



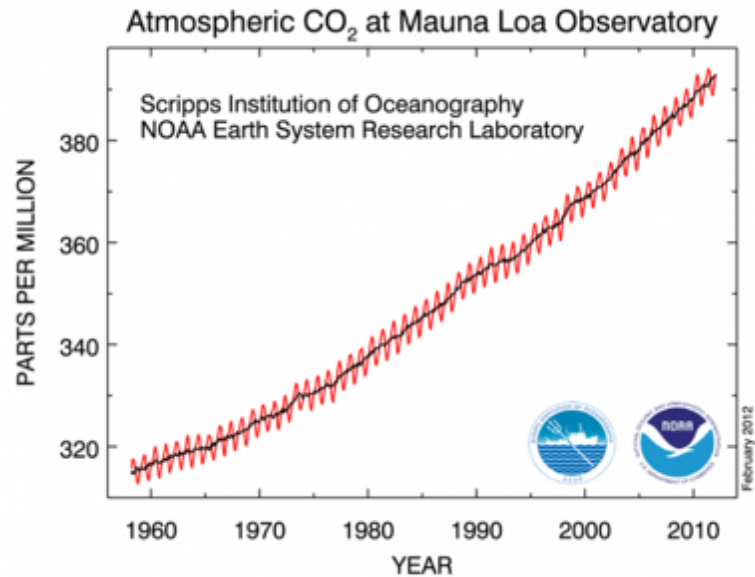
The Temporal Variability and Linear Trend of Atmospheric Carbon Dioxide Concentration over Taiga of Central Siberia

A.V. Timokhina, A.V. Panov, A.A. Onuchin and S.V. Verkhovets

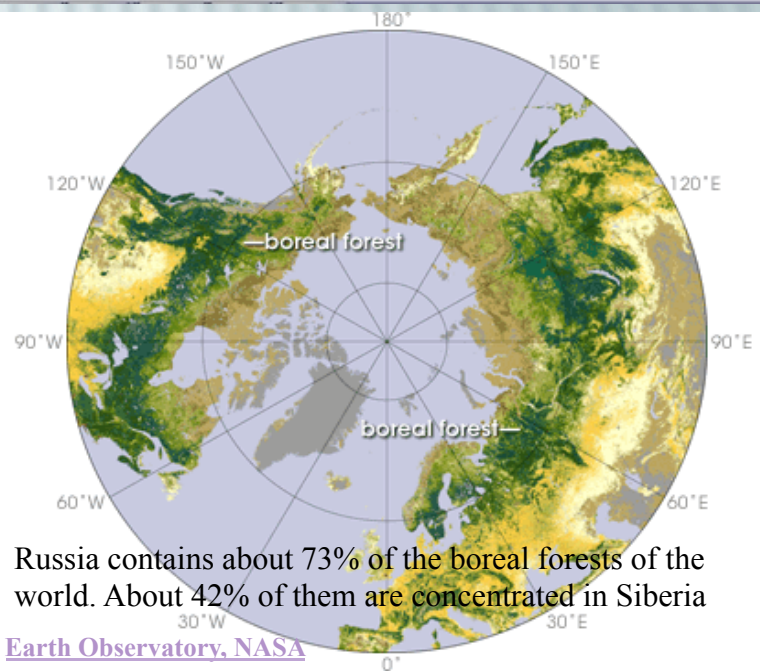
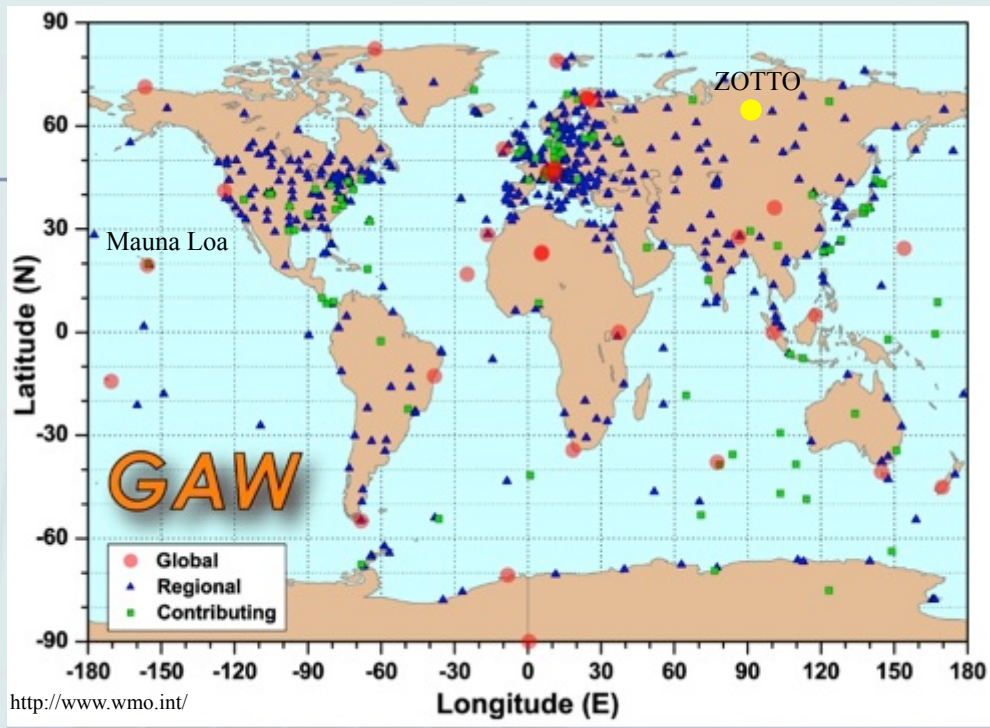
**Laboratory of biogeochemical cycles in forest ecosystems
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International Conference and Early Career Scientists School on Environmental Observations, Modeling and Information Systems
ENVIROMIS-2012, June 24-July 2, 2012, Irkutsk, Russia

