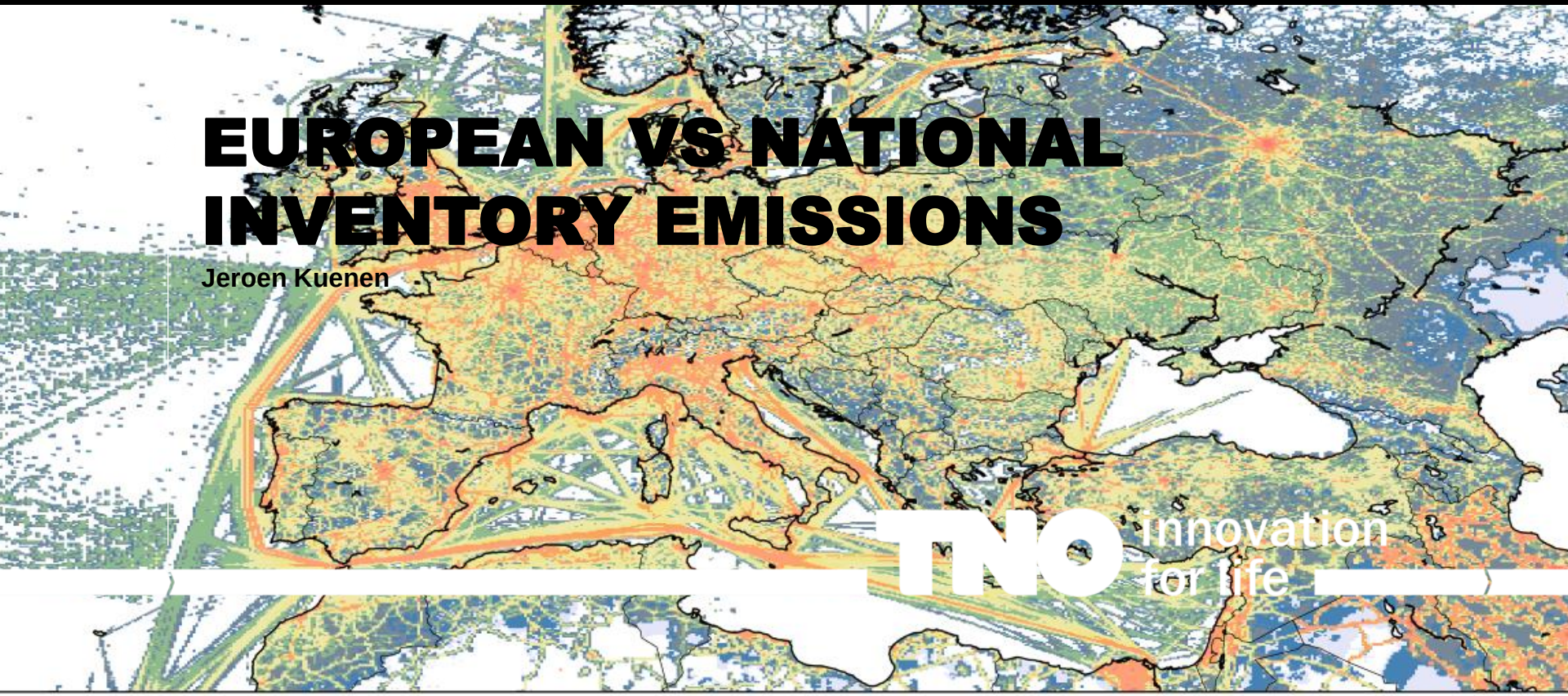


The TNO Emissions Team

Hugo Denier van der Gon
Antoon Visschedijk
Stijn Dellaert

OUTLINE

- Why European emission data?
- CAMS spatially explicit emission inventories
- A burning issue: residential wood combustion
- Validation of point sources using satellite data: an example for SO2

EUROPEAN WIDE EMISSION INVENTORIES

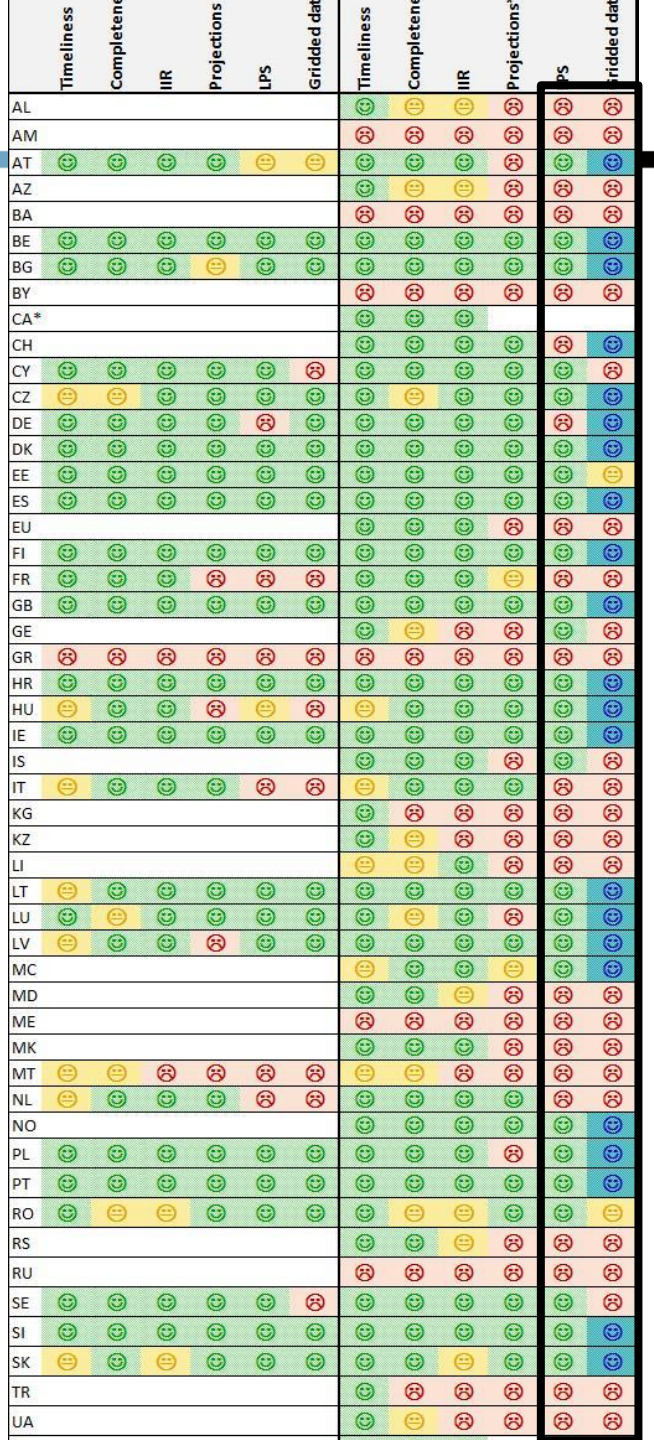
- Spatially distributed emission inventories are a crucial piece of input for air quality modelling and therefore the assessment of the impact of air pollution and the effectiveness of air quality improvement measures in Europe

- Ideally these are just created by combining the various country inventories
  - Gridded data are reported every 4 years under CLRTAP and NECD

