AGU PUBLICATIONS

GeoHealth

Supporting information for

Current and future disease burden from ambient ozone exposure in India

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bar) and 2050 (2nd bar) exposed to population-weighted ambient surface O_3 concentrations above 50 ppb (WHO AQG, Indian NAAQS) in each scenario.

Supplementary Figure 6: Sensitivities of health impacts due to O_3 exposure in India to demography and baseline mortality rates. (a) Mortality rate per 100,000 population. (b) Total annual premature mortality. Impacts are estimated using either Jerrett et al., (2009) (red) and Turner et al., (2016) (purple) relative risks with LCC_{min}. For each panel, the control (CTL) scenario is compared against the NPS and CAS scenarios. For each panel, the five bars (left to right) show estimates for 2015 with 2015 population, age, and baseline mortality, 2050 with 2050 population, age, and baseline mortality, and 2050 with population from 2015 (POP2015), population age grouping from 2015 (AGE2015), and baseline mortality rates from 2015 (BM2015).

Additional Supporting Information (Files uploaded separately)

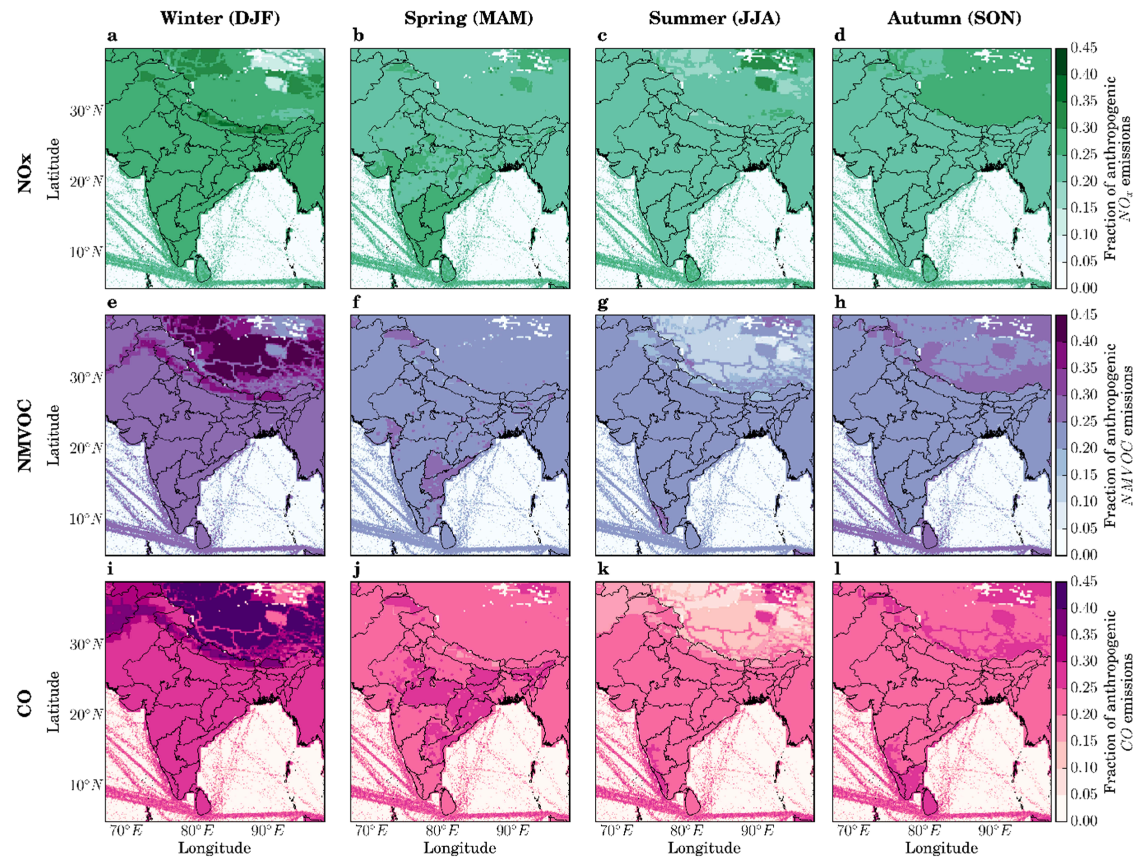
Supplementary data containing results per Indian state per scenario.

