Ministry of science and education of Russian Federation
RUSSIAN STATE HYDROMETEOROLOGICAL UNIVERSITY

Volcanic ash distribution using hydrodynamic mesoscale regional model

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Objectives

- Volcanic ash: impacts on climate change and aircraft;
- Methods of volcanic ash observation;
- Forecast of volcanic ash transport (case study: *Eyjafjallajökull* eruption in April 2010).

What is volcanic ash?

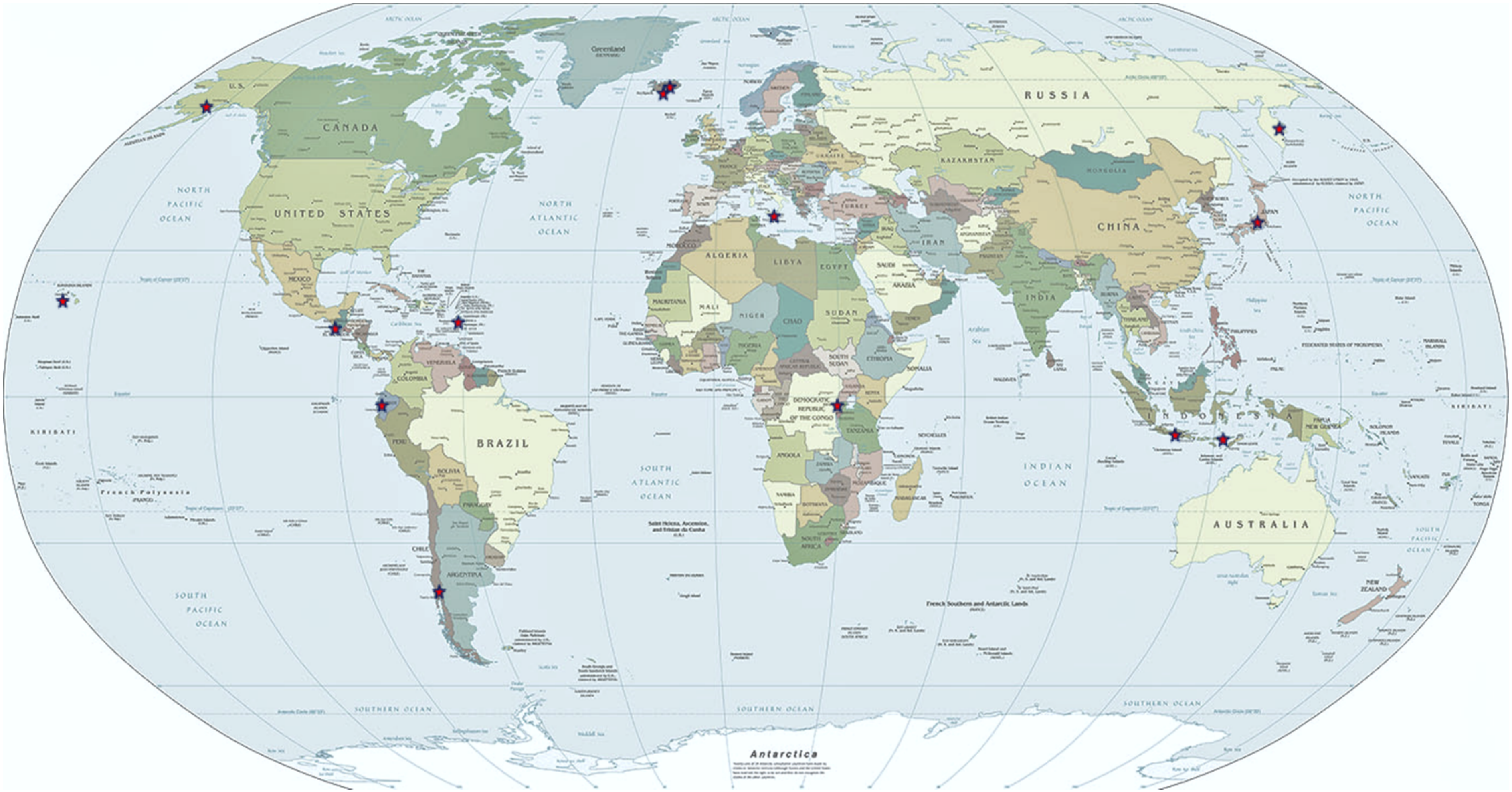
- Volcanic ash consists of fine-grained rock, mineral fragments, and glass shards (less than 2 mm in diameter) generated during eruptions.

(Stuefer, 2013)

https://www.meteoprog.kz/ru/news/45032/

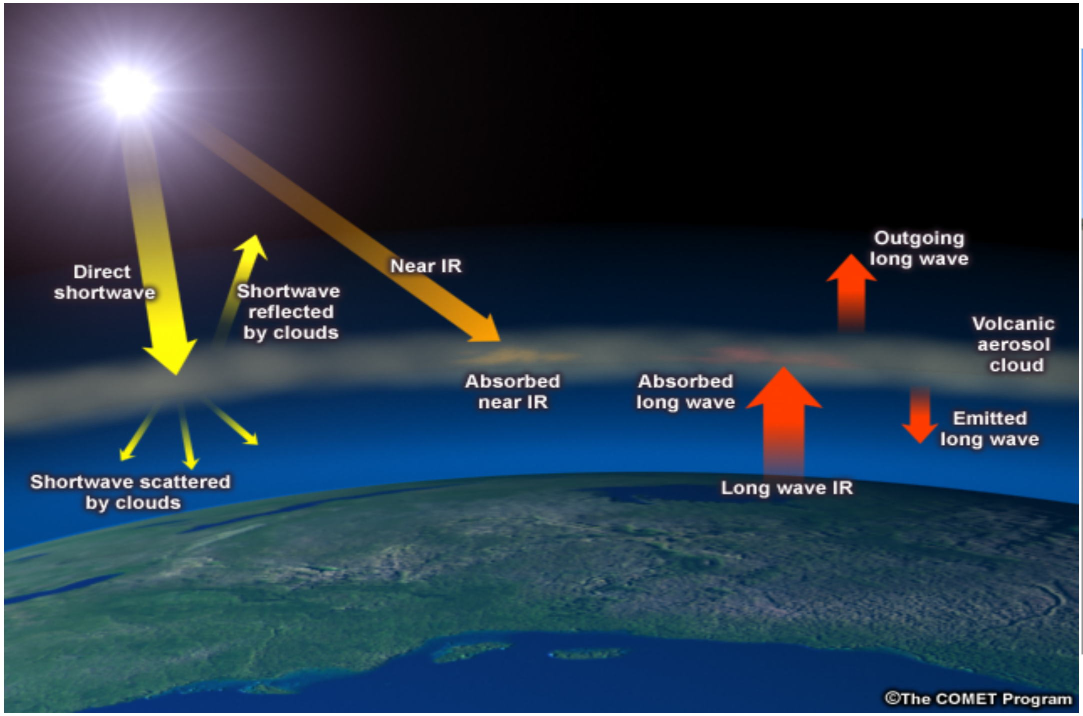
Eruption of Krakatau, Nov 2010, Sergey Lyahovec

