МИНИСТЕРСТВО НАУКИ
И ВЫСШЕГО ОБРАЗОВАНИЯ
РОССИЙСКОЙ ФЕДЕРАЦИИ

ЧИСЛЕННОЕ МОДЕЛИРОВАНИЕ ИЗМЕНЕНИЯ ХИМИЧЕСКОГО СОСТАВА НИЖНЕЙ И СРЕДНЕЙ АТМОСФЕРЫ В КОНЦЕ XX - НАЧАЛЕ XXI ВЕКОВ

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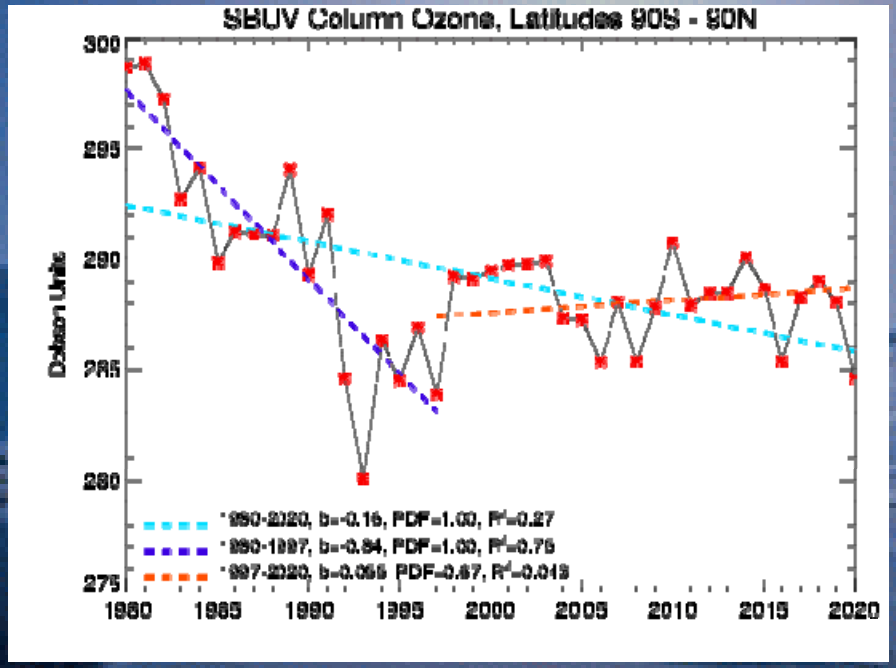
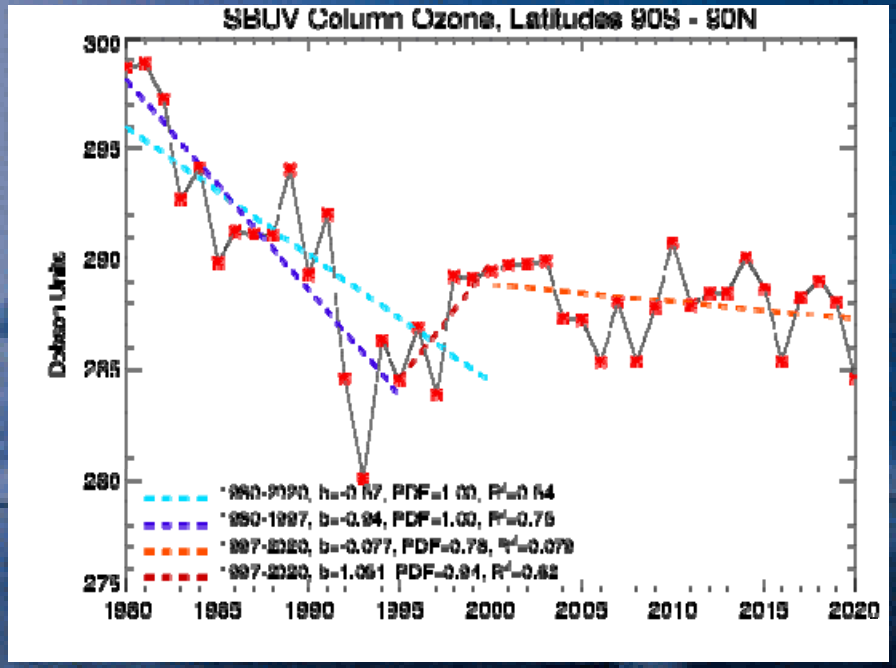
ТУРБУЛЕНТНОСТЬ, ДИНАМИКА АТМОСФЕРЫ И КЛИМАТА
МОСКВА, 19-21 НОЯБРЯ 2024 г.

Globally Mean Column Ozone Interannual Variability

- **Solar Backscattered Ultra Violet (SBUV) Instrument**





- Montreal Protocol regulates the production and consumption of nearly **100** man-made chemicals referred to as ozone depleting substances (ODS)
- The Montreal Protocol on Substances that Deplete the Ozone Layer is a global agreement to protect the Earth's ozone layer by phasing out the chemicals that deplete it.
- The landmark agreement was signed by **197** countries in **1987** and entered into force in **1989**.

Solar Backscattered Ultra Violet (SBUV) Data

A's polar orbiting satellites carrying the SBUV/2 instrument.

