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Using satellite data to constrain CAMS emissions

SEEDS final general assembly, 5-6 December 2023

Jeroen Kuenen (TNO) & CAMS emissions team

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The CAMS emissions portfolio

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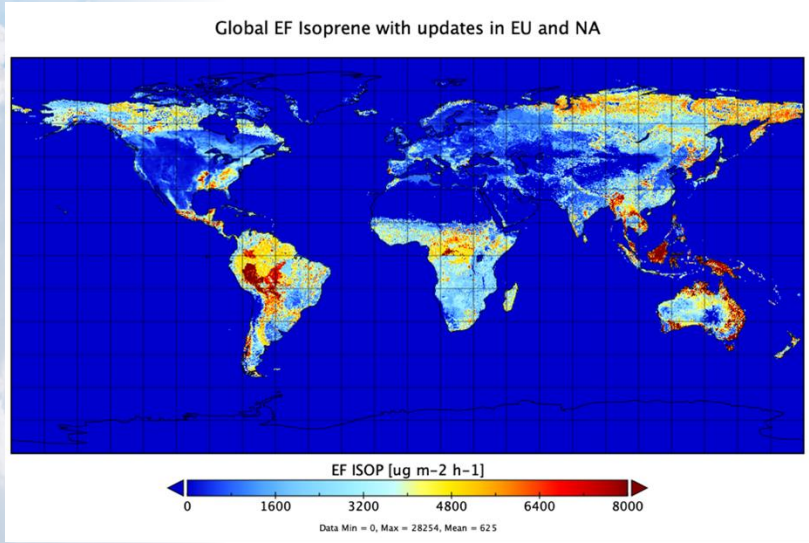
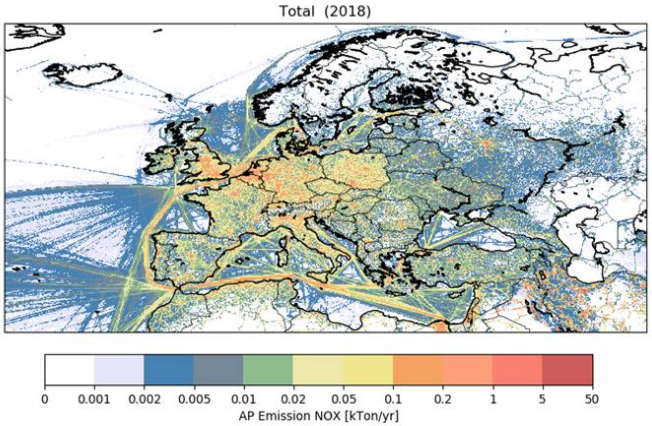
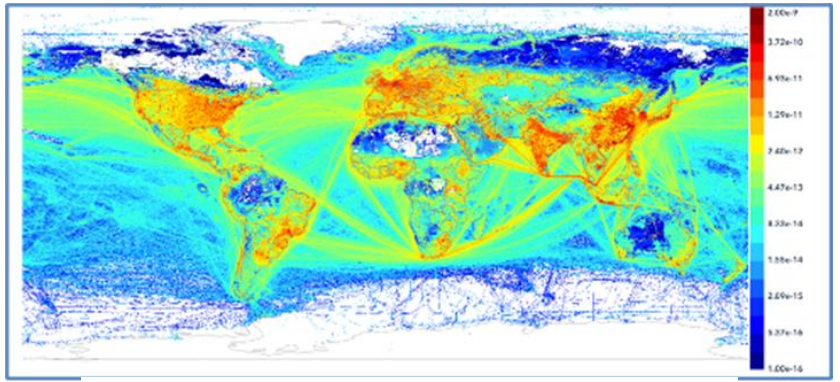
CAMS emission products provide state-of-the-art emission information for both anthropogenic and natural sources, as input to the CAMS production systems but also as stand-alone products



CAMS-GLOB-BIO-v3.1 Emission potential maps for isoprene



CAMS-REG-v5.1 NOx emissions 2018 (kg/grid cell) Kuenen et al., ESSD (2022)



CAMS-GLOB-ANT-v5.2 NOx emissions 2021 (kg/m²/s)

