

Pórður Arason

Mælingar og skráning á niðurslætti eldinga til jarðar á Íslandi

apríl 2003 - mars 2004

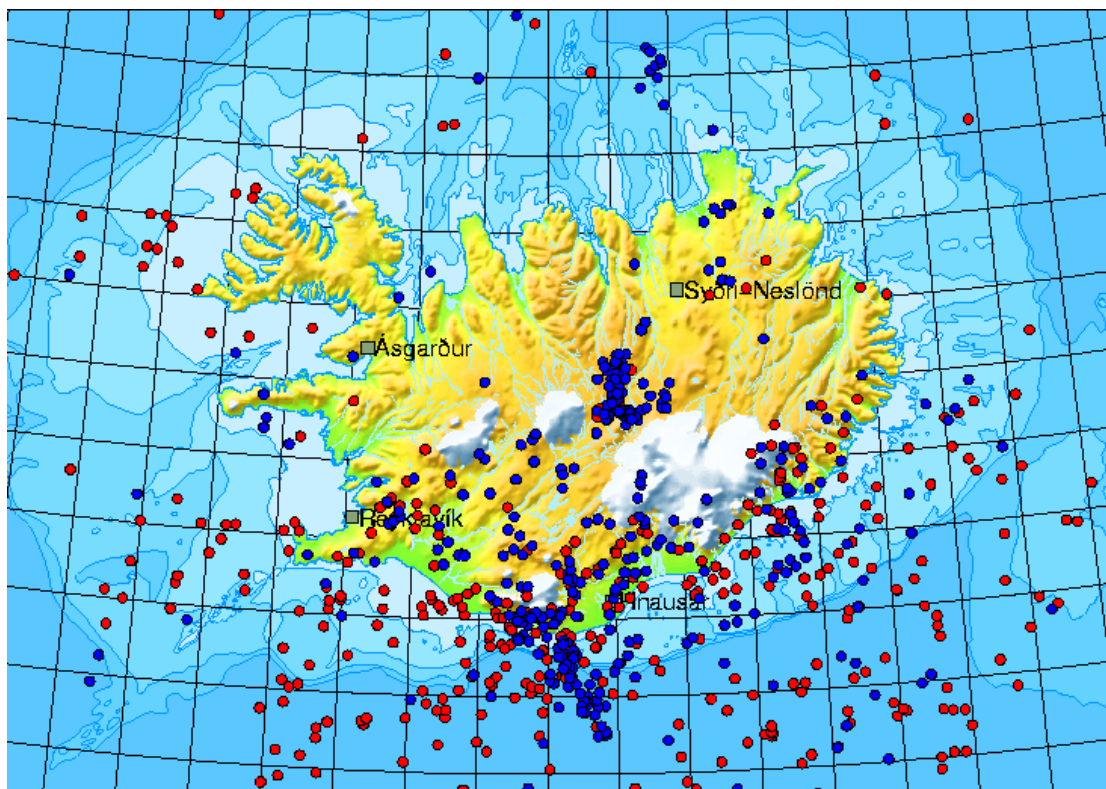
Ársskýrsla 2004, unnin fyrir Samstarfsnefnd um rannsóknir á eldingum:
Flugmálastjórn Íslands, Hitaveitu Suðurnesja hf, Landssíma Íslands hf, Landsvirkjun,
Löggildingarstofu, Og Vodafone, Orkuveitu Reykjavíkur, Rafmagnsveitur ríkisins, Samband
íslenskra tryggingafélaga og Veðurstofu Íslands

Efnisyfirlit

Inngangur	5
Rekstur mælistöðva	6
Flokkun LLP-eldingamæliskeyta	8
ATD sferics eldingar við Ísland	11
Annáll þrumuveðra við Ísland	12
Viðauki – ICLP greinar og EGU útdrættir	23
Comparison of data from a lightning location system and atmospheric parameters from a numerical weather prediction model	25
Seasonal and interannual variability of thunderstorms in Iceland and the origin of airmasses in the storms	31
The origin of airmasses in major thunderstorms in Iceland and the predictability of the storms	37
Climatology of thunder in Iceland	39

Inngangur

Hér er lýst mælingum á eldingum og fyrstu úrvinnslu gagnanna á Veðurstofu Íslands fyrir sl. ár, apríl 2003 til mars 2004. Greinargerðin er lögð fram á ársfund samstarfsnefndar um rannsóknir á eldingum 7. maí 2004. Þetta er sjöunda ársskýrslan sem lögð er fyrir ársfund samstarfsnefndarinnar og er nú í fyrsta sinn sett upp sem hluti ritraðar greinargerða frá Veðurstofu Íslands. Tíu stofnanir og fyrirtæki standa að þessu rannsóknasamstarfi, sem hófst sem tilraunaverkefni átta stofnana 1996. Gengið var frá nýjum samstarfssamningi til fimm ára í maí 2003. Aðilar að samstarfinu eru nú Flugmálastjórn Íslands, Hitaveita Suðurnesja hf, Landssími Íslands hf, Landsvirkjun, Löggildingarstofa, Og Vodafone, Orkuveita Reykjavíkur, Rafmagnsveitur ríkisins, Samband íslenskra tryggingafélaga og Veðurstofa Íslands.



Mynd 1. Staðsettar eldingar við Ísland á því tæplega sjö ára tímabili sem LLP-eldingastaðsetningakerfið hefur verið virkt eða frá júní 1997 til mars 2004. Rauðir deplar sýna jákvæðar eldingar og bláir neikvæðar, en formerki eldinga ákvarðast af rafhleðslu þrumuskýs miðað við jörðu.

Stjórn samstarfsnefndarinnar 2003-2004 var þannig skipuð

Eymundur Sigurðsson, fulltrúi Landsvirkjunar, formaður

Guðleifur M. Kristmundsson, fulltrúi Orkuveitu Reykjavíkur, ritari

Þórður Arason, fulltrúi Veðurstofu Íslands, meðstjórnandi

einnig störfuðu með stjórninni

Helga Jóhannsdóttir og Gísli Júlíusson

Í þessari greinargerð er birt yfirlit um rekstur eldingamælistöðva og kerfi á Veðurstofunni. Unnið var úr mælingum LLP-eldingamælikerfis samstarfsnefndarinnar (LLP, Lightning location and protection). Á mynd 1 má sjá staðsetingu eldinga úr LLP-kerfinu sl. sjö ár. Tekinn var saman fjöldi eldinga úr ATD sferics eldingakerfi bresku veðurstofunnar, sem nefndin hefur aðgang að (ATD, Arrival time difference). Þá er gefið yfirlit um þau þrumuveður sem hafa gengið yfir landið undanfarið ár samkvæmt þessum mælikerfum og mönnuðum athugunum á veðurstöðvum Veðurstofu Íslands. Að lokum eru í viðauka tvær rannsóknagreinar sem unnið hefur verið að á Veðurstofunni. Stefnt er að því að kynna efni þessara greina á alþjóðlegri eldingaráðstefnu næsta haust.

Þess er vænst að niðurstöður eldingarannsóknanna muni nýtast jafnt í vísindalegum tilgangi í samhengi við alþjóðarannsóknir á þessu sviði, sem og í hagnýtum tilgangi fyrir þær stofnanir og fyrirtæki sem að verkefnum standa.

