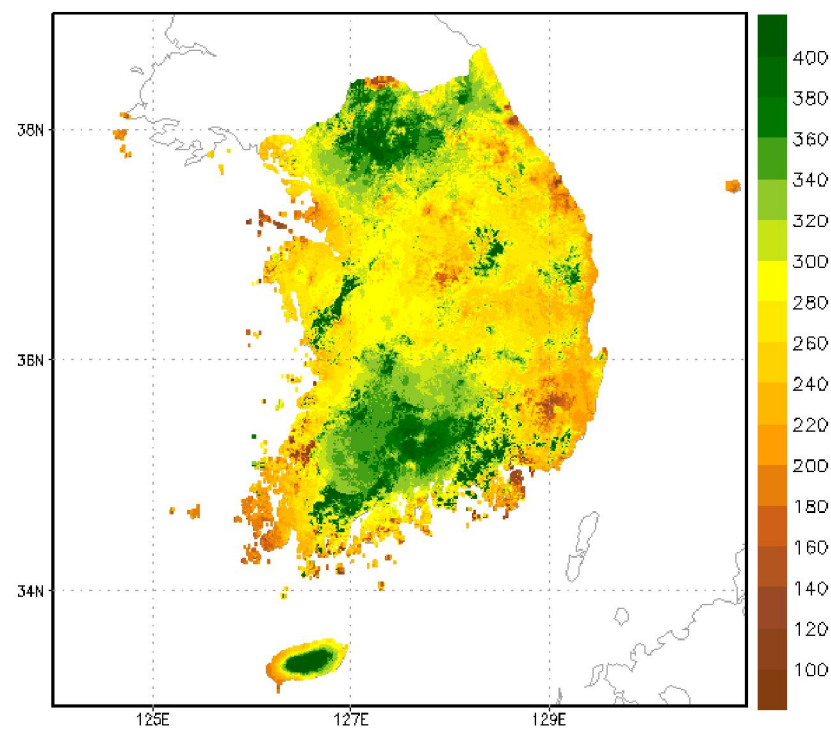
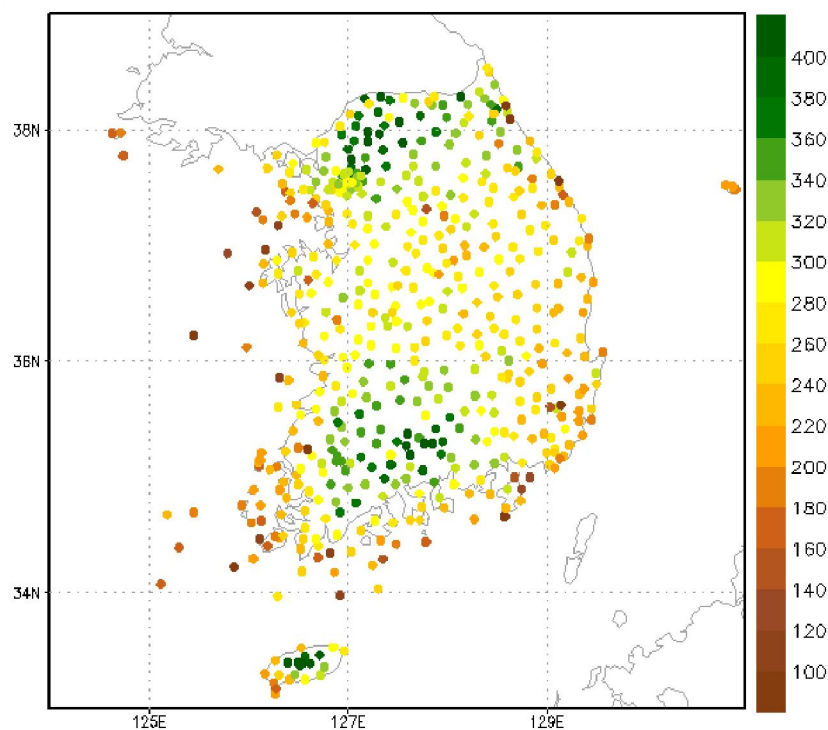
2000년대 연강수량



# Observation (12km) vs PRISM (1km)

PRCP

2000년대 월강수량 (8월)



