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Afforestation For Valley Urban Air Pollution Control

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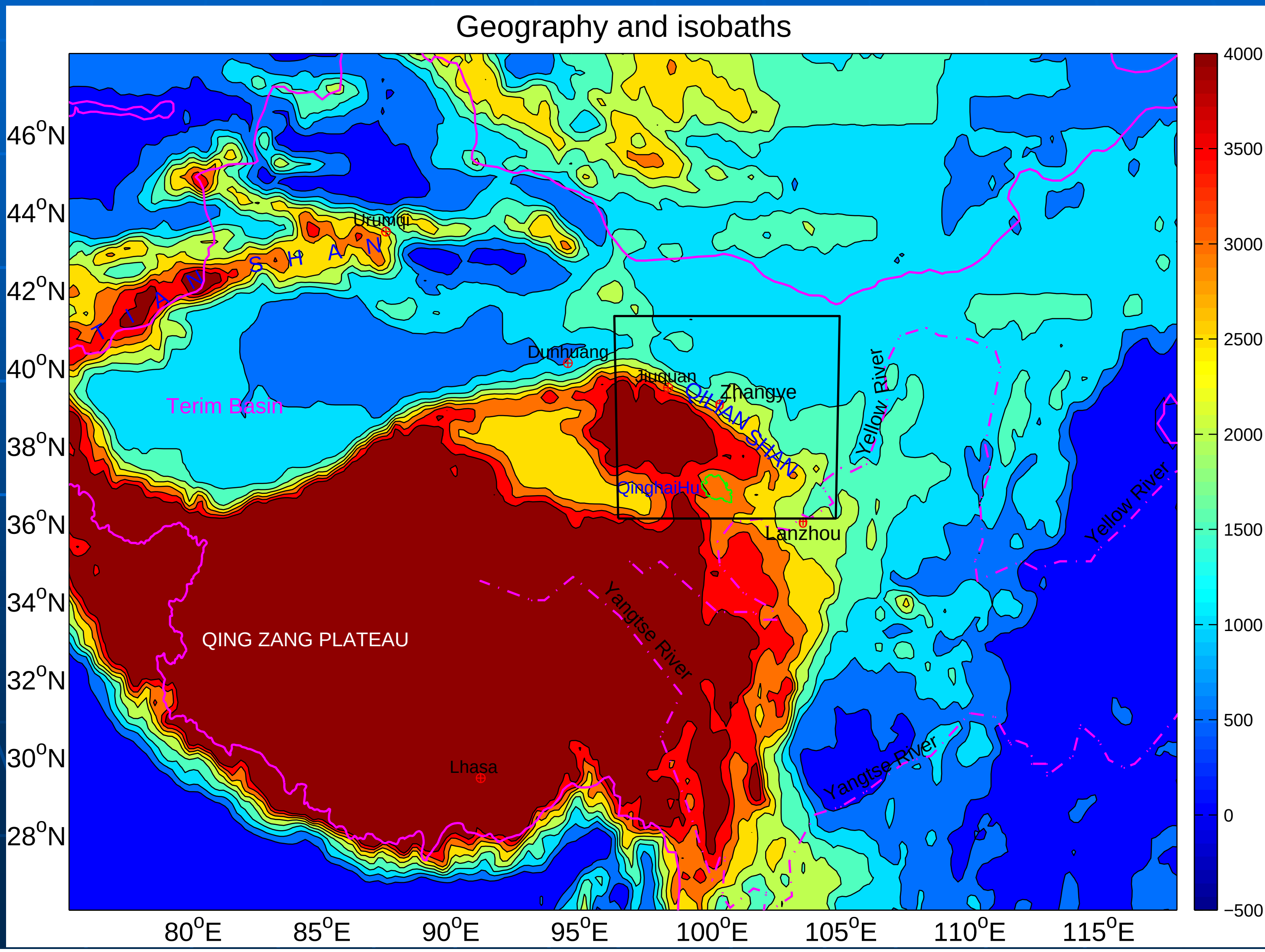
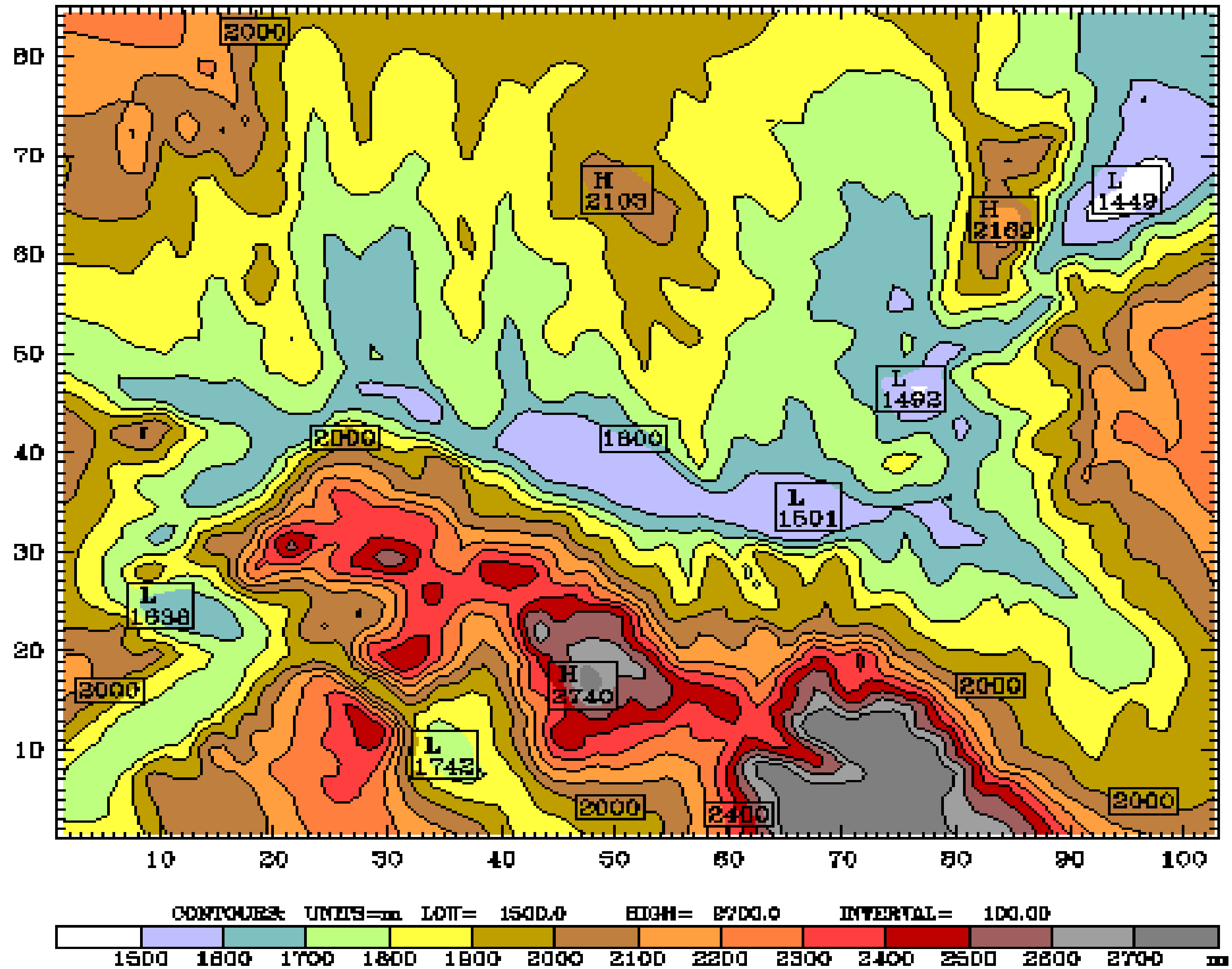


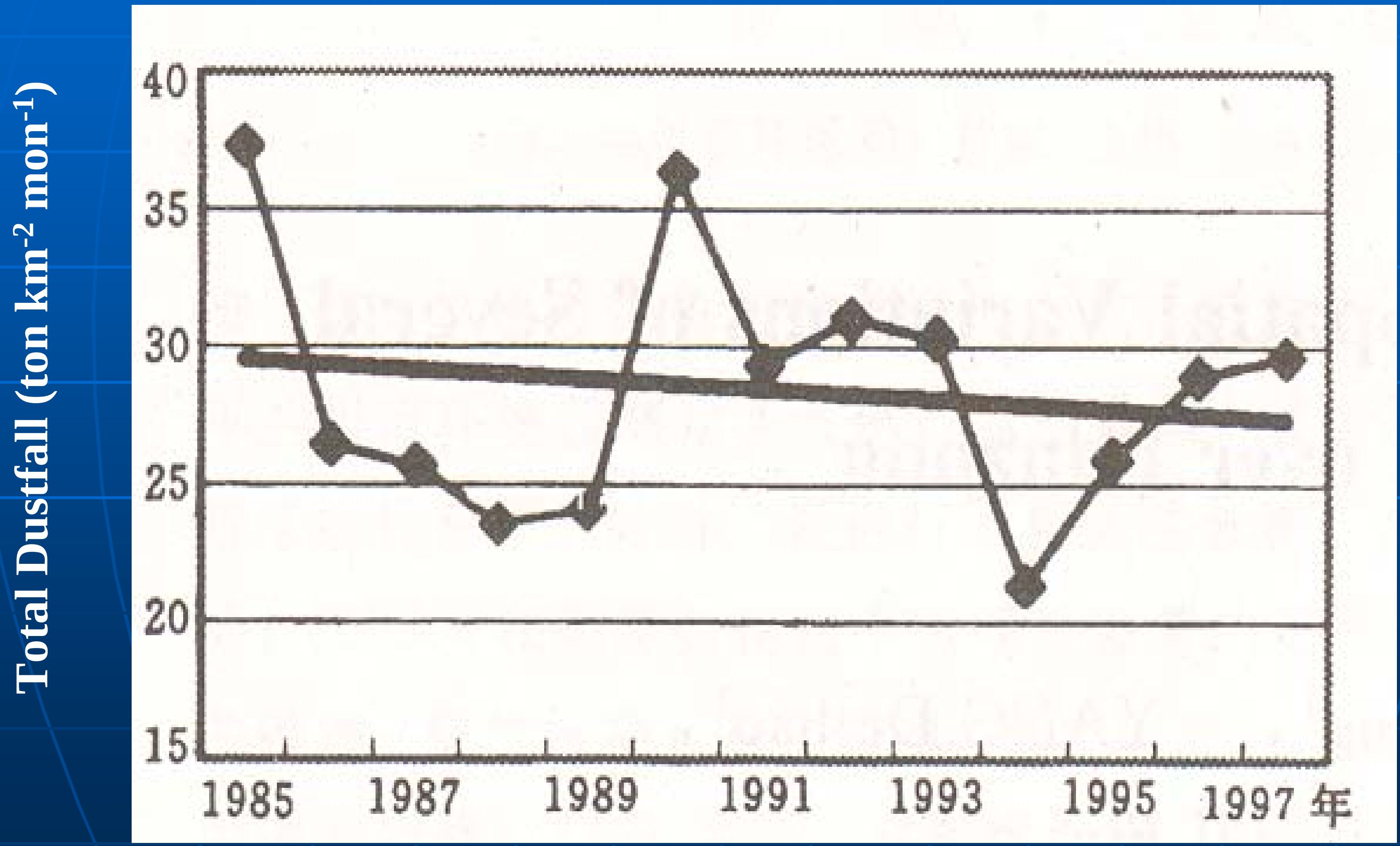
Topography around Langzhou



Lanzhou – One of the Most Polluted Cites in China

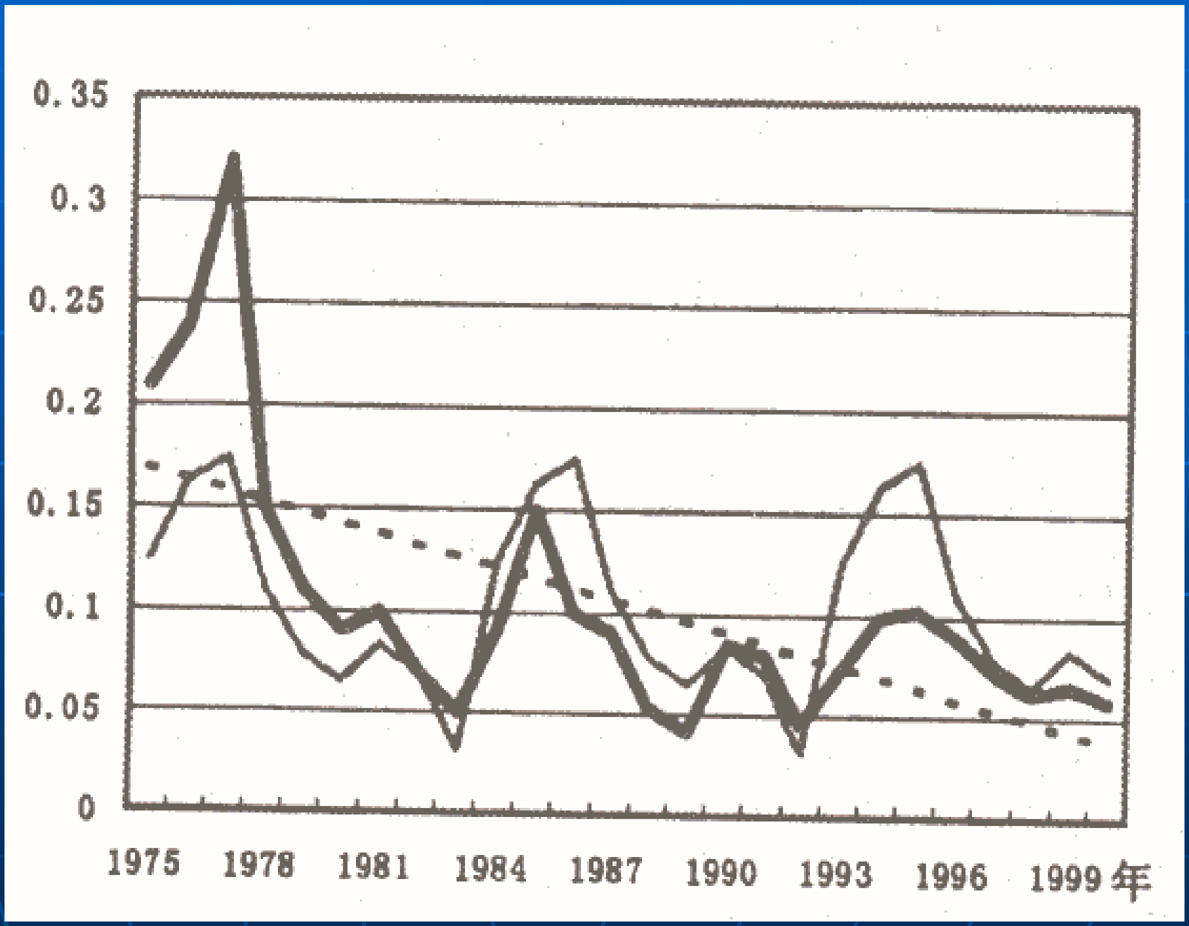
In the past two decades, the air pollution problem has been improved.

