Last modified 66 minutes ago

Results from sedimentation tests

Background

The UKCA aerosol sedimentation code is implemented in flux form, which limits the fall speed to 0.5 dz/dt. There is evidence that this is having a detrimental impact on dust simulation, and would be expected to affect all aerosol components in the coarse mode. There are a couple of options for increasing the fall speed, the simplest of which is to sub-step the sedimentation only.

I have obtained some timestep diagnostics of Courant number, e.g.:

```
COUR(:) = VGRAV_AV_0(:) * DTC / DZ(:)
```

As it stands the code limits `VGRAV_AV_0` and `VGRAV_AV_3` such that the Courant number < 0.5:

```
VGRAV_LIM(:)=0.5*DZ(:)/DTC
```

With a 1-hour timestep (as used for UKCA in the standard N96 GA4/GA6 configuration), there are Courant numbers up to ~60, indicating the need for a much shorter timestep (30 seconds using the current limit). By the end of a 30-day run, Courant numbers have grown to ~350, which suggests that sedimentation is not reducing particle diameter as it should, allowing other processes to grow it unchecked.

Tests sub-stepping sedimentation

I have performed some tests sub-stepping the sedimentation to get around the CFL limitation on the current implementation. These tests loop over the whole of the routine `ukca_ddepaer_incl_sedi`, as it is not trivial to sub-step the sedimentation without the deposition (the latter makes use of the level 1 sedimentation velocity so something like a mean velocity would need to be saved during the sedimentation sub-steps).

1-month tests with 4 different timesteps

Tests performed:

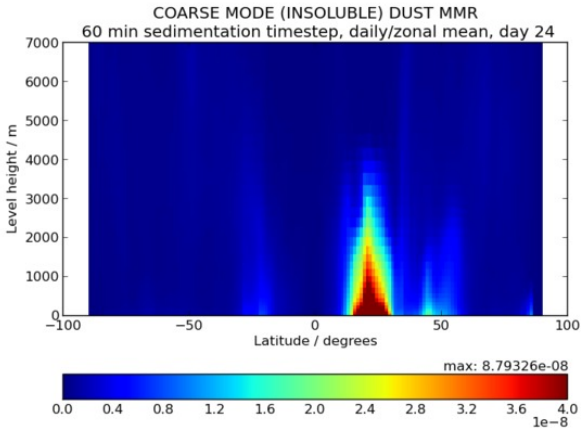
- antrb: 60 minute sedimentation timestep (i.e. no sub-stepping: control run) Identical to antba.
- antrd: 20 minute sedimentation timestep (matches UM timestep but not the same as doing the sedimentation every UM timestep as the phasing between emission/advection and sedimentation is different)
- antrg: 5 minute sedimentation timestep
- antrc: 30 second sedimentation timestep

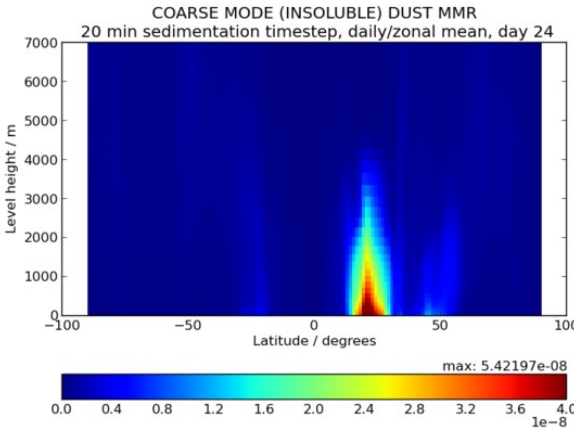
In summary, based on 1-month runs, the largest differences are between the 60-minute and 20-minute timesteps. There are few differences between the 5-minute and 30-second runs, suggesting that 5 minutes is sufficient for a short-term solution. The additional cost of the 5-minute sub-stepping is minimal, while the 30-second sub-step adds 10-20%.

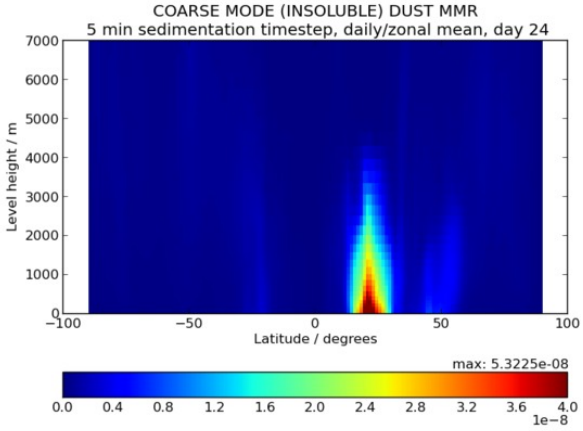
The next step is to perform a 1-year run with the 5-minute sub-stepping so that the overall impact on the aerosol simulation can be assessed. If this is successful, the longer-term plan is to look at semi-lagrangian advection to remove the need for sub-stepping.

