



The results of CAIMANs project

FUTURE TIME AIR DISPERSION MODEL RESULTS FOR THE TREND SCENARIO

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Mitigation Air Pollution in the Mediterranean Port Cities
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Programme cofinancé par le Fonds Européen
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Development Fund



Air Quality in the Future due to Passenger Ships

Ship plumes dispersion in the future determined mostly by:

✓ **Future emissions** according to:

- **Development trends of the Port Authorities**
(e.g. changes in ship traffic, infrastructural interventions etc)
- **Legislation** (Annex VI of the International Convention for the Prevention of Pollution from Ships by the International Maritime Organization):



- **Reduction of the sulfur content in ship fuels in the cruising and maneuvering** modes (to 0.5% m/m on and after 1 January 2020)
- **Post-2010 vessels meeting the Tier II standards resulting in 20% lower NOx emissions** (4% average annual replacement rate for vessels was assumed according to the state-of-the-art reports)

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✓ **Meteorology** (assumed to be that of the present year 2013)



Air Quality Goals Set by EU

Annual Air Quality Limits (AQL)

Macro-pollutants

- ✓ **NO₂** = 40 µg/m³
- ✓ **PM₁₀** = 40 µg/m³
- ✓ **PM_{2.5}** = 25 µg/m³

Micro-pollutants

- ✓ **Pb** = 0.5 µg/m³
- ✓ **As** = 6 ng/m³
- ✓ **Ni** = 20 ng/m³
- ✓ **Cd** = ng/m³
- ✓ **BaP** = 1 ng/m³

Daily AQL (Macro-pollutants)

- ✓ **SO₂** = 125 µg/m³ exceeded 3 days/year (i.e. 99.2 percentile of daily concentration timeseries)
- ✓ **PM₁₀** = 50 µg/m³ exceeded 35 days/year (i.e. 90.4 percentile of daily concentration timeseries)

Hourly AQL (Macro-pollutants)

- ✓ **NO₂** = 200 µg/m³ exceeded 18 days/year (i.e. 99.8 percentile of hourly concentration timeseries)
- ✓ **SO₂** = 350 µg/m³ exceeded 24 days/year (i.e. 99.7 percentile of hourly concentration timeseries)

The CAIMANS Approach

- ✓ **Criterion:** Long-term (i.e annual) and/or Short-term (i.e. daily, hourly) pollutant statistics from the dispersion of ship plumes **EXCEEDING 5% of the AQL ARE HIGHLIGHTED.**

❑ Which are the pollutants not satisfying the criterion in the future?

	NO2	SO2	PM10	PM2.5	Ni	Pb	As	Cd	BaP
Barcelona	✓	✓	✓		✓				
Genoa	✓								
Marseille	✓	✓			✓				
Thessaloniki	✓	✓	✓						
Venice	✓	✓							

➤ NO2 for all cities

➤ SO2 for most cities



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AQ Results to be Presented

1. Maps of Future time Concentrations

- ✓ **NO2**: Annual values / 99.8 percentile of hourly concentration timeseries
 - Critical values: 2 $\mu\text{g}/\text{m}^3$ / 10 $\mu\text{g}/\text{m}^3$
- ✓ **SO2**: Annual values / 99.7 percentile of hourly concentration timeseries
 - Critical values: 1 $\mu\text{g}/\text{m}^3$ / 17.5 $\mu\text{g}/\text{m}^3$
- ✓ **PM10**: 90.4 percentile of daily concentration timeseries
 - Critical value: 2.5 $\mu\text{g}/\text{m}^3$
- ✓ **Ni**: Annual values
 - Critical value: 1 ng/m^3

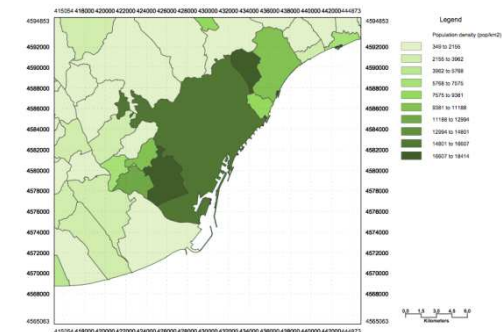
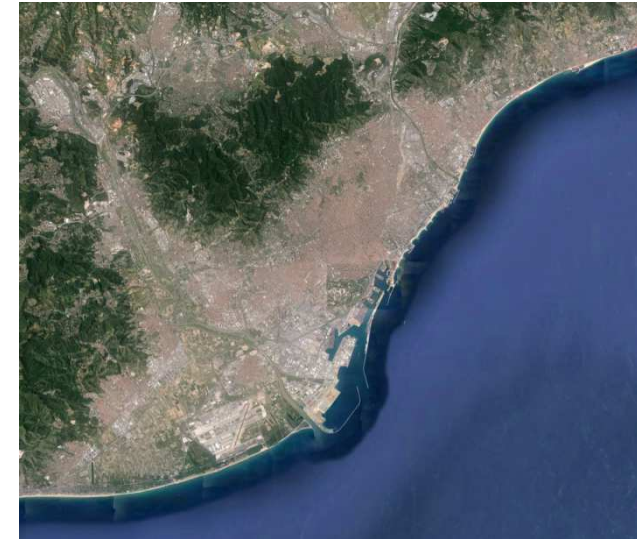
2. Maps/Barcharts of Differences for the above mentioned statistics with respect to AQL defined as:

- ✓ **Diff = (Future value – Present value) / AQL**



Configuration of Future Air Dispersion Modeling for Barcelona

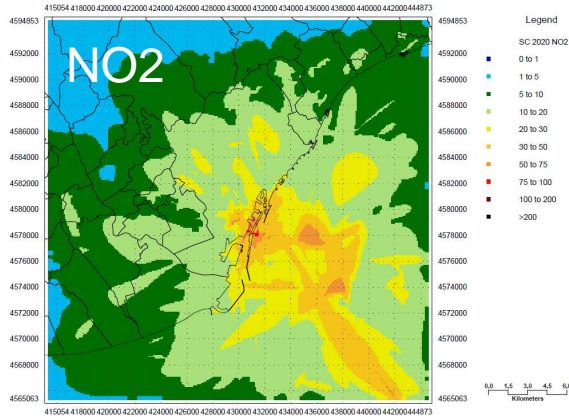
- **No increase in the number of cruise ship calls, but increase in the number of passengers (+20% for Ro-Pax and cruise) and hence GT of ships, resulting in an about 18% increase of pollutant emissions.**
- Modeling Tool: **CALPUFF v6.4**
- Meteorological Model: **CALMET (driven by WRF)**
- Reference Year: **2020**
- **Ships simulated as discrete point sources along the ship route (accounting for the ship velocity). In the hotelling phase, emissions simulated as continuous releases from stationary point sources.**



