IAEA ANSN / ISSC - REGIONAL WORKSHOP ON
"Volcanic, Seismic, and Tsunami Hazard Assessment Related to NPP Siting Activities and Requirements"
Jakarta, Indonesia, 13-17 June 2011

Dispersion of Radioactive Effluents in Air and Surface Water Impact, Radiological Aspects

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International Atomic Energy Agency

Lecture 18

Acceptability of a Site

Dispersion links

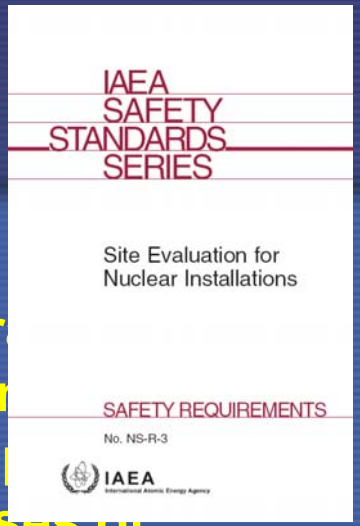
unavoidable discharges of the plant

with

impacts to man and environment

(⟷ Dose Limits)

NS-R-3 General Criteria



2.22. In the evaluation of a site to determine its potential r
impact on the region for operational states and accide
conditions that could lead to emergency measures, ap
estimates shall be made of expected or potential releases o
radioactive material, with account taken of the design of the installation and its safety features. These estimates shall be confirmed when the design and its safety features have been confirmed.

2.23. The direct and indirect pathways by which radioactive material released from the nuclear installation could potentially reach and affect people and the environment shall be identified and evaluated; in such an evaluation specific regional and site characteristics shall be taken into account, with special attention paid to the function of the biosphere in the accumulation and transport of radionuclides.

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NS-R-3: General Criteria

2.24. The site and the design for the nuclear installation shall be examined in conjunction to ensure that the radiological risk to the public and the environment associated with radioactive releases is acceptably low.

2.25. The design of the installation shall be such as to compensate for any unacceptable potential effects of the nuclear installation on the region, or otherwise the site shall be deemed unsuitable.

NS-R-3: Site Characteristics

4.1 A meteorological description of the region shall be developed, including descriptions of the basic meteorological parameters, regional orography and phenomena such as wind speed and direction, air temperature, precipitation, humidity, atmospheric stability parameters, and prolonged inversions.

4.2. A programme for meteorological measurements shall be prepared and carried out at or near the site with the use of instrumentation capable of measuring and recording the main meteorological parameters at appropriate elevations and locations. Data from at least one full year shall be collected, together with any other relevant data that may be available from other sources.

NS-R-3: Site Characteristics

4.3. On the basis of the data obtained from the investigation of the region, the atmospheric dispersion of radioactive material released shall be assessed with the use of appropriate models. These models shall include all significant site specific and regional topographic features and characteristics of the installation that may affect atmospheric dispersion.

Objectives: Impact

International Basic Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (IAEA, BSS, No. 115)

Normal exposures of individuals of the public (average doses to the relevant critical groups of members of the public)

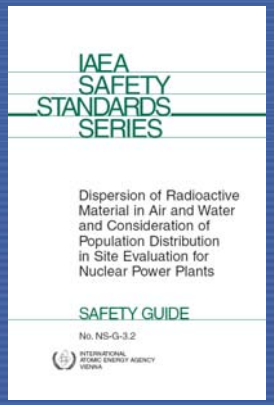
Caused by the possible combination of exposures from authorized practices

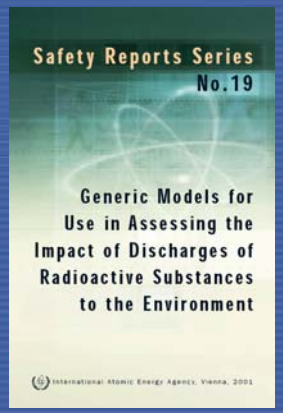
Shall be restricted to

- **an effective dose of 1 mSv in a year**
- **in special circumstances to an effective dose of up to 5 mSv in a single year provides that the average dose of five consecutive years does not exceed 1mSv per year,**
- **an equivalent dose to the lens of the eye of 15 mSv in a year and**
- **an equivalent dose to the skin of 50 mSv in a year.**

Outline

1. Determination of Exposure Pathways (Site Specific)
2. Source term, Source Conditions
3. Assessment of Dispersion Conditions at the Site
   i. Dispersion Conditions Atmoshpere
   ii. Dispersion Calculation Atmosphere
   iii. Dispersion Conditions Surface Water
   iv. Dispersion Calculation Surface water
4. Receptor Points to be Considered
5. Transfer through Food Chains
6. Calculation of Dose





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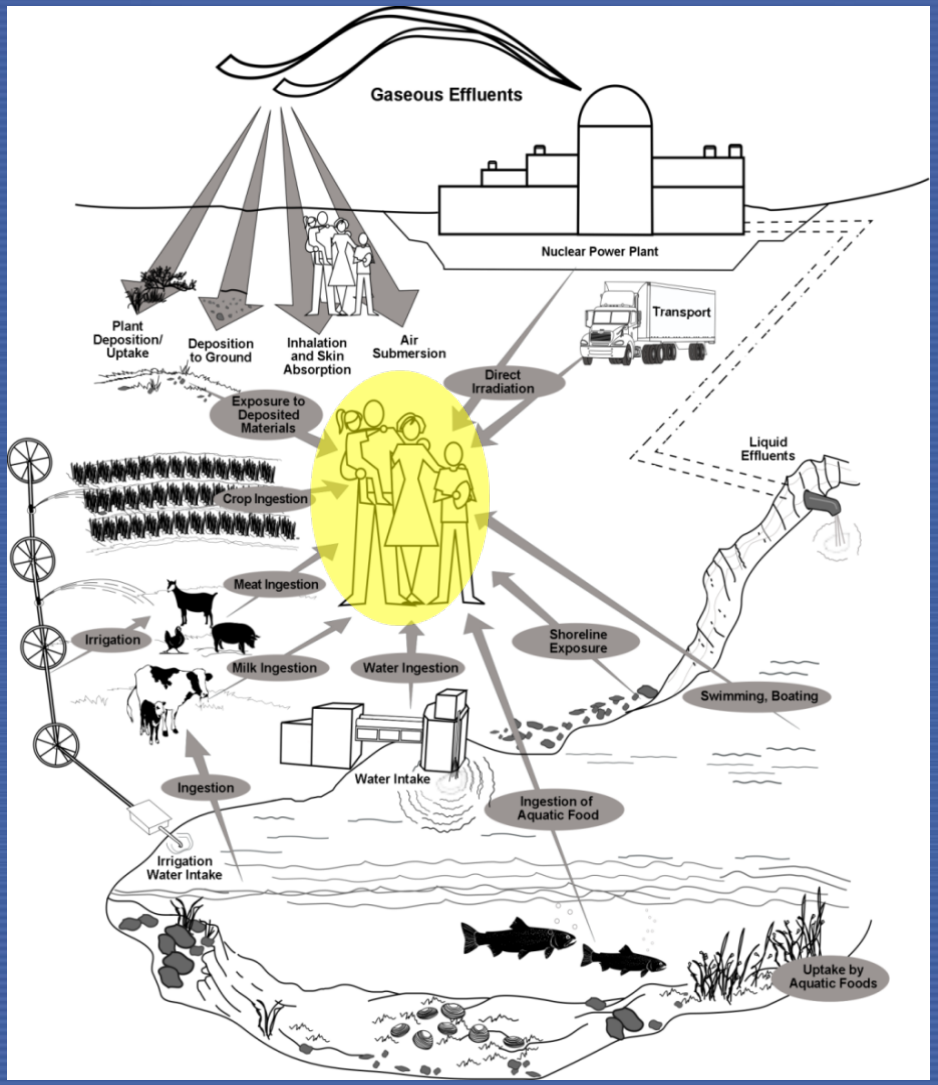
Exposure Pathways

Exposure of reference person (ICRP 23)



Exposure Pathways Gaseous Effluents

Typical European Sites

- External β-radiation within the exhaust air plume (β-submersion)
- External γ-radiation from the exhaust air plume (γ-submersion)
- External γ-radiation of the activity deposited on the ground (ground radiation)
- Internal irradiation originating from radionuclides inhaled with the air (inhalation)
- Internal irradiation caused by the consumption of contaminated food (ingestion)
  - atmosphere → plants (vegetables)
  - atmosphere → fodder → cow → milk
  - atmosphere → fodder → animal → meat

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Exposure Pathways: Surface Water

Typical European Sites

- External γ-radiation of the activity deposited on the ground (ground radiation, radiation from surface water and sediments)
  - Stay on banks, shores
  - Stay on sediments
  - Swimming
  - Boating
- Internal irradiation caused by the consumption of contaminated food (ingestion)
  - Surface water → fish
  - Surface Water → irrigation → plants (vegetables)
- Use of sediments as fertilizer

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NS-G-3.2: Land and Water Use

Investigation of land and water use in the vicinity of the plant (sec. 4.1 ... 4.7)

NS-G-3.2

- Purpose
  - Operation of the plant affects the population, land and water use determines important parameters
  - parameters affecting the feasibility of an emergency plan.
- Agricultural uses, its extent, and the main crops and their yields;
- Dairy farming, its extent and yields;
- Industrial, institutional and recreational purposes, its extent and the characteristics of its use;

NS-G-3.2: Land and Water Use

- Water used for commercial, individual and recreational fishing
- Water used for commercial purposes, including navigation, community water supply, irrigation and recreational purposes
- Land and of water supporting wildlife and livestock;
- Direct and indirect pathways for potential radioactive contamination of the food-chain;
- Products imported to or exported from the region which may form part of the food-chain;
- Free foods such as mushrooms, berries and seaweed. Present uses of water, changes in uses of water in the region, such as for irrigation, fishing and recreational activities, should also be considered.

NS-G-3.2: Land and Water Use

- Consideration of any population centres for which drinking water is obtained from water bodies that may be affected by a nuclear power plant
- Movement and quality of the groundwater for areas where drinking water is obtained from springs, wells
- Water used for drinking by humans and animals, and for municipal and industrial purposes
  - average and maximum rates of water intake by users
  - distance of the intake from the potential source of radioactive discharges
- Water used for irrigation
  - rate of water use
  - area of irrigated land
  - types and yields of agricultural products, and their usual consumers

NS-G-3.2: Land and Water Use

- Water used for fishing
  Species fished, and their abundance and yields in water used for commercial, individual and recreational fishing
- Water used for recreational purposes
  Number of persons engaging in swimming, boating and other recreational uses, and the time spent on these activities
- Investigations should cover a reasonably large area. If a nuclear power plant is located on a river bank, users downstream from the site should be identified. If the site is near a lake, all users of the lake should be identified. If a site is on an ocean coast, users of the sea out to a few tens of kilometres in all directions should be identified

Exposure Pathways

Additional assessment is required, if further typical habits at the site are supposed to have relevant consequences to resulting exposures of the members of the critical group

E. g., near a French NPP located at the Channel (Northern Sea between England and France) for some fishermen seaweed is a major part of daily food. This specific exposure pathway has been considered and compliance with existing exposure limits has been shown.

Scope

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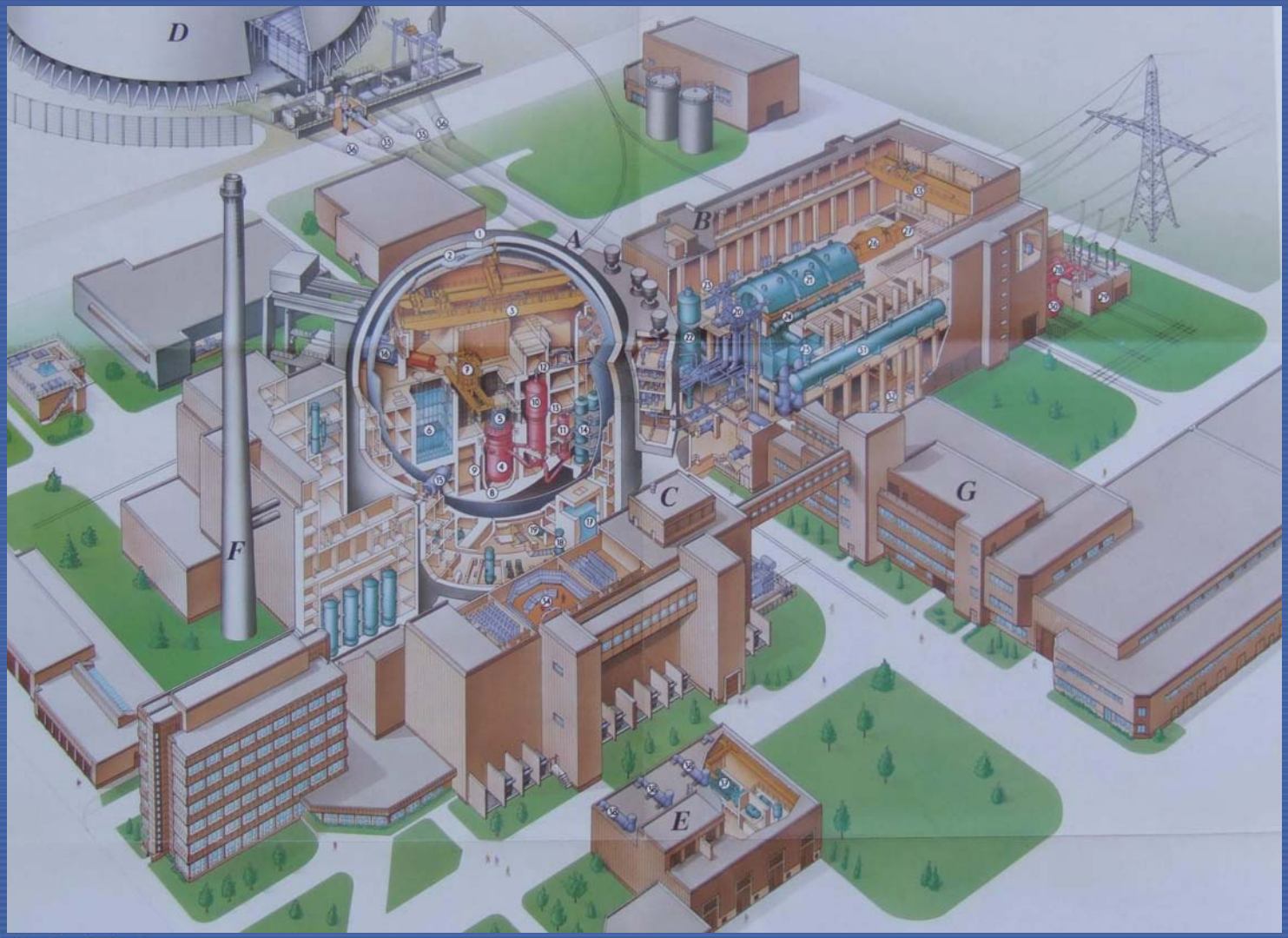
Source



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Source Term: Atmosphere, Water

Radioactive Discharges

Gaseous effluents

- Radioactive gases (incl. C-14), Iodine, aerosols, Tritium
- Long term
- Short term
- normal operation
- accidental releases

Liquid effluents

- Fission products, activation products, Tritium
- normal operation

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NS-G-3.2: Source (Atmosphere)

Radioactive Source Parameter (sec. 2.8) NS-G-3.2

- Radioactivity
  - Rate of discharge of each important nuclide and the total activity of each important nuclide released in a specified period;
  - Variation of the rate of discharge of each important nuclide;
- Chemical characteristics of the material released;
- Physical properties of the material released (e.g. temperature)
- Geometry and mechanics of the discharge (e.g. stack height, velocity).

