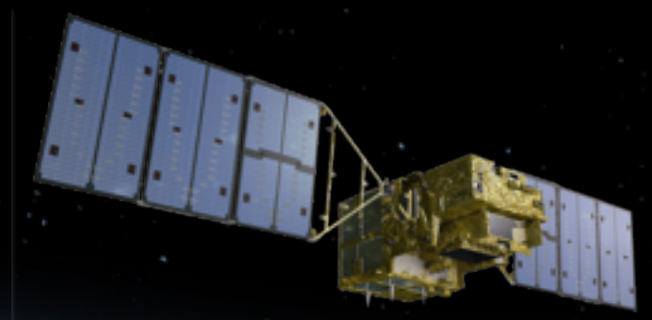
Satellite observations as a tool for studying carbon emissions over Asia

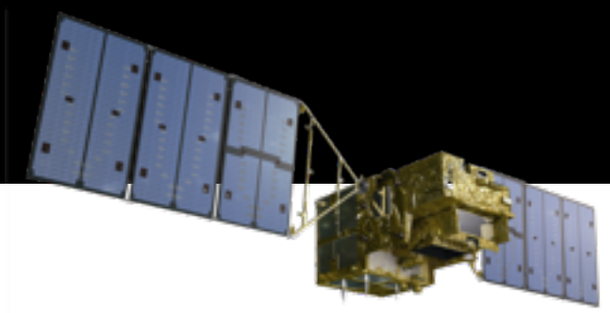
Tom Oda (CSU-NOAA)

Thanks to:
S. Maksyutov, H. Boesch, A. Butz, A. Ganshin, S. Guerlet, R. Parker, C. O'Dell, S. Oshchepkov, Y. Yoshida, R. Zhuravlev, T. Yokota, C. Elvidge, K. Baugh, D. Hsu and many others...

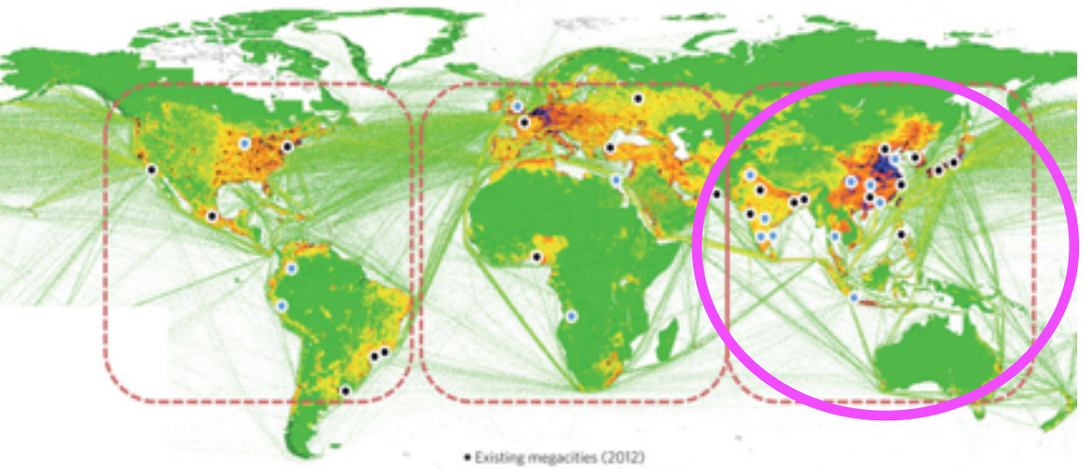


TO from Colorado State University (CSU) /NOAA Earth System Research Laboratory; SM, SO, YY, TY from NIES, Japan; AG and RZ from Central Aerological Observatory, Russian Fed.; AB from Karlsruhe Institute of Technology, Germany; SG from SRON, Netherlands; HB, AC from University of Leicester, UK; CO from CSU.

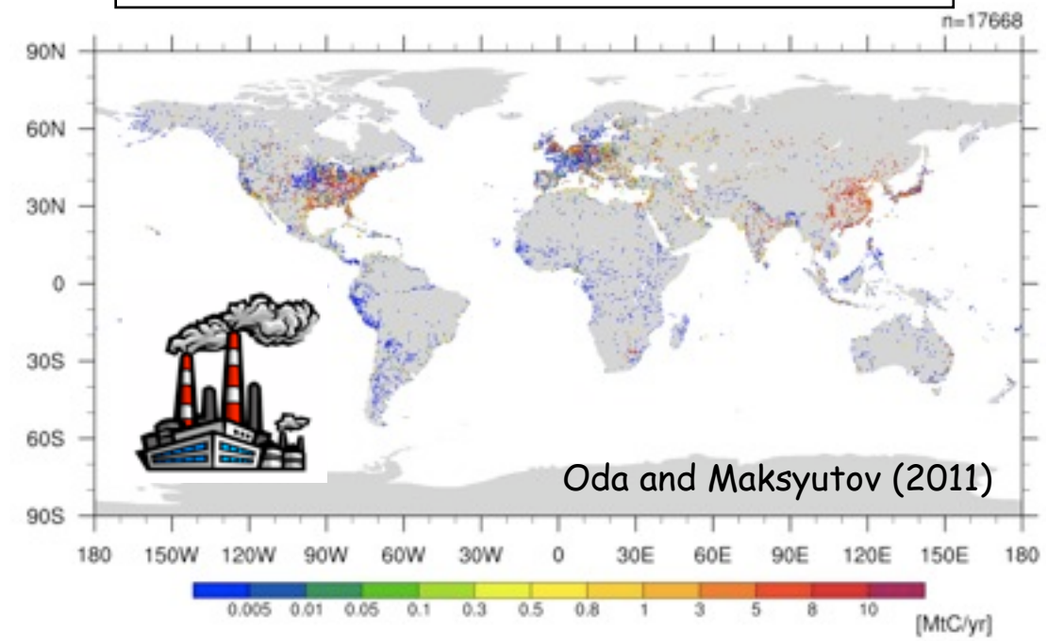
Towards MRV...

