COUPLING CUMULUS PARAMETERISATION AND CONTAMINANT TRANSPORT IN GLOBAL MODELS

Trond Iversen and Øyvind Seland

Dep. of Geosciences, Meteorology and Oceanography Section,
University of Oslo, (MetOs-UiO) Norway

AeroCom Workshop JRC, Ispra March 2004

AerOzClim Aerosols, Ozone and Climate

RegClim Regional Climate under Global Warming

Introduction

- Biases in vertical distribution of sulphur due to deep convective processes shown by:
  - Barth et al. (2001)
  - Iversen and Seland (2002)
  - COSAM (2001), in particular 3 GCMs
- Such biases are traditionally of little concern in regional sulphur models for the lower troposphere with heavily parameterized chemistry

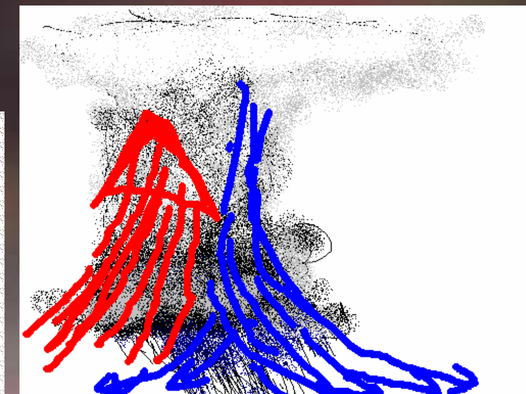
The CCM-Oslo

- Basis: NCAR CCM3.2, Atmospheric GCM
- T42 semi- lagrangian, 18 levels
- Deep convection (Zhang and McFarlane, 1995)
- Prognostic scheme for cloud water (Rasch and Kristjánsson, 1998)
- Deposition of contaminants based on Barth et al (2000)
- Emission from IPCC numbers given for the year 2000 **(AeroCom-A)**

$(q_t)_k = (F_p^u + F_p^d + F_p^a)_k \quad ; \quad k = 1,\ldots,K$

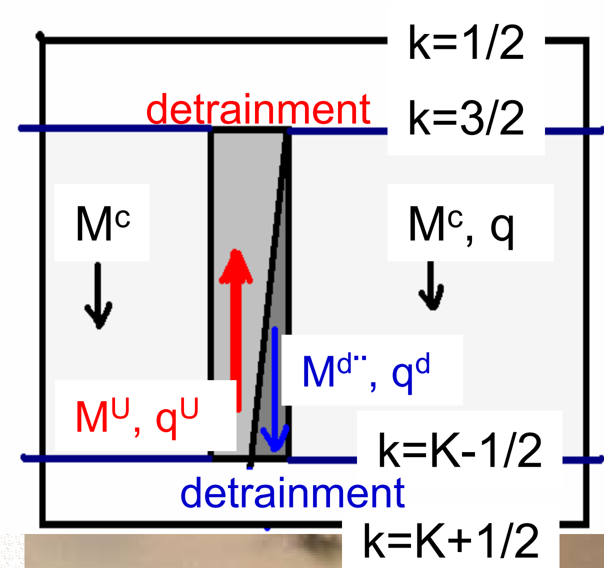
The deep convection scheme

(Zhang and McFarlane, 1995)



- Based on Arakawa Schubert plume ensemble concept q
- Uses mass-fluxes (transport of mass through per horiz. grid square per time unit - positive upwards). For levels k-1/2 on top of layers k:
  - updrafts: $M^u = \frac{M^u_{K\text{-}1/2}}{\lambda_0 (z - z_{K-1/2})} [\exp(\lambda_D (z - z_{K-1/2})) - 1]$
  - downdrafts: $M^d = \frac{-\alpha M^u_{K\text{-}1/2}}{2\lambda_0 (z_D - z)} [\exp(2\lambda_0 (z_D - z)) - 1]$

  $M^u_{K\text{-}1/2} = CAPE/(\tau F), \lambda_D \text{ and } \lambda_0 = \text{fractional entrainment rate}$
  - Ambient clear air (sinking): $M^c = -(M^u - M^d)$



- For a contaminant with mixing ratio q:

$$(q_t)_k = (\partial F^u / \partial p + \partial F^d / \partial p + \partial F^c / \partial p)_k \; , k = 1,2,\ldots,K$$

$$F_k^{u,d} = M_k^{u,d} q_k^{u,d}, F_k^c = -M_k^u q_k + M_k^d q_k, k = 1 + 1/2, \ldots, K - 1/2$$

- q^u and q^d are determined by the closing budget:

(flux out + detrainment) = (flux in + entrainment)

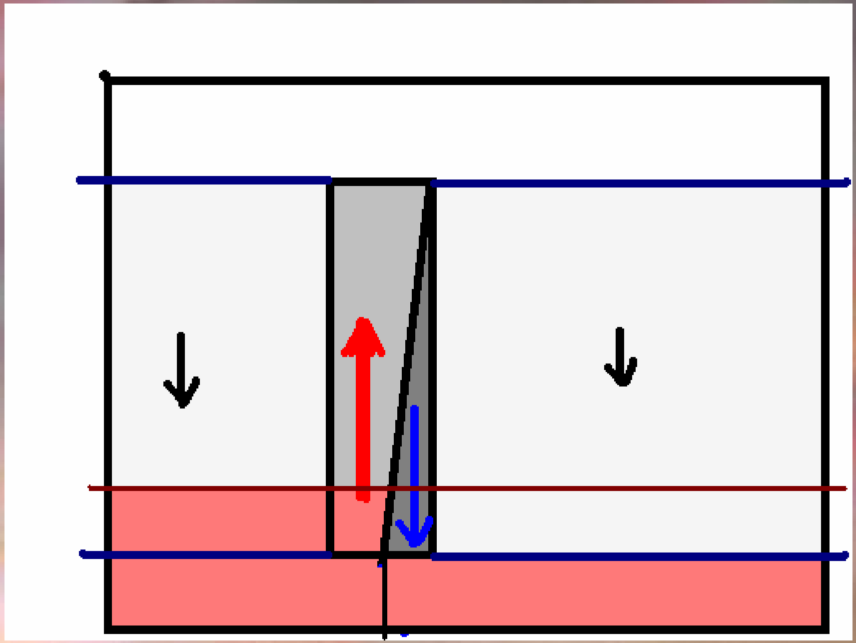
The deep convection scheme
(Zhang and McFarlane, 1995)

Questionables:

- Air detrains cloud tops at level of negative buoyancy only
- The scheme provides no information on exchange of contaminants between
  - updrafts and downdrafts
  - between cloudy and ambient clear air

Wet deposition and chemistry

- Scavenging in convective clouds only by impaction, and in geometrical cloud fraction.
- Deposition and chemistry are separate from the convective transport.



Tests of processes linked to the convective parameterisation

- Test 1: No convective transport; *Nocon*
- Test 2: Convective transport but no non-local in-cloud scavenging; *Fcon*
- Test 3: Non-local scavenging below level of maximum creation of precipitation;*Scav*
- Test 4: Complete mixing of tracers between updrafts and downdrafts; *Exch*