The Keeling Curve is a graph which show a continuous change in concentration of carbon dioxide in Earth's atmosphere since 1958 year.



Atmospheric CO₂ concentration increased from 280 to 398 ppm (40%) since the beginning of the industrial period until 2010 (<http://www.esrl.noaa.gov>).



Russia contains about 73% of the boreal forests of the world. About 42% of them are concentrated in Siberia

[Earth Observatory, NASA](#)

In the framework of the project “Observing and Understanding Biogeochemical Responses to Rapid Climate Changes in Eurasia”, a scientific platform ZOTTO (the Zotino Tall Tower Observation) has been constructed in 2006 to enable the continuous monitoring of trace gases on a regional scale as an optimum approach for the determination of long-term trends in GHG.



Photo by S.V. Verkhovets



Source is www.zottoproject.org

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The aim of our study was:

to estimate the seasonal variability and lenir trends of atmospheric CO₂ over Taiga of Central Siberia for 3 years

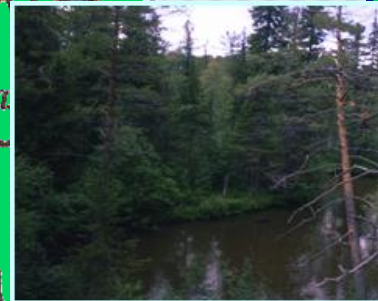
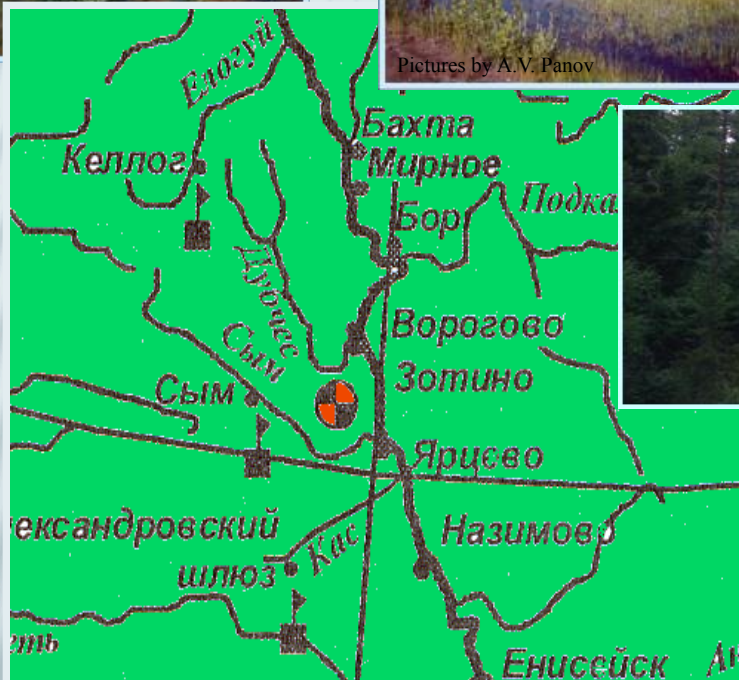
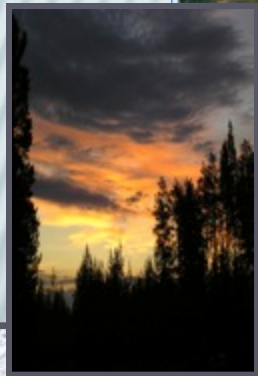
The tasks of our work were:

