Geob 402
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Assignment 2 – Hysplit modelling

The Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT) model is a system for computing simple air parcel trajectories, as well as complex transport, dispersion, chemical transformation, and deposition simulations (Stein et al. 2015). The model is a hybrid between the Lagrangian approach, which relies on a moving frame of reference for the advection and diffusion calculations as the trajectories or air parcels move from their initial location, and the Eulerian methodology, which uses a fixed three-dimensional grid as a frame of reference to compute pollutant air concentrations (Stein et al. 2015). The model relies on archives or forecast of meteorological data to calculate the potential trajectories of pollutants based on different atmospheric conditions. The dispersion of the pollutant is modelled based on a three dimensional particle distribution, which incorporates the advection of the particles in the model domain based on a wind and turbulent component (Stein et al. 2015).

The effects of forest fire and atmospheric haze has been a major issue in the Southeast Asia region. It is important to understand the influence of synoptic conditions on the trajectories of the haze pollutants, which include particulate matter (PM 2.5 and 10), other gases like Carbon dioxide (CO_2), oxides of Nitrogen (NO_x), and other hydrocarbons (Heil et al. 2007, Heil & Goldammer, 2001). Forest fires are very common in this region due to natural (e.g. droughts) causes, but also the anthropogenic effects of land clearing by slash and burn methods during the dry southern monsoon season from June to October (Heil & Goldammer, 2001, Mahmud, 2009). Atmospheric haze associated with a large-scale fire can spread across Southeast Asia to as far as southern Thailand, Vietnam, and even the Philippines. This often results in above-normal concentrations of PM values in populated city areas, which is detrimental to the public health. Therefore, I decide to model the potential dispersion and concentration of smoke haze from a theoretical episode of forest fire in the south eastern Sumatra forest of Indonesia, and the western Kalimantan forest of Borneo. I will model the 120 hours (5 days) trajectory and concentration of the pollutants from the sources, and compare it to corresponding synoptic maps and satellite imagery.

One of the worst period of forest fires was during the El Nino event of 1997 to 1998, and there have been many studies conducted regarding this incident (e.g. Heil & Goldammer, 2001, Koe et al. 2001, Heil et al. 2007). These events have led to one of the worst cases of air pollution in the region, and is a major problem for the big cities in the region such as Singapore, Kuala Lumpur, etc. (Koe et al. 2001). For the comparison of how synoptic conditions might affect the trajectory of pollutants, I have chosen two distinctive dates which are quite different in terms of their atmospheric conditions and synoptic weather patterns. The first would be 18 September 1997, as the September/October period is often considered to be the peak of the forest fire episodes (Heil & Goldammer, 2001). The period from June to October coincides with the dry southern monsoon and the intentional clearing of vegetation to prevent the spread of forest fires, which often leads to elevated atmospheric haze in the region (Heil & Goldammer, 2001). The second date is 25 February 1998, which is presumably under the influence of the northeast monsoon rather than the southwest monsoon.

Therefore, the two different dates and synoptic conditions should produce very different dispersion patterns of pollutants from the sources.

