ASSESSMENT of LONG-TERM TREND of TURKEY'S GREENHOUSE GAS EMISSIONS USING MANN KENDALL TEST

Fatma Öztürk

Abant İzzet Baysal University, Faculty of Engineering and Architecture, Environmental Engineering Department, Turkey

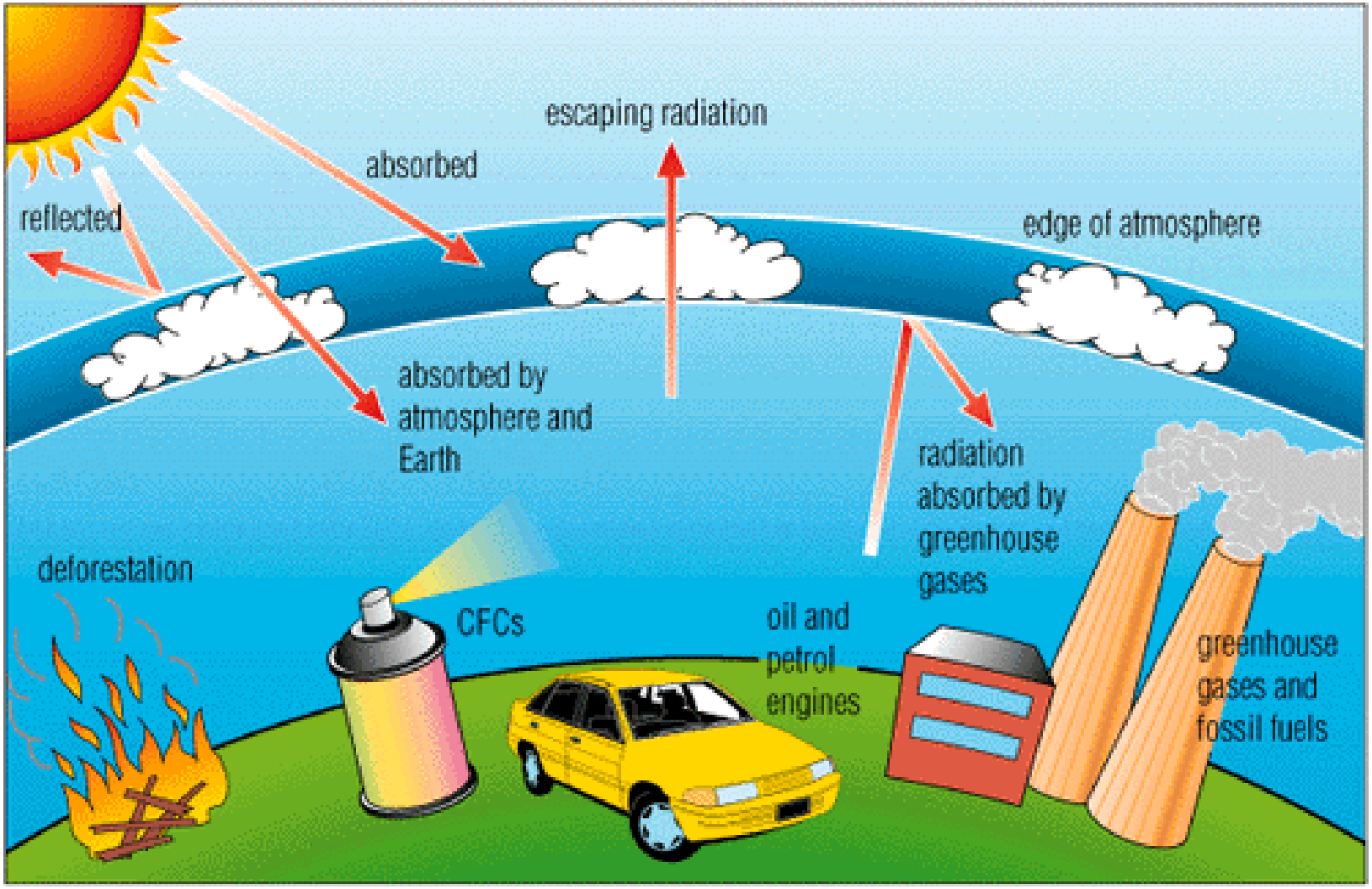
Visiting Scientist as Post-Doctoral Student

NOAA, ESRL, Chemical Sciences Division, CO

CONTENT

- Introduction
  - What is Greenhouse Effect?
  - Greenhouse gases (GHGs)
  - Kyoto Protocol
  - Turkey's Position in Kyoto Protocol
- Methodology
  - Mann Kendall test
  - Sen's slope estimator
- Results
  - GHG-specific trends
  - Sector-specific trends
  - Comparison with other countries
- Conclusion

What is Greenhouse Effect?



Major Greenhouse Gases

	Lifetime (years)	Global Warming Potential (GWP) time horizon		
		20 years	100 years	500 years
Methane (CH_4)	12	72	25	7.6
Nitrous oxide (N_2O)	114	310	298	153
PFC-14 (CF_4)	50,000	5,210	7,390	11,200
PFC-116 (C_2F_6)	10,000	8,630	12,200	18,200
Sulfur hexafluoride (SF_6)	3200	16,300	22,800	32,600

Source: "IPCC Fourth Assessment Report: Climate Change 2007"

