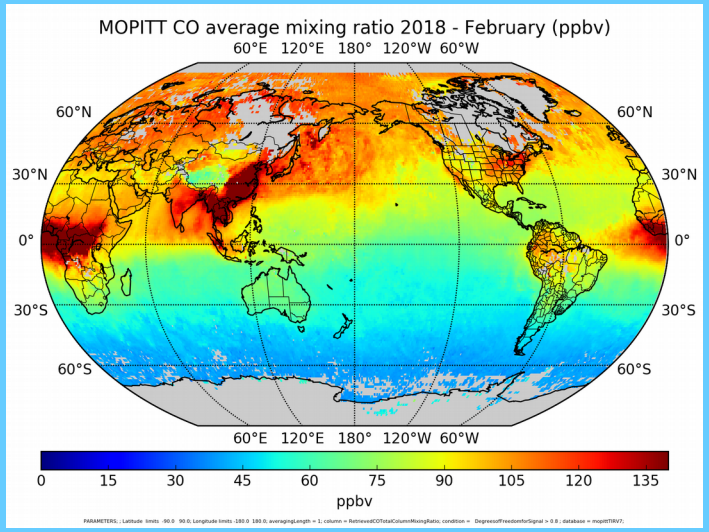
Measurements of Carbon Monoxide from Space using the MOPITT Instrument



James R Drummond
Department of Physics and Atmospheric Science, Dalhousie University
And
Department of Physics, University of Toronto
james.drummond@utoronto.ca

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Authors

- **James R. Drummond,**
- **With help from**

– **Florian Nichitiu (UoT)** - **Jason Zou (UoT)**
– **David Edwards (NCAR)** - **John Gille (NCAR)**
– **Merritt Deeter (NCAR)** - **Helen Worden (NCAR)**

- **The NCAR Data Processing Team**

–National Center for Atmospheric Research (NCAR), Boulder, CO

- **The MOPITT Science Team**

- james.drummond@utoronto.ca Tel: 416-978-4723
- James.drummond@dal.ca Tel: 902-494-2324

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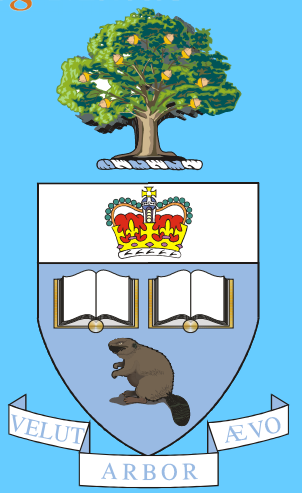


NSERC CRSNG
People. Discovery. Innovation.

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

Environment Canada
Environnement Canada

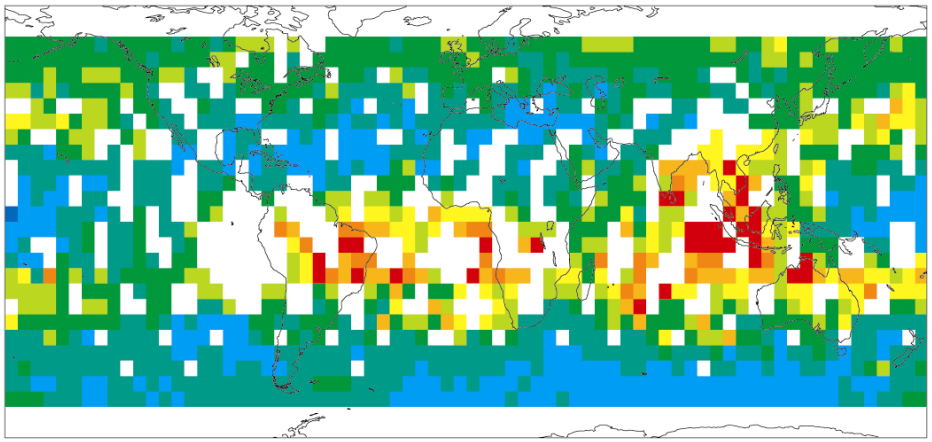
Instant Major CO facts...

- Mixing ratio about 60-300ppbv
  - –Higher in major pollution zones
- Produced by incomplete combustion
  - –Forest fires, grass fires
  - –Industrial activity
- Removed by OH
- Measuring CO gives us a "window" into the tropospheric chemistry and transport

Measurement of Air Pollution from Satellites (MAPS)

Carbon Monoxide Mixing Ratios in Middle Troposphere

SRL-2 September 30 - October 11, 1994



Mixing Ratio (ppbv)

