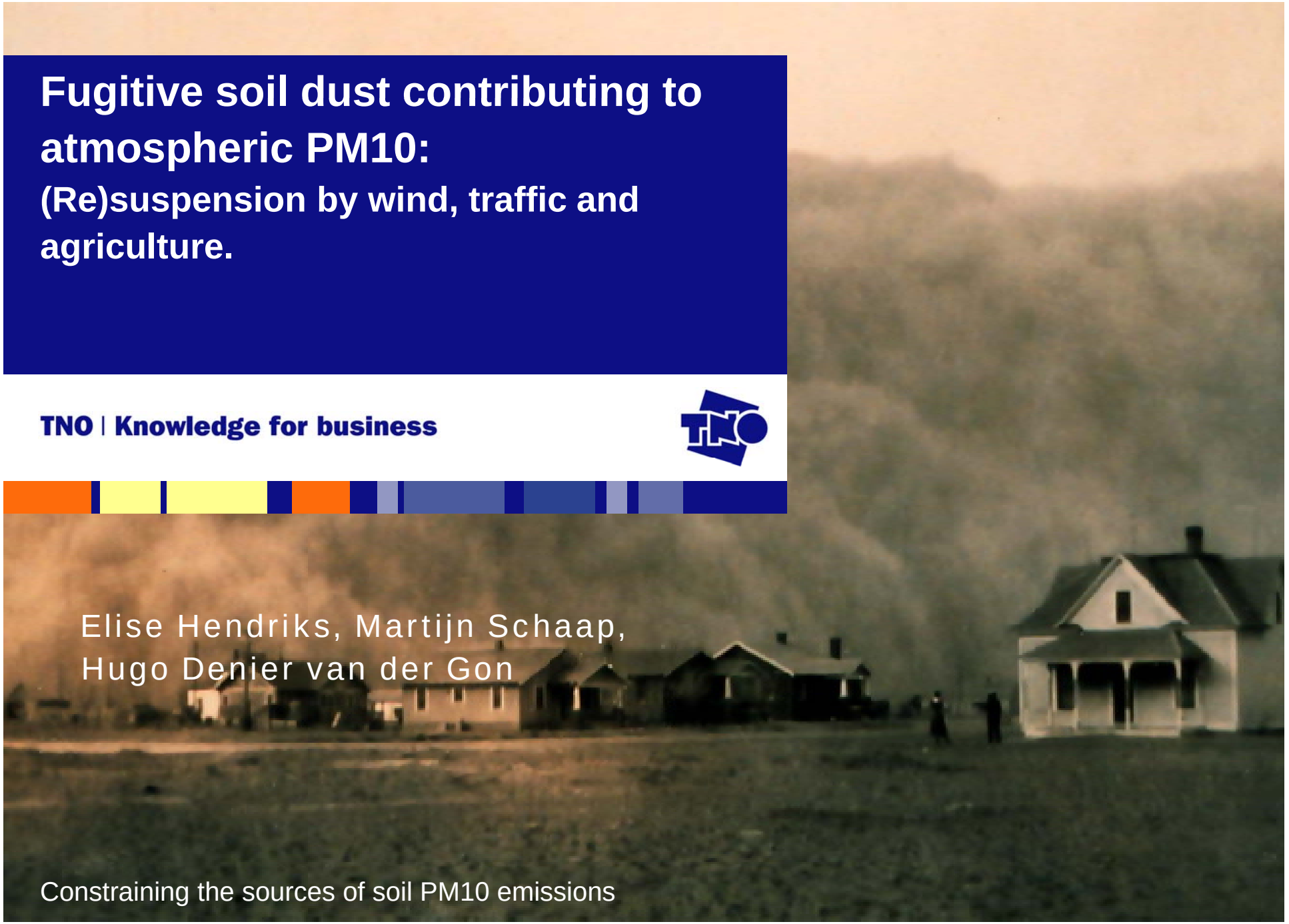
Fugitive soil dust contributing to atmospheric PM10:

(Re)suspension by wind, traffic and agriculture.

TNO | Knowledge for business



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Constraining the sources of soil PM10 emissions

Today

- Importance
- Sources of fugitive soil dust
- Methodology based on empirical approaches
- First results
- Next steps and challenges

The relative importance of fugitive soil dust as a fraction of total PM10 or PM2.5

- 5-40% of PM10 may be soil dust
- Even in PM2.5 it may be important (2-20%)
- Higher in Southern EU
- Street and urban locations are elevated
- Apparently rural (agriculture) sources are not dominating?

	Central EU			Southern EU		
	Rural	**Urban**	**Street**	**Rural**	**Urban**	**Street**
% in PM10	**5-10**	**10-15**	**12-15**	**12-40**	**25-30**	**25-37**
% in PM2.5	**2-8**	**2-8**	**5**	**8-20**	**10-20**	**10-15**

Source: Querol 2006

Average annual contribution of fugitive soil dust to ambient PM10 concentrations in NL

- Empirical formula based on composition of Dutch top soils to estimate crustal material (CM) in PM10 using chemical composition:

$$\text{Mass CM} = 0.49*[Si] + (2.36*[Si]+2.70*[Al])$$

Location	De Zilk	Vredepeel	Overschie	Overtoom
n	31	45	42	49
avg (ug/m3)	2.4	5.4	5.0	3.3

Calculated using data from Visser et al., 2001.

