Instituto Venezolano de Investigaciones Científicas

Atmospheric Nitrogen deposition

Tibisay Pérez

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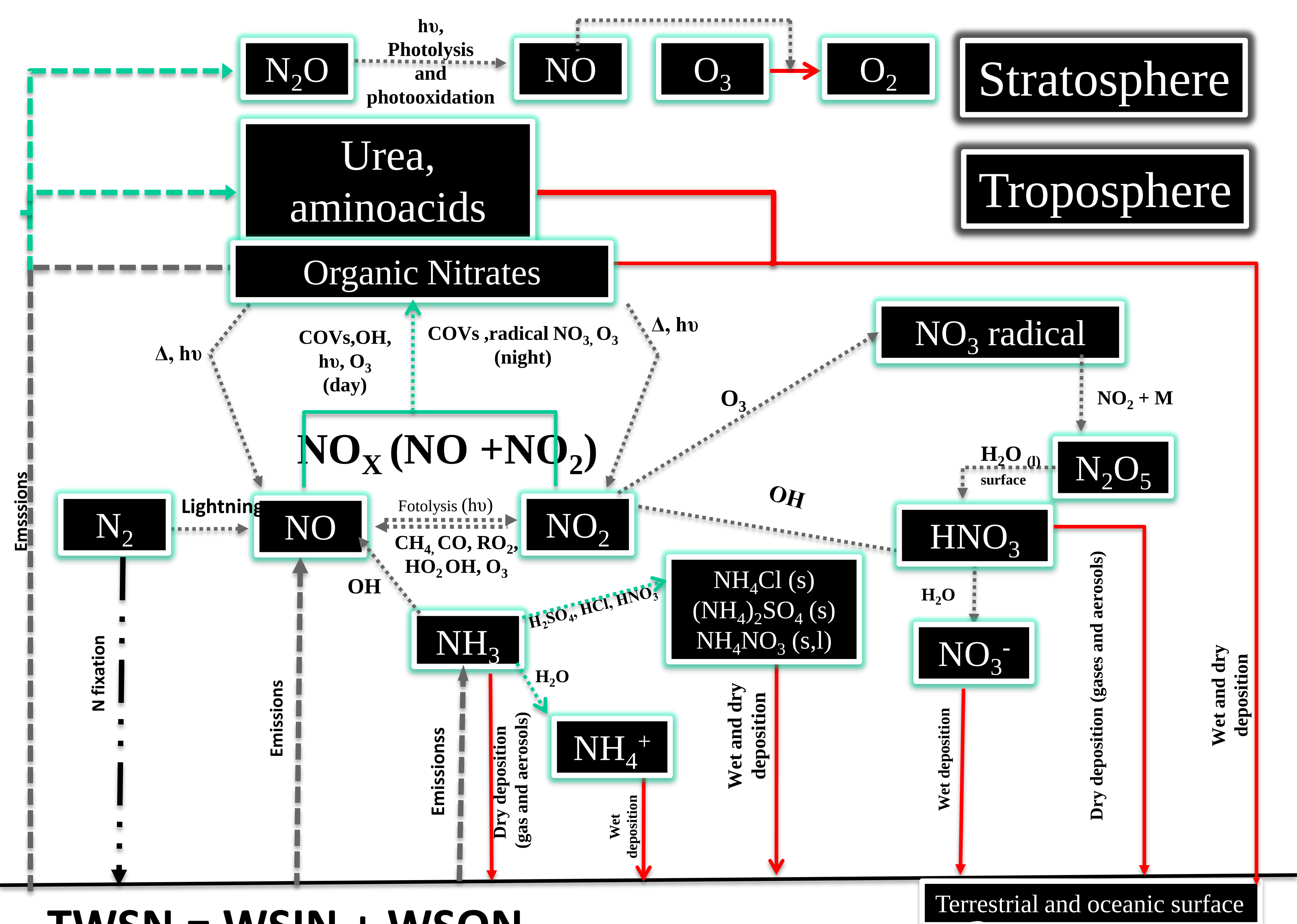
August 6th, 2016.

School of Advanced Science on nitrogen cycling, environmental sustainability and climate change. 31 July – 10 August 2016, São Pedro, SP – Brazil.



TWSN = WSIN + WSON

(Slide borrowed from Rafael Rasse 's PhD thesis defense, Atkinson, 2000; Finlayson-Pitts and Pitts, 2000; Atkinson and Arey, 2003; Seinfeld and Pandis, 2006)

Why N_2O is so relevant after Montreal Protocol?

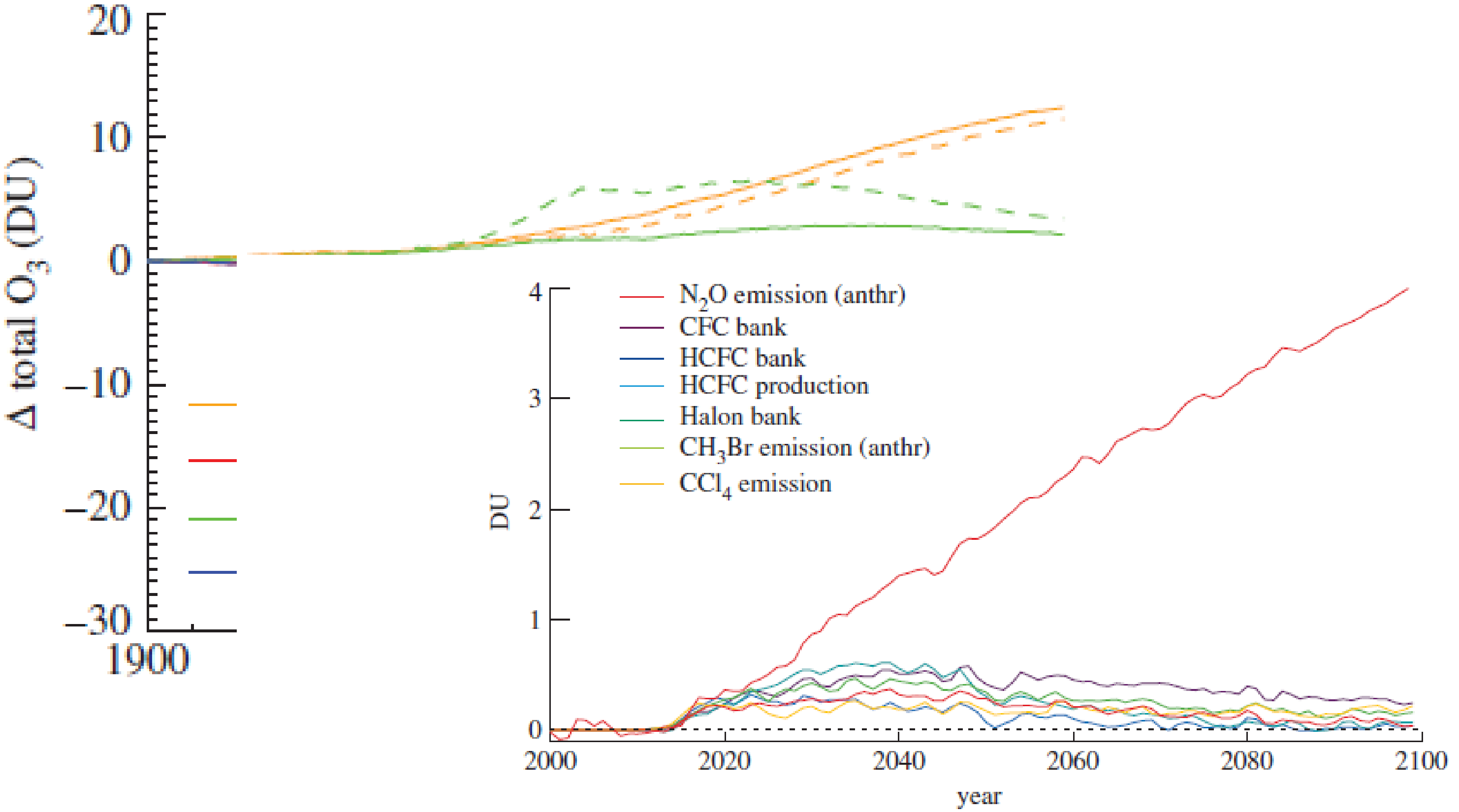
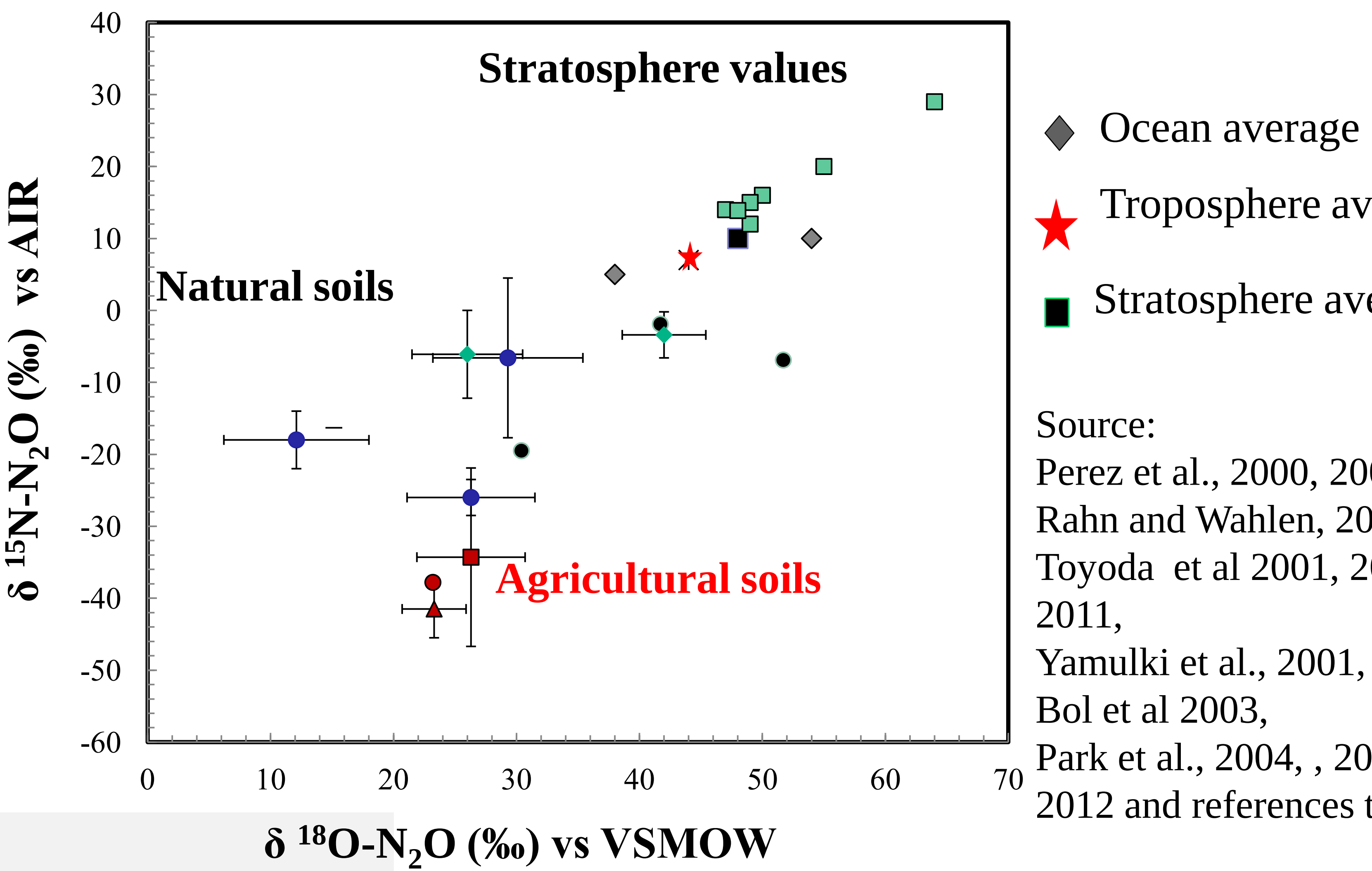


Figure 7. The changes in global mean ozone owing to elimination of anthropogenic N_2O emissions after 2010 when compared with the effect of eliminating the emissions of the CFC banks, HCFC production and banks, the halon banks, anthropogenic methyl bromide and carbon tetrachloride. The elimination of anthropogenic N_2O emission has the largest potential for reducing ozone depletion in the future. Adapted from fig. 4 of Daniel *et al.* [28].

Portmann, R. W. et al., (2012) Stratospheric ozone depletion due to nitrous oxide: influences of other gases.

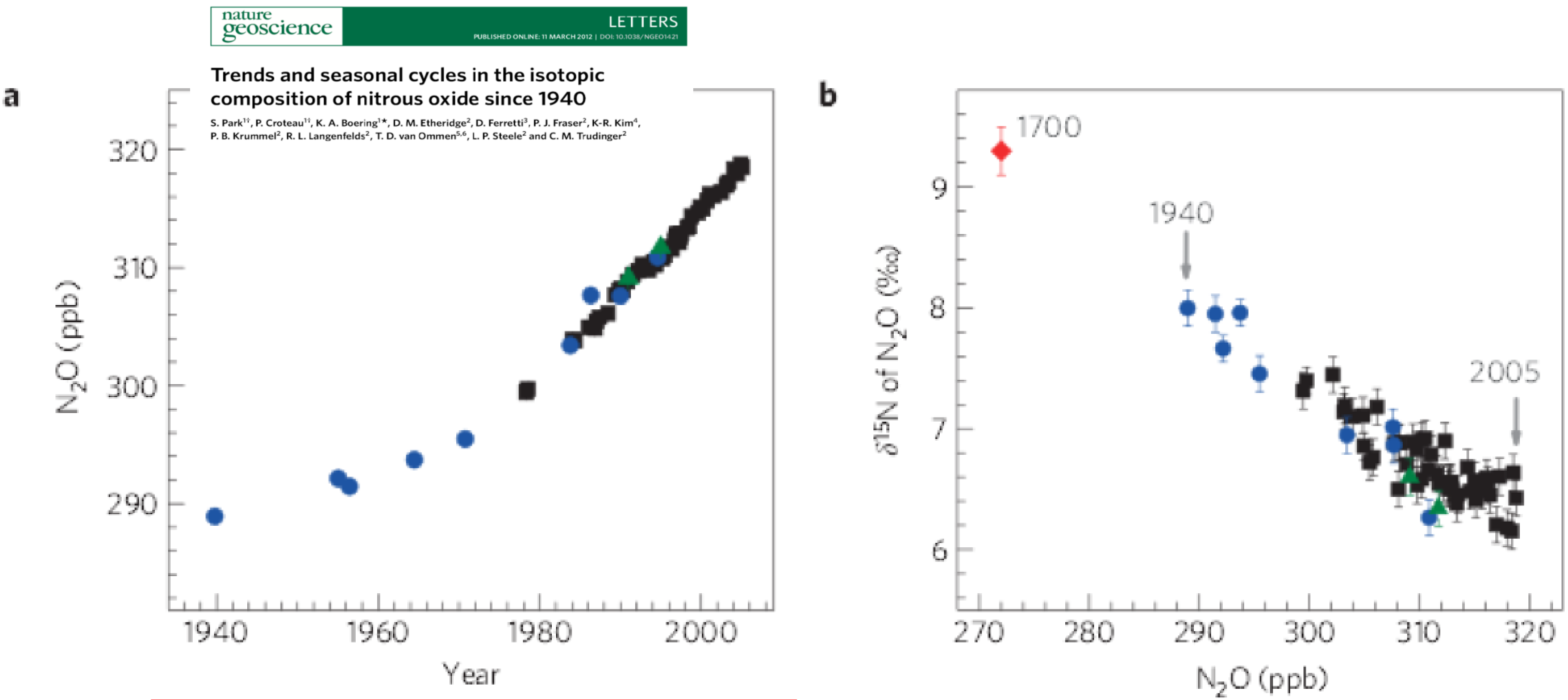
Phil. Trans. R. Soc. B (2012) 367, 1256–1264. doi:10.1098/rstb.2011.0377

Natural ecosystems emitted N_2O that is enriched in ^{15}N compared to fertilized soils



Source:
Perez et al., 2000, 2001;
Rahn and Wahlen, 2000.
Toyoda et al 2001, 2002 and 2011,
Yamulki et al., 2001,
Bol et al 2003,
Park et al., 2004, , 2011, 2012 and references therein)

Tropospheric N_2O isotope trend inferred from archived air samples from Cape Grim



Decrease in $\delta^{15}N$ of 0.3 ‰/decade

Fertilizer use

Hot spots of N_2O found in permafrost peatlands

Peat Circles

Diameter 4 to 25 m
Areas 10 to 500 m^2

Cover ≈ 4% the peat plateau

Peat plateau covers ≈ 20% of Arctic and the total land area of the tundra zone (7.34×10^6 km^2)

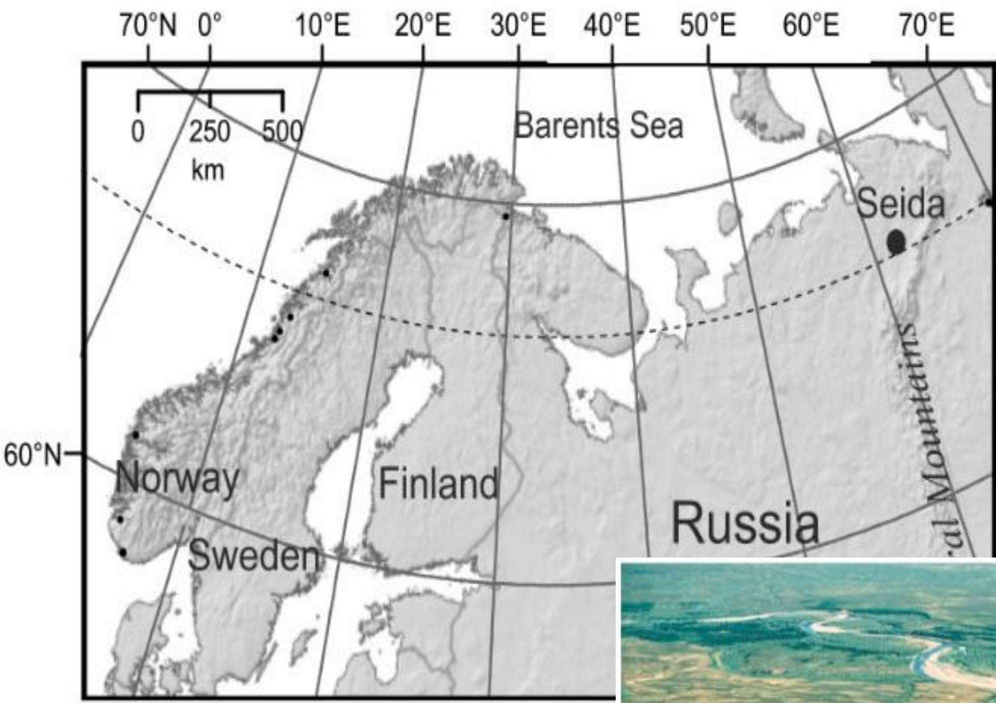
nature geoscience LETTERS
PUBLISHED ONLINE: 15 FEBRUARY 2009 | DOI: 10.1038/NGEO434

Large N_2O emissions from cryoturbated peat soil in tundra

Maija E. Repo[1], Sanna Susiluoto[2], Saara E. Lind[1], Simo Jokinen[1], Vladimir Elsakov[3], Christina Biasi[1], Tarmo Virtanen[2] and Pertti J. Martikainen[1]*

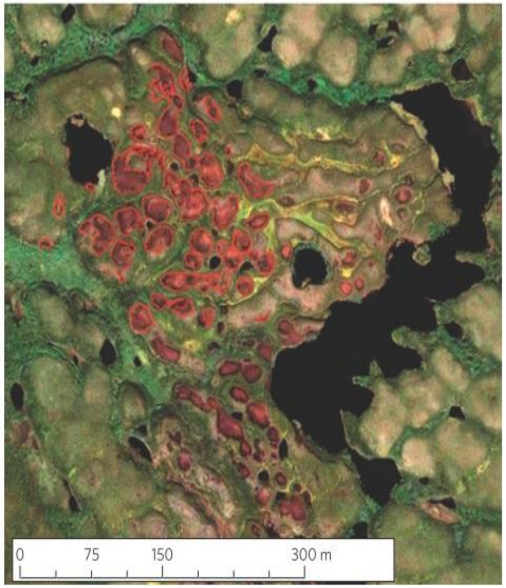
Would the enhanced emissions from tundra pit circles shift tropospheric N_2O isotopic composition?