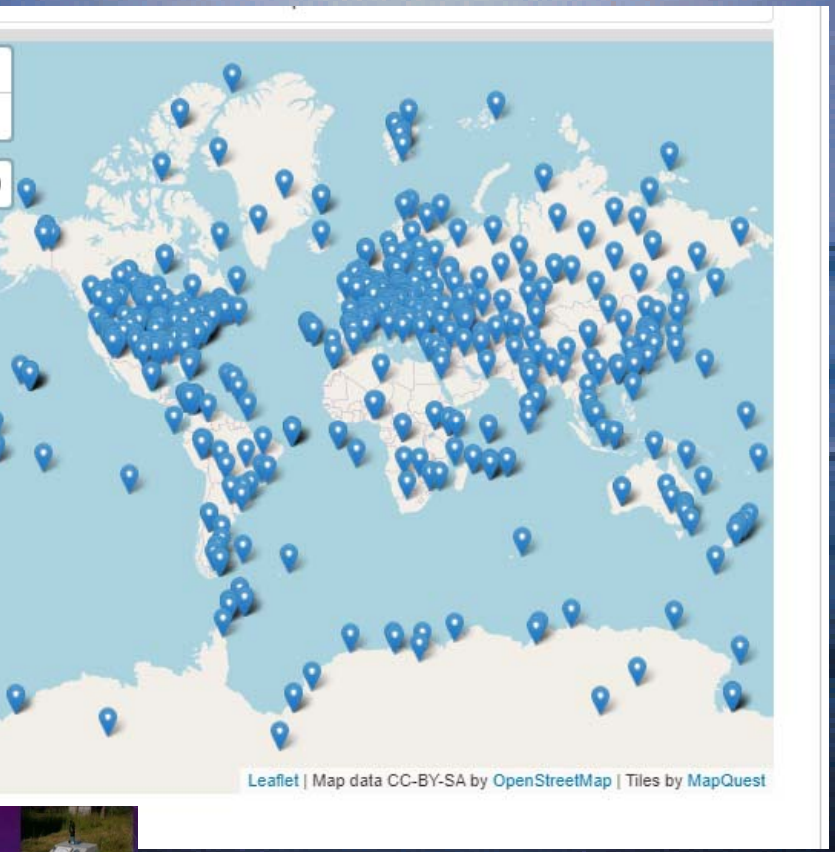
- Space satellites with the SBUV type equipment crossed the equator approximately 14 times a day at the same local mean solar time, i.e., in longitude, the aisle points were at an angular distance of ~ 26 ° from each other.
- Measurements with SBUV (SBUV / 2) instruments are performed near the local vertical within an angle of ± 11.3 °.
- The SBUV spatial resolution is 180 × 180 km², the SBUV / 2 resolution is 168 × 168 km².

SBUV Overpass algorithm interpolates satellite measurements to values at the

Total Ozone Mapping Spectrometer (TOMS) and Ozone Monitoring Instrument (OMI)

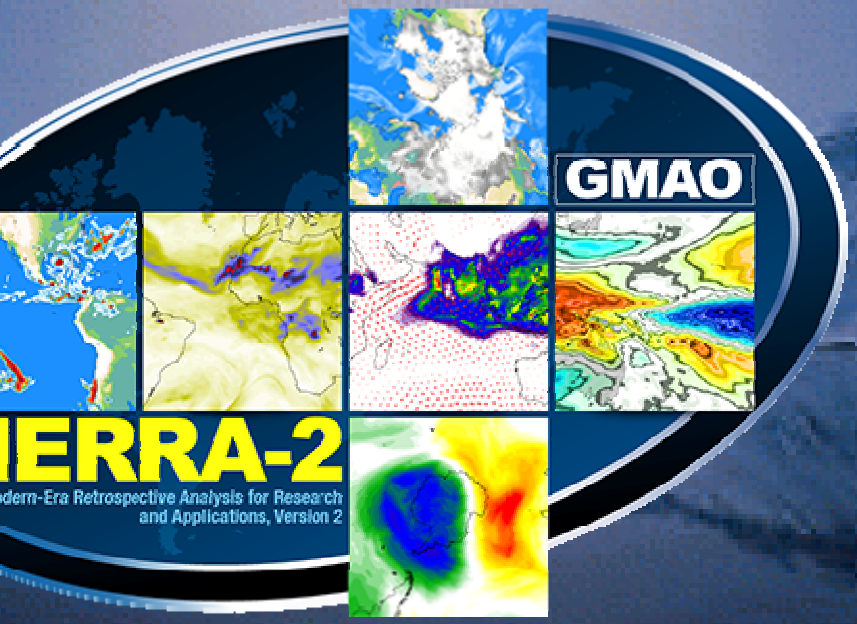
Total Ozone Mapping Spectrometer (TOMS) is a NASA satellite instrument for measuring
e concentration. Of the five instruments built, four entered successful orbit on the Nimbus-7,
eor–3, Advanced Earth Observing Satellite (ADEOS), and Earth Probe (EP) satellites.
uments on the Nimbus-7 and Meteor–3 satellites produced a continuous set of data on the total
e content from November 1978 to December 1994. The instrument on the ADEOS satellite gave
from 1996 to mid-1997, but did not cover a full year. Since mid-1996, when the Earth Probe
lite was launched, the TOMS instrument on that satellite transmitted data on the total ozone
ent until 2006. As a continuation and replacement of the TOMS series of instruments, an ozone
itoring instrument (OMI) was launched on the Aura satellite in 2004, which provides data on the

World Ozone and Ultraviolet radiation Data Centre (WOUDC)



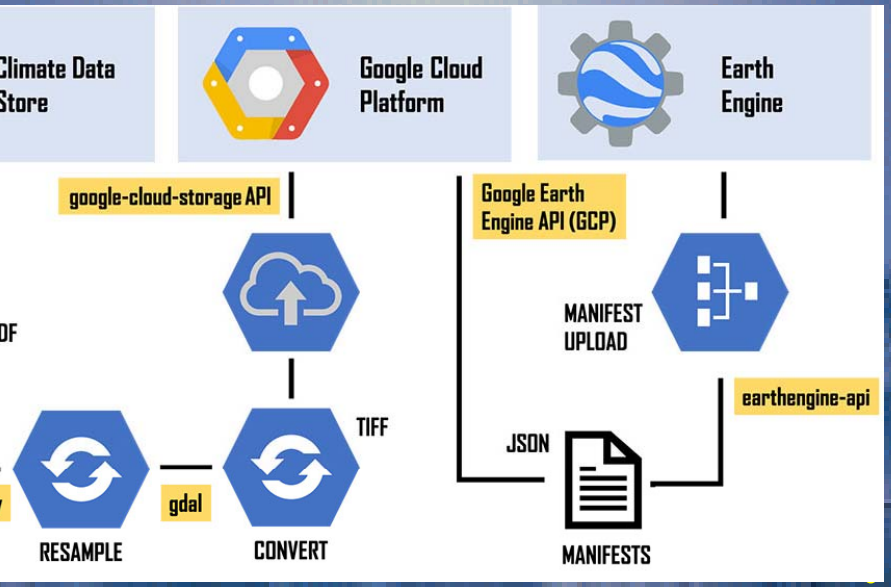
- There are over 500 ground based registered stations in the archive from over 150 contributors.
- Ozone data set categories include total column ozone and vertical profile data from lidar measurements, ozonesonde flights, and the Umkehr technique. Ultraviolet (UV) radiation data set categories include broadband, multiband, and high resolution spectral data types.

dern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2)



