Application of Seasonal Forecast for Electric Power Companies

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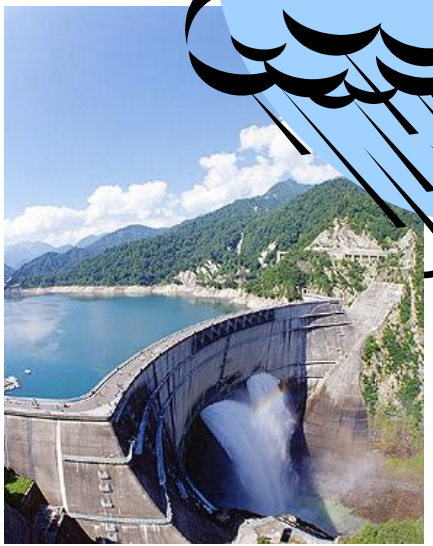
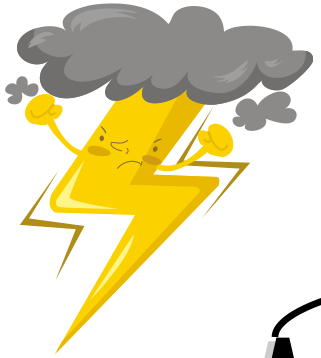
CRIEPI Central Research Institute of Electric Power Industry

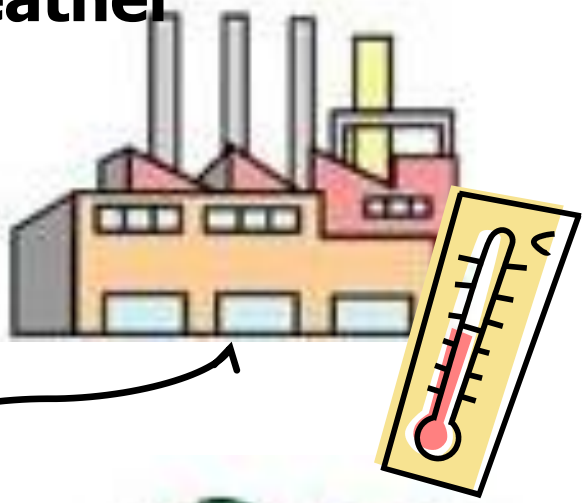
Introduction

Relationship between Electricity and Weather

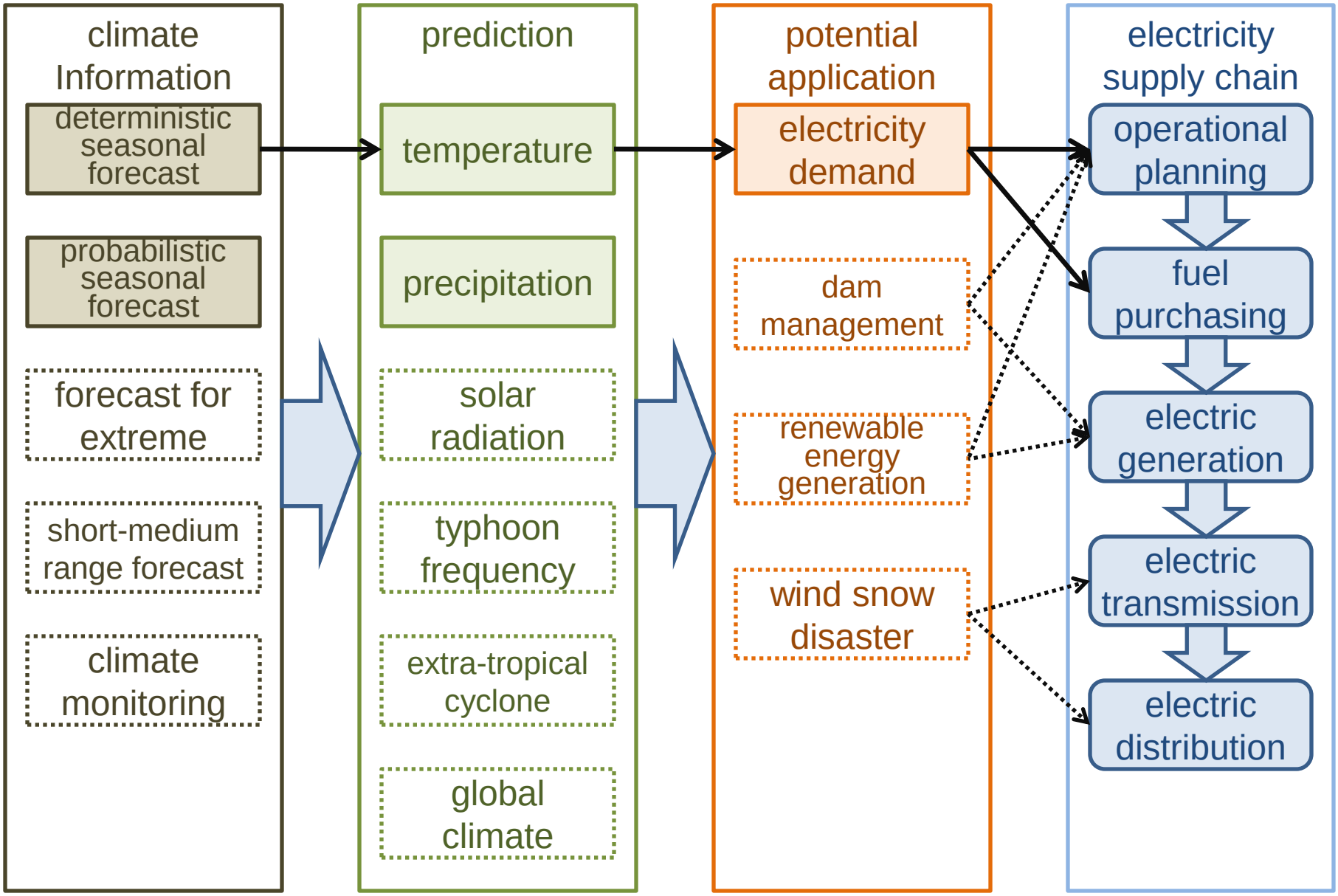
relationship between electricity and weather







Introduction
Climate information for electric power companies

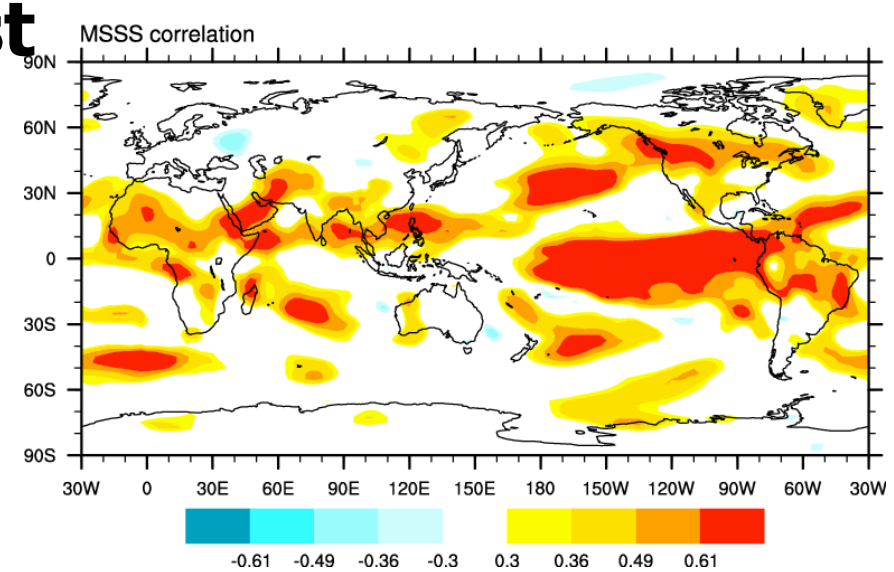


Seasonal Forecast
using APCC Downscaled Forecast

General seasonal forecast

- Low skill of seasonal forecast in mid-latitude
- Low-resolution of seasonal forecast based on numerical model

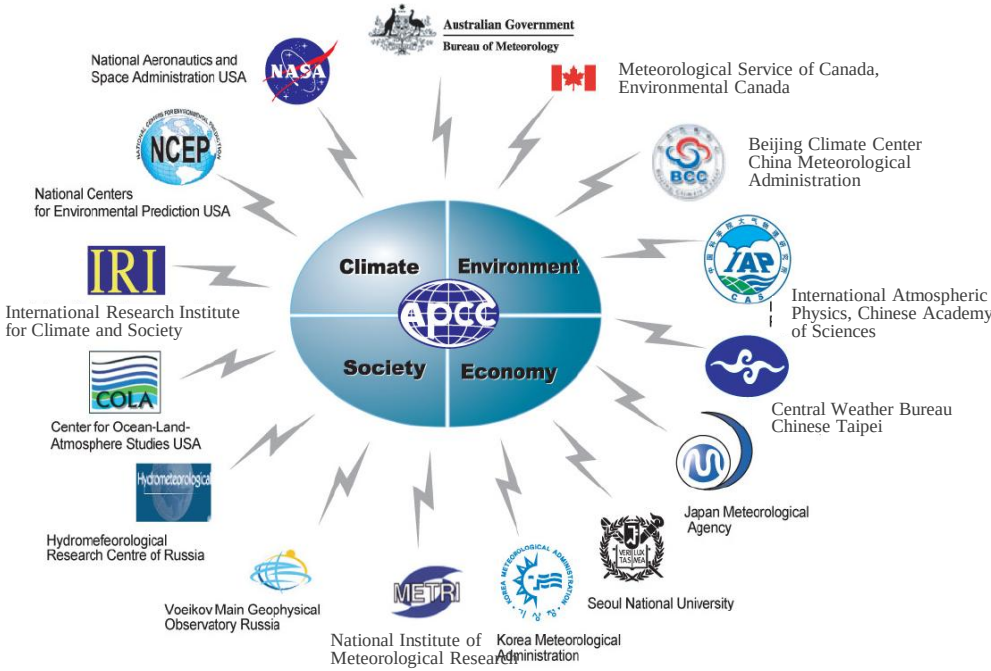
➔ Difficulties to develop applications using the seasonal forecast



Anomaly correlation of hindcast

Features of APCC seasonal forecast

- Multi-model ensemble
- Statistical downscaling



Objectives

- Development of seasonal forecast using statistical downscaling with multi-model ensemble for Japan
- Optimization of downscaled forecast using multi-model ensemble to improve the forecast skill
- Application of the seasonal forecast: electricity demand

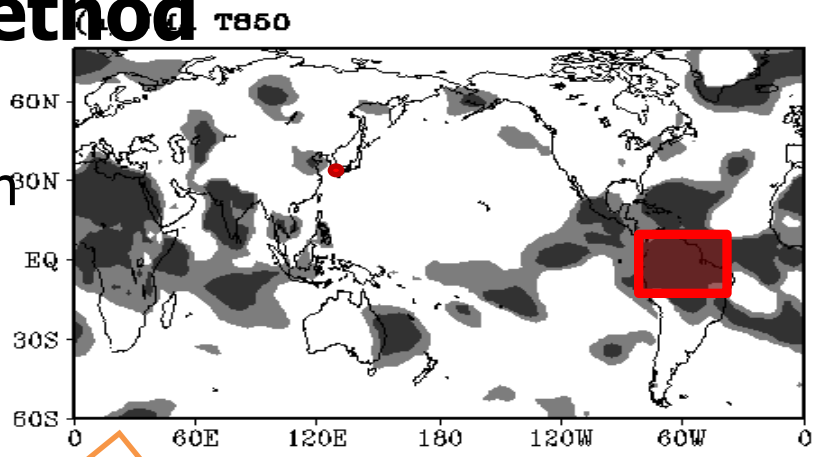
Model and Data

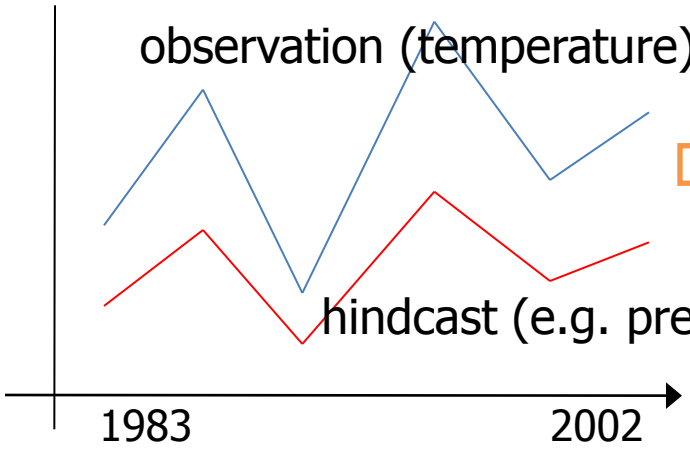
- monthly mean temperature observed by AMeDAS
  - 500 stations
- APCC 3-month forecast using multi-model ensemble (7 models) provided by CWB(Chinese Taipei), MSC(Canada, 4 models), POAMA(Australia), NCEP(USA)
- Hindcast period: 1983-2002
- Total sale of electricity of Tokyo Electric Power Company (TEPCO)