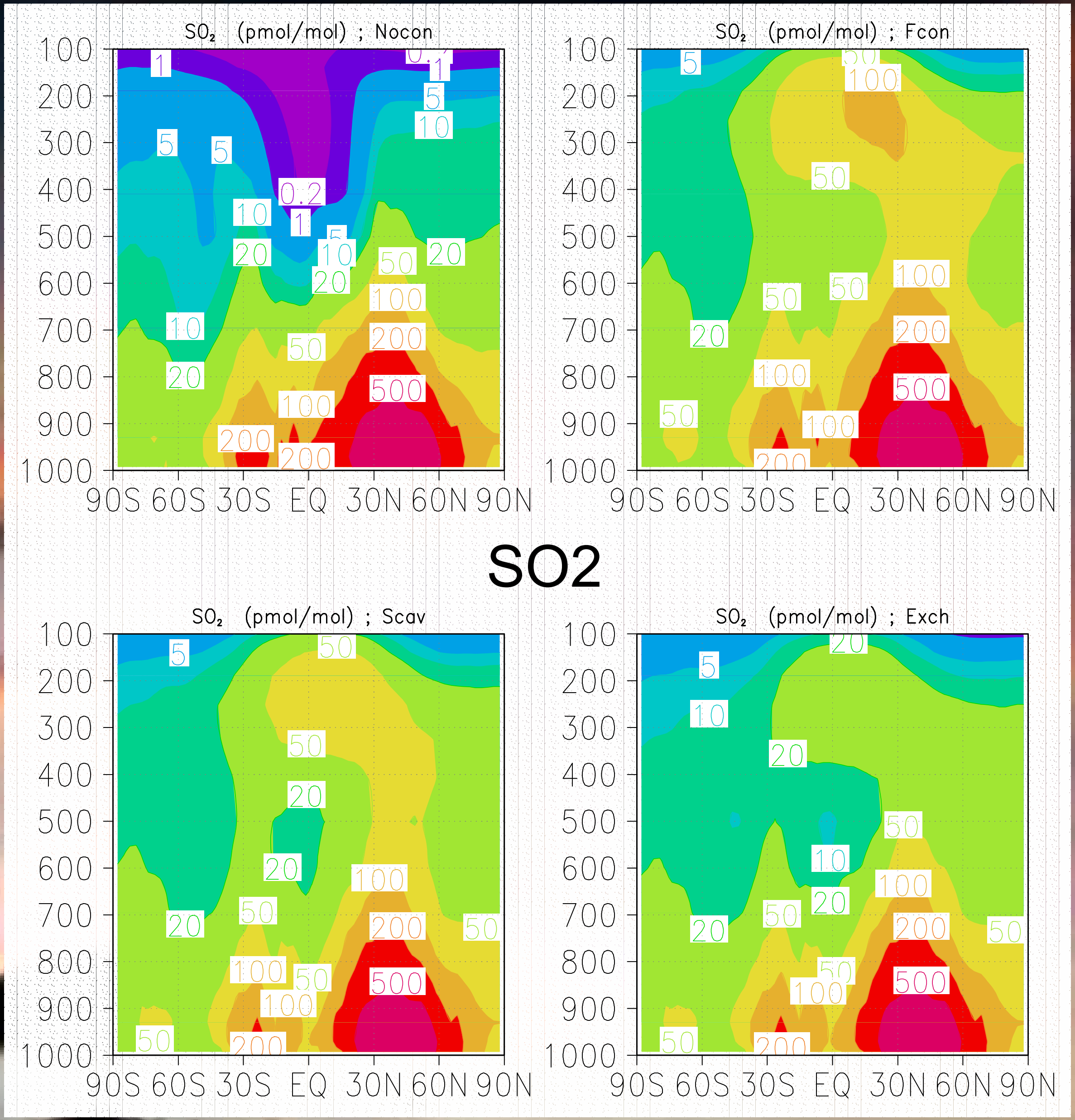
SO2

Nocon

Fcon

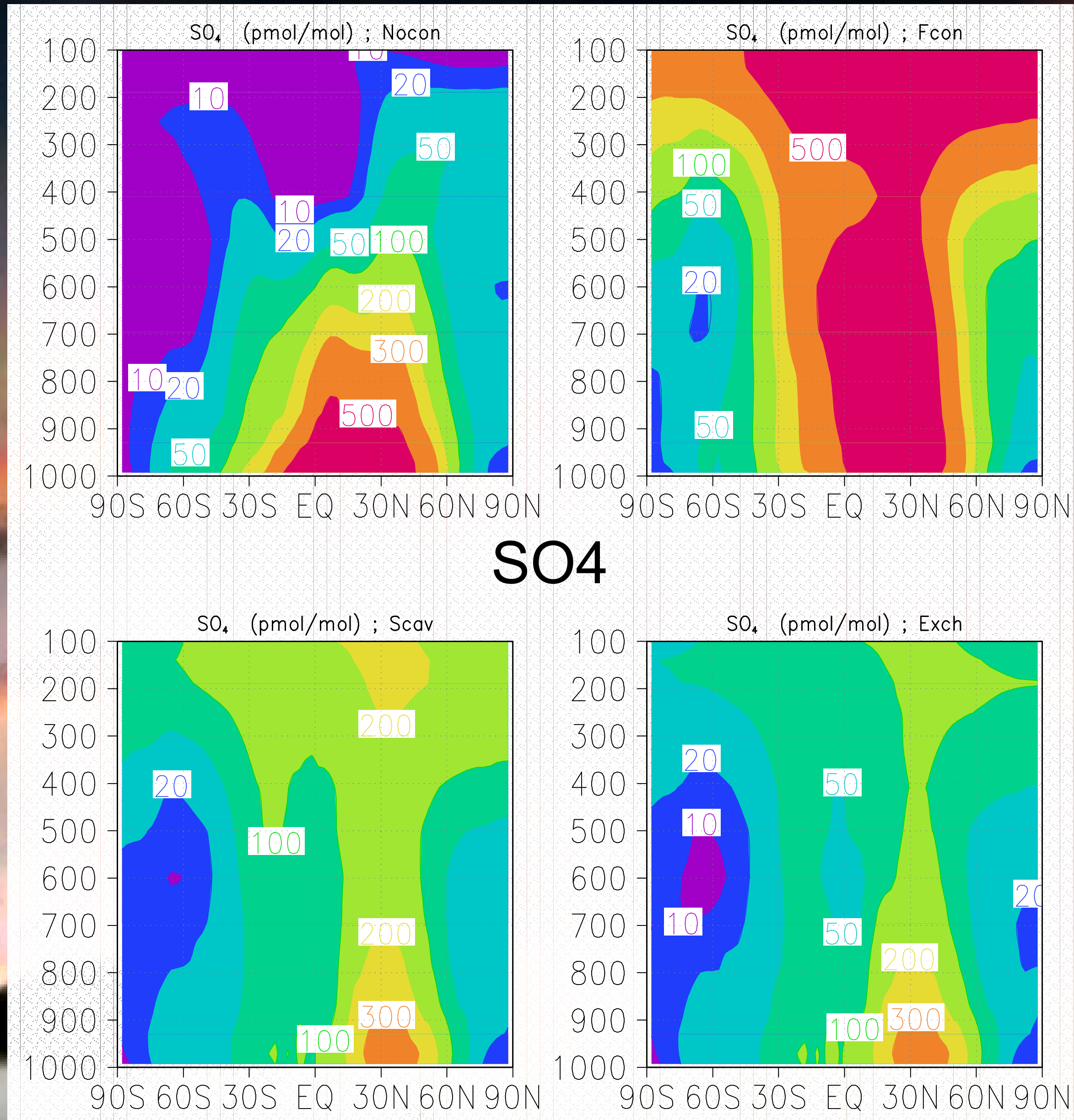
Scav

Exch



Nocon

Fcon



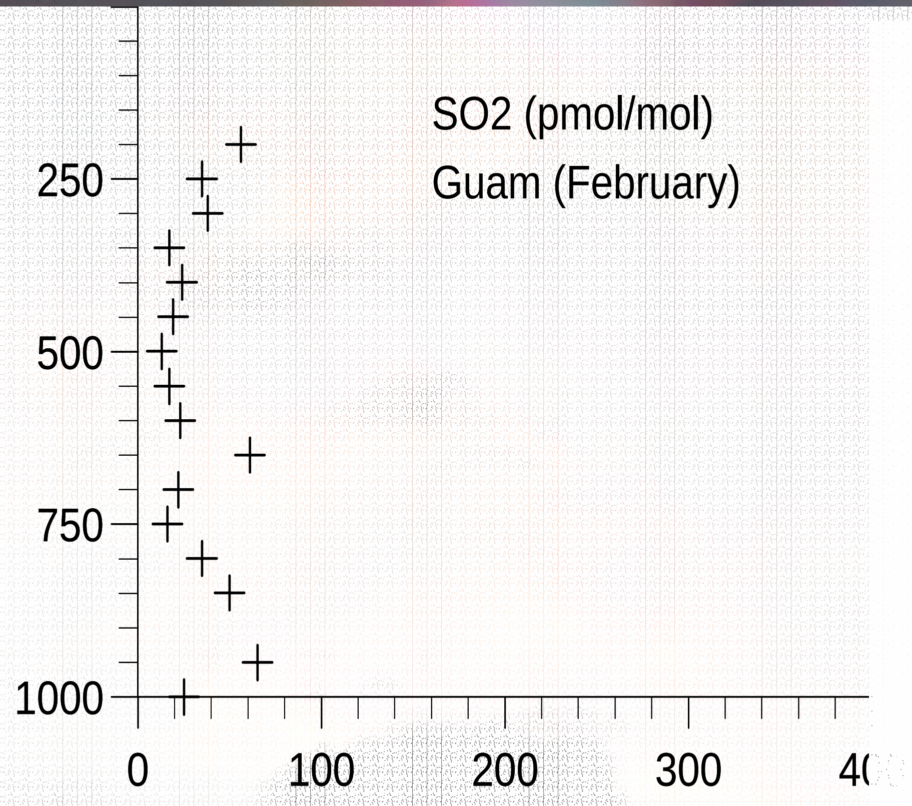
Scav

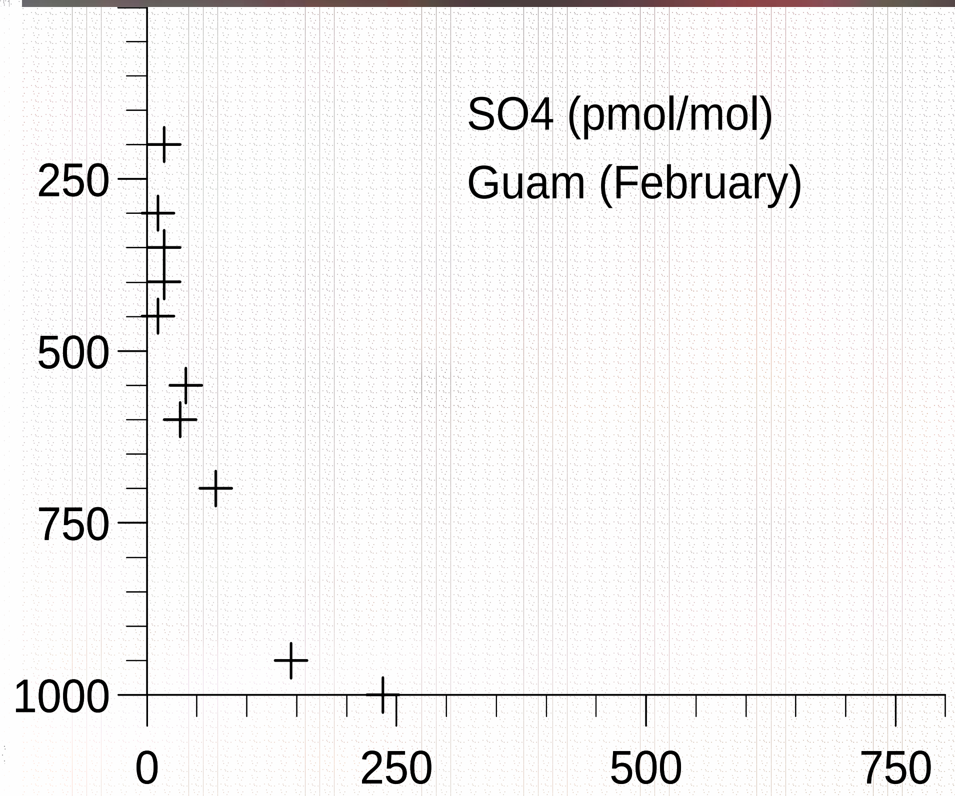
Exch

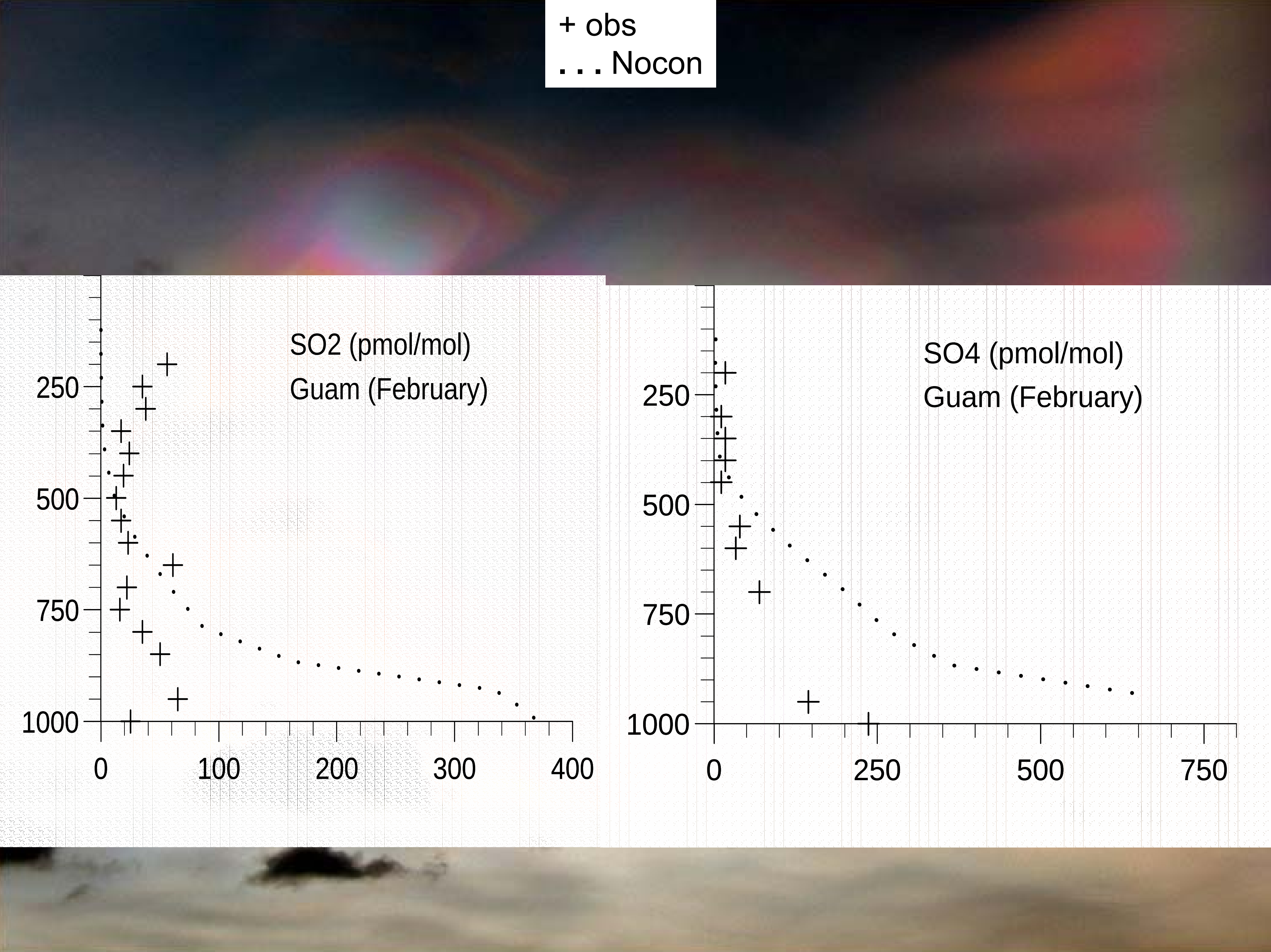
