Air quality modelling of fugitive dust emissions caused by agricultural activities using two different chemical transport models

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1. INTRODUCTION

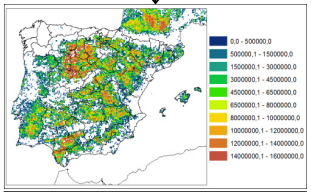
Fugitive dust emissions caused by agricultural activities (i.e. land preparation and harvesting) contribute to the ambient particulate matter mass (i.e. coarse fraction), especially in Mediterranean countries like Spain, characterised by large agricultural and some semiarid regions. This work describes the integration and modelling of fugitive dust emissions caused by agricultural operations within the CALIOPE air quality forecast system and over Spain (http://www.bsc.es/caliope/es). An estimation methodology based on Schaap et al. (2009) was implemented inside the system in order to analyse the contribution of this source to PM_{10} concentrations.

The CALIOPE air quality system was applied on a 4km horizontal resolution grid covering the whole Iberian Peninsula, with a temporal resolution of 1 hour and using two different chemistry transport models (i.e. CMAQv5.0.1 and CHIMEREv2013b) so the impact of different dry deposition schemes on the modelled PM_{10} concentrations was also analysed. The concentration results obtained running the two simulations (one for each chemical transport model) were evaluated against observational data from AirBase stations (EEA, 2013).

2. METHODOLOGY

$$E_{io}(k,h) = A(k) \cdot EF_{io} \cdot M_{mjs} \cdot \left(W_{djs} \Big/ \sum_{d=1}^{7} W_{djs} \cdot N_{dm} \right) \cdot H_{hjs}$$

Methodology adapted from Schaap et al. (2009) and implemented in the HERMESv2.0 model (Guevara et al., 2013), the emission core of the CALIOPE air quality forecast system.

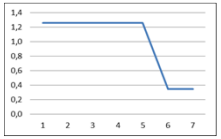


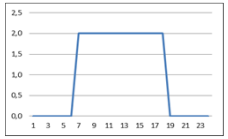
Arable lands [m²] from CORINE Land Cover (EEA, 2012)

EF (mg·m⁻²)		
Operation type	PM_{10}	Reference
Harvesting (wheat)	650	Gaffney et al. (2003)
Harrowing	82	Öttl et al. (2007)
Cultivating	186	Öttl et al. (2007)
Discing	137	Öttl et al. (2007)
Ploughing (dry)	1050	Öttl et al. (2007)

Emission Factors (EF) applied (Gaffney et al., 2003; Öttl el at., 2008)

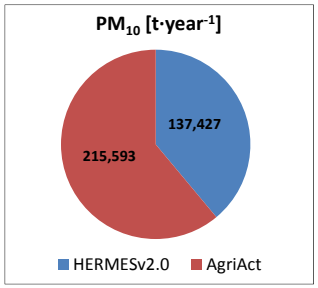
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fertilization & Growing season				Harvest			Land Preparation & Seeding				
				Harvesting			Harrowing				
							Discing				
							Ploughing				
							Cultivating				



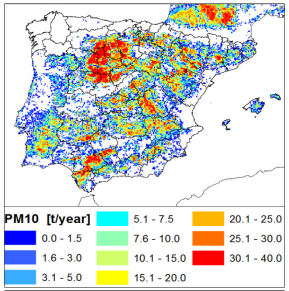


Temporal profiles (monthly, weekly, hourly) applied (Schaap et al., 2009; FEGA, 2012)

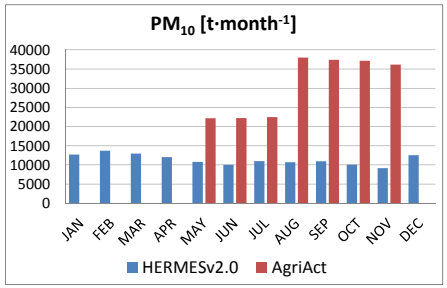
3. EMISSIONS



Annual PM_{10} emissions [t·year⁻¹] released by total SNAP sectors (HERMESv2.0) and agricultural activities (AgriAct) for Spain 2009