Statistical Downscaling Method

step 1: to search coupled pattern between historical observation and hindcast

step 2: to estimate regression coefficient for downscaling





$$y = a + b\,x$$

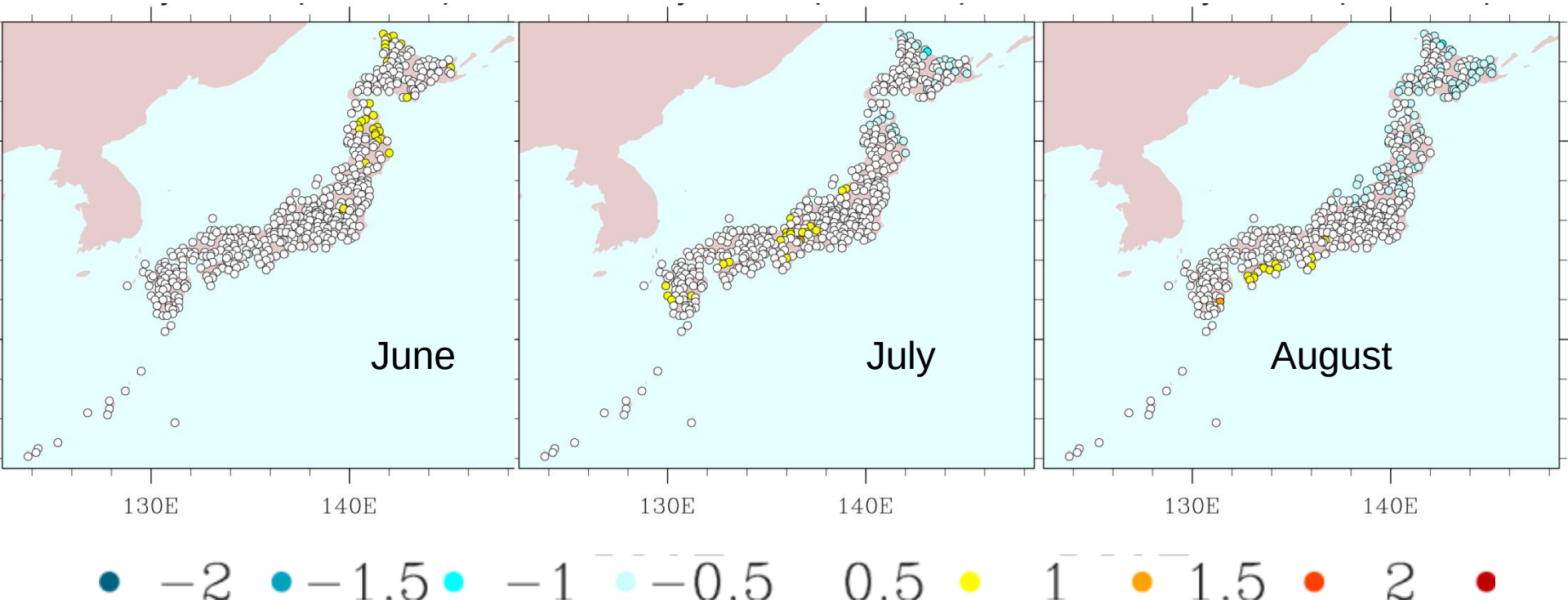
fcst	predictor
y_1	temperature
y_2	U wind
y_3	V wind
	:
y_i	pressure

predictor selection

step 3: to predict seasonal climate in each predictor

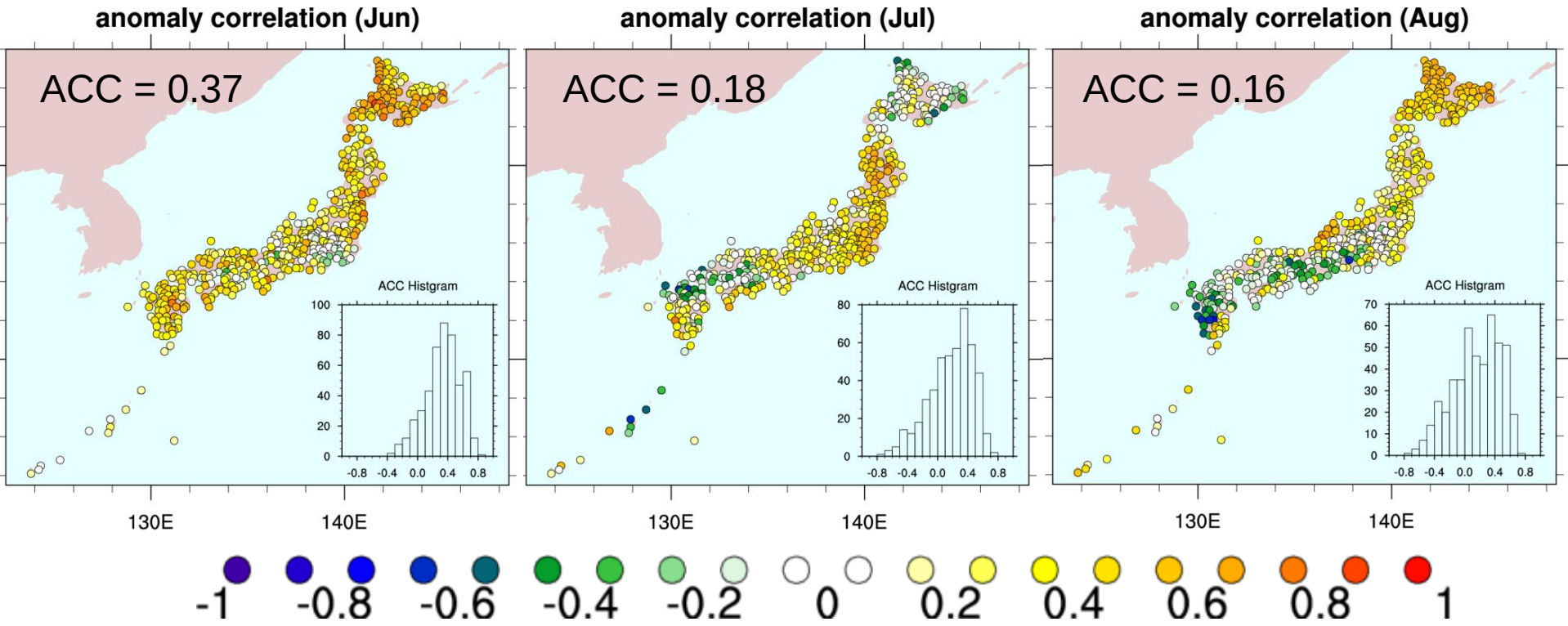
step 4: to select the best predictor based on cross-validation

APCC seasonal forecast based on statistical downscaling (2010 JJA)



APCC downscaled forecast can provide high-resolution seasonal forecast. The forecast predicts cold summer in northern and eastern Japan, and hot summer in western Japan.

Verification by anomaly correlation



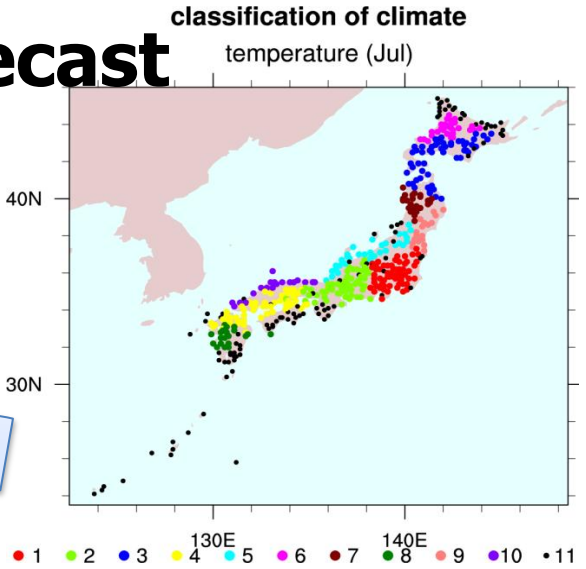
large variability of skill score even in similar climatology

➔ Unstable of the downscaled method

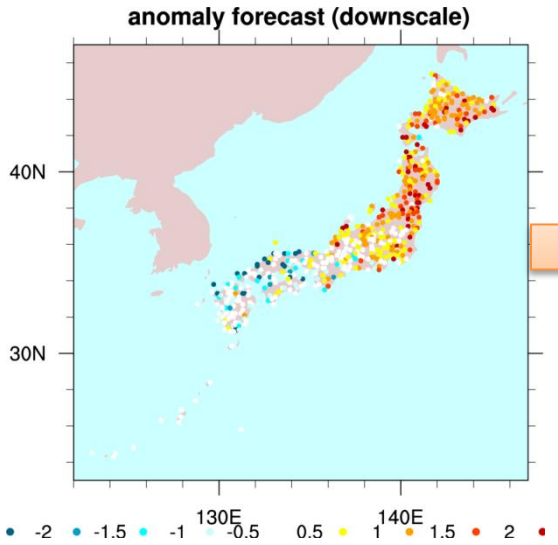
Is it possible to improve the forecast skill using averaging of forecast in similar climatology like ensemble mean?