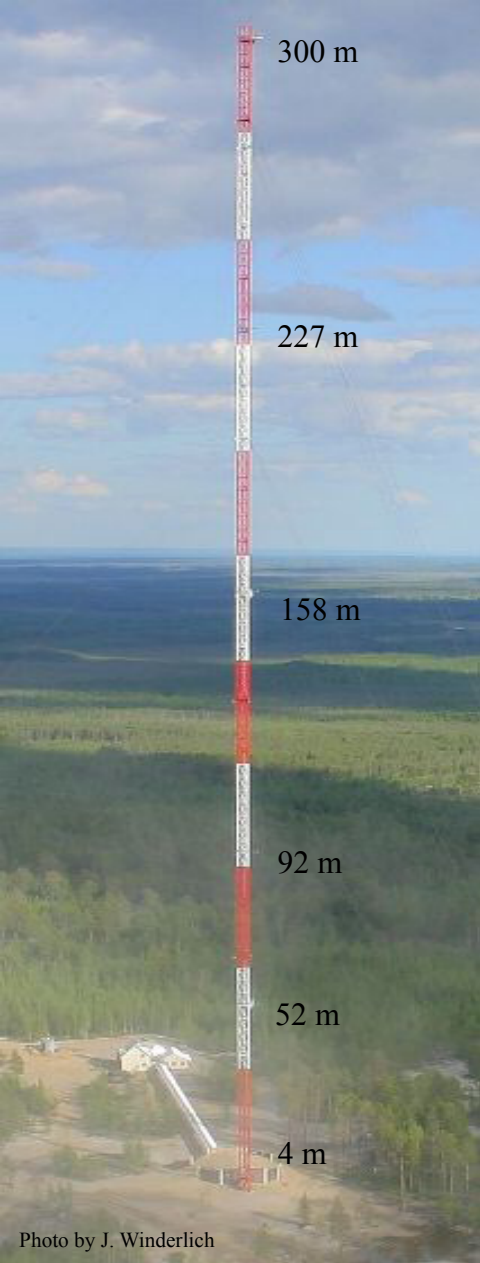
1. To analyze the annual patterns of CO₂ mixing ratio;
2. To estimate the amplitude and trends in atmospheric CO₂ concentration.

Photo by S.V. Verkhovets



The ZOTTO is situated in the boreal zone of central Siberia at 60° N 89° E, 114 m a.s.l. (Zotino, Krasnoyarsk region). The Yenisei River divides the ZOTTO footprint into two distinct parts, with pine forests and bogs on the west, and dark coniferous taiga on the east.





300 m

227 m

158 m

92 m

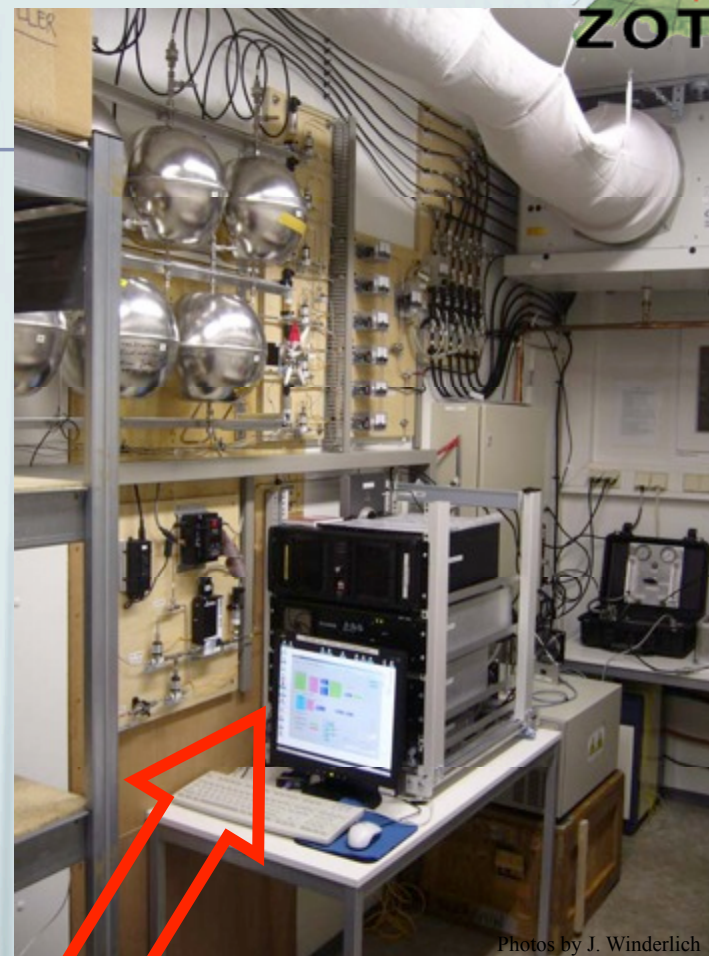
52 m

4 m

Continuous measurements

1. Samples of air are analyzed at six heights on the tower (4, 52, 92, 156, 227, 300 m).

2. CO₂ concentration (mixing ratio) is measured by EnviroSense 3000i Multi-Species Atmospheric Monitor (Picarro, USA) established in container near bottom of tower with measuring frequency of twice per minute.