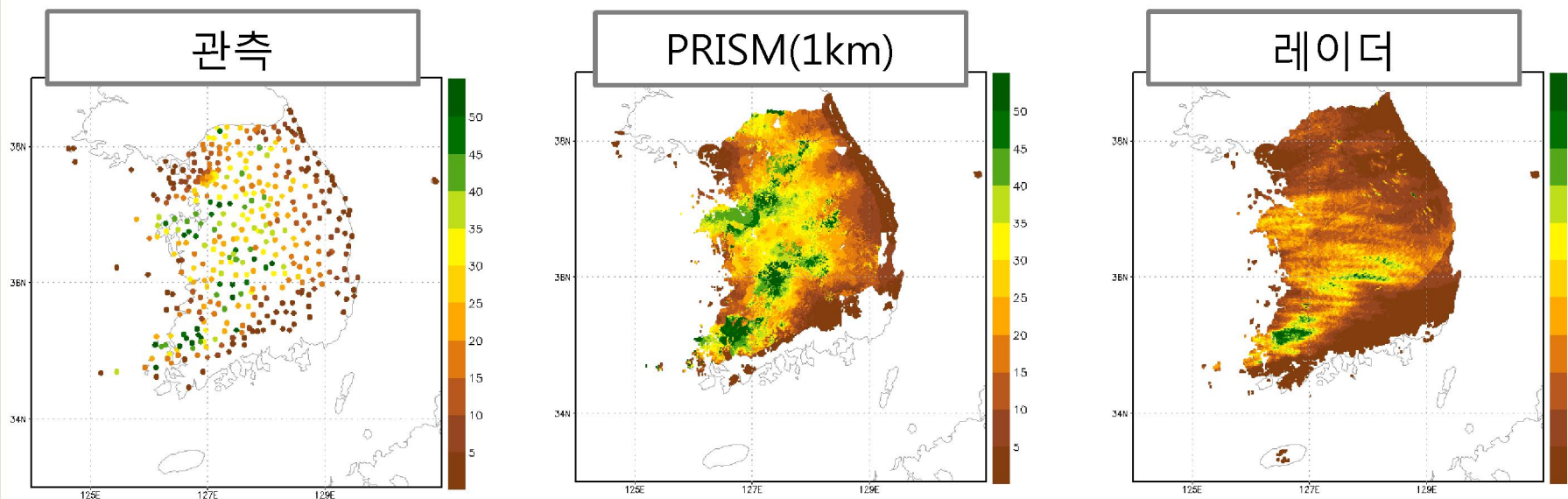


# 격자 자료의 검증

## 격자점 검증

	T_mean. (°C)		T_max. (°C)		T_min. (°C)		Prcp. (mm/day)	
	Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE
JAN.	0.00	0.37	0.02	0.46	-0.03	0.53	0.07	0.63
FEB.	0.00	0.36	0.01	0.46	-0.03	0.52	0.03	0.68
MAR.	0.00	0.36	0.01	0.47	-0.02	0.51	0.05	0.67
APR.	0.00	0.34	0.01	0.48	-0.03	0.53	0.01	1.05
MAY.	0.00	0.33	0.00	0.50	-0.03	0.50	0.07	1.35
JUN.	0.00	0.34	0.01	0.51	-0.02	0.48	0.05	1.65
JUL.	0.02	0.34	0.02	0.51	0.01	0.45	0.06	2.55
AUG.	0.01	0.35	0.32	2.16	0.00	0.48	0.09	2.65
SEP.	0.00	0.35	0.02	0.47	-0.02	0.49	0.09	1.88
OCT.	0.00	0.35	0.02	0.44	-0.03	0.55	0.06	1.02
NOV.	0.00	0.36	0.02	0.43	-0.02	0.55	0.03	0.66
DEC.	0.00	0.37	0.02	0.45	-0.03	0.54	0.04	0.48
AVE.	0.00	0.35	0.04	0.61	-0.02	0.51	0.05	1.27

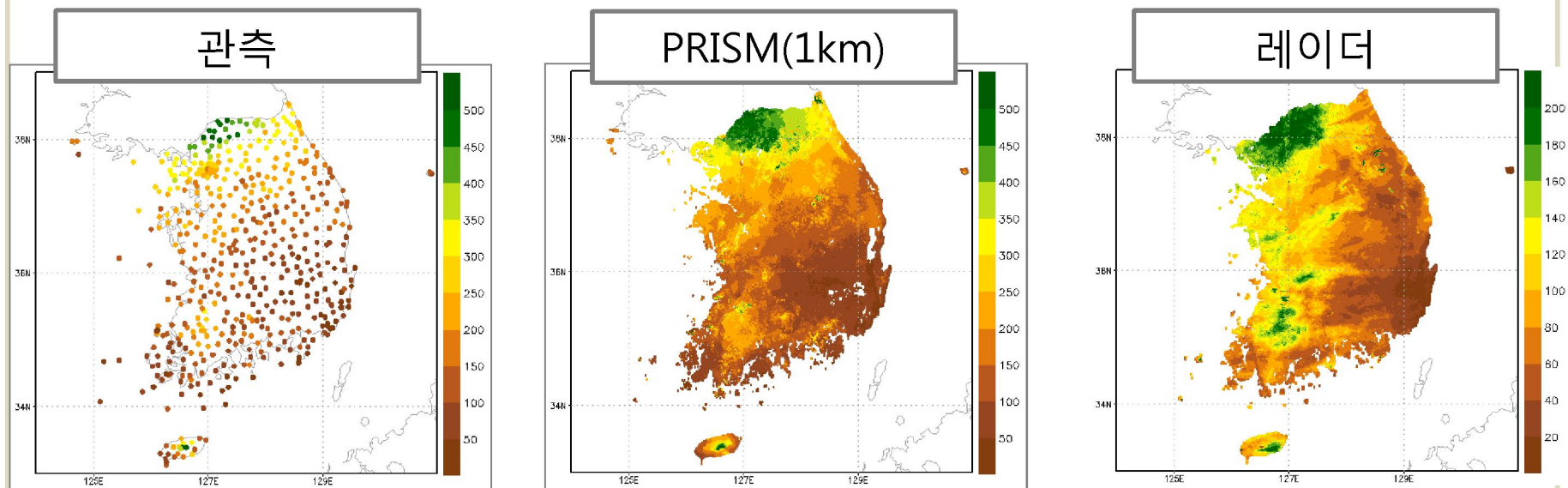
## 격자 자료의 검증 (Radar & PRISM)



	관측	PRISM	레이더
공간평균 (mm/day)	15.7	18.0	11.6

일 강수량의 사례 (2009년 8월 20일)

# 격자 자료의 검증 (Radar & PRISM)

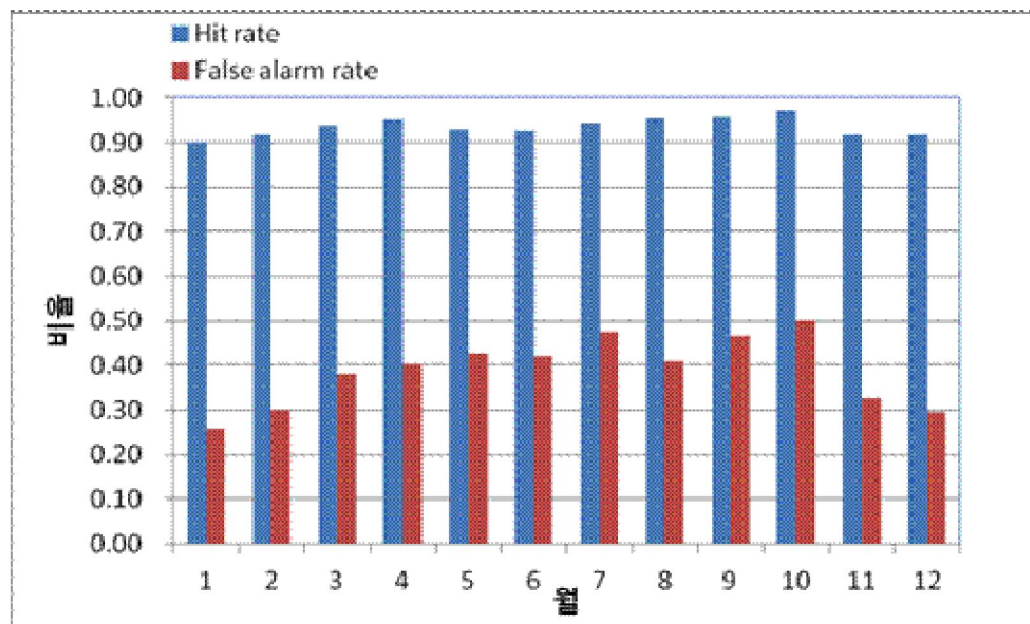


	관측	PRISM	레이더
공간평균 (mm/month)	174.1	178.7	90.4

일 강수량의 사례 (2009년 08월)

# 격자 자료의 검증 (Radar)

## 강수영역 성능검증



H. R. = 레이더 강수(O) / 관측에서 강수(O)  
 F. A. R. = 레이더 강수(O) / 관측에서 강수(X)

## 격자점 검증

	mm/day	
	Bias	RMSE
JAN	-4.54	3.75
FEB	-3.79	3.46
MAR	-2.51	4.04
APR	-1.44	3.27
MAY	-2.71	5.83
JUN	-0.96	5.96
JUL	-5.81	11.01
AUG	-4.21	8.98
SEP	-2.34	7.06
OCT	-1.64	4.11
NOV	-2.29	3.84
DEC	-2.21	3.40
AVE.	-2.87	5.39