Study Site



Discontinuous permafrost
Subarctic East European tundra
($62^0$57'E, $67^0$03'N)

Annual precip. ≈ 505 mm
Mean annual temp. ≈ -5.8 °C
Growing season: Mid Jun-August



Research Project DEFROST

Graduate student
Jenie Gil

DEFROST
Impacts of a changing cryosphere-
Depicting ecosystem-climate feedbacks from permafrost, snow and ice

J. Gil[1], T. Perez, K. Boering, P.J. Martikainen, C. Biasi

Academy of Finland, project CryoN 2010-2014
European Union 7th Framework Program under project(DEFROST)-Nordic Centre of Excellence Program

We wanted to know also which microbial/chemical processes contribute to the pit circle N_2O production

Bare peat soil profile

3 soil profile (PC1;PC2;PC3)

[N_2O]; [CO_2]
$\delta^{15}N_2O$; $\delta^{18}O$; ^{15}N-SP
[NH_4] ; [NO_3] and $\delta^{15}N$
Soil T; [O2]; soil moisture

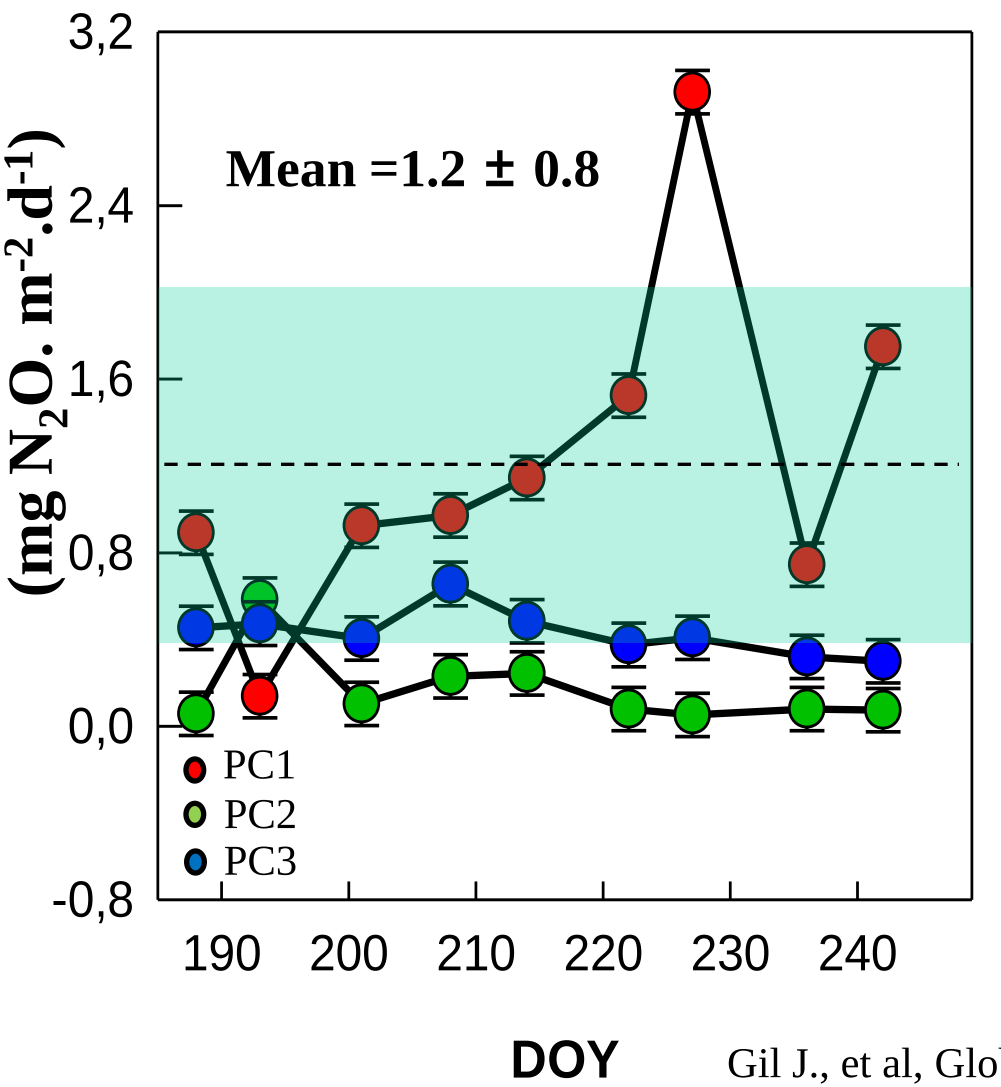
Bare peat soil surface (Static chamber)

3 bare surface (PC1;PC2; PC3; 5 frames)

N_2O and CO_2 Fluxes
$\delta^{15}N_2O$; $\delta^{18}O$; ^{15}N-SP
[NH_4] ; [NO_3] and $\delta^{15}N$
Soil environmental parameters
Weather measurements

Bare peats surface in sub-arctic tundra emit substantial amounts of N_2O

0.1 to 3.4 mg N_2O m^{-2} d^{-1}



Tropical forests
(0.09 – 2.5 mg N_2O m^{-2} . d^{-1})

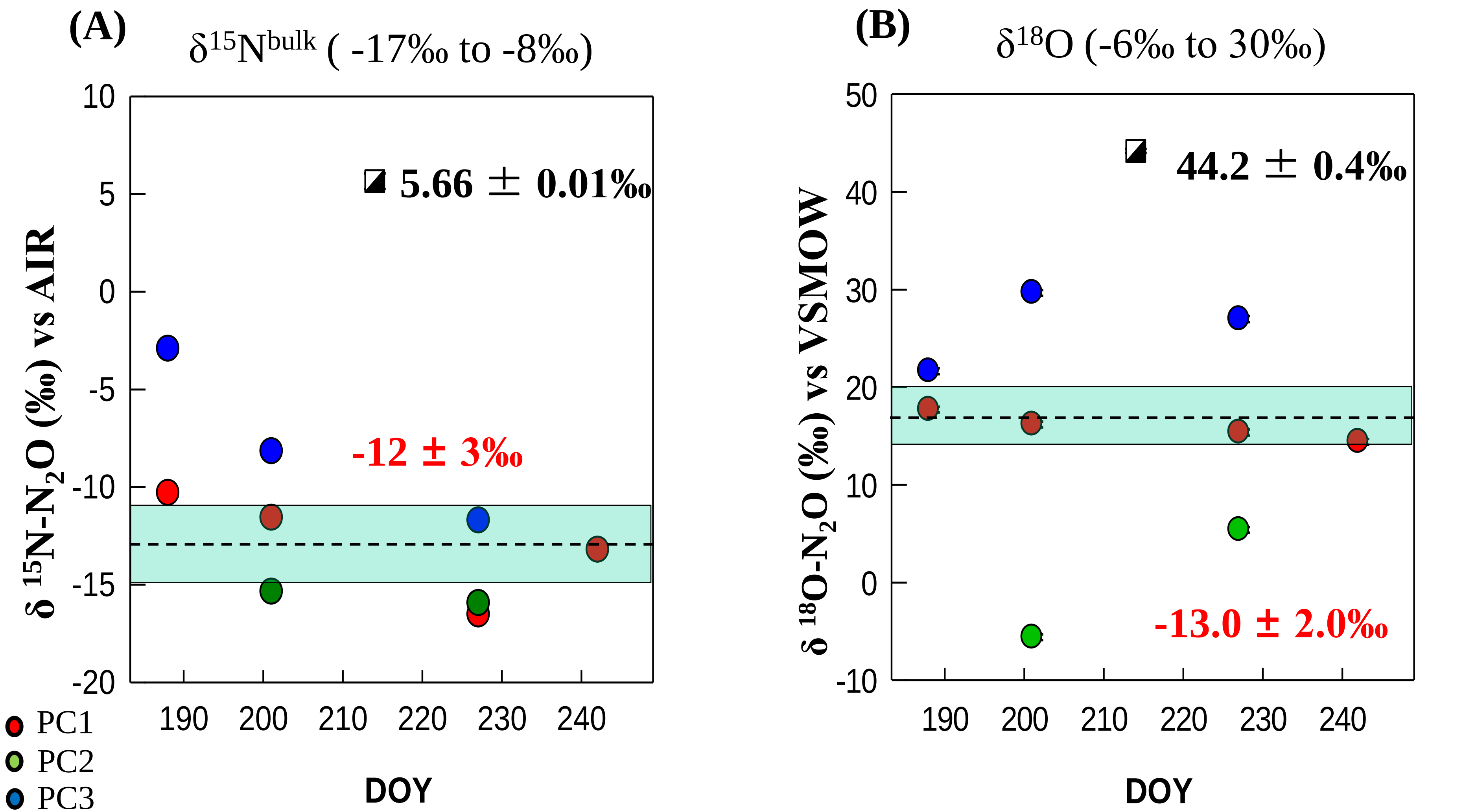
Drained boreal peatlands/agriculture
(0.1 – 15.1 mg N_2O. m^{-2} . d^{-1})

2007 (1.9 – 31 mg N_2O. m^{-2}. d^{-1})

2008 (3.7 – 13.9 mg N_2O. m^{-2}. d^{-1})

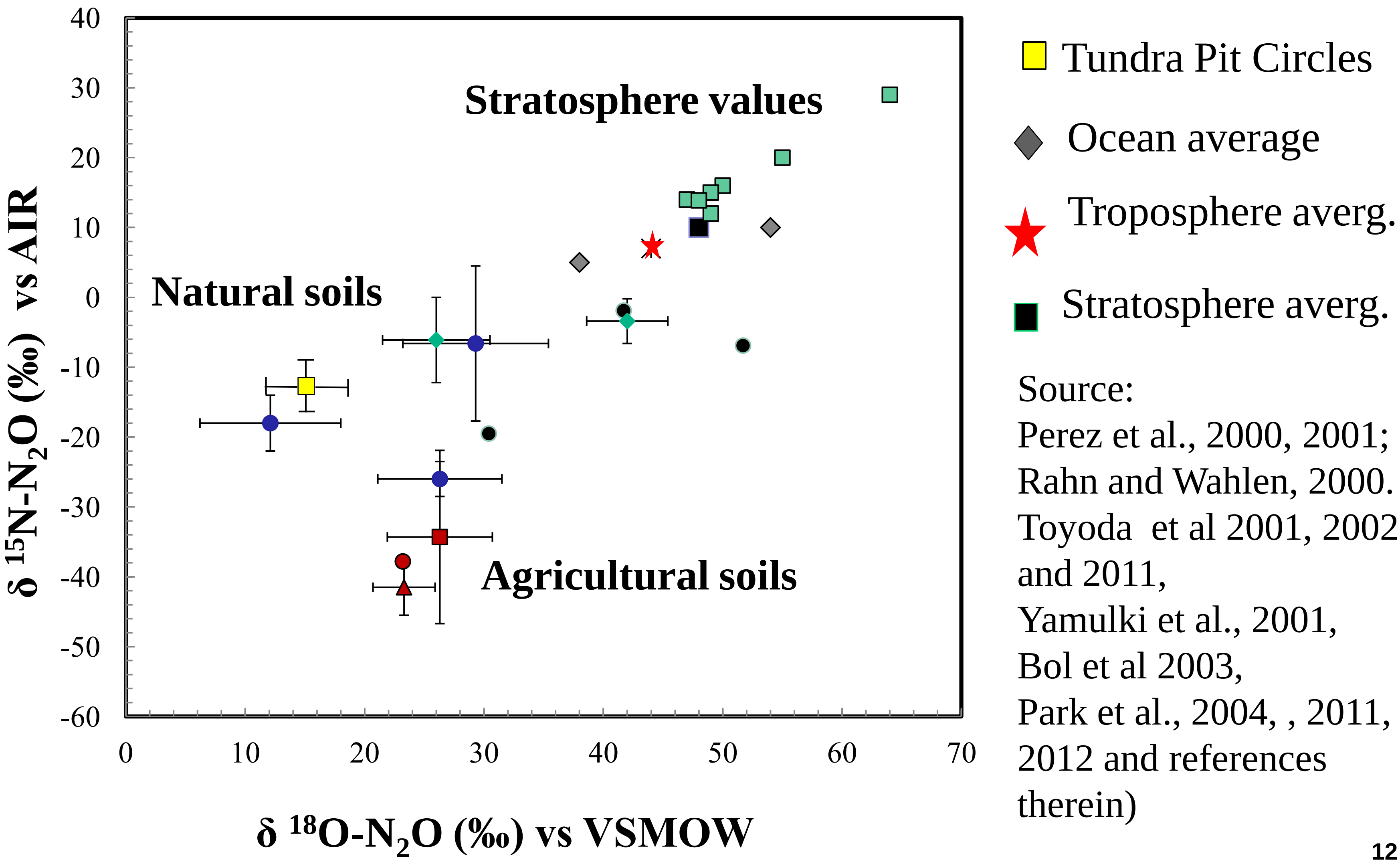
Gil J., et al, Global Biogeochemical Cycles under final revisions

The first data for $\delta^{15}N^{bulk}$ of N_2O emitted from Arctic tundra so far…



Gil J., et al, Global Biogeochemical Cycles under final revisions

Natural ecosystems emitted N_2O that is enriched in ^{15}N compared to fertilized soils



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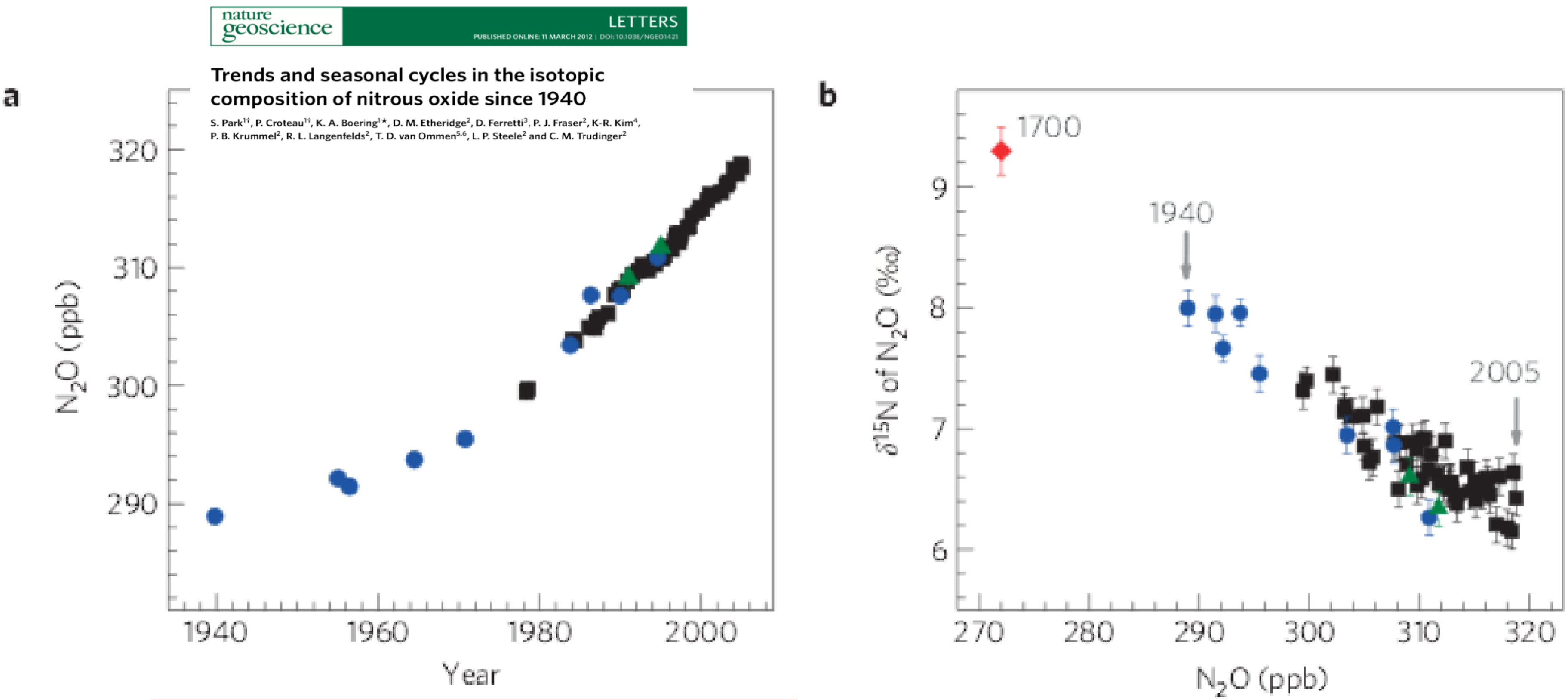
Yamulki et al., 2001,
Bol et al 2003,
Park et al., 2004, , 2011, 2012 and references therein)

Gil J., et al, Global Biogeochemical Cycles under final revisions

N_2O isotope trend might slow down due to global warming of artic tundra



Decrease in $\delta^{15}N$ of 0.3 ‰/decade

Fertilizer use

Reactive Nitrogen (Nr) in the troposphere

Ecosystem relevant nitrogen species

Reactive nitrogen (Nr-trace levels)