30 45 60 75 90 105 120 135 150 165+

NASA LANGLEY RESEARCH CENTER / ATMOSPHERIC SCIENCES DIVISION

Instant Major CO facts…

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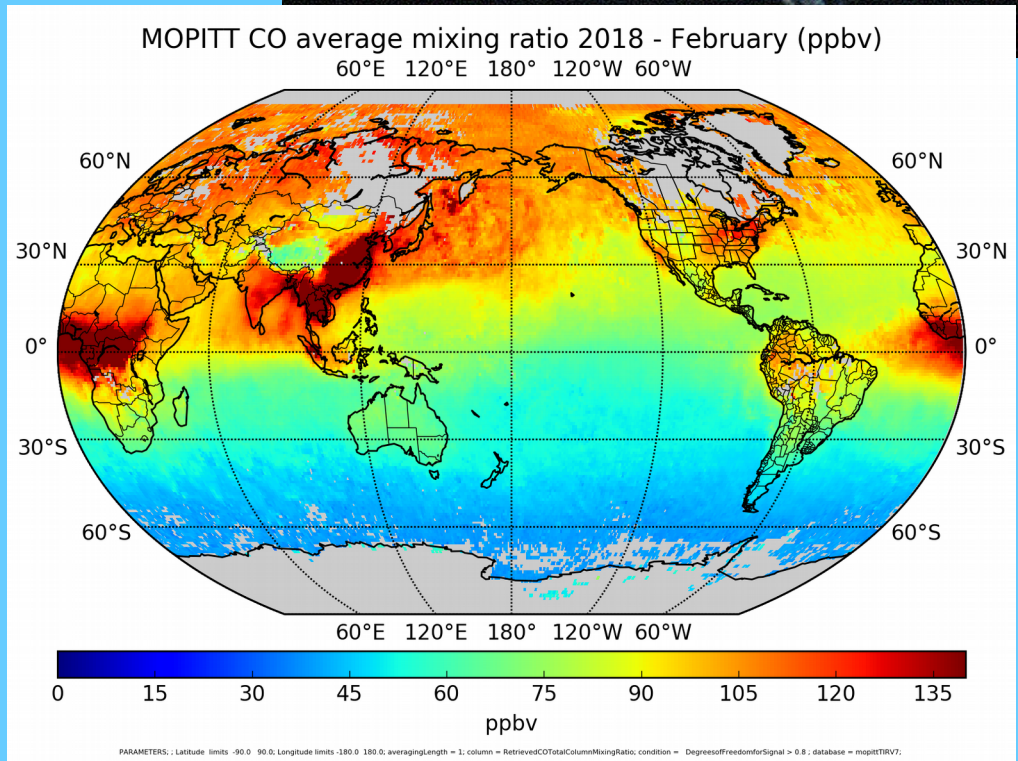
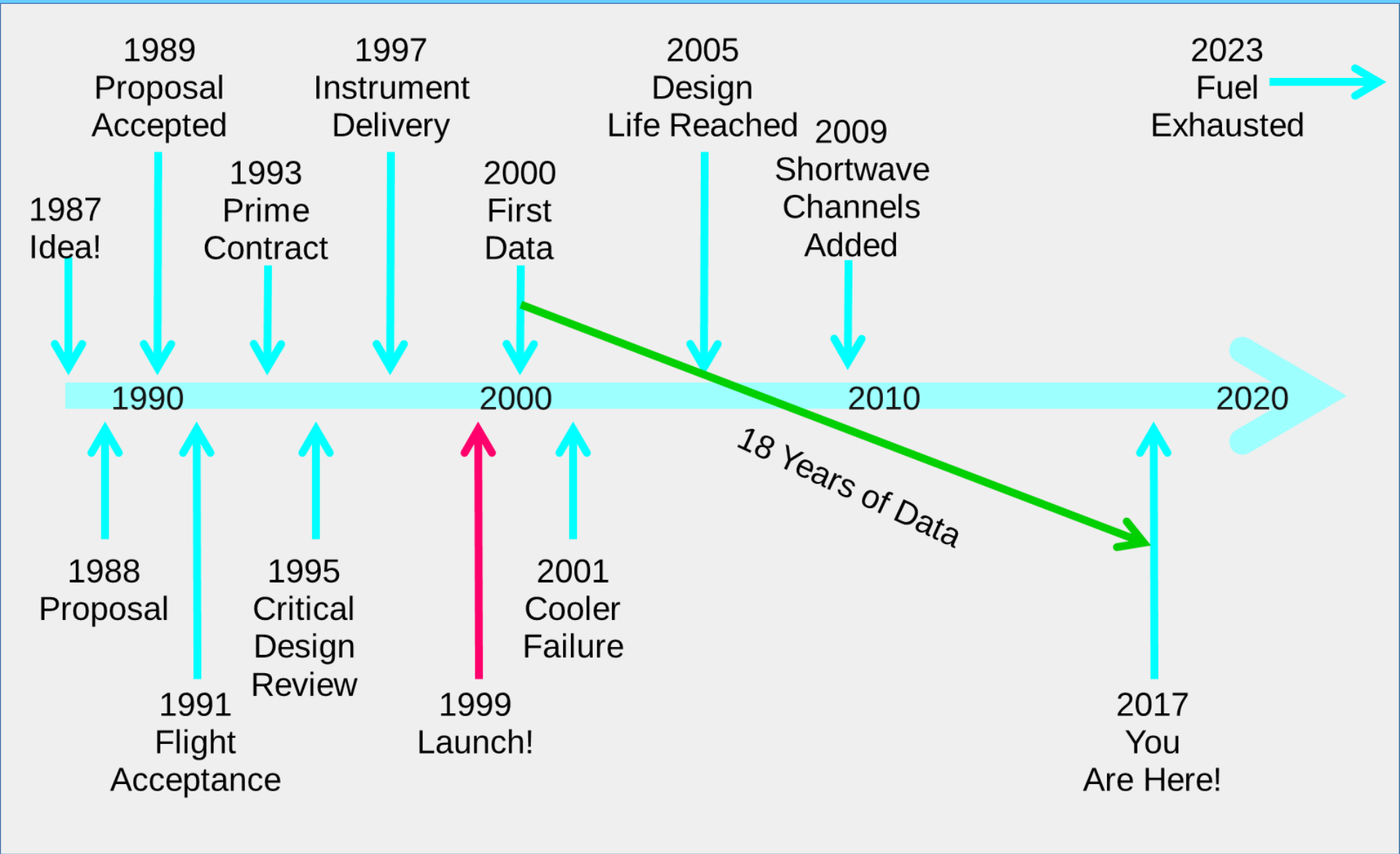