# **PRISM 산출 결과 비교**

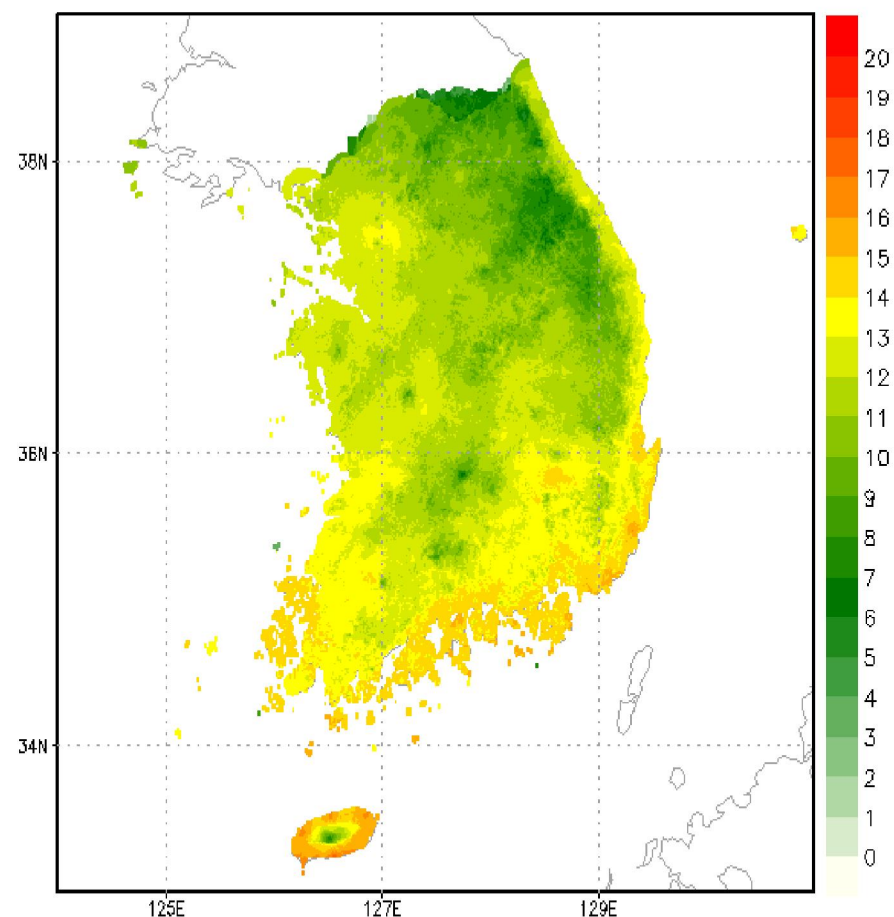
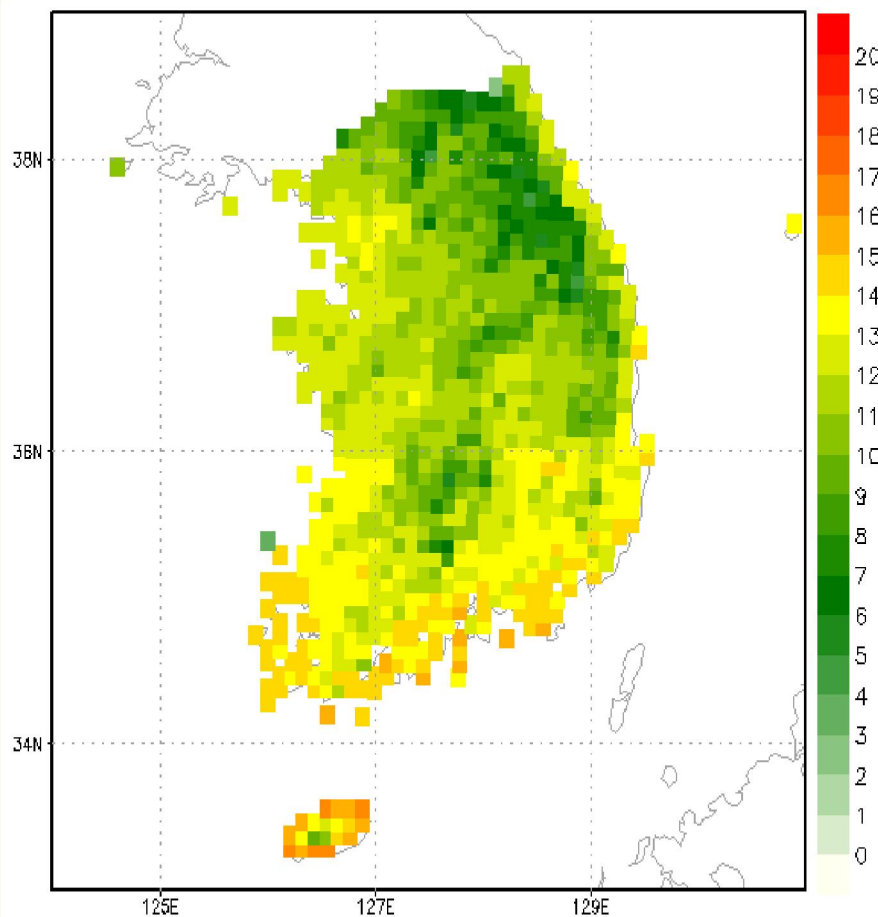
## **10KM vs 1KM**



