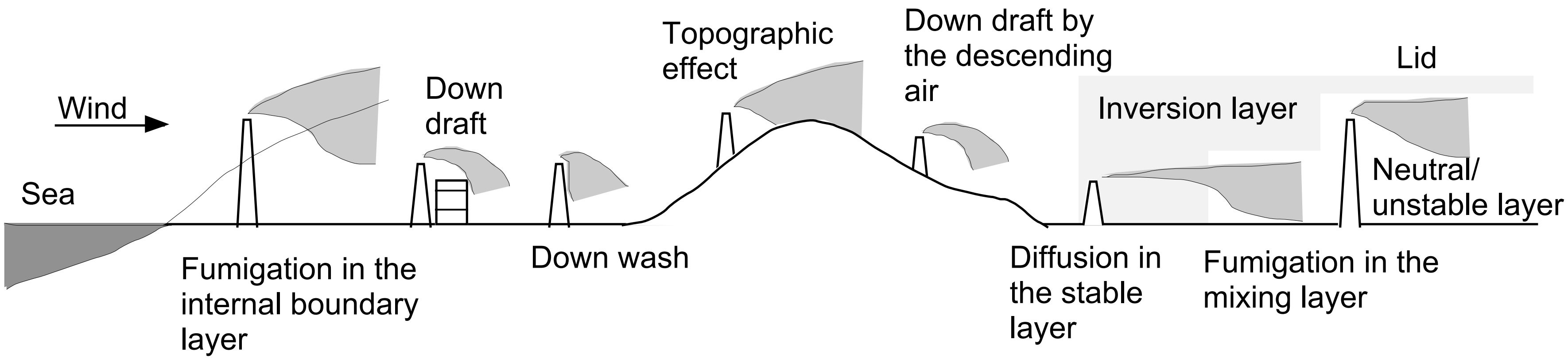
1. Atmospheric Diffusion of Stack Gases

Atmospheric diffusion is the process of diluting air pollutants by atmospheric turbulences. Historically, Taylor, G.I. (1921) firstly published a theory on the atmospheric diffusion in the steady and homogeneous atmospheric turbulence field. Sutton (*Micrometeorology*, 1953), and Paquill (*Atmospheric Diffusion*, 1961) remarkably contributed to the modeling of atmospheric diffusion. There are so many parameters influencing to the atmospheric diffusion, and that makes the forecasting of atmospheric diffusion not so easy.



Parameters relating atmospheric diffusion

- **Fumigation in the internal boundary layer**

  A tall stack near the **coast line** exhausts the gas into **stable layer of sea wind**. In daytime, heated surface forms an **internal boundary layer** begun from the coast line. When the exhausted gas in the stable layer is involved into the boundary layer, a sudden diffusion of the gas occurs and the density of the pollutants near the surface increase.

- **Down draft**

  When hills or **buildings** are exist in the windward or the leeward of the stack, sometimes, the gas is dragged down by the descending wind.

- **Down wash**

  When the stack gas exit velocity become less than 1.5 ~ 2 times of wind speed, the gas is dragged down along the stack.

- **Topographic effect**

  In some cases, the geographical point of maximum ground-level concentration closes to the stack, and introduces higher concentration of the gas at the ground.

- **Down draft by the descending air**

  Topographical descending air, sometimes, causes the gas dragged down.

- **Existence of the inversion layer and the diffusion**

  The inversion layer acts important role in the atmospheric diffusion. The atmospheric stability is very stable in the inversion layer, then the stack gas diffusion is **suppressed**. In the corruption of inversion layer, sometimes, **fumigation** of the gas is risen. The inversion layer being on the top of the mixing layer, roles as a **lid**.

2. Estimation of the Air Pollutant Concentration

The atmospheric behavior of air pollutants exhausted from power plants, factories, car traffics can be estimated using:

- **Field tracer experiment with the meteorological observation**
- **Physical model experiment (wind tunnel experiment/ water-tank experiment)**
- **Numerical model experiment .**

Air pollutants concentration estimation methods were developed with the combination of the **field experiments** and the **physical model experiment** such as wind tunnel. In the development story, so many field experiments were carried out **to evaluate the physical models**. Nowadays the **numerical model** becomes a major estimation method succeeding the experiences of the physical model and the field experiments.

Air pollutants concentration estimation methods

Experiment type		Method	Characteristics
Tracer experiment		releasing the tracer gas from the pre-defined point, and to observe the diffusion of gas measuring the concentration of the tracer on the each networked observation points.	•can observe real phenomenon •has not reproducibility
Physical model	Wind tunnel	settling up topography/ buildings models into a wind tunnel, and making the observations of air current and diffusion of tracers under the temperature/ wind speed control.	•can satisfy the rule of similarity •must use large scale equipments
	Water-tank	observing the diffusion measuring the density of coloring matter	•can visualize the diffusion process easily •has difficulty to satisfy the rule of similarity
Numerical model	Diffusion equation	calculating the distribution of pollutants using diffusion formulas	•can evaluate the long-term concentration easily •has limitations for the complex terrain case, etc.
	Numerical Integration model	calculating the air current/ pollutants concentrations with the numerical integration of kinetic equations and diffusion equations.	•can evaluate the diffusion on the complex terrain field considering the thermal effects.