Rekstur mælistöðva

Á starfsárinu voru fjórar eldingamælistöðvar úti á landi og ýmis tæki og hugbúnaður á Veðurstofunni sem tengjast eldingamælingum.

Syðri-Neslönd við Mývatn – LLP eldingamælistöð

LLP-stöðin var ekki heimsótt á árinu. Hún var síðast skoðuð af Þórði Arasyni og Sigvalda Árnasyni 14. september 2002. Rekstur stöðvarinnar hefur gengið mjög vel og ekkert athugavert komið upp. Stöðin er mjög næm á eldingar í samanburði við hinar stöðvarnar.

Hnausar í Meðallandi – LLP eldingamælistöð

Slökkt hefur verið á LLP-stöðinni undanfarið ár, eða allt frá 9. janúar 2003.

Ásgarður í Dölum – LLP eldingamælistöð

LLP-stöðin er löngum hljóð, en vaknar og gefur gagnlegar mælingar þegar þrumuveður eru nálægt landinu. Síðast var stöðin heimsótt í september 2001 af Þórði Arasyni og Árna Sigurðssyni.

Reykjavík – LLP eldingamælistöð

Rekstur LLP-stöðvarinnar gekk vel á starfsárinu, en allnokkuð er af suði sem stöðin skráir og eru því skeyti nokkuð mörg.

Keflavíkurflugvöllur – ATD Sferics eldingamælistöð

Stöðin er í eigu bresku veðurstofunnar, en gegn aðstoð við rekstur hennar höfum við aðgang að mæligögnum fyrir norðanvert Atlantshaf. Rekstur stöðvarinnar hefur gengið mjög vel.

Reykjavík – LLP innhringimiðstöð

PC-tölva á Veðurstofunni sér um að hringja inn gögn frá öllum þremur LLP-eldingamælistöðvunum. Hringt var í stöðvarnar á 3 klst fresti á starfsárinu. Gögnin voru skráð á miðlægan disk yfir tölvunet. Innhringitölvun er tengd GPS-tæki þannig að hægt er að umreikna alla atburði yfir á réttan tíma. Rekstur innhringitölvunnar gekk vel á árinu.

Reykjavík – EFMS bylgjuskráningarkerfi

EFMS-bylgjuskráningarkerfið skráir bylgjuform eldinga, en ekki er unnið sérstaklega úr gögnunum (EFMS, Elektrisk feltnálesystem). Loftnetið brotnaði, líklega í óveðri 2. mars 2004, og kapall slitnaði. Gert var við það 16. mars 2004.

Þrumuspár

Þrumuspár voru áfram reiknaðar út frá franska veðurlíkaninu Arpège. Reiknaður er lóðréttur hitastigull úr líkaninu og þeir reikningar notaðir til að meta hættu á myndun þrumuveðra. Þessir reikningar eru gerðir einu sinni á sólarhring. Þrumuviðvaranir eru sendar í tölvupósti. Á árinu hófst vinna við að stórbæta þrumuspár.

Vefurinn

Vefsíður samstarfsnefndarinnar voru sem fyrr á <http://www.vedur.is/athuganir/eldingar>. LLP-vefsíður voru uppfærðar á klukkustundarfresti. Vegna bilunar í tölvukerfi Veðurstofunnar komu gögn úr LLP-kerfinu ekki á vefinn frá lokum febrúar 2004. Engin mæligögn töpuðust vegna þessa ástands. Sferics síður með bresku gögnunum fyrir norðanvert Atlantshaf voru uppfærðar á 30 mín fresti. Þrumuspásíður voru uppfærðar einu sinni á sólarhring.

ALDF - eldingamælistöðvar

Samstarfsnefndin keypti á árinu 2003 fjóra ALDF-eldinganema af dönsku veðurstofunni (ALDF, Advanced lightning direction finder). Stefnt er að því að ALDF-tækin, framleidd um 1990, taki við af LLP-tækjunum sem eru frá því um 1980. Á starfsárinu var unnið við að tengja ALDF-nemana við PC-tölvur og GPS-tæki og útbúa innhringimiðstöð fyrir þetta kerfi ásamt tilheyrandi forritun. Þessari vinnu er ekki lokið.

Flokkun LLP-eldingamæliskeyta

Í þessum kafla er sýnt, mest með töflum, hvernig skeyti frá LLP-mælistöðvum verða að samtímaatburðum, og úr samtímaatburðunum eru valdar eldingar við Ísland. Kaflinn er sambærilegur við álíka kafla í ársskýrslum samstarfsnefndarinnar 1999 til 2003.

Í **töflu 1** er sýndur fjöldi skeyta frá eldingamælistöðvunum, mánuð fyrir mánuð síðastliðið ár, apríl 2003 til mars 2004. Fyrst er sýndur heildarfjöldi skeyta í mánuði og hafa þau verið lægst 563 í október 2003 og hæst 9574 í janúar 2004. Þar næst er sýndur fjöldi skeyta frá hverri stöð RE: Reykjavík, SN: Syðri-Neslönd, ÁS: Ásgarður. Engin gögn eru frá Hnausastöðinni á þessu tímabili. Að lokum er sýndur fjöldi stakra skeyta og fjöldi skeyta sem koma á sama tíma og skeyti frá annarri stöð, en 232 skeyti koma samtímis skeytum frá annarri mælistöð. Meirihluti samtímaskeytanna komu um sumarið 2003.

Tafla 1. Flokkun skeyta frá eldingamælistöðvum

Mánuður	Fjöldi	RE	SN	ÁS	Stök	Samtíma
2003-04	1927	1837	84	6	1921	6
2003-05	567	359	196	13	557	10
2003-06	590	410	167	12	578	12
2003-07	2391	1959	377	55	2320	71
2003-08	3469	2988	441	40	3411	58
2003-09	956	634	230	92	926	30
2003-10	563	452	89	22	554	9
2003-11	679	556	105	18	670	9
2003-12	5575	5506	56	13	5564	11
2004-01	9574	9358	203	13	9560	14
2004-02	741	598	96	47	741	0
2004-03	2215	2171	26	18	2213	2
Samtals	29247	26828	2070	349	29015	232

Þau 232 skeyti sem komu ekki stök mynda 106 samtímaatburði. Í 92 skipti eru einungis skeyti frá tveimur stöðvum í samtímaatburði og í 14 tilvikum skynja allar þrjár stöðvar samtímaatburð.

Í **töflu 2** má sjá flokkun samtímaatburðanna 106 eftir mánuðum, þar sem gallaðir atburðir eru tíndir burt og búið til úrval fyrir frekari úrvinnslu. Í 46 tilfellum verður atburður ónothæfur vegna mettunar á a.m.k. einni stöð en þá fást engar upplýsingar um stefnu í eldingu. Ef einungis ein stöð gefur stefnu er ekki hægt að finna nothæfa staðsetningu og eru þessir atburðir ekki notaðir frekar í þessari úrvinnslu. Þó ein stöð mettist, en e.t.v. tvær sem skynja stefnu er atburðurinn notaður. Í 4 tilfellum skynjuðu einungis tvær stöðvar eldinguna, en hún var á grunnlínu stöðvanna, annað hvort milli stöðvanna eða í beinni línu út frá þeim. Miðað var við 10° grunnhorn frá grunnlínu. Staðsetning slíkra eldinga verður alltaf mjög ónákvæm og voru þessir atburðir ekki notaðir frekar. Í engu tilfelli var þekkt suð-stefna frá Reykjavík eða Syðri-Neslöndum í skeyti á sama tíma og skeyti frá annarri stöð. Í 3 tilvikum voru samtímaatburðir tíndir burt vegna andstæðrar pólnar. Í 3 tilvikum var um augljóslega ósamstæð gögn að ræða. Eftir þessa hreinsun erum við með skráningu á 50 eldingum. Þetta eru mun færri eldingar en undanfarin ár. Hér kemur til að einungis þrjár stöðvar voru í gangi, en einnig hafa áberandi fá þrumuveður gengið yfir landið sl. vetur.