RATIONALE

- However, reporting of gridded & LPS data by countries is not complete and not consistent
  - In 2017 first reporting of gridded data at 0.1°x0.1° under EMEP but still half the countries did not submit at all (for LPS data something similar)
  - CEIP does a great job in gapfilling gridded inventories but they only have very little time to do this which does not help the quality

- This – combined with other comparability/consistency issues between different inventories – makes the European-wide consistent inventory still needed to support the users



Smiley table (CEIP)

CAMS

- Copernicus Atmospheric Monitoring Service (CAMS)
  - Builds on work being done in MACC, -II and –III projects (FP7, H2020)
  - Operational services for atmosphere by combining (satellite) measurements and modelling tools, including air quality forecasts and assessment of air pollution episodes

- Model assessment rely on complete & consistent emissions information
  - TNO developed TNO_MACC inventories (presented in the years before)
  - Explicit project under CAMS umbrella to prepare new annual gridded emission maps for 2000 – present day for Europe
  - Also includes emissions for global domain & natural sources and more (temporal profiles, PM/VOC splits, etc.)

CAMS HIGH RESOLUTION EUROPEAN EMISSIONS DATA FOR AIR POLLUTANTS & GHG

History

1. TNO-MACC-I 2003-2007 (No CO_2)
2. TNO-MACC-II (2003-2009)
3. TNO-MACC-III (2000-2011) + CO_2
4. *No update since end of MACC-III, a problem for many users because 2011 is no longer a recent year!*

Policy (related) use

1. Input for MACC/CAMS AQ forecasts over Europe + reanalysis
2. Input for national AQ forecasts and research –often use national emission data but need the outside domain; list of users very long!
3. Benchmark for other initiatives

CAMS-81 start Sept 2017: priority is providing the most recent year asap

Deliverables (Short-term)	Available
D81.1.1.1 Regional emissions for 2015 (SNAP)	March 2018
D81.1.1.2 European emissions time series 2000-2015 (GNFR)	Sept 2018
D81.1.1.1 Regional emissions for 2016 (GNFR)	Early 2019

METHODOLOGY IN A NUTSHELL

Official reported emissions (CEIP/UNFCCC)

GAINS & EDGAR emission datasets

TNO internal estimates

- Small combustion
- Inland shipping
- Agricultural waste burning
- Etc.

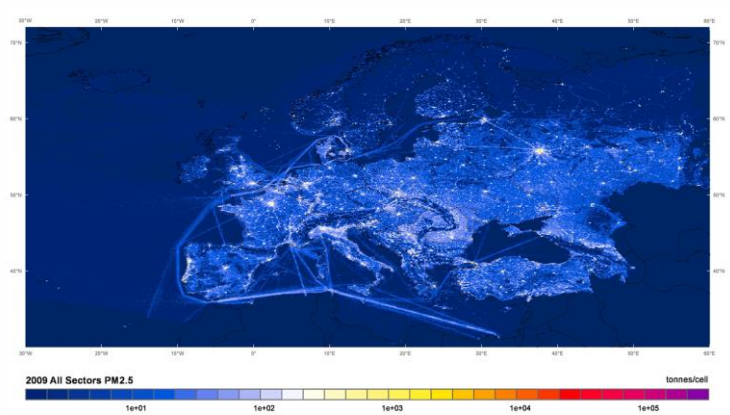
~ 80 subsectors: aggregated NFR with fuel splits

CAMS 81 emissions by subsector

Shipping grids *(FMI)*

Spatial proxies

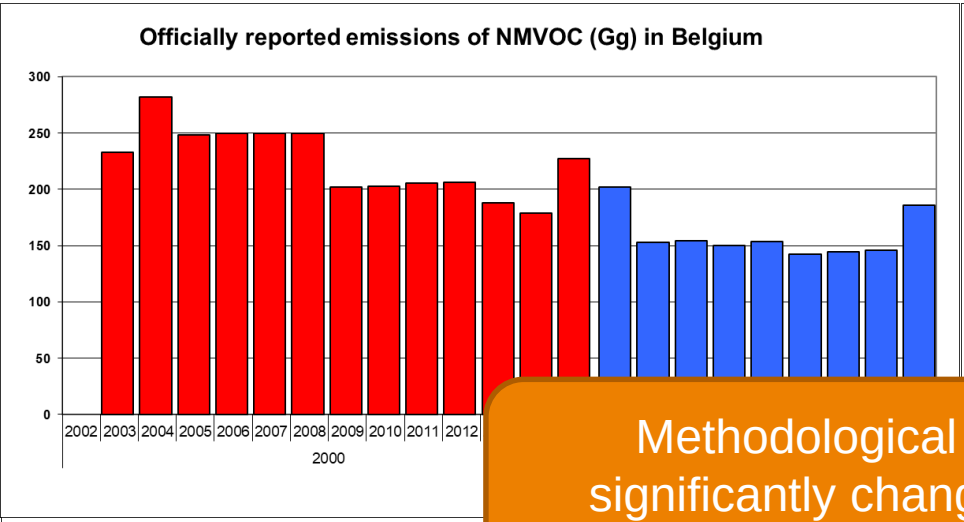
- Population
- Road transport
- Animal densities
- E-PRTR, etc. etc.

