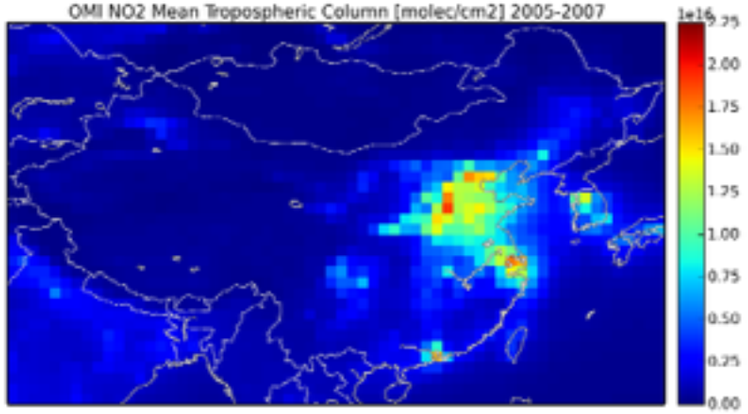
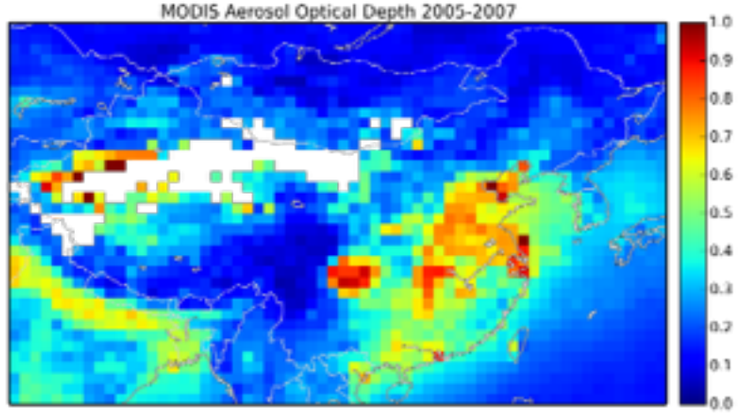
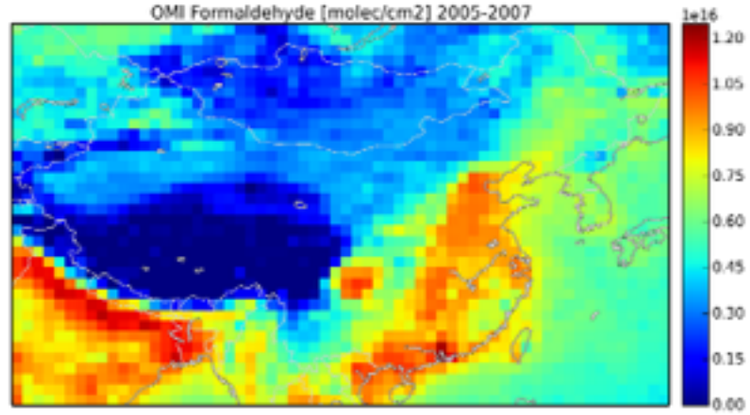
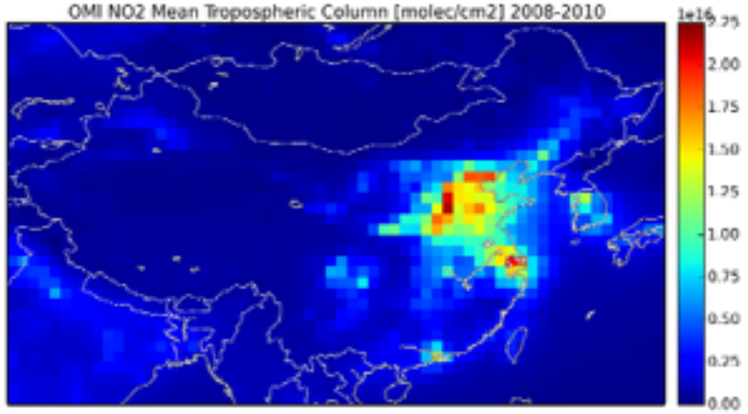
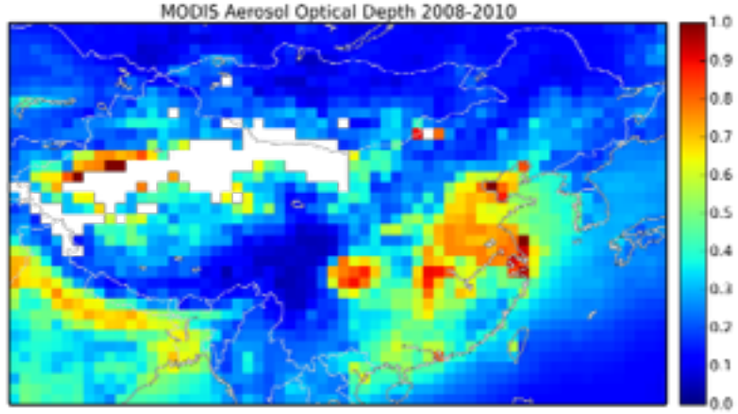
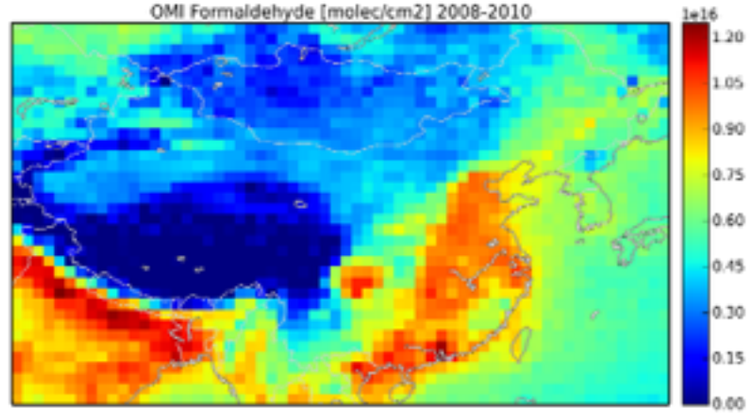
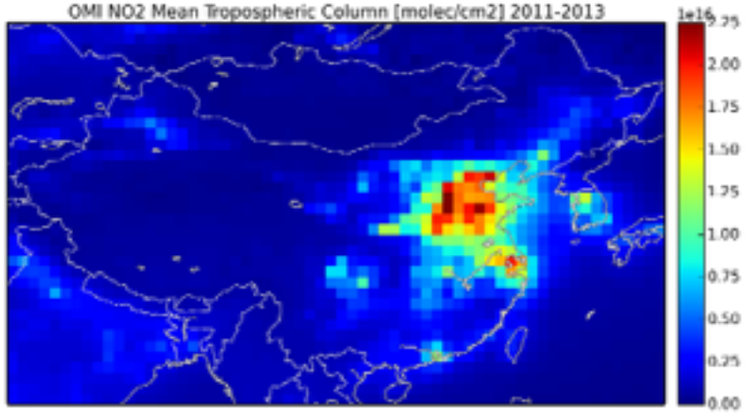
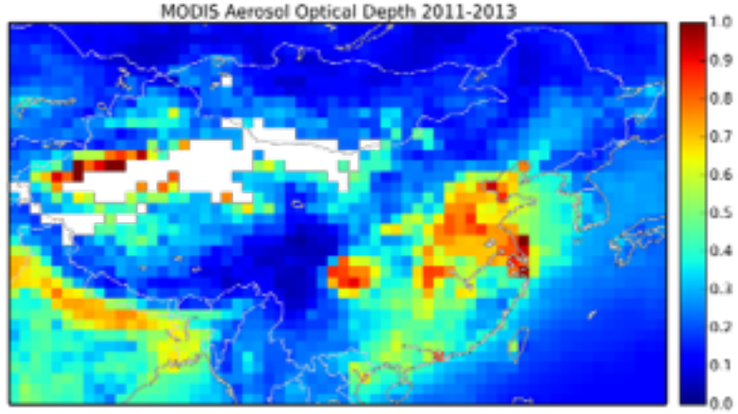
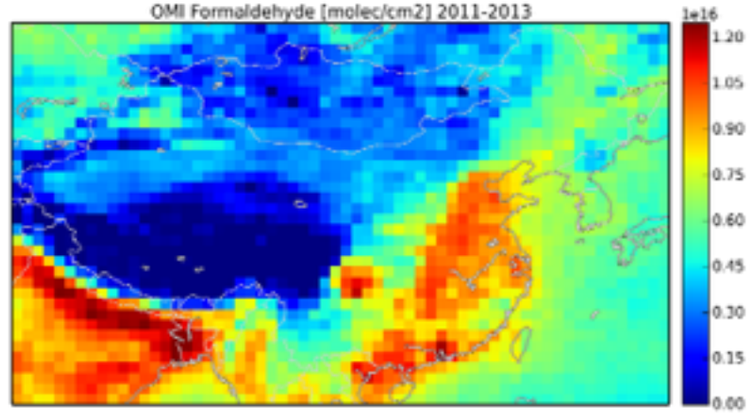
Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

Decadal Regional Trends in Trace Gases and Reflectance as Measured with the Ozone Monitoring Instrument

Pepijn Veefkind, Folkert Boersma, Quintus Kleipool, Isabelle Desmedt and Pieternel Levelt

	OMI NO_2	MODIS AOD	OMI HCHO
2005-2007			
2008-2010			
2011-2013			

Data Sets

- NO_2: DOMINO version 2.0 monthly mean from temis.nl
- HCHO: monthly provided by Isabelle De Smedt from BIRA
- OMI TOA reflectances
- AOD: MODIS Aqua collection 5.1, MISR
- AOD fine mode: POLDER Parasol
- Time period: 2005-2013
- Regridded to 1x1 degree lat-lon grid