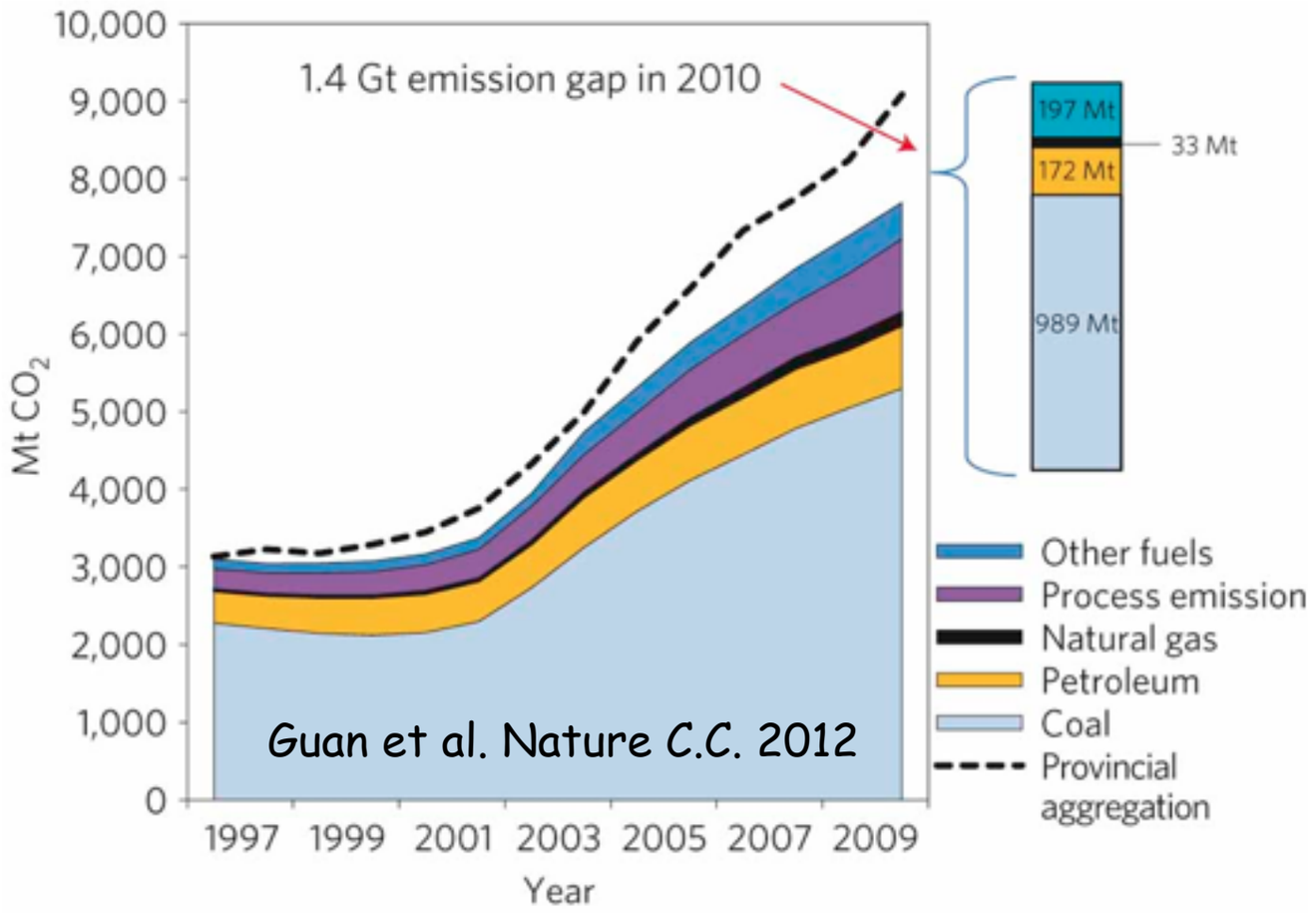


Duren and Miller (2012)



Large Point Sources (LPS)

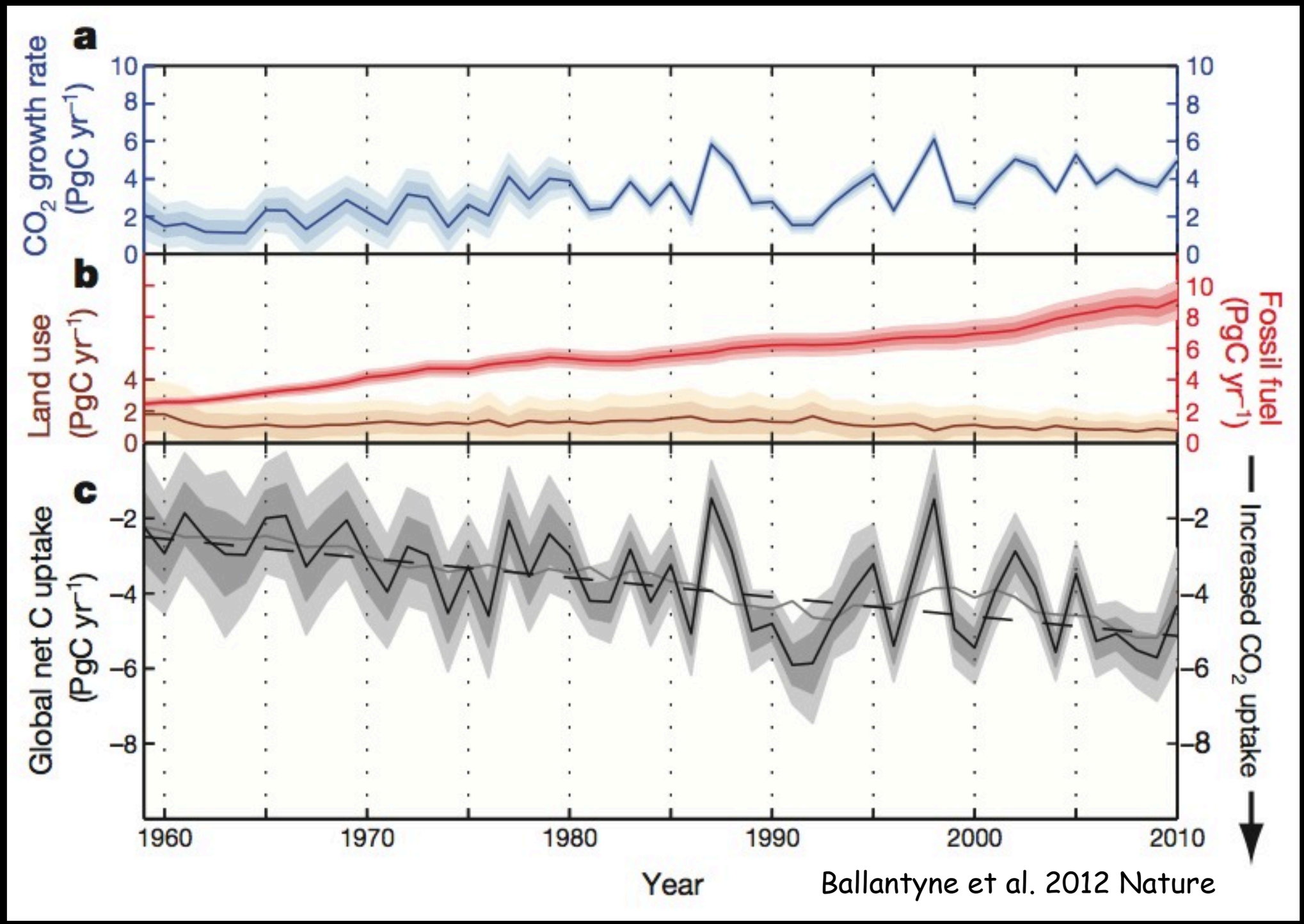




NOTE: We are NOT measuring emissions :(

We needs for an independent tool to measure emissions.

Global carbon budget



Ballantyne et al. 2012 Nature

Our knowledge of natural sources and sinks are still uncertain

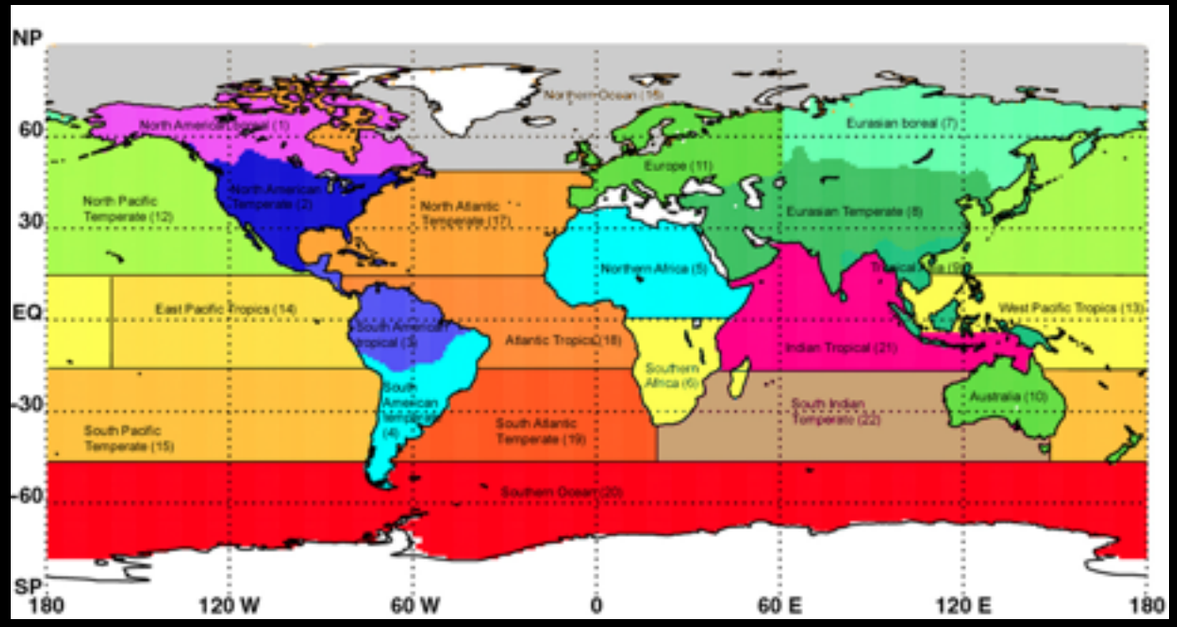
CO2 (natural!) source and sink inversion problem