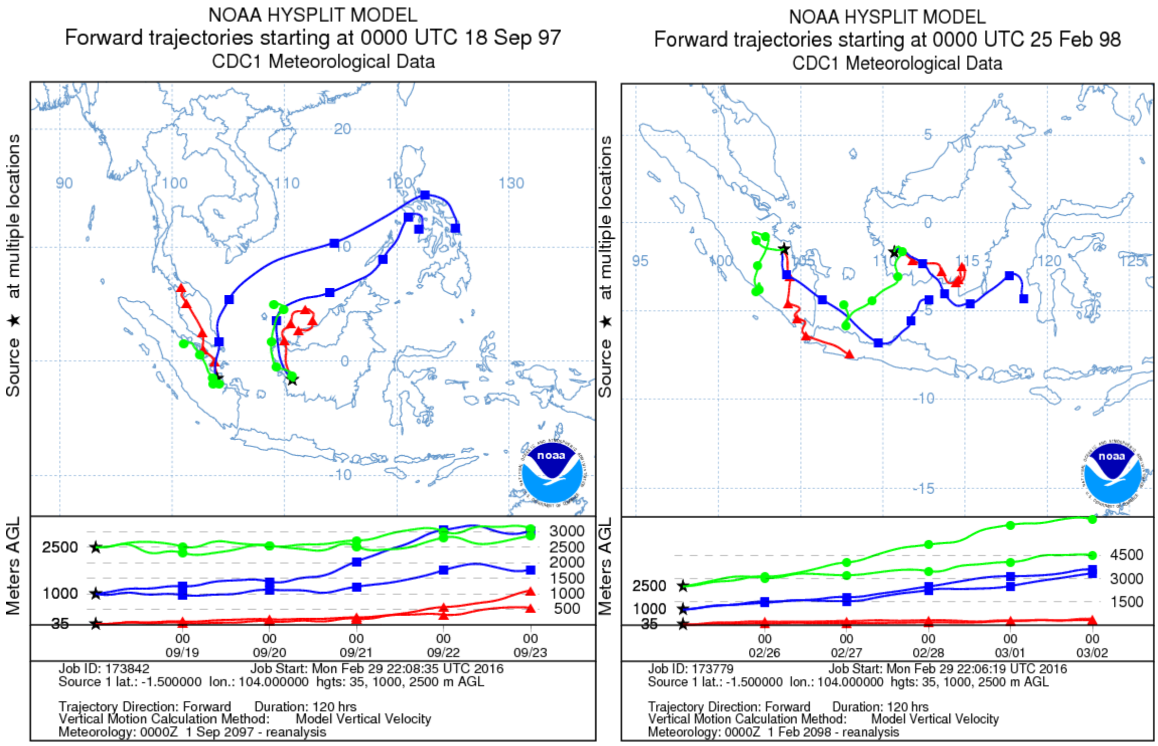


Fig.1. Hysplit model forward trajectory for two separate events of forest fires in 18 September 1997, and 25 February 1998 respectively.

Synoptic influence on the trajectories of pollutants

Looking at the two separate events for 18 September 1997 and 25 February 1998, we can identify the different patterns in trajectory of pollutants from the sources. Fig.1. shows the projected 120 hours (5 days) forward trajectory of the pollutants for the two separate dates. In the case of September, it is clear the trajectory has a northward direction, traveling up till as far as the coast of Vietnam and Philippines. This will have major implications to air quality in the major cities and countries such as Singapore, Malaysia, Brunei, etc. The northward direction of the trajectories is driven by the locations of low and high pressure system over the region. There is a distinct low pressure system forming over the South China Sea, and relatively higher pressures south of Indonesia (fig. 2 & fig. 3). Because there is no influence of Coriolis force in the tropics, so wind don't usually flow parallel to the isobars. Therefore, this resulted in the northwards trajectory of the pollutants. Looking at fig. 4, we can see the wind direction at both sea level (1000mb) and the mid troposphere (500mb), both of which supports the results of the HYSPLIT model. These wind patterns are characteristics of a southern monsoon wind circulation during the main burning season, which led to the cross-equatorial transport of haze (Heil & Goldammer, 2001, Koe et al. 2001).

The effect of the fire haze is often confined in the lower troposphere, due to strong subsidence and atmospheric stability (Heil & Goldammer, 2001, Koe et al. 2001). These processes are amplified especially during the ENSO abnormally period. Looking at fig. 1, we can see that the HYSPLIT trajectory for September does appear to be confined somewhere at 3000m above ground level, whereas in February the trajectories went above 4500m. This evidence supports the idea of strong subsidence and confinement of pollutants in the lower troposphere during the September period of 1997. This might have also resulted in the high concentrations of pollutants in Singapore and Malaysia, which extends to the southern coast of Vietnam (fig. 5). The difference in release height also results in quite different trajectories. For example, looking at fig. 1, pollutants at 1000m travels much further than those released at 2500m and 35m. Therefore, it is important to consider the average height that pollutants are introduced to the atmosphere. There is more uplifting during the February event, as we can see from the height of the trajectories in fig. 1.