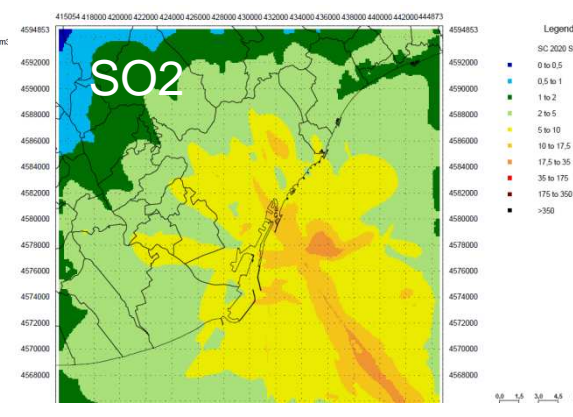
Barcelona 30x30 km² simulation domain (100 m resolution). Total pop.: 3,280,290 hab.

Future Time AQ Results for Barcelona: Short term NO2 and SO2

Concentrations



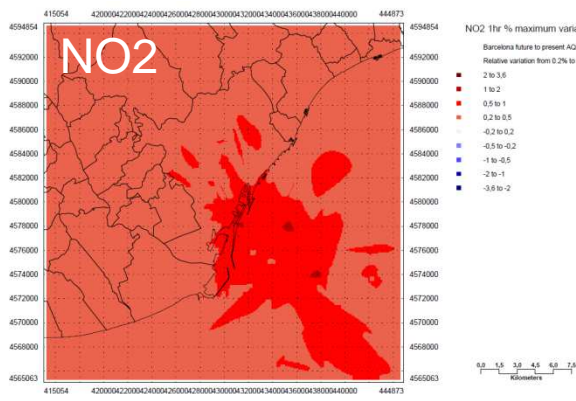
Max = 267µgr/m³, 133% of AQL



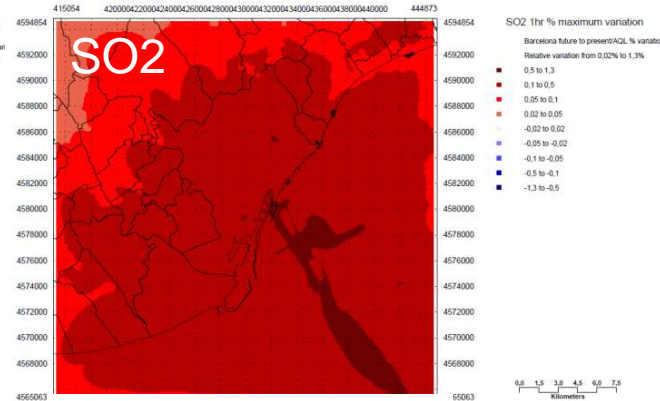
Max = 31µgr/m³, 9% of AQL

- Main impact of ship plumes over the port area related to hotelling emissions phase
- Significant contributions of ship manoeuvring phases