- The Modern-Era Retrospective analysis for Research and Applications, version 2 (MERRA-2) is a global atmospheric reanalysis produced by the NASA Global Modeling and Assimilation Office (GMAO). It spans the satellite observing era from 1980 to the present.
- High spatial (½° latitude by ⅝° longitude by 72 model levels) and temporal (hourly) resolution;
- Incorporates observations from more recent satellite instruments
- Improved estimates of surface mass balance and surface temperatures over ice sheets

uropean Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis v5 (ERA5)

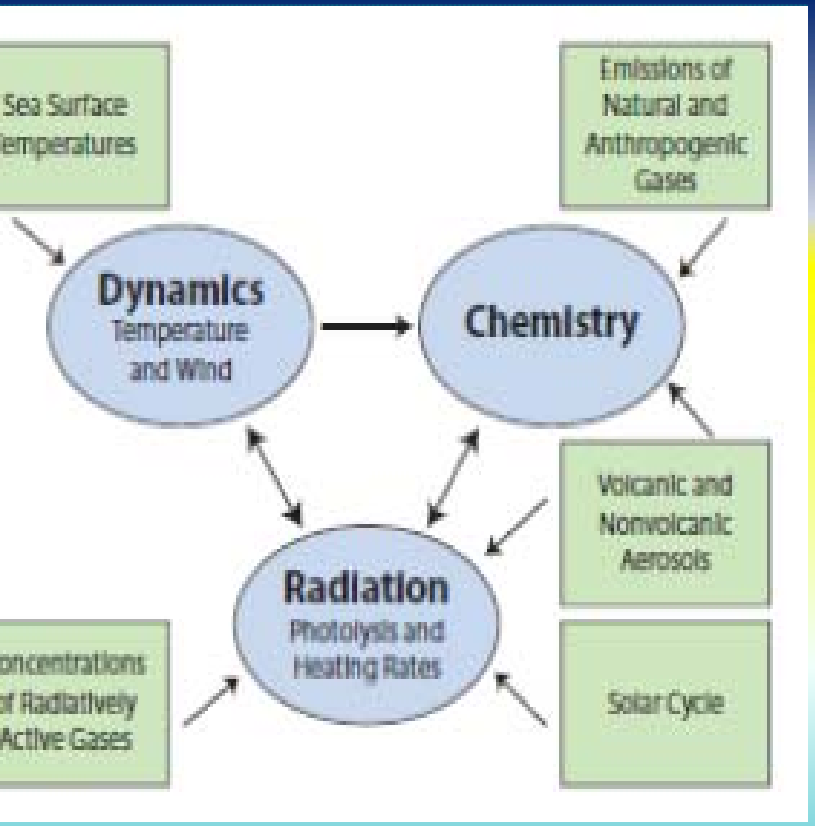


ERA5 provides hourly estimates of a large number of atmospheric, land and oceanic climate variables. The data cover the Earth on a 30km grid and resolve the atmosphere using 137 levels from the surface up to a height of 80km. ERA5 includes information about uncertainties for all variables at reduced spatial and temporal resolutions.

ERA5 combines vast amounts of historical observations into global estimates using advanced modelling and data assimilation systems.

- Quality-assured monthly updates of ERA5 (1959 to present) are published within 3 months of real

Химико-Климатическая модель ИВМ РАН - РГГМУ



MCM60 – Атмосфера, аэрозоль, океан

Глобальный охват - температура, скорости ветра, влажность и давление (Базовая версия 73 высотных уровней от 0 до 60 км)

Изменчивость кислородных, азотных, водородных, хлорных, бромных, серных и углеводородных малых газов (74 газа, 174 химических реакции, 51 фотолиз)

Задание поверхностных потоков или концентраций парниковых и озоноразрушающих газов;

Модель формирования и эволюции полярных стратосферных облаков (PSC);

Гетерогенные процессы на поверхности атмосферного аэрозоля и **PSC**;

Учет влияния изменчивости температуры поверхности океана и площади его покрытия льдом

Chemistry-climate model initiative (CCMI)

- CCMI-2022 Chemistry-climate model initiative, phase 2 is a World Climate Research Programme (WCRP) Stratosphere-Troposphere Processes and their Role in Climate (SPARC) project to study the evolution of the ozone layer using chemistry-climate model simulations. CCMI-2022 data will support the World Meteorologcial Organisation (WMO)/ United Nations Environment Programme (UNEP) Scientific Assessment of Ozone Depletion Report 2022.

odel	Center and Location	Resolution	References
-MIROC3.2	NIES, Japan	T42 L34	[34,35]
	CCCma, Environment and Climate Change Canada, Canada	T47 L71	[36,37]
'MA	MESSy-Consortium, Germany	T42 L47	[38,39]
)MA	MESSy-Consortium, Germany	T42 L90	[38,39]
I	NASA/GSFC, USA	2.0° × 2.5°, L72	[40–43]
M	Seoul National University, Korea	1.9° × 1.875°, L47	[44]
	GAME/CNRM Meteo-France, France	2.0° × 2.0°, L47	[45,46]