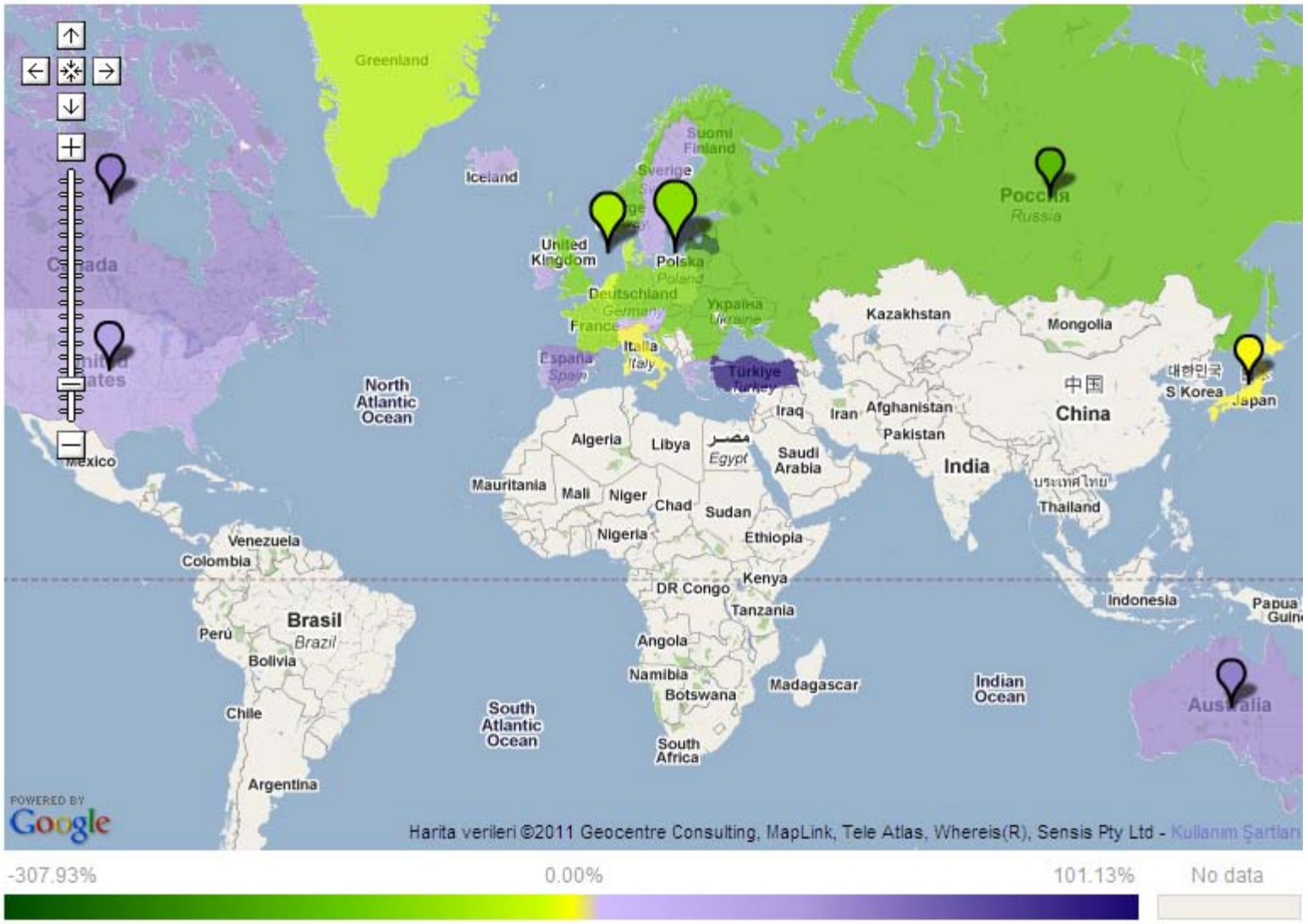
KYOTO PROTOCOL

- The Kyoto protocol is an international treaty related to the United Nations Framework Convention on Climate Change (UNFCCC or FCCC)
- Aim is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (man-made) interference with the climate system
- The Kyoto Protocol establishes legally binding commitments for the reduction of four greenhouse gases: CO_2, CH_4, N_2O, SF_6), and two groups of gases (HFCs and PFCs)
- By 2011, 192 countries have ratified the protocol, which was initially adopted for use on 11 December 1997 in Kyoto, Japan and which entered into force on 16 February 2005
- Under Kyoto, industrialized countries agreed to reduce their collective GHG emissions by 5.2% compared to the year 1990

Turkey's Position in Kyoto Protocol

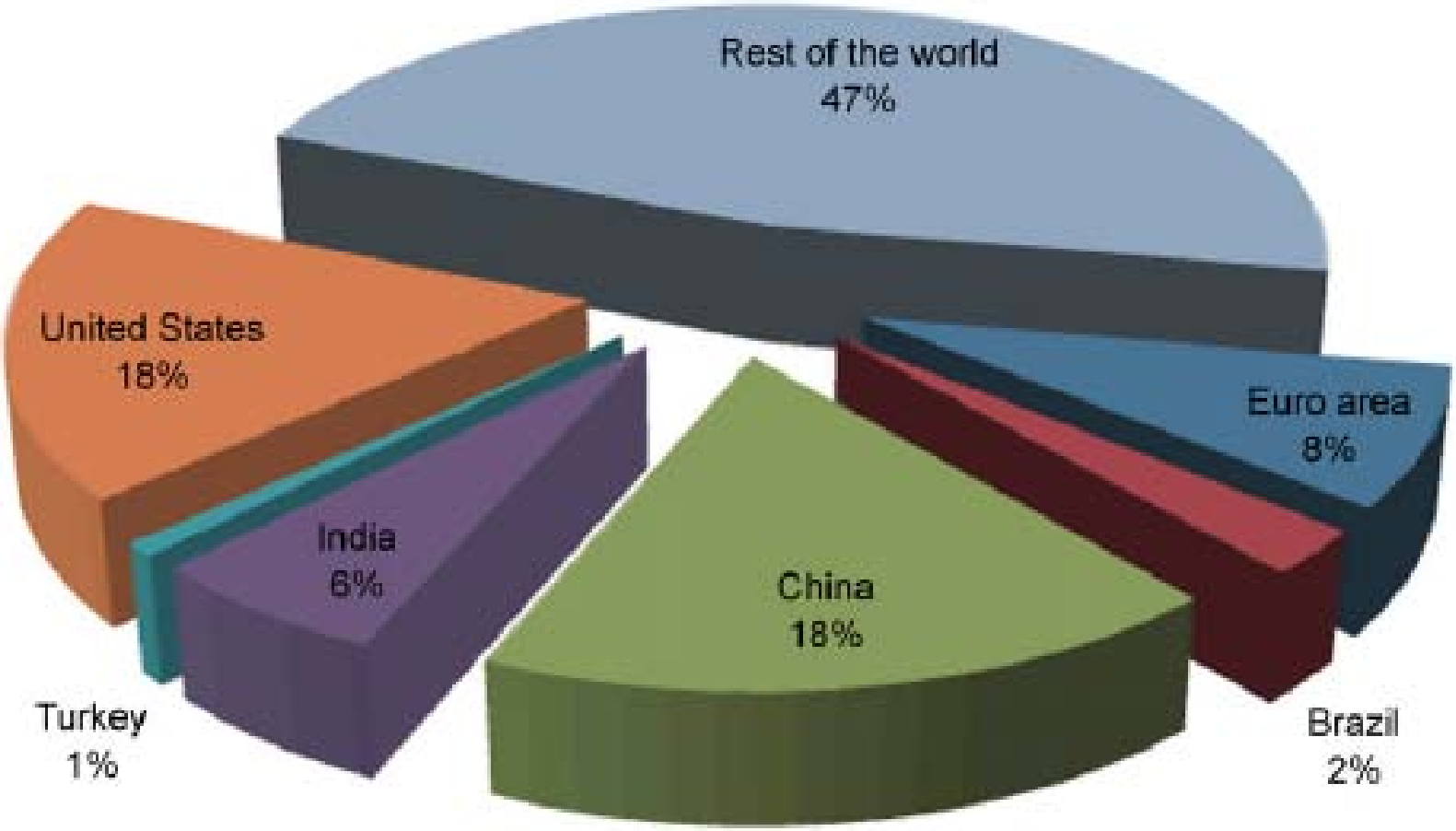
- Turkey was initially listed in both Annexes I and II of the UNFCC in 1992
- She was granted its omission from Annex II and remained in Annex I in 7th Conference of Parties, Marrakech, 2001
- She has signed UNFCCC on May 24, 2004 and ratified Kyoto Protocol (KP) on Feb 5, 2009
- European Union (EU) aims at reducing environmental pollutants 30 % below the 1990 levels by 2020
- KP demands the reduction of GHG emissions to 5.2 % lower than the 1990 level during 2008-2012

Global Map of ANNEX-I Countries btw 1990-2008 including LULUCF



Turkey, Iceland, Spain, Portugal, Australia, ….