Burdens and Residence times

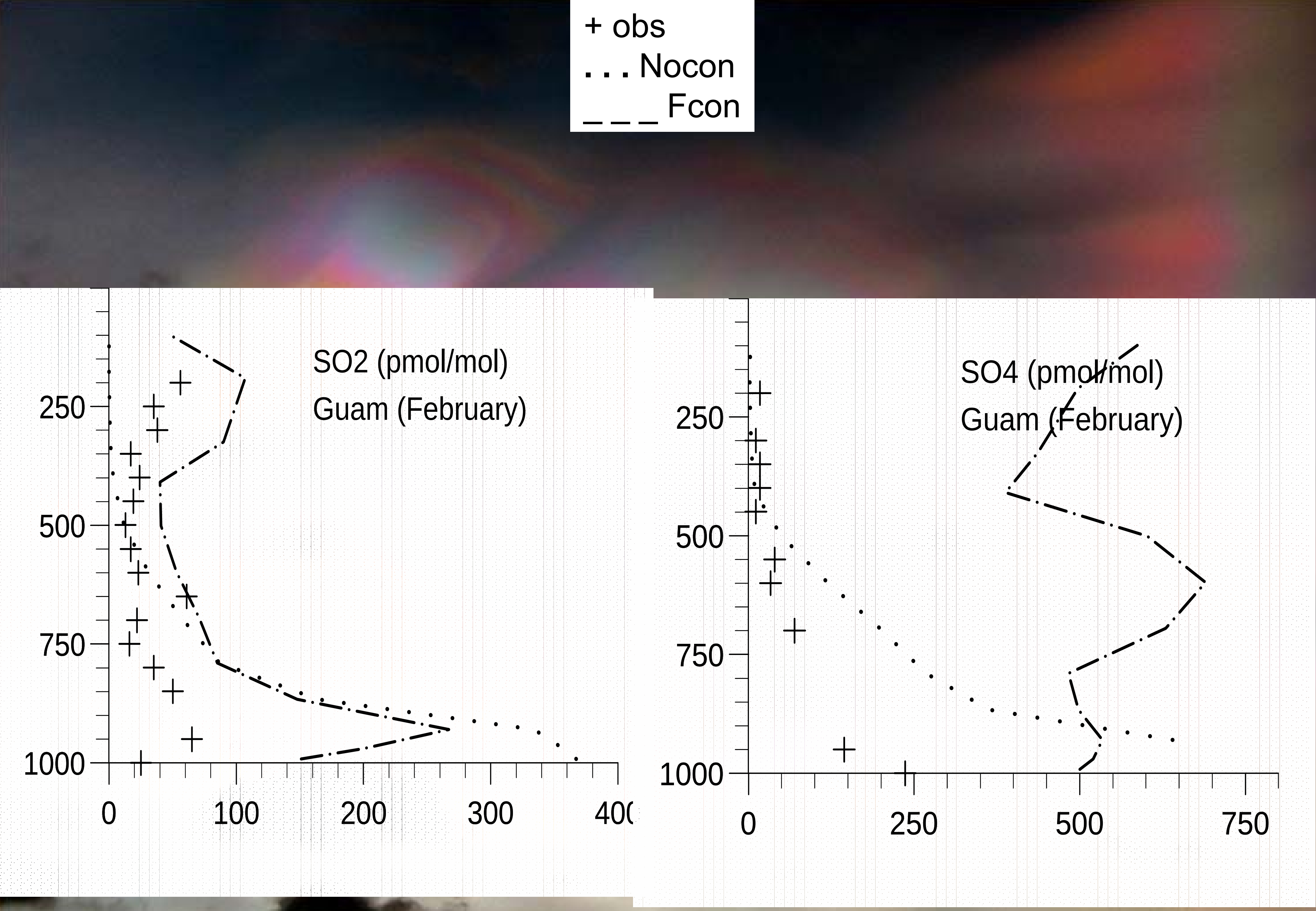
	SO_2 Burden Tg(S)	SO_2 T days	SO_4 Burden Tg(S)	SO_4 T days
Nocon	0.40	1.6	0.60	4.1
Fcon	0.52	2.1	2.40	14.6
Scav	0.42	1.7	0.63	4.4
Exch	0.39	1.6	0.44	3.1
AeroComA$_{new}$	0.37	1.5	0.47	3.2
AeroComB	0.34	1.5	0.48	3.7

