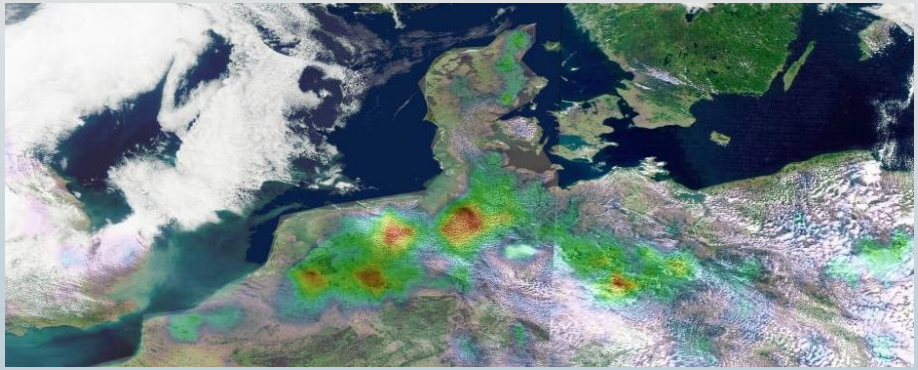
Global to local observations of atmospheric ammonia with IASI

Lieven Clarisse, Pierre Coheur, Daniel Hurtmans, Cathy Clerbaux, Frank Dentener



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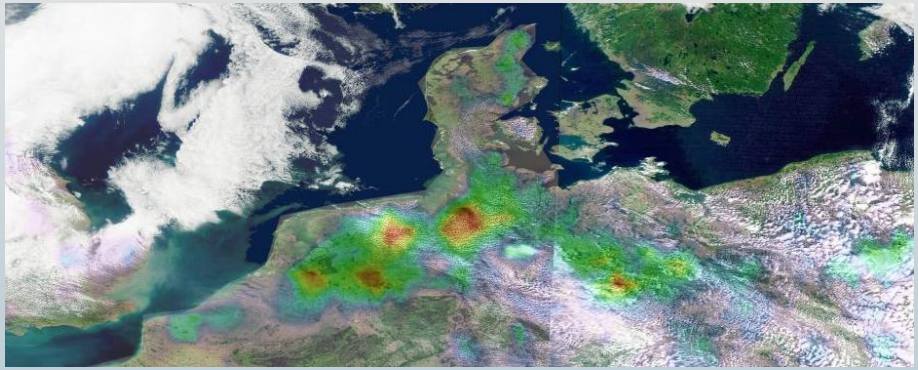
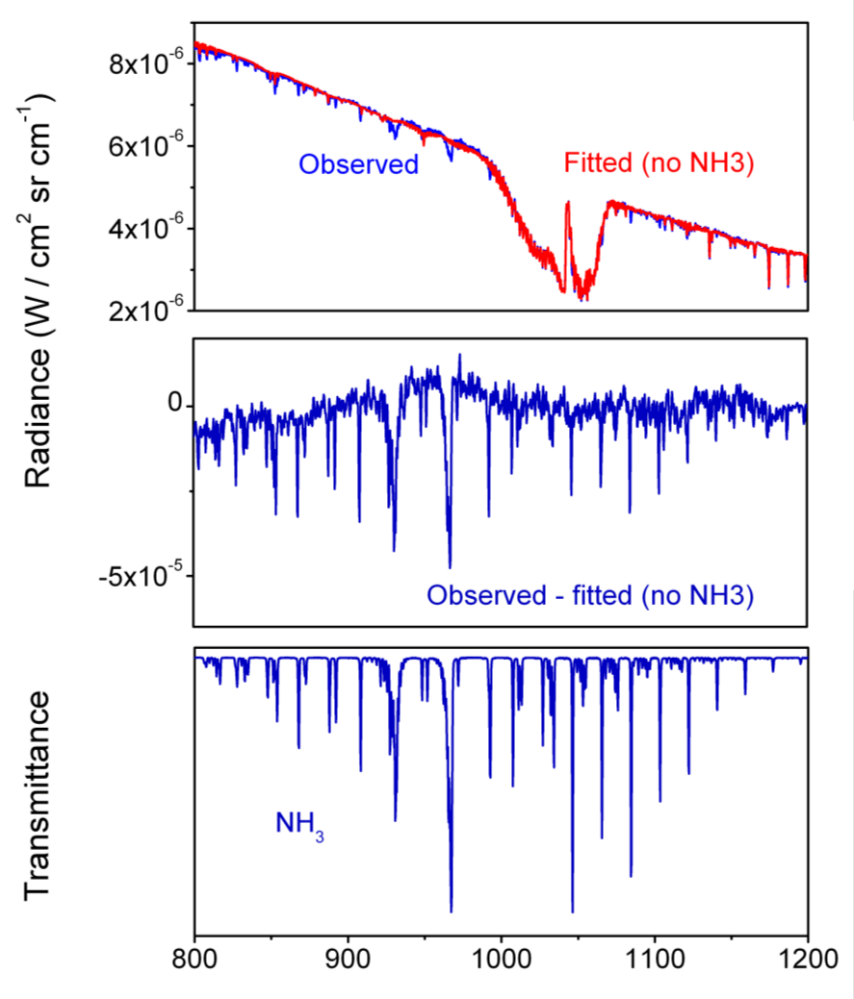
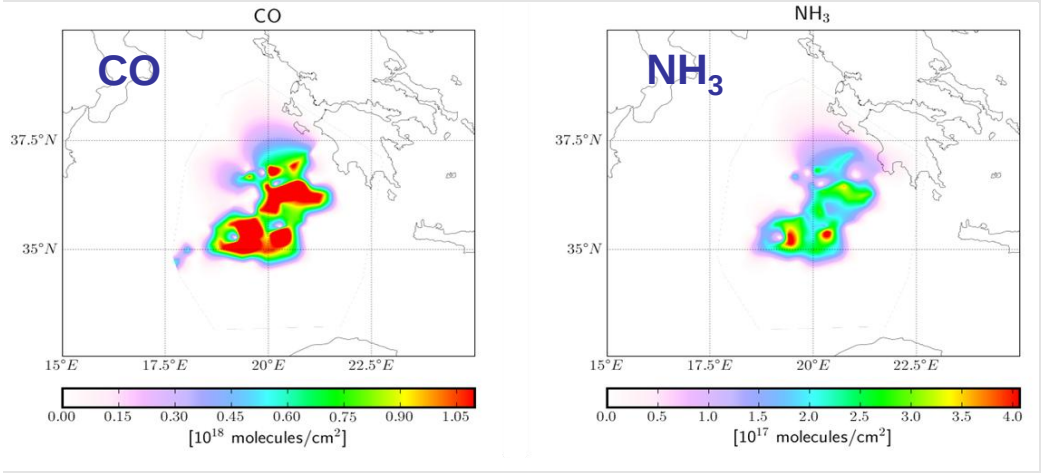


First IASI observations of NH_3 in fire plumes

Coheur et al; ACP 2009



Fires in Greece from August 25, 2007



$\partial NH_3 / \partial CO$

0.157 at emission spot

0.014 after 24 hours

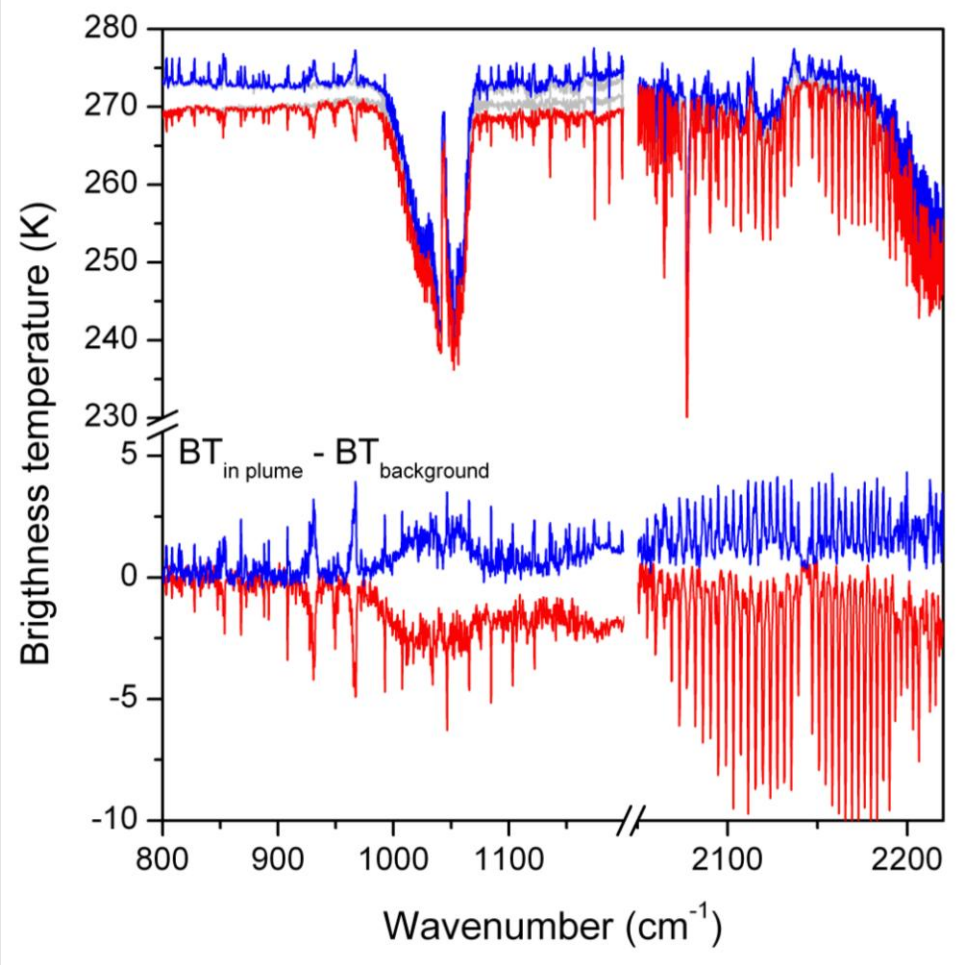
→Chemistry in fire plumes

Solene's talk (last before lunch)

