

Unintended Weather Modification



Examples of Unintended Changes

- Weather changes due to cloud seeding.
- Weather changes due to other activities.



Possible Mechanisms - Dynamic

- Cloud-Environment Interaction
 - Compensating Subsidence
 - Pressure Field Changes
 - Downdraft/low-level Outflow
 - Dynamic Intensification
- Dynamic Intensification
 - Larger Storm
 - Longer-lived Storm
 - Change of Storm Motion



Possible Mechanisms - Microphysical

- Downwind Transport of Seeding Material
 - AgI Deactivation Rates
 - AgI Transport/diffusion
 - Does not enter cloud.
 - Carried into anvil by ice crystals.
 - Detrained from sides of cloud.
 - Brought down in evaporating precipitation.
- Downwind Transport of Ice Crystals
 - Ice crystal seeding by anvils.
 - Thermal effects of cirrus shield.

Extended-area Effects

- Studies have been mixed
 - Periodic seeding in Arizona tied to rainfall patterns in New York!
 - Whitetop found large effects in all directions from target area
 - North Dakota seeing small rainfall increases downwind of target areas
- We're having enough trouble finding direct effects of seeding, so indirect effects not likely to be very large.

Inadvertent Weather Modification

- Weather changes due to human activities not done to alter the weather.
- Why address in the class?
 - Effects are greater than all planned activities.
 - Effects may need to be considered in planning a cloud seeding project.
 - Much can be learned from these effects.

Scales of Inadvertent Modification

- Range in space from miles to thousands of miles, and in time from minutes to days

- Local

Obvious and Certain

- Regional

Becoming Apparent

- Global

Possible Warming



Possible Parameters Affected

- Visibility
- Sunshine
- Cloudiness
- Precipitation
- Thunderstorms
- Temperature
- Wind
- Fog
- Humidity



General Types of Activity

- Urban
- Non-urban Production Centers
- Rural Non-agricultural Land Use
- Agriculture
- Transportation



Urban Changes

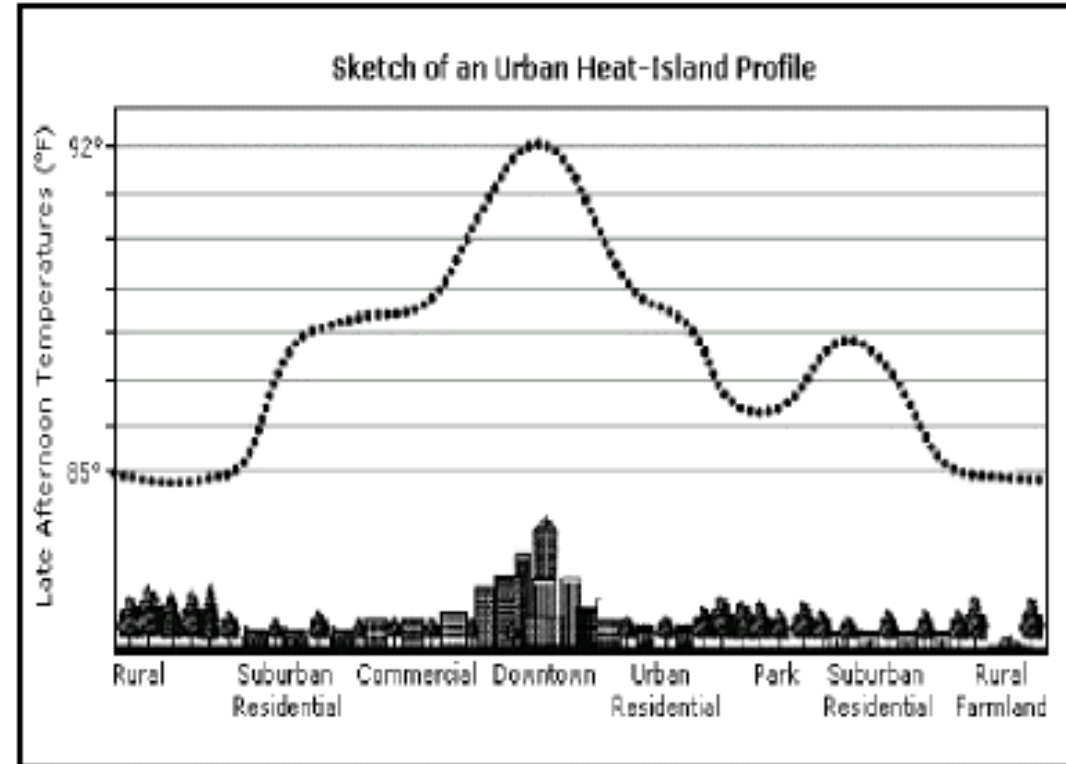
Table 4-2.--Weather changes (percent) resulting from major urbanization in the Northern Hemisphere^a