+ obs

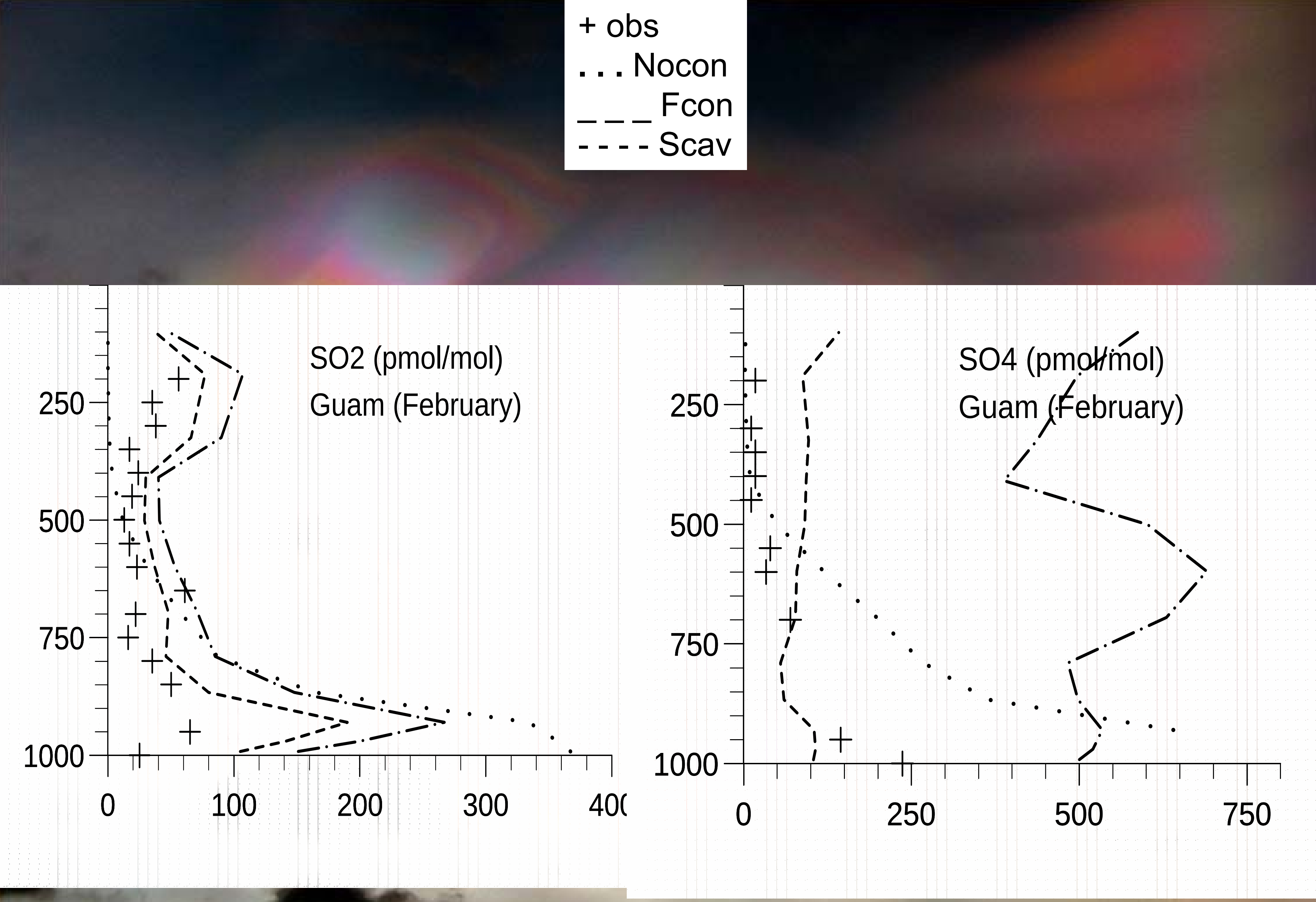

SO2 (pmol/mol)
Guam (February)
250
500
750
1000
0
100
200
300


SO4 (pmol/mol)
Guam (February)
250
500
750
1000
0
250
500
750

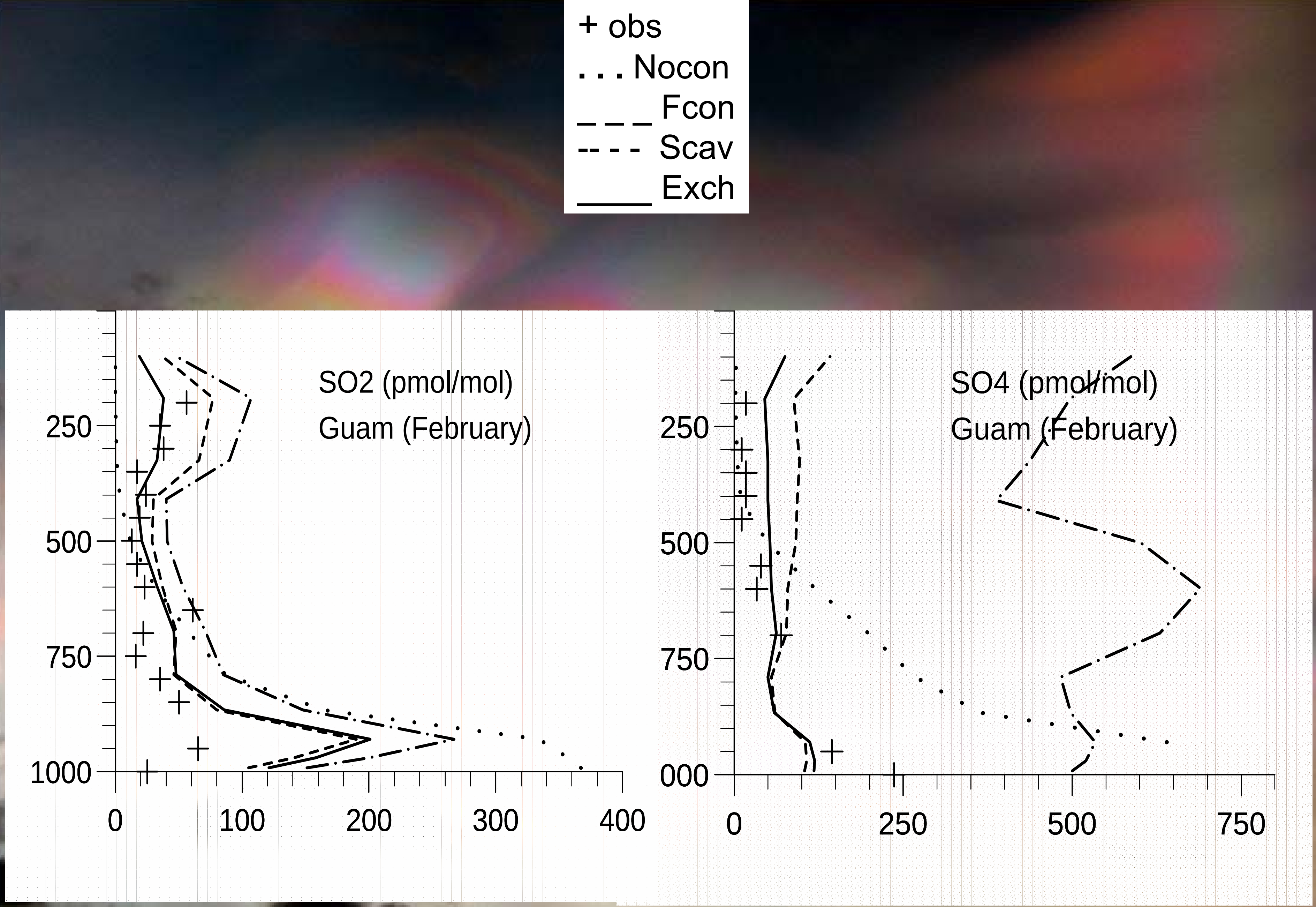

+ obs
. . . Nocon
SO2 (pmol/mol)
Guam (February)
250
500
750
1000
0
100
200
300
400
SO4 (pmol/mol)
Guam (February)
250
500
750
1000
0
250
500
750

