# *MAGLA*
# *(Fog)*

## *Basic processes and societal impacts*

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**Challenges in meteorology 3**
**EXTREME WEATHER AND IMPACT ON SOCIETY**
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1. Introduction: basic physical mechanisms

2. Kinds of fog and formation mechanisms

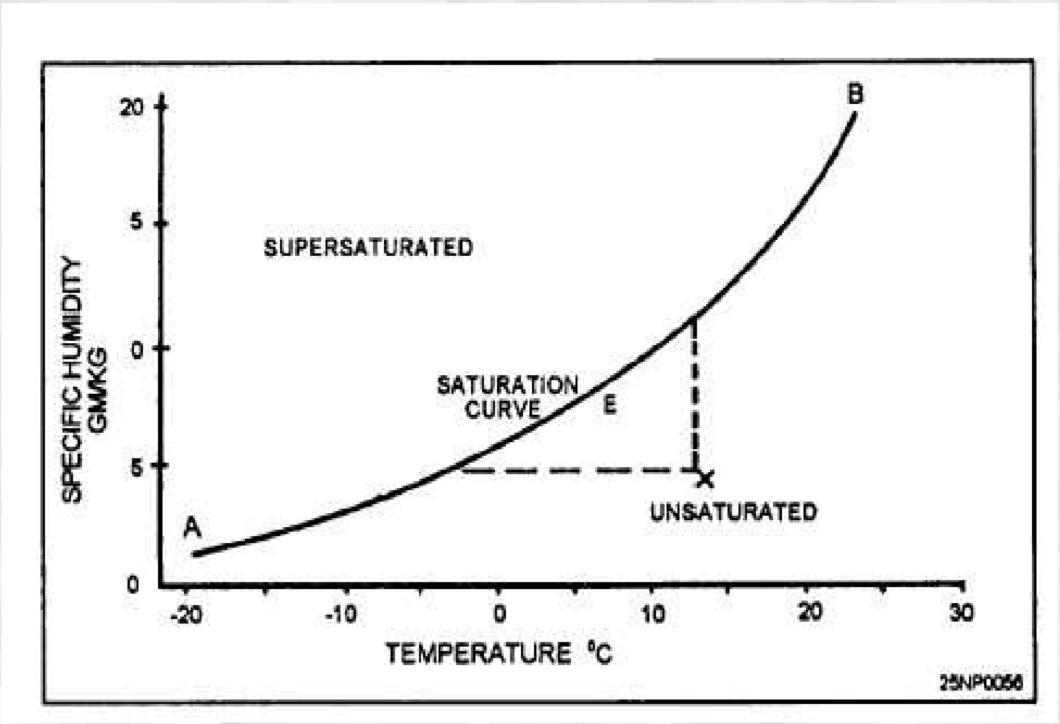
3. Monitoring and forecasting

4. Impacts and mitigation

**Definition of fog:**
**presence of microscopic water droplets reducing visibility under 1000 m (equivalent to water liquid content above 0.1g water/m3)**

**Definition of dense fog: visibility under 200 m**

**==> High related risks in road, airport and harbour operation**




***To reach saturation:***

i) lower temperature at q ct
ii) evaporate into air at T ct
iii) both

***To dissipate fog:***

i) increase T at q ct
ii) eliminate q at T ct
iii) both

***Sensitive to the following parameters***:

a) Condensation Nuclei available:
need enough to form many small drops
b) Mechanisms performing T/q changes:
different rates of formation/dissipation
c) Topographical characteristics of the formation area:
* closed areas may generate long-lasting fog events
* forced ascents may generated fog over slopes.

## Areas prone for fog formation:

1. Over land: terrain depressions in the bottom of valleys and large basins
   (usually formed by radiative cooling of the surface)

2. Coastal areas, where thermal heterogeneities are present and sustained.
   (warm advection over a colder surface)

3. Slopes: generated by a forced topographic ascent
   (condensation by cooling in an adiabatic expansion)

4. Warm water surfaces evaporating to cold air
   (condensation forced in already saturated air)

## Valleys and coastal areas: most of the population and infrastructures

**Although mechanisms are essentially understood:**
**large number of false alarms and missed hits in forecasting**
**====> Formation sensitive to small changes in (T,q)**
**often difficult to predict adequately at night**
**or with erroneous inputs**

## Possible role of dew and frost related to fog formation:

**When surface elements are such that they can keep radiative temperatures much lower than air (grass leaves for instance)**
**due to calm conditions and low thermal conductivity of air**
**==> lower saturating water vapor ==> condensation starts first on them**