Supplementary Table 1: Model Setup and parameterisation used in the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) model.

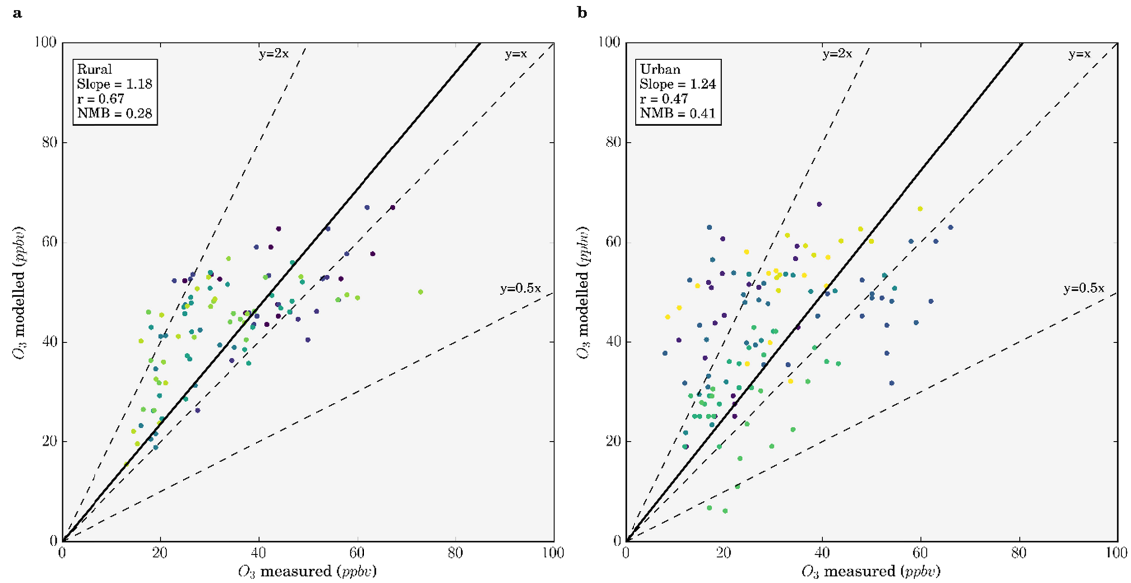
Model Setup and Parameterisation	
Process	**Method**
Domain	60° to 100° East, 0° to 40° North
Timestep	180 seconds, with Runge-Kutta 2^{nd} and 3^{rd} order time integration
Horizontal	Resolution of 30 km along a 140 × 140 grid, with Arakawa C-grid staggering and 2^{nd} to 6^{th} order advection schemes
Vertical	33 vertical levels (top at 10 hPa) with terrain-following hydrostatic pressure coordinates and 2^{nd} to 6^{th} order advection schemes
Precipitation microphysics	Thompson scheme (Thompson et al., 2008)
Longwave radiation	RRTM longwave (Mlawer et al., 1997), called every 30 mins
Shortwave radiation	RRTM shortwave (Pincus et al., 2003), called every 30 mins
Boundary layer physics	Mellor-Yamada Nakanishi and Niino 2.5 (Nakanishi et al., 2006), called every timestep
Land surface	Noah Land Surface Model (Ek et al., 2003)
Convective parameterisation	Grell 3-D ensemble (Grell et al., 2002), called every 60 seconds
Gas-phase chemistry scheme	MOZART-4 using KPP (Emmons et al., 2010), chem_opt=201 (Hodzic & Knote, 2014), called every 12 mins
Photolysis scheme	Madronich fTUV (Tie et al., 2003), called every 30 mins
Aerosol scheme	MOSAIC 4-bin (Zaveri et al., 2008), called every 12 mins
Dust	GOCART online with AFWA, dust_opt=3 (Chin et al., 2000, 2002)
Initial & boundary chemistry/aerosol	MOZART-4 / GEOS5 (NCAR, 2016)
Initial & boundary meteorology	NCEP GFS and NCEP FNL (NCEP et al., 2000, 2007)

Supplementary Table 2: Ambient surface O_3 observation site details.