Tafla 2. Flokkun samtímaatburða

Mánuður	Samtíma	Mettun	Grunnlína	Suð	Pólun	Ósamstæð	Val
2003-04	3	0	0	0	0	0	3
2003-05	5	2	0	0	0	0	3
2003-06	6	2	2	0	0	0	2
2003-07	31	24	0	0	1	1	5
2003-08	26	8	1	0	0	1	16
2003-09	15	1	1	0	0	0	13
2003-10	4	1	0	0	0	0	3
2003-11	4	1	0	0	0	1	2
2003-12	4	1	0	0	0	0	3
2004-01	7	5	0	0	2	0	0
2004-02	0	0	0	0	0	0	0
2004-03	1	1	0	0	0	0	0
Samtals	106	46	4	0	3	3	50

Af þessum 50 völdu samtímaatburðum er stór hluti þar sem stefnur eru nær samsíða, sem bendir til að eldingarnar séu mjög fjarlægjar. Valinn var rammi umhverfis Ísland sem markast af 60°-70°N og 0°-40°V og valdar þær eldingar sem staðsetjast innan rammans. Við þetta fækkaði eldingunum niður í 24 og er 60°N baugurinn nær eingöngu takmarkandi. Til að velja enn frekar eldingar á landi og rétt umhverfis landið var valinn hringur með 400 km geisla og miðju í 65°N, 19°V. Erum við þá komin með 20 eldingar, 13 yfir sjó og 7 yfir landi.

Tafla 3 sýnir flokkun allra staðsettra eldinga frá upphafi mælinga. Goseldingar í töflunni eru fyrir Grímsvatnagosið 1998 og Heklugosið 2000.

Í **töflu 4** má sjá flokkun þeirra 20 eldinga sem falla innan 400 km hringsins. Sjá má fjölda eftir formerki eldinga, hve margar stöðvar tóku þátt í staðsetningu og fjarlægðarbíl frá landsmiðju. Eldingarnar eru það fáar að ekki er efni til að álykta mikið um straumstyrk þeirra, en þó var hann sem fyrr að jafnaði hærri í jákvæðum eldingum. Þannig var straumstyrkurinn +41 til +167 kA í jákvæðu eldingunum átta (meðaltal 100 kA), á meðan hann var -25 til -171 kA í neikvæðu eldingunum tólf (meðaltal 88 kA).

Tafla 3. Staðsetning eldinga

Ár	Val	Innan ramma	Óstöðugar	Innan hrings	Sjór	Land	Gos
1997 (7 mán)	198	100	8	72	45	27	-
1998	617	236	8	131	66	65	9
1999	141	88	10	39	29	10	-
2000	372	240	1	179	70	109	6
2001	576	293	1	134	110	24	-
2002	405	171	2	128	102	26	-
2003 (3 mán)	147	91	4	69	30	39	-
2003 (9 mán)	50	24	2	20	13	7	-
2004 (3 mán)	0	0	0	0	0	0	-
	(50)	(24)	(2)	(20)	(13)	(7)	
Samtals	2506	1242	36	772	465	307	15

Rammi miðast við svæðið 60°-70°N og 0°-40°V. Hringur miðast við 400 km geisla frá 65°N, 19°V.

Tafla 4. Flokkun eldinga innan hrings fyrir tímabilið 2003-04 til 2004-03

	Fjöldi	Neikvæðar	Jákvæðar	2 stöðvar	3 stöðvar	Fjarlægð (km)
Sjór	13	10	3	13	0	219-389
Land	7	2	5	7	0	133-189
Samtals	20	12	8	20	0	133-389

ATD sferics eldingar við Ísland

Gegn aðstoð við að reka ATD sferics eldingamælistöð á Keflavíkurflugvelli, sem er í eigu bresku veðurstofunnar, fær Veðurstofa Íslands aðgang að gögnum Bretanna. Á 30 mín fresti er náð í nýjustu ATD sferics gögn frá bresku veðurstofunni. Gögnin eru vistuð og teiknuð á kort af N-Atlantshafi fyrir vefsíðu. Nákvæm tímasetning ATD eldinganna, sem við höfum aðgang að, er örlítið villandi, því skráður er tíminn þegar gögnin eru skráð í gagnagrunn á bresku veðurstofunni, sem skeður e.t.v. 5-15 mín eftir niðurslátt eldingarinnar. Til stendur að leiðrétta þetta hjá Bretunum. Í **töflu 5** má

sjá fjölda eldinga á og við Ísland sem LLP- og ATD-kerfin hafa skráð á árinu. Tvö mestu þrumuveðrin voru 9. ágúst og 19. júlí 2003. Heildarfjöldi ATD eldinga á árinu er 515, innan hrings með 400 km geisla frá miðju landinu. Þennan fjölda þarf að bera saman við 20 eldingar skráðar af LLP-kerfinu. ATD sferics kerfið skráir eitthvað af skýjaeldingum, en LLP-kerfið er hannað til að hafna þeim. Ljóst má þó vera að LLP-kerfið skráir einungis lítið brot af raunverulegum eldingum á og við landið.

Tafla 5. *Fjöldi eldinga við Ísland eftir dögum*

Dagsetning	LLP	ATD	Dagsetning	LLP	ATD
2003-05-07	0	1	2003-10-27	0	1
2003-05-22	1	1	2003-10-28	1	2
2003-05-26	0	1	2003-11-04	1	4
2003-06-17	0	2	2003-11-05	0	11
2003-06-18	0	3	2003-11-13	0	1
2003-06-19	0	10	2003-12-03	0	1
2003-07-13	0	1	2003-12-20	0	1
2003-07-18	0	19	2003-12-24	0	3
2003-07-19	1	73	2003-12-25	0	2
2003-07-20	0	7	2004-01-07	0	1
2003-07-26	0	15	2004-01-08	0	6
2003-07-27	1	13	2004-01-16	0	1
2003-07-28	0	17	2004-01-17	0	11
2003-07-29	0	1	2004-01-23	0	12
2003-08-02	0	1	2004-03-02	0	4
2003-08-08	0	3	2004-03-11	0	1
2003-08-09	1	172	2004-03-12	0	6
2003-08-10	11	65	2004-03-13	0	27
2003-08-12	0	1	2004-03-14	0	3
2003-09-04	3	5	2004-03-18	0	3
2003-09-14	0	1	2004-03-27	0	1
2003-09-28	0	1	Samtals	20	515

Fjöldi miðast við eldingar innan hrings með 400 km geisla frá 65°N, 19°V.