On the other hand, 25 February produced very different dispersion patterns than September, and they are dispersed in a southward direction. The pollutants also did not travel as far, mostly within the region of Indonesia and Borneo. In contrast to the September scenario, there is now a distinct low pressure system forming over the northern Australia, with significantly higher pressures in the north of Indonesia and Brunei. This resulted in a southward flow of the pollutants due to winds traveling form the higher to lower pressure region. The southward flow of pollutants suggest that there will less impact on the areas north of the sources. The isobars for February shown in fig. 2 and fig. 3 are much widely spaced than those in September, suggesting slower wind speeds which may restrict the transport of pollutants. The dispersion of pollutants extend to only Java and southern Kalimantan, and result in a smaller affected area. This scenario might be more beneficial to Singapore and Malaysia, since the pollutants are not transported toward the North.

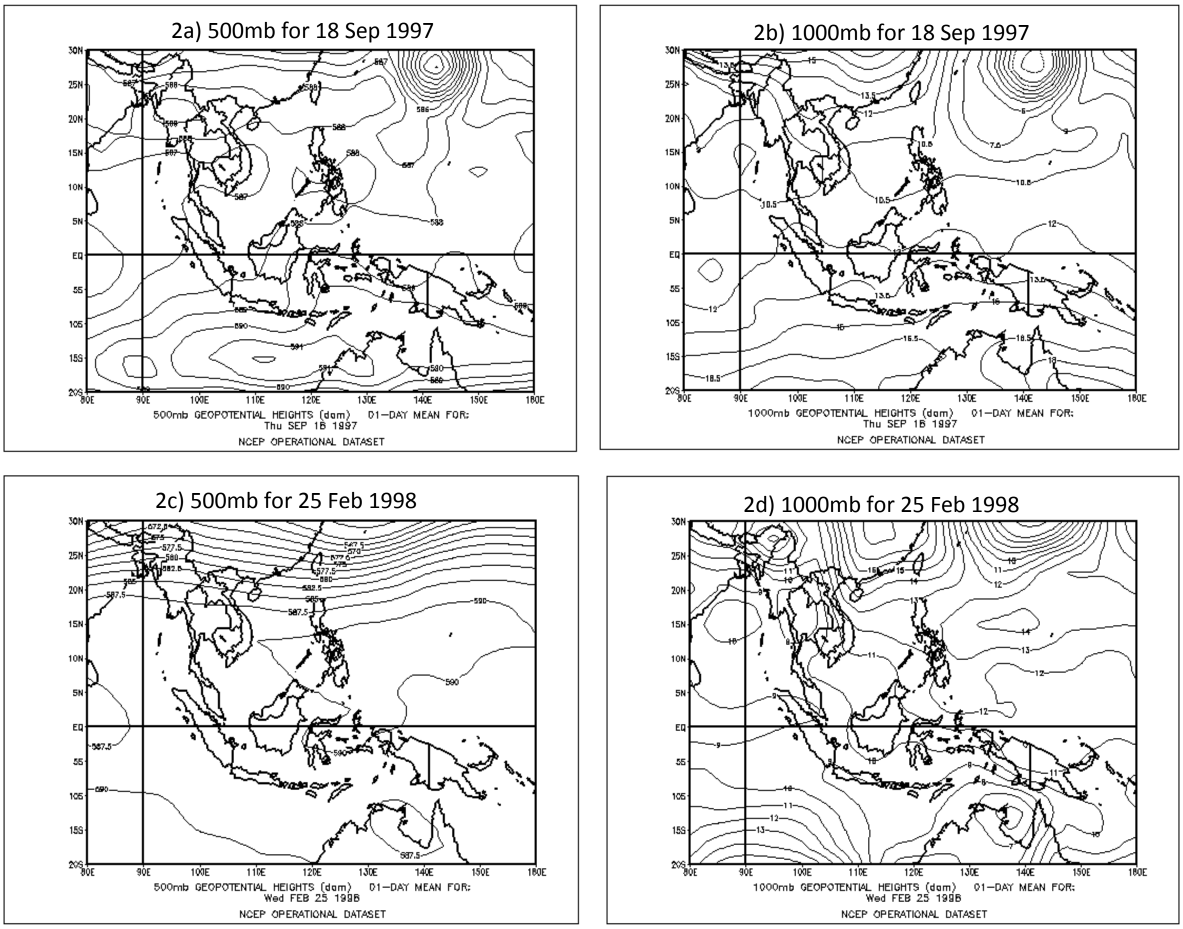
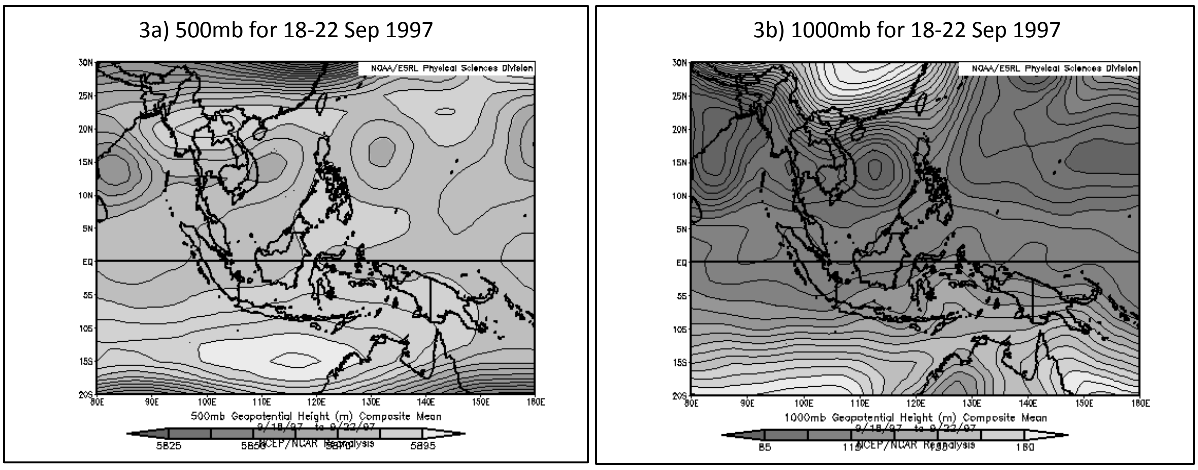


Fig. 2. Synoptic atmospheric pressure maps for 18 Sep 1997 and 25 Feb 1998 at 1000mb (sea level), and 500mb (Mid-troposphere)