Prescribed *Optimized*

$$C_{\text{obs}} = C_{\text{ff}} + C_{\text{oc}} + C_{\text{nbio}} + \sum_{i=1}^{N} C_{\text{res}}$$

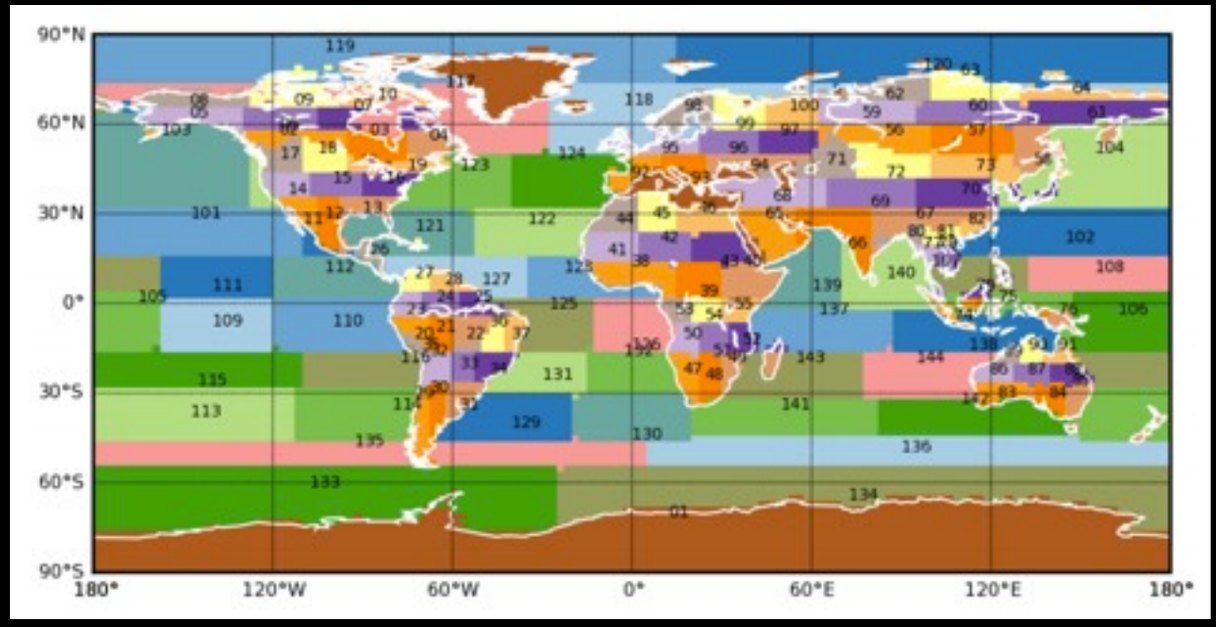
Gurney et al. 2005

Ground-based data only



Gurney et al. 2002 (N=22)

Ground-based data plus satellite

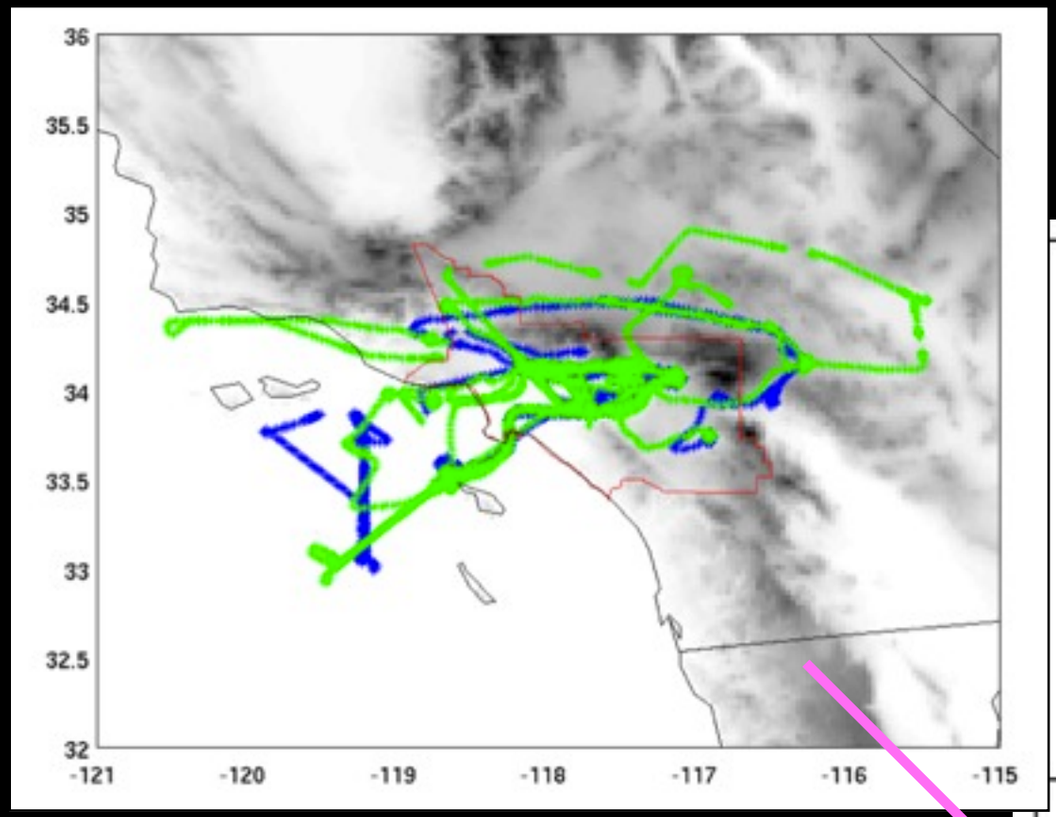


Feng et al. 2009 (N=144)

We are still working to achieved a robust picture of sources and sinks.

