Reread the IPCC Report: Aerosols Droughts and ENSO Events

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1. Abstract

The Technical Summary of Working Group One in the IPCC Fourth Assessment Report states that:

- **"changes in aerosols may have affected precipitation and other aspects of the hydrologic cycle more strongly than other anthropogenic forcing agents"; and**
- **"Simulations also suggest that absorbing aerosols, particularly black carbon, can reduce the solar radiation reaching the surface and can warm the atmosphere at regional scales, affecting the vertical temperature profile and the large-scale atmospheric circulation".**

Taking these two statements at face value I first identify eight seasonal, anthropogenic, regional scale, aerosol plumes which now occur each year and then report the correlation of the aerosol optical depth (AOD) of some of these plumes with climate anomalies in the higher latitudes and with ENSO events.

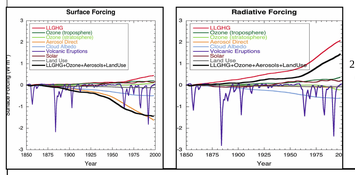
The eight identified aerosol plumes vary significantly in extent and AOD inter annually. They have also increased in geographic extent and AOD over recent decades as the population in the tropics, the origin of the majority of these plumes, has increased dramatically requiring increased levels of agriculture and commercial activity.

I show that: the AOD of the South East Asian Plume, occurring from late July to November, correlates with four characteristics of drought in south eastern Australia; the aerosol index of the Middle East Plume correlates negatively with rainfall in Darfur; and the volume of tephra ejected by volcanoes in south east Asia correlates: negatively with rainfall and water inflows into the Murray River in south eastern Australia; and positively with ENSO events over the period 1890/91 to 2006.

I conclude that aerosol plumes over south eastern Asia are the cause of drought in south eastern Australia and ENSO events and confirm the statements made in the IPCC Report with respect to these aerosol plumes. I propose a new component of surface aerosol radiative forcing, Regional Dimming, which interferes with the seasonal movement of the Inter Tropical Convergence Zone (ITCZ) and forces the regional Hadley Cells into anomalous seasonal positions producing blocking high pressure systems in the higher latitudes and causing climate change by altering the wind systems. The South East Asian Plume also creates ENSO events by altering or inhibiting the circulation of the Walker Cell which changes the MSL pressure relationship between Darwin and Tahiti creating Southern Oscillation Index (SOI) events and reducing the wind speed in the central Pacific Ocean causing an increase in the sea surface temperatures in the Nino 3.4 area.

Finally I suggest that further research on the effects of these eight regional scale aerosol plumes on the hydrologic cycle and large-scale atmospheric circulation using a global circulation model is crucial to the understanding and attribution of climate change and is urgently required.

2. The IPCC Report



Radiative Forcing at the Tropopause and Surface Forcing

IPCC AR4 Figure 2.23 Chapter 2 page 208

Globally and annually averaged temporal evolution of the instantaneous all-sky RF (R panel) and surface forcing (L panel) due to various agents, as simulated in the MIROC+SPRINTARS model (Nozawa et al., 2005; Takemura et al., 2005). This is an illustrative example of the forcings as implemented and computed in one of the climate models participating in the AR4. Note that there could be differences in the RFs among models. Most models simulate roughly similar evolution of the LLGHGs' RF

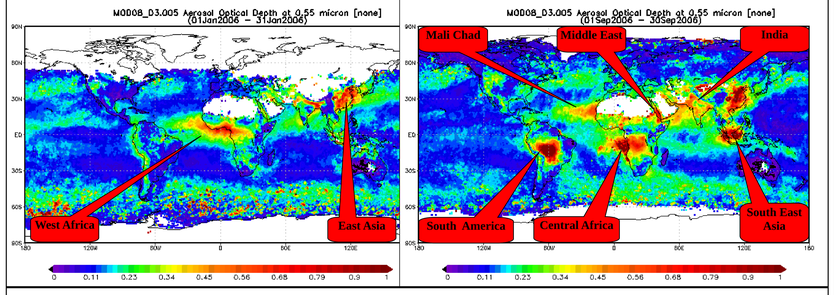
Note the evolution of the net effect for LLGHG + Ozone + Aerosol Direct + Land Use: Radiative Forcing at the tropopause follows the Long Lived Greenhouse Gases (LLGHG) Surface Forcing follows the Aerosol Direct effect very closely, is negative and now approximates the effects of the great volcanic eruptions of Krakatau and Pinatubo on a globally and annually averaged basis