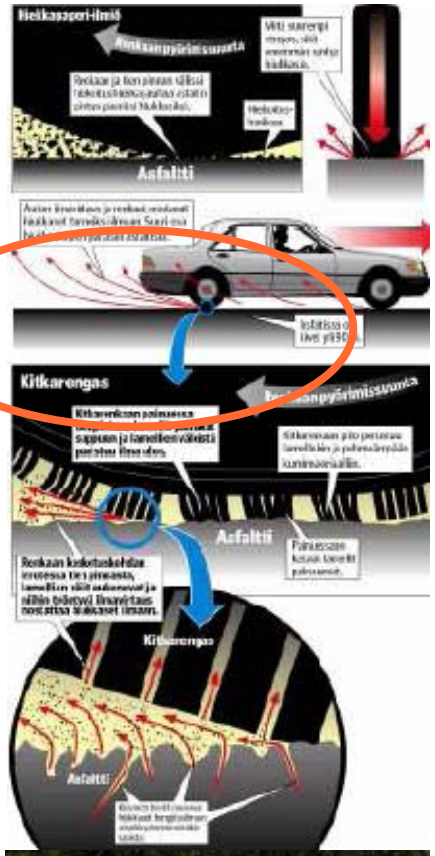
How important is crustal PM in relation to other sources in the Netherlands?

- Based on observations soil derived PM10 contributes about 3-6 ug/m3 (annual avg)
- Model approach: 1 kton/yr PM10 emission may cause a concentration of 0.05-0.1 ug/m3
- First guess; crustal PM10 emissions may be 30-60 kton/yr
- Primary emissions all other sources in the Netherlands are ~ 40 kton/yr
- Same order of magnitude!
- Health relevance may differ but understanding is important

Sources of fugitive soil dust

- **Wind erosion of (partly) bare soils**
- **Resuspension of road dust**
- **Agricultural land management**
- Driving on unpaved roads
- Handling of materials
- Building and construction activities
- ……..

Road dust

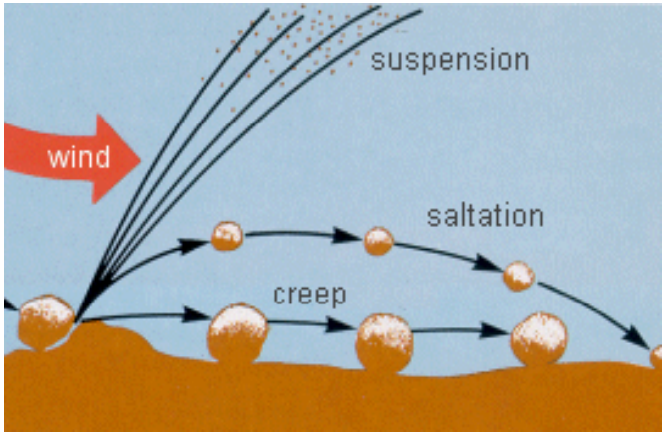


Windblown dust

Agricultural activity

Windblown Dust

- Indirect mobilization of dust by saltation*:
  Parametrization for vertical dust flux (F_V) as a function of wind friction velocity (u*):



$F_V=\alpha.F_H$

$F_H(D_p)=(K\rho_{air}/g)(1-R)(1+R)^2$ for $u^*>u^*_{th}(D_p)$

where

$R(D_p)=u^*/u^*_{th}(D_p)$

α : constant ratio between vertical dust flux and saltation flux, $\alpha=10^{-5}$-10^{-7}

K : 'desertness' factor, K=1 for desert, K=0.02 for arable land

$u^*_{th}(D_p)$: threshold friction velocity for saltation

$u^*_{th}(D_p)=u^*_{th,uncor}(D_p).f_w(w,w_t)/f_{eff}(z_0,z_{0s})$ with $u^*_{th,uncor}=0.217$m/s

$f_{eff}(z_0,z_{0s})$: effectiveness of shear stress on the soil surface, with z0 from ECMWF, $z_{0s}=4.10^{-6}$ m^{-1}, $f_{eff}=1$ for most effective wind shear (smooth surface)

$f_w(w,w_t)$: correction factor for soil moisture w:

now only $f_w=0$ in case of precipitation, $f_w=1$ for w above threshold w_t

Marticorena and Bergametti (1995) , Gomes et al. (2003), Alfaro et al. (2004), van Loon et al. (2005).

Windblown Dust

Below saltation threshold friction velocity only uplift of smallest particles, described with approach of Loosmoore and Hunt (2000):