NS-G-3.2: Source (Surface Water, Groundwater)

Radioactive Source Parameter (sec. 3.5) NS-G-3.2

- Radioactivity
- Chemical properties
- Physical properties of the liquid effluents discharged (d) Flow rates for continuous discharges, or volume and frequency for batch discharges
- The variation of the source term over the duration of the discharge
- The geometry and mechanics of discharges

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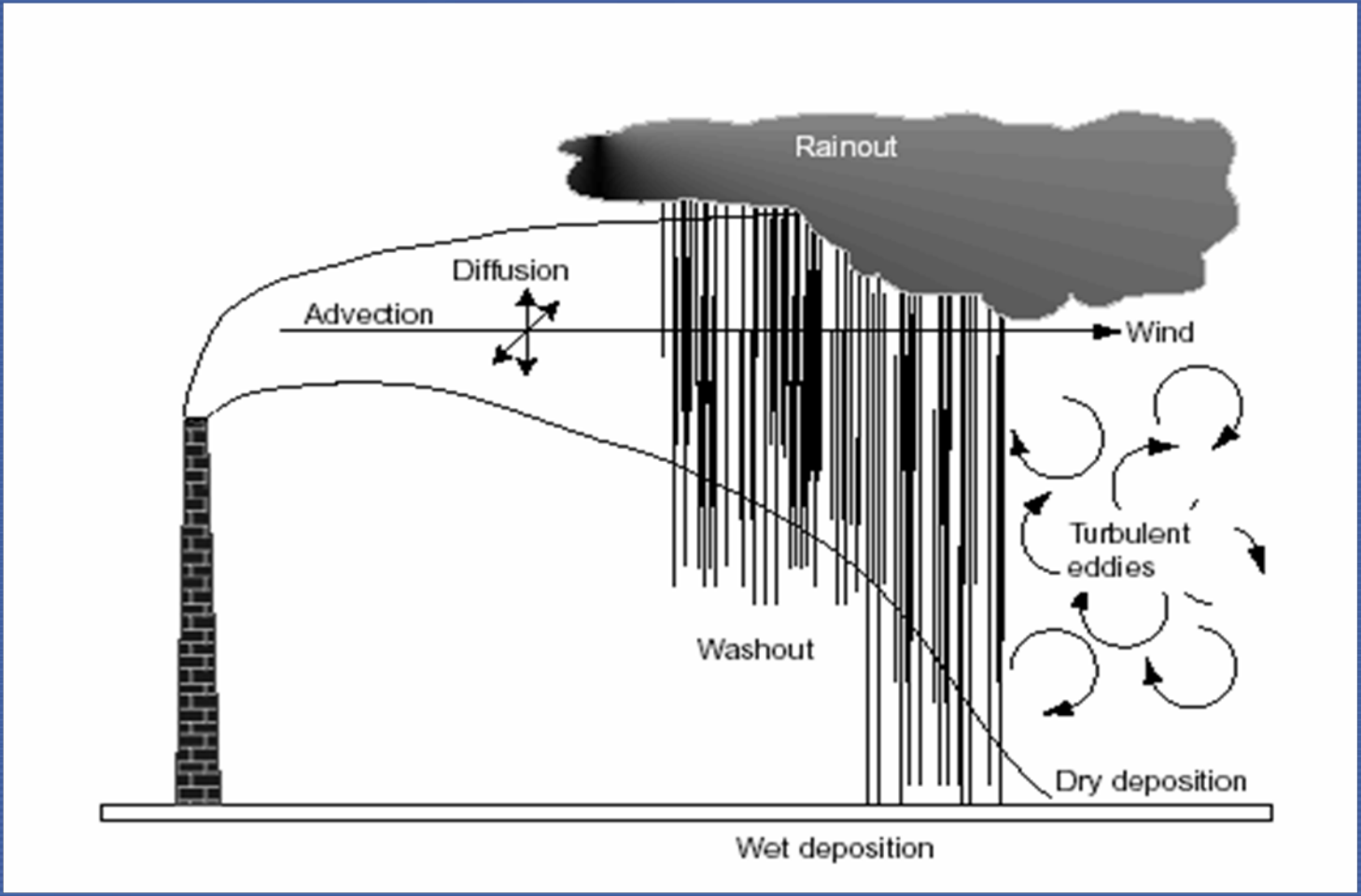
Dispersion in the Atmosphere



NS-G-3.2: Source (Atmosphere)

Investigation Programme for Meteorological data (sec. 2.10, 2.11) NS-G-3.2

- continuously collection and evaluation of meteorological parameters during normal operation of a nuclear power plant
  - Site specific meteorological parameters relating to calculations of atmospheric dispersion and statistical analyses
  - Site specific meteorological parameters as specified in the emergency plan
- Providing data for an adequate time period that are representative of the site (at least two full years [DS 417], precipitation much longer time periods)
  - before the start of plant construction
  - during the lifespan of the plant

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NS-G-3.2: Source (Atmosphere)

NS-G-3.2

Necessary data (Sec. 2.14)

- wind vectors (i.e. wind directions and speeds),
- specific indicators of atmospheric turbulence,
- precipitation,
- air temperatures,
- humidity,
- air pressure.

NS-G-3.2: Source (Atmosphere)

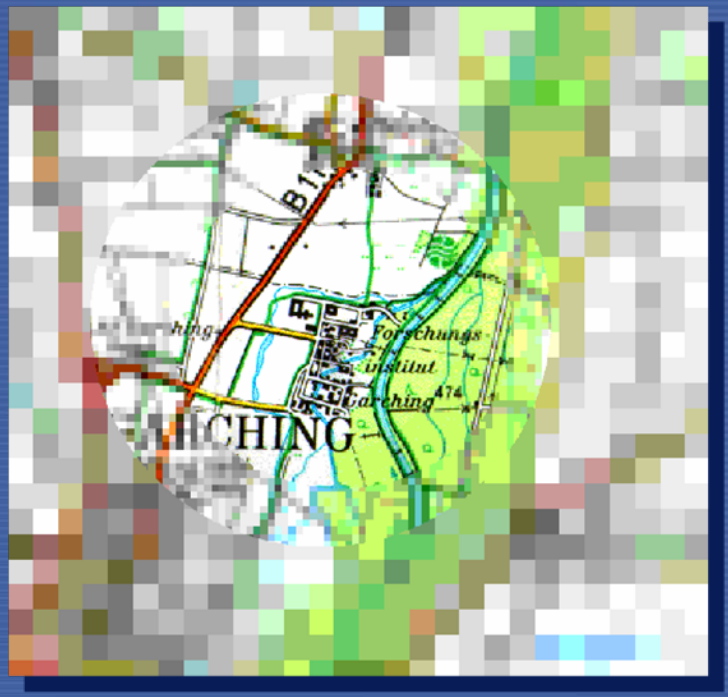
NS-G-3.2

Siting of the meteorological measurement system (sec. 2.16)

Meteorological equipment should be installed in such a way as to obtain data representing the dispersion conditions at release points. Examination of the terrain in the range of several kilometres around a nuclear power plant site is necessary. Topographical features of interest include valleys, principal ridges and coastlines. Isolated hills, wooded and forested areas and large artificial structures should be noted. Shallow valleys (less than 100 m deep and 5–10 km wide) should be considered because they can affect lower level winds. Equipment should be properly exposed and should be positioned far enough from any obstacles to minimize their effects on measurements. Ground cover and vegetation should be managed for the duration of the investigation programme, to avoid local influences.

Assessment of Dispersion Conditions at the Site

- Transport with the wind (advection)
- Diffusion caused by atmospheric turbulence
- Relevant Meteorological Conditions for Dispersion Calculations
  - windspeed
  - wind direction
  - atmospheric stability
  - precipitation
- Meteorological statistics for at least 2 consecutive years
- On site measurements: Meteorological tower, SODAR



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Meteorological Tower

Egypt, El Daaba site

Wind

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On-Site Meteorological Programme

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Doppler SODAR

SODAR:
Sonic detection and ranging

Height range: 15 m – 500 m

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Participation of National Meteorological Service

Determined on site meteorological parameter should be evaluated with respect to the standards and database of the national meteorological service

- correspondence of on-site data with database of national meteorological service
- use of data of the national meteorological service in case of failure of on site instrumentation
- calibration, certification of devices
- implementation of regional results

NS-G-3.2: Stability Classes for Dispersion Calculation

NS-G-3.2

Turbulence in the atmosphere (sec. 2.23)

Fluctuations in meteorological conditions are direct indicators of atmospheric turbulence. Depending upon the Dispersion model, turbulence can be determined by different parameters:

- Fluctuations in wind direction (sigma–theta method);
- Air temperature and temperature lapse rate (delta T method);
- Wind speed and solar radiation levels or sky cover during the daytime, and sky cover or net radiation levels at night-time (insulation method)
- Wind speed at different heights

Meteorological Site Conditions

Assessment of meteorological parameters

- wind direction: sectors
- windspeed: sectors
- category of atmospheric stability, e.g. Pasquill
- precipitation: sectors

4 parameter meteorological statistic

Met Statistic

Dispersion in Air

Figure 2. Typical plume dispersion patterns with pertinent to atmospheric turbilance characteristics.

§2-7.2 ATMOSPHERIC TRANSPORT AND DIFFUSION STUDIES 59

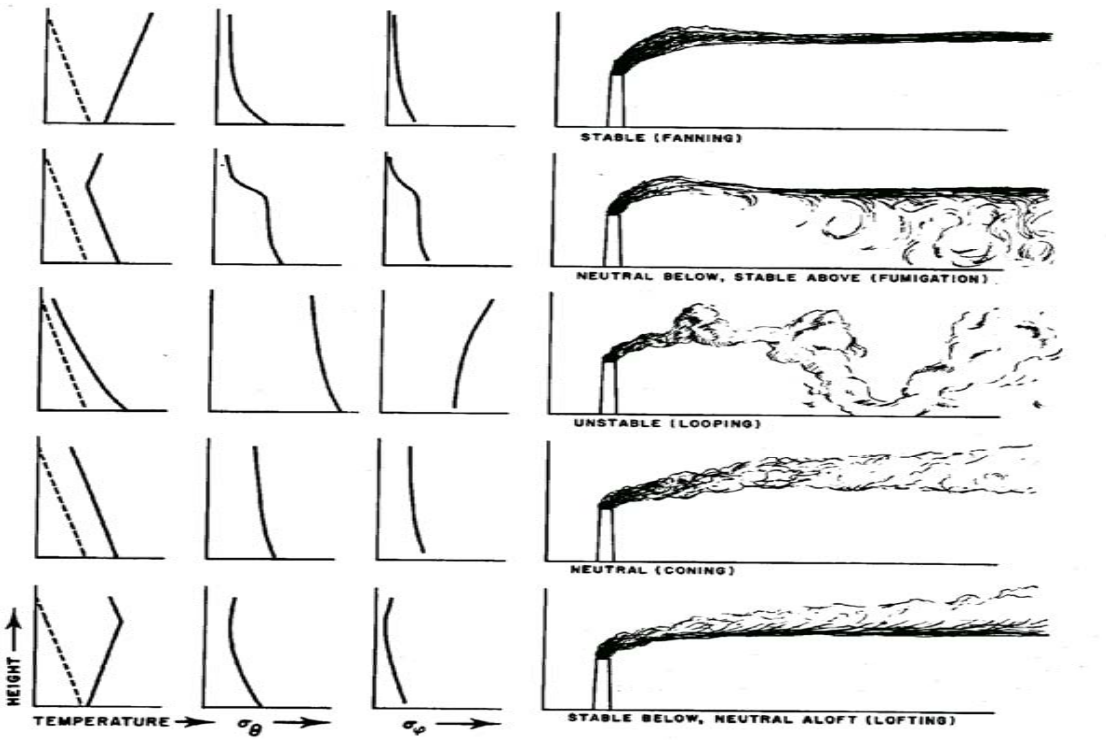

Fig. 2.40 — Various types of smoke-plume patterns observed in the atmosphere. The dashed curves in the left-hand column of diagrams show the adiabatic lapse rate, and the solid lines are the observed profiles. The abscissas of the columns for the horizontal and vertical wind-direction standard deviations (σ_θ and σ_φ) represent a range of about 0° to 25°.

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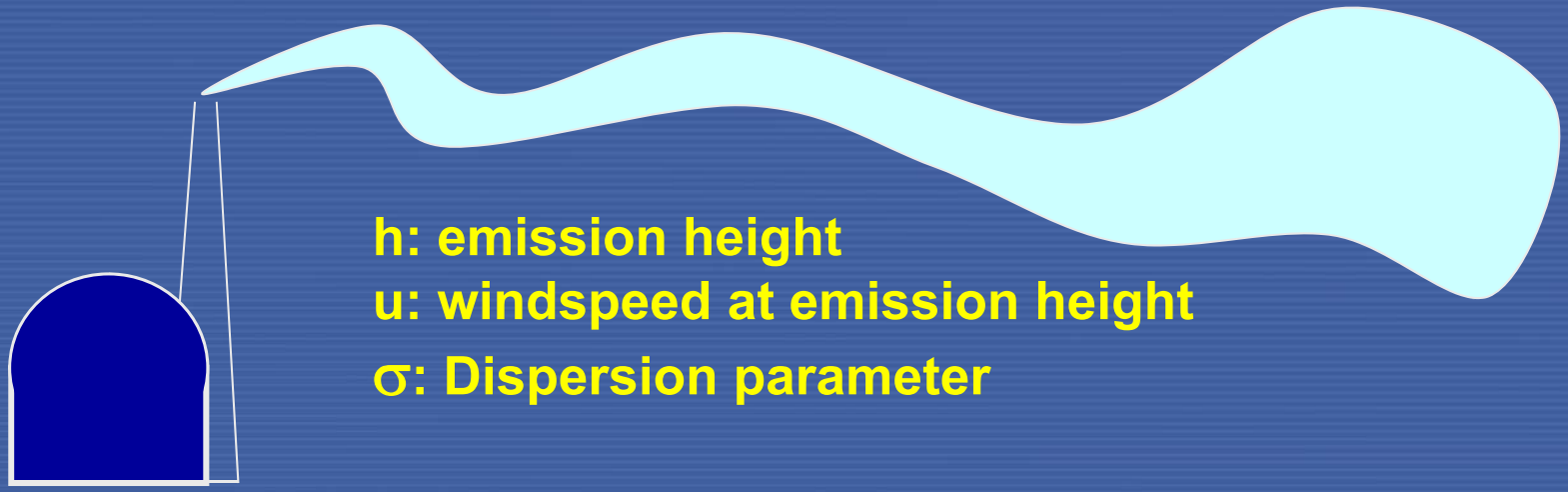
Determination of the Dispersion