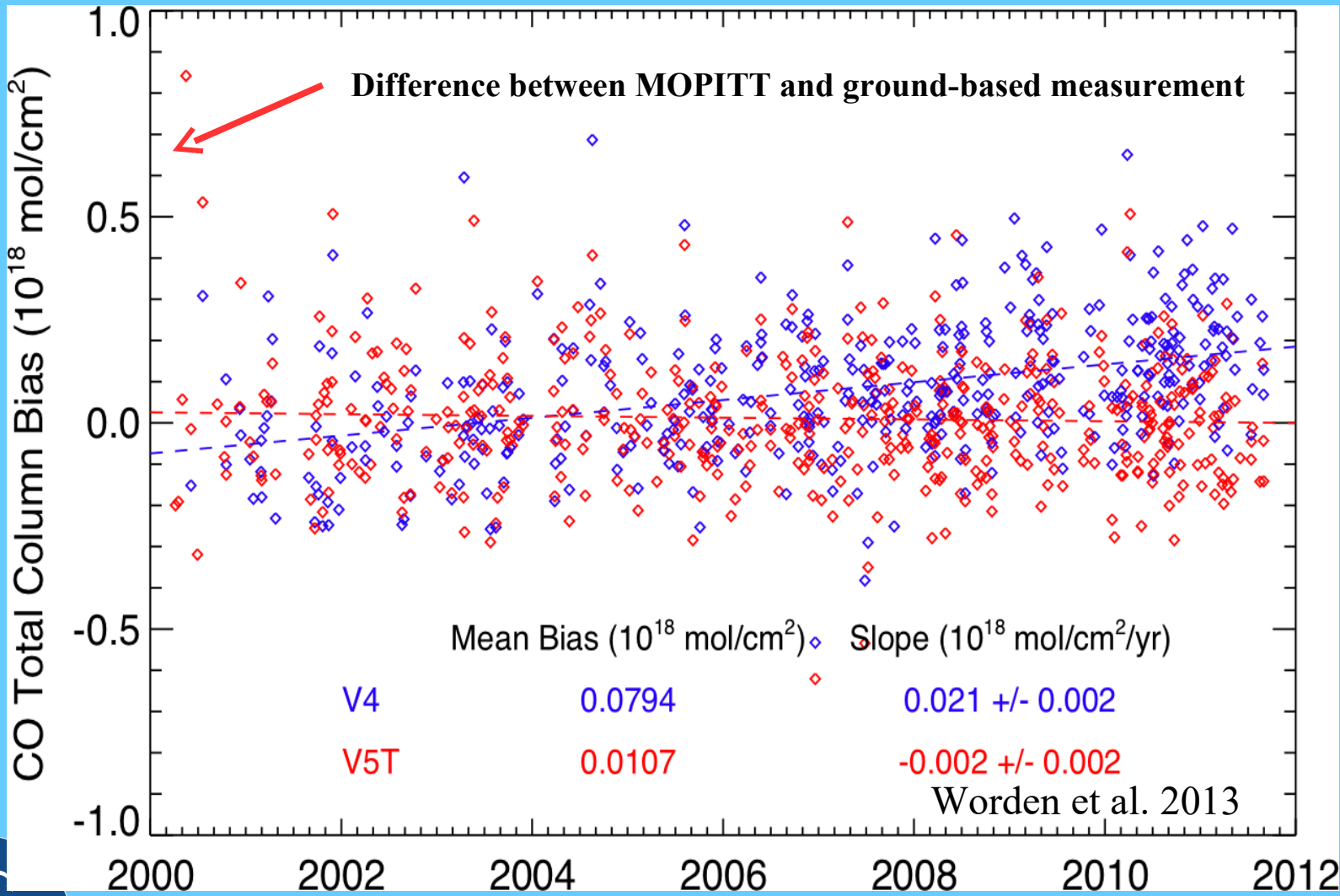
LAUNCH!!