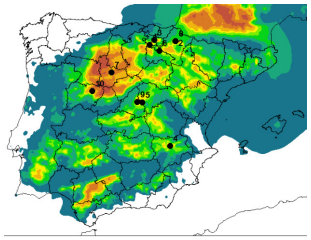


Spatial distribution of annual PM_{10} emissions [t·year⁻¹·cell⁻¹] released by agricultural activities for Spain 2009 (4 km x 4 km)

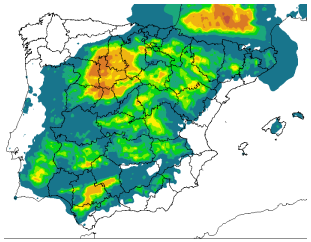


Temporal distribution of PM_{10} emissions [t·month⁻¹] released by total SNAP sectors (HERMESv2.0) and agricultural activities (AgriAct) for Spain 2009

4. AIR QUALITY CONCENTRATIONS

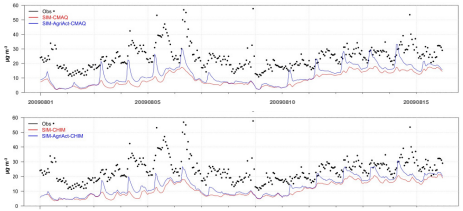


Contribution of PM_{10} [μg·m⁻³] (Hv2-ConAgr – Hv2-SinAgr) modelled with CALIOPE-CMAQ. Black dots represent the Airbase stations.



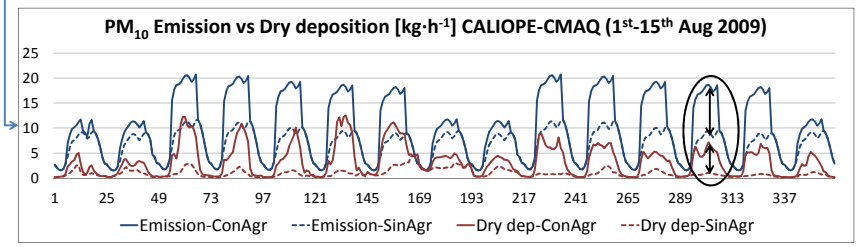
Contribution of PM_{10} [μg·m⁻³] (Hv2-ConAgr – Hv2-SinAgr) modelled with CALIOPE-CHIMERE.

4 simulations were run for 1st-15th Aug 2009: (i) CMAQ/CHIMERE, (ii) agricultural activities deactivated (Hv2-SinAgr)/activated (Hv2-ConAgr)



Observed (dots) and modelled (solid lines) time series of hourly mean concentrations [μg·m⁻³] for PM_{10} at selected AirBase stations using CMAQ (**Top**) and CHIMERE (**Bottom**).