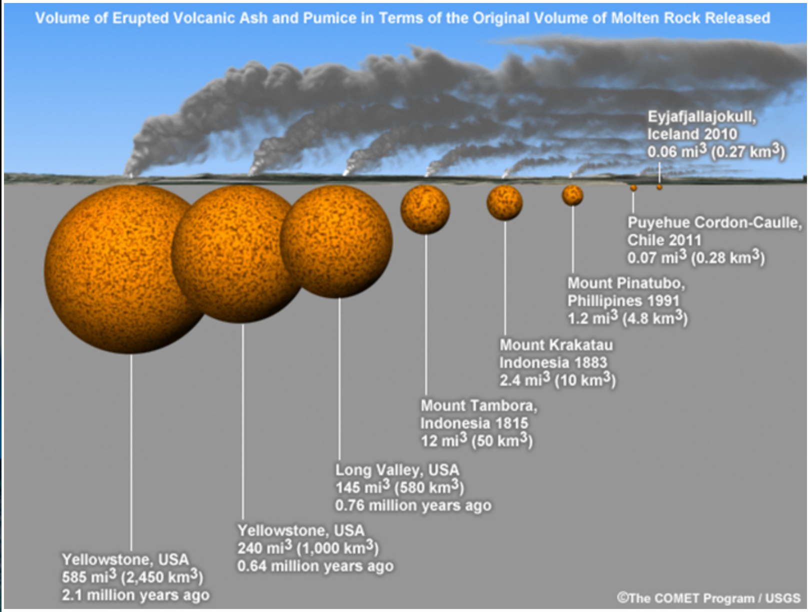
The largest volcanic eruption in XXI century



Role of the volcanic ash: Climate change

- Change the gas composition of the atmosphere;
- Increase the temperature of the atmosphere;
- Decrease the solar radiation reaching Earth's surface.

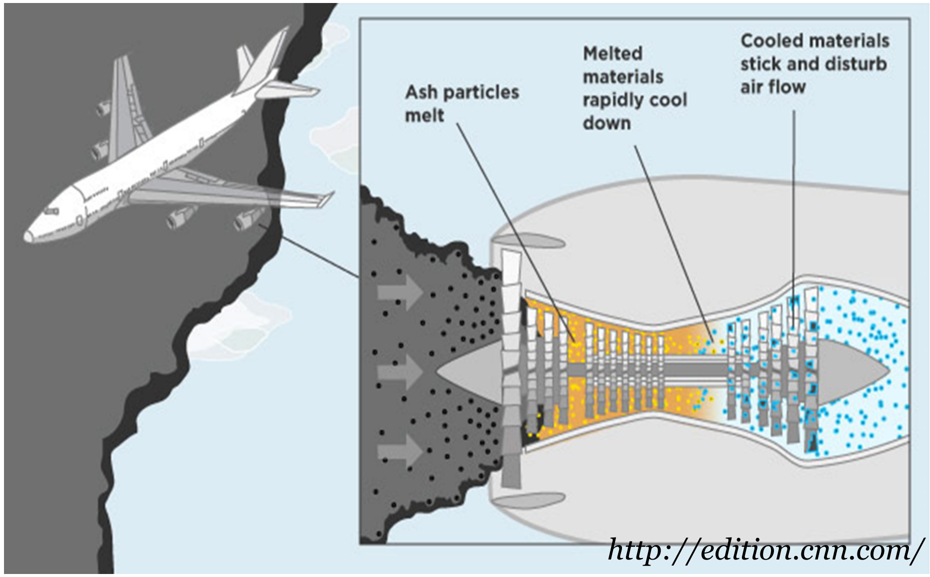




Role of the volcanic ash: Aircraft

- Ash particles can abrade forward-facing surfaces, including windscreens, fuselage surfaces;
- Ash contamination also can lead to failure of critical navigational and operational instruments;
- Moreover, the melting temperature of the glassy silicate material in an ash cloud is *lower* than combustion temperatures in modern jet engines.

http://www.thestar.com.my/news/

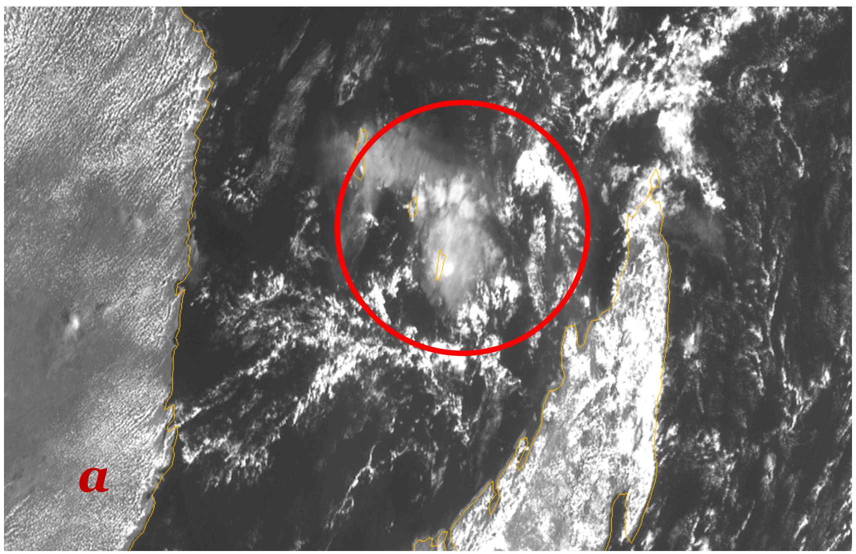


http://edition.cnn.com/

Satellite monitoring

Single-channel imagery:

- VIS channels, HRV (channel 12);
- IR3.9 (reflected component), IR10.8.