Total Dustfall Trend in Lanzhou (Wang et al. 2001)



SO^2 Trend in Lanzhou
(Wang et al., 2001)

SO² Concentration (mg/m³)

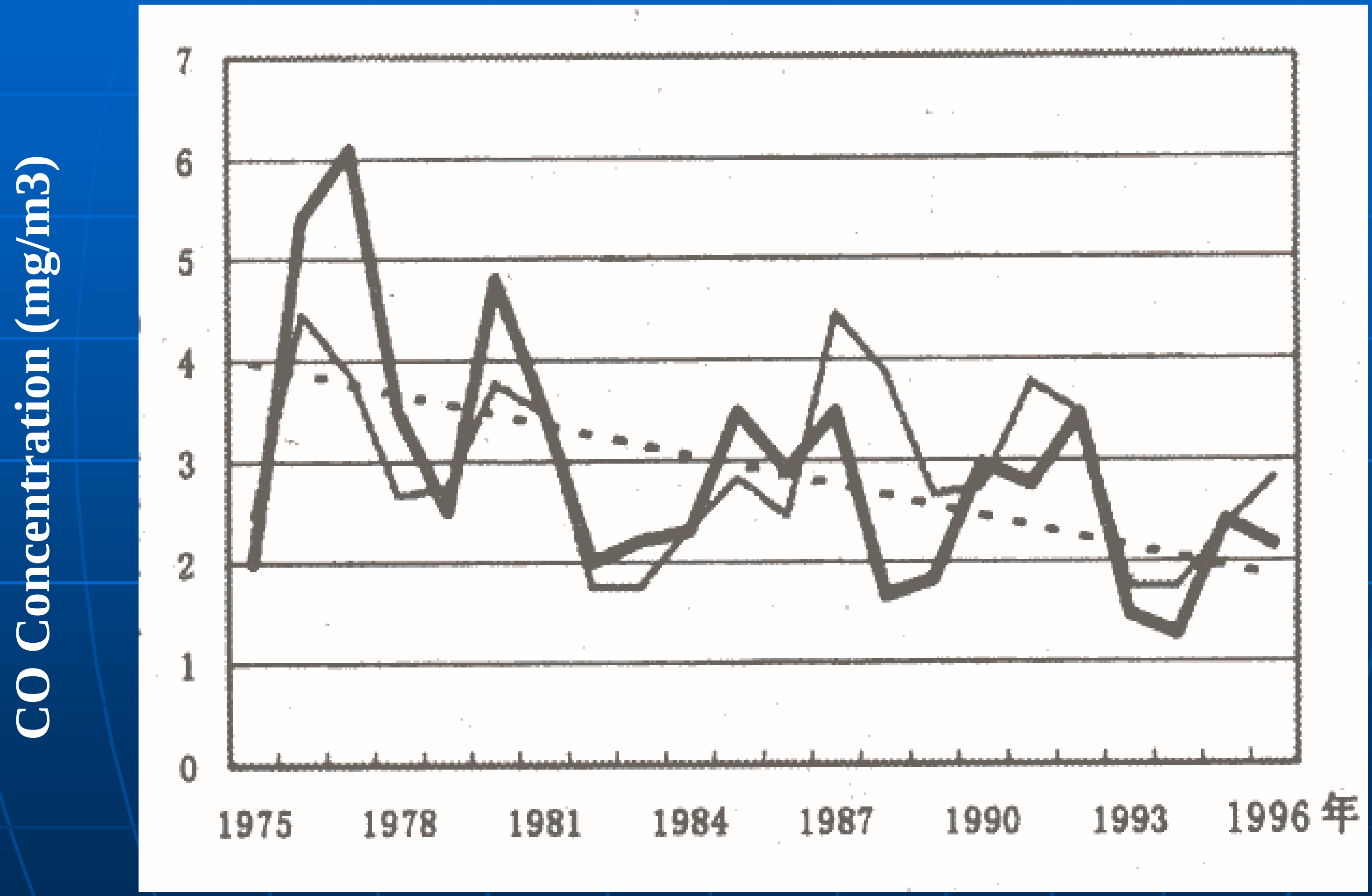


Bold solid curve - the observed data

Thin solid curve – main period, dashed line - trend

CO Trend in Lanzhou

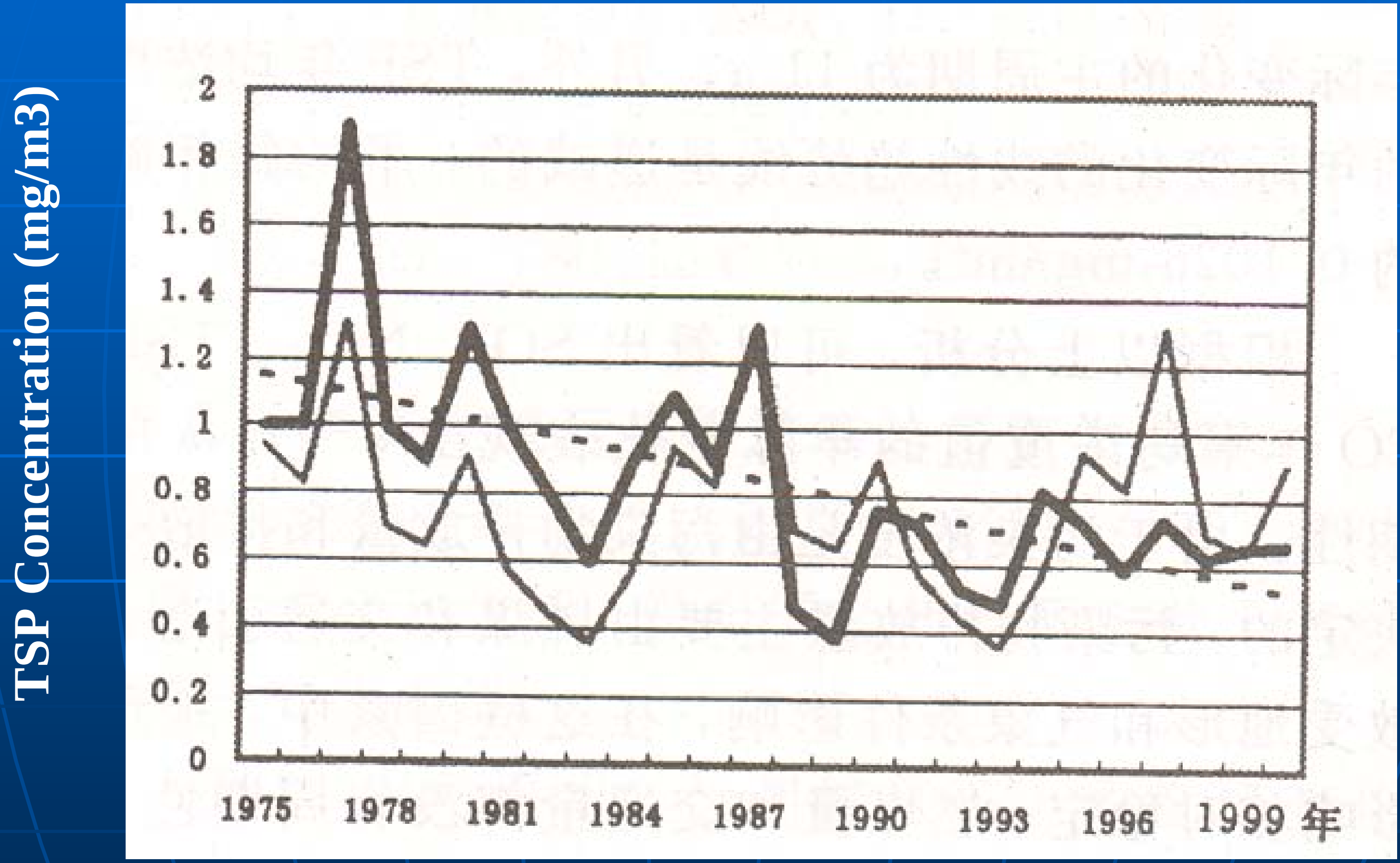
(Wang et al., 2001)



Bold solid curve - the observed data

Thin solid curve – main period, dashed line - trend

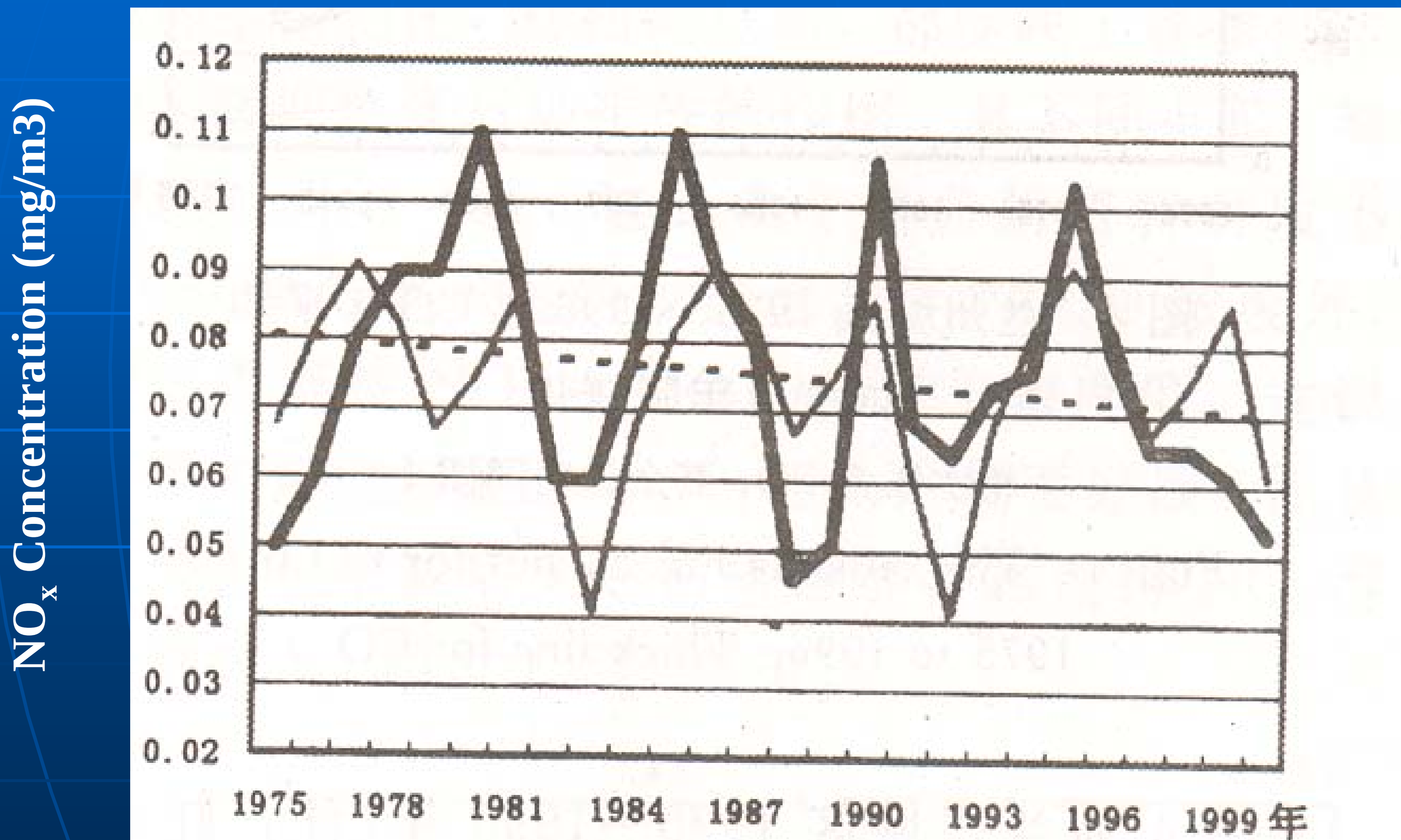
TSP Trend in Lanzhou
(Wang et al., 2001)



Bold solid curve - the observed data
Thin solid curve – main period, dashed line - trend

NO_x Trend in Lanzhou

(Wang et al., 2001)



Bold solid curve - the observed data

Thin solid curve – main period, dashed line - trend

Factors Affecting Air Quality

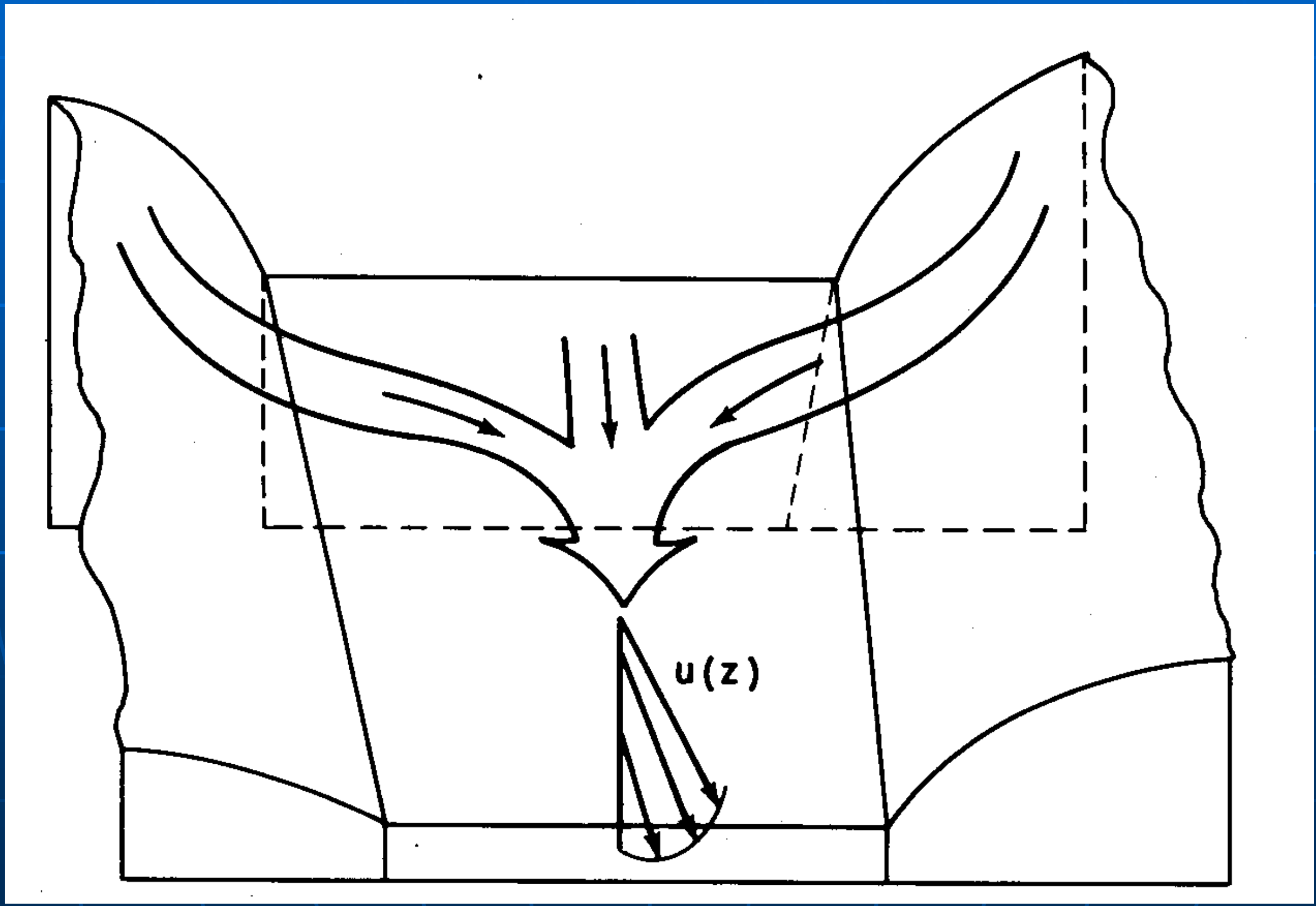
- Meteorological Conditions

  Stable stratification especially Inversion

  Low Winds

- Pollution Sources

Mountain-Valley Wind (at Night)



Three Major Tasks in Controlling Air Pollution

- Change Meteorological Conditions (Weakening the Inversion)
- Create Pollutant-Sinks
- Reduce the Pollutant Source-Level

Weakening of the Inversion

- Mountain-slope forestation weakens the mountain-valley circulation and in turn weakens the inversion.

Mountain Slope Afforestation

- Weakens the Inversion
- Creates Pollutant-Sinks

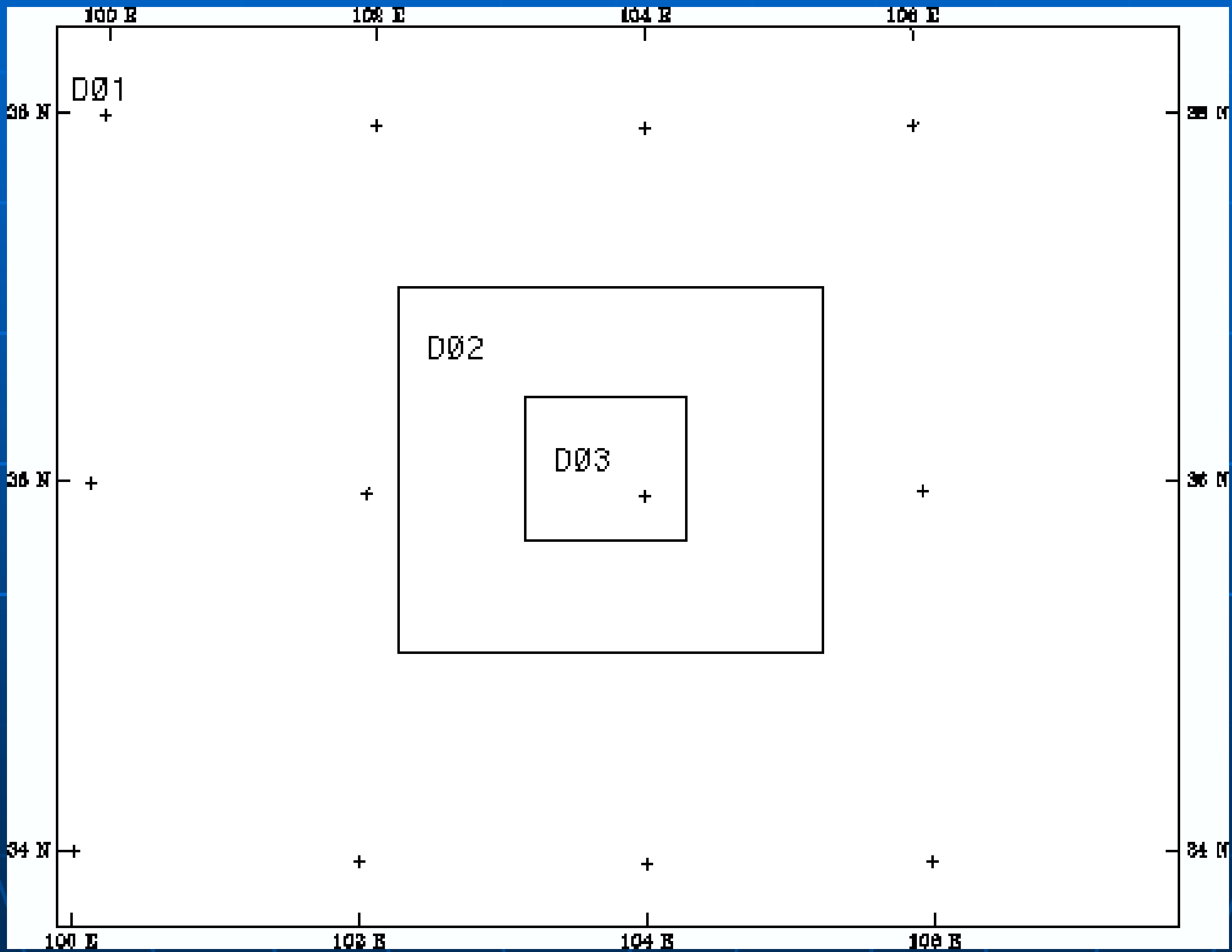
Model Simulation

- Effect of Mountain Slope Forestation Using Regional Atmospheric Modeling System (RAMS)

