DPSIR schema
and
numerical models
in
Air Quality management

July 8th 2013
CEFAP
Codroipo

ARPA FVG – CRMA
Agenzia Regionale per la Protezione dell'Ambiente del Friuli Venezia Giulia
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Regional Agency for Enviromental Protection – Friuli Venezia Giulia
Regional Center for Environmental Modelling

What we are talking of...

We are talking of:

ATMOSFERIC POLLUTION

AMBIENT-AIR QUALITY

(*not* of carbon dioxide and climatic changes;
not of indoor air pollution, *nor* of air quality in working environments; etc.)

In particular...
of using **mathematical models** to **describe** and **predict** these phenomena

What's the goal?
Protecting health, ecosystems and economy

... using **mathematical models** to **describe** and **predict** ATMOSFERIC POLLUTION

Why should YOU be particularly interested in it?

Because ARPA requires it in Environmental Impact Assessment Studies!

DPSIR framework

D.P.S.I.R. schema

to place the following elements and **relations** between them:

1. pollution **sources** (emissions)

2. **metheorology**

3. **quality of the air** we breathe

4. its **effects** on health, ecosystems and economy

5. **Legislation** in this matter and authorization processes

DPSIR is a "conceptual" and "qualitative" schema:
it becomes "quantitative" by means of mathematical models
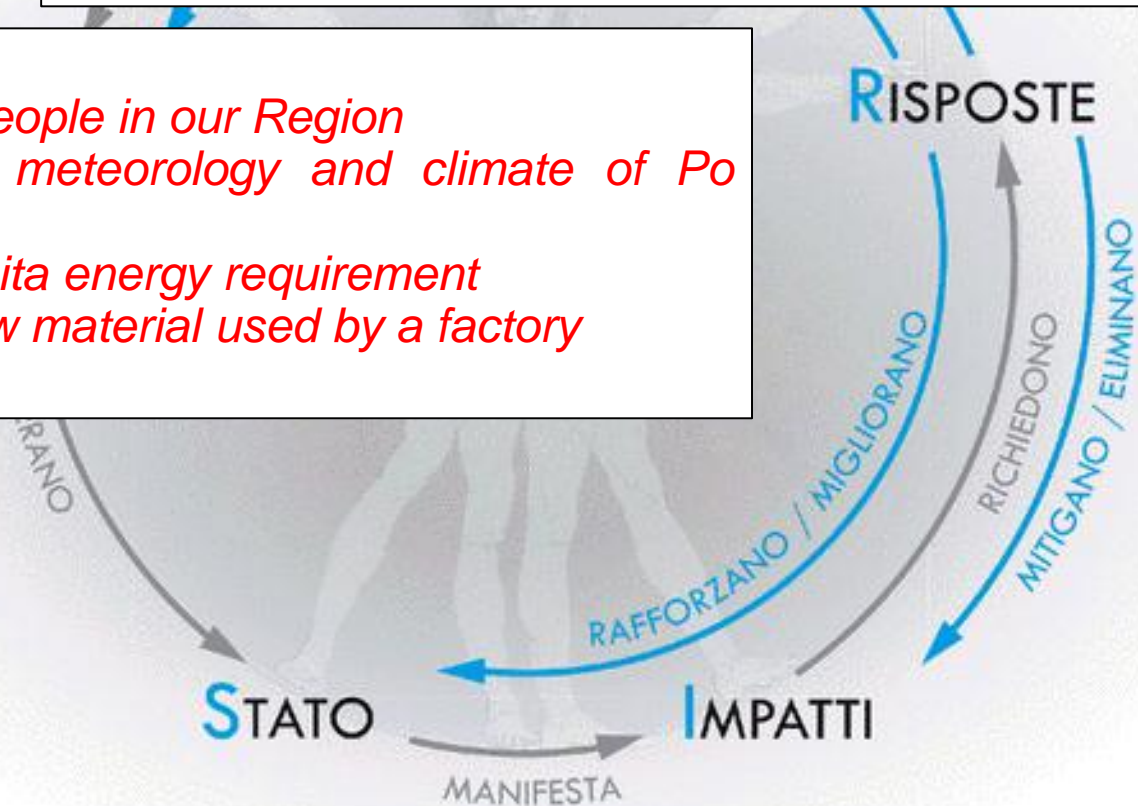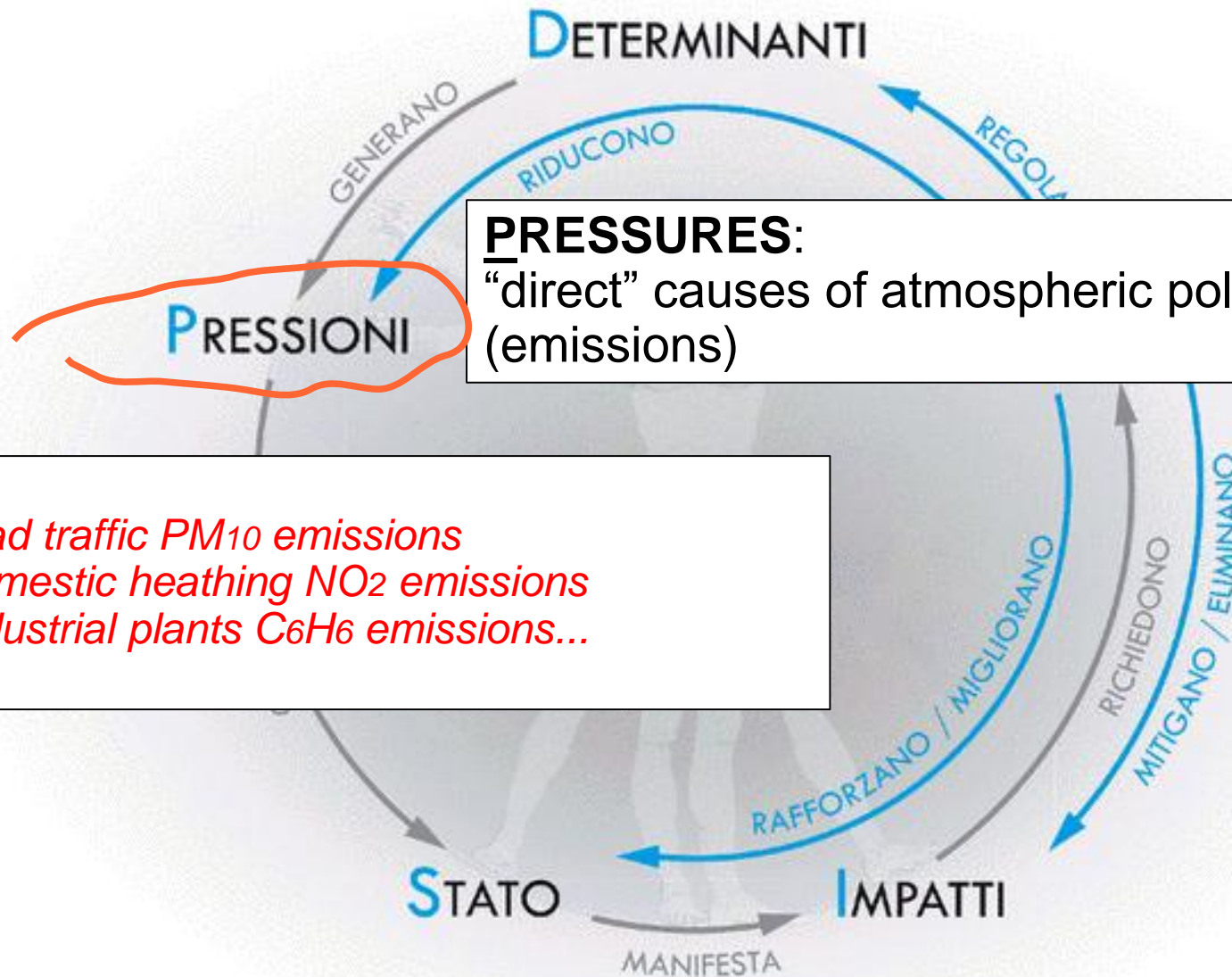
D.P.S.I.R.
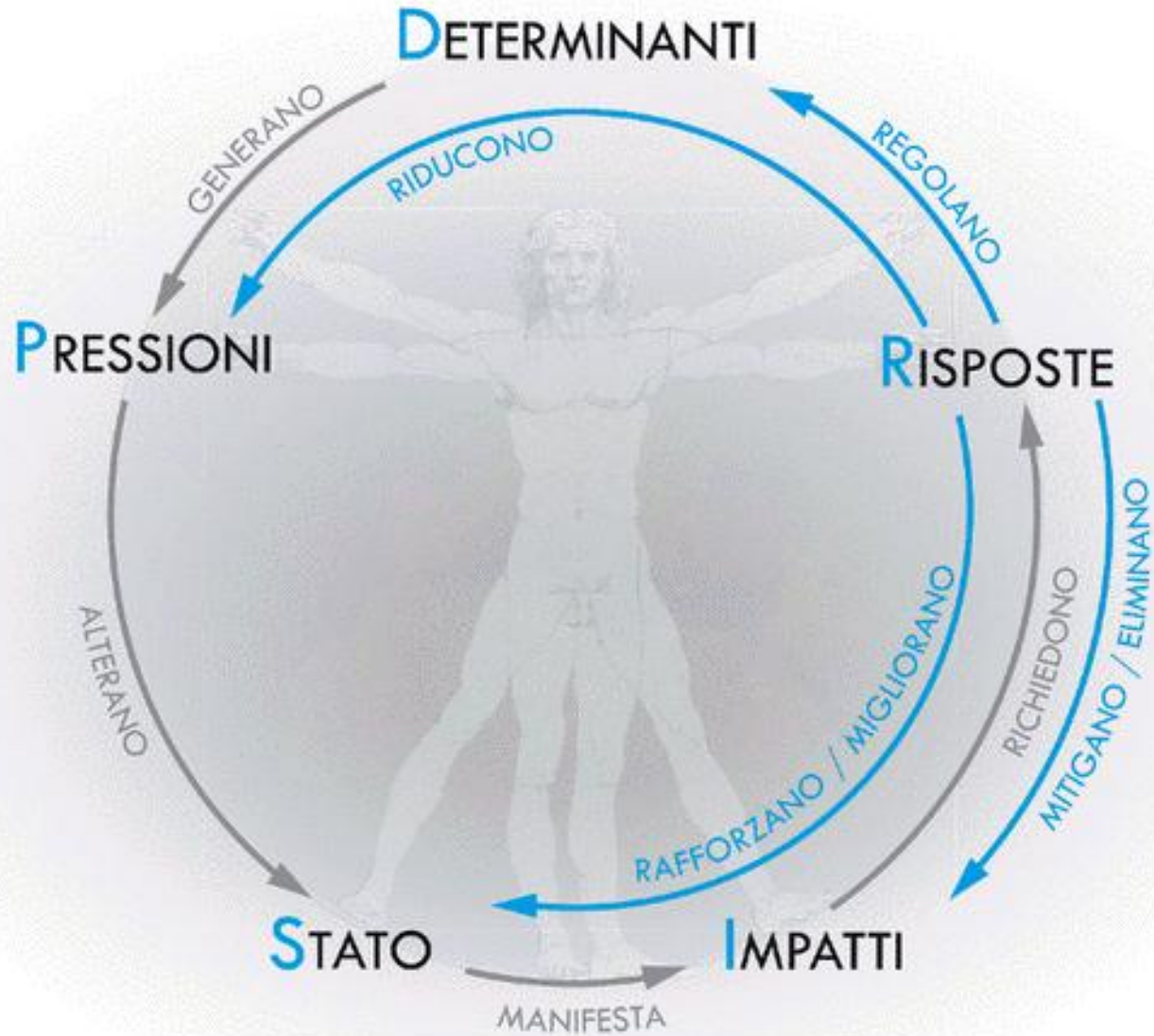
D.P.S.I.R.