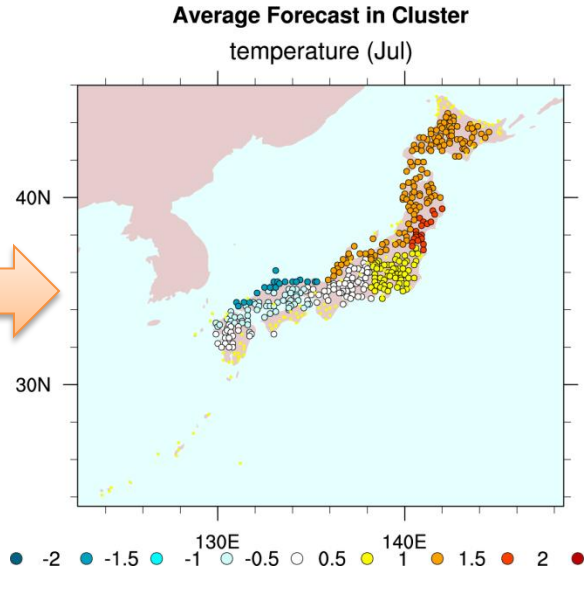
Optimization of downscaled forecast

1. Classification of climatology using cluster analysis
2. Average of forecast/hindcast in similar climatological stations
3. Verification of the forecasts



1) Classification





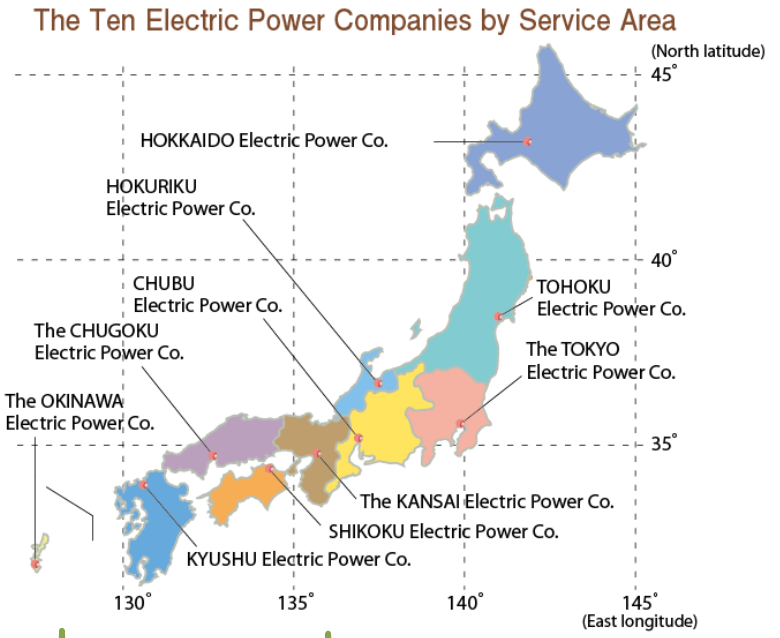
2) Regional average

3) Anomaly correlation

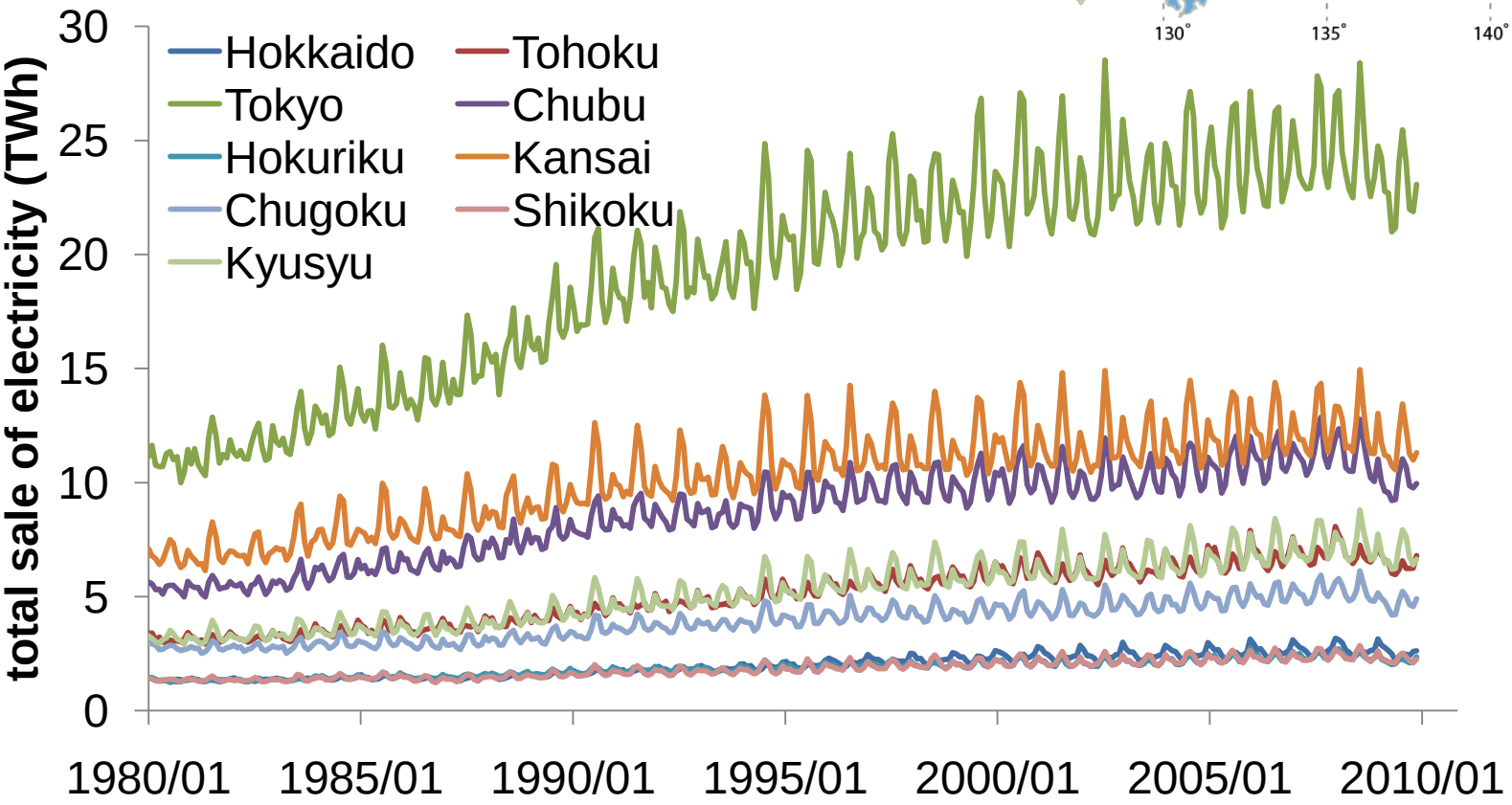
	regional average	individual
June	0.41	0.37
July	0.22	0.18
August	0.20	0.16
Average	0.28	0.24

Electricity Demand Prediction for Electric Power Companies

10 electricity companies in Japan



total sale of electricity



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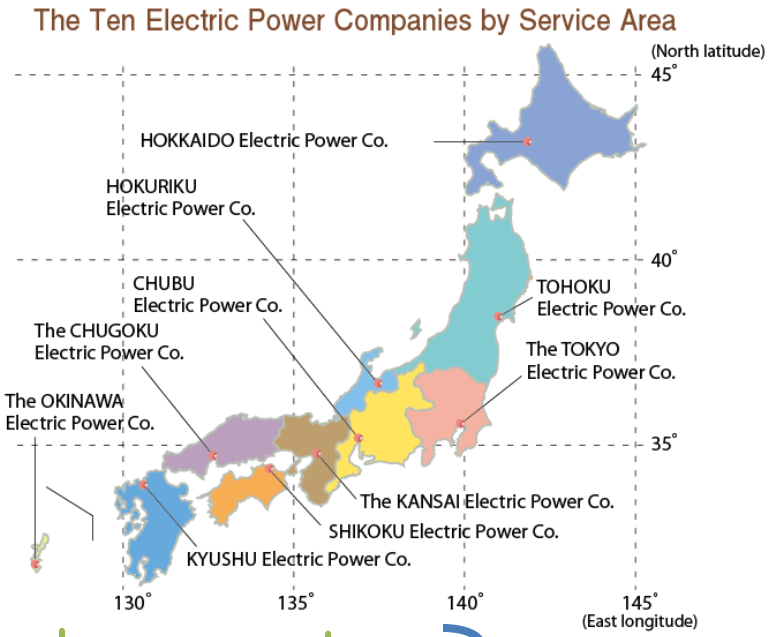

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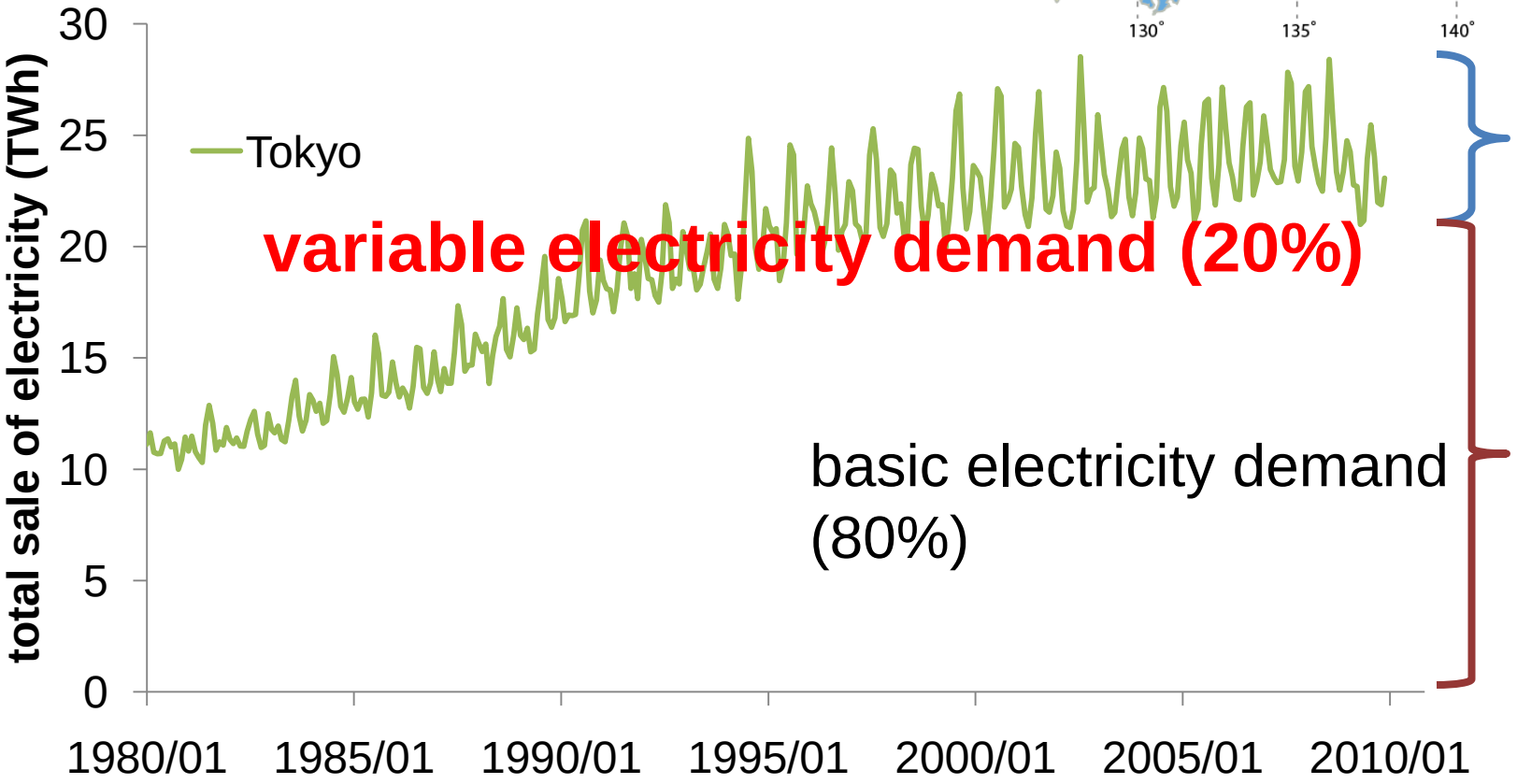
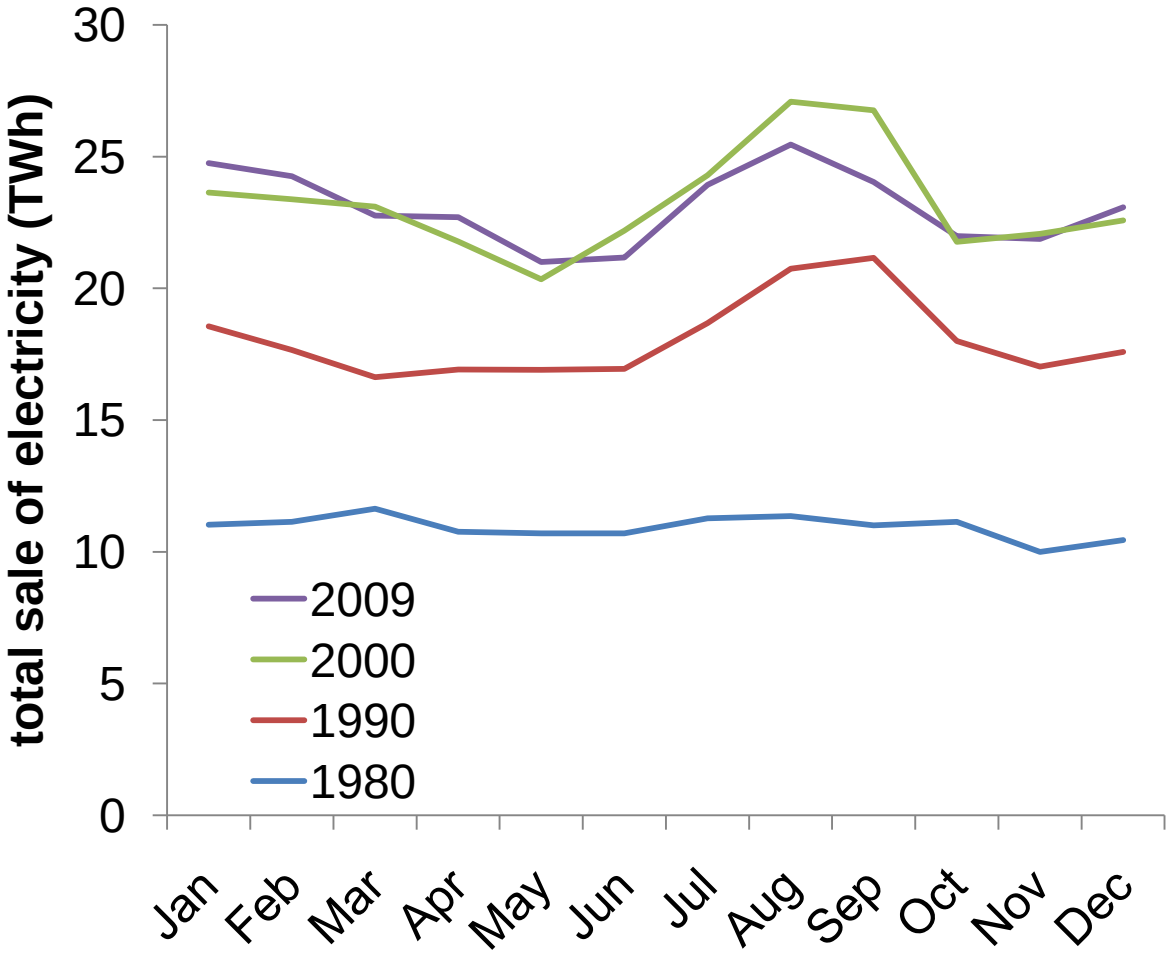