Weather phenomenon	Annual	Average changes compared to rural conditions	
		Cold season	Warm season
Contaminant volume	+1,000	+2,000	+500
Solar radiation	-22	-34	-20
Temperature (°C)	+2	+3	+1
Relative humidity	-6	-2	-8
Visibility frequency	-26	-34	-17
Fog frequency	+60	+100	+30
Wind speed	-25	-20	-30
Cloudiness frequency	+8	+5	+10
Rainfall	+14	+13	+15
Snowfall	+10	+10	--
Thunderstorm frequency	+15	+5	+30

^aFrom Changnon (1976)

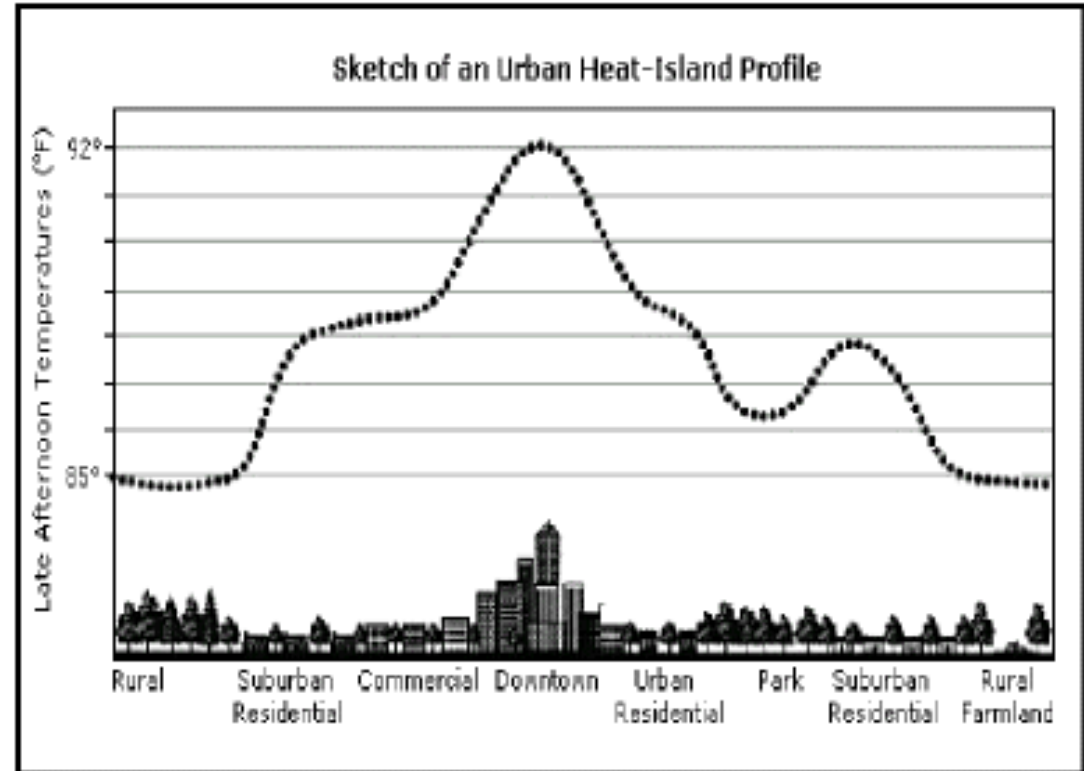
Urban Activity

- Contrasting Thermal Properties
- Less water for Evaporation
- Aerodynamic Roughness
- Heat, Gases and Particulates