DETERMINANTI

DRIVING FORCES:
"indirect" causes of atmospheric pollution

Es:
1. ~1,500,000 people in our Region
2. morphology, meteorology and climate of Po valley
3. mean per capita energy requirement
4. quantity of raw material used by a factory
...

RISPOSTE

RICHIEDONO

MITIGANO / ELIMINANO

RAFFORZANO / MIGLIORANO

...RANO

STATO

IMPATTI

MANIFESTA

ARPA FVG
Agenzia Regionale per la Protezione dell'Ambiente del Friuli Venezia Giulia

European Environment Agency (EEA)

D.P.S.I.R.

DETERMINANTI

GENERANO RIDUCONO REGOL...

PRESSIONI

PRESSURES:
"direct" causes of atmospheric pollution (emissions)

Es:
1. road traffic PM_{10} emissions
2. domestic heathing NO_2 emissions
3. industrial plants C_6H_6 emissions...
...

RAFFORZANO / MIGLIORANO   RICHIEDONO   MITIGANO / ELIMINANO

STATO   IMPATTI

MANIFESTA

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dell'Ambiente del Friuli Venezia Giulia

European
Environment
Agency (EEA)

D.P.S.I.R.

DETERMINANTI

GENERANO RIDUCONO REGOLANO

PRESSIONI RISPOSTE

RICHIEDONO MITIGANO / ELIMINANO

STATO

MANIFESTA
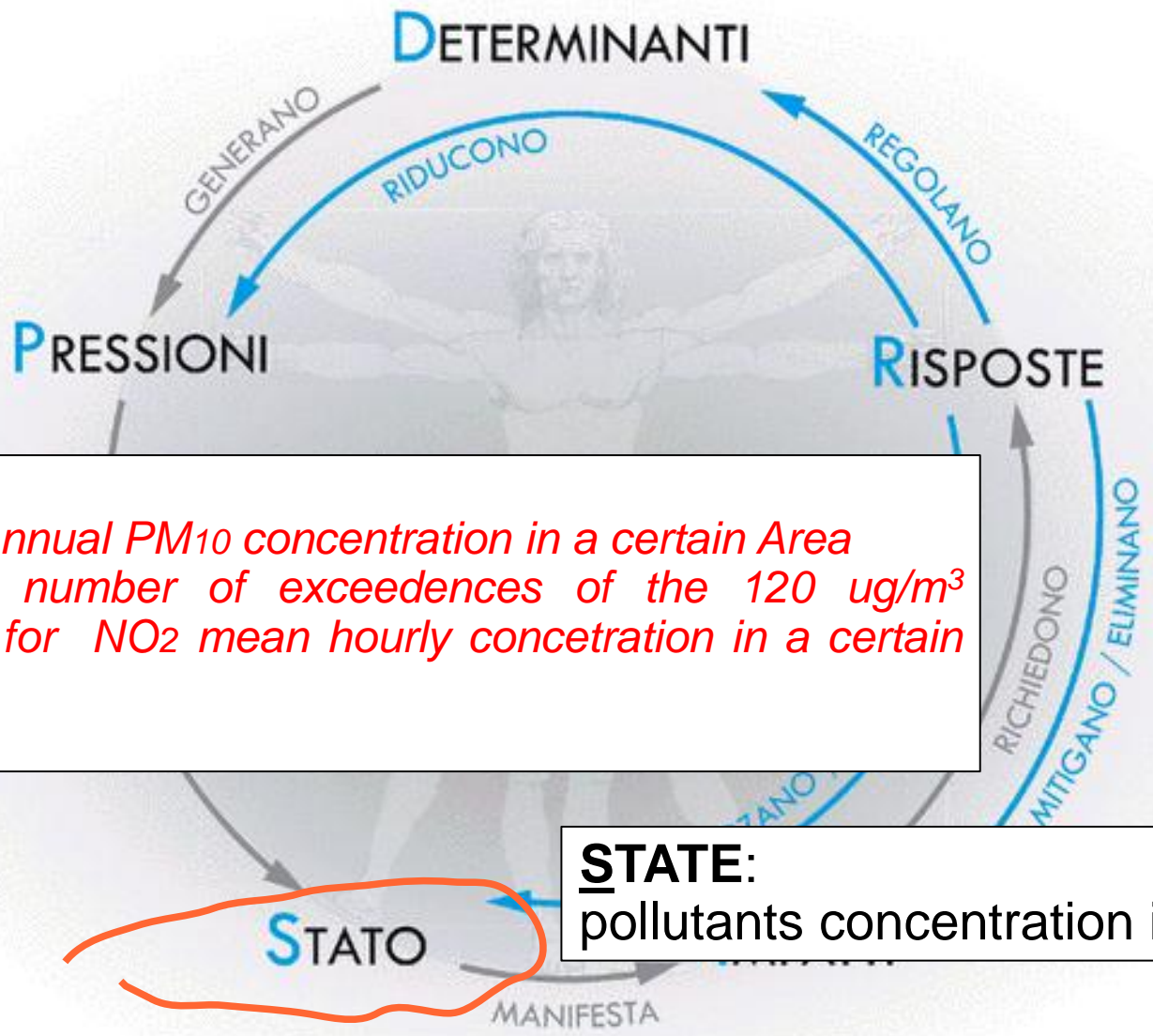
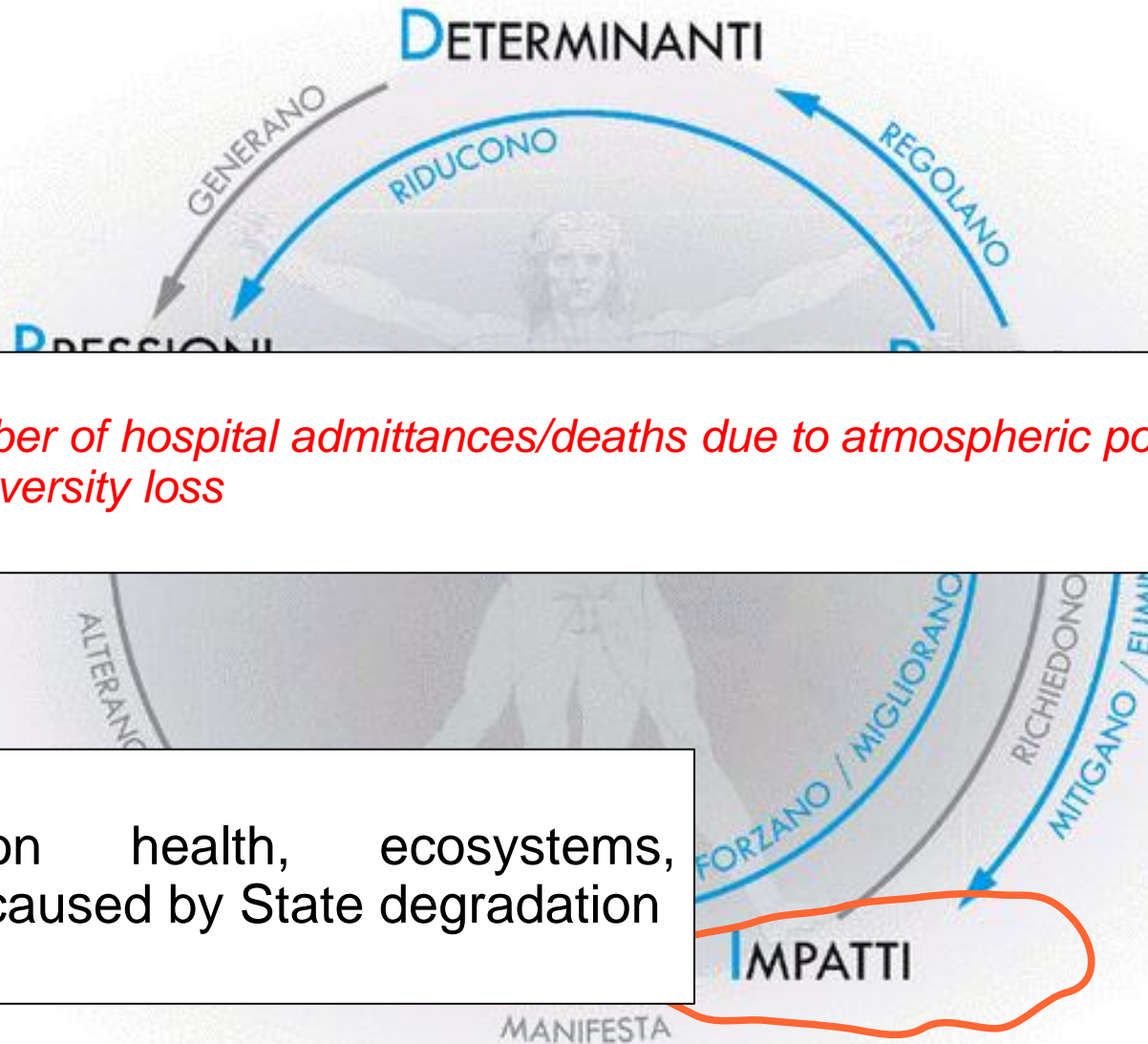*Es:*
1. mean annual PM10 concentration in a certain Area
2. yearly number of exceedences of the 120 ug/m³ threshold for NO2 mean hourly concetration in a certain Area
...

STATE:
pollutants concentration in air

ARPA FVG — Agenzia Regionale per la Protezione dell'Ambiente del Friuli Venezia Giulia

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D.P.S.I.R.

DETERMINANTI

GENERANO RIDUCONO REGOLANO

PRESSIONI

Es:
1. number of hospital admittances/deaths due to atmospheric pollution
2. biodiversity loss
...

