Air Quality Prediction in Beijing

Liu Weidong
Beijing Meteorological Bureau
Phone:86-10-88512940
E-mail: Liu_wd@yahoo.com

Content

- 1. Introduction
- 2. The Prediction Model of Air quality
- 3. Application of the Model in Beijing
- 4. Conclusion

1. Introduction

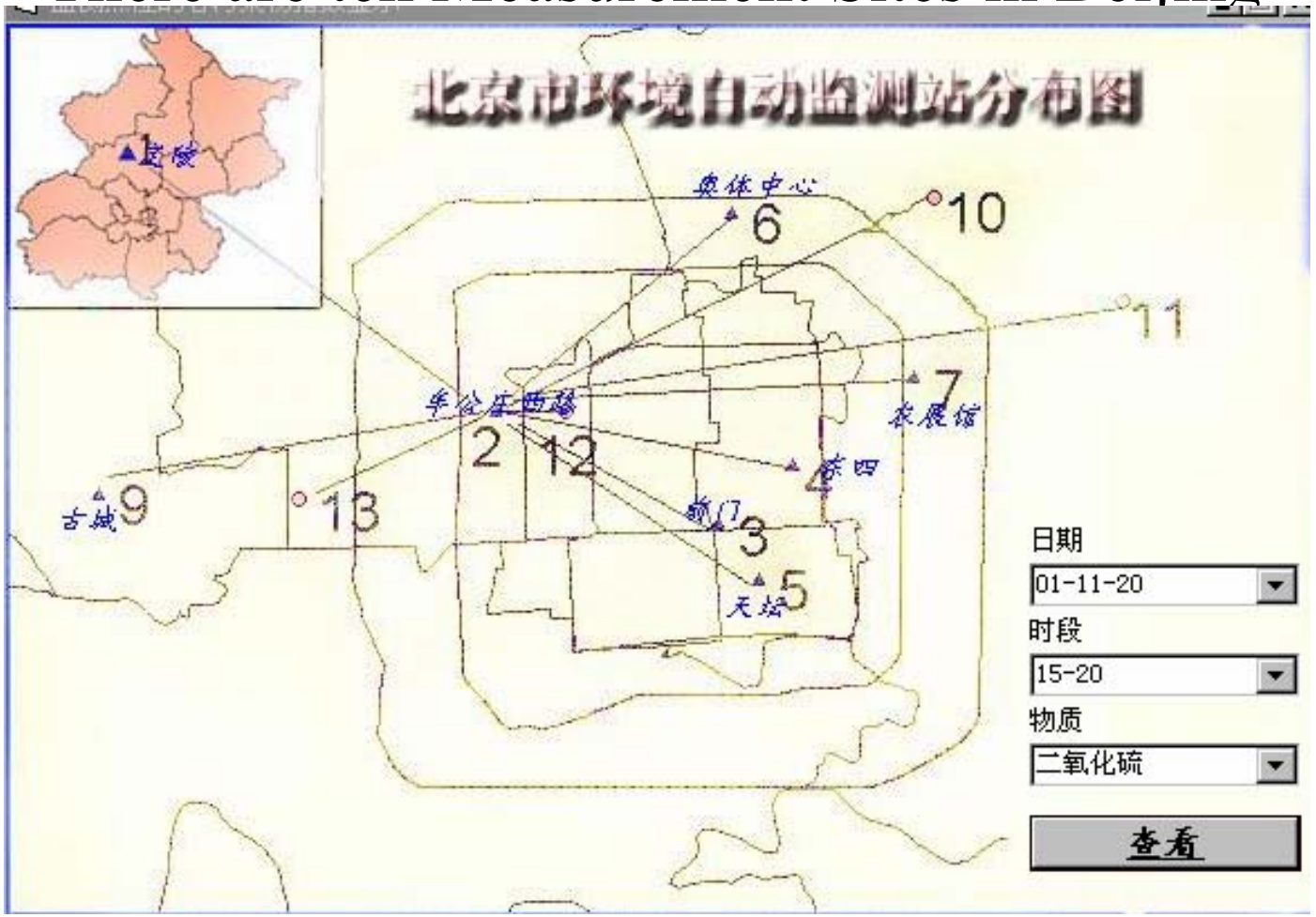
- 1.1 Main Pollutant in Beijing
- 1.2 Air Quality Measurement Network in Beijing

1.1 Main Pollutant

- PM10, the most serious pollutant
- SO2, (Winter)
- No2 (Winter)
- O3 (Summer)
- CO(Winter)

1.2 Air Quality Measurement Network

- There are ten Measurement Sites in Beijing



2. Study and Prediction Model of Air quality

- Atmospheric boundary layer and air quality evaluation;
- Relationship between atmospheric pollution , meteorological condition and urban layout and development.
- Air pollution forecast model and system

2.1 The Method of Air Pollution Forecast

- Potential Forecast
- Statistical Forecast
- Numerical Forecast
- Experiential correction

Air Pollution Potential Forecast

- Relation between pollution concentration and the surface's field of pressure
- Analysis of correlation between pollutant and each weather condition.(surface meteorological element,weather phenomenon, upper meteorological element)

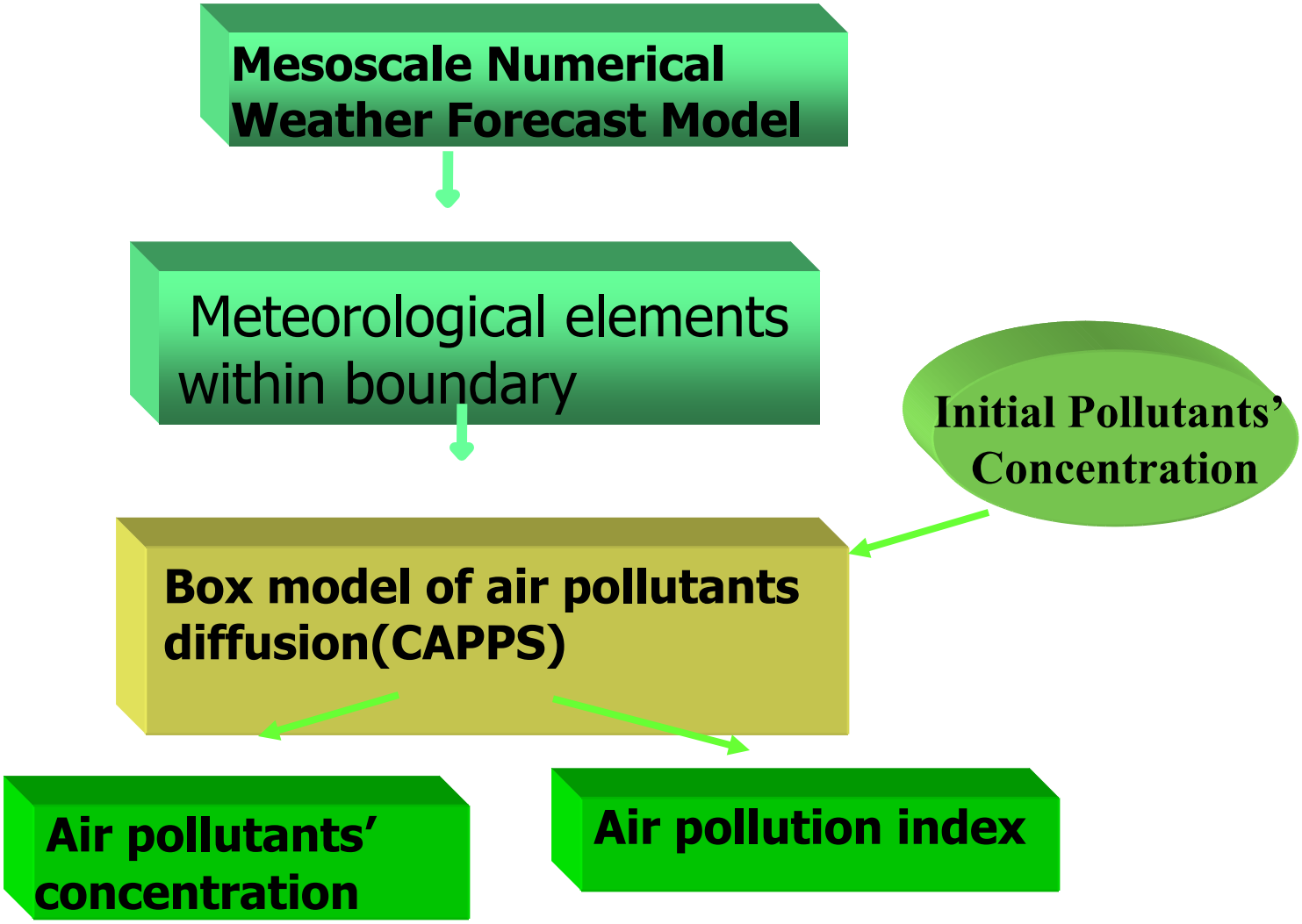
The statistical Method

- Select the factor for the forecast. (850hPa Temperature, relative humidity, surface weather situation,surface wind,upper wind,inversion,mixture height etc.)
- Get a statistical equations (stepwise regression analysis) in different seasons.
- Forecast main Pollutant's Concentration. (SO2、CO、NOX、PM10、O3)

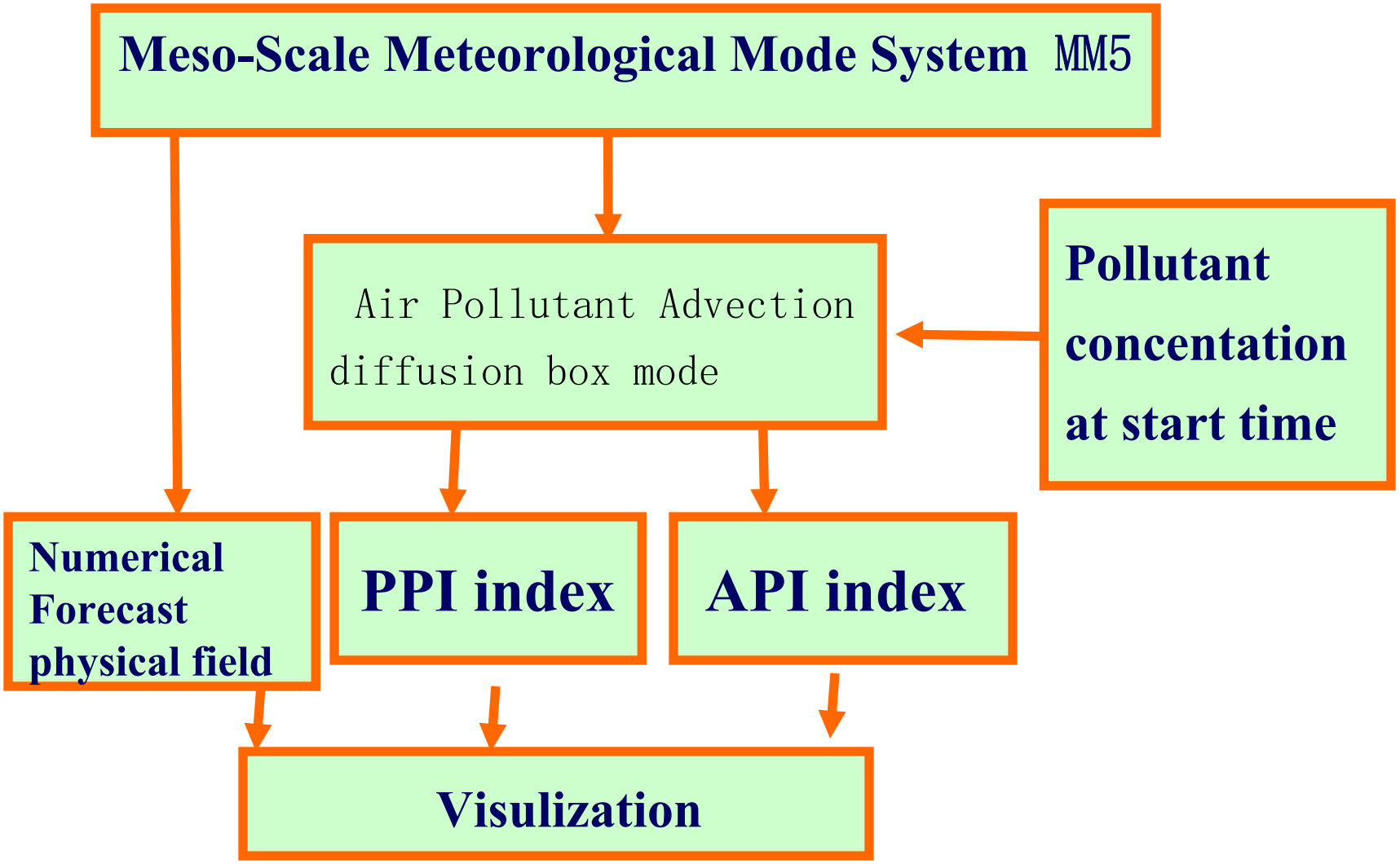
Numerical Forecast for Air Pollution

- City Air Pollution Prediction System (CAPPS)
- Based on the result of MM5 numerical weather forecast products.
- Rely on the previous real pollutant data.
- Output the air pollution index of SO2、NOX、CO、PM10 for the next day.