(Future – Present) Differences with respect to AQL



Max = +3.6% of AQL

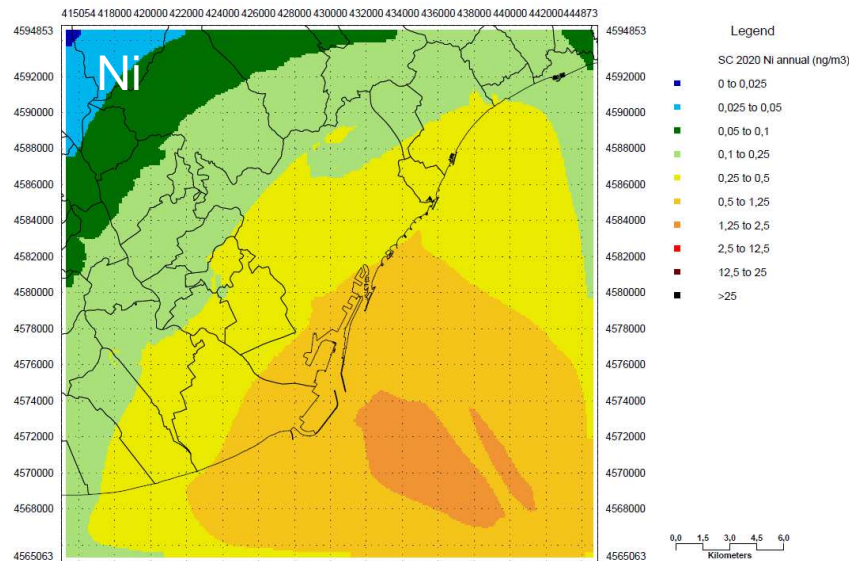


Max = +1.3% of AQL

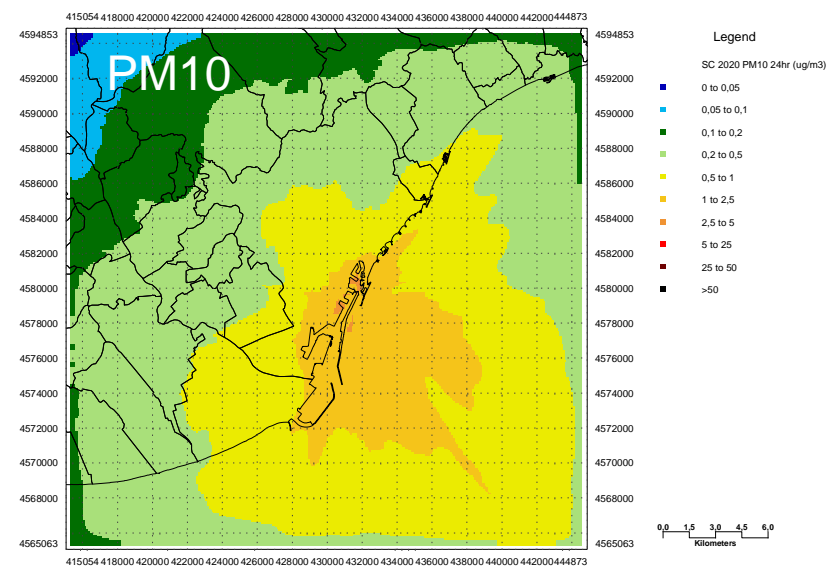
- Low increases of concentrations all over the domain
- The maximum increases are found over the track of ships approaching the port (both in cruise and maneuvering phases)



Future Time AQ Results for Barcelona: Ni and PM10



Max = 1.5 ng/m³, 7.7% of AQL



Max = 4.4 µg/m³, 8.9% of AQL

- Ni (tracer of ship activity) annual concentrations will exceed 5% of the AQL (20 ng/m³) all over the port area and in the cruise approach to the port.
- The most affected areas by future daily PM10 levels (exceeding 5% of the AQL) in the port are those related to the arrival and hotelling of Ro-Pax and cruises.

Configuration of Future Air Dispersion Modeling for Genoa

- **The harbour development plan by Genoa Port Authority now under discussion**
 - Assumed change in the number of ships on the basis of foreseen trends:
 - **+20% for cruise ships, +15% for ferries**
- Modeling Tool: **ADMS 4.0**
- Meteorological Model: **WRF-ARW + FLOWSTAR** (within ADMS code)
- Reference Year: **2020**
- **Ships in hotelling and maneuvering phase described as buoyant line sources** (respectively 30 m and 3200 m long, 5 m and 10 m large). Different heights assumed for cruises ships (60 m) and for ferries ships (30 m)

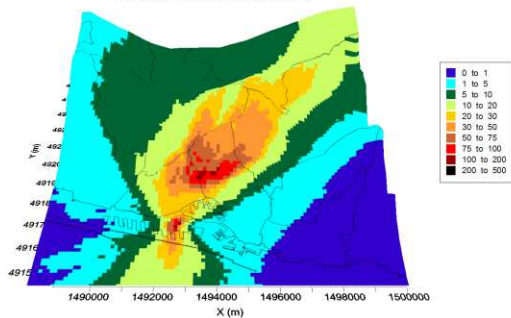


- Simulation domain for the Genoa area (violet box – 10km x 10km)
- The cyan box includes the touristic harbour

Future Time AQ Results for Genoa: NO2

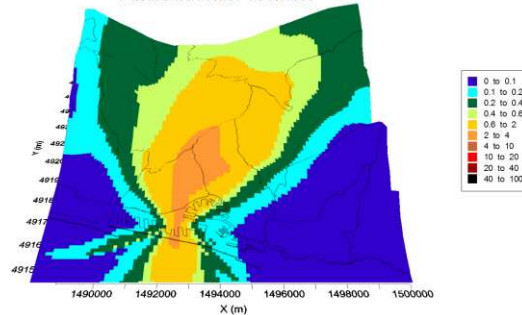
Concentrations

NO2 19° hourly maximum concentrations (ug/m3)
Future baseline scenario



Max = 310µgr/m³, 155% of AQL

NO2 annual mean concentrations (ug/m3)
Future baseline scenario



Max = 3.44µgr/m³, 8% of AQL

➤ Future increase of maritime ships traffic affects the already high values of NO₂ concentrations.

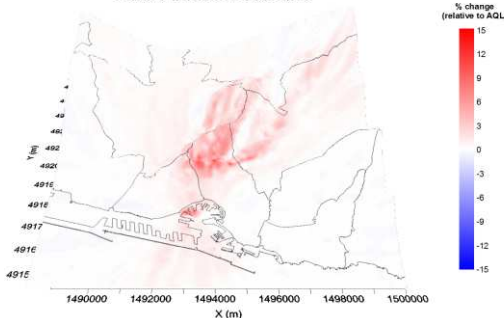
➤ Greater impact of the short term NO₂ values from ship plumes over:

✓ Harbour area (near the touristic traffic docks)

✓ Residential/hills area N-E side with respect to harbour area.

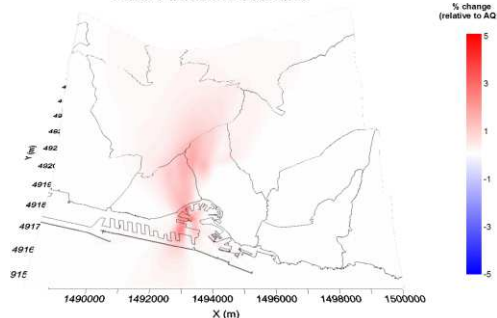
(Future – Present) Differences with respect to AQL

NO2 19° hourly maximum concentrations change
Future baseline scenario



Max increase = +14% of AQL

NO2 annual concentrations change
Future baseline scenario

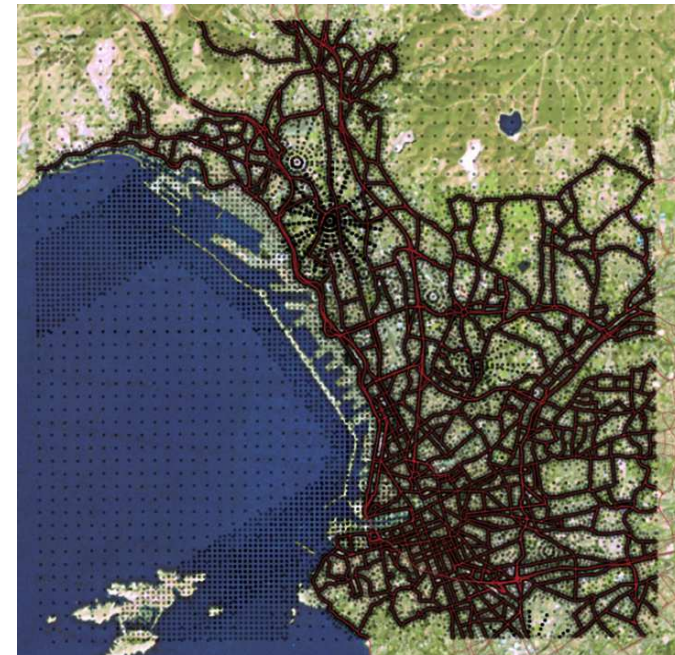


Max increase = +3% of AQL

➤ Future increases in percentile of hourly NO₂ timeseries more evident than NO₂ annual mean values increase.