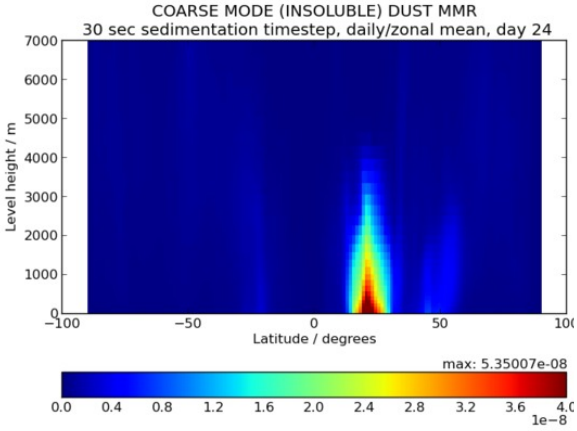
Plots of daily fields from a 30-day run: (click on plots for larger version)

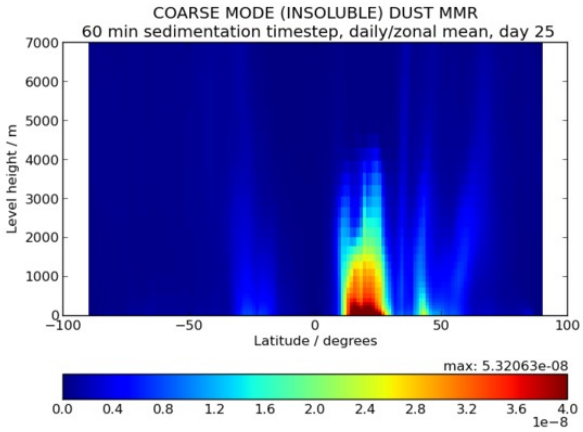
- Plots of coarse dust show that the shorter timestep runs have reduced loads, particularly after large emission events. The following plots show a large dust event in the Sahara on day 24 of the run (24th September), with much of the dust remaining airborne in the original run while most of the dust settles out by the next day in the sub-stepped runs.

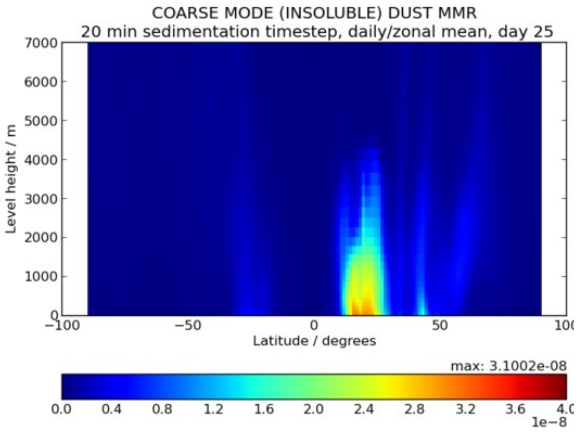

COARSE MODE (INSOLUBLE) DUST MMR
60 min sedimentation timestep, daily/zonal mean, day 24
Level height / m
Latitude / degrees
max: 8.79326e-08
1e−8

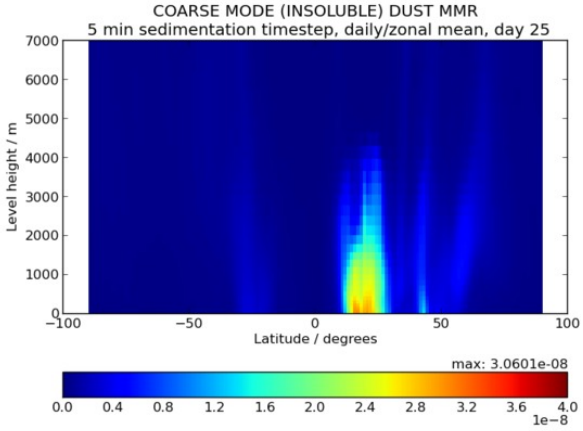

COARSE MODE (INSOLUBLE) DUST MMR
20 min sedimentation timestep, daily/zonal mean, day 24
Level height / m
Latitude / degrees
max: 5.42197e-08
1e−8

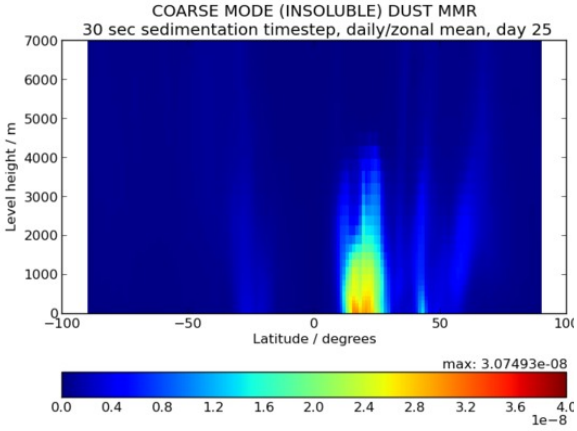

COARSE MODE (INSOLUBLE) DUST MMR
5 min sedimentation timestep, daily/zonal mean, day 24
Level height / m
Latitude / degrees
max: 5.3225e-08
1e−8