Model Description

- Nonhydrostatic
- Multi-grid System: 9 km, 3 km, 1 km
- 23 vertical levels, to 50 hPa
- 30”- Topography data
- Assimilation of observational data
- Land surface model
- Integration area: 720 km (E-W), 540 km (N-S)
  Centered at 103.8^{o}E, 36.1^{o}N

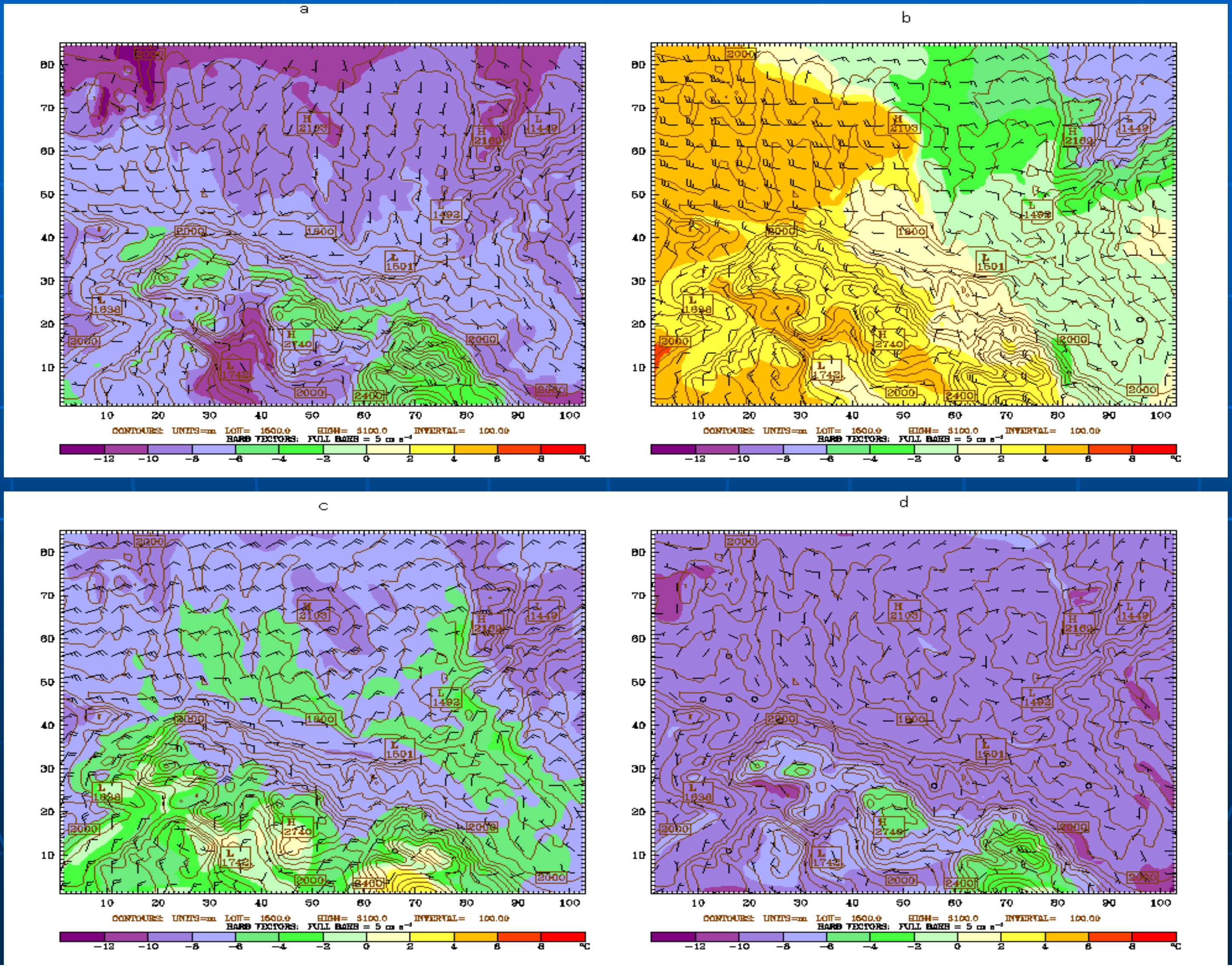
Multi-Grid System



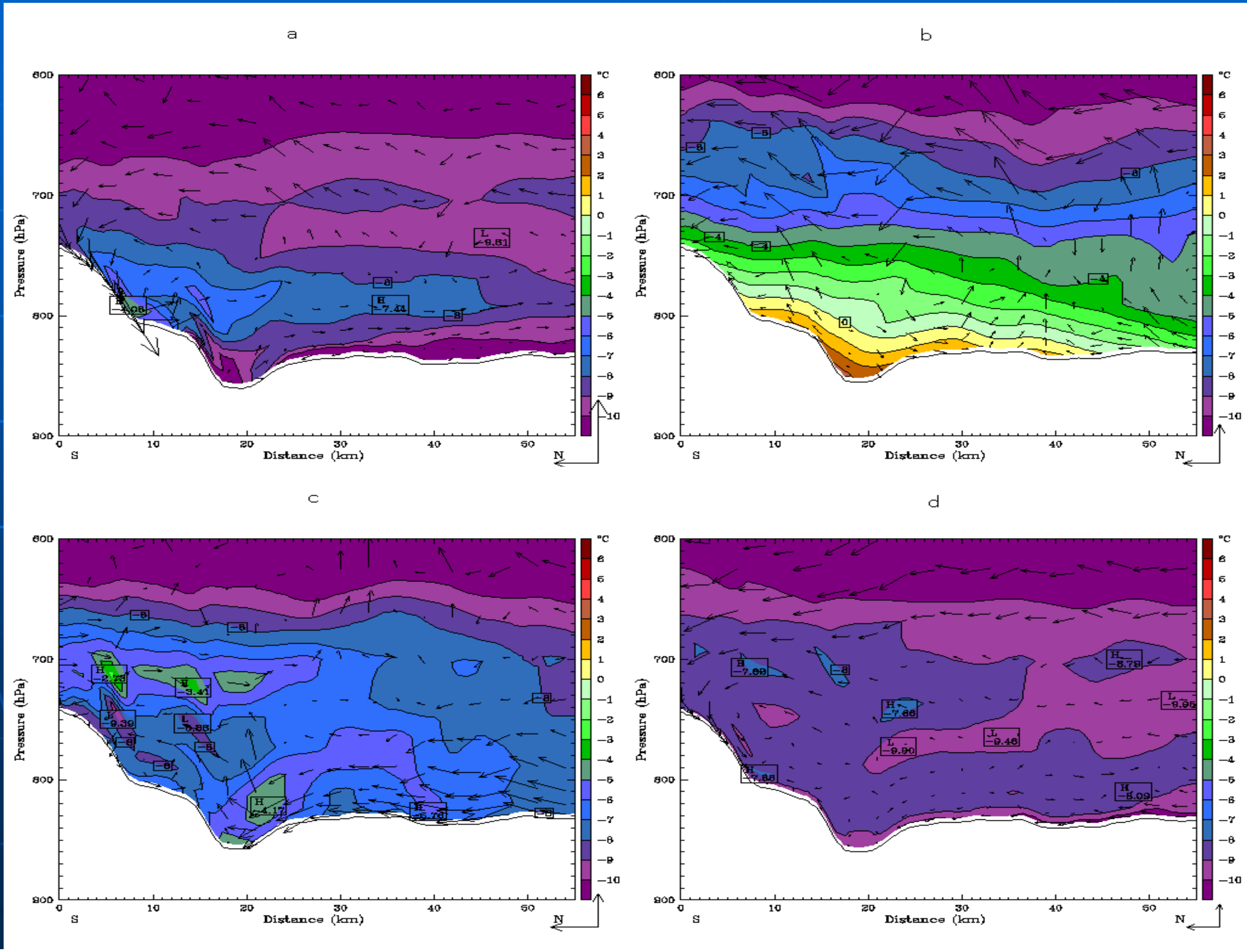
Model Integration – Control Run

- Winter Simulation (Dec 5 – 7, 2000)
- Initial Time: 08 BT, Dec 5, 2000
- Initial Conditions (NCEP Reanalysis)
- Lateral Boundary for the Largest Area (Every Six Hours, NCEP Reanalysis)
- Δt: 60 s, 30 s, 10 s

Simulated Wind and Temperature Fields at 800 hPa on: (a) 08, (b)14, (c) 20, (d) 02 BT



Simulated (v, w) and T in the north-south cross-section across the GaoLanShan Mountain on: (a) 08, (b)14, (c) 20, (d) 02 BT



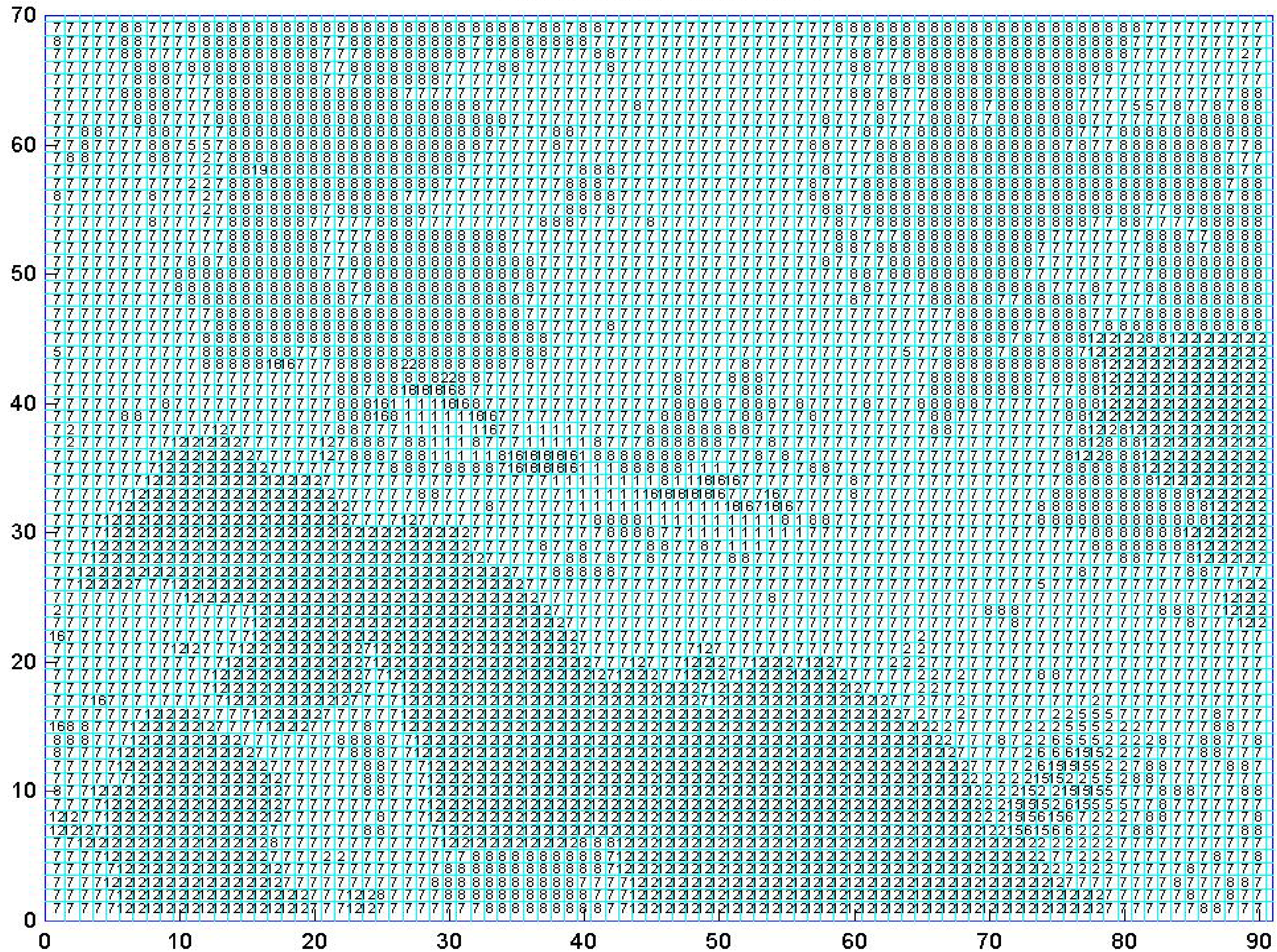
Three Types of Afforestation

- Green-A: All area above 2100 m
- Green-B: Northern Mountain (below 1800 m) and Valley
- Green-C: Northern and Southern Mountains (below 2200 m) with 40 km (E-W) x 26 km (N-S) and centered at Lanzhou

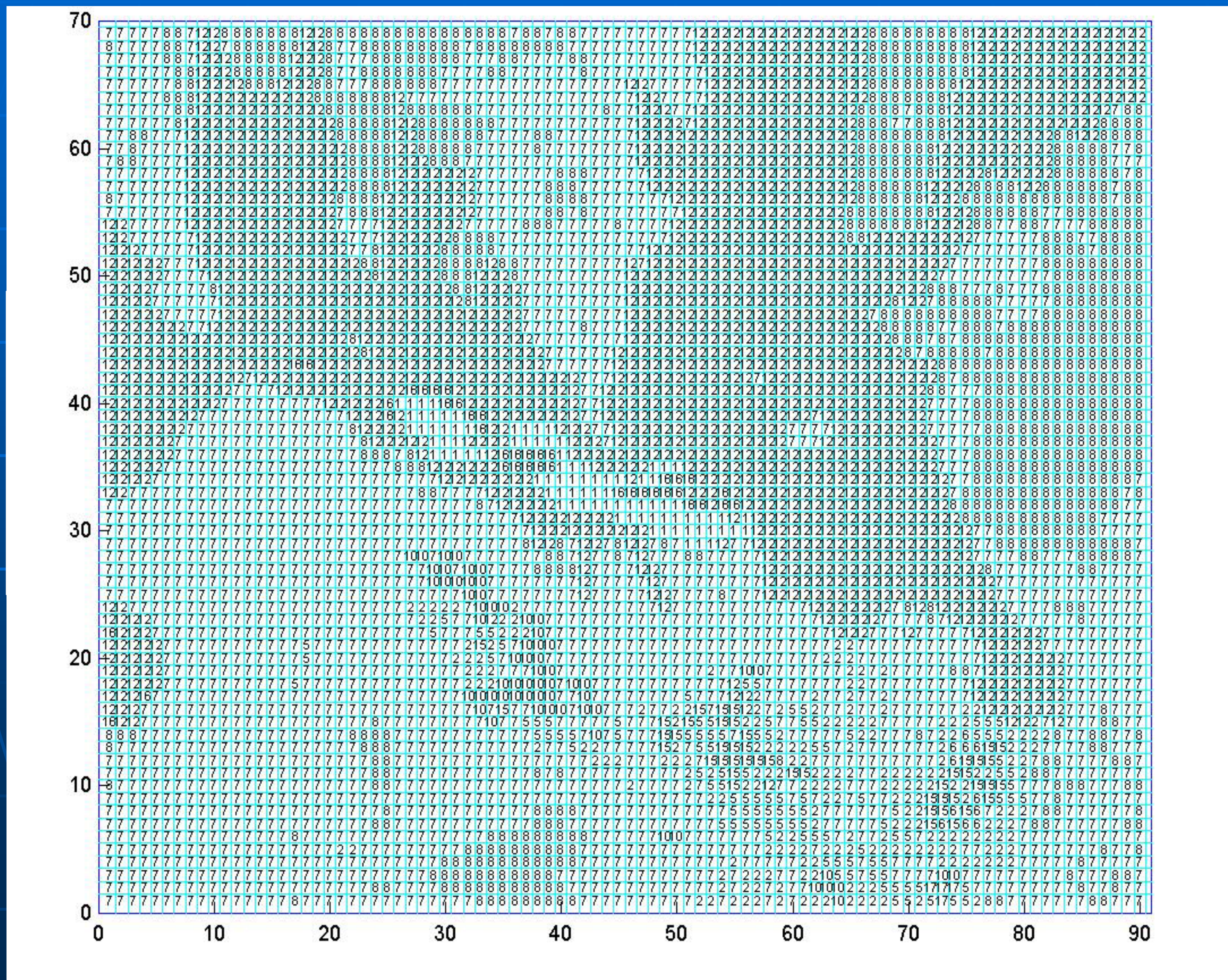
USGS Vegetation 25-Category

- 1 – Urban
- 2 – Drylnd Crop. Past.
- 3 – Irrg. Crop. Past.
- 4 – Mix. Dry/Irrg. C.P.
- 5 – Crop/Grs. Mosaic
- 6 – Crop./Wood Mosc
- 7 – Grassland
- 8 – Shrubland
- 9 – Mix. Shrb./Grs.
- 10 – Savanna
- ……….