Annáll þrumuveðra við Ísland

Gerð er grein fyrir þeim eldingum sem við höfum fréttir af eða hafa verið mældar af LLP- og ATD-eldingastaðsetningakerfunum á sl. ári, frá 1. apríl 2003 til 31. mars 2004. Þegar tímasetning er tiltekin frá veðurskeytastöðvum er átt við að vart var við þrumur og/eða eldingar einhvern tíma á gefnu tímabili. Á úrkomustöðvum

Veðurstofunnar er einungis mæld úrkoma og snjódypt einu sinni á dag, kl. 9 árdegis. Úrkomustöðvarnar skrá einnig hvort vart hafi verið við þrumuveður undangenginn sólarhring, þ.e. frá kl. 9 árdegis daginn áður, en nákvæmari tímasetning er ekki skráð.

Lýsing á einstökum veðrum og skemmdum

Sjá má staðsettar eldingar í apríl til júní á **mynd 2**.

- 8. apríl 2003:** Veðurathugunarmaður á úrkomustöð í Skaftafelli tilkynnti um þrumuveður undangenginn sólarhring.
- 7. maí 2003:** ATD sferics kerfið skráði eina eldingu 12 km NNV við Garðskaga kl. 04:50.
- 22. maí 2003:** LLP-kerfið staðsetti eina eldingu á Suðurlandi, 12 km NA af Hellu kl. 14:02. ATD sferics kerfið skráði eina eldingu 22 km VNV við LLP-eldinguna kl. 14:10. Þetta er trúlega sama eldingin.
- 26. maí 2003:** Veðurathugunarmaður á Grímsstöðum á Fjöllum tilkynnti um þrumuveður á síðustu klukkustund og miðlungs eða mikla rigningu á athugunartíma ($w = 92$) kl. 15. ATD sferics kerfið skráði eina eldingu 5 km SA af Grímsstöðum kl. 13:55.
- 7. júní 2003:** Í frétt Mbl. 10. júní sagði: „Talið er að elding hafi kveikt í húsi í Hveragerði á sunnudag. Eldur kom upp í millilofti og logaði upp í þakið en slökkviliðið í Hveragerði var fljótt á vettvang og tókst að koma í veg fyrir stórtjón“.
- 17. júní 2003:** ATD sferics kerfið skráði tvær eldingar um 13 km VSV við Sauðárkrók kl. 19:00.
- 18. júní 2003:** Veðurathugunarmaður í Æðey tilkynnti um þrumuveður milli athugunartíma ($W_1 = 9$) kl. 18 (einhverntíma á tímabilinu kl. 15-17). ATD sferics kerfið skráði tvær eldingar á Norðurlandi, nálægt Húsavík og Blönduósi kl. 15:25 og 18:30.
- 19. júní 2003:** Veðurathugunarmaður í Básum á Goðalandi tilkynnti um þrumuveður milli athugunartíma ($W_1 = 9$) kl. 18 (einhverntíma á tímabilinu kl. 12-17). Morguninn eftir tilkynnti veðurathugunarmaður á úrkomustöð á Skógum undir Eyjafjöllum um þrumuveður undangenginn sólarhring. ATD sferics kerfið skráði tíu eldingar á Mýrdalsjökulssvæðinu kl. 14:10 – 16:05.

Sjá má staðsettar eldingar í júlí til september á **mynd 3**.

- 13. júlí 2003:** ATD sferics kerfið skráði eina eldingu á Sprengisandi kl. 17:50.
- 18. júlí 2003:** ATD sferics kerfið skráði eina eldingu í Veiðivötnum, sex eldingar á Austurlandi og tólf austan við landið kl. 15:20 – 20:10.
- 19. júlí 2003:** LLP-kerfið staðsetti eina eldingu NA af landinu kl. 04:58. ATD sferics kerfið skráði 73 eldinar á og við landið, af þeim voru 63 á landi kl. 13:10 – 19:30, flestar norðan Vatnajökuls og nálægt Mýrdalsjökli. Kort með staðsettum eldingum í þessu þrumuveðri má sjá á **mynd 6**.
- 26. júlí 2003:** Veðurathugunarmenn í Reykjavík tilkynntu um þrumuveður milli athugana ($W_1 = 9$) kl. 18 (einhverntíma á tímabilinu kl. 15-17). Morguninn eftir tilkynnti veðurathugunarmaður á úrkomustöð í Vogsósum um þrumuveður undangenginn sólarhring. Í frétt Mbl. 28. júlí sagði: „Eldingu laust niður í Fokker-flugvél Flugfélags Íslands skömmu eftir flugtak frá Reykjavíkflugvelli á laugardag og var henni þegar snúið til baka. Um borð voru 28 farþegar auk áhafnar“. ATD sferics kerfið skráði ellefu eldingar þennan dag SA af landinu og fjórar eldingar 22-33 km NV af Reykjavík kl. 17:05 – 17:20.
- 27. júlí 2003:** Veðurathugunarmaður í Hjarðarlandi í Biskupstungum tilkynnti um að heyrst hafi í skruggum en engin úrkoma var á athugunarstað ($w = 17$) kl. 18. Morguninn eftir tilkynnti veðurathugunarmaður á úrkomustöð á Augastöðum í Borgarfirði um þrumuveður undangenginn sólarhring. Í frétt Mbl. 29. júlí sagði: „Eldingar skutu mönnum og dýrum skelk í bringu og húsin nötruðu undan þrumunum í gjörningaveðri sem gekk yfir Biskupstungurnar á sunnudagskvöld“. LLP-kerfið staðsetti tvær eldingar langt SA af landinu um morguninn. ATD sferics kerfið skráði nokkrar eldingar þennan dag SA af landinu og níu eldingar á Suðurlandi kl. 16:25 – 20:15.
- 28. júlí 2003:** Veðurathugunarmenn á úrkomustöðvunum Augastöðum, Stafni í Svartárdal og á Skeiðsfossvirkjun tilkynntu um þrumuveður undangenginn sólarhring þ. 29. Í frétt Mbl. 29. júlí sagði: „Blossar stóðu út úr rafmagnstöflum, ljós kviknaði á aflögðum ljósastaur, innstungur sviðnuðu og hross trylltust í þrumuveðrum sem hafa gengið yfir í Biskupstungum og við Öxarfjörð á síðustu tveimur sólarhringum“. ATD sferics kerfið skráði nokkrar eldingar um morguninn SA af landinu og 15 eldingar á Norður- og Vesturlandi kl. 14:30 – 21:15.

- 8.-10. ágúst 2003:** Veðurathugunarmaður á Hrauni á Skaga tilkynnti um að heyrst hafi í skruggum en engin úrkoma var á athugunarstað ($w = 17$) kl. 18 þ. 9. Veðurathugunarmaður á úrkomustöð á Augastöðum í Borgarfirði tilkynnti um þrumuveður undangenginn sólarhring þ. 10. LLP-kerfið staðsetti eina eldingu 13 km VSV af Ásgarði í Dölum kl. 16:44 þ. 9., og tíu eldingar N af landinu kl. 00:47 – 01:39 þ. 10., og eina eldingu 20 km SA af Kröfluvirkjun kl. 01:02 þ. 10. ATD sferics kerfið skráði mikinn fjölda eldinga SA af landinu kl. 19:35 þ. 8. til kl. 08:30 þ. 9. Síðan skráði kerfið 152 eldingar SA við Langjökul kl. 14:40 – 17:35 þ. 9. Að lokum var mikill fjöldi eldinga skráður fyrir norðan landið kl. 18:00 þ. 9. til kl. 08:30 þ. 10. Kort með staðsettum eldingum í þrumuveðrinu 9. ágúst má sjá á **mynd 7**.
- 12. ágúst 2003:** ATD sferics kerfið skráði eina eldingu 6 km sunnan við Grímsstaði á Fjöllum kl. 16:35.
- 4. september 2003:** LLP-kerfið staðsetti þrjár eldingar á Lónsöræfum kl. 18:27 – 18:29. ATD sferics kerfið skráði þrjár eldingar á Suðurlandi kl. 13:40 – 16:15.
- 13. september 2003:** Veðurathugunarmaður á Vatnsskarðshólum í Mýrdal tilkynnti um þrumuveður með eða án úrkomu á síðustu klukkustund ($w = 29$) kl. 18.
- 22.-23. september 2003:** LLP-kerfið skynjaði tíu eldingar langt suður af landinu kl. 22:16-01:53.