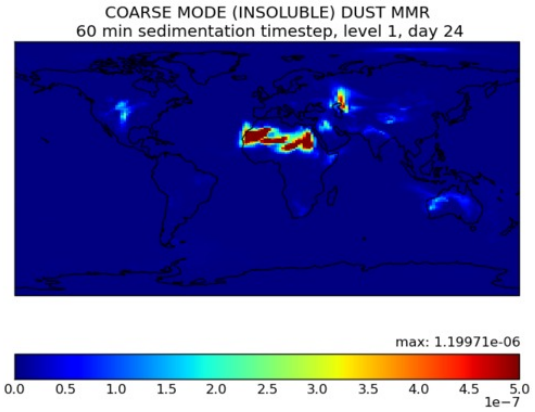

COARSE MODE (INSOLUBLE) DUST MMR
30 sec sedimentation timestep, daily/zonal mean, day 24
Level height / m
Latitude / degrees
max: 5.35007e-08
1e−8

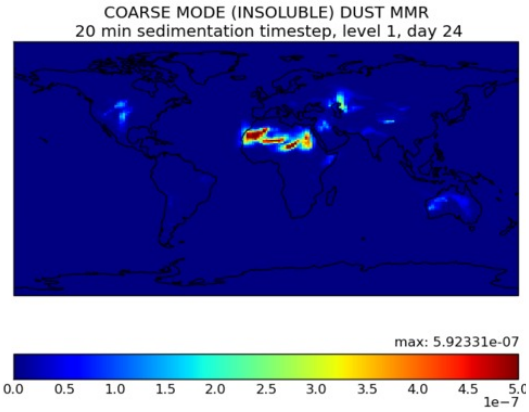

COARSE MODE (INSOLUBLE) DUST MMR
60 min sedimentation timestep, daily/zonal mean, day 25
Level height / m
Latitude / degrees
max: 5.32063e-08
1e−8

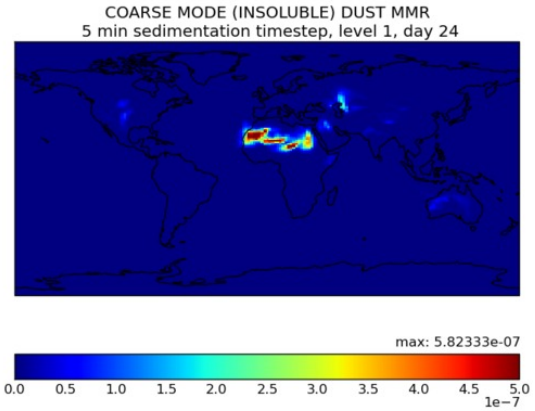

COARSE MODE (INSOLUBLE) DUST MMR
20 min sedimentation timestep, daily/zonal mean, day 25
Level height / m
Latitude / degrees
max: 3.1002e-08
1e−8

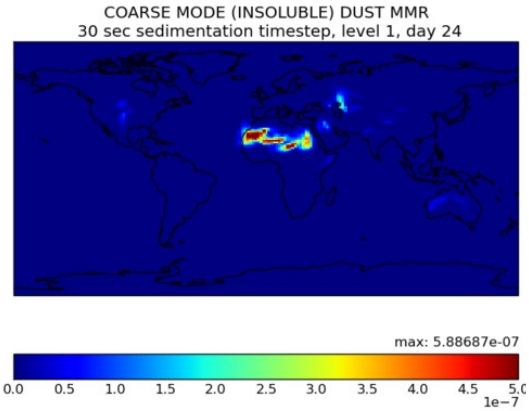

COARSE MODE (INSOLUBLE) DUST MMR
5 min sedimentation timestep, daily/zonal mean, day 25
Level height / m
Latitude / degrees
max: 3.0601e-08
1e−8

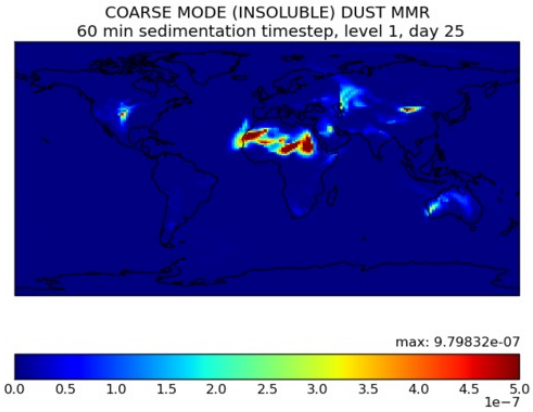

COARSE MODE (INSOLUBLE) DUST MMR
30 sec sedimentation timestep, daily/zonal mean, day 25
Level height / m
Latitude / degrees
max: 3.07493e-08
1e−8

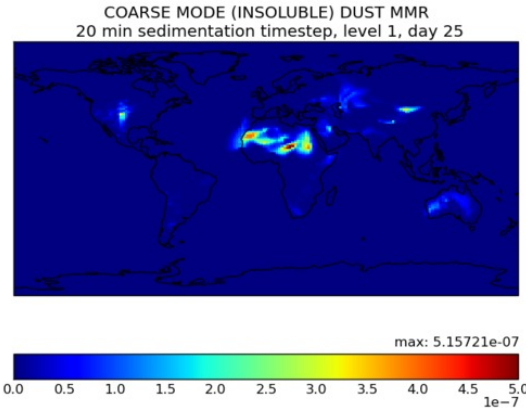

COARSE MODE (INSOLUBLE) DUST MMR
60 min sedimentation timestep, level 1, day 24
max: 1.19971e-06
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
1e−7