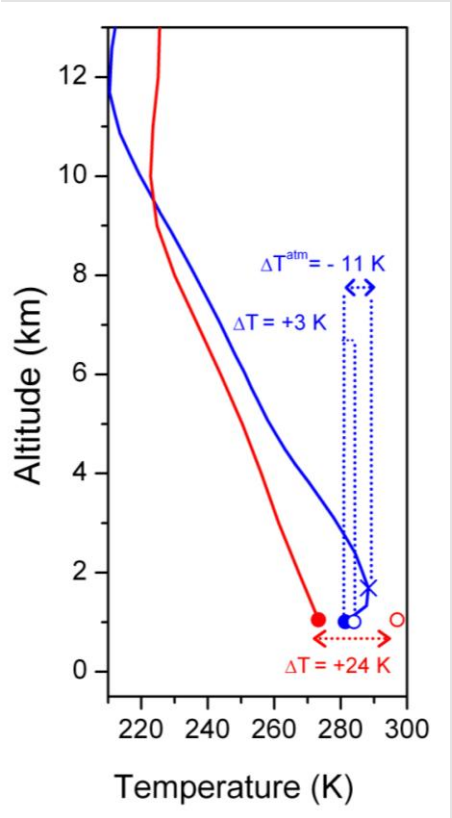
TES: First satellite observations of lower tropospheric ammonia and methanol, R. Beer et al; GRL May 2008

First IASI observations of NH_3 in fire plumes

Coheur et al; ACP 2009



Fires in Eastern Mongolia May 18, 2008



NH_3 seen in absorption or emission depending on T profile close to the surface

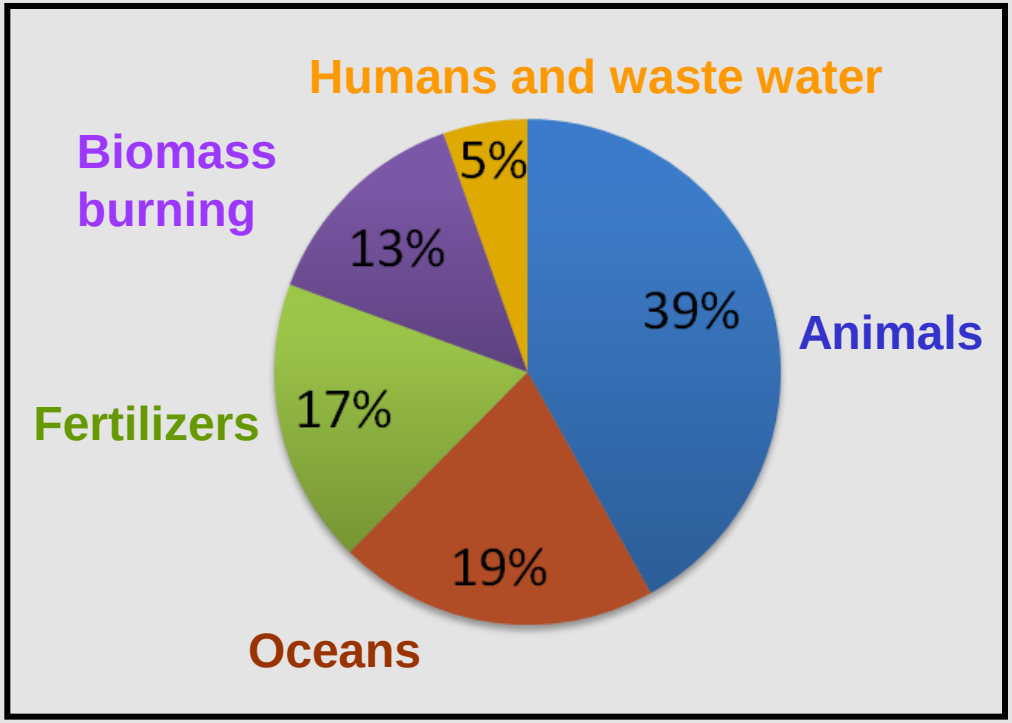
$\partial NH_3 / \partial CO$
0.013 at emission spot

First IASI observations of NH_3 in fire plumes

But fires represent only a small (locally strong) fraction of total emissions.

Emissions from agriculture dominates
fertilizers and animals account for 56 %

- Can IASI monitor NH_3?
- How well?
- Do we care?



Outline

- Ammonia and the perturbed N-cycle: Causes and consequences
- Global mapping of NH_3 using IASI radiance indexing
  - Method
  - Yearly averages: hotspots and description of sources
- Local (boundary layer) monitoring
  - How close to the surface do we see?
  - small-scale variations

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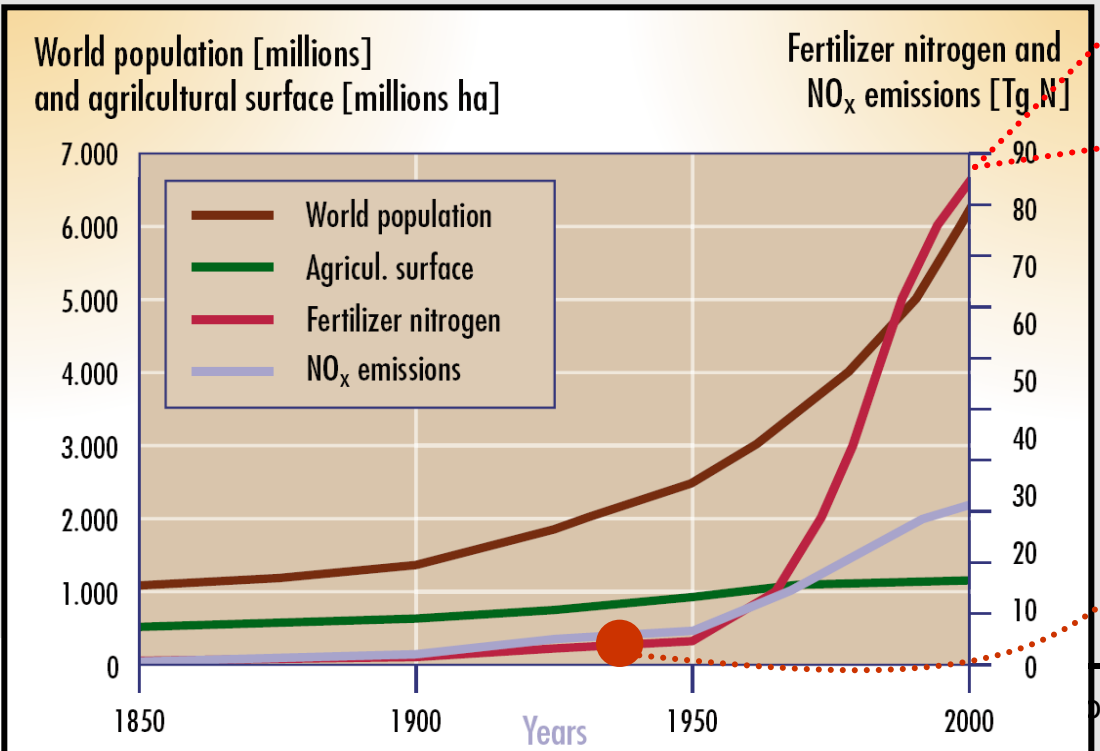
Ammonia and the perturbed N-cycle