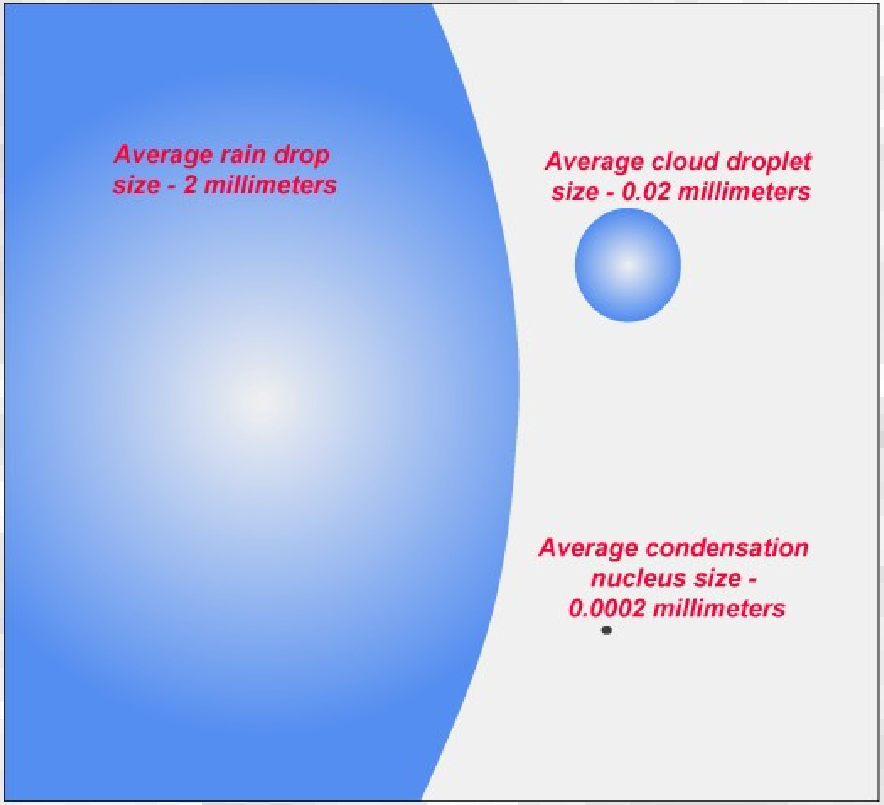
**This mechanism drains water out of air and may inhibit the formation of fog**

# Microphysics: fog creates more fog

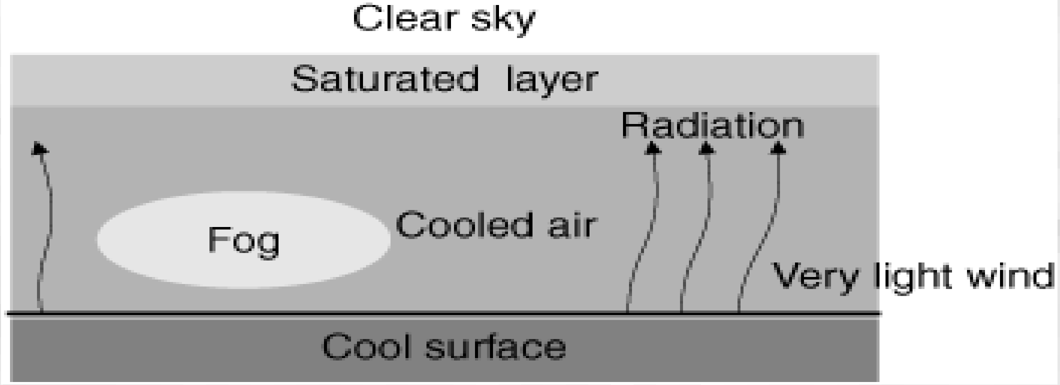
Condensation Nuclei: needed to lower surface tension and electric repulsion. If hygroscopic, they wet themselves with the condensated water.

Growing of the drop: Droplets radiate stronger than air, they cool faster and water vapour condensates over them like dew over leaves

For low air temperatures: less water vapor available in the air.
==> Fog is a phenomenon of initially temperated air masses.