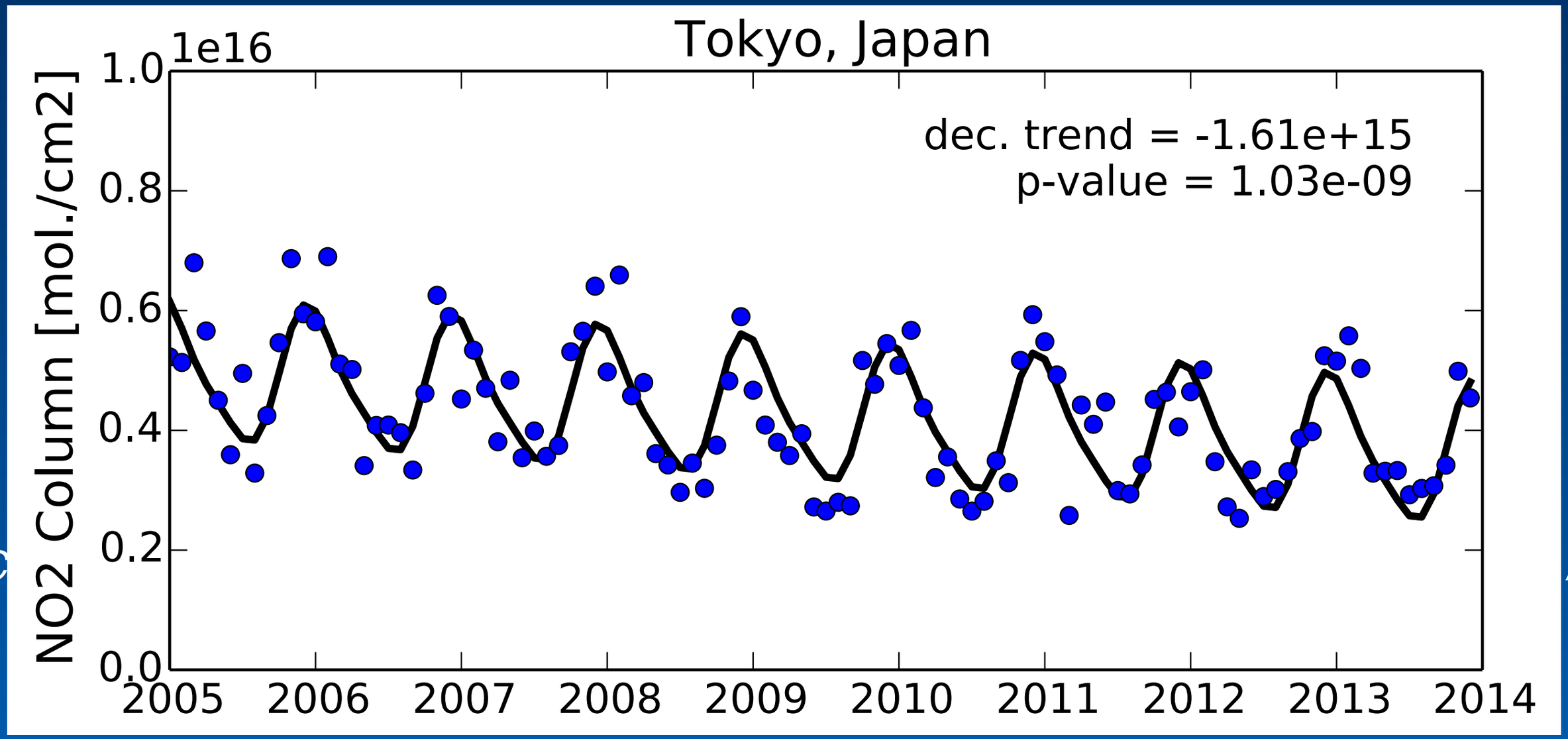
Trend Analysis

- 198 cities ranging in population from 2 to 34 million
- For each of the cities time series are extracted from the Level 3 datasets
  - The time series are fitted using the following formula:

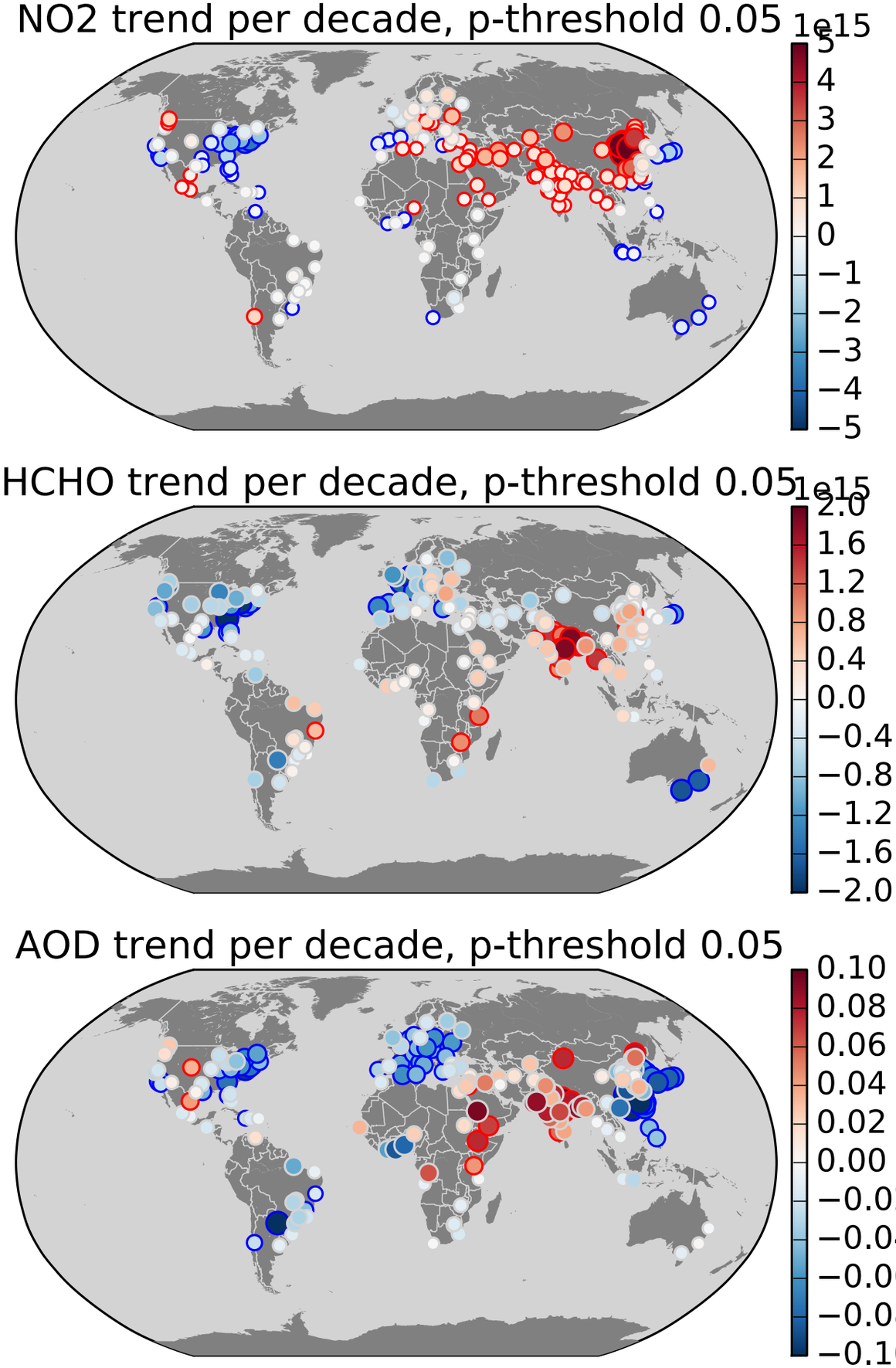
$$c(t) = a_0 + a_1 t + a_2 \sin(2\pi t) + a_3 \cos(2\pi t) + a_4 \sin(4\pi t) + a_5 \sin(4\pi t)$$

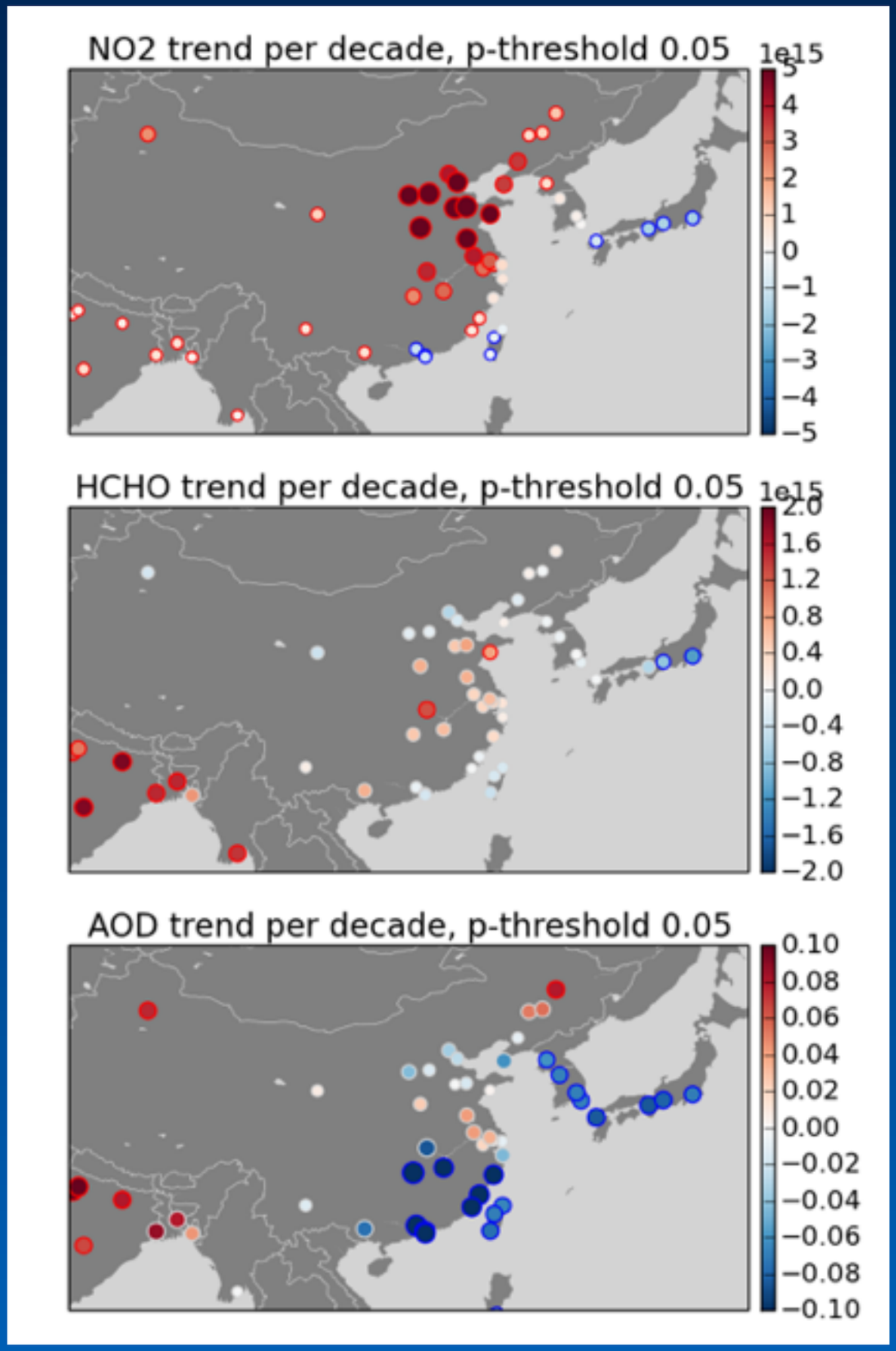
  - P-value to check the statistical significance.