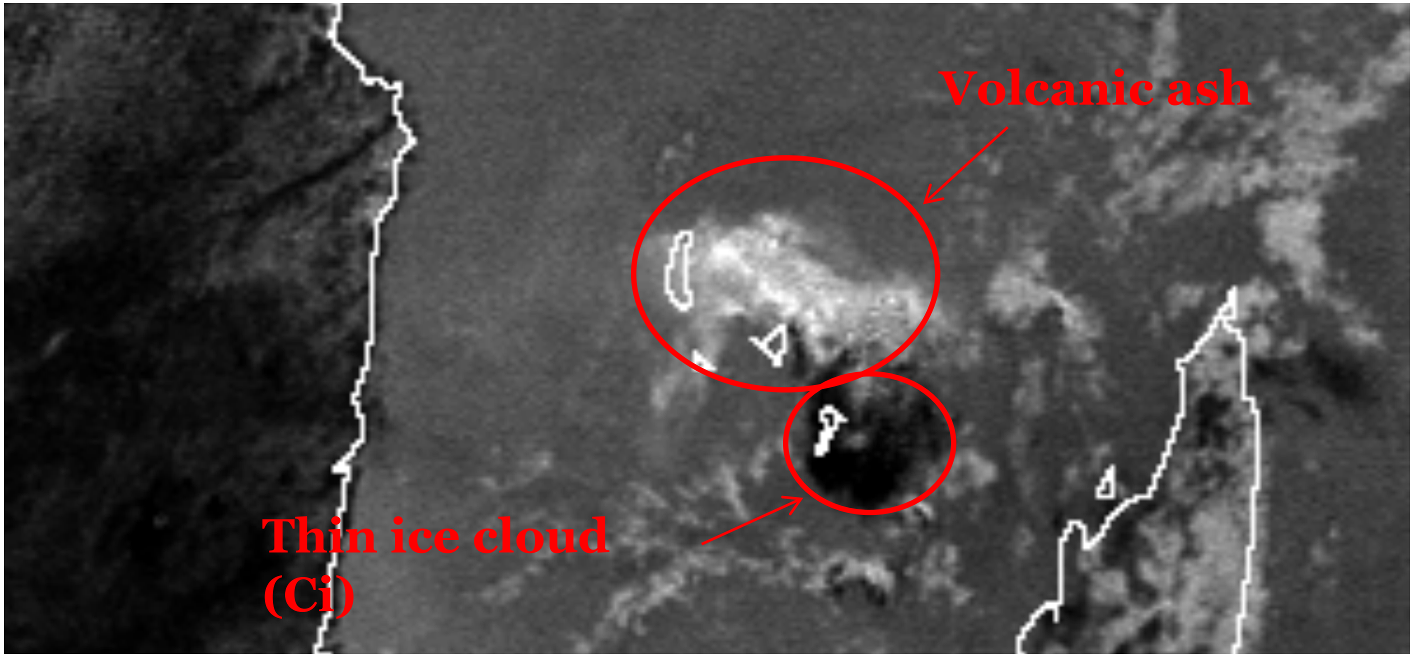


Comoros Islands. Ash plume in VIS channel *(a)* and IR3.9 channel *(b)* *(Jochen Kerkmann)*

Satellite monitoring

Multi-channel imagery:

- 10.8 μm – 12.0 μm brightness temperature difference (BTD);
- 3.9 μm - 10.8 μm BTD;
- 10.8 μm - 8.7 μm BTD;

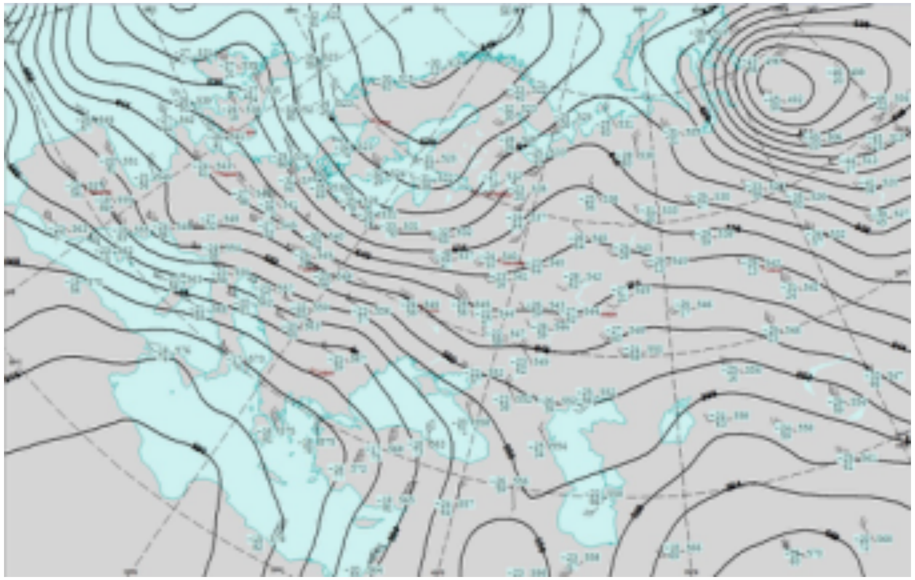


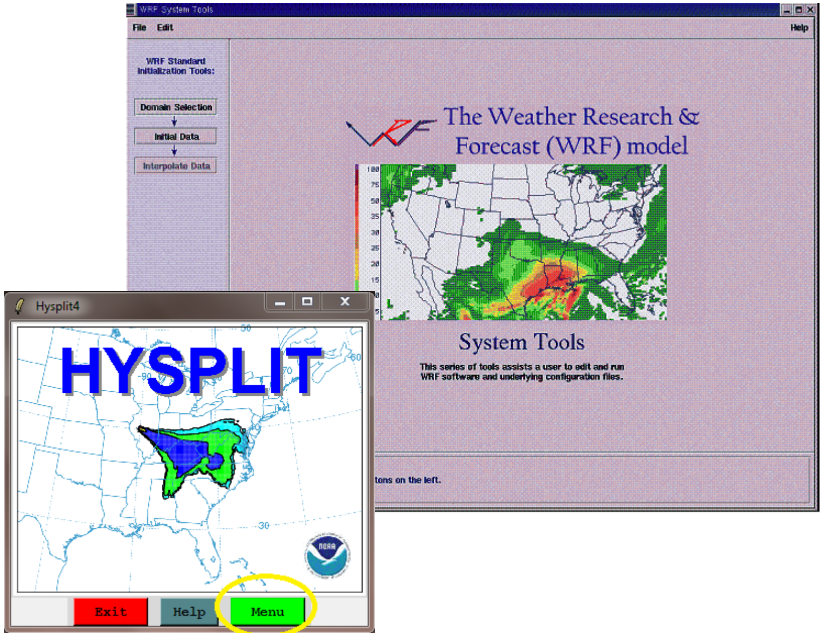
Comoros Islands. IR10.8 – IR12.0 (BTD)
(Jochen Kerkmann)

Methods of forecasting

- Synoptic method;

- Hydrodynamic method – *offline* (HYSPLIT), *online* (WRF – Chem).