Configuration of Future Air Dispersion Modeling for Marseille

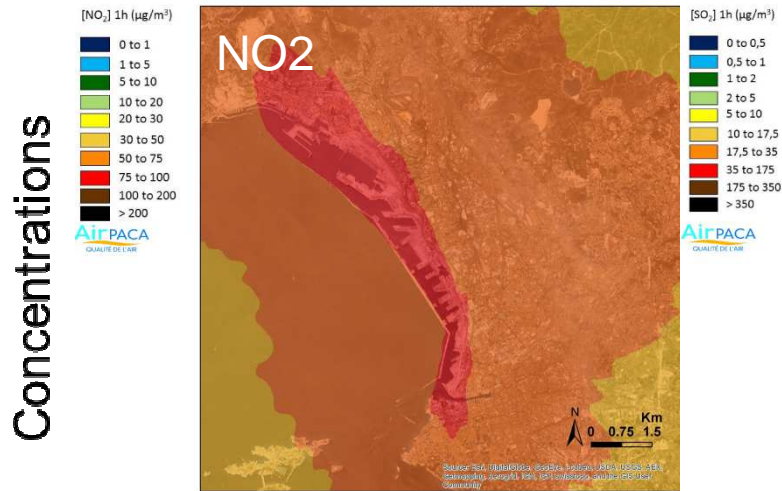
- **Increase in the number of passenger ships (ferry and cruise) is about 36%** resulting in an about 30% increase of pollutant emissions (only about 20% for NO₂).
- Modeling Tool: **ADMS Urban v3.1**
- Meteorology: **Hourly observation (METEO France)**
- Reference Year: **2025**
- **Ships simulated as volumetric sources** along the ship route and in the port (20 - 50m).



ADMS Urban simulation area and receptor points (grey dots).

Domain 12km x 12km.

Future Time AQ Results for Marseille: Short term NO2 and SO2



Max = 83µg/m³, 42% of AQL



Max = 90µg/m³, 26% of AQL

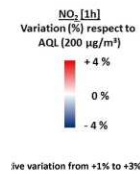
➤ Main impact of ship plumes over the port area related to hotelling emissions phase

➤ Significant contributions of ship plumes over the urban area

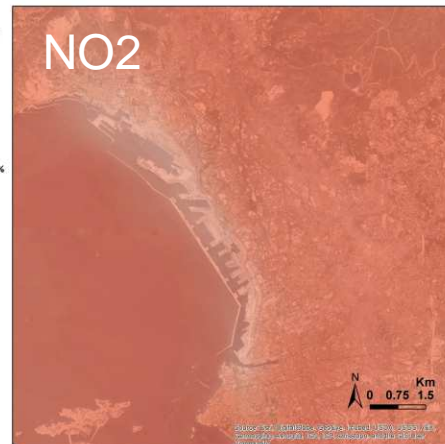
➤ Light increases of concentrations over the domain

➤ Lower NO₂ relative increases in the future over the port due to high initial values in the present time

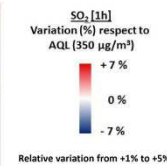
(Future – Present) Differences with respect to AQL



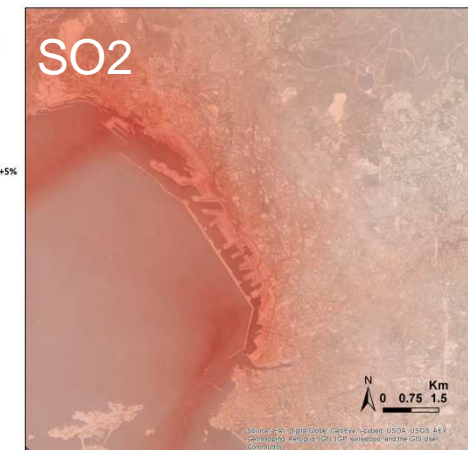
AirPACA
QUALITE DE L'AIR



Max = +3% of AQL



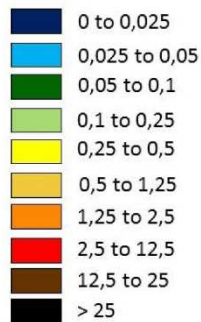
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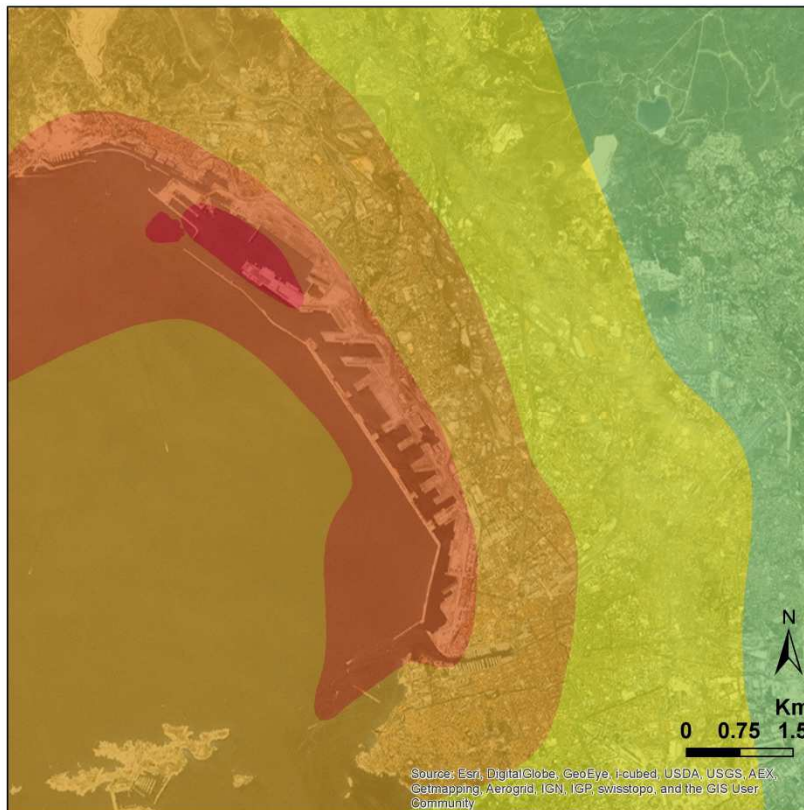
Max = +5% of AQL