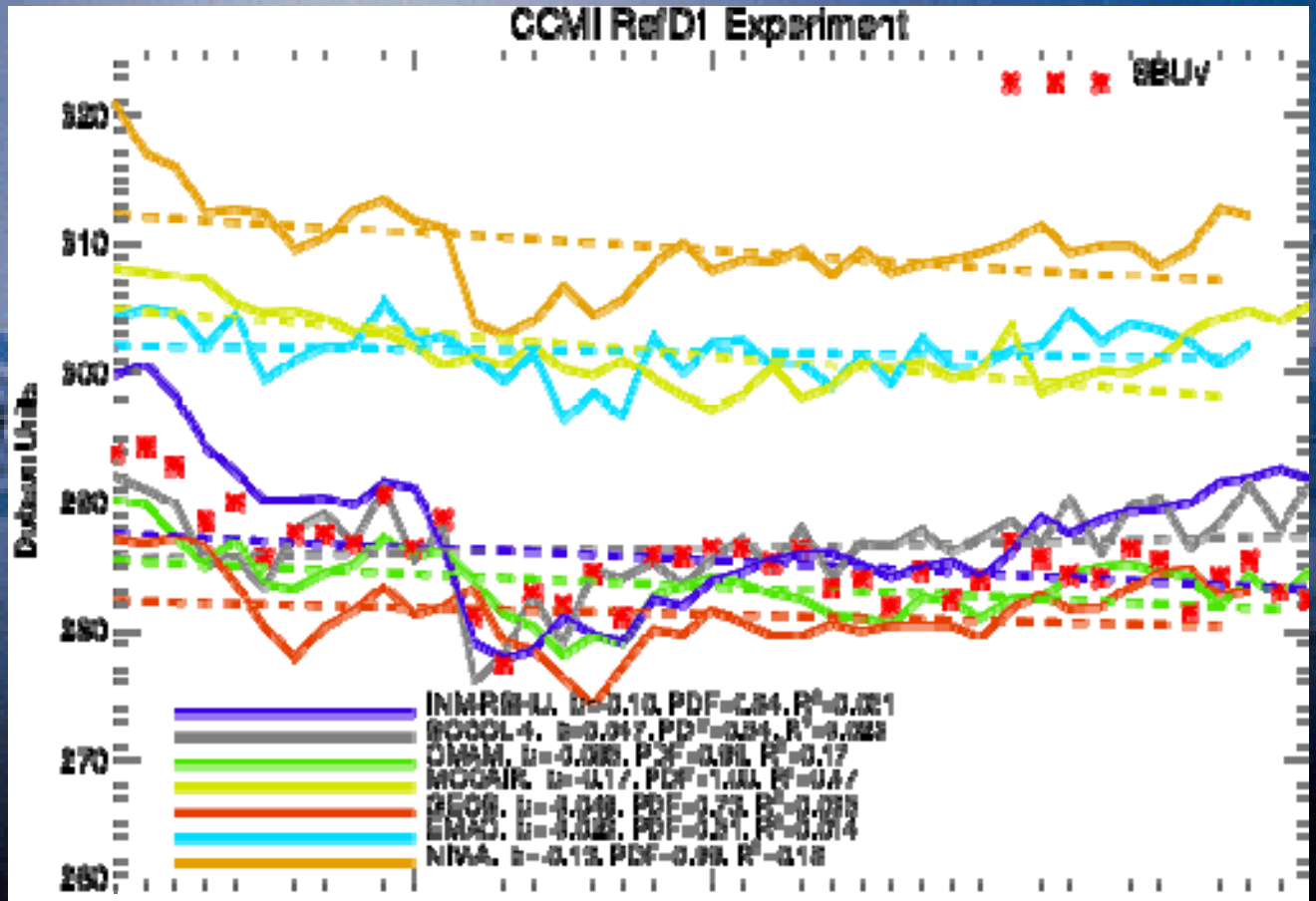
SOlar Climate Ozone Links (SOCOL) Chemistry-Climate Model

SOCOL-3 – фиксированный океан и аэрозоль

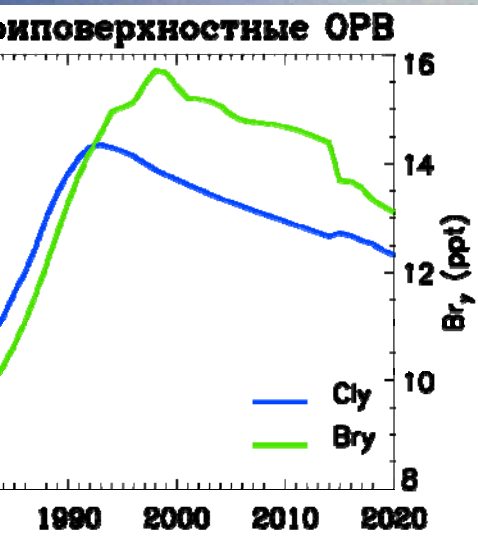
SOCOL-4 – интерактивный океан и аэрозоль

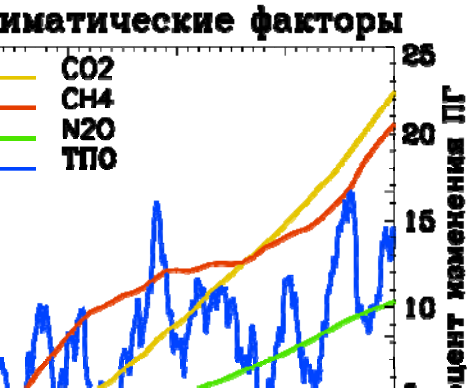
SOCOL is a comprehensive chemistry-climate model, covering the atmosphere from the Earth's surface up to the mesosphere (about 80 km). The current SOCOL generation consists of the middle atmosphere version of the general circulation model (GCM) MA-ECHAM5 and a modified version of the UIUC (University of Illinois at Urbana-Champaign) atmospheric chemistry-transport model MEZON. The chemistry module covers stratospheric homogeneous and heterogeneous ozone chemistry and the most relevant chemical processes for describing the tropospheric background chemistry including an isoprene oxidation mechanism. SOCOL can be run at different horizontal resolutions (spectral truncation T31 or T42) and vertical levels (39 or 90). Depending on the application SOCOL can be run with a mixed-layer or a deep ocean module or with the comprehensive sulfate aerosol module AER (Sheng et al., 2015). A detailed description and evaluation of the current model version SOCOLv.3 is presented by Stenke et al. (2013).

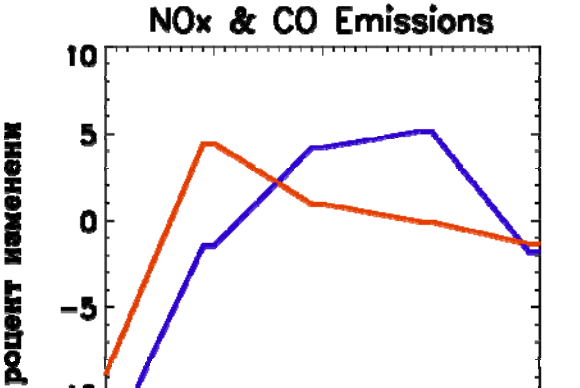
CCMI RefD1 ExtraPolar Ozone (60S – 60N)