Trend Analysis



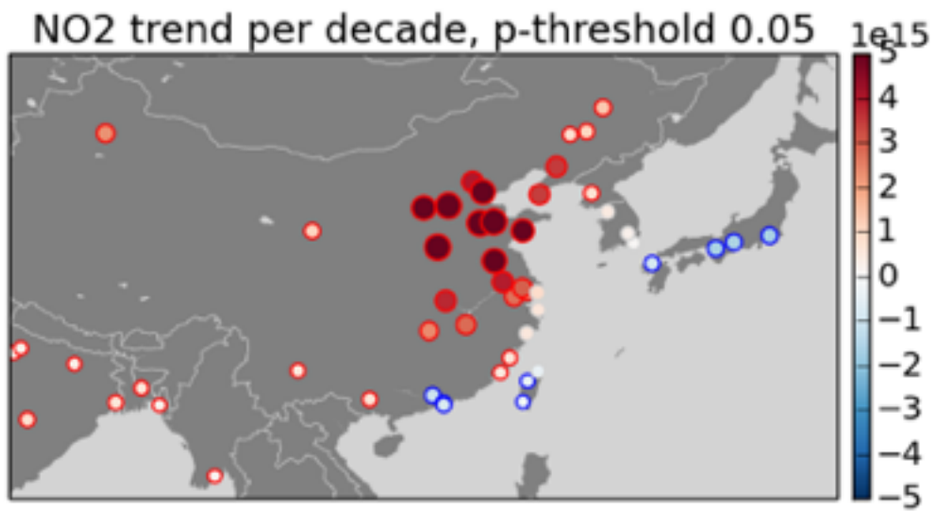
c πt)

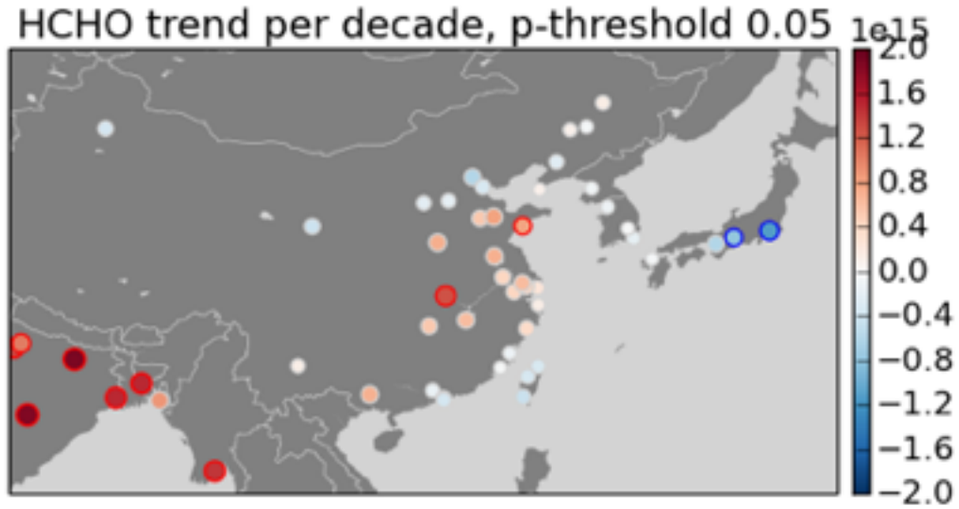

NO2 trend per decade, p-threshold 0.05
1e15
5
4
3
2
1
0
−1
−2
−3
−4
−5
HCHO trend per decade, p-threshold 0.05
1e15
2.0
1.6
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
−1.6
−2.0
AOD trend per decade, p-threshold 0.05
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10

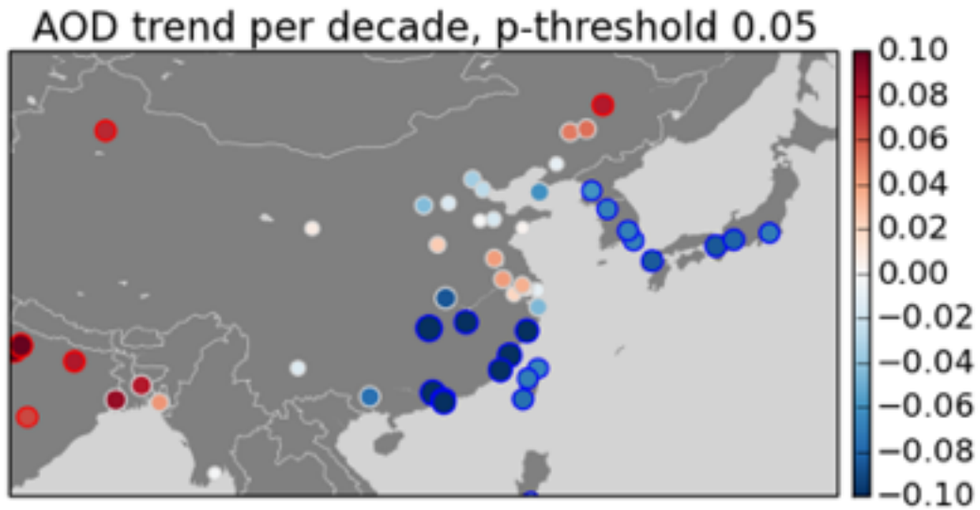

NO2 trend per decade, p-threshold 0.05
1e15
5
4
3
2
1
0
−1
−2
−3
−4
−5
HCHO trend per decade, p-threshold 0.05
1e15
2.0
1.6
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
−1.6
−2.0
AOD trend per decade, p-threshold 0.05
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10