CAMS emissions

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- Primary goal is to provide state-of-the-art and up-to-date emission information to the CAMS production systems
  - But great value for scientific community => the main datasets are publicly available (ECCAD, ADS)
- Natural (incl. biogenic) emissions are based on emission modelling while anthropogenic emissions are largely based on emission inventories
  - CAMS emissions are updated annually, adding more recent and updated information
  - In each European country, emission are estimated bottom-up, i.e. by using activity data and emission factors
  - In CAMS , a hybrid approach is followed by taking these country inventories, complement them with other estimates where necessary, and apply a uniform spatial distribution methodology *(Kuenen et al., ESSD, 2022)*

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CAMS-REG approach in a nutshell

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Official reported GHG emissions (UNFCCC CRF)

Official reported Air Pollutant emissions (EMEP CEIP)

Other emission datasets (most notably, IIASA GAINS)

TNO internal estimates Bottom-up checks

- Small combustion (wood)
- Non-international shipping
- Agricultural waste burning
- Etc.

All details in [Kuenen et al., ESSD, 2022]

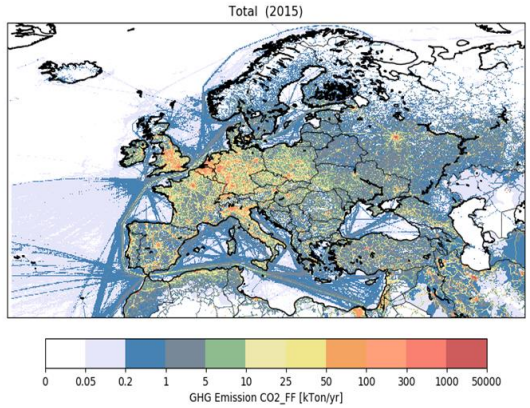
~250 subsectors: aggregated CRF/NFR with fuel splits

CAMS / TNO emissions by subsector

Shipping grids *(FMI/STEAM)*

Spatial proxies

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



Gridded European regional emission product (time series)

Annual emission grids accompanied by:

- Annual data broken down to hourly by using temporal profiles
- Speciation profiles for PM/NMVOC

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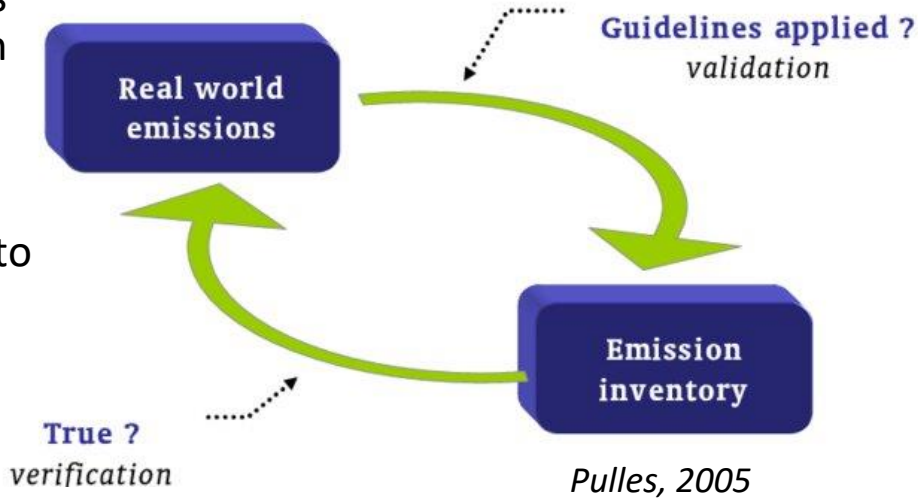
Verification against validation

Verification of bottom-up inventories is difficult: emissions cannot be “measured” beyond a single source

- Use of emissions in modelling studies and then comparing to concentration measurements (in-situ and/or satellite) is one way – but many uncertain aspects are included
- Comparison of different approaches to emission estimation is key to understand where issues may be
  - Comparison of different traditional inventories
  - Comparison to satellite-based emission estimates



