How IMO effectively tripled ship-borne CO_2 emissions in 13 years

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Sometimes we forget what we are trying to do. What's the real goal in reducing CO2 emissions? The answer is reducing or halting global warming. Reducing CO2 is only a means to that end.

The Second IMO GHG Study (GHG2) has a very important but little noticed chapter entitled Climate Impact.[1] It's really the only place in this seminal study which talks about the real goal. The chapter points out that as of 2007, ***ship emissions were cooling the planet.*** This conclusion was the result of the negative radiative forcing of the aerosols in ship emissions — mainly SO2 which oxidizes to the aerosol, sulfate (SO4) — dominating the positive radiative forcing of the CO2 in ship emissions. Radiative forcing (RF) is an attempt to quantify the impact of a particular pollutant on the earth's heat balance by estimating its equivalent in additional energy per second hitting the earth's atmosphere. The units are watts per meter squared. It's not easy to do, but Chapter 8 makes a pretty good attempt, based on what we knew in 2009.

GHG2 finds that as of 2007, the net effect of ship-borne emissions was equivalent to a -0.072 W/m2. This perhaps surprising result is generated mainly by the strong cooling effect of SO2. Ships emit only about 2% as much SO2 as CO2, yet the cumulative emissions of SO2 have a current RF of -0.097 W/m2 while those of CO2 have a current RF of +0.049 W/m2.[2] Up to now, a ton of SO2 is very roughly a 100 times more effective cooling agent than a ton of C02 is a heating agent.

As GHG2 points out, we need to add all sorts of caveats to this finding:

1. The RF numbers are subject to large errors and uncertainties, especially the indirect (cloud) effect of aerosols such as SO4.
2. The residence times in the atmosphere of aerosols is enormously different than that of CO2. For example, sulphates have a half-life in the atmosphere of about 10 days, while CO2 has a half-life measured in centuries. GHG2 points out that, if we stopped producing anything from ships today, the effect of the aerosols we've already put into the atmosphere would die out much sooner than the CO2, and the net RF from this past pollution would turn positive around 2050. To put it another way, if we did nothing about any of S, CO2 or NOx, the long term build up of CO2 will eventually dominate and the net RF will turn positive in 350 years.[3] ***The fact that shipping emissions are currently cooling on net is not an excuse for doing nothing about CO2.***
3. The difference in residence times also creates spatial differences in the net RF. CO2 lasts so long it can be regarded as being pretty evenly spread all over the globe. Aerosols are concentrated in the region where they are produced which in the case of shipping is focused in the mid to low northern latitudes. GHG2 estimates that as a result the net effect from shipping is a positive RF at the poles, which turns negative at about +/-60 degrees and has a minimum of an impressive -0.23 W/m2 at about 28N.

Despite all the caveats, we can be quite confident that in 2007, ship emissions were on net a cooling factor for the planet. Very recently, James Hansen has argued compellingly that the indirect (cloud) effect is at the upper end of the numbers used by GHG3 or higher.[4] Furthermore, point (2) can be turned around to say, if we reduce SO2 and NOx emissions, we will see the heating impact much sooner than the cooling effect if we were to reduce CO2. Finally, point (3) can be read to mean that shipping is heating up the Arctic and Antarctic slightly but strongly cooling the northern hemisphere hurricane belt.

So what have we done?

1. Imposed strict restrictions on NOx. As of 2011, for all sizable engines NOx emissions had to be reduced by about 20% which forces about a 2% increase in CO2 and prevents further improvements in CO2

[1] Marintek et al, Second IMO GHG Study, 2009-04-09, MEPC 59/24/Add.1, Annex 14, Chapter 8.

[2] The other major ship-borne pollutant NOx also has a net negative RF. Ships put out about 0.5% as much NOx as CO2, but that relatively small amount of material both creates ozone with a positive RF of +0.026 W/m2 and reduces the powerful greenhouse gas methane with a negative RF of -0.033 W/m2. The net effect of -0.007 W/m2 is an order of magnitude smaller than SO2 and CO2 but not negligible. Up to now, a ton of NOx is about a 28 times more effective cooling agent than a ton of CO2 is a heating agent.