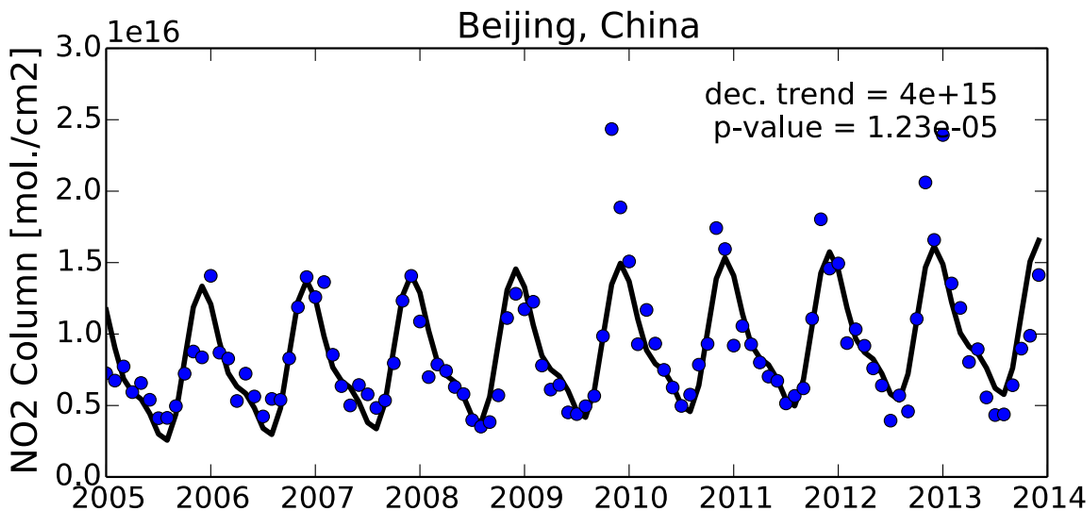
OMI

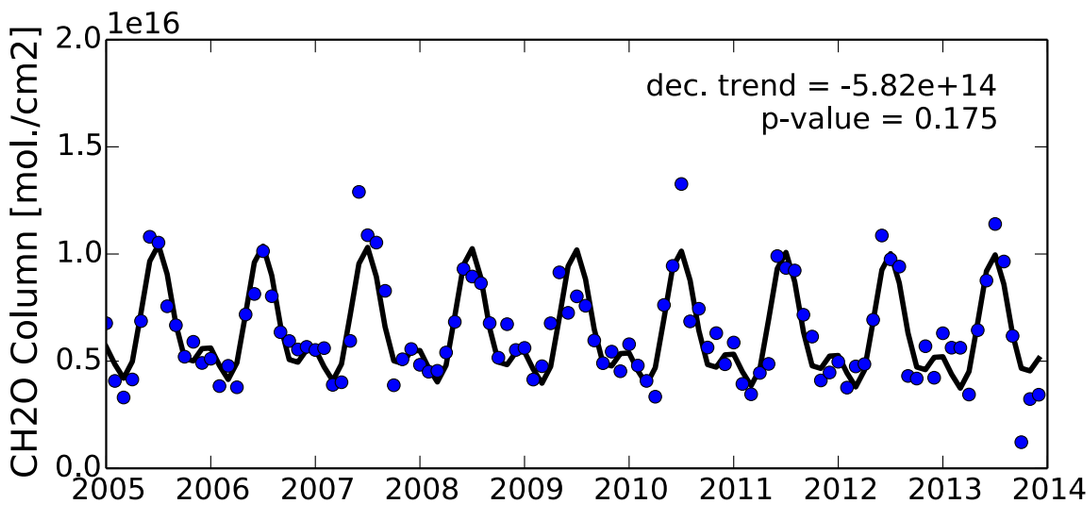
EOS AURA

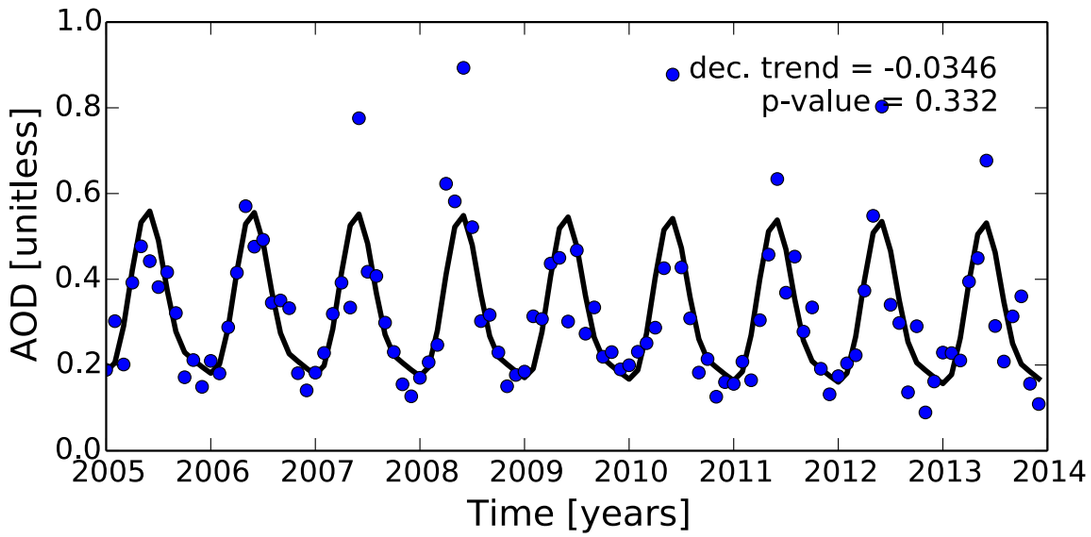

NO2 trend per decade, p-threshold 0.05
1e15
5
4
3
2
1
0
−1
−2
−3
−4
−5

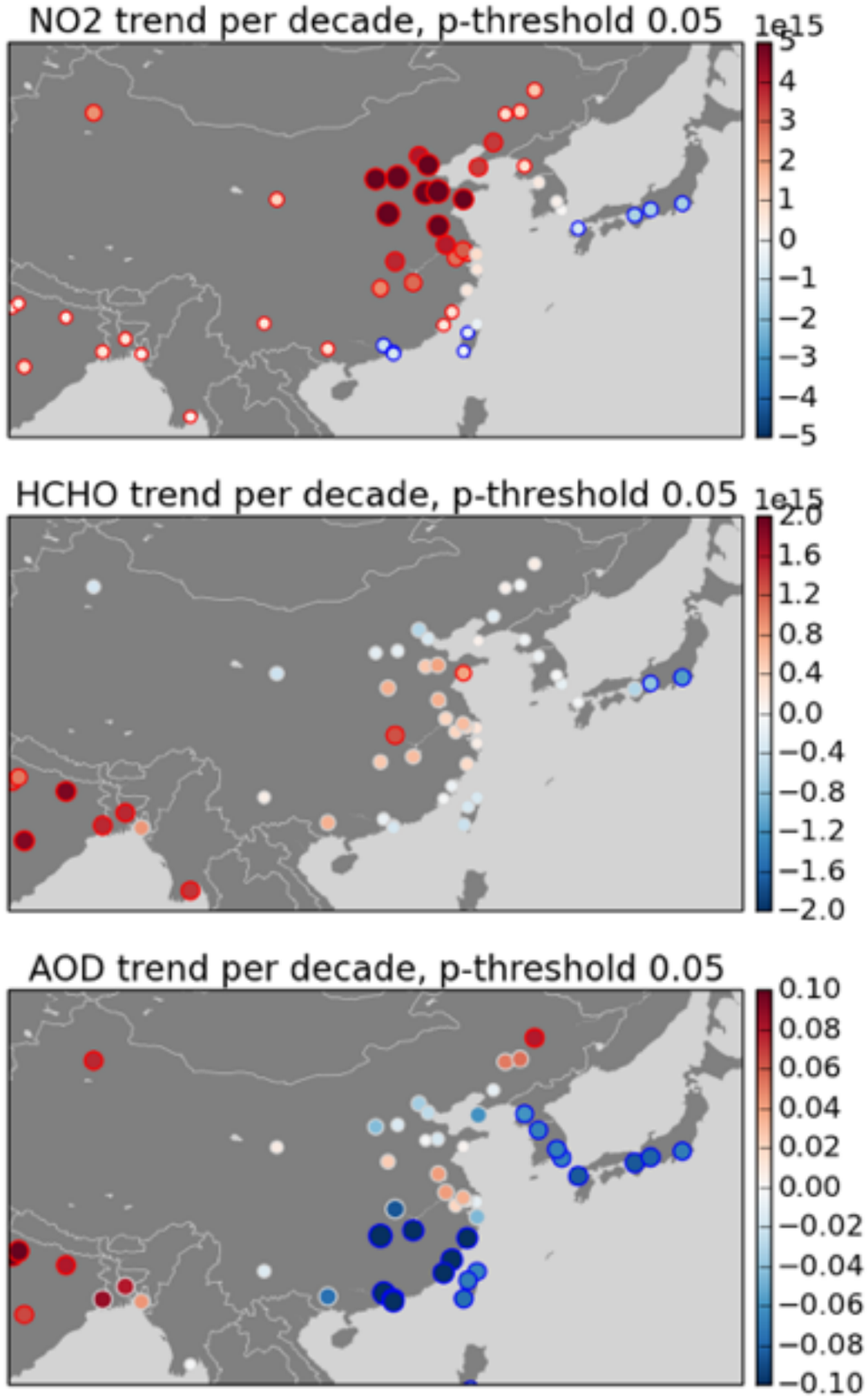

HCHO trend per decade, p-threshold 0.05
1e15
2.0
1.6
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
−1.6
−2.0

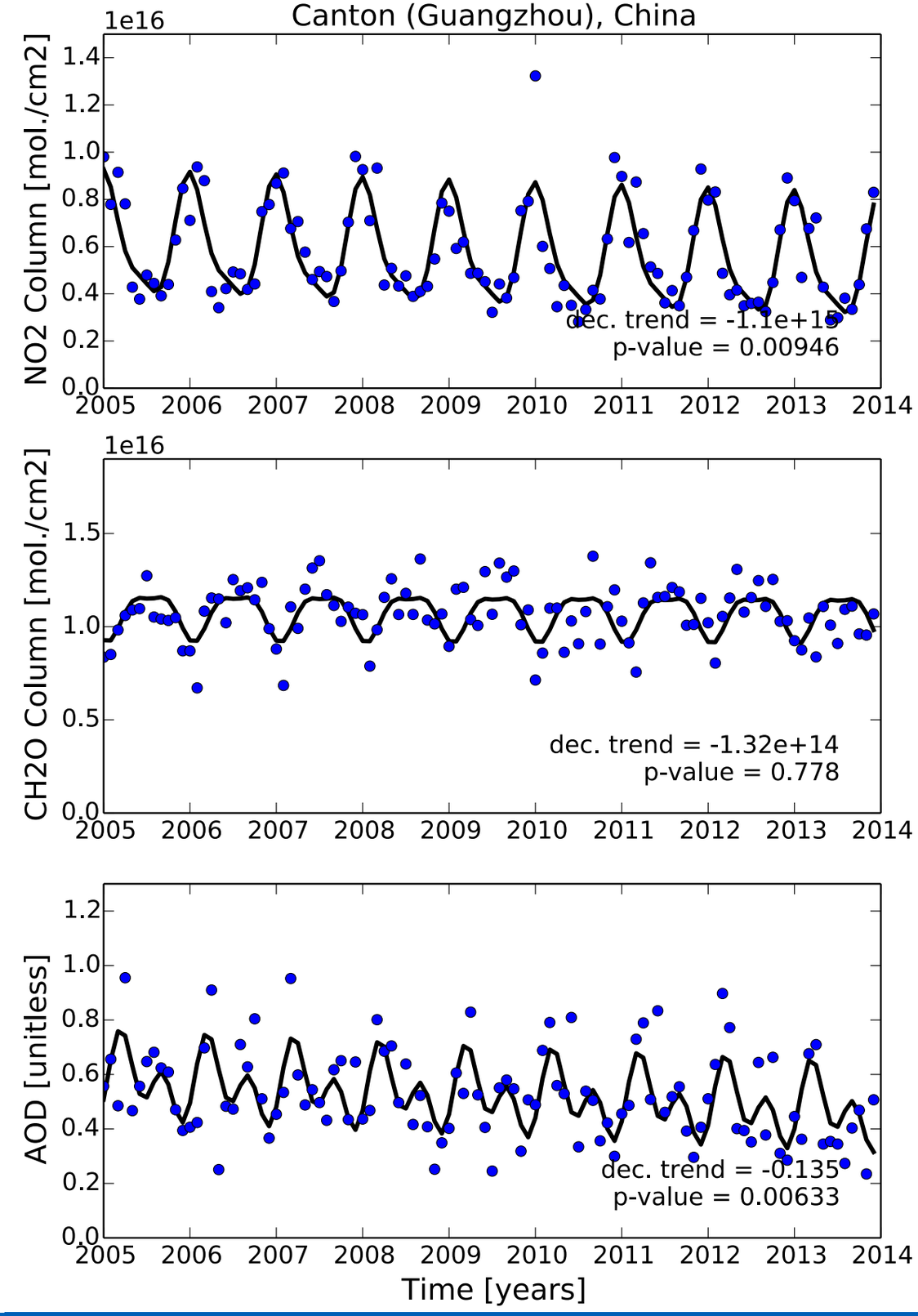

AOD trend per decade, p-threshold 0.05
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10


Beijing, China
1e16
NO2 Column [mol./cm2]
dec. trend = 4e+15
p-value = 1.23e-05
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014


1e16
CH2O Column [mol./cm2]
dec. trend = -5.82e+14
p-value = 0.175
2.0
1.5
1.0
0.5
0.0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014


AOD [unitless]
dec. trend = -0.0346
p-value = 0.332
1.0
0.8
0.6
0.4
0.2
0.0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Time [years]


NO2 trend per decade, p-threshold 0.05
1e15
5
4
3
2
1
0
−1
−2
−3
−4
−5
HCHO trend per decade, p-threshold 0.05
1e15
2.0
1.6
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
−1.6
−2.0
AOD trend per decade, p-threshold 0.05
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10


Canton (Guangzhou), China
1e16
NO2 Column [mol./cm2]
dec. trend = -1.1e+15
p-value = 0.00946
1e16
CH2O Column [mol./cm2]
dec. trend = -1.32e+14
p-value = 0.778
AOD [unitless]
dec. trend = -0.135
p-value = 0.00633
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Time [years]