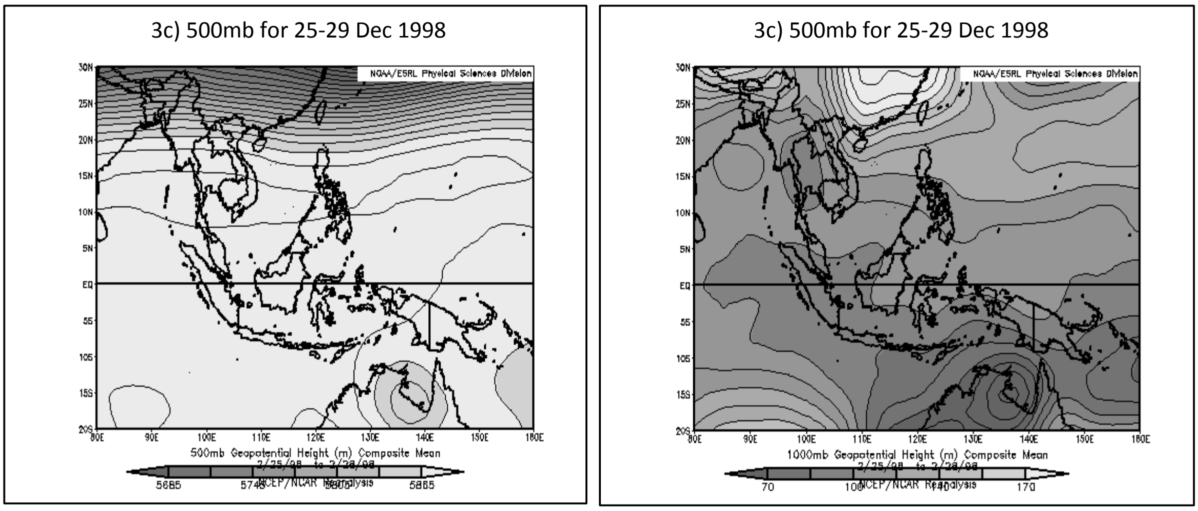


Fig. 3. Composite synoptic atmospheric pressure maps for 18–22 Sep 1997 and 25-29 Feb 1998, at 500mb and 1000mb.