Seasonality of electricity demand



Total electricity sale at Tokyo area. Seasonal variability of electricity demand is increased in last 30 years due to popularization of air conditioner.

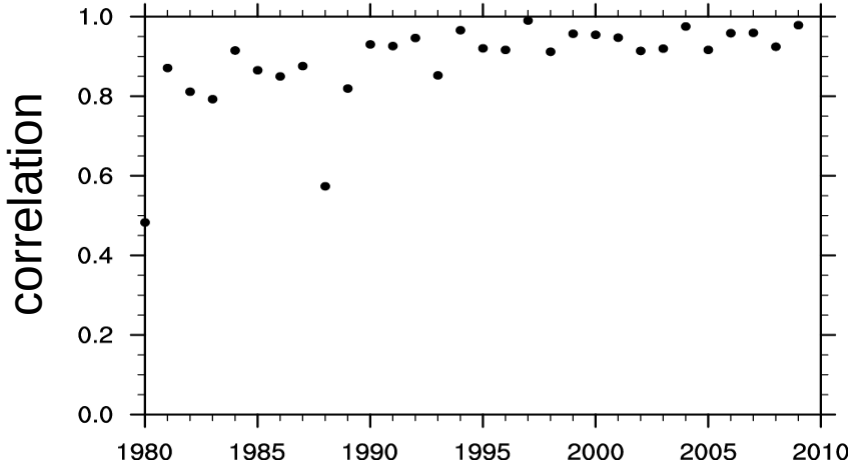
Electricity demand and Temperature

Parabolic relationship between electricity demand and monthly mean temperature

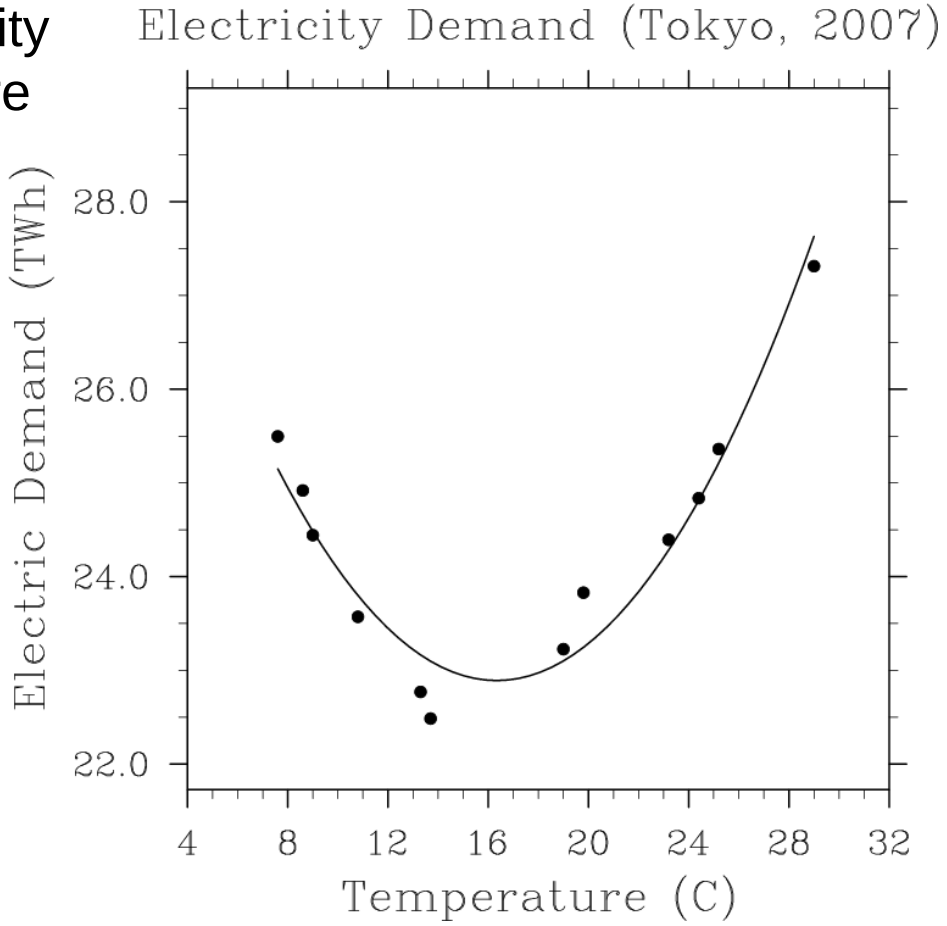
Parabolic relation hypothesis:

$$E = a (T - b)^2 + c$$

E: electricity demand
T: temperature
a: dependency
b: temperature on minimum electricity
c: minimum electricity demand



Time series of correlation of relationship between temperature and electricity demand with parabolic relation.

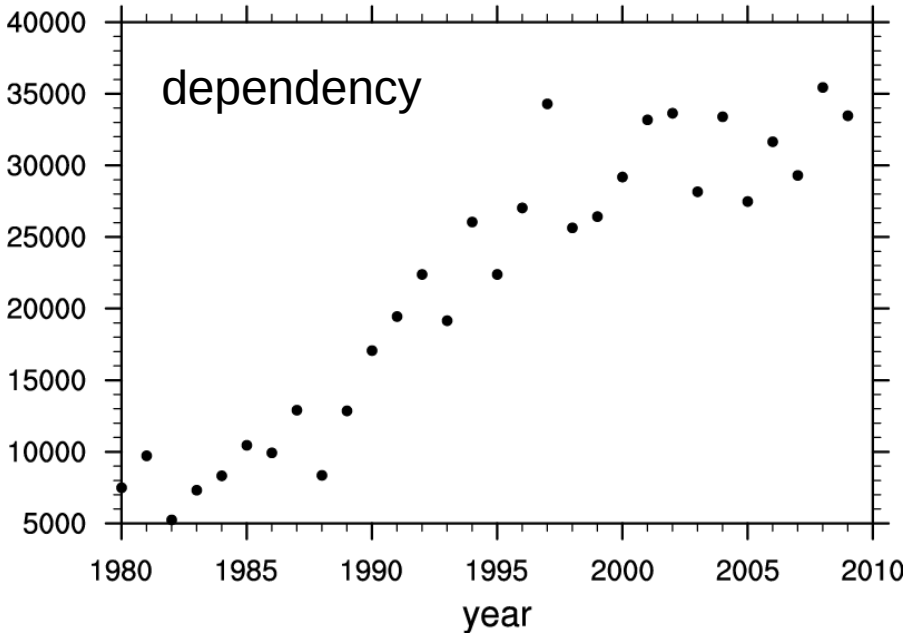


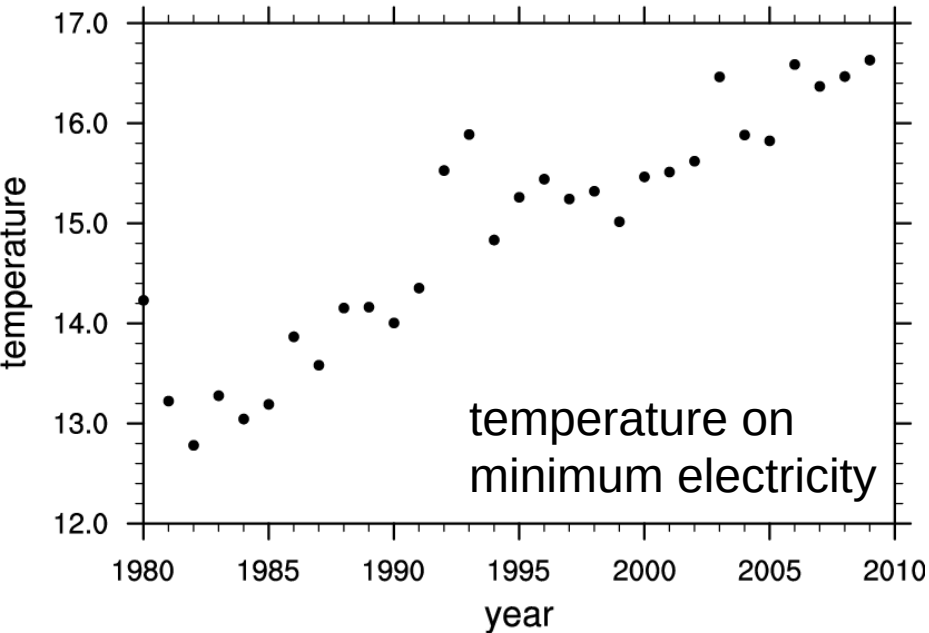
Relation between total electricity sale at TEPCO and temperature at Tokyo.