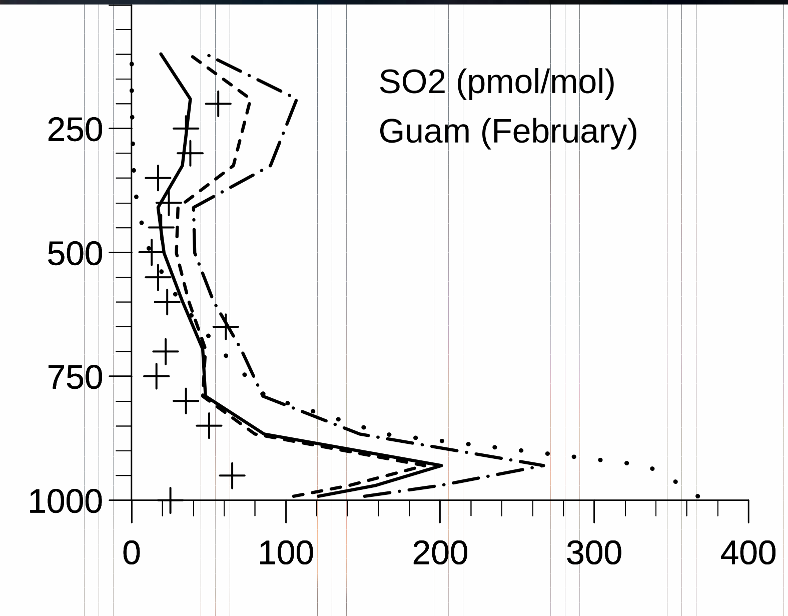


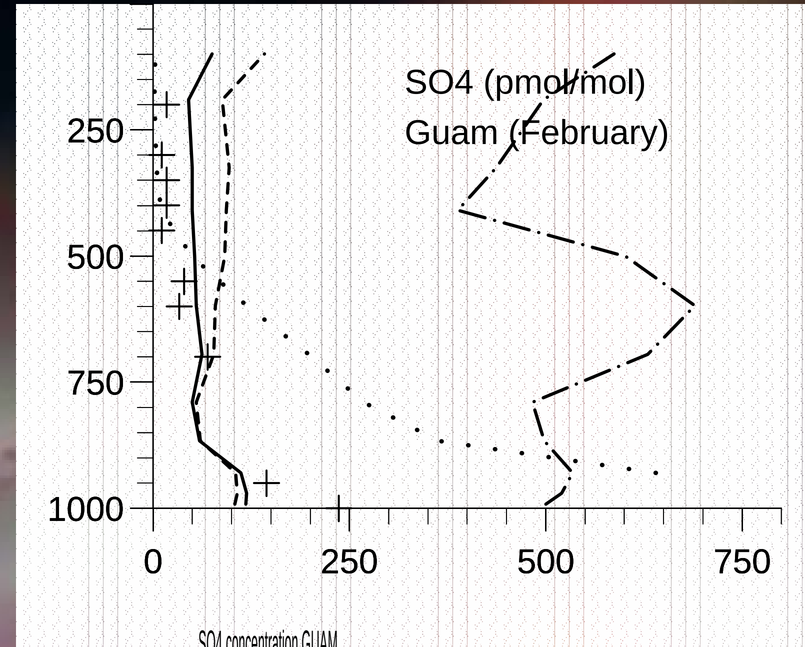
+ obs
. . . Nocon
_ _ _ Fcon
SO2 (pmol/mol)
Guam (February)
250
500
750
1000
0
100
200
300
400
SO4 (pmol/mol)
Guam (February)
250
500
750
1000
0
250
500
750

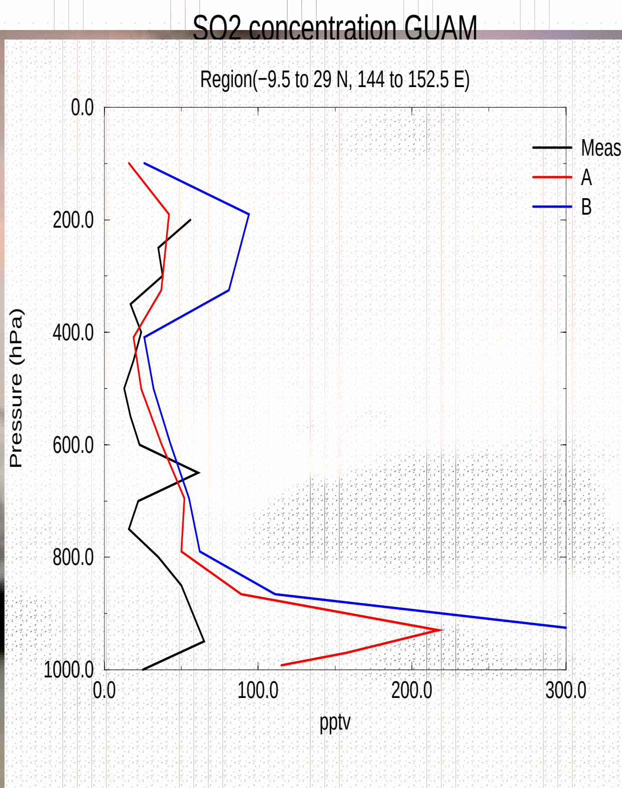


+ obs
. . . Nocon
_ _ _ Fcon
- - - - Scav
SO2 (pmol/mol)
Guam (February)
250
500
750
1000
0
100
200
300
400
SO4 (pmol/mol)
Guam (February)
250
500
750
1000
0
250
500
750

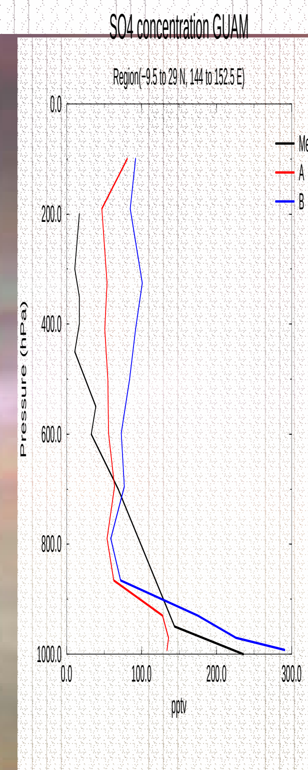

+ obs
. . . Nocon
_ _ _ Fcon
-- - - Scav
____ Exch
SO2 (pmol/mol)
Guam (February)
250
500
750
1000
0
100
200
300
400
SO4 (pmol/mol)
Guam (February)
250
500
750
000
0
250
500
750