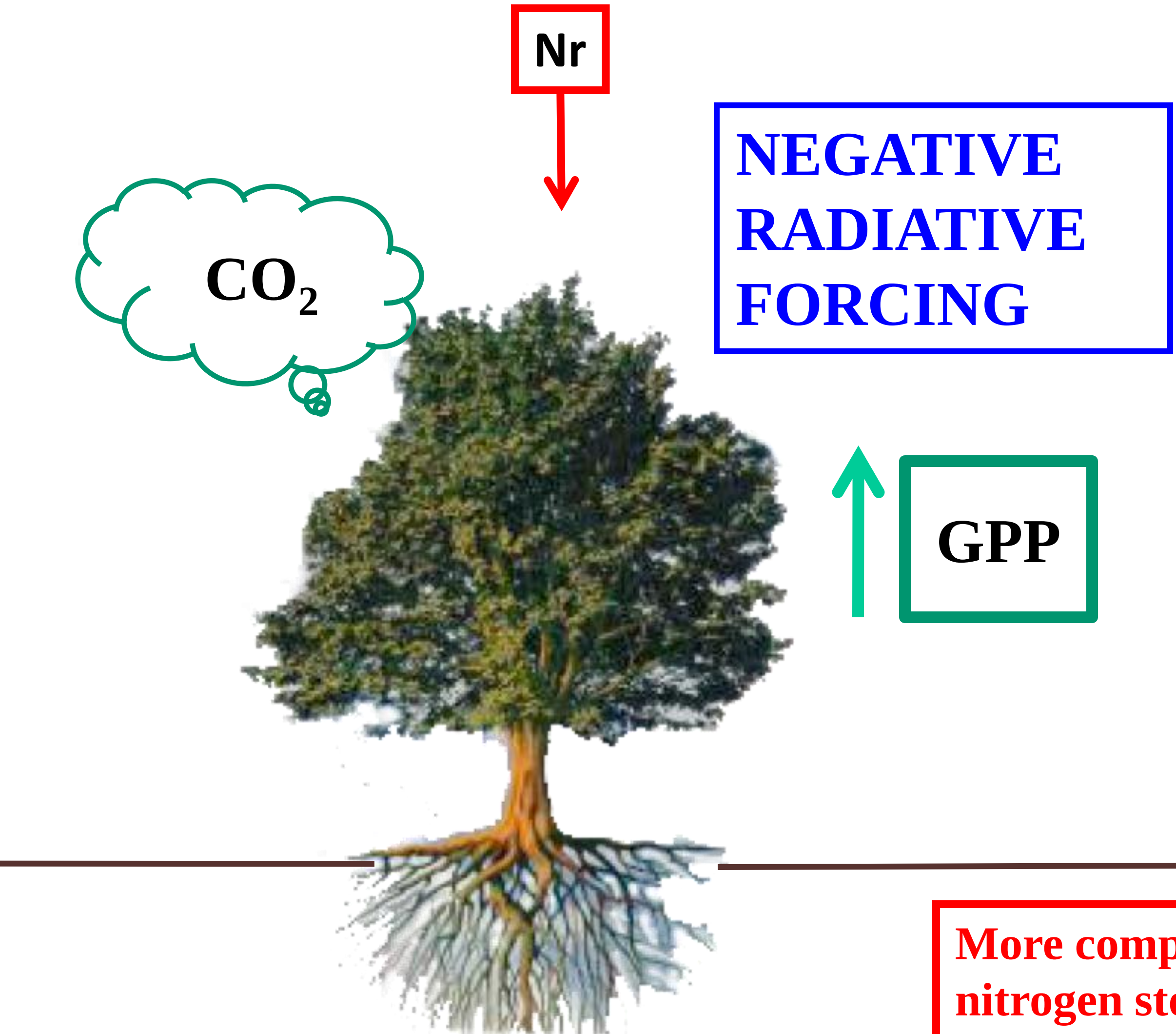
Inorganic	Organic
NH_3	Urea
NH_4^+	Aminoacids
$NO_x(NO+NO_2)$	Proteins
HNO_3	Nucleic acids
N_2O	Organic nitrates
Radical NO_3	Plant derived part

WSIN (NH_4^++NO_3^-+NO_2^-):

WSON:

TOTAL DISSOLVED NITROGEN (TDN)=WSIN + WSON

Why Nr matters on an global perspective



FLUXNET temperate evergreen needleleaf forest sites.
NPP ↑ with ↑ nitrogen deposition (up to 8Kg N/ha yr).

Tropical forest (not N limited) sites need more information particularly systematic Nr atmospheric deposition network

More comprehensive measurements of nitrogen stocks and cycling at the global network of carbon monitoring sites are required

Fleischer et al., 2013, GBC 27 (1), 187–199.

All the Nr species have been considered?

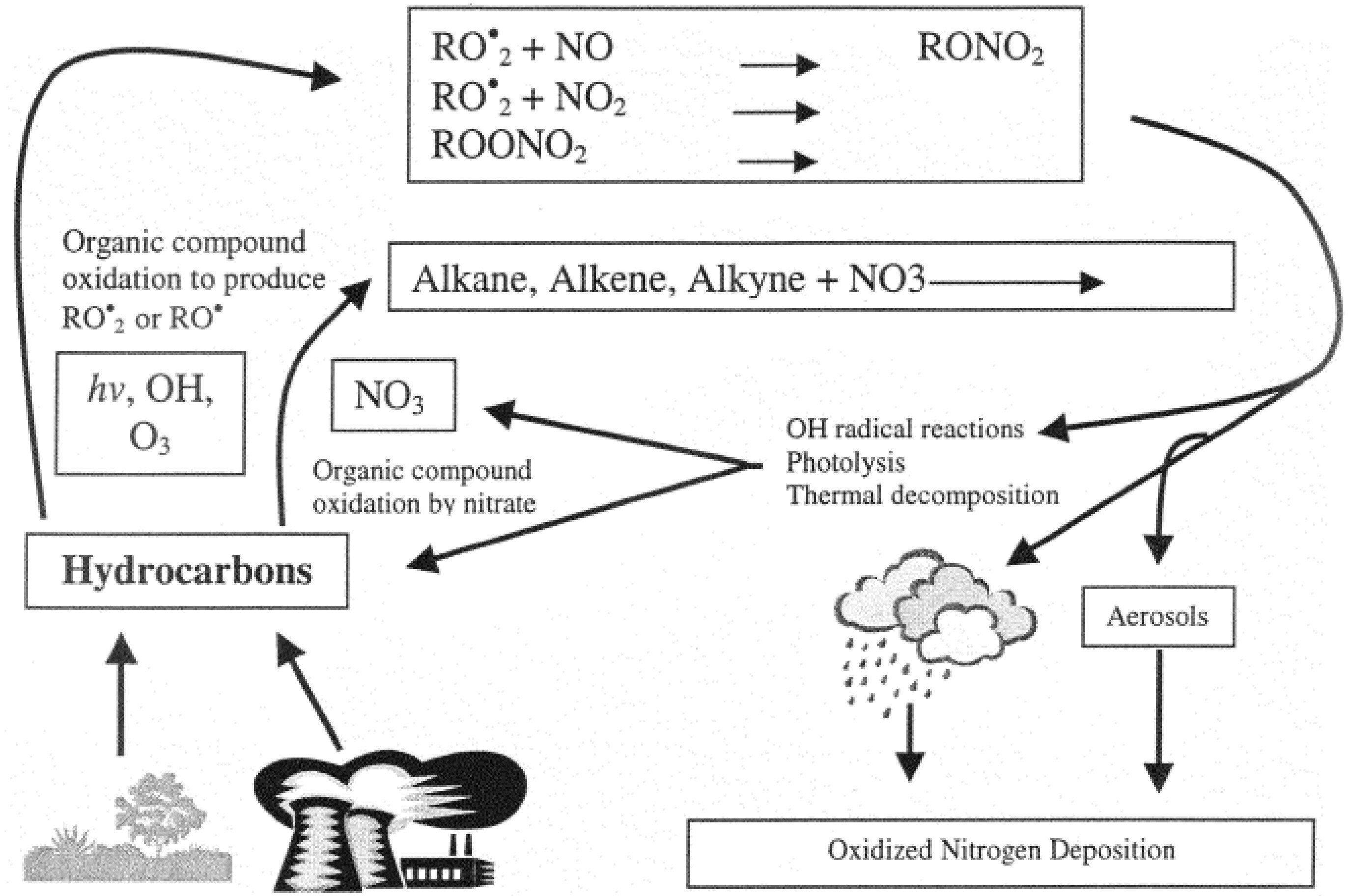
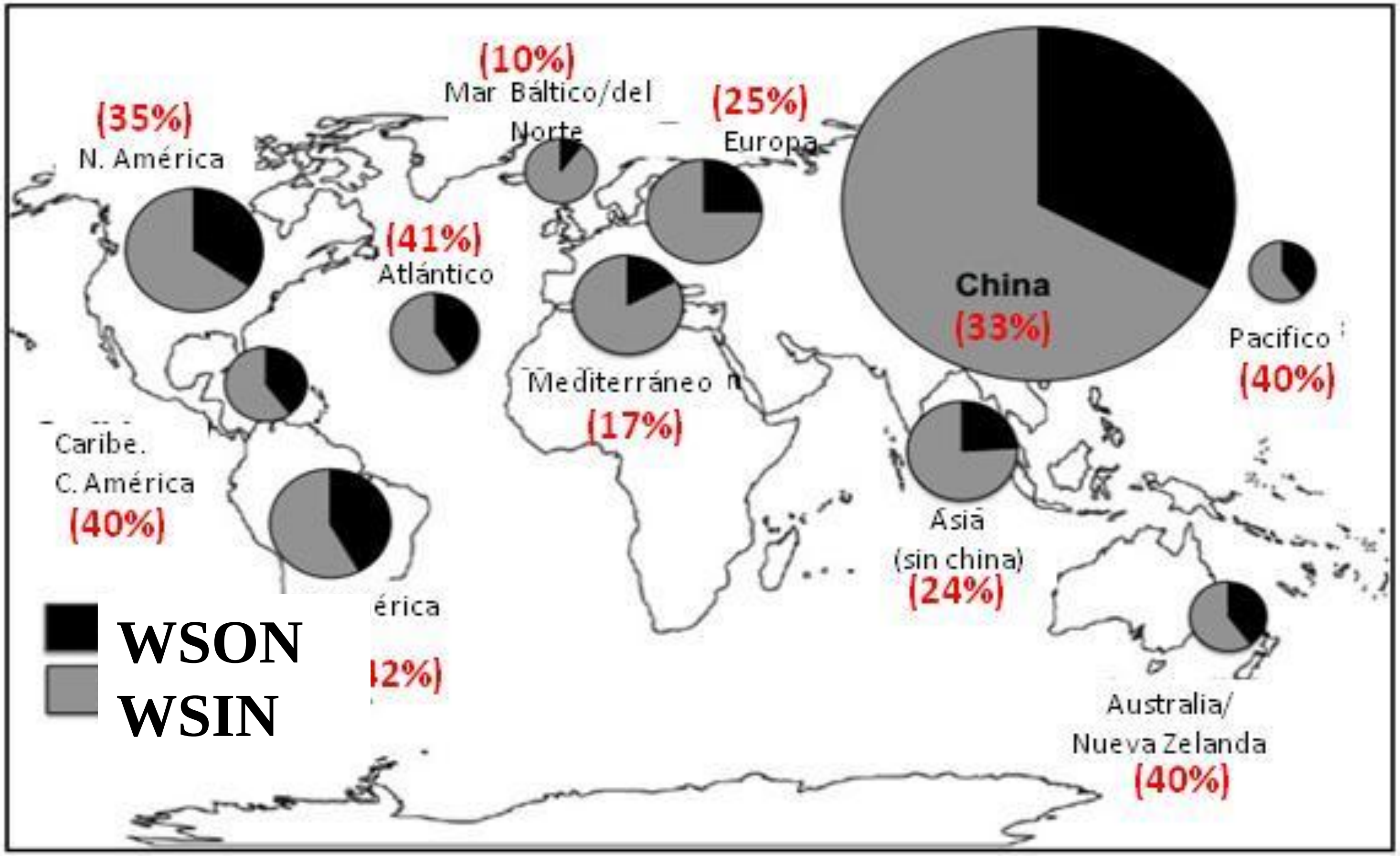


Figure 1. Simplified gas phase formation reactions and removal processes for organic, oxidized N species.

Neff, J. et al (2002). The origin, composition and rates of organic nitrogen deposition: A missing piece of the nitrogen cycle? Biogeochemistry 57/58: 99–136, 200

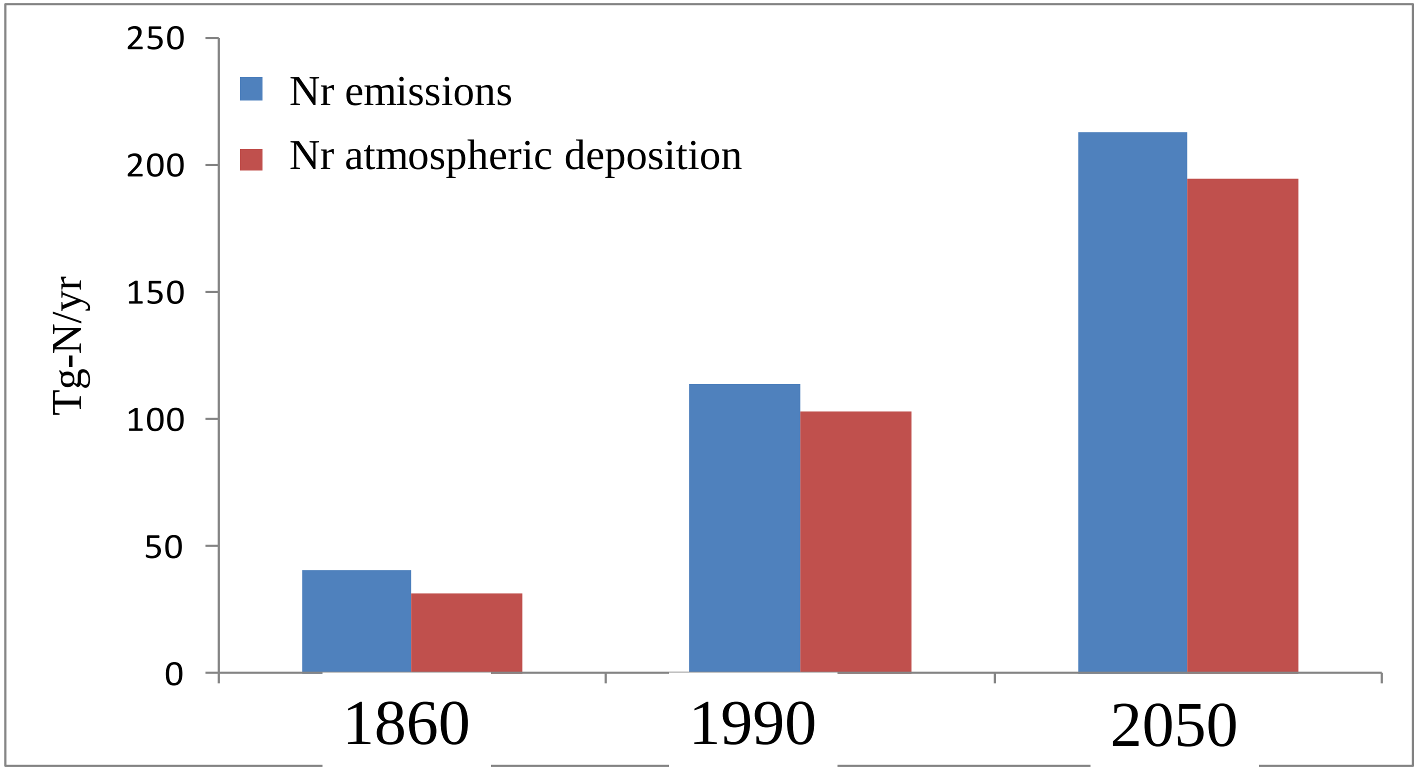
Relative contribution of WSON to Nr in wet deposition

(32 ± 11)%



Cornell (2011). Environmental Pollution 159:2214

Global reactive nitrogen (Nr) change through time

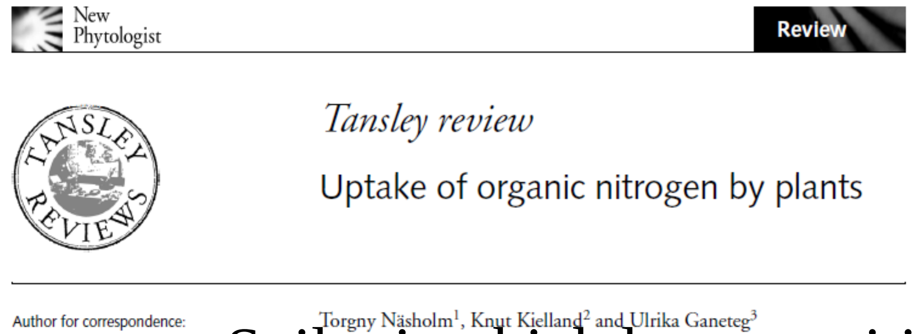


WSON is not included

(Galloway et al., 2004. Biogeochemitsry. 70)

Bioavailability of WSON

Plants


New Phytologist

Review

Tansley review

Uptake of organic nitrogen by plants

Author for correspondence:

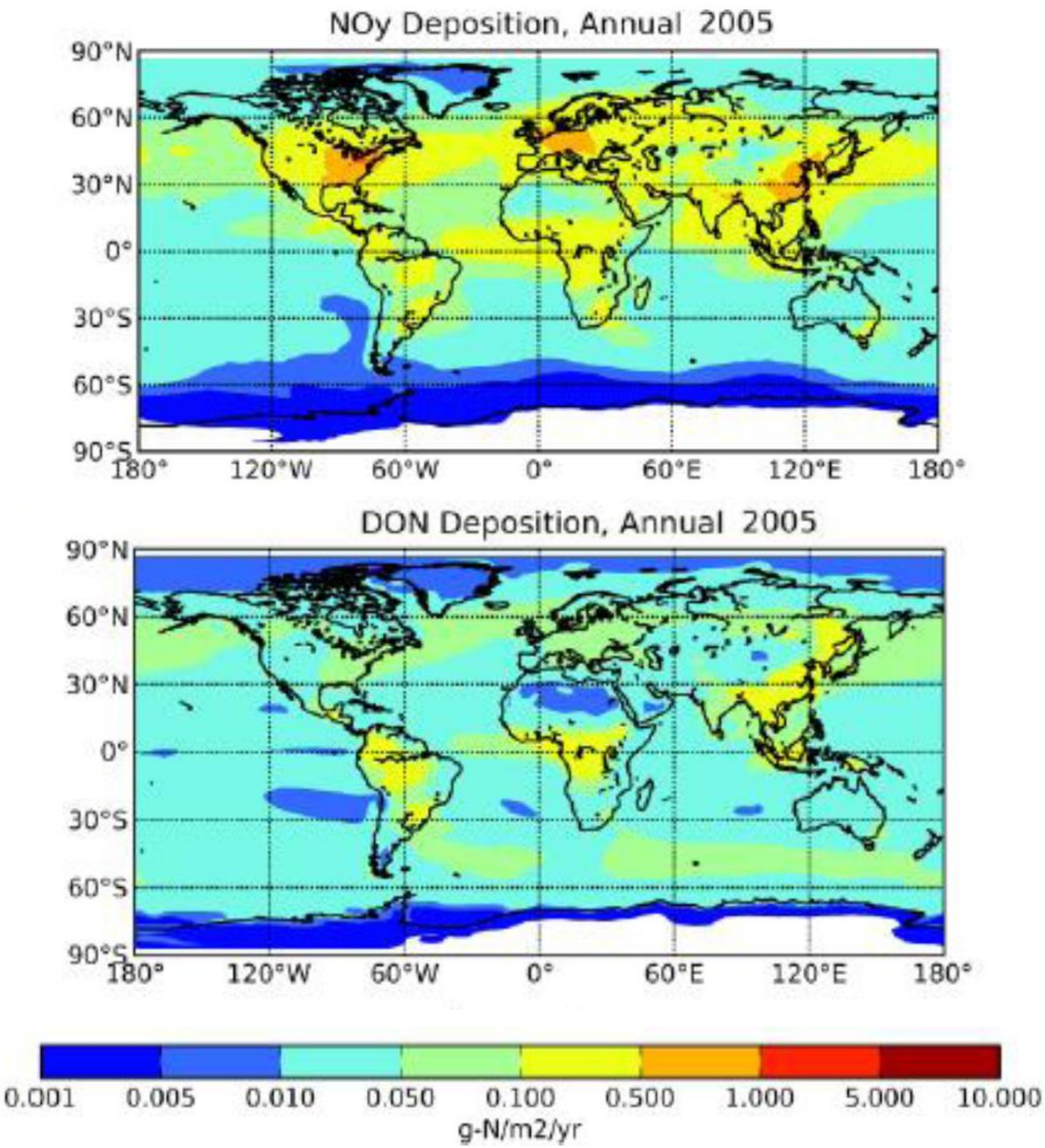
Torgny Näsholm[1], Knut Kielland[2] and Ulrika Ganeteg[3]

Ocean

Soils

Soil microbial decomposition of bioavailable organic nitrogen

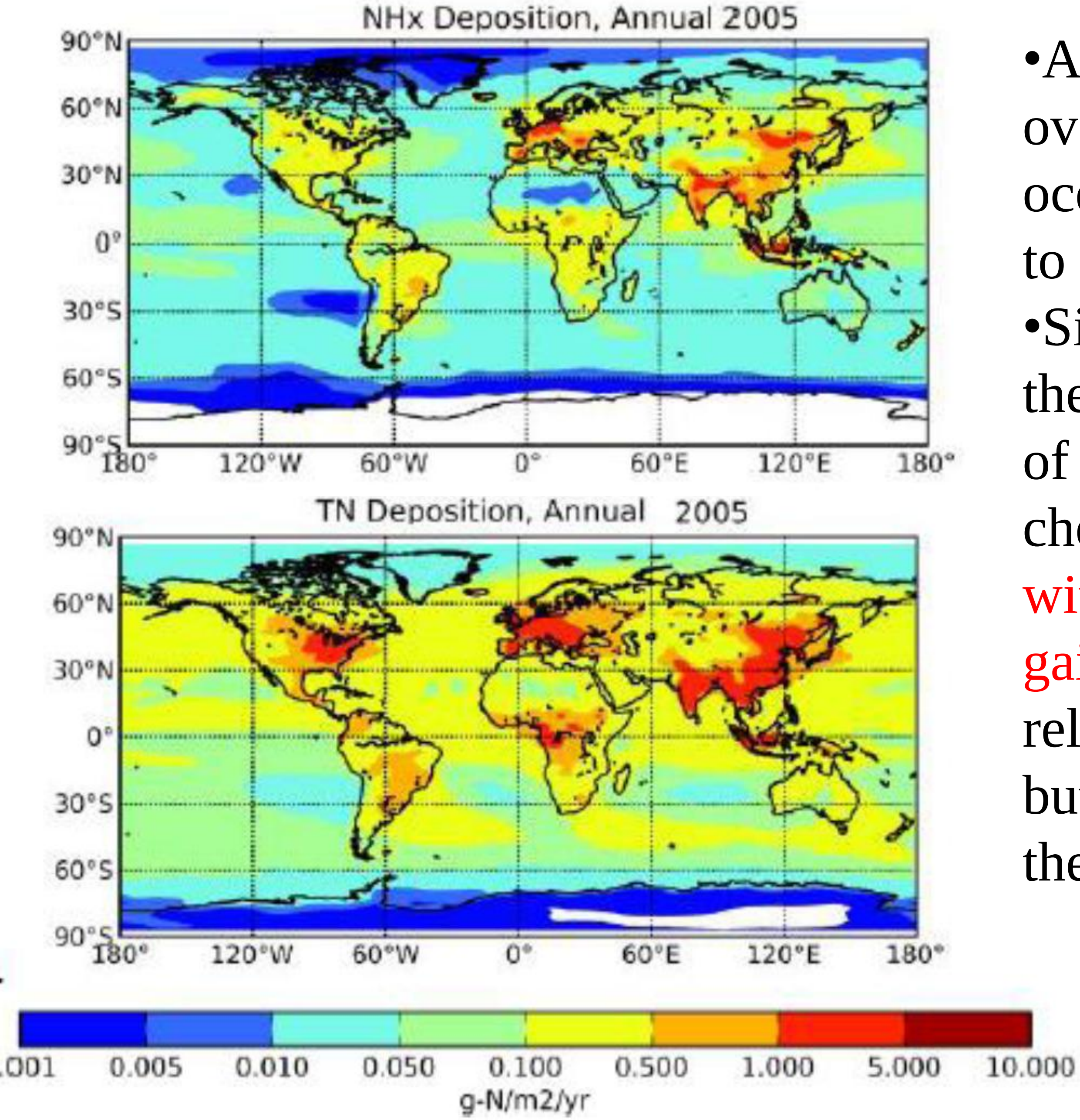
Bioavailability of DON			
DON	**bioavailability of DON (%)**	**Time of uptake**	**References**
Estuarines	**40-72**	**10-15 days**	**Seitzinger and Sanders 1999**
Aquatic Systems	**12-72**	**Days –weeks**	**Bronk 2002**
Marine ecosystem	**20-30**	**-**	**Violaki et al., 2009**
Marine ecosystem	**46-80**	**-**	**Wedyan et al., 2007**
Marine ecosystem	**20-30**	**hours –few days**	**Peierls and Paerl, 1997**



Atmospheric chemistry-transport model (TM4-ECPL)

- •Organic nitrogen 60% anthropogenic.
- •Total N deposition estimate increases by about 20% relative to simulations without ON.
- •About 20-25% of total deposited N is ON.
- •About 10% of the emitted nitrogen oxides are deposited as ON instead of inorganic nitrogen(IN) as is considered in most global models.

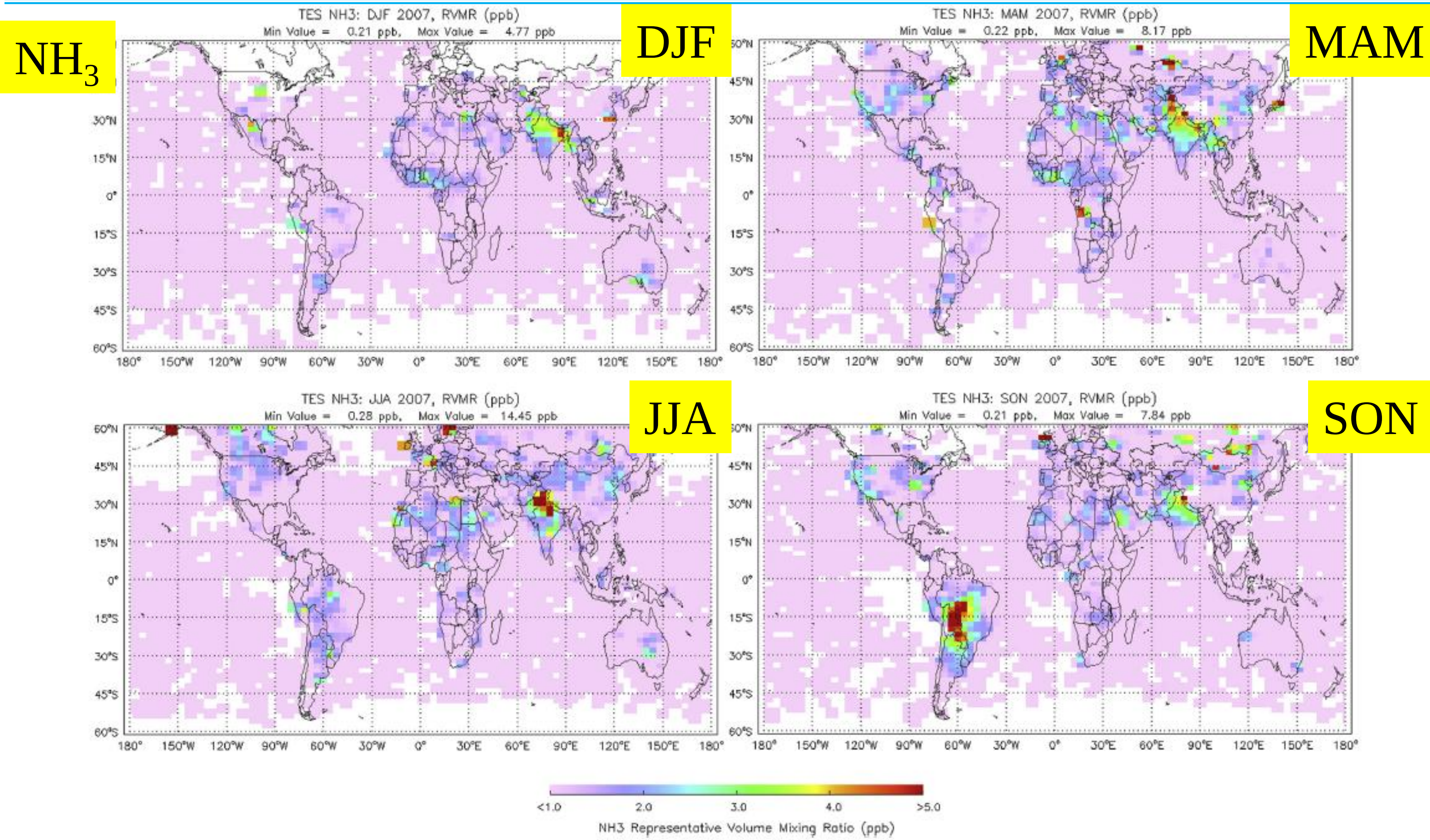
Kanakidou, M., S. et al 2016: Past, Present and Future Atmospheric Nitrogen Deposition. J. Atmos. Sci. doi:10.1175/JAS-D-15-0278.1, in press.



- Almost a 3-fold increase over land (2-fold over the ocean) of TN from 1850 to present.
- Significant changes in the regional distribution of N deposition and chemical composition, with reduced compounds gaining importance relative to oxidized ones, but very small changes in the global total flux.

Kanakidou, M., S. et al 2016: Past, Present and Future Atmospheric Nitrogen Deposition. J. Atmos. Sci. doi:10.1175/JAS-D-15-0278.1, in press.

Satelite information a valuable tool for global Nr estimates



Luo, M. et al., 2015. Satellite observations of tropospheric ammonia and carbon monoxide: Global distributions, regional correlations and comparisons to model simulations. Atmospheric Environment 106 (2015) 262-277.

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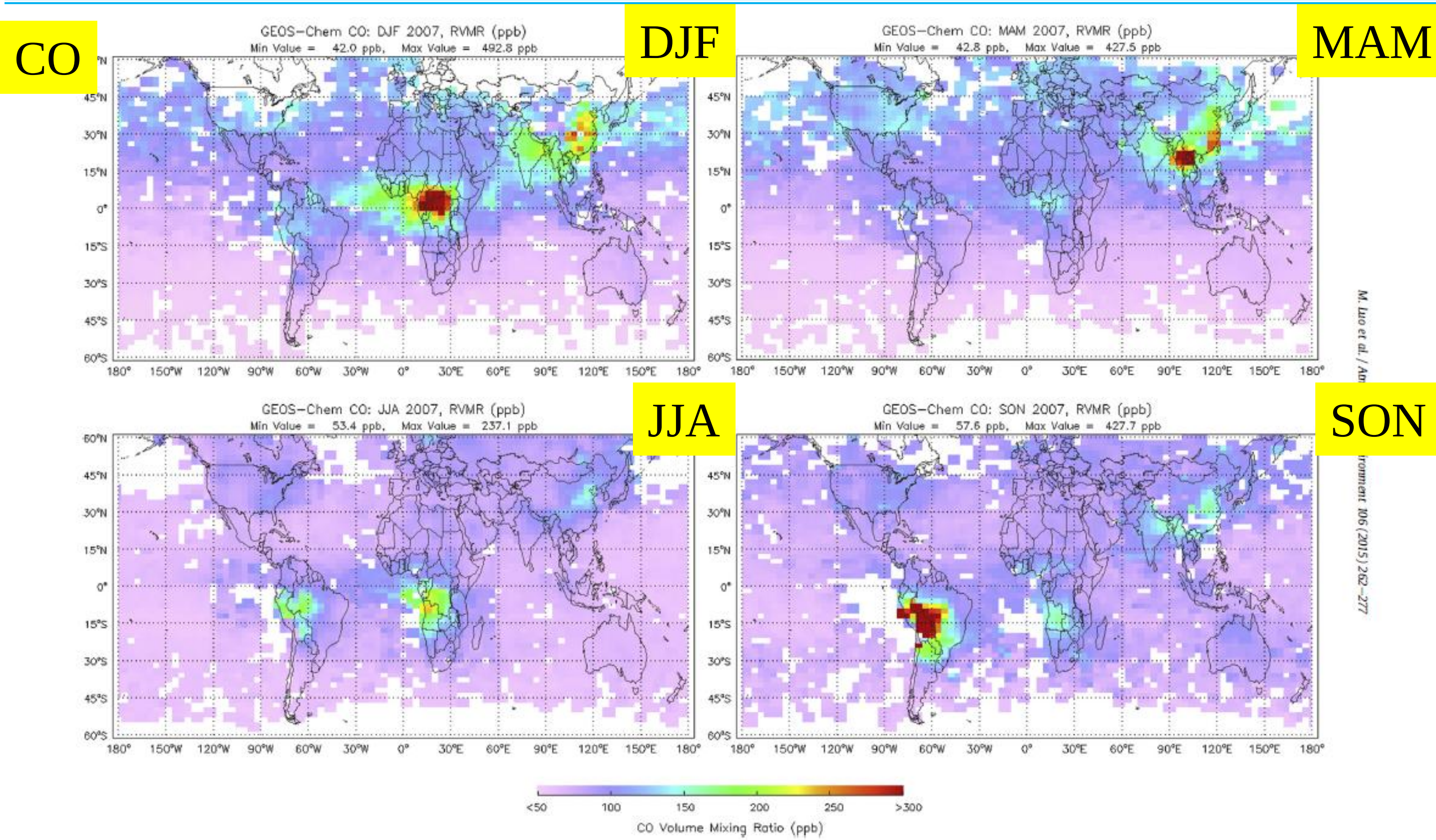

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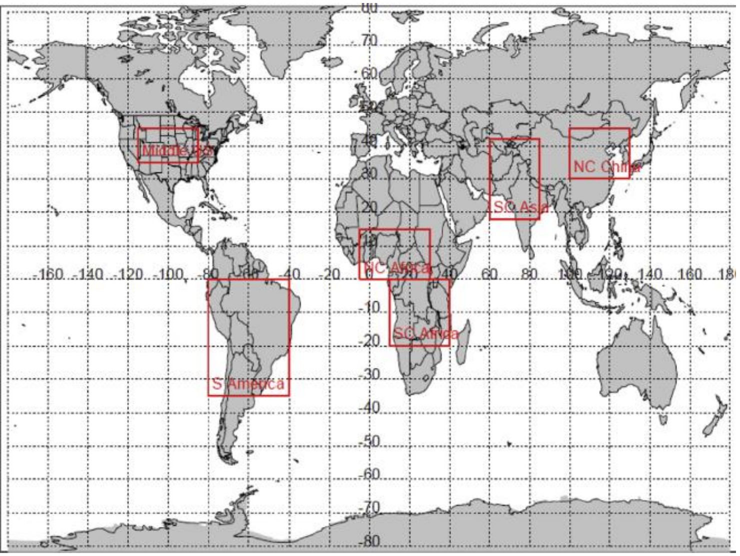
Partitioning NH_3 sources