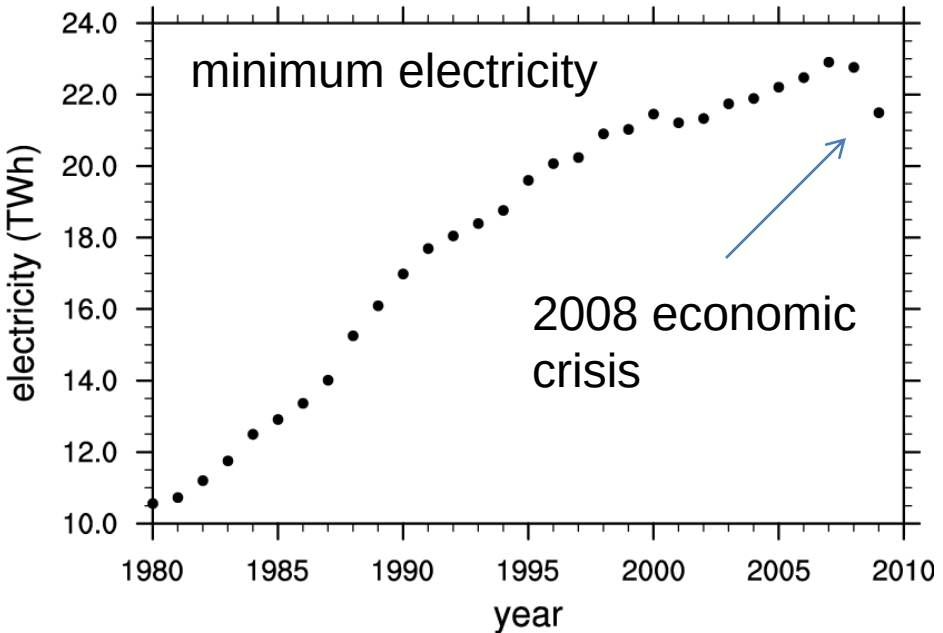
Electricity demand and Temperature

Parameter of parabolic function indicates,

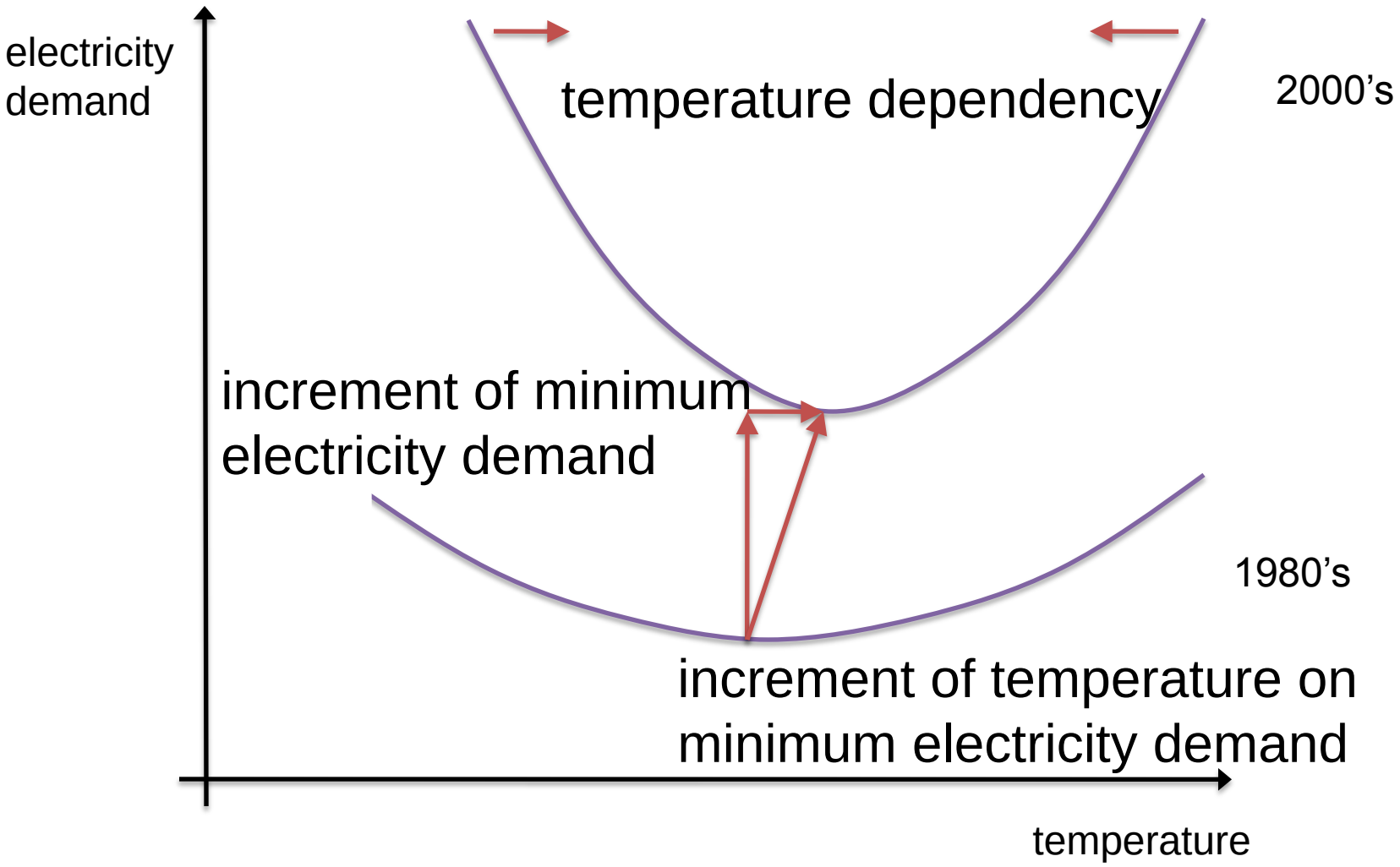
- increase of dependency of electricity demand on temperature
- increase of temperature on minimum electricity demand
  - for heating in winter
- increase of minimum electricity demand







Changing of relationship between temperature and electricity demand in last 30 years

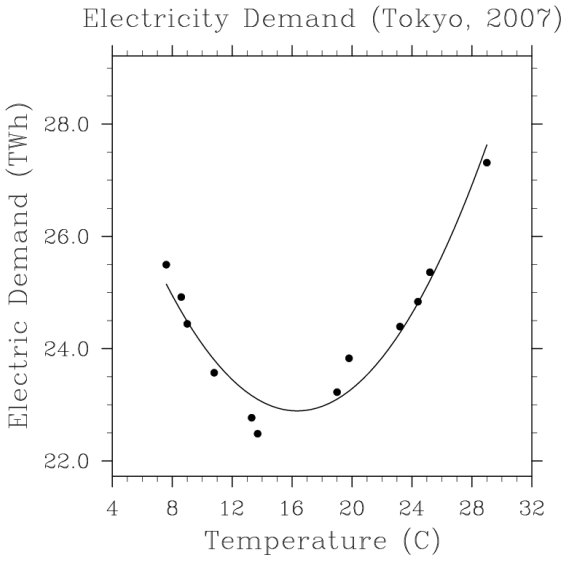


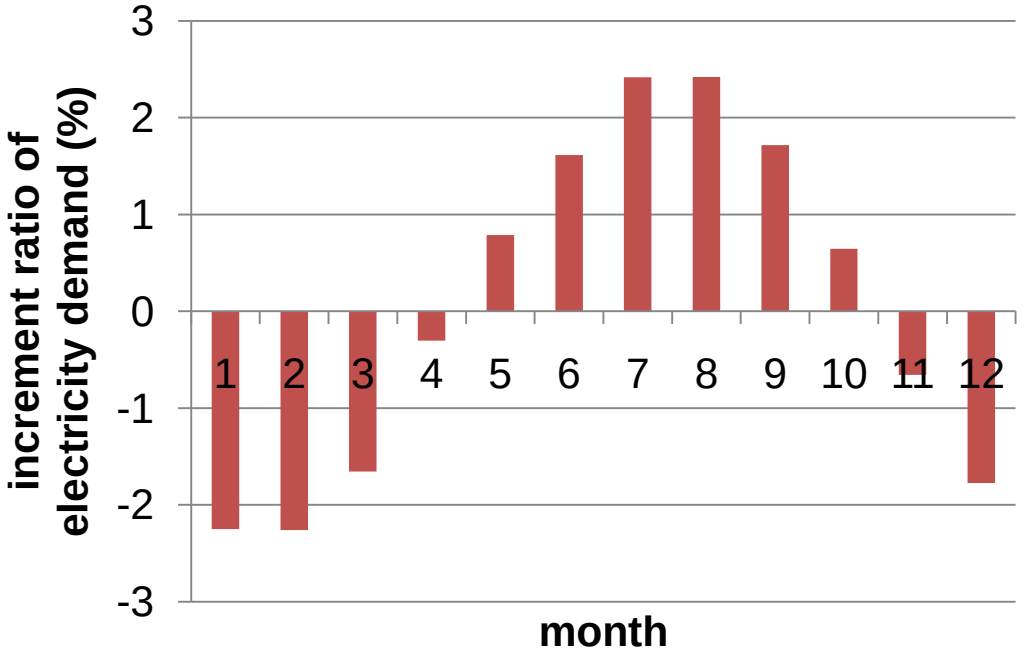
Electricity demand prediction

1. Electricity power companies prefer increment ratio of electricity demand over the precious year.

2. Increment ratio of electricity demand by 1C temperature increase is estimated by the parabolic approximation and climatological monthly mean temperature.

3. Based on temperature anomaly forecast provided by APCC, the electricity demand is predicted.

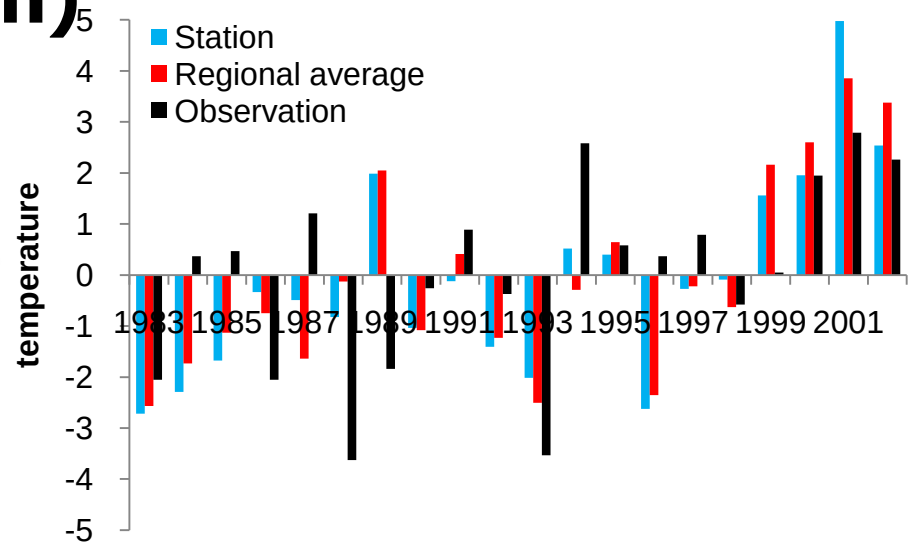




Electricity demand prediction (preprocess, verification)

1. Download of temperature anomaly forecast from APCC.

$$T'(i) = T(i) - T_{clim} \qquad i: year$$



2. Difference of temperature from observed temperature in previous year

$$T_d(i) = T'(i) - T'_{obs}(i\text{-}1)$$

3. Growth rate of total sale of electricity

$$E_g(i) = E(i) - E(i\text{-}1)$$

4. Verification using correlation

$$Corr(T_d(i), E_g(i))$$

Electricity demand prediction (preprocess, verification)