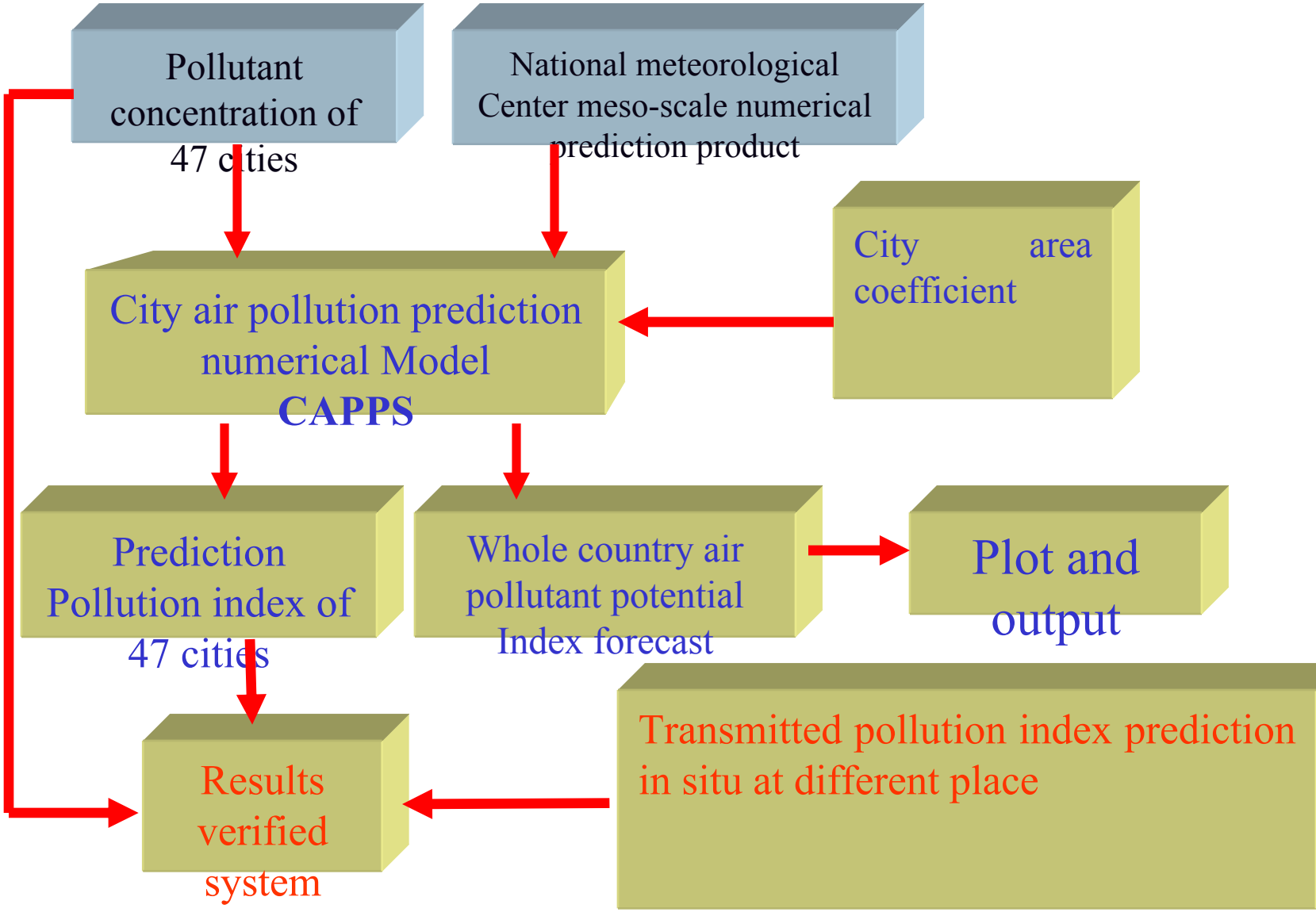
Flow chart of numerical forecasting technology for urban air pollution



Single city CAPPS system scheme



Multi-cities CAPPS Scheme



Introduction of CAPPS

- Pollution Index and Potential Prediction (by CAPPS model)

  Establishment of Advective Diffusion Equation and Grid-cell Prediction Model

- The advective diffusion equation of airborne pollutants without considering chemical reactions can be written as:

$$\frac{\partial c}{\partial t} + \vec{V} \cdot \nabla c = \sum q_i \delta(\vec{r}_i) - \nabla \cdot (c\vec{v}_d) - \nabla \cdot (c\vec{v}_w) + \nabla \cdot \vec{\vec{k}} \cdot \nabla c$$

After averaging over each cell,

$$\frac{\partial \bar{c}}{\partial t} + \frac{1}{\tau}\iiint_{\tau} \vec{V} \cdot \nabla c \, d\tau$$

$$= \frac{1}{\tau}\iiint_{\tau} \sum q_i \delta(\vec{r}_i)\, d\tau - \frac{1}{\tau}\iiint_{\tau} \nabla \cdot (c\vec{v}_d + c\vec{v}_w)\, d\tau + \frac{1}{\tau}\iiint_{\tau} \nabla \cdot \vec{\vec{k}} \cdot \nabla c \, d\tau$$

and using the virtual turbulent transport speed (the concept from model "PIC")

$$\mathrm{v_t} = \left(u_t = \overline{u'c'} / c \,,\; v_t = \overline{v'c'} / c \,,\; w_t = \overline{w'c'} / c \right)$$

the prediction equation of mean concentration can be obtained as

$$\tau \frac{\partial \bar{c}}{\partial t} = Q - \oiint_S c(\vec{V} + \vec{V}_t + v_d + v_w) \cdot d\vec{s}$$

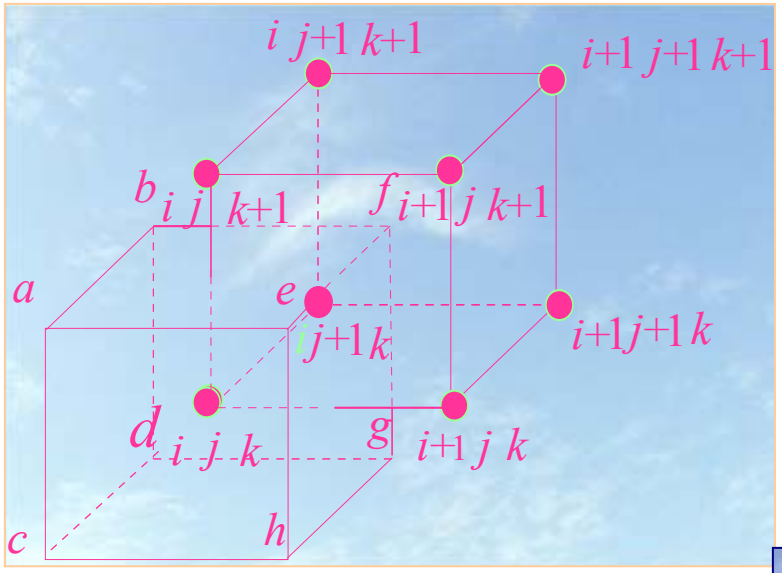
where

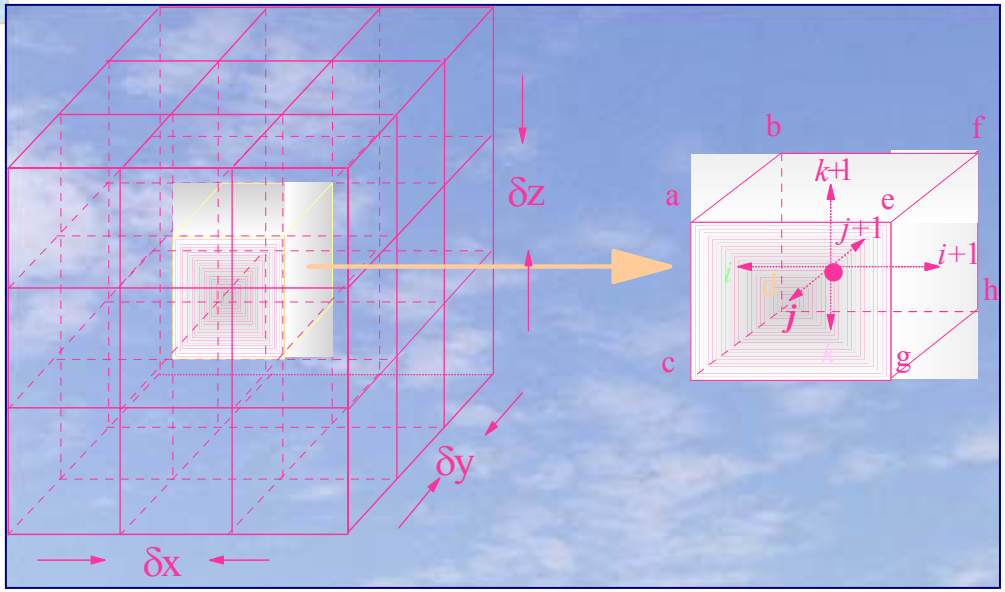
$$V_C = \frac{1}{\bar{c}} \oiint_S c(\vec{V} + \vec{V}_t + v_d + v_w) \cdot d\vec{s}$$