What we want to do - LA case

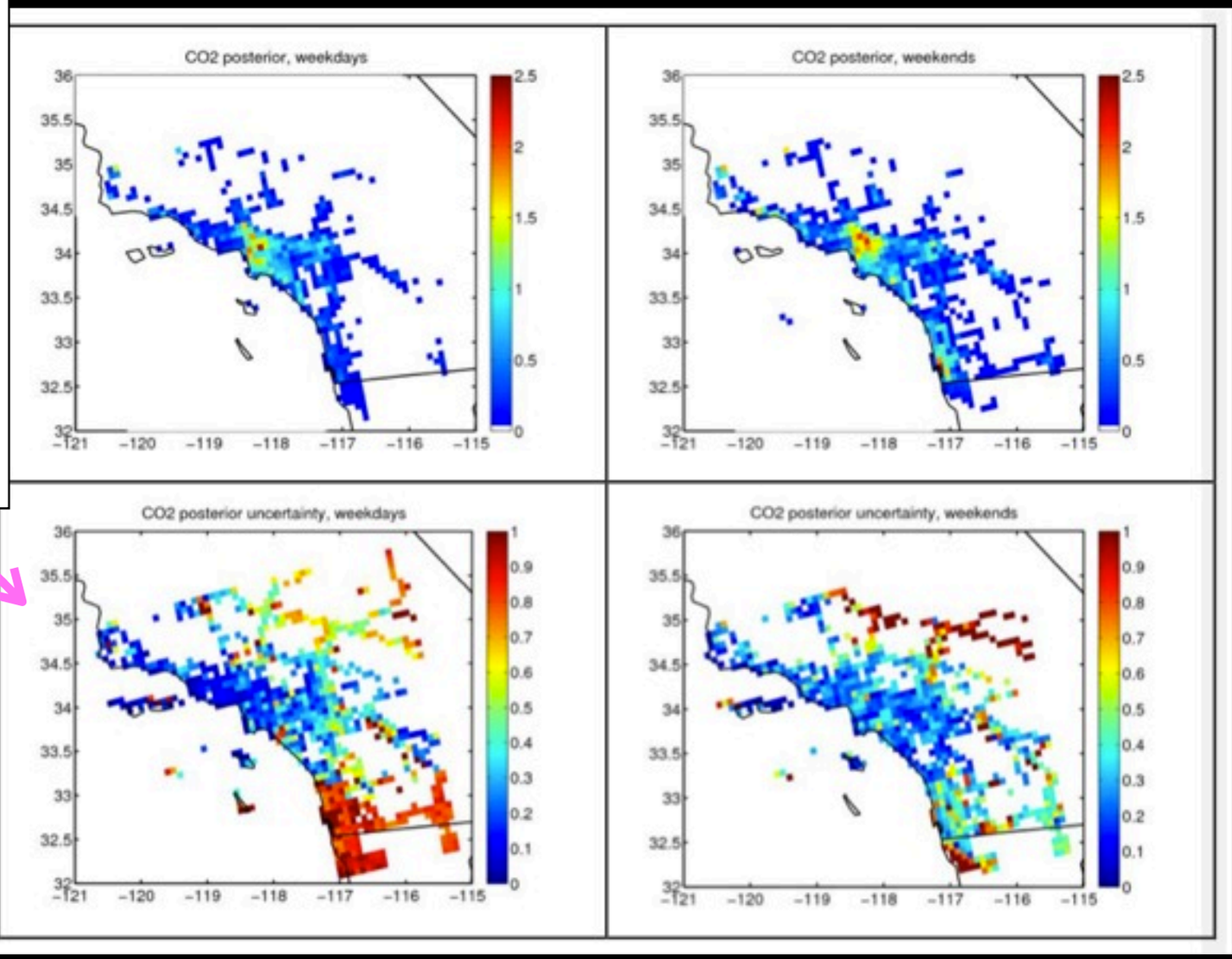
NOAA P3 Aircraft measurements



Inversion

Note: This inversion is not the same method as mentioned before.

Emission estimates

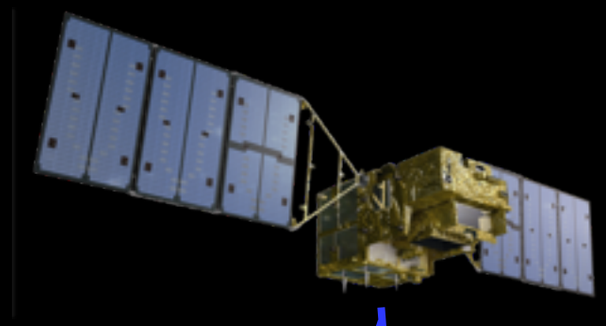


See more in

Brioude et al. (2013) ACP

Inversions could be used as a tool to study human CO2 emissions.

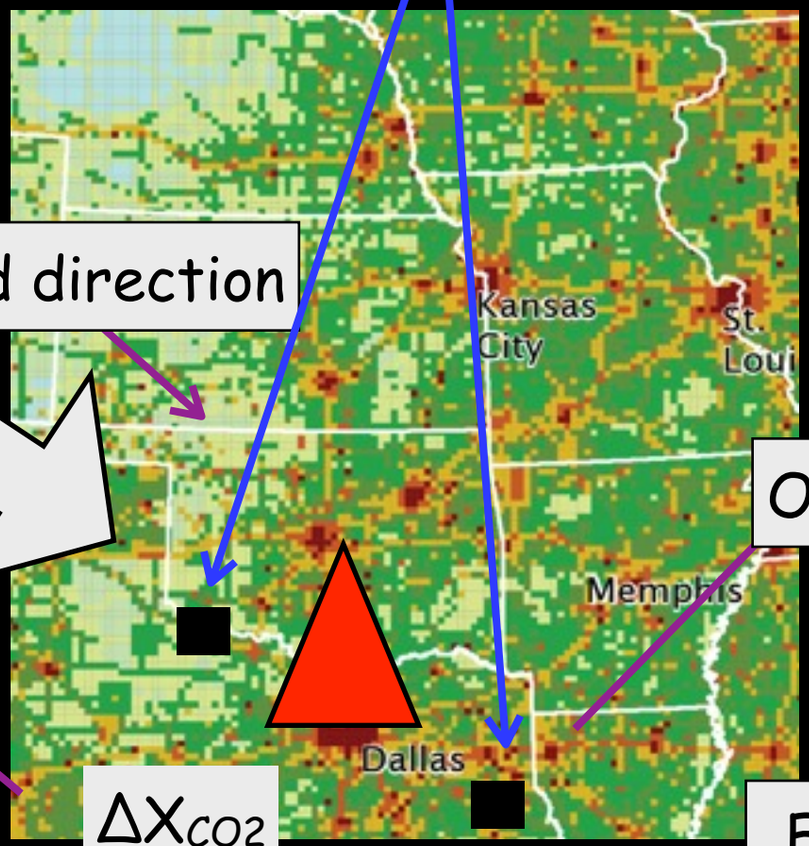
A system for verifying reported emissions



Commands

@NIES & JAXA

Wind direction



Obs. locations

ΔX_{CO2}

FFCO2 data*

*The image taken from Vulcan web.

Inverse system

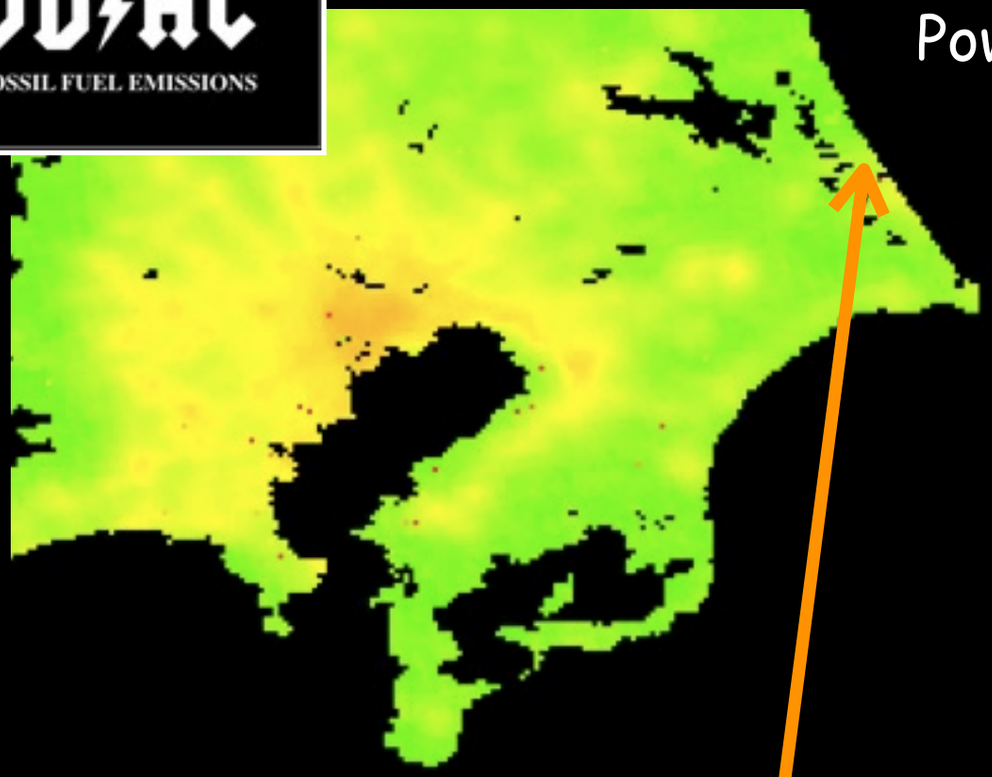
Modeling

Satellite observation

Based on satellite observations and inverse modeling.