1. Download of temperature anomaly forecast from APCC.

   $T'(i) = T(i) - T_{clim}$ *i: year*

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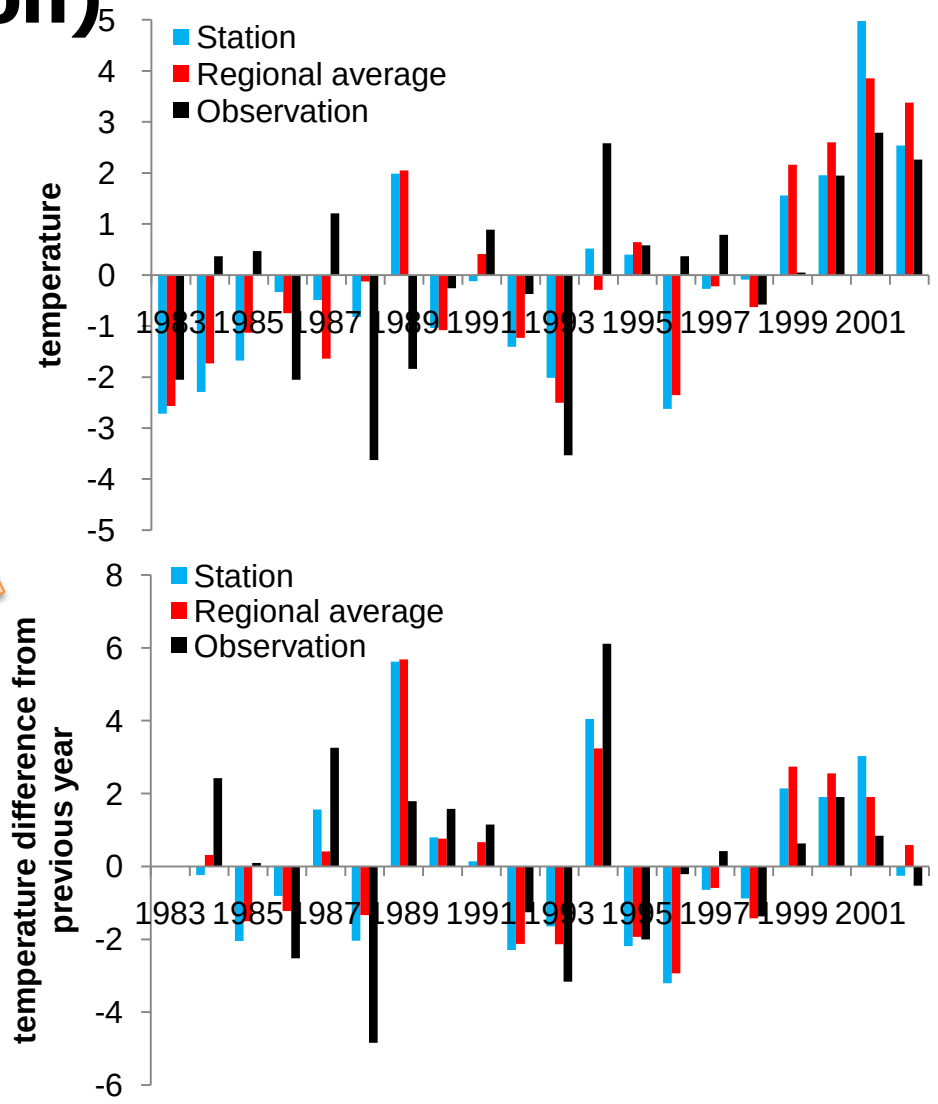

Electricity demand prediction (preprocess, verification)

1. Download of temperature anomaly forecast from APCC.

   $T'(i) = T(i) - T_{clim}$ i: year

2. Difference of temperature from observed temperature in previous year

   $T_d(i) = T'(i) - T'_{obs}(i-1)$

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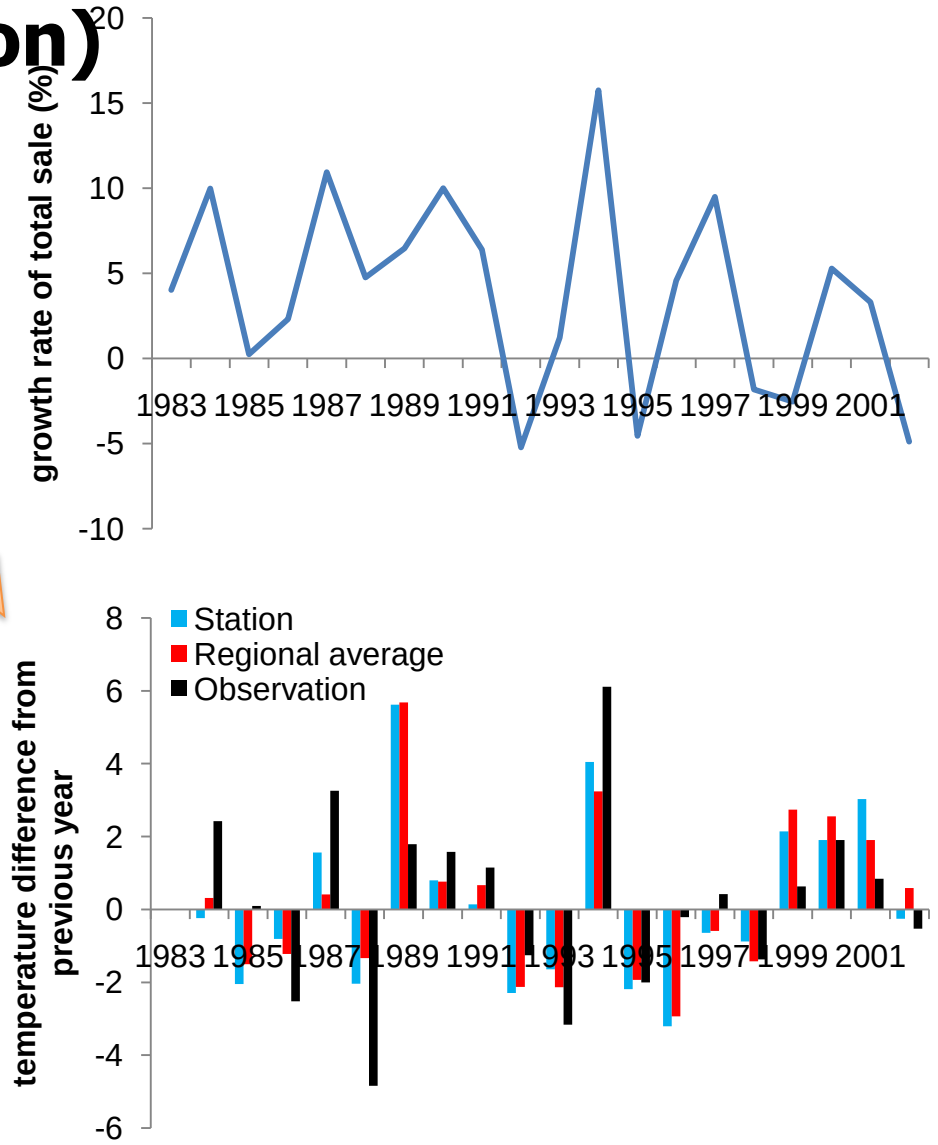

Electricity demand prediction (preprocess, verification)

1. Download of temperature anomaly forecast from APCC.

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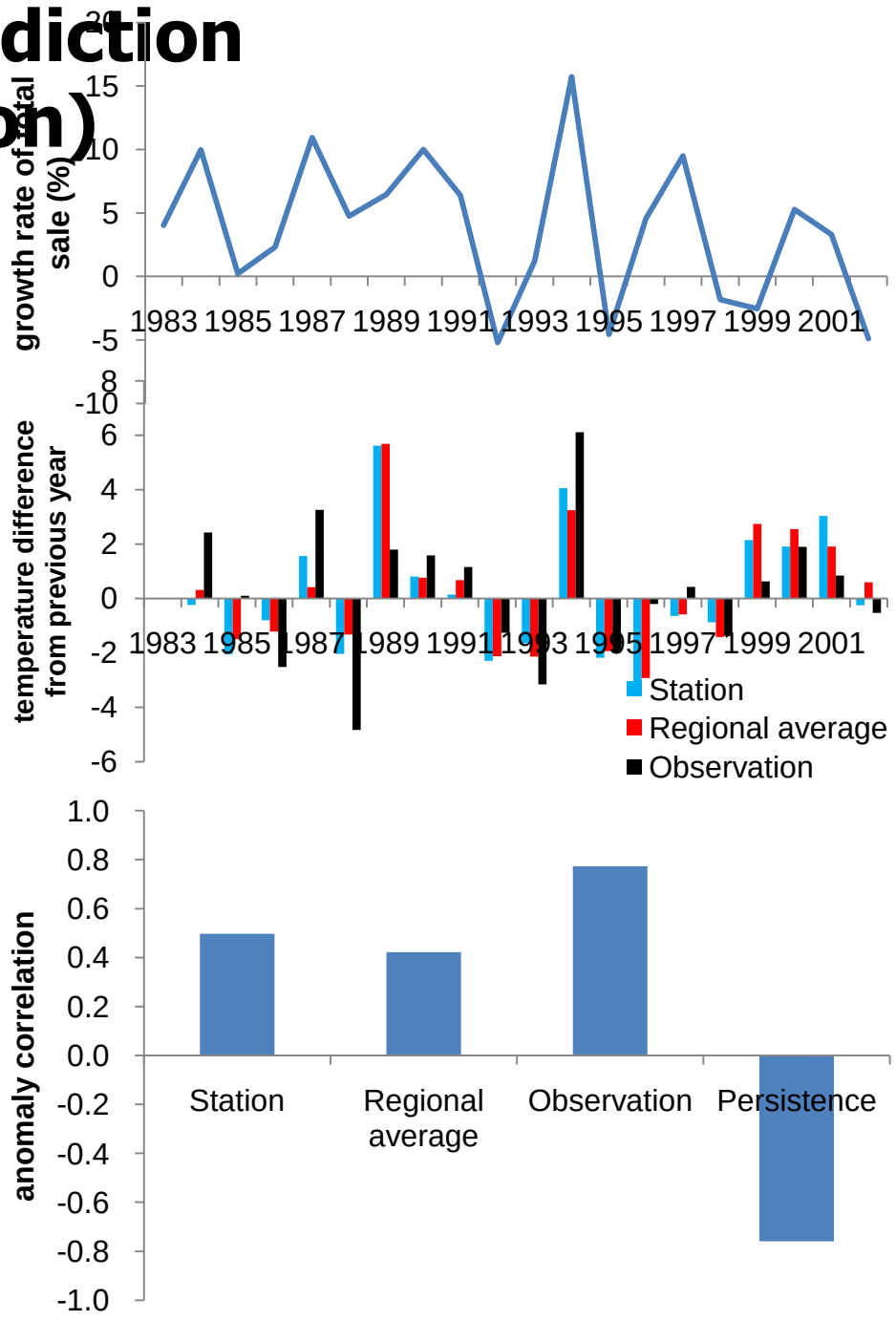


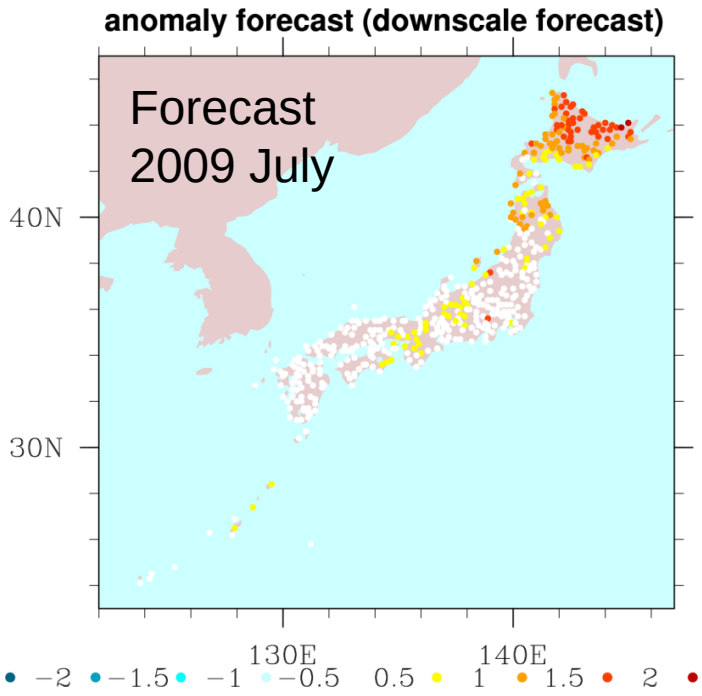
Electricity demand prediction for 2009 July using 2009 JJA forecast