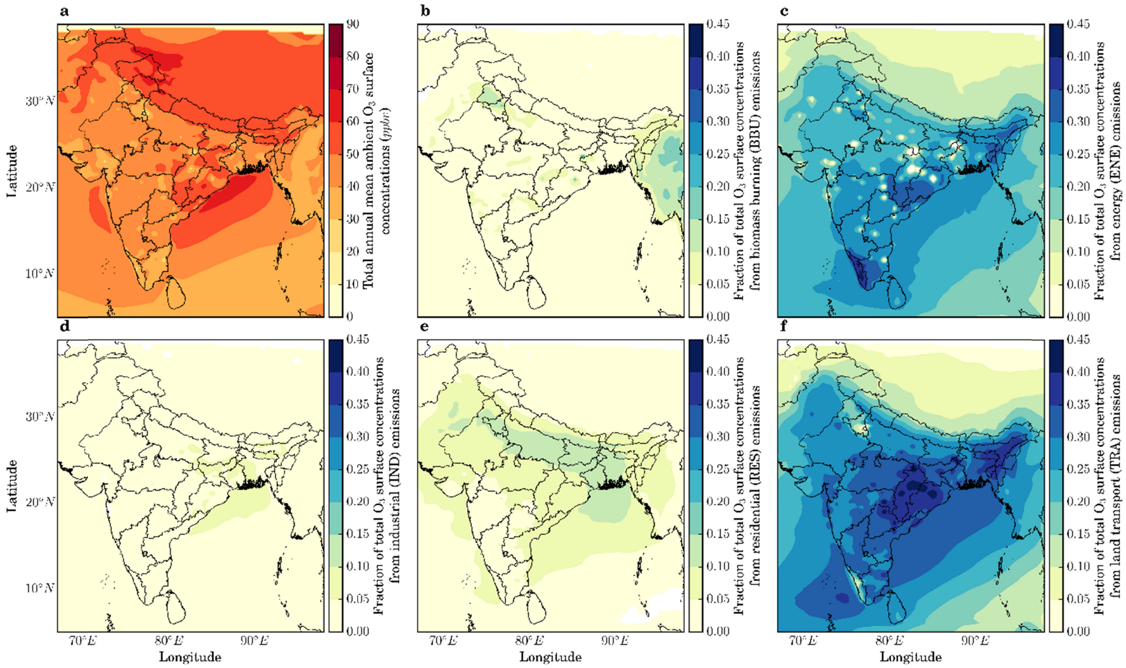
Site	Type	Latitude (°N)	Longitude (°E)	Altitude (m)	Data period	Reference
Ahmedabad (ABD)	Semi-arid, urban	23.00	72.60	49	1993 – 1996	(Lal et al., 2000)
					2002 – 2003	(Sahu & Lal, 2006)
		23.03	72.58	53	2011	(Mallik et al., 2015)
Anantapur (ANP)	Semi-arid, rural	14.62	77.65	331	2002 – 2003	(Reddy et al., 2008)
					2008 – 2009	(Reddy et al., 2010)
Bhubaneswar (BHB)	Coastal, rural	20.30	85.83	45	2010 – 2012	(Mahapatra et al., 2014)
Delhi (DEL)	Urban	28.65	77.27	220	1997 – 2004	(Jain et al., 2005)
Gadanki (GDK)	Rural	13.50	79.20	375	1993 – 1996	(Naja et al., 2002)
Jabalpur (JBL)	Semi-urban	23.17	79.92	411	2013 – 2014	(Sarkar et al., 2015)
Kannur (KNN)	Semi-rural	11.90	75.40	5	2009 – 2010	(Nishanth et al., 2012)
Kanpur (KNP)	Urban	26.46	80.33	125	2009 – 2013	(Gaur et al., 2014)
Kullu (KLU)	Semi-urban	31.90	77.12	1154	2010	(Sharma et al., 2013)
Mt. Abu (MAB)	High altitude, rural	24.60	72.70	1680	1993 – 2000	(Naja et al., 2003)
Nainital (NTL)	High altitude, rural	29.37	79.45	1958	2006 – 2008	(Kumar et al., 2010)
					2009 – 2011	(Sarangi et al., 2014)
Pune (PNE)	Semi-urban	18.54	73.81	600	2003 – 2004	(Beig et al., 2007)
Pantnagar (PNT)	Semi-urban	29.00	79.50	231	2009 – 2011	(Ojha et al., 2012)
Trivandrum (TRV)	Coastal, rural	8.55	77.00	5	2007 – 2009	(David et al., 2011)
Udaipur (UDP)	Urban	24.58	73.68	598	2010 – 2011	(Yadav et al., 2014)