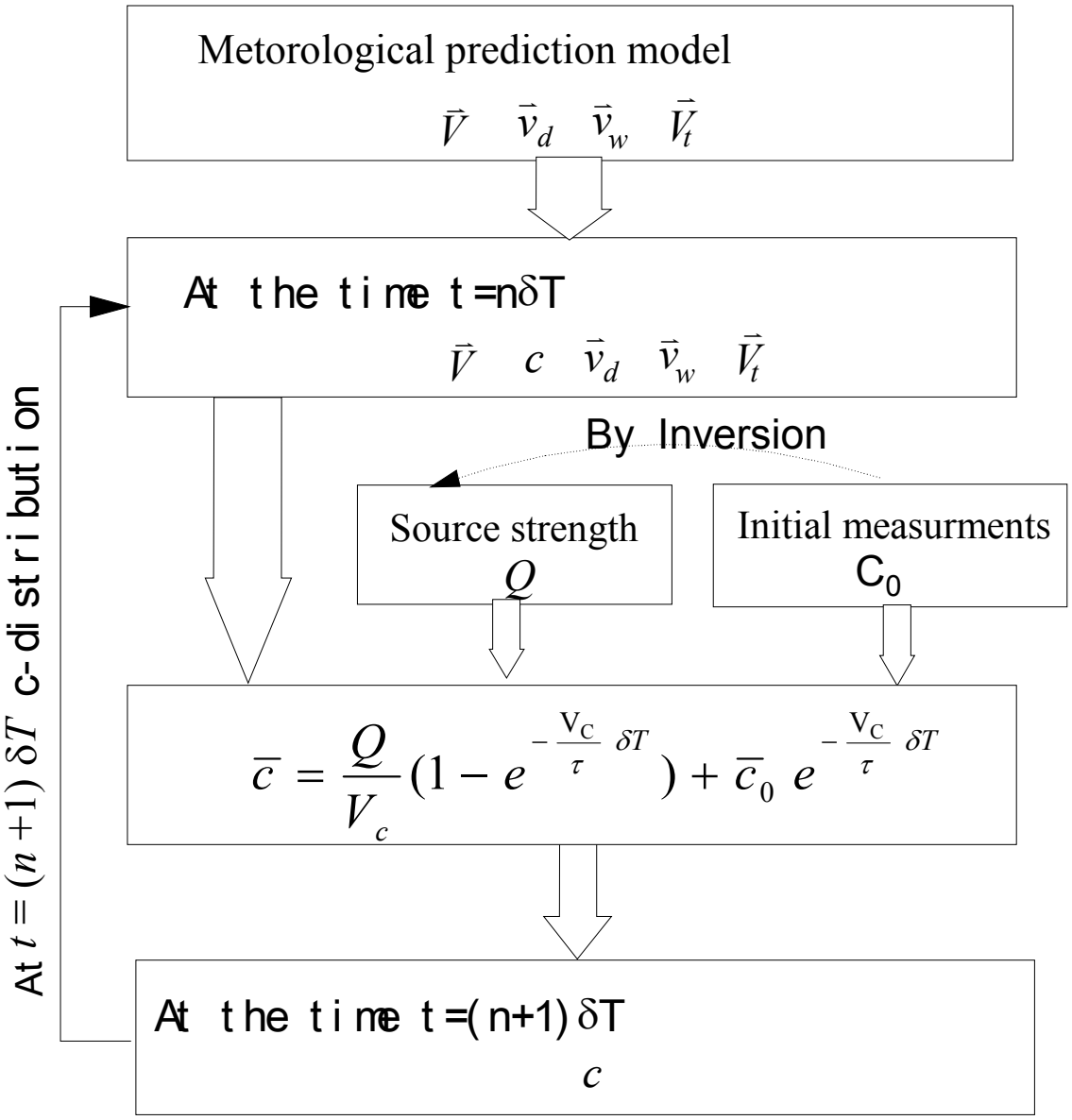
and

$$\bar{c} = \frac{Q}{V_c}(1 - e^{-\frac{\mathrm{V_C}}{\tau}\delta T}) + \bar{c}_0 \, e^{-\frac{\mathrm{V_C}}{\tau}\delta T}$$

The grid-cell in CAPPS model





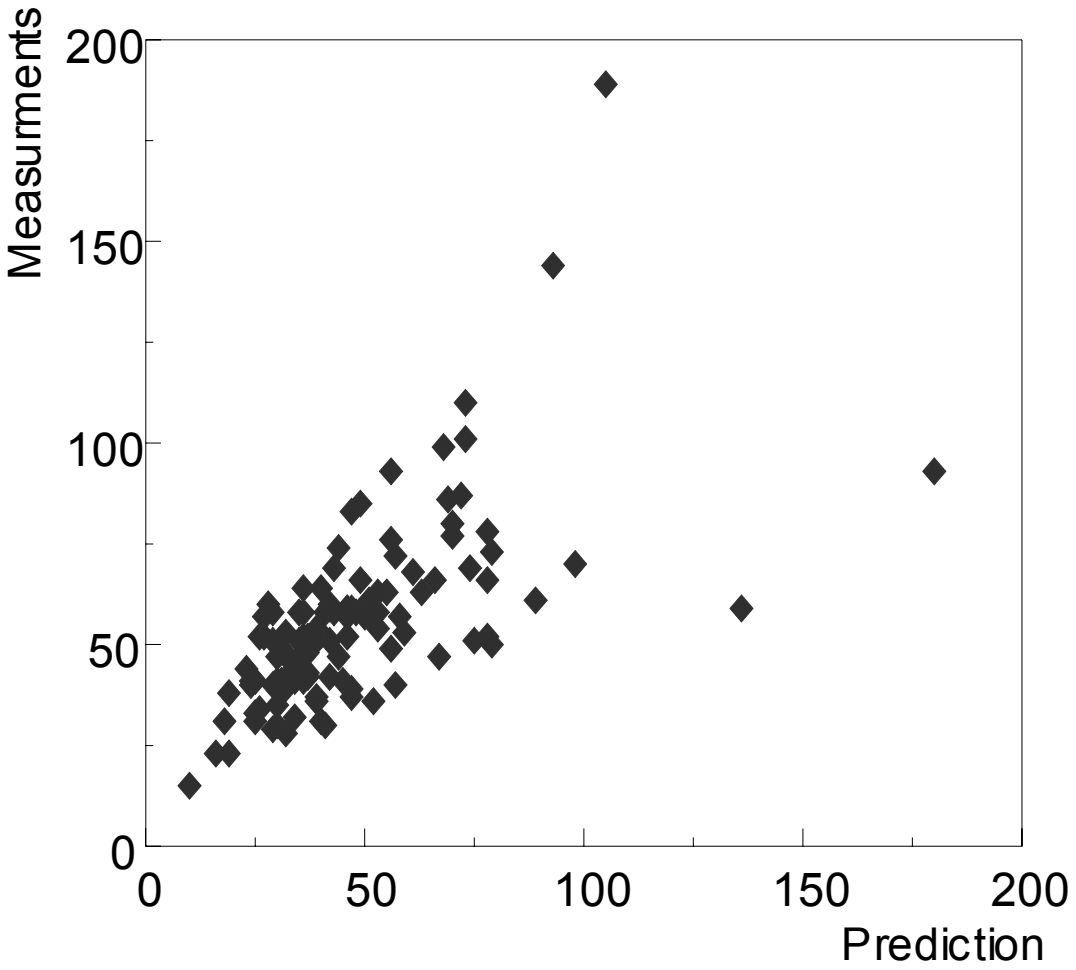


The flowchart of the grid-cell model

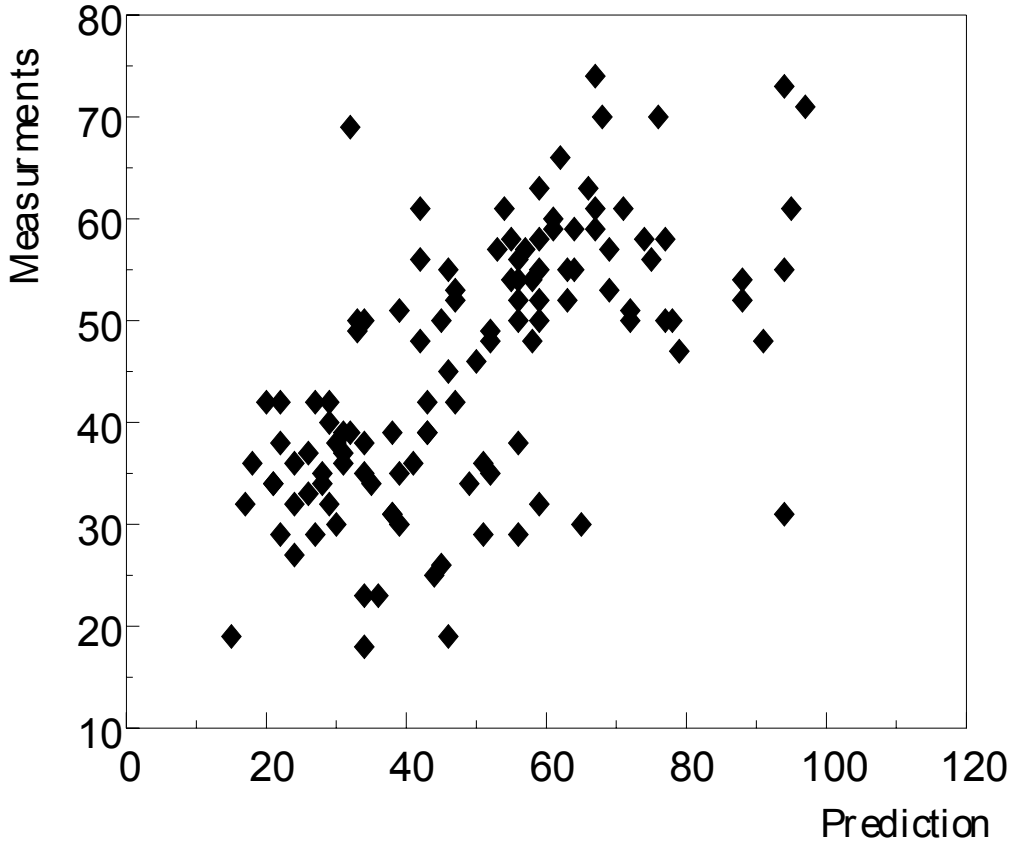
Air Pollution Potential Index and Trial Prediction of the Pollution Index

- In order to assess the performance of the above calculation, the day to day predictions of daily mean SO_2, TPS and NO_x concentrations were made at Shanghai on August-December 1998.
- The number of days with both predicted and measured concentrations is 118
- and the comparison and correlation analysis were made between PSI predictions and the corresponding measurements.
- PSI index is defined as:

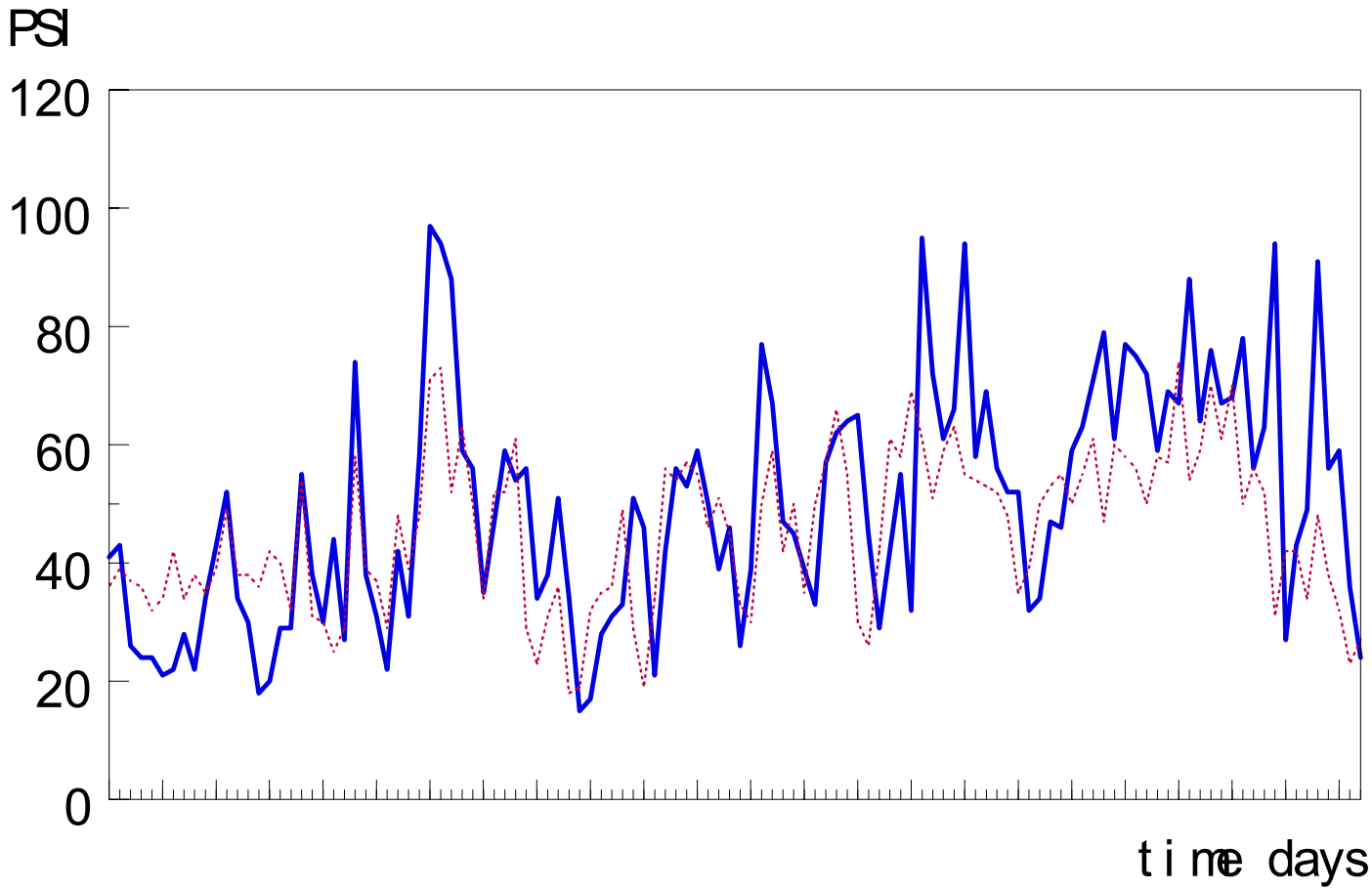
$$PSI=\left(\frac{\text{predicted or measured pollutant concentration}}{\text{national standard concentration}}\right)\times 100$$