Modeling system

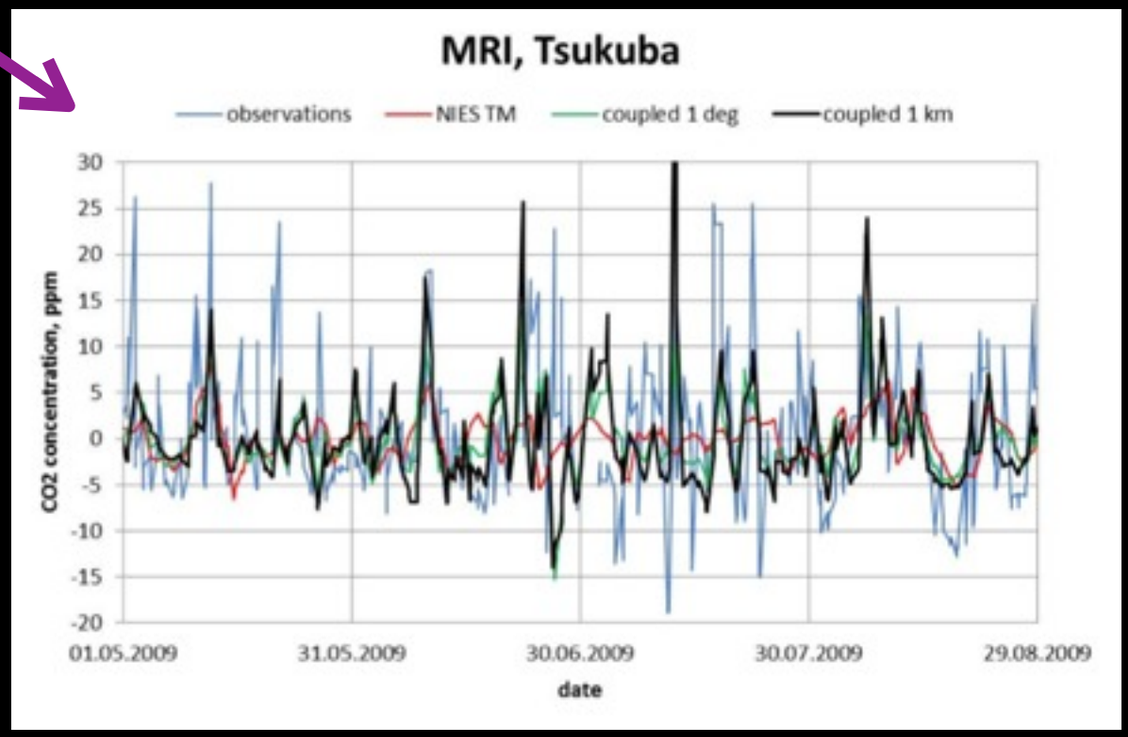
ODIAC
FOSSIL FUEL EMISSIONS



Power plant included :)

1x1km ODIAC FFCO2 emission data
(Oda and Maksyutov, 2011)

Lagrangian-Eulerian coupled ;)



GELCA transport model
(Ganshin et al, 2012; Oda et al. 2012)

Emission distribution method is needed.

- We have estimates for national and regional totals.
- Yet the estimates need to be prepared in a gridded form to incorporate into models.
- Sub national spatial distributions and temporal variations need to be estimated.
- In particular, fossil fuel CO2 emissions need to be accurately prescribed in inverse flux estimation framework.

$$F(x, y, t) = \lambda \bullet F_{bio}(x, y, t) + \lambda \bullet F_{oce}(x, y, t) + F_{ff}(x, y, t) + F_{fire}(x, y, t)$$