Shares of World Greenhouse Gas Emissions in 2005

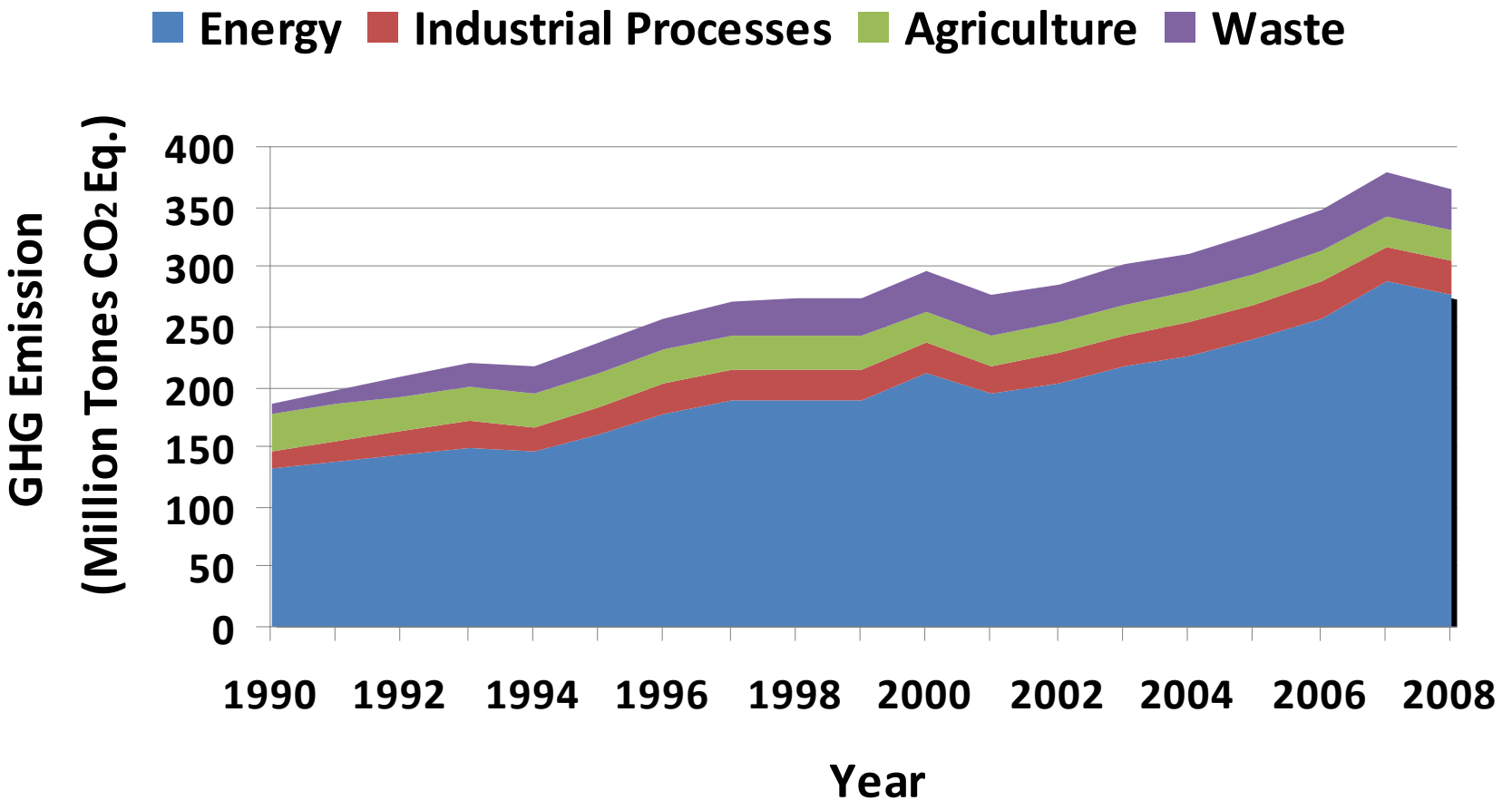


Source: Erdoğdu, E., Renewable and Sustainable Energy Reviews 14 (2010), 1111-1117

METHODOLOGY

- **SOURCE of DATA**
  - **GHG emission data for ANNEX-I countries from UNFCCC web page btw 1990 and 2008**
  - **Yearly mean values of sector-specific and GHG-specific data**
  - **GHG's:CO_2, CH_4, N_2O, PFCs, SF_6**
  - **Sectors: Energy, Industrial Processes, Agriculture, Waste**
    - **Excluding LULUCF (Land Use, Land Use Change and Forestry)**
- **TREND ANALYSIS**
  - **Non-parametric trend analysis tests: Mann-Kendall Test & Sen's Slope Estimator**
  - **Excel Template by Finish Meteorological Service**

Sector-specific GHG emissions between 1990 and 2008



- **96 % increase in total GHG emissions (without LULUCF)**

METHODOLOGY

MANN KENDALL TEST:

- Non-parametric test to detect trend
- Mann (1945) and Kendall (1975) (Gilbert, 1987)
- An excel template (MAKESENS) by Finnish Meteorological Institute

1

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k)$$

$$\operatorname{sgn}(x_j - x_k) = \begin{cases} 1 & if \quad x_j - x_k > 0 \\ 0 & if \quad x_j - x_k = 0 \\ -1 & if \quad x_j - x_k > 0 \end{cases}$$

WHERE;

- n= number of years
- x_j & x_k= annual values in years `j` and `k`, j>k, respectively

METHODOLOGY

2

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5) \right]$$

q= number of tied (equal value) groups, t_p= number of data values in the p^{th} group

3

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if \quad S < 0 \end{cases}$$

4 **TEST OF TREND**

H_0: no-trend

H_1:monotonic increasing or decreasing trend

H_0 rejected if $Z > Z_{1-\alpha/2}$

MAKESENS performs calculations at four different significance levels

(α=0.001, 0.01,0.05 and 0.1)

METHODOLOGY

SEN's SLOPE METHOD:

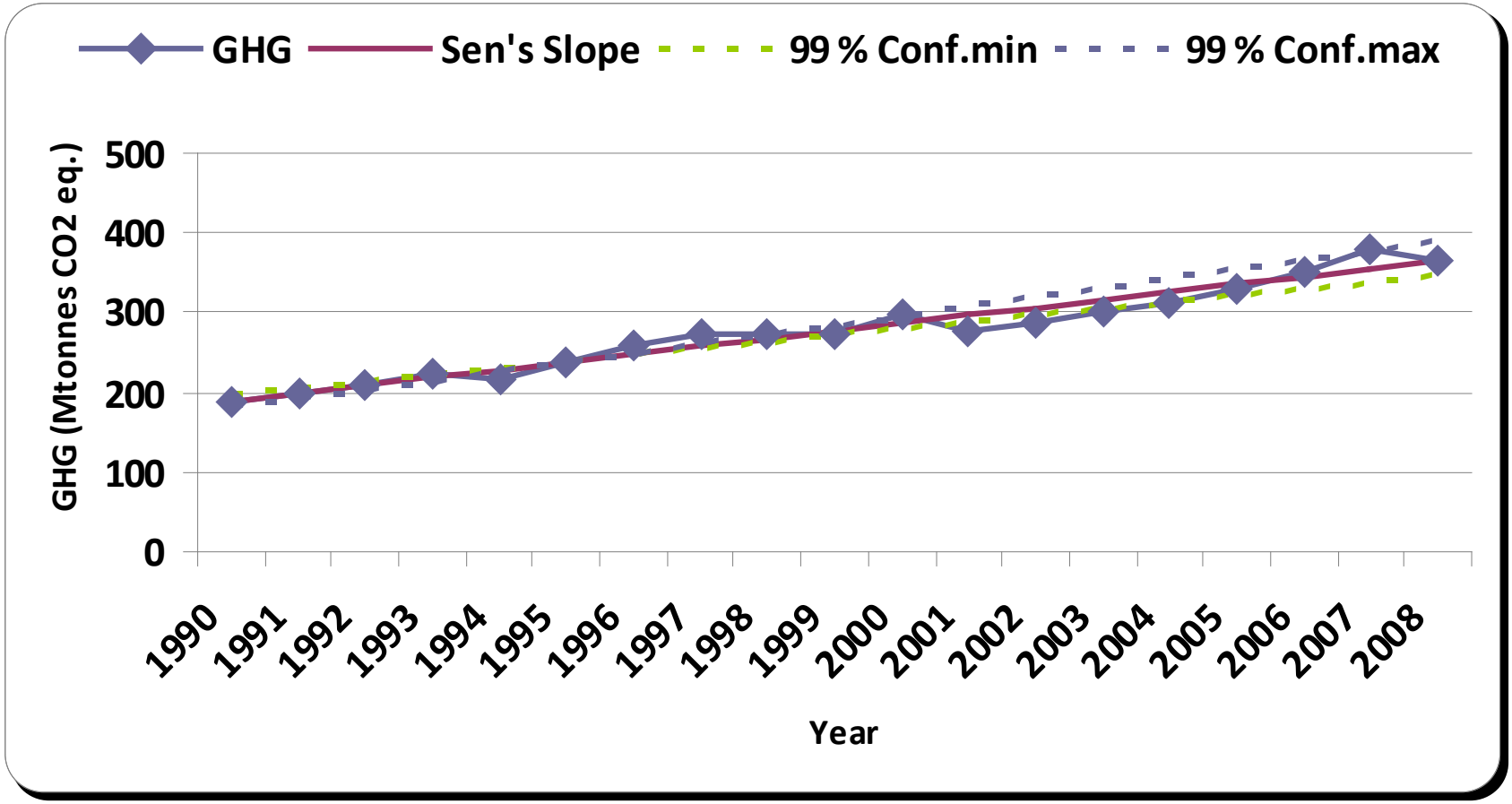
$$f(t) = Qt + B$$

$$Q_i = \frac{x_j - x_k}{j - k}$$

Q_i values for each data pair are calculated and **median value** is taken as final **slope of trend**

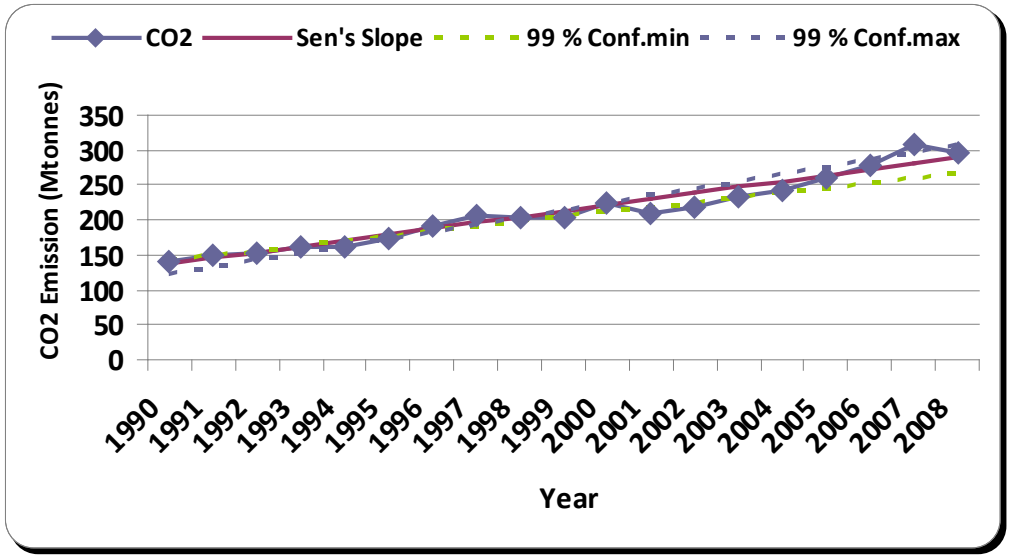
- True slope of existing trend (change per year)
- Sen's non-parametric method
- Sen (1968) (Gilbert,1987)
- An excel template (**MAKESENS**) by Finnish Meteorological Institute
- Confidence interval around the slope

TOTAL GHG EMISSIONS



- Increasing trend with α=0.001 significance level
- The rate of increase (Sen's Slope) is 9.75 Mt/year

GHG-specific Trend btw 1990-2008



CO_2:

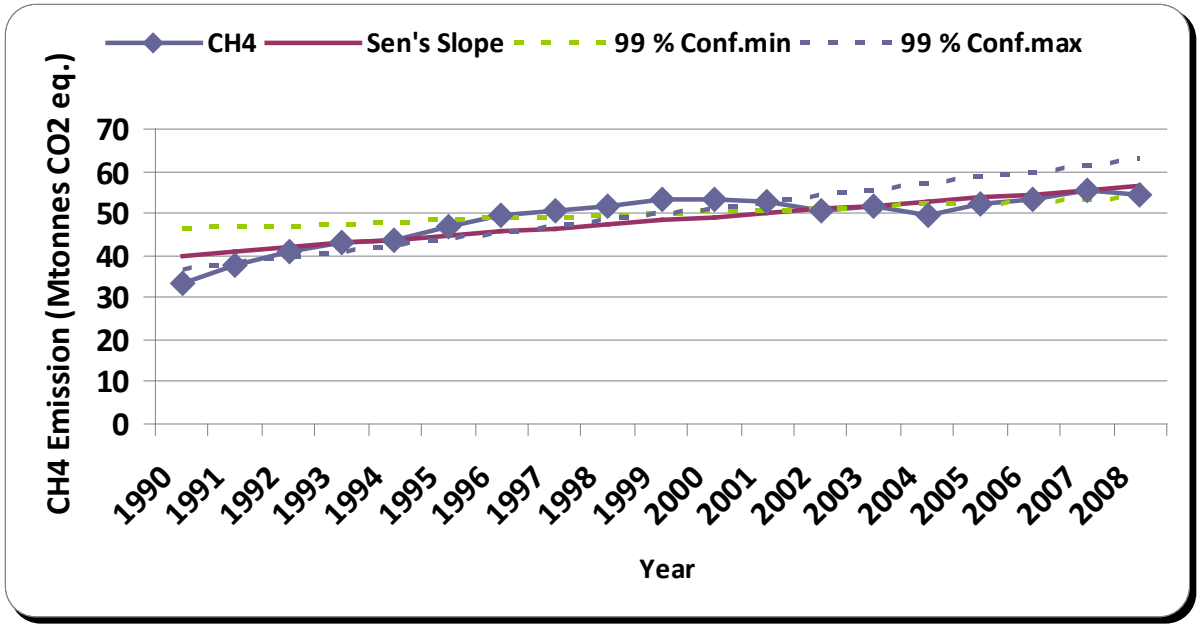
Rate of increase 8.44 Mt/yr

@ α=0.001 significance level

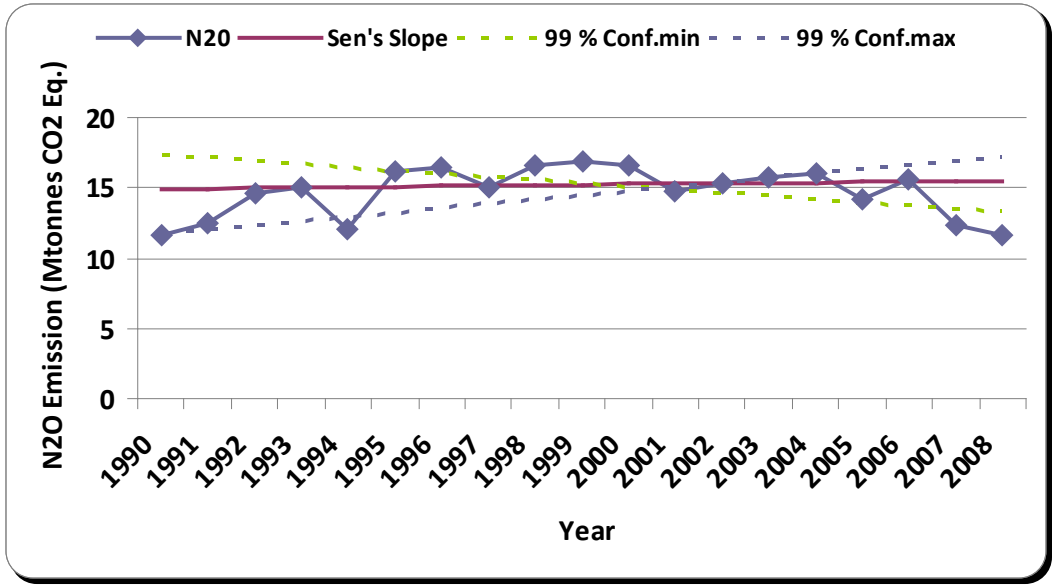
CH_4:

Rate of increase 0.9 Mt/yr

@ α=0.001 sig. level



GHG-specific Trend btw 1990-2008



N_20:

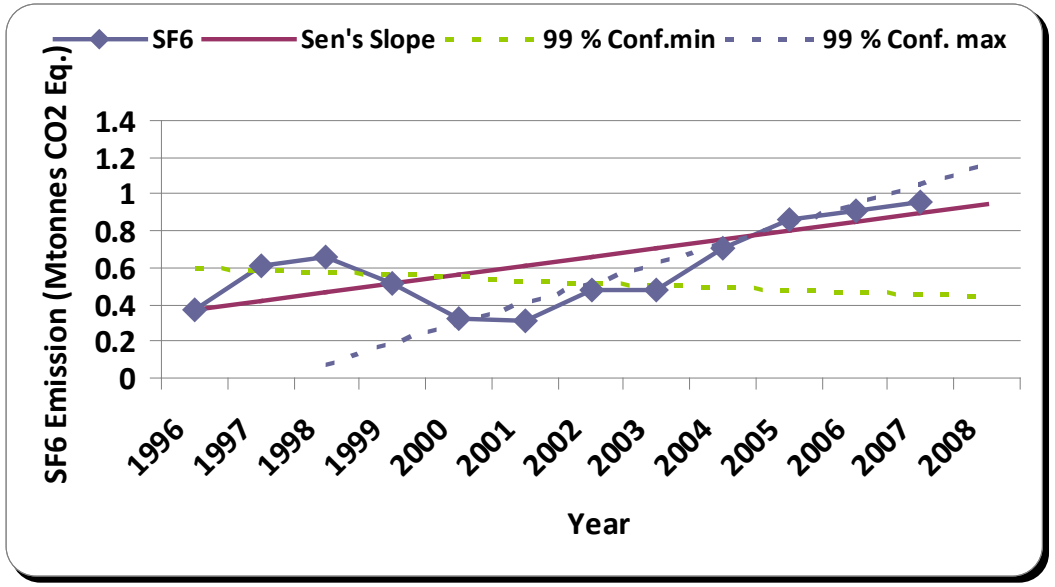
Rate of increase 0.035 Mt/yr

@ > α=0.1 significance level

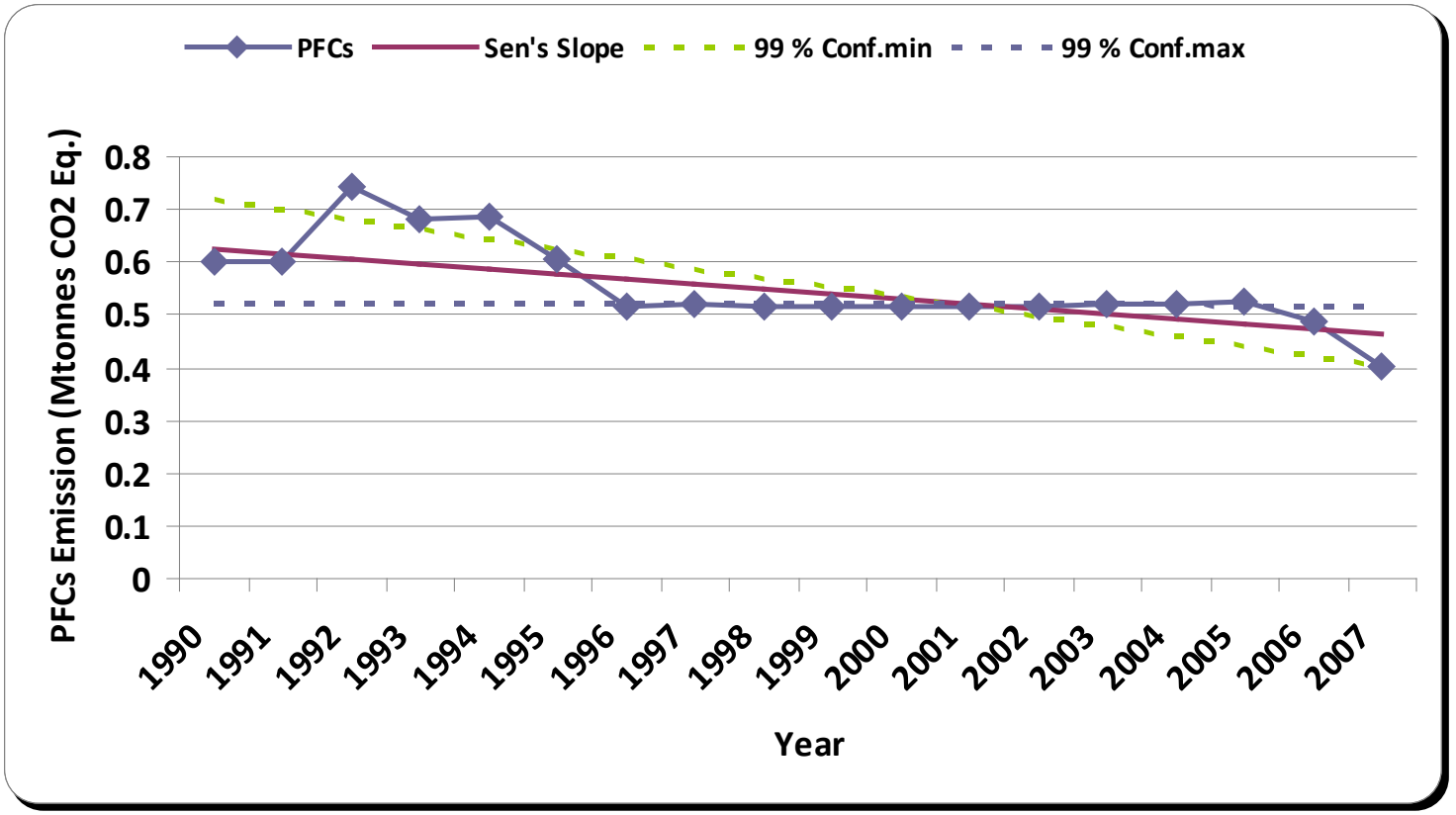
SF_6:

Rate of increase 0.048 Mt/yr

@ α=0.05 significance level

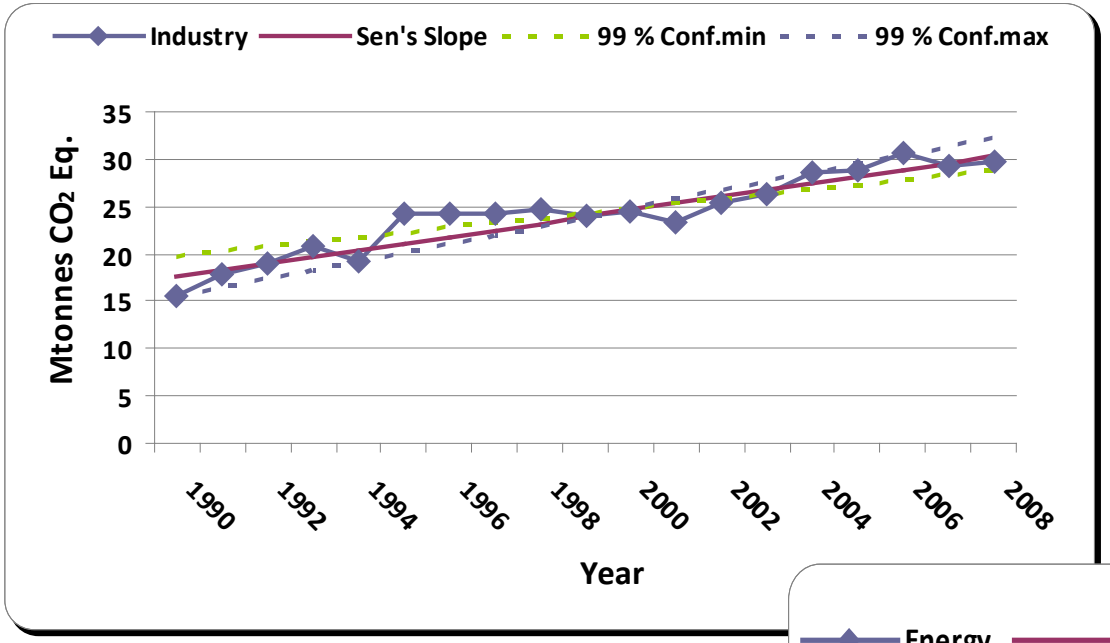


GHG-specific Trend btw 1990-2008



PFCs: **Rate of decrease 0.010 Mt/yr @ α=0.01 significance level**

Sector-specific Trend btw 1990-2008



Industry:

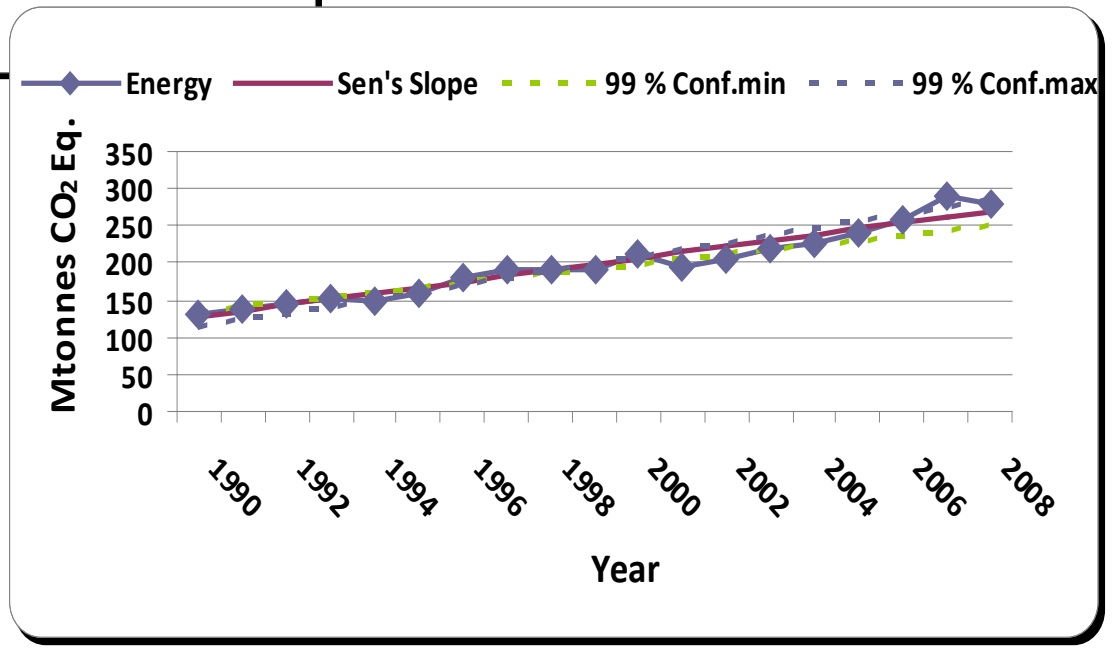
Rate of increase 0.700 Mt/yr

@ α=0.001 significance level

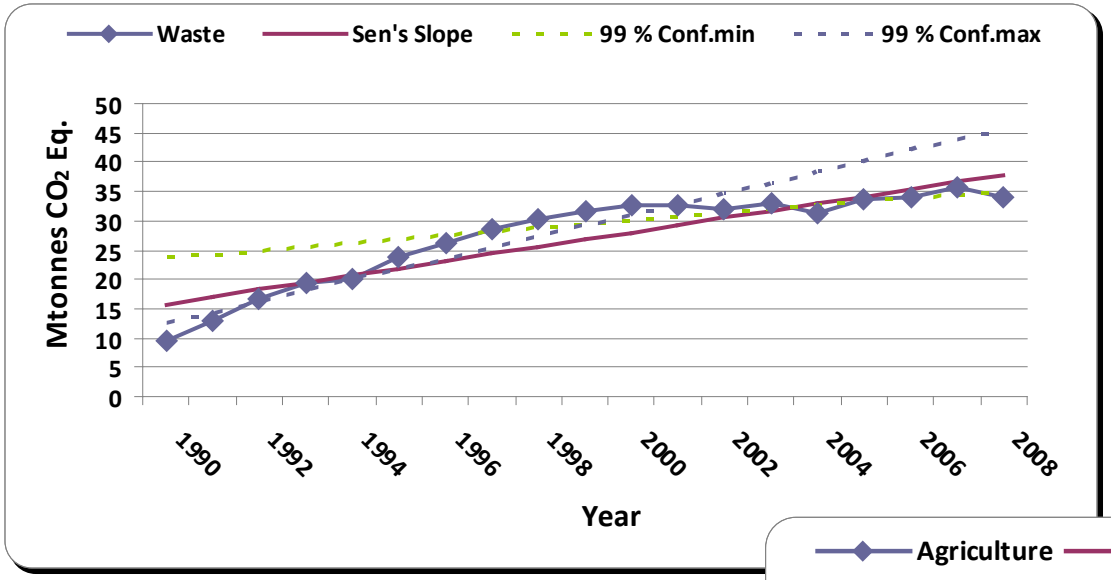
Energy:

Rate of increase 7.9 Mt/yr

@ α=0.001 significance level



Sector-specific Trend btw 1990-2008



Waste:

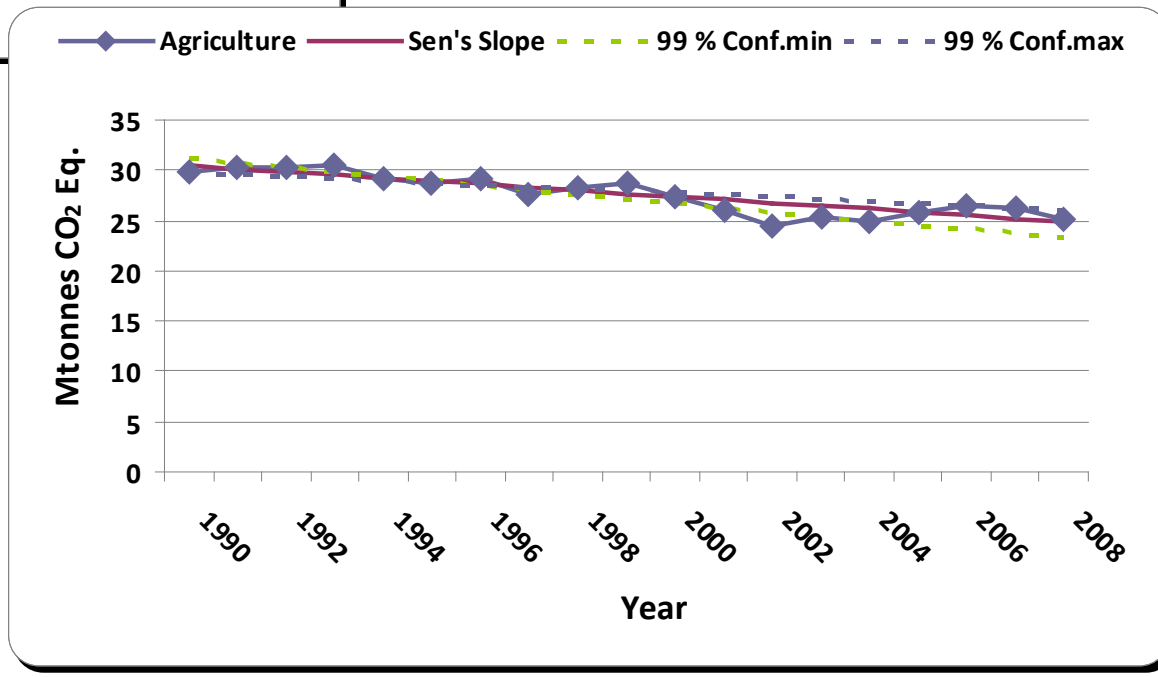
Rate of increase 1.23 Mt/yr

@ α=0.001 significance level

Agriculture:

Rate of decrease 0.308 Mt/yr

@ α=0.001 sig. level



Comparison with other European countries

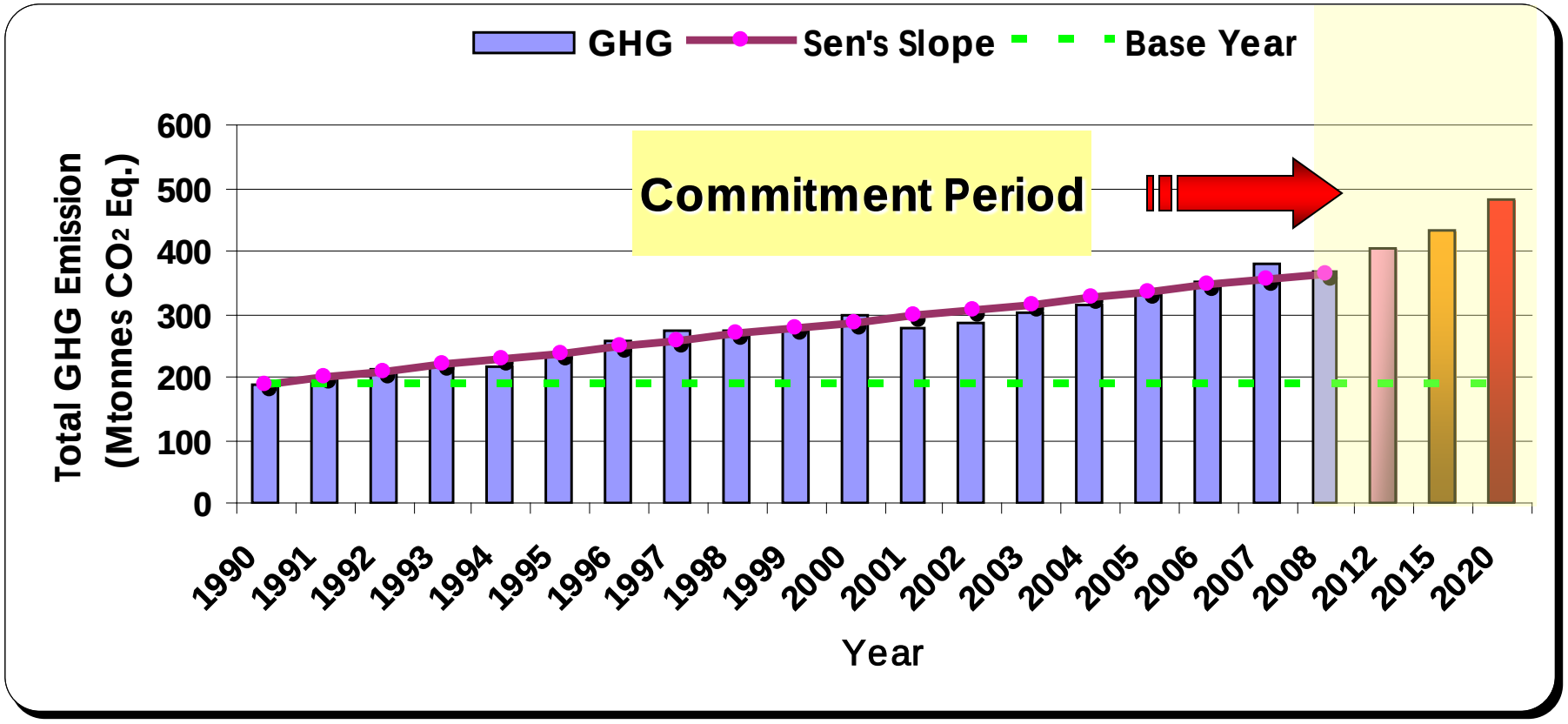
UPWARD TREND (Mt/yr)