- $F_V=3.6\ u^{*3}$ for $u^*<u^*_{th}$

Windblown dust parametrisations applied to

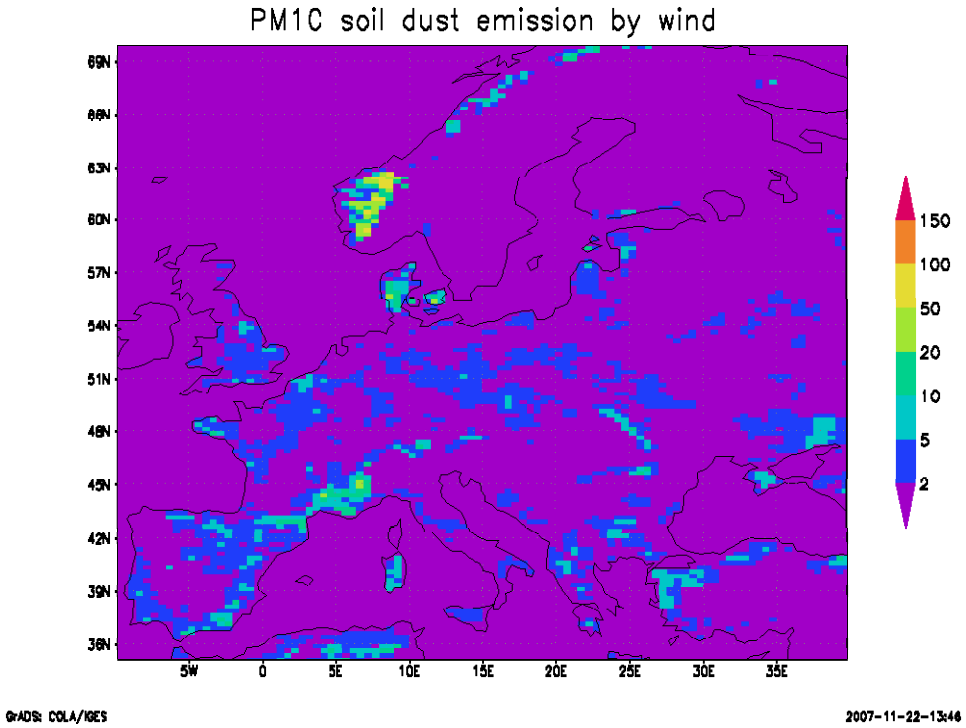
- all arable lands (CORINE, 2003)

No regional dependencies yet

First indications:

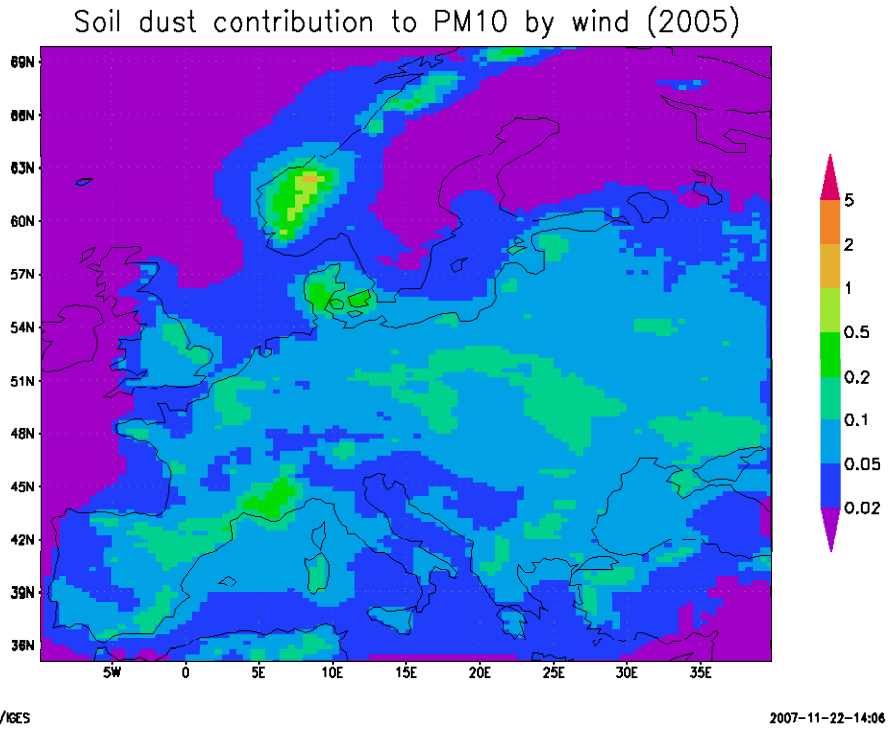
- Dust emission via saltation is roughly order of 0.3-1.5 kg/ha over arable land
- Contribution of saltation initiated soil dust is a factor 10-100 larger than dust emission without saltation.

Windblown dust contribution to PM10



<- emission [g.gridcell^{-1}.s^{-1}]

2 g.gridcell^{-1}.s^{-1} ~ 1 kg .yr^{-1}.ha^{-1}



concentration [ug.m^{-3}] ->

<1.6 ug.m^{-3}

Next steps for windblown dust modelling

- More detailed information on landuse, also temporal information, needs to be taken into account:
  - apply newest Corine landuse database example:
    Arable land divided in subclasses; land under croppage cycle, 'ever-irrigated' land etc
  - use soil texture information

- Corrections for vegetation, wetland and snow;
  'Simple definition' for the fraction of erodible surface
  $A_e=(1-A_v)(1-A_w)(1-A_s)$
  A_v: vegetated area, A_w: wetland, A_s: snow cover

- Soil moisture correction; w from ECMWF and empirical relation for f_w (Fecan et al, 1999)

A first approximation of fugitive dust (re)emitted by traffic

- Road wear; Pavements consist of rock material. Road wear - based on tunnel study is 3-4 mg per vehicle kilometre (vkm). Literature EF's are 8-10 mg/vkm: consistent lower limit 3-4 mg/vkm.