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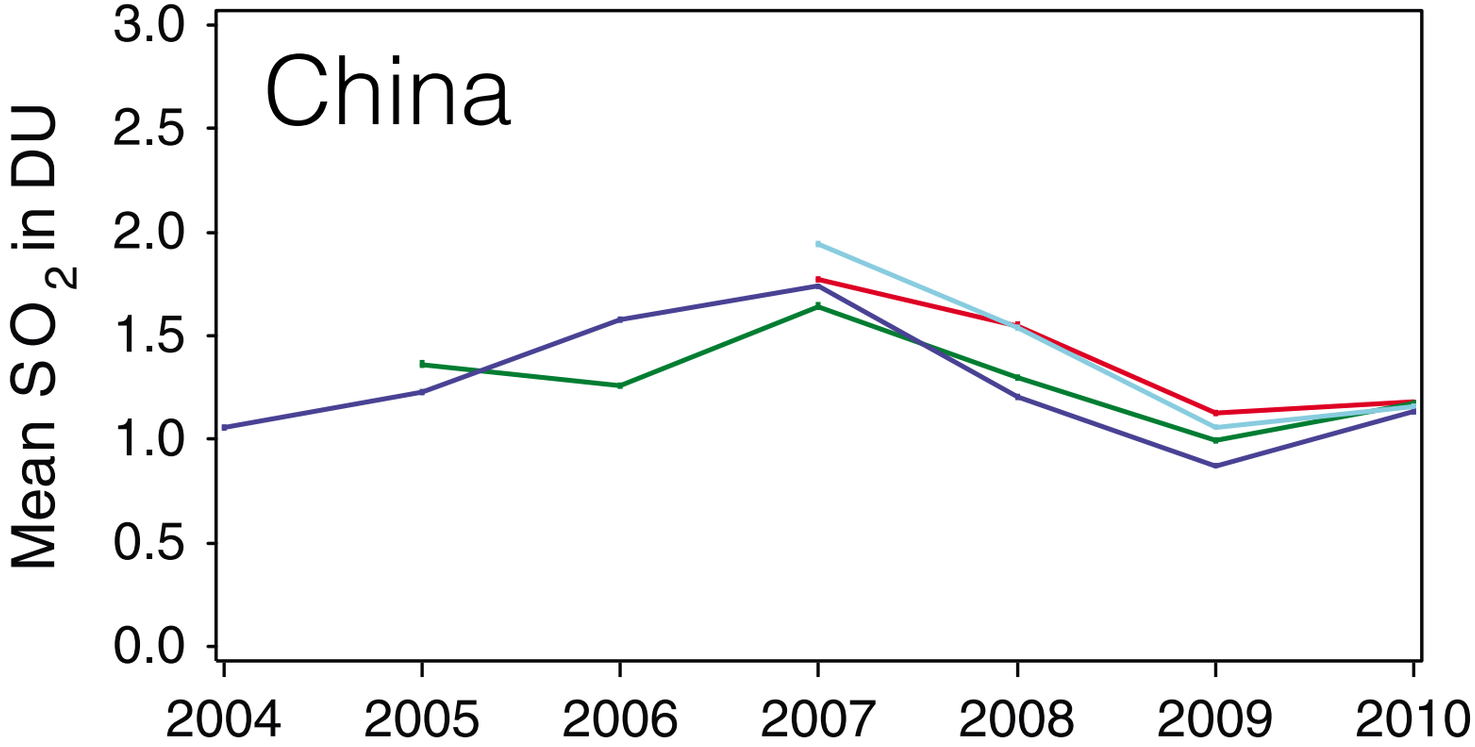
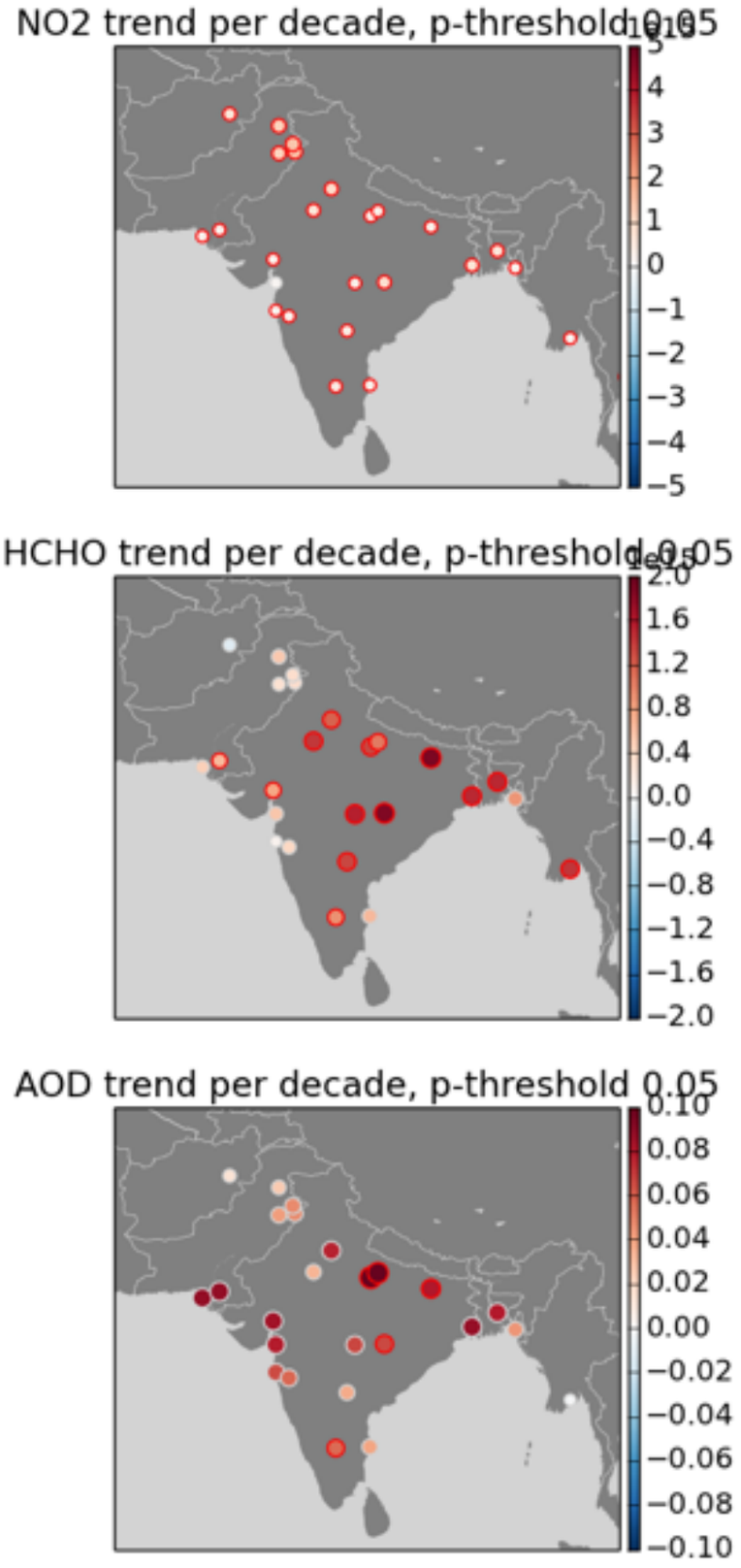
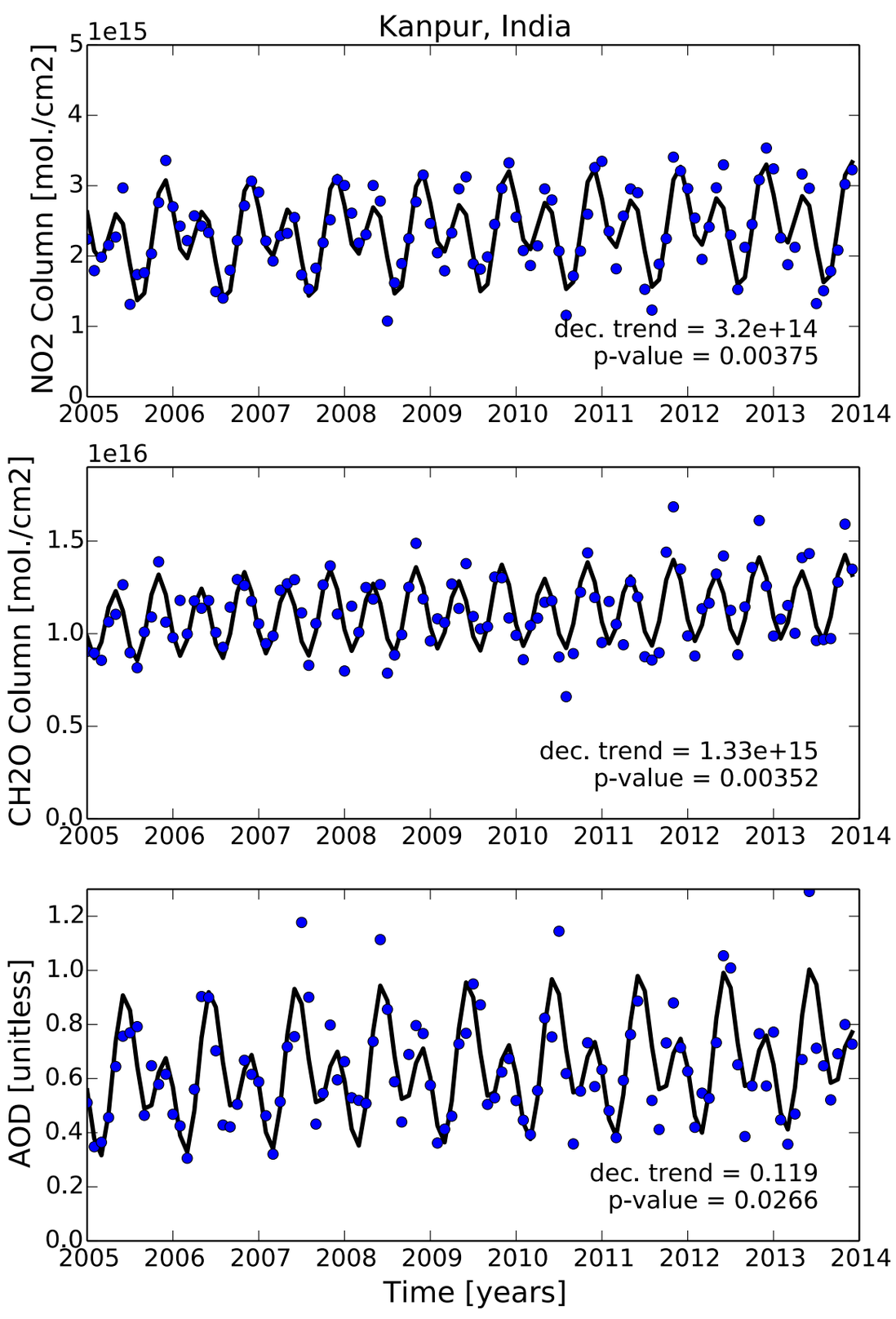
Application of OMI, SCIAMACHY, and GOME-2 satellite SO_2 retrievals for detection of large emission sources

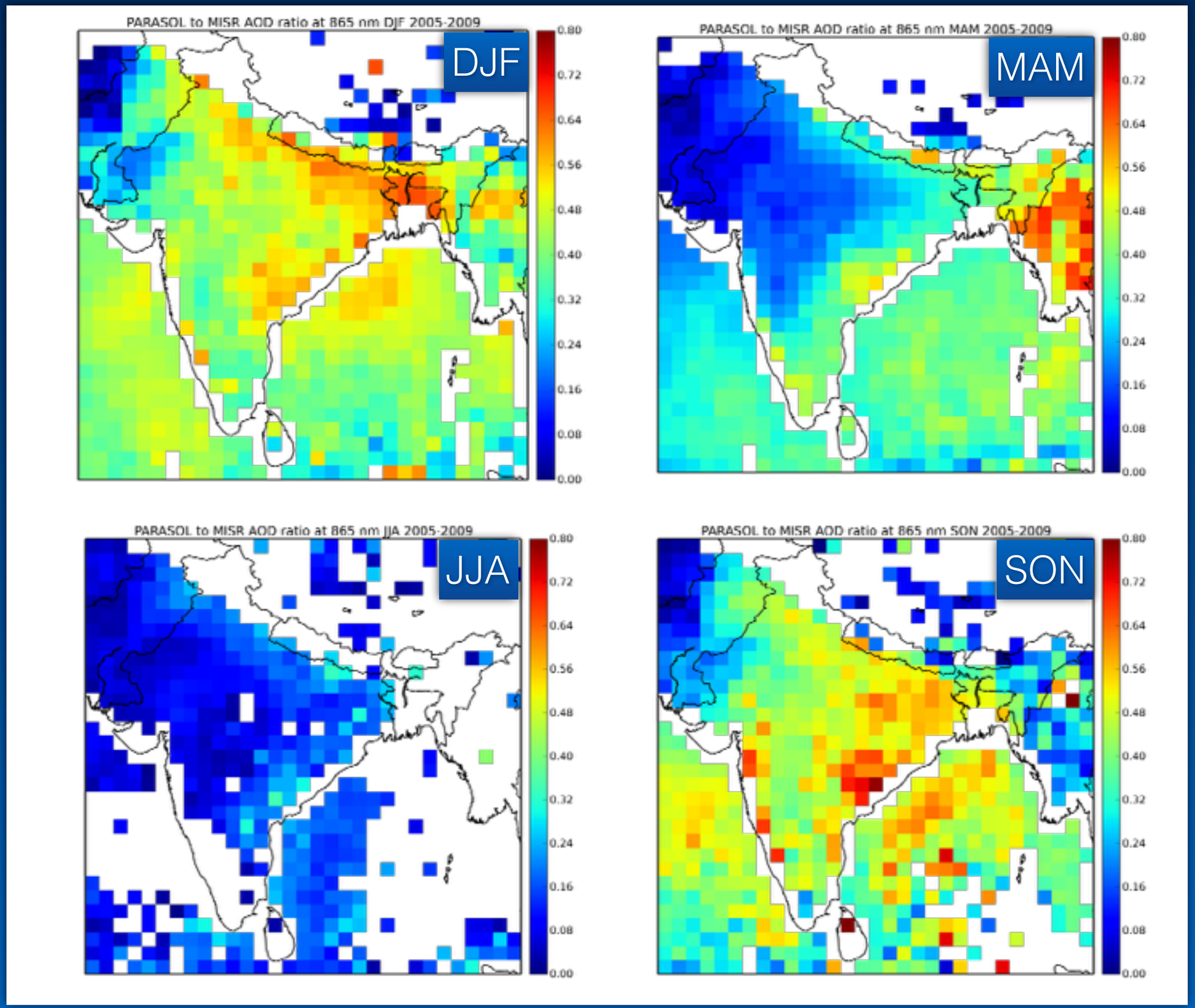
V. E. Fioletov,[1] C. A. McLinden,[1] N. Krotkov,[2] K. Yang,[2,3] D. G. Loyola,[4] P. Valks,[4] N. Theys,[5] M. Van Roozendael,[5] C. R. Nowlan,[6] K. Chance,[7] X. Liu,[7] C. Lee,[8] and R. V. Martin[6,7]