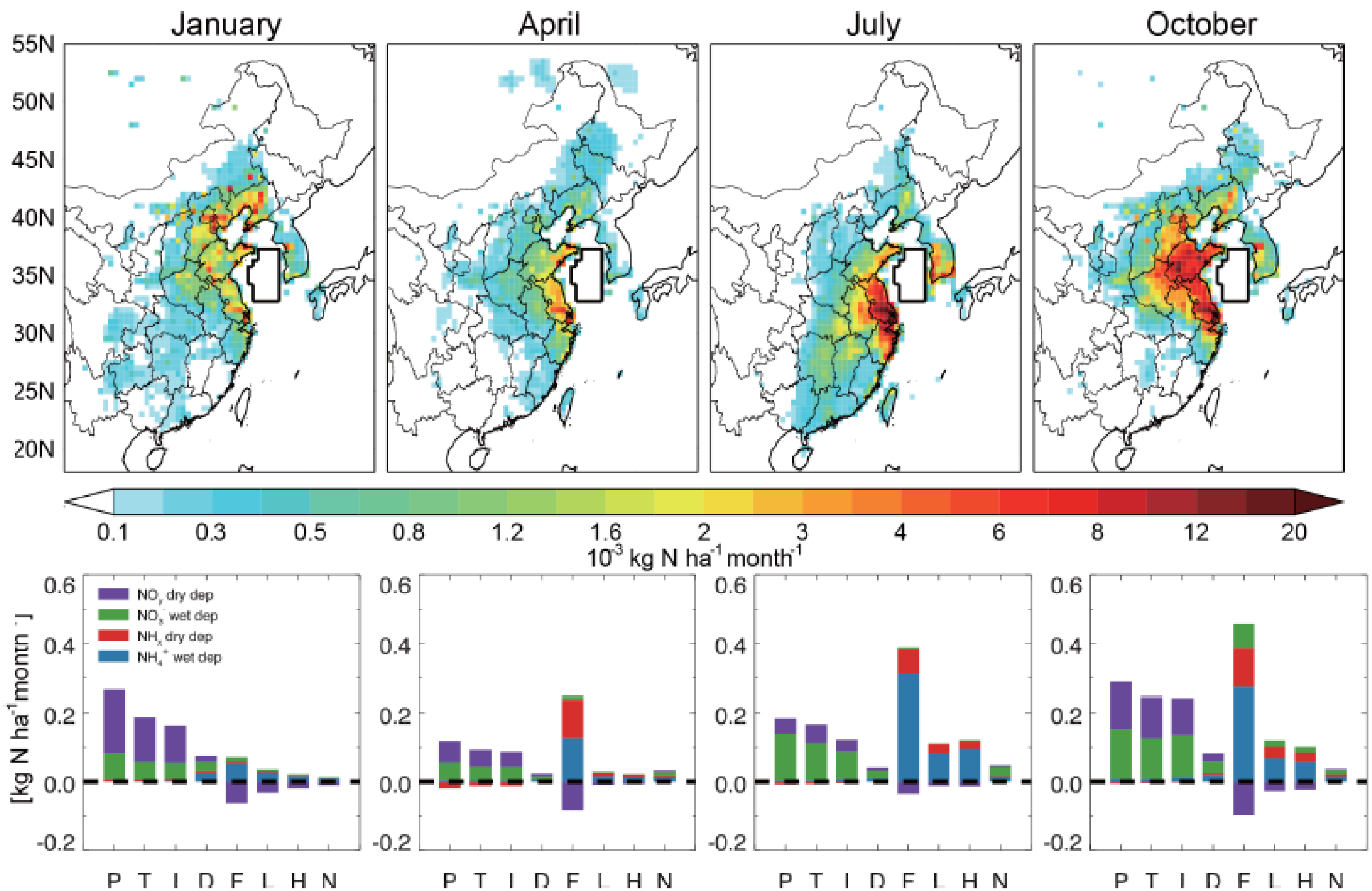
NH_3/CO



Region	Season	TES		GC		Class
		Slope	Corr Coef	Slope	Corr Coef	
SC Asia	DJF	0.052±0.002	0.61	0.019±0.001	0.61	High NH_3
	MAM	0.041 ±0.002	0.38	0.029±0.001	0.46	High NH_3
	JJA	0.120 ±0.005	0.44	0.082 ±0.003	0.37	High NH_3
	SON	0.047±0.002	0.45	0.027±0.001	0.52	High NH_3
NC China	DJF					
	MAM	0.015±0.001	0.24	0.017±0.002	0.14	High NH_3
	JJA	0.018±0.001	0.09	0.032 ±0.001	0.45	High NH_3
	SON	0.038±0.001	0.12	0.026±0.002	0.44	High NH_3
Mid US	DJF					
	MAM					
	JJA	0.049±0.002	0.28	0.041 ±0.002	0.34	High NH_3
	SON	0.082±0.009	0.12	0.048±0.004	0.55	High NH_3
Average		**0.051±0.003**		**0.036±0.002**		**High NH_3**
S America	DJF					
	MAM					
	JJA					
	SON	0.015±0.000	0.64	0.011±0.000	0.74	BB
SC Africa	DJF					
	MAM					
	JJA	0.013±0.001	0.11	0.014±0.001	0.62	BB
	SON	0.011±0.001	0.19	0.016±0.001	0.70	BB
NC Africa	DJF	0.014±0.001	0.52	0.008±0.000	0.73	BB
	MAM	0.023±0.001	0.38	0.017±0.001	0.37	BB
	JJA					
	SON					
Average		**0.015±0.001**		**0.013±0.001**		**BB**

Luo, M. et al., 2015. Satellite observations of tropospheric ammonia and carbon monoxide: Global distributions, regional correlations and comparisons to model simulations. Atmospheric Environment 106 (2015) 262-277.

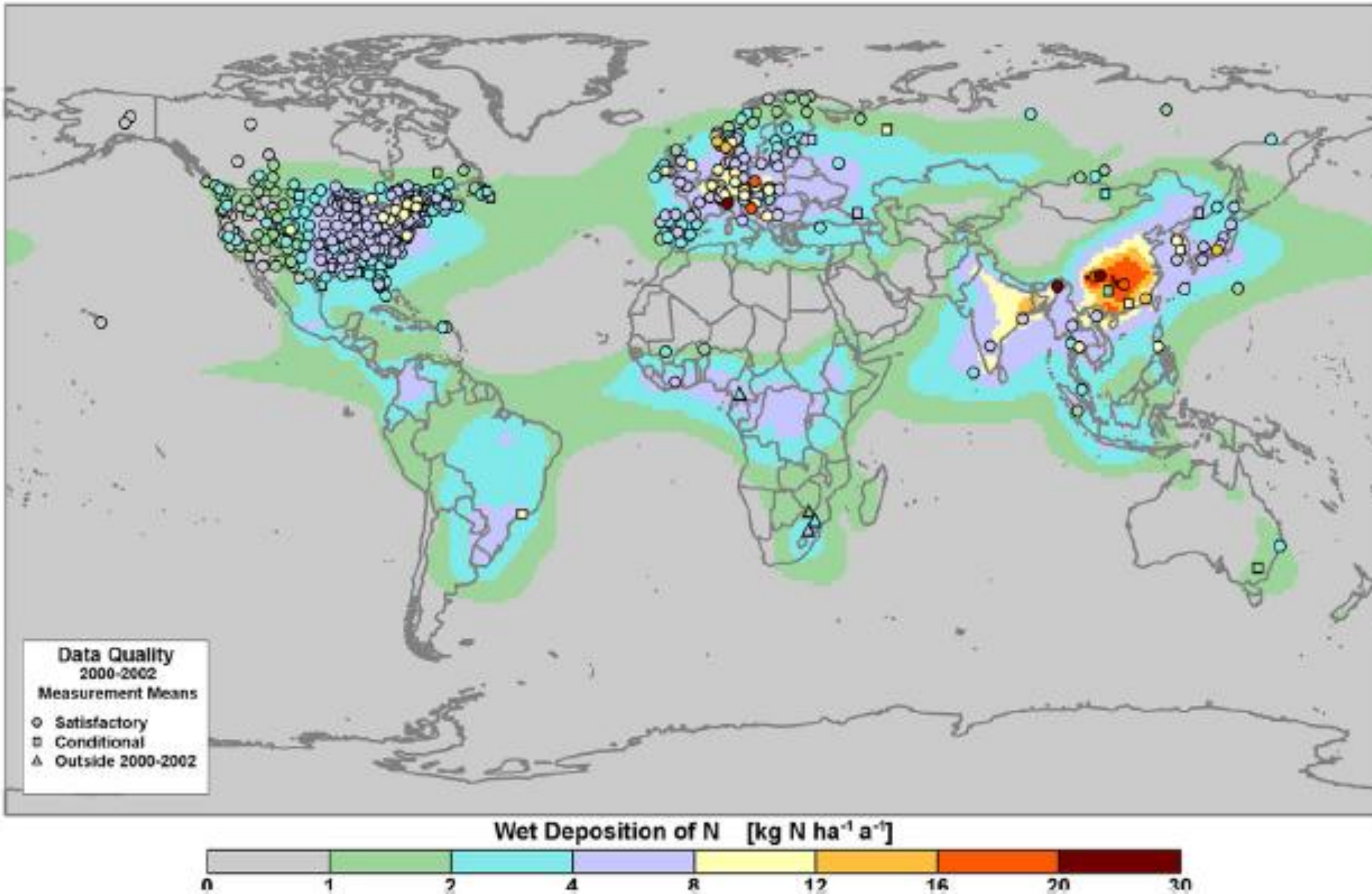
Partitioning N_r sources



P=Power plant
T=Transport
I=Industry
D=Domestic
F=Fertilizer use
L=Livestock
H=Human waste
N=Natural emissions

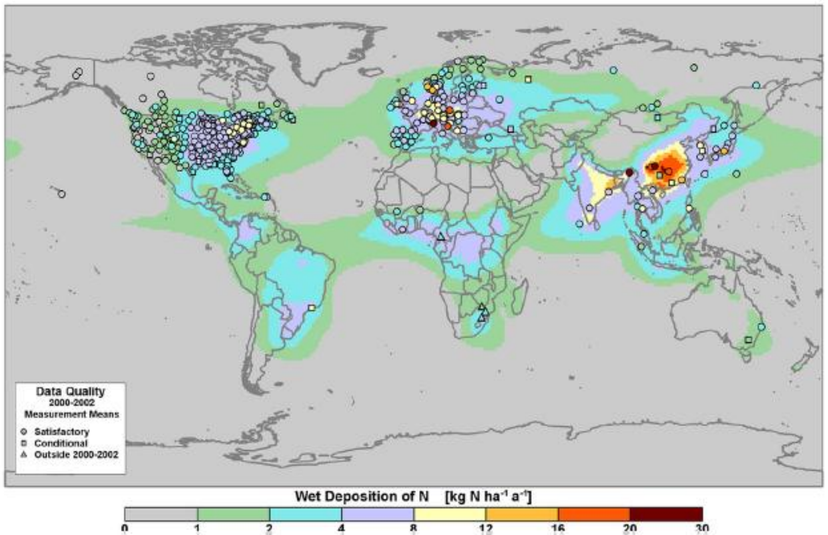
Zhao, Y. et al., 2015.Atmospheric nitrogen deposition to the northwestern Pacific: seasonal variation and source attribution. Atmos. Chem. Phys., 15, 10905–10924.

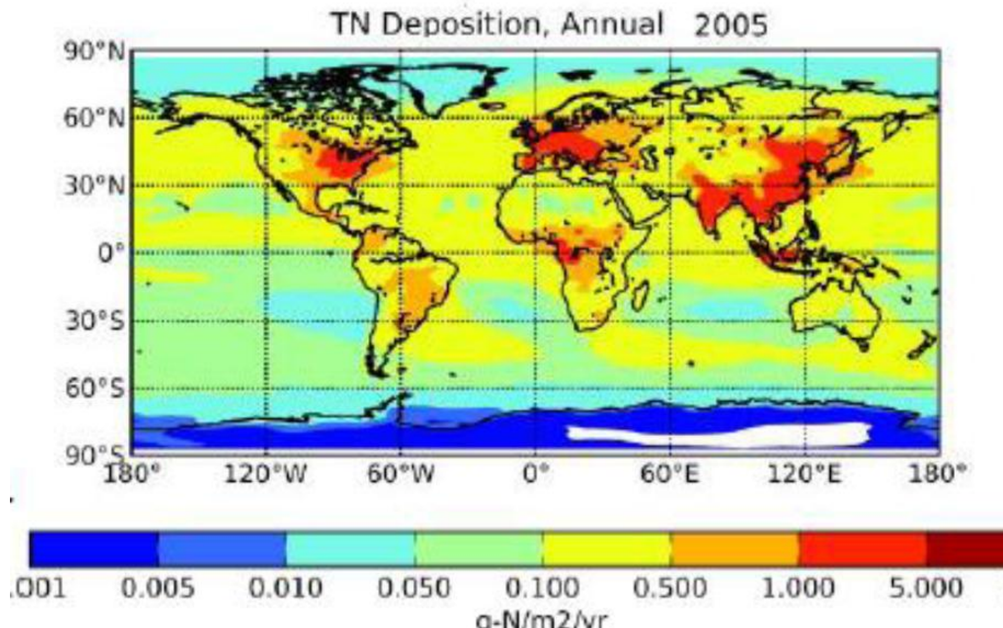
Ground based N_r monitoring



Vet, R. et al (2014). A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. Atmospheric Environment 93. 3-100.

Comparison between estimates

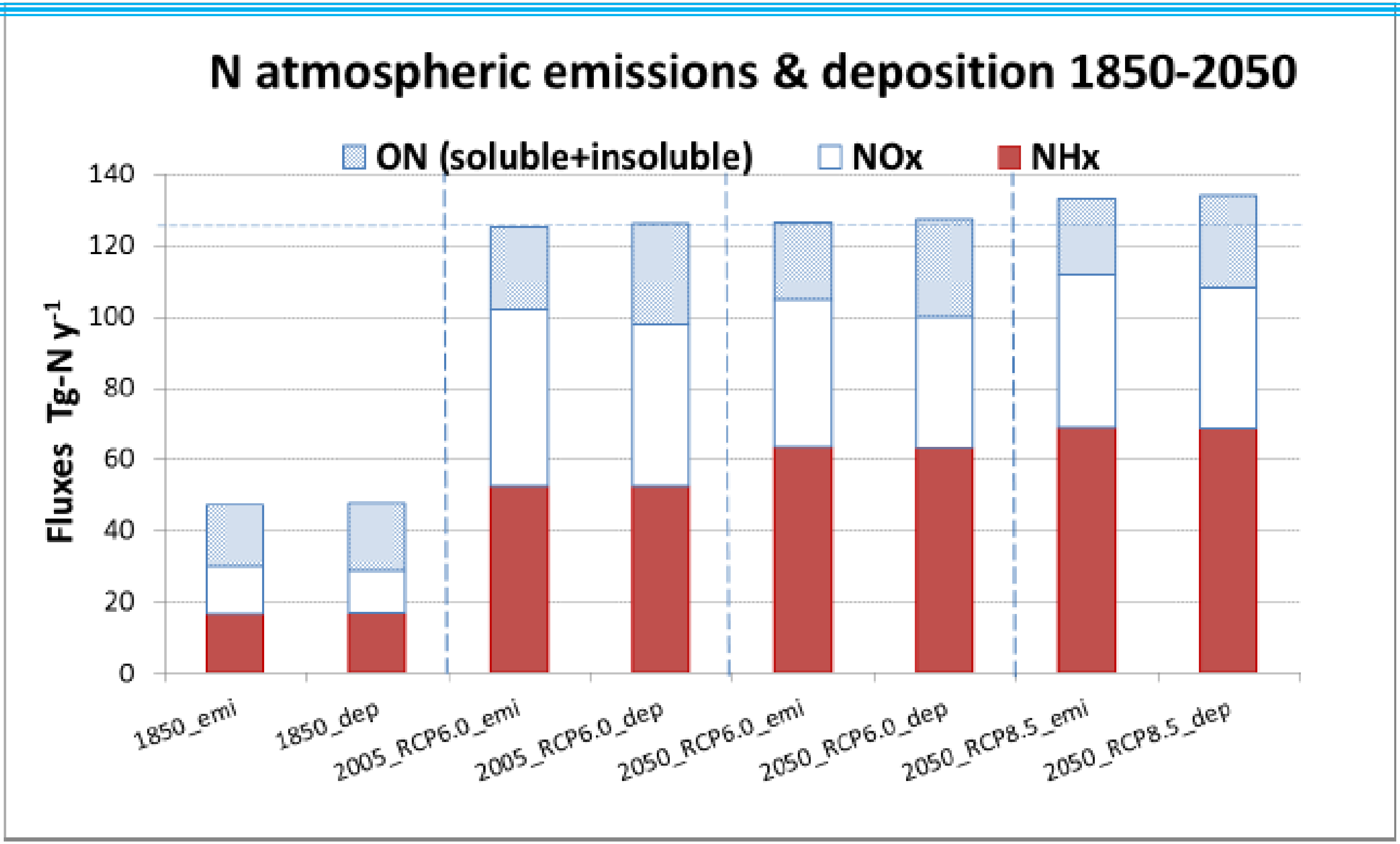




Vet, R. et al (2014). A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. Atmospheric Environment 93. 3-100.

Kanakidou, M., S. et al 2016: Past, Present and Future Atmospheric Nitrogen Deposition. J. Atmos. Sci. doi:10.1175/JAS-D-15-0278.1, in press.

Inclusion of WSON in new estimates!



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How to assess N deposition in Latin Ameria and the Caribbean?

www.sciencemag.org SCIENCE VOL 340 12 APRIL 2013

Published by AAAS

ENVIRONMENT

Latin America's Nitrogen Challenge

A. T. Austin,[1] M. M. C. Bustamante,[2] G. B. Nardoto,[2] S. K. Mitre,[2] T. Pérez,[3] J. P. H. B. Ometto,[4] N. L. Ascarrunz,[5] M. C. Forti,[4] K. Longo,[4] M. E. Gavito,[6] A. Enrich-Prast,[7] L. A. Martinelli[8*]

Human impacts on the N cycle require sustainable ecological solutions to preserve ecosystem and human health.

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Current Opinion in Environmental Sustainability

Innovations for a sustainable future: rising to the challenge of nitrogen greenhouse gas management in Latin America

CrossMark

Mercedes MC Bustamante[1], Luiz A Martinelli[2], Jean PHB Ometto[3], Janaina Braga do Carmo[4], Víctor Jaramillo[5], Mayra E Gavito[5], Patricia I Araujo[6], Amy T Austin[6], Tibisay Pérez[7] and Sorena Marquina[7]

Nitrogen Cycling in Latin America: Drivers, Impacts and Vulnerabilities (Nnet)

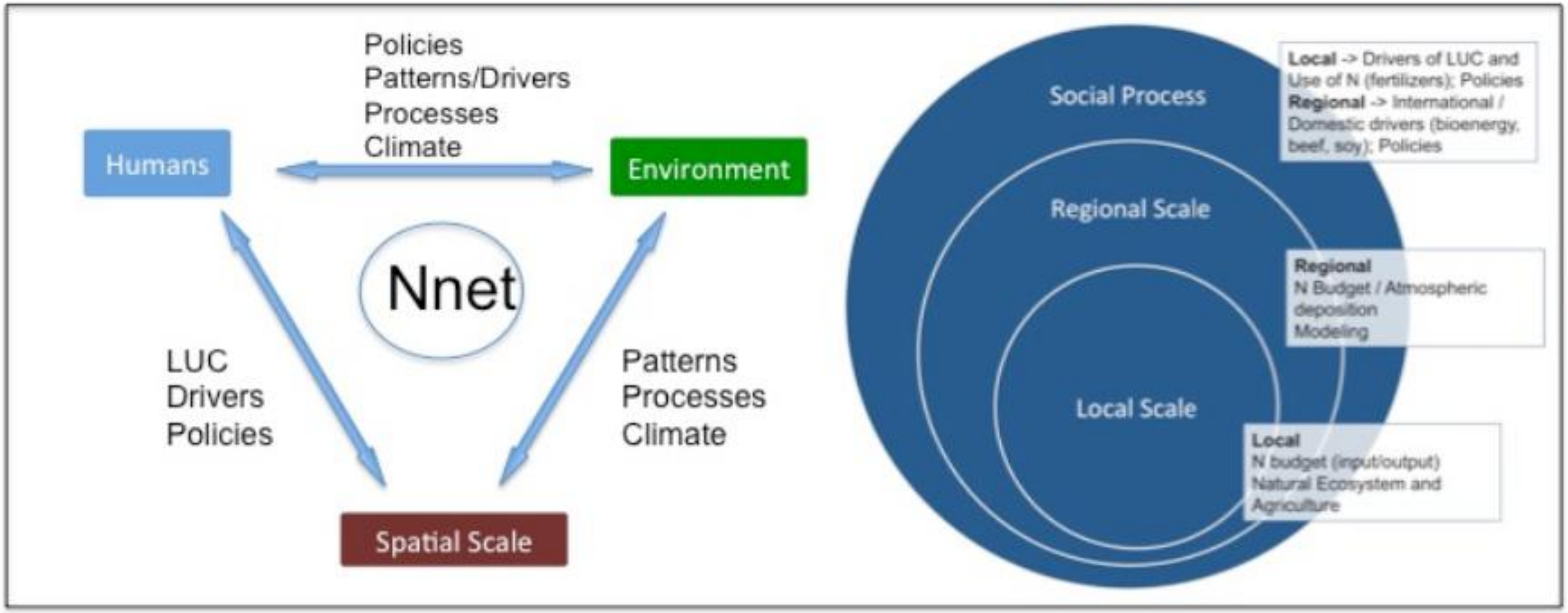
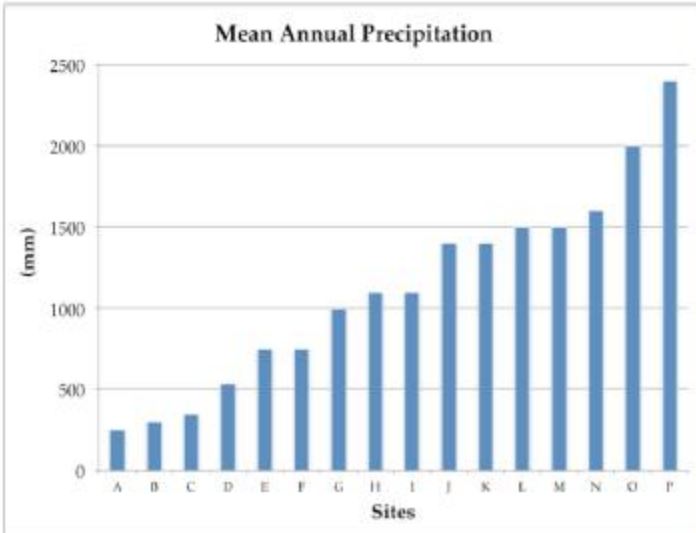


Figure 1.: Integration of different components of the Nitrogen Human Environment Network (Nnet) and the different levels of study with interdependent and interconnected drivers.