10km 해상도

일 평균기온

1 km 해상도

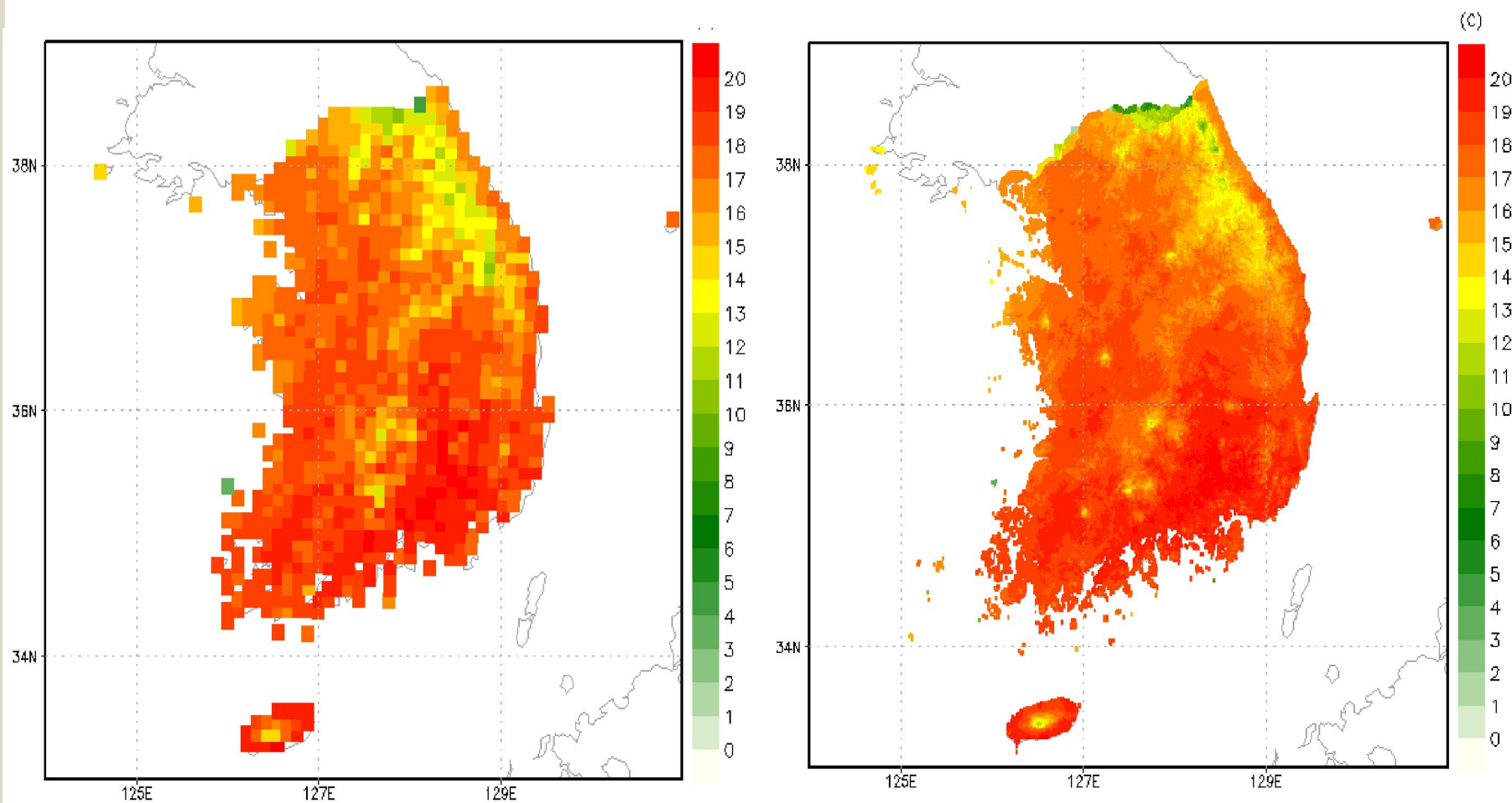


최근 10년 평균

10km 해상도

일 최고기온

1 km 해상도

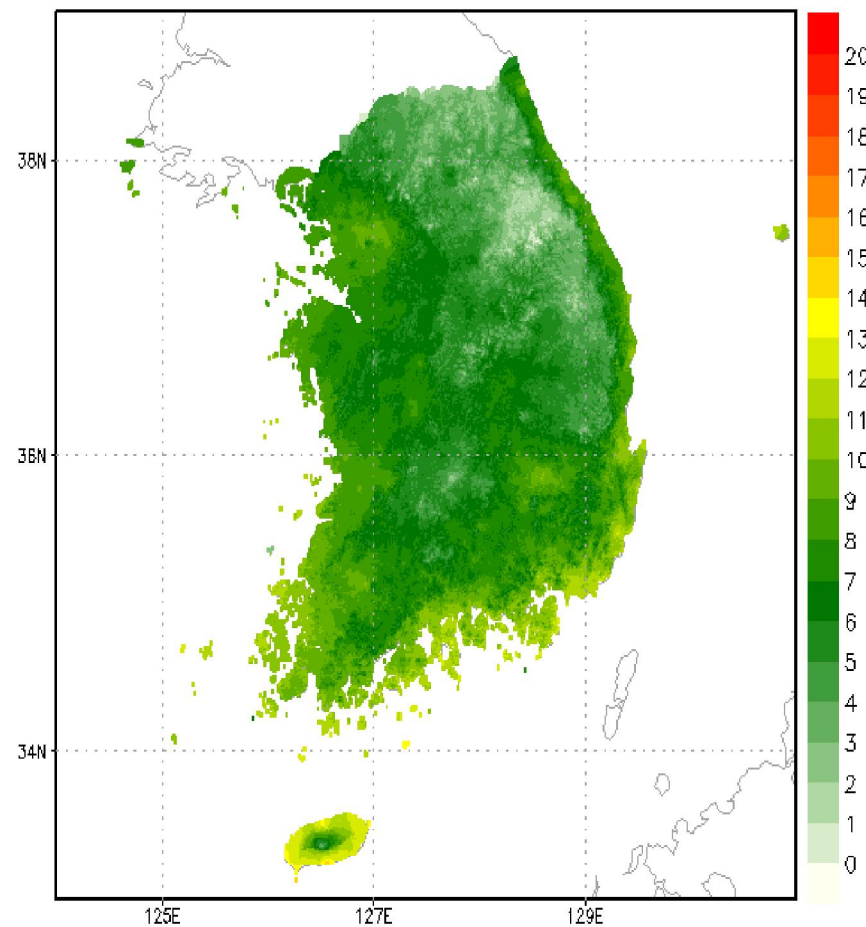
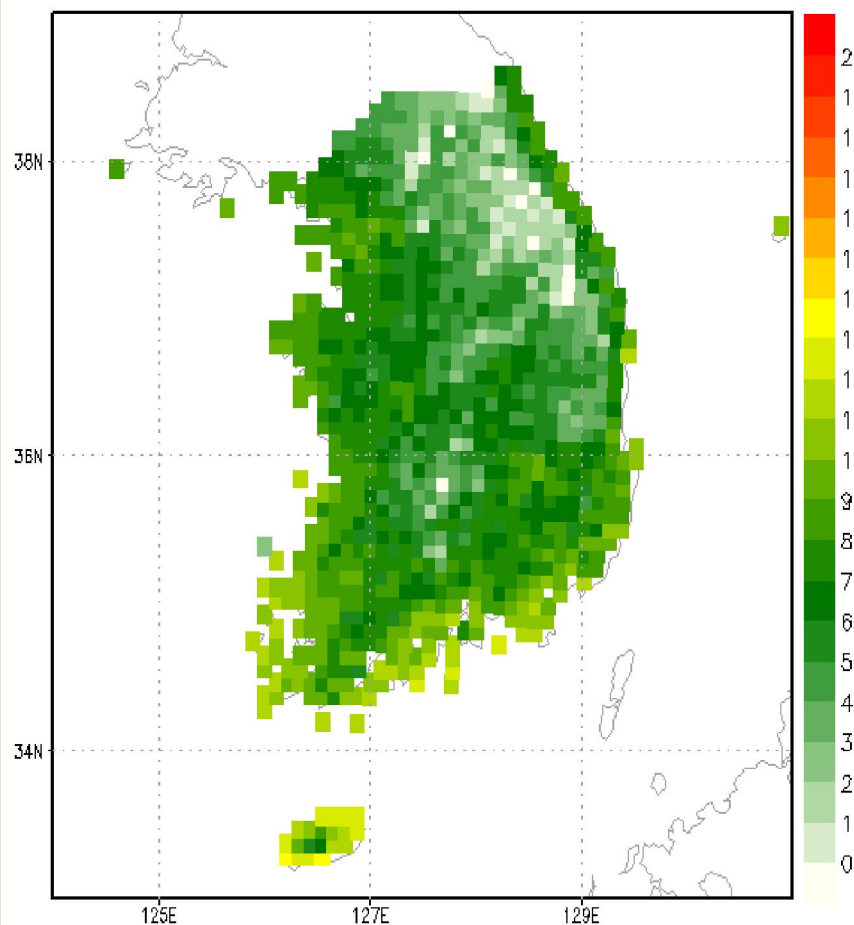