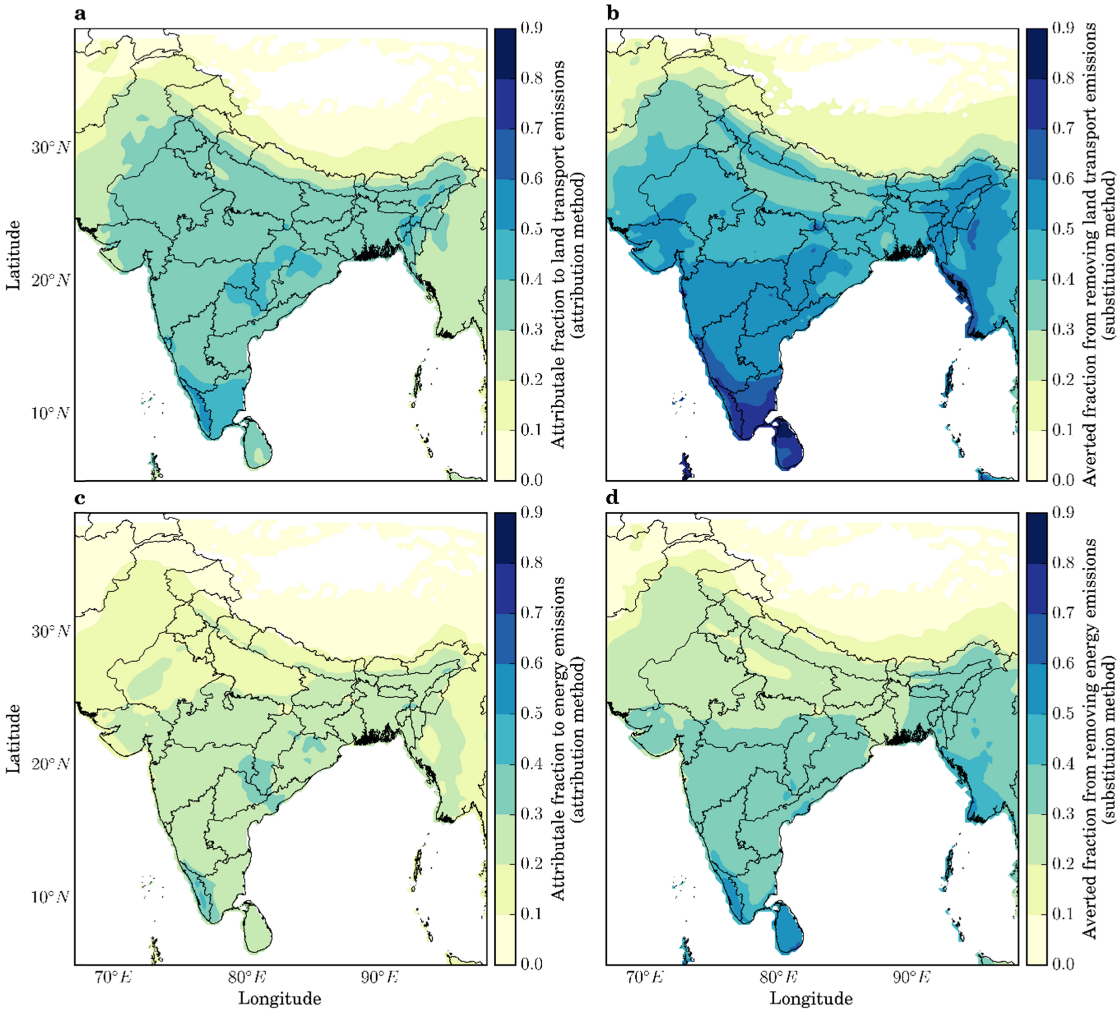
Supplementary Figure 1: Fractional contribution per season to total anthropogenic emissions. Fractional contribution to total anthropogenic emissions of NOx from winter (DJF), spring (MAM), summer (JJA), and autumn (SON) to anthropogenic emissions of (a – d) nitrogen oxides (NOx), (e – h) non-methane volatile organic compounds (NMVOC), and (i – l) carbon monoxide (CO).