- Successful launch
  - –Terra satellite
  - –Dec 18, 1999, 18:57GMT
  - –9 seconds before end of the millennium!
- Orbit:
  - –polar, sun synchronous,
  - –Altitude, 705km, inclination 98.4
  - –10:30am descending node

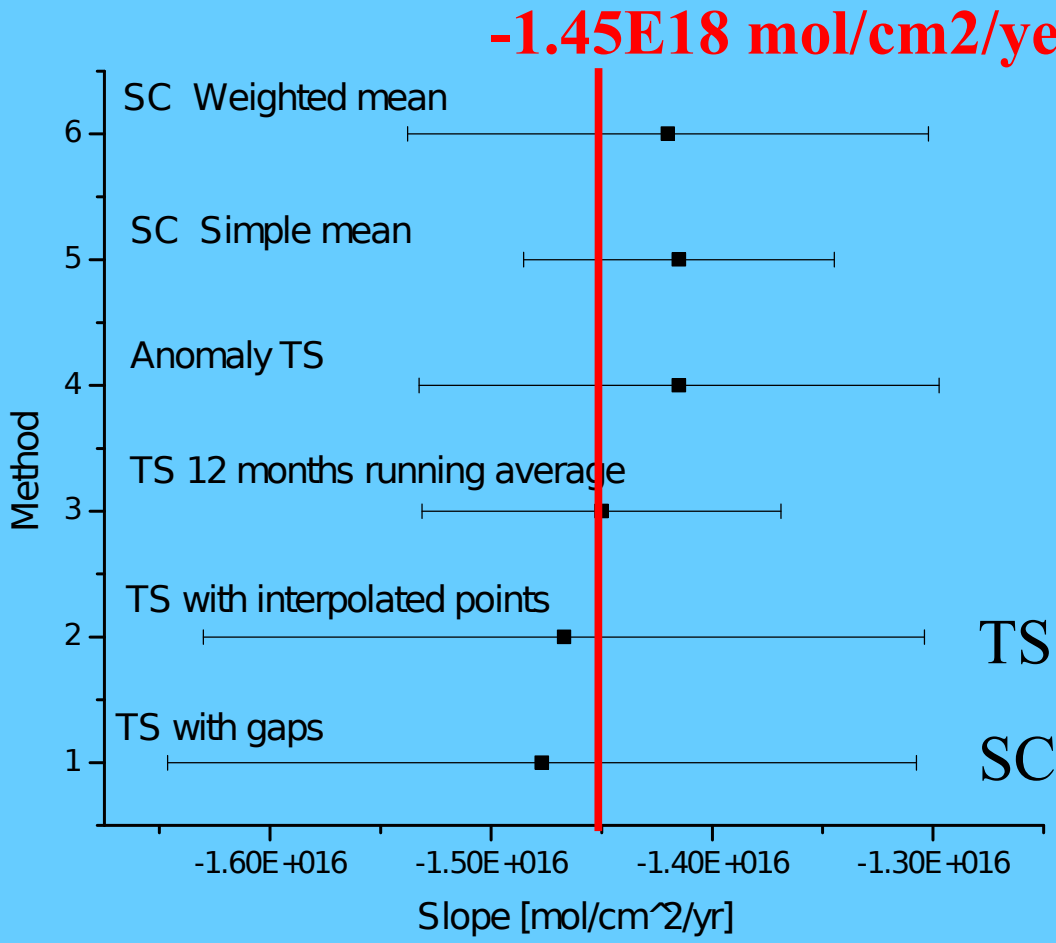
MOPITT Timeline



Validation

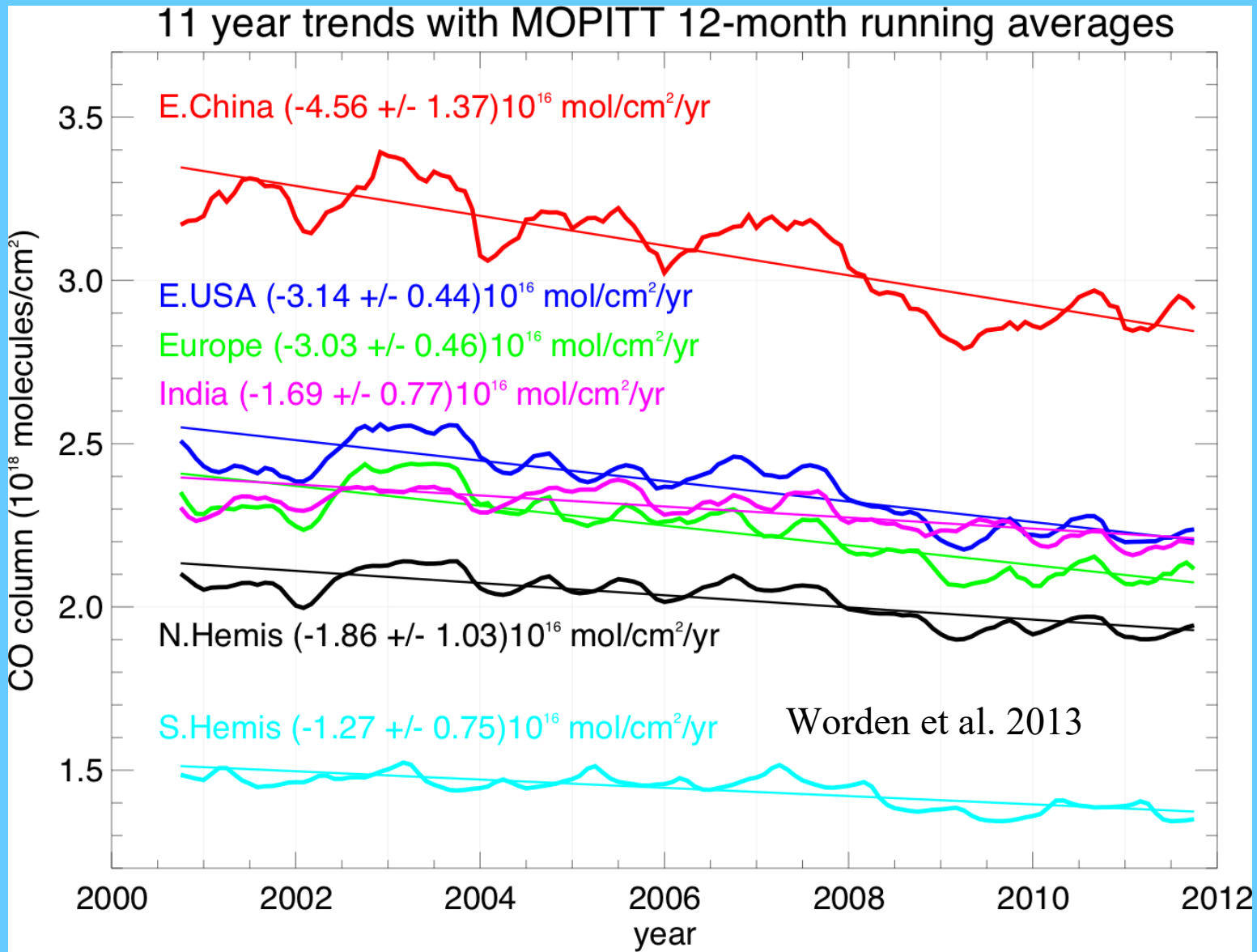

Difference between MOPITT and ground-based measurement
CO Total Column Bias (10^{18} mol/cm^2)
1.0
0.5
0.0
-0.5
-1.0
2000
2002
2004
2006
2008
2010
2012
Mean Bias (10^{18} mol/cm^2)
Slope (10^{18} mol/cm^2/yr)
V4
0.0794
0.021 +/- 0.002
V5T
0.0107
-0.002 +/- 0.002
Worden et al. 2013

Trend Analysis

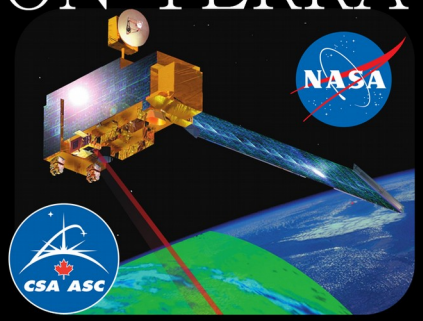


TS = time series

SC = seasonal cycle


11 year trends with MOPITT 12-month running averages
E.China (-4.56 +/- 1.37)10^16 mol/cm^2/yr
E.USA (-3.14 +/- 0.44)10^16 mol/cm^2/yr
Europe (-3.03 +/- 0.46)10^16 mol/cm^2/yr
India (-1.69 +/- 0.77)10^16 mol/cm^2/yr
N.Hemis (-1.86 +/- 1.03)10^16 mol/cm^2/yr
S.Hemis (-1.27 +/- 0.75)10^16 mol/cm^2/yr
Worden et al. 2013
CO column (10^18 molecules/cm^2)
3.5
3.0
2.5
2.0
1.5
2000
2002
2004
2006
2008
2010
2012
year

MOPITT ON TERRA



YEARS

18

The NASA Terra satellite was launched on Dec. 18, 1999. Today, CSA's MOPITT instrument continues to provide global measurements of carbon monoxide.

ORBITS

95,830

Terra and the MOPITT instrument have performed over 95,830 Sun-synchronous orbits around the Earth at an altitude of 705km.

DISCOVERIES

31

11/3

The data provided by MOPITT has enabled over 31 important scientific discoveries, including the decrease of global carbon monoxide over the past decade. 11 involve Canadians, and 3 are Canadian-led