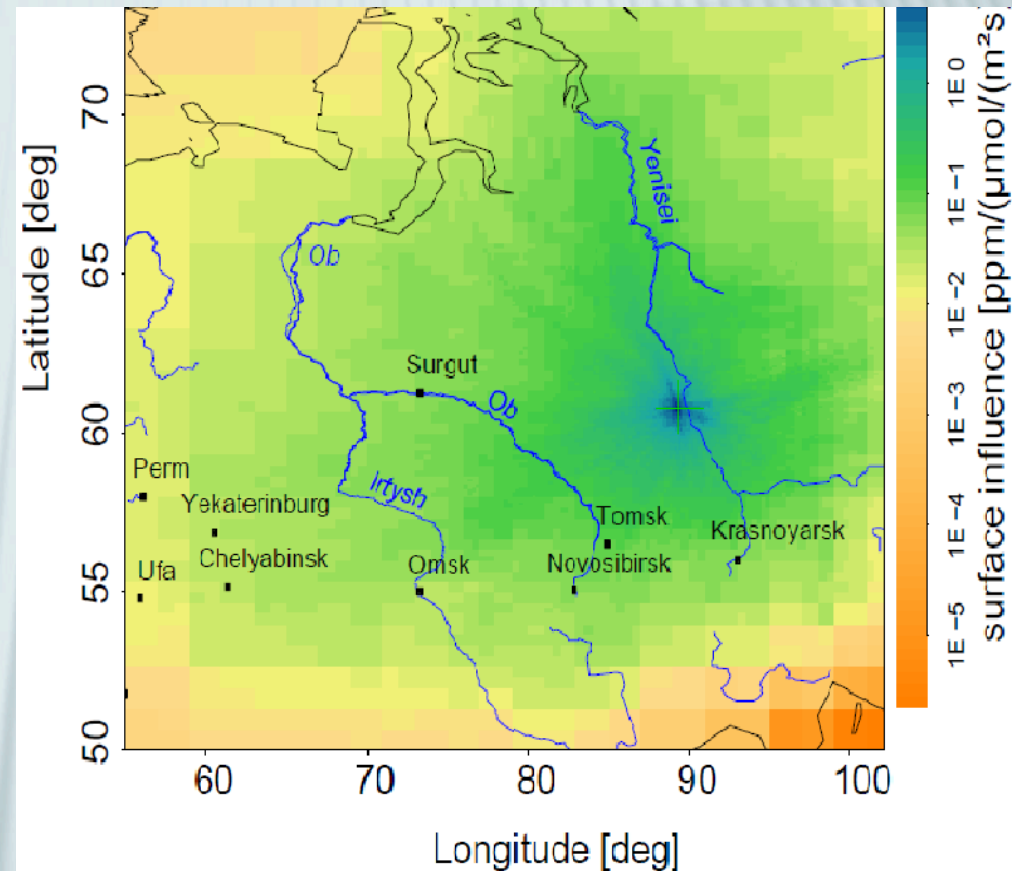


Photos by J. Winderlich

EnviroSense 3000i (Picarro, USA)

STILT (Stochastic Time-Inverted Lagrangian Transport model) footprint for ZOTTO 301m level made from 5 days back trajectories from 1.5.–30.11.2009 based on ECMWF* forecast data

The field near of the tower has the main influence on the measured mixing ratios – up to 10 ppm/m²s. The area with a surface influence above 0.1 ppm/m²s covers about 1*10⁶ km² of Siberia.