Sjá má staðsettar eldingar í október til desember á **mynd 4**.

- 6. október 2003:** Veðurathugunarmaður á úrkomustöð á Ísafirði tilkynnti um þrumuveður undangenginn sólarhring.
- 10. október 2003:** Veðurathugunarmaður á úrkomustöð á Stóra-Vatnshorni í Dölum tilkynnti um þrumuveður undangenginn sólarhring.
- 27.-28. október 2003:** Veðurathugunarmenn á Keflavíkurflugvelli tilkynntu um þrumuveður milli athugunartíma ($W_1 = 9$) kl. 24 þ. 27. (einhverntíma á tímabilinu kl. 21-23). LLP-kerfið staðsetti eina eldingu 14 km SSV af Hvolsvelli kl. 03:15 þ. 28.
- 4.-5. nóvember 2003:** Veðurathugunarmaður á Stórhöfða í Vestmannaeyjum tilkynnti um þrumuveður milli athugunartíma ($W_1 = 9$) kl. 24 þ. 4. (einhverntíma á tímabilinu kl. 21-23), og þrumuveður með eða án úrkomu á síðustu klukkustund ($w = 29$) kl. 03 þ. 5. Að morgni þ. 5. tilkynnti

veðurathugunarmaður á úrkomustöð á Vogsósum um þrumuveður undangenginn sólarhring. Í frétt Mbl. 20. nóvember sagði: „Komið hefur í ljós að skemmdirnar á Urðarvita í Vestmannaeyjum fyrir skömmu voru ekki af mannavöldum heldur náttúrunnar. Þrír starfsmenn Siglingastofnunar komu til Eyja og staðfestu þeir að elding hafi laskað vitann“. LLP-kerfið staðsetti eina eldingu langt suður af Reykjanesi kl. 21:54 þ. 4. ATD sferics kerfið skráði fjölda eldinga suður af landinu þessa tvo daga, 10 þeirra náðu norður fyrir 62°N, en engar inn á land.

- 3. desember 2003:** Veðurathugunarmenn á úrkomustöðvunum Hítardal og Hjarðarfelli á Snæfellsnesi tilkynntu um þrumuveður undangenginn sólarhring þ. 4. LLP-kerfið skynjaði þrjár eldingar langt suður af landinu kl. 11:33-11:39. ATD sferics kerfið skráði eina eldingu á Suðurlandi kl. 16:05.
- 22. desember 2003:** Veðurathugunarmaður á Sauðanesvita á Tröllaskaga tilkynnti um að heyrst hafi í skruggum en engin úrkoma var á athugunarstað (w = 17) kl. 12.
- 24. desember 2003:** ATD sferics kerfið skráði tvær eldingar í Þórsmörk kl. 03:10 og 05:45.

Sjá má staðsettar eldingar í janúar til mars á **mynd 5**.

- 8. janúar 2004:** ATD sferics kerfið skráði fjórar eldingar á SA landi kl. 00:55 – 04:10.
- 17. janúar 2004:** Veðurathugunarmaður á úrkomustöðinni Kvískerjum í Öræfum tilkynnti um þrumuveður undangenginn sólarhring þ. 18. ATD sferics kerfið skráði nokkrar eldingar SA af landinu kl. 13:25 – 17:25.
- 23. janúar 2004:** Veðurathugunarmenn tilkynntu um þrumuveður undangenginn sólarhring á úrkomustöðvunum Vogsósum þ. 23. og Kvískerjum þ. 24. ATD sferics kerfið skráði allmargar eldingar S af landinu og frá Reykjanesi til Hafnar kl. 00:00 – 20:00.
- 2. mars 2004:** Í frétt Mbl. 3. mars sagði: „Eldingu laust niður í Fokker-flugvél Flugfélags Íslands á leið til Akureyrar upp úr kl. tvö í gær eða um tíu mínútum eftir að vélin hóf sig á loft af Reykjavíkflugvelli“. Eldingin fór inn og út um nef vélarinnar. Henni var snúið við til skoðunar. Einhverjir á Veðurstofunni

töldu sig hafa heyrt í þrumu (skv. Halldóri Björnssyni). ATD sferics kerfið skráði nokkrar eldingar S af landinu og tvær inni á landi kl. 18:45 og 22:30.

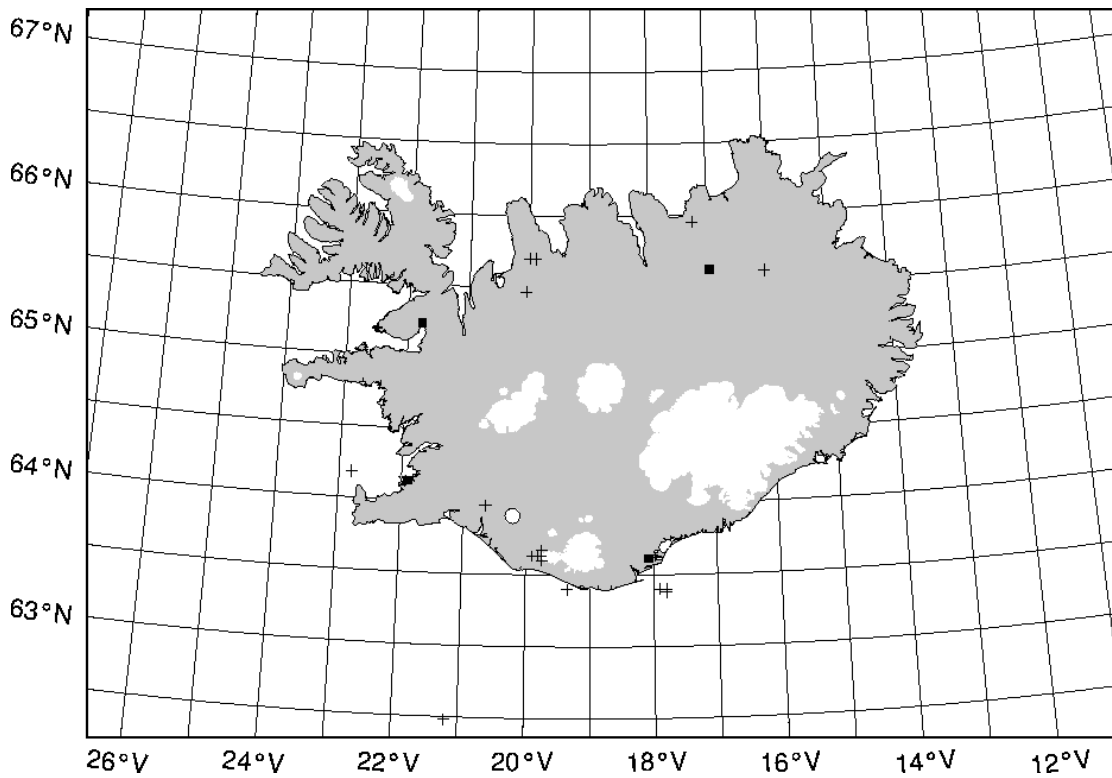
12.-14. mars 2004: Veðurathugunarmenn tilkynntu um þrumuveður undangenginn sólarhring á úrkomustöðvunum Kvískerjum þ. 13., Kerlingardal við Mýrdalsjökul þ. 13., Stafafell í Lóni þ. 13., Hánefsstöðum í Seyðisfirði þ. 13. og Skaftafelli þ. 14. ATD sferics kerfið skráði 40 eldingar frá Öræfasveit til Seyðisfjarðar kl. 18:50 þ. 12. til kl. 09:20 þ. 14. Kort með staðsettum eldingum í þrumuveðrinu 13. mars má sjá á **mynd 8**.