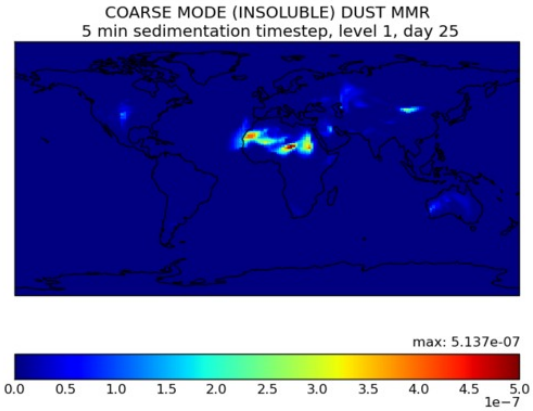

COARSE MODE (INSOLUBLE) DUST MMR
20 min sedimentation timestep, level 1, day 24
max: 5.92331e-07
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
1e−7

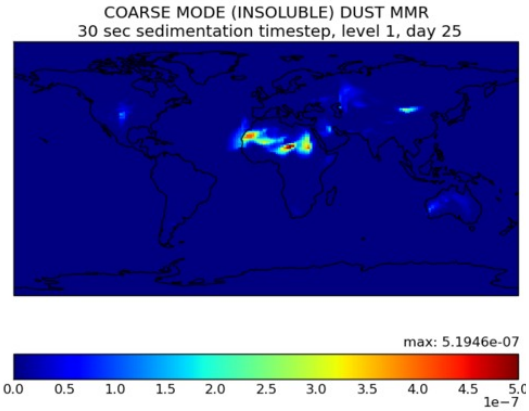

COARSE MODE (INSOLUBLE) DUST MMR
5 min sedimentation timestep, level 1, day 24
max: 5.82333e-07
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
1e−7


COARSE MODE (INSOLUBLE) DUST MMR
30 sec sedimentation timestep, level 1, day 24
max: 5.88687e-07
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
1e−7