10년 평균

10km 해상도

일 최저기온

1 km 해상도



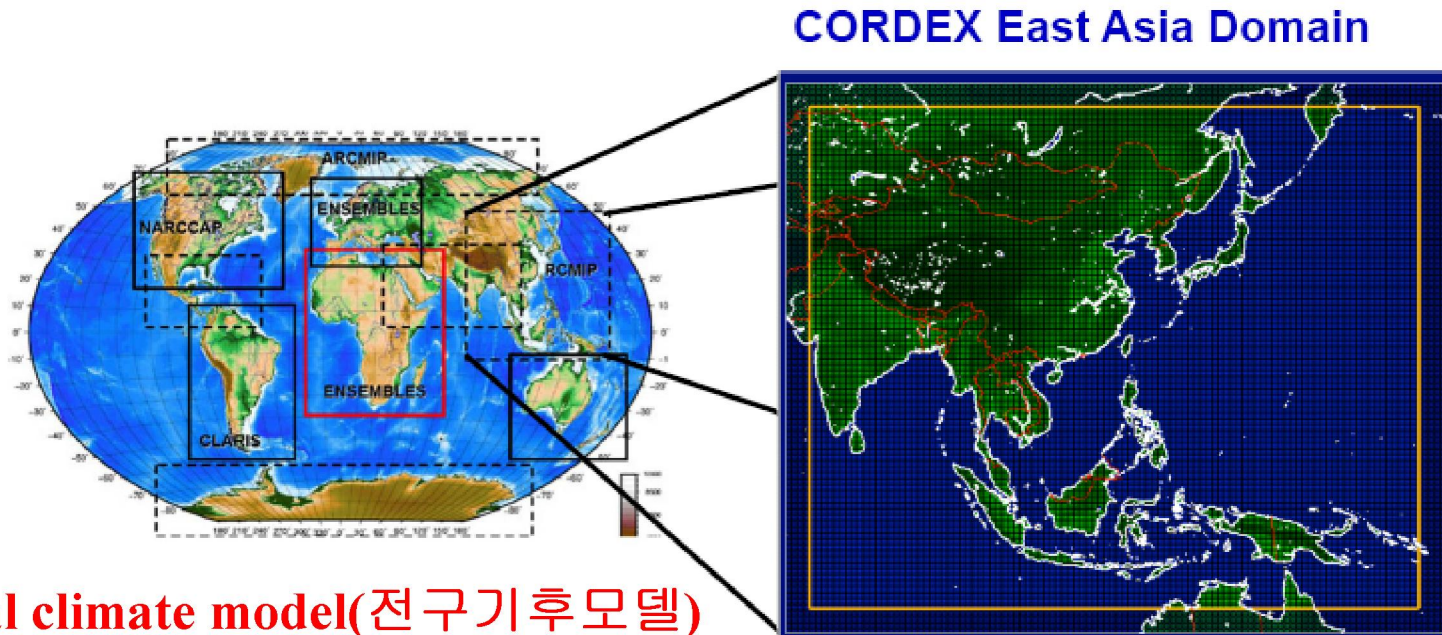
10년 평균

The slide features a white background with a blue header bar at the top and a green footer bar at the bottom. The text "PRIDE MODEL SCENARIO" is centered in a large, bold, black font, and "1KM" is centered below it in a slightly smaller, bold, black font.