Future Time AQ Results for Marseille: Ni

[Ni] annual (ng/m³)



AirPACA
QUALITE DE L'AIR



➤ Ni is a specific tracer for the maritime emissions (heavy fuel combustion)

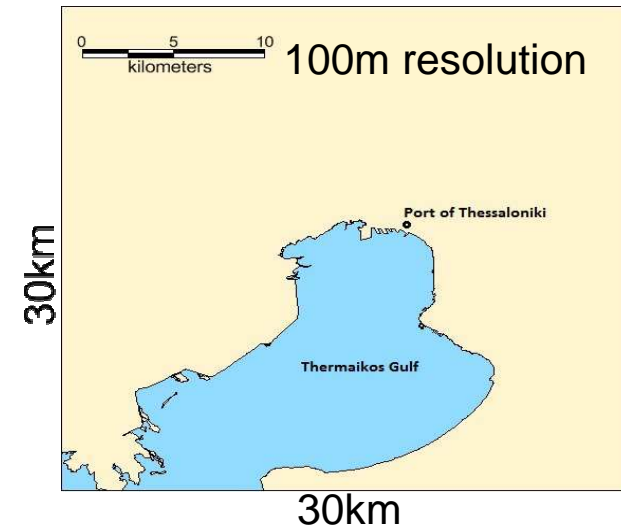
➤ Ni annual concentrations will exceed 5% of the AQL (20ng/m³) all over the port area

➤ Maximal Ni concentrations are forecasted over the cruise terminal (northern part of the port)

➤ Concentrations over the urban area will remain lower than 5% of the AQL

Configuration of Future Air Dispersion Modeling for Thessaloniki

- **Important increase in the number of ships (284% for cruise ships and 150% for other passenger ships) resulting in an about 200% increase of pollutant emissions (only SO₂ emissions are +15%).**
- Modeling Tool: **CALPUFF v6.4**
- Meteorological Model: **CALMET (driven by WRF)**
- Reference Year: **2025**
- **Ships simulated as discrete point sources along the ship route (accounting for the ship velocity). Instantaneous emission puffs every 1 minute. In the hotelling phase, emissions simulated as continuous releases from stationary point sources.**

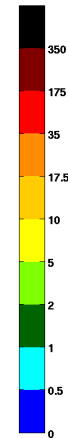
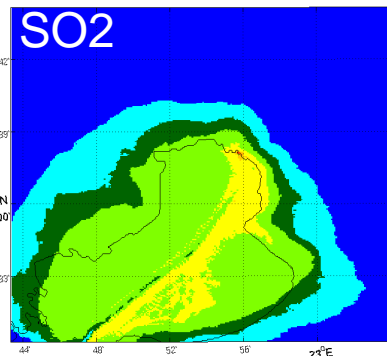
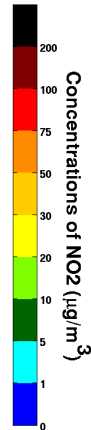
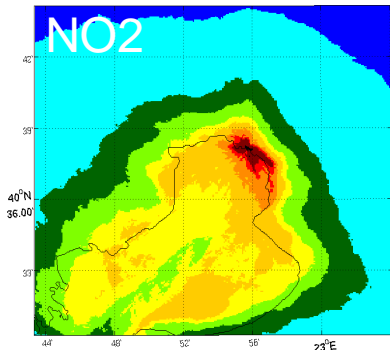


Future Time AQ Results for Thessaloniki: Short term NO2 and SO2

99.8 percentile of the hourly NO2 concentrations timeseries

99.7 percentile of the hourly SO2 concentrations timeseries

Concentrations



Max = 354µg/m³, 177% of AQL

Max = 38µg/m³, 11% of AQL

➤ Greater impact of the short-term NO2 values from ship plumes over:

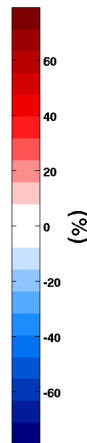
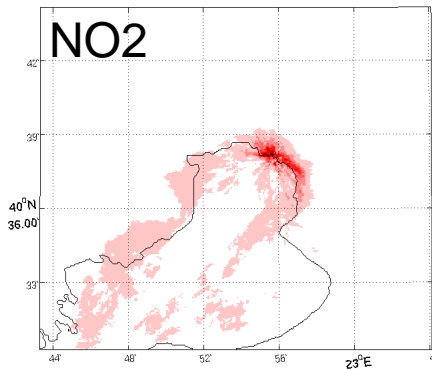
✓ Municipality of Thessaloniki and neighboring coastal municipalities

✓ Maritime areas of the modeling domain

➤ SO2 impact only over the Port.