[3] Fuglestvedt et al, Shipping Emissions from Cooling to Warming of Climate, Environmental Science and Technology, Vol43, No 24, 2009.

[4] Hansen, J, et al, Earth's Energy Imbalance and Implications. Hansen of course is the man who called the world's attention to global warming.

efficiency when better materials allow higher peak temperatures. In 2016, NOx is supposed to be reduced by a factor of 5 in the Emissions Control Areas which include pretty much all the heavily traveled coastlines in the northern hemisphere out to about 200 miles. In reducing NOx we have both reduced cooling and increased heating.

2. Virtually banned SO2 emissions. Under present IMO regulations, the max allowable sulfur in BFO will go from 4.5% in 2007 (really no limit) to 0.5% in 2020. We will lose essentially all the -0.1 W/m2 from sulfur. ***In the near term, this is roughly equivalent to tripling ship-borne CO2 emissions in little more than a decade.*** Thanks to the thermal inertia of the planet, it will take a while for this loss to show up in global temperatures. But if we go out 50 years, this loss of cooling will result in about a 0.05C increase in global mean temperature.[5] A twentieth of a degree might not seem like a lot, but Hansen et al argue that it will result in a 1 meter rise in sea level.[6]
3. And we generated a substantial increase in refinery CO2 emissions. For a medium quality crude such as Urals, Stockle and Knight estimate going from 4.5%S to a mix of 3.5% and 1.5%S fuel oil, will increase CO2 emissions for a 200,000 BPD refinery from about 4000 tpd to about 5000 tpd, or from about 0.8 tons CO2/per ton of BFO to about 1.0.[7] Since combustion of a ton of fuel generates about 3.1 tons of CO2, a 0.2 ton per ton increase at the refinery is equivalent to about a 7% increase overall. 0.5%S will be much tougher. In fact, it is not at all clear we can feasibly convert all resid to low sulfur fuel.

Meanwhile we have done nothing about CO2, except propose an unsafe, absurdly inefficient, and nearly totally ineffective index called EEDI.[8] The problem is that it is relatively easy to reduce SO2, and easier to reduce NOx than CO2. So that's what we do.

There are good reasons to be concerned about NOx and SO2 other than global warming. NOx is the key factor in smog and smog is not good for human health, certainly not in concentrated form. SO2 produces acidification of forests can change the biological make-up of fresh water lakes, and has its own health effects. CTX is not saying we should forget about these impacts. They must be considered, but also we must consider and think rationally about the cooling benefits of these emissions.

Ships have an interesting and nearly unique property when they are regarded as aerosol injectors: they can inject their aerosols a long way from population centers. NOx for example has a half-life in the atmosphere of about a day. If a ship is more than a couple of days upwind of a population center, the smog cost of the pollution is near zero; but we still get the full cooling benefit. Sulfur's a little tougher but still there are large areas of the ocean where SO2 emissions will have little societal impact in terms of acidification, etc, but we still get the full cooling benefit, that is, 100 to possibly 160 tons worth of CO2 for every ton of SO2.

In the past, we have legislated each form of pollution separately. A rational approach would consider them together, and synchronize the reductions. If we monitored stack gas emissions, as suggested in Direct Taxation of Stack CO2 Emissions, we could develop ship location dependent regulation which takes into account the relationship between the pollutants.

What we are doing now is just about the worst possible approach to global warming.

[5] Fuglestvedt et al, Shipping Emissions from Cooling to Warming of Climate, Environmental Science and Technology, Vol43, No 24, 2009., Figure 2.

[6] Hansen, ibid, p 14.

[7] Stockle and Knight, Impact of low-sulphur bunkers on refineries, PTQ Catalysis, 2009, p 27-31. IPIECA came up with similar figures for additional refinery CO2, plus a 38 billion dollar additional capital cost for EU refineries alone. See Global environmental impact and marine fuel supply impact of proposed options to revise Marpol Annex VI, BLG 11/5/14, 2007-02-09. These dollars represent real resources and of course more emissions in the manufacturing and construction process.

[8] Devanney, J, EEDI Absurdities Center for Tankship Excellence, 2011. Devanney, J, EEDI Won't Work Center for Tankship Excellence, 2010.