- Dispersion Calculation using Gaussian Plume Model
  - If necessary (buildings etc.), modifications as indicated in the literature, e. g. IAEA Safety Reports Series No. 19 GENERIC MODELS
- Numerical Wind Field and Dispersion Models
  - e. g. with Lagrange-type Diffusion Calculation

codes

Dispersion model

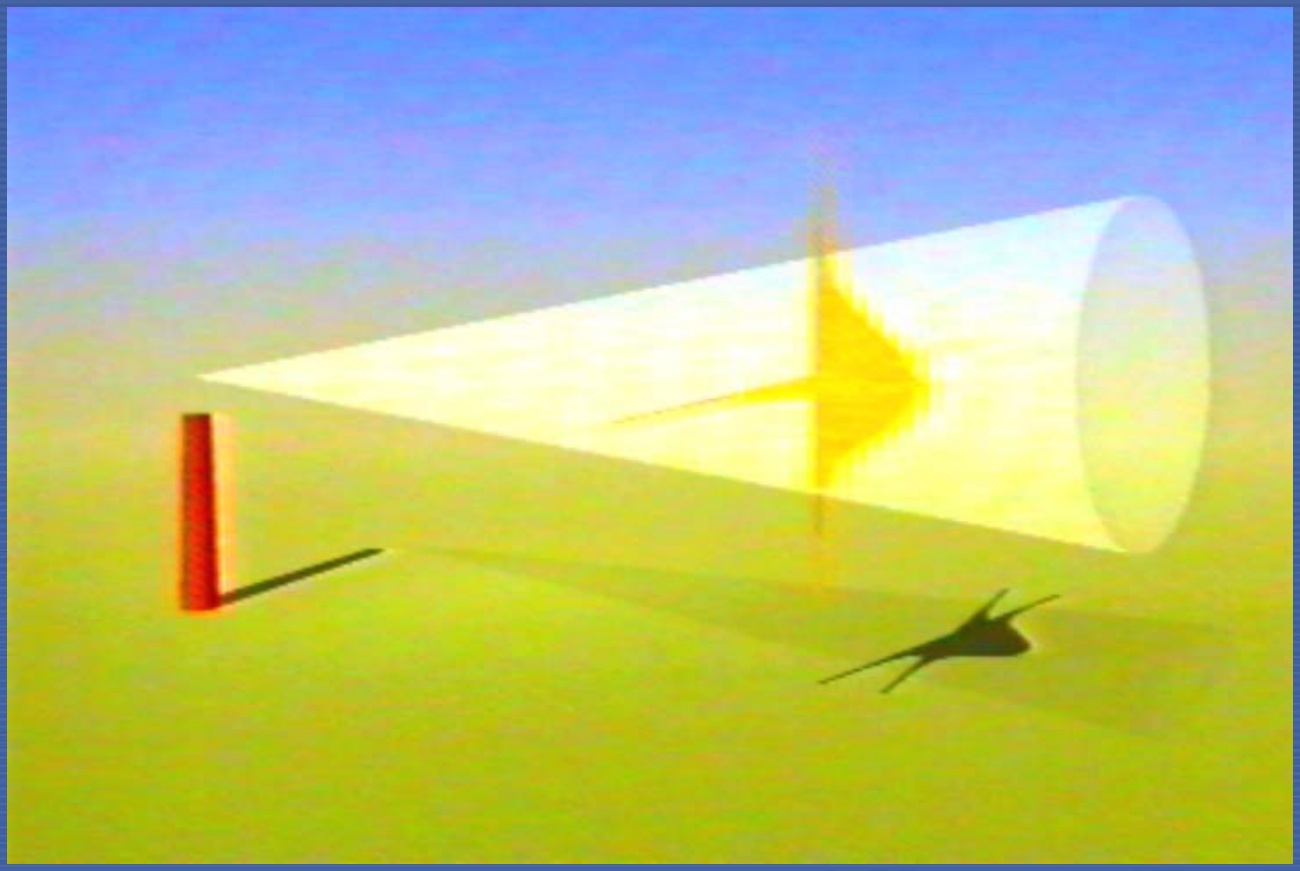


h: emission height
u: windspeed at emission height
σ: Dispersion parameter

Dispersion model → h, u,σ → Dispersion factor χ

Dispersion factor χ → C ~χ → near ground activity concentration C

Gaussian Plume Model (pic.)



Condition: Steady state in space and time

Dispersion in Air

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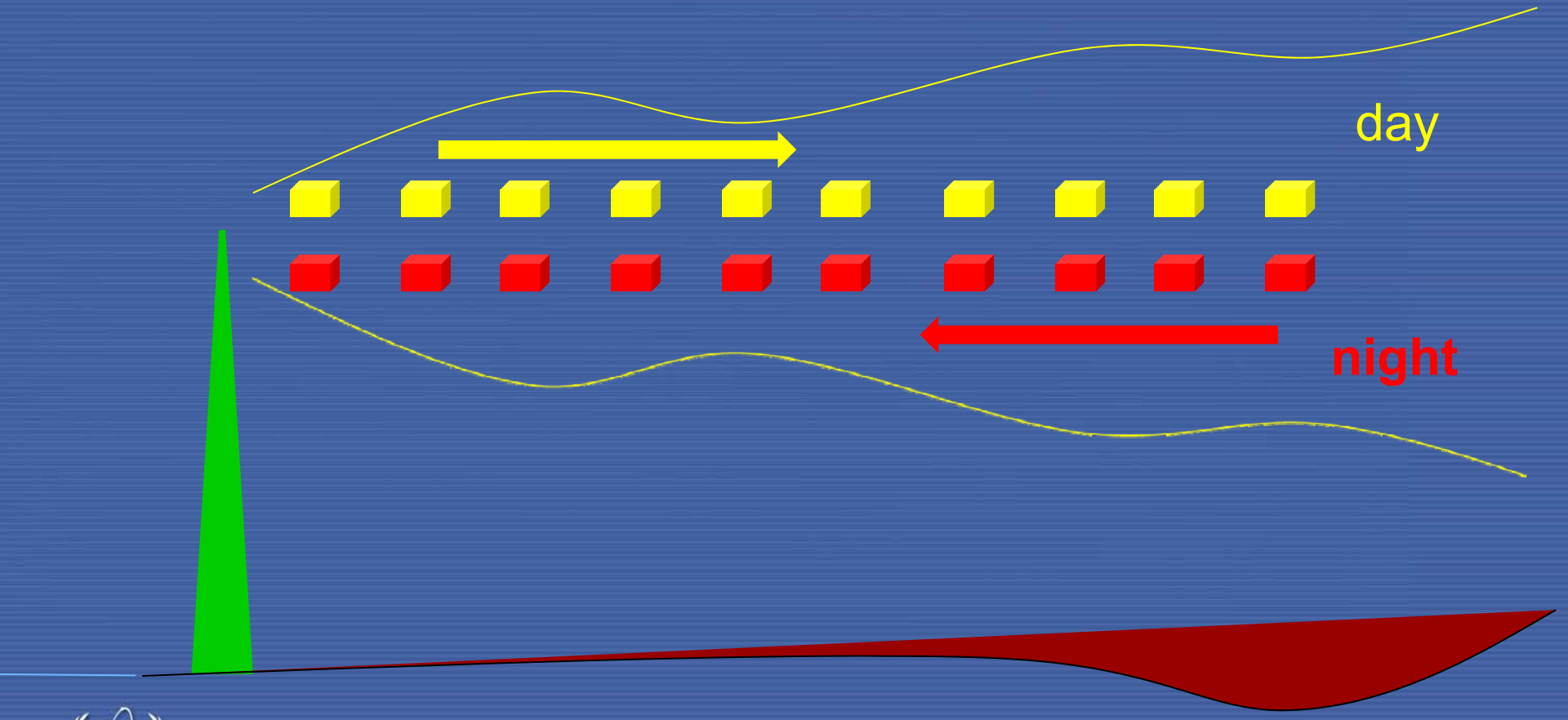
Influences on the Atmospheric Diffusion

- Buildings
- Relief of the Terrain
- Vegetation
- Thermal Buoyancy
- Thermal Wind Systems, e. g.
  - hillside down wind systems
  - mountain/valley wind circulation
  - cold air flow
  - sea breeze

back

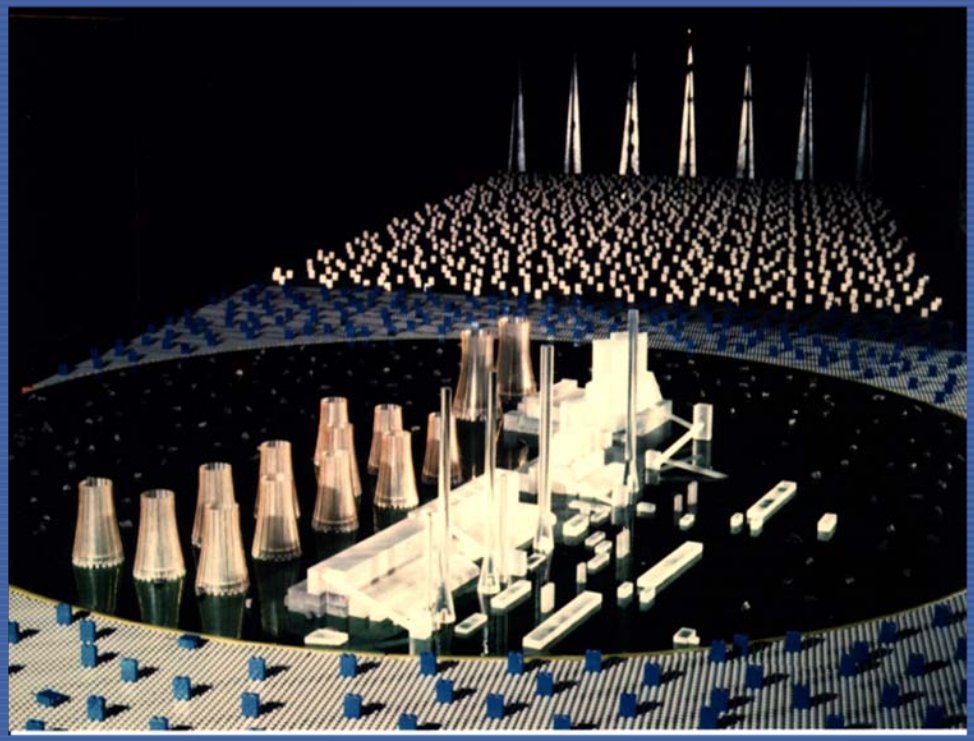
LAND SEA BREEZE



Atmospheric Boundary Layer Wind Tunnel

Investigation of Influences like:

- orography of the site
- buildings
- cooling tower plume
- locally different roughness

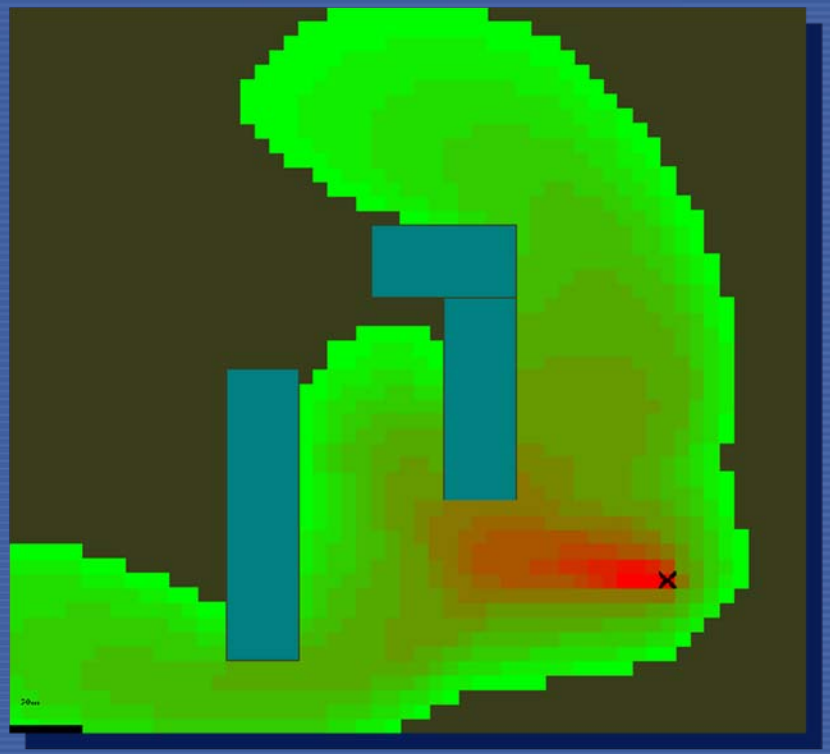


Modified Disp Parameter

Diffusion Calculation

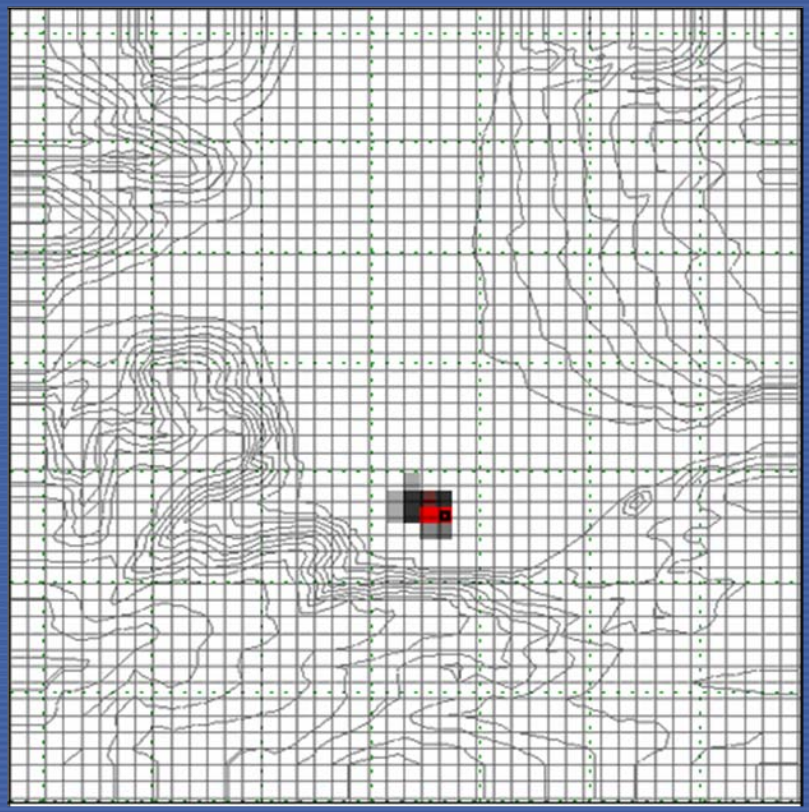
Example:

The influence of buildings on the downwind side of a pollutant is considered by numerical modelling (Lagrange Particle Dispersion Model)



Lagrange-type diffusion calculation

- including wind field simulation with a diagnostic wind field model
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 1 ->>



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Lagrange-type diffusion calculation

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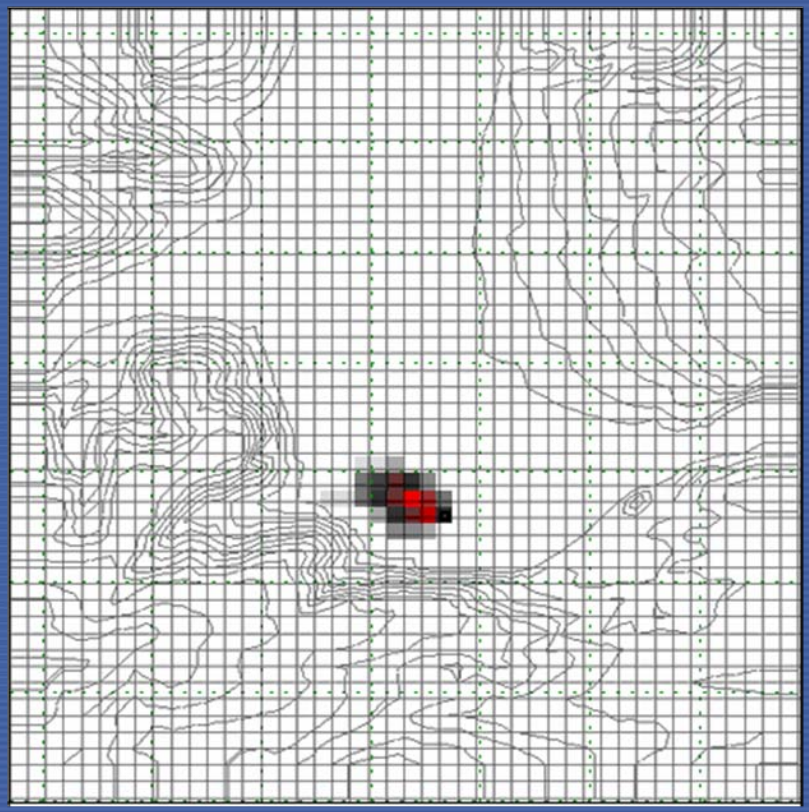
    - time step 2 ->>