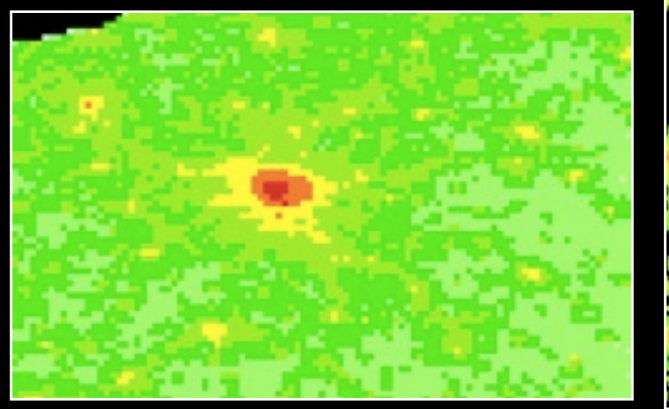
Optimized

Imposed

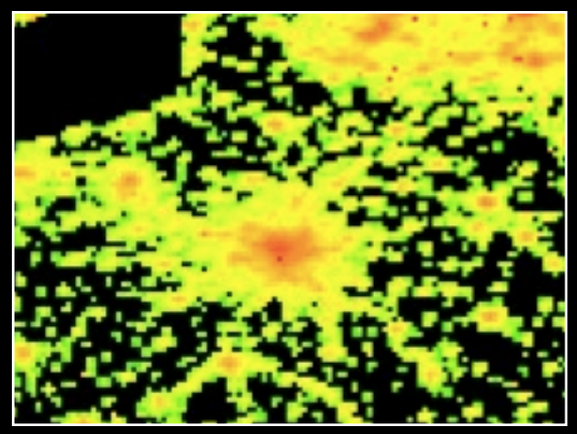
from NOAA CarbonTracker web

Nightlight as a spatial proxy for CO2 emissions

Population

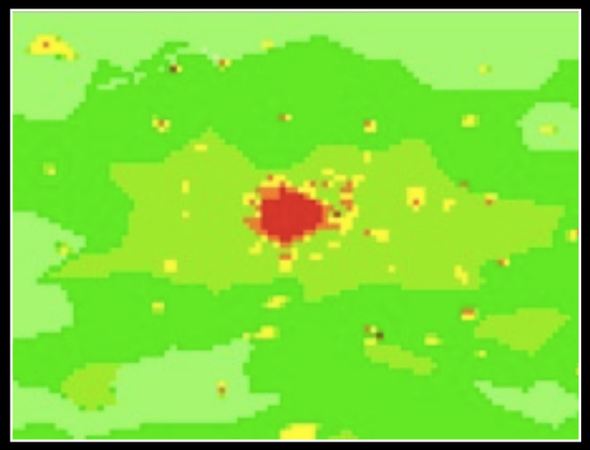


Nightlight

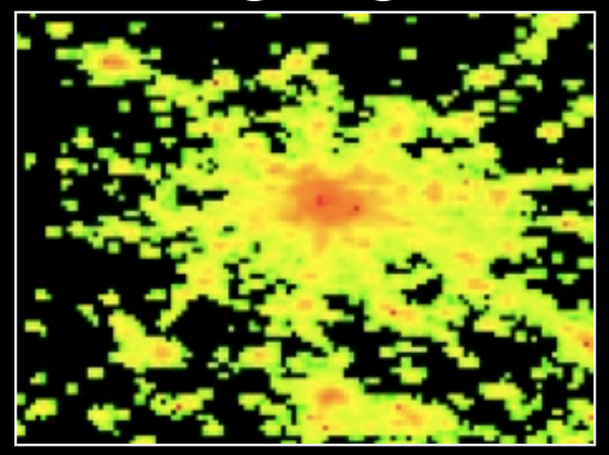


Paris

Population



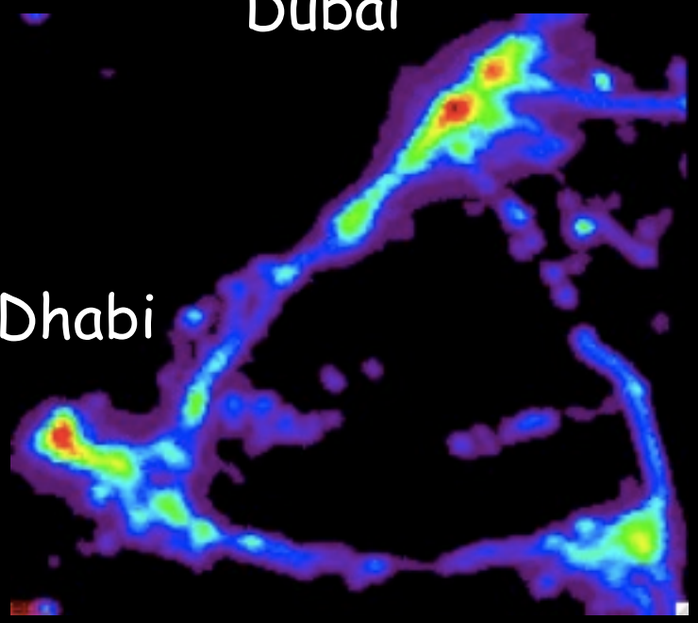
Nightlight



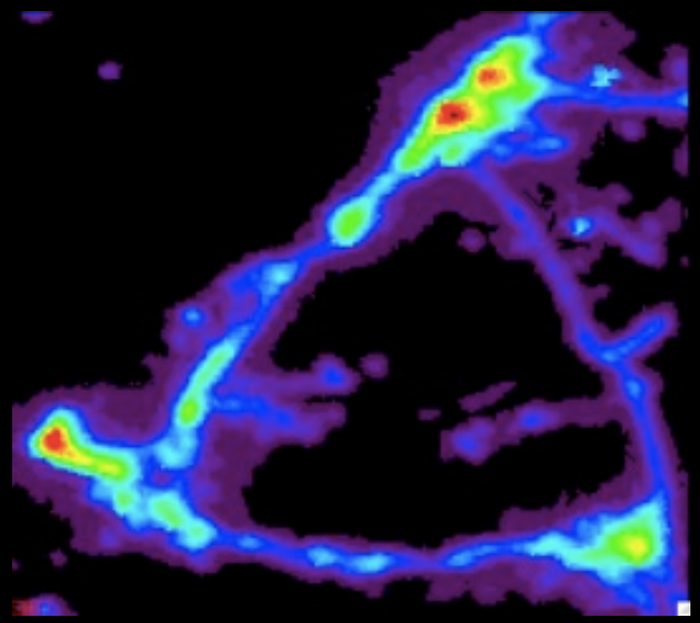
Moscow

Dubai

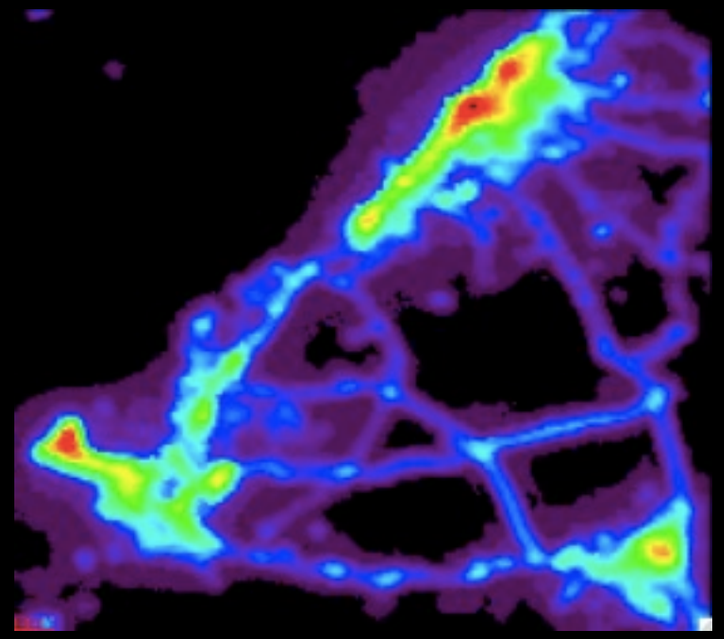
Abu Dhabi



1996-97



1999



2006

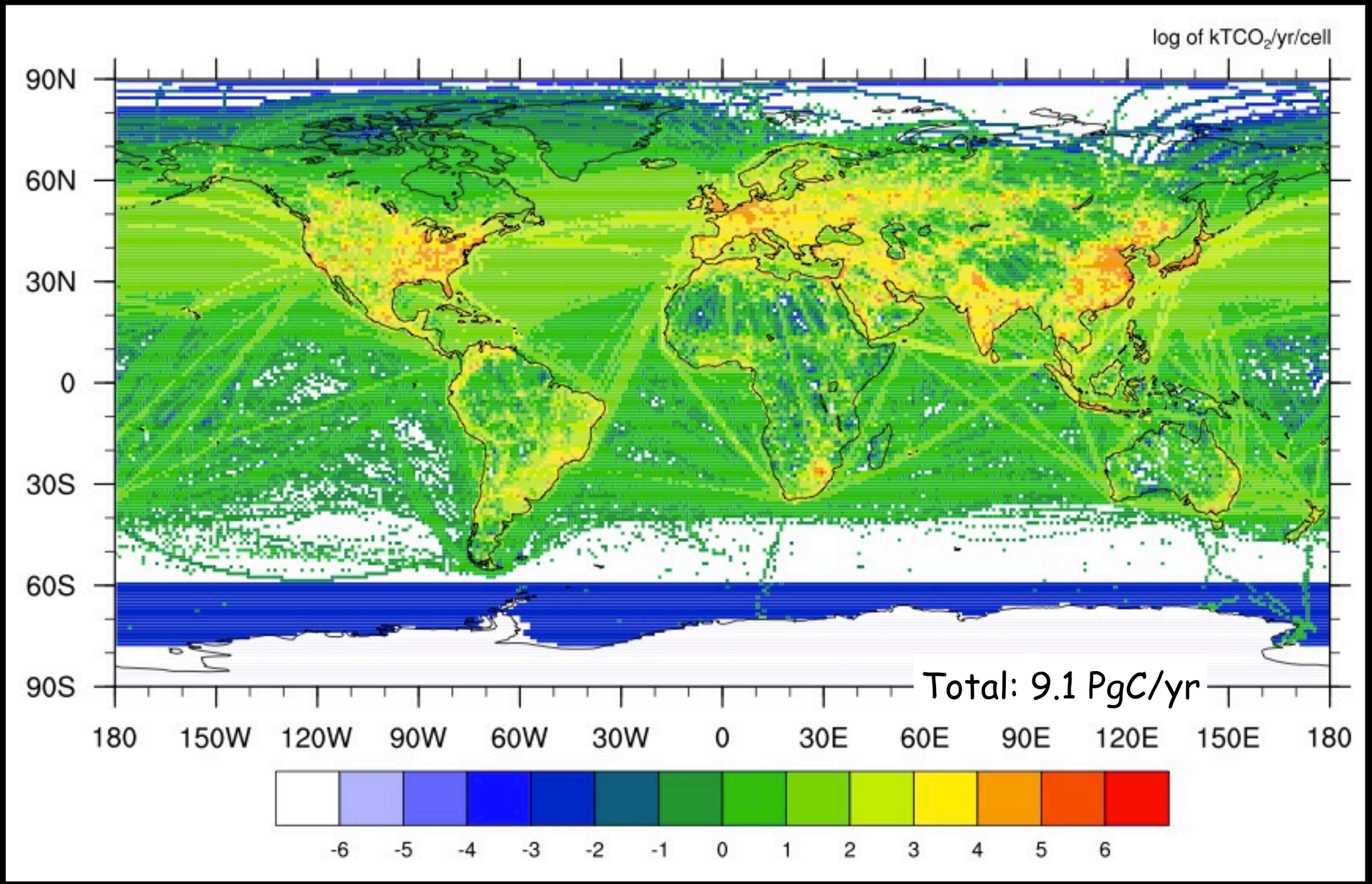
Nightlight data provided by Chris Elvidge, Kim Baugh and David Hsu@NOAA/NGDC