3. U.S. Climate Change Science Program

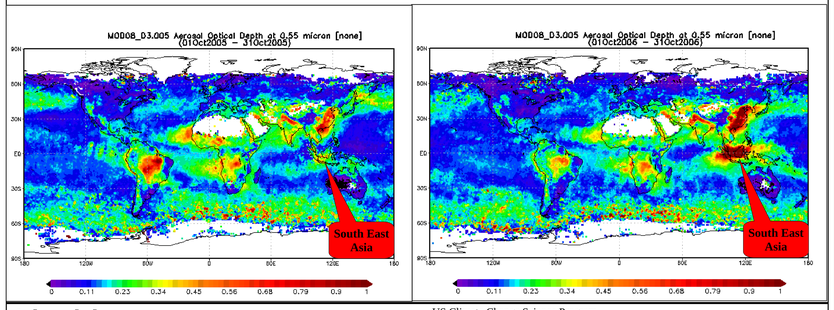
This program submitted a report in September 2008 entitled "Climate Projections Based on Emissions Scenarios for Long-Lived and Short-Lived Radiatively Active Gases and Aerosols" which states inter alia:

"…..projected changes in pollutant levels, primarily over Asia, may significantly increase surface temperature and reduce rainfall over the summertime continental United States throughout the second half of the twenty-first century"

4. The Eight Continental Scale Aerosol Plumes (2006 Data)



5. Inter-Annual Variation of Aerosol Plumes (Oct 2005 (L) and 2006 (R))



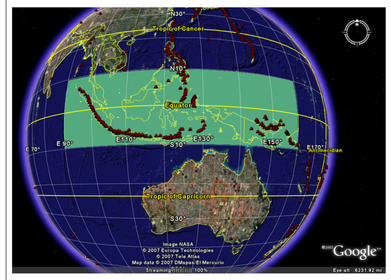
Acknowledgements

Data and information was sourced from:

- NASA: Analyses and visualizations used in this poster were produced with the Giovanni online data system, developed and maintained by the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC).
- NOAA
- NCEP / NCAR
- IPCC Fourth Assessment Report
- US Climate Change Science Program
- Google Earth
- Murray Darling Basin Commission
- Global Volcanism Program at the Smithsonian Institution
- Australian Bureau of Meteorology

I also thank: Dr O. Mayo and Mr R. Mayo for assistance with the statistics; and Professor S. Greenhalgh of the University of Adelaide, Dr W. Grace of the Grace Research Network in South Australia and Dr Leon Rotstayn of CSIRO, Aspendale, Victoria, Australia for discussion and comments.

6. Drought - South Eastern Australia - Recent

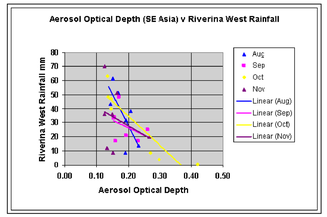


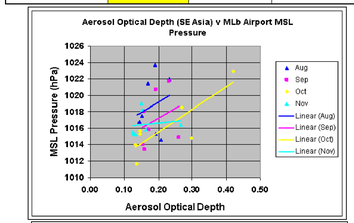
The AOD in the Green Area Lat 10S to 10N and Long 90E to 160E was correlated with:

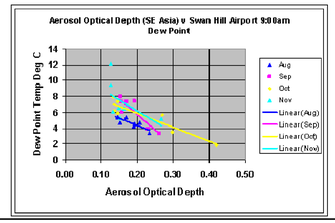
- Rainfall in Riverina West Rainfall District (RWRD) in south eastern Australia
- Dew point (as a humidity proxy) in Swan Hill on the south west boundary of the RWRD
- Mean Sea Level (MSL) Pressure in Melbourne in south eastern Australia
- Sea Surface Temperature (SST) in the Green Area

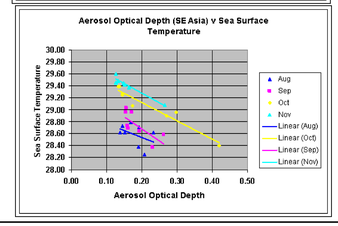
for the years 2000 to 2006 and the results are shown in the table below where the cell shade indicates significance (Yellow < 0.01 Green < 0.05). Note that the largest correlations appear in October when the anthropogenic South East Asian Plume reaches its greatest extent and AOD.

	SST in the Area	RWRD Rainfall	Swan Hill Dew Point	Melbourne Airport MSL Pressure
Aug	-0.44	-0.72	-0.82	0.21
Sep	-0.68	-0.39	-0.89	0.31
Oct	-0.89	-0.92	-0.92	0.84
Nov	-0.94	-0.30	-0.54	0.12

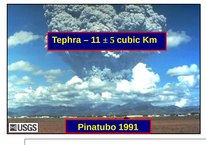




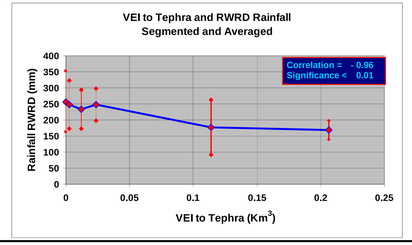


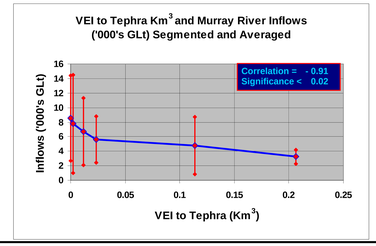


7. Drought - South Eastern Australia - Historic



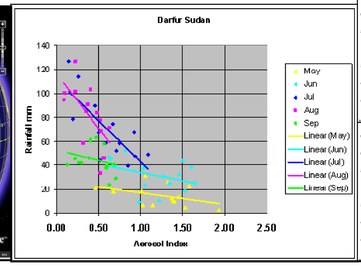
Accepting that the anthropogenic South East Asian Aerosol Plume in the green area has caused recent droughts in Australia from August to November the question of what caused historic droughts in Australia becomes what could have caused similar aerosol plumes? The answer is, of course, volcanoes. The Google Earth image shown above includes the volcano overlay from the Global Volcanism Program (GVP) at the Smithsonian Institution. Each red triangle is one or more volcanoes. The GVP provided a database of all volcanic eruptions since 1800 which demonstrates that the green area hosted 17% of all eruptions in 3% of the global surface. The database provides the Volcanic Explosivity Index (VEI) of the majority of eruptions and this VEI was converted to tephra volume using data from the GVP website. The VEI data is integer based and the VEI to Tephra data falls naturally into segments. As the VEI data are "estimates" the data is very noisy. To reduce the noise the segments were averaged for both VEI to Tephra and rainfall/river inflows for the months April to October, the southern wet season in Australia, and then plotted and correlated. The results are shown below with error bars ± 1 std deviation