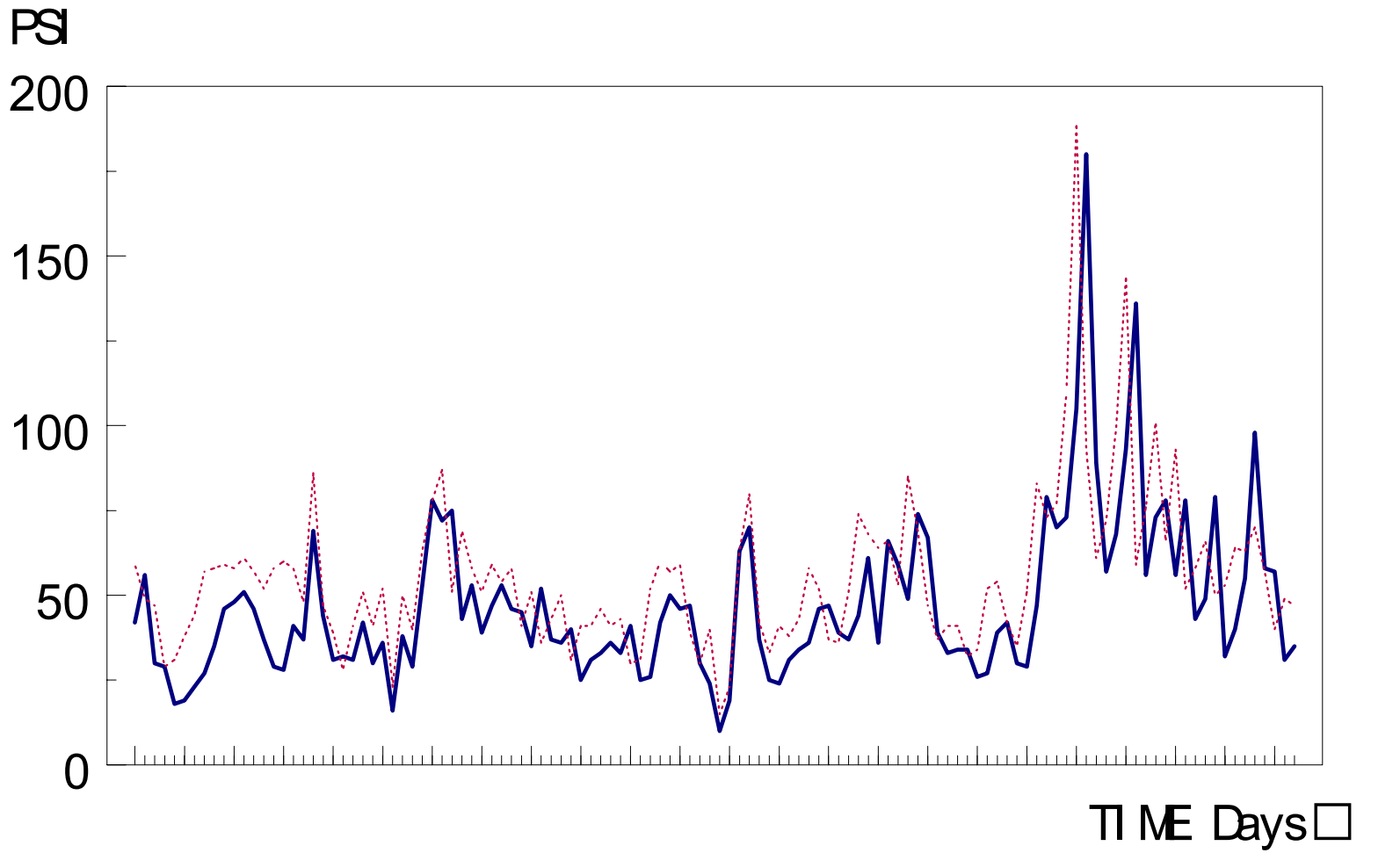
The comparission of predition and measrements of so_2 pollution index



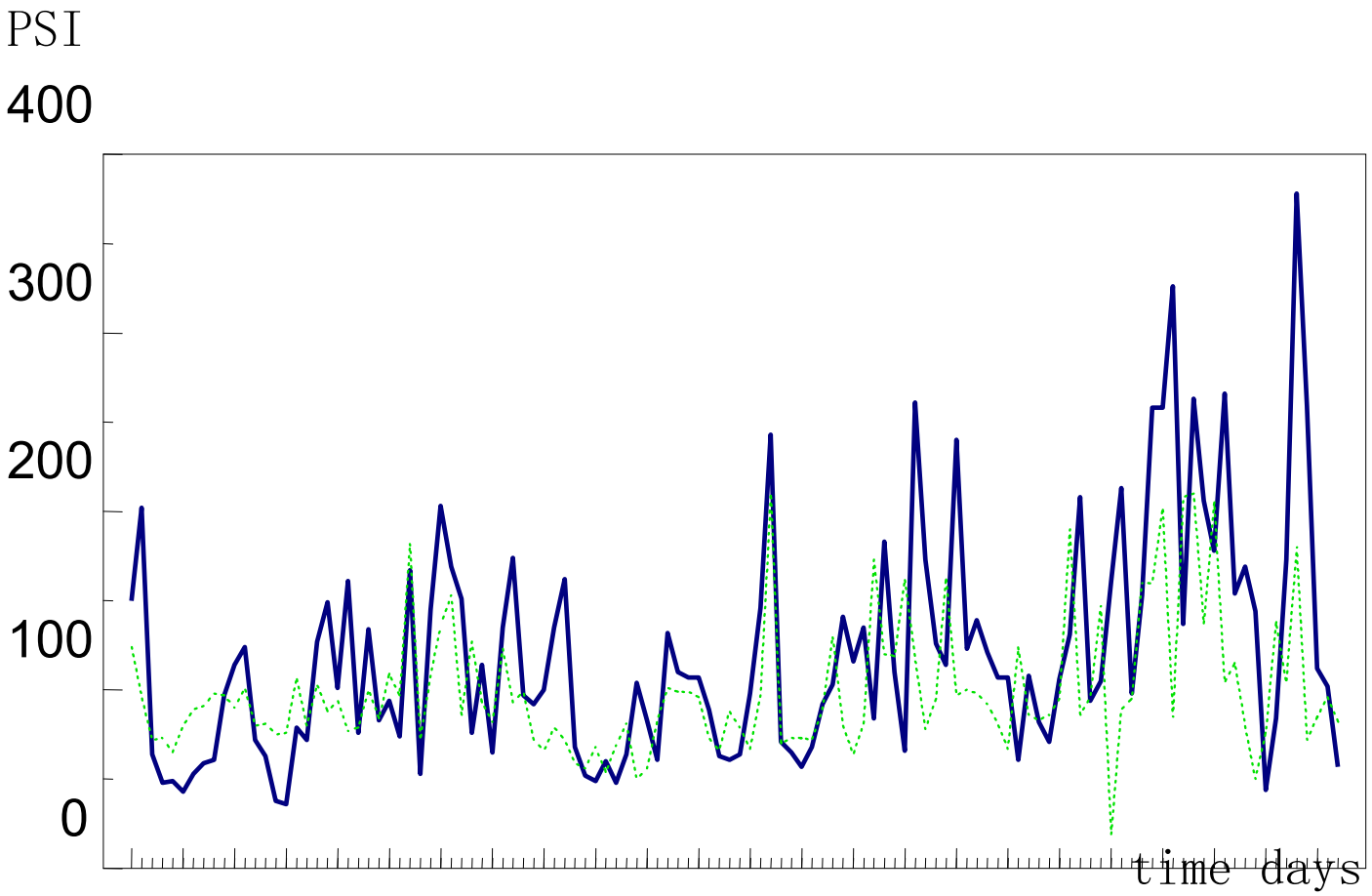
The comparission of predition and measrements of TSP pollution index



SO2 prediction (solid blue) and measurments (virtual red)



TSP prediction (solid blue) and measurments (virtual red)

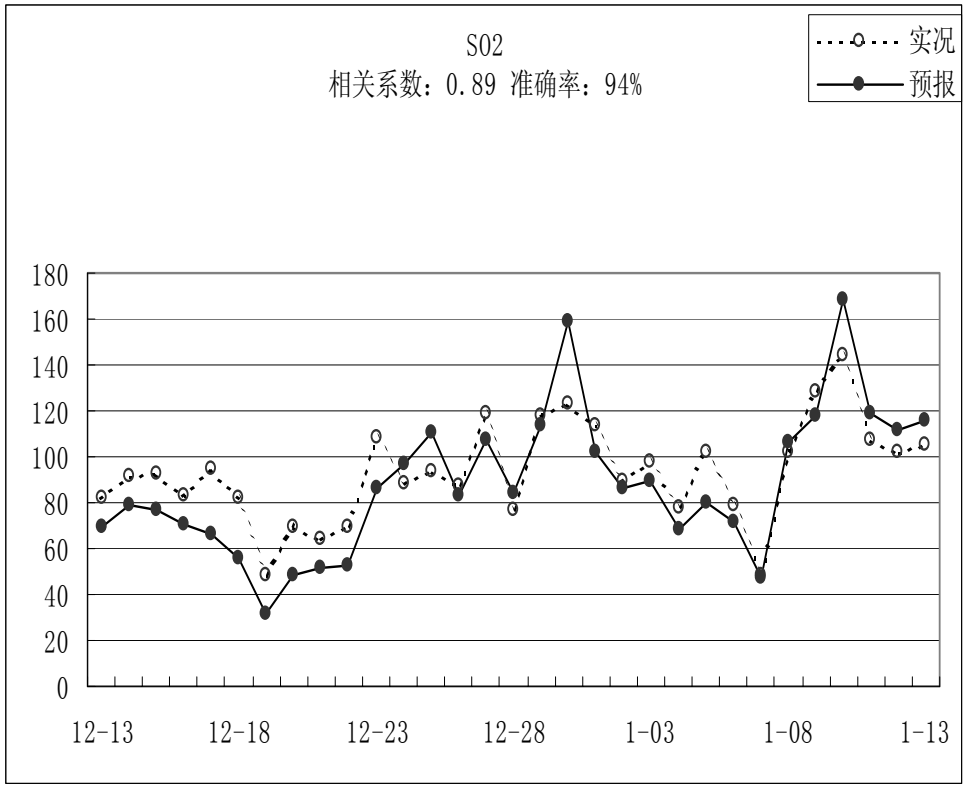


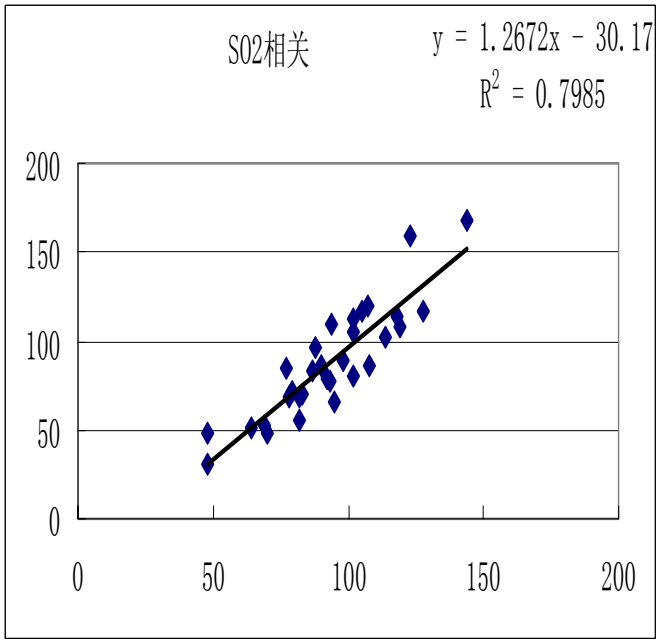
NOx prediction(solid blue)and measurments(virtual green)