Percentage differences relative to AQL for 99.8 percentile of the hourly NO2 concentrations timeseries between future and present scenarios

(Future – Present)
Differences
with respect to AQL



Max = +80% of AQL

➤ Important future increases in percentile of hourly NO2 timeseries over:

✓ Port area

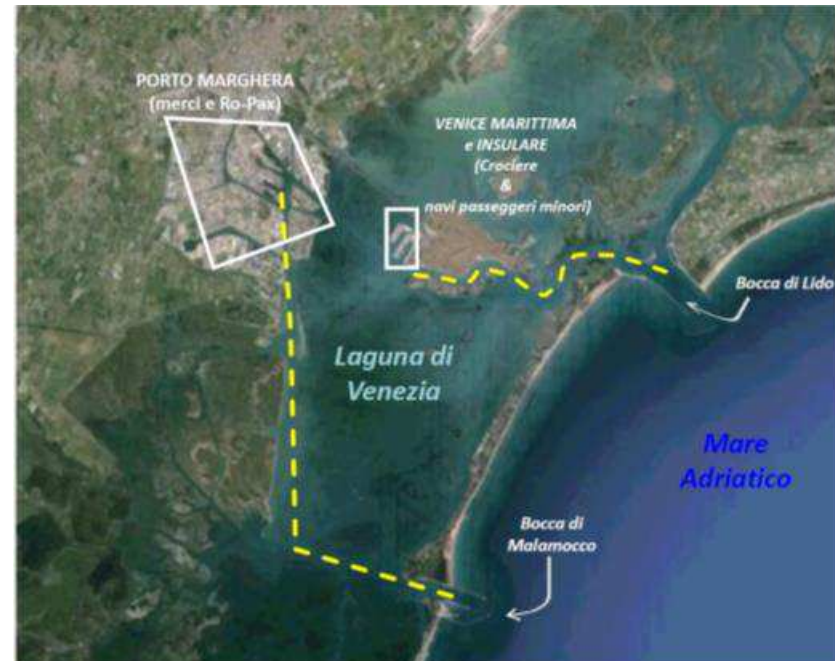
✓ City center and Eastern part of the city which is closer to the Port.

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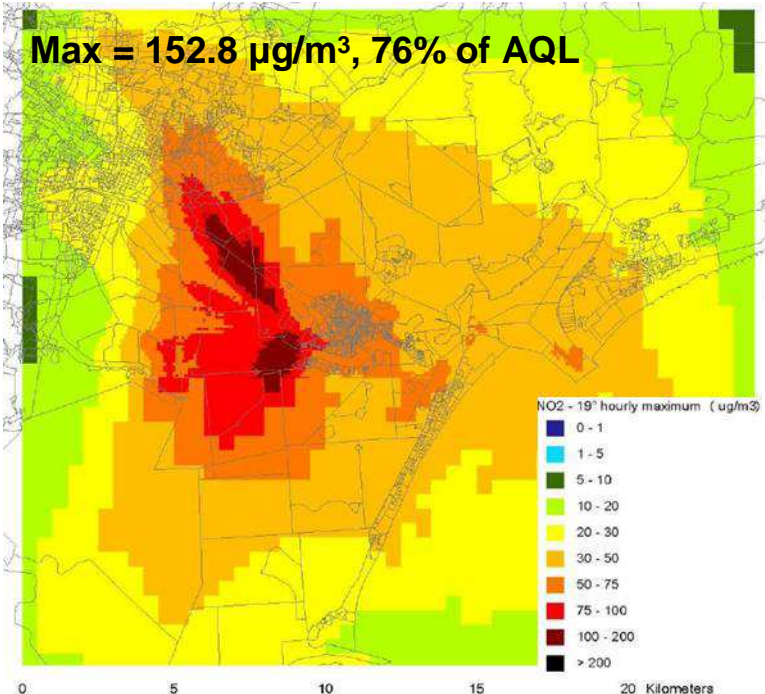
Configuration of Future Air Dispersion Modeling for Venice

- Reference Year: **2020**
- **No increase in the number of cruise ship calls**, but **no more implementation of the Blue Flag Agreement** (this means the usage of both MDO/MGO and BFO during the maneuvering phase)
- **New Ro-Pax terminal in Fusina** (Porto Marghera area) **with a increase of Ro-Pax calls from around 240 in 2013 to 500 in 2020; no more Ro-Pax docked in the Marittima terminal**
- Same model configuration and same meteorology of the present scenario: **CALPUFF v5.8, ships simulated as discrete point sources (continuous releases from stationary point sources).**