Базовые Сценарии Изменения Влияющих Факторов







BAS – учитывается влияние всех факторов

SAD_only – учитывается только изменчивость стратосферного аэрозоля

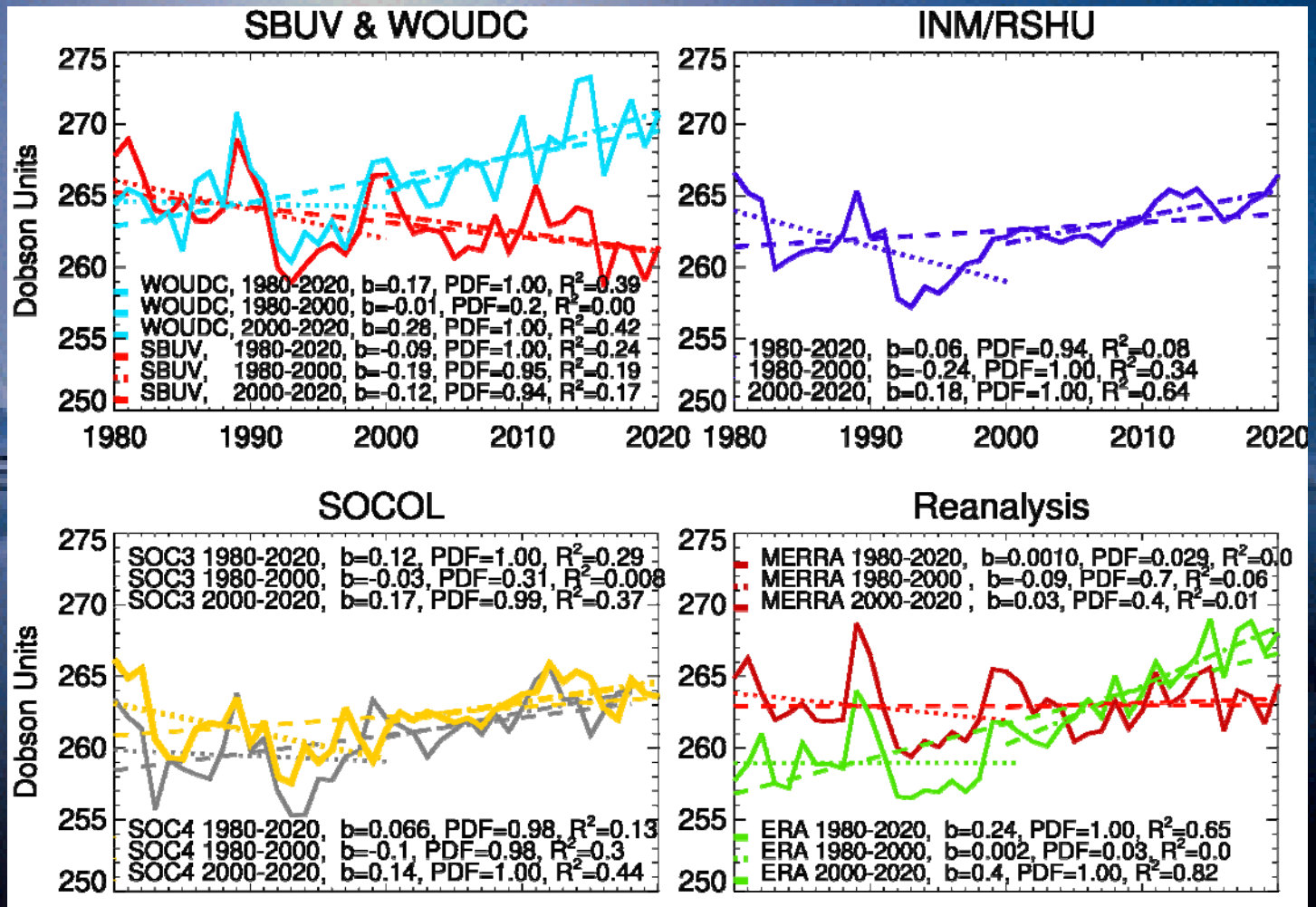
SST_only - учитывается только изменчивость температуры поверхности океана

GHG_only - учитывается только изменчивость парниковых газов

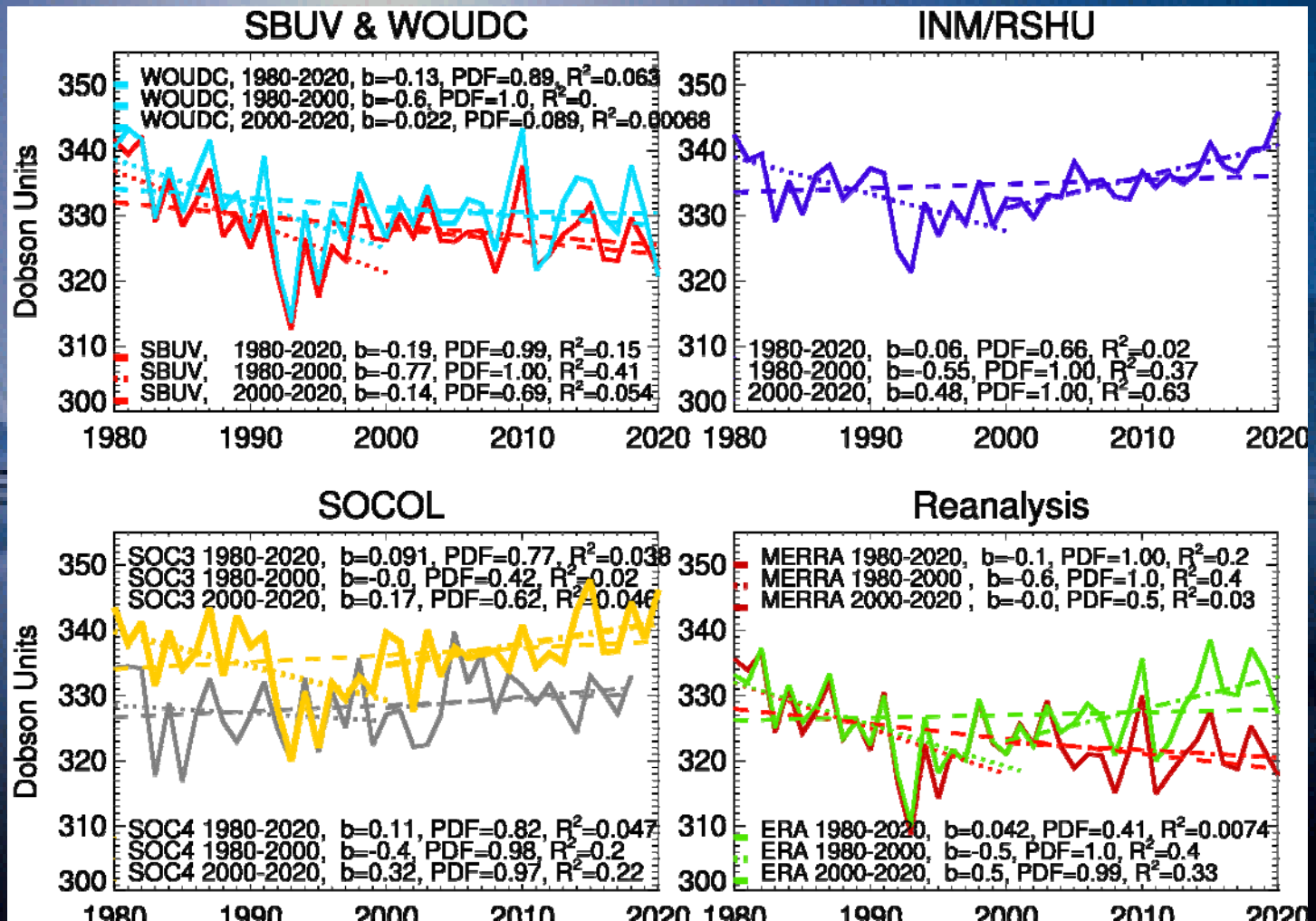
NOx_only – учитывается только изменчивость источников окислов азота