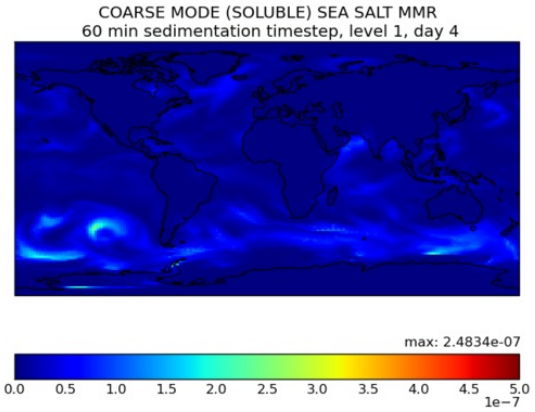


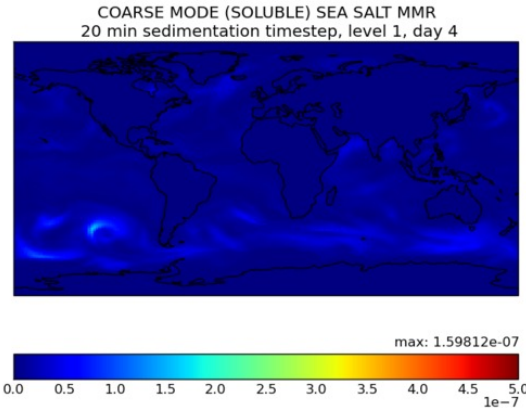


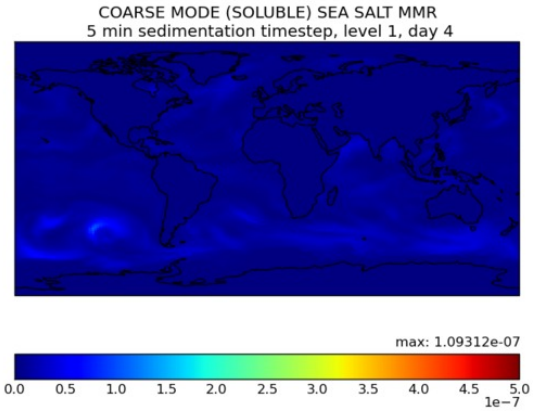


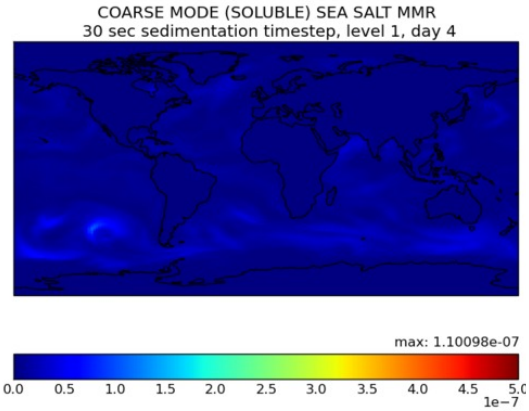


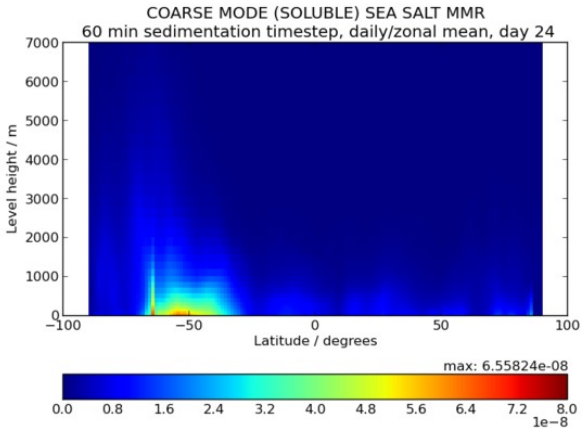
- Plots of coarse sea salt show a similar effect with significantly reduced loads, though the emissions are less episodic. Level 1 MMR on day 4 gives an illustration of this, but also shows a strange-looking stripe across the Antarctic peninsula. Zonal mean MMR on day 24 similarly shows a single-column spike which looks like a numerical artefact. The shorter timestep runs do not have these anomalies.

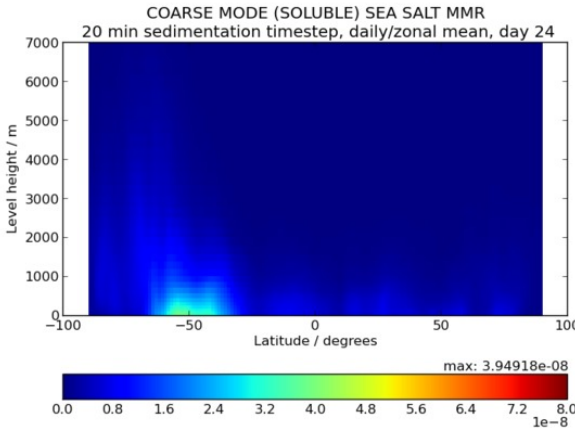

COARSE MODE (SOLUBLE) SEA SALT MMR
60 min sedimentation timestep, level 1, day 4
max: 2.4834e-07
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
1e−7

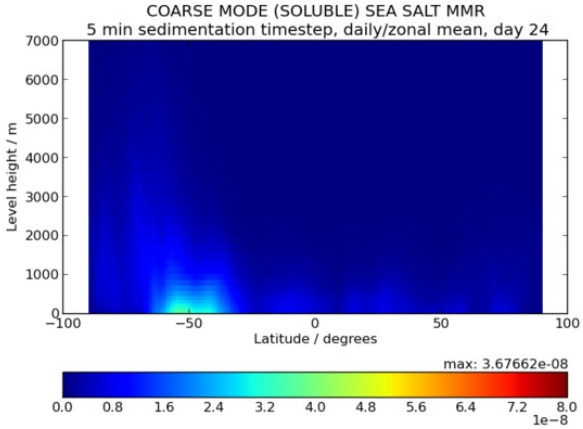

COARSE MODE (SOLUBLE) SEA SALT MMR
20 min sedimentation timestep, level 1, day 4
max: 1.59812e-07
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
1e−7

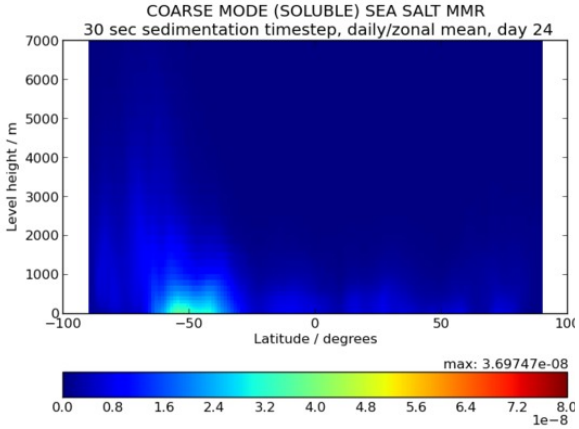

COARSE MODE (SOLUBLE) SEA SALT MMR
5 min sedimentation timestep, level 1, day 4
max: 1.09312e-07
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
1e−7


COARSE MODE (SOLUBLE) SEA SALT MMR
30 sec sedimentation timestep, level 1, day 4
max: 1.10098e-07
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
1e−7