# Radiation fog

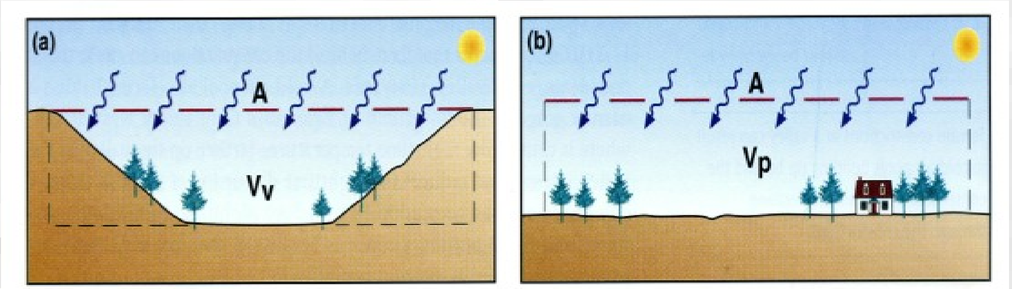



***Formation***

***In calm nights with clear skies (anticyclonic conditions), net radiation is strongly negative and usually not compensated by any other flux**

***Radiative cooling forms a thermal surface inversion, more shallow as the wind is weaker**

***Sustained cooling for air near the ground until it reaches saturation ==> Fog**



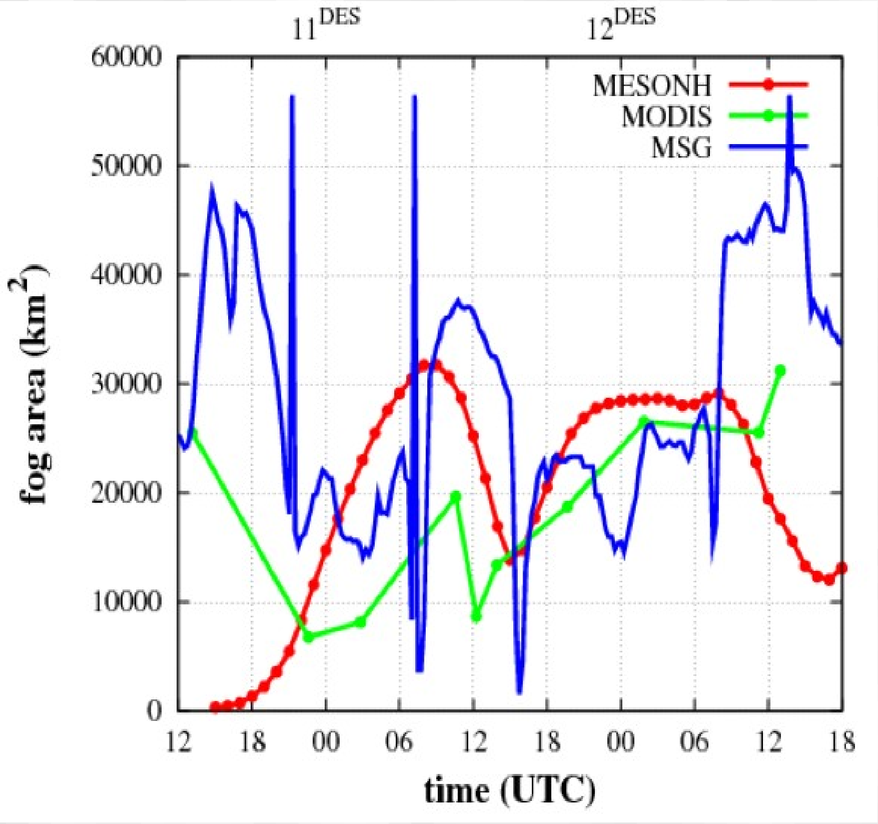

***Where***

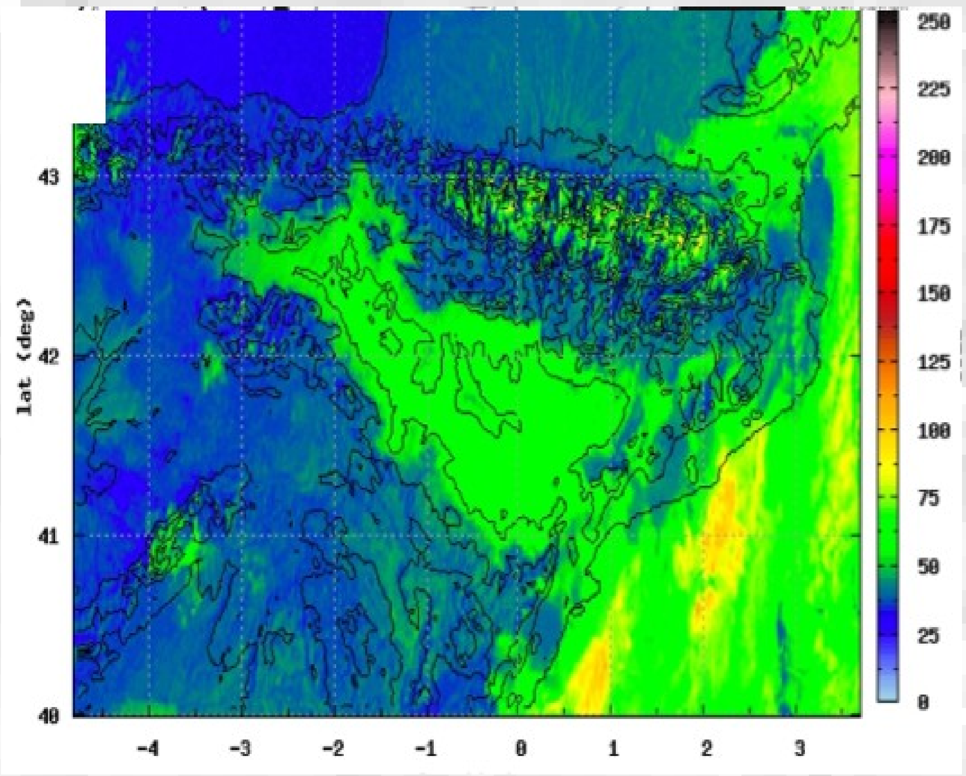
***Flat areas: center of basins**
***Narrow Valleys: larger cooling area for less volume of air to cool**
***Basins confined by topography**
***Not in Sloping terrain (not confined): air flows downslope**