- Resuspension by traffic; Same order of magnitude as primary road traffic emissions - based on observational data using relationships between PM and NOx emissions

- Observations of road wear and resuspension; coupled (vkm), road wear is << than resuspension

A first approximation of fugitive dust (re)emitted by traffic

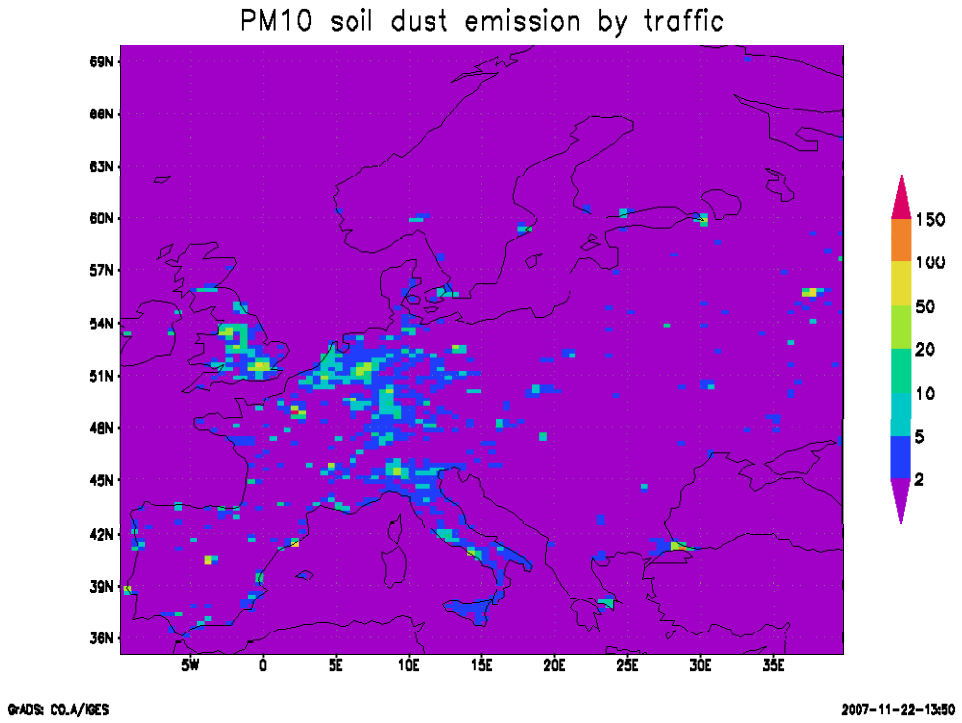
- Emission depends on e.g. dust load, road condition, car type and traffic intensity

Simplified approach:

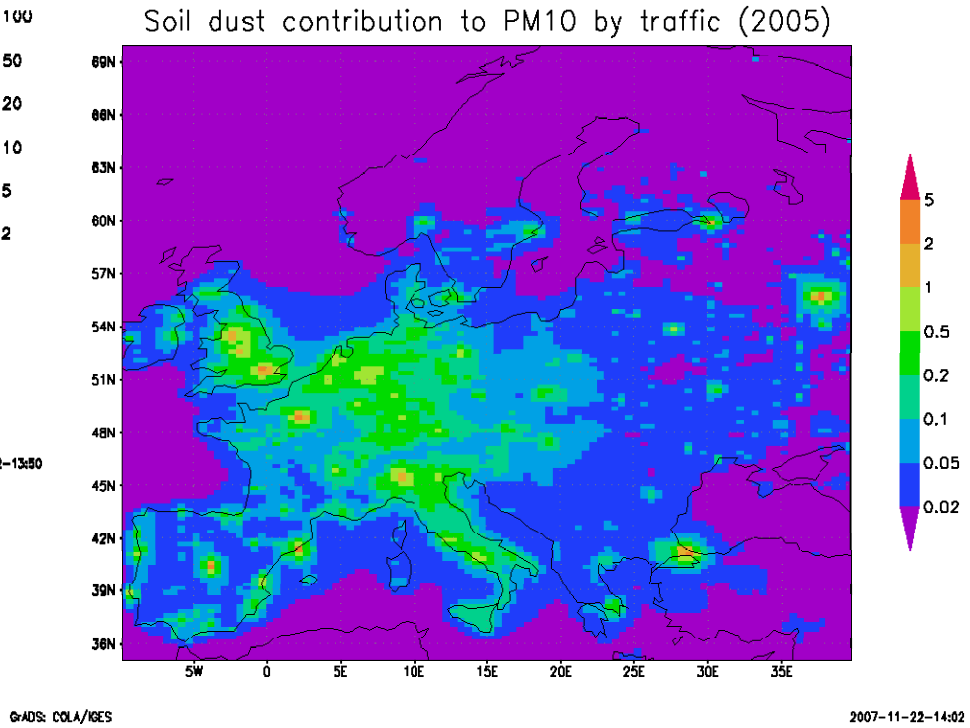
- Separated EF's for
  - 3 types of roads (highway, rural, urban)
  - 2 types of traffic (HDV, LDV)
- No emission in case of precipitation
- Again, no regional dependency yet

EF PM2.5-10	HW	Rur	Urb
HDV	140	220	320
LDV	16	22	32

Fugitive soil dust (re)emitted by traffic with separated EF's



<- emission [g.gridcell^{-1}.s^{-1}]



concentration [ug.m^{-3}] ->
<2.5 ug.m^{-3}

Next steps for (re)emitted road dust modelling

Take into account differences in **road surface dust load** over Europe;

- dustier Spanish roads.., similar in Italy, Greece?
- studded tyre and sanding in Scandinavian winter (->high PM values in spring)

Thus, apply road dust load factor on EF's based upon indications from measured data in Spain, Sweden and central European locations.