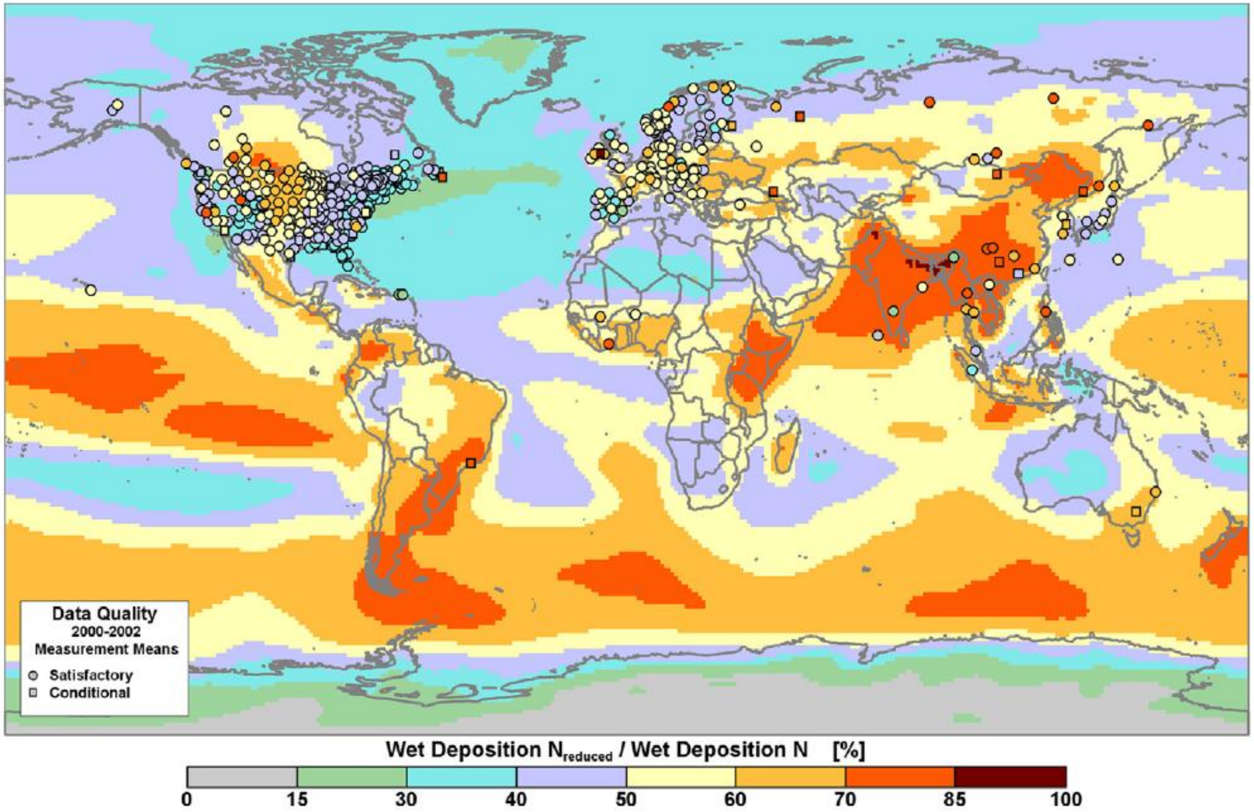
N atmospheric deposition and BNFcomponents



Site	Ecosystem
A	Alpine
B	Sclerophyllous savanna
C	Alpine
D	Caatinga
E	Chaco dry savannas and woodlands
F	Tropical dry forest
G	Altos de Pipe
H	Transition tropical forest-dry tropical forest
I	Cerrado / savannas and gallery forests
J	Pantanal
K	La Iguana
L	Mata Atlântica
M	Alpine
N	Wet tropical forest
O	Transition tropical forest-dry tropical forest
P	Mata Atlantica

Figure 2: Sampling sites and precipitation gradient

Nreduced becoming important



Vet, R. et al (2014). A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. Atmospheric Environment 93. 3-100.

N atmospheric deposition from Venezuela

WSON concentrations in total suspended particles (TSP) and wet deposition

Total Suspended Particles

	Concentration (µg-N m^3 aire)	WSON/TN (%)
Venezuela	0,07-1,3	35-72%
Other studies	0,01-2,1	10-64%

Wet deposition

	Concentration (µg-N/L)	WSON/TN (%)
Venezuela	**0,34-0,96**	51-92%*
Other studies	**0,04-0,31**	5-84%

* Maracaibo excluded

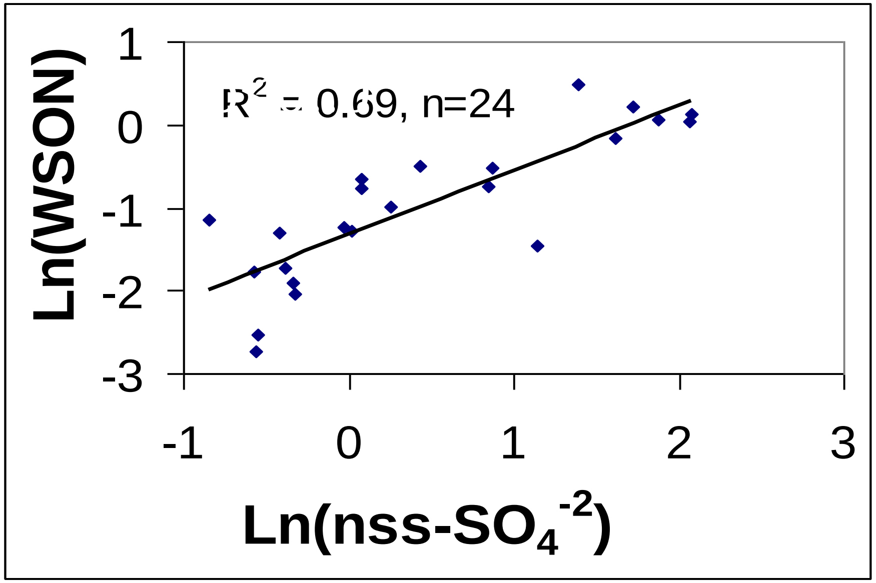
Venezuela → ↑ [NOS] % [NOS] ↑

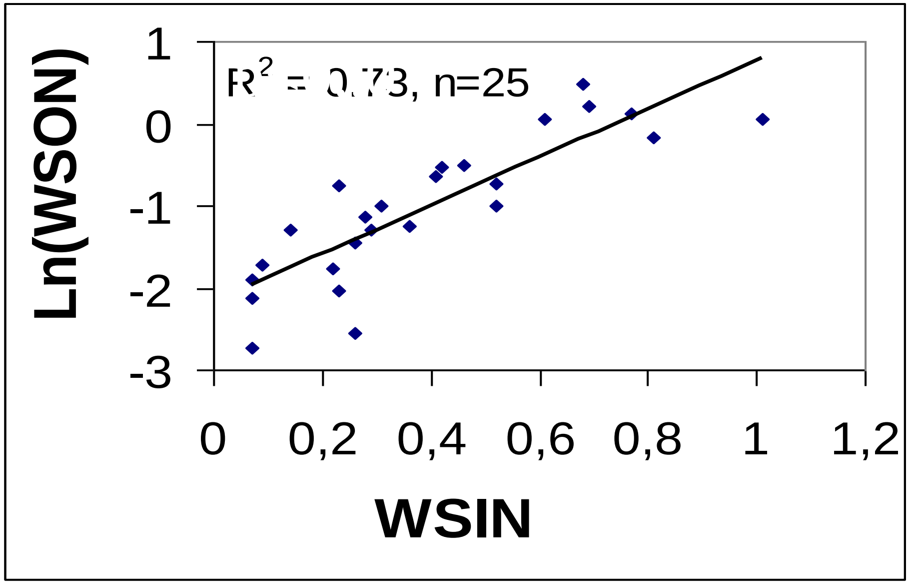
Canaima National Park (30.000 km²)

Morales et al., .2001. Water, Air, and Soil Pollution 128, 207-221; Pacheco et al., 2004. Tellus 56B; Canelón et al., 2007 Eos Trans. AGU, 88(52).

N atmospheric deposition from Venezuela

WSON and WSIN from TSP in remote continental and oceanic sites





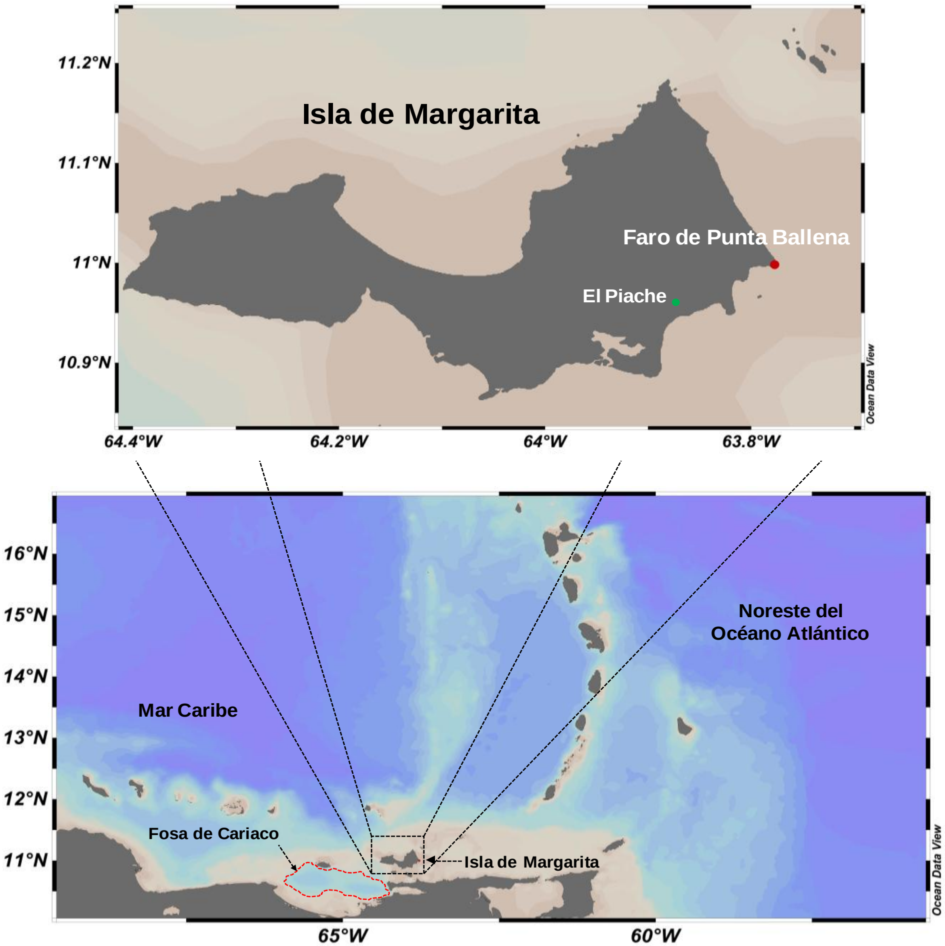
SOA derived:

•Remote continental sites: biomass burning

•Remote coastal and oceanic sites: Long range transport and tropospheric oxidation of VOCs including DMS

Canelón et al., 2007 Eos Trans. AGU, 88(52).

N atmospheric deposition from Venezuela



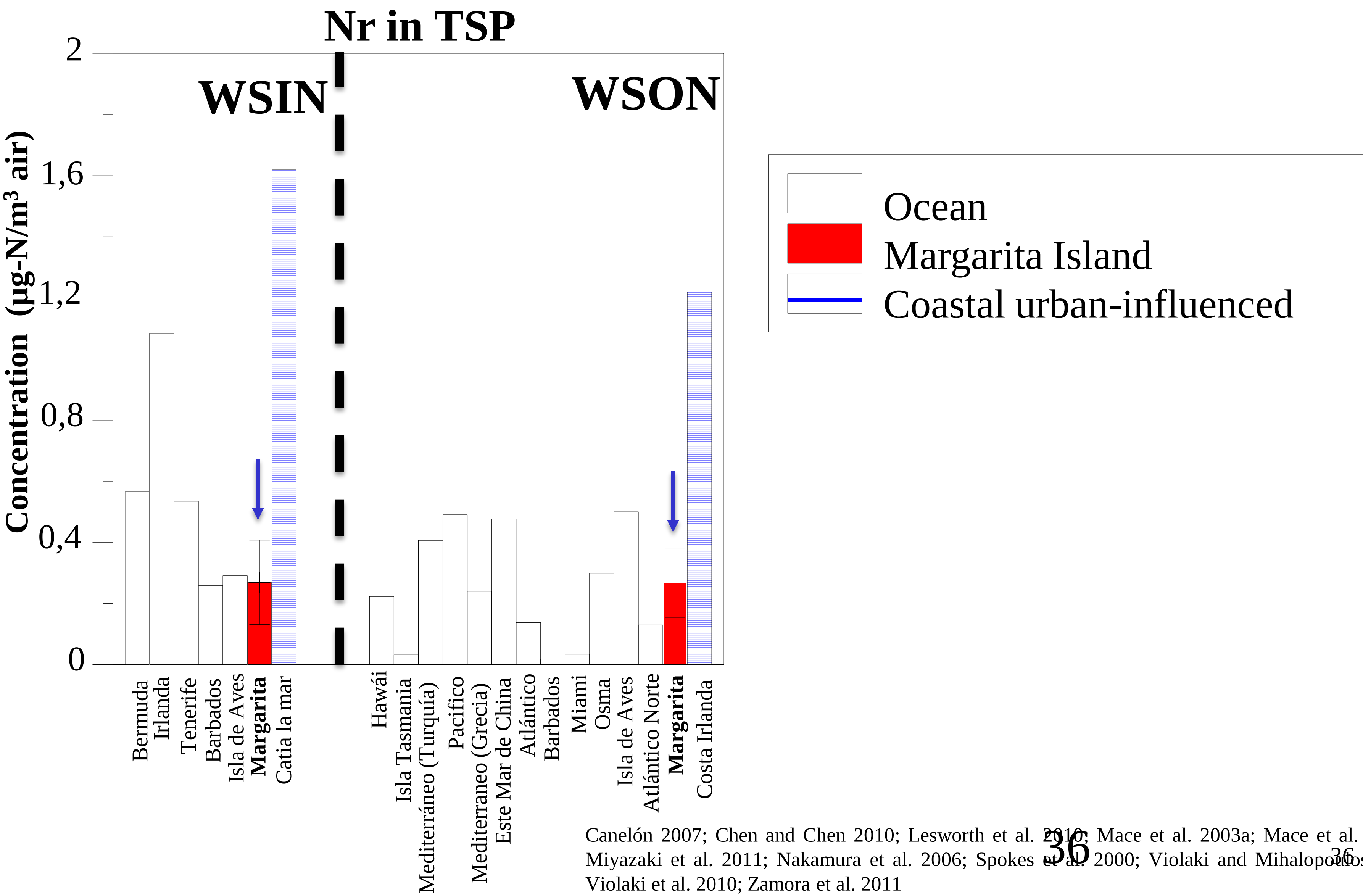
Margarita Island

Venezuelan Navy Hidrography Division (DHN)

Rainy season and dry season collection

Cariaco oceanic time series: http://imars.marine.usf.edu/CAR/

N atmospheric deposition from Venezuela



Canelón 2007; Chen and Chen 2010; Lesworth et al. 2010; Mace et al. 2003a; Mace et al. 2003b; Miyazaki et al. 2011; Nakamura et al. 2006; Spokes et al. 2000; Violaki and Mihalopoulos 2008; Violaki et al. 2010; Zamora et al. 2011