J. Winderlich et al., 2010

*European Centre for Medium-Range Weather Forecasts

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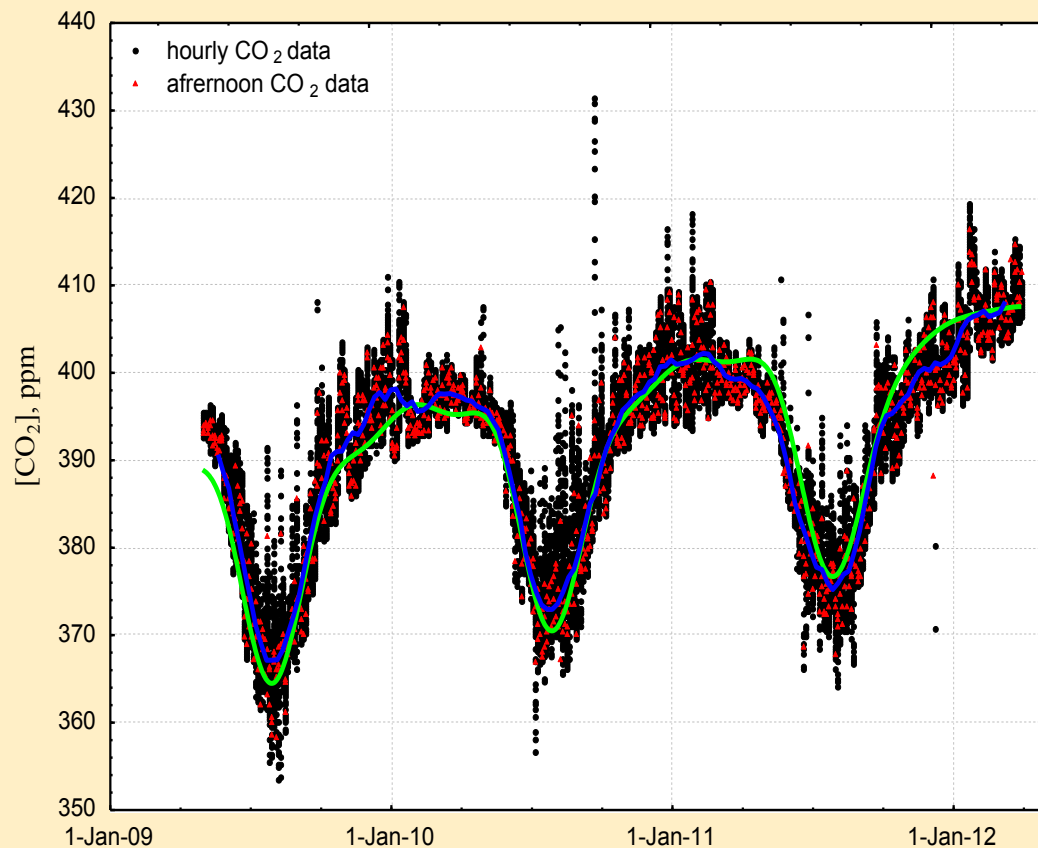
The smoothing procedure of CO₂ data to derive the trend at annual time scales and the amplitude of the seasonal variation

$$*F(x) = a_0 + a_1x + \sum_{n=1}^4 \left(b_n \sin\left(\frac{2\pi}{365}nx\right) + c_n \cdot \cos\left(\frac{2\pi}{365}nx\right) \right)$$

Where, x is time in day, $a_0 + a_1x$ is liner trend;
 b_n and c_n are fitting coefficients.

$$\begin{aligned} F(x) = & (383.0059 \pm 0.63) + (0.0156 \pm 0.001) \cdot x \\ & + (-11.92 \pm 0.18) \cdot \sin\left(\frac{2\pi \cdot x}{365}\right) + (1.03 \pm 0.19) \cdot \cos\left(\frac{2\pi \cdot x}{365}\right) \\ & + (0.61 \pm 0.29) \cdot \sin\left(2 \cdot \frac{2\pi \cdot x}{365}\right) + (5.17 \pm 0.19) \cdot \cos\left(2 \cdot \frac{2\pi \cdot x}{365}\right) \\ & + (2.03 \pm 0.19) \cdot \sin\left(3 \cdot \frac{2\pi \cdot x}{365}\right) + (-0.03 \pm 0.28) \cdot \cos\left(3 \cdot \frac{2\pi \cdot x}{365}\right) \\ & + (0.09 \pm 0.19) \cdot \sin\left(4 \cdot \frac{2\pi \cdot x}{365}\right) + (-0.24 \pm 0.19) \cdot \cos\left(4 \cdot \frac{2\pi \cdot x}{365}\right) \end{aligned}$$

The 7-days averages was calculated from afternoon data, then weekly averages were slid by 5 weeks window running (black line).