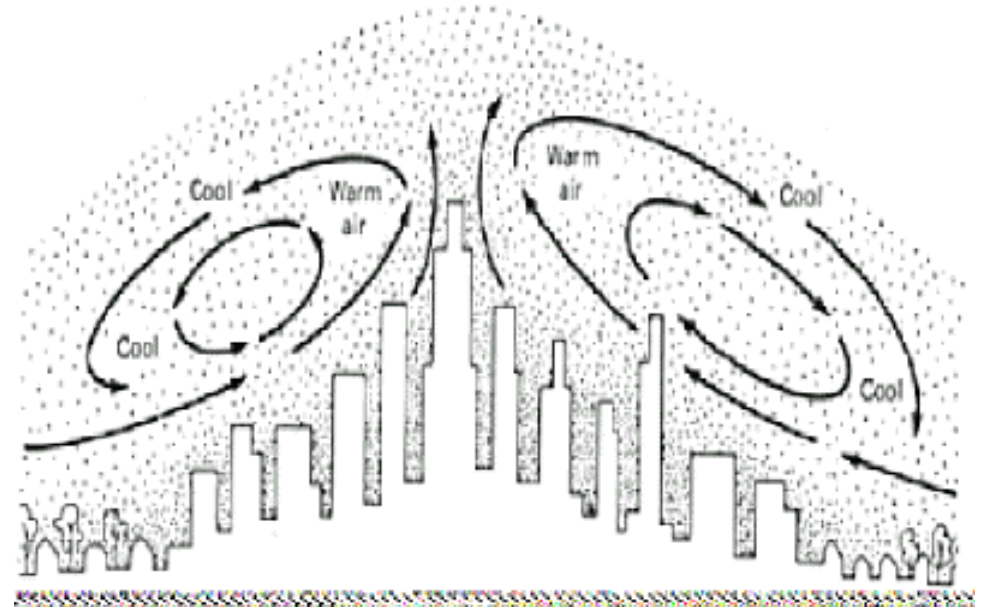
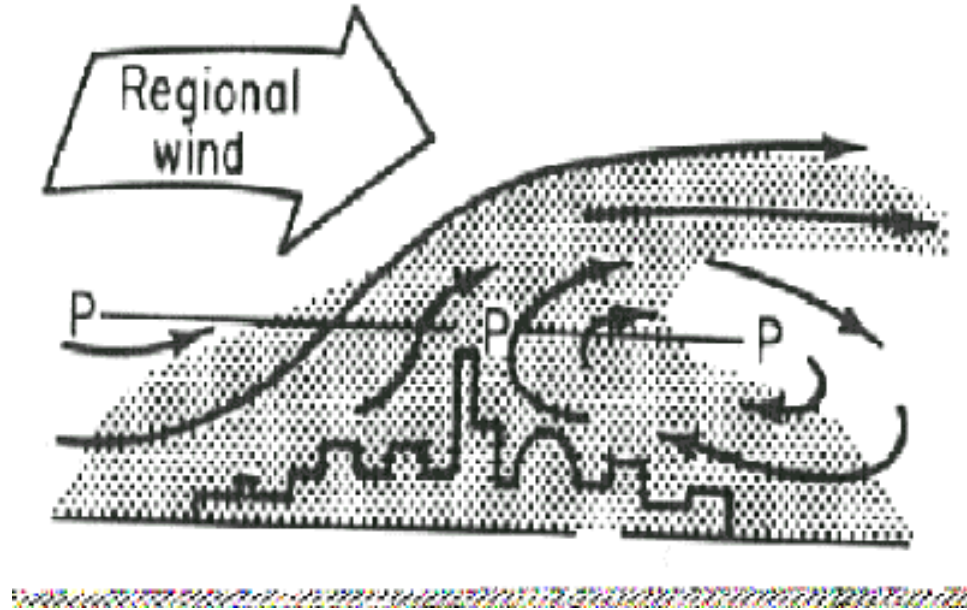