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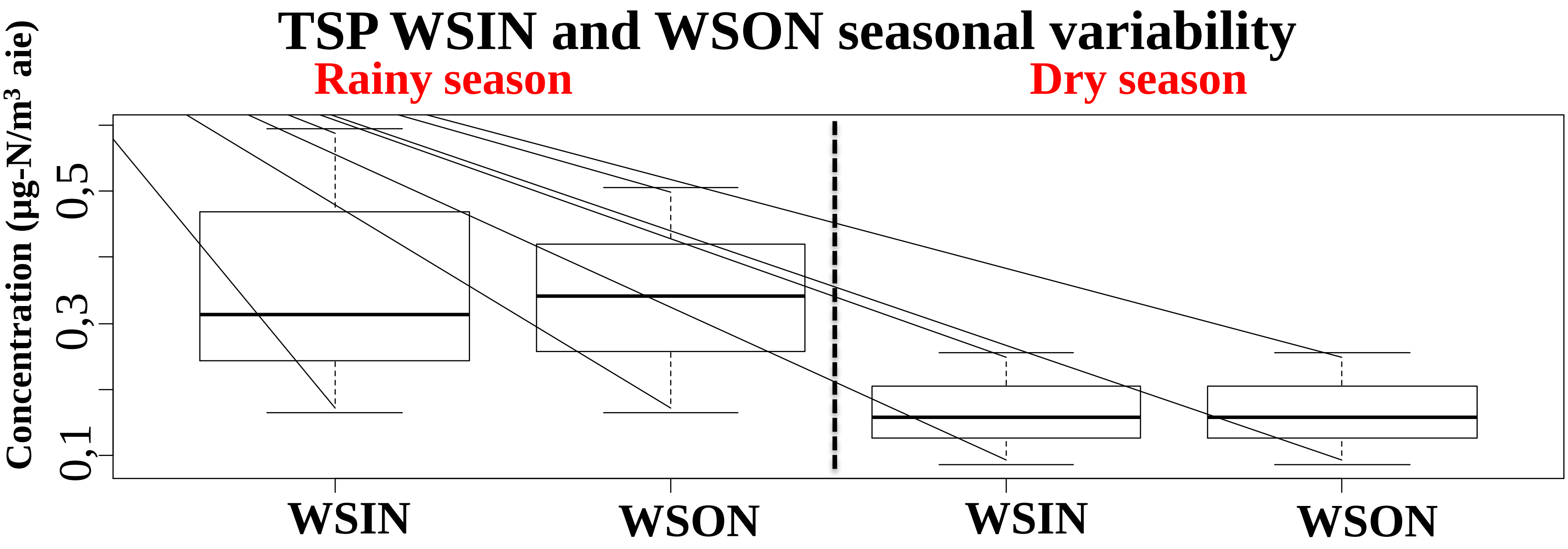
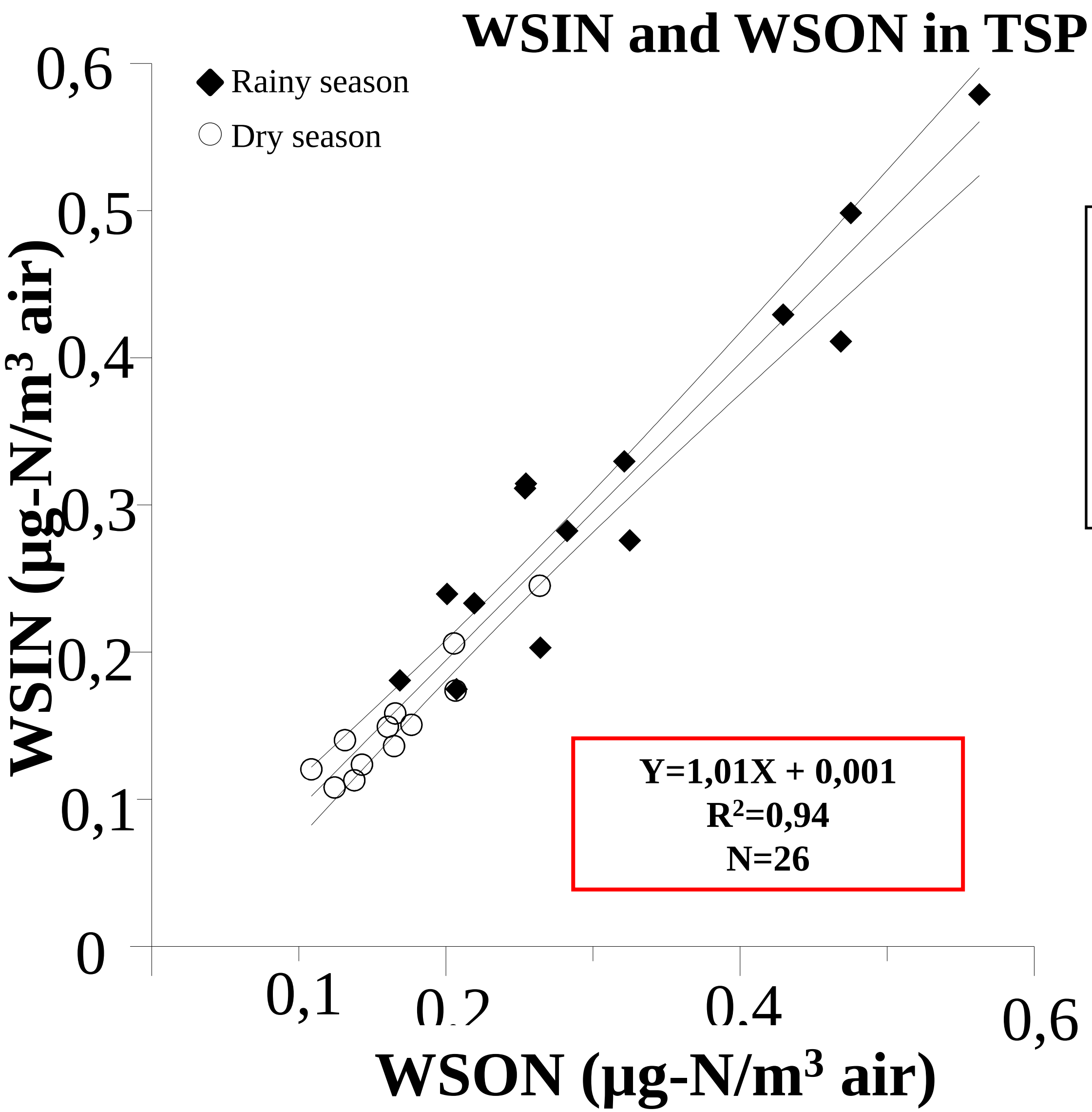
N atmospheric deposition from Venezuela



[WSIN] and [WSON] rainy season> dry season
(ρ<0,01;N=28)

WSON/WSIN ratio ~ 1:1 possible similar sources

N atmospheric deposition from Venezuela



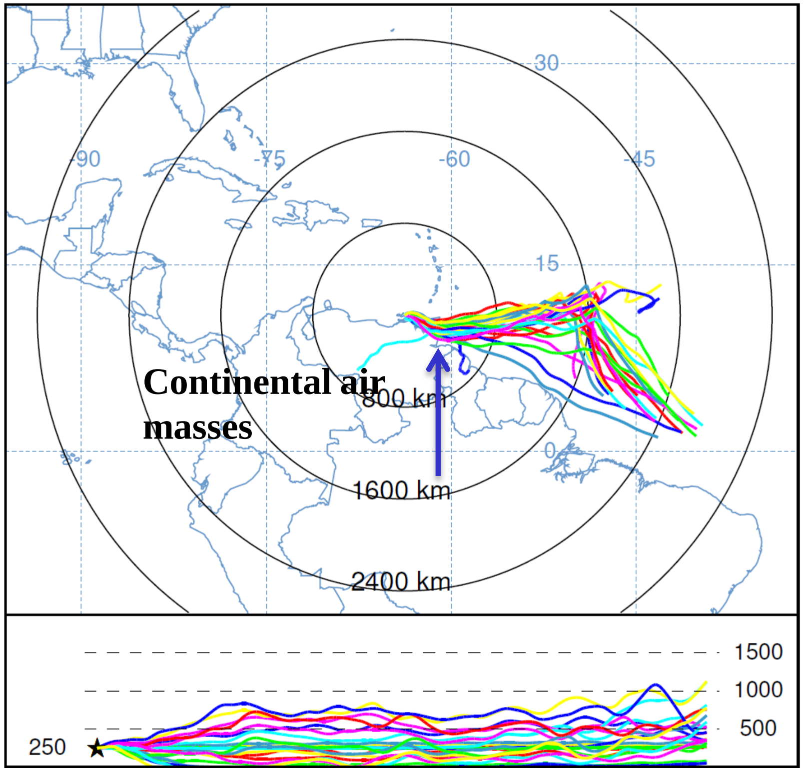
Mean concentration values

[WSIN] and [WSON] rainy season> dry season (ρ<0,01;N=28)

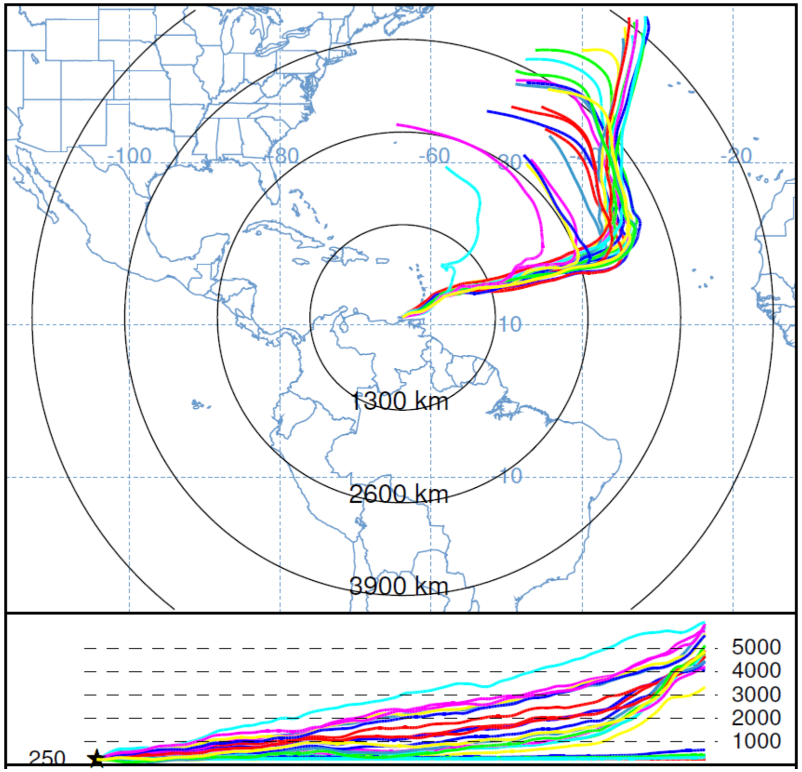
N atmospheric deposition from Venezuela

Back trajectories and meteorological data

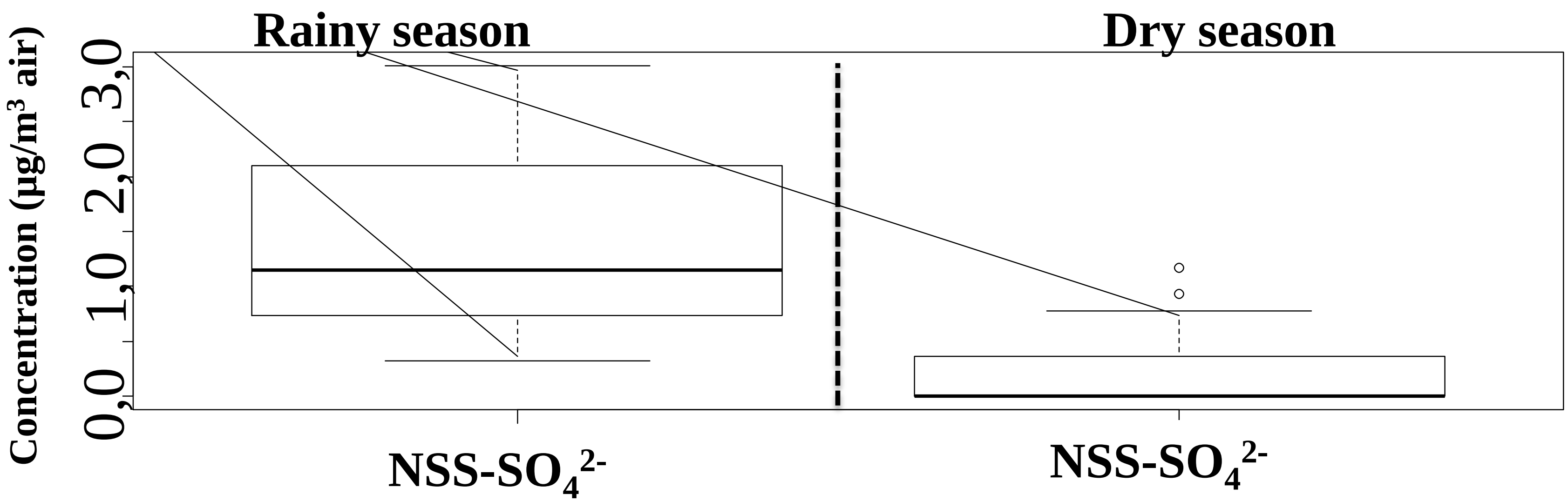
Rainy season



Dry season



N atmospheric deposition from Venezuela

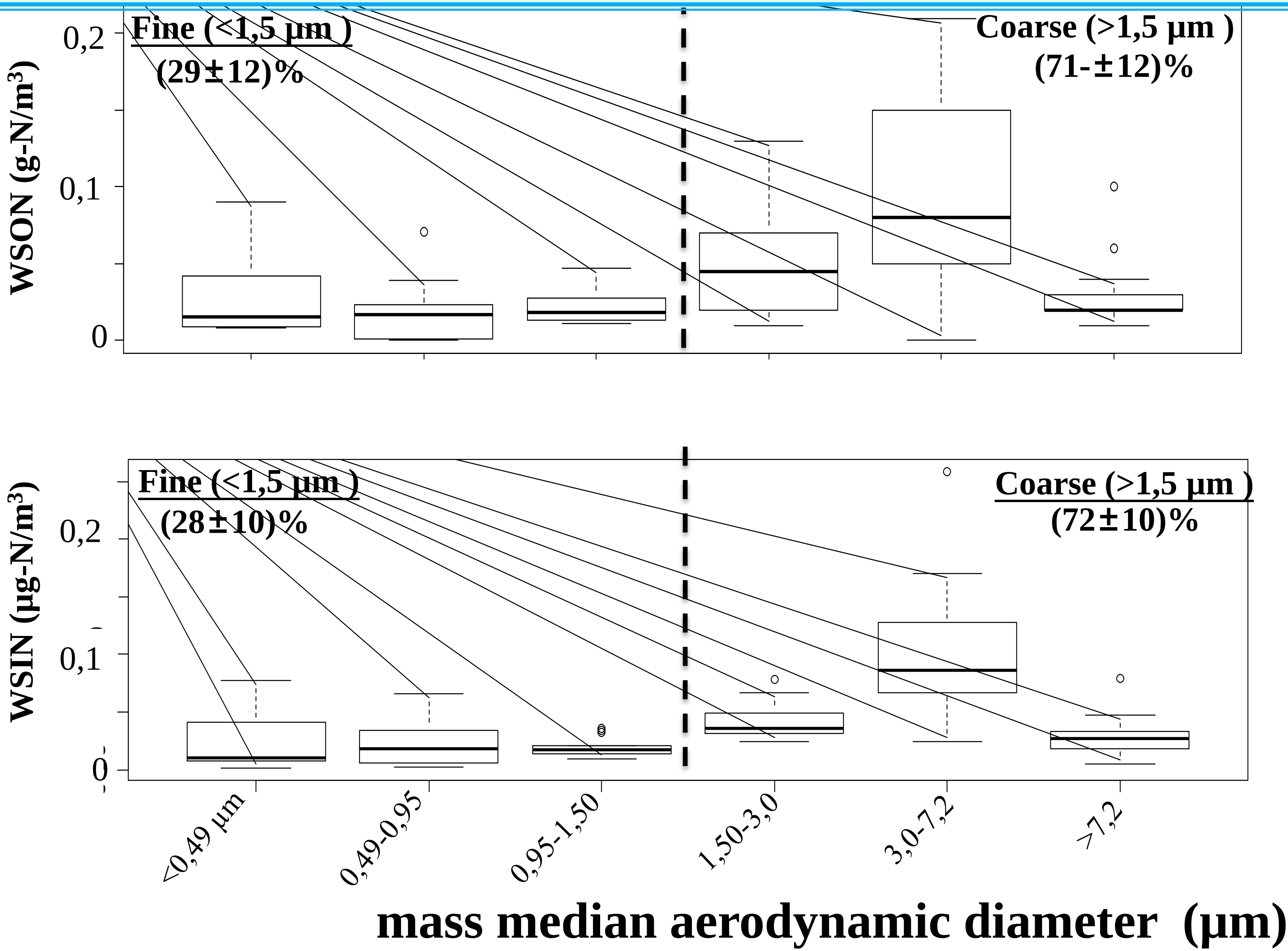


[NSS-SO_4^{2-}] Rainy season > dry season (ρ<0,01;N=28)

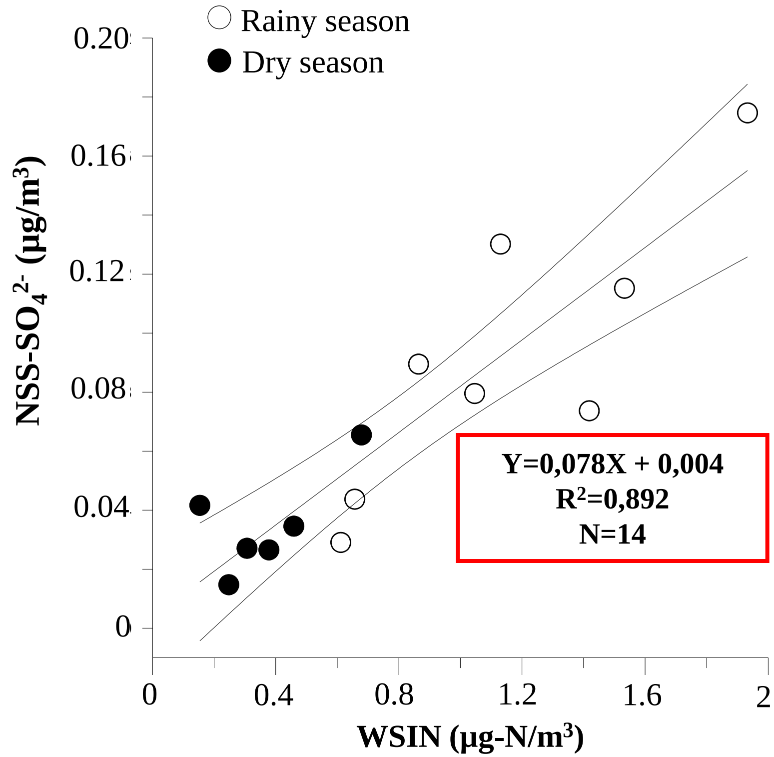
[WSIN] Vs [NSS-SO_4^{2-}] (R^2=0,423; ρ<0,05;N=28)
[WSON] Vs [NSS-SO_4^{2-}] (R^2=0,480; ρ <0,05;N=28)

