1. Describe the Observations:

These are the measurable environmental variables that the model will use directly. For climate resilience in cities, the observations include:

- Temperature
- Humidity
- Precipitation
- Air quality indices (e.g., PM2.5, NO_2, O_3)
- Soil moisture
- Water levels in drainage systems
- Energy consumption
- Disaster reports (floods, heatwaves, etc.)

These values are collected over time (e.g., hourly, daily, weekly), forming a multivariate time series of observations.

2. Type of HMM Problem:

The hidden states (e.g., the underlying climate resilience conditions or risk levels) are not predefined, making this an unsupervised learning problem using HMMs.

This means:

- The hidden states might represent latent regimes such as:
  - "Stable urban climate"
  - "Rising climate stress"
  - "High vulnerability"
  - "Crisis mode"

But since these are not observed directly, the HMM has to learn them through patterns in the observed data.

3. Training Algorithm:

a. What values are known at the start?

- The observation sequences over time (e.g., environmental sensor data).
- The number of hidden states (chosen manually based on domain knowledge or model selection techniques like BIC).
- The assumption that observations follow some distribution (e.g., Gaussian for continuous data).

b. What values are unknown and need to be learned?

- Initial state distribution (π): Probability of starting in each hidden state.
- Transition probabilities (A): Probabilities of moving from one hidden state to another.
- Emission probabilities (B): Parameters defining how likely an observation is, given a hidden state. For continuous data, this includes:
    - Mean vector and covariance matrix for each state (if using multivariate Gaussians).

4. Parameter Updates:

During training (typically using the Baum-Welch algorithm, an instance of the Expectation-Maximization (EM) algorithm), the following HMM parameters are updated:

- π (Initial probabilities): Updated to reflect the probability of the model starting in each state based on observed data.
- A (Transition matrix): Updated based on how often transitions between hidden states are inferred.
- B (Emission parameters):
    - For Gaussian emissions, the mean and covariance of each state's emission distribution are updated.