Anthropogenic nitrogen fixation

Energy
→ NO_x

Food
→ NH_3



Future trends highly uncertain

Haber-Bosch

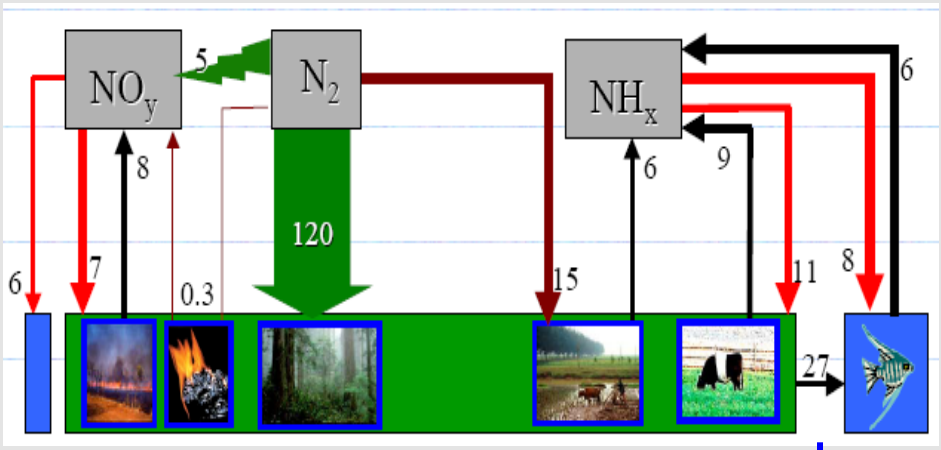
$N_2+3H_2 \rightarrow 2NH_3$

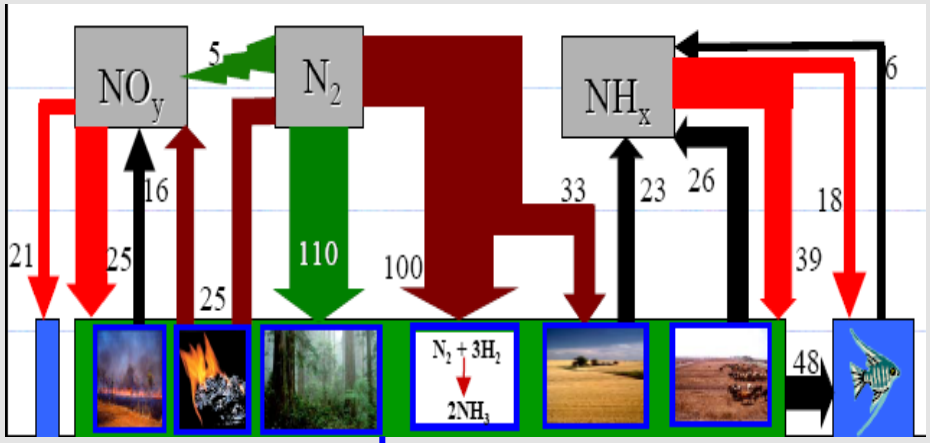
Today ~40 % the world population depends on Haber Bosch process

Ammonia and the perturbed N-cycle

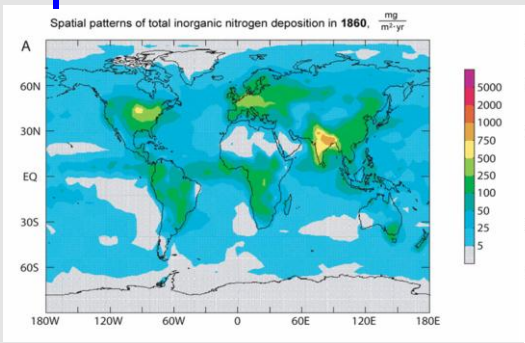
1860 **1995**

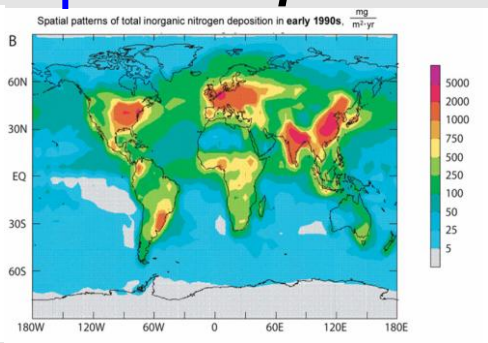
N-fluxes





N-deposition



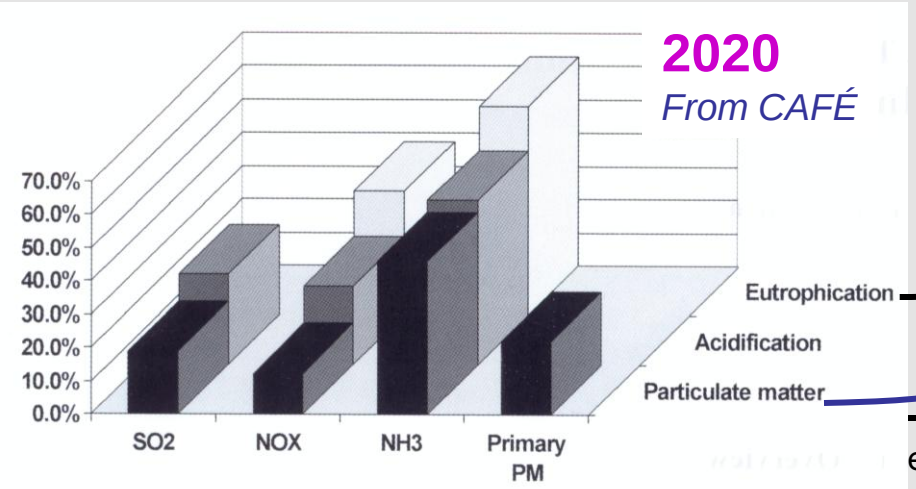


Adapted from Galloway, 2003

Ammonia and the perturbed N-cycle

Anthropogenic nitrogen fixation

Form of Nr	*Ecosystem*	*Impacts*	*scale*
NO_x	Atmosphere	Acid precipitation / AQ (BL O_3, PM)	Regional
NH_3	Atmosphere	AQ (PM)	Regional / local
N_2O	Atmosphere	Climate / Stratospheric ozone	Global
NH_3 + other Nr	Aquatic	Eutrophication / acidification	Regional / local
NH_3 + other Nr	Terrestrial	Acid deposition / biodiversity loss	Local



Gulf of Mexico dead zone

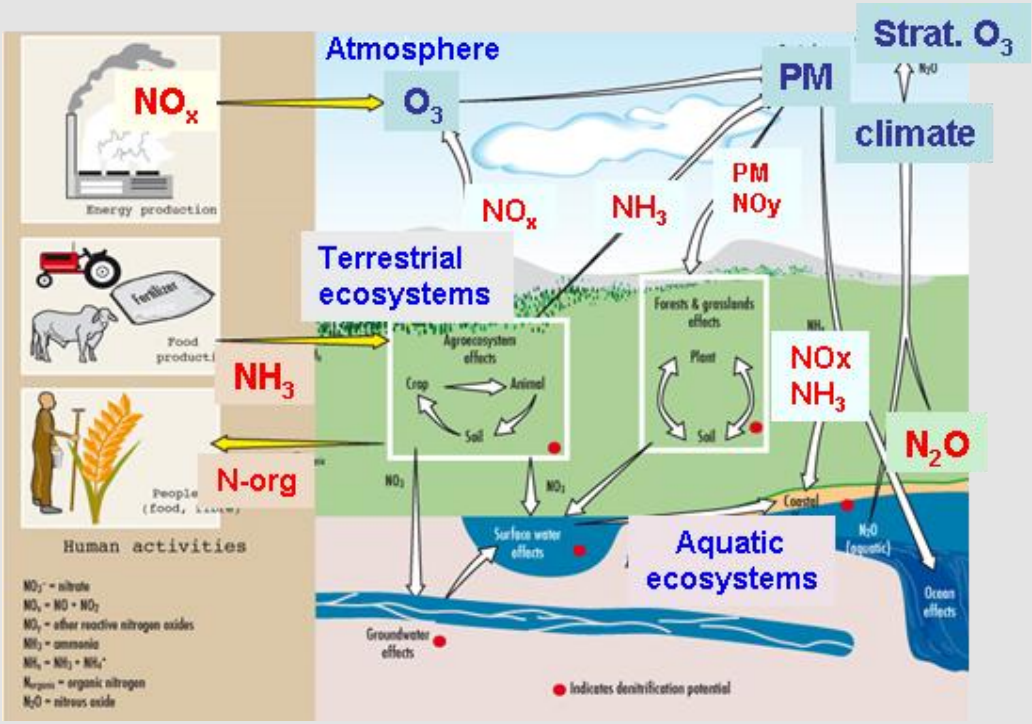
NH_3 likely to become the dominating primary anthropogenic source to particles in ambient air

eur, IASI Conference, Sévrier, January 2010

Ammonia and the perturbed N-cycle

***The nitrogen cascade (Galloway, 2003)**: Circulation of anthropogenic Nr in Earth's atmosphere, hydrosphere, and biosphere has a wide variety of consequences, which are magnified with time as Nr moves along its biogeochemical pathway. The same atom of Nr can cause multiple effects in the atmosphere, in terrestrial ecosystems, in freshwater and marine systems, and on human health. We call this sequence of effects the nitrogen cascade.*

As the cascade progresses, the origin of Nr becomes unimportant.