CO_only – учитывается только изменчивость

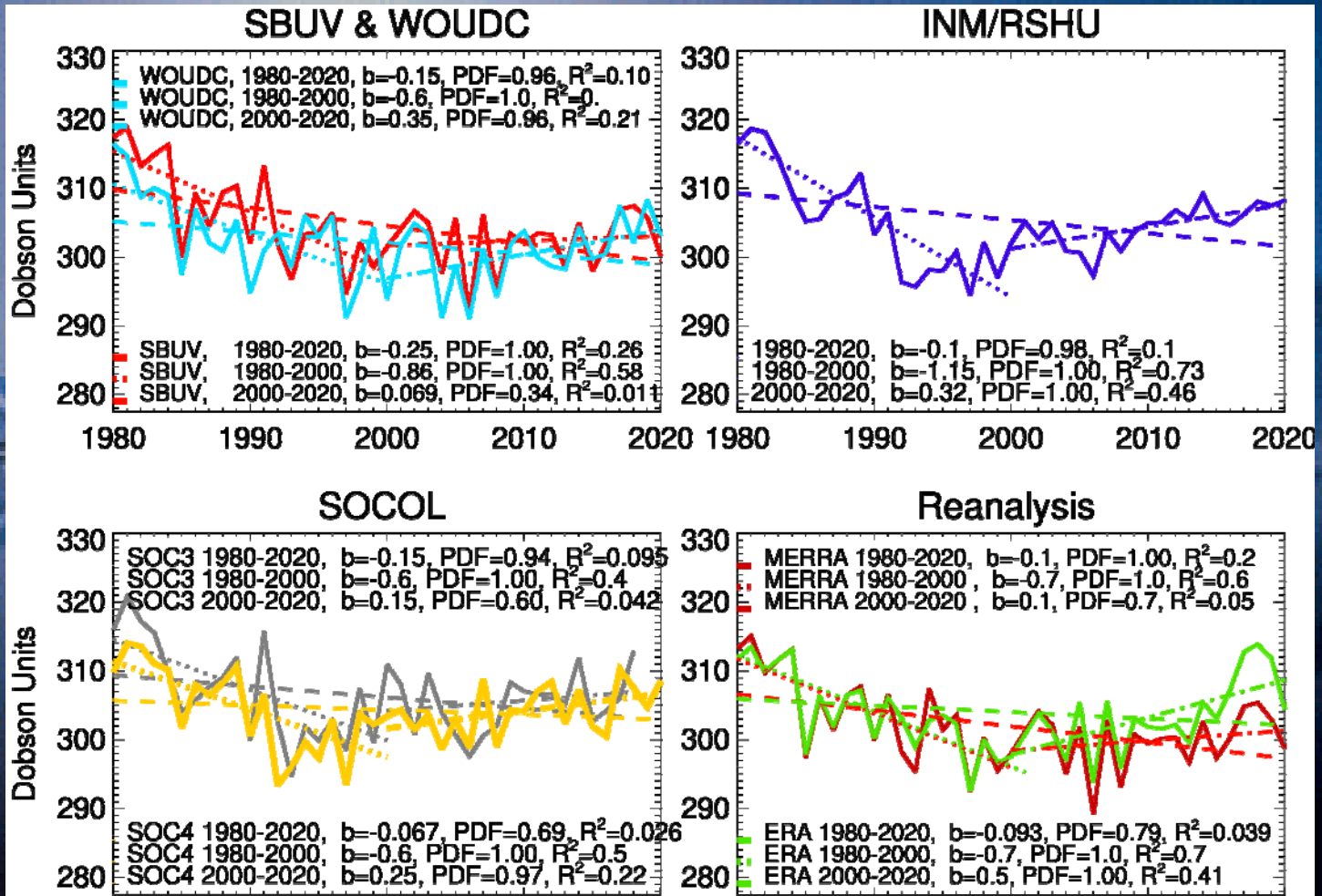
opical Column Ozone Variability



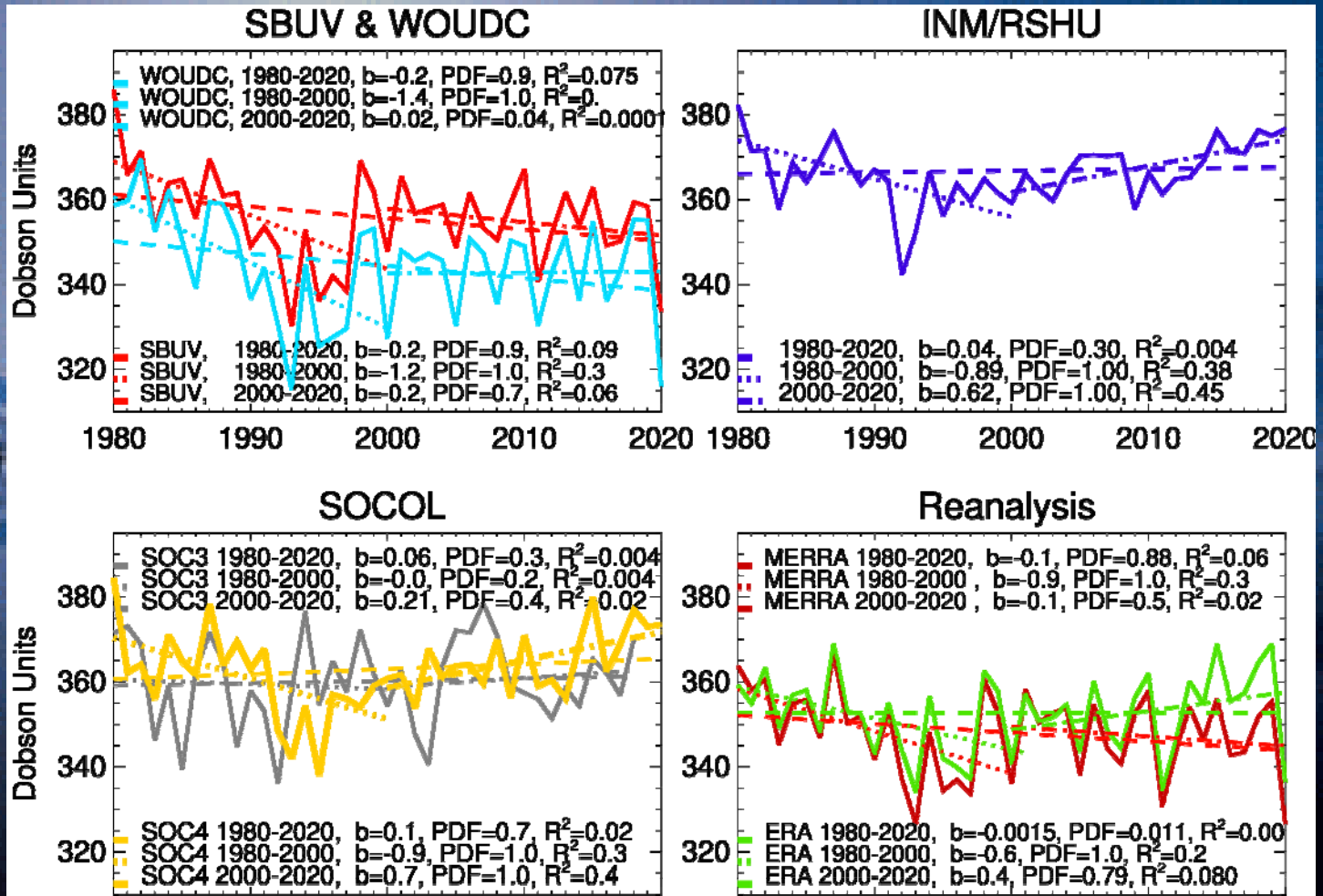
rthern Mid-latitude Column Ozone



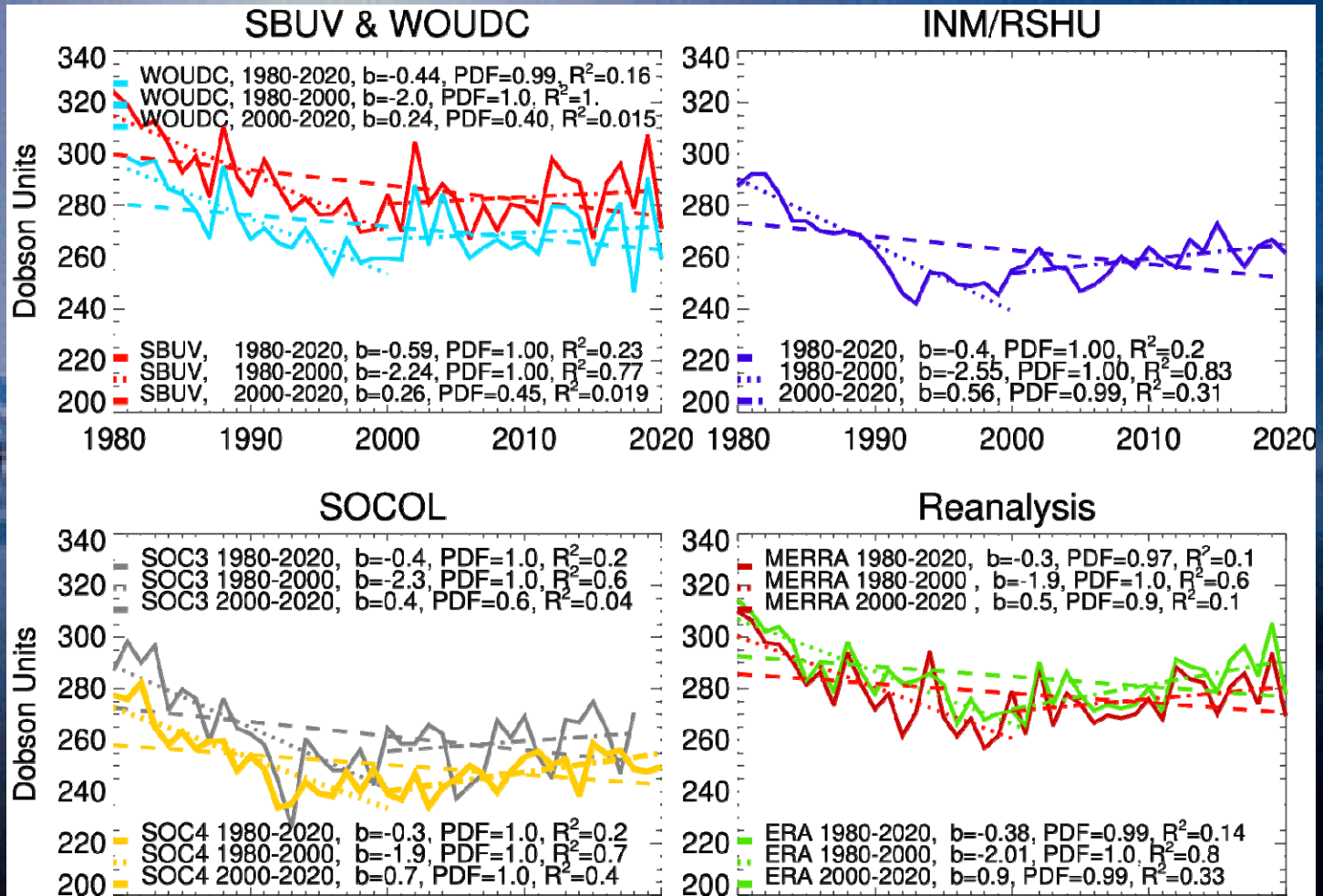
uthern Mid-latitude Column Ozone



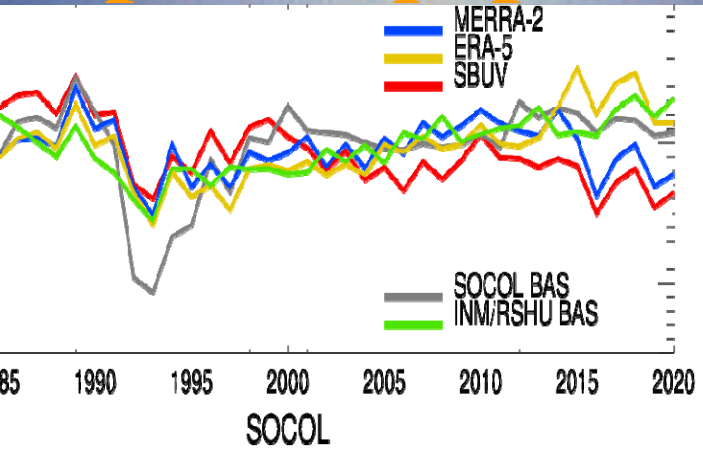
Arctic Column Ozone

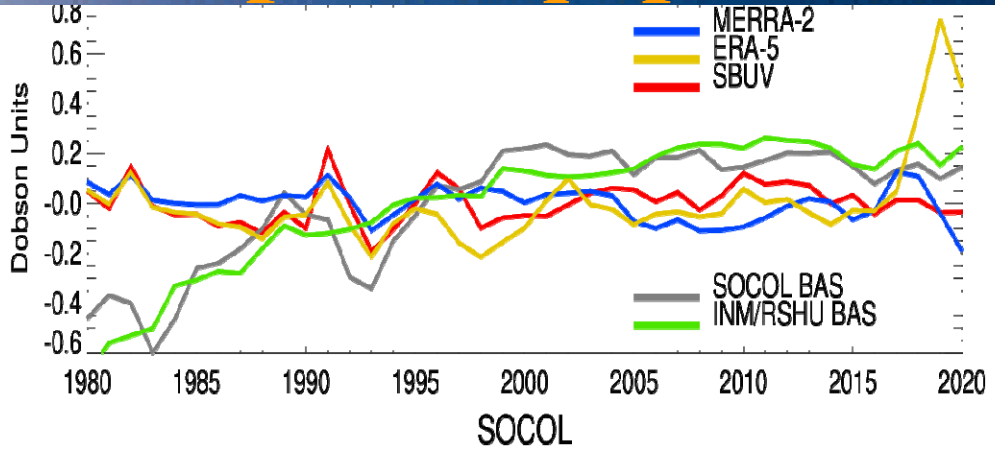


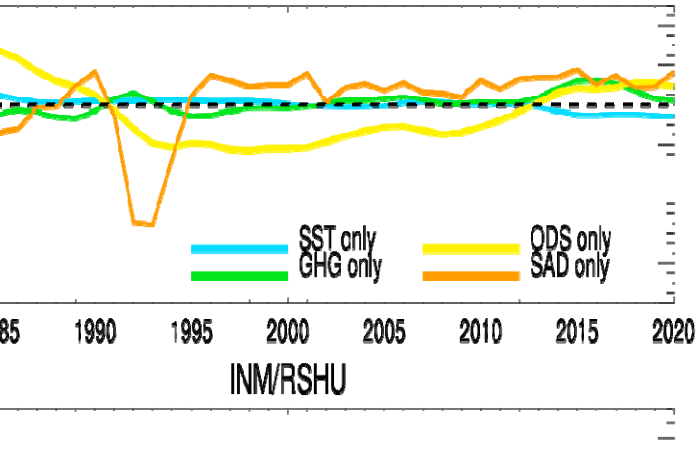
Antarctic Column Ozone

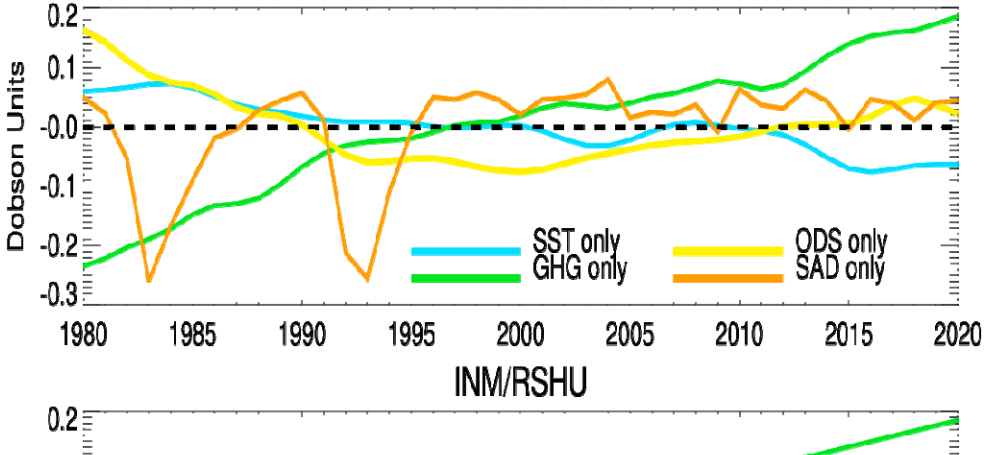