Pulles, 2005

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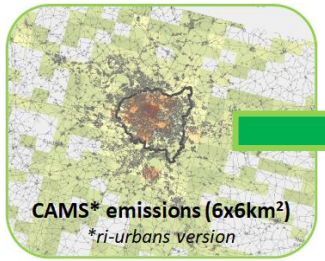
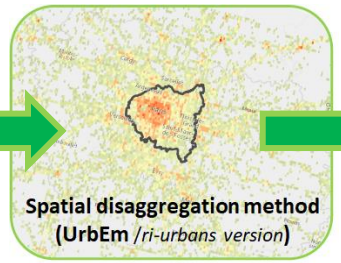
Comparing emission inventories

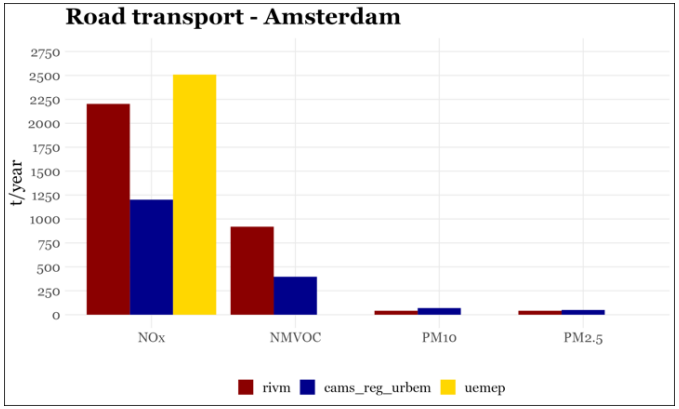


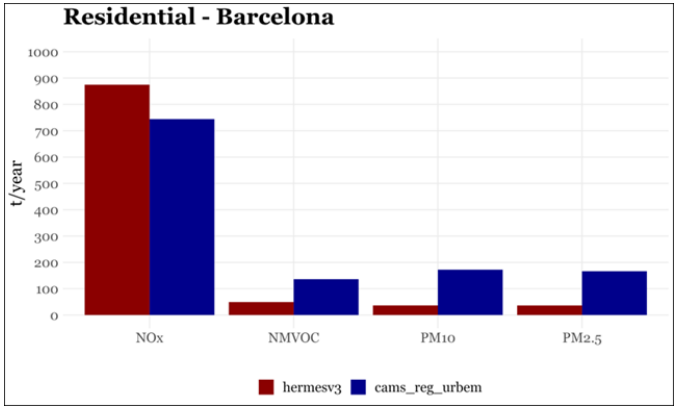


1. Amsterdam
2. Athens**
3. Barcelona
4. Birmingham
5. Bologna
6. Hamburg
7. Helsinki
8. London
9. Madrid
10. Milan
11. Paris**
12. Rotterdam
13. Zurich

*** provided also for CTM simulations (NOA, FORTH)*

Comparing national/European scale to local city inventories in support of urban AQ assessment





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Verification of spatial distribution

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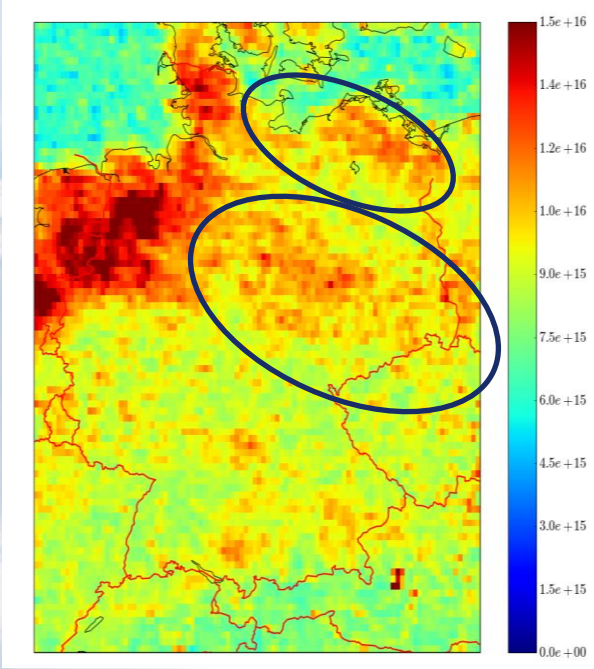
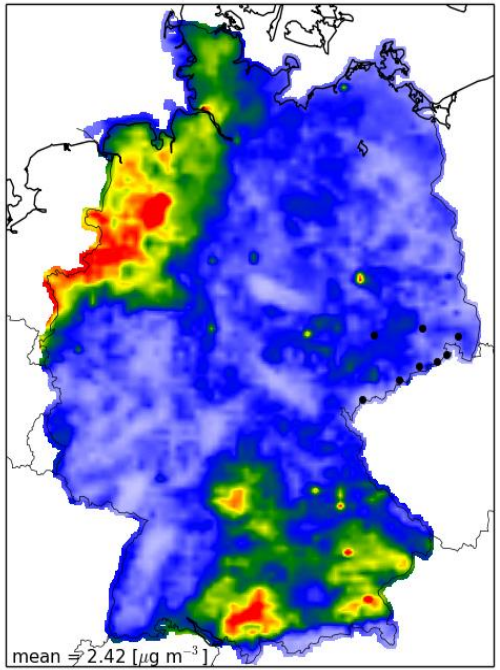
- Satellite data identifies regions in Germany with substantial NH3 emisisons which were not in the emission inventories

