MEASURING AND SIMULATING PARTICULATE MATTER IN THE UTLS

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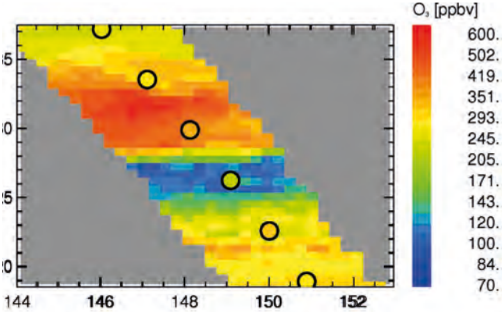
CHARACTERISATION OF PARTICULATES IN THE UPPER TROPOSPHERE / LOWER STRATOSPHERE

- ESA-study May 2016 – January 2018
- aftermath of Earth Explorer 7 proposal for PREMIER satellite instrument
- objective: particle detection capabilities of MIPAS compared to PREMIER IRLS

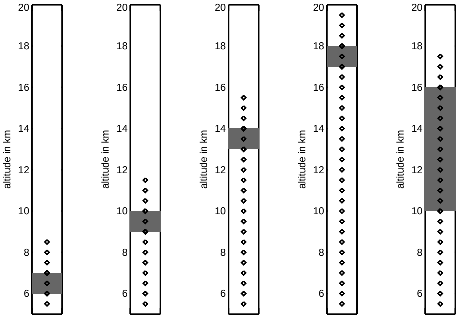
MIPAS & IRLS



PREMIER report, 2012

	MIPAS	IRLS-CM	IRLS-DM
spectral range	685 – 2410 cm – 1 in 5 bands	710 – 1010, 1070 – 1650 cm^{-1}	
spectral sampling	0.0625 cm^{-1}	0.2 cm^{-1}	1.25 cm^{-1}
vertical sampling	1.5 km	0.6 km	0.6 km
horizontal sampling	410 km	100/72 km	50/24 km

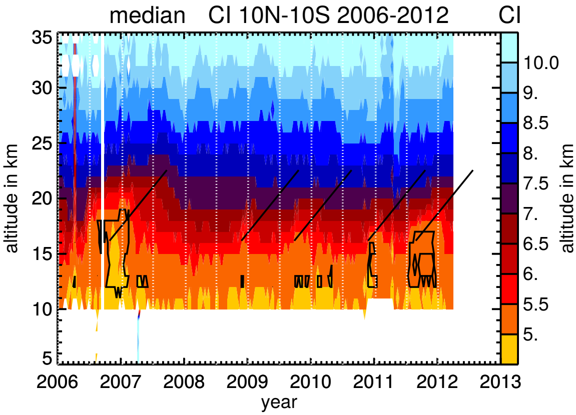
1D SIMULATIONS

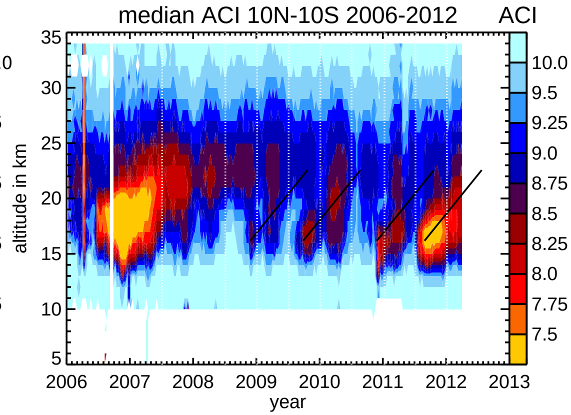


$\sum$ = 238 260 spectra

- study based on simulations
- methods tested with MIPAS
- 1D simulations for ice, sulfate aerosol, and ash
- systematic sampling of parameter space
- further 1D, 2D, and 3D complex test cases for ice clouds, ultra thin cirrus, and PSCs