REPORTS

3

MOPITT measurements have been used in 3 international reports, including the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.

MEASUREMENTS

Canada's MOPITT instrument onboard Terra has performed over 1.386 billion CO retrievals in the Earth's atmosphere over its 18 year lifetime.

PUBLICATIONS

426

83

Over 426 journal articles using MOPITT instrument data have been published by scientists worldwide. 83 involve Canadians.

RESEARCHERS

1283

55

A total of 1283 authors from around the globe have published articles related to CSA's MOPITT mission. 55 authors are from Canadian institutions.

INSTITUTIONS

353

13

A total of 353 institutions worldwide have been involved in publications related to Canada's MOPITT instrument. 13 are Canadian.

COUNTRIES

41

Researchers from 41 countries have used MOPITT results for air quality, numerical modelling, and forest fire studies.

May 2018

IWGGMS

Credit: ASC/CSA, GoC, 2018

Recent Discoveries with MOPITT

Influence of El Niño on Carbon Dioxide

MOPITT CO measurements were used to verify OCO-2 atmospheric CO_2 concentrations, which discovered that the tropical Pacific Ocean does not affect atmospheric CO_2 during El Niño events.

See *Chatterjee et al., Science 358, eaam5776, 2017*

Oct. 2017

Contrasting Carbon Cycle Responses

MOPITT CO observations were used to optimize biomass burning rates, and in collaboration with other satellite CO_2 data, discovered that the 2015-16 El Niño released more carbon into the atmosphere, marking the largest growth of CO_2 on record.

