Modelling the self-lifting of smoke layers caused by forest and bush fires using Large Eddy Simulations

Student M. Sc. project at Geosciences and Remote Sensing, TU Delft in collaboration with KNMI researchers

In the attached folder a number of hypotheses are put forward to explain why the smoke of fires such as shown in this pictures can sometimes be found in the stratosphere [16 km or higher]. One hypothesis from KNMI researchers J. de Laat and R. Boers suggests that the absorption of sun light can heat the layers up so much that they can rise by their own self-created buoyancy, the so-called self-lifting mechanism. In this project we seek to model the self-lifting mechanism using a high resolution model of the atmospheric turbulent structure. This model, called Dutch Atmospheric Large Eddy Simulation model [DALES] is capable to resolve the structure of a smoke plume at a spatial resolution of 100 m or less. When this smoke layer is embedded into an elevated atmospheric layer we ask the questions:

1) What happens if sun light is absorbed by the smoke-filled atmospheric layer?
2) How much is this layer heated up?
3) What is the temporal evolution of the smoke layer?
4) Does it self-destruct by turbulent motions caused by the heating?
5) Or does it lift to high altitudes?

Along the way we will vary the optical properties of the smoke, the smoke density and the initial structure of the smoke layer in order to find if the intrinsic properties of the smoke layer have a deciding influence on its fate.

Of course, in the end we hope to find an answer to the ’ burning ’ question whether we can believe that the self-lifting could be responsible for the occurrence of smoke layers at altitudes of up to 16 km.

Project duration: The scope of the project will be dependent on the whether it will be a (shorter) batchelor or a (more extended) masters project

Student must be interested in running numerical models and have an interest in the physics of the interaction of sun, smoke and steaming hot atmospheres. See: http://www.youtube.com/watch?v=1pktXJArQpo

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How come we find smoke from bush or forest fires at an altitude of 16 km in the atmosphere?

This satellite picture show the smoke development caused by large bush fires in the summer of 2010. These fires originated in the region south and east of Moscow. The satellite is positioned at an altitude of 700 km and this pictures spans a region of 700 square kilometers. Hundreds of such pictures have been taken in the last ten years and our knowledge of smoke and dispersion of pollutants has greatly increased. It appears that on some occasions the smoke resides at extremely high altitudes in the atmosphere [up to 16 km]. Several hypotheses have been developed to explain these high smoke plumes.

One plausible hypothesis is that large weather systems transport these smoke plumes to the high regions of the troposphere [7—10 km], but this does not explain why smoke particles can be found at altitudes where there is no weather, namely the region above 12 km, the so-called stratosphere.

About 10 years ago, another hypothesis was developed: the heat of the fire would be so intense that large cumulus clouds would develop, the pyrocumulus cloud [see top left of the picture]. These pyrocumuls clouds would pump large amounts of smoke into the stratosphere in a manner resembling a mini eruption of a volcano. However, we find that such mini vulcanoes only rarely occur. Also, there are often many fire sources [see lower left] where no clouds occur at all. Therefore, an another explanation must be found if such fires are capable of transporting the smoke to higher altitudes.

A new hypothesis developed at KNMI presumes that smoke and soot particles absorb sunlight and are able to transfer this radiation to the ambient air which heats up and creates lift. In the region left we see a couple of large fire sources with so much smoke development that the earth beneath the smoke cannot be seen by the satellite detectors. This means that there must be a large amount of smoke in the atmosphere. And this one of the two most important prerequisites necessary for this hypothesis to work: There must be sufficient smoke particles in the air so that the air can heat up appreciably.

The other rerequisite, just as important, is that there is sufficient sun light. At night, or under the shield of a large cloud deck, the smoke layer cannot heat up to create enough lift.

Calculations have shown that thick smoke layers such as visible at the left can lift 2-4km per day, the so-called self-lifting mechanism. And this is sufficient to deposit the smoke into the stratosphere in 4 days.

1) Boers, R., J. de Laat, D. C. Stein Zweers, and R. J. Dirksen (2010), Lifting potential of solar-heated aerosol layers, Geophys. Res. Lett., 37, L24802, doi:10.1029/2010GL045171. email: reinout.boers@knmi.nl
2) J. de Laat, D.C.Stein Zweers, O. Tuinder (2011), A solar escalator: evidence of self lifting of smoke by absorption of solar Radiation in February 2009 Black Saturday plume. Submitted to JGR. Email: jos.de.laat@knmi.nl

Source: MODIS, NASA Earthobservatory