# **PRIDE MODEL SCENARIO**

## **1KM**

## 국가 표준 기후변화 시나리오 개발을 위한 체계도 (기상청)



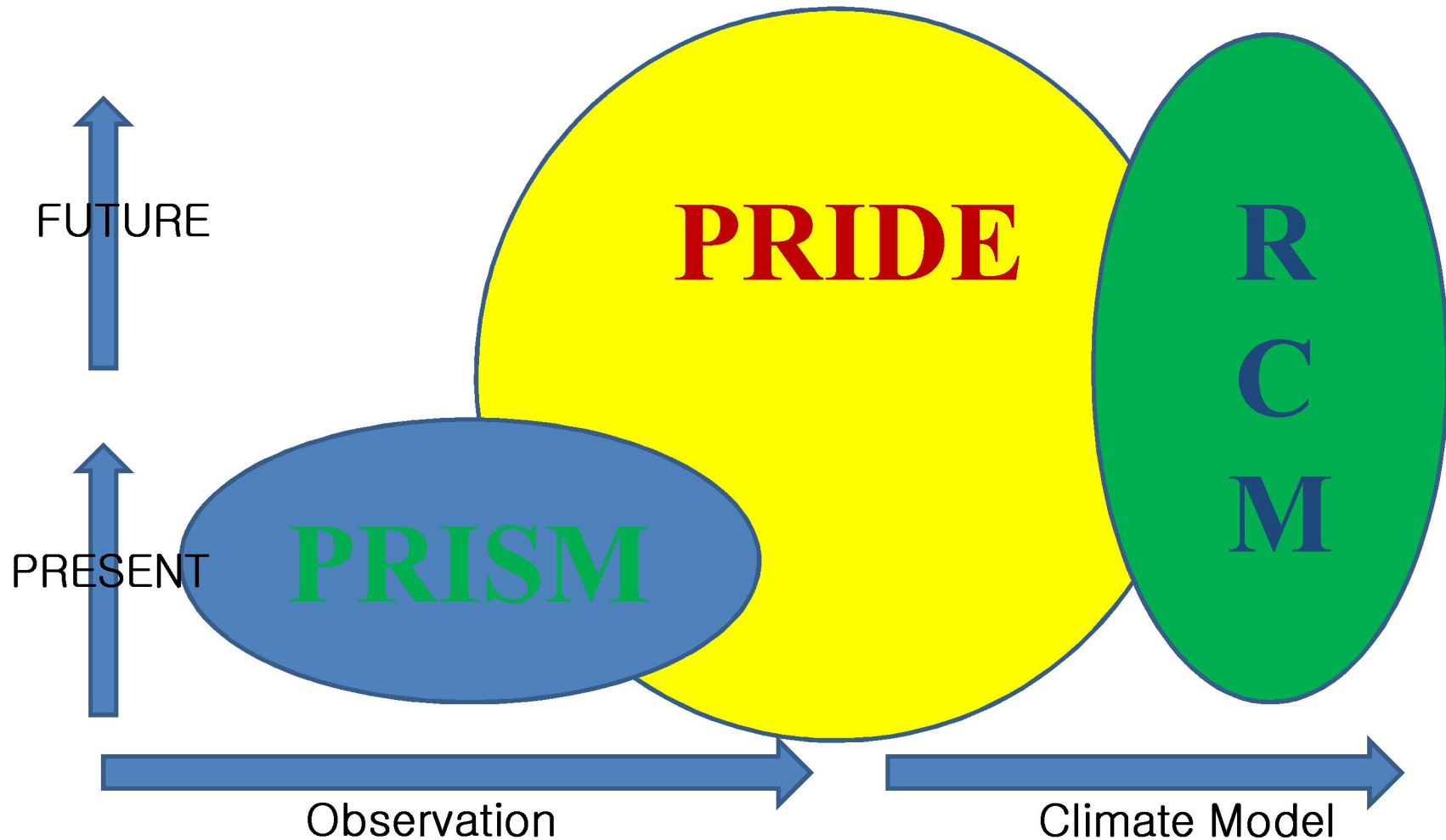
**Global climate model(전구기후모델)**  
**135km, 60km**

**RCM (지역기후모델)**  
**Asia 50km, Korea 12.5km**

**PRIDE Model (PRISM based Downscaling Estimation Model)**  
**(Korea 1km grid data)**

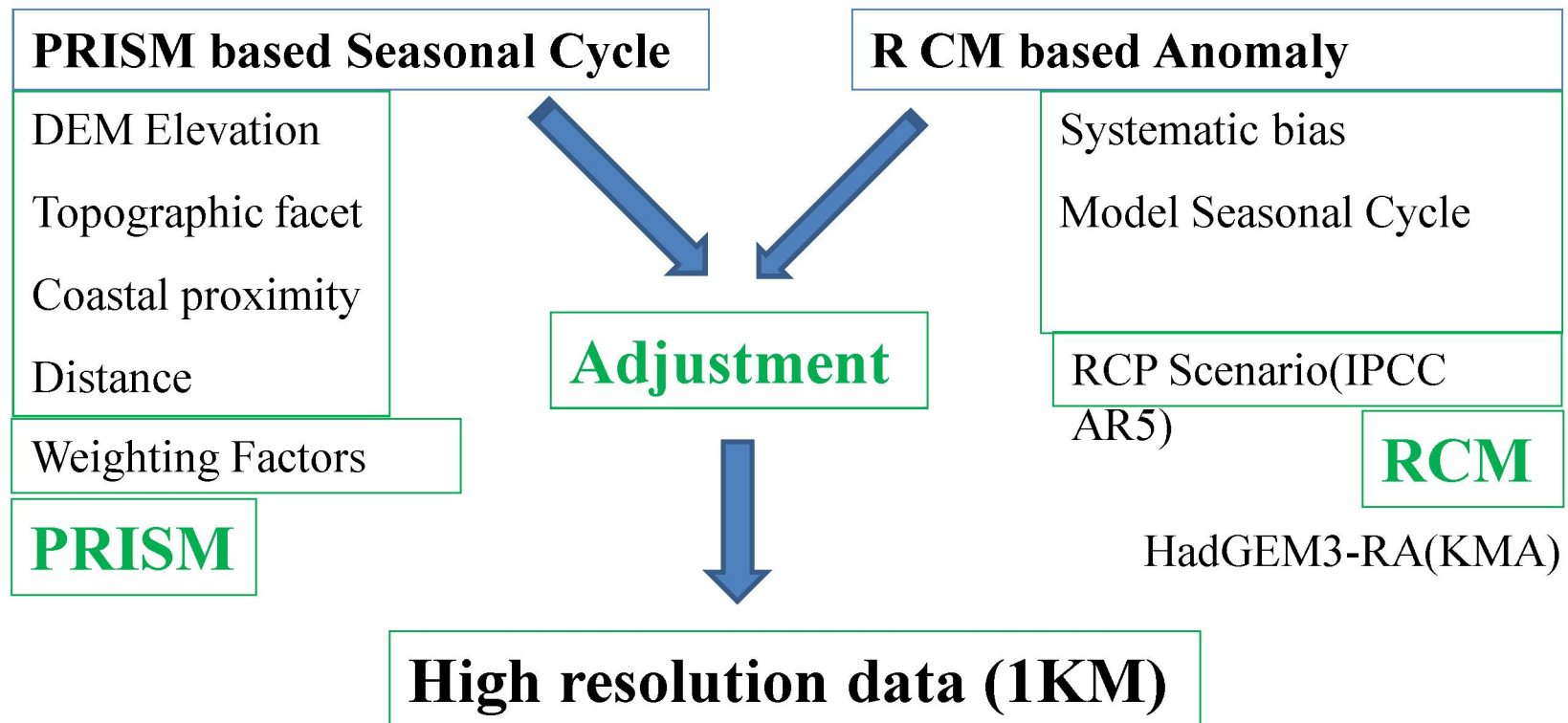


# PRIDE MODEL



**Schematic Diagram of PRIDE MODEL**

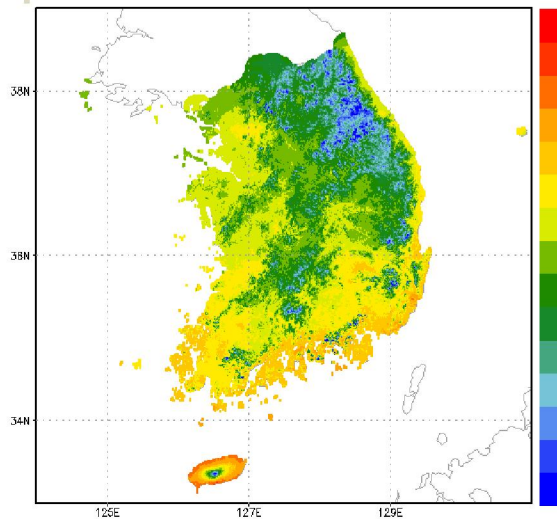
### PRISM based Downscaling Estimation Model