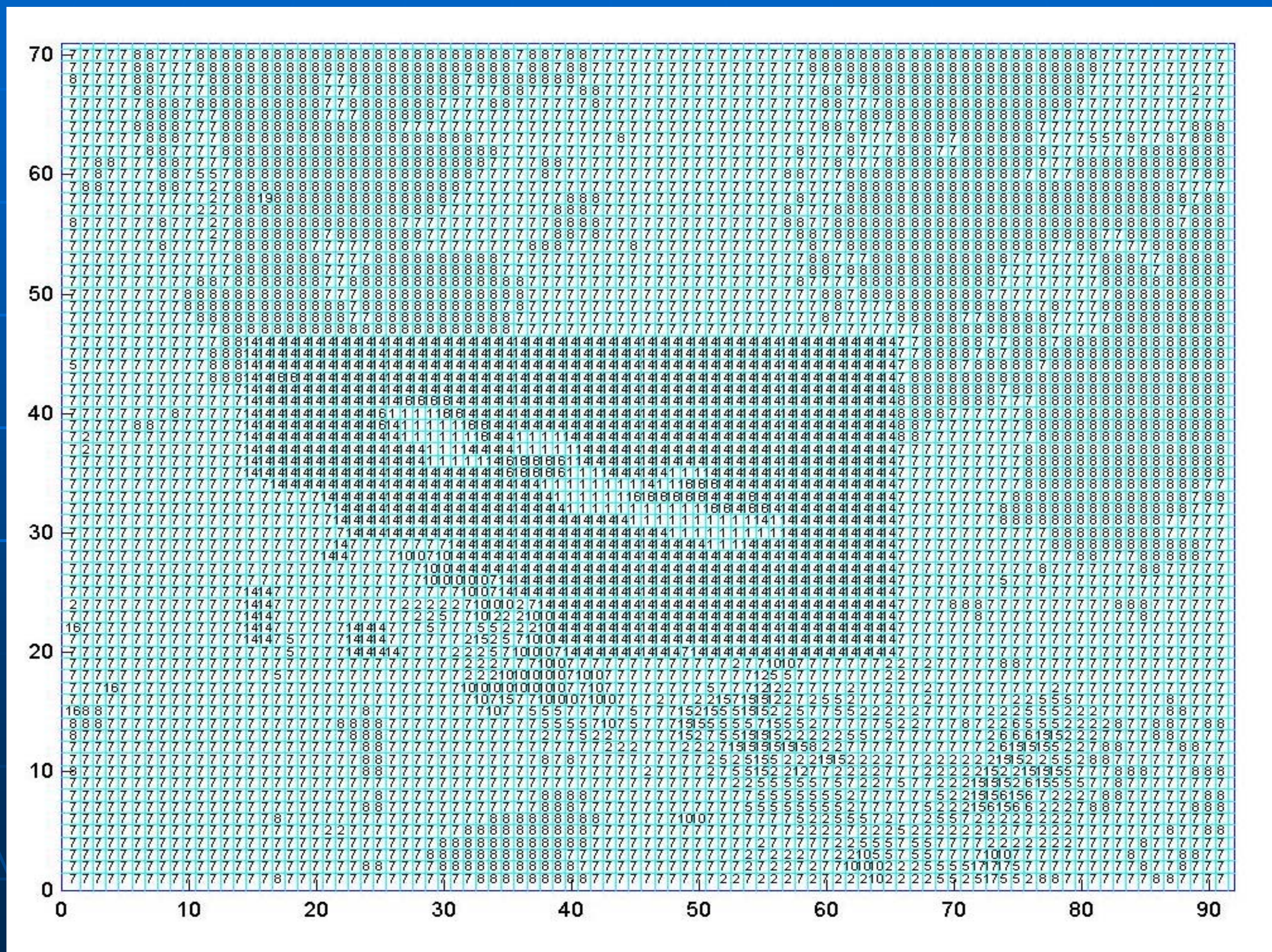
Green-A



Green-B

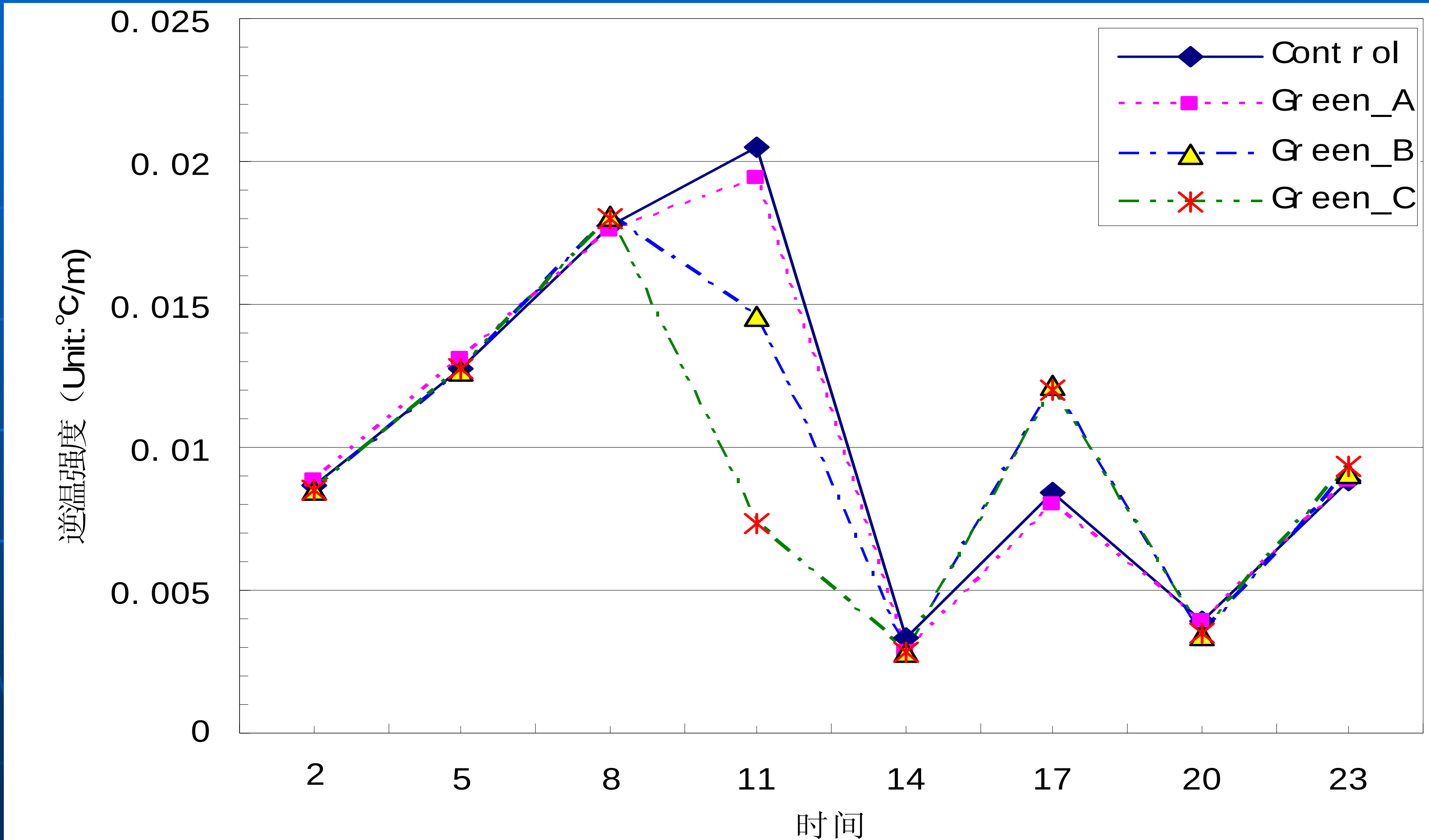


Green-C



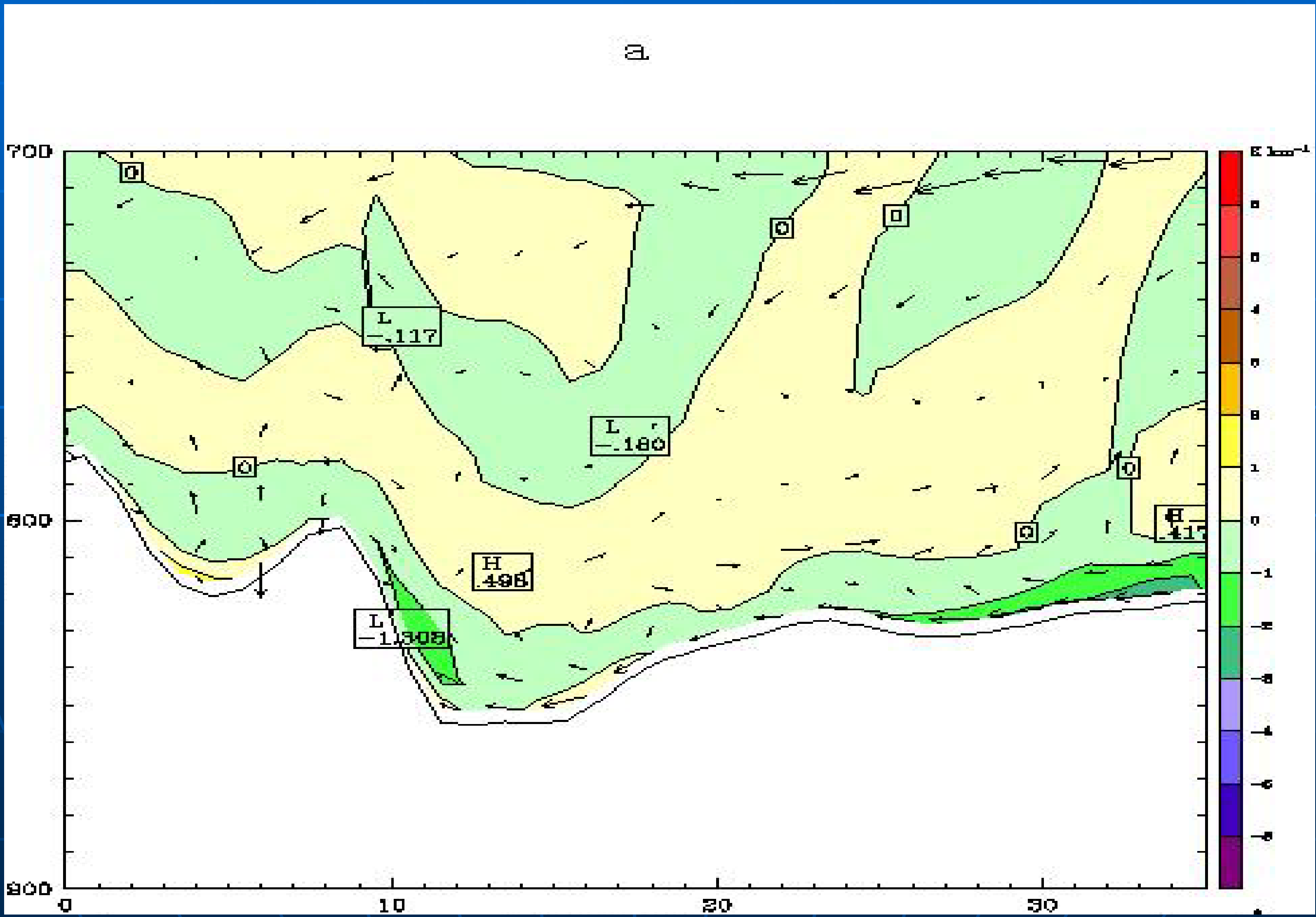
Reduction of Inversion Strength

Inversion Strength (unit: °C/m)

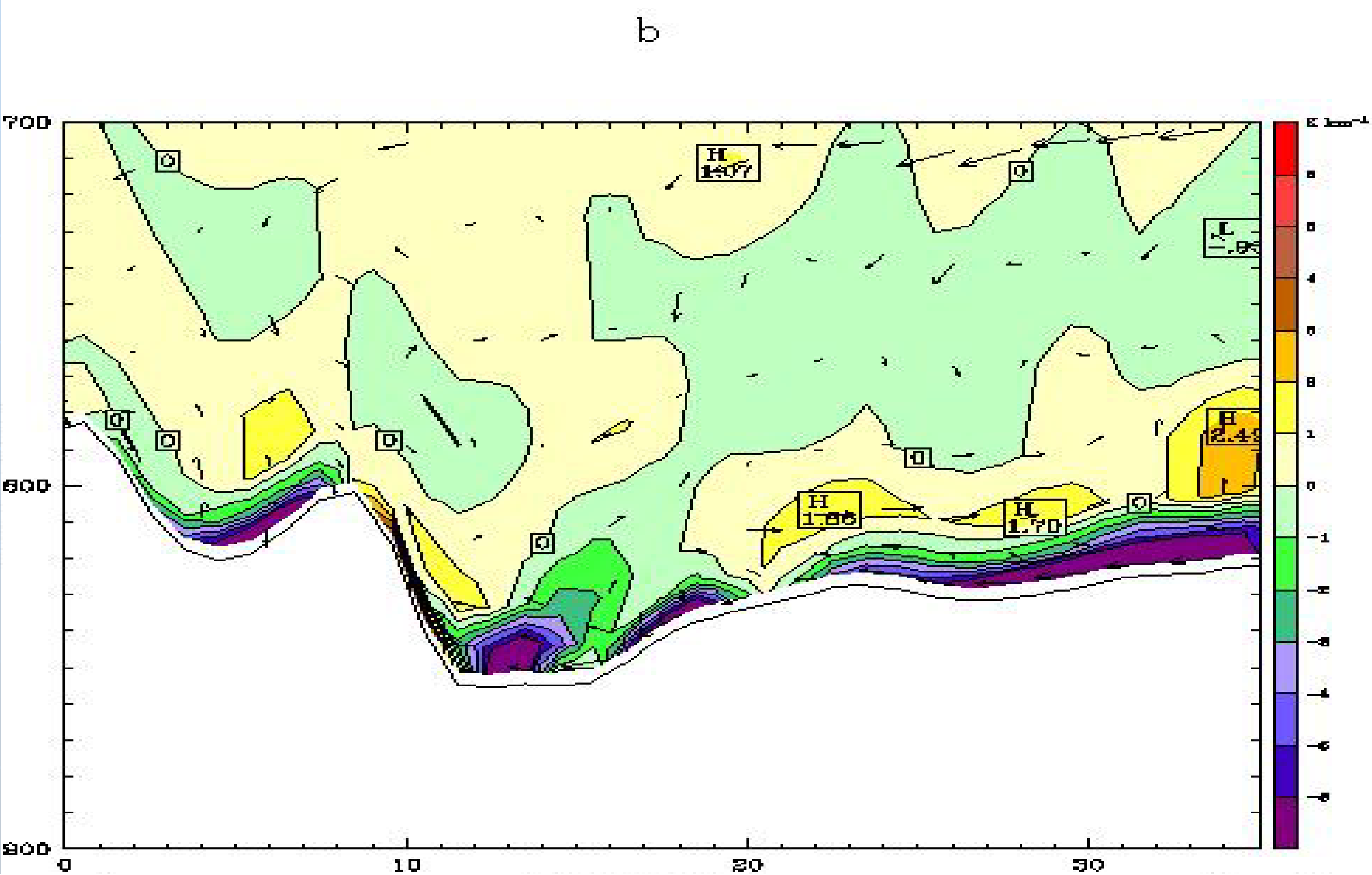


Time (BT)

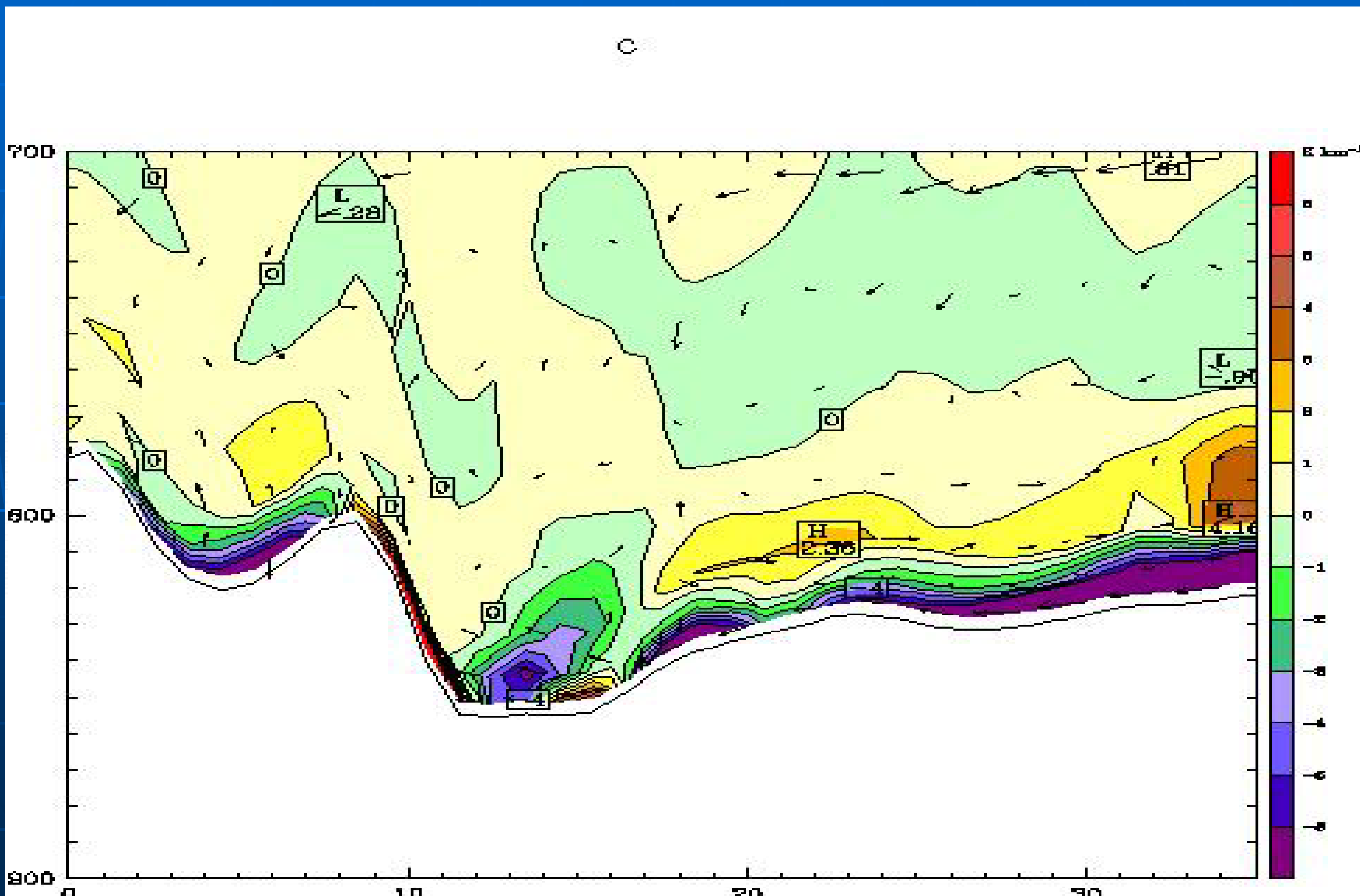
Reduction of Stability (Lapse Rate) ($^oC/m$)
Green-A minus Control



