SUPPLEMENTARY DATA

Tables

Stations	Latitude	Longitude	Altitude	Period
Arrival Heights	-77.80	166.67	184	1996-2015
Marambio	-64.24	-56.62	198	2011-2015
Neumayer	-70.65	-8.25	42	1993-2015
South Pole	-89.98	-24.80	2810	1975-2015
Syowa	-69.00	39.58	16	1997-2015

Table S1: Details of Antarctica based stations used in this study. Here latitudes and longitudes are in degrees; whereas altitudes are in meters from the mean sea level (msl).

Table S2: Tuning of Temporal Causal Discovery Framework (TCDF) hyperparameters. Here, we have shown the prediction performance in terms of mean absolute scaled error (MASE) at different train and test split fractions (0.5, 0.75 and 0.9). MASE values in bold show the best performance.

Hyperparameter	split: 0.5	split: 0.75	split: 0.9
Hidden layers: 1 Kernel Size: 2 dilation coefficients: 2	0.7313	0.7389	0.7393
Hidden layers: 1 Kernel Size: 3 dilation coefficients: 3	0.8979	0.9696	0.8674
Hidden layers: 1 Kernel Size: 4 dilation coefficients: 4	0.8381	0.8587	0.8230
Hidden layers: 2 Kernel Size: 2 dilation coefficients: 2	0.4540	0.4821	0.4521
Hidden layers: 2 Kernel Size: 3 dilation coefficients: 3	0.6736	0.6995	0.6981
Hidden layers: 2 Kernel Size: 4 dilation coefficients: 4	0.7930	0.7840	0.8722

Table S3: Regression coefficients (coefficient +/- standard error of coefficient) of the MLR fit for surface ozone concentration at different stations in Antarctica [Neumayer, Syowa, South Pole and Arrival Heights].

	Arrival Heights	Neumayer	South Pole	Syowa
SOLAR	-0.0403 +/- 0.0695	-0.1324 +/- 0.0626	-0.0663 +/- 0.0661	0.0880 +/- 0.0903
QBO ₃₀	-0.1057 +/- 0.1975	-0.1161 +/- 0.1778	-0.1908 +/- 0.1878	-0.0343 +/- 0.2566
QBO ₅₀	0.0385 +/- 0.2162	0.0459 +/- 0.1946	-0.0370 +/- 0.2057	-0.0579 +/- 0.2813
MEI	0.1345 +/- 0.0498	0.0964 +/- 0.0448	0.0750 +/- 0.0473	0.1827 +/- 0.0646
AAO	0.1628 +/- 0.0576	0.2099 +/- 0.0522	-0.0208 +/- 0.0545	0.1925 +/- 0.0755
HF	0.0127 +/- 0.0670	0.1295 +/- 0.0603	0.2574 +/- 0.0637	0.1120 +/- 0.0869
PV	1.0299 +/- 0.0468	0.7029 +/- 0.0348	0.8140 +/- 0.0426	1.0242 +/- 0.0499
AOD	-6.2747 +/- 0.6595	-6.7785 +/- 0.6040	-0.8649 +/- 0.6291	-8.2624 +/- 0.8574



Figure S1: Geographical locations of ground stations measuring surface ozone concentration considered in this study.



Figure S2: Schema of Temporal Causal Discovery Framework (TCDF).



Figure S3: Variation in the frequency of Ozone Enhancement Events (OEE). Left) Monthly climatology of number of OEEs. Right) Inter-annual variation in the occurrence of OEEs.



Figure S4: Time Series of the frequency of Ozone Enhancement Events (OEE).



Figure S5: Monthly climatology of Stratosphere-Troposphere Transport (STT).



Figure S6: Time series of the potential drivers of surface ozone variability at Neumayer station. Here NEUM is surface ozone at Neumayer station, AOD represents AOD at 550nm, PV is potential vorticity at 200 hPa, HF is heat flux at 200 hPa, AAO represents Antarctic oscillation, MEI is Multi-variate ENSO index, QBO represents Quasi-biennial oscillation and SOLAR represents solar flux.



Figure S7: Least absolute shrinkage and selection operator (LASSO) regression fit for the monthly time series of surface ozone concentration at Neumayer station. Here, the regularizer is represented with λ whereas the goodness of fit is estimated using the coefficient of determination (R^2).



Figure S8: Prediction of surface ozone at South Pole station for validation dataset using the temporal convolutional network (TCN) applied for causal discovery in TCDF. Surface ozone dataset was split into training and validation samples. The TCN was trained using optimised hyperparameters for 500 epochs with the training sample, which constitutes 75% of the surface ozone time series. Here, the goodness of fit is denoted by R^2 .



Figure S9: Causal graphs generated using PCMCI algorithm with the linear Partial Correlation (ParCorr) conditional independence test for three different significance threshold [0.1, 0.05, 0.01] at all 4 stations (Neumayer, Syowa, South Pole and Arrival Heights) considered in this study.



Figure S10: Causal graphs generated using PCMCIplus algorithm with the linear Partial Correlation (ParCorr) conditional independence test for three different significance threshold [0.1, 0.05, 0.01] at all 4 stations (Neumayer, Syowa, South Pole and Arrival Heights) considered in this study.



Figure S11: Causal graphs generated using PCMCIplus algorithm with the non-linear Gaussian process regressions and a distance correlation (GPDC) test for three different significance threshold [0.1, 0.05, 0.01] at all 4 stations (Neumayer, Syowa, South Pole and Arrival Heights) considered in this study.