### Forecasting human exposure to atmospheric pollutants in Portugal

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## Exposure to air pollution

#### Why should we care about human exposure?

#### Pollutant concentration



# The objective

Forecast human exposure to atmospheric pollutants in Portugal

Development of a module to calculate the human exposure

Incorporation into the operational air quality forecast system for Portugal

# The methodology



Comprehension and use of the air quality forecasting system

2 Development of a model to calculate the human exposure

Incorporation and testing of the human exposure model on the air quality forecasting system

### The air quality forecasting system



### The air quality forecasting system

#### 1<sup>st</sup> simulation European domain

2<sup>nd</sup> simulation domain



### The air quality forecasting system



- Beginning: 2005
  2 years of testing and validation
- Information available: 2007 Internet and Media

#### www.dao.ua.pt/gemac/previsao\_qar

#### Human exposure

How it is calculated?



#### Human exposure

#### Which microenvironments?



### The human exposure model

- Fortran programme that can be linked to air quality models
- Indoor sources not considered
- Pollutants: O<sub>3</sub>, NO<sub>x</sub>, PM<sub>10</sub> and PM<sub>2.5</sub>
- Microenvironments:
  - Home
  - Work/school
  - Other indoors (restaurants, gyms, shopping centre, cinema/theatre)
  - Outdoor