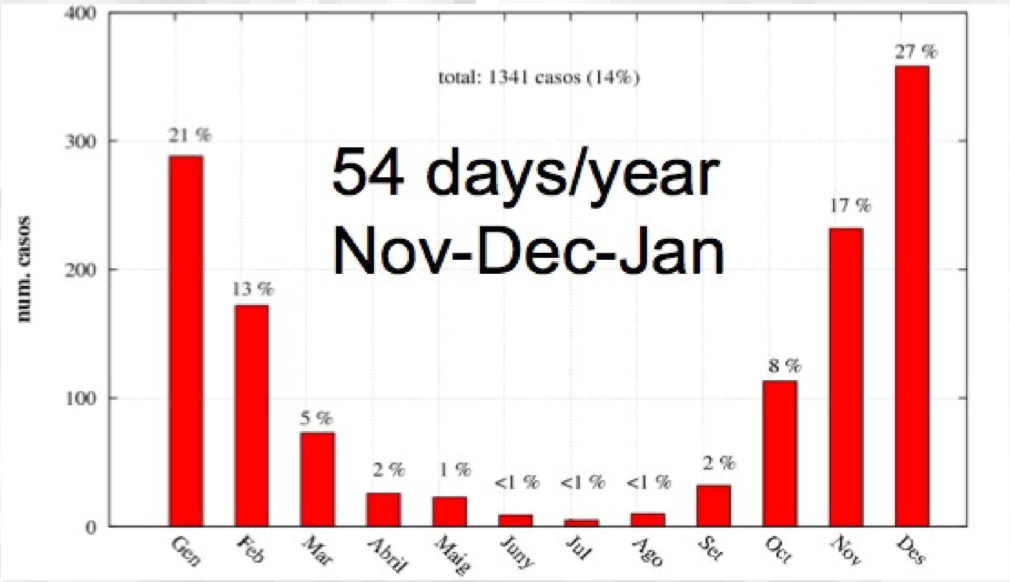
## Radiation fog

*Persistance and extension*

***Once a radiation fog is set, it may last for several days and occupy mostly all available space in a basin, needing a change of mass air to eliminate it most of the times.**