Urban Activity

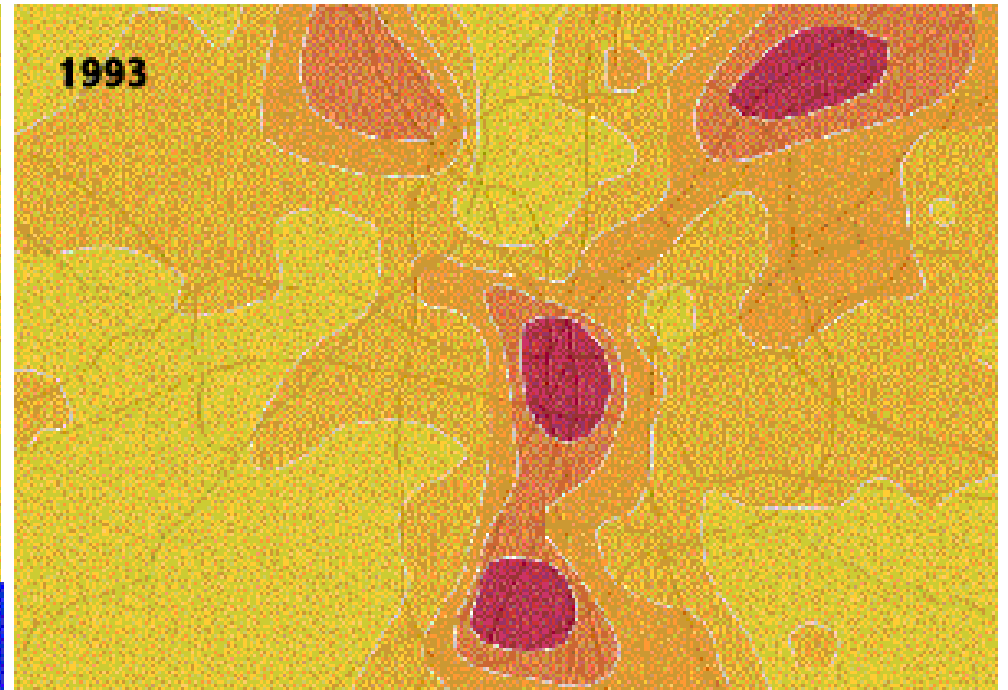
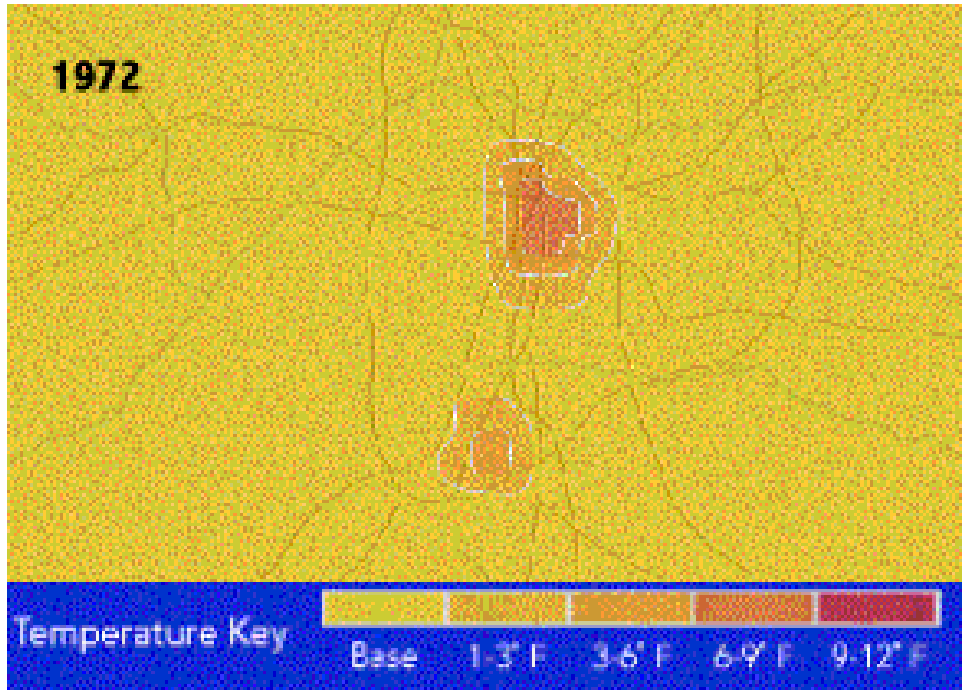
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Aerodynamic Roughness



