Afforestation For Valley Urban Air Pollution Control

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Central China

Geography and isobaths

- Yellow River
- Yangtze River
- Urumqi
- Lhasa
- Dunhuang
- Jiuquan
- Lanzhou
- Terim Basin
- QING ZANG PLATEAU

- 80°E 85°E 90°E 95°E 100°E 105°E 110°E 115°E
- 28°N 30°N 32°N 34°N 36°N 38°N 40°N 42°N 44°N 46°N

- Isobaths range from -500 to 4000 meters.
Topography around Langzhou
Lanzhou – One of the Most Polluted Cities in China

In the past two decades, the air pollution problem has been improved.
Total Dustfall Trend in Lanzhou (Wang et al. 2001)
SO\textsuperscript{2} Trend in Lanzhou
(Wang et al., 2001)

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)

TSP Concentration (mg/m³)

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°E, 36.1°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)
- \( \Delta t: \) 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
- 4 – Mix. Dry/Irrg. C.P.
- 5 – Crop/Grs. Mosaic
- 6 – Crop./Wood Mosc
- 7 – Grassland
- 8 – Shrubland
- 9 – Mix. Shrb./Grs.
- 10 – Savanna

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Green-B
Green-C
Reduction of Inversion Strength

![Graph showing the reduction of inversion strength over time.](Image)
Reduction of Stability (Lapse Rate) (°C/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
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
SO₂ – Sources in 2000 (1000kg)

Topography and isobaths (m), SO₂ Source in 2000 (1000kg)

◇ Industrial □ Residential
NOx Sources in 2000 (1000 kg)

The NOx in 2000 (1000 kg)

◇ Industrial   □ Residential
Dust Sources (1000 kg)

The Yan Chen in 2000 (1000 kg)

◇ Industrial □ Residential
CO Sources (1000 kg)

The CO in 2000 (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

101–202

36 36.01 36.02 36.03 36.04 36.05 36.06 36.07 36.08 36.09

0.02 0.035 0.055 0.07 0.085 0.105 0.12 0.14 0.155 0.17 0.19 0.205
NO_x

07h Dec 11, 2000

NOX=100 ug/m^3
13 h, Dec 11, 2000

NO$_x$

NOX=100 ug/m$^3$
22h, Dec 11, 2000

NO\textsubscript{x} = 100 \, \text{ug/m}^3
NONO

07h, Dec 12, 2000

NO\textsubscript{x}

NO\textsubscript{x}=100 \text{ ug/m}^3
TSP

13h, Dec 11, 2000

TSP=300 ug/m³

Sunday
TSP

22h, Dec 16, 2000

TSP = 300 ug/m^3

Saturday
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.