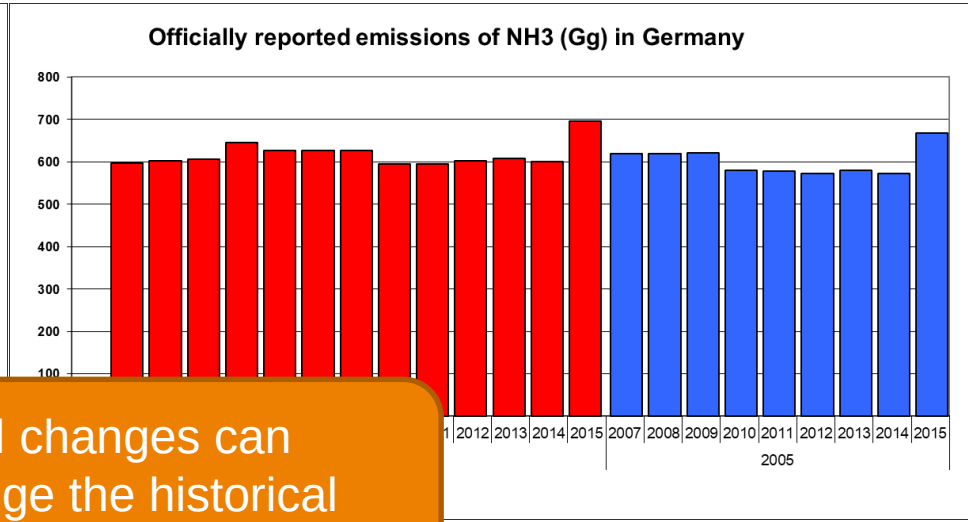


CAMS 81 regional emission product

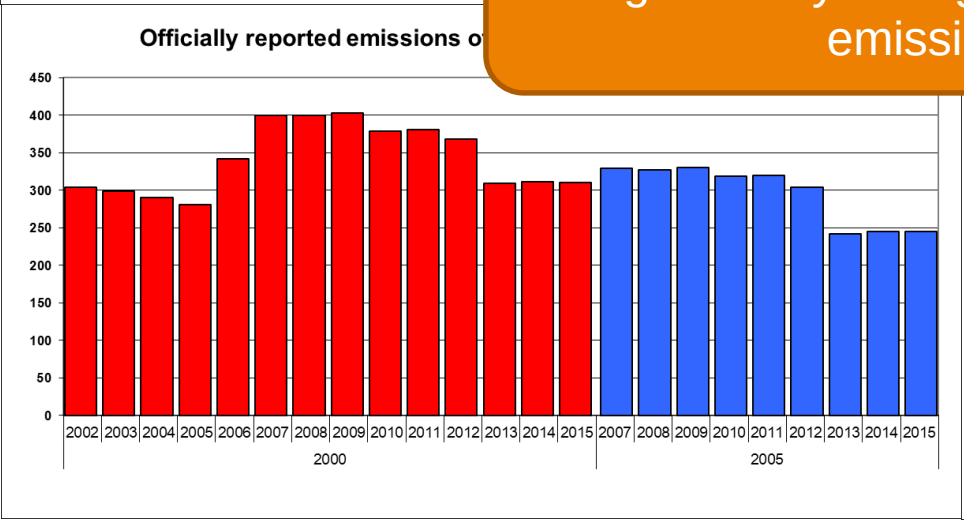
Pollutants/Gases:
NOx, SO2, NH3,
NMVOC, CO
PM10, PM2.5
GHGs: CH4, CO2

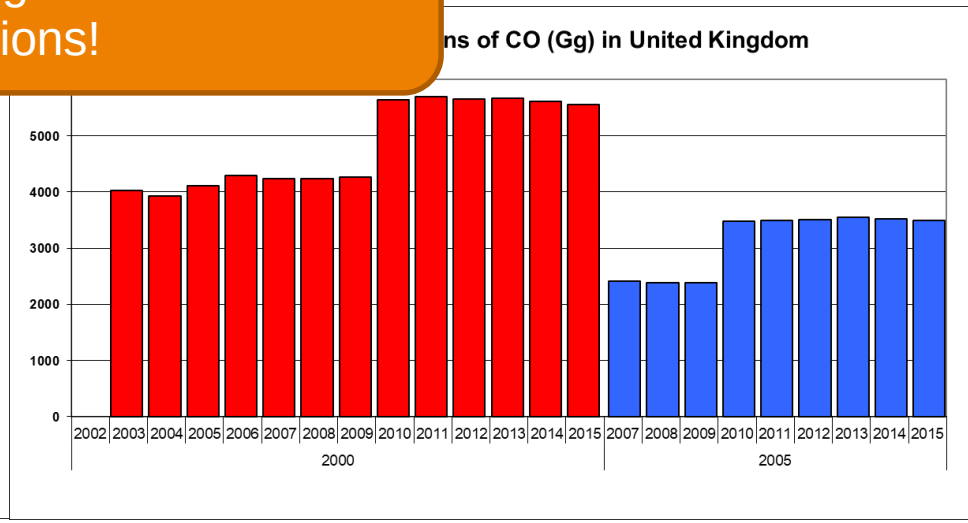
WHY REVISITING ALL YEARS?





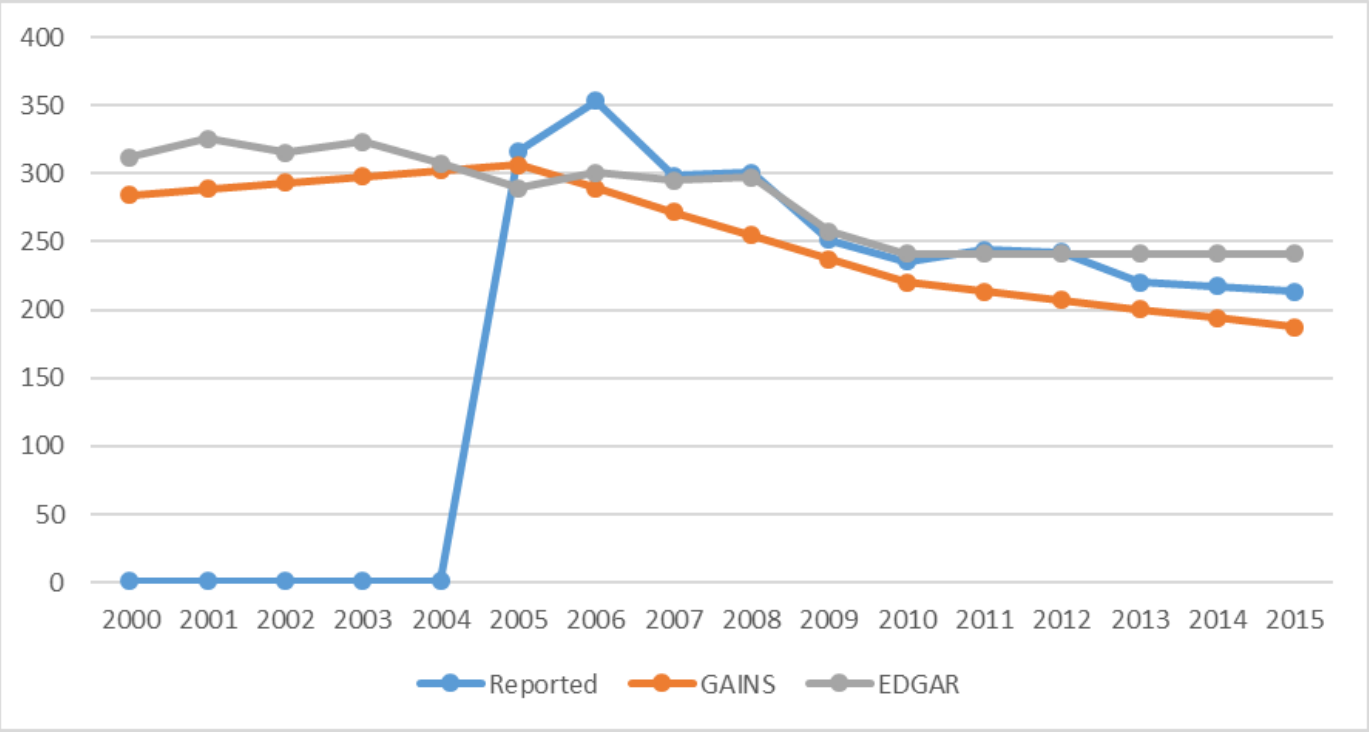
Methodological changes can significantly change the historical emissions!