Application of the Model in Beijing

Beijing Institute of meteorology sciences

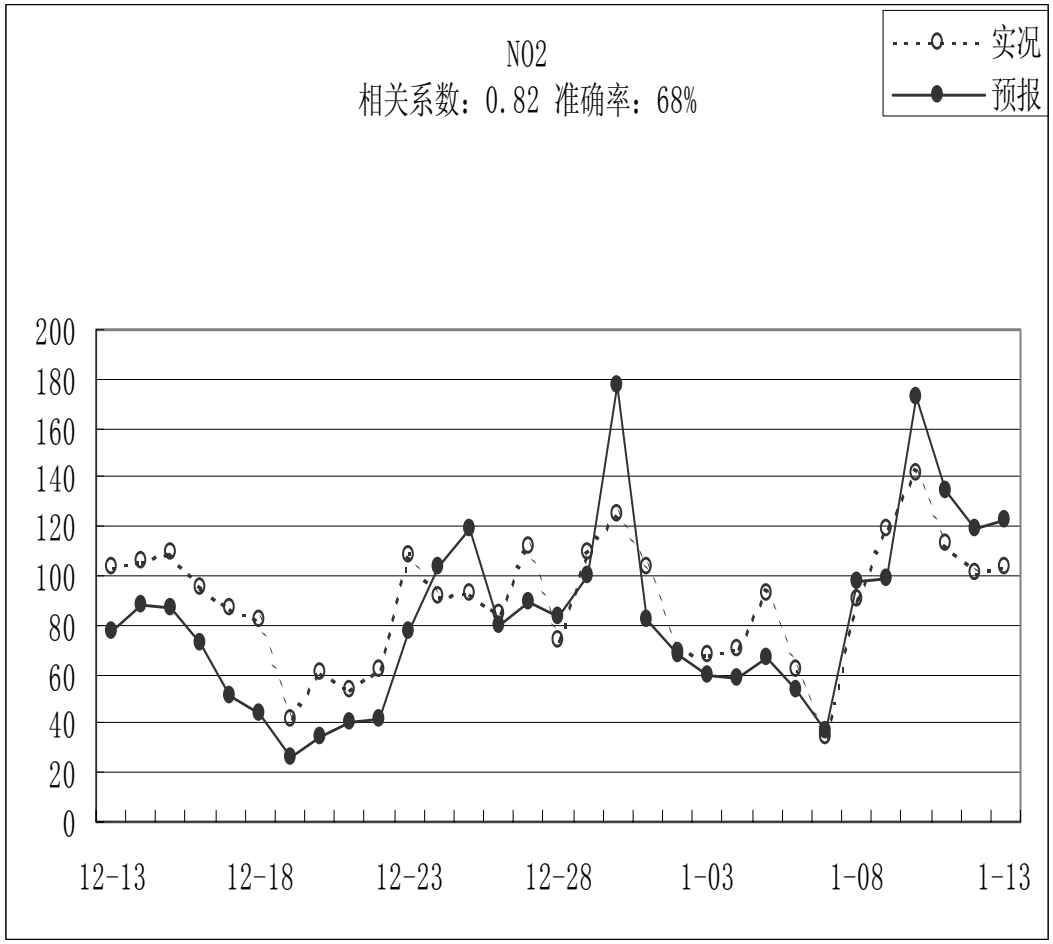
Winter

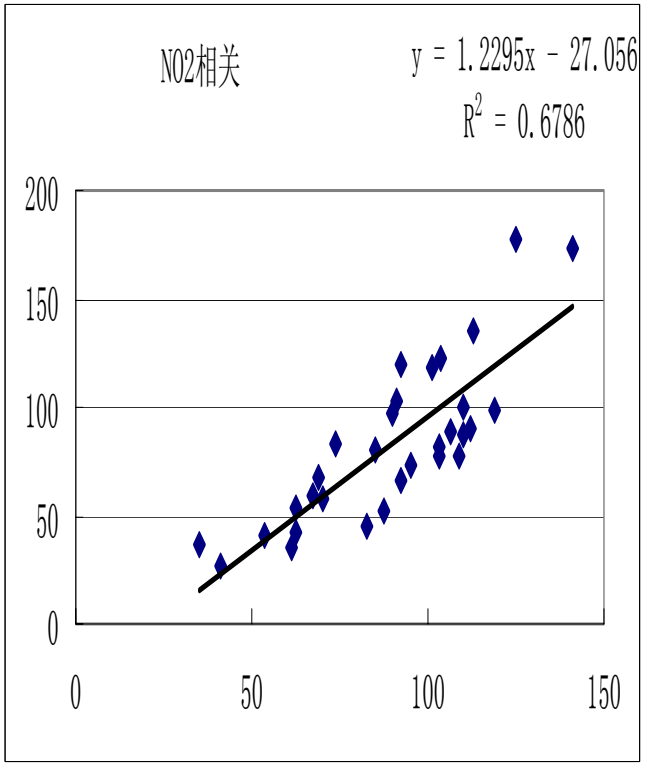




The correlation coefficient between measurements and prediction of SO_2 (1999/12/13-2000/1/13)

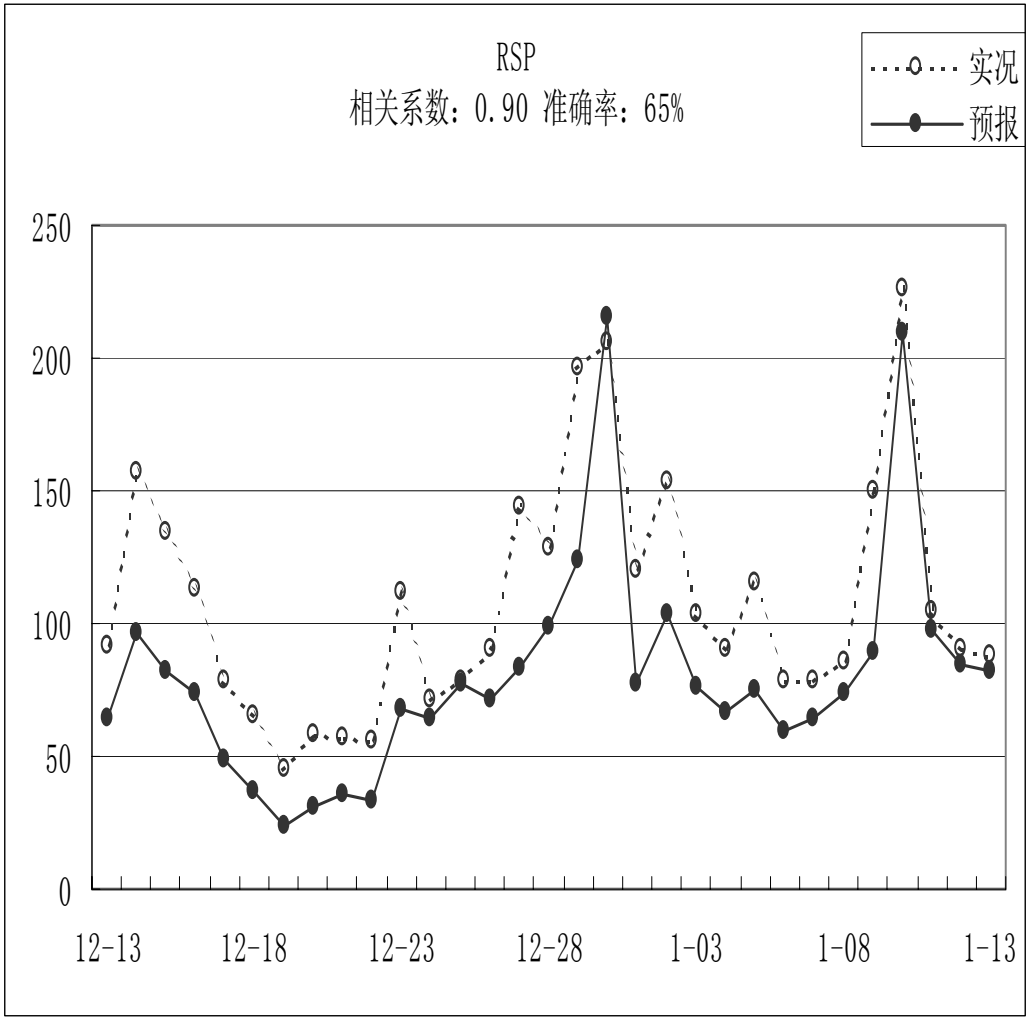
Winter

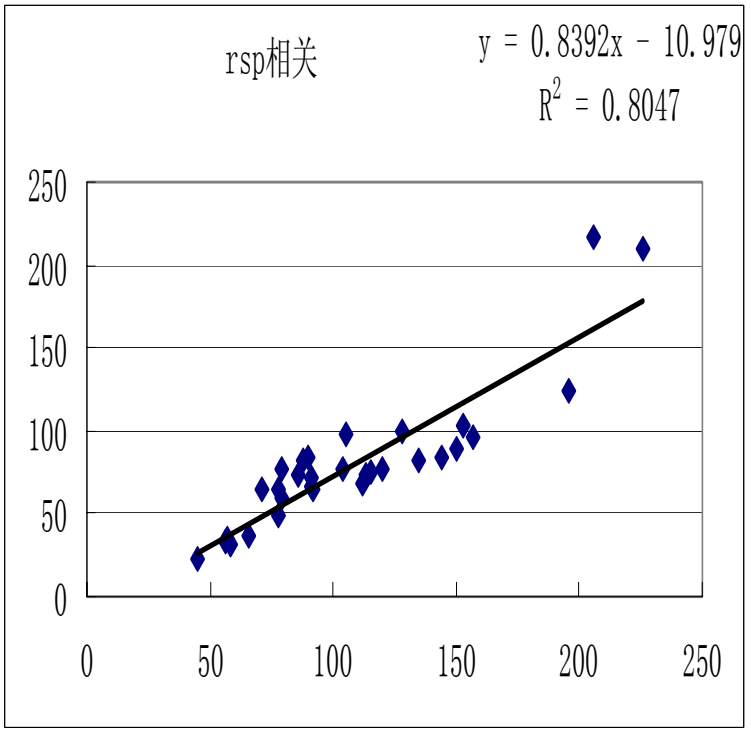




The correlation coefficient between measurements and prediction of NO_2 (1999/12/13-2000/1/13)