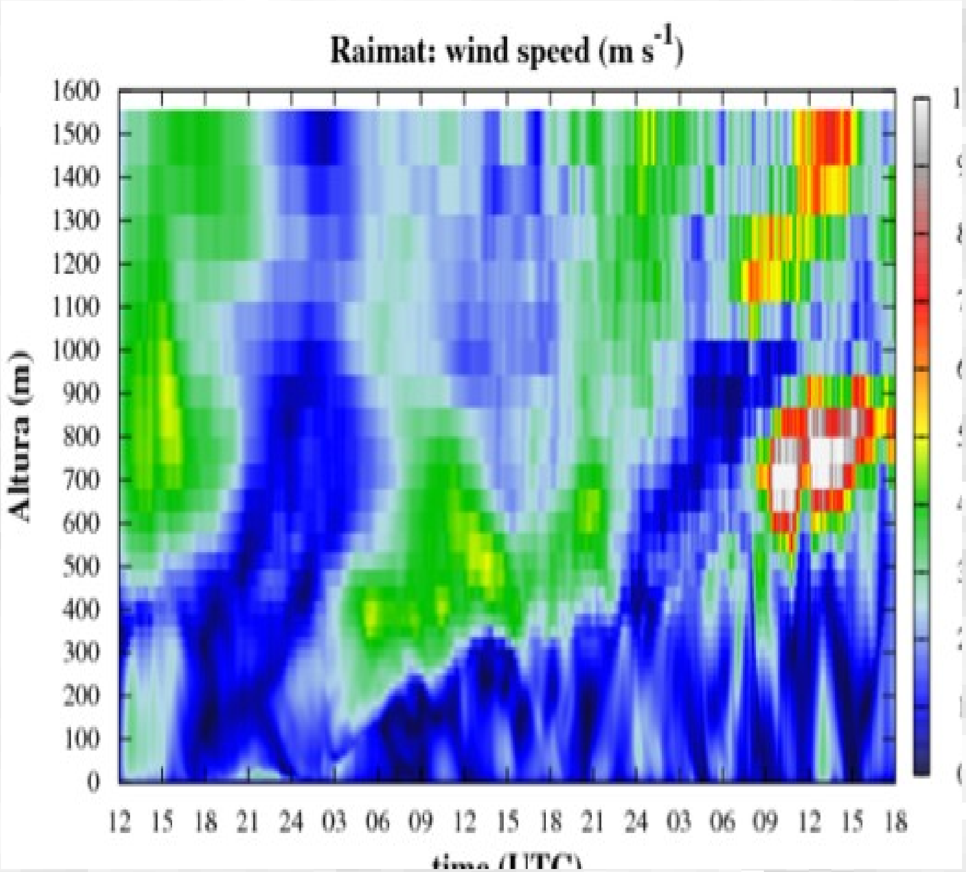



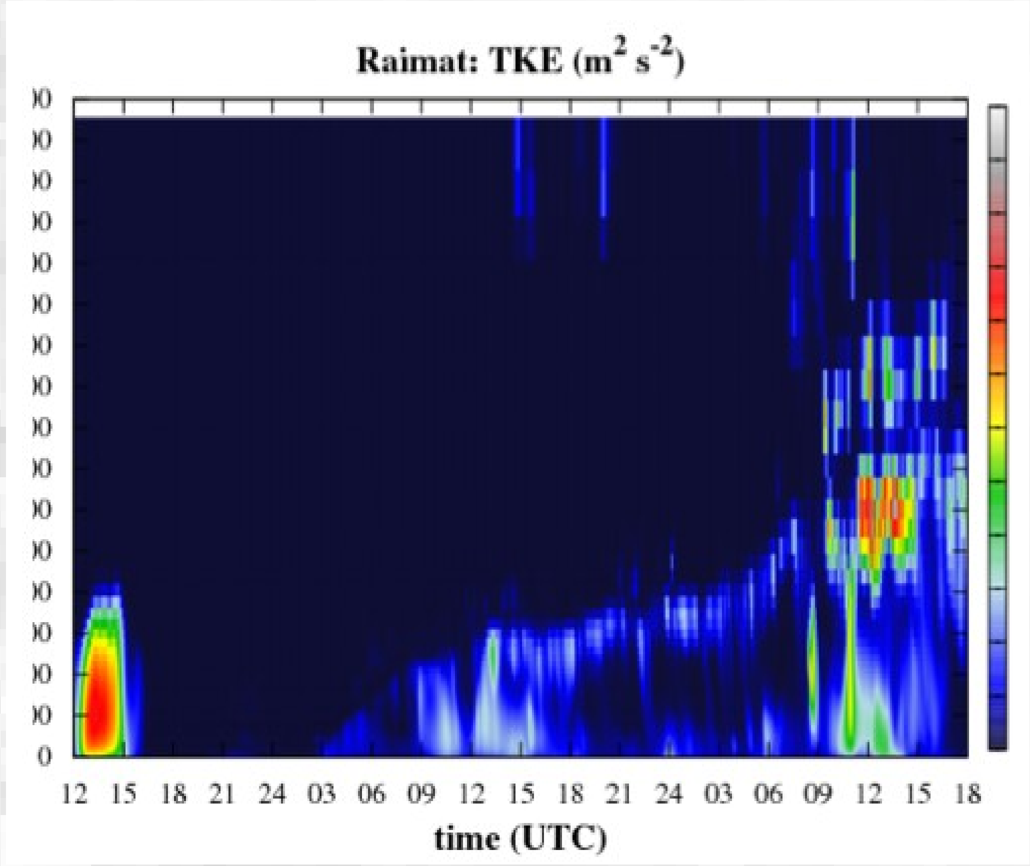
# Radiation fog

*Evolution processes*

***Downslope flows over the fog layer may increase fog depth by entrainment at the top ==> deeper fog layers**

***Once the fog is formed is essentially dominated by top radiative cooling and it becomes a weekly convective later!