CHECKING REPORTED DATA

- Compare with other emission estimates (GAINS, EDGAR)
- Look at time series consistency and gapfill missing years where needed



IMPROVED METHODOLOGIES FOR SPATIAL DISTRIBUTION

- More detailed point source representation
  - Use latest E-PRTR for major point sources to the extent possible
  - Use EEA combined E-PRTR – LCPD dataset for power plants and CARMA database for “other” countries
- Improved estimates & map for international shipping
- Updated road transport distributions based on open street map
- Agriculture: include spatial variation of manure spreading

- These are just a few topics currently being worked on – feeding into the CAMS emission inventories when ready

DATA USED FOR PUBLIC POWER AND HEAT SECTOR, EU

LCP
Plant name
Location
Plant type
Emission of NOx, SOx and dust
Fuel use by fuel type
→Estimated CO2 emissions
Years: 2004 – 2015

Gapfilling from LCP dataset:
- Fuel type
- Emissions of NOx, SOx, dust and CO2 when missing in EPRTR dataset
- Plants when missing in EPRTR dataset

E-PRTR
Facility name
Location
Sector
Emissions of CO2, NOx, SO2 and PM10
Years: 2001, 2004, 2007–2015

Creating final product

Platts WEPP
Plant name
Location
Unit type
Fuel type
Electric capacity
Sector (e.g. utility, autoproducer in paper prod.)
Year start of operation
Year retired (if applicable)

Gapfilling from Platts WEPP dataset:
- Fuel type when missing in LCP dataset (e.g. waste plants)
- Crosscheck to see if all large electricity plants have been included
- Crosscheck with sector to see if facility is part of Public power and heat sector

TNO power plant DB
Facility name
Location (coordinate + country)
Fuel type
Pollutant
Share of plant in country emissions by fuel type

EXAMPLE POINT SOURCES "ENERGY"

Aim: Creating dataset of all plants/facilities in sector 1A1a Public power and heat production including emissions, fuel type and coordinates, for years 2000 – 2015.
Datasets available: E-PRTR; LCP; Platts WEPP; CARMA

Substantial changes occur over 2000-2015 (closure, end-of-pipe measures, fuel changes, …) by making an year-specific product we capture real-world dynamics

E-PRTR CO2 emissions missing while facility was still active

Emissions of PM10 and SOx likely below threshold value?

Labor intensive but crucial:
the table provides an impression for one facility (don't look at the details ;-)

TNO_ID	Unit	Pollutant	2001	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
TNO_0041	kg	CO2	551,000,000	672,000,000			417,000,000		780,000,000	818,000,000	653,000,000	762,000,000	738,000,000	968,000,000	888,000,000
TNO_0041	kg	NOX	1,870,000	2,230,000			1,130,000	672,000	626,000	312,000	289,000	401,000	295,000	449,000	402,000
TNO_0041	kg	PM10	136,000	51,500											
TNO_0041	kg	SOX	2,020,000	2,230,000			1,340,000	841,000	457,000						

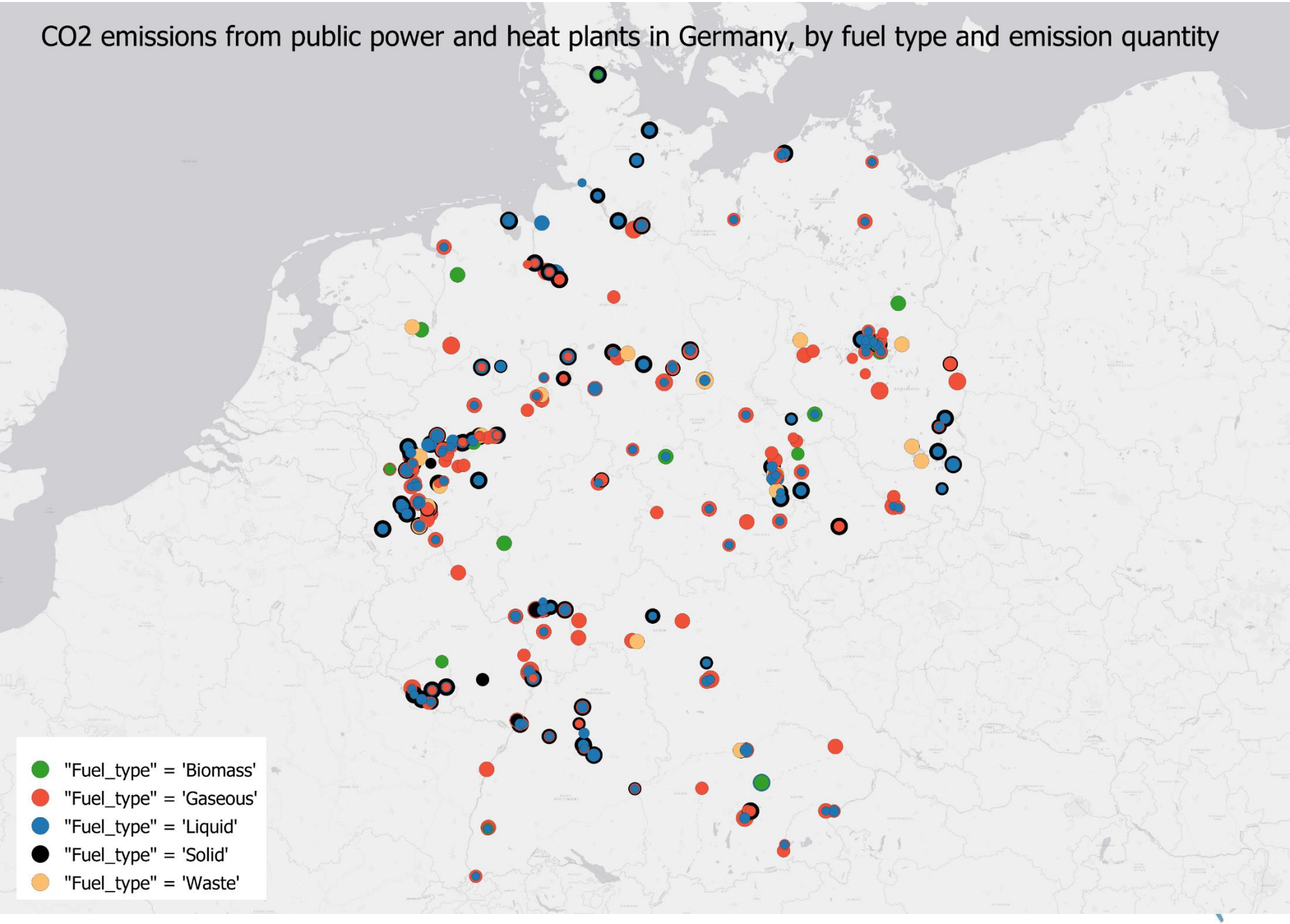
TNO_ID	Unit	Pollutant	2001	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
TNO_0041	kg	CO2	551,000,000	672,000,000	616,228,442	592,208,455	417,000,000	361,225,059	780,000,000	818,000,000	653,000,000	762,000,000	738,000,000	968,000,000	888,000,000
TNO_0041	kg	NOX	1,870,000	2,230,000	1,897,200	1,633,680	1,130,000	672,000	626,000	312,000	289,000	401,000	295,000	449,000	402,000
TNO_0041	kg	PM10	136,000	51,500	25,100	95,140	34,960	36,300	13,000	70	60	70	2,600	3,428	12,036
TNO_0041	kg	SOX	2,020,000	2,230,000	1,960,500	1,929,580	1,340,000	841,000	457,000	-	-	-	3,700	43,000	33,543

From LCP- PM & SOx look strange..