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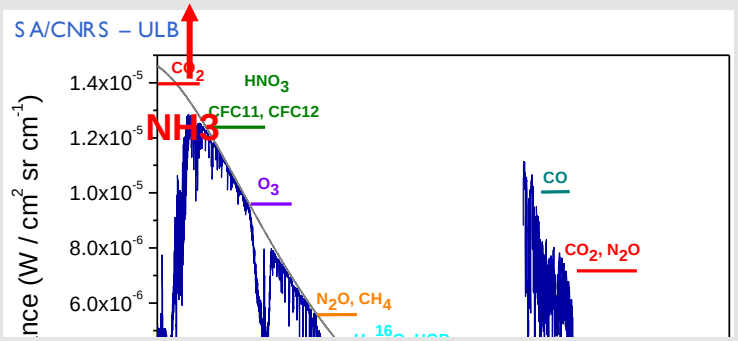
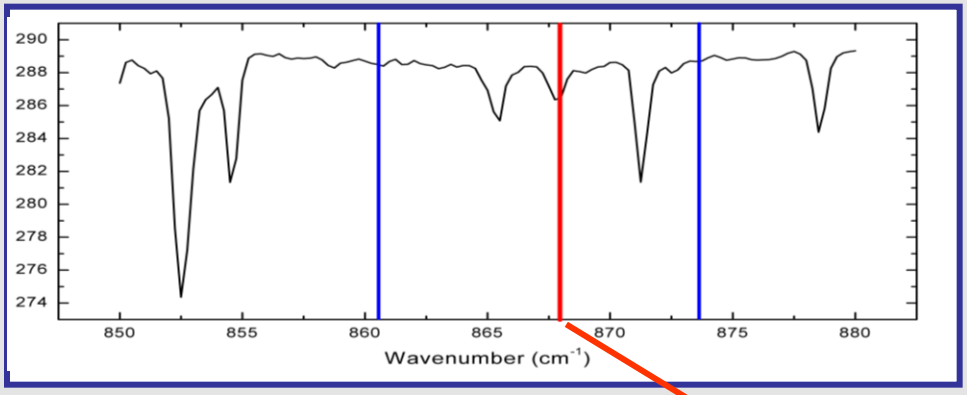
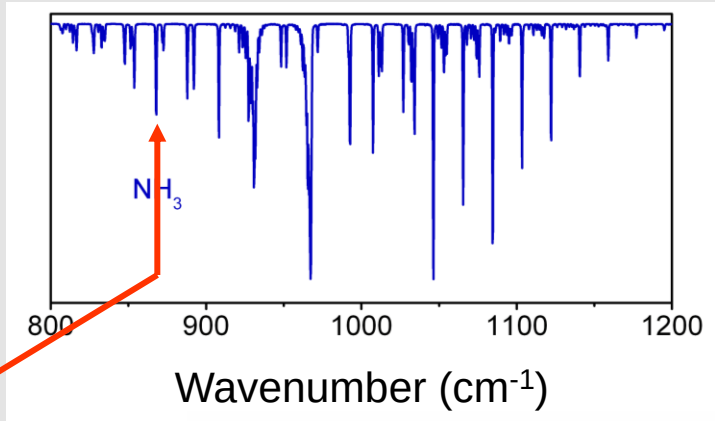
  - How close to the surface do we see?
  - daily to yearly variations



Global mapping using radiance indexing

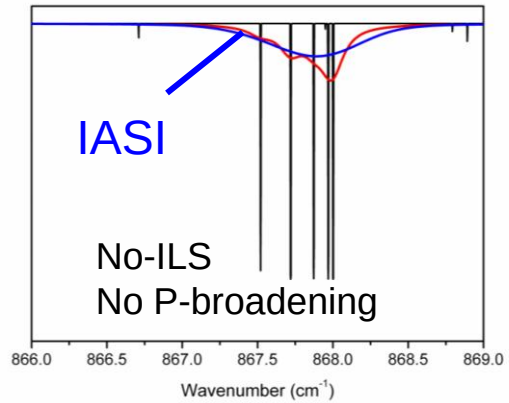
1. Brightness temperature difference





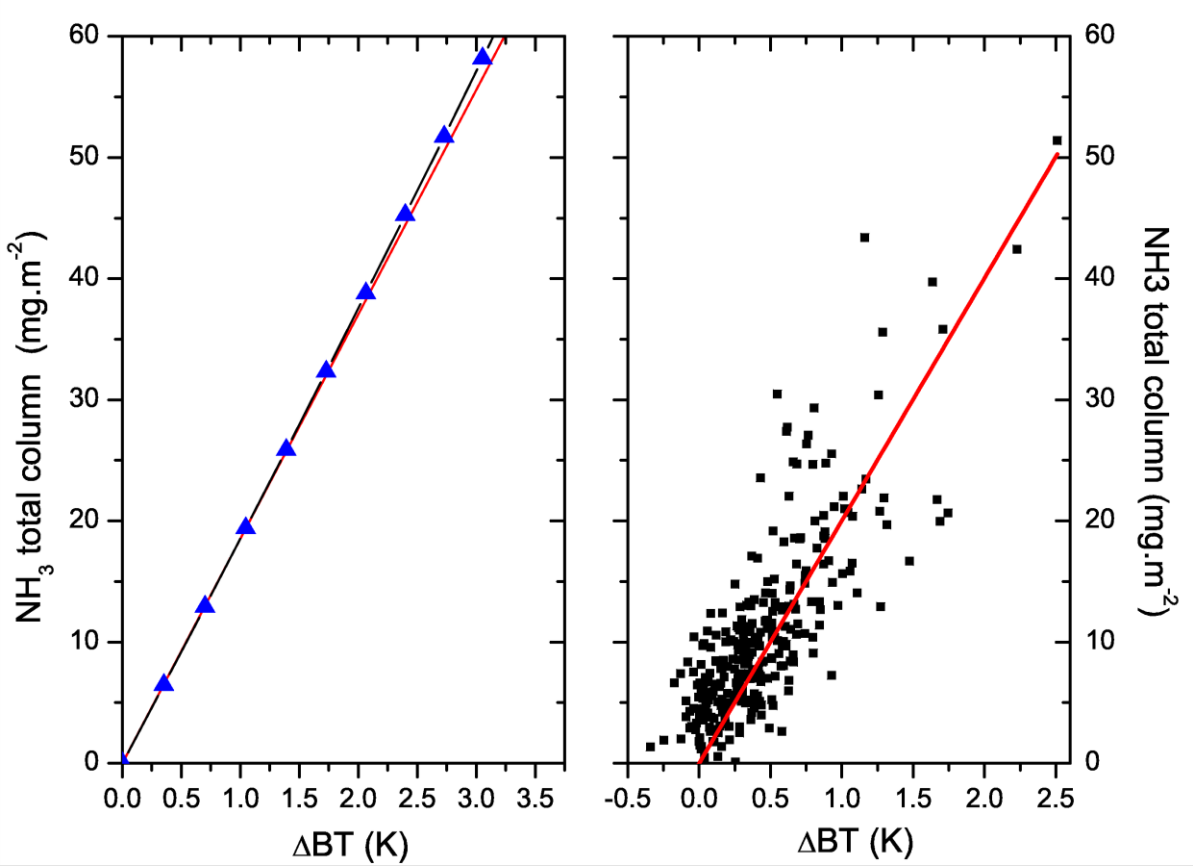
Target feature at 867.75 cm^{-1}
Two window channels

$$\Delta BT = BT_{target} - BT_{window}$$



Global mapping using radiance indexing

2. Brightness temperature difference → Total columns *(Curve of growth)*



1K → 15 ± 7.5 mg.m^{-2}

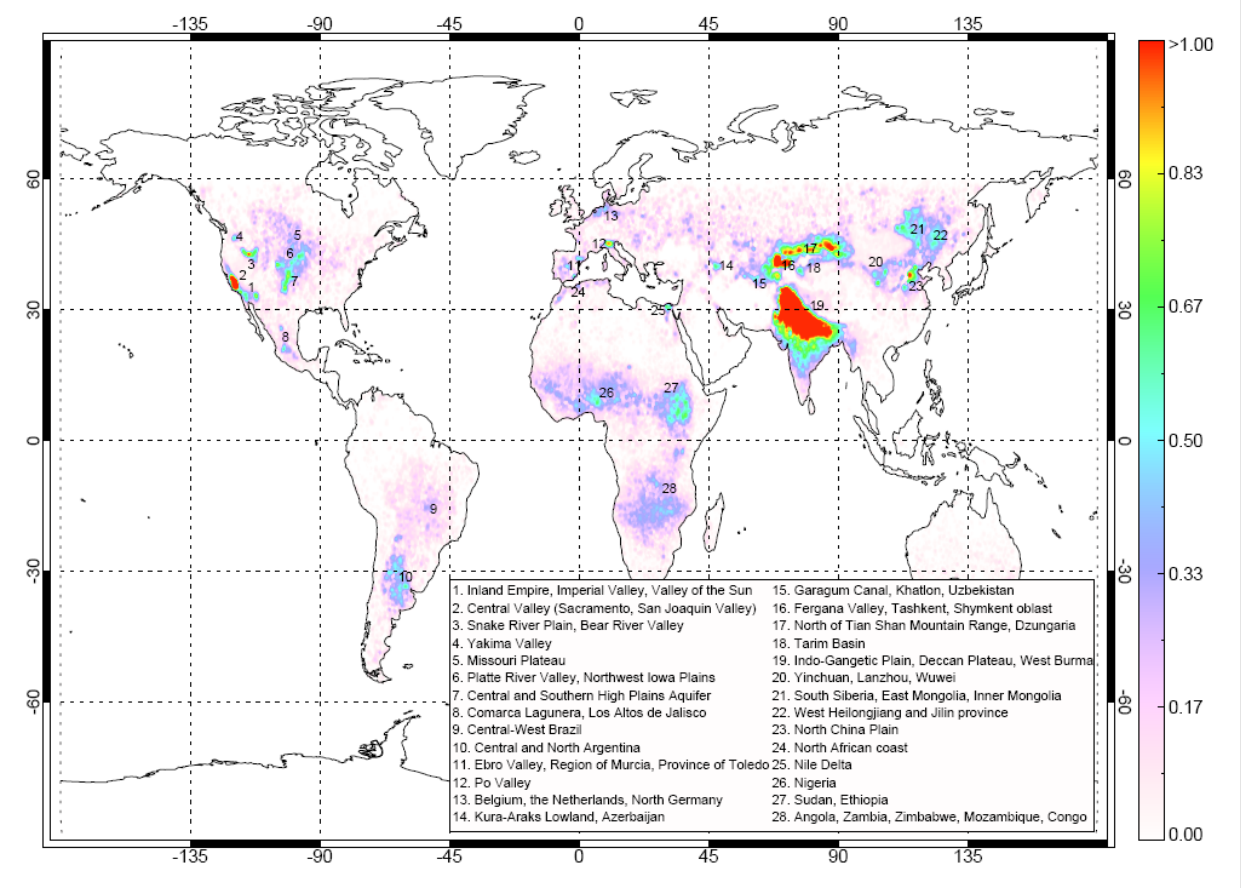
Advantages
- Simple
- Fast (NRT global)
- Robust