ALTERANO FORZANO / MIGLIORANO RICHIEDONO MITIGANO / ELIMIN

IMPACTS:
effects on health, ecosystems, economy, caused by State degradation

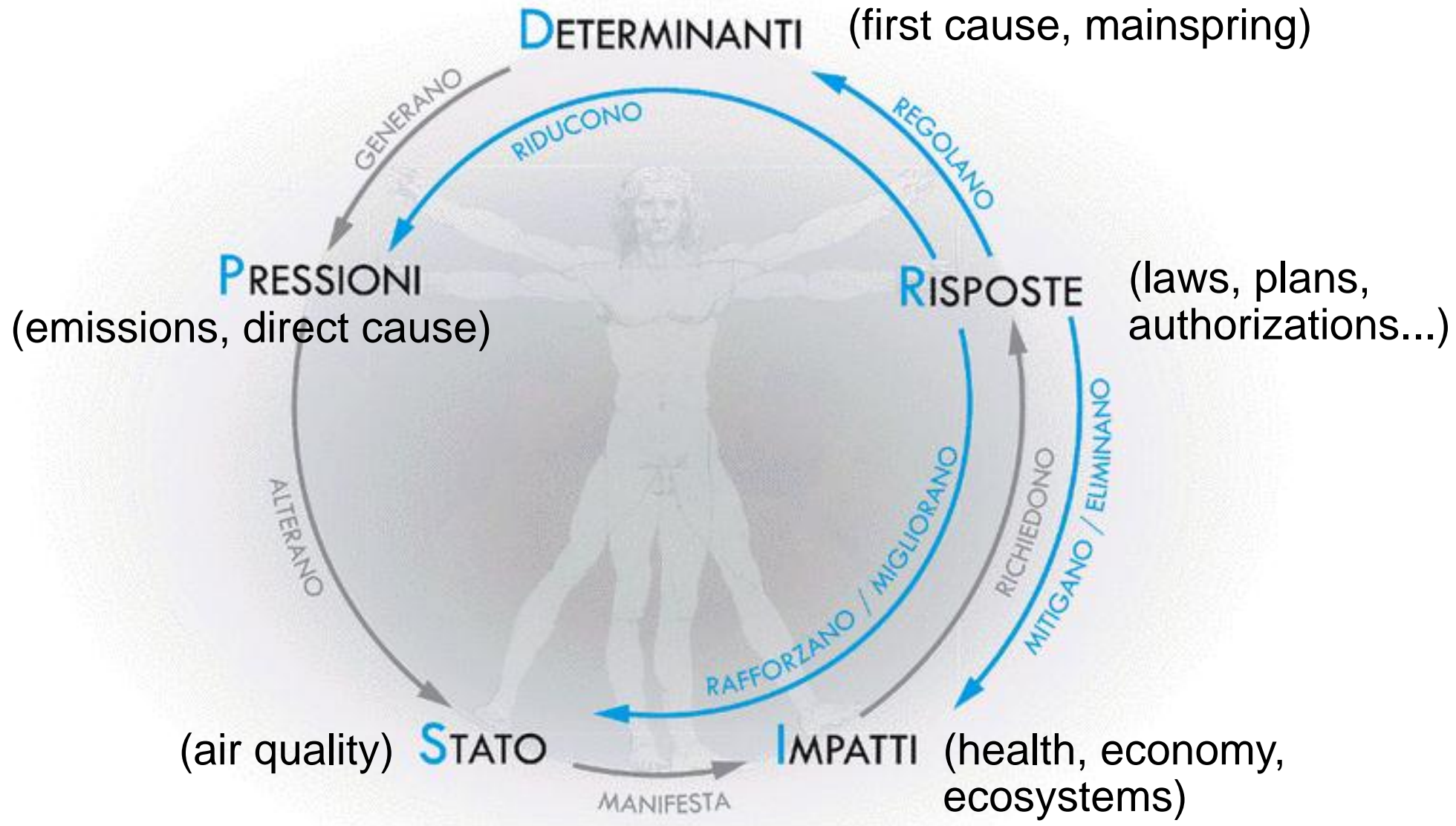IMPATTI

MANIFESTA

D.P.S.I.R.

RESPONSES:
actions to riduce Impacts

PRESSIONI   RISPOSTE
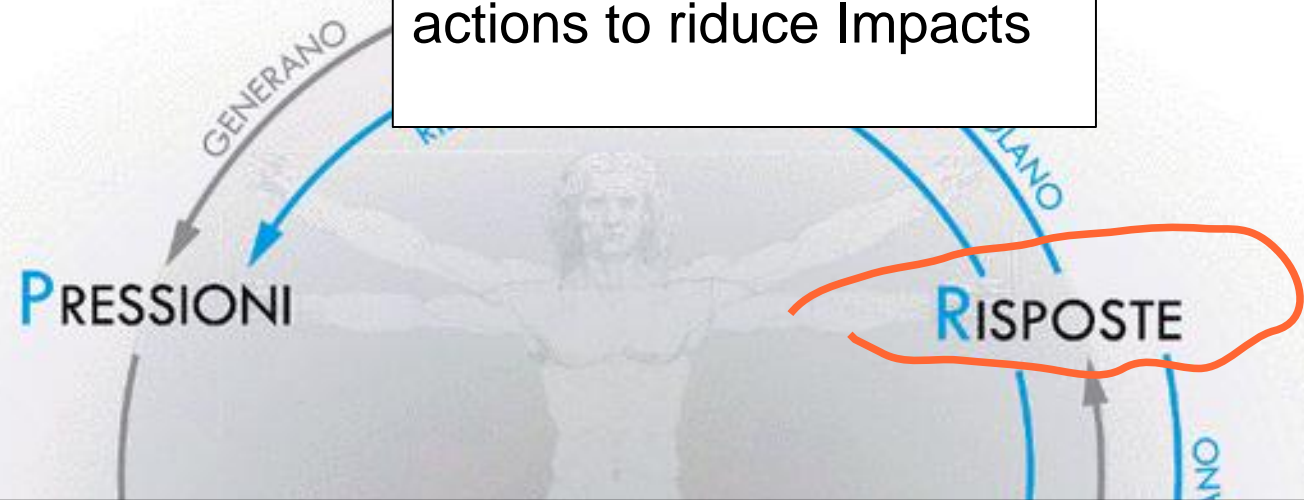
Es:
- Legislation on Emissions and Air Quality
- regional, national and european planning
- limitations in authorizations
- voluntary actions (Environmental Certification EMAS / ISO14001 -> Environmental Politics)
- research and development
- sustainable development models (information, good practices...)
- ...

MANIFESTA

D.P.S.I.R.

DETERMINANTI (first cause, mainspring)

PRESSIONI (emissions, direct cause)

RISPOSTE (laws, plans, authorizations...)