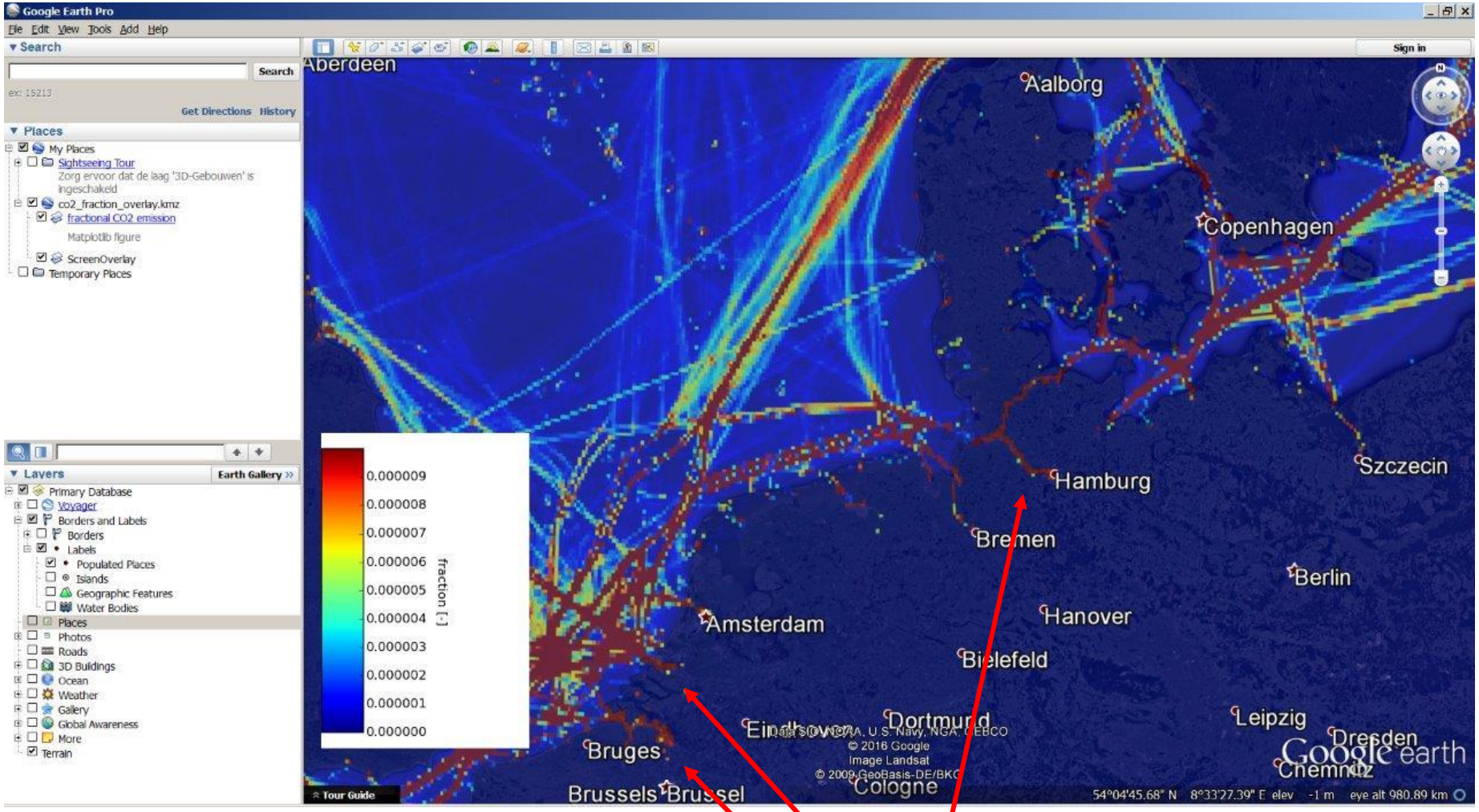
After gapfilling using LCP
But this is only possible for CO2, NOx, PM10 (dust) and SOx (SO2)

Same facility: Amercoeur #2 in 2009 closed # 3 in 2009 started

CO2 emissions from public power and heat plants in Germany, by fuel type and emission quantity