Heat, Particulates, and Gases



Urban

- METROMEX
 - St. Louis, late 1960s
 - Looked at effects in and around urban area
 - Found significant changes both in city and downwind in rural areas
 - 30% increase in rainfall.
 - 40% increase in heavy rains and storms.
 - 100% increase in strong surface winds.
 - 100% increase in hail-fall intensities.

Non-agricultural Land Use Changes

- Deforestation

- Increased solar radiation at the ground
 - Greater surface temperature extremes
 - Possible Droughts



- Over-grazing

- More dust, less moisture

- Strip mining

- Albedo change



Agricultural Land Use Changes

- Burning
 - Increase Nuclei (CCN, IN)
 - Affect Cloud Processes
- Irrigation
 - Higher Humidities
 - Lower Albedo
 - Lower Temperatures
 - Rain Increases over large areas



Transportation Changes

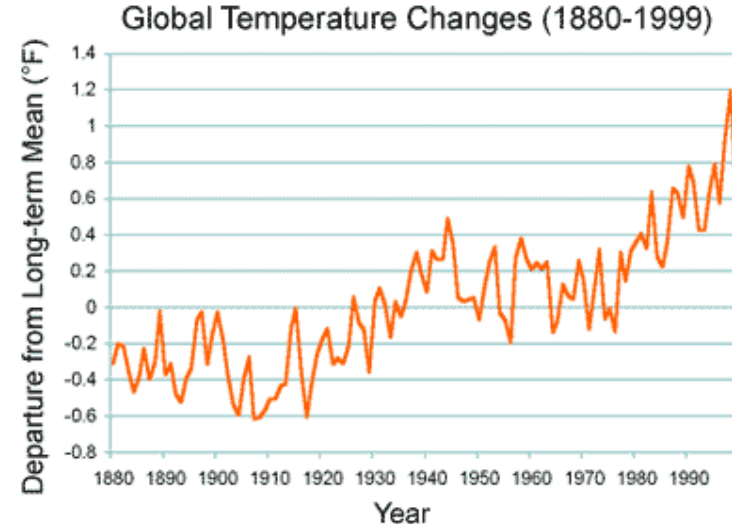
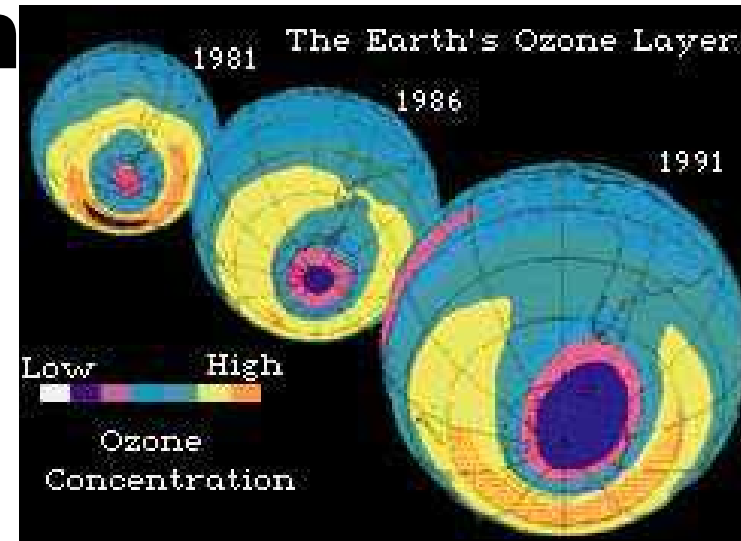
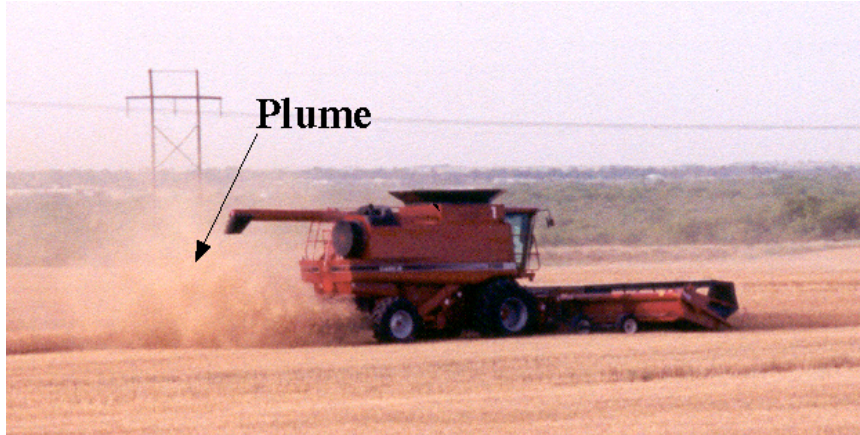
- Aircraft
 - Exhaust
 - Ozone effects, particulates
- Contrails
 - Reduced solar radiation
 - Falling ice crystals