Other questions:

Dust load wetness parametrization on basis of … ?

Road surface soil type on basis of soil type information ?

Fugitive (soil) dust due to agricultural activity

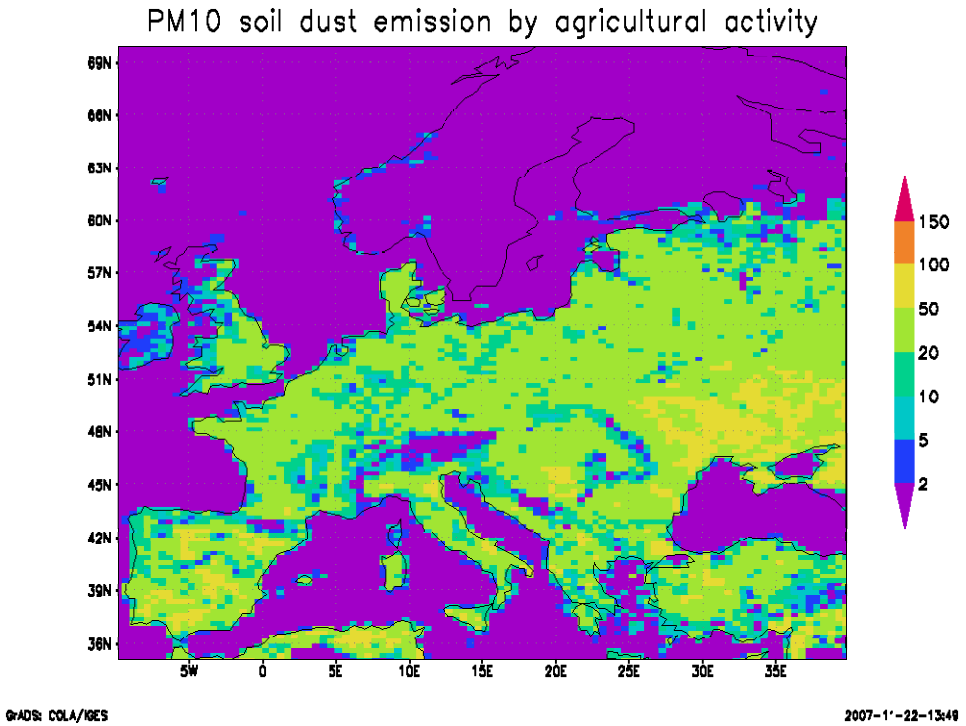
Agricultural activity includes: ploughing, discing etc
Characteristics: short periods, high PM emissions

First pragmatic approach:

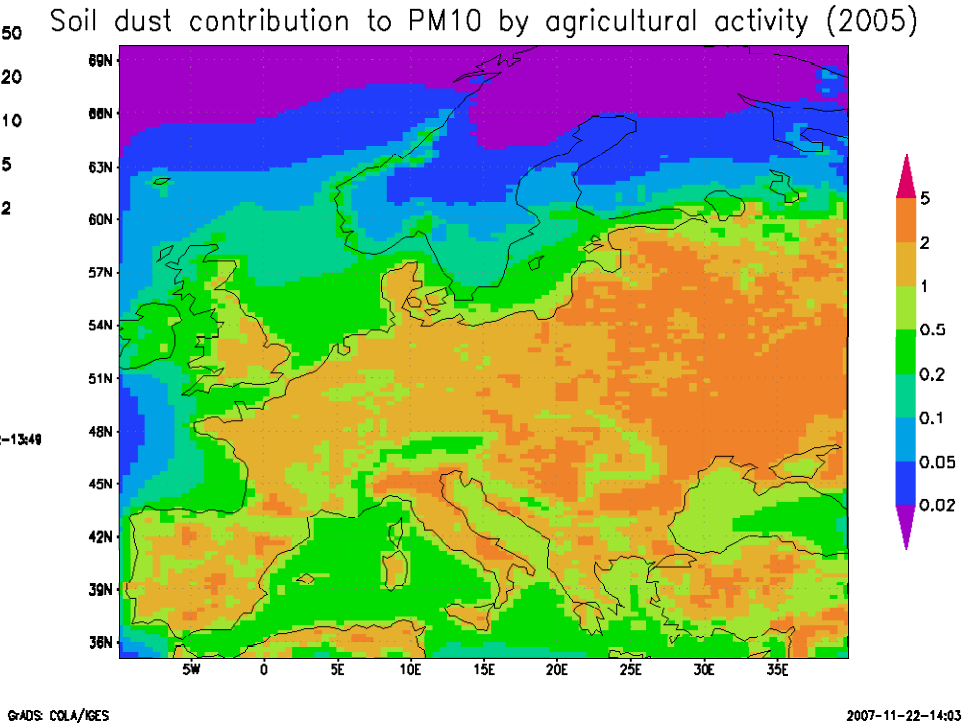
- Emission based upon EF's for ploughing, discing accumulated in spring months
- Emission based upon harvesting EF's for harvest months
- No emission in other seasons

jan	Feb	Mrt	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
winter		land prepa-ration & seeding		growing season			harvest			winter prepa-ration	