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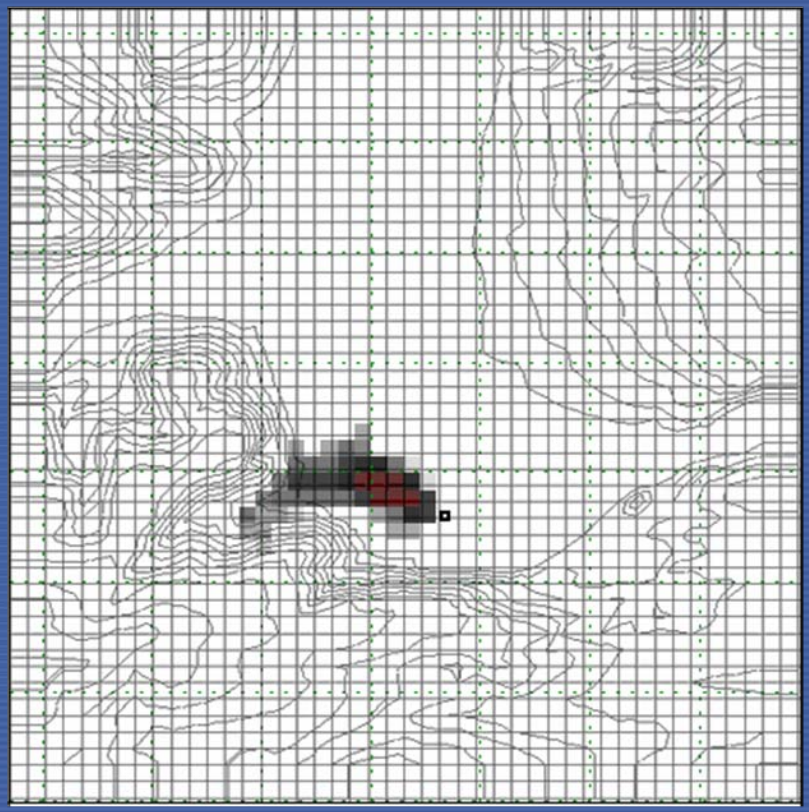

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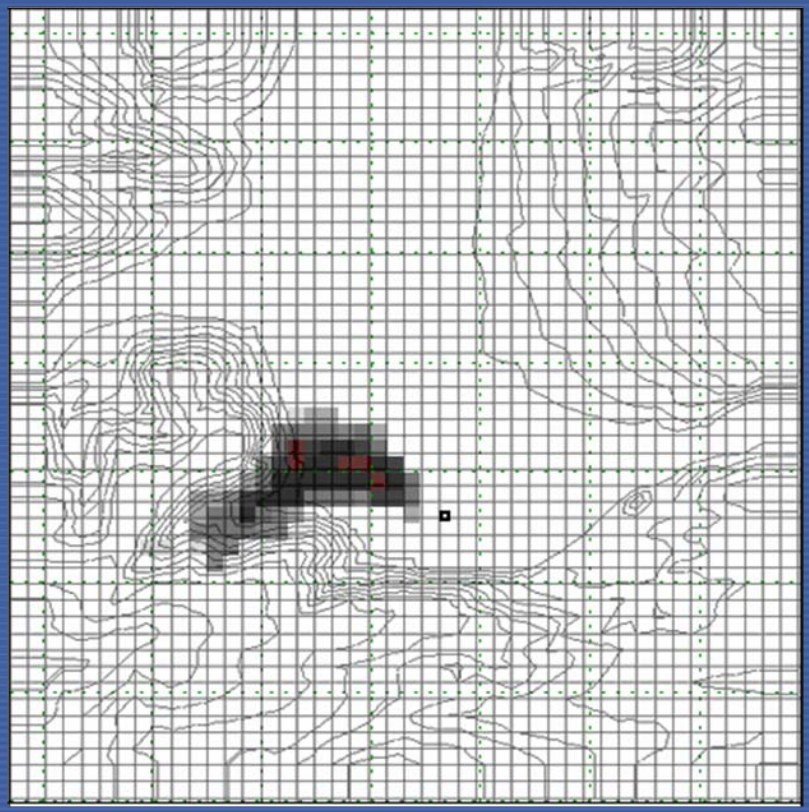

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Lagrange-type diffusion calculation

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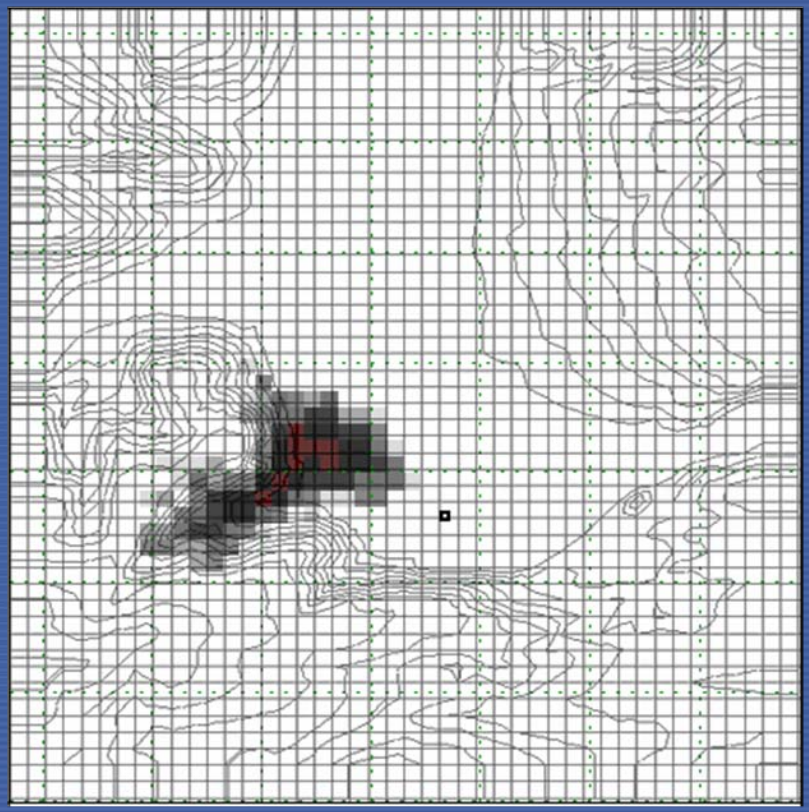
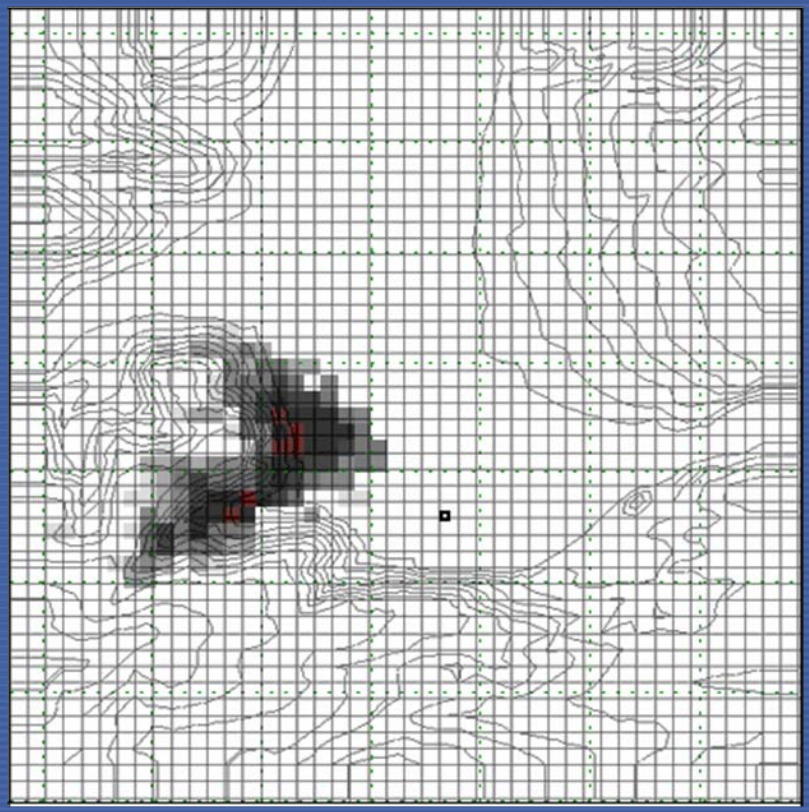
    - time step 5 ->>



Lagrange-type diffusion calculation

- including wind field simulation with a diagnostic wind field model
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 6 ->>



Lagrange-type diffusion calculation

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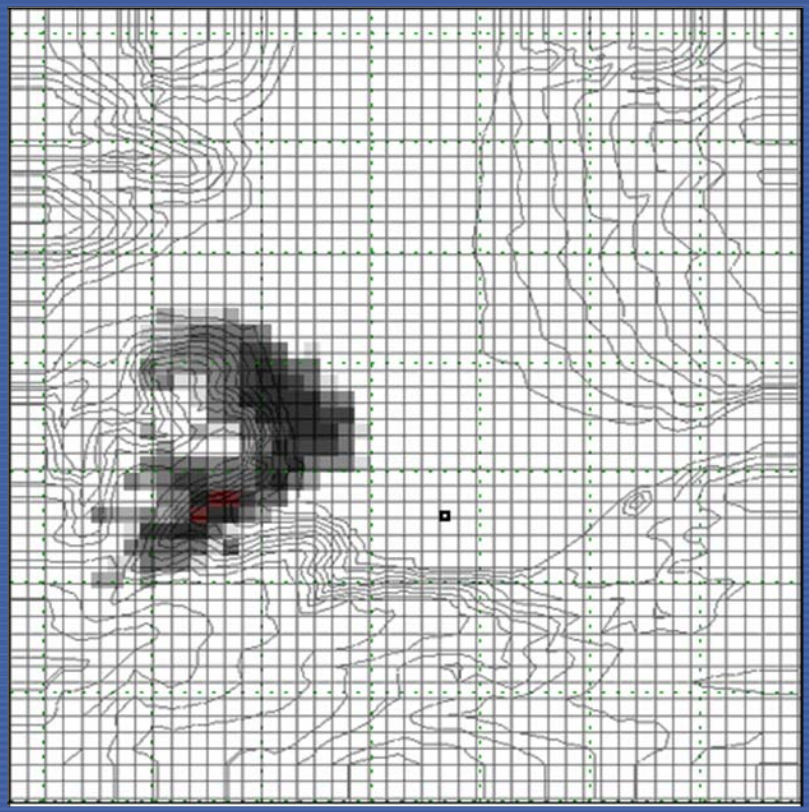
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 7 ->>



Lagrange-type diffusion calculation

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- characteristics of the example
  - short time release from a stack
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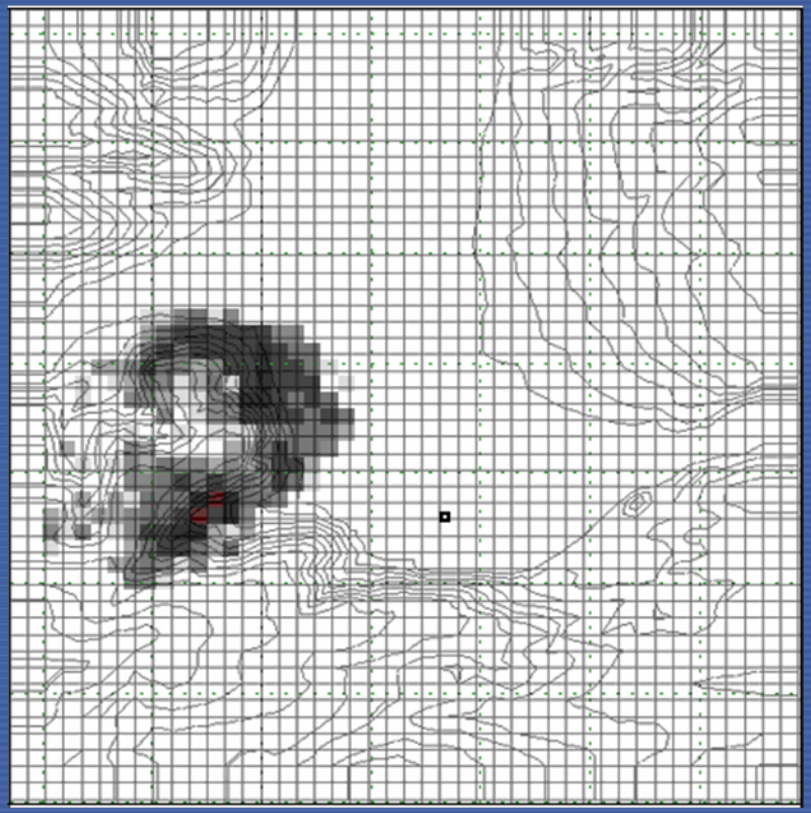
    - time step 8 ->>



Lagrange-type diffusion calculation

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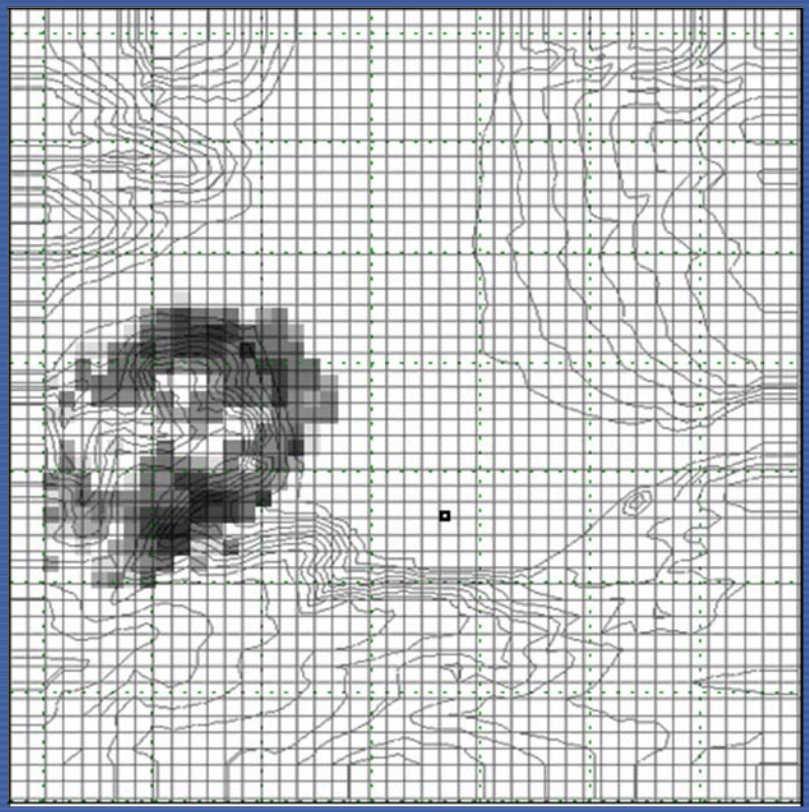
    - time step 9 ->>