**



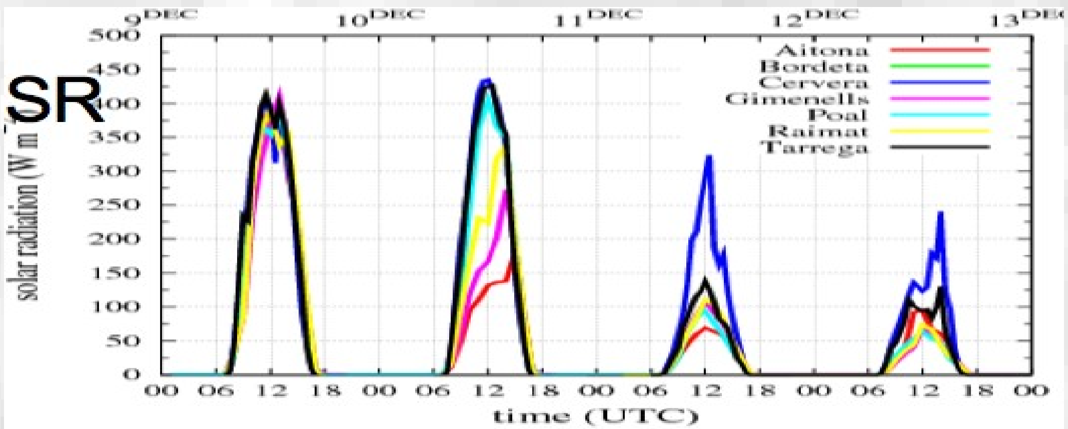
# Radiation fog

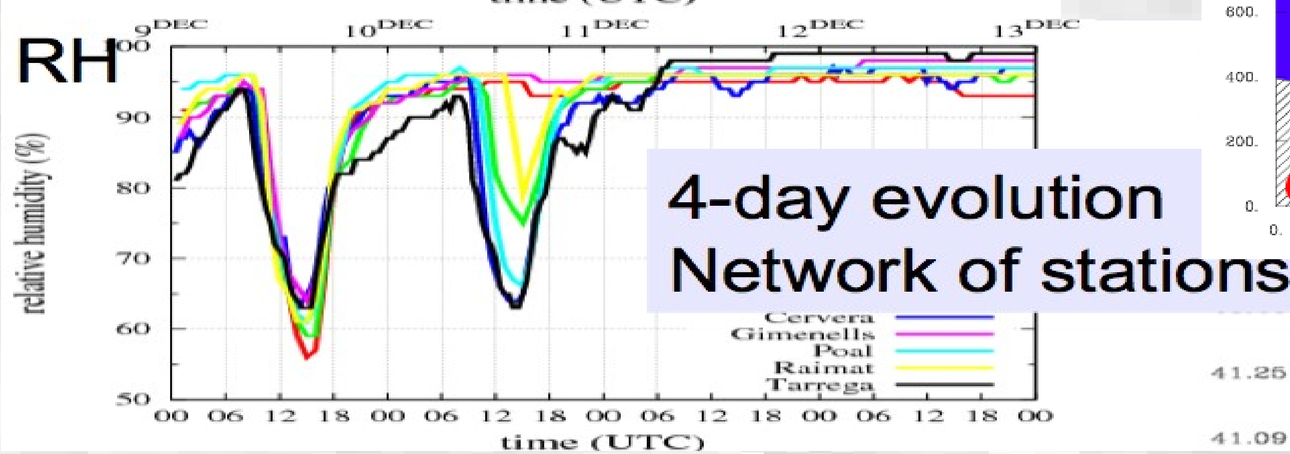
*Diurnal cycle*

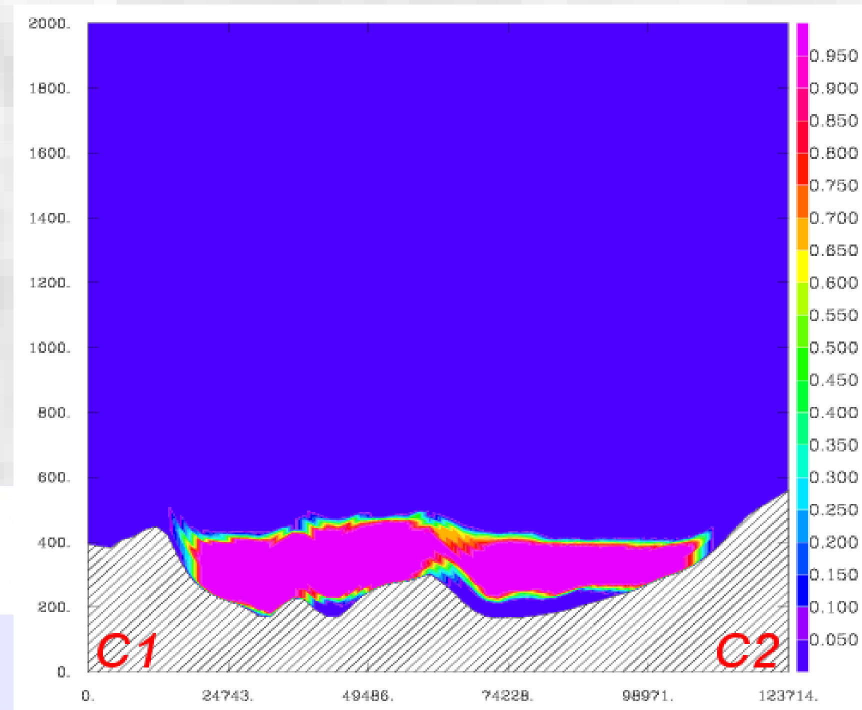
***Near noon, sun radiation may reach the surface, heating temporarily the layer near the ground and dissipating it ==> falsely called “lifting of the fog layer”**