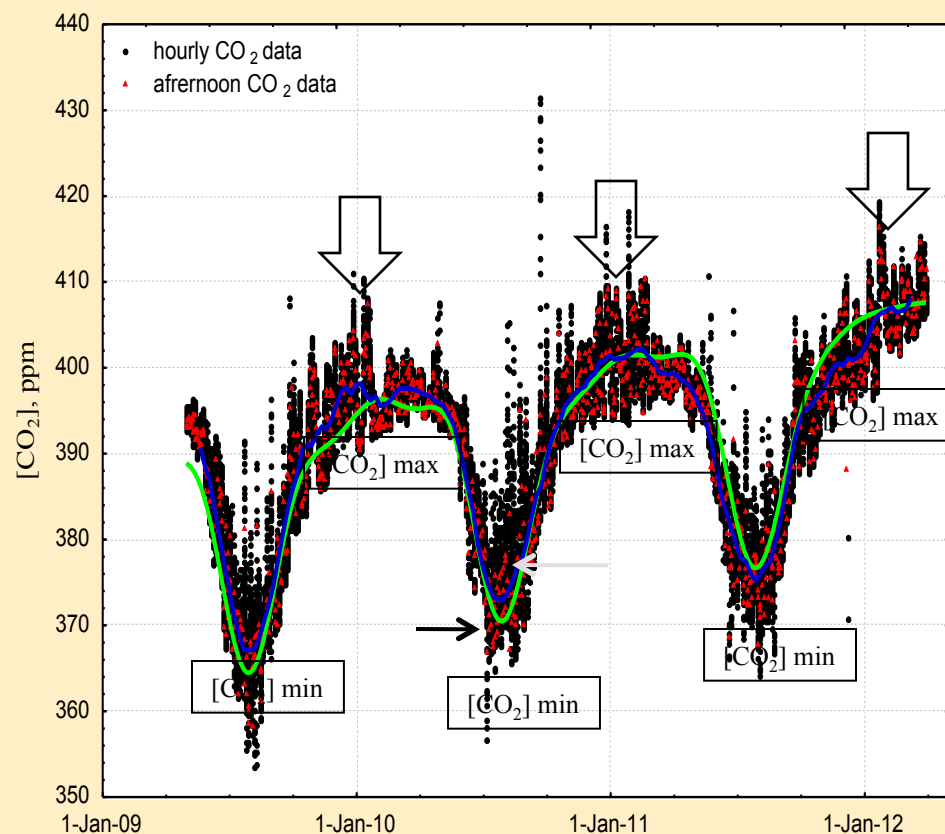
*K.W. Thoning, P.P. Tans and W. D. Komhyr, 1989; P.S. Bakwin et al., 1998; E. Kozlova et al., 2008; GAW Report No. 184,2009; R. L. Thompson et al., 2009; M. E. Popa et al., 2010; J. Winderlich et al., 2010; A. T. Vermeulen et al., 2010;

Annual cycle of CO₂ mixing ratio at Zotino Tall Tower

The annual minimum of CO₂ mixing ratio occurs at the end of July to the begin of August on the base of both models;

The annual maximum of CO₂ mixing ratio appears in January- February from both fitting models.

According to the harmonic fitting model, seasonal cycle amplitude of atmospheric CO₂ in period 2009 - 2011 was 28.6 ppm; The value calculated on the base of 5-weeks running fitting model was 28.7 ppm in 2009, 27.2 ppm in 2010 and 29.9 ppm in 2011.