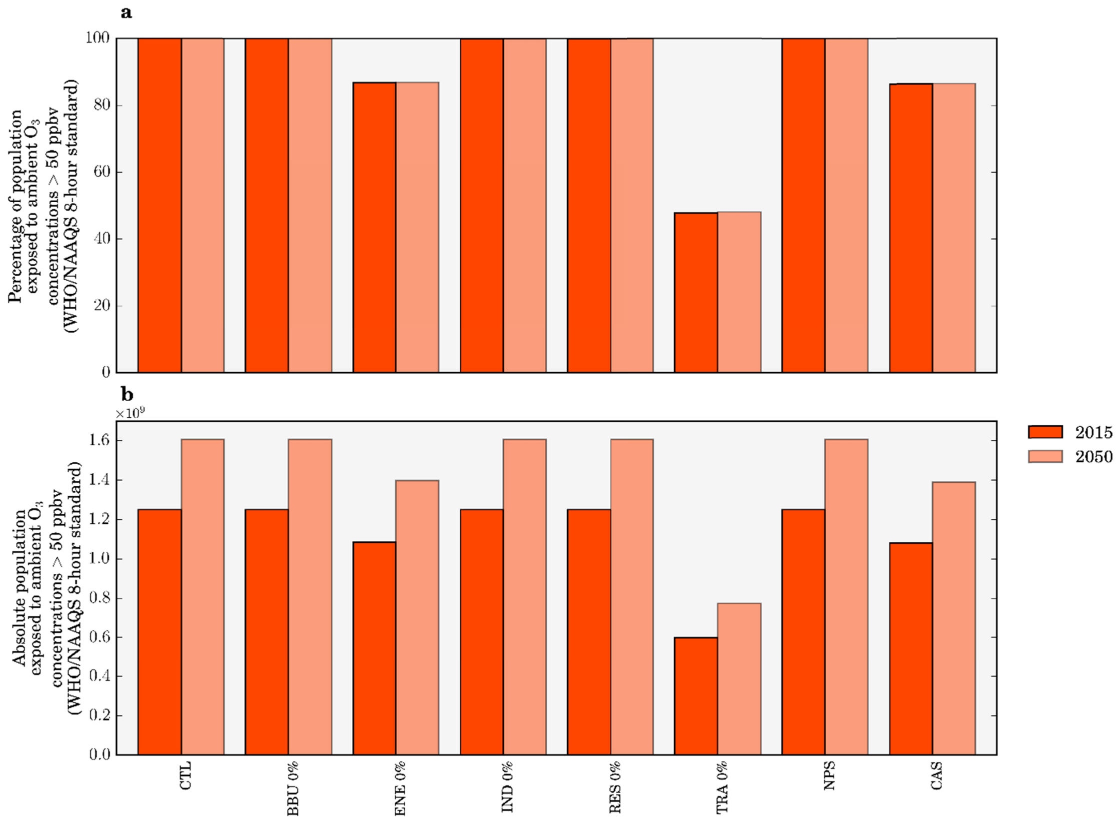
Supplementary Figure 2: Comparison of rural and urban observed and simulated O_3 concentrations. (a) Comparison of annual and monthly-mean ambient surface O_3 concentrations from rural observation sites. We show the rural site best fit line as solid, and the 1:1, 2:1, and 1:2 lines as dashed. Rural site normalised mean bias (NMB) = 0.28, the rural site best-fit line has slope = 1.18, and rural site Pearson's correlation coefficient (r) = 0.67. (b) Comparison of annual and monthly-mean ambient surface O_3 concentrations from urban observation sites. We show the urban site best fit line as solid, and the 1:1, 2:1, and 1:2 lines as dashed. Urban site NMB = 0.41; the urban site best-fit line has slope = 1.24, and urban site r = 0.47. Colours of filled circles grouped by site.