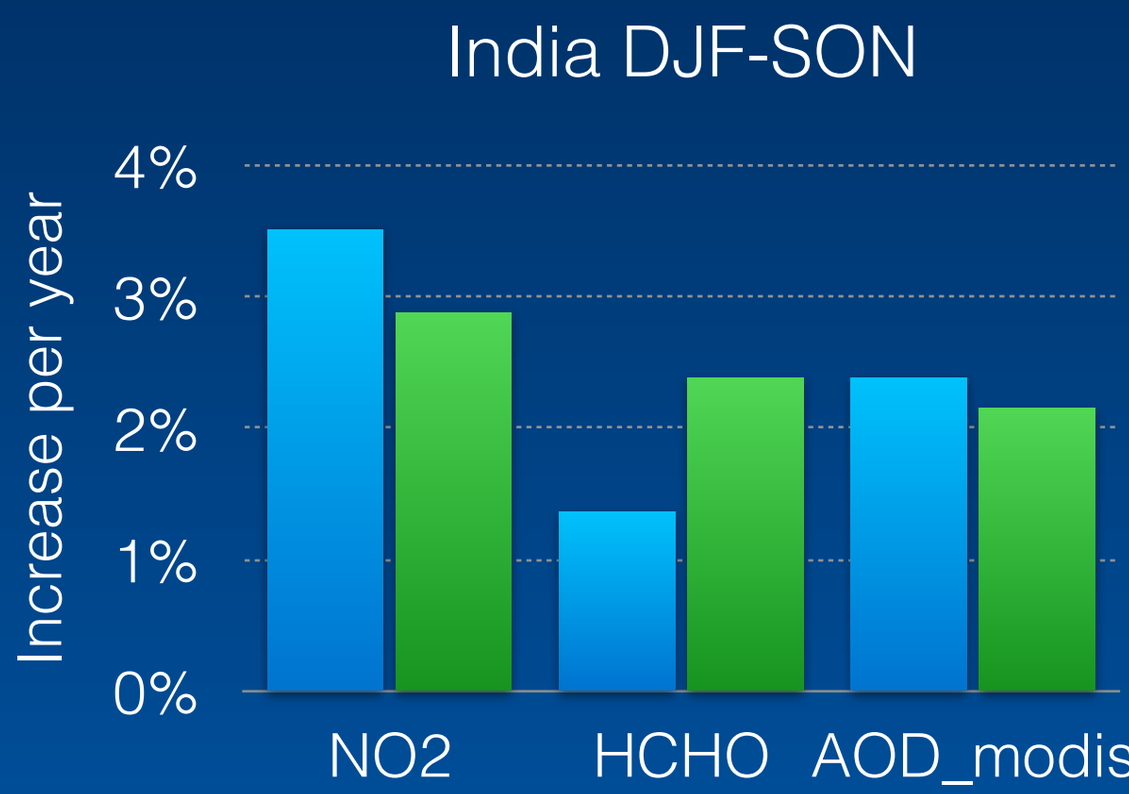

NO2 trend per decade, p-threshold 0.05
1e15
5
4
3
2
1
0
−1
−2
−3
−4
−5
HCHO trend per decade, p-threshold 0.05
1e15
2.0
1.6
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
−1.6
−2.0
AOD trend per decade, p-threshold 0.05
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10

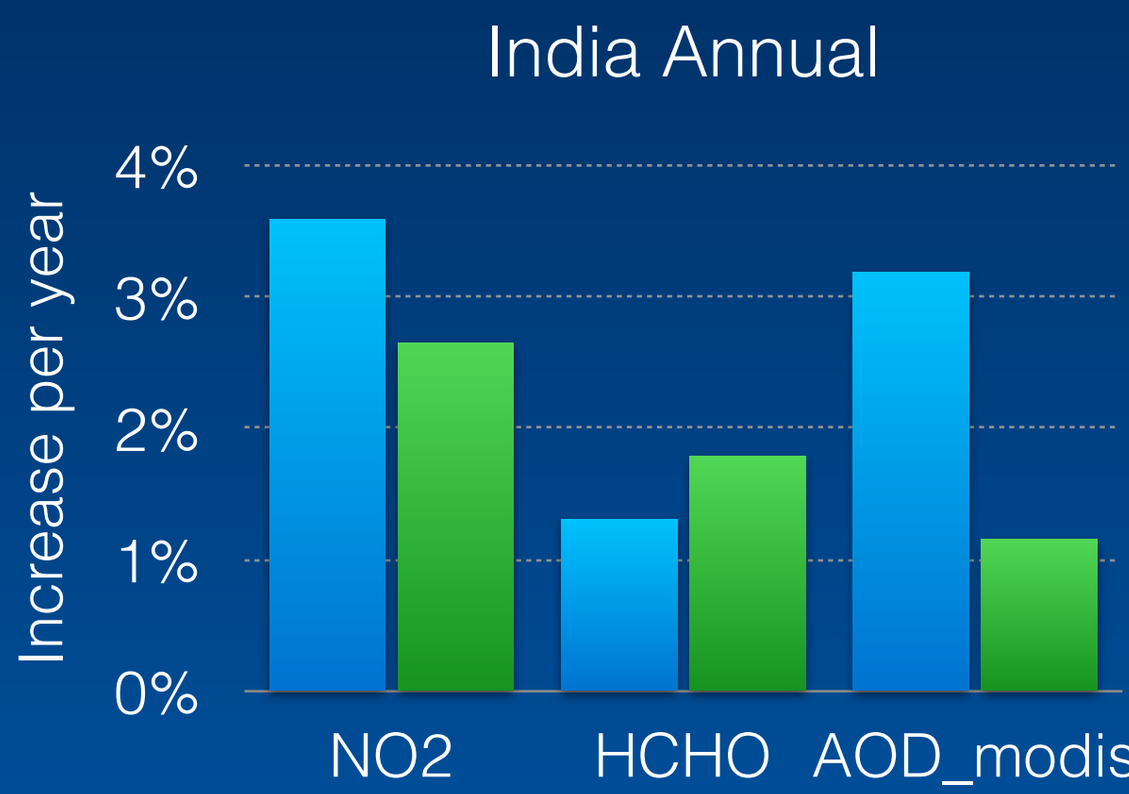

Kanpur, India
1e15
NO2 Column [mol./cm2]
dec. trend = 3.2e+14
p-value = 0.00375
1e16
CH2O Column [mol./cm2]
dec. trend = 1.33e+15
p-value = 0.00352
AOD [unitless]
dec. trend = 0.119
p-value = 0.0266
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Time [years]

Antropogenic vs Natural Aerosols

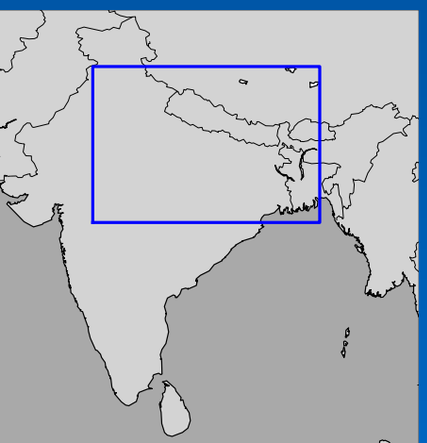


N-India

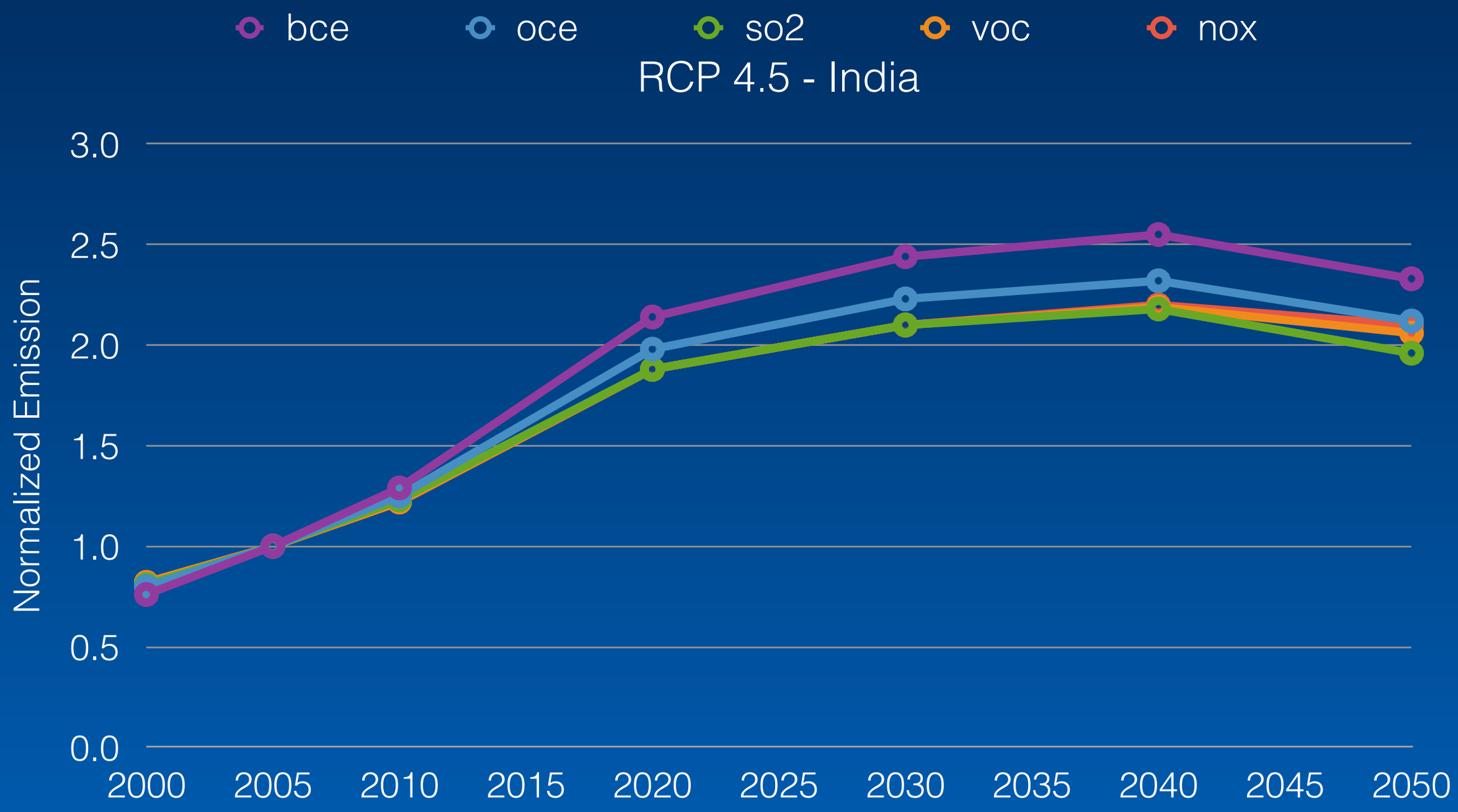




Period 1: [2008-2010] vs [2005-2007]
Period 2: [2011-2013] vs [2008-2010]