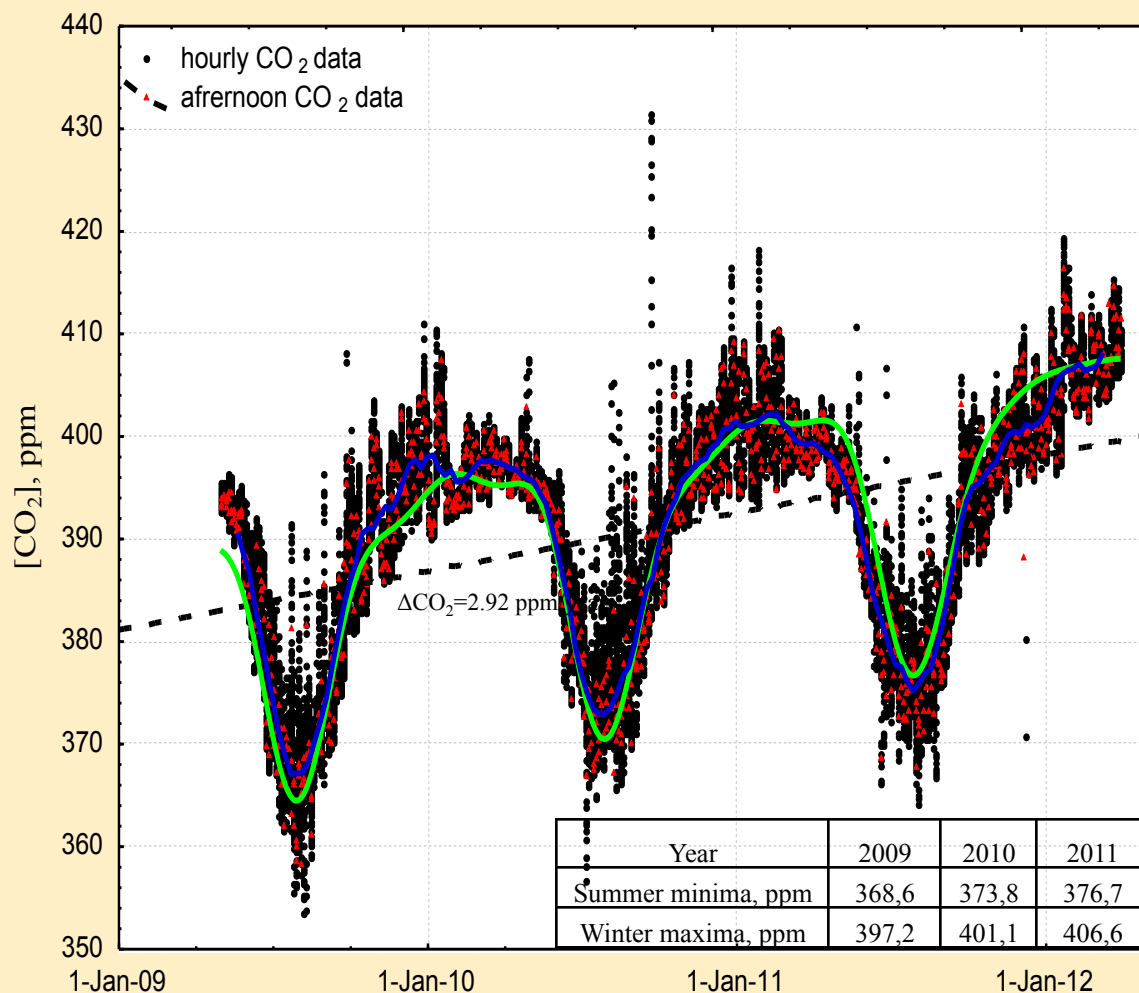


Linear trend of CO₂ mixing ratio at ZOTTO

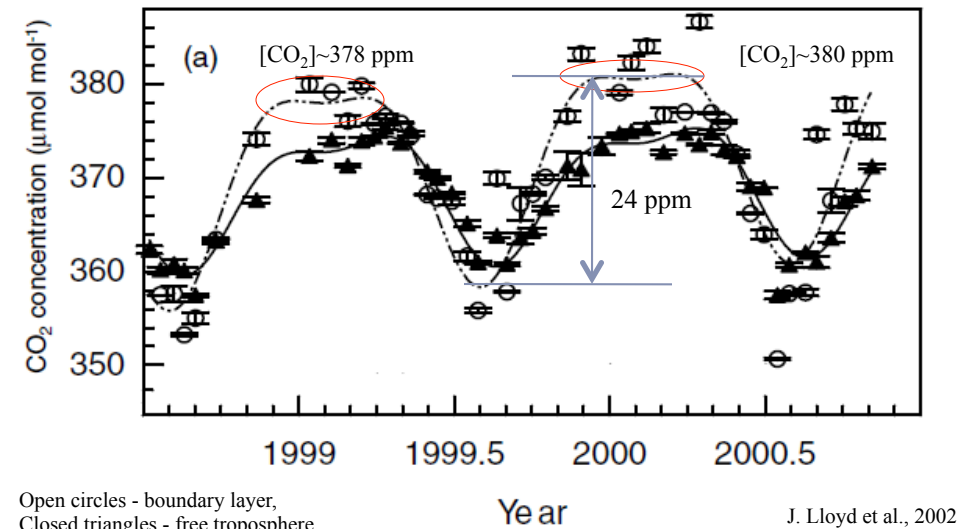
The linear trend of $(383.0 \pm 0.63) + (0.008 \pm 0.001) \cdot x$ ppm per day converts to 2.92 ppm per year

In the summer time CO₂ grown rate was 4.05 ppm per year (2009-2011 yr.)

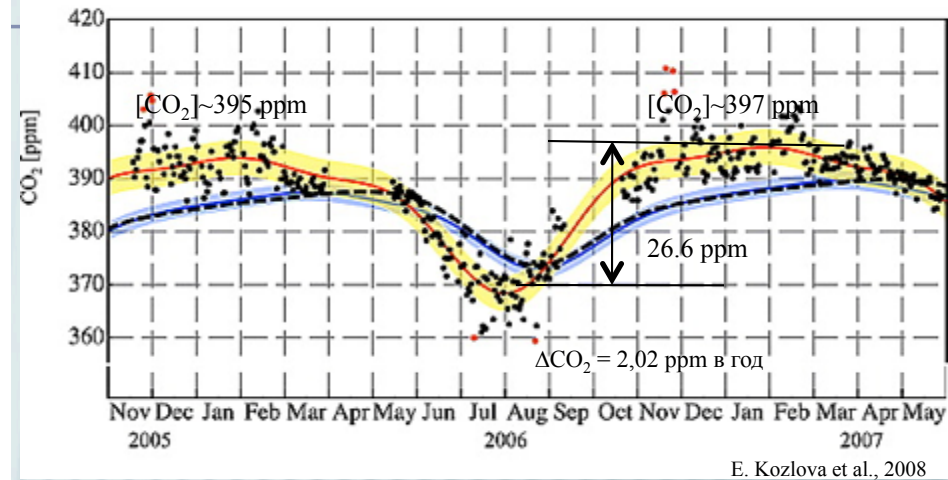
In the winter time CO₂ grown rate was 4.68 ppm per year (2010-2012 yr.)



