

Wildfires in the Arctic

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> Megafires such as this one in Canada's Northwest Territories last year are transforming the boreal forest. PHOTO: KYLE THOMAS

Largest ever wildfire in Greenland seen burning from space

New Scientist, 2017



PARTIC & August 2017



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By Michael Le Page

The largest wildlife over detected by statistics in the starty in covered county of Greenland continues to spread. Lard authorities are and to be moduleting ways to halt the black, but it is not dear whether they have the successry security.

Main - News - Press Release - News fro solution are something reasons.



Unprecedented wildfires in the Arctic

- Tags: Environment Climate change Pollution Public Isakh
- 12 Published 12 July 2019

WMO, 2019



NOAA, 2017

Wildfire still burning in Greenland tundra in mid-August 2017

Actor In Dillero

August 19, MIT.

An uncountry large the continued to been in the banks of western Committed on August 10, 20 C - wave scenariose for a place before known the investment to its contracts or cap and glocker-filled (costs.

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Aerosols emitted from wildfires could significantly affect global climate through perturbing global radiation balance.

From Impacts of Wildfire Aerosols on Global Energy Budget and Climate: The Role of Climate Feedbacks, Jiang Y. et al., 2020

https://www.nationalgeographic.org/encyclopedia/wildfires/

Aerosols emitted from wildfires could significantly affect global climate through perturbing global radiation balance.

The feedback mechanisms between fire and climate interactions are still a great challenge and remain fundamentally uncertain

From Impacts of Wildfire Aerosols on Global Energy Budget and Climate: The Role of Climate Feedbacks, Jiang Y. et al., 2020

https://www.nationalgeographic.org/encyclopedia/wildfires

19/04/21



Objective

Draw an overall picture of the sources and radiative effects of wildfires burning in August 2017 at THAAO and in the Arctic

Achieved through a multi faceted approach: taking into considerations observations concerning the chemistry and physics of the atmosphere, as well as modelling.

- Having the chance to observe two atmospheric states (normal condition and "wildfires" condition)
 - Measure the atmospheric parameters which are involved in radiative budget
 - Model the atmosphere in a point location for which all these observations are available
 - Use obtained modelling parameters (formulating some hypotheses) to extend the impact assessment to a wider geographical area affected by wildfires

Outline

- Tile 1: Radiation from ground measurements
 - AOD (sun-photometer), SW, PAR, all-sky camera
- Tile 2: Chemistry from ground measurements
 - Air sampling, FTIR
- Tile 3: Chemistry from satellites
- Tile 4: Modelling of back trajectories
- Tile 5: Modelling of atmospheric chemistry
- Tile 6: Modelling of radiative impacts
 - Spatial extrapolation



THAAO Thule High Arctic Atmospheric Observatory (76.5°N, 68.8°W)



http://www.thuleatmos-it.it

Instruments











Cimel Sun photometer (AERONET; NASA) SolData Sun Photometers (ENEA) PM10 sampler (Univ. Firenze/ENEA) H₂O isotope analyzer (Univ. Alaska)

Pyrometer (ENEA) All-sky camera (ENEA) Ceilometer (ENEA)







Ground-based measurements

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https://www.britannica.com/science/wildfire

AOD for different lambda





All sky camera @THAAO

18 August 2017 – 1h frames



21 August 2017 – 1h frames

2017 Aug 21 00:00:41 CUT



SW and PAR radiation comparison



Radiation: summary





Chemistry of the atmosphere from FTIR



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Chemistry of the atmosphere: FTIR



NH₃ -> Ammonia 19/04/21 H₂CO -> Formaldehyde

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Chemistry of the atmosphere: air sampling

PM10 sampling head, with an airflow of 2.3 m³/h

Automatic continuous measurements every 48 hours

Teflon filters are then 47 mm in diameter, with 2.0 μm nominal porosity, shipped frozen.

PM10 mass is determined by the difference of the filters weight before and after the sampling.

Filters are cut in two halves for ions (ion chromatography) and the metal determination (ICP-AES).



Chemistry of the atmosphere: ground measurements





- More complex interpretation
- UCC = Upper Continental Crust
- LS = Local Soil reference

Satellite-based measurements

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aqua-satellite-captures-devastating-wildfires-in-oregon/

Tile 3

Chemistry of the atmosphere from satellites







user existing region was defined by 40 286. 76 396, 49 896, 76 596. This data pill also limits the analyzable region to the two this parts \$12.596, 76 391. This antisytable region indicator the spatial limits of the subadded granulas that each title making this insulatable region.



- Area-averaged
- Column averaged

From "Giovanni" platform giovanni.gsfc.nasa.gov/giovanni/



Since 2019 also TROPOMI onboard Sentinel 5P

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CALIOP - Aerosol backscatter profile

Level 1 CALIOP data (v. 4.10, Vaughan et al. (2004)) were used to retrieve the aerosol backscatter profile. CALIOP attenuated backscatter data were averaged over a horizontal path of about 50 km, and a 300 m running average was calculated along the vertical coordinate. 20 August 2017 21 August 2017



INGV, Rome, Italy

CALIOP - Aerosol type attribution



Elevated smoke and polluted dust

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CALIOP retrievals

Two aerosol layers around 3 and 11 km of elevation



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MODIS AOD









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Atmospheric dynamics for sources attribution

https://www.nationalgeographic.com/science/article/heat-wave-thawed-siberia-now-on-fire PHOTOGRAPH BY KIRILL KUKHMAR, TASS/GETTY IMAGES

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HYSPLIT

- Trajectories obtained from HYSPLIT model
 - a) 19 August 2017 (69 trajectories)
 - b) 20 August 2017 (67 trajectories)
 - c) 21 August 2017 (69 trajectories)





- NCEP dataset was employed as the meteorological reanalysis input
- 144 hours backwards in time
- 3-hourly time-step.
- Subdivided into three classes according to their altitude:
 - lower troposphere: 250, 500, 750 m asl in red;
 - mid-troposphere: 1000, 2000, 3000 m a.s.l. in blue;
 - upper troposphere: 7000, 8000, 9000 m asl in green.