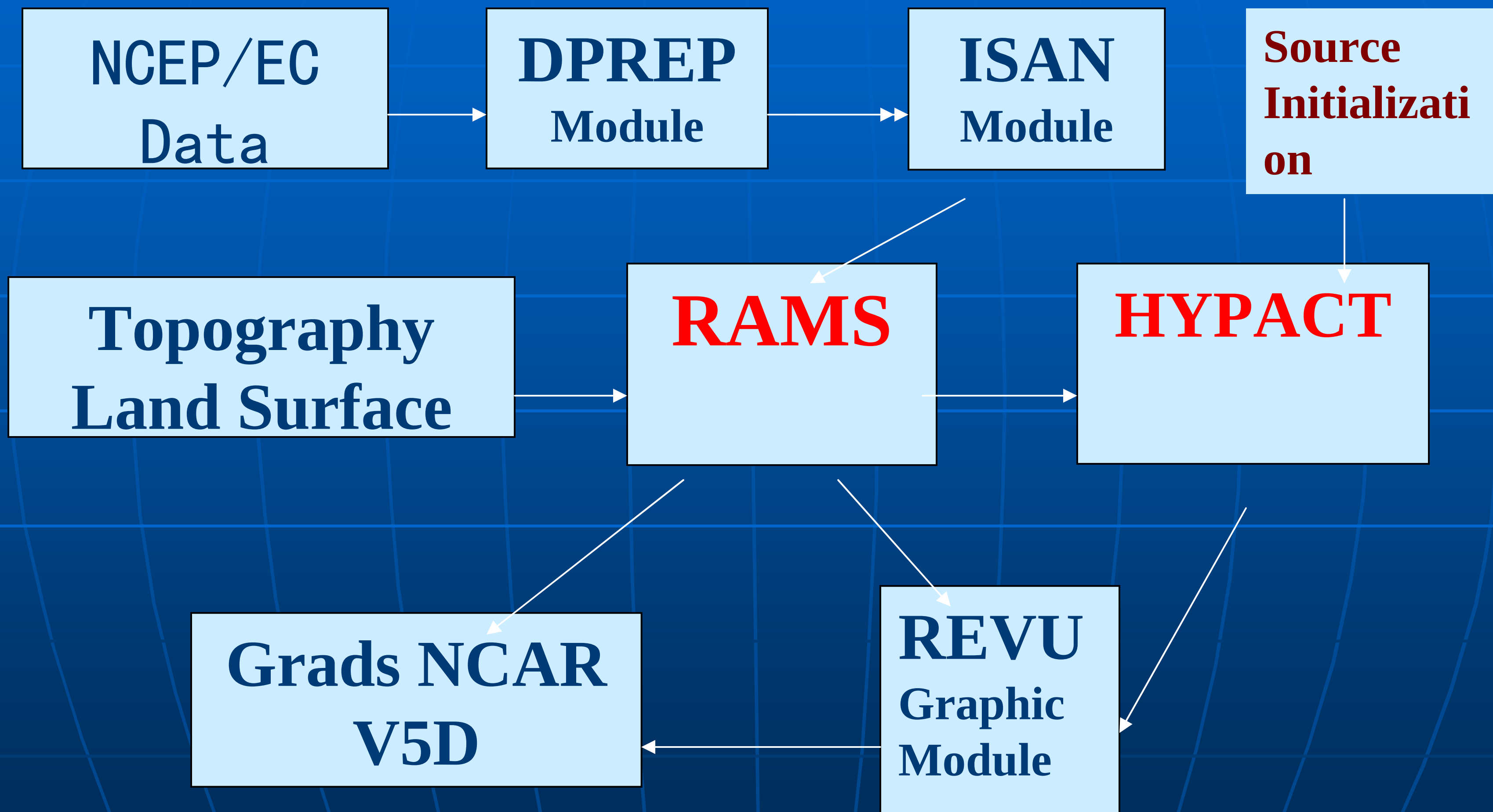
Reduction of Stability (Lapse Rate) (°C/m) Green-B minus Control



Reduction of Stability (Lapse Rate) (°C/m)
Green-C minus Control



Coupled RAMS-NYPACT Model



Lagrange Method

$$X(t+\Delta t) = X(t) + (u + u')\Delta t$$

$$Y(t+\Delta t) = Y(t) + (v + v')\Delta t$$

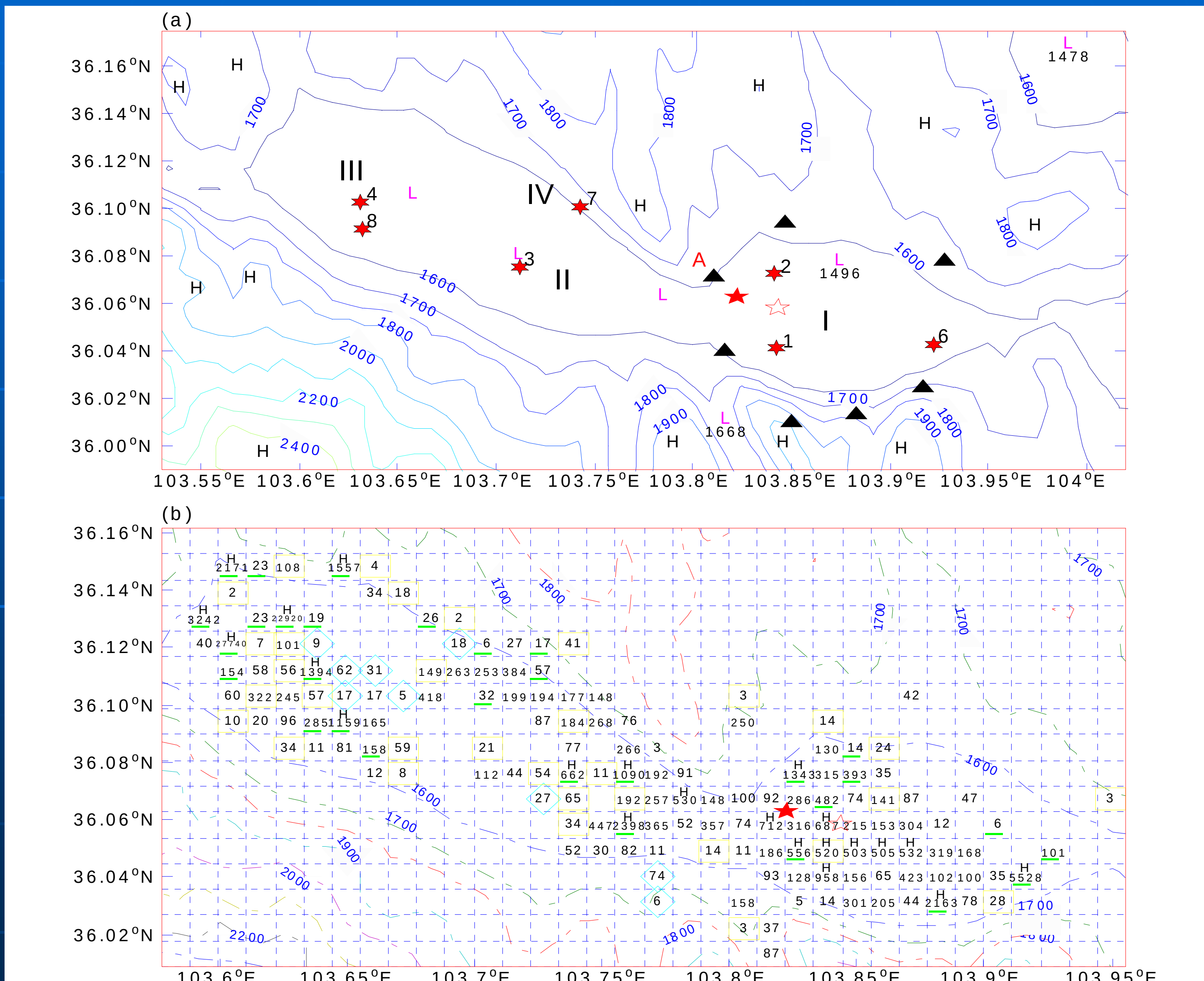
$$Z(t+\Delta t) = Z(t) + (w + w' + w_p)\Delta t$$

(u,v, w) on Grid

(u',v', w') on Subgrid （Turbulence)

w_p Vertical Velocity caused by external forcing

Topography and TSP Sources in 2000 (1000 kg) in Lanzhou (a Valley City)



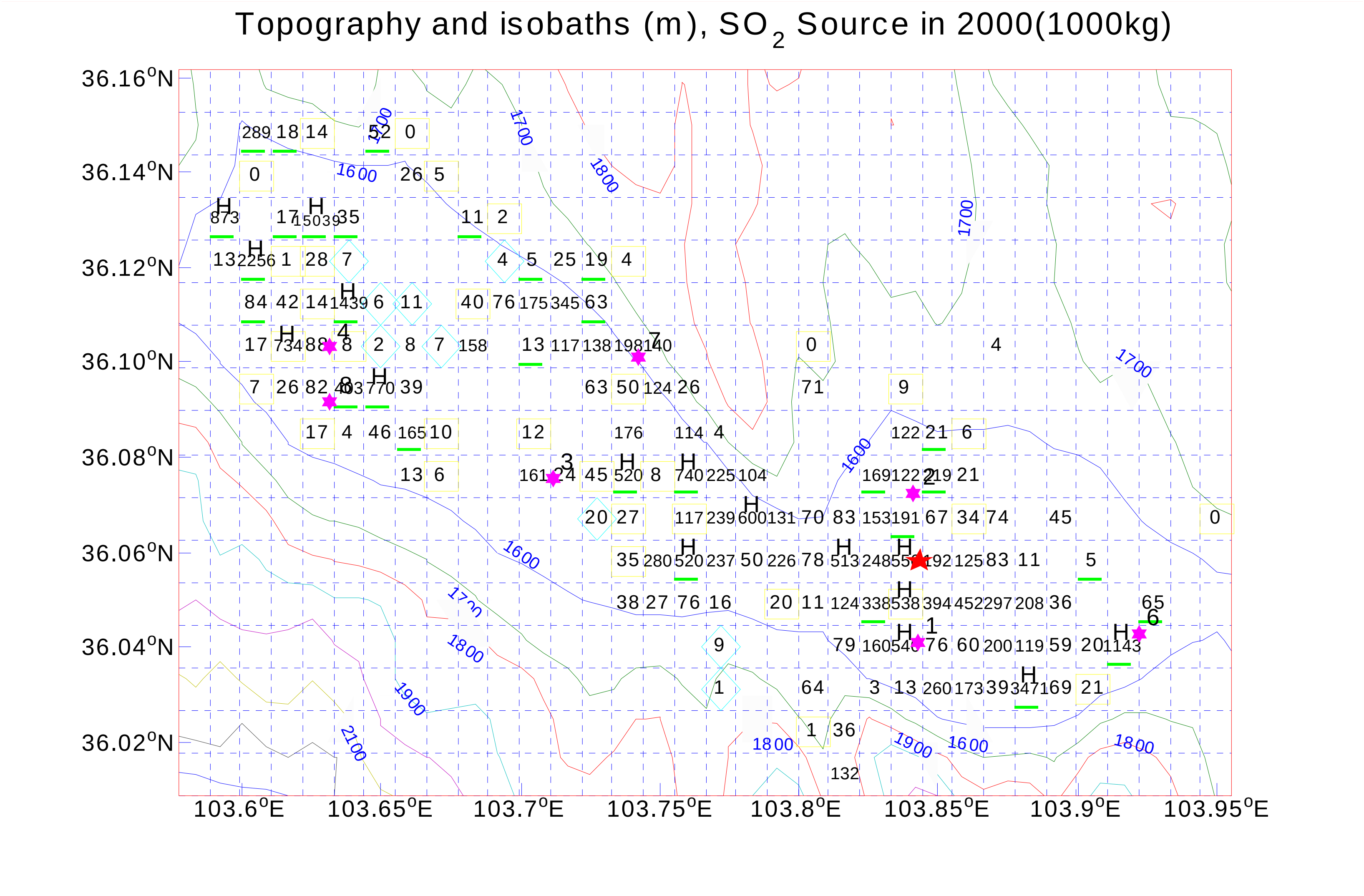
(a) Seven Stations (six-angle star)

(b) TSP Sources

◇ Industrial

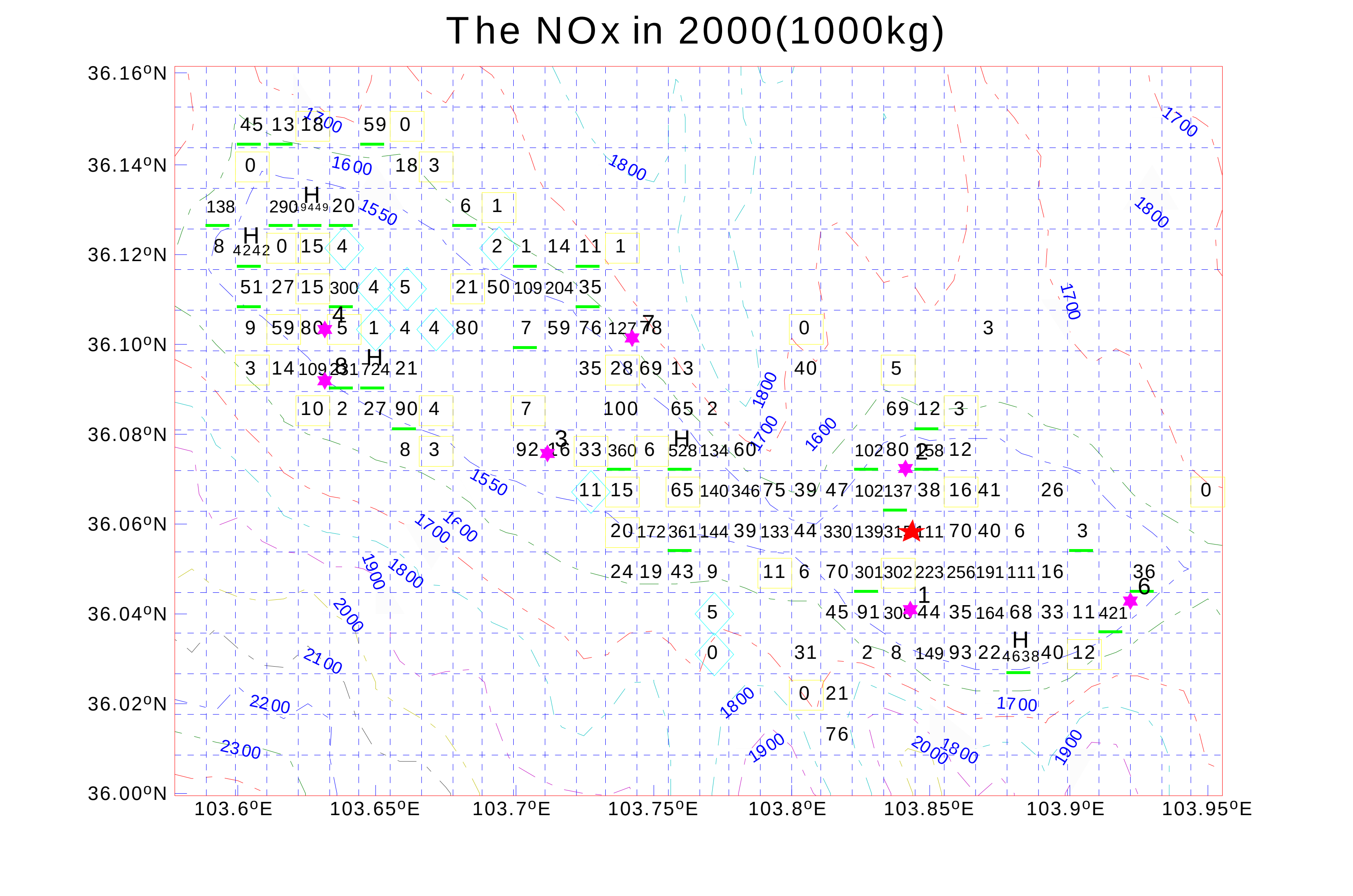
□ Residential

SO_2 –Sources in 2000 (1000kg)