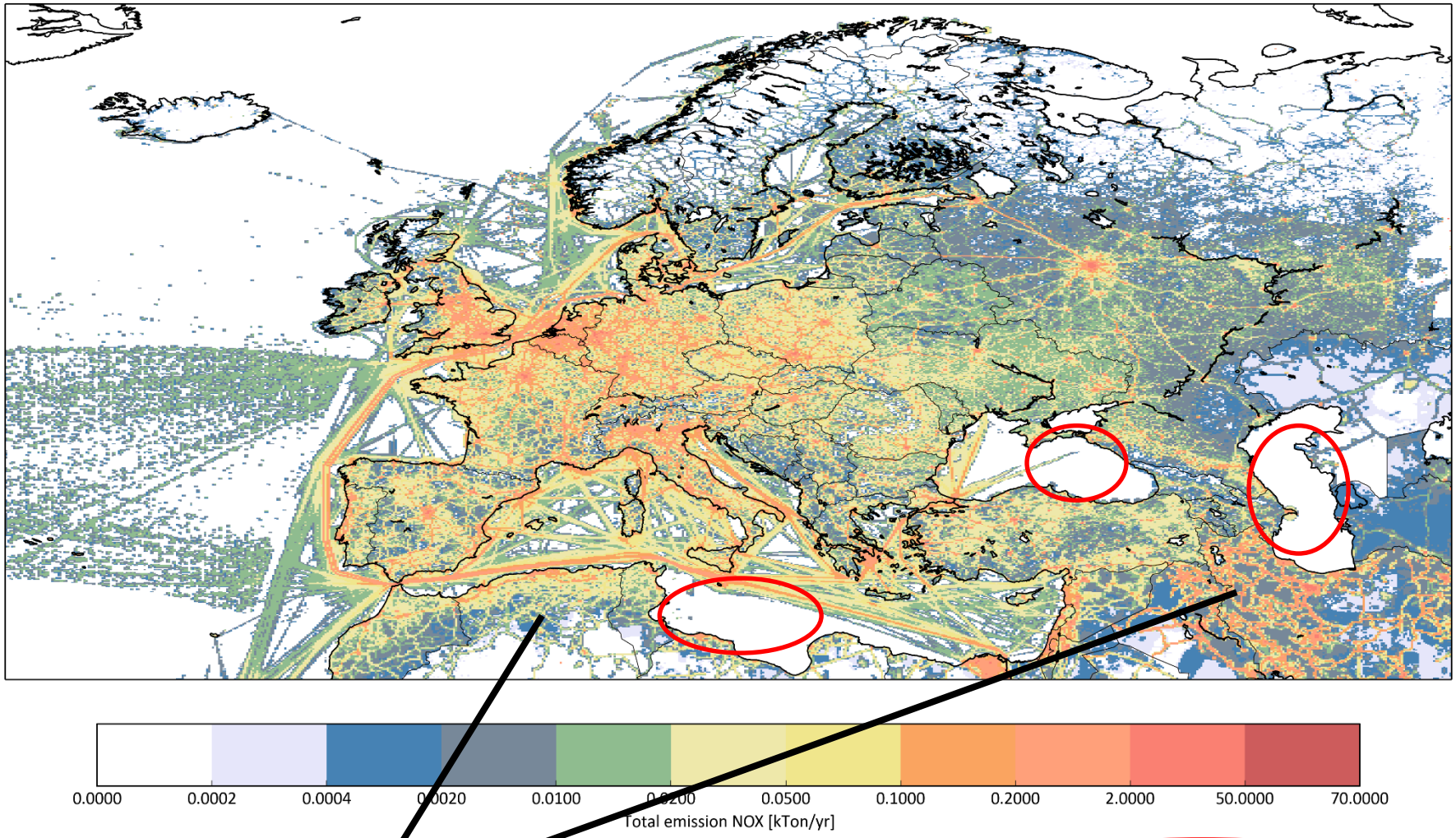


A MUCH FINER RESOLUTION INTERNATIONAL SHIPPING GRID INCLUDING MONTHLY EMISSION PROFILES

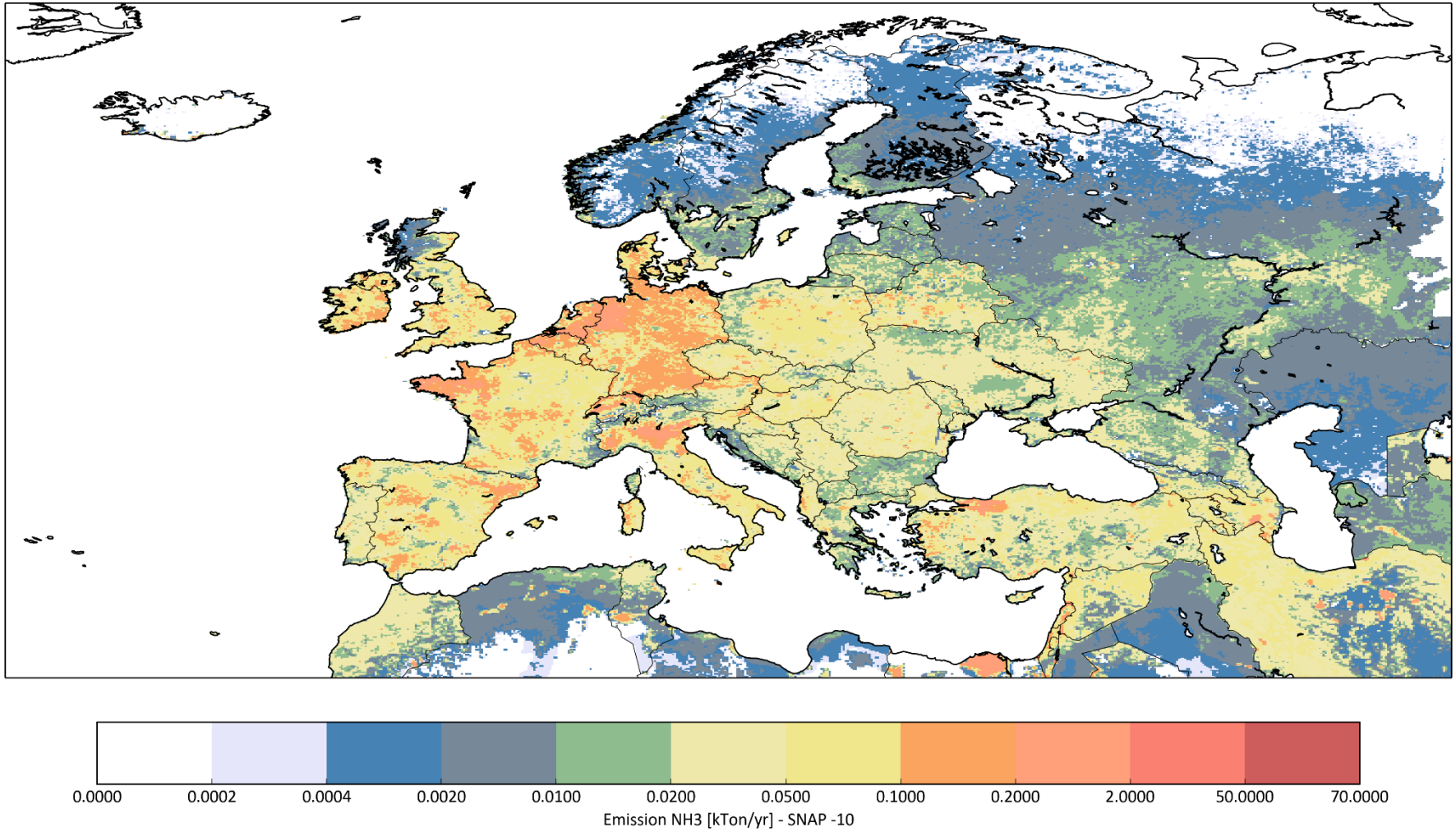


Note the detailed penetration of the track towards the ports

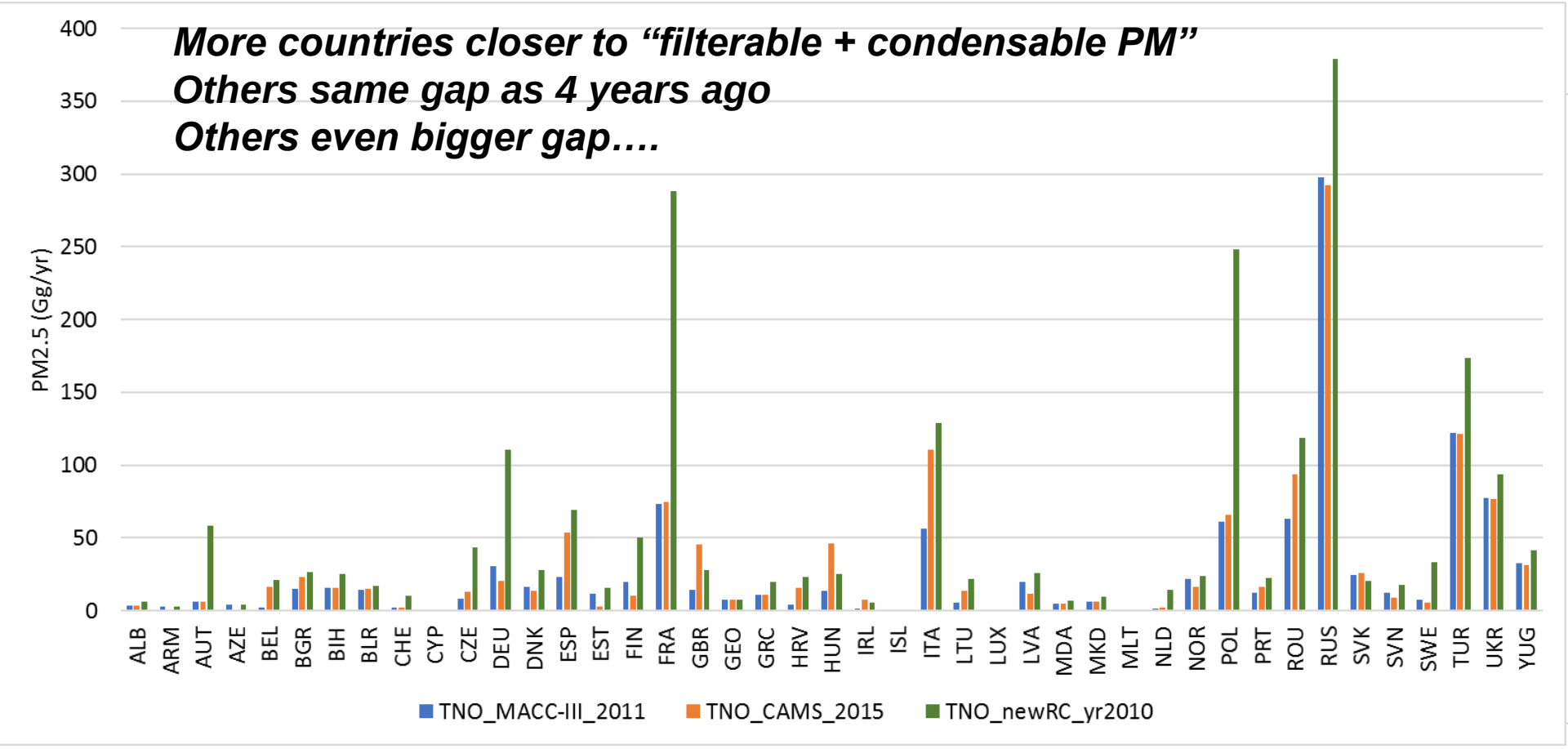
RESULTING EMISSION GRID (NOX)