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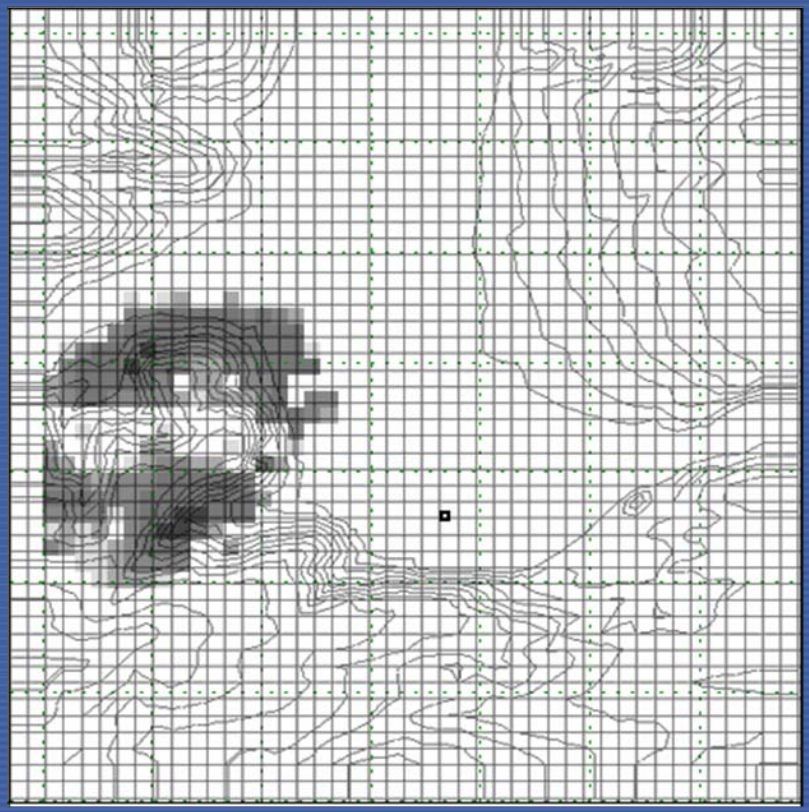

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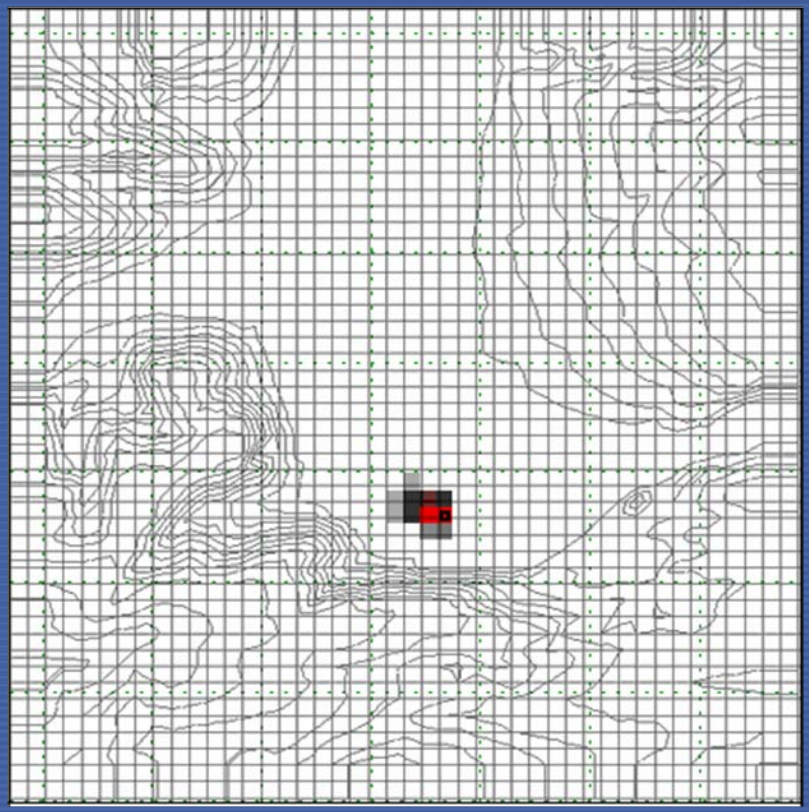

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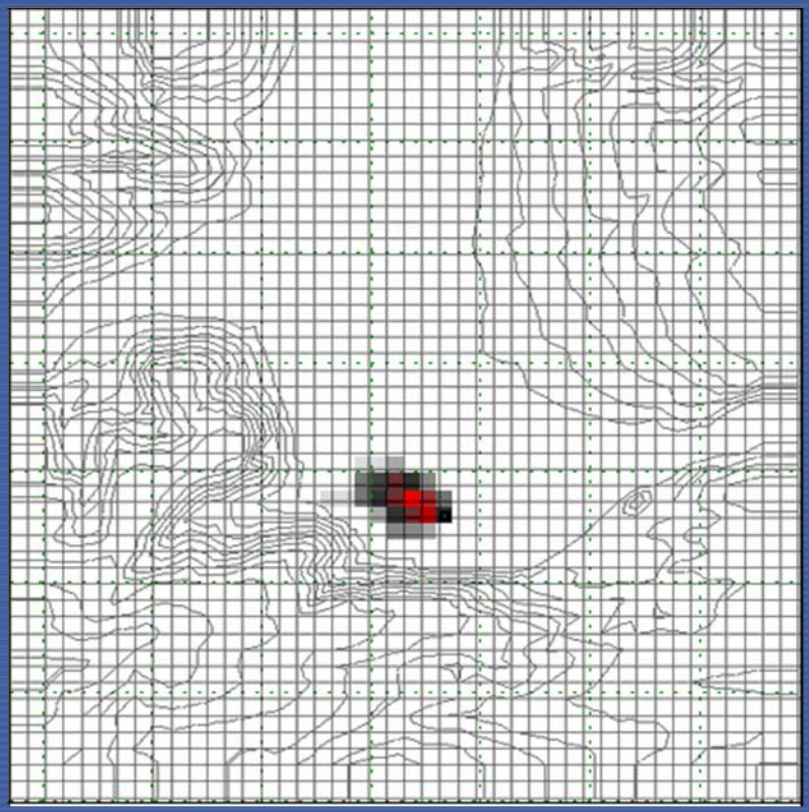

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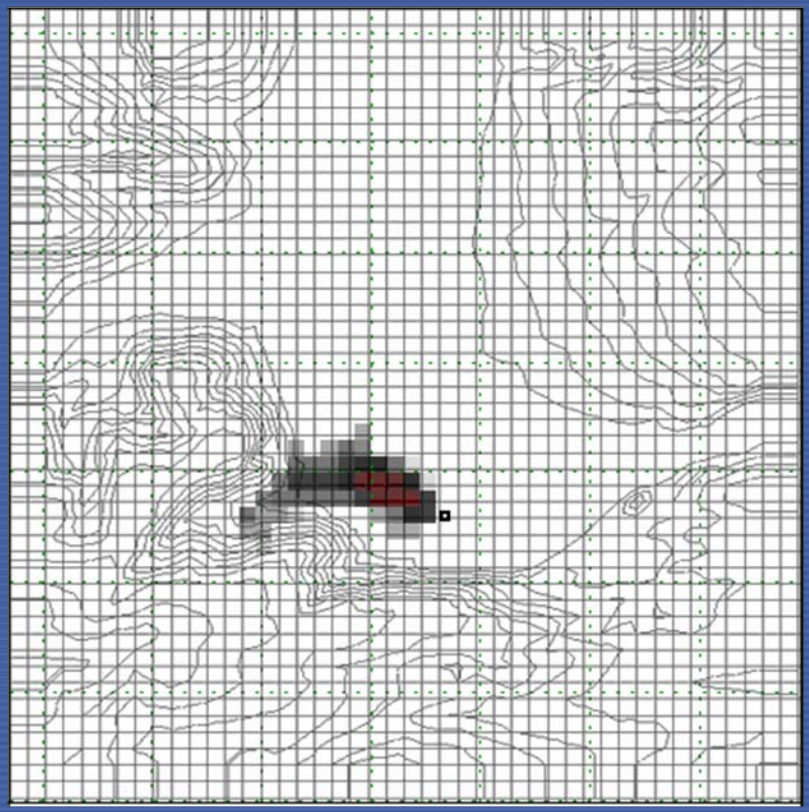
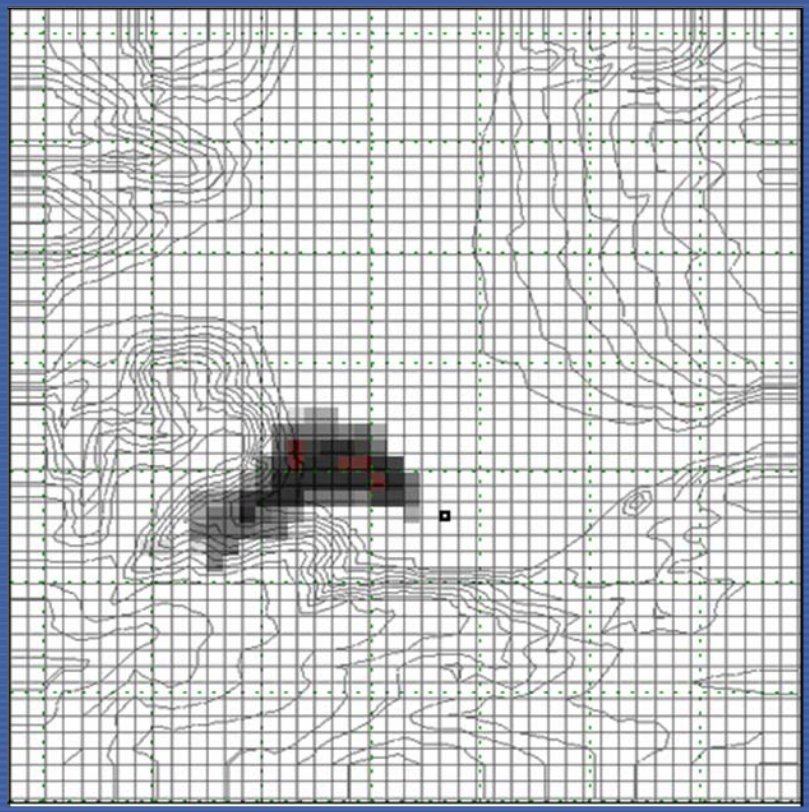
  - complex orographic site
    - time step 3 ->>



Lagrange-type diffusion calculation

- including wind field simulation with a diagnostic wind field model
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 4 ->>



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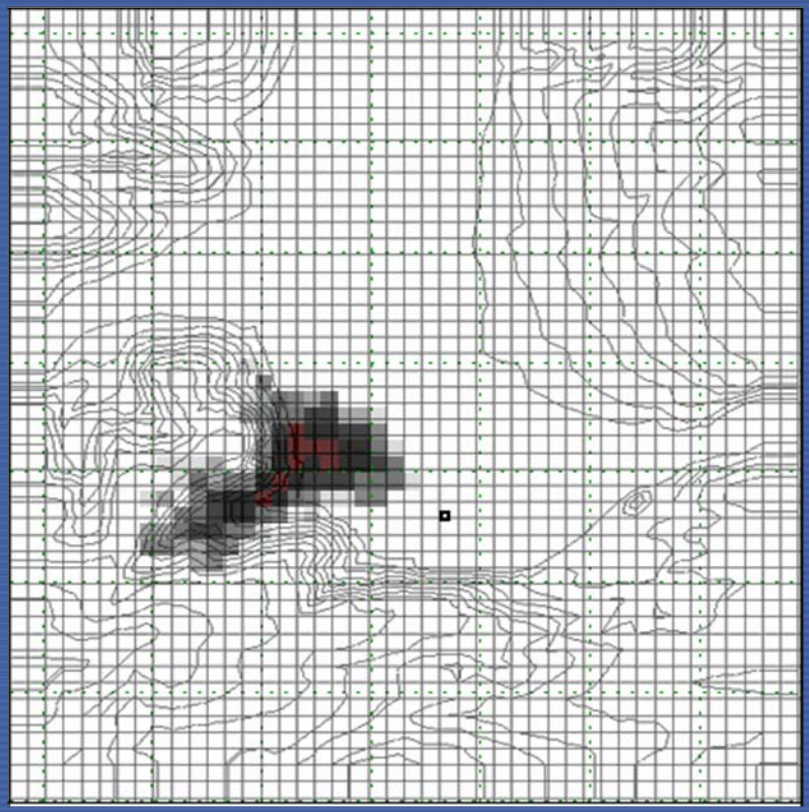
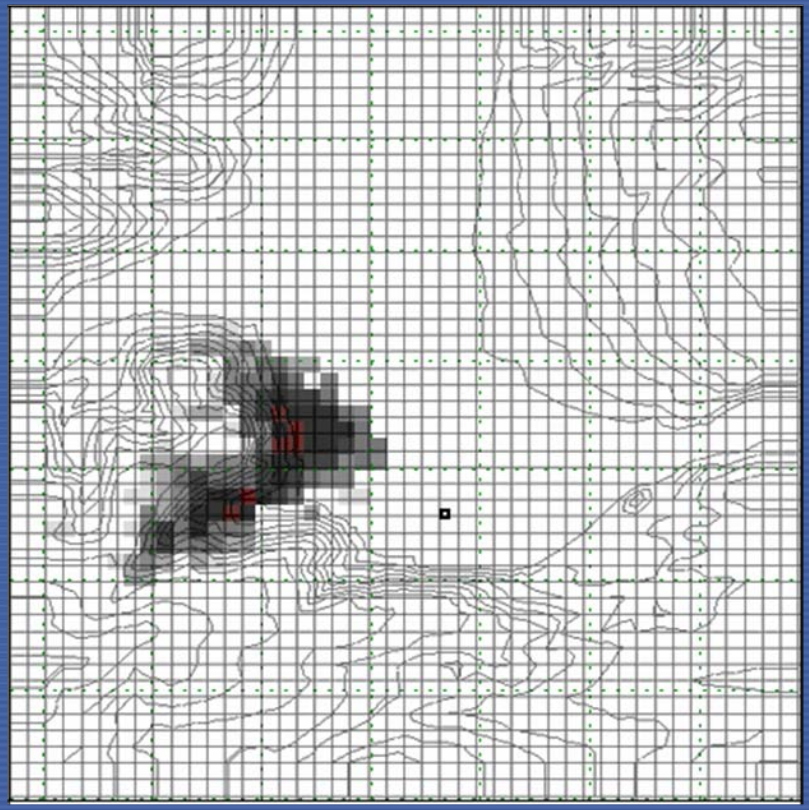
Lagrange-type diffusion calculation

- including wind field simulation with a diagnostic wind field model
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 5 ->>



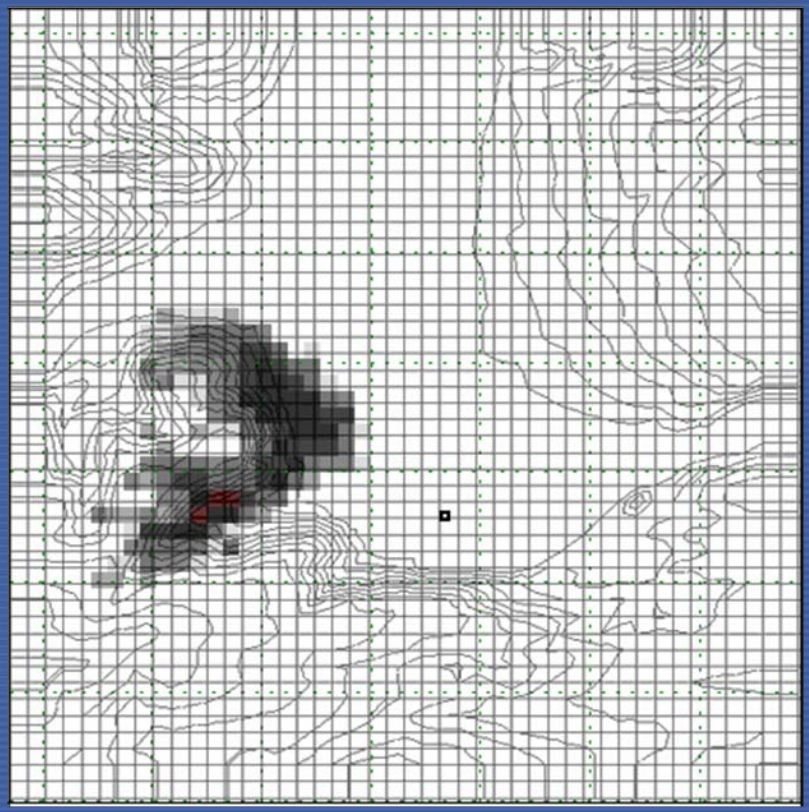
Lagrange-type diffusion calculation

- including wind field simulation with a diagnostic wind field model
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 6 ->>