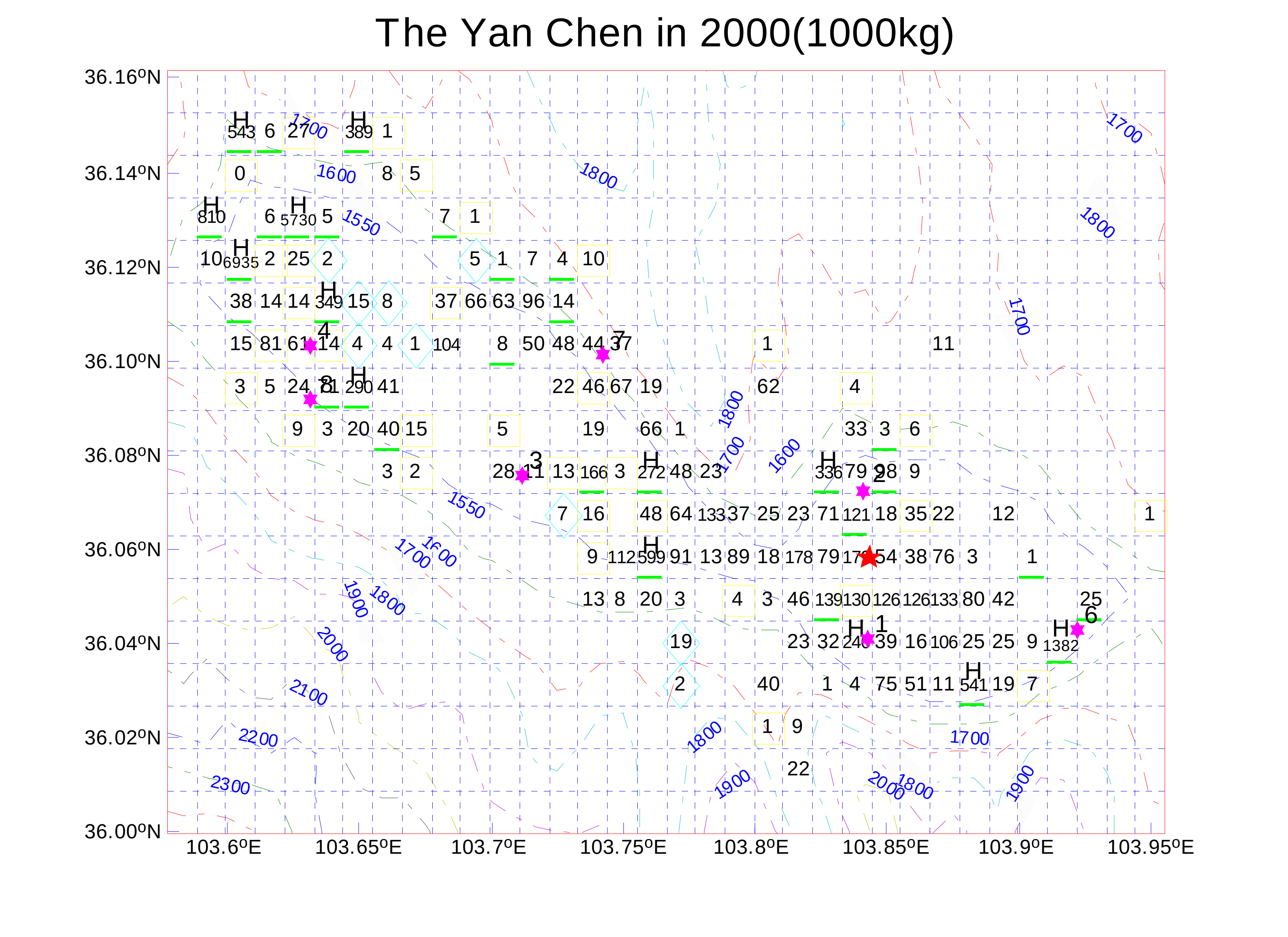
◇ Industrial □ Residential

NO_x Sources in 2000 (1000 kg)



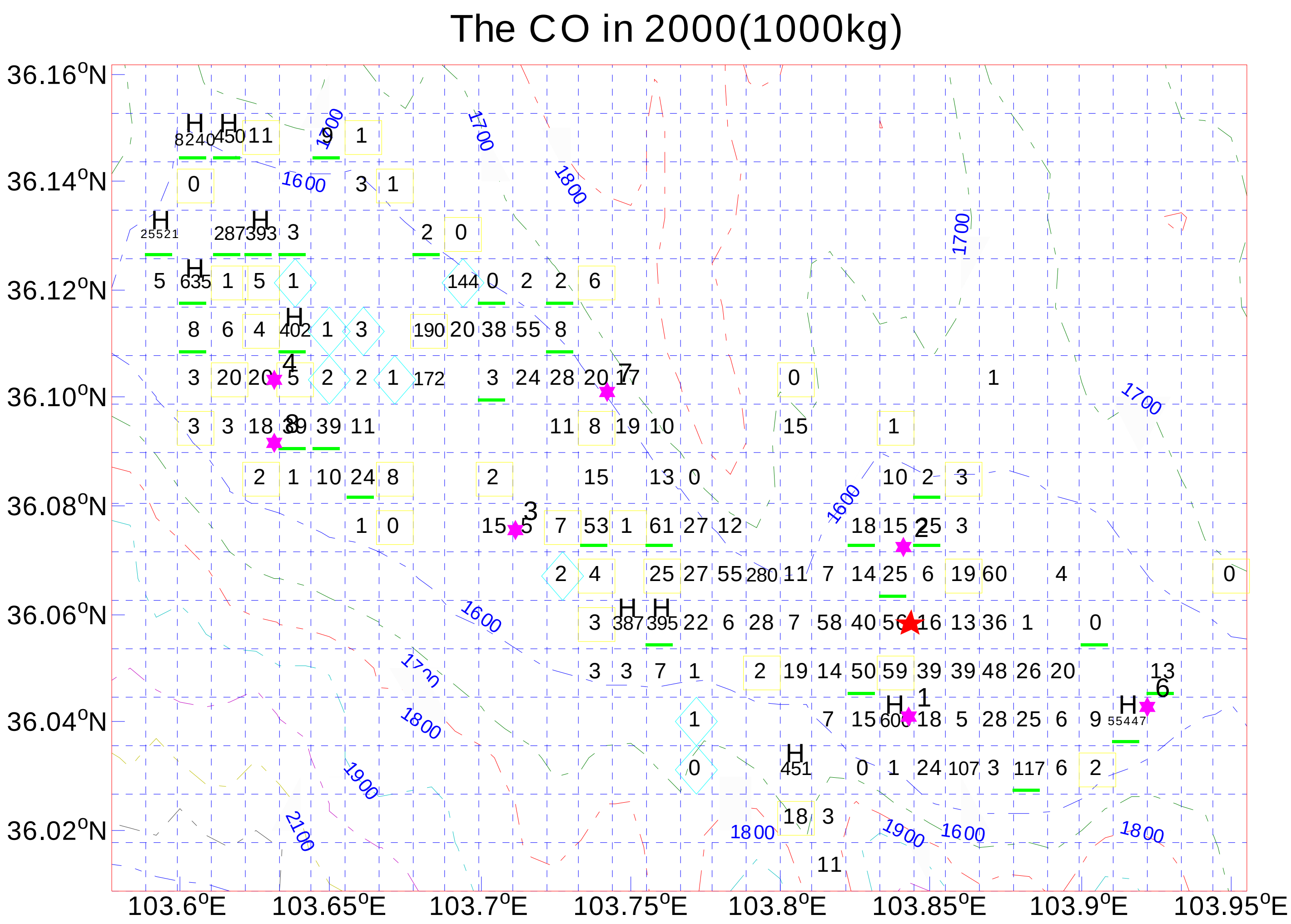
◇ Industrial □ Residential

Dust Sources (1000 kg)



◇ Industrial □ Residential

CO Sources (1000 kg)

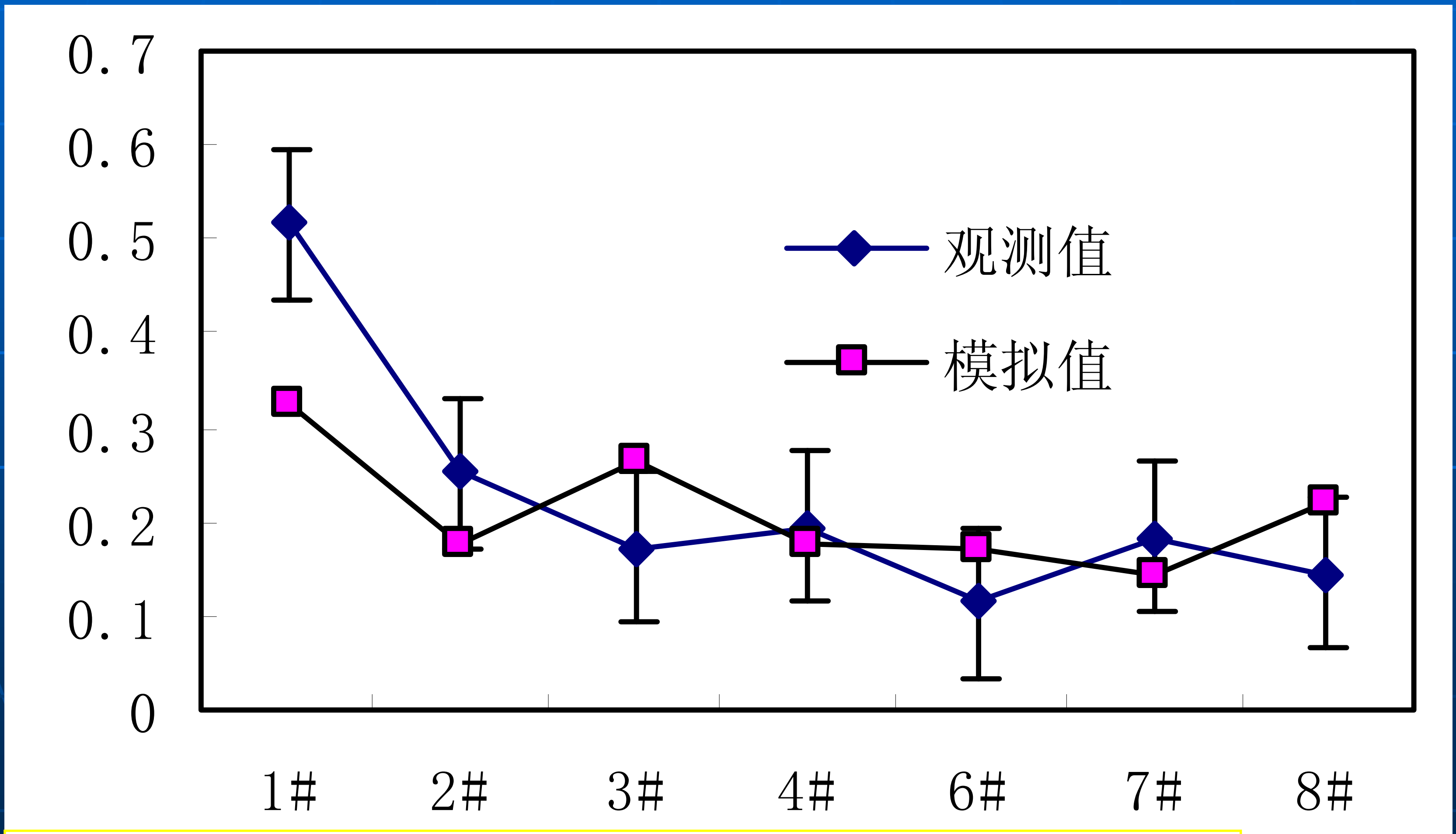


◇ Industrial □ Residential

Simulated and Observed

SO_2 Concentration (mg/m^3) on

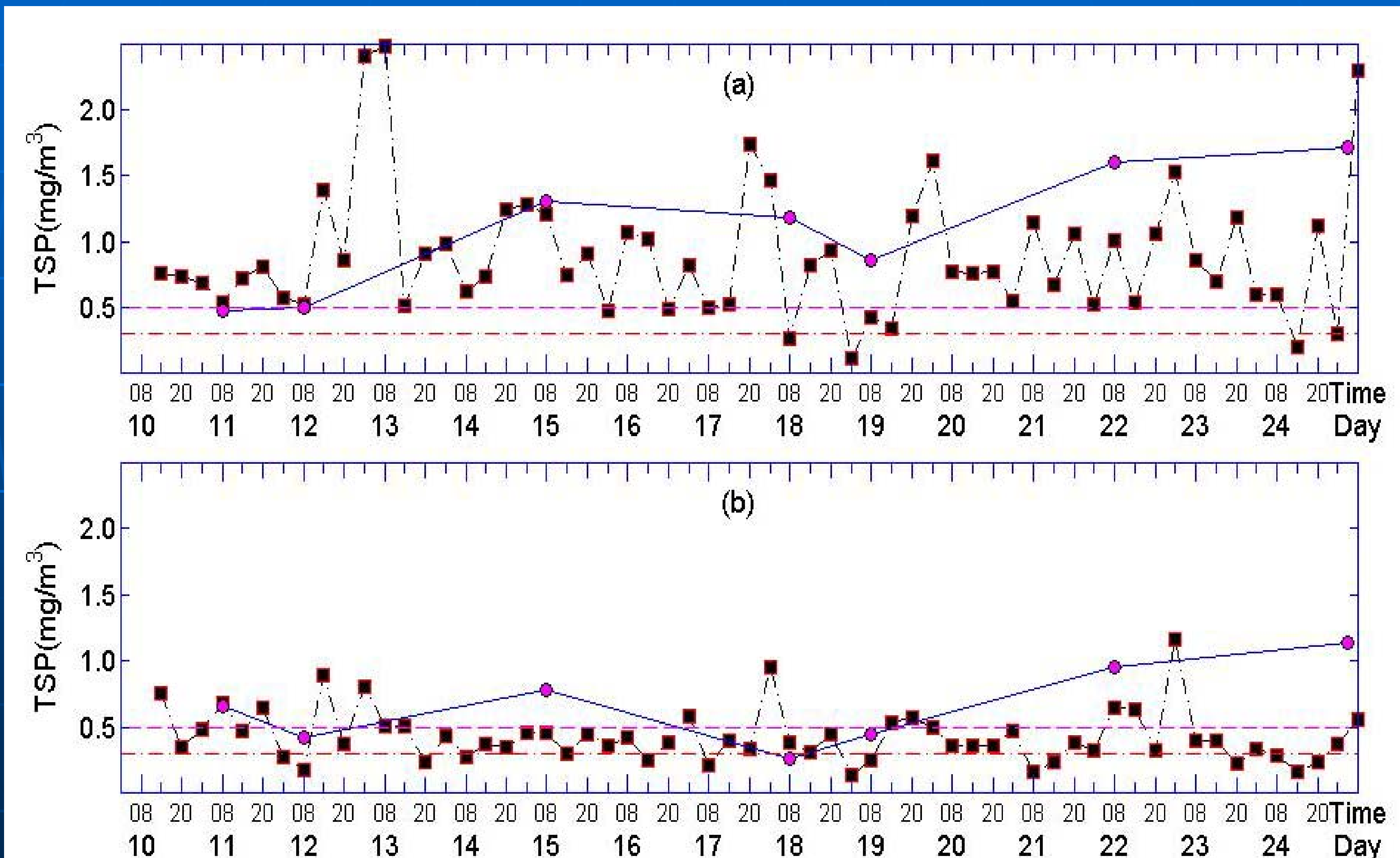
December 25, 2000



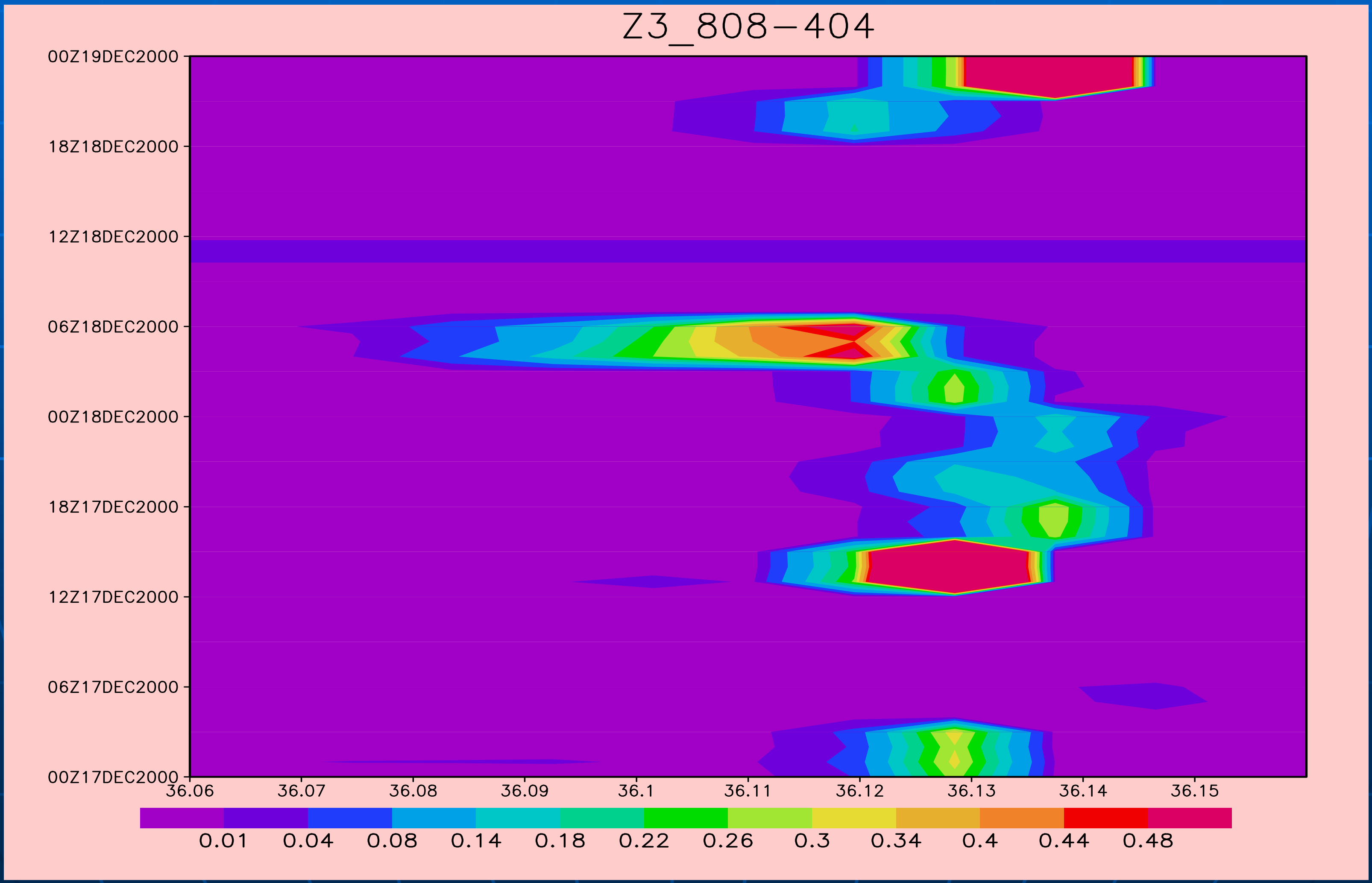
Simulated (□), Observed (◇)