Near NASA Wallops on December 3, 2021.
Picture by David Delene.

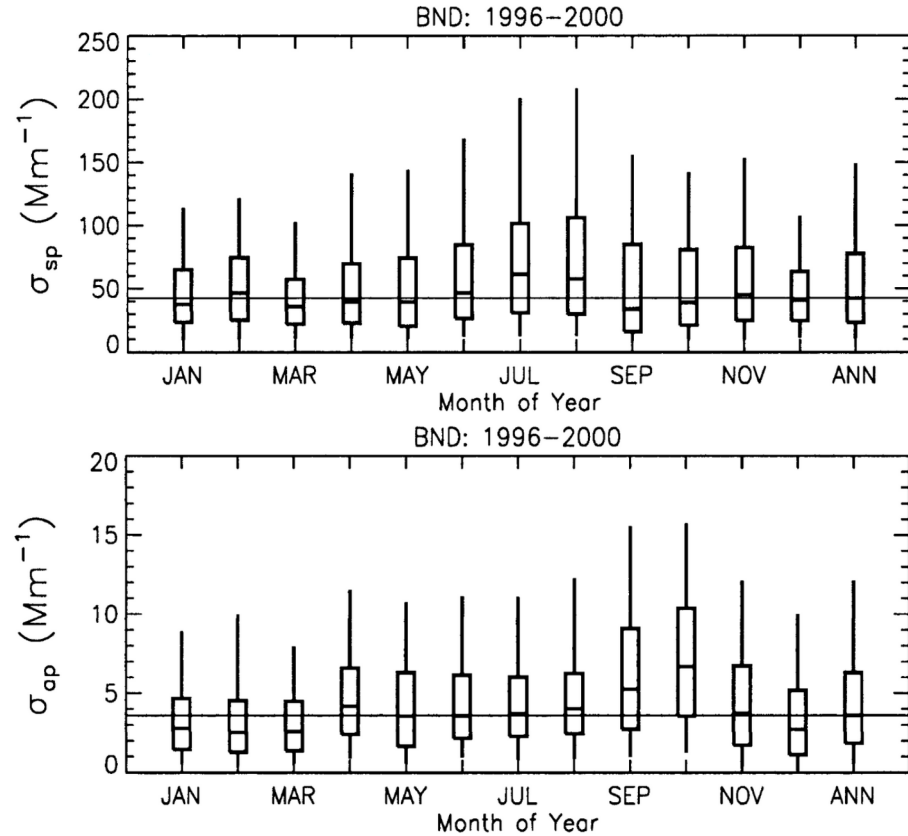
Climate Modification

- Fluorocarbons
 - Ozone hole
- Carbon Dioxide
 - Global Warming
- Dust, Clouds
 - Global Warming/cooling

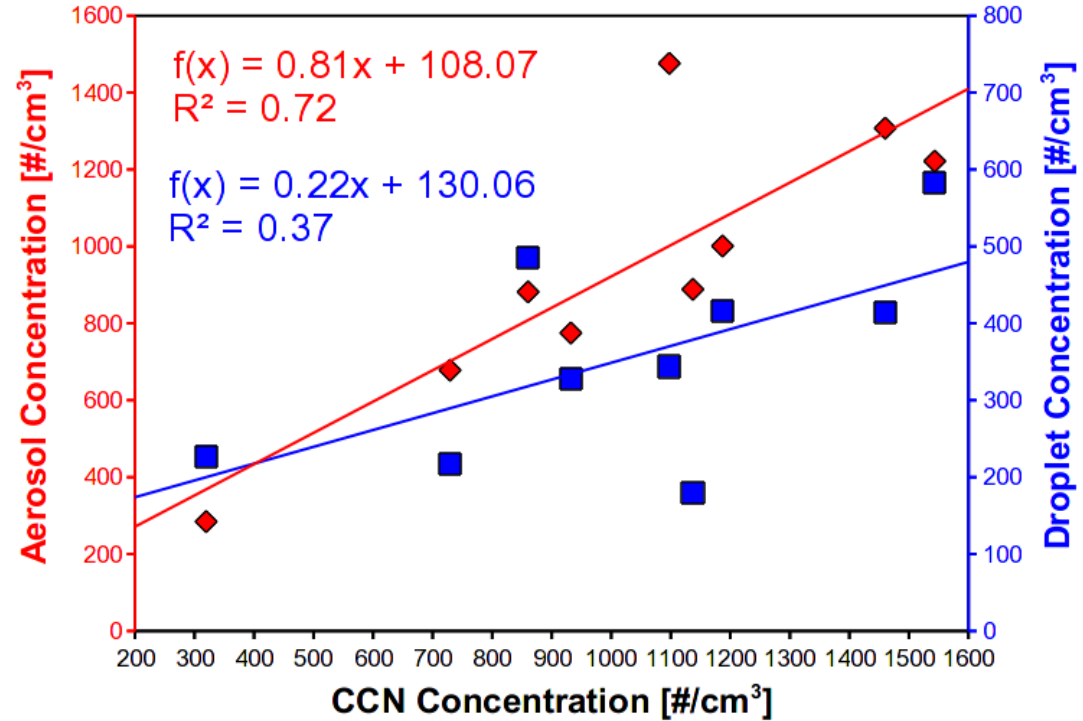


Source: National Climatic Data Center, 2000. Climate of 1999 - Annual Review.
Online at <http://www.ncdc.noaa.gov/olclimate/research/1999/ann/ann99.html>

Direct/Indirect Impact of Particles



Delene, D. J., and J. A. Ogren, Variability of aerosol optical properties at four North American surface monitoring sites, *Journal of Atmospheric Sciences*, 59, 1135-1150, 2002.



Delene, D. J., C. Grainger, P. Kucera, D. Langerud, M. Ham, R. Mitchell, and C. Kruse, The Second Polarimetric Cloud Analysis and Seeding Test, *Journal of Weather Modification*, 43, 14-28, 2011, URL: <http://www.weathermodification.org/publications/index.php/JWM/article/viewArticle/147>.