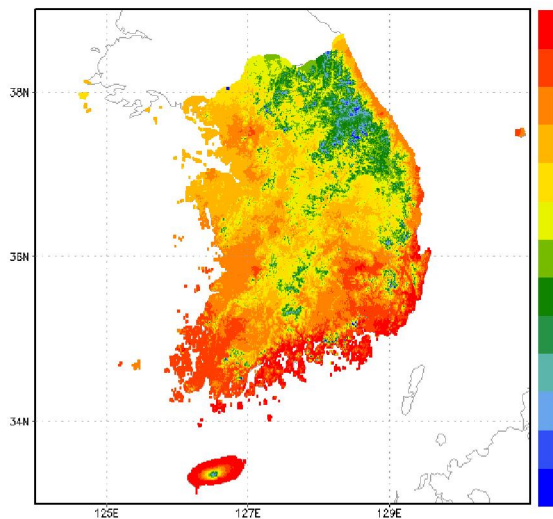
# 한반도 온난화 (Tmean)

PRIDE MODEL

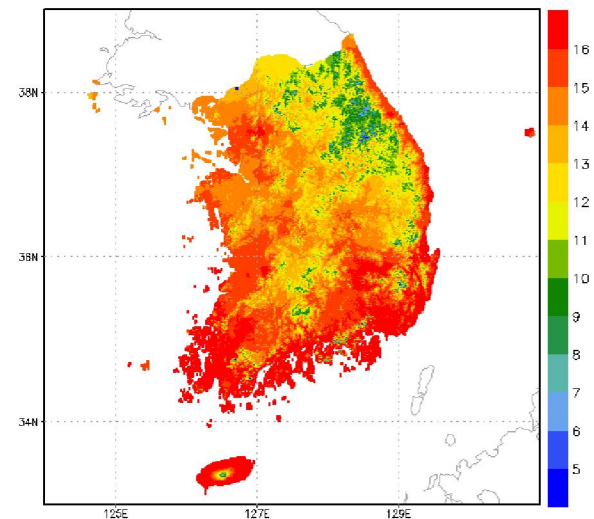
2000년대



2030년대



2050년대

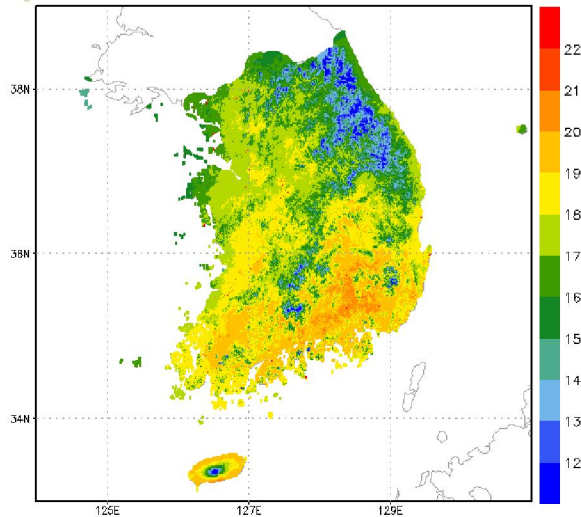


- ▷ 폭염 빈발 가능성이 높아진다.
- ▷ 말라리아 등의 질병 빈도가 증가할 수 있다.
- ▷ 물부족, 전력수요 급증에 따른 위험 가중될 수 있다.

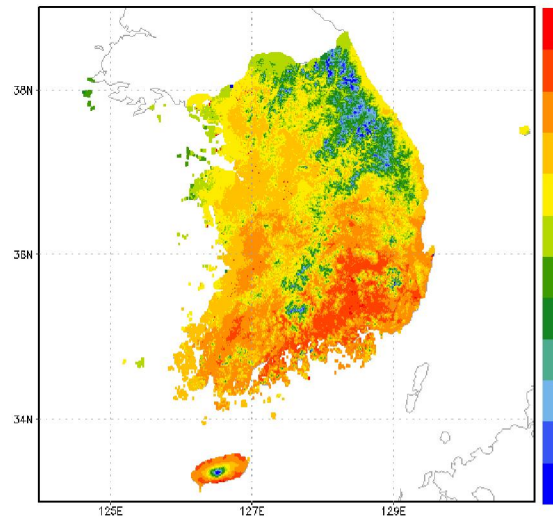
# 한반도 온난화 (Tmax)

## PRIDE MODEL

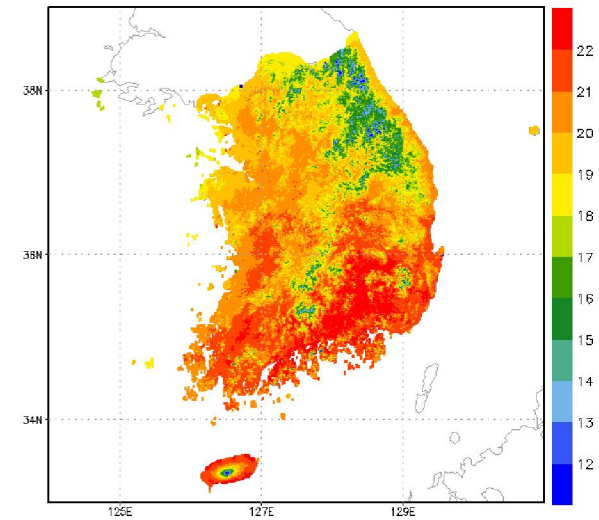
2000년대



2030년대



2050년대

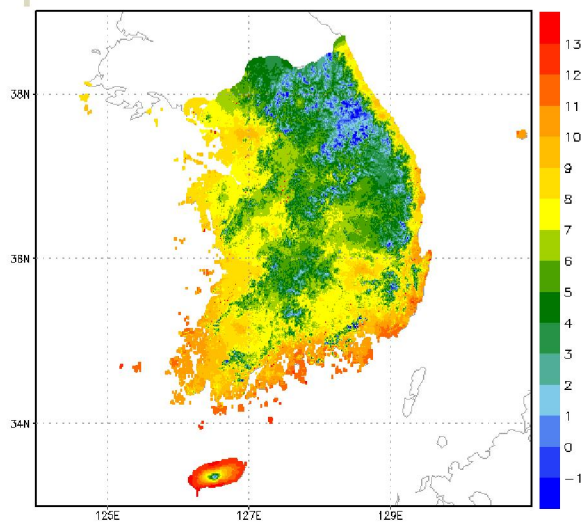


1. 폭염 빈발 가능성이 높아진다.
2. 말라리아 등의 질병 빈도가 증가할 수 있다.
3. 물부족, 전력수요 급증에 따른 위험이 가중될 수 있다.