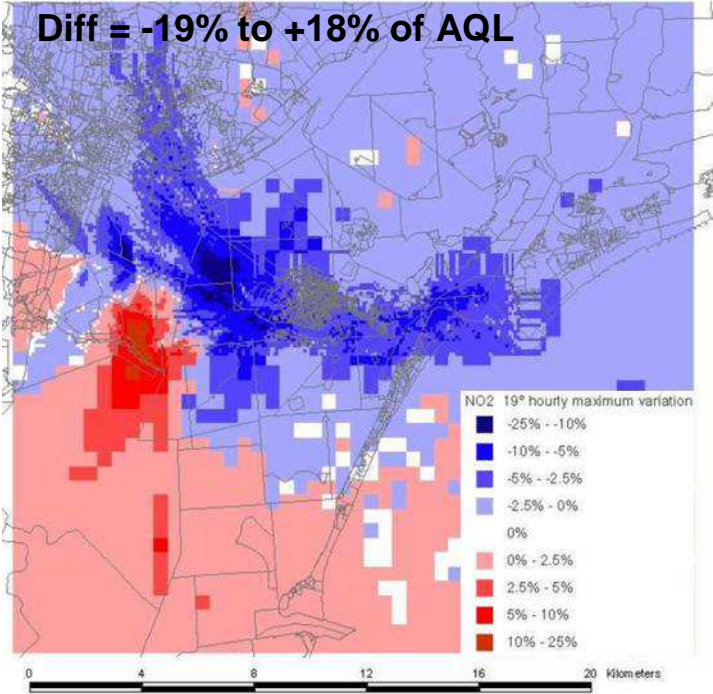


Future Time AQ Results for Venice: Short term NO₂

Concentrations



(Future – Present) Differences with respect to AQL



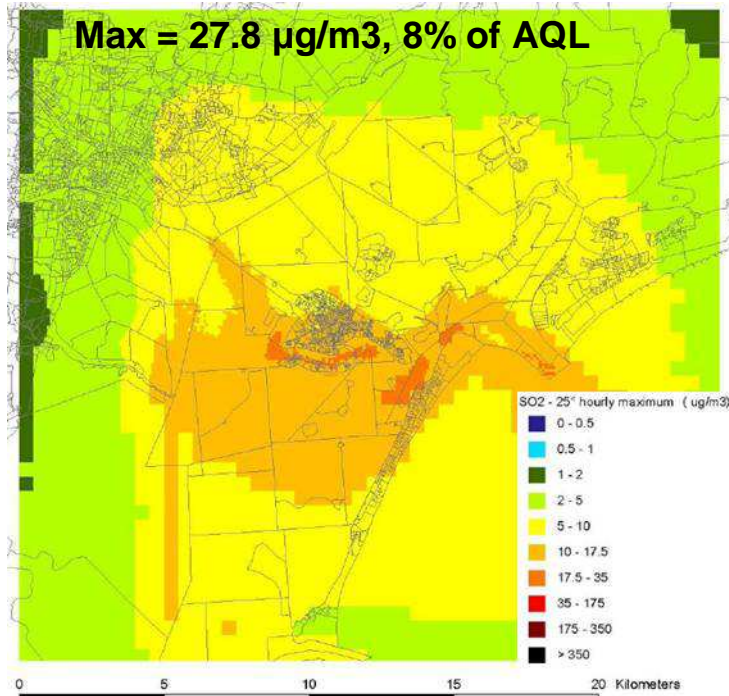
- Max concentrations related to cruise ships in hoteling phase.
- Domain wide max value decreases by 11% with respect to the 2013 scenario.
- Relative variation from -2% to -10% in the most populated area, due to:
 - the displacement of Ro-Pax from Marittima to Fusina terminal;
 - the fleet renewal foreseen by IMO legislation.

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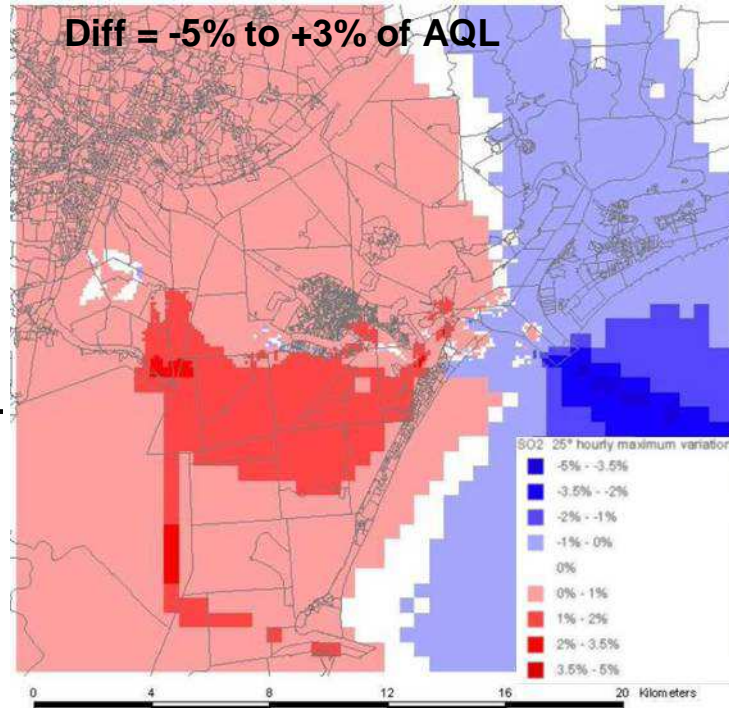


Future Time AQ Results for Venice: Short term SO₂

Concentrations



(Future – Present) Differences with respect to AQL

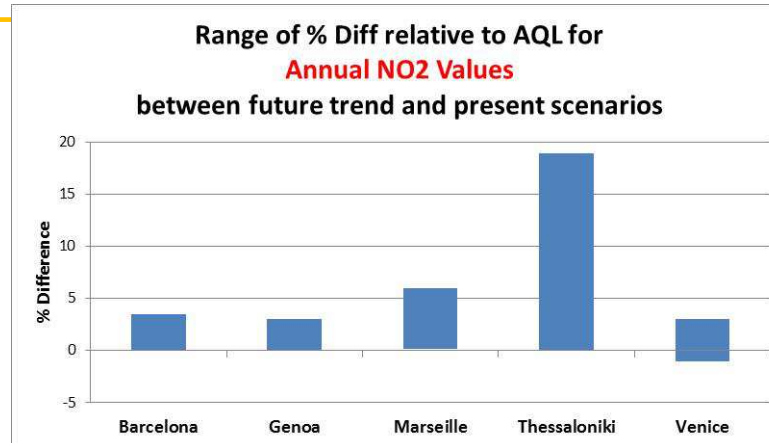
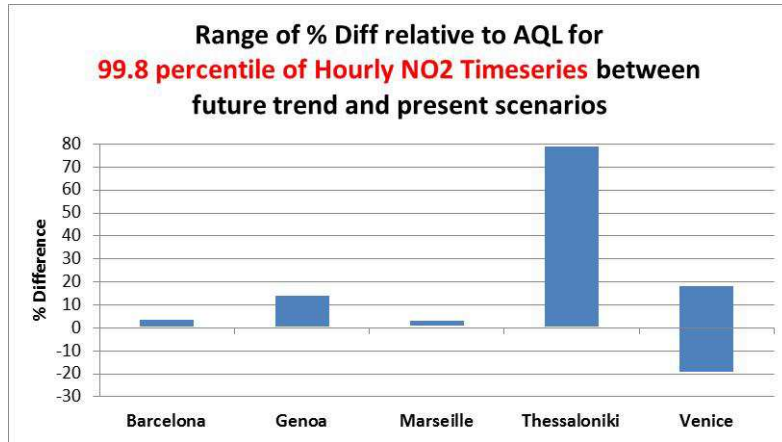


- Max concentrations related to cruise ships in manoeuvring phase.
- Domain wide max value increases by 24% with respect to the 2013 scenario.
- Slight relative increase from +1% to +2% in the most populated area with respect to the 2013, if the Blue Flag won't be confirmed in the future scenario.