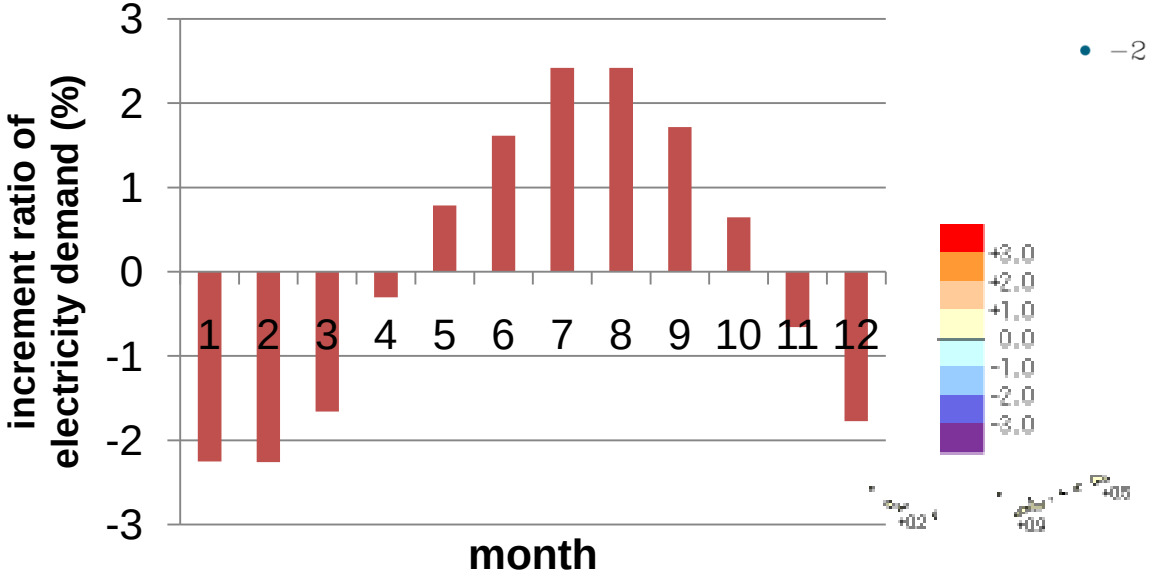
1. Comparison of predicted temperature with observed temperature in previous year

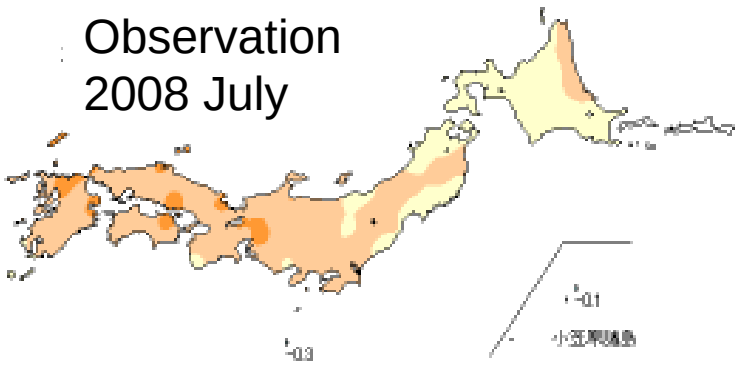
$$T_d(i) = T_{fcst}(i) - T_{OBS}(i\text{-}1)$$

i: *year*

2. Prediction of electricity demand based on increment ratio of electricity demand







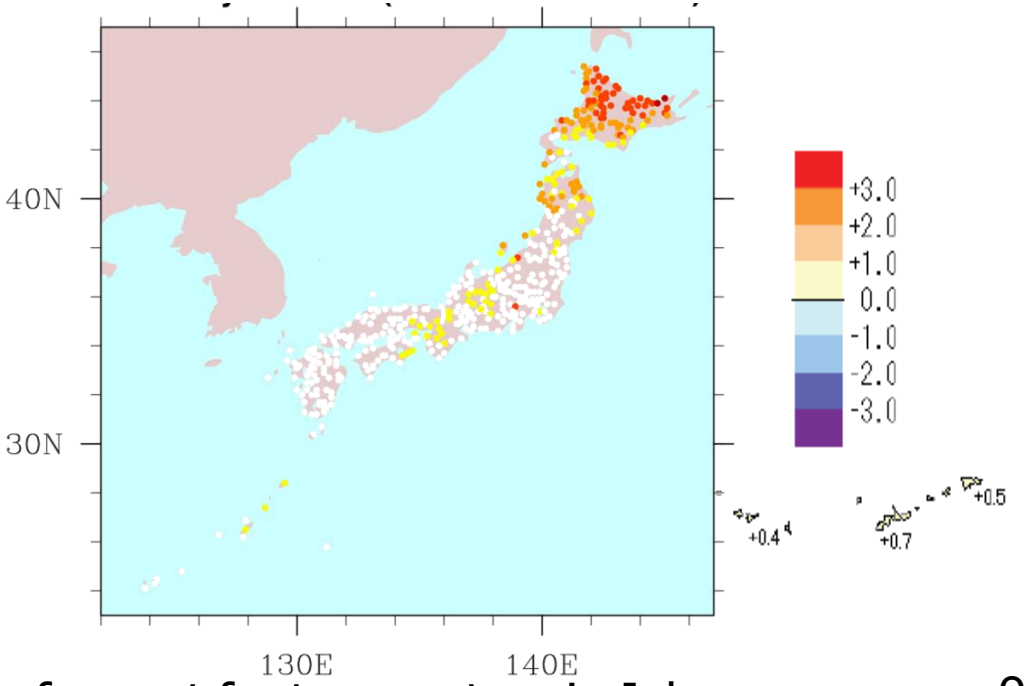
(from JMA)

Prediction of electricity demand for Jul and Aug 2009 (May 27, 2009)

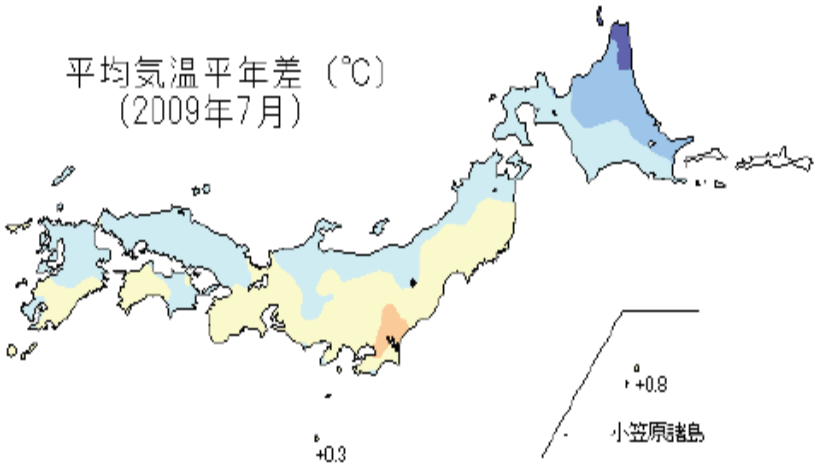
In eastern Japan, the electricity demand is expected increasing by 2% except for economic environment. In western Japan, the electricity demand is expected decreasing by 2-4%.

Result of electricity demand in July 2009

Outside the liberalized segment, lighting demand increased by 2.4% due principally to a longer meter-reading period than the last year, in spite of decreased cooling demand resulted from lower July temperature compared with a year before. (reported from The federation of electric power companies of Japan)

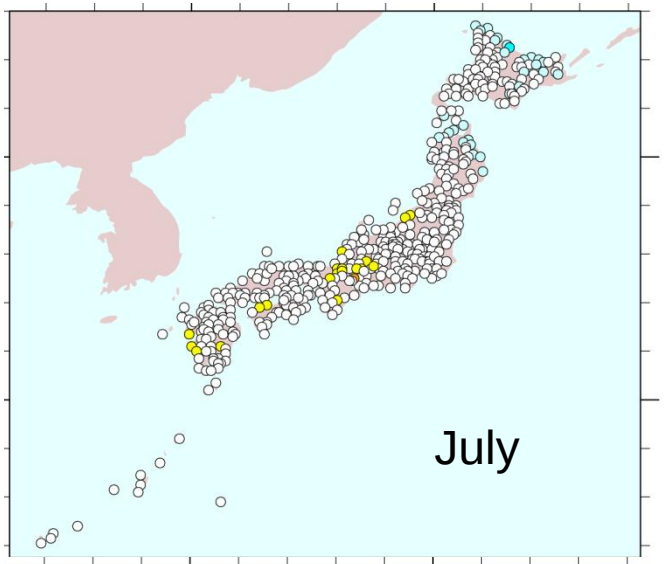


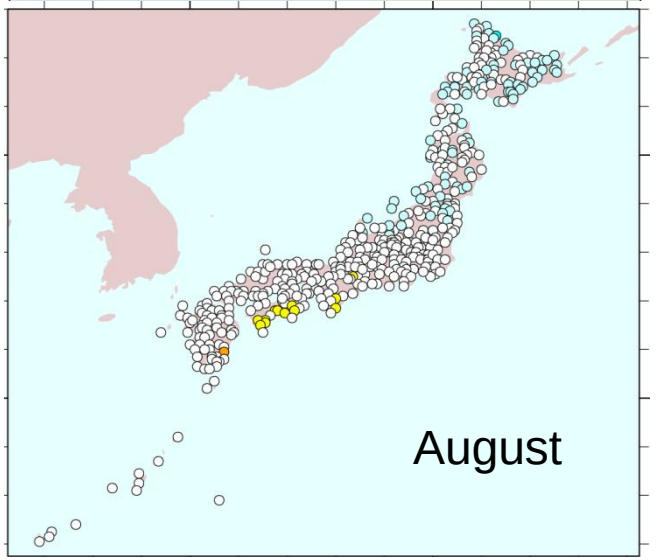
forecast for temperature in July.



observation for temperature in July.

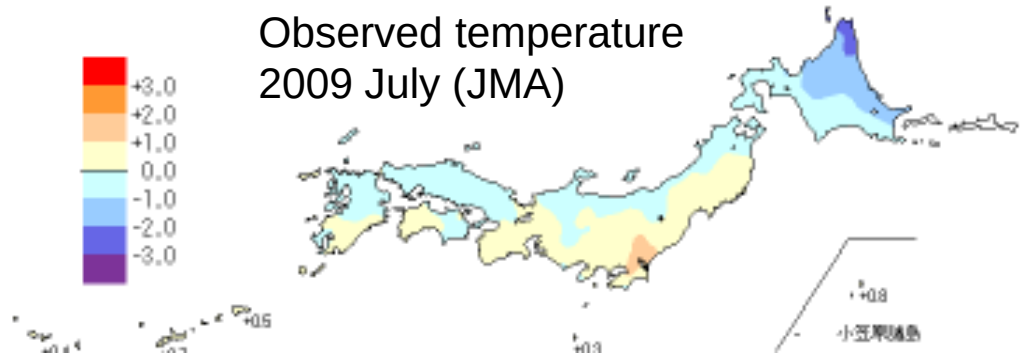
Prediction of electricity demand for Jul and Aug 2010 (Jun 3, 2010)





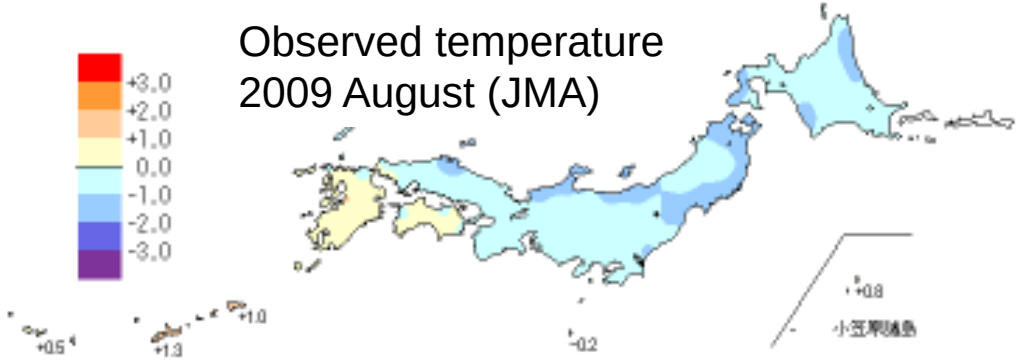
−2 −1.5 −1 −0.5 0.5 1 1.5 2

forecast for temperature.