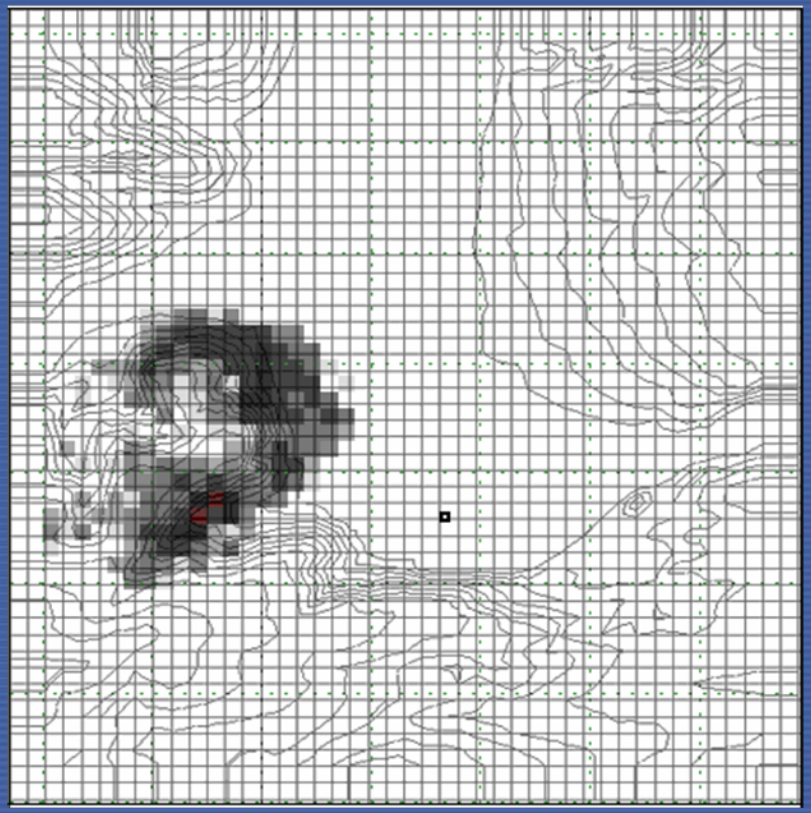
Lagrange-type diffusion calculation

- including wind field simulation with a diagnostic wind field model
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 7 ->>



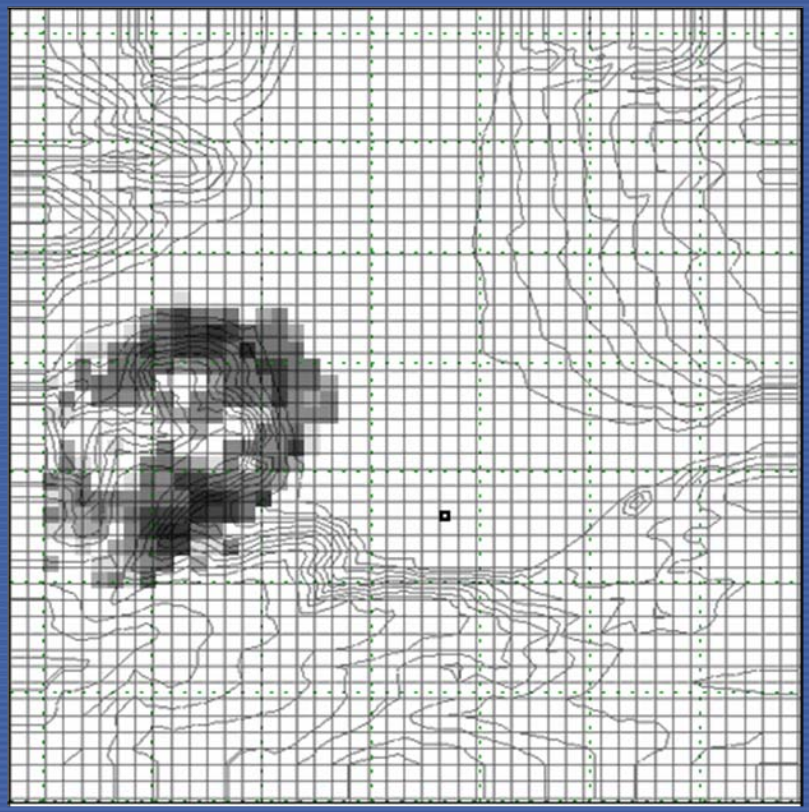
Lagrange-type diffusion calculation

- including wind field simulation with a diagnostic wind field model
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 8 ->>



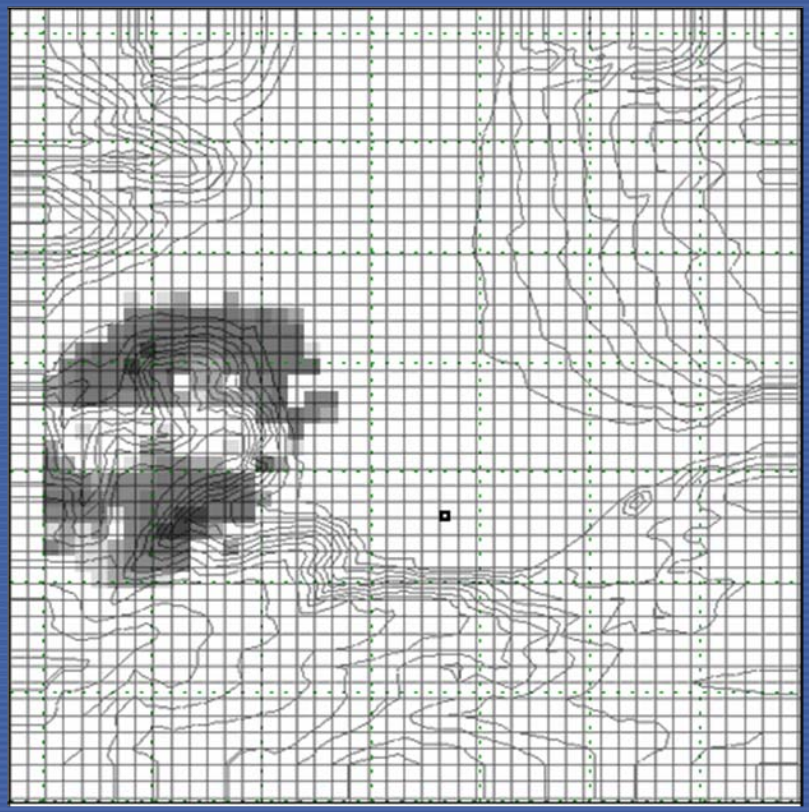
Lagrange-type diffusion calculation

- including wind field simulation with a diagnostic wind field model
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 9 ->>



Lagrange-type diffusion calculation

- including wind field simulation with a diagnostic wind field model
- characteristics of the example
  - short time release from a stack
  - complex orographic site
    - time step 10 ->>



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Deposition: Fallout, Washout

Calculation of the Deposition of Radionuclides on the Ground and Plants using deposition rates

Fallout Factor

The ground contamination BF in Bq/m² by dry deposition is proportional to the time integral of the concentration in the near-to-ground air in Bq∗s/m³, whereby the fall-out constant v_g in m/s (also called fall-out speed) is the proportionality constant

Short term fallout factor F

$$F = v_g * x \quad 1/m^2$$

Long term fallout factor F_i

$$F_i = v_g * x_i \quad 1/m^2$$

Washout Factor

The ground contamination B_w in Bq/m² from precipitation during a short-term emission is calculated by an integration over z of the concentration distribution multiplied by the washout constant Λ in 1/s

Short-term washout factor [1/m²]

$$W = \frac{\Lambda}{u \cdot \sqrt{2\pi}} \sigma y$$

For the exact calculation of the long-term washout factor a 4-parameter precipitation statistic is necessary.

$$Wi = \frac{N}{2 \cdot \pi \cdot x} \cdot \sum_{jmt} q_{ijmt} \cdot \frac{\Lambda i}{u_{jm}}$$

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Surface Water Bodies

- Rivers
- Estuaries
- Coastal Waters
- Lakes

NS-G-3.2: Source (Surface Water, Groundwater)

Monitoring Programme for Surface Water and Groundwater (sec. 3.7 ... 3.11) NS-G-3.2

- Providing a baseline for site evaluation (siting and plant operation)
- two years before the start of plant construction (possible changes in the groundwater regime)
- Groundwater monitoring by samples, continued throughout the lifetime of the plant
- Monitoring of surface water starting before the start of construction of the plant, continued for its lifetime.
- Surface water and groundwater in the site region should be sampled regularly

NS-G-3.2: Data Rivers

Necessary data for sites at rivers (Sec. 3.15)

- Channel geometry NS-G-3.2
- River flow rate (monthly averages, flow rates of downstream tributaries of the river)
- Extremes in the flow rate from available historical data
- Temporal variation of the water level
- Tidal variations in water level and flow rate
- Interactions between river water and groundwater
- River temperature
- Thickness of the top layer if thermal stratification of water in the river occurs.
- Extreme temperatures (available historical data)

NS-G-3.2: Data Rivers

- Concentrations of suspended matter
- Characteristics of deposited sediments
- Distribution coefficients for sediments and for suspended matter Background levels of activity in water, sediment and aquatic food
- Seasonal cycles of phytoplankton and zooplankton
- Spawning periods and feeding cycles of major fish species.

NS-G-3.2: Data Estuaries

Necessary data for sites at estuaries (Sec. 3.16)

NS-G-3.2

- Salinity distribution
- Sediment displacements, load of suspended matter, rate of buildup of deposited sediment layers, movement of these sediments with the tide
- Channel characteristics
- Distribution coefficients for sediments and for suspended matter
- Background levels of activity in water, sediment and aquatic
- Seasonal cycles of phytoplankton and zooplankton
- Spawning periods and feeding cycles of major fish species

NS-G-3.2: Data Sea

NS-G-3.2

Necessary data for sites at the sea (Sec. 3.18)

- General shore and bottom configuration in the region, data on bathymetry (several kilometres), Amount and character of sediments in the shallow shelf waters
- Speeds, temperatures and directions of any near shore
- Duration of stagnation and characteristics of current reversals
- Thermal stratification of water layers and its variation with time,
- Load of suspended matter, sedimentation rates and sediment distribution coefficients
- Background levels of activity in water, sediment and aquatic food
- Seasonal cycles of phytoplankton and zooplankton
- Spawning periods and feeding cycles of major fish species.

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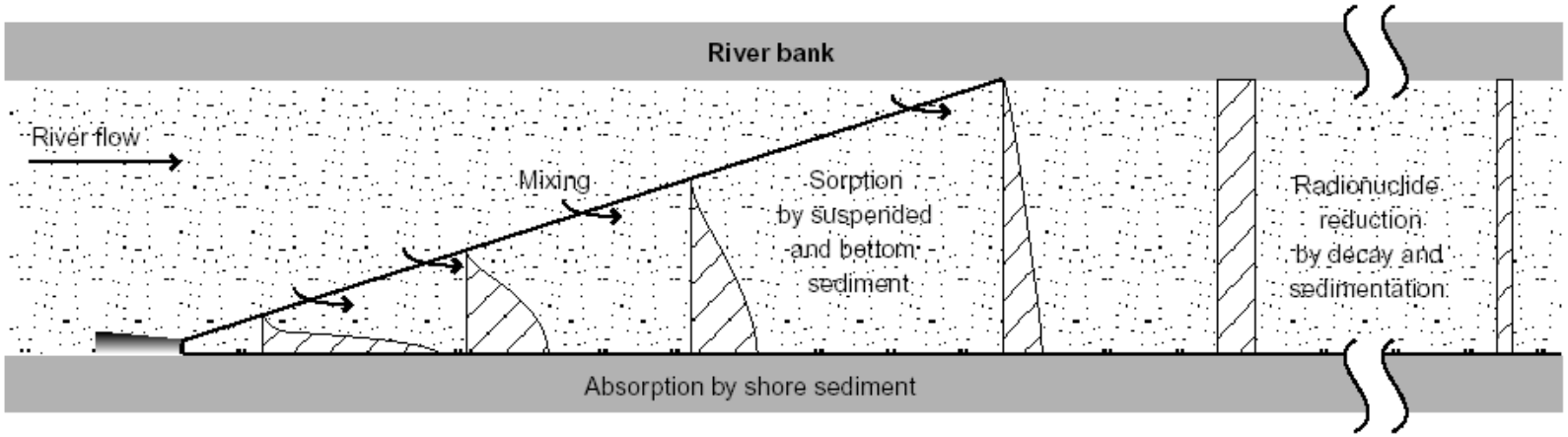
Transport of Radionuclides in Surface Water

Relevant Aspects

- **Initial Mixing**
- **Transport Processes**
- **Far Field Mixing**
- **Sediment Effects**

Rivers



Relevant Aspects:

-Initial Mixing: Concentration of cooling water outlet

-Far Field Mixing (tributaries)

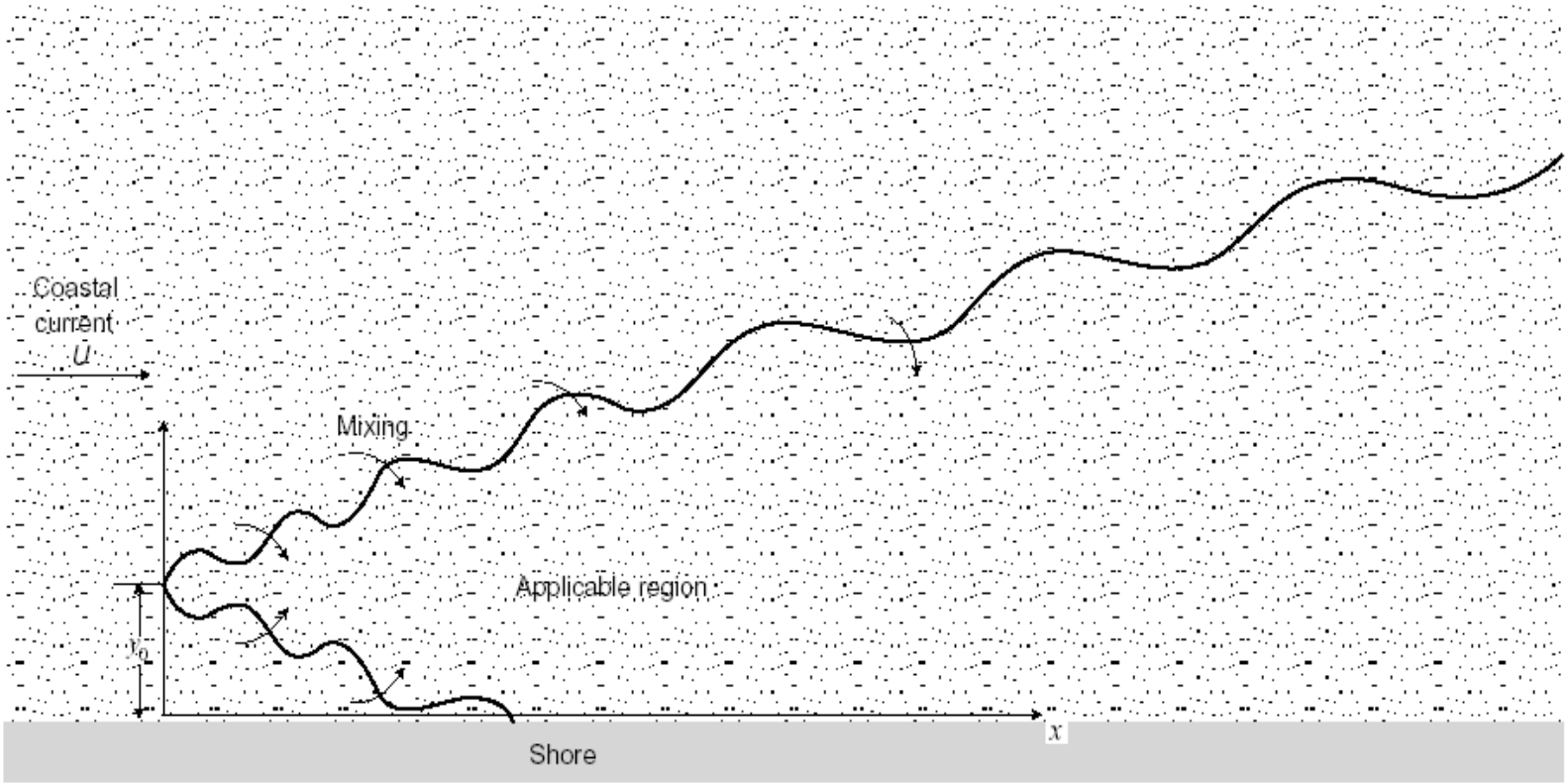
-Sedimention Effects

Sedimentation: Distribution Coefficient

$$K_d = \frac{\text{sediment sorbed radionuclide concentration per unit weight of sediment (Bq/kg)}}{\text{dissolved radionuclide concentration per unit volume of water (Bq/L)}}$$