Satelite-IASI-NH3: 8-year average



Modelled mean surface NH3



Emission inventories use proxies e.g. number of farms to distribute country totals

However in eastern Germany part of emissions are missed because the proxy is less suitable (farmers often have larger land areas)

→ Used to improve the emission inventories

Dammers et al. 2019

Verification of emissions: ammonia

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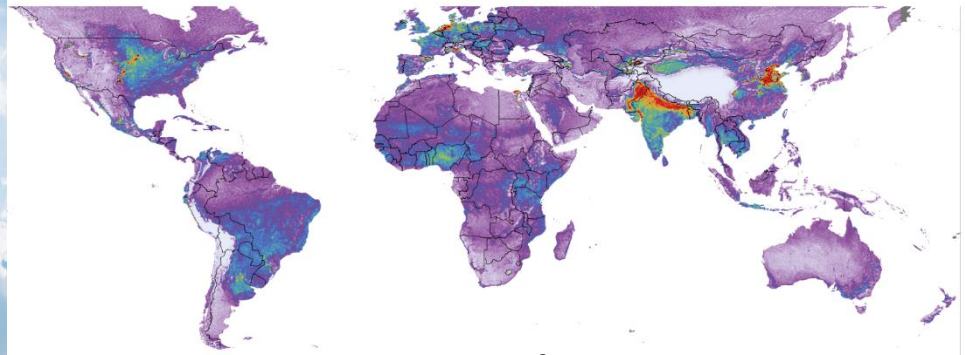
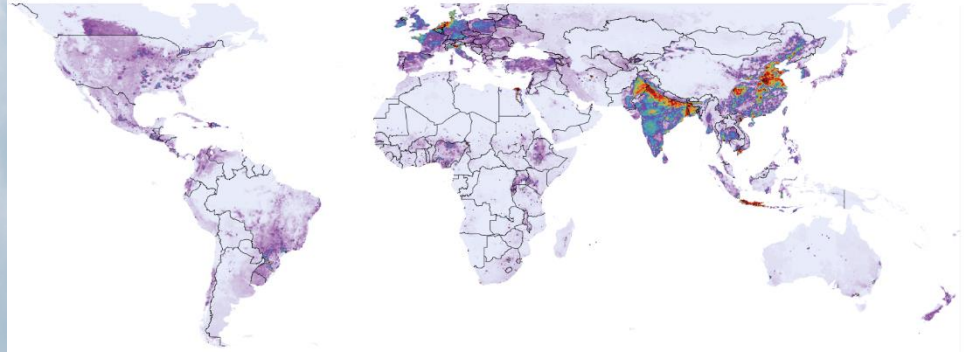
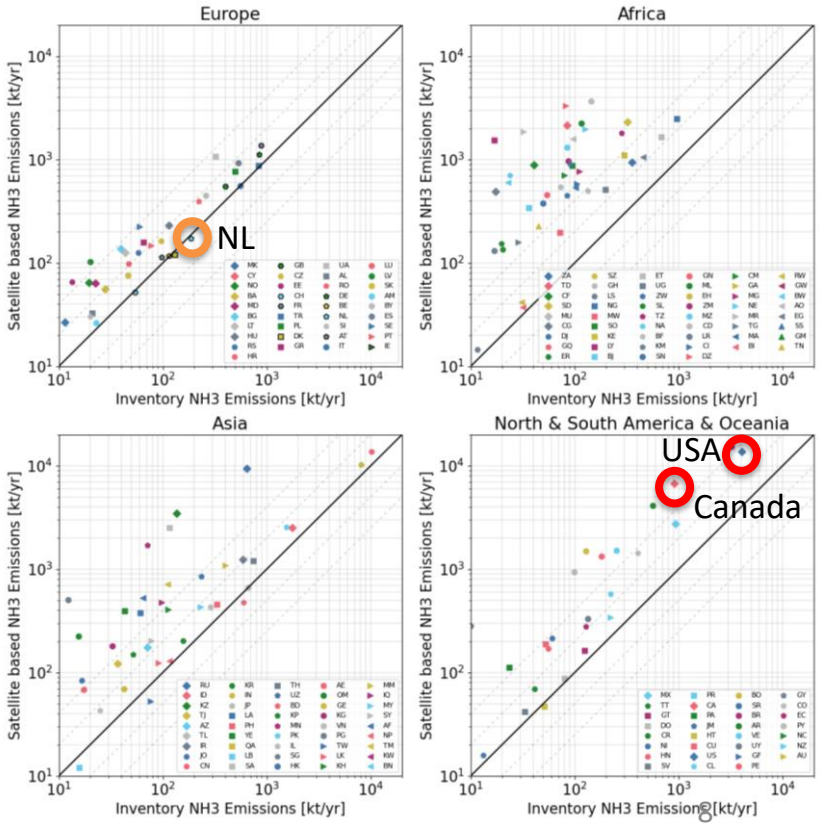