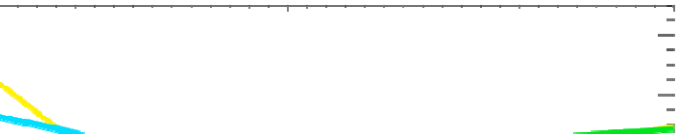
...менение глобального озона в нижней **стратосфере и тропосфере**

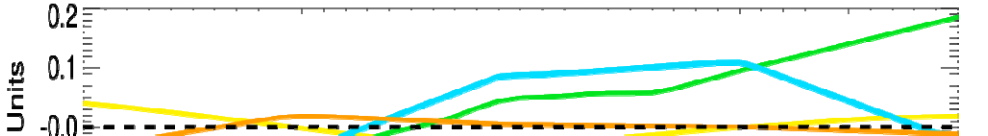












Заключение

CCMI модели в основном корректно воспроизводят межгодовую изменчивость содержания озона, но отличаются в оценке абсолютной величины его общего содержания

В оценке трендов общего содержания озона даже данные измерений и реанализа часто показывают разнонаправленные тенденции

В полярных районах модели не воспроизводят случаи резко отличающихся от общей тенденции зим с увеличенным или уменьшенным содержанием озона

Резкое сокращение содержания стратосферного озона в начале 90х с последующим резким увеличением к началу 2000х связано с вулканическими выбросами и солнечной активностью, а не с влиянием Монреальского Протокола, направленного на сокращение содержания озоноразрушающих веществ

Содержание озона в тропосфере определяется