#### Input data to human exposure model

Population distribution in each hour of the day for each microenvironme



### Input data to human exposure model

Population distribution

	A	В	c	D	E	F	G	н	1	J	К	L	м	N	0	P	0	R	S	T	U	Ų	W	×	Y	z	AA	AB	AC
1	\$	0	0	0	0	0	0	101	0 5977	0 76.17	6725	1305	2047	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	25	5984	9586	7207	6284	4323	166	0	29	0	0	0	0	0	995	831	925	1913	1299	634	0	0	0
4	0	0	0	0	0	0	7534	9663	9102	5619	5574	5299	11	582	968	1209	964	2710	1322	3167	1390	1426	2308	2957	2957	1427	0	0	0
5	0	0	0	0	0	0	20879	21998	13855	9457	9166	4363	2268	1484	1484	1484	2905	7491	7316	5774	1579	1425	2693	2957	2957	1065	0	0	0
6	0	0	0	0	0	0	18860	27039	14521	20948	17303	4765	4325	2409	1717	1787	3590	7491	5021	3548	2923	1930	2383	2957	2716	1142	583	440	0
7	0	0	0	0	0	0	12243	32961	29266	49700	44937	14411	6707	4877	3828	2747	4051	5375	3469	3685	3727	2560	2639	2857	1940	1052	1192	1551	385
*	0	0	0	0	0	0	42266	53926	54248	88963	67024	36333	19695	0024	4(15	3319	3453	3451	3452	3143	3904	2183	4922	2468	1653	1080	1430	1199	22
10	0	0	0	0	0	0	13376	d612d	56988	54976	60339	44210	22270	14483	9260	13386	4268	3564 d6d3	3779	3042	2899	1947	1693	1421	1407	1407	506	434	0
11	ů.	ò	, 0	ů.	ů.	ů.	0	119935	144666	78225	55778	34151	21912	19451	14226	13204	6821	4507	3118	2620	2228	1744	1639	1471	860	244	0	ò	0
12	0	0	0	0	0	0	0	105961	254662	\$7597	38837	30179	21962	12151	15421	14540	6375	3493	2978	2334	1880	1743	1733	1376	64	0	0	0	0
13	0	0	0	0	0	0	0	25876	171493	122373	32645	15202	10715	9526	14232	10194	5477	3944	2735	2050	2039	1836	1269	581	0	0	0	0	0
14	0	0	0	0	0	0	0	12572	73597	60276	12184	8743	6577	6135	6666	5897	5020	3154	2439	2084	2032	16.01	1066	3	0	0	0	0	0
15	0	0	0	0	0	0	0	12606	47503	63317	12490	7347	5988	4645	4245	3928	4082	2755	2749	2257	1986	1339	1339	368	0	0	0	0	0
10	0	0	0	0	0	0	0	24493	25795	15639	9529	6293	6245	17112	14005	10059	6254	3016	2245	2901	2101	1092	1373	622	0	0	0	0	0
18	ů.	0	ů.	ů.	ŏ	ŏ	1427	46412	32903	15108	13559	7401	9448	17658	15083	9612	8461	4143	3593	5721	4946	2390	1466	447	ů.	ŏ	Ŏ	ŏ	0
19	0	0	0	0	0	0	3384	14269	24666	16866	13183	7680	8364	10903	11102	7627	5362	5001	5594	6074	6074	2824	1545	622	0	0	0	0	0
20	0	0	0	0	0	0	5543	11431	11984	15192	9478	4364	10188	8490	9003	6353	5693	4630	6211	5409	3988	2042	1701	470	0	0	0	0	0
21	0	0	0	0	0	0	8417	10007	10191	18530	8926	6253	8006	6617	9058	6679	6257	7794	8565	3695	1647	1696	1701	745	0	0	0	0	0
22	0	0	0	0	0	2104	16533	11627	22789	41668	18670	7658	4537	4417	5161	7428	9028	8857 44E9	7402	2986	1129	1029	575	1	0	0	0	0	0
24	0	0	0	0	0	2292	15745	8038	9430	10653	10351	8319	1845	1232	1215	3732	9978 d112	4496	4498	2096	873	\$70	43	0	0	0	0	0	0
25	0	ò	, 0	, 0	0	6800	9577	9364	8857	7467	4633	4136	2179	1251	1294	1727	3808	3872	3630	\$00	757	757	635		, 0	ò	O	Ö	0
26	0	0	0	0	123	19203	19287	9624	9407	7635	5334	3543	3488	2270	1580	2616	3808	3808	3789	1113	757	757	482	0	0	0	0	0	0
27	0	0	0	0	6381	21772	22163	18121	10617	7477	4698	3719	3601	3299	2185	3137	3294	3808	3775	2966	1196	756	52	0	0	0	0	0	0
28	0	0	0	0	9628	19731	20837	19056	11960	10095	5955	3050	2084	2062	2320	1735	1266	2206	3799	3387	802	617	0	0	0	0	0	0	0
29	0	0	0	6222	12000	12364	11514	15858	12511	12340	11866	5/4/	2466	1898	2059	1322	1316	\$01	558	185	3	0	0	0	0		0	0	0
31	285	0	2826	18677	18292	11007	11384	11568	13246	24888	4286	5691	5647	3822	1460	1383	1303	1420	1988	\$15	ő	ů.	0	0 0	ů.	ŏ	ů.	ŏ	0
32	0	10419	19999	10537	17273	\$007	10306	11415	8565	2176	1890	5576	5661	2676	1536	1043	1000	3465	4113	1665	Ó	0	0	0	0	ò	0	ò	0
33	0	2637	17539	12578	8515	8249	10453	11134	7139	1536	1506	3517	2782	2080	1632	997	985	3198	5477	5035	0	0	0	0	0	0	0	0	0
34	0	7804	18428	14741	12300	106.02	14673	11432	9836	4605	1589	1976	2080	1885	919	1000	1063	1246	3352	1709	647	15	0	0	0	0	0	0	0
35	0	16150	18692	16770	14363	10026	10656	8882	5333	2491	1834	2075	1541	881	831	985	1347	1001	783	1414	1440	3131	818	0	0	0	0	0	0
37	9744	43238	67425	95142	31020	21125	5042	3554	1219	1819	1812	1509	1222	1206	1329	2011	2790	3254	2961	3921	35%4	2452	105	0	0	0	0	0	0
38	59640	131623	221323	230920	4213	5609	5099	8922	3551	1630	1518	1607	1189	1091	1074	1480	2778	3742	4584	4173	2877	374	ů.	, v	ů.	ŏ	, v	ŏ	0
39	49359	143239	317000	307664	31338	11304	11207	11985	10466	4265	1603	1506	1341	1533	1591	3504	2278	3064	2894	1431	62	0	0	0	0	0	0	0	0
40	0	0	58374	183618	146899	18693	12749	11644	4788	3032	1572	1528	2443	4190	3523	4206	2136	1569	1142	922	0	0	0	0	0	0	0	0	0
41	0	0	614	45413	56193	30516	38730	6117	1760	1257	1377	1509	3100	4250	4250	4250	2948	1677	1362	545	0	0	0	0	0	0	0	0	0
42	0	0	1284	15054	15447	675	2036	749	854	898	1069	1455	2931	4147	4250	3889	3863	2502	2417	678	160	0	0	0	0	0	0	0	0
44	ŏ	0	0	ő	0	0	628	1634	1230	1013	902	898	991	1199	1960	1330	1182	1620	1902	1673	1077	10	1	0	0	ő	0	0	0
45	0	Ó	Ó	0	ó	Ő	743	1751	1751	1725	1436	1242	1180	1631	2570	1889	1755	1563	1709	1709	1488	753	558	Ő	ů.	ŏ	Ő	Ŏ	Ő
46	0	0	0	0	0	0	1923	2566	2059	1782	1356	1305	1305	2497	3030	2634	2062	1505	1638	1709	1692	1475	457	0	0	0	0	0	0
47	0	0	0	0	0	786	4680	2851	2839	2782	2515	1611	1686	3013	3042	3042	2193	1442	1445	1580	776	189	33	0	0	0	0	0	0
48	0	0	0	0	0	94	4467	3732	2839	2776	2586	2144	2329	3042	3042 16.4F	3042	2110	1442	1442	1103	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	911	1566	1532	1315	\$72	1044	1354	1354	964	605	672	621	337	524	0	0	0	0	0	0	0	0	0
51	0	ő	0	0	ó	Ő	1030	1490	1490	1490	1143	\$72	1207	1320	849	605	605	571	53	0	Ő	ů	Ő	Ő	0	ŏ	Ő	ŏ	Ő
52	0	0	0	0	0	0	864	1490	1490	1471	1030	936	969	1015	681	605	604	455	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	996	1490	1491	1694	1976	941	969	1076	858	585	580	580	84	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	100	1543	1601	1591	3041	5188	3277	1971	6273	4866	2058	842	1763	494	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	442	16 / 2	5349	24702	4345	5200	16260	8253	\$253	5242	4250	2932	12225	4225	0	0	0	0	0	0	0	0	0	0
57	ů.	ő	0	0	220	2757	6160	5601	5925	13060	9571	13108	7074	17029	27839	20001	2123	46	4225	0	ŏ	0	0	0	0	ŏ	0	ŏ	- i
58	0	Ó	Ó	0	245	551	0	0	0	0	0	0	31	11048	25491	8074	0	0	0	Ó	0	Ö	0	Ó	Ő	Ö	Ó	Ö	- i
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er hour er microenvironment er week / weekend