Ammonia seen from space



Best available knowledge based on emission inventories

Dammers et al. – in review



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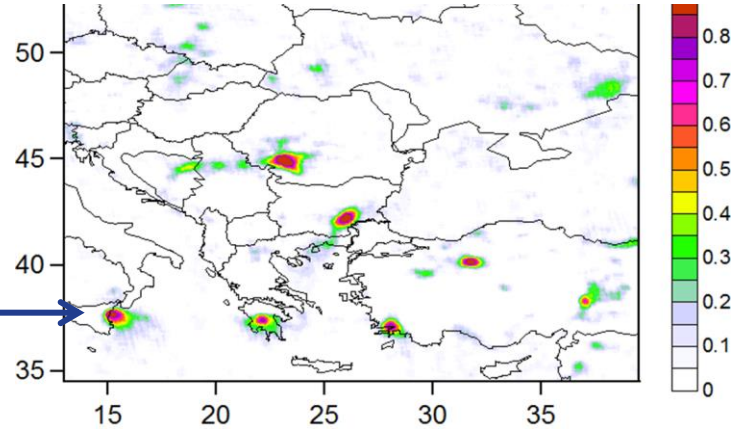
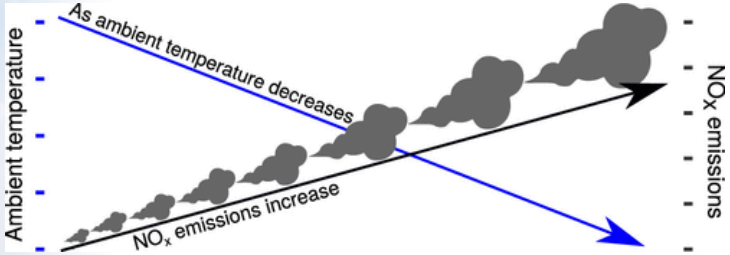
What can satellite data bring?