Fugitive (soil) dust due to agricultural activity



<- emission [g.gridcell^{-1}.s^{-1}]



concentration [ug.m^{-3}] ->
<4.0 ug.m^{-3}

Challenges in modelling of agriculturally mobilized soil dust

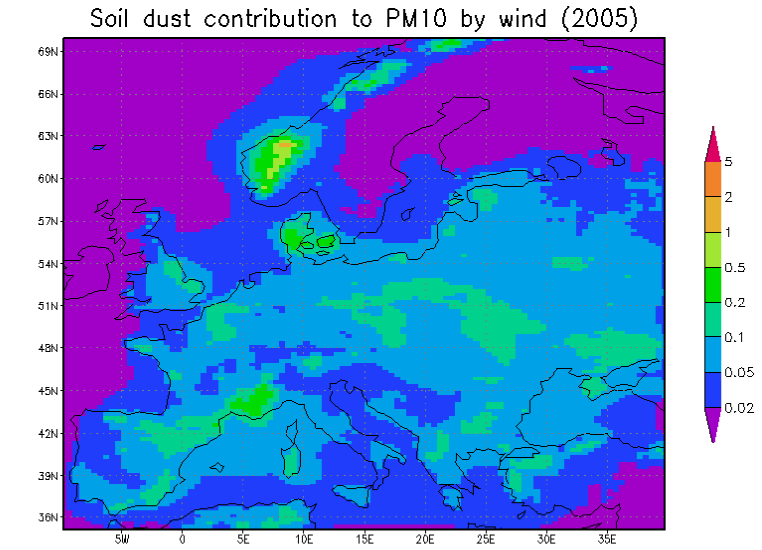
- EF's are poorly known... only few in literature. Always given in weight/area units, conversion to g/m2.h is necessary,
- Often unspecified soil/organic fractions
- Landuse, soil texture & moisture, croppage cycle is required Corine landuse, soil texture map, soil moisture ECMWF
- Furthermore, simple parametrizations for above dependencies should be formed

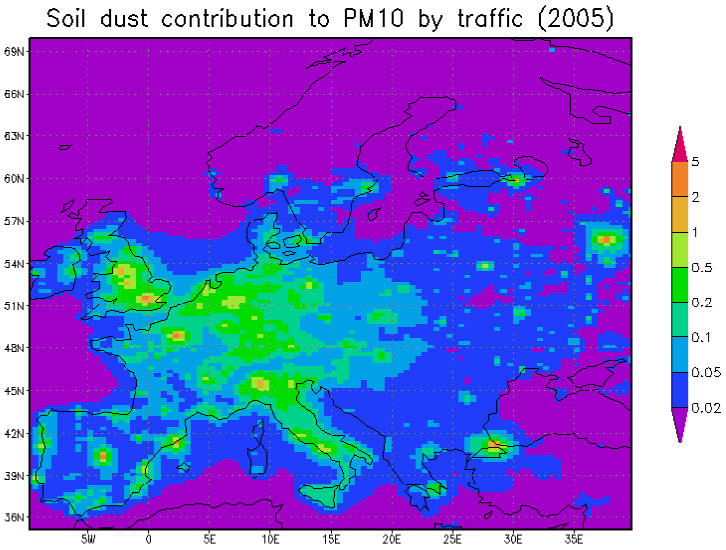
Example EF's:

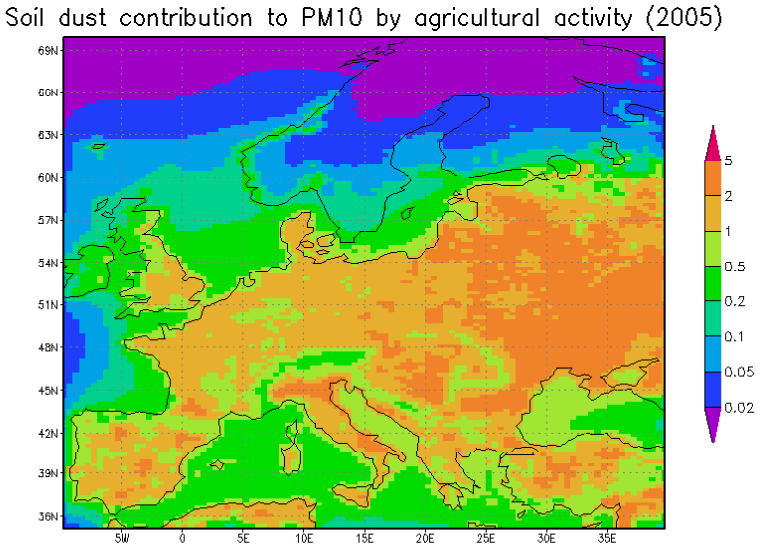
	EF PM2.5 (kg/ha)	EF PM10 (kg/ha)
Harrowing [a]	0.29	0.82
Discing[a]	0.12	1.37
Cultivating [a]	0.06	1.86
Ploughing dry[a]	1.86	10.5
Ploughing moist[a]	0.05	1.2
Harvesting Cereal[b]	?	4.1-6.9
Harvesting Corn[c]	?	1.9