NH3 FROM AGRICULTURE
(DISTRIBUTION STILL TO BE UPDATED)

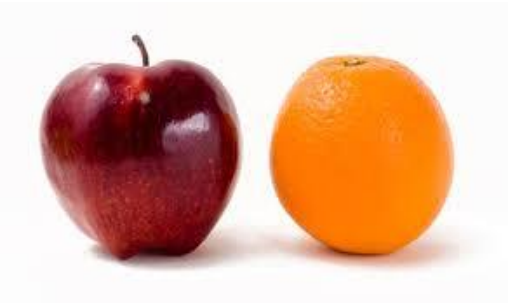


A PERSISTENT ISSUE… RESIDENTIAL COMBUSTION (WOOD & COAL)



- *TNO_newRC is update based on Denier van der Gon et al. (ACP, 2015), base year = 2010; a consistent estimate of PM2.5 from small combustion including condensable fraction*

EMISSION INVENTORIES AND SATELLITE DATA



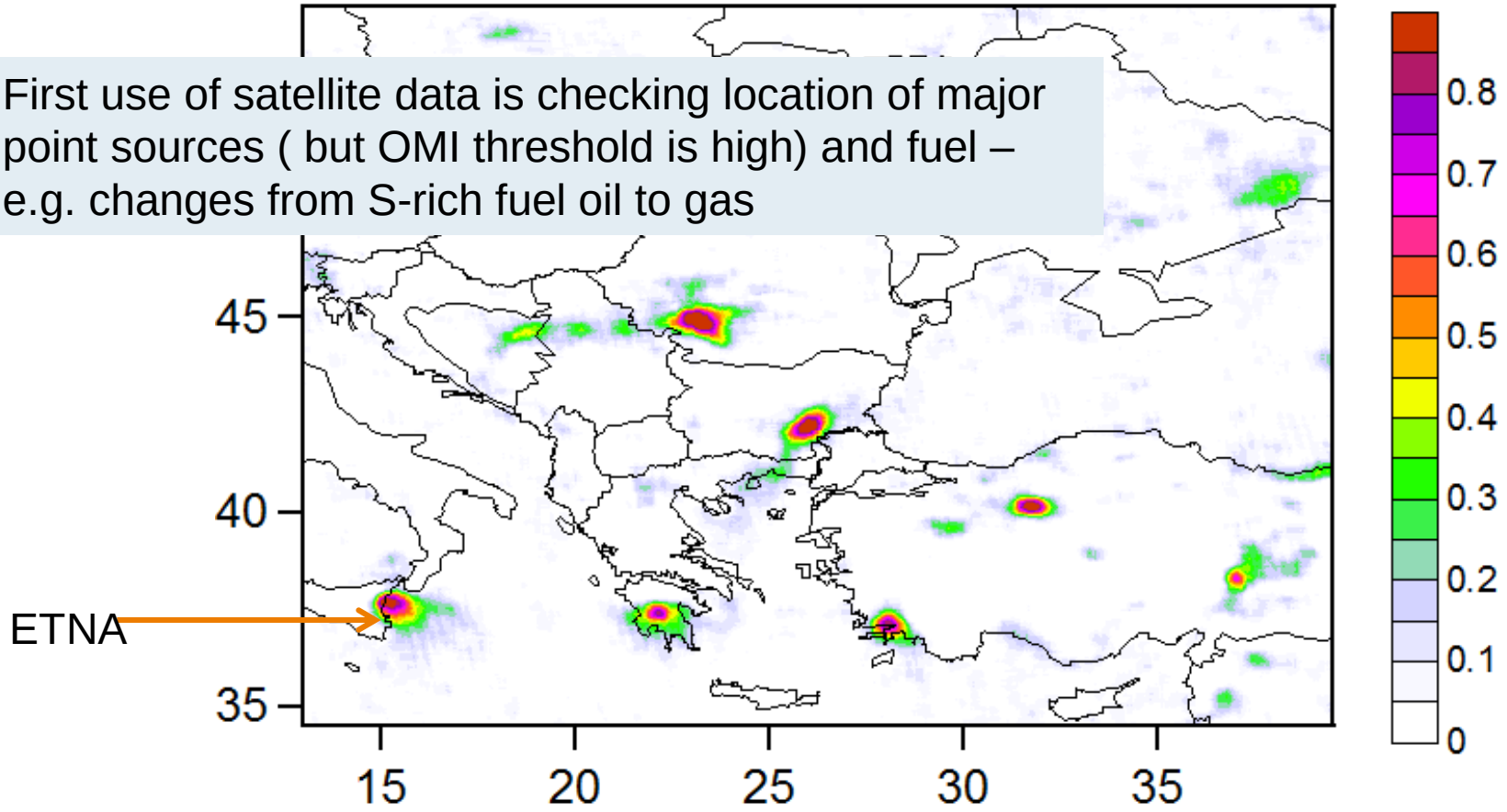
or….