TSP Concentration at Two Stations

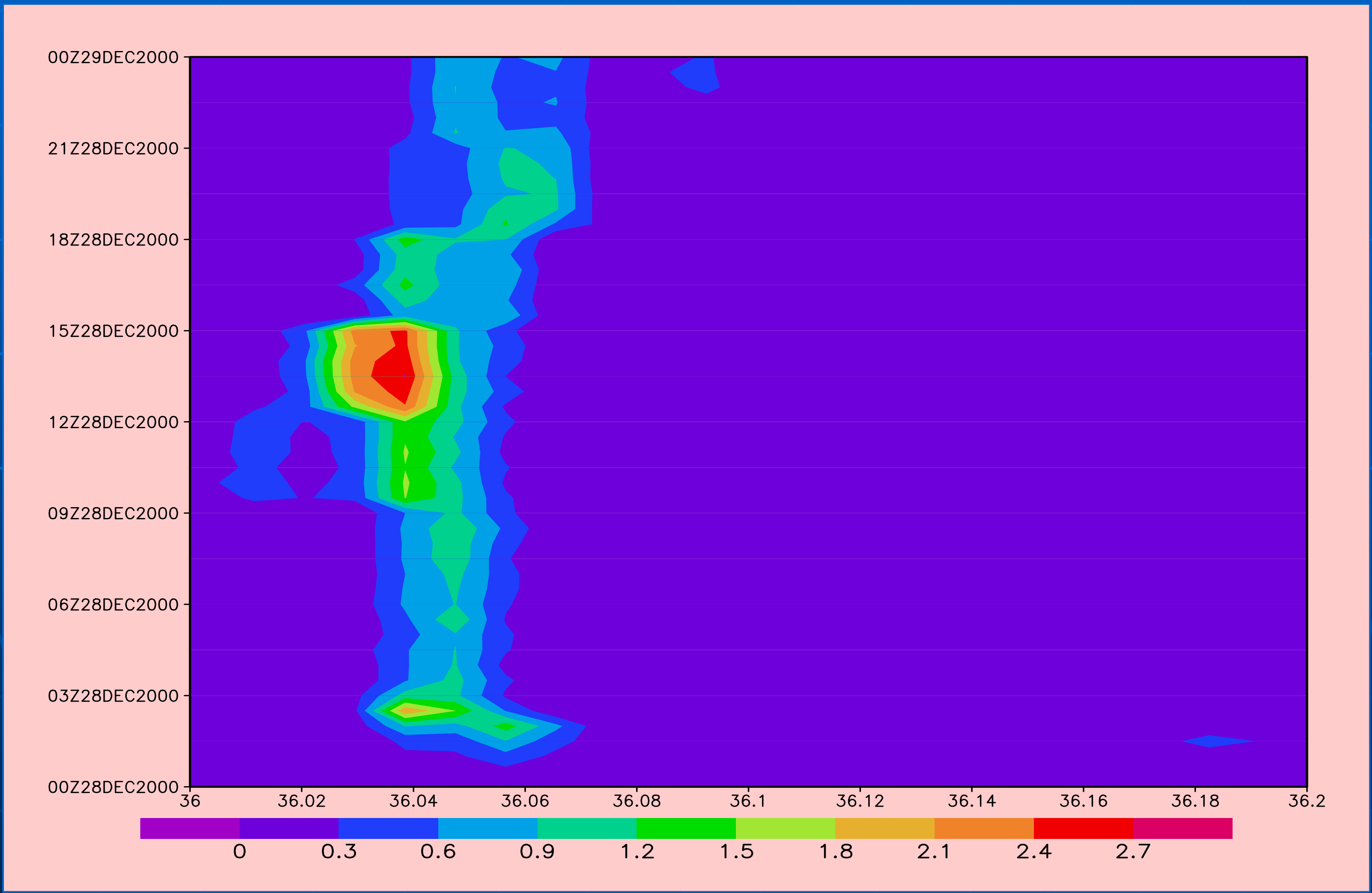
Simulated (dashed), Observed (Solid)



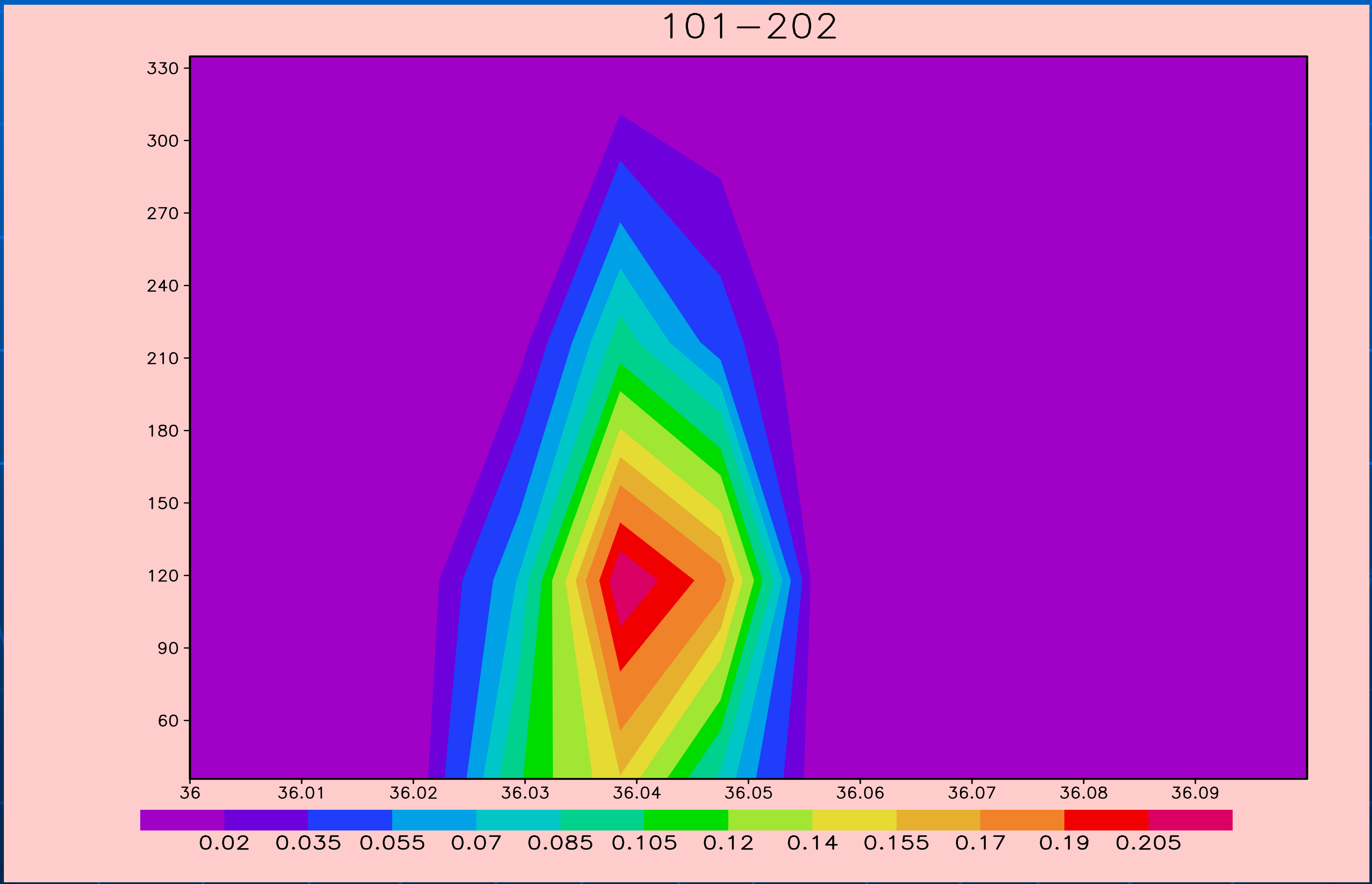
SO_2 Time-Latitude Cross-Section (Dec 17-19, 2000)



SO_2 Time-Latitude Cross-Section (December 28-29, 2000)