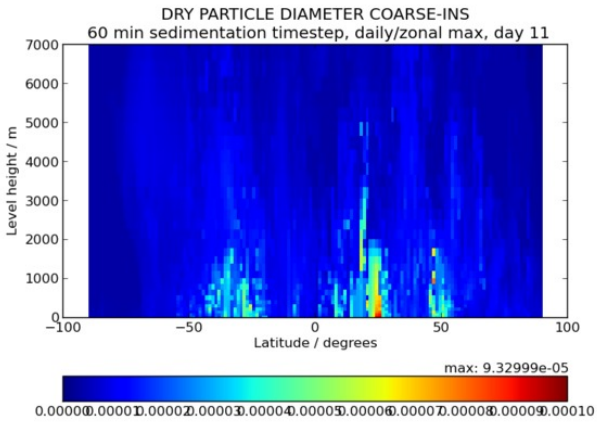


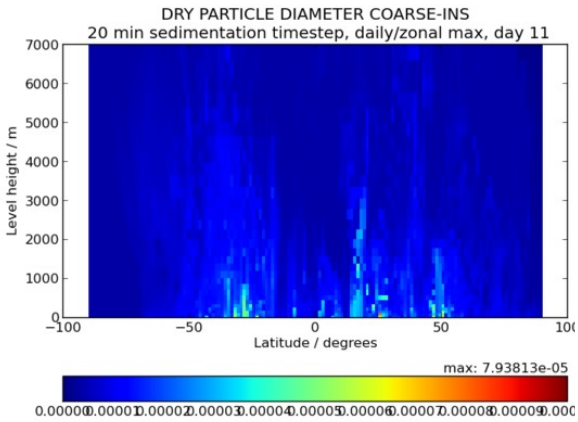


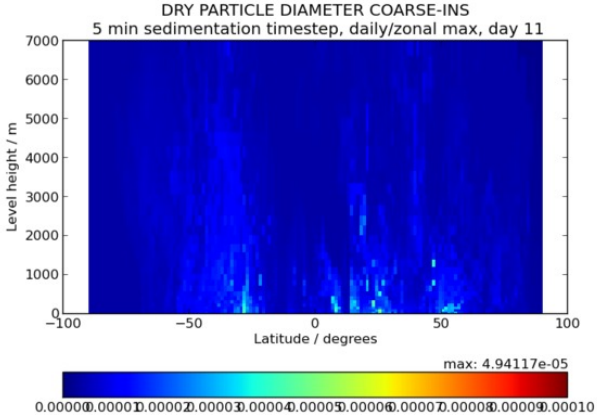


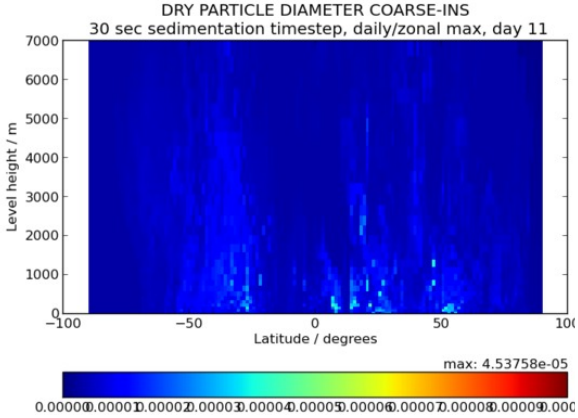


- Sizes. There is a clear reduction in the maximum particle diameter for the insoluble mode, but little impact on the soluble mode. The following plot shows a the zonal-max daily-max diameter for the coarse insoluble mode on a single day:









- Animations (on Met Office system): http://www-hc/~hadtq/sedits
- Max daily-mean depositions and max daily-max particle diameters:

Stash	Name	60 mins	20 mins	5 mins	30 secs
38218	DRY DEPOSITION SEA-SALT ACC (SOL)	0.692812	0.616945	0.594463	0.588165
38219	DRY DEPOSITION SEA-SALT COARSE (SOL)	369.97	405.555	482.238	480.719
38233	DRY DEPOSITION DUST ACCUMULATN (SOL)	5.68714	5.39227	5.28437	5.25683
38234	DRY DEPOSITION DUST COARSE (SOL)	126.584	177.827	125.136	124.655
38235	DRY DEPOSITION DUST ACCUMULATN (INS)	23.8147	21.4548	37.8558	6252.33
38236	DRY DEPOSITION DUST COARSE (INS)	678.427	958.843	926.289	4493.51
38407	DRY PARTICLE DIAMETER COARSE-INS	1.03E-04	9.15E-05	6.15E-05	1.61E-04 *
38411	WET PARTICLE DIAMETER COARSE-SOL	1.19E-04	6.85E-05	7.79E-05	8.54E-05

* This large peak in the 30-second run occurs on a single day at 2 grid points over the Sahara. Generally the max sizes in the 30-second run are slightly smaller than the 5-minute run.

- Max courant number on last timestep:

	60 mins	20 mins	5 mins	30 secs
max courant	364.3	78.4	5.7	0.57
num points	2288	867	288	78

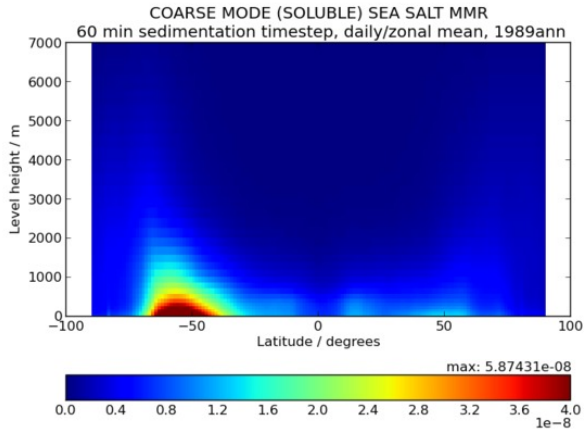
** = number of points exceeding the vgrav limit for the PE, level and mode with the highest Courant number.