ODIAC CO2 emissions distribution

Resolution (°)	Population		Nightlights		FFDAS		Brenkert 1998		**This study**	
	diff (MtC)	correl	diff (MtC)	correl	diff (MtC)	correl	diff (MtC)	correl	diff (MtC)	correl
0.5	1213	0.70	1360	0.68	1143	0.74	-	-	744	0.87
1.0	1006	0.80	1087	0.81	900	0.85	1045	0.75	474	0.94
2.0	806	0.84	810	0.88	651	0.91	788	0.84	315	0.97
3.0	670	0.87	691	0.90	545	0.92	654	0.87	262	0.98
4.0	608	0.88	641	0.92	479	0.93	644	0.87	206	0.99

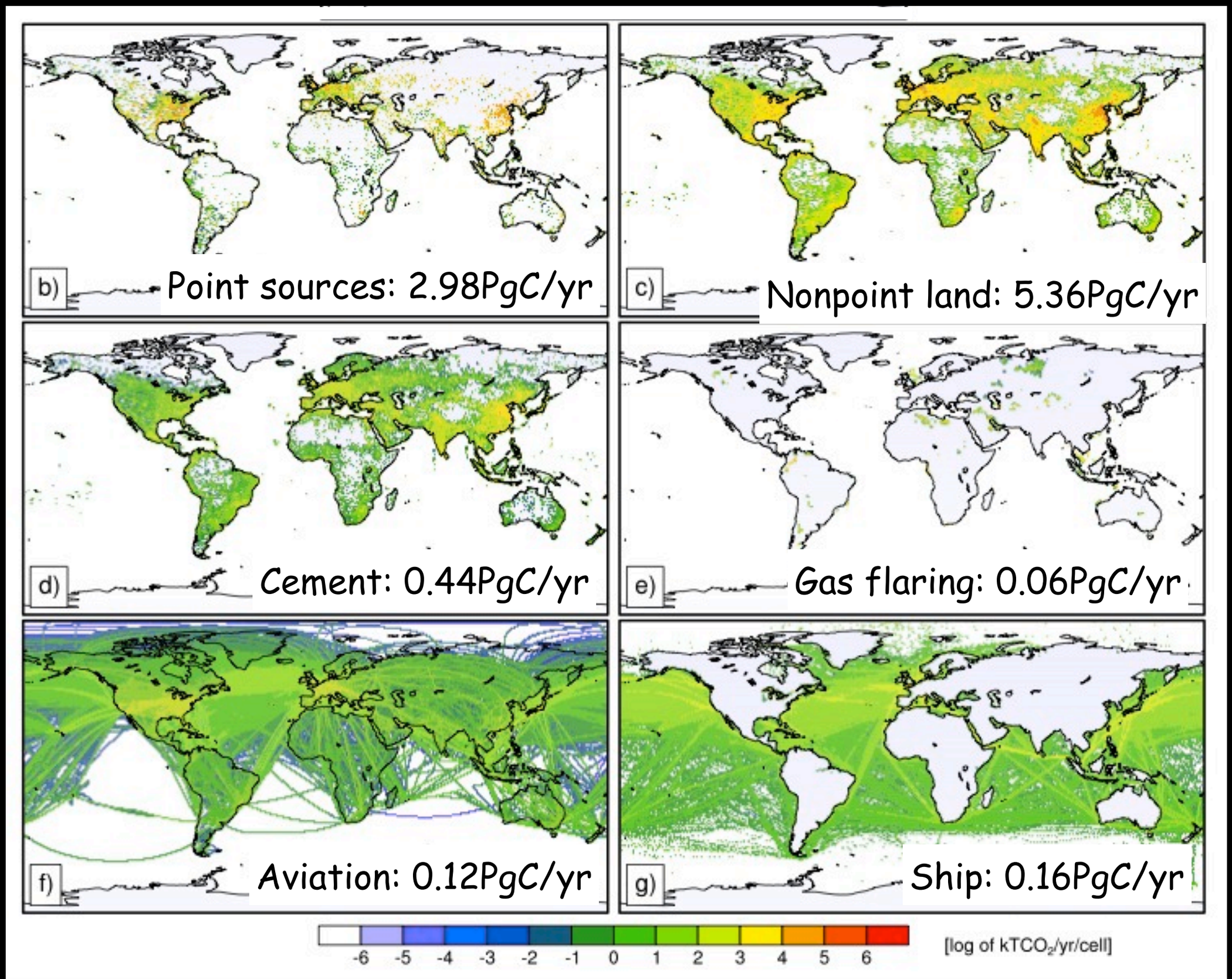
Oda and Maksyutov (2011)

Global emissions field Y2010 - ODIAC ver.3.0

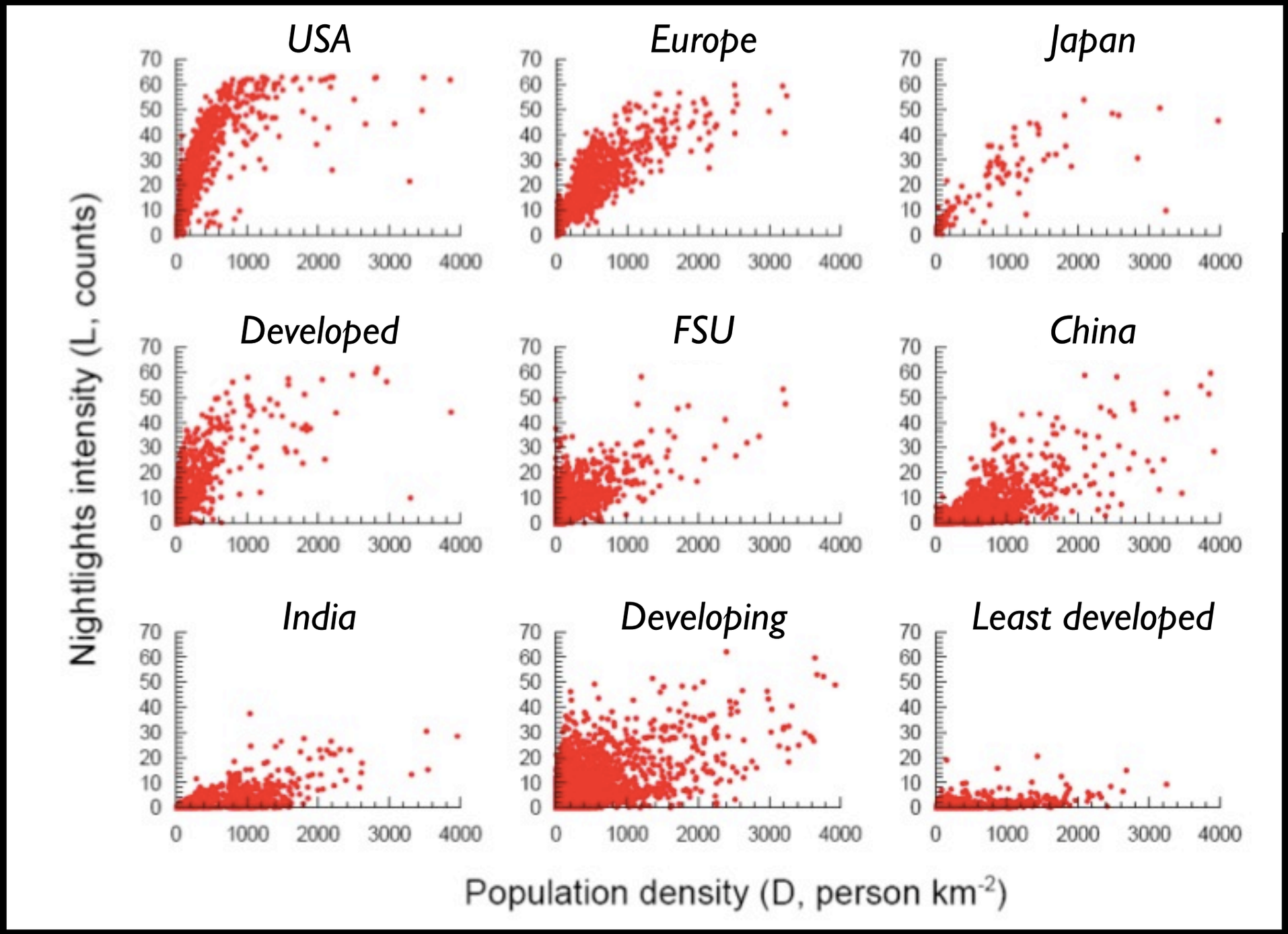


Odiac emission dataset can be updated and provided in a timely manner.