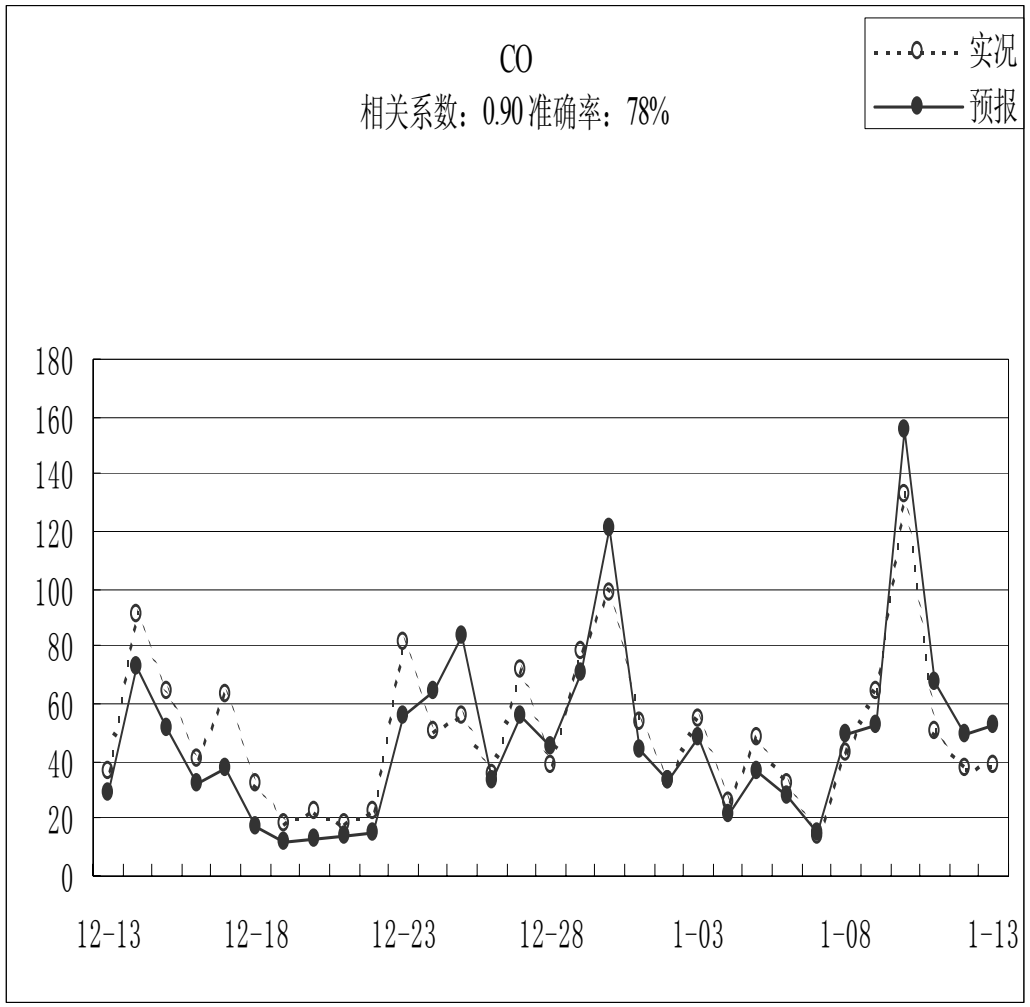
Winter

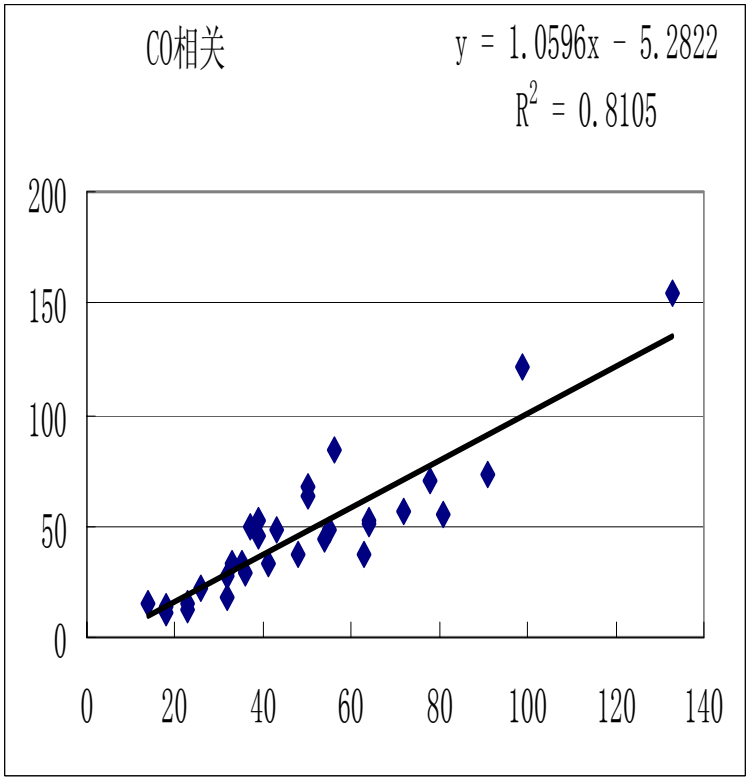




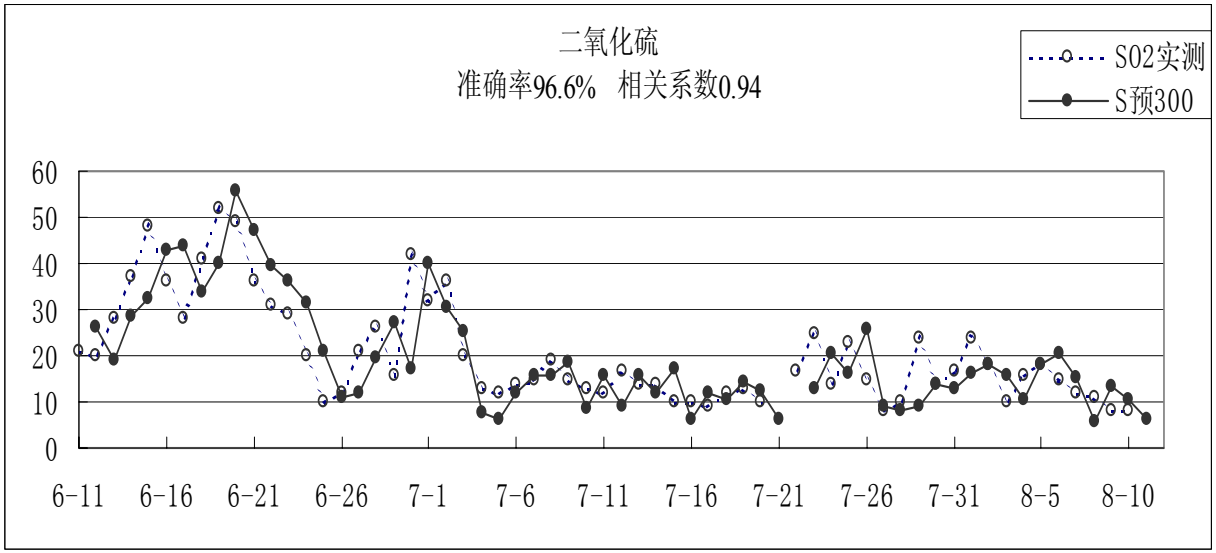
The correlation coefficient between measurements and prediction of PM10 (1999/12/13-2000/1/13)

Winter



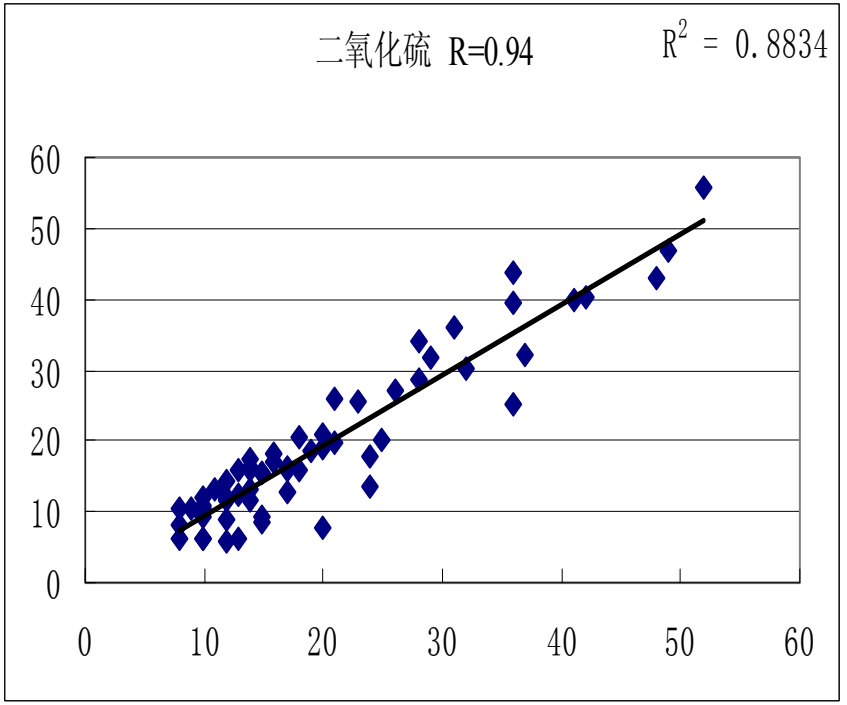


The correlation coefficient between measurements and prediction of CO (1999/12/13-2000/1/13)

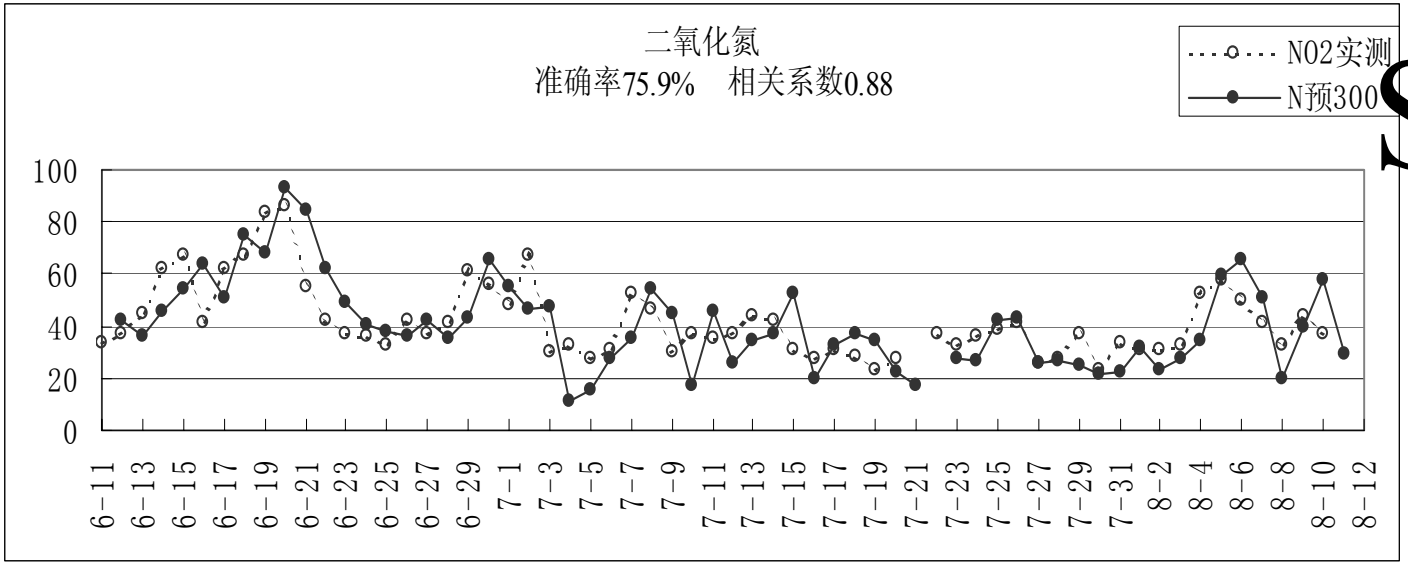


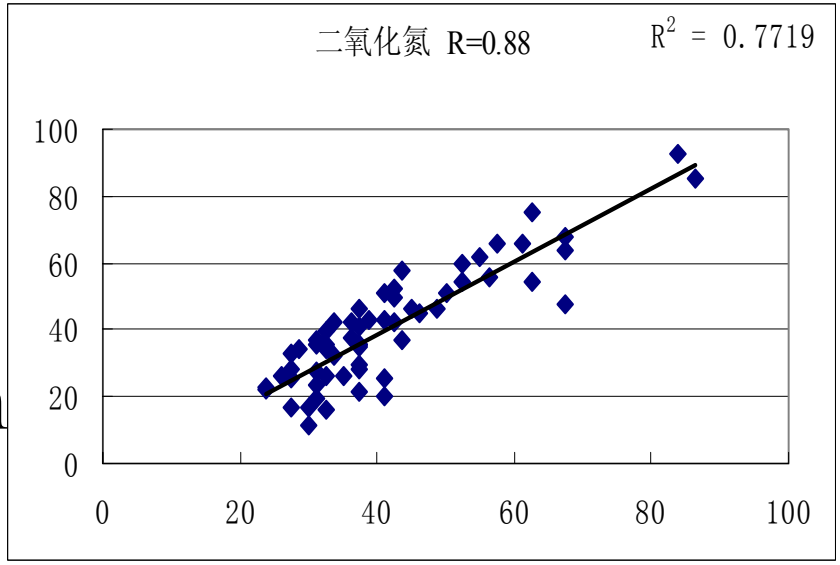
Summer

The correlation coefficient between measurements and prediction of SO_2 (2000/06/11-2000/8/10)