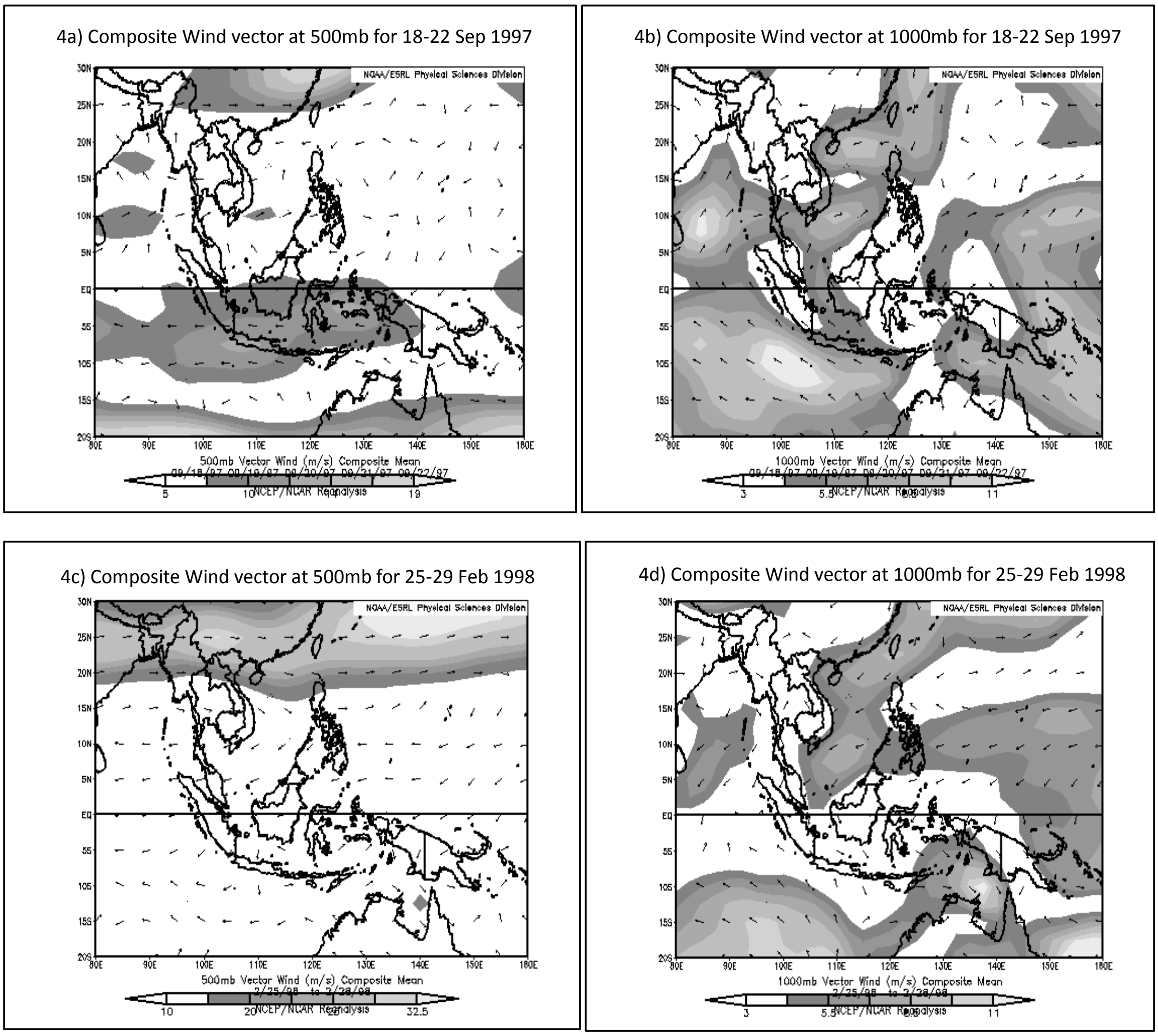


Fig.4. Composite wind vector maps for 25-29 February 1998 and 18-22 September 1997, at 500mb and 1000mb.