- Inventories are well-developed for most developed countries – but satellite based emissions are a useful resource for verification
- But requires relatively large point source emissions and/or limited other emissions in the region

Checking point source locations e.g. for SO2



Fioletov et al., ACP, 2017 https://doi.org/10.5194/acp-17-12597-2017



Grange et al., Env. Sci. Tech., 2019

Satellite data can also contribute to a better understanding of seasonal variation of emissions, e.g. temperature dependency of road transport emissions

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Anthropogenic emission inventories

- Emission inventories are a key data source in policy
  - Emission reduction commitments e.g. UNFCCC/Paris Agreement, CLRTAP Gothenburg Protocol, EU NEC Directive
- However, issues may exist as these inventories rely on the availability of high-quality underlying information

"Traditional" emission inventories e.g. CAMS-REG/CAMS-GLOB-ANT	Satellite-based emission inventories
All relevant pollutants are possible	Selected pollutants only
Only "known" anthropogenic sources but **with sector detail**	**All sources** (incl. natural) but only totals (no sectoral breakdown)
Not always fully consistent between countries	Inherently **consistent across domain**
Spatially distributed emissions using proxies and point source (reported) data	**Spatial distribution explicit** in the observations
Only annual data, use of profiles for higher temporal resolution	**Good temporal disaggregation** (e.g. daily value)

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Take stock of SEEDS products – NOX & NH3

- Satellite-based estimates offers an <u>independent methodology</u>
  - Results likely differ, as there are uncertainties and biases in both of them
  - Hence difficult to draw quick conclusions on such comparisons
- Focus on
  - Assessing trends if possible => differences?
  - Comparisons by country: does a comparison look very different for one or a few specific countries? Can this be linked to a certain country?
  - Comparisons for specific regions: any hot-spots missing? (major industrial complex, large city, …)

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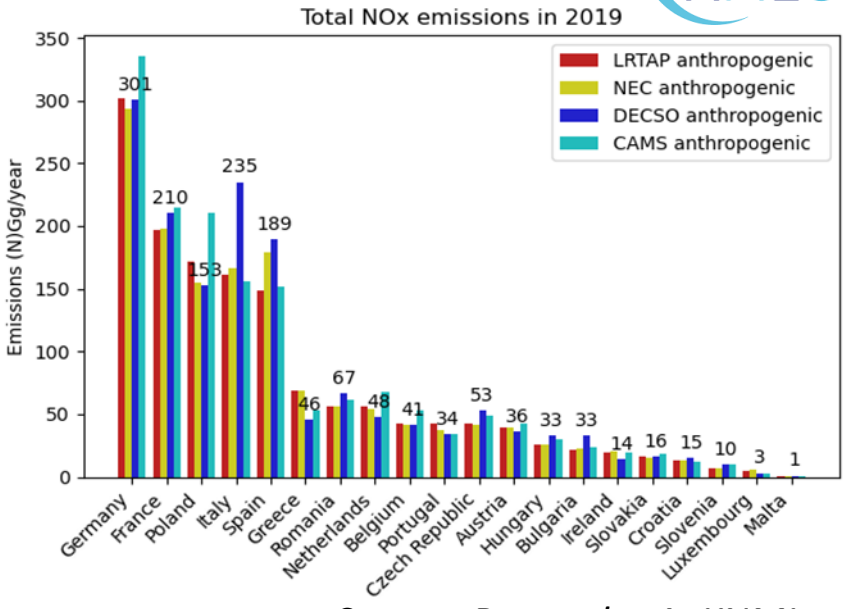
Comparing between countries

- Assess differences and similarities between inventory-based and satellite-based
  - Which countries are in good agreement? And for which countries differences are larger?
  - Do we see discrepancies for specific point sources?
  - What are methodological differences between the bottom-up inventories?
- This needs a deep dive into such comparisons involving both sides!



Source: R. van der A, KNMI

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Next steps

- Traditional “bottom-up” emission inventories will remain important for policy applications (e.g. NEC Directive reporting)
  - Countries responsible for their own national system & methodology
  - Range of pollutants and sector breakdown needed
  - Hence, we need to keep working on improving these with the latest knowledge available

- But… satellite-based estimates can be very useful to fill gaps where bottom-up estimates are lacking
  - Verify potential missing areas of emissions or identify large discrepancies
  - Provide estimates in regions where no bottom-up emissions are available