See *Liu et al., Science 358, eaam5690, 2017*

Oct. 2017

Carbon Dioxide Fluxes

MOPITT CO data was used to verify OCO-2 CO_2 and fluorescence data, which discovered the effect of ocean temperature and rainfall on CO_2 released by oceans and the biosphere.

See *Eldering et al., Science 358, eaam5745, 2017*

Oct. 2017

Fire Carbon Emissions in Asia

MOPITT CO data was used to estimate the amount and variability of fire carbon emission in equatorial Asia from 1997-2015. It was discovered that fire severity could be predicted by 1 to 2 months by observing water deficit.

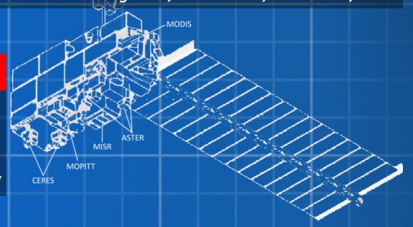
See *Yin et al., GRL 43, 10472, 2016*

Oct. 2016

Decreasing Carbon Monoxide Emissions

CO data from MOPITT was used with a scientific atmospheric model to discover that decreasing anthropogenic CO leads to increased CO chemical production, and shorter CH_4 lifetimes.

See *Gaubert et al., GRL 44, 9985, 2017*



May 2016

Remote-sensing of Fires

MOPITT fire observations showed that higher combustion efficiency was a small contributing factor to the 2010 CO emissions, and was consistent with other satellite data.

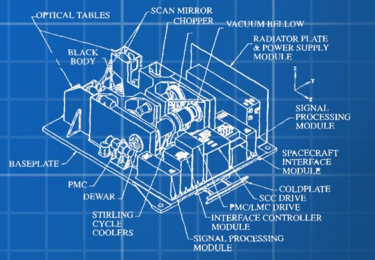
See *Bloom et al., GRL 42, 1268, 2015*

Feb. 2015

Evidence of Policy Success in Improving Air Quality

MOPITT CO data was used to validate ground measurements of CO emissions near London, England. Data from 1997-2014 showed the decrease of CO emissions in the UK due to the adoption of certain emission reduction policies. It was concluded that effective improvement in ambient CO is possible with strong action and policy.

See *Lowry et al., Nature Sci. Rep. 6, 25661, 2016*



Jan. 2014

Space Measurements of Atmospheric Pollutants

CO data from MOPITT was used to verify satellite measurements of pollution from a severe pollution episode in January 2013. The pollution was caused by anthropogenic emissions and a high pressure weather system. The discovery showed that satellites can detect boundary layer pollution, in support of air quality evaluation and management.

See *Boynard et al., GRL 41, 645, 2014*

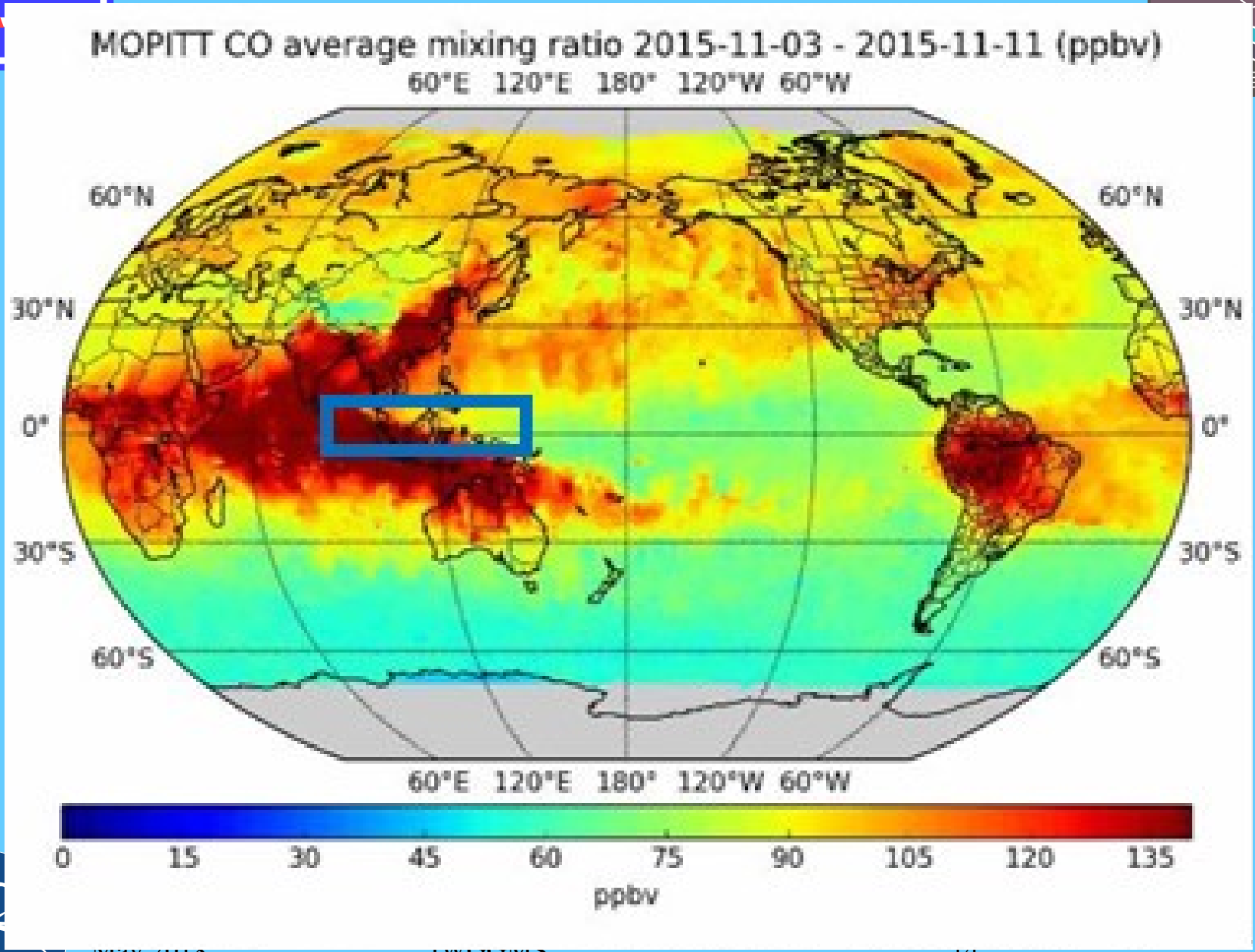
Canadian Space Agency | Agence spatiale canadienne