***The same mechanism erodes the shallower fog layer over the basin slopes.**

***Later the fog layer is reconstructed as the sun becomes unable to penetrate the layer**



## Advection fog

It is usually the mechanism generating fog over the sea and at the coastal areas.

Over the sea: warm advection (southern in our hemisphere) or arrival over a thermal discontinuity in water

Near the coast:

1) land warm outflows in summer over the sea,

2) sea warm inflow in winter over the land

3) early spring and late autumn: morning coastal fogs
(meandering of warm sea air over cold land)

4) offshore downslope flows blowing over colder water

## Evaporation and mixing fog

**Steam fog: evaporation in colder air ==>**
**over land it needs an inversion and happens in cold air pools, over marshs**
**over the sea, in areas of open water surrounded by marine ice**

**The same mechanism may happen for precipitation falling into colder air, where the water will evaporate and eventually lead to saturation (warm fronts)**

## Fog over slopes by adiabatic expansion

In selected places it is very frequent, such as in the north coast of the Canary Islands under trade wind regime, under the subsidence inversion.

# Monitoring and forecasting

**Forecast of (T,q) at 2 m is difficult for models. Knowledge of aerosol load of air is low for a particular place and time.**

**Besides, once fog is set, the main physical mechanisms on action differ and the error in the forecast increases.**

**==> Because of its large impact in human activities:**

**i) mechanisms must be studied**

**ii) fog must be closely monitorized**

**iii) forecast must be in the short-range with appropriate tools**

**iv) Forecast in the mid-range must be essentially an indication of likeliness**

## Monitoring

1) Areas where fog occurs are well known locally. Locate sensors there and perform statistical analysis of the data. Access to data in real time.

2) Currently fog measurement with visibility sensors is possible and made routinely in airports and they are also installed in sensitive spots in roads.

3) Satellite surveillance: areas covered by low clouds and fog can be determined using satellite images. Separation between fog and low clouds needs access to meteorological data.

4) Numerical studies of the phenomena: areas with recurrent fog episodes maybe studied through numerical modeling in order to determine the main characteristics of the fog episode and the process conducting to its establishment, maintenance and dissipitation

## Impacts and mitigation

1) ***On human health***: pollutants in urban areas may act as condensation nuclei. Fog stays in place and the acidic water may enter the lungs. Smog caused great increase in mortality and morbidity in London in 1952, through respiratory and cardiovascular affectation.