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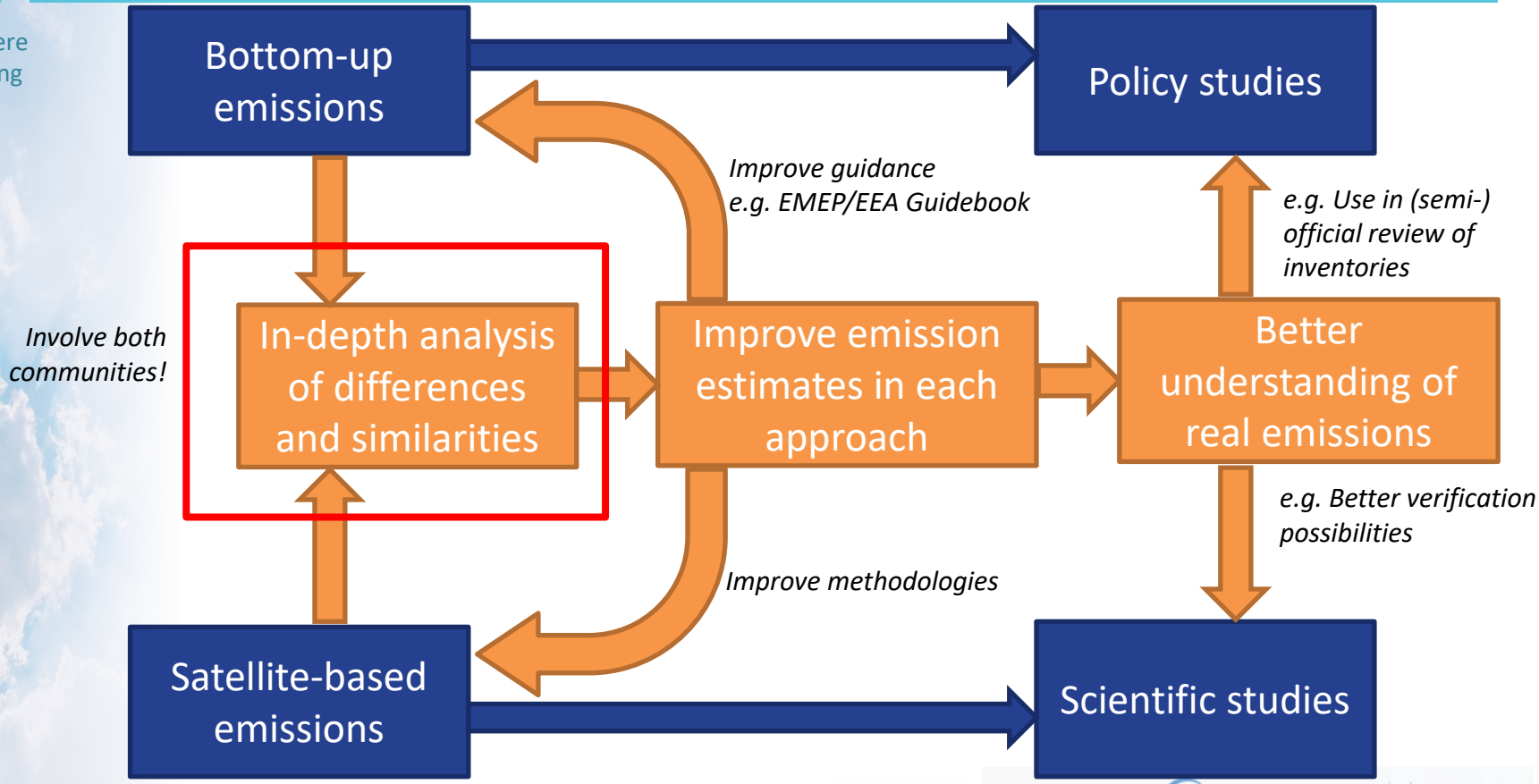
Next steps



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Conclusions

- Both bottom-up and satellite-based emission inventories have their pros and cons => but combined they can bring added value!
- First use of satellite data for emission inventories:
  - Assessment of emission trends
  - Compare differences per country between approaches
  - Large point source validation
- Emission inventories from individual countries are and will remain a key piece of input in policy processes, but satellite data can help & steer improvements
- Effort needed to bring together the inventory & satellite-based communities to discuss and analyse the differences and similarities in more detail

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Thank you

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Thank you for your attention!

Jeroen.Kuenen@tno.nl

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