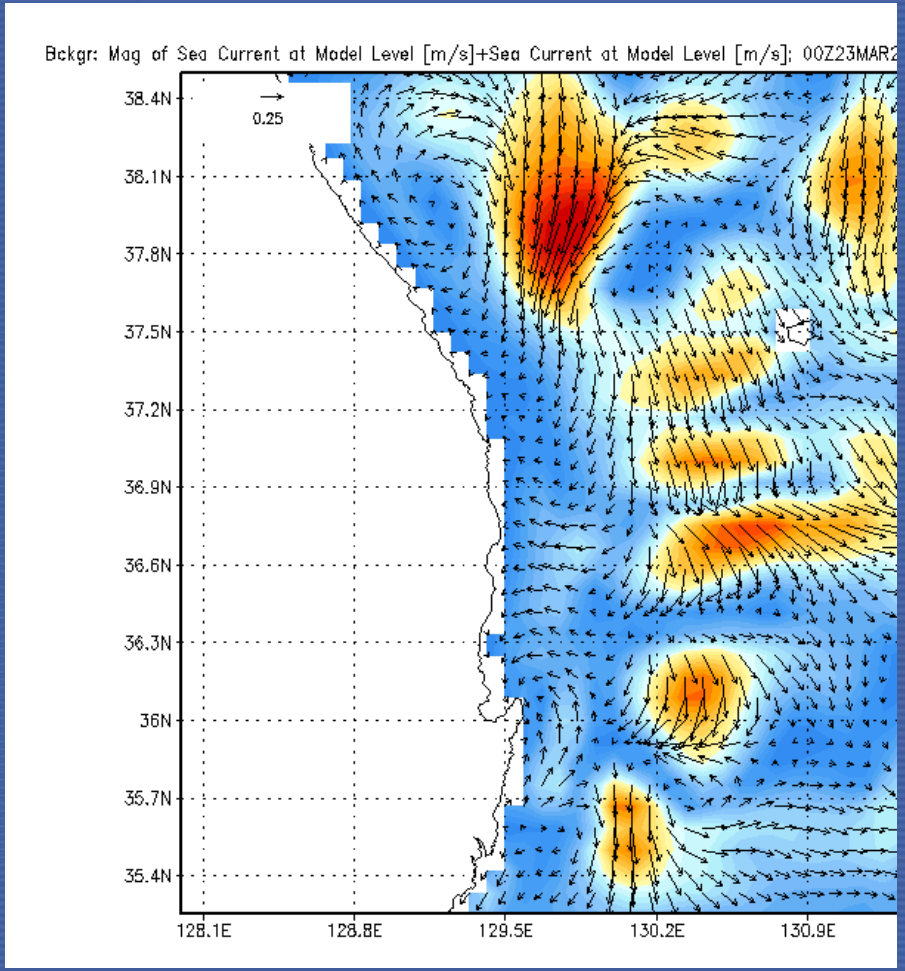
time, radio nuclides are adsorbed to suspended material

Coastal Waters



Sea Dispersion Model

RIAM Model
Originally implemented with respect to conventional aspects it is appropriate to determine the dispersion of liquid effluents to the sea



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Receptor Points to be Considered

- Representative Person acc. to ICRP 101:
  ≤ 5y (infant); 6-15y (child); 16-70 y (adult)
- Population data
- Relevant Areas for radiological assessment
  - Normal operation: plant fence
  - Accidents: fence, exclusion zone
- Relevant receptor points ⟺ most unfavourable point of impact
- Development during life span of the plant

Exclusion Zone

An exclusion zone is a specified area immediately surrounding a nuclear facility and under control of the licensee or the operator. The exclusion zone extends from the reactor core to about 1km

France, Germany	none
Canada	yes
U.S.	yes

10 CFR 100: The applicant should determine an exclusion zone of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 250 mSv or a total radiation dose in excess of 3 Sv to the thyroid from iodine exposure.

10 CFR 10 100

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Foodchains

Transportation Scenarios for Contamination of Human Food

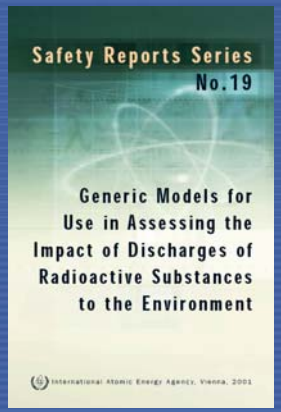
- Deposition by dry or wet processes (Fallout, Washout, Rainout)
- Initial interception and retention by vegetation surfaces
- Translocation to the edible tissues of vegetation
- Post-deposition retention by vegetation and soil surfaces
- Uptake by roots
- Adhesion of soil particles on to vegetation surfaces
- Direct ingestion of surface soil by humans or grazing animals
- Transfer of radionuclides in soil, air, water and vegetation into the milk and meat of grazing animals
- Transfer of radionuclides in surface water to the terrestrial system by spray irrigation
- Transfer of radionuclides in surface water to sediment and to aquatic biota

Transfer Factors

Description of Transport Mechanisms using Concentration/Transfer Factors F

- Bq/kg plant tissue per Bq/kg dry soil
- animal‘s daily intake of a radionuclide to milk d/L
- animal‘s daily intake of a radionuclide to flesh d/kg

Literature, e. g.



Karl-Heinz Lehmann

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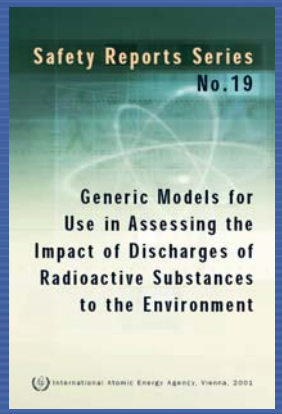
Contamination of Human Food

Concentration of Radionuclides in

- human food crops C_v (Bq/kg)
- animal produce: C_m (Bq/L) for milk / C_f (Bq/kg) for flesh resulting from
  - air concentration C_A (Bq/m^3)
  - ground deposition rate d_i (Bq·m^{-2}·d^{-1})
  - water concentration C_W (Bq/m^3)

Literature, e. g.



Uncertainties using the Food Chain Models Described in IAEA Safety Report Series No. 19

- The models for terrestrial food chain transfer are thought to be generally conservative. In particular, they do not include any allowance for the reduction in radionuclide concentrations owing to food preparation and processing, which can be significant.
- The models for transfer of radionuclides to milk and meat are based on information for cattle. However, it is expected that their use for other animals should not lead to substantial underestimation. In particular, the predicted concentrations in milk should not be more than a factor of three less than the actual concentration, even for milk from other species.
- For predicting the transfer of radionuclides to aquatic foods, a simple concentration factor approach is adopted through the use of bioaccumulation factors. These factors have been chosen specifically for screening procedures and thus are thought to be conservative.

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Calculation of the Radiation Exposure

Assessment of absorbed doses to human organs due to

- direct exposure (submersion, immersion)
- intake of radioactive substances (inhalation, ingestion)

Absorbed Dose $D = c * A$

c= dose coefficient (published by ICRP)

A= incorporated activity (organ)

Calculation of the Radiation Exposure

Equivalent Dose

$H_T = \sum_R w_R * D_{T,R}$ [J/kg= Sievert(Sv)]

w_R: radiation weighting factor

$D_{T,R}$: absorbed dose J/kg = Gray(Gy)

Effective Dose

$E = \sum_T w_T * H_T$ [J/kg= Sievert(Sv)]

w_T: tissue weighting factor

go to weighting factors

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Results (example)

Altersgruppen/ Pfade "Schilderlies"	>17Jahre	>12-≤17Jahre	>7-≤12Jahre	>2-≤7Jahre	>1-≤2Jahre	≤1Jahr
EXTERNE + INHALATION						
Gammasubmersion	25	27	31	34	38	39
Betasubmersion	0	0	0	0	0	0
Gammabodenstrahlung	1	1	1	1	1	1
Inhalation	0	0	0	0	0	0
INGESTION						
sonstige Pflanzen	4	5	7	10	10	5
Blattgemüse	17	23	28	47	71	37
Milch	32	66	98	196	345	103
Fleisch	8	10	12	18	8	3
Muttermilch						274
Gesamt	87	132	176	305	472	462

gaseous effluents

effective dose [micro-Sv per year]

Nuklide %/effektive Dosis	>17Jahre	>12-≤17Jahre	>7-≤12Jahre	>2-≤7Jahre	>1-≤2Jahre	≤1Jahr MFP	≤1Jahr MM
Co-60	84	87	87	88	86	91	83
Cs-137	7	5	4	3	2	2	3
H-3	5	4	5	5	5	3	6
I-131	2	2	3	3	5	2	6
Zn-65	1	1	1	1	1	1	2

liquid effluents

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International Atomic Energy Agency

Thank you for your attention

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Dispersion Calculation Codes

Examples for codes

- Gaussian models
  PC-CREAM
  www.hpa-radiationservices.org.uk/pccream

- Lagrange particle dispersion models
  ARTM
  www.bfs.de/en/ion/anthropg/artm_model.html

back to Determ of Dispersion

Radiation Weighting Factor w_R

Type, energy	Radiation Weighting Factor w_R
Photons	1
Electrons, Myons	1
Neutrons, energy < 10 keV	5
10 keV to 100 keV	10
> 100 keV to 2 MeV	20
> 2 MeV to 20 MeV	10
> 20 MeV	5
Protons, except recoil protons, energy > 2 MeV, charged pions	2
Alpha paticles, fission fragments, heavy nuclei	20

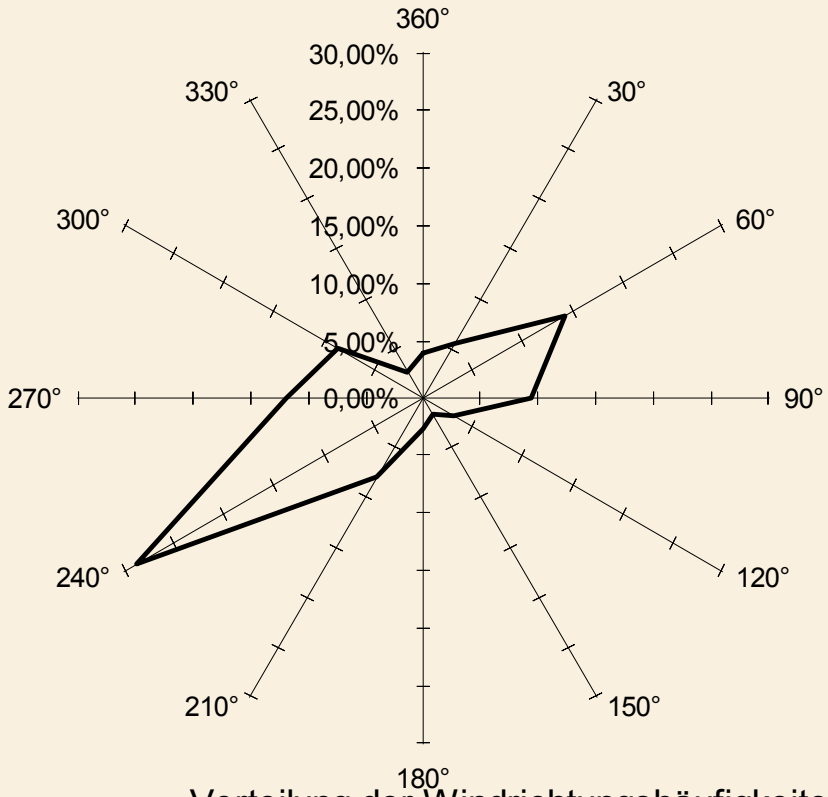
Tissue Weighting Factor w_T

Table 3. Recommended tissue weighting factors.

Tissue	Tissue weighting factor, w_T	Sum of w_T values
Bone-marrow (red), colon, lung, stomach, breast, remainder tissues[a]	0.12	0.72
Gonads	0.08	0.08
Bladder, oesophagus, liver, thyroid	0.04	0.16
Bone surface, brain, salivary glands, skin	0.01	0.04
Total		1.00

[a] Remainder tissues: Adrenals, extrathoracic (ET) region, gall bladder, heart, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, prostate (♂), small intestine, spleen, thymus, uterus/cervix (♀).

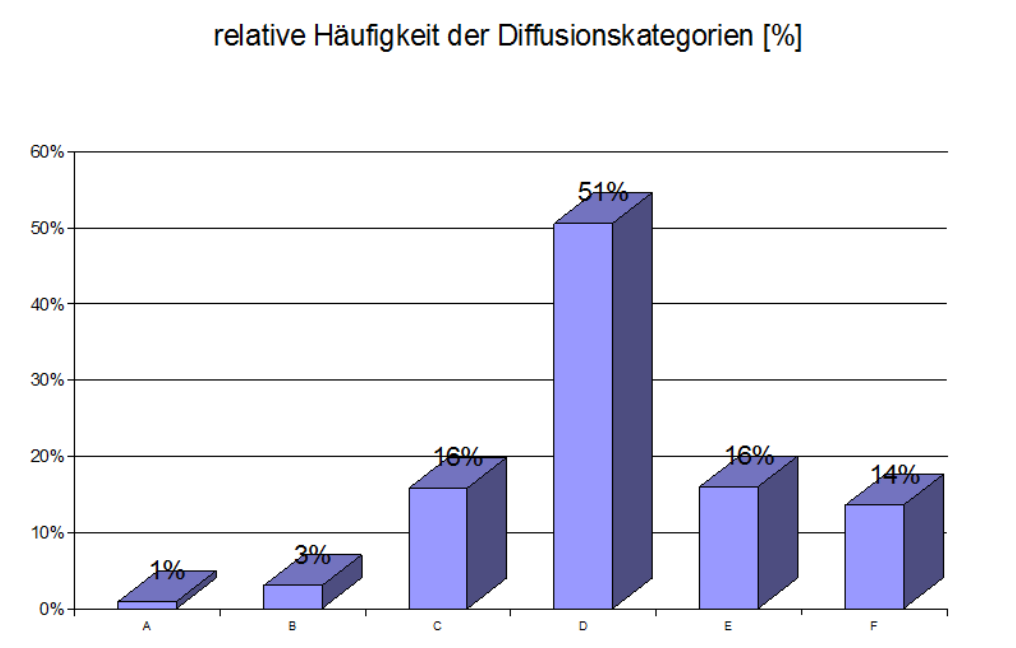
Winddirection



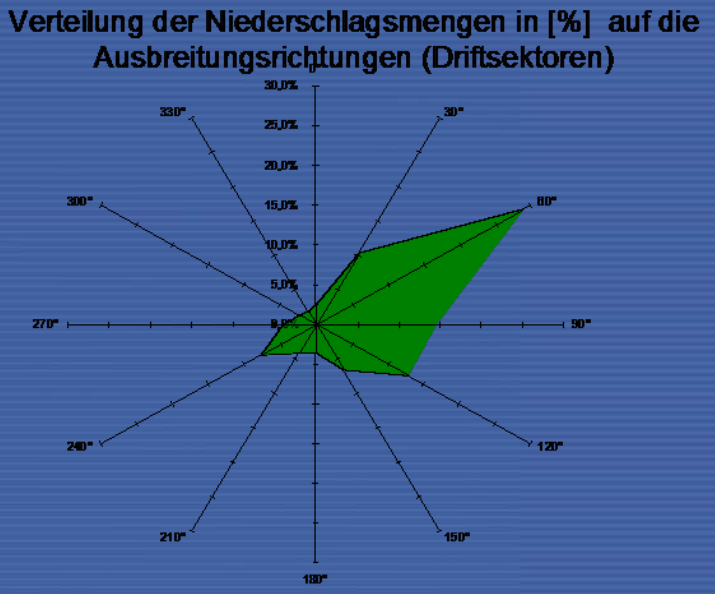
Verteilung der Windrichtungshäufigkeiten