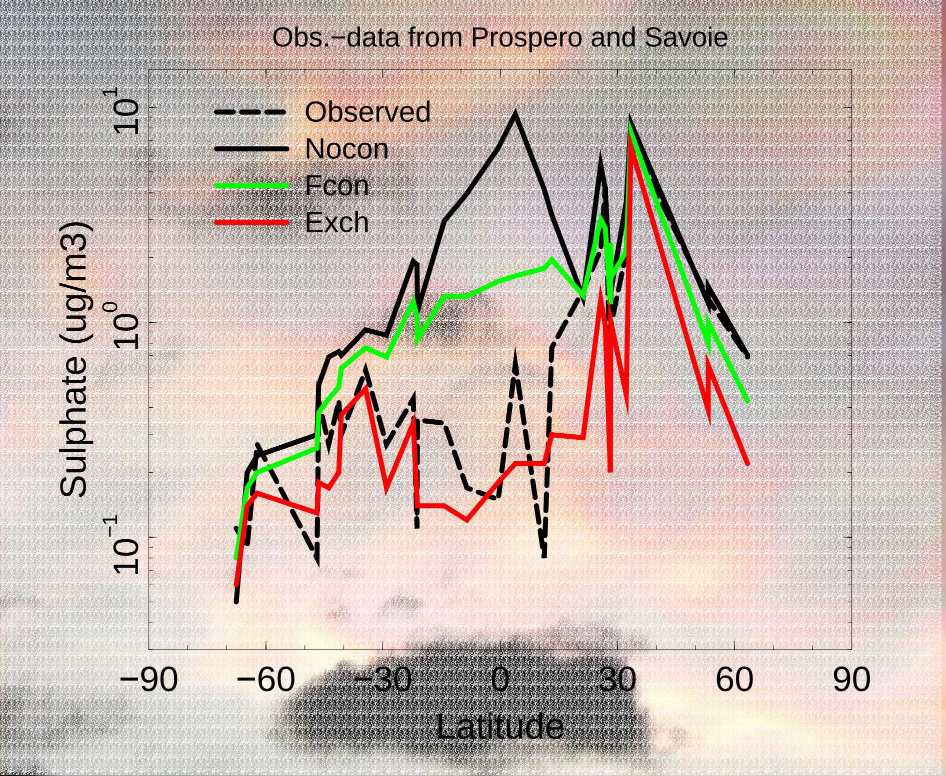


Measured
AeroComA
AeroComB

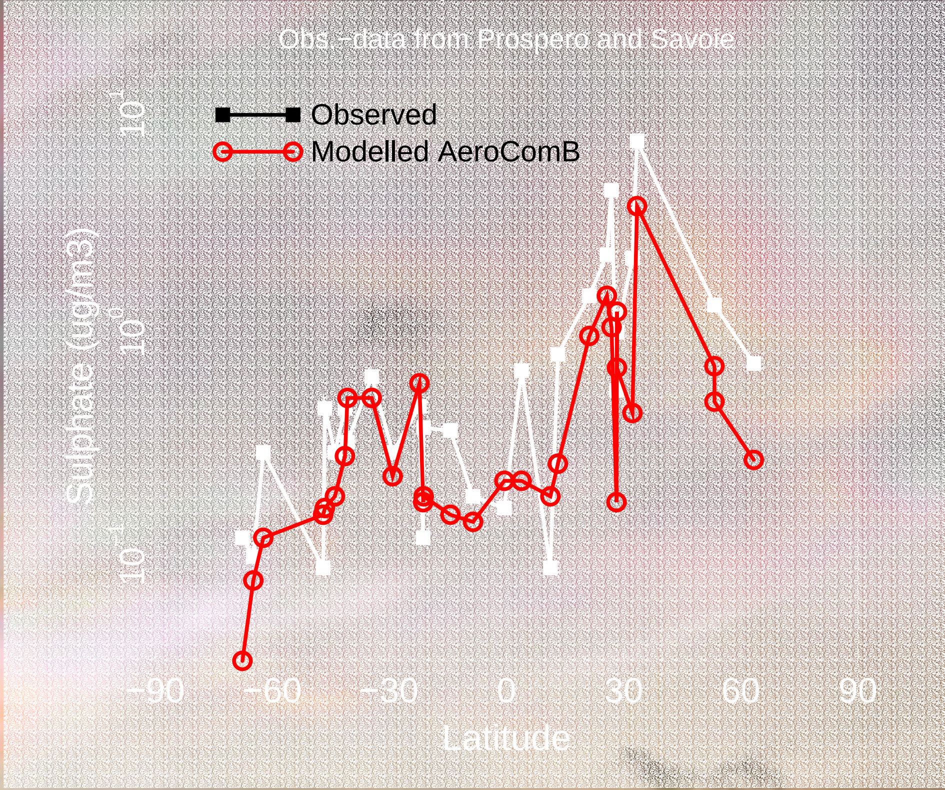


Sulphate in Oceanic areas

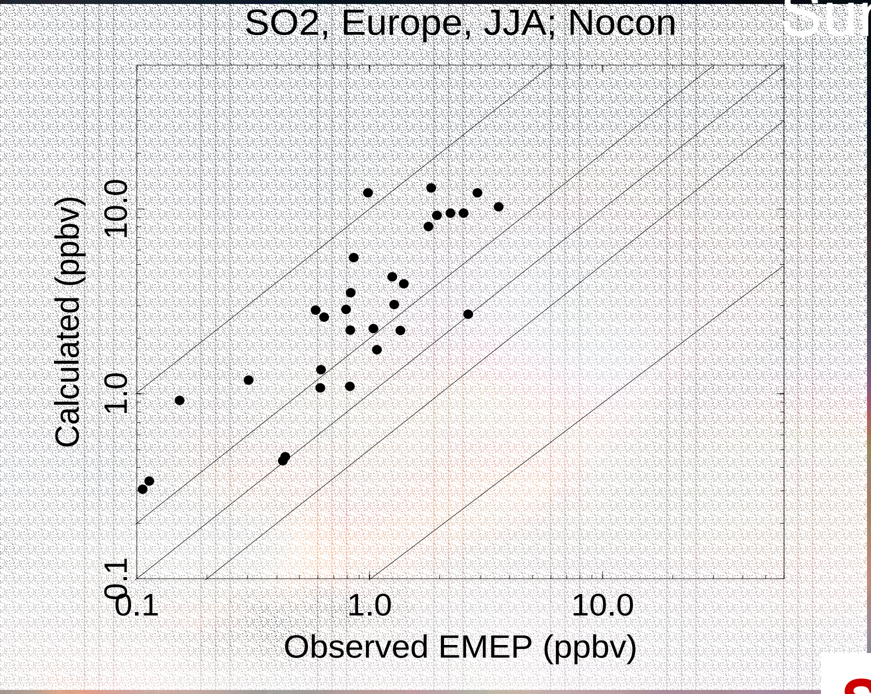
Annual nss−sulphate in oceanic areas

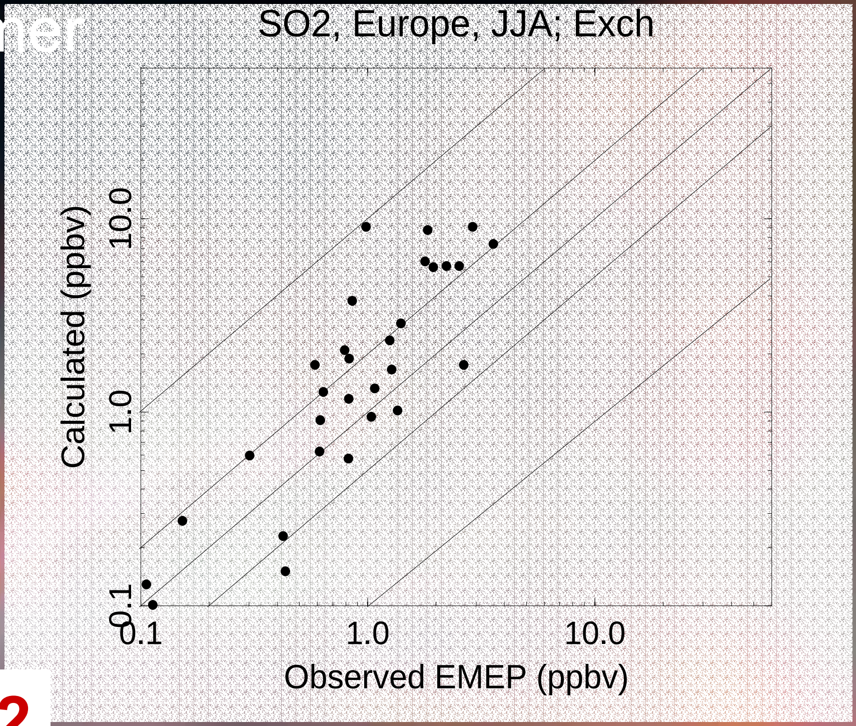


AeroComB

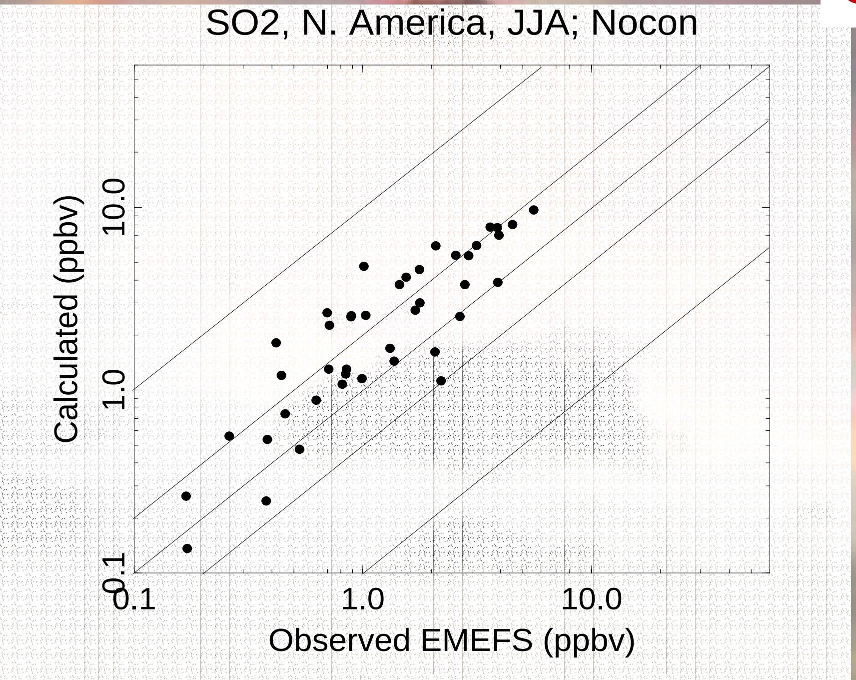


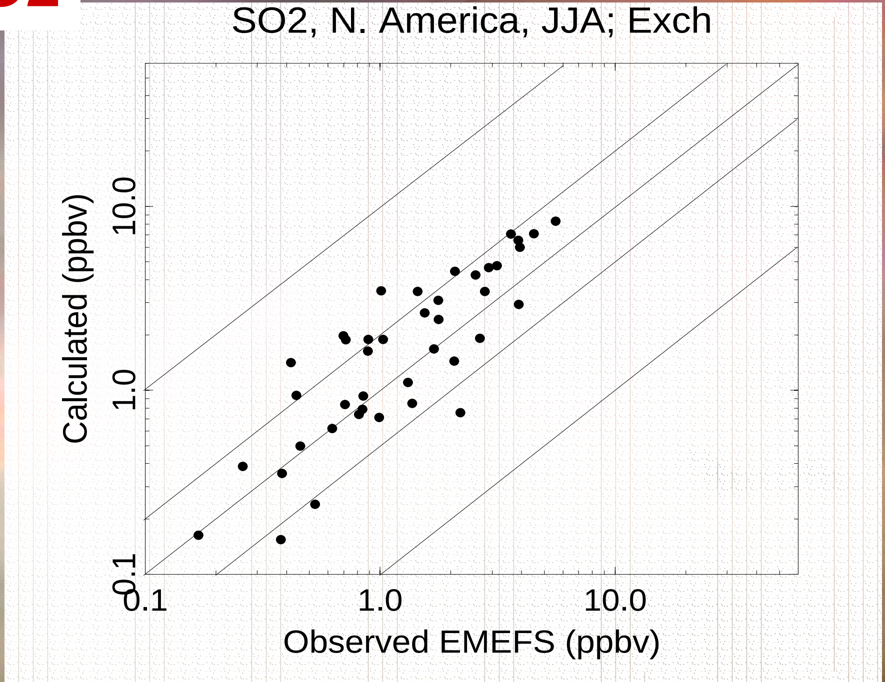
Summer


SO2, Europe, JJA; Nocon
Calculated (ppbv)
Observed EMEP (ppbv)
0.1
1.0
10.0

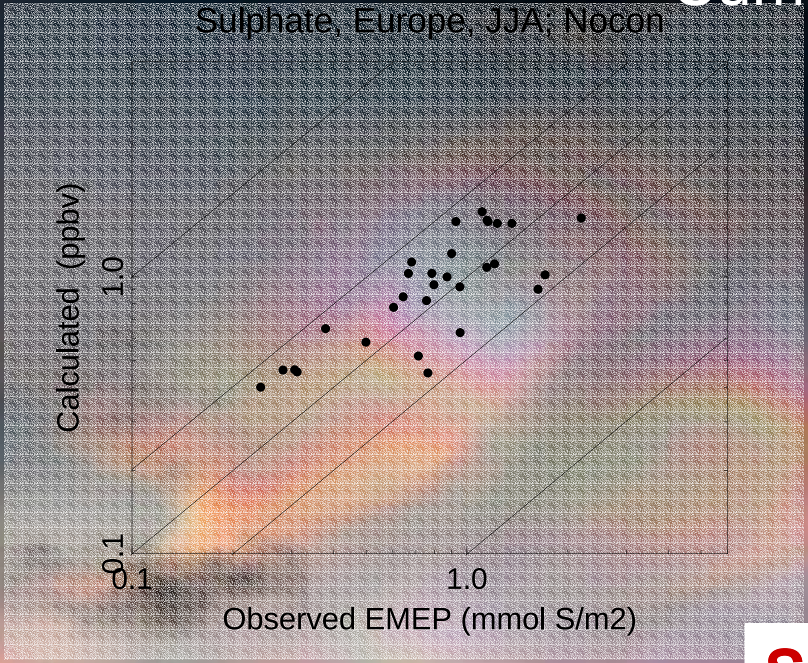

SO2, Europe, JJA; Exch
Calculated (ppbv)
Observed EMEP (ppbv)
0.1
1.0
10.0

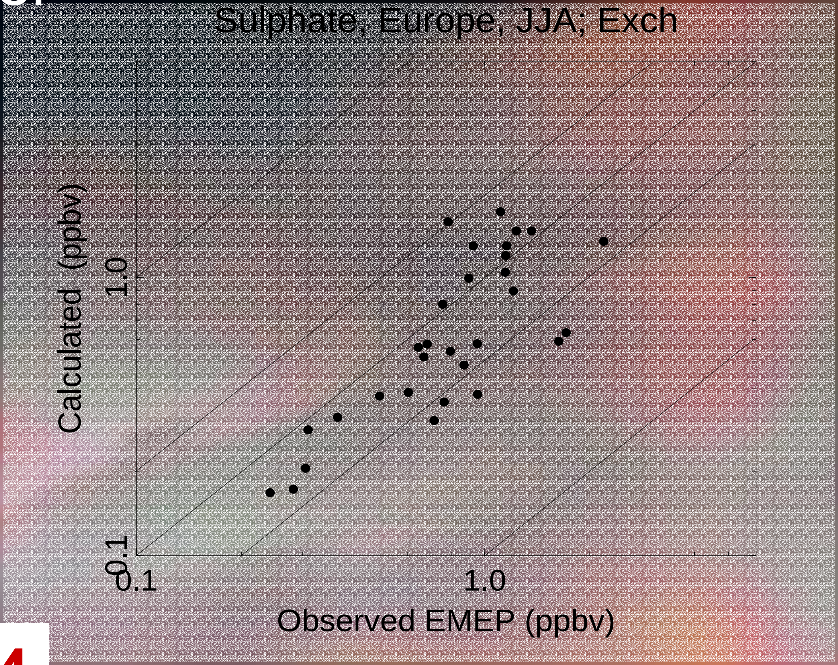
SO2


SO2, N. America, JJA; Nocon
Calculated (ppbv)
Observed EMEFS (ppbv)
0.1
1.0
10.0

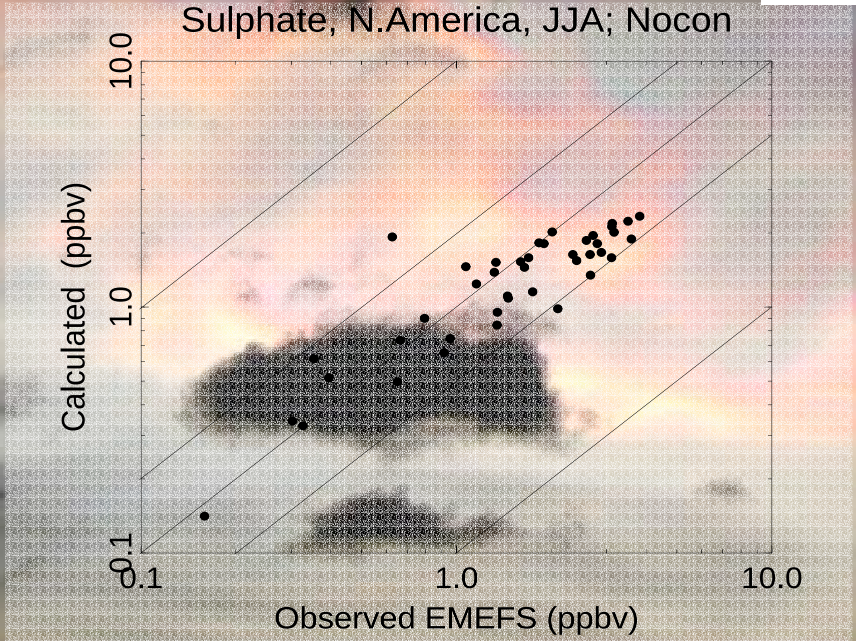

SO2, N. America, JJA; Exch
Calculated (ppbv)
Observed EMEFS (ppbv)
0.1
1.0
10.0

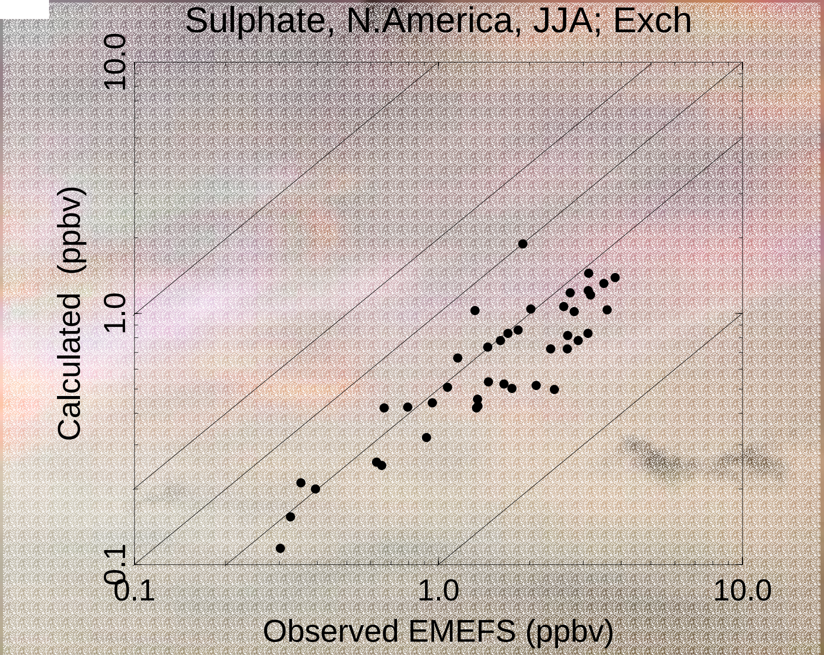
Summer