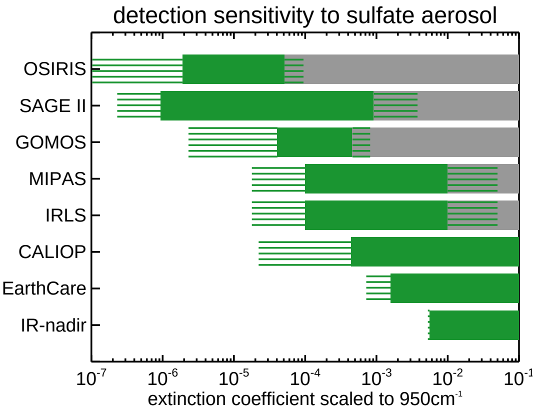
CLOUD-INDEX AND AEROSOL-CLOUD-INDEX





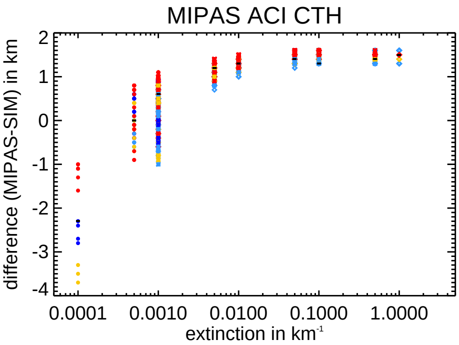
The CI has a higher sensitivity towards ice clouds, whereas the ACI has a higher sensitivity towards aerosol.

AEROSOL DETECTION SENSITIVITY: COMPARISON



OSIRIS:	Rieger et al., AMT, 2014; Fromm et al., JGR,2014
SAGE II:	Wang et al., GRL, 1995; Thomason et al., ACP, 2008
GOMOS:	Vanhellemont et al., ACP, 2008; Robert et al., AMT, 2016
MIPAS:	Sembhi et al., ACP, 2012; Griessbach et al., AMT, 2016, this study
IRLS:	this study
CALIOP:	Winker et al., JAOT, 2009
EarthCare:	`http://esamultimedia.esa.int/docs/SP_1279_1_EarthCARE.pdf`
IR nadir:	Ackerman et al., JGR, 1997

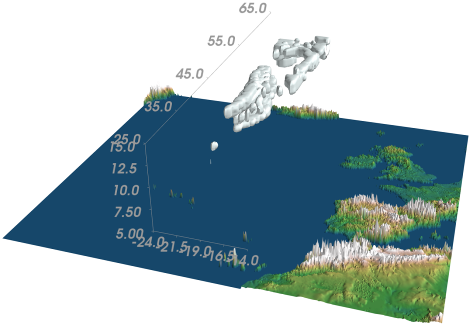
SPATIAL DETECTION: CLOUD TOP HEIGHT



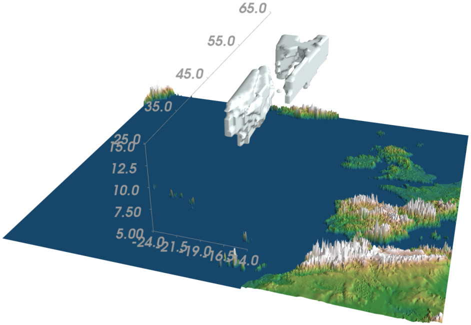
	overestimation	underestimation
literature:	up to 2 km	up to -4.5 km
MIPAS	1.7 (1.6) km	−3.0 (3.7) km
IRLS-CM	0.7 (0.6) km	−3.5 (3.5) km
IRLS-DM	0.7 (0.6) km	−2.6 (3.1) km

Cloud top height accuracy depends on vertical sampling, field of view, cloud coverage (broken, closed), and **extinction.**

SPATIAL DETECTION: 3D-STRUCTURES



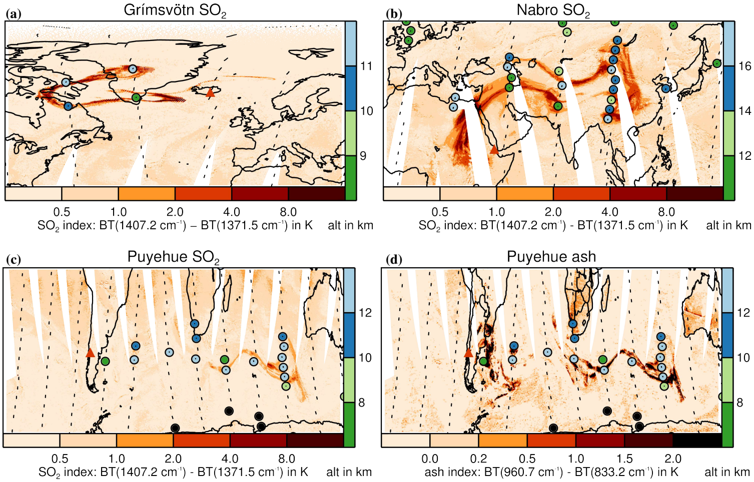
3D ice cloud structure



IRLS: retrieved 3D ice cloud structure

Retrieval of 3D cloud structures not possible with MIPAS.