Station	Measured mean [μg·m⁻³]	Modeled mean [μg·m⁻³]				MB [μg·m⁻³]				r				RMSE [μg·m⁻³]			
		CALIOPE-CMAQ		CALIOPE-CHIMERE		CALIOPE-CMAQ		CALIOPE-CHIMERE		CALIOPE-CMAQ		CALIOPE-CHIMERE		CALIOPE-CMAQ		CALIOPE-CHIMERE	
		Hv2-SinAgr	Hv2-ConAgr	Hv2-SinAgr	Hv2-ConAgr	Hv2-SinAgr	Hv2-ConAgr	Hv2-SinAgr	Hv2-ConAgr	Hv2-SinAgr	Hv2-ConAgr	Hv2-SinAgr	Hv2-ConAgr	Hv2-SinAgr	Hv2-ConAgr	Hv2-SinAgr	Hv2-ConAgr
1	26.6	6.8	10.1	8.4	10.8	-19.9	-16.6	-18.3	-15.8	0.22	0.22	0.16	0.24	21.8	19.2	20.4	18.2
2	19.0	5.9	8.6	9.1	10.9	-13.1	-10.4	-9.9	-8.1	0.45	0.55	0.35	0.48	15.3	12.8	12.9	11.2
3	15.3	7.9	10.2	11.3	13.0	-7.4	-5.1	-4.1	-2.3	0.25	0.20	0.22	0.21	14.7	14.1	13.5	13.2
4	41.1	18.2	20.5	18.5	20.3	-22.9	-20.6	-22.6	-20.8	0.11	0.18	0.08	0.13	29.4	27.5	29.5	28.0
5	20.2	13.1	15.4	14.3	16.4	-7.1	-4.7	-5.9	-3.8	0.10	0.16	0.09	0.15	20.9	20.0	20.6	19.8
6	14.6	6.3	8.6	9.1	10.9	-8.3	-6.0	-5.5	-3.7	0.23	0.33	0.18	0.28	13.5	11.9	12.1	11.1
7	20.8	7.3	10.9	8.9	11.9	-13.6	-9.9	-12.0	-8.9	0.57	0.68	0.6	0.65	16.4	12.9	15.0	12.3
8	19.9	5.7	8.8	8.7	10.8	-14.2	-11.2	-11.2	-9.1	0.32	0.45	0.27	0.44	17.2	14.5	14.9	12.9
9	39.1	12.8	16.1	13.8	16.9	-26.3	-23.1	-25.3	-22.2	0.20	0.21	0.20	0.25	40.4	38.5	39.9	37.6
10	26.6	8.1	11.4	9.3	12.2	-18.5	-15.2	-17.3	-14.4	0.60	0.54	0.62	0.63	21.0	18.4	19.8	17.2
TOTAL	24.5	9.3	12.1	11.2	13.5	-15.2	-12.3	-13.3	-11.0	0.34	0.37	0.29	0.34	22.6	20.7	21.7	20.0



(**Top**) Statistics obtained with the four simulations on an hourly basis for 1st-15th Aug 2009: measured mean [μg·m⁻³], modelled mean [μg·m⁻³], mean bias [MB, μg·m⁻³], correlation coefficient (r), and root mean square error [RMSE, μg·m⁻³]
(**Left**) Time series of PM_{10} emissions and dry deposition [kg·h⁻¹] taking into account agricultural activities (ConAgr) and without them (SinAgr) and using CMAQ for the period 1st to 15th Aug 2009.

Δ Emissions	1250.2 kg
Δ Dry deposition	866.9 kg
% Dry deposition	69%

5. CONCLUSIONS

- The total amount of PM_{10} emitted by agricultural activities (215,593 t·year⁻¹) is 40% higher than the rest of HERMESv2.0 emissions (137,427 t·year⁻¹) and contributes by 57% to the total Spanish PM_{10} emitted. Emissions are spatially distributed across the arable land areas, with contributions up to 40 t·year⁻¹·cell⁻¹. In terms of temporal allocation most of them occur during the land preparation period (i.e. 69%, August to November).
- In terms of air quality, PM_{10} modelled concentrations are only affected in or in the vicinity of arable land areas (up to 6 μg·m⁻³ in August). The inclusion of emissions from agricultural activities allows for a reduction of the average MB of ~3 μg·m⁻³ (CMAQ) and ~2 μg·m⁻³ (CHIMERE) at those stations located near arable land areas. On the other hand, correlation factors are increased up to 0.13 (CMAQ) and 0.17 (CHIMERE).
- All these positive effects are, however, limited by the dry deposition mechanisms of both models, which are found to be a significant sink for the agricultural fugitive dust emissions (up to ~ 69% of total extra emitted PM_{10} emissions in the case of CMAQ).

6. REFERENCES

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