Kort af þrumuveðrum ársins

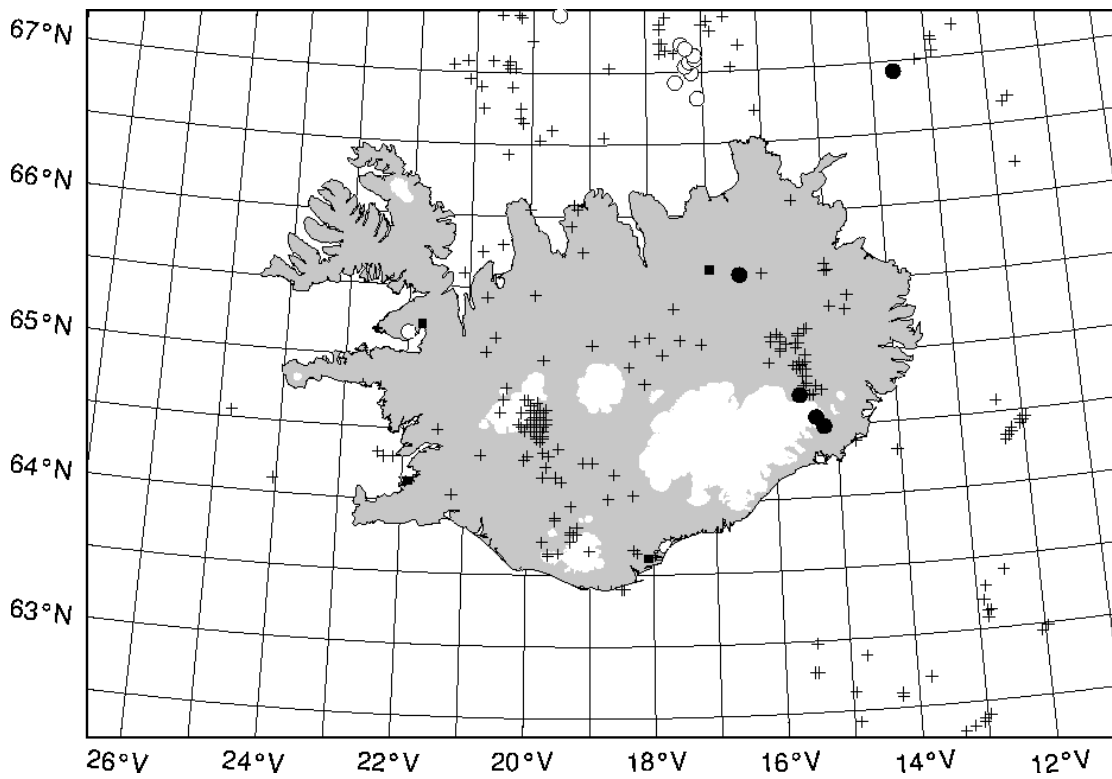
Á **myndum 2 til 5** eru sýnd þriggja mánaða tímabil með staðsetningarkortum. Staðsetningarkortin sýna staðsettar eldingar með LLP-eldingamælikerfinu, þar sem jákvæðar/neikvæðar eldingar eru sýndar með fylltum/opnum hringjum. Eldingastaðsetingar úr ATD sferics kerfinu eru sýndar með plús merki (+). Mælistöðvarnar eru sýndar með litlum ferningum. Hafa ber í huga að mældar eldingar eru innan nokkuð stærra svæðis en staðsetningarkortin sýna, og því sjást ekki allar eldingarnar á kortunum.

Myndir 6 til 8 sýna þrjú mestu þrumuveður ársins, 19. júlí 2003, 9. ágúst 2003 og 13. mars 2004.

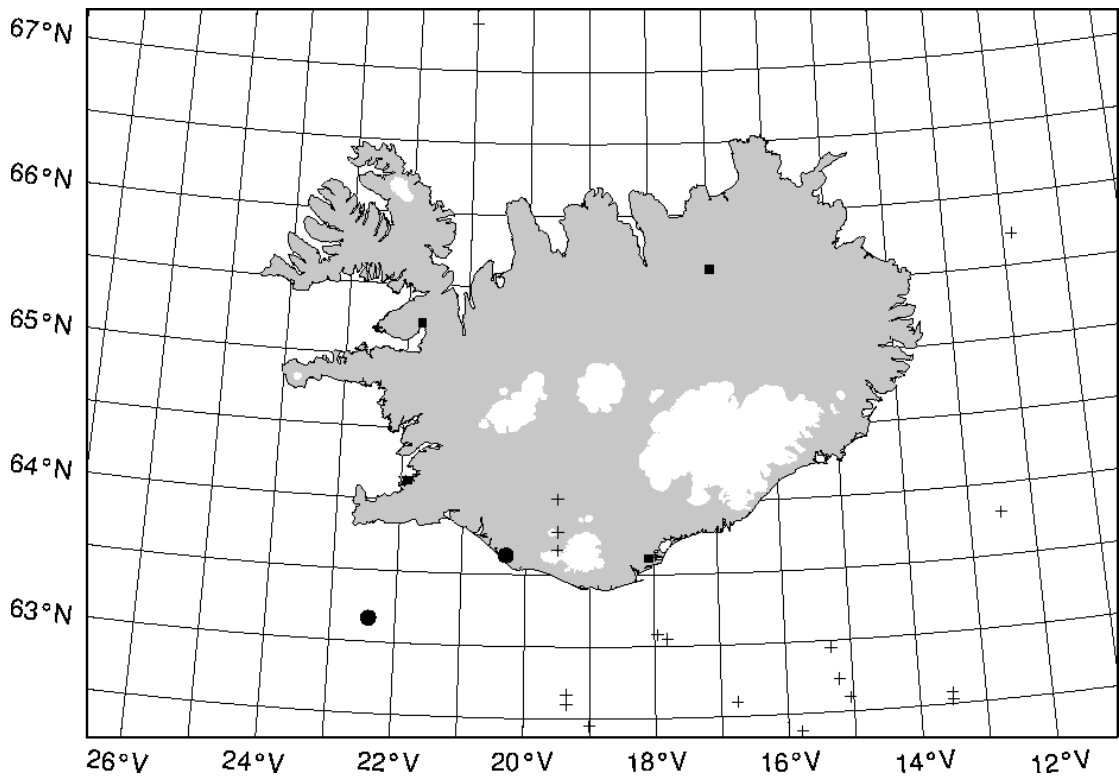
Á **mynd 9** er yfirlit yfir allt mæliárið. Á **mynd 10** eru allar eldingar úr LLP-eldingamælikerfinu frá júní 1997 til mars 2004 sýndar á einu korti. Á **mynd 11** eru allar eldingar úr breska ATD sferics eldingamælikerfinu frá september 1998 til mars 2004 sýndar á einu korti.