AEROSOL-ICE DISCRIMINATION



aerosol detection

(Griessbach et al., AMT, 2016)

- sulfate: 99.7 % (3974/3986)
- basalt: 42.7 % (12432/29212)
- ice: 2.0 % (291/14767)

ash detection

(Griessbach et al., AMT, 2014)

- sulfate: 16.5 % (654)
- basalt: 59.8 % (6387)
- ice: 0 % (0)

VOLCANIC AEROSOL CLASSIFICATION

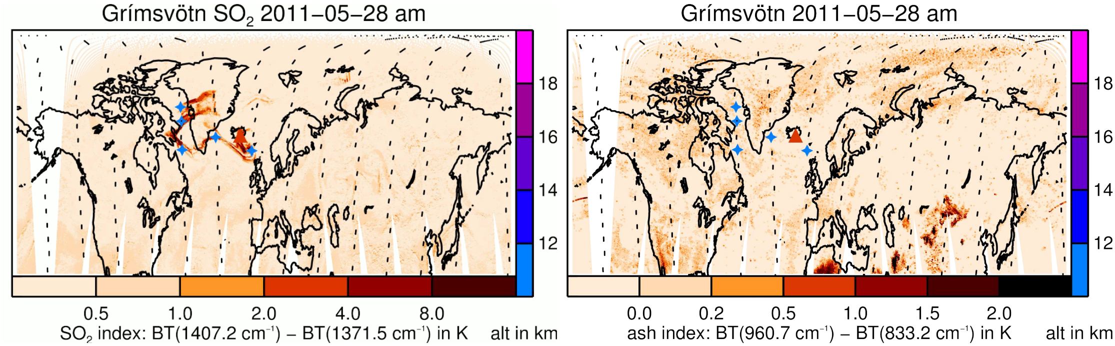
		detections	sulfate	ash	unknown
MIPAS	ice	291	2 (1 %)	289 (99 %)	0 (0.0 %)
	sulfate	3974	3608 (91 %)	0 (0.0 %)	366 (9 %)
	ash	12635	0 (0 %)	12235 (97 %)	400 (3.2 %)
	ash non	13152	0 (0 %)	12781 (97 %)	371 (3 %)
IRLS-CM	ice	259	113 (44 %)	146 (56 %)	0 (0 %)
	sulfate	3493	2770 (79 %)	26 (1 %)	697 (20 %)
	ash	3372	0 (0 %)	3130 (93 %)	242 (7 %)
	ash non	10559	0 (0.0 %)	10112 (96 %)	447 (4 %)
IRLS-DM	ice	360	0 (0 %)	142 (39 %)	218 (61 %)
	sulfate	5113	3732 (73 %)	0 (0.0 %)	1381 (27 %)
	ash	11725	1 (0 %)	9108 (78 %)	2616 (22 %)
	ash non	12254	0 (0 %)	9707 (79 %)	2547 (21 %)

With the new volcanic aerosol classification 95.4% (15843) could be assigned to an aerosol type. Only 4.6% (766) remained indistinguishable. Compared to 6387 spectra found by ash detection method, the ash detection rate has nearly doubled.

VERIFICATION OF AEROSOL CLASSIFICATION

Grimsvötn:

- mainly sulfate aerosol; little ash
- plume at trans-Atlantic flight levels

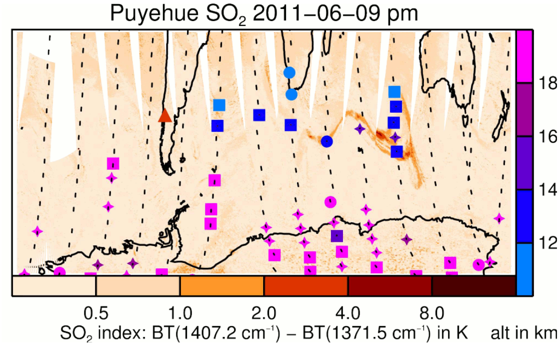


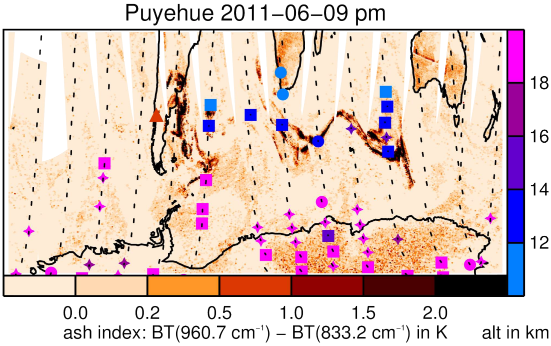
◆ – sulfate aerosol ■ – ash ● – unknown

VERIFICATION OF AEROSOL CLASSIFICATION

Puyehue:

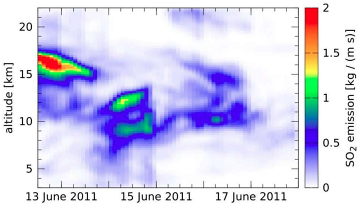
- rich in ash, but also some sulfate
- PSCs in polar vortex and at higher altitude; PSC classification should be used



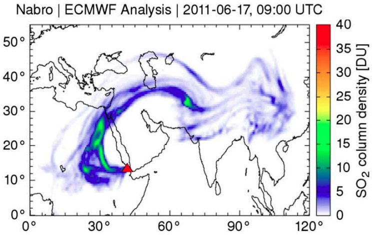


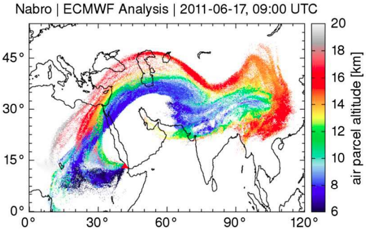
◆ – sulfate aerosol ■ – ash ● – unknown

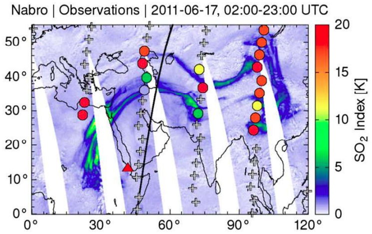
3D VOLCANIC PLUME TEST CASES



- reconstruction of altitude resolved emission time series
- based on AIRS SO_2 observations
- Lagrangian transport model: Massive-Parallel Trajectory Calculations (MPTRAC)
- Lagrangian plume dispersion simulations



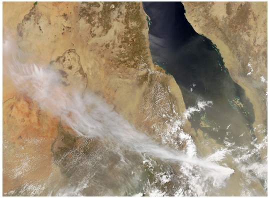




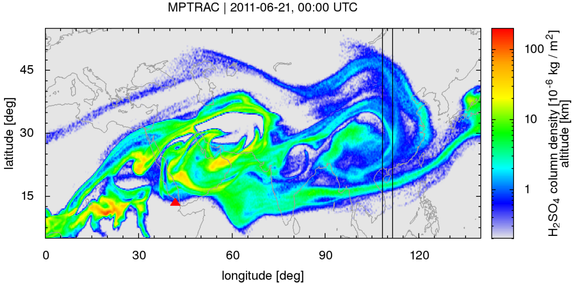
Nabro: Heng et al., GMD, 2015, Hoffmann et al. ACP, 2015; Sarychev: Wu et al., ACP, 2017

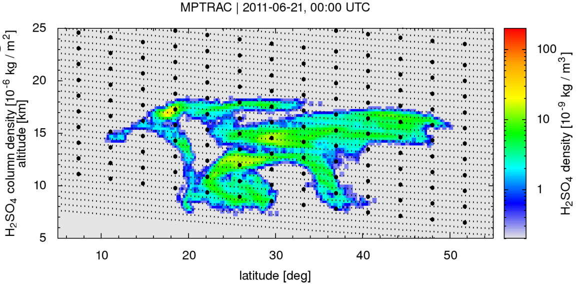
NABRO ERUPTION

Nabro (13.37 N, 41.7 E, 12 June – July 2011)
particularly complex plume transport
associated with the Asian monsoon circulation



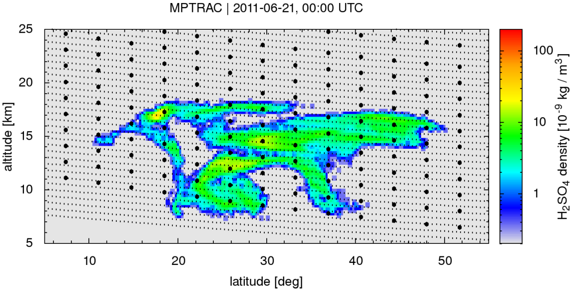
https://de.wikipedia.org/wiki/Nabro



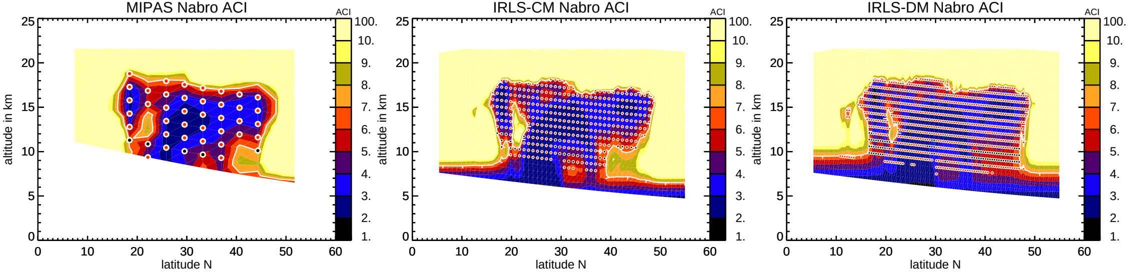


Selection of one feature-rich latitude-height cross section as test case and generation of MIPAS and IRLS spectra