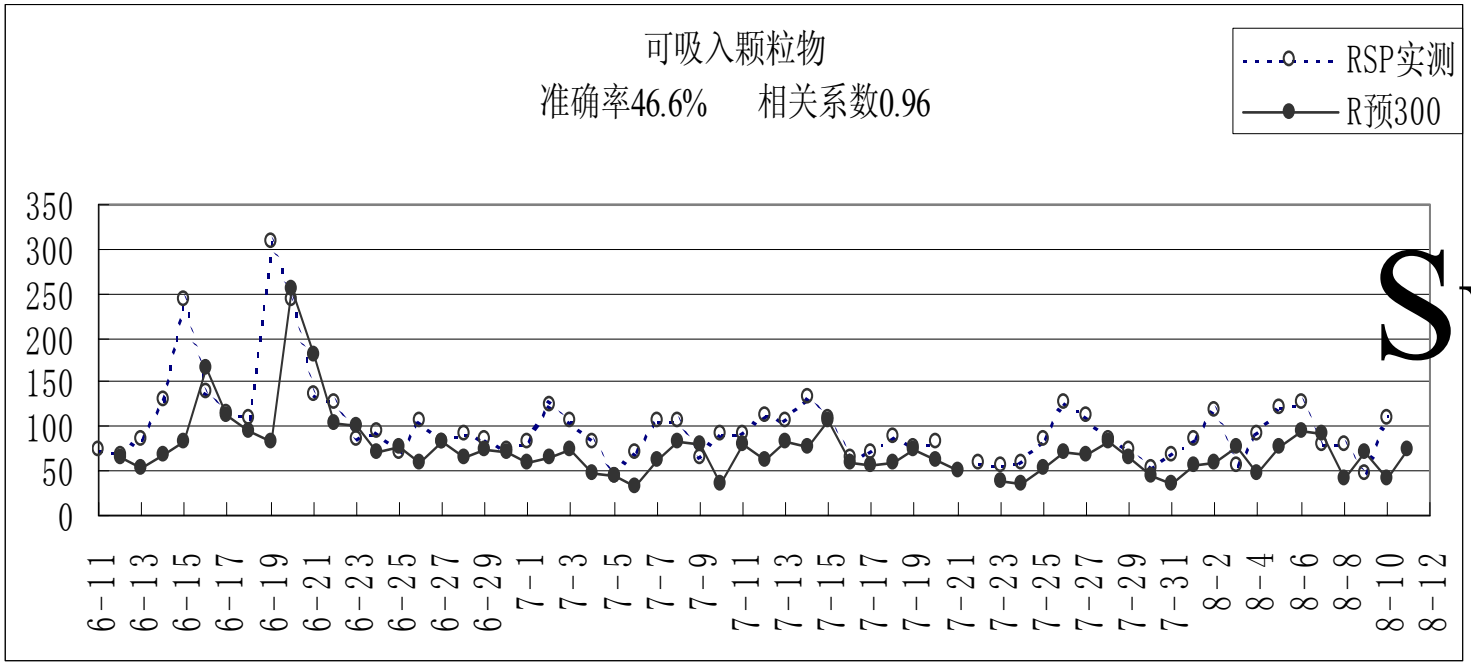


Summer



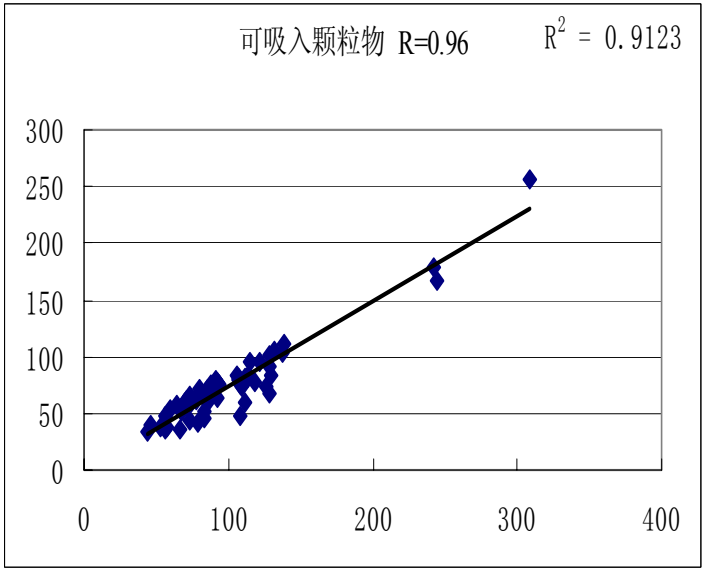


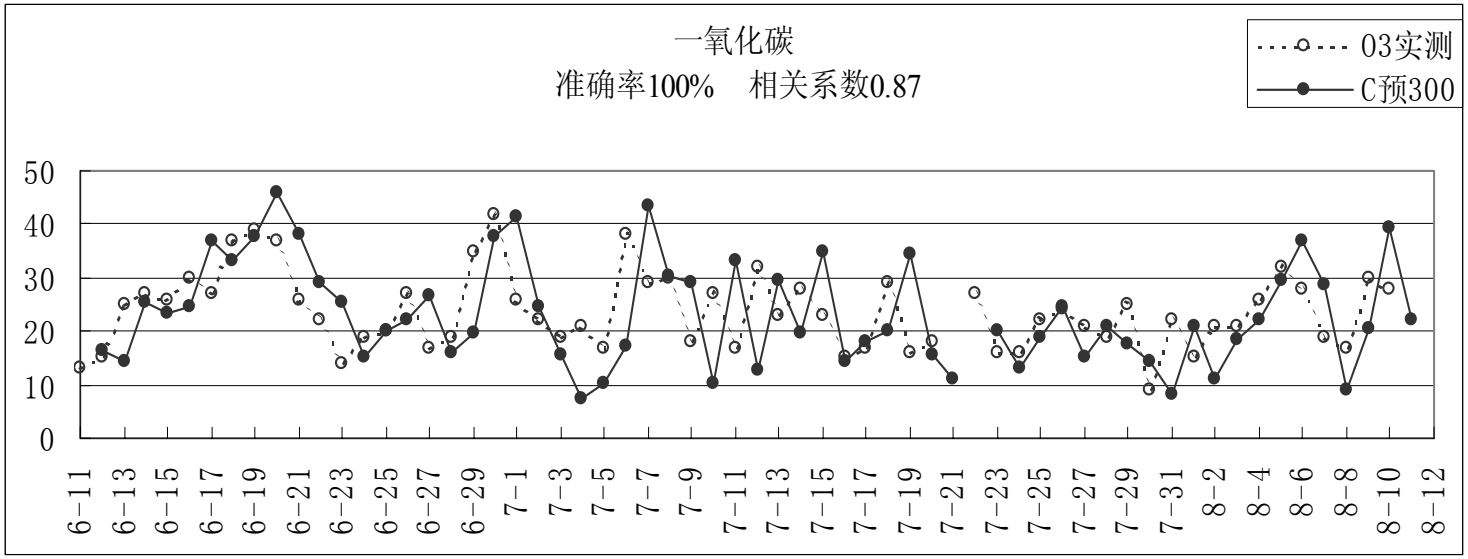
· The correlation coefficient between measurements and prediction of NO_2 (2000/06/11-2000/8/10)



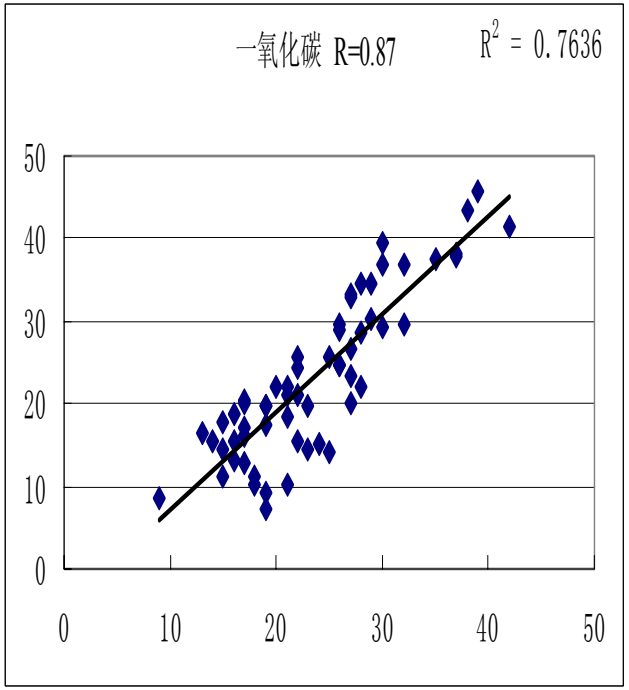
Summer

The correlation coefficient between measurements and prediction of PM10 (2000/06/11-2000/8/10)





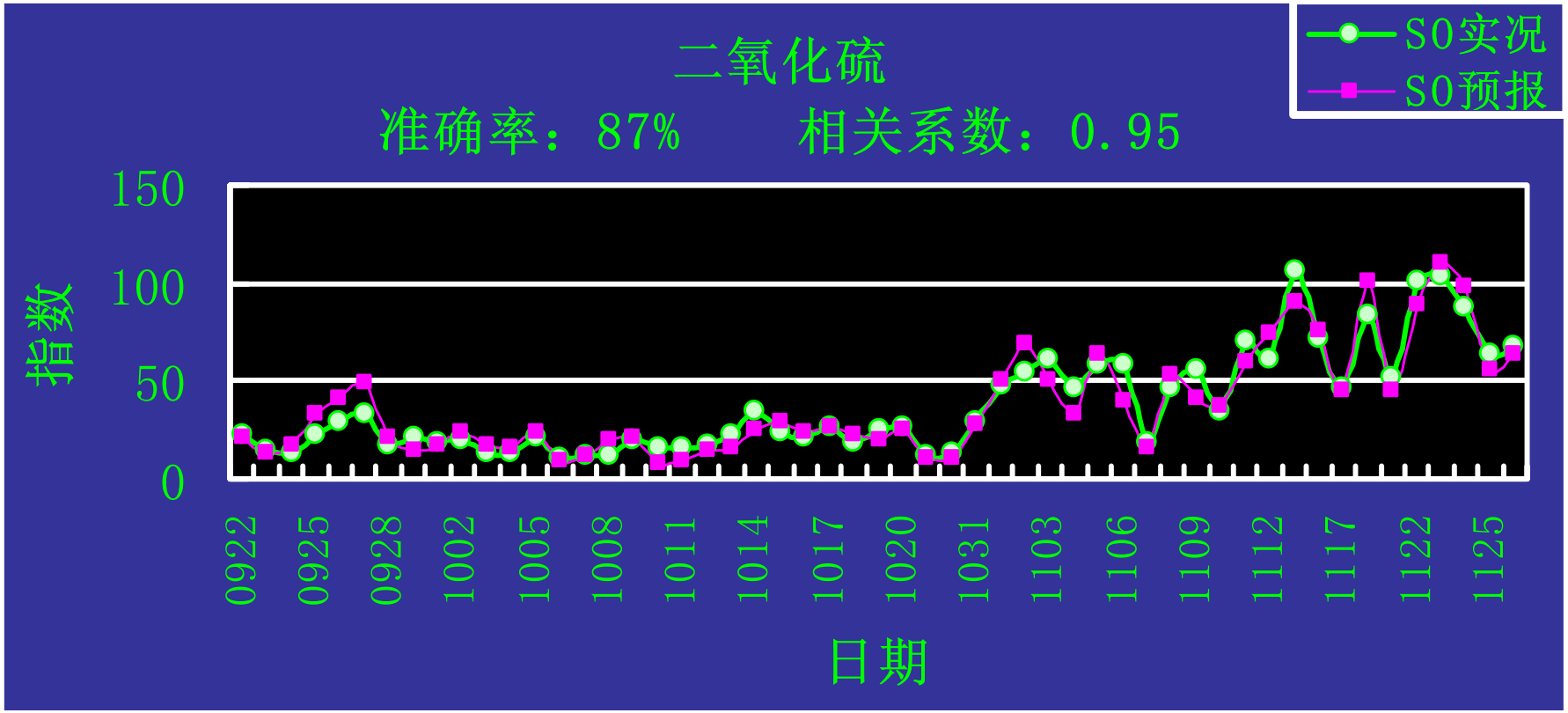
The correlation coefficient between measurements and prediction of CO (2000/06/11-2000/8/10)