Structure of practical work

- To use the WRF (ARW) model to get a standard set of data (*u* and *v* components of wind speed);

↓

- To produce the best wind forecast by choosing the right Planetary Boundary Layer physics scheme in the WRF model;

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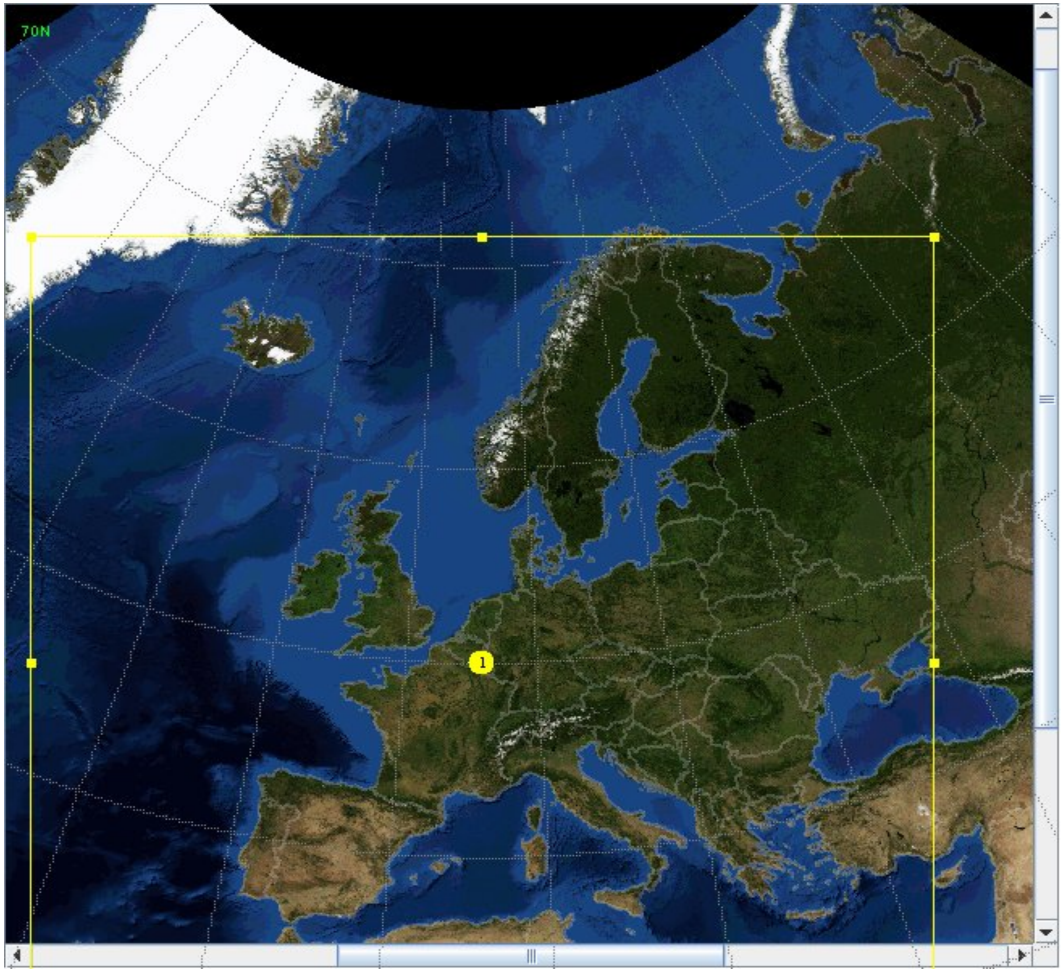
- To use these parameters as forcing in the HYSPLIT model.

Simulation area



Simulation domain:

- 300×200 grid cells,
- 18 km resolution,
- 35 sigma levels.

Planetary Boundary Layer:

- Asymmetric Convective Model version 2 (ACM2);
- Bougeault-Lacarrere (BouLac);
- Mellor-Yamada-Nakanishi-Niino (MYNN);

Sounding stations for estimation

- Estimation from 15 April 12 UTC – 16 April 12 UTC;
- Isobaric levels - 850, 700, 500, 300 hPa.

Data provided by the http://weather.uwyo.edu

Estimation of wind speed and direction

15.04.2010 12 UTC			850 hPa				700 hPa				500 hPa				300 hPa			
station	lat	lon	ff	dd	u	v	ff	dd	u	v	ff	dd	u	v	ff	dd	u	v
03005	60,13	-1,18	**15,9**	**306**	12,96	-9,26	**20,2**	**300**	17,50	-10,09	**25,1**	**298**	22,24	-11,59	**37,9**	**309**	29,43	-23,91
03238	55,01	-1,52	**7,1**	**14**	-1,79	-6,91	**8,2**	**16**	-2,23	-7,87	**13,3**	**20**	-4,52	-12,54	**12,4**	**339**	4,48	-11,59
01415	58,86	5,66	**9,8**	**328**	5,24	-8,31	**13,5**	**305**	11,08	-7,73	**17,6**	**312**	13,05	-11,80	**18,5**	**306**	14,97	-10,95
01241	63,7	9,6	**15,0**	**276**	14,95	-1,59	**15,7**	**275**	15,67	-1,23	**24,0**	**267**	23,93	1,48	**27,8**	**261**	27,43	4,43
10035	54,53	9,55	**5,0**	**347**	1,10	-4,89	**4,4**	**13**	-1,01	-4,27	**5,9**	**13**	-1,36	-5,77	**7,4**	**20**	-2,56	-6,97
02527	57,66	12,5	**4,8**	**283**	4,73	-1,06	**5,0**	**294**	4,60	-2,00	**7,6**	**299**	6,59	-3,72	**12,0**	**273**	12,02	-0,53
02365	62,53	17,45	**8,1**	**290**	7,60	-2,72	**10,1**	**288**	9,64	-3,09	**24,9**	**247**	22,98	9,70	**32,5**	**243**	28,99	14,71
02185	65,55	22,13	**6,3**	**245**	5,68	2,63	**9,3**	**260**	9,22	1,56	**18,4**	**247**	16,96	7,18	**34,6**	**243**	30,68	15,95
02963	60,81	23,5	**9,5**	**257**	9,23	2,06	**11,1**	**285**	10,70	-2,79	**10,0**	**293**	9,23	-3,95	**13,8**	**265**	13,78	1,30
26038	59,38	24,58	**5,2**	**274**	5,17	-0,34	**9,3**	**283**	9,09	-2,07	**14,0**	**282**	13,73	-2,86	**10,8**	**248**	10,03	3,98
10184	54,1	13,4	**2,7**	**14**	-0,67	-2,67	**2,6**	**90**	-2,57	0,00	**7,6**	**53**	-6,07	-4,54	**5,2**	**47**	-3,86	-3,54
12120	54,75	17,53	**1,3**	**240**	1,09	0,63	**3,1**	**44**	-2,13	-2,20	**5,1**	**58**	-4,31	-2,69	**4,0**	**91**	-3,99	0,08
02591	57,65	18,35	**2,0**	**295**	1,80	-0,83	**0,7**	**251**	0,69	0,24	**7,8**	**234**	6,30	4,62	**7,3**	**328**	3,87	-6,14
26063	59,95	30,7	**5,5**	**278**	5,44	-0,76	**8,0**	**298**	7,08	-3,82	**9,3**	**304**	7,70	-5,24	**19,1**	**321**	12,09	-14,79