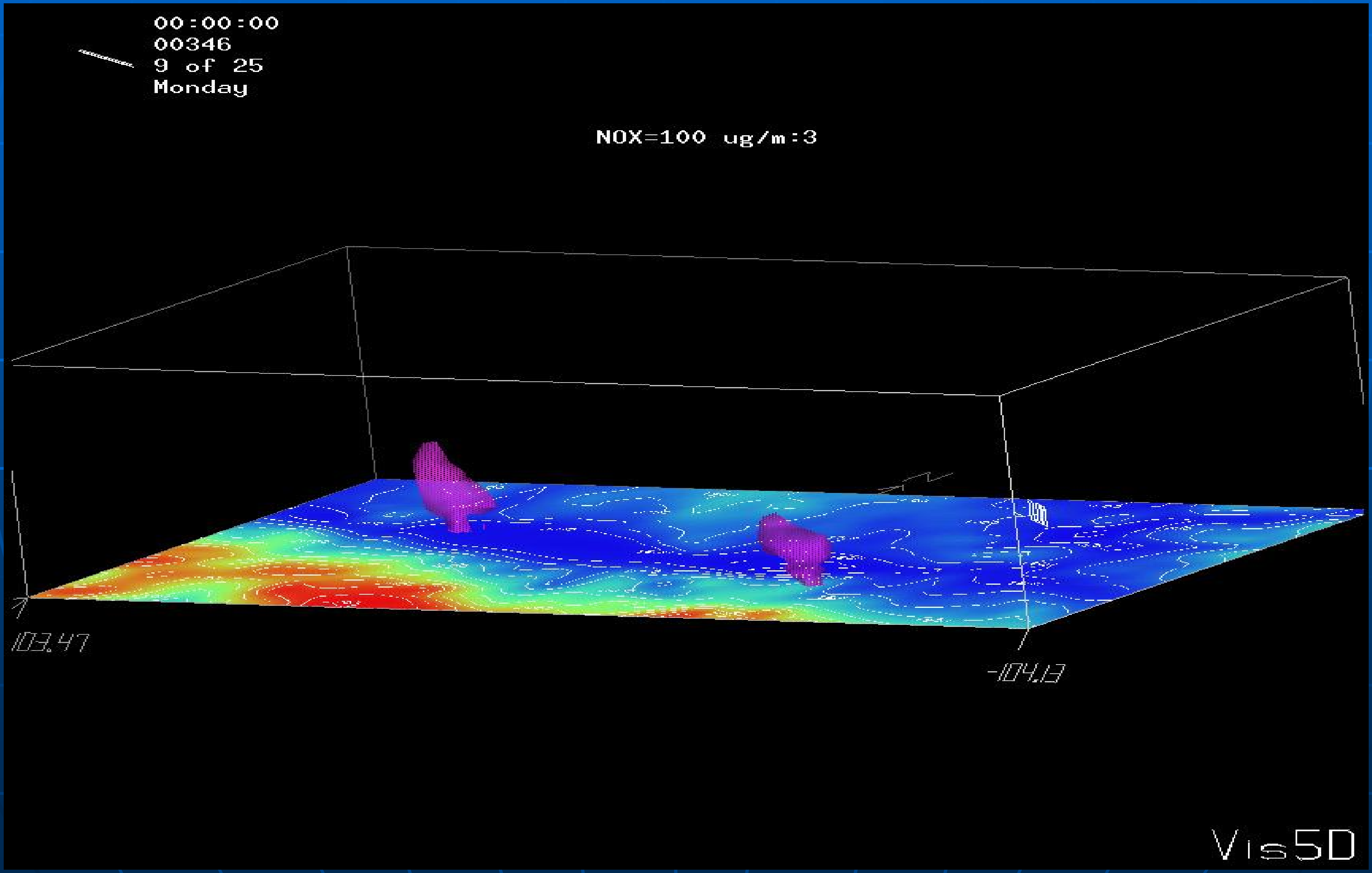


SO_2 (y, z) Cross-Section



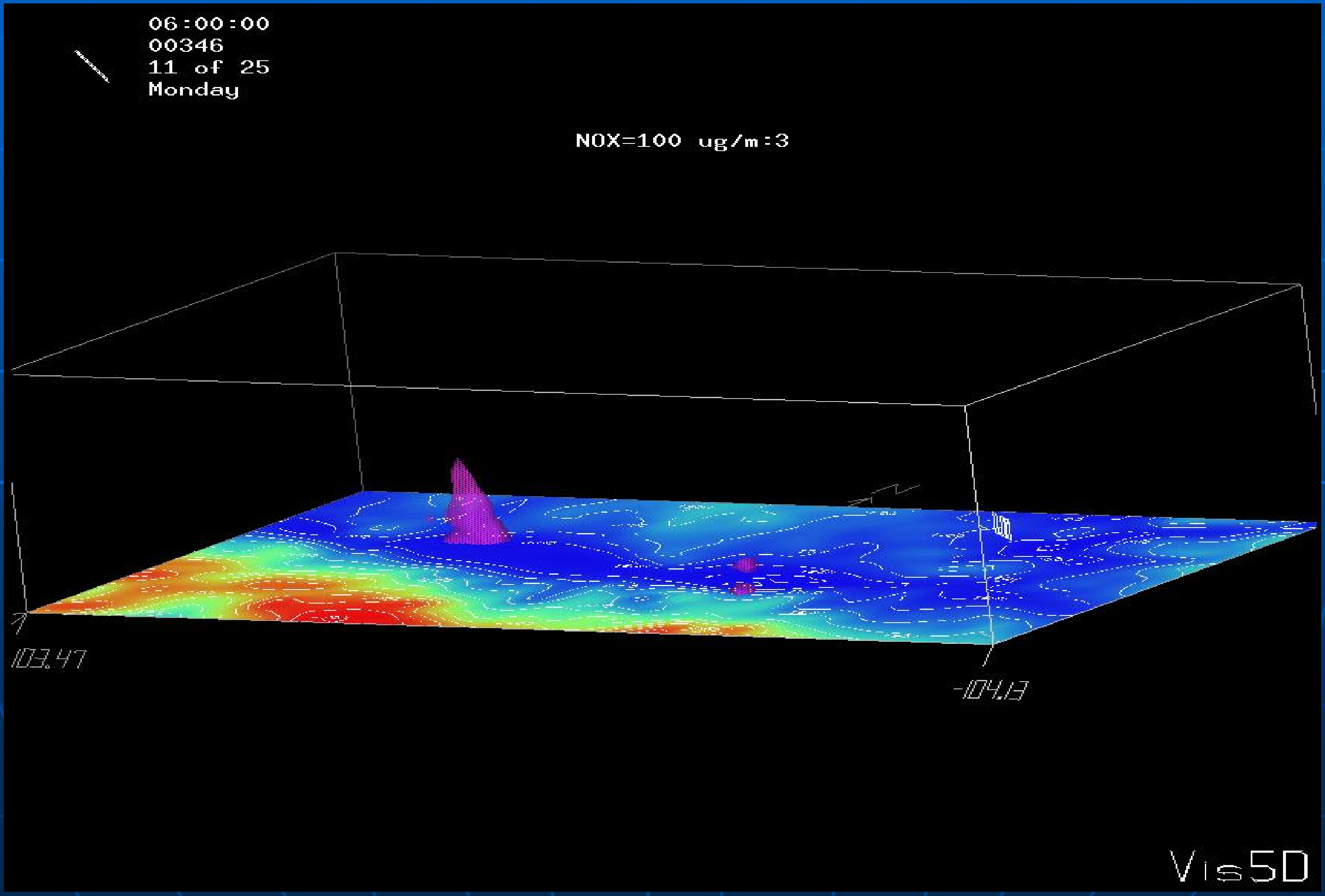
NO_x

07h Dec 11, 2000



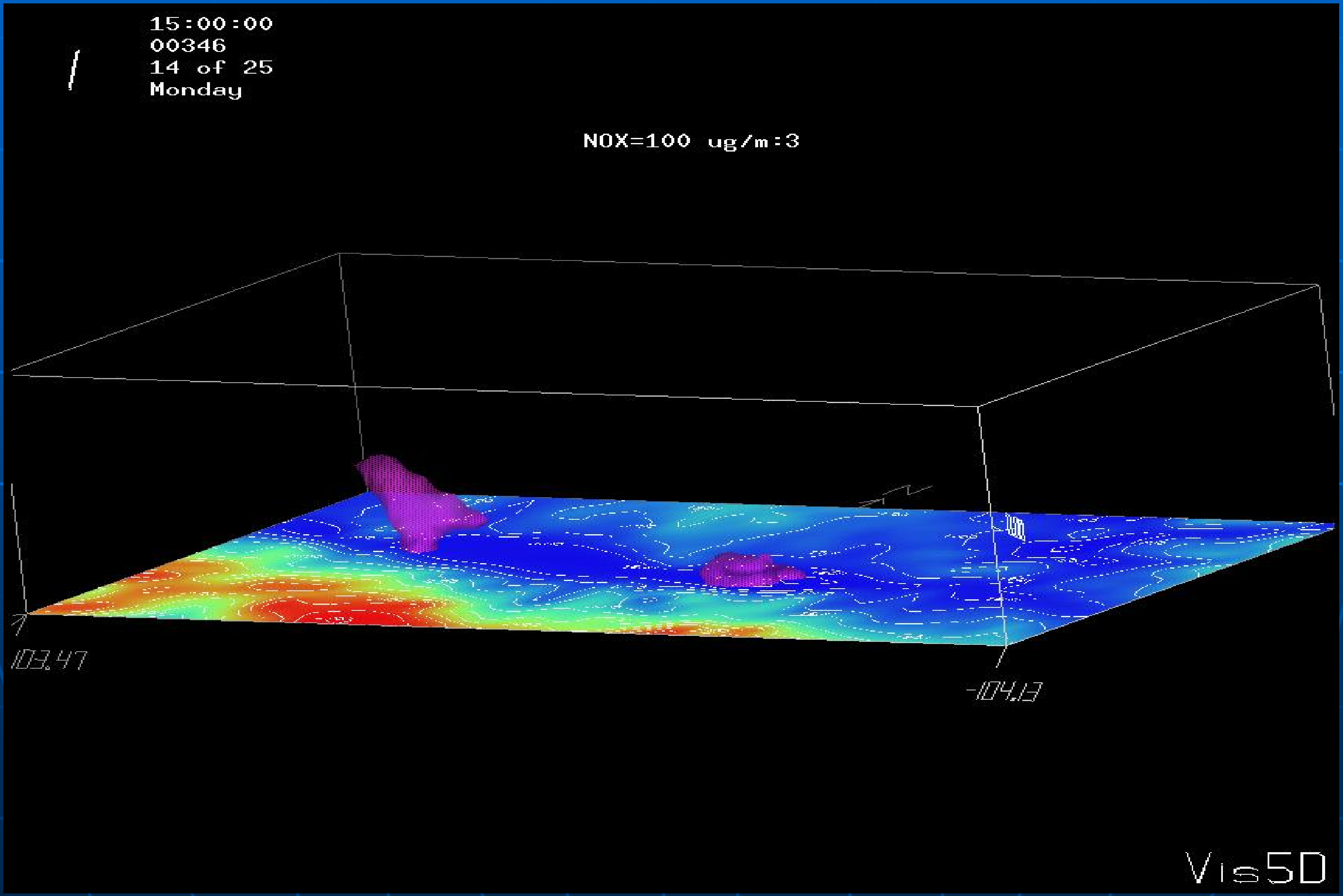
NO_x

13 h, Dec 11, 2000



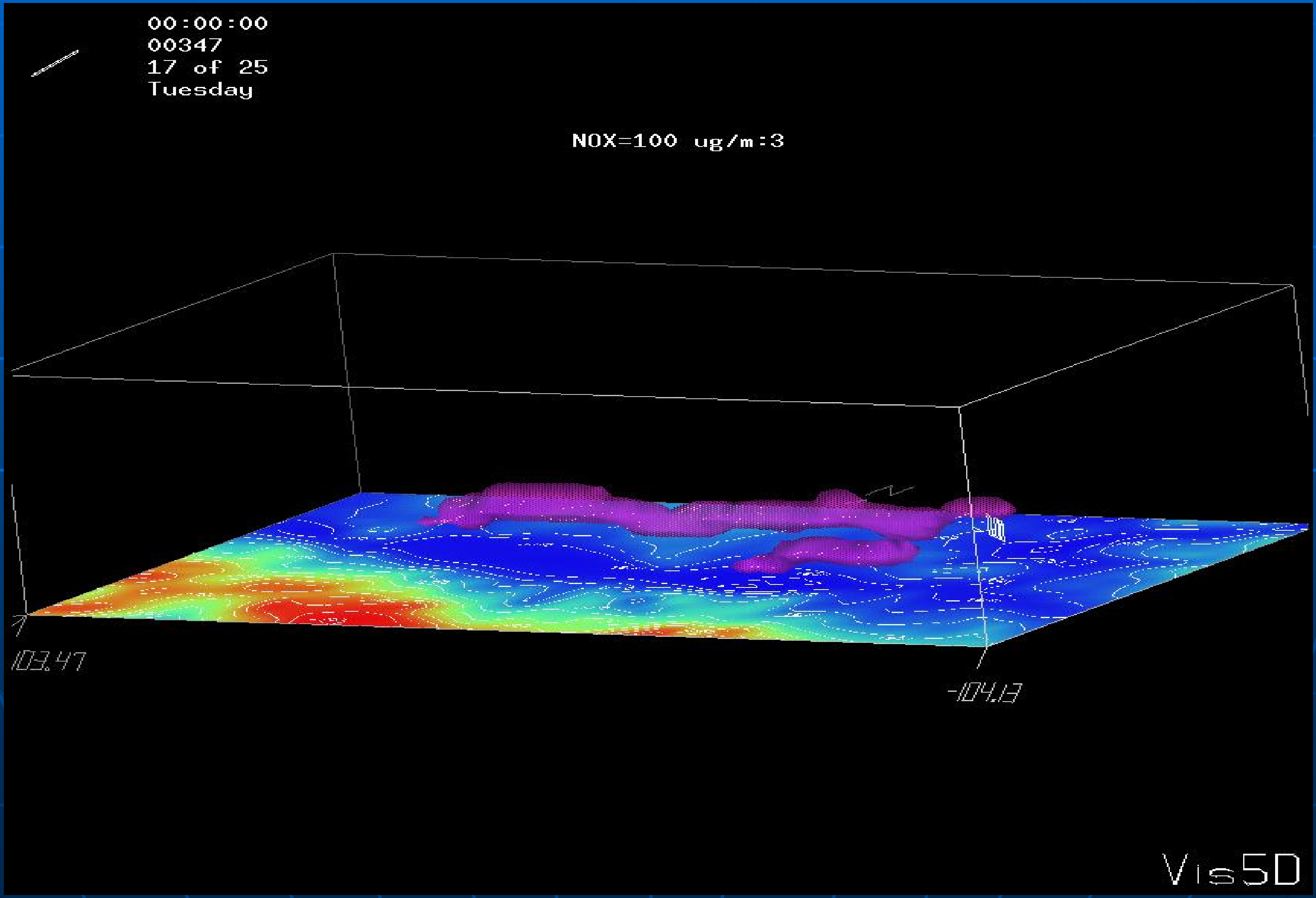
NO_x

22h, Dec 11, 2000



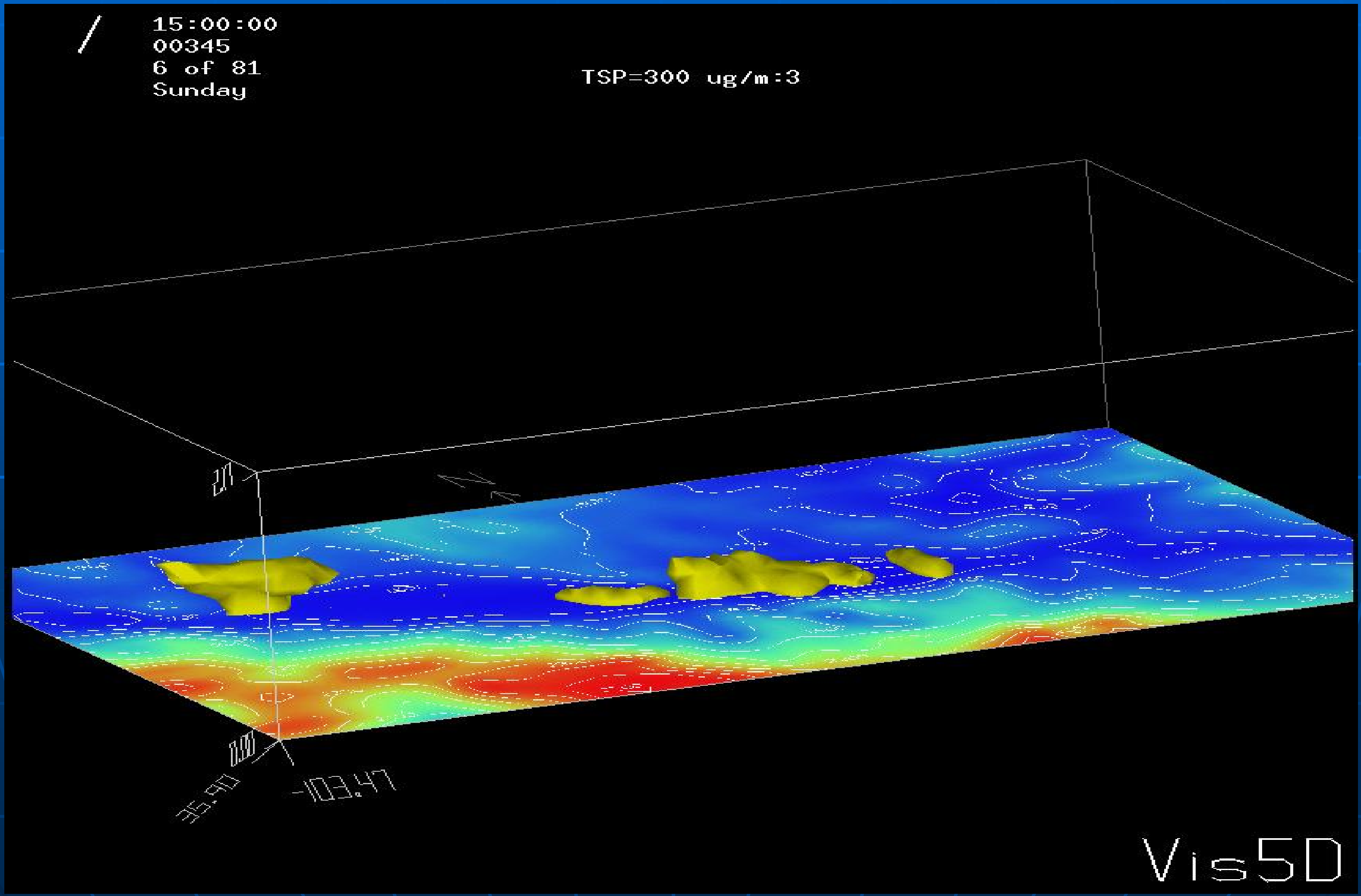
NO_x

07h, Dec 12, 2000



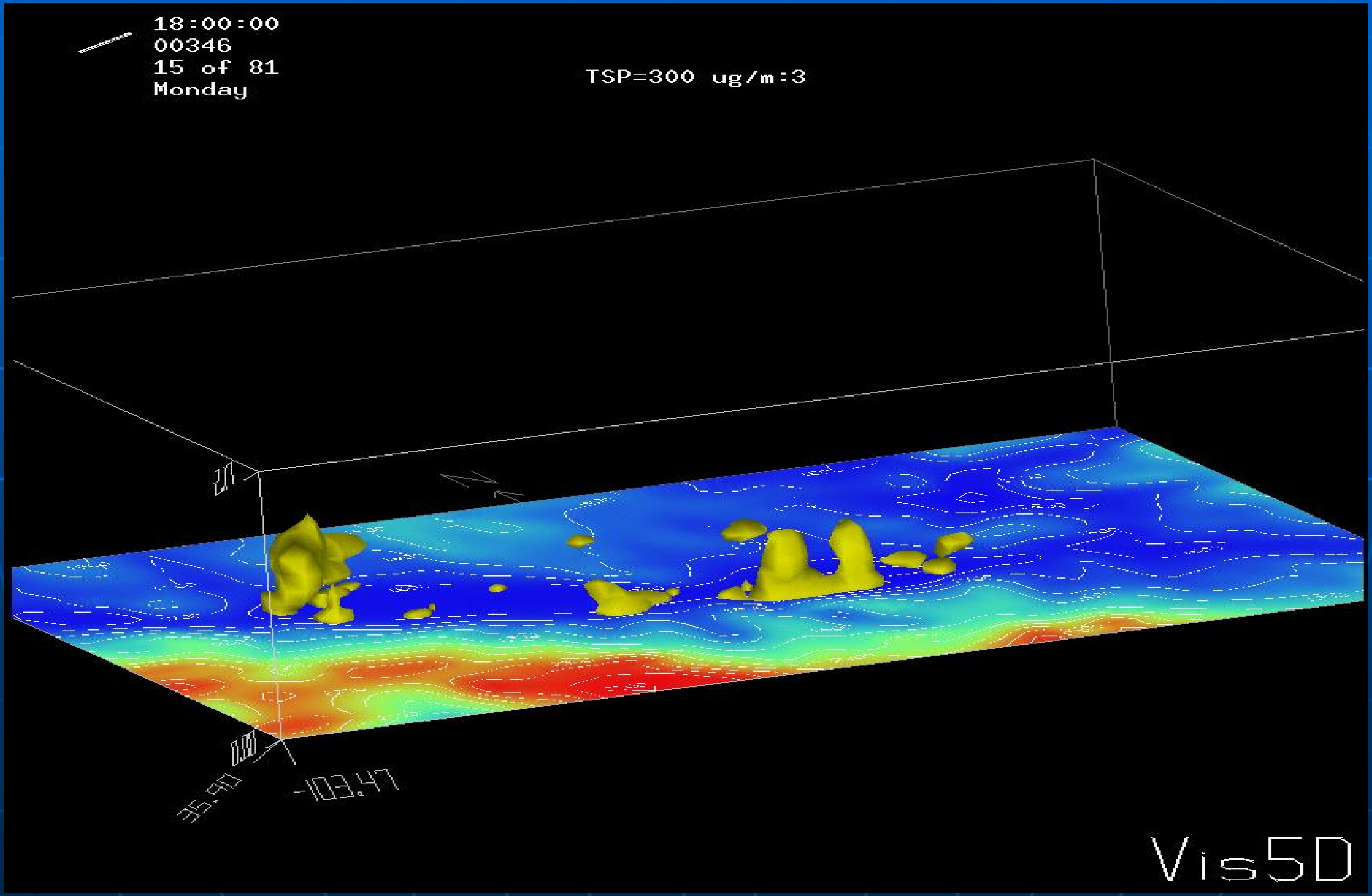
TSP

13h, Dec 11, 2000



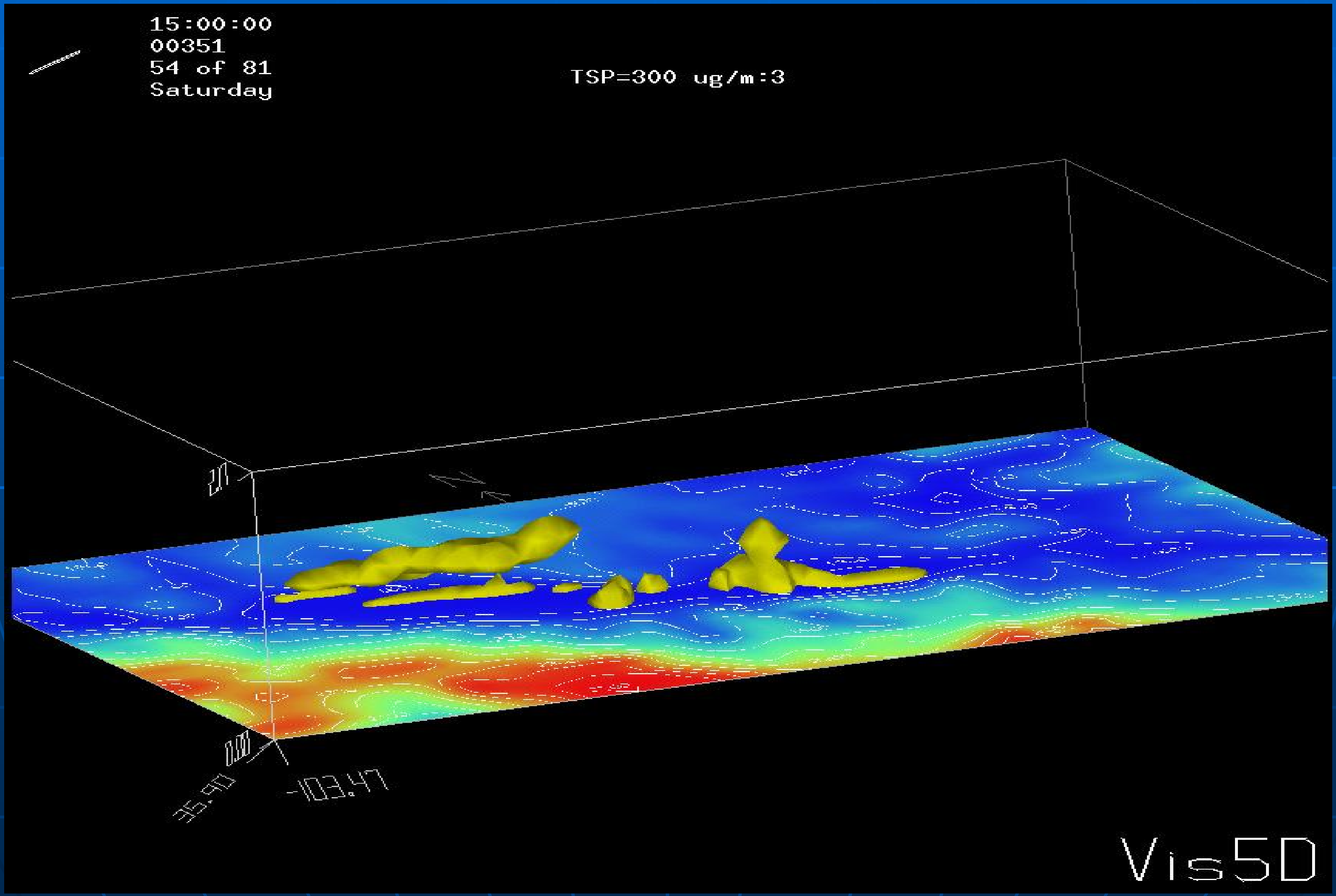
TSP

01h, Dec 12, 2000



TSP

22h, Dec 16, 2000



Conclusions

- Afforestation improves the air quality through destabilizing the atmosphere and providing sinks for pollutants.

- RAMS-HYPACT has capability to simulate and predict the transport of the pollutants.