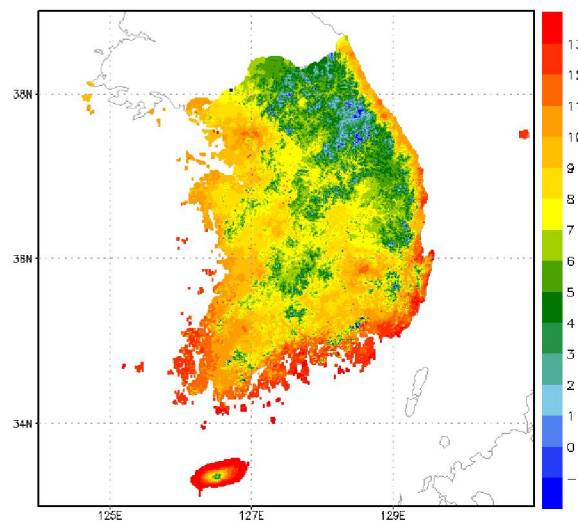
# 한반도 온난화 (Tmin)

PRIDE MODEL

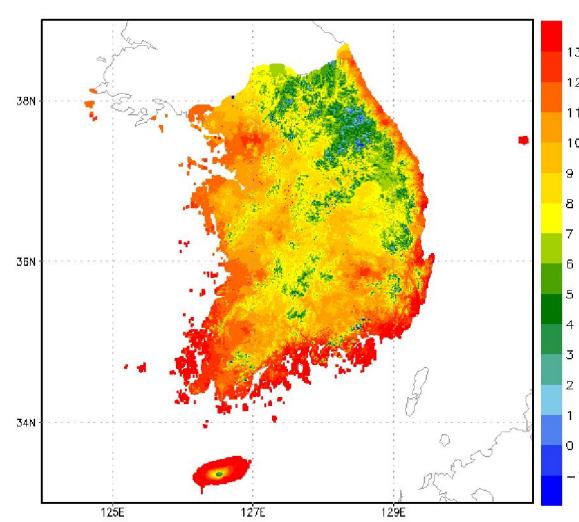
2000년대



2030년대



2050년대



▷ 열대야 발생 빈도 가능성이 높아진다.

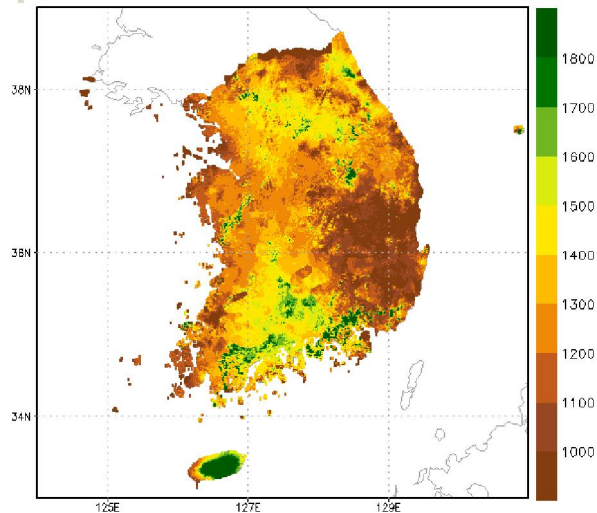
▷ 전력수요 급증에 따른 위험이 가중될 수 있다.



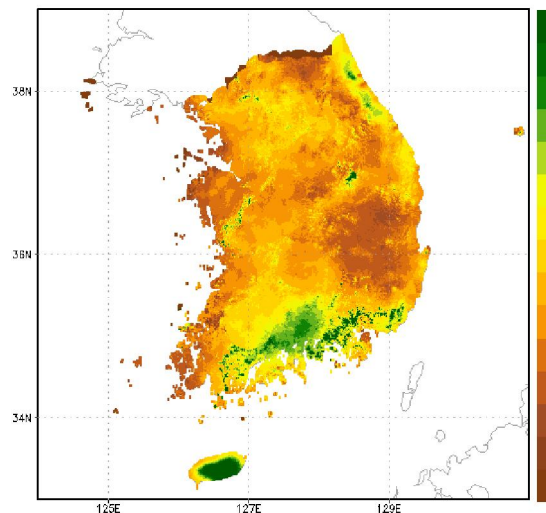
# 한반도 강수량 (PRCP)

## PRIDE MODEL

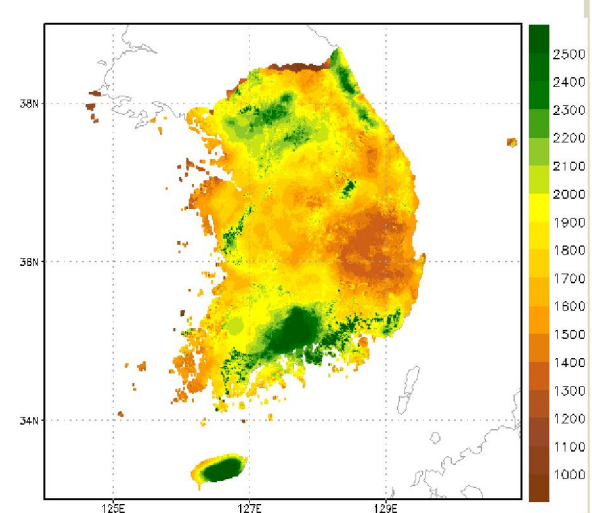
2000년대



2030년대



2050년대



▷ 집중호우 빈발 가능성이 높아진다.

▷ 홍수피해 가능성이 높아질 수 있다.

▷ 대형 재난으로 인명 및 경제적 손실 가능성 증가한다.

# 향후 계획

1. 관측 격자 자료 생산 (PRISM 기반)  
PRISM에 기반하여 고해상도 격자자료 생산기술확보  
1km 해상도 격자자료 생산 완료 예정
2. 기후변화 시나리오 격자자료 생산 (PRIDE MODEL 기반)  
PRIDE MODEL에 기초한 고해상도 격자자료 생산기술확보  
1km 해상도 격자자료 생산 완료 예정 (AR5 RCP 8.5 기반)
3. 극한지수 시나리오 격자자료 생산 예정  
폭염, 열대야 등 기온관련 극한지수  
호우 등 강수량관련 극한지수
4. 기후변화 시나리오 자료 제공  
기상청 기후변화정보센터(CCIC) 홈페이지([www.climate.go.kr](http://www.climate.go.kr))

**고맙습니다**



## 태국 홍수 (2011년 11월 7일~ 방콕)



KBS

피해규모(11월 8일 기준)

사망자: 507명

이재민 3백만명

피해액: 18조원

11월부터 건기  
2011.4~10: 2000mm  
(기후평균 연강수량 :1400mm)