- ACM2 – data of wind speed (ff, m/sec) and direction (dd, grad.)

15.04.2010 12 UTC			850 hPa				700 hPa				500 hPa				300 hPa			
station	lat	lon	ff	dd	u	v	ff	dd	u	v	ff	dd	u	v	ff	dd	u	v
03005	60,13	-1,18	**16,5**	**300**	-8,21	14,31	**22**	**295**	-9,25	19,96	**28**	**305**	-16,00	22,98	**38**	**310**	-24,35	29,18
03238	55,01	-1,52	**7,5**	**15**	-7,24	-1,94	**8**	**355**	-7,97	0,72	**17**	**10**	-16,74	-2,95	**12**	**335**	-10,86	5,10
01415	58,86	5,66	**10,5**	**325**	-8,58	6,05	**17,5**	**295**	-7,35	15,88	**20,5**	**300**	-10,20	17,78	**23,5**	**320**	-17,96	15,16
01241	63,7	9,6	**13,5**	**290**	-4,58	12,70	**13,5**	**275**	-1,14	13,45	**20,5**	**275**	-1,74	20,43	**21,5**	**250**	7,40	20,19
10035	54,53	9,55	**5**	**335**	-4,53	2,13	**4**	**30**	-3,46	-2,00	**6**	**40**	-4,60	-3,86	**6**	**45**	-4,24	-4,24
02527	57,66	12,5	**9,5**	**330**	-8,21	4,77	**14,5**	**280**	-2,48	14,29	**28,5**	**270**	0,07	28,50	**22,5**	**275**	-1,91	22,42
02365	62,53	17,45	**6**	**280**	-1,03	5,91	**12,5**	**275**	-1,06	12,46	**14**	**245**	5,94	12,68	**27**	**240**	13,55	23,35
02185	65,55	22,13	**10,5**	**295**	-4,41	9,53	**11,5**	**250**	3,96	10,80	**16**	**220**	12,28	10,26	**23,5**	**220**	18,03	15,07
02963	60,81	23,5	**12**	**265**	1,07	11,95	**11,5**	**280**	-1,97	11,33	**9**	**250**	3,10	8,45	**7**	**240**	3,51	6,05
26038	59,38	24,58	**9,5**	**250**	3,27	8,92	**12,5**	**235**	7,19	10,22	**13,5**	**250**	4,65	12,68	**24,5**	**245**	10,40	22,18
10184	54,1	13,4	**1**	**0**	-1,00	0,00	**2**	**5**	-1,99	-0,17	**4**	**30**	-3,46	-2,00	**8,5**	**75**	-2,21	-8,21
12120	54,75	17,53	**4**	**245**	1,70	3,62	**2**	**270**	0,00	2,00	**3**	**300**	-1,49	2,60	**4**	**90**	0,00	-4,00
02591	57,65	18,35	**3**	**265**	0,27	2,99	**5,5**	**270**	0,01	5,50	**8**	**295**	-3,36	7,26	**13**	**280**	-2,23	12,81
26063	59,95	30,7	**4**	**300**	-1,99	3,47	**7**	**270**	0,02	7,00	**9,5**	**300**	-4,73	8,24	**14,5**	**310**	-9,29	11,13

- Actual data of wind speed (ff, m/sec) and direction (dd, grad.)