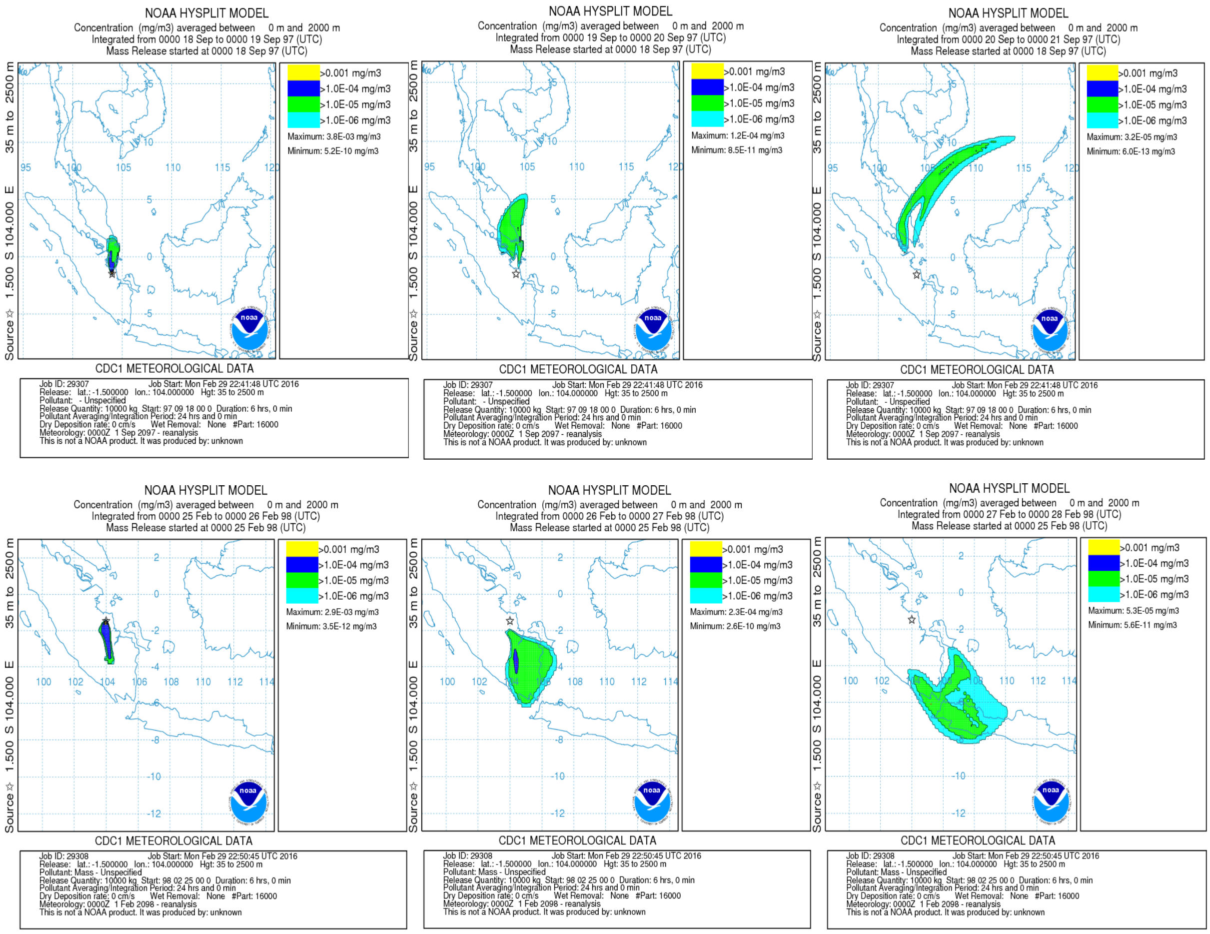


Fig. 5. Concentration of pollutants after 6 hours of release; for 18 September 1997 and 25 February 1998.

Limitations of the model

This model does not account for more local and regional scale process such as the effects of land and sea breezes, which may change the trajectory of the pollutants. This might result in diurnal variations of trajectories and concentrations, based on the offshore and inland winds throughout the day. The study from Mahmud (2009) highlights how the presence of strong low level southwesterlies over the straits of Malacca can result in daytime sea breezes, derived from The Air Pollution Model (TAPM) which accounts for these smaller scale processes. This suggest the weakness in using the HYSPLIT model analysis, since it only accounts for the synoptic conditions. We have to also consider processes and factors such as turbulence, and even the depth of the mixing level, which all affects how air parcels and particles move through the domain. The model is also limited by complex terrains, and the effects of any topographic constrains such as mountain barriers, etc. Furthermore, the dispersion model also assumes that the release rate is constant throughout the release period, which may not reflect the actual event of a forest fire in real life scenarios.

It is also important to consider the effects of rainfall and clouds, and how it might contribute to the removal of particles from the atmosphere. Looking at fig. 6, it is obvious that the amount of precipitable water and cloud cover in the atmosphere is significantly different for the two events. Particle can be removed from the atmosphere by gravitational settling, precipitation, and cloud scavenging (Heil & Goldammer, 2001). Looking at the visible and water vapour satellite image for 18 Sep (fig. 6.), there are some cloud cover east of the smoke plume, which may be due to more Cloud Condensation Nuclei (CCN) in the atmosphere. This might lower concentrations of pollutants due to the wet removal of particles from the atmosphere by precipitation. In the September image, we can clearly see the effects of the haze in the Southeast Asia region, and the distinct dry southern monsoon region mentioned by the various studies (Heil & Goldammer, 2001, Koe et al. 2001, Heil et al. 2007).