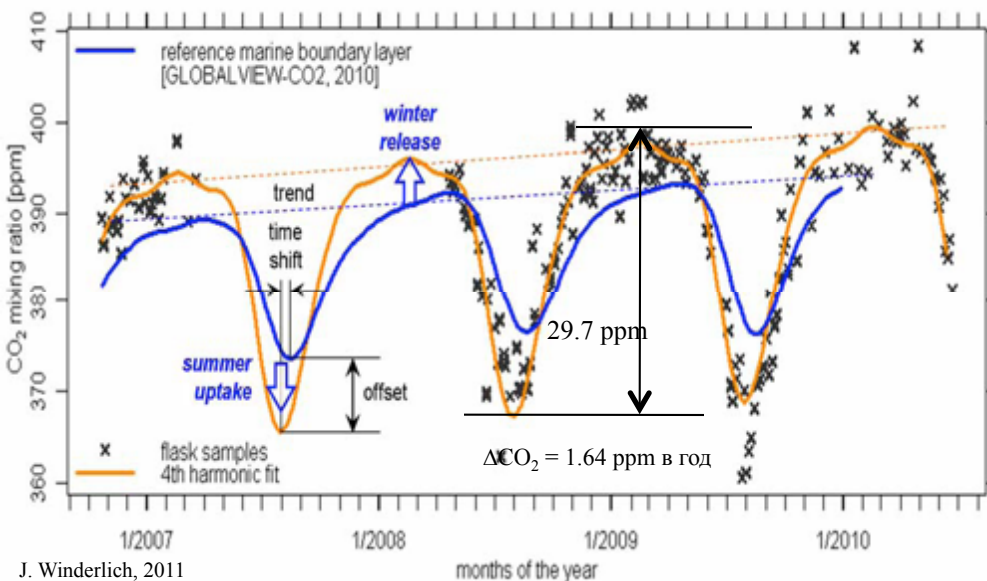
The aircraft measurements of CO₂ mixing ratio in Central Siberia



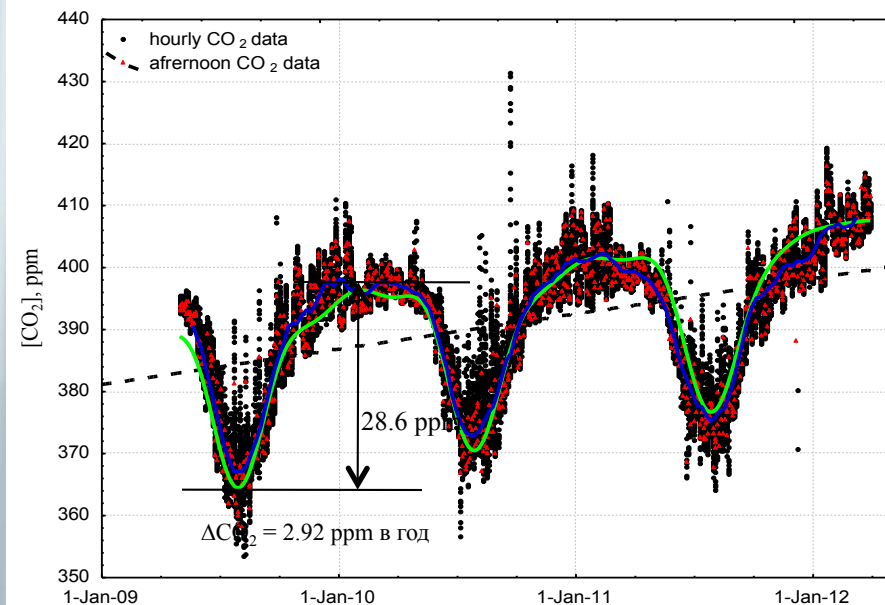
A quasi-continuous mode (gas-analyzes complex ZOTTO)



A Regular flask sampling of air at ZOTTO



A quasi-continuous mode (gas-analyzes complex ZOTTO)



Conclusions:

1. Annual minimum of CO₂ mixing ratio occurs in July – August. On inter-annual basis of CO₂ minimum may shift 2 weeks earlier, as shown in 2010. Annual maximum of CO₂ concentration appears in January-February of all years but demonstrate high synoptic variation.
2. According to the harmonic fitting model, seasonal cycle amplitude of atmospheric CO₂ in 2009 – 2011 is 28.6 ppm. Inter-annual amplitude based on 5-weeks running fitting model was 28.7 ppm in 2009, 27.2 ppm in 2010 and 29.9 ppm in 2011;
3. The atmospheric CO₂ concentration over the Siberian boreal zone is shown increase rapidly (2.92 ppm per year) during observation period of last 3 year. In the summer time CO₂ growth rate was 4.05 ppm per year what is about 1% of annual CO₂ concentration. In winter time CO₂ growth rate was 4.68 ppm per year.

**Thank you for your
attention!**