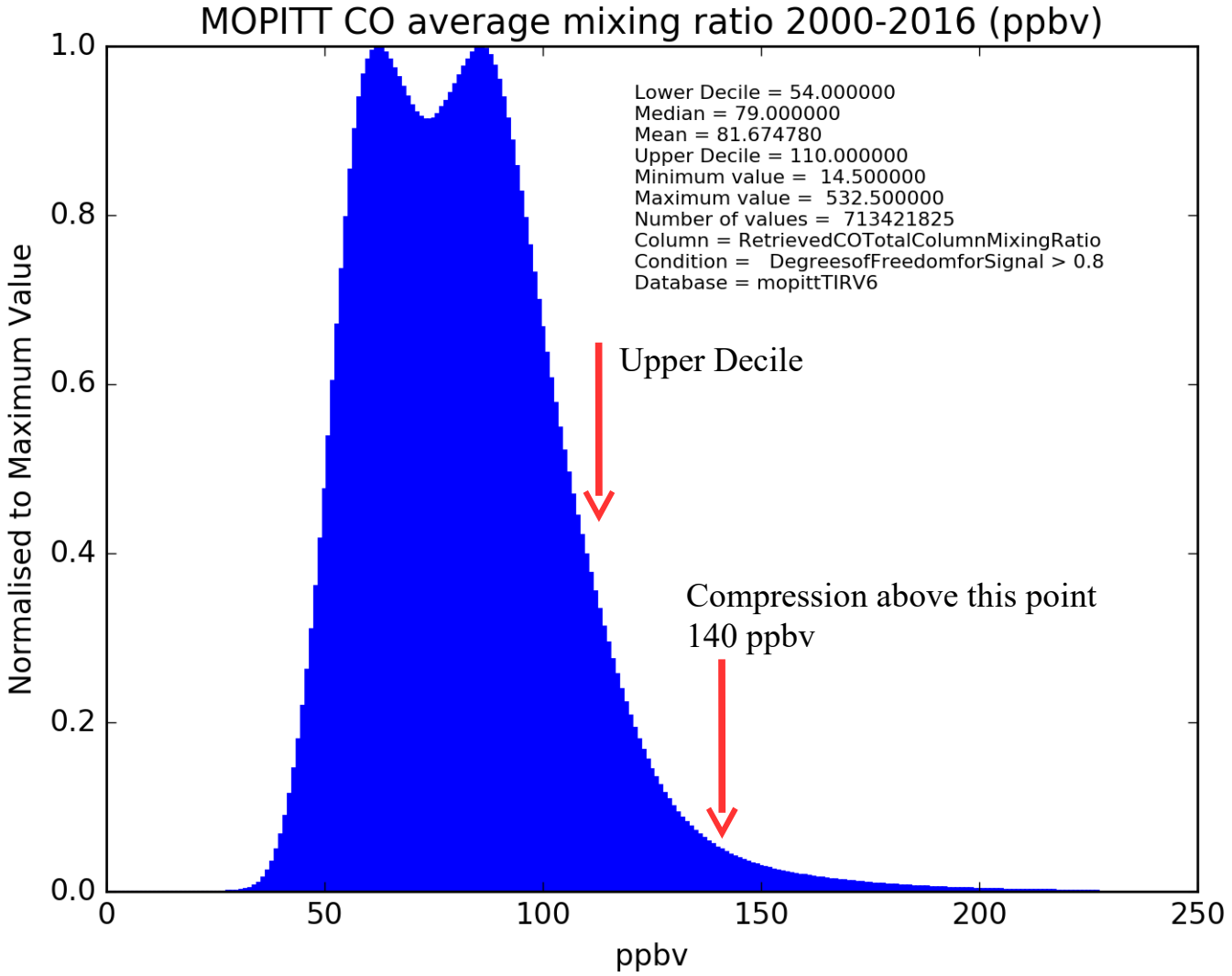
Canada

Credit: ASC/CSA, GoC, 2018

A Few Notes

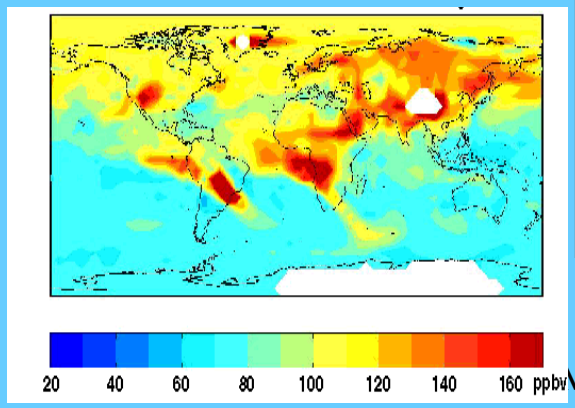
- MOPITT cannot see through clouds
- MOPITT does not measure everywhere at once
  - How to fill in gaps (or "if" to fill in gaps)
  - To interpolate or not to interpolate
- MOPITT has a "weighting function" which need to be remembered. There is some vertical information, but it is limited
- MOPITT naturally measures the "total column" in units of molecules/cm^2 or similar, but the most familiar unit is "parts per billion by volume" or "ppbv"
- So we approximate the "average column mixing ratio" as the total column/surface pressure and scaled to "ppbv"
- There are a very few really high values that may be real or may be artifacts. If we scale to those values the bulk of the data gets compressed and variations are hard to see in the colour scale.

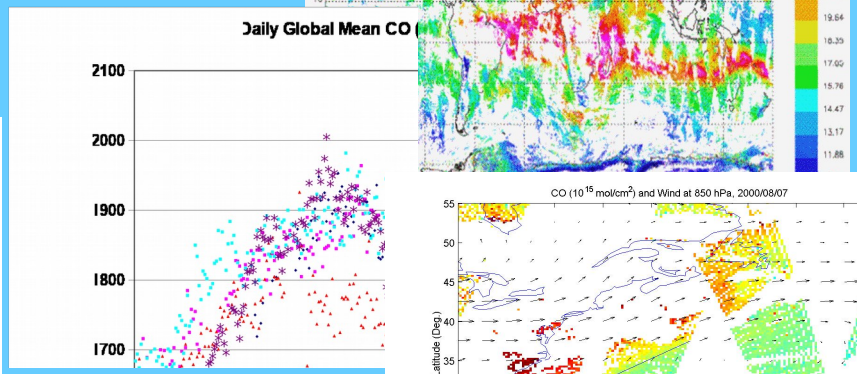

MOPITT CO average mixing ratio 2015-11-03 - 2015-11-11 (ppbv)