- Emission Inventory = individual source (sector based) ; annual total emission; pollutants correlated and proportional (same origin)
- Satellite = column, no split in sources; no complete coverage (clouds); single species BUT… measurement-based and independent

- Satellite derived emission for European locations is (almost) never 1:1 comparable with a single source in the EI – exception (very) large point sources
- Trends should be somehow comparable?
  - Yes, but not straightforward (meteo variation, annual patterns…)

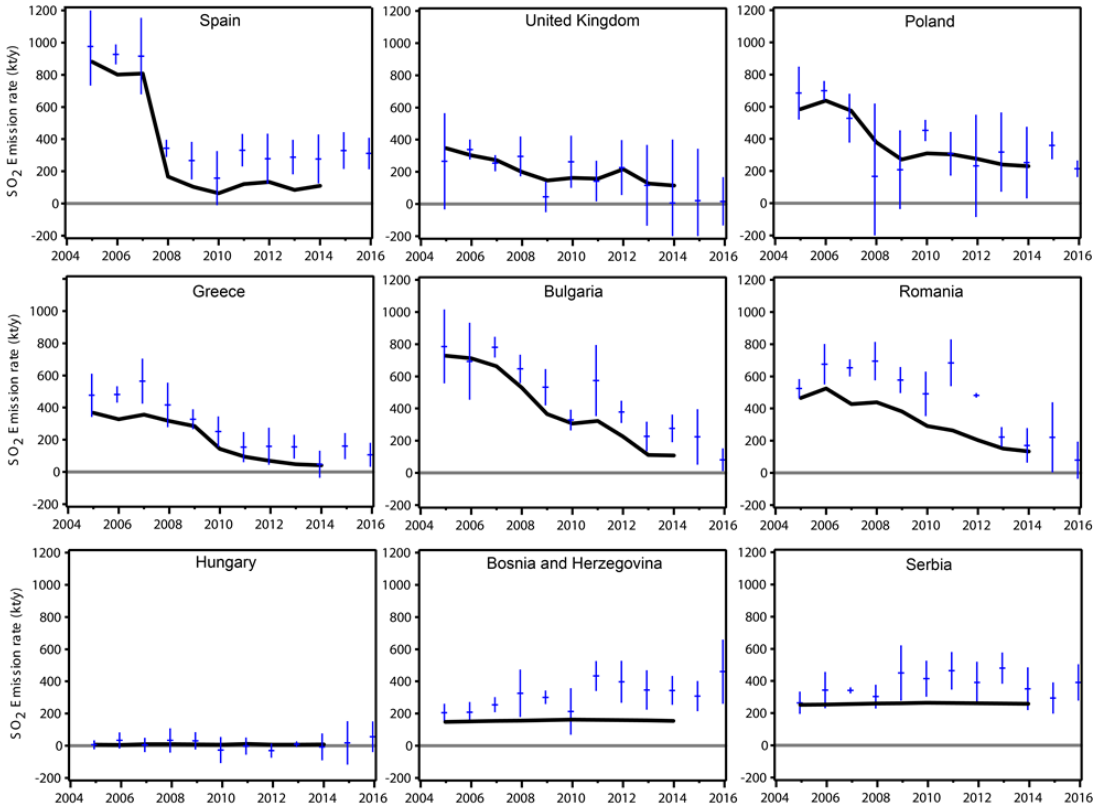
EXAMPLE OF PROCESSED OMI OBSERVATION OF SOUTH-EUROPE SO2 EMISSIONS FOR 2005 – 2010

First use of satellite data is checking location of major point sources (but OMI threshold is high) and fuel – e.g. changes from S-rich fuel oil to gas



Source: Fioletov et al., Atmos. Chem. Phys., 17, 12597-12616, https://doi.org/10.5194/acp-17-12597-2017 , 2017.

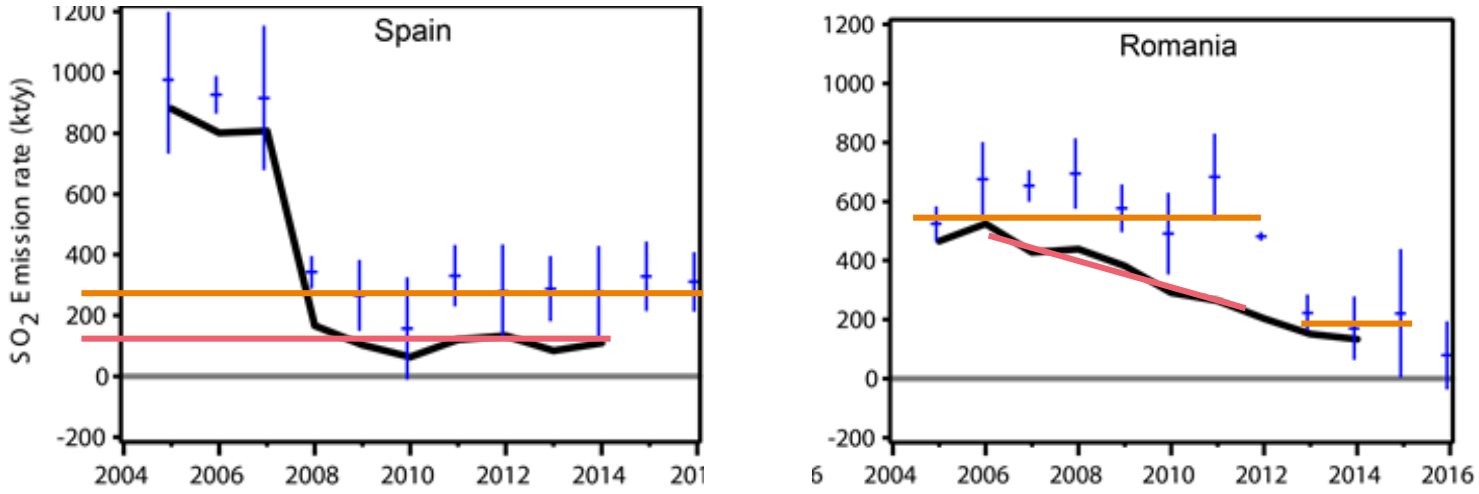
OMI-BASED (BLUE BARS) AND REPORTED/ESTIMATED (BLACK LINES) SO2 EMISSIONS FOR DIFFERENT EUROPEAN COUNTRIES.



Source: Fioletov et al., Atmos. Chem. Phys., 17, 12597-12616, https://doi.org/10.5194/acp-17-12597-2017 , 2017.

- E-PRTR reported emissions were used for all countries except Serbia and Bosnia and Herzegovina, where TNO-MACC estimates were used. The error bars represent 2 standard errors of the annual mean calculated by averaging three seasonal (spring, summer, autumn) OMI-based emission estimates.

OMI-BASED (BLUE BARS) AND REPORTED/ESTIMATED (BLACK LINES) SO2 EMISSIONS FOR DIFFERENT EUROPEAN COUNTRIES.



- Spain: Trend confirmed but the discrepancy is still 100 kt/yr – Important but errors/uncertainties possible on both sides…
- Romania: Emission reduction in the reporting started ~5 years before the satellite sees it..
- Relevant to investigate and correct for improved emissions (and Tropomi threshold will be lower) but nobody's task
- E-PRTR reported emissions were used for all countries except Serbia and Bosnia and Herzegovina, where TNO-MACC estimates were used. The error bars represent 2 standard errors of the annual mean calculated by averaging three seasonal (spring, summer, autumn) OMI-based emission estimates.

CONCLUSIONS

- Verification of emissions data is important to further increase the “accuracy” of our inventories
  - Different methodologies for different countries are fine, but they should result in “consistent” emission estimates
  - Residential wood combustion is a key sector where these consistency issues currently exist => **improving this is crucial**
- Copernicus Atmospheric Monitoring Service brings updated & improved emission maps for Europe (& the world) for recent years for uptake by CAMS modelling community and beyond
  - CAMS emissions work should support TFEIP, and vice versa
- Satellite observations are becoming temporally & spatially better and are already able to distinguish emissions from point sources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