Meteorological Statistics

Stability categories turbulent – neutral - stable



Precipitation vs. drift sector



back to Disp Cond

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Gaussian Plume Model

$$C' = \frac{A}{2\pi\sigma_y\,\sigma_z\,u}\exp\frac{-y^2}{2\sigma_y^2}\left\{\exp\left[\frac{-(z-H)^2}{2\sigma_z^2}\right] + \exp\left[\frac{-(z+H)^2}{2\sigma_z^2}\right]\right\}$$

C(x,y,z)	=	radioactivity concentration (Bq/m³) at a point (x,y,z)
x	=	downwind distance (m)
y	=	crosswind distance (m)
z	=	height above ground
A	=	release rate (Bq/s)
u	=	mean wind speed (m/s)
σ_x,σ_y	=	diffusion parameters (m) which are a function of downwind distance x, and atmospheric stability
H_{eff}	=	effective release height (m)

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Diffusion Parameters

The diffusion parameters are exponential functions of the source distance:

$$\sigma_y = p_y * x^{qy}$$

$$\sigma_z = p_z * x^{qz}$$

In Germany, such diffusion parameters have been determined through experiments carried out by KFA Jülich and FZ Karlsruhe. The coefficients p_y, q_y, p_z, q_z have been compiled for various source heights. This coefficients contain a ground-roughness representative for Germany.

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Short Term Diffusion Factor

The time-integrated near-to-ground concentration under the dispersion axis (y=0, z=0), related to the unit of the emitted amount A, is defined as short-term diffusion factor [s/m³].

$$\dot{\chi} = \frac{1}{A} \int_{\Delta t} C' \, dt = \frac{1}{2\pi \sigma_y \, \sigma_z \, u} \exp\left(- \frac{H^2}{2\sigma_z^2} \right)$$

Long Term Diffusion Factor

The long-term diffusion factor χ_i in wind direction sector i, which has to be applied to quasi-continuous, permanent emissions, is obtained by a determination of the azimuthally mean of the concentration distribution over wind direction sector i and by a superposition of the contributions from the 6 diffusion categories j and the M wind speed classes m

$$\overline{\chi} = \sqrt{\frac{2}{\pi}} \frac{N}{2\pi x} \sum_{j=1}^{6} \left\{ \frac{\exp\left(-\frac{H^2}{2\sigma_{z\,j}{}^2}\right)}{\sigma_{z\,j}} \sum_{m=1}^{M} \frac{P_{ijm}}{u_{jm}} \right\}$$

N = number of wind direction sectors, e. g. N=12, the sector will then have an aperture angle of 30°)

P_{ijm} = frequency of wind direction sector i for diffusion category j and Wind speed class m

M = number of wind speed classes

Long term diffusion factor max. ≈ 1E-06 s/m³ (European site)

back to Gaussian Plume Model

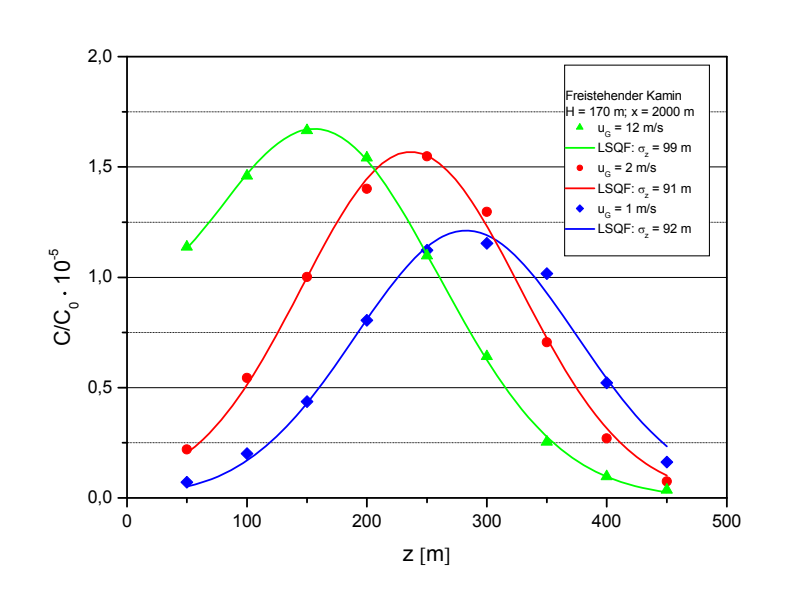
Wind Tunnel Experiments: Cooling Towers

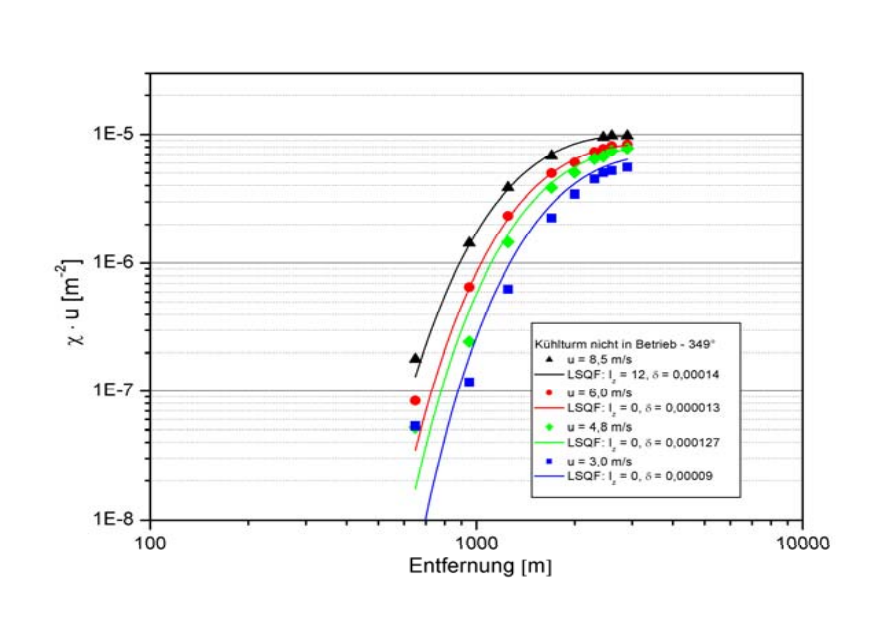
$\sigma \rightarrow \Sigma$

$$\Sigma_{y/z}(x) = \sqrt{\sigma^2_{y/z}(x) + \frac{I^2_{y/z}}{\pi}}$$

H_{eff}

$$H(x) = H_s \cdot \exp(-\delta \cdot x)$$

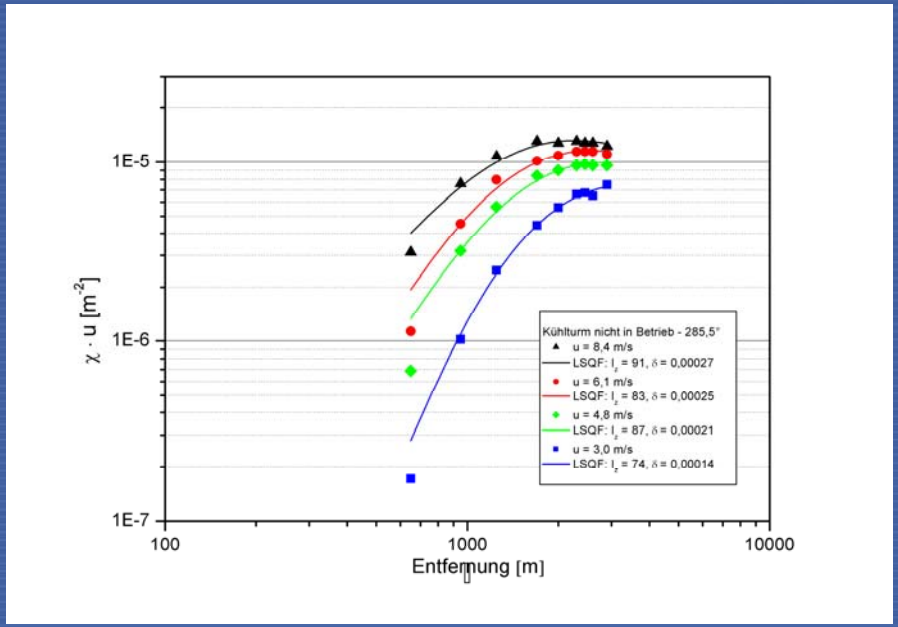




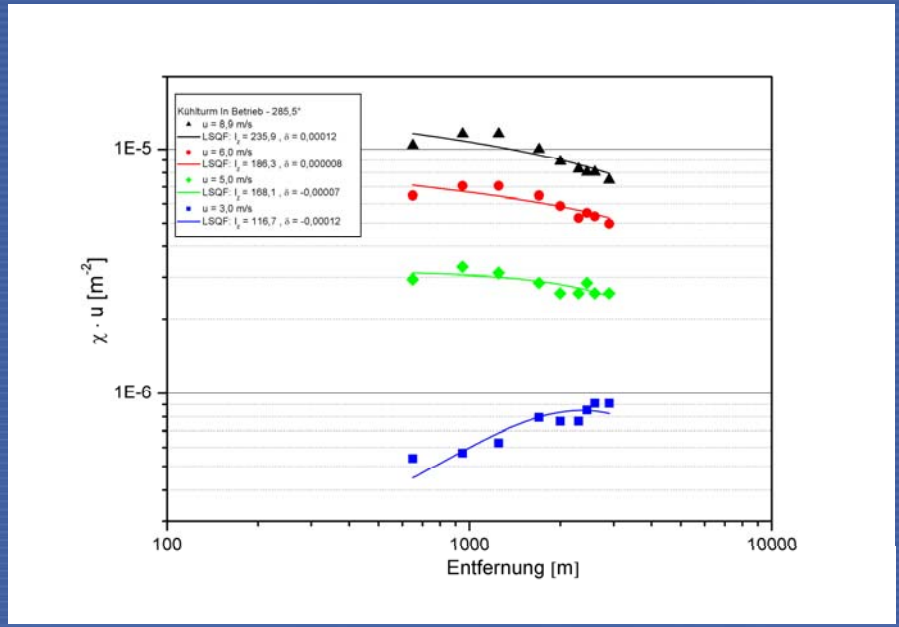
Wind Tunnel Experiments: Cooling Towers

Influence of Cooling Towers

out of operation



in operation



back to Wind Tunnel

Emission Control

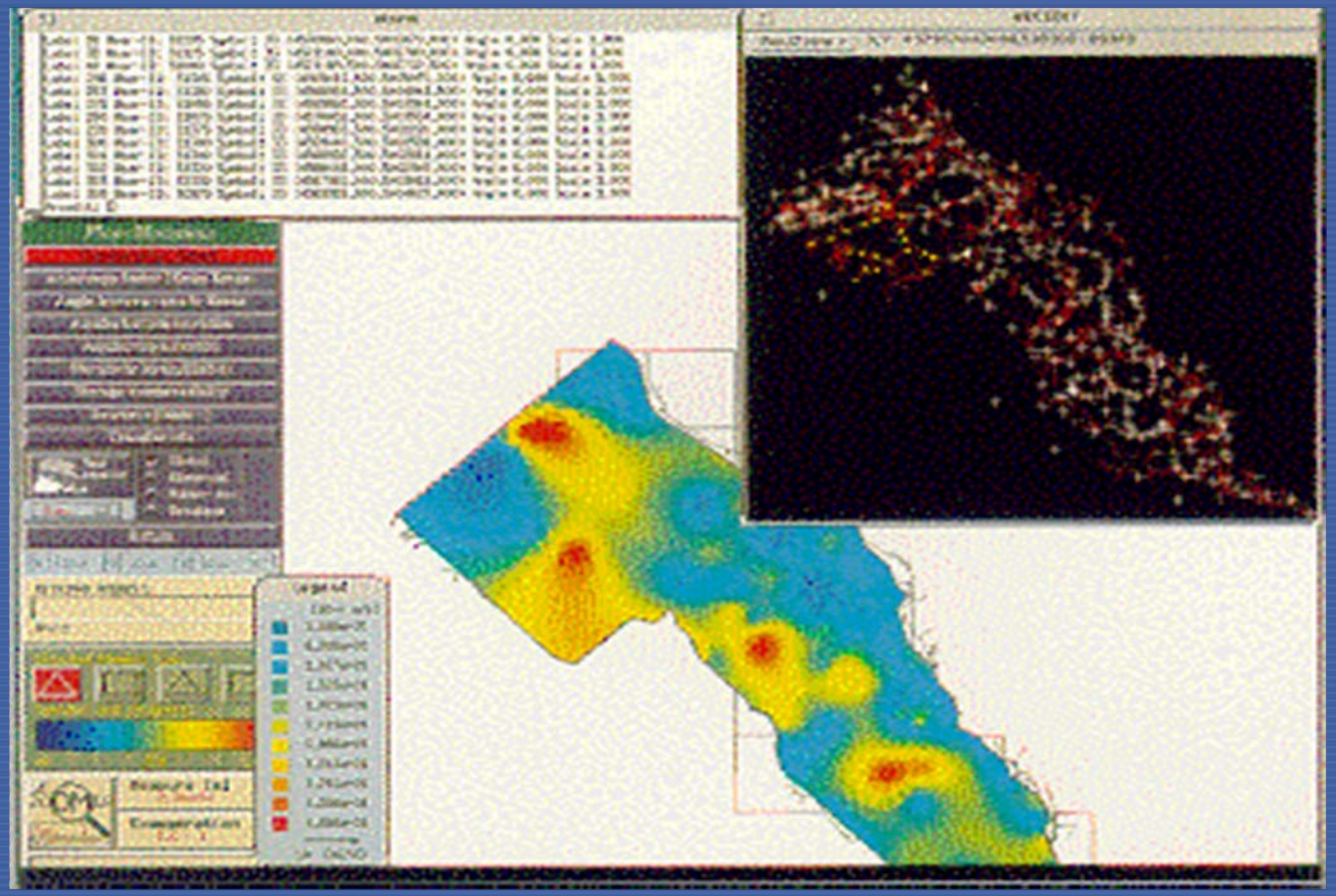
Monitoring Releases of Airborne Radioactive Substances from the Stacks of Nuclear Facilities during

- Normal Operation
- Incidents and
- Accidents

Emission Control

- Representative sampling out of the stack
- Particle losses in transport systems
- Monitoring the effluent flow rate through the stack
- Monitoring the airborne radioactive substances in the stack
  - noble gases (integral or nuclide specific)
  - particles (integral, beta- or gamma activity)
  - iodine (in inorganic or other chemical forms)

Transport of Radionuclides in Groundwater



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