a. Field experiment - tracer

To evaluate the enhanced atmospheric diffusion model and/or to estimate the specific diffusion, such as the diffusion on the complex terrain, in the city, or the diffusion under long range transporting, the tracer experiments are carried out in the fields. A **tracer experiment** is performed releasing the tracer gas from the pre-defined point, and to observe the diffusion of gas measuring the concentration of gas on the each networked observation points. For the tracer gas, **SF_6** (sulfur hexafluoride) has been used, and recently, the group of cyclohexane: such as perfluoromethlcyclohexane (PMCH), and ortho-perfluorodimethylcyclohexane (o-PDCH), are used because the detection limit is very low (10^{-15} liter/liter). These tracer was used at the projects evaluating long range transport model, such as CAPTEX (downwind distance 1100 km) or ANATEX (downwind distance 3000 km).

NOTE: Cross Appalachian Tracer Experiment (CAPTEX), Across North America Tracer Experiment (ANATEX)

b. Field experiment - meteorological measurement

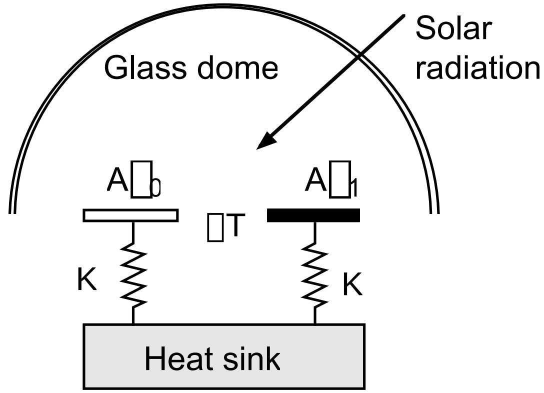
For the local/ regional scale field experiment, meteorological measurements are performed to obtain the diffusion field characteristics:

- **ground meteorological measurements**:

  wind-speed, wind-direction, temperature, humidity, solar radiation, net radiation, etc.

Aerovane (windmill anemometer)

Pyranometer



$$I = \frac{K}{A(\varepsilon_0 - \varepsilon_1)} \Delta T$$

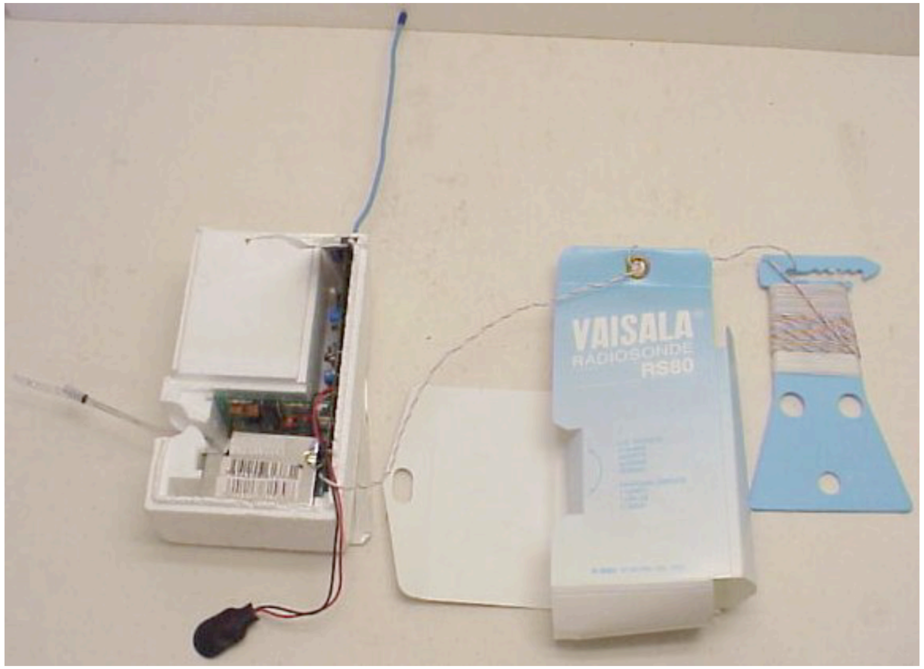
Principal of the pyranometer

K: thermal conductance,
A: aria,
ΔT: temperature difference,
ε: emissivity

•**vertical measurement for temperature/ humidity/ wind profile -1:**

(1) simultaneously measurement using **low-level radio sondes**.
The sonde using observation requires man-power and is not suited for the continuous measurement.

(2) meteorological observation tower



Radio-sonde and the receiver

•vertical measurement for temperature/ humidity/ wind profile -2:

Recent years, the **remote sensing techniques** for the upper air soundings can be served:
(1) **remote wind sensing:**
Doppler sound radar can measure wind components (speed, direction, and vertical wind speed) and the standard deviations of wind components, and is used to develop new atmospheric **diffusion models**.
(2) **remote temperature sensing:**
Radio Acoustic Sounding System (RASS) can measure the temperature profile.

Doppler sound radar

NOTE: Doppler Sodar utilize the reflection of sound wave by the atmospheric turbulence. RASS measures the sound wave speed Vs from the radio wave Doppler reflected progressing sound wave, and obtains the temperature from Vs. w