60°E 120°E 180° 120°W 60°W
60°N
30°N
0°
30°S
60°S
60°E 120°E 180° 120°W 60°W
0 15 30 45 60 75 90 105 120 135
ppbv

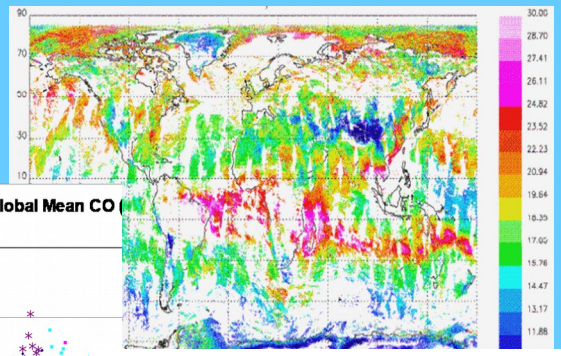

MOPITT CO average mixing ratio 2000-2016 (ppbv)
Lower Decile = 54.000000
Median = 79.000000
Mean = 81.674780
Upper Decile = 110.000000
Minimum value = 14.500000
Maximum value = 532.500000
Number of values = 713421825
Column = RetrievedCOTotalColumnMixingRatio
Condition = DegreesofFreedomforSignal > 0.8
Database = mopittTIRV6
Upper Decile
Compression above this point
140 ppbv
Normalised to Maximum Value
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
ppbv

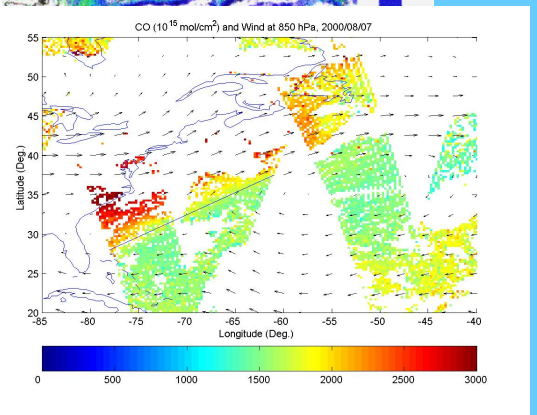
Conclusions

- MOPITT has acquired over 18 years of data on CO
- The instrument continues to perform well
- The data show considerable year-to-year variation
  - "Chemical weather"
- Data are being used for a variety of scientific studies
- We need more of this….









MS