# Input data to human exposure model

Indoor/outdoor coefficients for each microenvironment

	Microenvironments													
	Summe	ne Winte	Work/summe	school	Others indoors									
	r	r	r	Winter	r	Winter								
03	0.60	0.40	0.80	0.60	0.80	0.60								
NO <sub>x</sub>	0.80	0.70	0.85	0.75	0.90	0.80								
BM <sub>10</sub>	0.75	0.65	0.80	0.70	0.80	0.70								
5	0.60	0.48	0.80	0.70	0.90	0.80								

[Poupard et al., 2004] ; [Baek et al., 1996] ; [Lee et al., 1997] ; [Dimitroulopoulou et al., 2006] ; [Chau et al., 2001]; [Wallace et al., 2005] ; [Franck et al., 2003] ; [Hanninen et al., 2004] ; [Lazaridis et al., 2003]

The influence of outdoor concentrations is higher in summer (ventilation!)

Home is the microenvironment with a smaller indoor/outdoor coefficient.



Exposure forecast (3 days) O<sub>3</sub>, PM10, NOx, PM2.5

### Results – 2007 year application

#### Annual average per inhabitant



Monitoring values NO<sub>x</sub> 22 - 102  $\mu$ g.m<sup>-3</sup>.h (15 Countries from America, Asia and Europe) PM<sub>10</sub> 10 - 120  $\mu$ g.m<sup>-3</sup>.h PM<sub>2.5</sub> 20 - 40  $\mu$ g.m<sup>-3</sup>.h (Lisbon)

### Results – 2007 year application

 $O_3$ 

#### 8h maximum value per



#### 8h maximum value for total



O<sub>3</sub> exposure higher in the northern inland and southern regions O<sub>3</sub> total exposure higher in metropolitan areas of Porto and Lisbon

#### Results – 2007 year application

#### Human exposure time series for Porto and Lisbon



#### Final comments

The methodology developed is the main goal to retain because the uncertainty of results greatly depends on the input data used. This application is a valuable tool for people awareness and health protection.

- Possibility of application of this human exposure model with different air quality models (forecast mode or not)
- High individual exposure values for NOx and PM were found in the metropolitan area of Porto (and also Lisbon)
- High individual exposure values for  $O_3$  are found in the northern and inland regions of Portugal.

#### Future work

Improvement of the exposure model:

- estimation on indoor sources (in particular for PM)
- indoor/outdoor coefficients
- microenvironments description and quantification

Investment on field campaigns with direct human exposure monitoring, also useful for model validation

Thank you for your attention