Observed temperature
2009 July (JMA)

In eastern Japan, the electricity demand is expected same level as last year. In western Japan, the electricity demand is expected increasing by 2-4%.



Observed temperature
2009 August (JMA)

In Japan, the electricity demand is expected same level as last year.

Requirement of weather/climate prediction by electric power companies in Japan

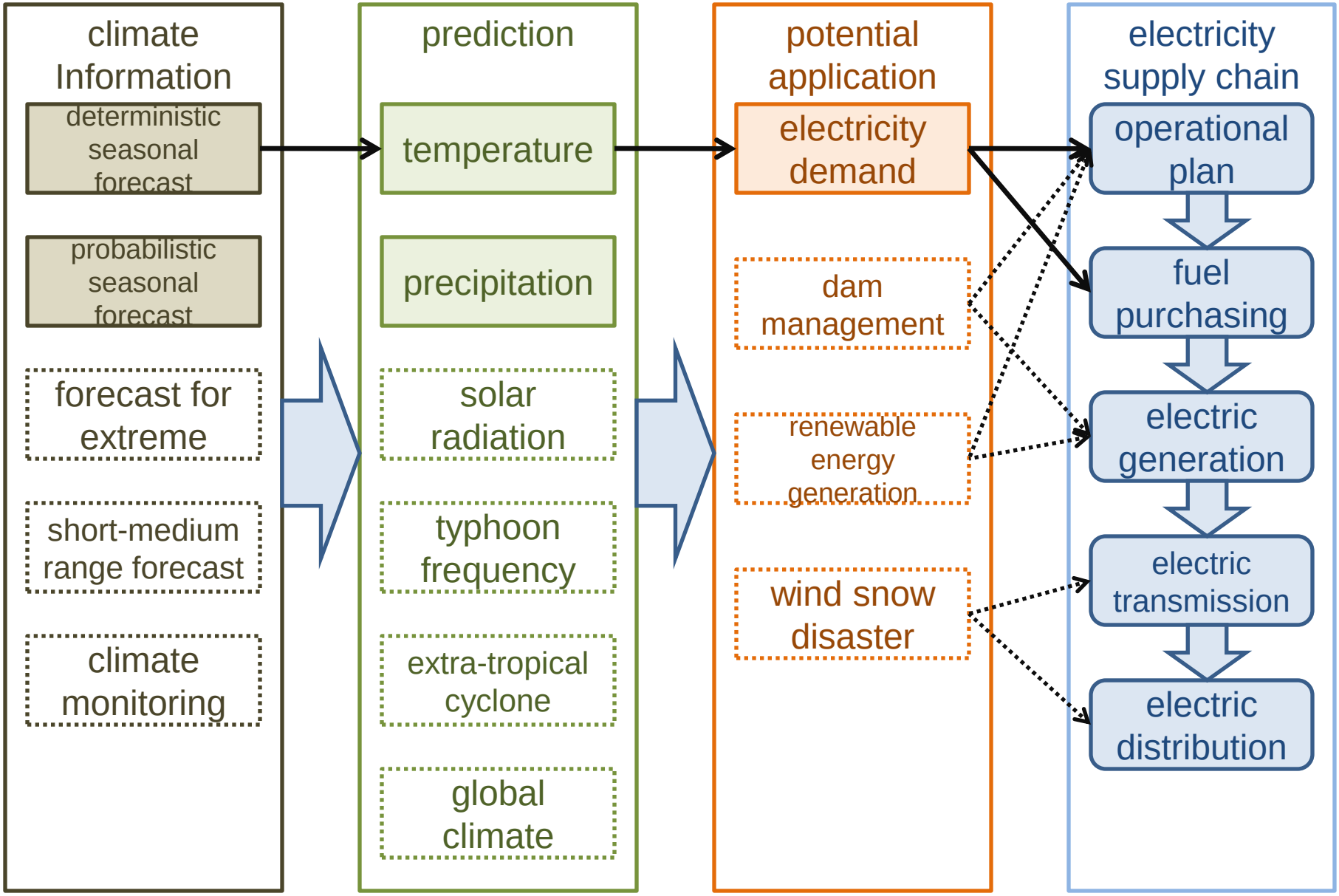
- 1~3days forecast
  - maximum temperature in summer for electricity demand peak
  - prediction for wind generation and solar power generation in near future
- seasonal forecast
  - seasonal electricity demand
  - spot oil price for purchasing
- 1~2 year forecast
  - planning for operational management of electric transmission and distribution
  - maintenance planning for electric power plants
- climate change
  - reduction of CO2 emissions
- reliability information of seasonal forecast
  - probability forecast

Summary

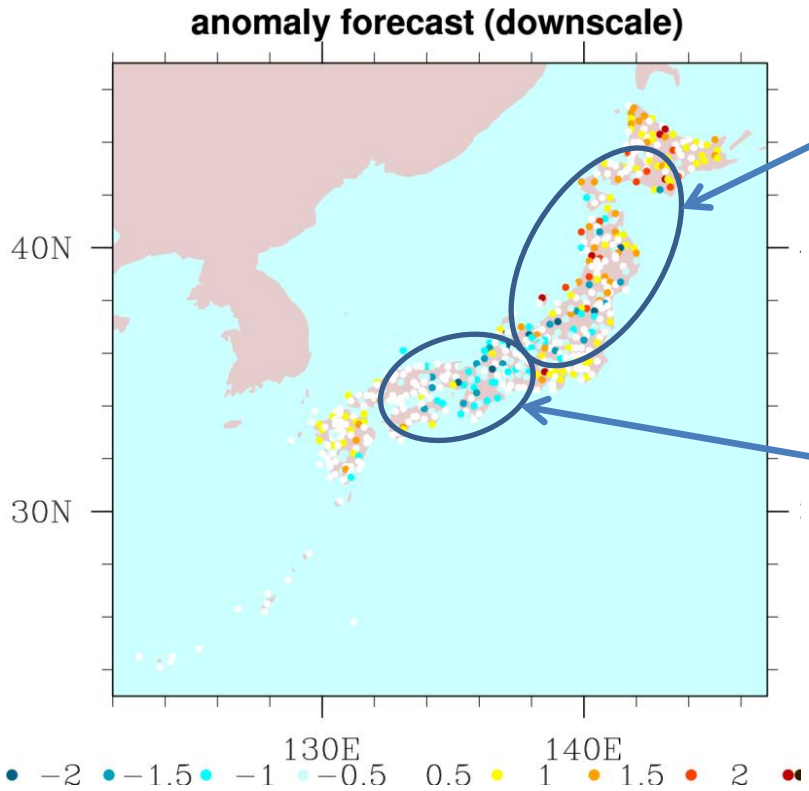
- We develop seasonal prediction for Japan using APCC statistical downscaling method.
- Regional averaging of forecast in similar climatology can increase skill score of the seasonal forecast.
- Electricity demand in Japan has a high correlation with monthly mean temperature.
- Temperature dependency of electricity demand is increasing in last 30 years. Temperature of minimum electricity demand is also increasing due to heating in winter.
- Electricity demand prediction system has been developed using APCC statistical downscaling forecast. However forecast skill of the electricity demand depends on skill of the seasonal forecast.
- Electricity power companies require reliable forecast and 1~2 year forecast.

Thank you for the attention

Climate information for electricity companies



Optimization of downscaled forecast

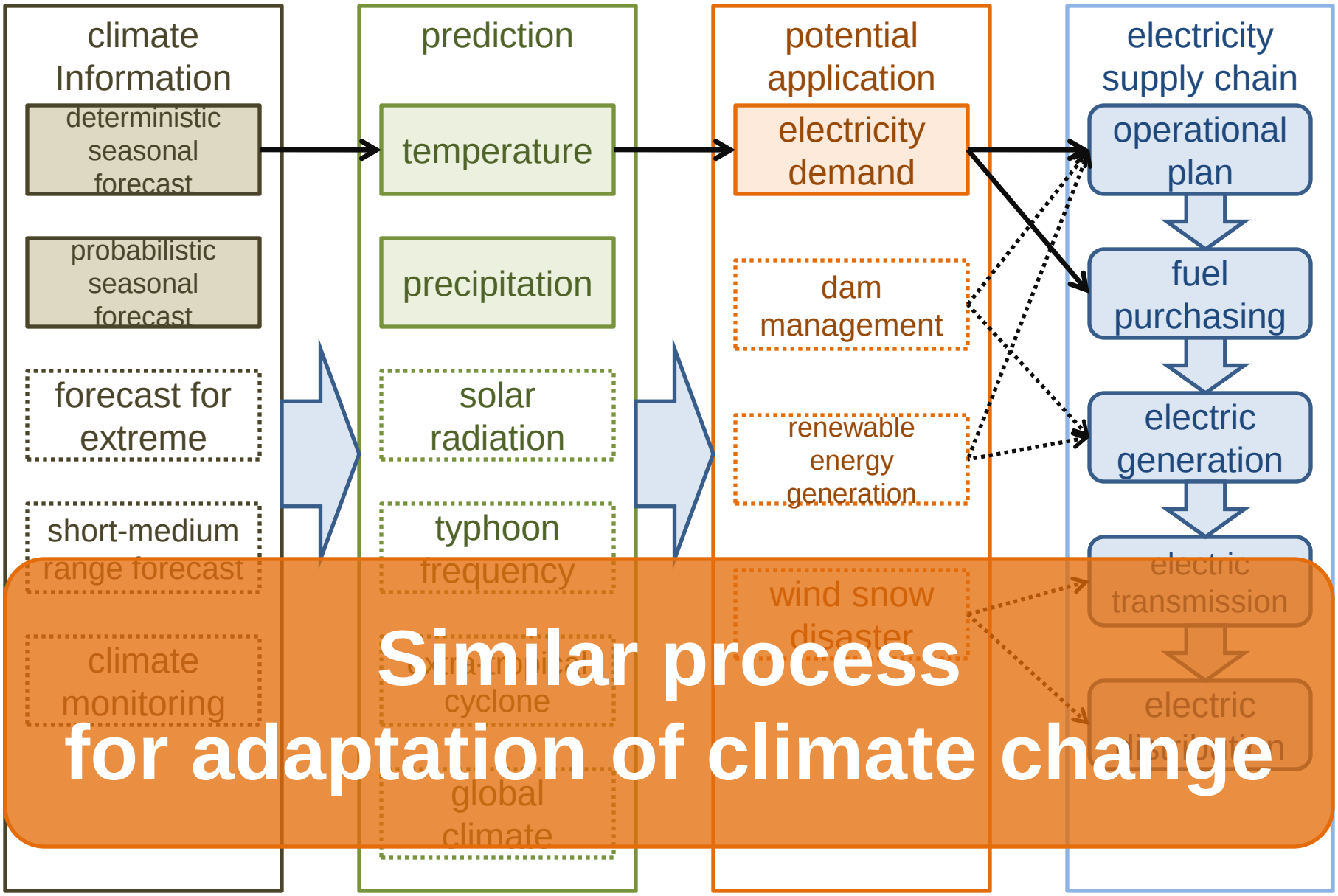


wide inter-station spread
➔low reliability of the forecast?
➔unstable results of the statistical downscaling?

narrow inter-station spread
➔high reliability of the forecast?
➔stable results of the statistical downscaling?

Is it possible to improve the forecast skill score using average of forecast in similar climatological stations (like ensemble mean)?

Climate information for electricity companies



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  - optimization of the forecast
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Collaboration Plan: Application of seasonal forecast