NABRO SULFATE AEROSOL



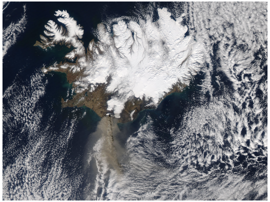
white – aerosol
black – ash
orange – sulfate



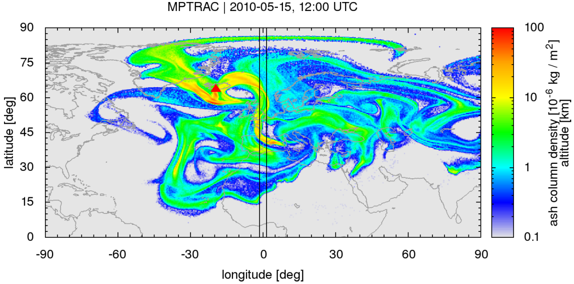
EYJAFJALLAJÖKULL ERUPTION

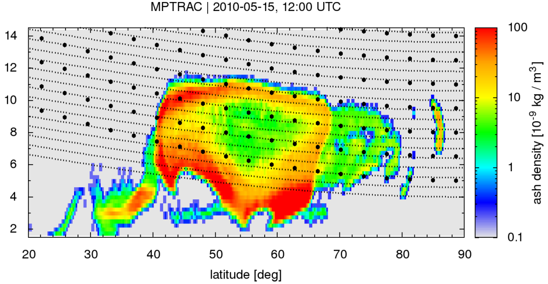
Eyjafjalla (63.63 N, 19.63 W, 14 April – 9 June 2011)

volcanic plume rich in volcanic ash caused aircraft groundings in mid- and northern Europe;
high economic impact

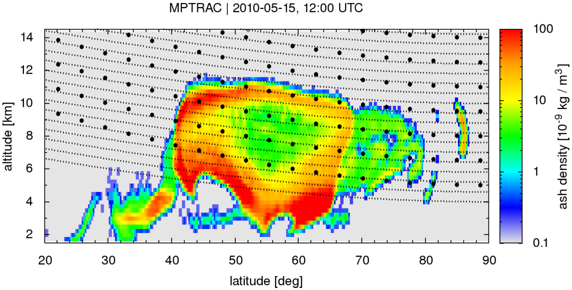


https://www.flickr.com/photos/gsfc/4530571145





EYJAFJALLA VOLCANIC ASH



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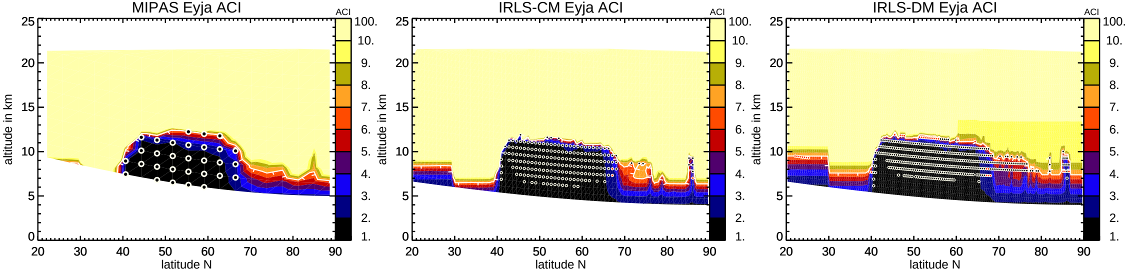

CONCLUSIONS

1. detection sensitivity: IRLS covers extinction range window where UV/VIS gets optically thick and IR nadir is not sensitive
2. top altitude: FOV, vertical sampling, broken cloud conditions, and extinction determine retrieved top altitude
3. aerosol classification: separation of ash and sulfate
4. IRLS vs MIPAS: MIPAS methods are applicable to IRLS
5. IRLS vs MIPAS: significantly better spatial resolution with IRLS