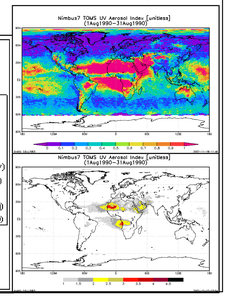




8. Drought - Darfur

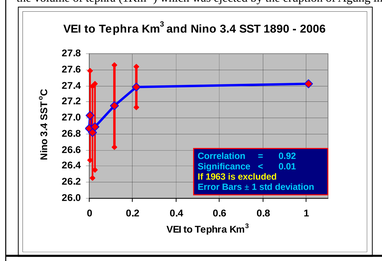
The majority of rainfall occurs in July and August in Darfur (pale brown area in the Google Earth image below) when the Inter Tropical Convergence Zone moves to the north of Darfur. Aerosol plumes over and to the south of Darfur prevent the ITCZ moving north and cause drought. The Aerosol Index (AI) of the area to the south of Darfur (light red) was correlated with rainfall in Darfur for the period 1979 to 1992 (Nimbus 7 data) and the results are shown below. The correlation coefficients are –0.76 July and –0.64 August with significance < 0.01 and 0.05 respectively. The two AI images for August 1990 show the extent of the Middle East Plume and its origins. (Note the origins of the Mali Chad Plume can also be seen in the lower image)

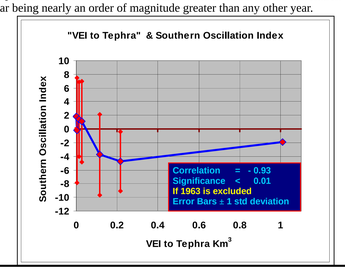




9. El Niño / ENSO Events

It is well known that drought in Australia correlates with El Niño / ENSO events and having established that drought in Australia is caused by anthropogenic and natural aerosol plumes in the green area shown in the centre panel it is no surprise to find that the VEI to Tephra data correlates with the Sea Surface Temperature (SST) in the Nino 3.4 area and with the Southern Oscillation Index (SOI). The annually averaged VEI to Tephra data was segmented and averaged and correlated with the annual average SST in the Nino 3.4 area and the annual average SOI for the period 1890 / 91 to 2006. 1963 data was excluded from the correlation due to the volume of tephra ($1Km^3$) which was ejected by the eruption of Agung in that year being nearly an order of magnitude greater than any other year.





10. Regional Dimming Model

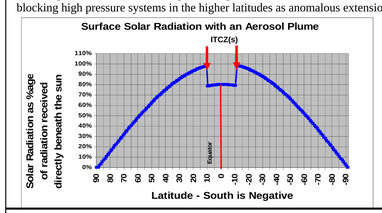
Continental scale, optically dense aerosol plumes in the tropics interfere with the seasonal movement of the ITCZ. Depending on their optical depth, size, season and location such plumes may either split the ITCZ into northern and southern components separated by many degrees of latitude or stop the seasonal movement of the ITCZ. These effects move the southern and northern Hadley Cells and consequently the entire atmospheric circulation system in the region of the aerosol plume into abnormal seasonal positions. This causes significant climate change near the longitudes of the plume in the tropics, by modifying the local wind systems. In the higher latitude regions remote from the aerosol plume the plumes create persistent, blocking, high pressure systems as abnormal extensions of the Hadley Cells and can also, in some regions, such as Australia, reduce the amount of water vapour in the atmosphere in the higher latitudes by cooling the sea surface in the tropics. If the aerosol plume extends beyond the tropics, one component of the ITCZ may even be forced outside the tropics resulting in extremely anomalous conditions in the higher latitudes. The South East Asian Plume, by interfering with the movement of the ITCZ and Hadley Cells, also affects the circulation of the Walker Cell and causes El Niño/SOI or ENSO events.

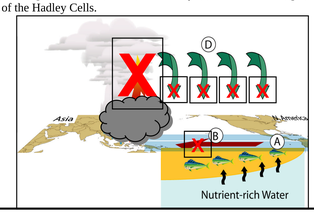
It should be noted here that aerosol plumes have an immediate effect on the atmospheric circulation system. When the plume appears the surface immediately cools and the rising air, which drives the Walker and Hadley Cells, fails in the area of the plume resulting in a split ITCZ, Hadley Cells in anomalous seasonal positions creating blocking high pressure systems in the higher latitude, and suppressed Walker Cell circulation… And all in a few, very few, days.