(air quality) **STATO**

IMPATTI (health, economy, ecosystems)

GENERANO · RIDUCONO · REGOLANO · ALTERANO · RAFFORZANO / MIGLIORANO · RICHIEDONO · MITIGANO / ELIMINANO · MANIFESTA

DSPIR schema holds at every spatial and management scale:
global, national, regional... down to each single factory or activity

There is no use in trying to describe and manage atmospheric pollution phenomenon without considering all these elements.

... no use also in order to obtain an authorization!

Policy makers, Institutions responsable of environmental regulation, authorizations and planning, MUST keep in consideration ALL aspects of the phenomenon.

In Environmental Impact Evaluation, there is no use in describing the source (Pressure) alone.

Or, on the other hand, in measuring air quality (State) without correlating it with sources (Pressures).

We need MATHEMATICAL MODELS in order to make these relationships QUANTITATIVE.

DSPIR schema holds at every spatial and management scale:
global, national, regional... down to each single factory or activity

There is no use in trying to describe and manage atmospheric pollution phenomenon without considering all these elements.

Institutions (Regional and local administrations, public agencies) are expected to provide/publish the following frameworks:
- Driving Forces (Energy Plan, General Plan, meteorological data...)
- Pressures (Atmospheric Emissions Inventory)
- State (air quality monitoring network data, basin photochemical models)
- Responses (laws and regulations, Plans, authorizations)

Environmental impact studies must refer to these informations.

These informations must be completed with specific ones, refering to the specific plant / infrastructure / Plan we are dealing with.

This rule holds in all the following cases:
- *Environmental Impact Assessment (it.VIA)*
- *Strategic Environmental Assessment (it. VAS)*
- *IPPC (it. AIA)*
- *authorizations released by provincial administration (it. AUA)*
- *authorization of plants for energy production from renewable sources*

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We introduced:

D.P.S.I.R. schema

as a framework for the following elements and their **relations**:

1. **meteorology** = DRIVING FORCE (one of the Driving Forces)

2. pollution **sources** (emissions) **= PRESSURES**

3. outdoor **air quality** = STATE

4. its **effects** on health, ecosystems and economy **= IMPACTS**

5. **Legislation** and authorizations **= RESPONSES**

In most cases, Legislation allows us not to drive our analysis up to the determination of Impacts (on health and ecosystems): it gives us "ready-to-use" limit values to the pollutants concentration in ambient-air (State).
It means that impact analysis (risk analysis) has been already done, in order to define these limits. We refer to "criteria pollutants".

If we are dealing with pollutants for which these limits are not defined ("non-criteria pollutants", es: formaldehyde, dioxins...), Impacts evaluation (risk analysis) should be performed.

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DPSIR
And
Mathematical Models

MATHEMATICAL MODELS

Why do we need them?
in order to **describe** and **forecast** atmospheric pollution, making DPSIR schema and relations **quantitative** ones.

Quantification: an attempt to give the best information to citizens and policy makers.

Forecast: impacts must be evaluated **BEFORE** a plant or an infrastructure is realized (Environmental Impact Assessment Study)

MATHEMATICAL MODELS

ANY <u>QUANTITATIVE</u> DESCRIPTION of the "atmospheric pollution" phenomenon and of the "relationships" between its "actors" IS A <u>MATHEMATICAL</u> MODEL.

It can be explicit or hidden. Simple or complex. Analytical or numeric. Lagrangian or eulerian...

I can go outdoor, measure the concentation of Nitrogen dioxide (NO2) and say: "today in Codroipo we have 40 ug/m3"

I've just applied a mathematical model.

The simplest one: <u>identity</u> in time and space.
I stated that everywhere (in Codroipo) and everytime (today) the situation is the same.

It can be suitable or not, according to the "question" I must answer to.

Still I didn't say anything about sources: where does NO2 come from?

MATHEMATICAL MODELS

ANY <u>QUANTITATIVE</u> DESCRIPTION of the "atmospheric pollution" phenomenon and of the "relationships" between its "actors" IS A <u>MATHEMATICAL</u> MODEL.

It can be explicit or hidden. Simple or complex. Analytical or numeric. Lagrangian or eulerian...

If I say that NO_2 emissions from a heating plant are "negligible", it means that:
- I quantified them (kg/year, mg/sec)
- I applied some kind of rule... e.g. I verified that they're less than 5%, or 1%, or what else (I will write it down...), respect to the NO_2 emissions of a certain area

*But, at the end, we are interested to what happens to the air we breathe (**S**tate), not to the emissions by theirselves (**P**ressure)*

When we say that an "emission is negligible" we omit some steps...
"if the source is negligible, its effects will be negligible as well..."

In most cases, this approach will be considered admissible.

But... what, if the Zone where the emission takes place is ALREADY above the NO_2 limit value stated by Legislation (nonattainment area)?
Can a further worsening, even if "small", still be considered admissible?

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Models, DPSIR and authorizations

DRIVING FORCES (1):
- quantity of raw material
- number of workers
- hours of activity
- quantity of final product
...

Knowledge of the INDUSTRIAL PLANT:
allow to put DRIVING FORCES in relation with EMISSIONS (stack and fugitive), by means of **EMISSIONS FACTORS**

PRESSURES:
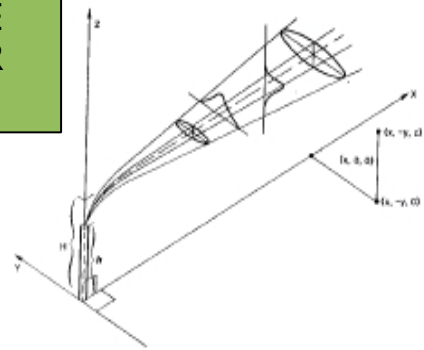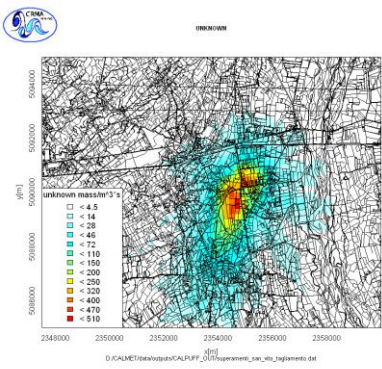pollutants **MASS FLUX** [mass/time], NOT CONCENTRATION [mass/volume].
SOURCE must be described by means of the parameters required by MODELS (area, height, emissions velocity and temperature, pollutants mass flux...)