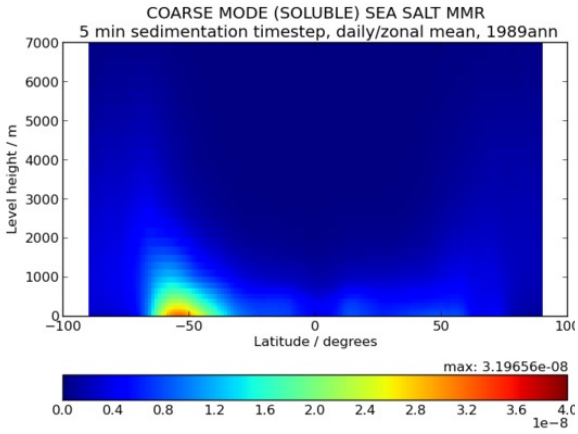
1-year test with 5-minute timestep

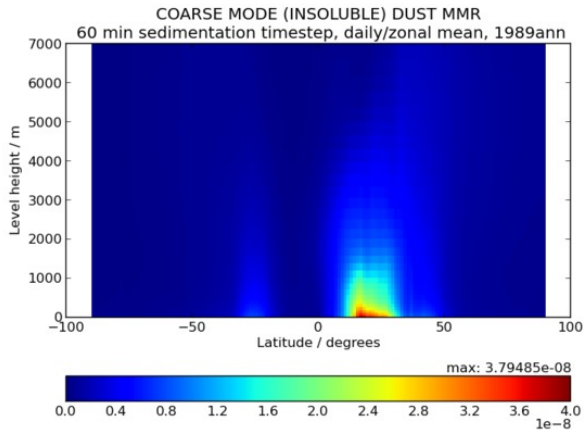
Runs compared:

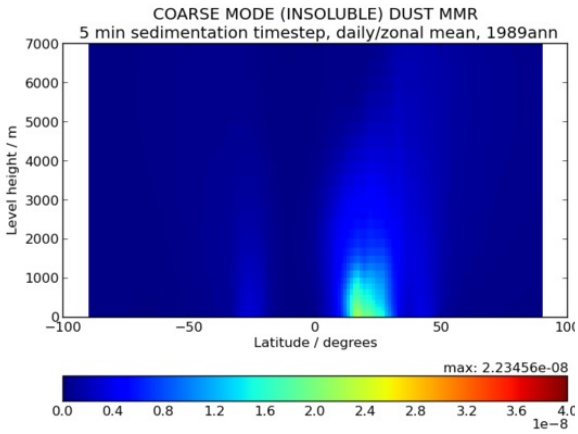
- antba: UM8.4 GA6+GLOMAP including sol&ins dust, and including bugfixes for ACTIVATE qsmr, vgrav*0.5 bugs (identical to antrb with different STASH)
- antrj: as antba but with 5 minute timestep for aerosol sedimentation and deposition (identical to antrg with different STASH)

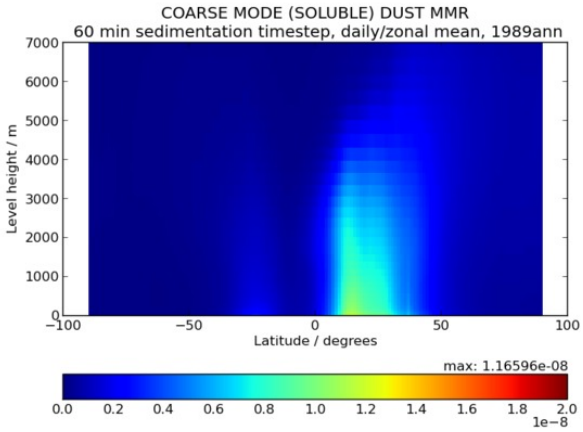
The results broadly confirm the picture from the 1-month runs. Dust and sea-salt loads are reduced significantly. There is a smaller reduction in sulphate, and very slight reductions in OC and BC. Plots for all coarse mode species in the lower 7km are shown below; the small modes appear identical in the annual mean zonal mean (as expected). Jane is planning to run the results through the UKCA evaluation suite for a wider assessment.