Emission breakdown



Nightlight may not work very well...



Raupach et al. (2009)

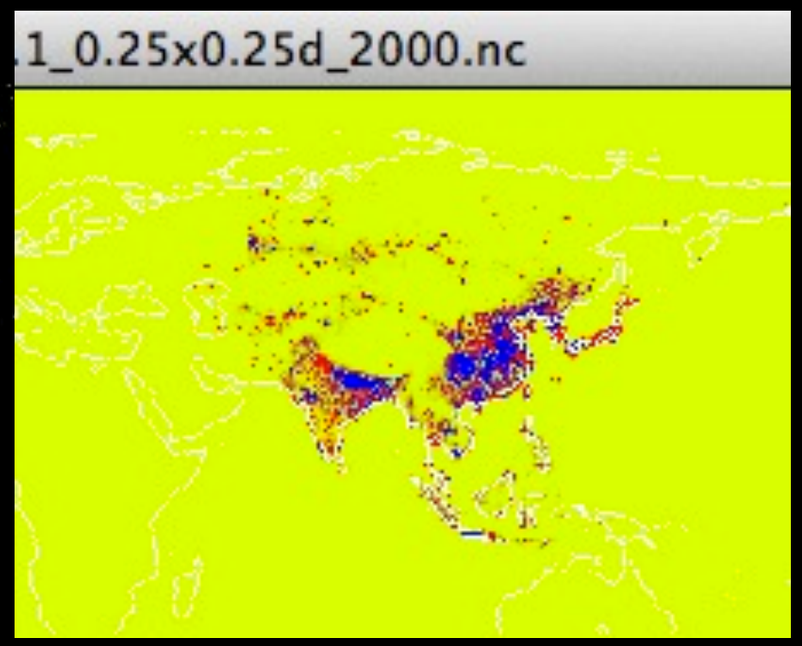
So let's see how Odiac behaves over Asia ;)

I did compare new product to Reas v2.1, but...

- In v3.1 Odiac product, Y2006 nightlight was used to estimate spatial emissions distribution over 2000-2011 (no interannual change!).
- I used updated nightlight data delivered from Elvidge group (Y2000,2002,2004 and 2005) to get the v3.2 product and compared them as well as v3.1 product to REAS v2.1.
- SORRY, I FAILED TO RETRIEVE DATA. THE VPN WAS NOT ESTABLISHED :(
- In short, v3.2 showed smaller absolute difference (SUM (ABS(ODIAC-REAS))) by 5% (R=0.6 or so), meaning nightlight is still brining in emission distribution info even when applied to Asian regions.
- Transport sector seems to be underestimated according to diff maps I created (need to confirm).

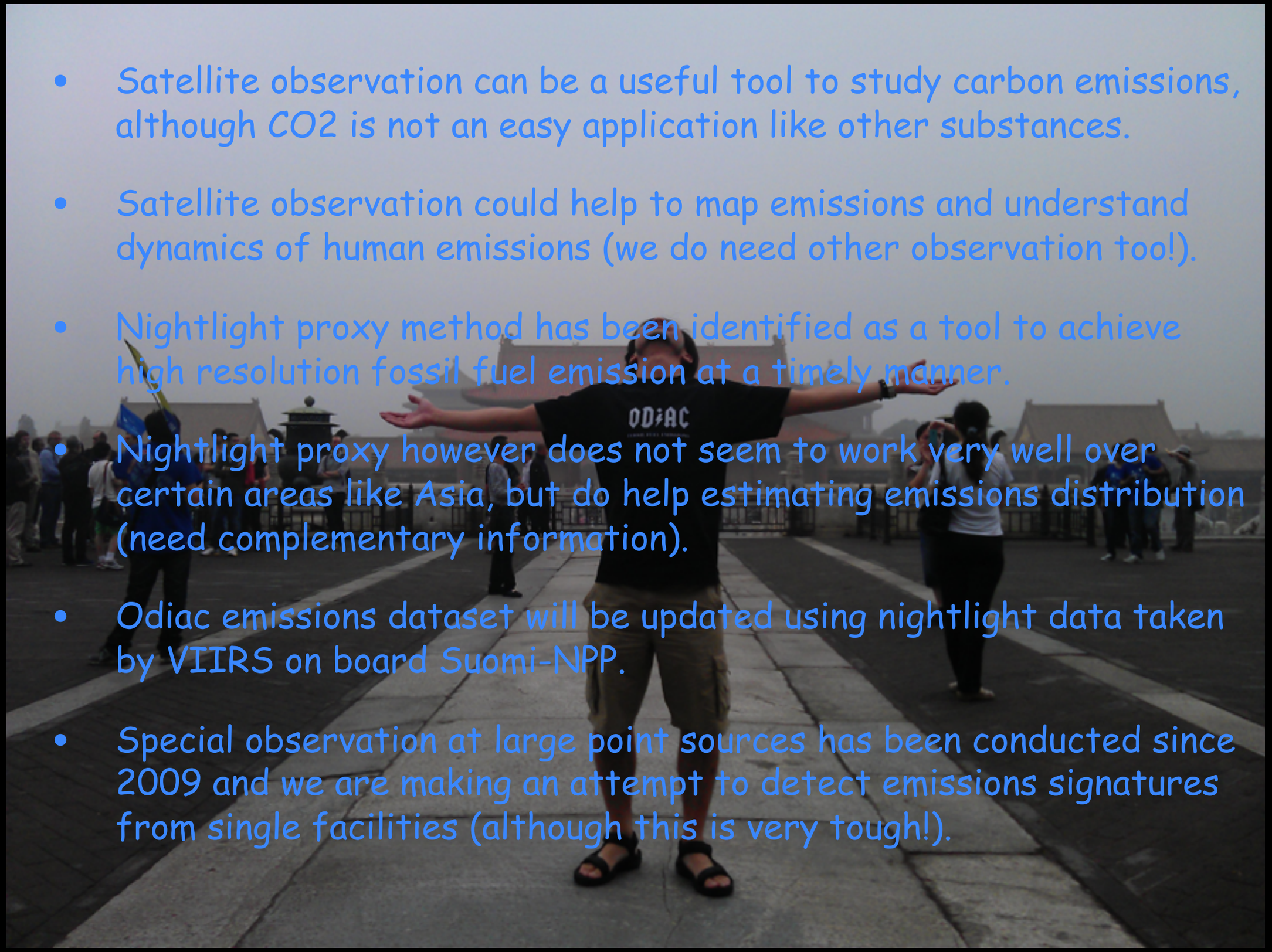
NOTE: Data for different year

Poor snapshot on my display...



Tends to put more emissions along populated regions.
(This is what we expected from low correlation between lights and emissions.)

Summary



- Satellite observation can be a useful tool to study carbon emissions, although CO2 is not an easy application like other substances.
- Satellite observation could help to map emissions and understand dynamics of human emissions (we do need other observation too!).
- Nightlight proxy method has been identified as a tool to achieve high resolution fossil fuel emission at a timely manner.
- Nightlight proxy however does not seem to work very well over certain areas like Asia, but do help estimating emissions distribution (need complementary information).
- Odiac emissions dataset will be updated using nightlight data taken by VIIRS on board Suomi-NPP.
- Special observation at large point sources has been conducted since 2009 and we are making an attempt to detect emissions signatures from single facilities (although this is very tough!).