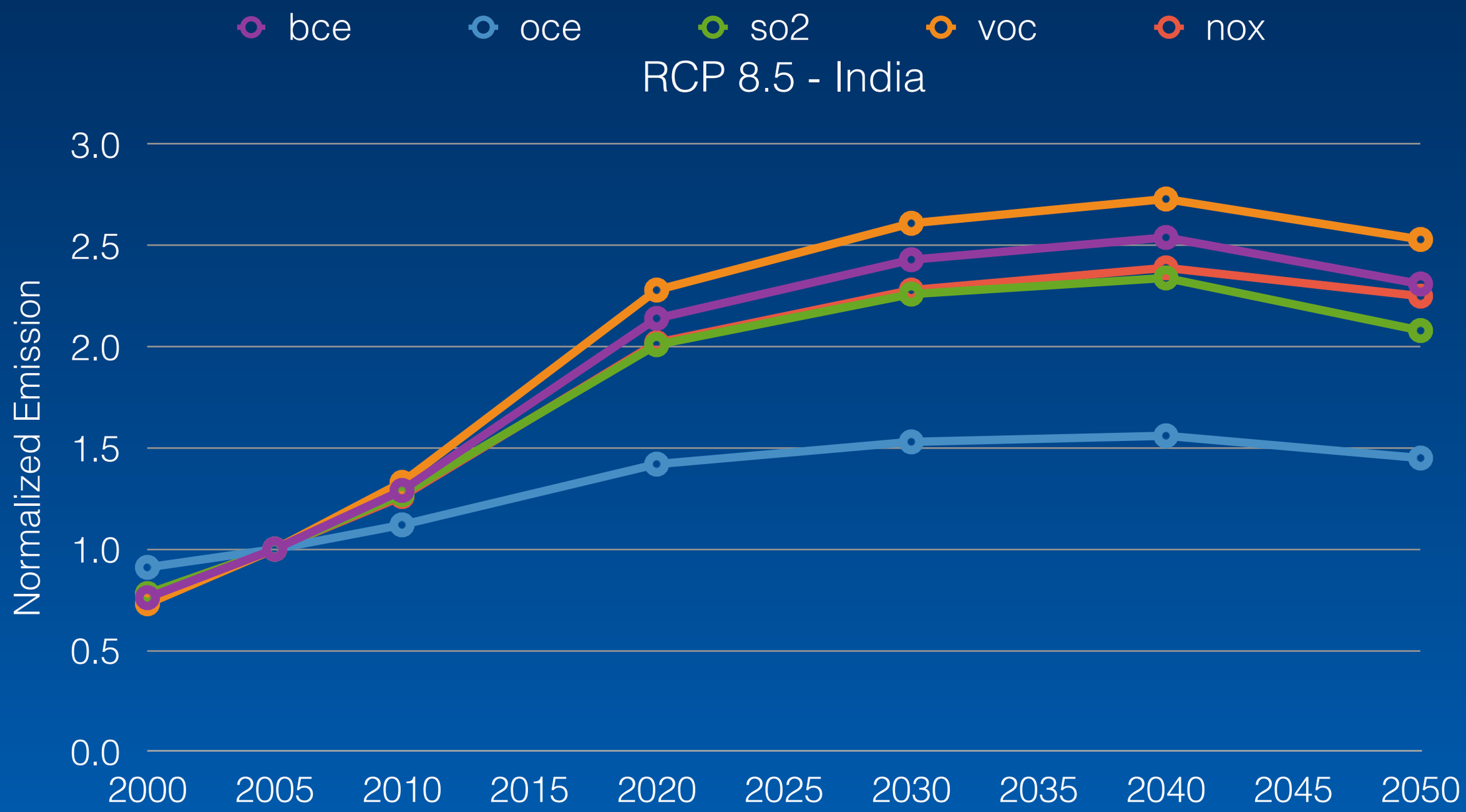


Emission Scenarios - India



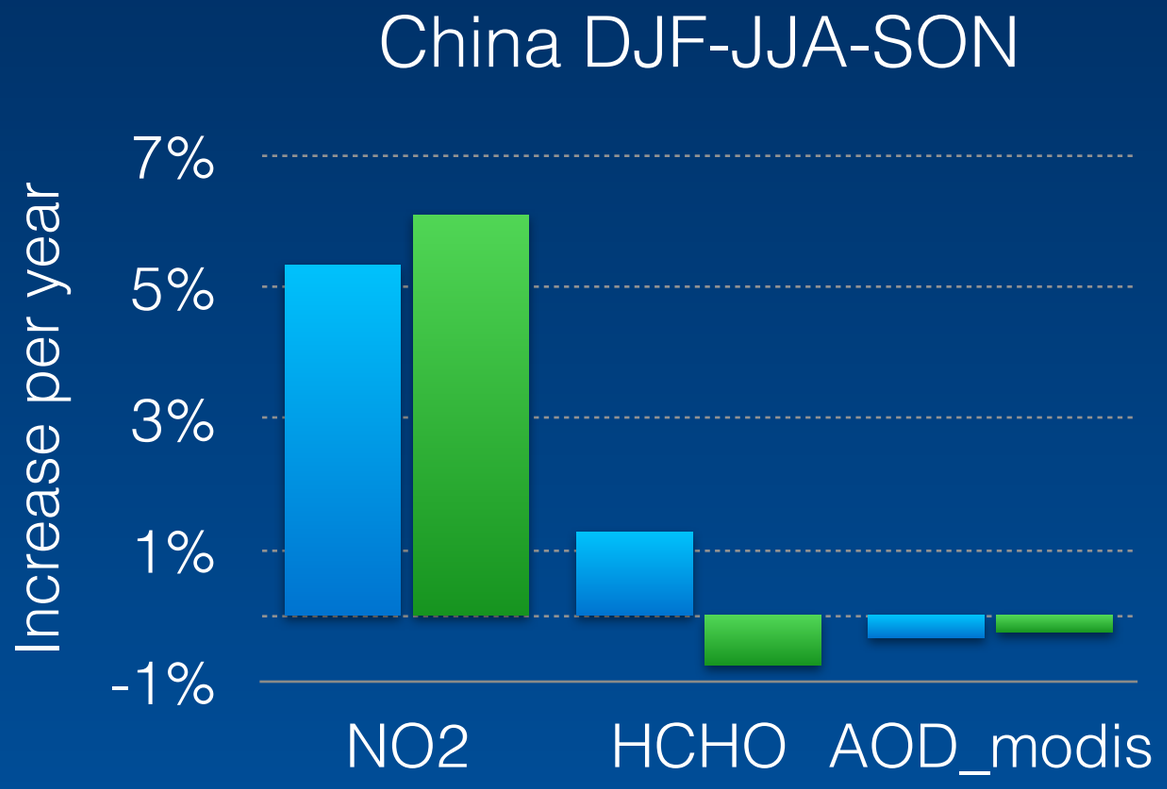
http://tntcat.iiasa.ac.at/RcpDb

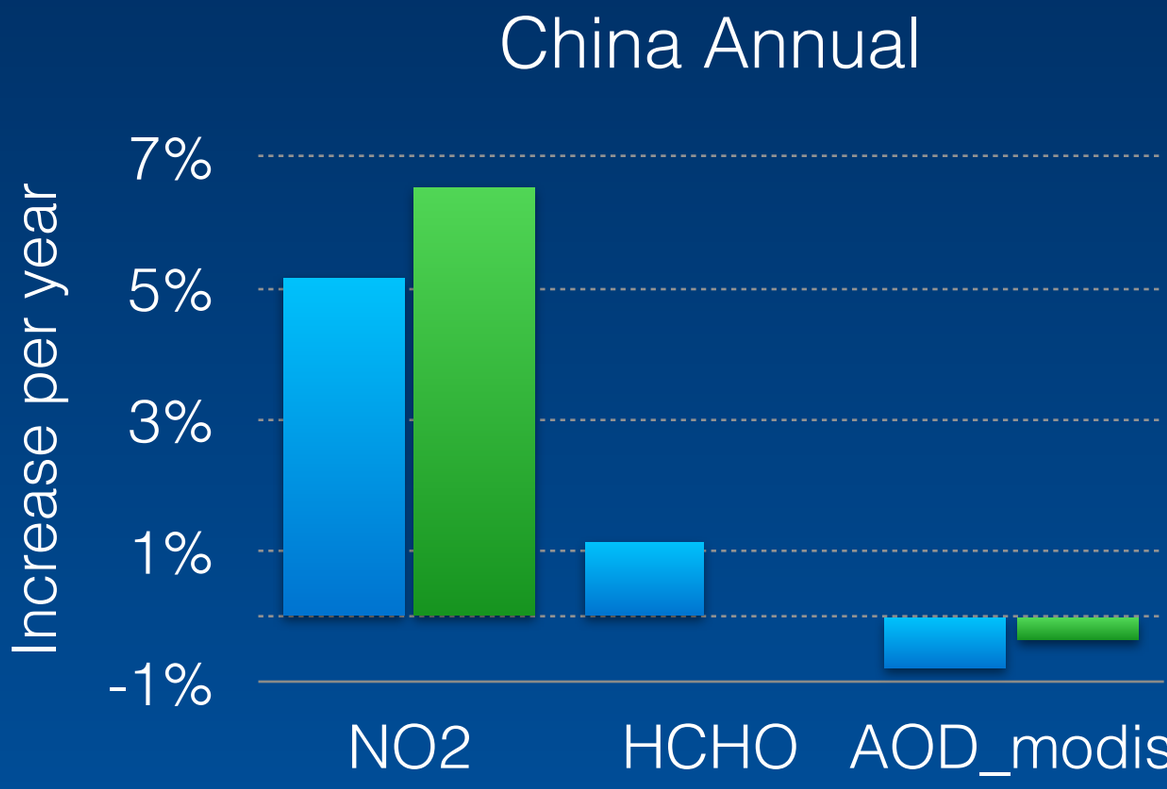
Emission Scenarios - India



http://tntcat.iiasa.ac.at/RcpDb

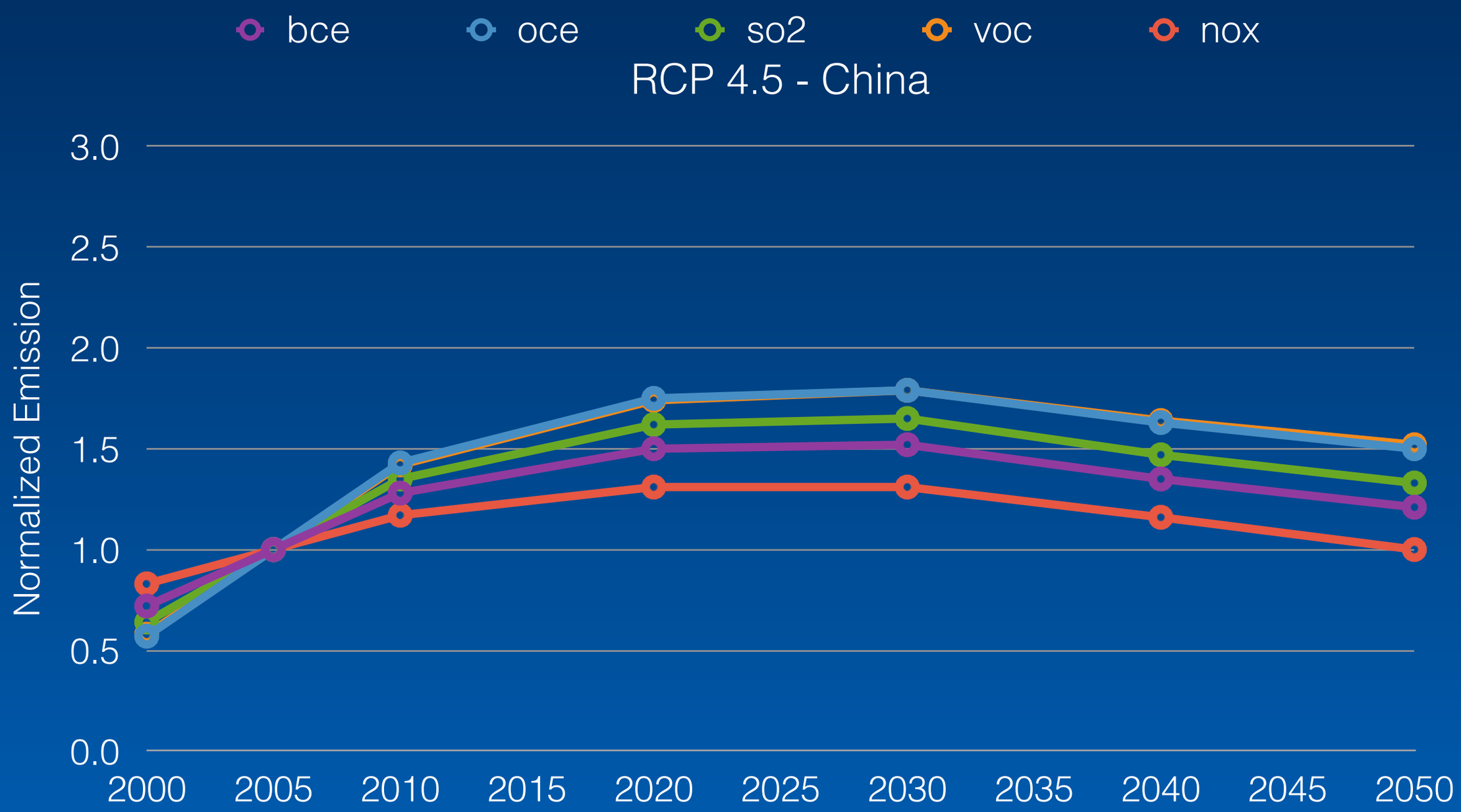
NE-China





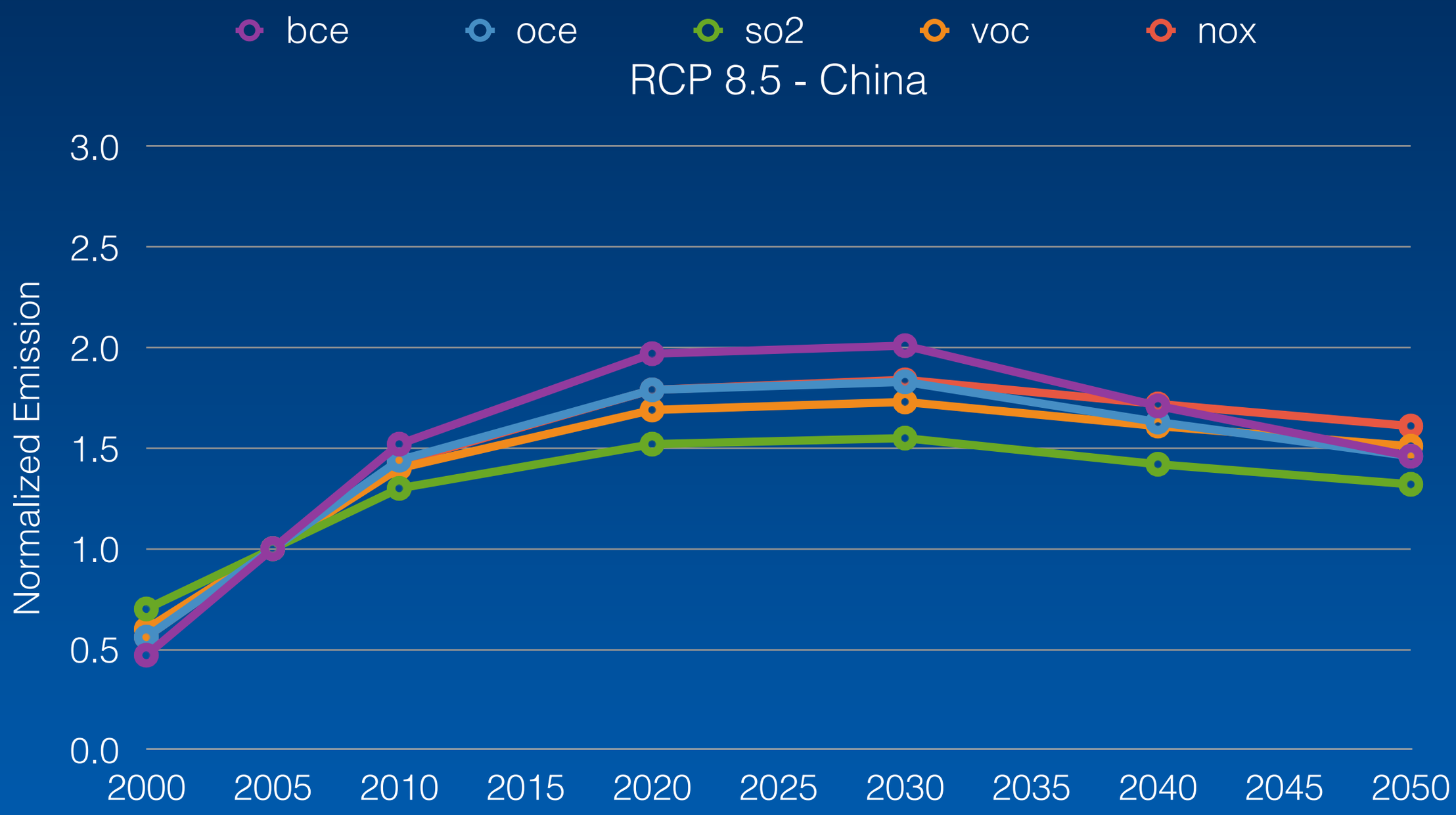
Period 1: [2008-2010] vs [2005-2007]
Period 2: [2011-2013] vs [2008-2010]

Emission Scenarios - China



http://tntcat.iiasa.ac.at/RcpDb

Emission Scenarios - China



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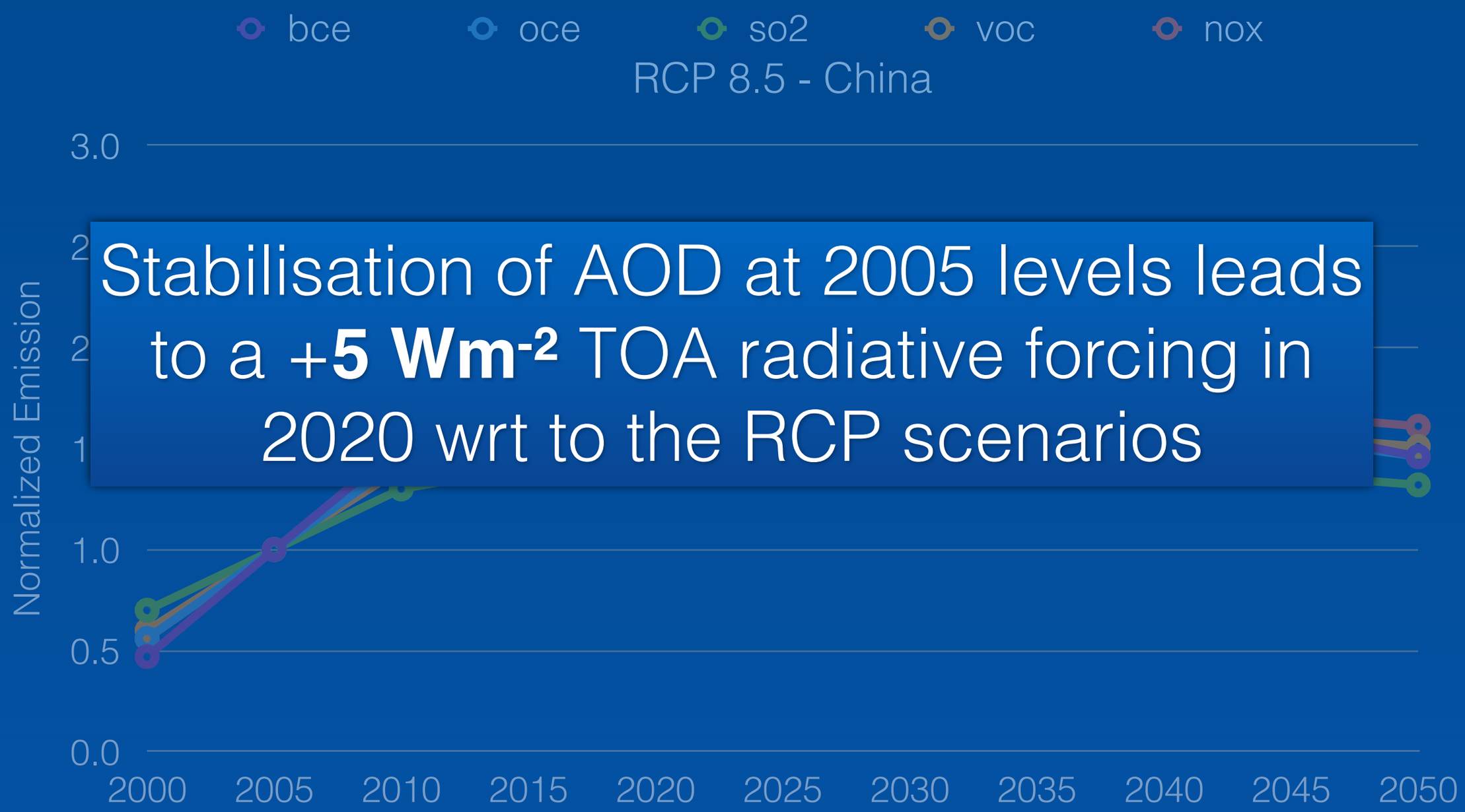
Emission Scenarios - China



Stabilisation of AOD at 2005 levels leads to a +**5 Wm^{-2}** TOA radiative forcing in 2020 wrt to the RCP scenarios

http://tntcat.iiasa.ac.at/RcpDb

Conclusions

- The OMI/Aura dataset is excellent for trend studies.
- Over India NO_2, formaldehyde and AOD are increasing. The increases are in line with the Rcp emission databases.
- Over NE China NO_2 is increasing in line with the Rcp database. In disagreement with Rcp, AOD has not been increasing from 2005-2013, likely due to air quality measures.
- The absence of a trend in AOD over China leads to an additional +5 Wm^{-2} TOA regional radiative forcing wrt to the Rcp database.