1. SPAIN: 10
2. TURKEY:9.7
3. ITALY: 3.8
4. GREECE: 2.0
5. PORTUGAL: 1.5

DOWNWARD TREND (Mt/yr)

1. UKRAINE: 17.8
2. GERMANY: 11.6
3. GREAT BRITAIN: 7.6
4. POLAND: 4.0
5. ROMANIA: 2.5

Future Projections



- Assuming Sen's slope remains same, GHG's for 2012, 2015, and 2020
- 230 % surplus in GHG emissions as compared to KP case (2008-2012)
- ~ 370 % surplus in GHG emissions as compared to EU case (2020)

Turkey's Policy to reduce GHG's

INCLUDE:

- Cleaner technologies
- Renewable energy technologies
- Efficient energy conversion technologies

NOT INCLUDE:

- Carbon taxation
- Emission trading
- Specific target for emission reduction

CONCLUSION

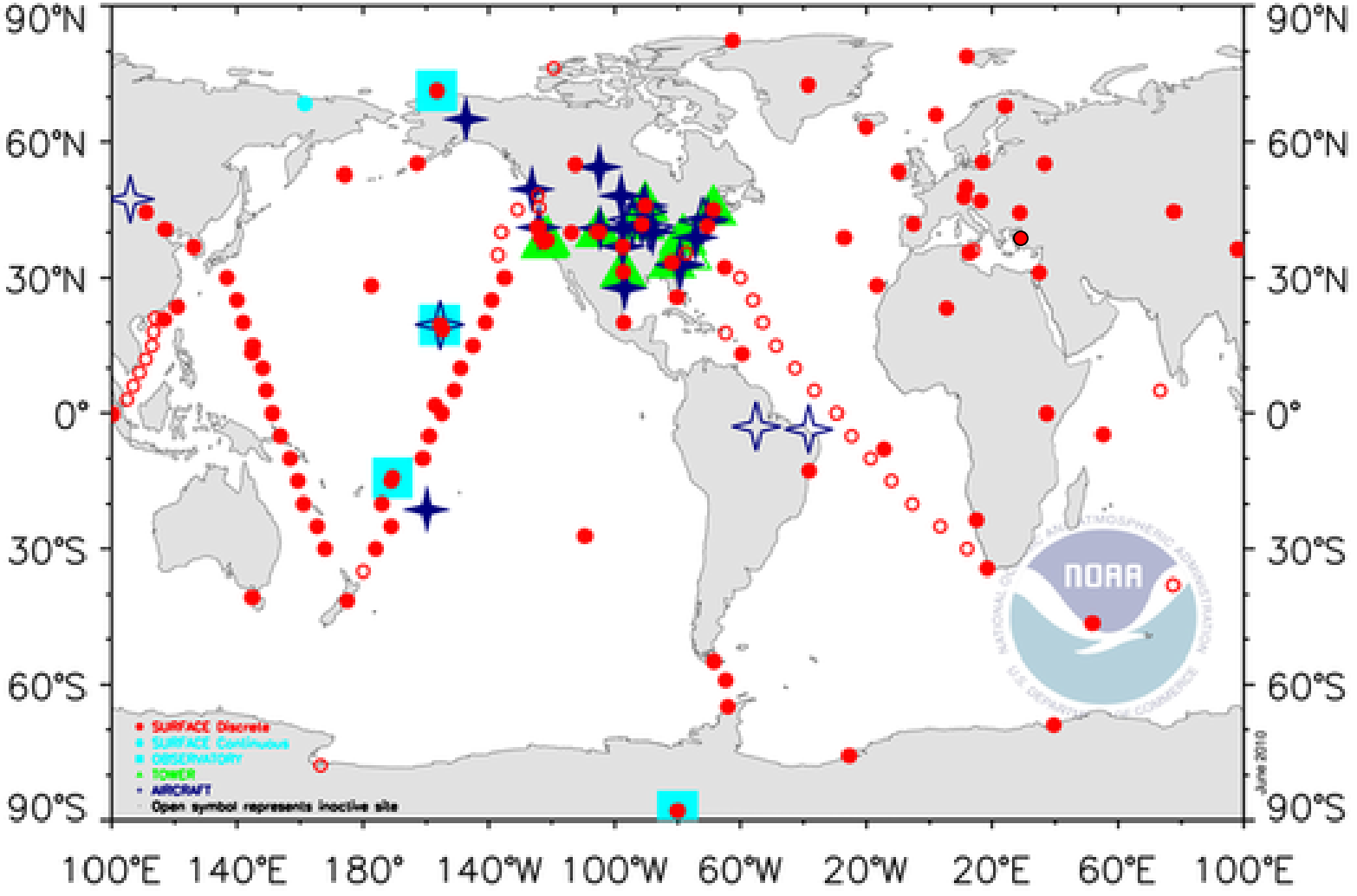
- Total GHG emissions increased with a rate of 9.75 Mt/year btw 1990-2008
- Highest increase observed for CO_2; CH_4, N_20, SF_6 increased
- Decreasing trend was detected for PFCs
- Emissions from industry, energy and waste increased; while those of agriculture decreased
- Second highest rate of increase was detected for Turkey after Spain in Europe
- Future emission scenarios
- 230 % surplus in GHG emissions as compared to KP case (2008-2012)
- ~370 % surplus in GHG emissions as compared to EU case (2020)

References

1. Gilbert, R.O., (1987), Statistical methods for enironmental pollution monitoring
2. IPCC Fourth Assessment Report: Climate Change 2007
3. Erdoğdu, E., Renewable and Sustainable Energy Reviews 14 (2010), 1111-1117
4. UNFCCC web page: http://unfccc.int/ghg_data/items/3800.php
5. Finnish Meteorological Institute, MAKESENS excel template

Cooperative Measurement Programs

NOAA ESRL Carbon Cycle



NOAA ESRL Carbon Cycle operates 4 measurement programs. Semi-continuous measurements are made at 4 baseline observatories, a few surface sites and from tall towers. Discrete surface and aircraft samples are measured in Boulder, CO. Presently, atmospheric carbon dioxide, methane, carbon monoxide, hydrogen, nitrous oxide, sulfur hexafluoride, the stable isotopes of carbon dioxide and methane, and halocarbon and volatile organic compounds are measured. Contact: Dr. Pieter Tans, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6678, pieter.tans@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.