11. Walker and Hadley Circulation

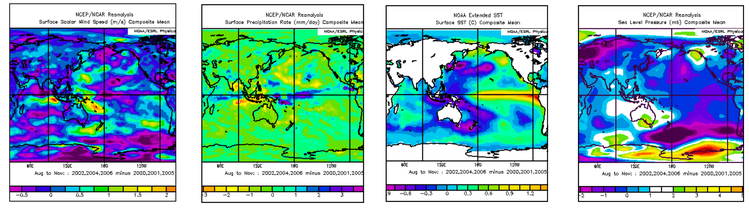
The Walker Cell rotates over the Pacific Ocean driven by the surface heat from solar radiation over the western Pacific Ocean/South East Asia which warms the air causing it to rise. The right image below shows a NOAA diagram modified with an aerosol plume over south east Asia. The plume stabilises the atmosphere in the region with the top of the plume being warmer than the lower atmosphere thus preventing the air from rising over south eastern Asia and switching off the Walker Cell.

The effect on the Hadley Cell is shown in the left diagram below which shows the surface heat as a percentage of the heat received at the equator plotted against latitude assuming the sun is over the equator with an aerosol plume which has a surface forcing effect of –20% extending from 10N to 10S latitude. This plume results in the highest solar surface heating occurring at the northern and southern edges of the plume and this forces the Hadley Cells to anomalous positions and creates blocking high pressure systems in the higher latitudes as anomalous extensions of the Hadley Cells.





12. NCEP / NCAR Climate Reanalysis Showing El Niño / ENSO



The four panels above show the anomalies caused by the anthropogenic South East Asian Plume averaged over Aug to Nov in 2002, 2004 and 2006 :

- Scalar Wind Speed (Left) - Reduced wind speed (central Pacific & south eastern Australia) and increased wind speed south of Tasmania and over New Zealand
- Rainfall (Centre Left) - Reduced rainfall over most of Australia and increased rainfall over Central America
- SST (Centre Right) - Classic El Niño SST warm tongue over the central and eastern Pacific Ocean
- MSL pressure (Right) - Higher over Australia and lower over the eastern Pacific giving a negative Southern Oscillation Index

The panels were constructed by summing the months of August to November in three years of highest AOD (2002, 2004 and 2006) of the anthropogenic South East Asian Plume using the "Green Area" in October and subtracting the three years of lowest AOD in October (2000, 2001 and 2005) to show the anomalies caused by the high AOD of the South East Asian Plume. Data was sourced from the NCEP/NCAR climate reanalysis at www.cdc.noaa.gov/cgi-bin/Composites/printpage.pl

13. Conclusions

1. **Aerosol plumes, as suggested by the IPCC Fourth Assessment report and the U.S. Climate Change Science Program, do have a significant effect on the atmospheric circulation, hydrologic cycle and global climate.**
2. **Droughts in south eastern Australia are caused by anthropogenic and natural aerosol plumes which form the South East Asian Plume in the green area above.**
3. **El Niño / ENSO events are caused by the South East Asian Plume which has both anthropogenic and natural origins.**
4. **Due to the correlation of El Niño /ENSO events with VEI to Tephra from volcanic eruptions, the five possible causal relationships of two correlated events A and B which are : (1) A causes B; (2) B causes A; (3) C, another event, causes A and B simultaneously; (4) It's a coincidence; and (5) the relationship is complex including feedback; are reduced to (1) and (4) as deep earth processes cause volcanic eruptions and (2), (3) and (5) are clearly logically impossible. Then with correlation magnitudes over 0.9 effectively eliminating the possibility of coincidence, the only logical conclusion which can be made is that volcanic tephra causes El Niño / ENSO events.**
5. **Droughts in Darfur are caused by the Middle East Plume.**