Limitations
- No explicit RT (thermal contrast!)
- No profile information

Global mapping using radiance indexing

2008 average

→ 28 emission hotspots identified

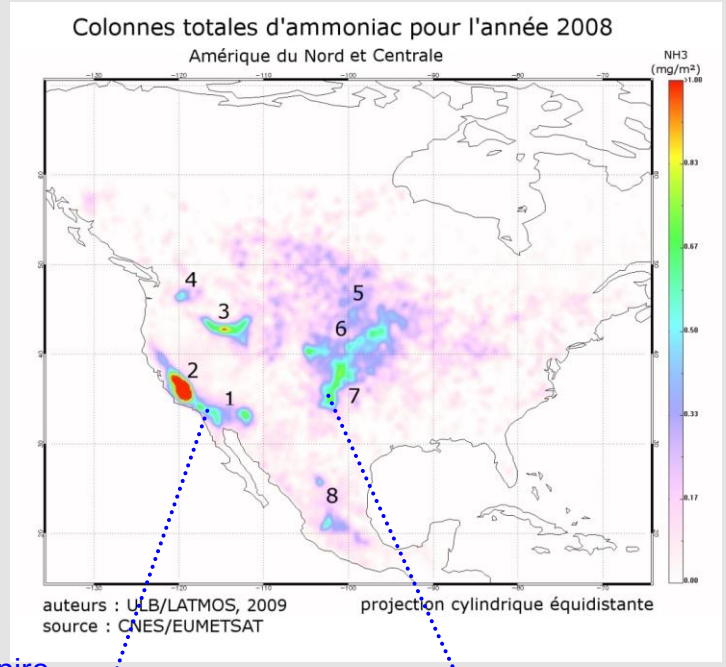


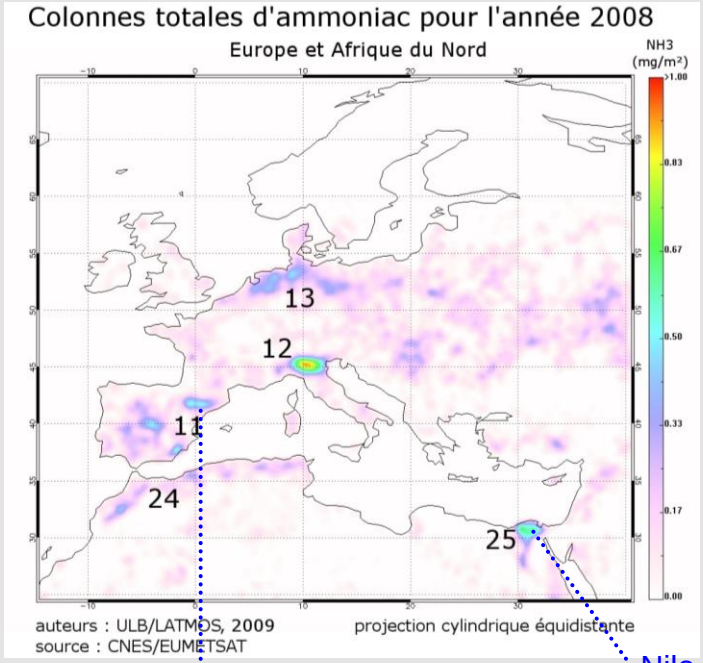
Clarisse et al., Nature Geo 2009

Global mapping using radiance indexing

2008 average

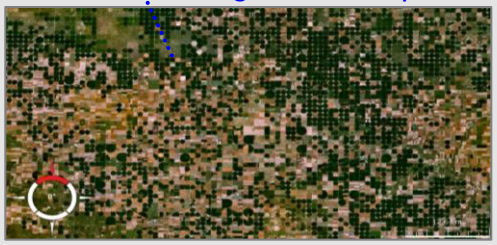
The link to agriculture





Inland empire

High Plains Aquifer



Ebro valley

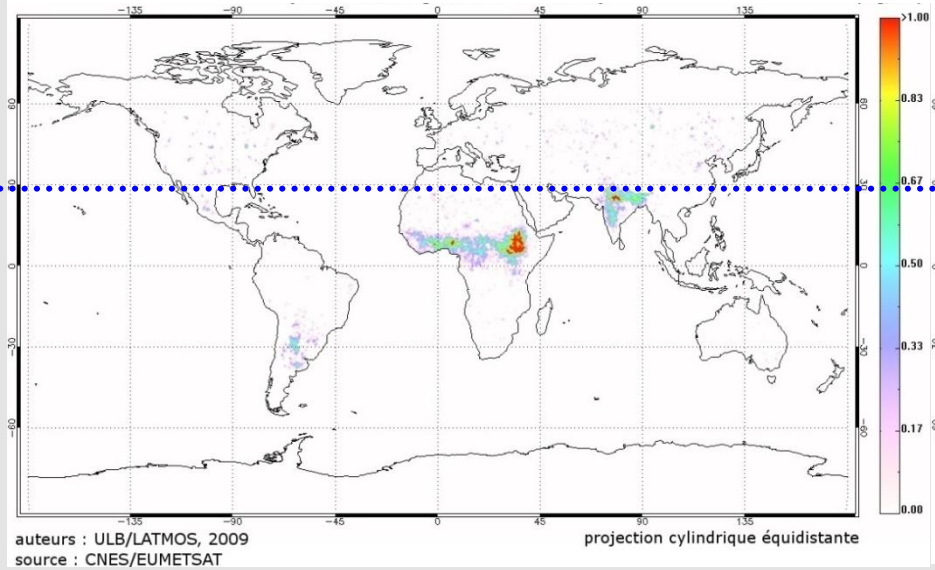
Nile Delta

Global mapping using radiance indexing

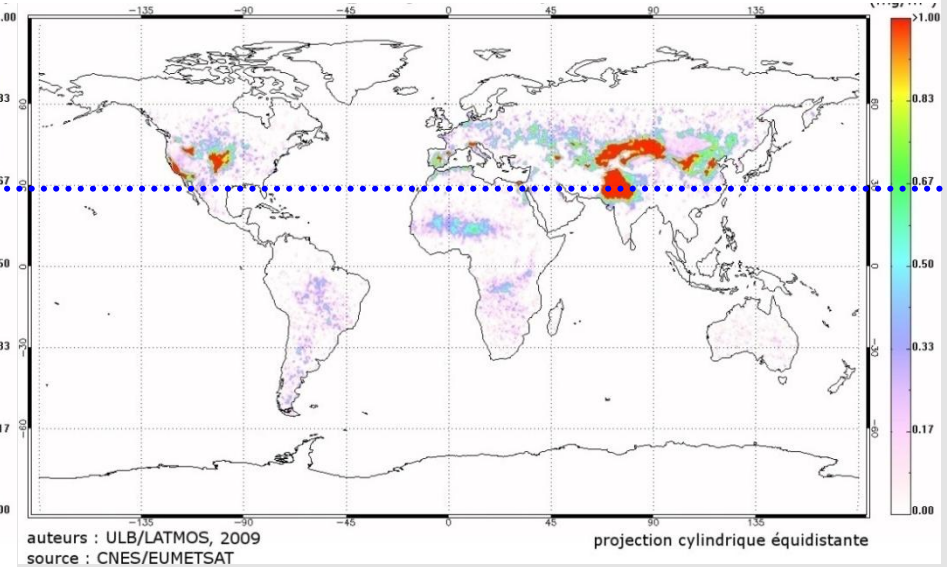
2008 average

The link to agriculture

December/January/February



June/July/August

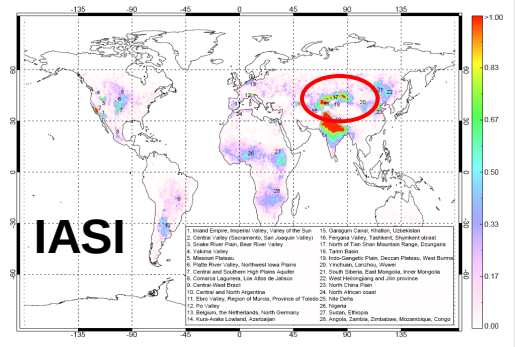


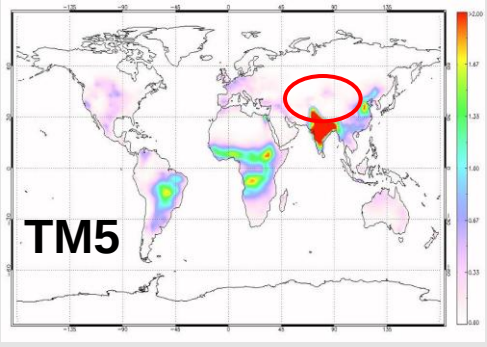
Increased fertilizer use + enhanced volatilisation in NH during summer