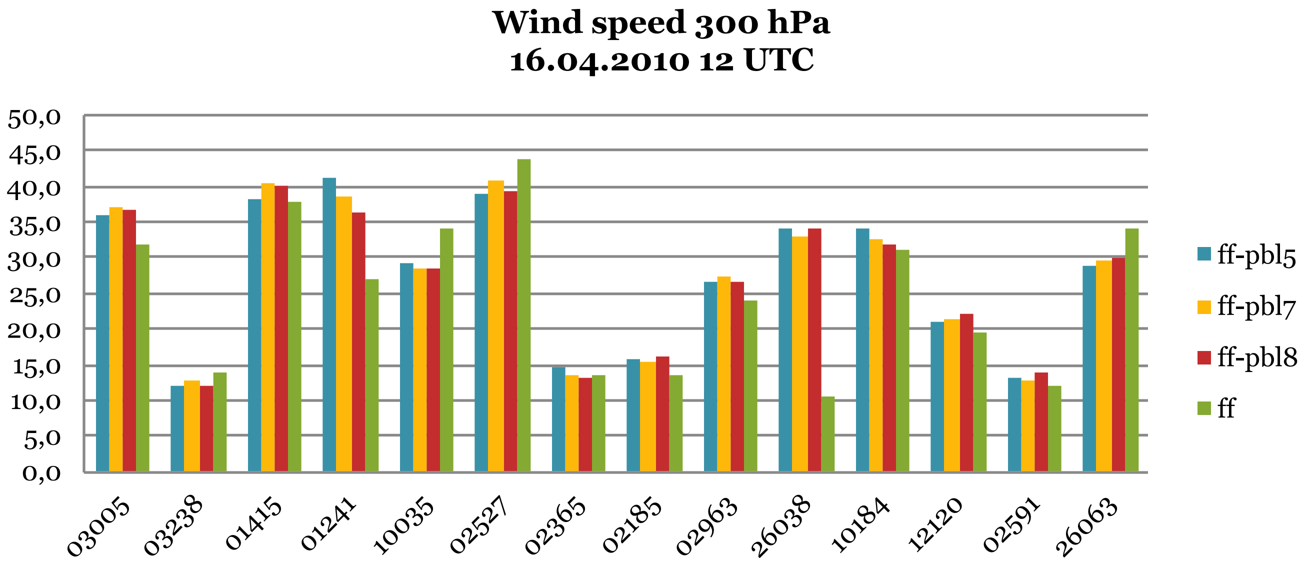
Estimation of wind speed and direction

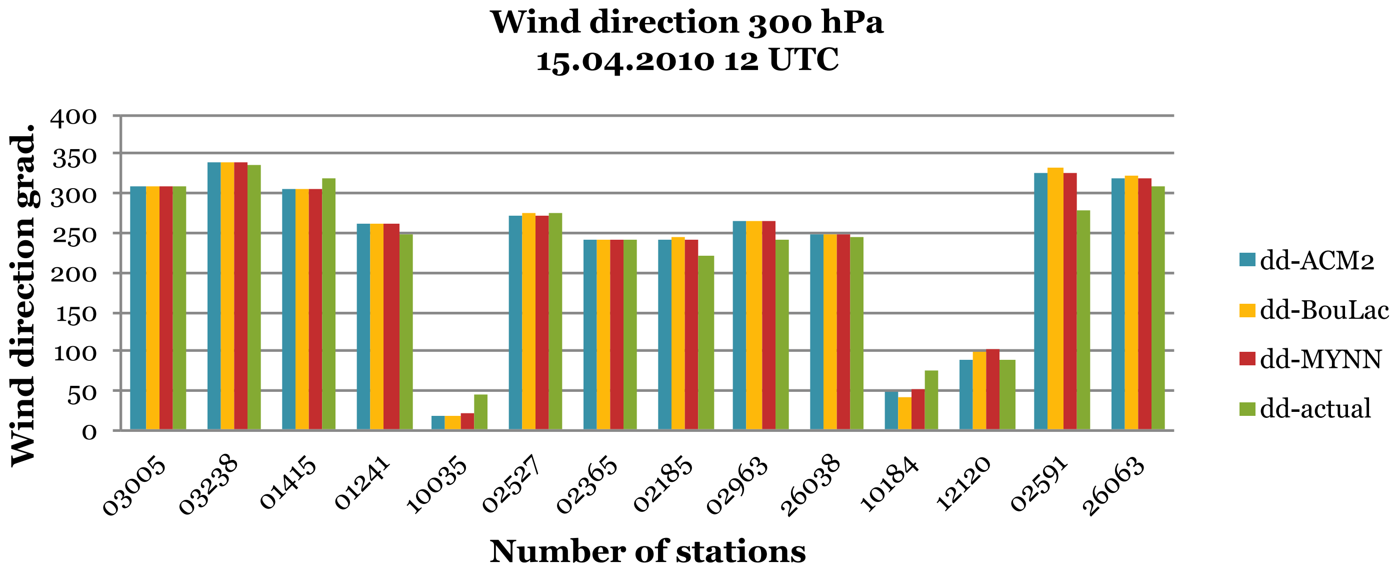
	ff 850 hPa			ff 700 hPa			ff 500 hPa			ff 300 hPa		
ACM2	abs	rel	cor	abs	rel	cor	abs	rel	cor	abs	rel	cor
03005	0,57	0,57	0,86	1,80	1,80	0,85	2,92	2,92	0,60	0,08	0,08	0,80
03238	0,36	0,36		0,18	-0,18		3,67	3,67		0,42	-0,42	
01415	0,67	0,67		3,99	3,99		2,90	2,90		4,96	4,96	
01241	1,53	-1,53		2,22	-2,22		3,48	-3,48		6,29	-6,29	
10035	0,01	-0,01		0,39	-0,39		0,07	0,07		1,42	-1,42	
02527	4,65	4,65		9,48	9,48		20,93	20,93		10,47	10,47	
02365	2,07	-2,07		2,38	2,38		10,95	-10,95		5,51	-5,51	
02185	4,24	4,24		2,15	2,15		2,42	-2,42		11,08	-11,08	
02963	2,55	2,55		0,45	0,45		1,04	-1,04		6,84	-6,84	
26038	4,32	4,32		3,18	3,18		0,52	-0,52		13,71	13,71	
10184	1,75	-1,75		0,57	-0,57		3,58	-3,58		3,27	3,27	
12120	2,74	2,74		1,06	-1,06		2,08	-2,08		0,01	0,01	
02591	1,01	1,01		4,77	4,77		0,19	0,19		5,74	5,74	
26063	1,50	-1,50		1,05	-1,05		0,18	0,18		4,60	-4,60	

- absolute (abs) error;
- relative (rel) error;
- correlation (cor).

	dd 850 hPa			dd 700 hPa			dd 500 hPa			dd 300 hPa		
ACM2	abs	rel	cor	abs	rel	cor	abs	rel	cor	abs	rel	cor
03005	5,61	-5,61	0,98	5,02	-5,02	0,45	7,41	7,41	0,80	0,84	0,84	0,99
03238	0,52	0,52		339,28	339,28		9,77	-9,77		3,94	-3,94	
01415	2,85	-2,85		9,95	-9,95		12,18	-12,18		13,75	13,75	
01241	13,88	13,88		0,47	0,47		8,49	8,49		10,87	-10,87	
10035	12,40	-12,40		16,75	16,75		26,86	26,86		24,92	24,92	
02527	47,26	47,26		13,53	-13,53		29,49	-29,49		2,40	2,40	
02365	9,77	-9,77		12,84	-12,84		2,16	-2,16		3,13	-3,13	
02185	49,76	49,76		10,41	-10,41		27,07	-27,07		22,57	-22,57	
02963	7,52	7,52		4,66	-4,66		43,23	-43,23		24,66	-24,66	
26038	23,81	-23,81		47,89	-47,89		31,83	-31,83		3,37	-3,37	
10184	14,09	-14,09		84,95	-84,95		23,16	-23,16		27,63	27,63	
12120	5,05	5,05		226,08	226,08		242,06	242,06		1,09	-1,09	
02591	29,86	-29,86		19,38	19,38		61,19	61,19		47,83	-47,83	
26063	21,97	21,97		28,40	-28,40		4,30	-4,30		10,80	-10,80	