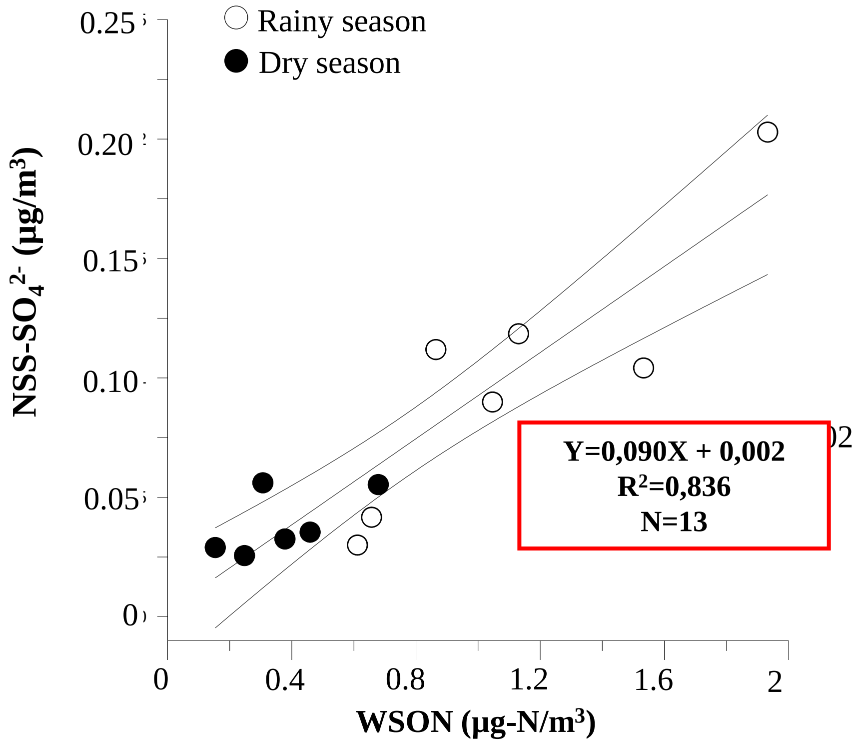
Back trajectories, meteorological data, [CO] and [NSS-SO_4^{-2}] → **Fossil fuel combustion and/or Biomass Burning during rainy season**

N atmospheric deposition from Venezuela



Identifying sources of WSIN and WSON

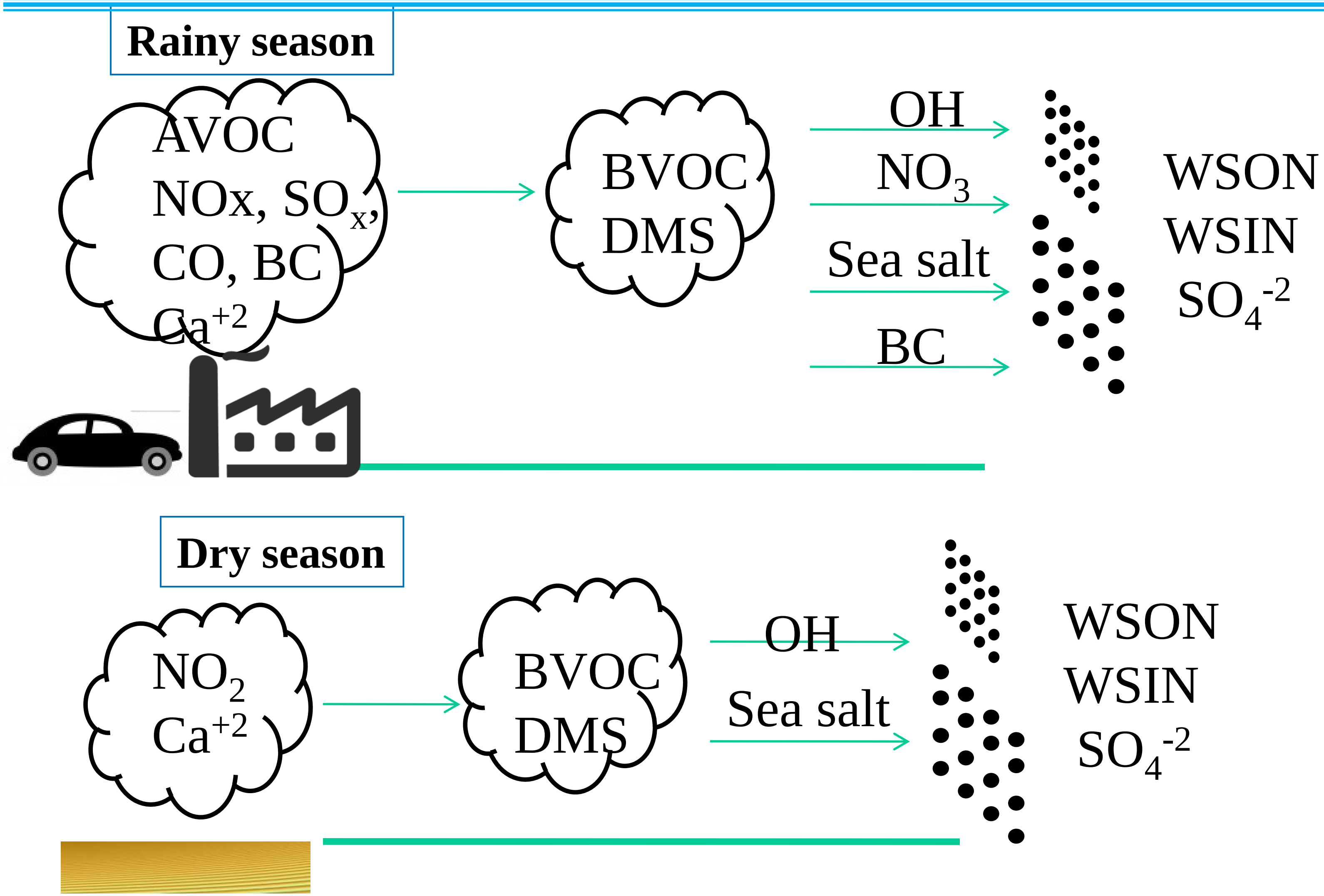




Nitrogen species	nss-SO_4^{2-}	nss-K^+	nss-Ca^{2+}	WSON
		Fine fraction		
WSIN	**0.892****	0.326	**0.656****	**0.898****
WSON	**0.836****	0.330	**0.659****	-
		Coarse fraction		
WSIN	-0.203	0.054	0.325	**0.898****
WSON	-0.086	0.092	0.346	-

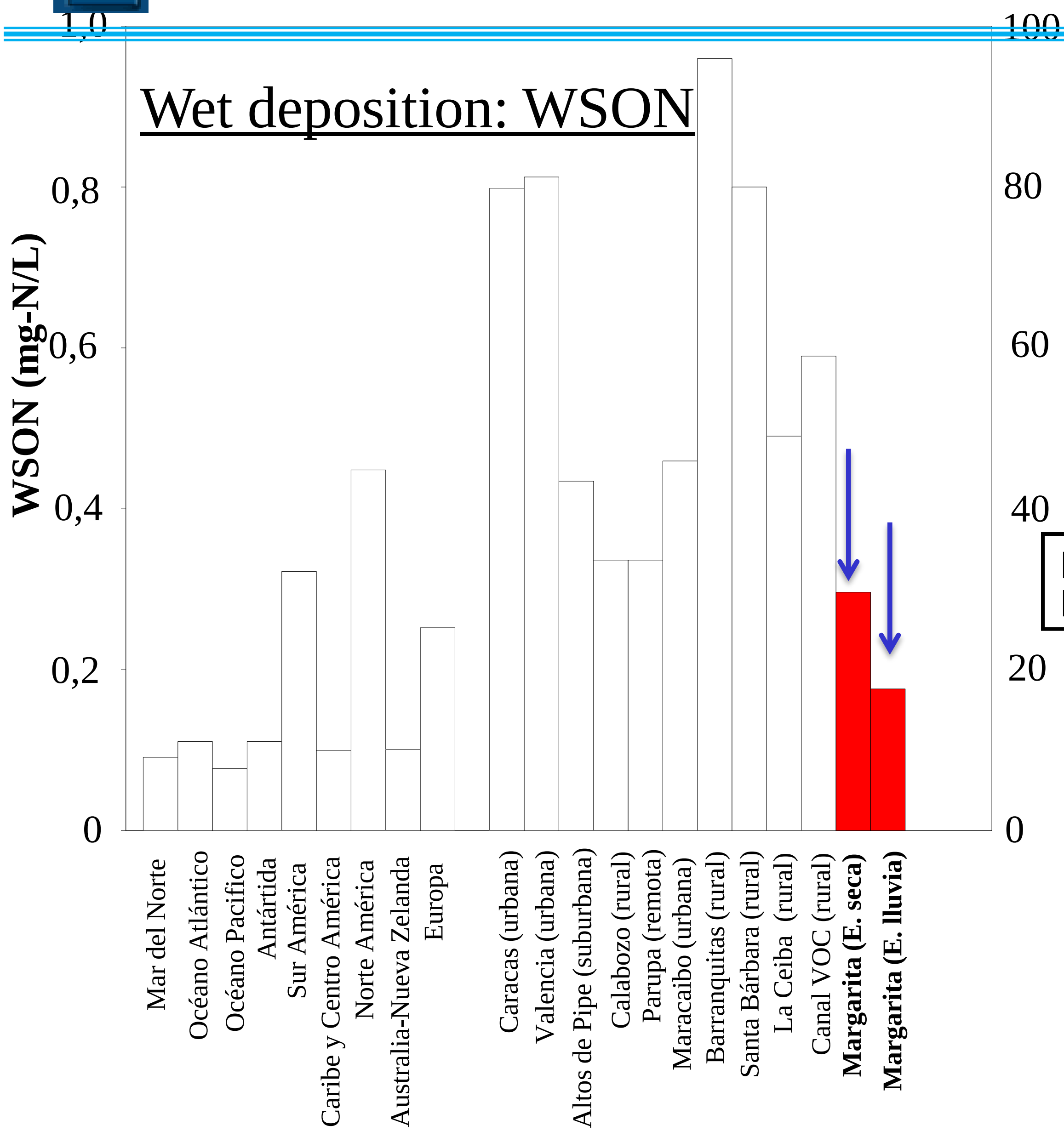
**Correlation is significant at the 0.01 level

Identifying sources of WSIN and WSON



Chen and Chen, 2010; Rollins et al., 2012; Osthoff et al., 2009; Stark et al., 2007.

Partition of WSIN and WSON

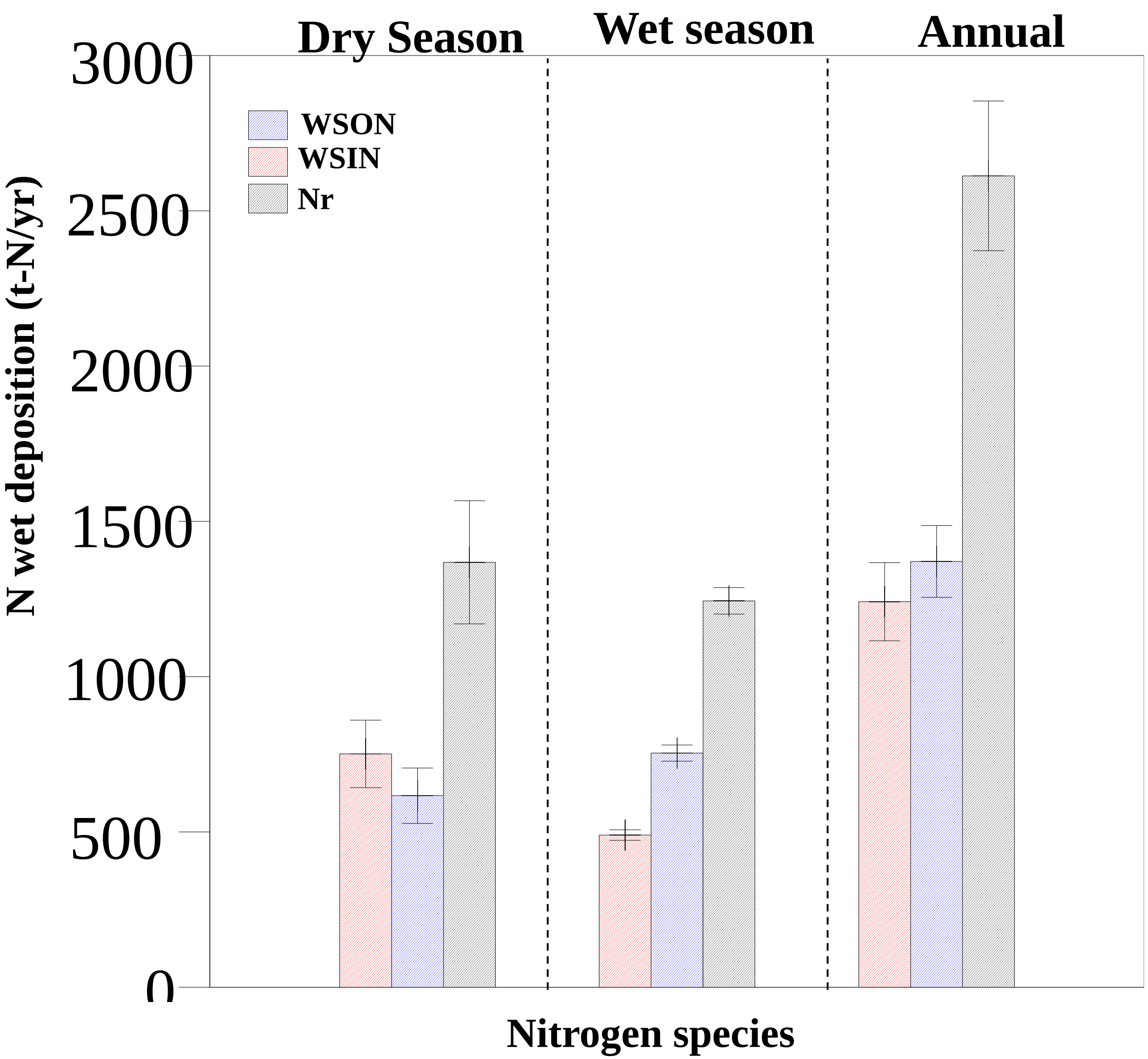


Other studies
Margarita Island

WSON ~ 50% Nr

[WSIN] Vs [Vpreci] (R^2=-0,587; ρ<0,05;N=12)
[WSON] Vs [Vpreci] (R^2=-0,440; ρ <0,05;N=12)

N annual wet deposition (NDw)



ND_w: 2,4x10^3 t-N/año

No seasonal variation

WSIN: (48±5) %

WSON: (53±4) %

N annual dry deposition (NDd)

$ND_d = (\Sigma\, V_{ni} \times [NS]_{ni}) \times$ Cariaco basin area

N dry deposition (ND_d)

V_{ni}: constant deposition velocity (cm/s)

$[NS]_{ni}$: N concentration (μg-N/m^3)

Cariaco trench basin area: 12600 Km^2

Total N atmospheric deposition (ND_t) = ND_w + ND_d

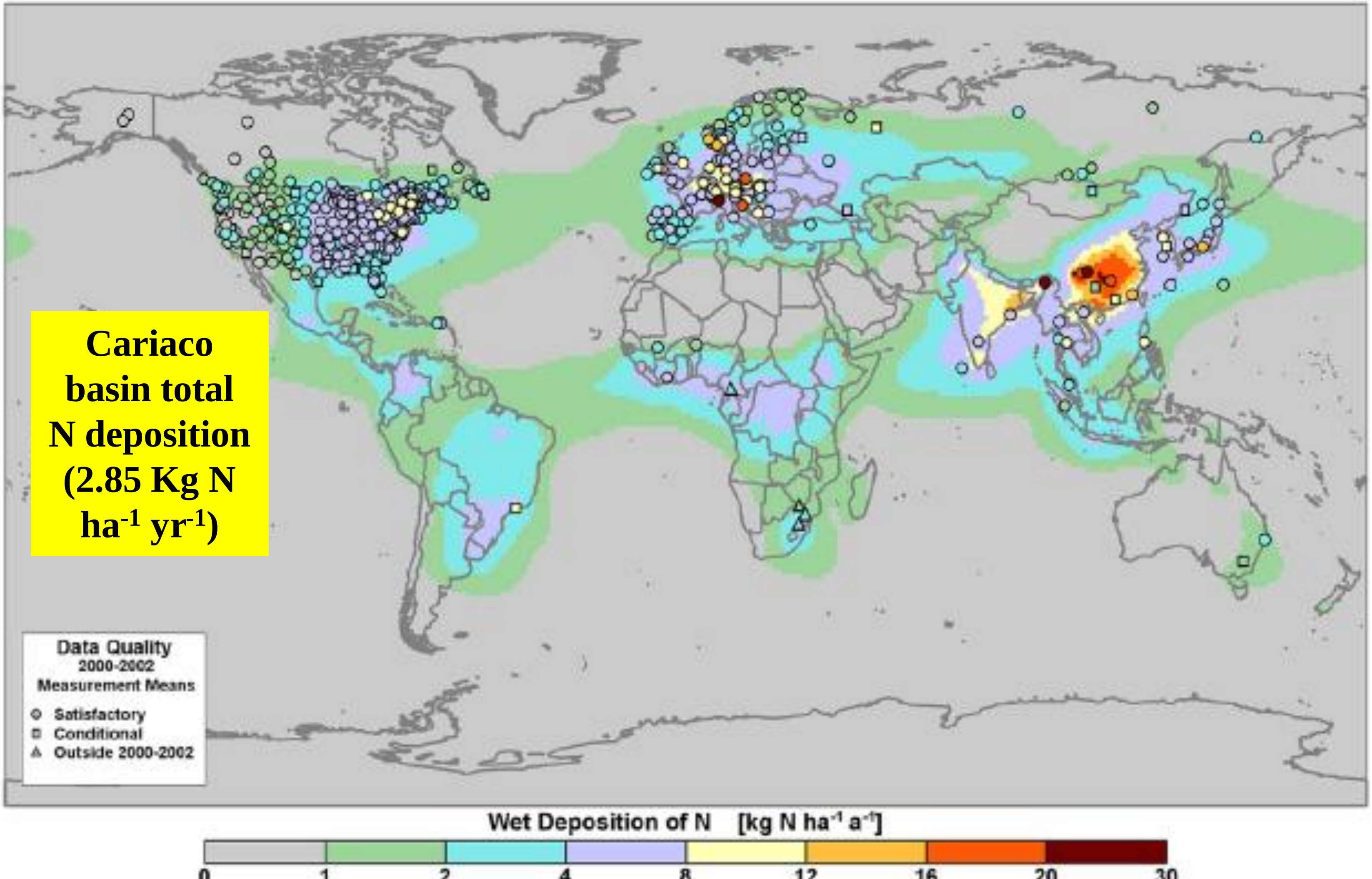
N annual dry deposition (NDd)

Total N atmospheric deposition in the Cariaco Basin

Atmospheric N deposition	T-N/year	%WSIN	%WSON
Dry deposition	**$1,2x10^3$**	**47±22**	**53±24**
Wet deposition	**$2,4x10^3$**	**48±5**	**53±4**
Total deposition	**$3,6x10^3$**	**48±23**	**53±24**

N wet deposjtion= (68 ± 6)%
N dry deposition= (31 ± 14)%

Comparison of Ndeposition with satelite and ground based measurements



Vet, R. et al (2014). A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. Atmospheric Environment 93. 3-100.