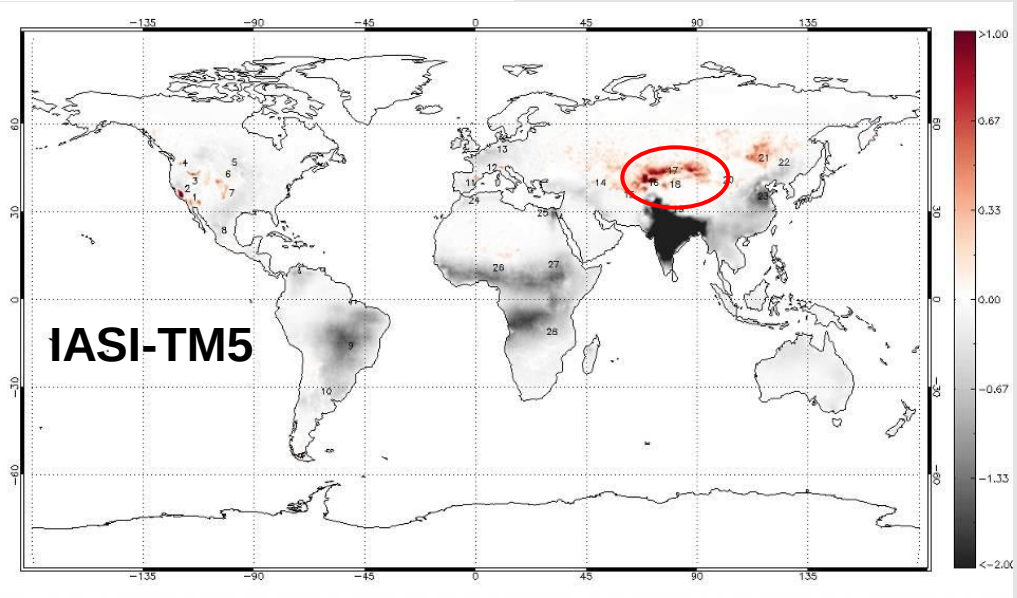
(+ also enhanced surface sensitivity…)

Global mapping using radiance indexing

Comparison with models





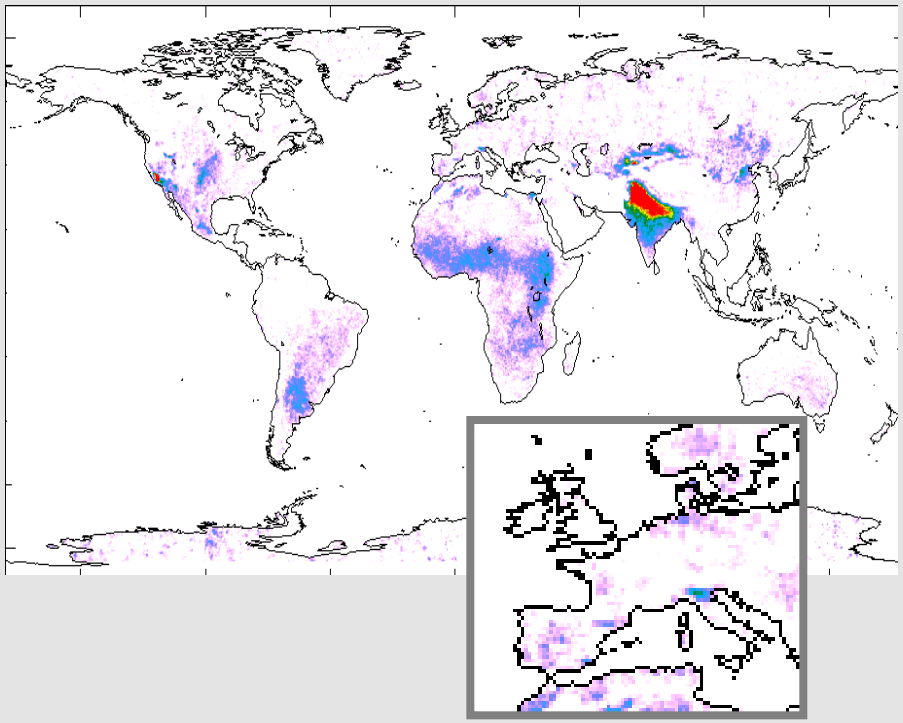


IASI > TM5 → Missing emissions

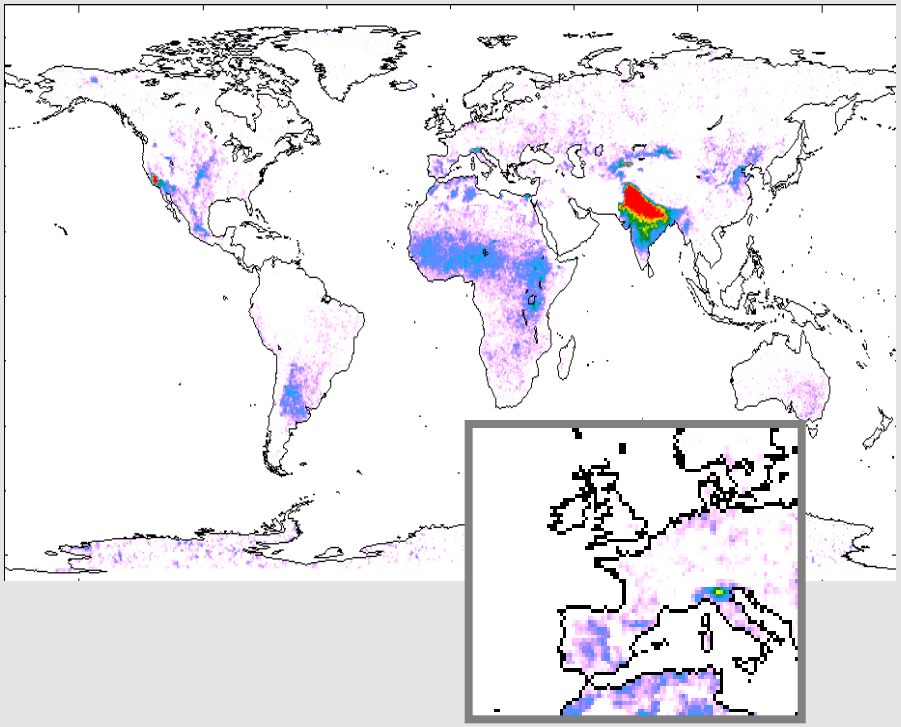
IASI < TM5 → Detection threshold
Daily 0.2K → 3mg/m^2
Monthly 0.08K → 1.2mg/m^2
(Thermal contrast!)

Global mapping using radiance indexing

2008 average



2009 average



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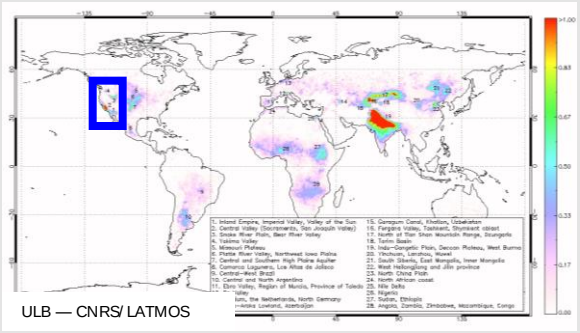
US central valley

- Typical agricultural valley
- Elevated NH_3 and PM levels throughout the year
- Large temperature variations at surface
  (including temperature inversions)

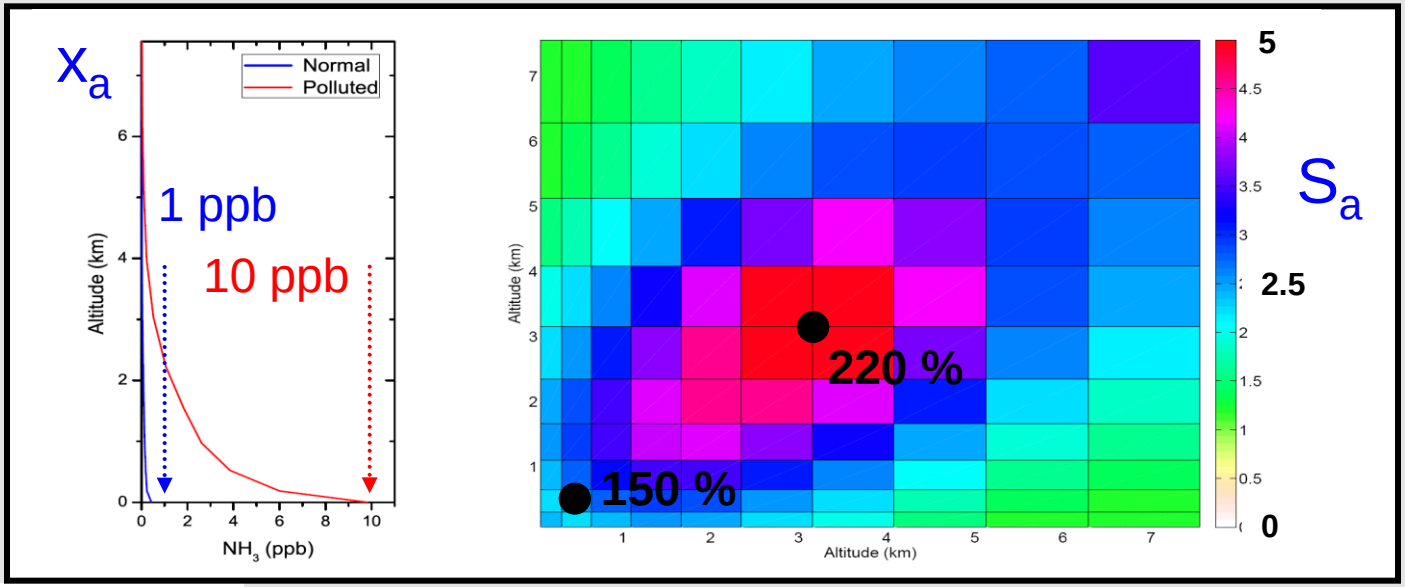
2008 yearly average



Retrievals using Atmosphit (line-by-line RTM + OE inversion)