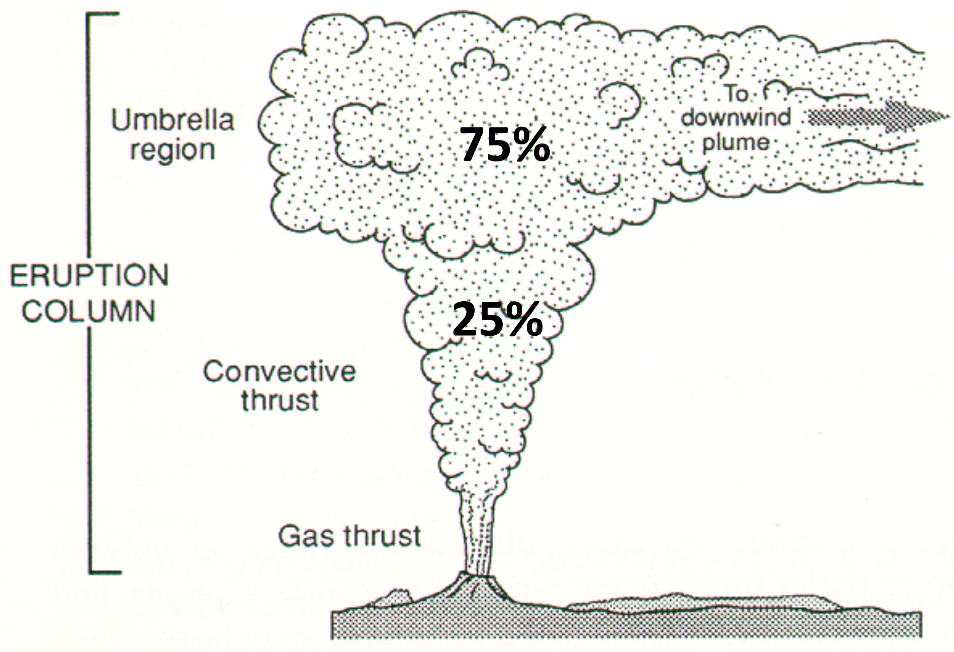
Estimation of wind speed and direction





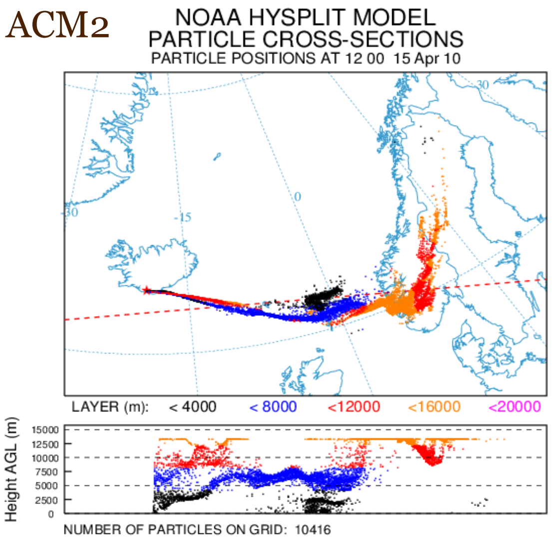
Mass distribution of volcanic ash

- A large volcanic plume has "umbrella" shape;
- Linear distribution from the vent to the "umbrella".

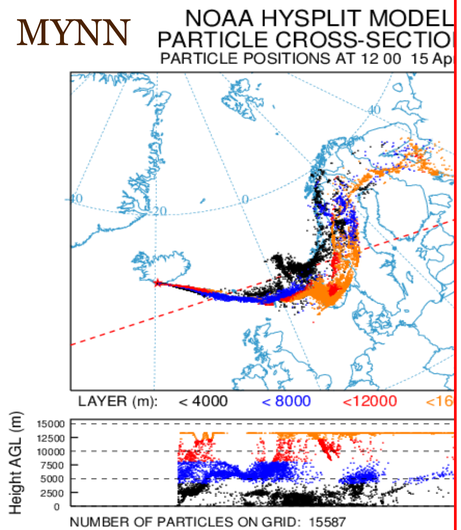


LABEL	Diameter	Percent	Release rate
P006	0.6µm	1%	0.008E+16 µg/m³
P020	2.0µm	7%	0.068E+16 µg/m³
P060	6.0µm	25%	0.250E+16 µg/m³
P200	20.0µm	67%	0.670E+16 µg/m³