Visible | Water Vapour

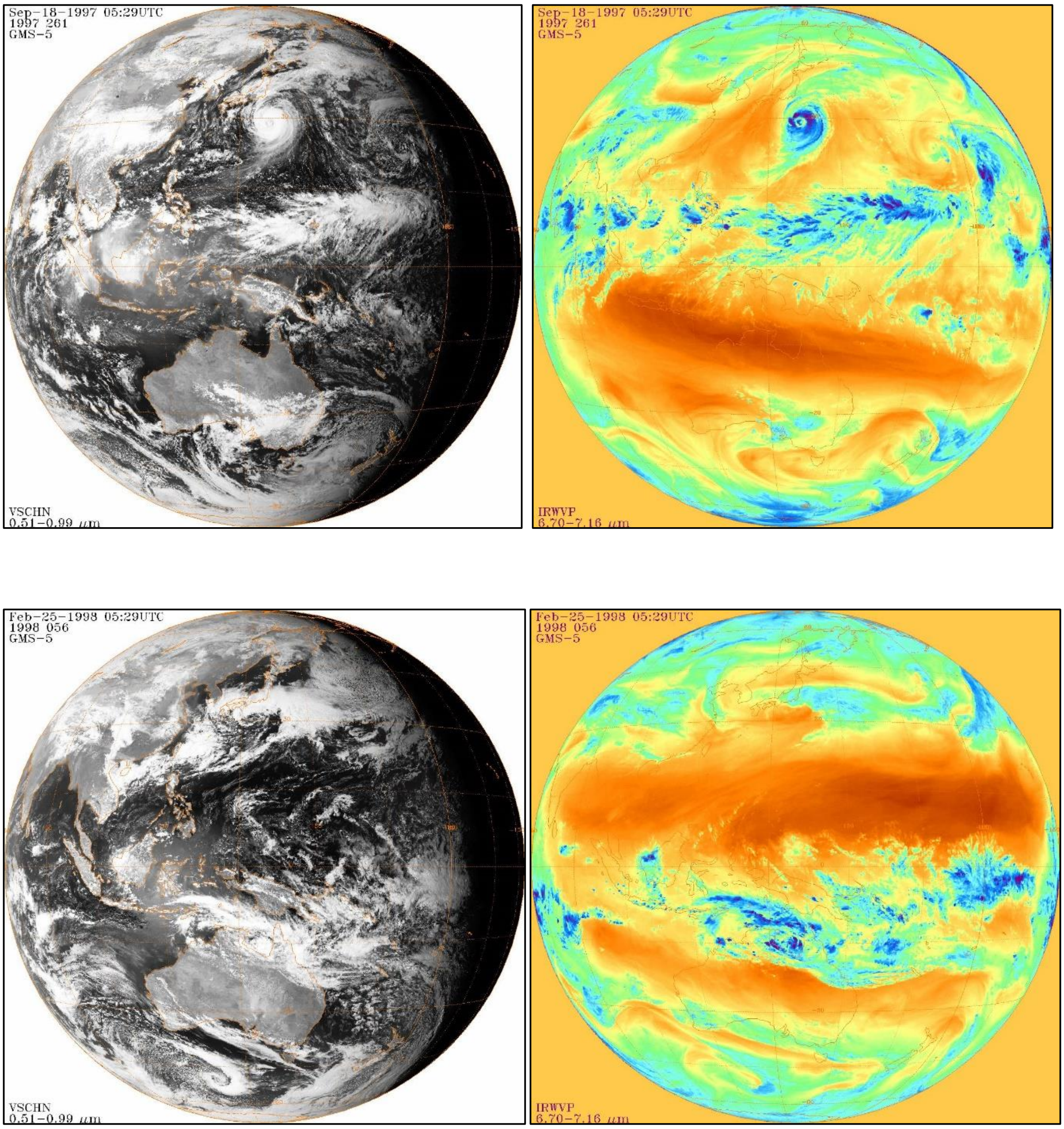


Fig. 6. Satellite image from NOAA GMS-5 Satellite showing in the Visible and Water vapour channel, for 18 Sep 1997 and 25 Feb 1998. (http://www.ncdc.noaa.gov/gibbs)

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NOAA Satellite and Information Service. National Environmental Satellite, Data, and Information service (NESDIS). Downloaded on Sat Mar 5 2016, from http://www.ncdc.noaa.gov/gibbs

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