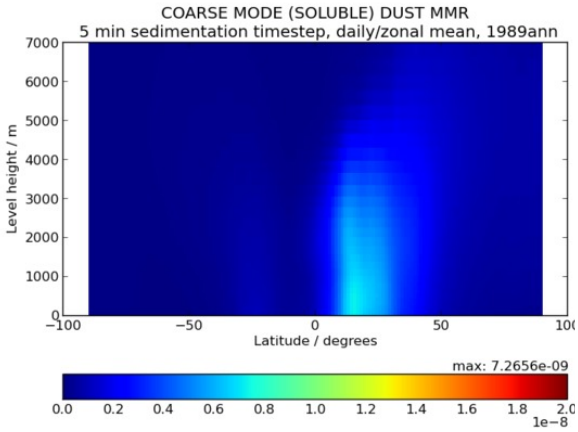


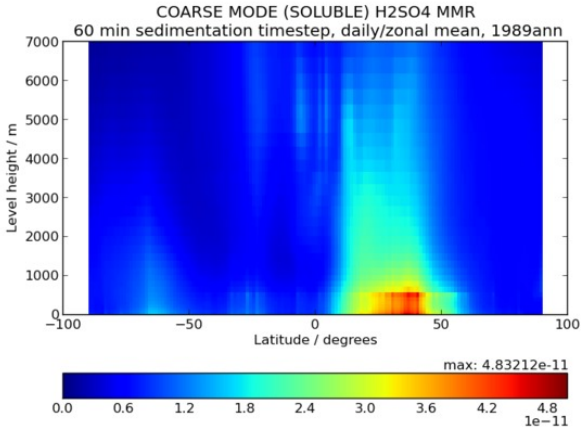


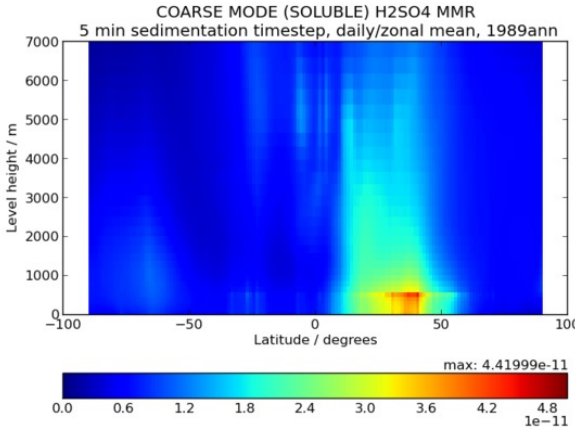


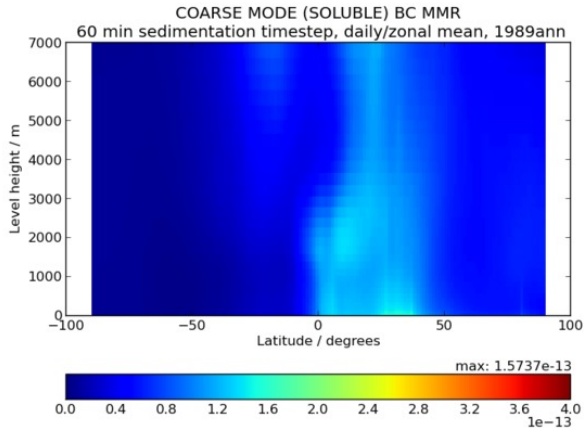


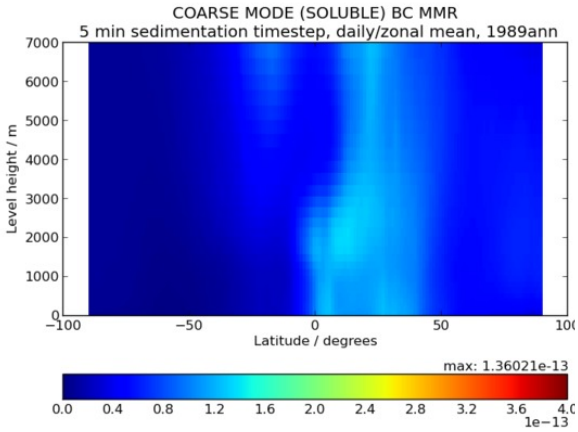

COARSE MODE (SOLUBLE) DUST MMR
60 min sedimentation timestep, daily/zonal mean, 1989ann
Level height / m
Latitude / degrees
max: 1.16596e-08
1e−8

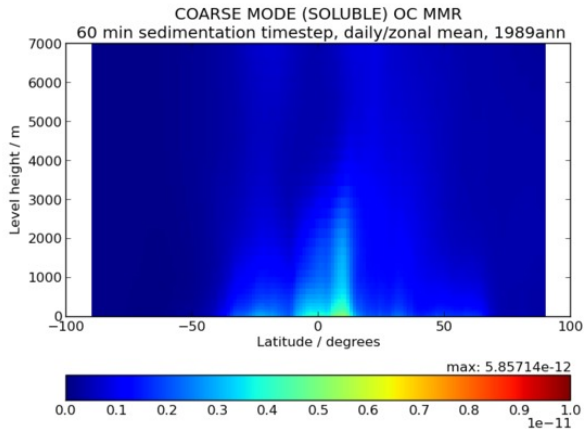

COARSE MODE (SOLUBLE) DUST MMR
5 min sedimentation timestep, daily/zonal mean, 1989ann
Level height / m
Latitude / degrees
max: 7.2656e-09
1e−8

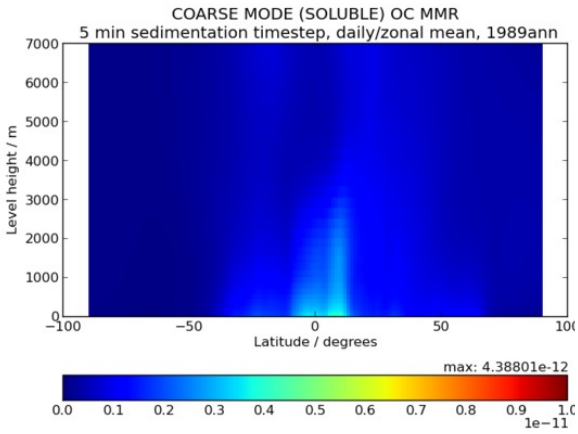

COARSE MODE (SOLUBLE) H2SO4 MMR
60 min sedimentation timestep, daily/zonal mean, 1989ann
Level height / m
Latitude / degrees
max: 4.83212e-11
1e−11


COARSE MODE (SOLUBLE) H2SO4 MMR
5 min sedimentation timestep, daily/zonal mean, 1989ann
Level height / m
Latitude / degrees
max: 4.41999e-11
1e−11









Attachments