Sulphate, Europe, JJA, Nocon
Calculated (ppbv)
Observed EMEP (mmol S/m2)
0.1
1.0

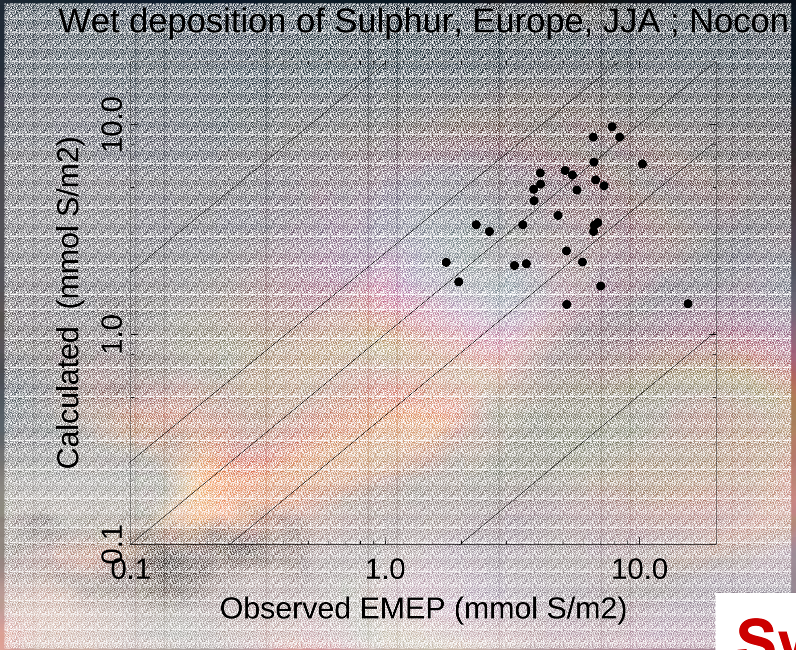

Sulphate, Europe, JJA; Exch
Calculated (ppbv)
Observed EMEP (ppbv)
0.1
1.0

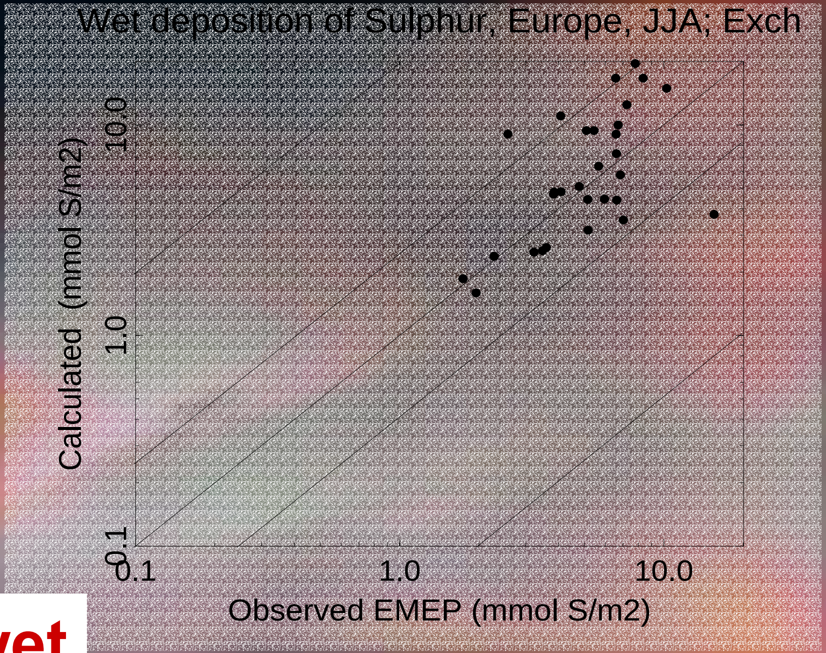
SO4


Sulphate, N.America, JJA; Nocon
Calculated (ppbv)
Observed EMEFS (ppbv)
0.1
1.0
10.0

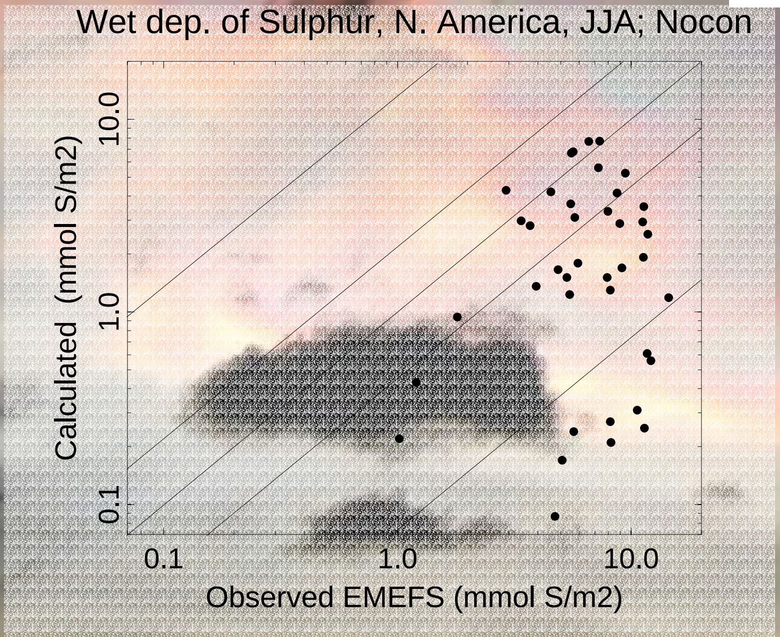

Sulphate, N.America, JJA; Exch
Calculated (ppbv)
Observed EMEFS (ppbv)
0.1
1.0
10.0

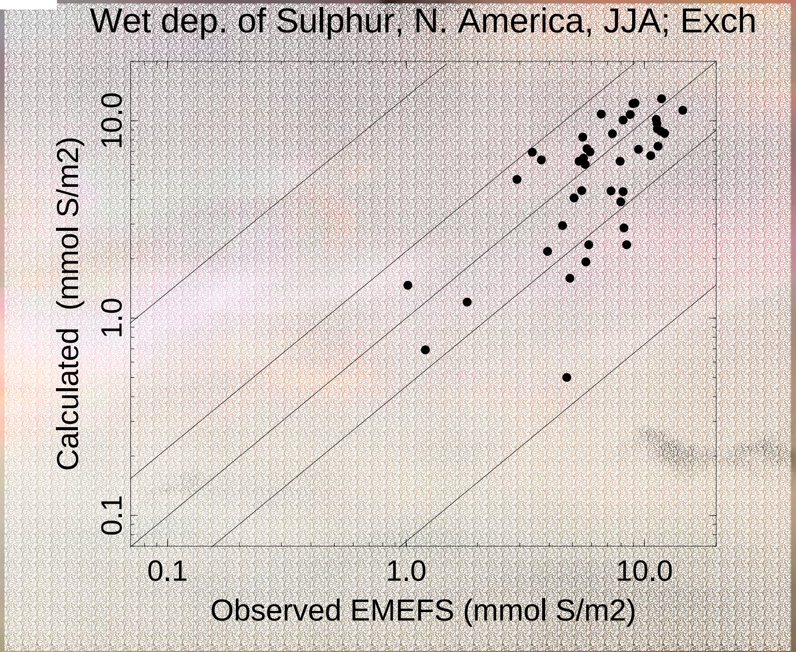
Summer


Wet deposition of Sulphur, Europe, JJA ; Nocon
Calculated (mmol S/m2)
Observed EMEP (mmol S/m2)
0.1
1.0
10.0


Wet deposition of Sulphur, Europe, JJA; Exch
Calculated (mmol S/m2)
Observed EMEP (mmol S/m2)
0.1
1.0
10.0

Swet


Wet dep. of Sulphur, N. America, JJA; Nocon
Calculated (mmol S/m2)
Observed EMEFS (mmol S/m2)
0.1
1.0
10.0


Wet dep. of Sulphur, N. America, JJA; Exch
Calculated (mmol S/m2)
Observed EMEFS (mmol S/m2)
0.1
1.0
10.0

In Conclusion

- Introducing increased scavenging and exchange between updraft and downdraft reduces the biases in deep convective transport
- Still unsolved:
  - Difference between extratropical, continental convection and tropical (ITCZ) convection
  - Interactions between sulphur chemistry and convective cloud water.

References

COSAM-intercomparison:

Barrie, L.A. et al., (2001) *Tellus 53 B* 615-645

NCAR CCM3:

Sulphur transport:

Barth, M.C. , Rasch, P.J., Kiehl, J.T. Benkowitz, C.M. and Schwartz S.E. (2000) *J. Geophys. Res*. D1 1387-1415

Deep Convection:

Zhang, G.J. And McFarlane N.A. (1995) *Atmos. Ocean, 33*, 407-446

Cloud modelling:

Rasch, P.J. and Kristjansson, J.E. (1998) *J. Clim 11*, 1587-1614

CCM-Oslo (our version):

Iversen, T. and Seland, Ø. (2002) *J. Geophys. Res. D1,* Vol 107