**==> Improve air quality**

2) ***On agriculture***: it keeps the plant leaves wetter longer => plagues

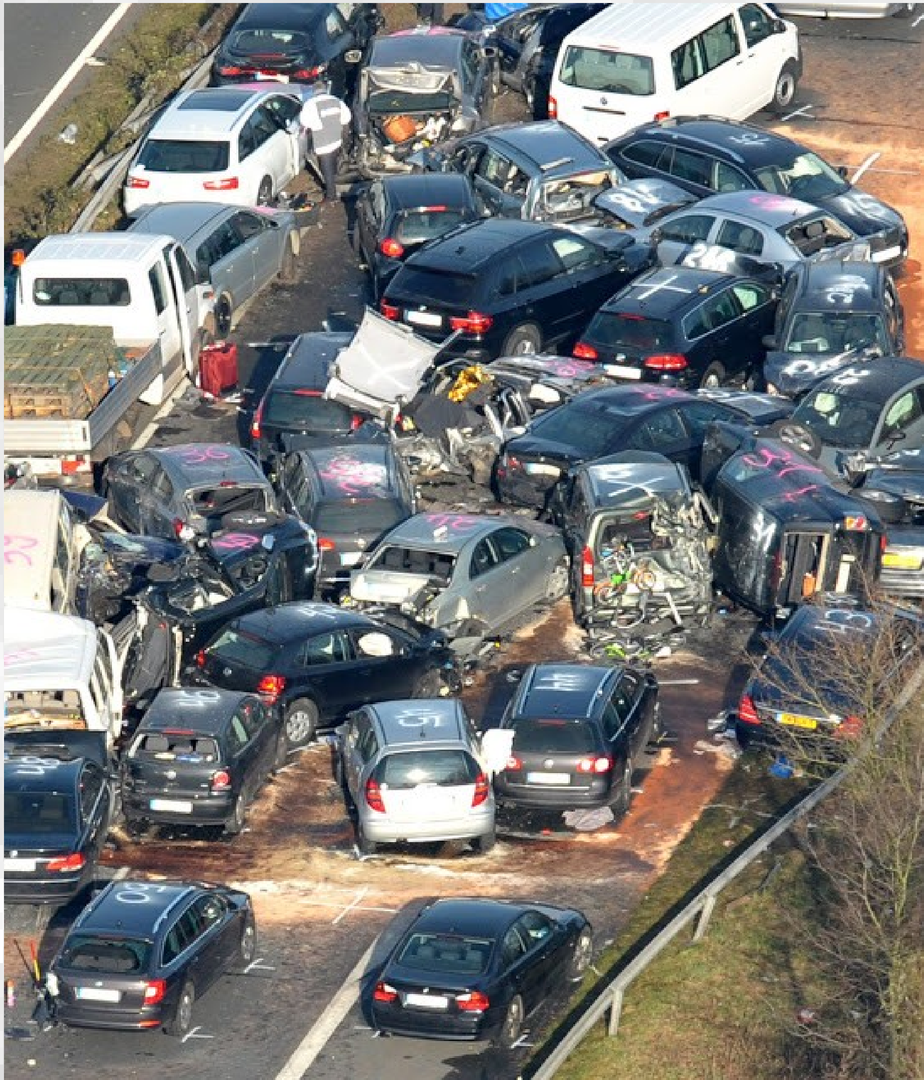
It diminishes the amount of received PAR ==> affects growth

Water can be captured with appropriate nets: used in Atacama desert

**==> Avoid if possible areas prone for fog formation**

# Impacts and mitigation

3) ***On road traffic***: **speed reduction and higher likeliness of car crashing, which can be massive in busy roads. Drivers capabilities reduced in low visibility conditions: shorter reaction times required. Fog and heavy rain are the most important weather factors related to car accidents.**
**Only 3% of accidents are fog-related and they can explain 1% of total deaths on the road**



**==> Increase attention and caution in the road**

**==> try dissipation of fog in selected spots.**

## Impacts

4) ***Airport operations***: main factor producing flight cancellations with a huge economical impact.
Airports usually located in fog prone areas (in flat areas in valleys or the coast).
1% of the operation time is affected by fog in average.
50% of the delays caused by meteorological affectations
Incidents related with taxi and parking operation.

==> Use aircraft and airports able to allow landing in fog (expensive)

In winter, fog may lead to icing on wings
==> de-icing implies severe delays

5) ***On maritime transport***:
In-harbour: operations severely restricted. Rotterdam has fog 1.4% of the time.

Out-harbour: persistent fog in busy areas (English channel, China Sea) increases the risk of collision.
4% of marine accidents around Japan took place in fog (30 per year), mostly approaching harbours. Usually failure in following signaling procedures (acoustic and light) involved.

==> Use radar monitoring

## Modification/dissipation of fog

Cloud seeding: microphysics are understood; allowing larger drops to form would imply sedimentation of water.

Cloud warming: Heating the fog layer would eventually lead to evaporation

==> main difficulty: open air is not a closed laboratory, air is around and will respon to artificially generated gradients. Efforts have been very often useless.

Impact on ecosystems: if chemical products are used often over the same place, their deposition on the surface may lead to environmental problems.

For shallow fog: promote entrainment of warmer and drier air from above could be an (expensive) option.

## Instead

Recommended strategy: continuous surveillance and better equipement of vehicles and infrastructures (detectors of proximity and GPS-like navigation)

## Main conclusions

1. Fog is a phenomenon well understood but difficult to predict adequately because its forecast depends critically on the values of wind speed, temperature and humidity in the surface layer (bad in stable conditions).

2. Radiation fog may be very persistent and it depends on the shape of the topography. It shows a diurnal cycle, with "lifting" and lateral erosion. Advection fog is affecting seriously transport infrastructures in coastal areas.

3. Successful forecast of fog must rely on a combination of strategies, including local studies, continuous surveillance and adapted numerical tools.

4. Economical impacts and casualties caused by fog are significant. Dissipation techniques are far from effective. Caution is the best option.

# Hvala!

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