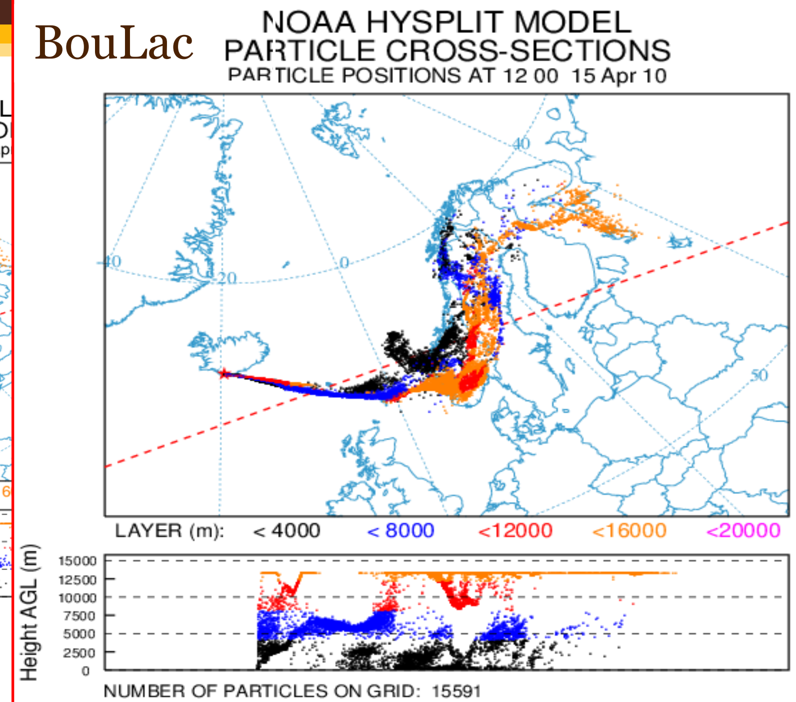
ACM2

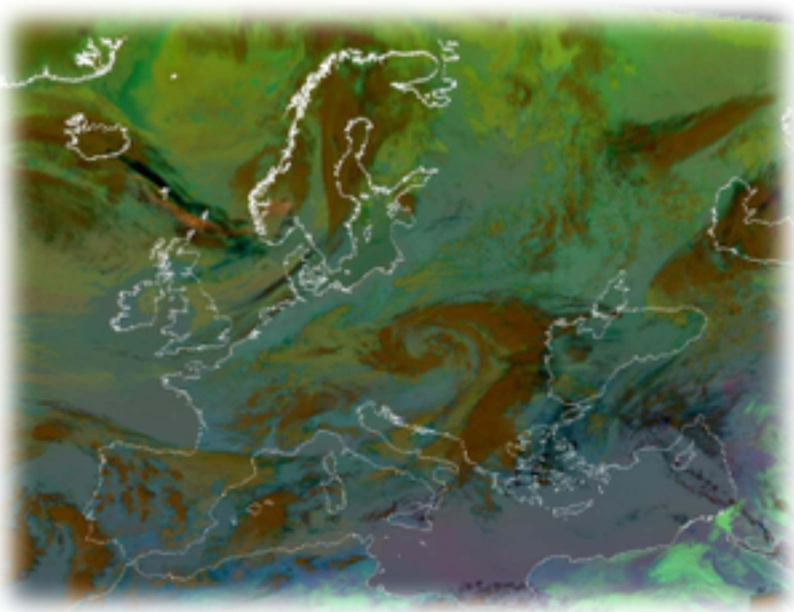


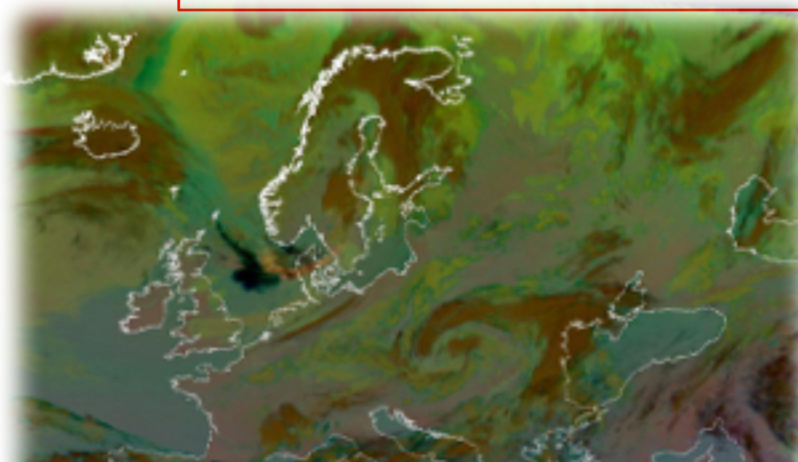
MYNN



BouLac





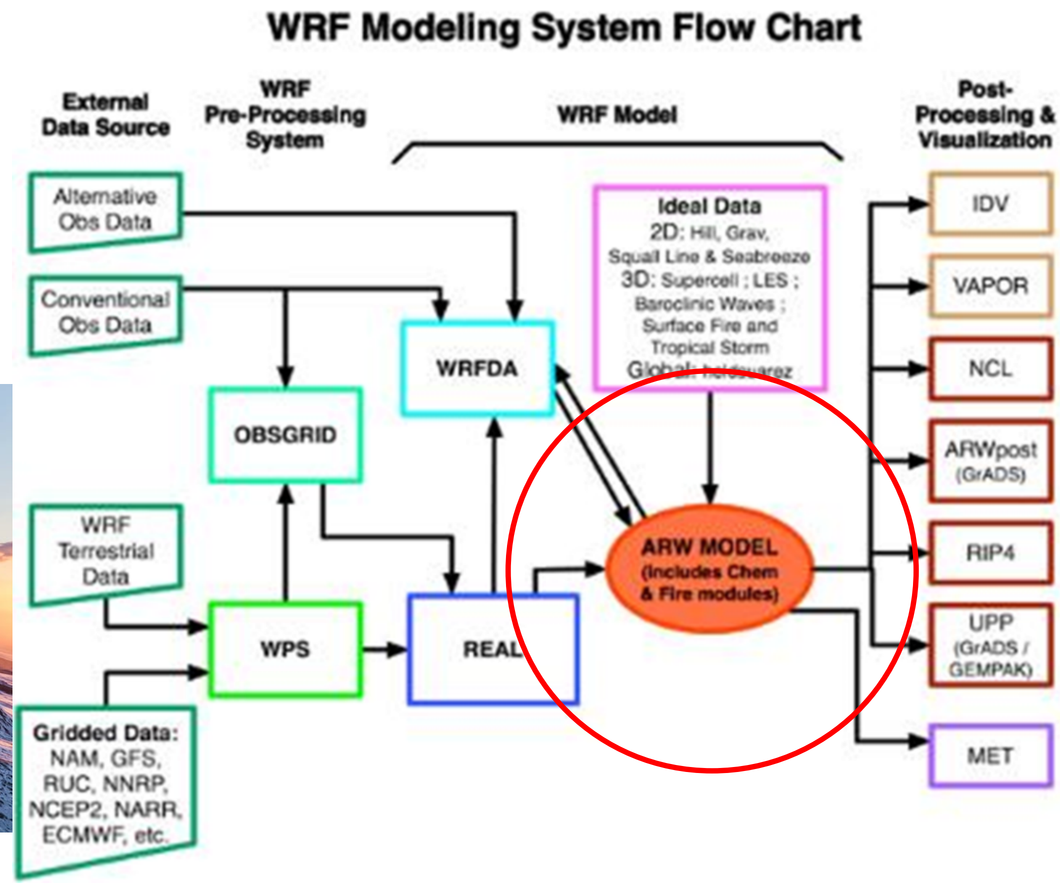


RGB satellite imagery;
15-16 April, 00 UTC

Further work

- Use WRF-Chem model for future eruptions *(Kamchatka Peninsula)*

Tolbachik volcano eruption, Kamchatka Peninsula



Conclusions

- Results in this work showed that the WRF (ARW) as a hydrodynamic mesoscale model make a verisimilar forecast of main meteorological data;

- Analysis of HYSPLIT pictures and satellite imagery showed that the HYSPLIT model with atmospheric forcing using BouLac parametrization gave more accurate estimation of ash trajectory and is more suitable to forecast the volcanic ash transport but insignificantly.

Thank You!