Summer

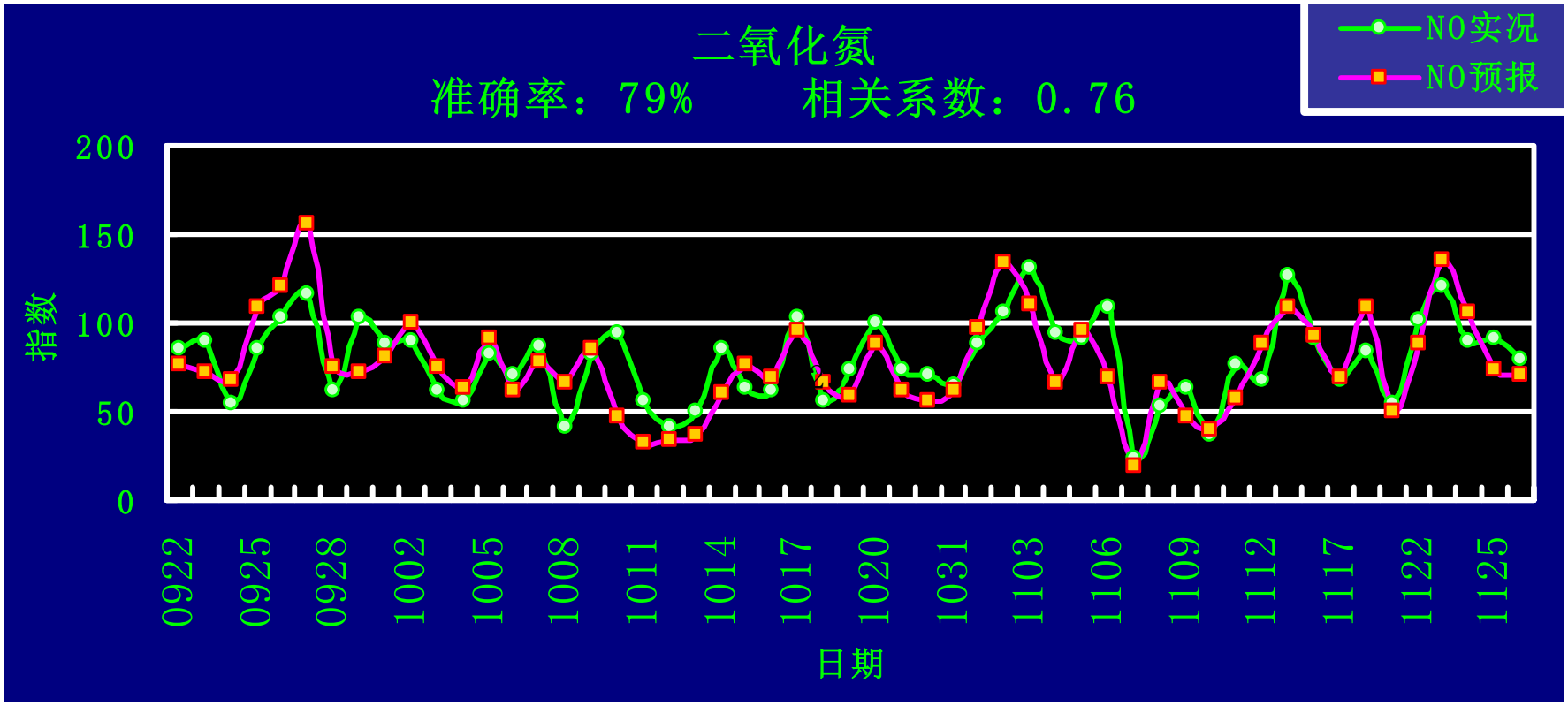
The correlation coefficient between measurements and prediction of SO2 (2000/09/22-2000/11/25)

Fall



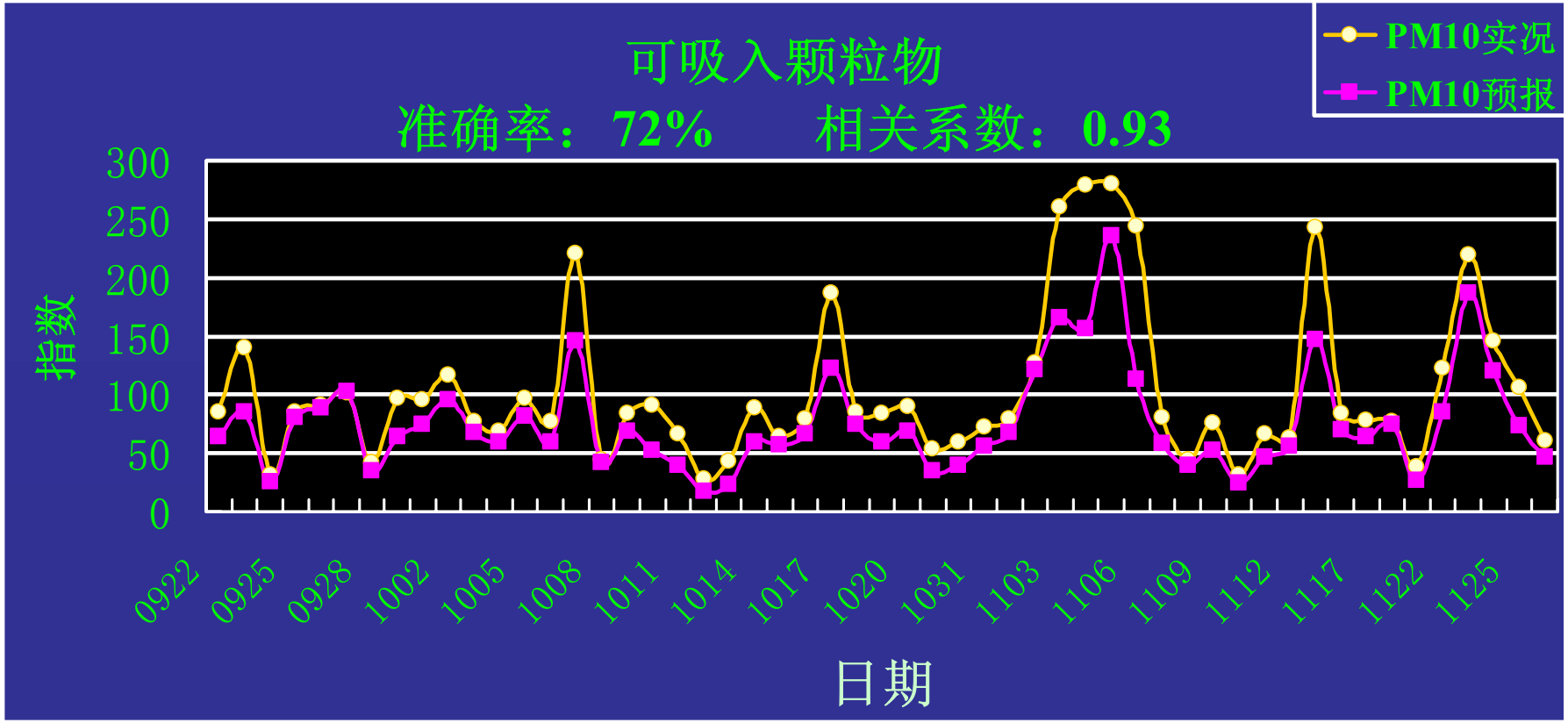
The correlation coefficient between measurements and prediction of NO2 (2000/09/22-2000/11/25)

Fall

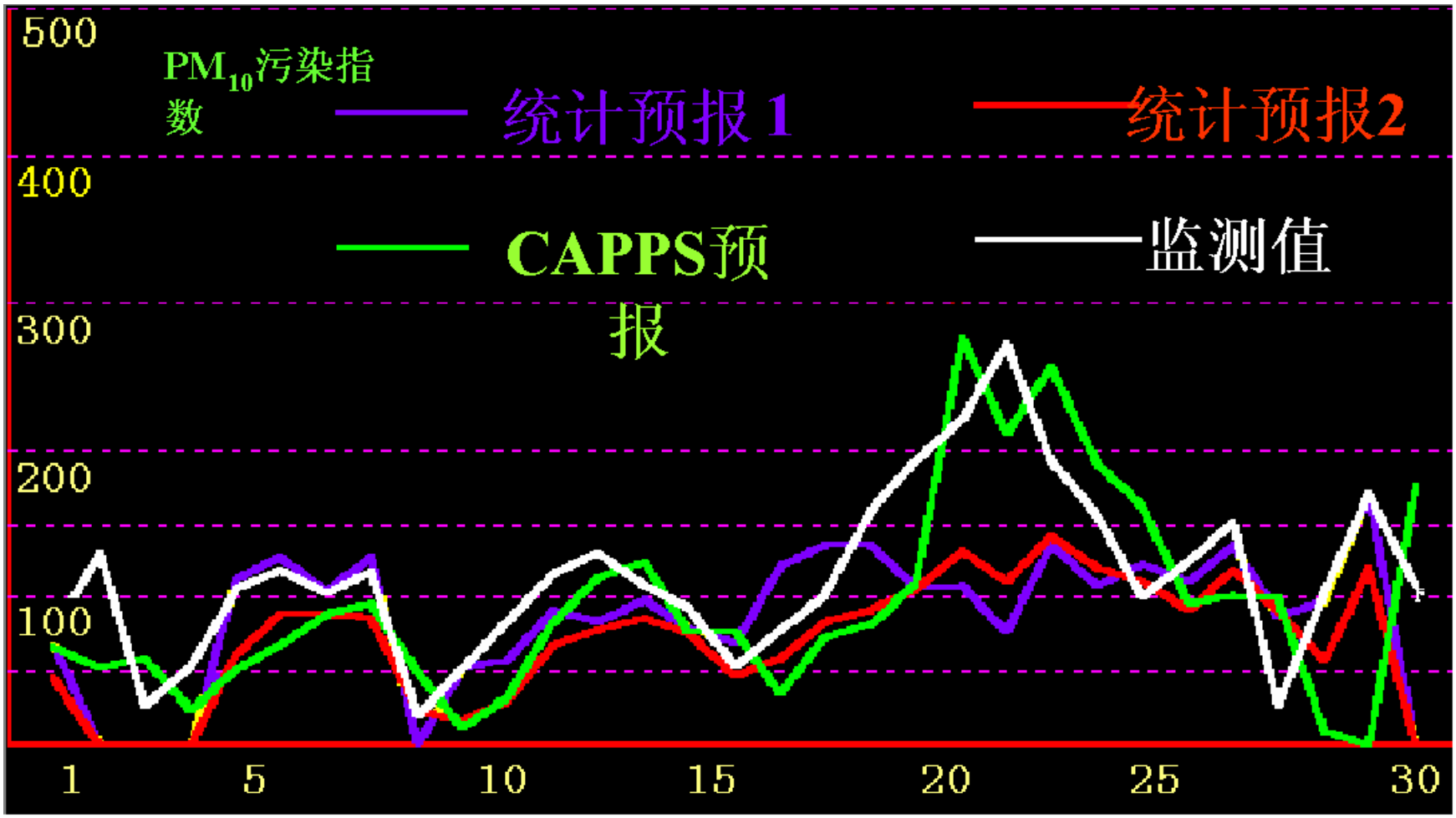


The correlation coefficient between measurements and prediction of PM10 (2000/09/22-2000/11/25)

Fall



2001/Oct/ The comparison between the prediction by statistic approach and Capps



4. Conclusion remark

For prediction of urban air quality, the simple grid-cell Prediction Model without the requirement of emission inventories is helpful.

Study in the future

- The mechanism and regulating principle about air,water and soil pollution in Beijing city and it's neighbor
- The operational system study of air pollution forecast (especially the heavy air pollution pre-warning system)
- *Photochemical model*
- Need high resolution atmospheric - chemistry model ---emission inventory