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Range of Spatial Differences with Respect to AQL: Conclusions



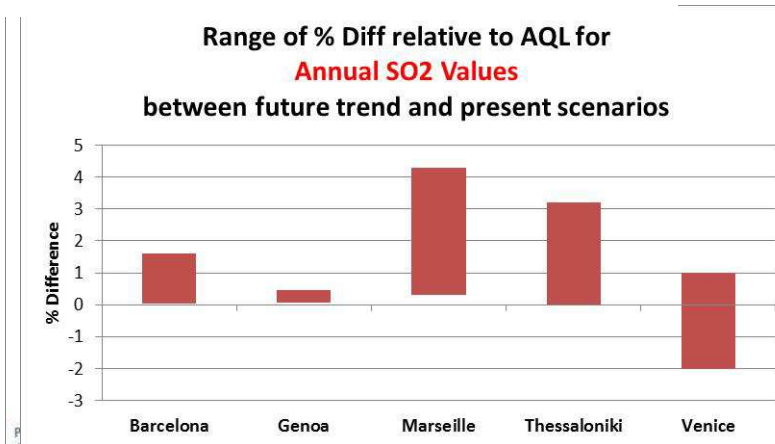
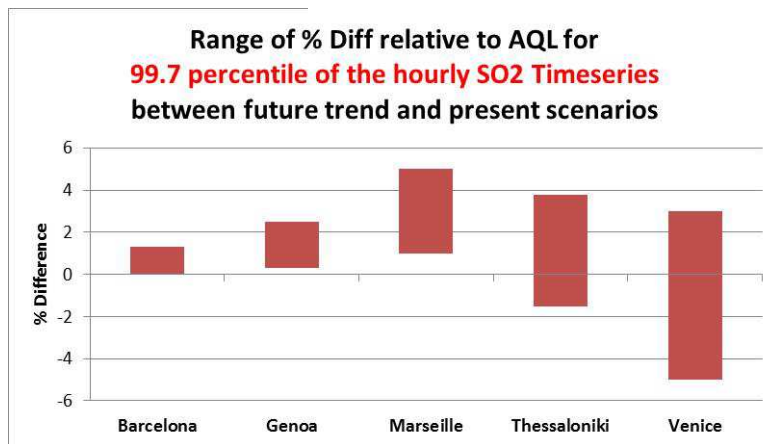
NO2



✓ Moderate increases and decreases in Venice for the short-term values

NO2 →

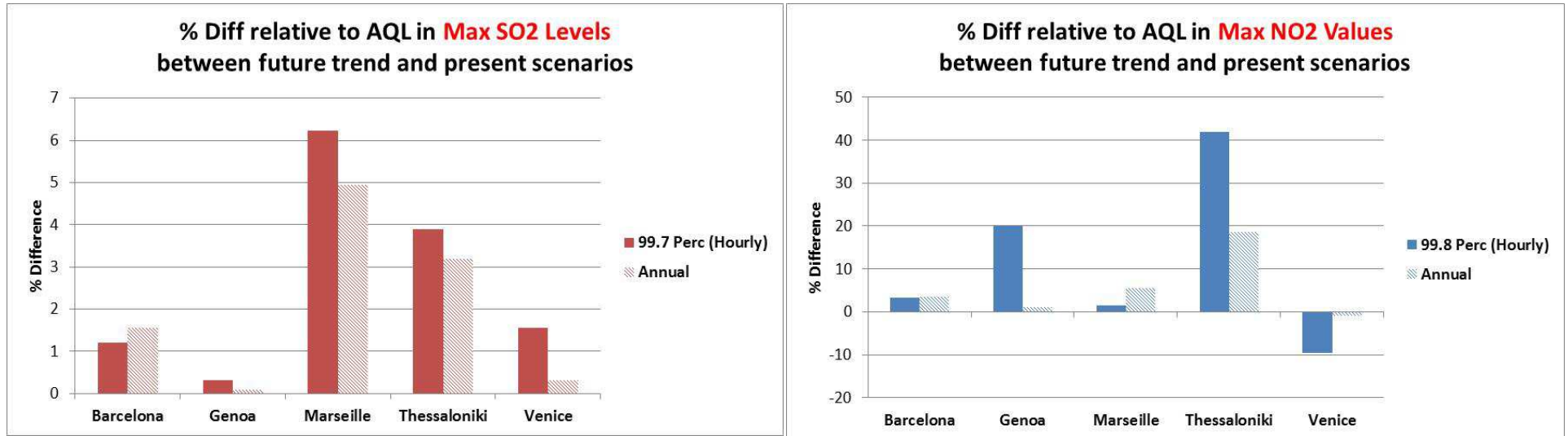
- ✓ High increases in Thessaloniki
- ✓ Moderate increases in Genoa for the short-term values
- ✓ Low increases in Barcelona and Marseille



SO2 →

- ✓ Low increases in all study areas (up to +5%)
- ✓ Low decreases in Venice and Thessaloniki (down to -5%)

% Differences in the NO2 and SO2 Domain Wide Maximum Values with Respect to AQL: Conclusions



- In the future, in most cases, the changes in short term NO2 and SO2 max values are more pronounced compared to those in annual values.
- Increases are identified in SO2 max levels being higher for Marseille (~5 - 6%) and Thessaloniki (~3 - 4%). For the other study areas the increases are less than 2%.
- Increases are identified in NO2 max levels being the highest for Thessaloniki. Only in Venice NO2 max levels are reduced in the future.
- In the study areas where only changes in future ship traffic are considered (i.e. all except for Venice), the increases in NO2 max values are higher than those for SO2 suggesting a more effective control of SO2 concentrations due to passenger ship traffic in the future.

CAIMANs: Cruise and passenger ship Air quality Impact Mitigation ActionNs

Thank you for Your Attention

Lead Partner: Environmental Protection Agency of Veneto Region ARPAV – Padoa (IT)
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Partners:

University of Genoa, Department of Physics (IT) www.labfisa.ge.infn.it
Aristotle University of Thessaloniki (GR) <http://lap.physics.auth.gr>
AIR PACA – Air quality observatory (FR) <http://airpaca.org/>
Spanish Research Council - Institute of Environmental Assessment
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