Models

STATE:
air quality indeces in the area prone to plant emissions fall-out dell'impianto.
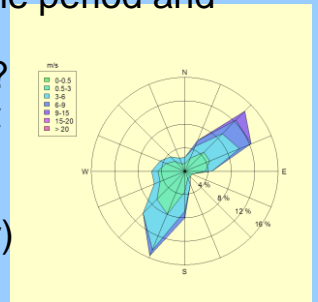STATE must be evaluated BEFORE and AFTER

DRIVING FORCES (2):
models require some **meteorological** variables.
They must be given with adeqate spatial and temporal resolution, and for an adequate time period and spatial domain.
Adequate for what?
To define the effect on STATE (pollutants concentration in air)

IMPACT:
for non-criteria pollutants or nonattainment areas, RISK ANALYSIS...

Models, DPSIR and authorizations: source description

DRIVING FORCES (1):
- quantity of raw material
- number of workers
- hours of activity
- quantity of final product
...

Tipologia per suini in accrescimento:

Pavimento totalmente fessurato con vacuum system

Knowledge of the INDUSTRIAL PLANT:
allow to put DRIVING FORCES in relation with EMISSIONS (stack and fugitive), by means of **EMISSIONS FACTORS**

PRESSURES:
pollutants **MASS FLUX** [mass/time], NOT CONCENTRATION [mass/volume].
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◆ Fattore di emissione oggetto della ricerca:

Suini: 1.5 kg NH_3/posto x anno

14 kg CH_4/posto x anno

0.167 kg PM_{10}/posto x anno

http://www.agricoltura.regione.lombardia.it/shared/ccurl/769/330/AL_20090412_3674_relazione_conclusiva_AGR_MS.pdf
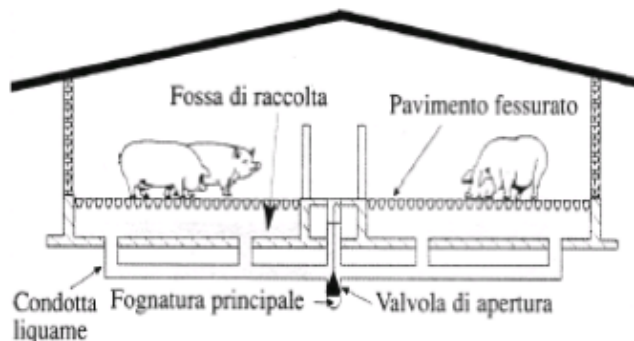

E.g.
A swine livestock emits 1.5 kg NH3/year per head of cattle and 1000 heads of cattle are hosted...
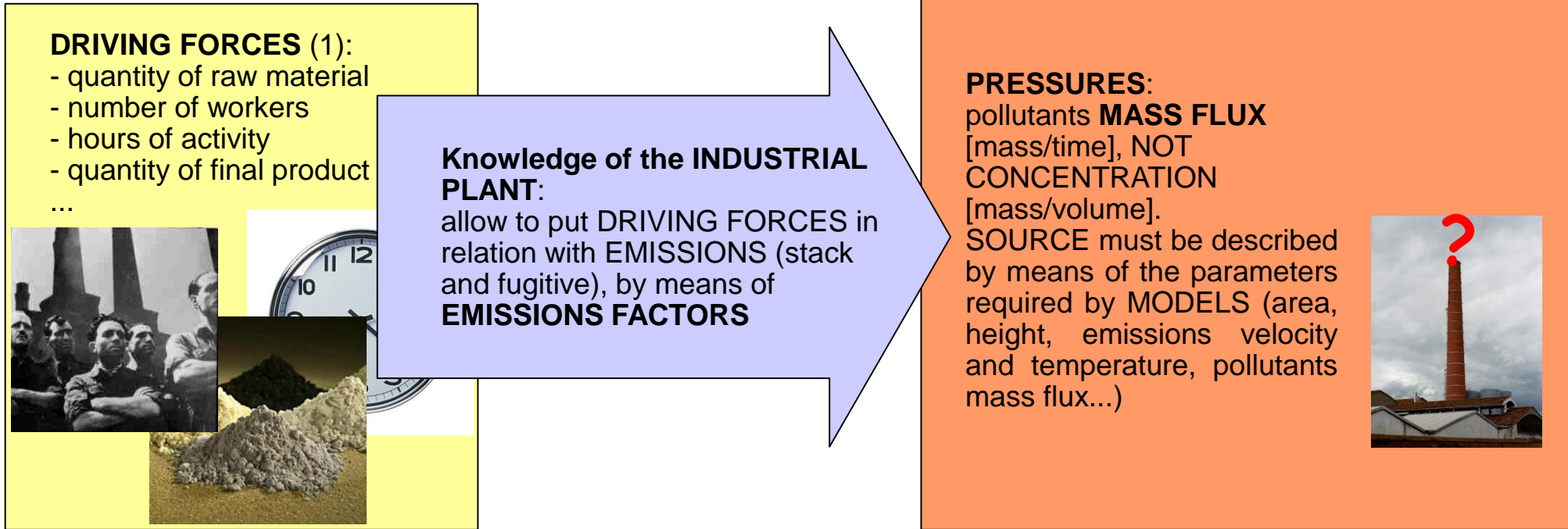This means:
1000 [cattles] * 1.5 [kg/year NH3]= 1.5 [t/year NH3]
1.5 [t/year] / 8760 [hours/year] = 0.17 [kg/h NH3]

Later we will see HOW models use these informations...