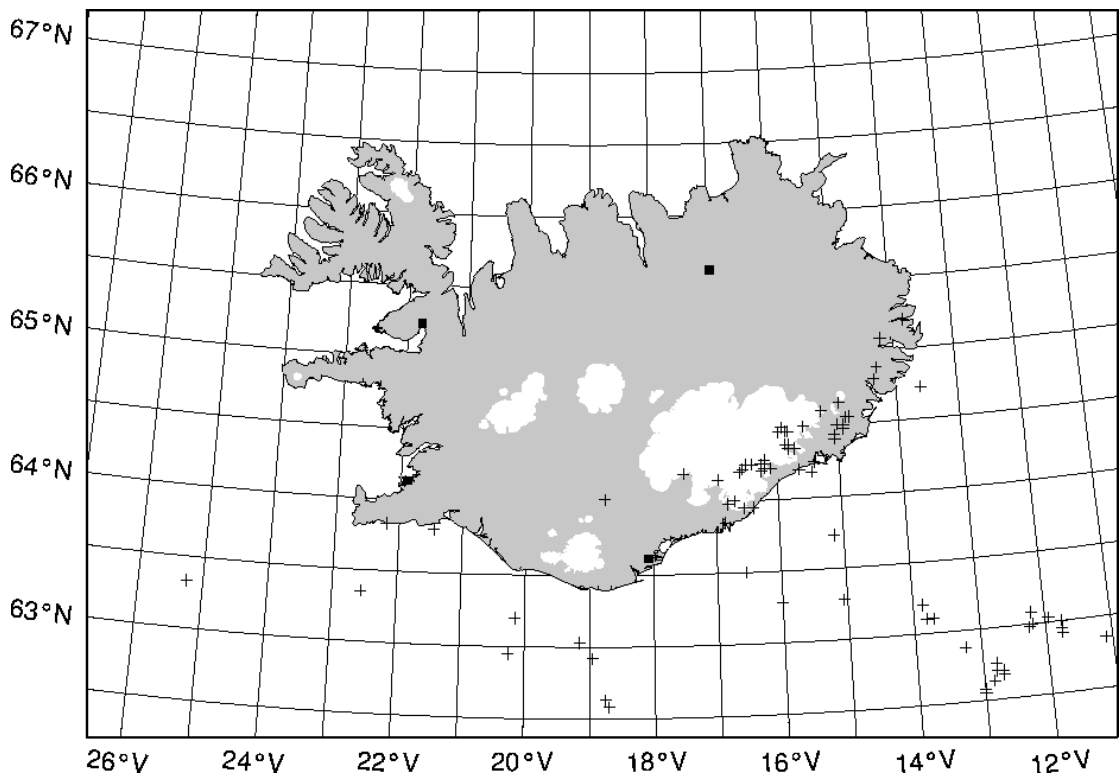
Mynd 2. Eldingar í apríl til júní 2003



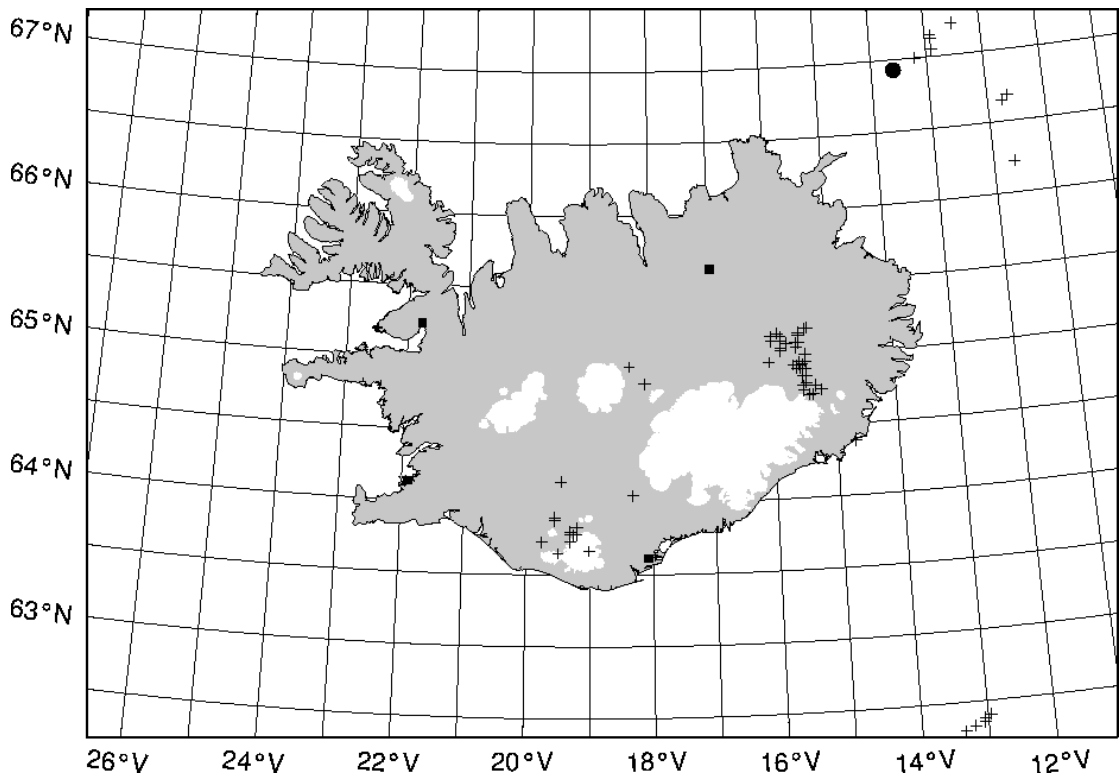
Mynd 3. Eldingar í júlí til september 2003