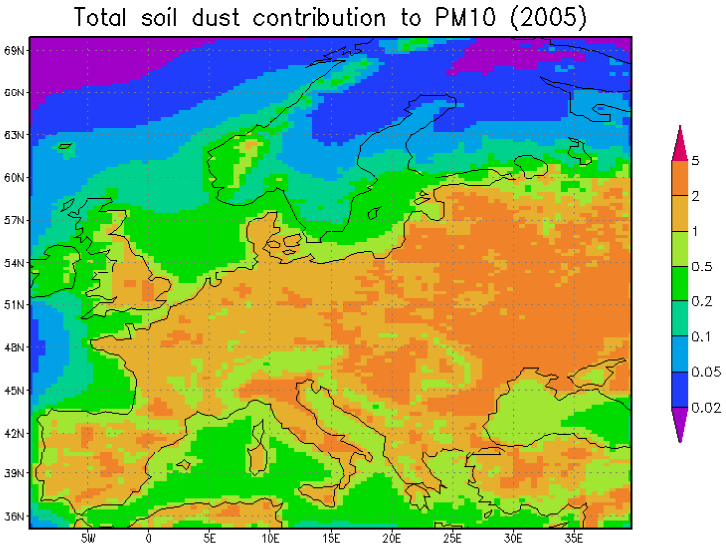
[a] Ottl et al, 2005, Funk et al, 2007,
[b] Funk et al, 2007, [c] Gaffney et al, 2006.

Soil dust contribution to fugitive PM10







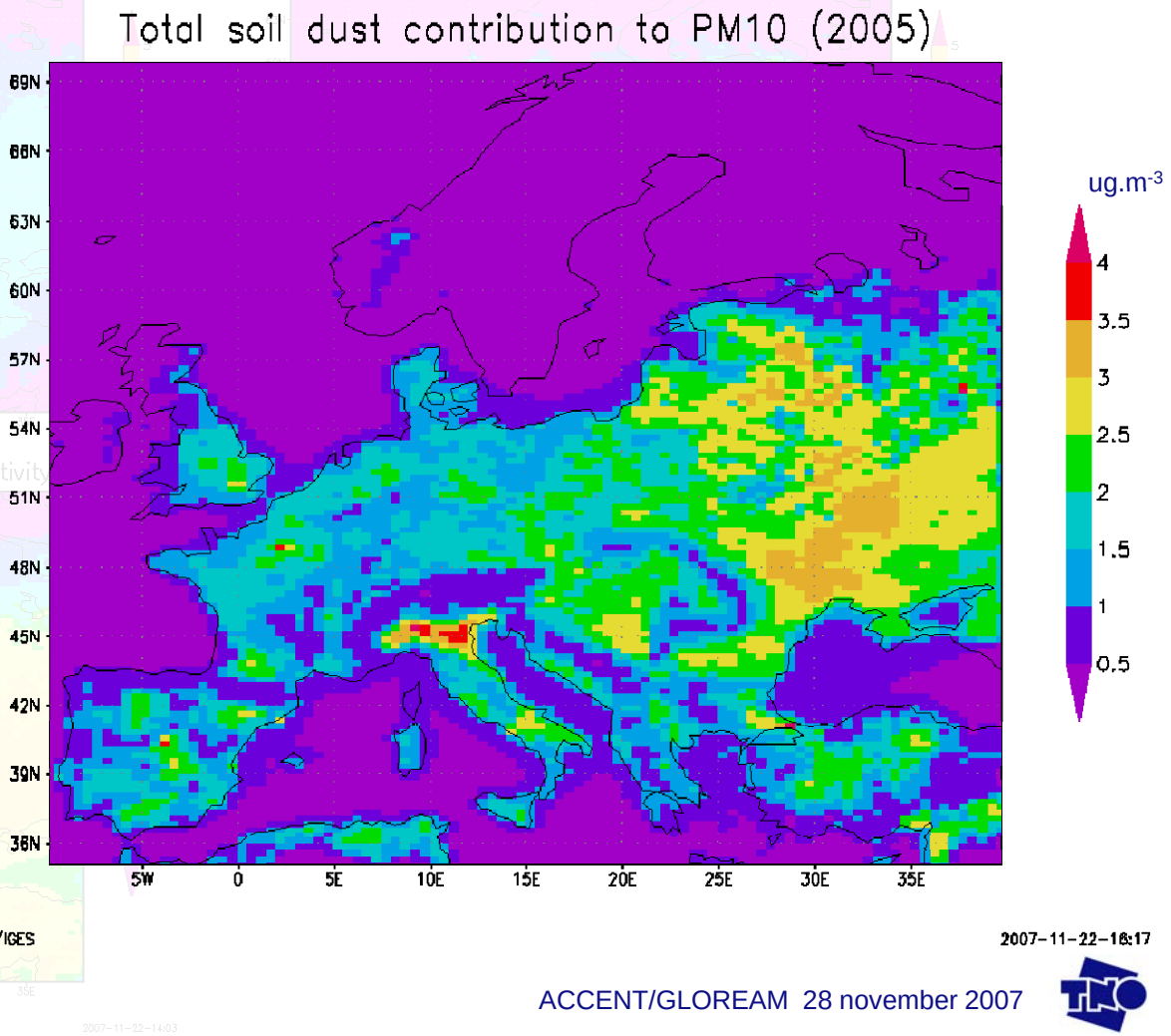


ug.m^{-3}

)07

Soil dust contribution to fugitive PM10

- Maximum concentrations;
  4 ug.m^{-3}
- Agricultural activity by far largest contribution to soil dust PM10;
  <4 ug.m^{-3}
- Traffic resuspension;
  <2.5 ug.m^{-3}
- Wind erosion;
  <1.6 ug.m^{-3}



Summarizing next steps & challenges

Include:

- TM5 boundary conditions of desert dust
- Updated landuse database
- Soil texture → silt content, dust type & load information
- ECMWF soil moisture
- Regional dependent road dust load; 'climatic' and 'winter' factor
  - ↗ infer from measured data of related PM emissions at different locations in Europe

Develop and improve:

- Knowledge on emission factors
- Parametrizations for croppage calendar, agricultural activity calendar, climatic factor.