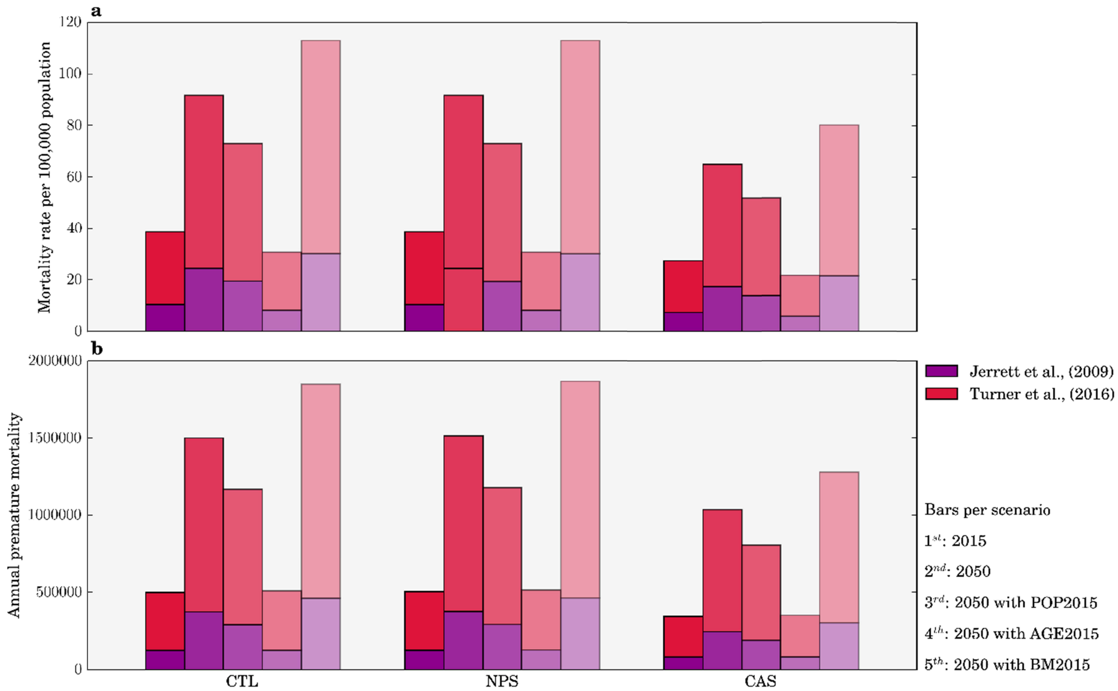
Supplementary Figure 3: Fractional contribution per source to total annual-mean ambient O_3 surface concentrations. (a) Total annual-mean ambient O_3 surface concentrations. (b – f) Fractional contribution from biomass burning (BBU), power generation (ENE), industrial non-power (IND), residential energy use (RES), and land transport (TRA).



Supplementary Figure 4: Dominant source contributions to premature mortality burden due to O_3 exposure across India in 2015. (a) Attributable fraction of premature mortalities from land transport emissions (attribution method). (b) Averted fraction of premature mortalities from removing land transport emissions (subtraction method). (c) Attributable fraction of premature mortalities from energy emissions (attribution method). (d) Averted fraction of premature mortalities from removing energy emissions (subtraction method). All health impacts are calculated using Turner et al., (2016) RR and LCC_{min}.



Supplementary Figure 5: The impact of scenarios on O_3 metrics. (a) Percentage of population in 2015 (1st bar) and 2050 (2nd bar) exposed to population-weighted ambient surface O_3 concentrations above 50 ppb (WHO AQG, Indian NAAQS) in each scenario. (b) Absolute population in 2015 (1st bar) and 2050 (2nd bar) exposed to population-weighted ambient surface O_3 concentrations above 50 ppb (WHO AQG, Indian NAAQS) in each scenario.



Supplementary Figure 6: Sensitivities of health impacts due to O_3 exposure in India to demography and baseline mortality rates. (a) Mortality rate per 100,000 population. (b) Total annual premature mortality. Impacts are estimated using either Jerrett et al., (2009) (red) and Turner et al., (2016) (purple) relative risks with LCC_{min}. For each panel, the control (CTL) scenario is compared against the NPS and CAS scenarios. For each panel, the five bars (left to right) show estimates for 2015 with 2015 population, age, and baseline mortality, 2050 with 2050 population, age, and baseline mortality, and 2050 with population from 2015 (POP2015), population age grouping from 2015 (AGE2015), and baseline mortality rates from 2015 (BM2015).

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