Prior information built from TM5 1x1 output,
With xa and Sa >1ppb surface (polluted)

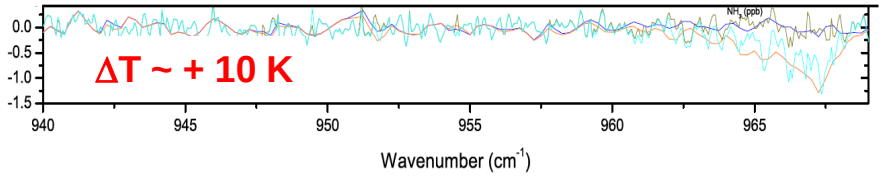
Clarisse et al., accepted for publication in JGR



US central valley

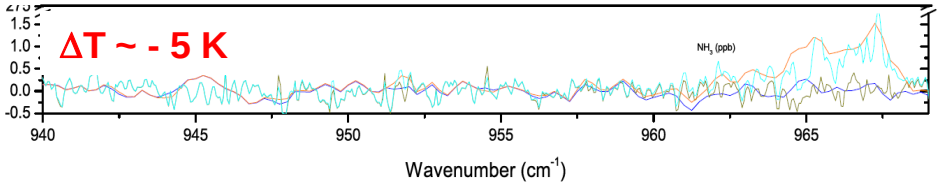
Two good cases for surface sensitivity

Large POSITIVE thermal contrast (AM)



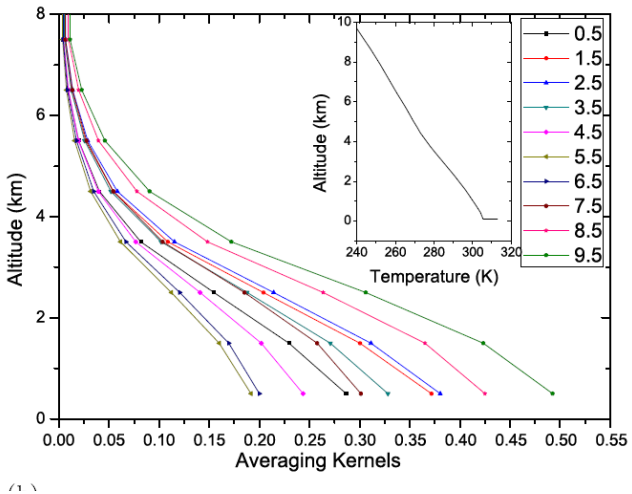
Significant **absorption** contribution from ammonia in the TOA radiance spectrum

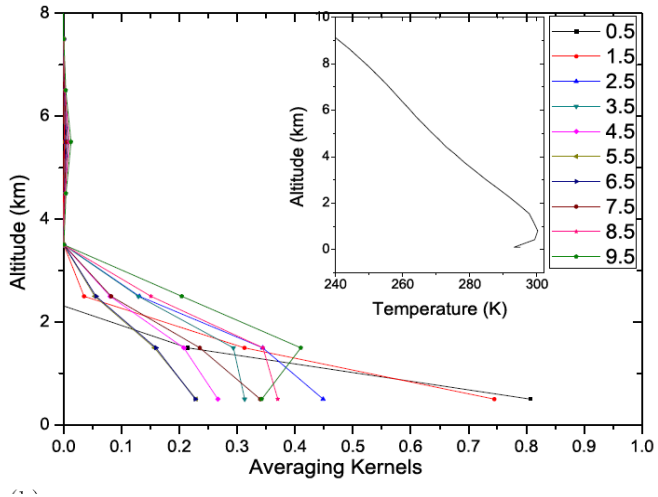
Temperature inversion (PM)



emission contribution from ammonia in the TOA radiance spectrum

Averaging kernels





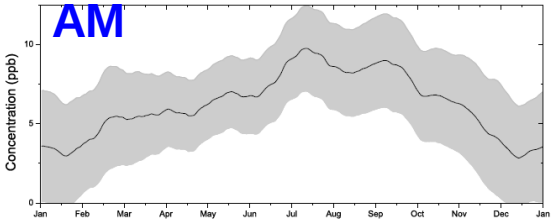
US central valley

NH3 vmr at 700 m

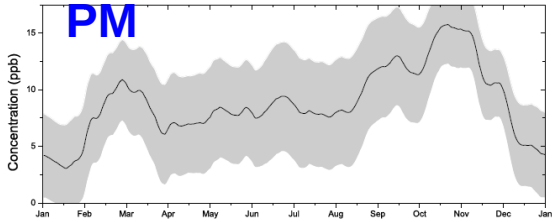
DOFS

Z of max. sensitivity

ΔT

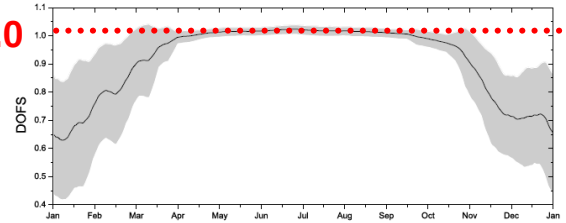


(a) NH_3 concentration at 700m (IASI morning orbit)

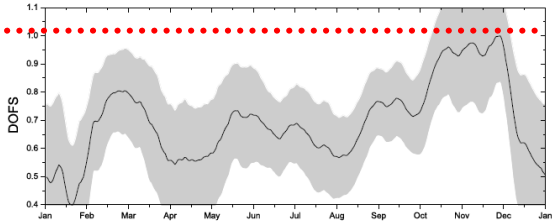


(b) NH_3 concentration at 700m (IASI evening orbit)

1.0

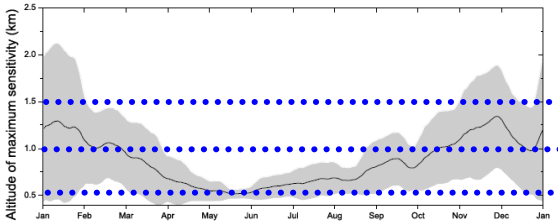


(c) DOFS (IASI morning orbit)

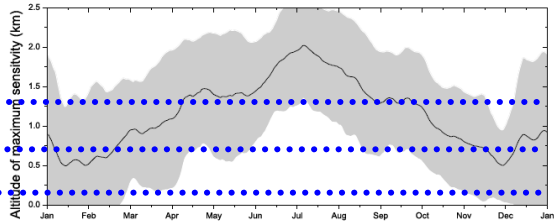


(d) DOFS (IASI evening orbit)

1.5
1.0
0.5

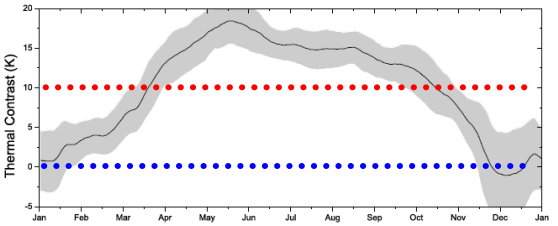


(e) Altitude of maximum sensitivity (IASI morning orbit)



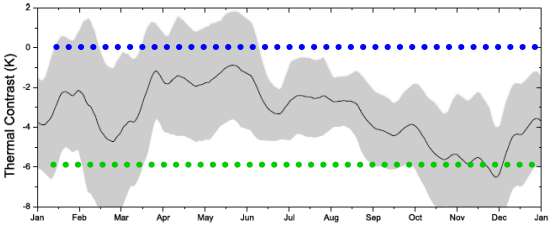
(f) Altitude of maximum sensitivity (IASI evening orbit)

+10
0



(g) Thermal Contrast at 500m (IASI morning orbit)