Validation

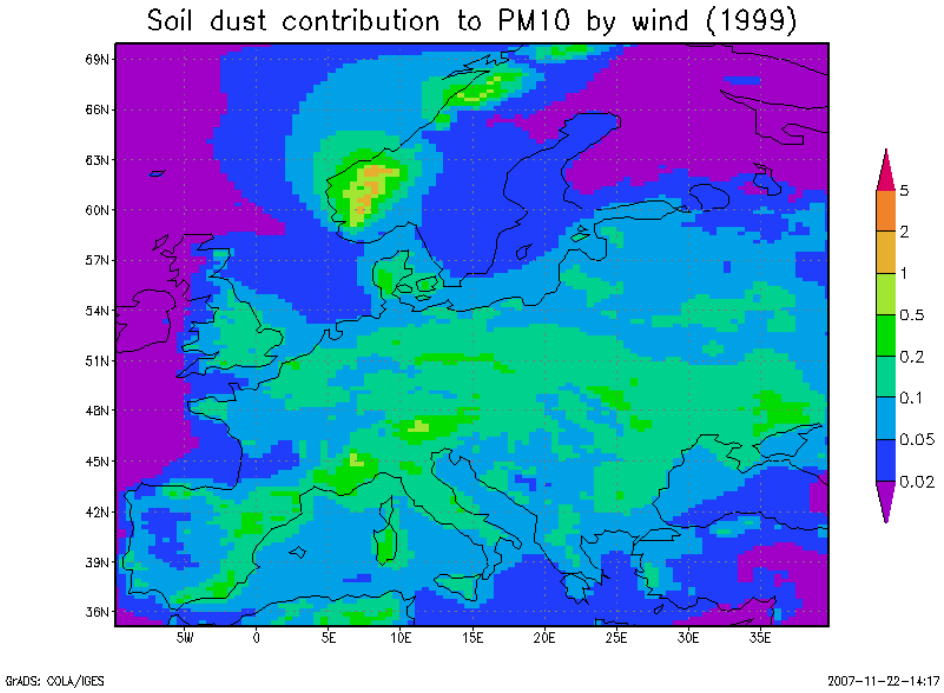
Additional question(s):

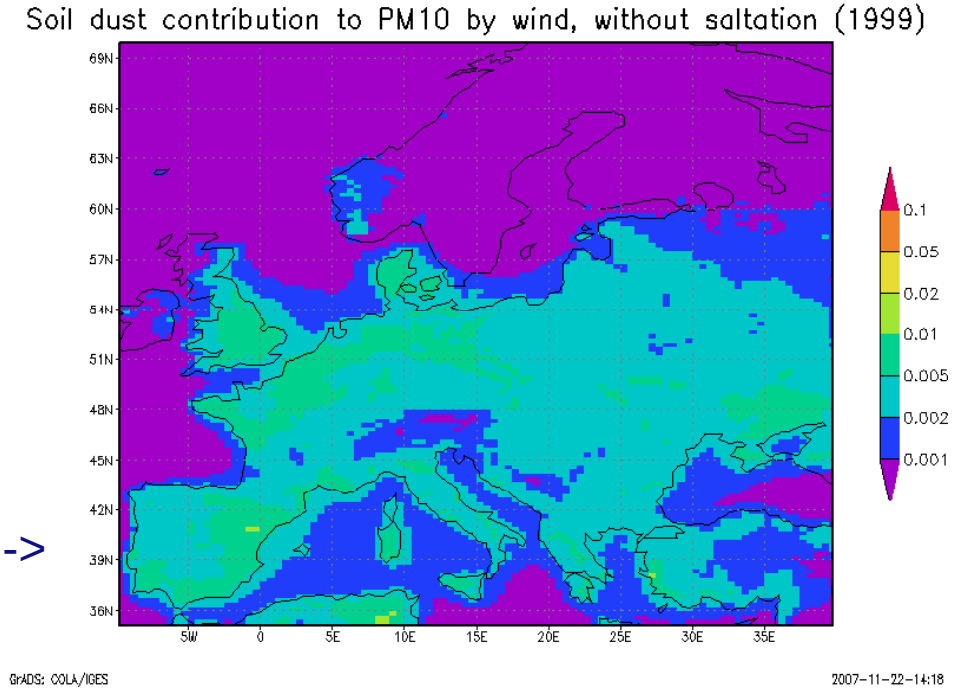
Level of complexity of croppage type and cycle??

…


TO BE CONTINUED...

Windblown dust fraction of PM10 without saltation





Factor 10-100 smaller! ->