Models, DPSIR and authorizations: source description

DRIVING FORCES (1):
- quantity of raw material
- number of workers
- hours of activity
- quantity of final product
...

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SOURCE must be described by means of the parameters required by MODELS (area, height, emissions velocity and temperature, pollutants mass flux...)

?

E.g.

An incineration plant emits ... NO2 per hour and is in function for 8000 hours/year

A paint booth emits ... Toluene per painted chair and produces 600 chairs/day

A road...

Later we will see HOW models use these informations.

DPSIR schema...

... is a framework that holds **ALL** and **ONLY** the informations needed for an impact establishment.

To be avoided:
- "steps skipping"
- "informations drowning" (DPSIR) in a tide of paper
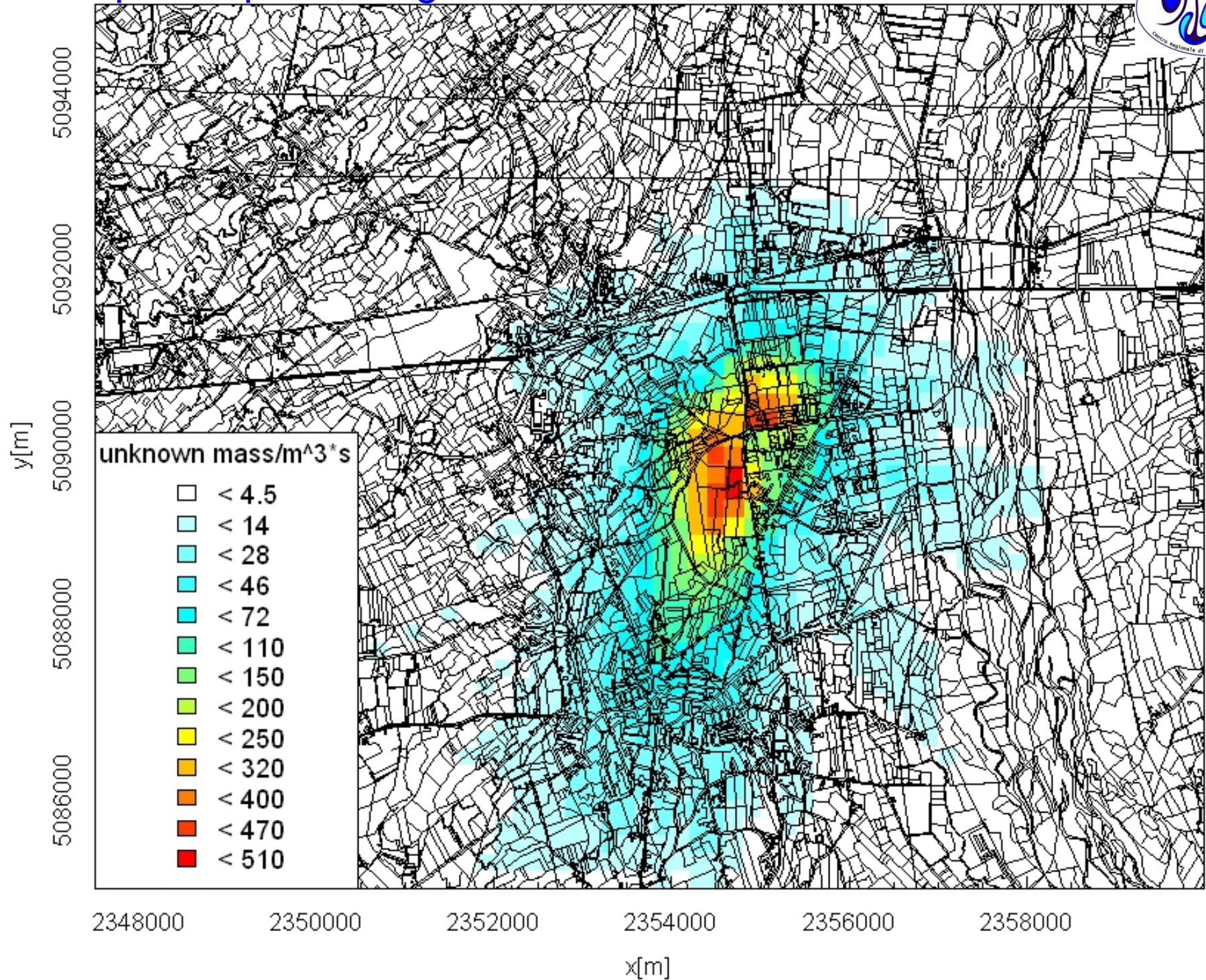
Mathematical **models**...

... differently from field **measures**, guarantee:

- **cause-effect** links quantitative interpretation (meteo, emissions, concentration in ambient-air, abatment systems... **DPSIR**)

- **prognosis** in space (area estimation instead of single points) and time (scenarios)

BUT... they are heavily ERROR PRONE!!

DPSIR schema...

1. *"The DPSIR framework used by the EEA",* European Environment Agency, Kongens Nytorv 6, 1050 Copenhagen K, Denmark
http://root-devel.ew.eea.europa.eu/ia2dec/knowledge_base/Frameworks/doc101182/#

Mathematical models...

1. Roberto Sozzi, *"La Micrometeorologia e la Dispersione degli Inquinanti in Aria", APAT - CTN ACE, 2003*
http://www.arpalazio.net/main/aria/didattica/

2. US EPA, *Technology Transfer Network - Support Center for Regulatory Atmospheric Modeling*
http://www.epa.gov/scram001/