0
-5

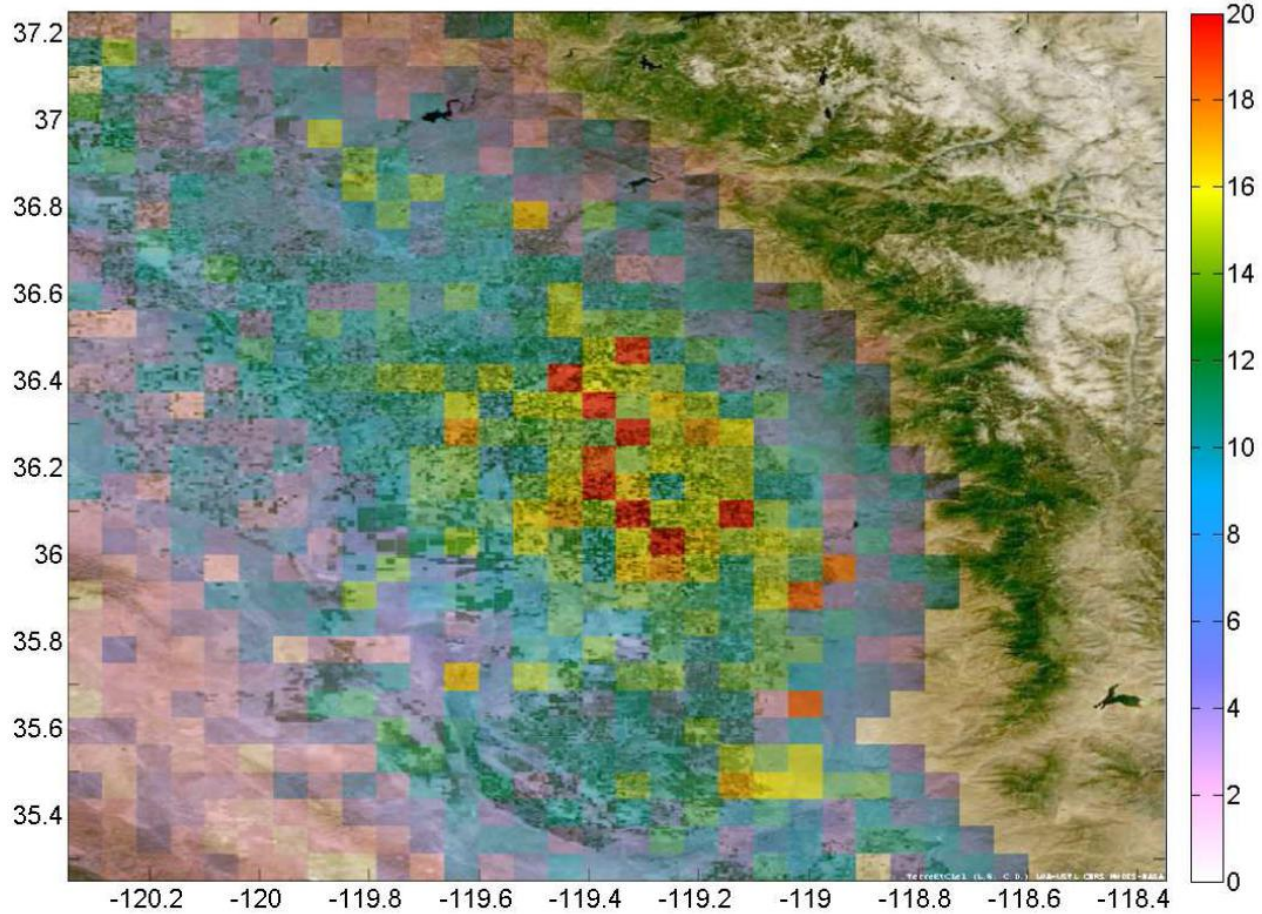


(h) Thermal Contrast at 500m (IASI evening orbit)

Clarisse et al., accepted for publication in JGR

Local source monitoring

US central valley



0.0675° × 0.0675°

Sources at "micro"-scale and on a (close to) daily basis

Clarisse et al., accepted for publication in JGR

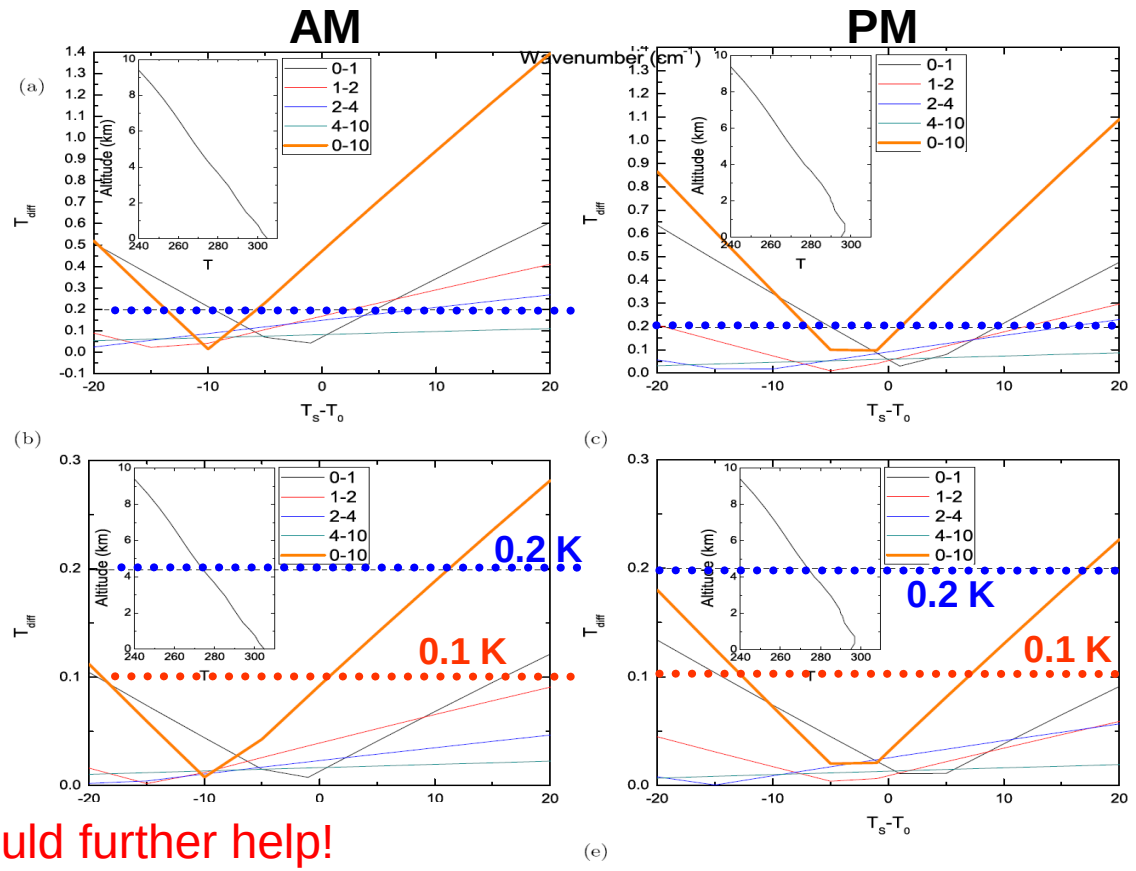
NH3 from IASI –conclusions-

- first example of volatilization processes seen from TIR nadir sounders
- first example of significant boundary layer sensitivity in favorable cases of atmospheric thermal structure (→ detection down to 5 ppb!)
- Allows detecting sources globally, and monitoring the largest on a daily basis

Towards the next generation

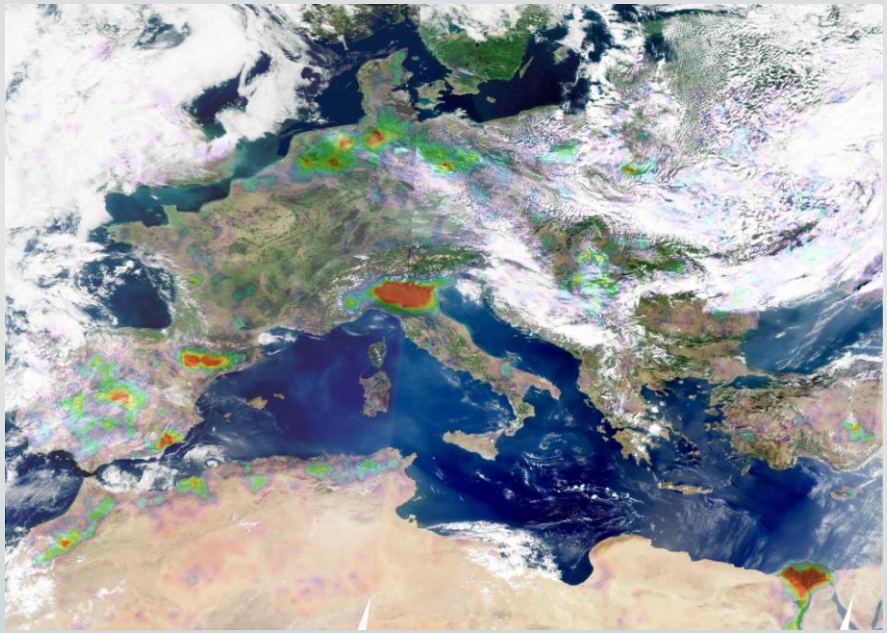
High BL pollution

Moderate BL pollution



+ higher spectral resolution would further help!

Global to local observations of atmospheric ammonia with IASI



SPECAT/ULB
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P.F. Coheur
D. Hurtmans
F. Karagulian
J.L. Lacour
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