Radiative Transfer modelling

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MODTRAN objective

- Simulation of the SW irradiance components (upward and downward)
- Calculation the Aerosol Radiative Effect (ARE) and the Atmospheric Heating Rate (AHR) profile.

$$ARE = (SW \downarrow -SW \uparrow)_{aer} - (SW \downarrow -SW \uparrow)_{no_aer}$$

IN GENERAL

Radiative Effects represents the instantaneous radiative impact of atmospheric particles on Earth's energy balance Radiative Forcing is calculated as the change of Radiative Effects between two different periods (e.g., preindustrial and present-day) [or, in our case, with or without aerosols]

MODTRAN input I

- AOD values from AERONET Sunphotometer (340, 380, 440, 500, 675, 870, 1020, and 1640 nm, then fitted with 4th order polynomial to retrieve missing values in the SW interval 340-300 nm and 1640-3000 nm)
- The IWV was adjusted to the value measured by the HATPRO microwave radiometer.
- The total ozone content was set equal to the value measured by the Ozone Monitoring Instrument (OMI)
- Broadband surface albedo measured at THAAO
- The vertical aerosol extinction profile was derived from the CALIOP backscattering profile
- AOD value at 500 nm is 0.63
- The standard sub-Arctic summer atmosphere (McClatcheyet al., 1972) was chosen for the vertical profiles of meteorological and gas profiles (below 10 km the HATPRO temperature profile was used)
- The spectral aerosol absorption and scattering properties, i.e. single scattering albedo (SSA) and asymmetry factor (g), were derived from the literature after RT simulations in the aerosols-free case

MODTRAN input II

- Extinction: is the sum of scattering and absorption, so it represents total effect of medium on the radiation passing through it
- Fixed extinction to backscatter coefficient using a value compatible for the presence of dust and smoke particles
- The CALIPSO profile was truncated at 1 km to eliminate possible contamination of the signal due to surface reflection in the lowermost section of the atmosphere



MODTRAN settings

- Highest spectral resolution (0.1 cm⁻¹) in the 0.3-2.8µm interval
- The vertical resolution is 1 km up to 25 km, 5 km up to 60 km, and 10 km up to 100 km
- 78° SZA → the smallest angle with AOD measurements on 21 August 2017

MODTRAN processing

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343.000	1.4997984+#1	1.709326e+01	6.438247e+08	1.487353e+08	2.687637e+00	1.021495e+08	
304.000	1.731212e+01	1.968946e+#1	7.4003580+00	1.6345838+88	3.108358e+40	1.1777976+00	
345.000	2.666458e+#1	3.852658e+81	1.143822e+#1	2.5420536+08	4.841135e+80	1.8204494+00	
305.000	2.754423e+01	3.0545454+05	5.565834e+03	2.547107e+00	4.925832e+40	1.049101e+00	
307.000	3.892428e+#1	4.444759e+#1	1.667436e+83	3.652493e+00	7.100935e+00	2.653807e+08	
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318.000	1.362324e+#2	1,4381896-82	5.585825e+03	1.278358e+01	2.355464e+#1	8.888844e+00	
319,000	1.611656e+#2	1.681876e-82	6.587864e+81	1.512314e+01	2.776797e+#1	1.048354e+01	
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MODTRAN results: aerosols-free case

MODTRAN aerosols-free case was run to estimate:

- The best modelling parameters not available from measurements And then to:
- the Atmospheric Radiative Effect
- the Atmospheric Heating Rate profiles up to the top of the aerosol layer detected by CALIOP

$$ARE = (SW \downarrow -SW \uparrow)_{aer} - (SW \downarrow -SW \uparrow)_{no_aer}$$

MODTRAN results: the 21 August simulation

- The largest AHR values (+0.50 K/day) are found between 8 and 12 km
- The largest extinction in the CALIPSO profile is between 3 and 6 km.

This behaviour is due to the dependence of the ARE on the SZA. For very low Sun, scattering and absorption by aerosol are more effective at higher altitude.



MODTRAN results

- The AREE is ARE per unit of AOD at 500 nm
- For highly reflecting surfaces the AREE is very low and nearly constant
- The impact of absorbing BB aerosols, being locally produced or transported mainly in summer, when larger surfaces are free of snow, may be remarkable for the Arctic surface radiation budget.



h = elevation z = zenith angle, A = Az angle, measured measured from measured up from horizon vertical from N

 A = Azimuth angle, measured clockwise from North

19/04/21

Meysam Mahooti (2021). NREL's Solar Position Algorithm (SPA) MATLAB Central File Exchange. Retrieved March 18, 2021.





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Aerosol Radiative Effect



Tile 6

Zoom in



19/04/21

Summary & Conclusions

Radiation

- Chem of atm [ground]
- Chem of atm [sat]
- **Chem/Phys Modelling**

Rad modelling



- 1. Sources of wildfires have been investigated through air sampling and model back-trajectories
- 2. Radiative modelling of the atmosphere and of the event of August 2017 at Thule High Arctic Atmospheric Observatory has been performed and compared to previous findings in literature
- 3. Spatial extrapolation has been applied to assess the radiative effect over a wider area



Contacts

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> Megafires such as this one in Canada's Northwest Territories last year are transforming the boreal forest. PHOTO: KYLE THOMAS