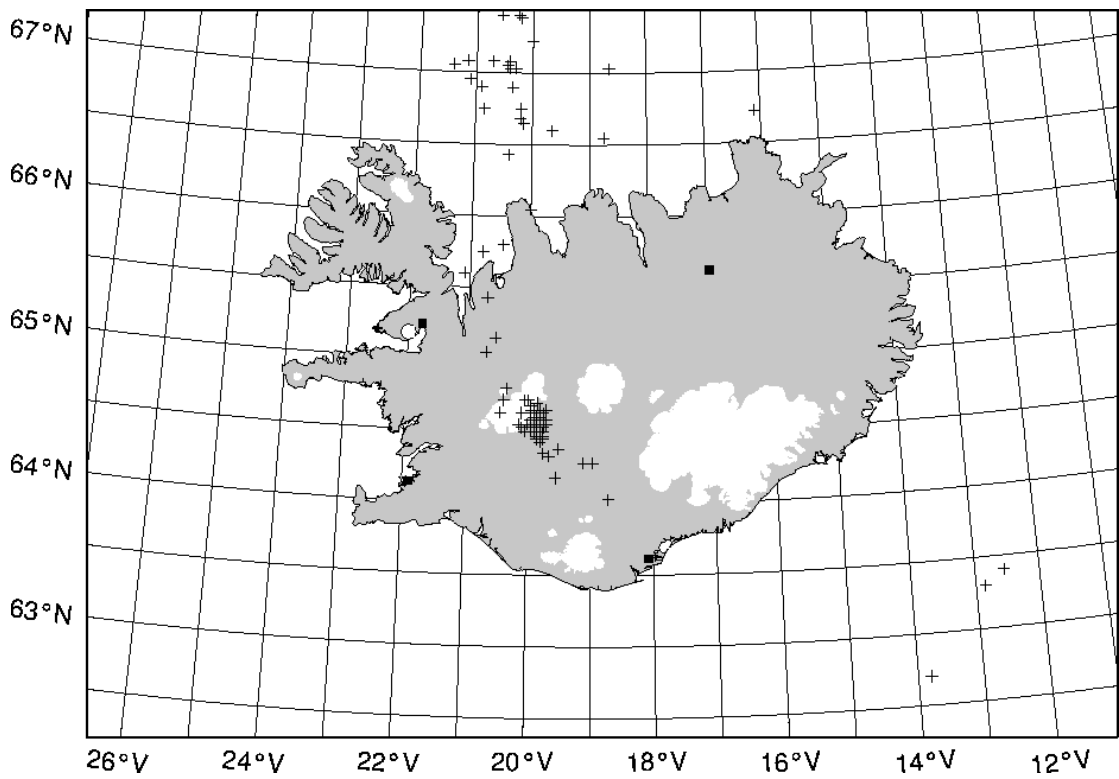
Mynd 4. Eldingar í október til desember 2003



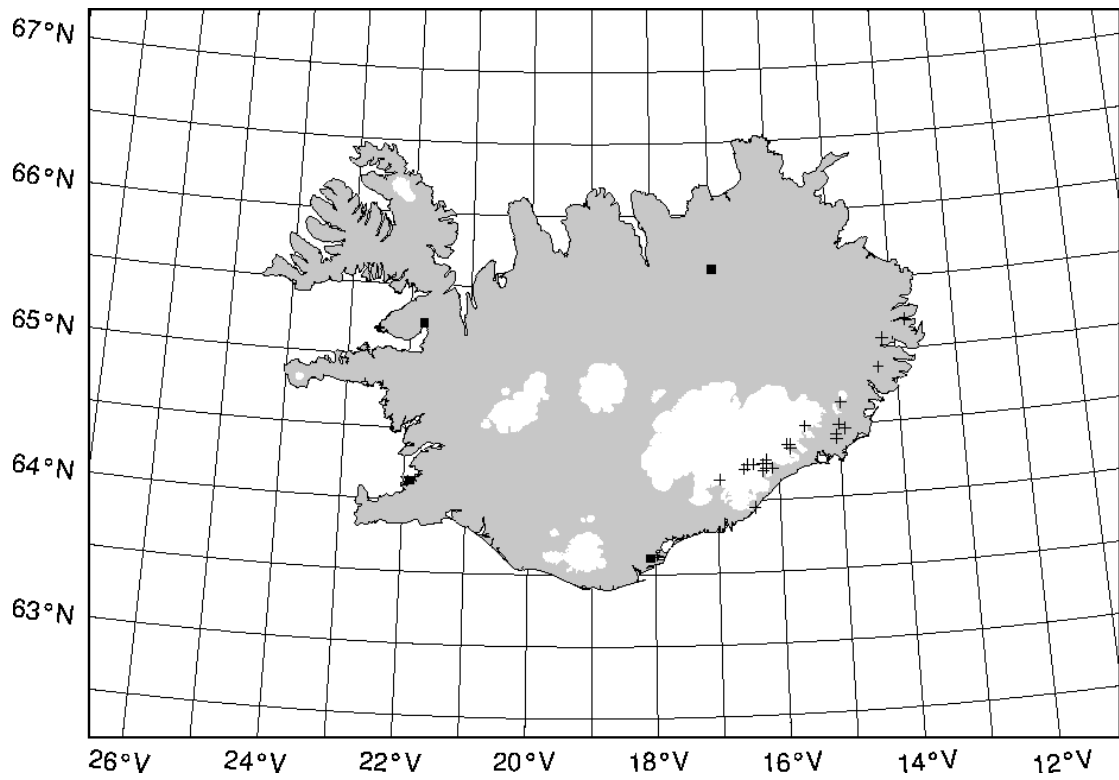
Mynd 5. Eldingar í janúar til mars 2004



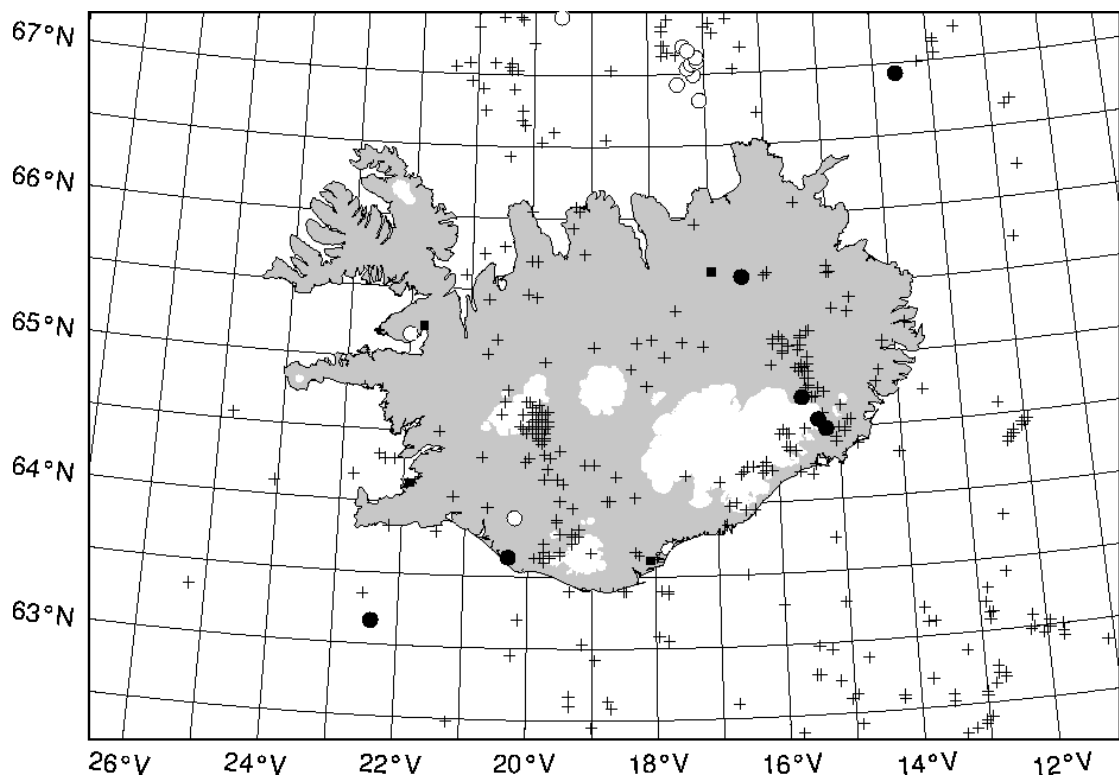
Mynd 6. *Þrumuveðrið 19. júlí 2003*



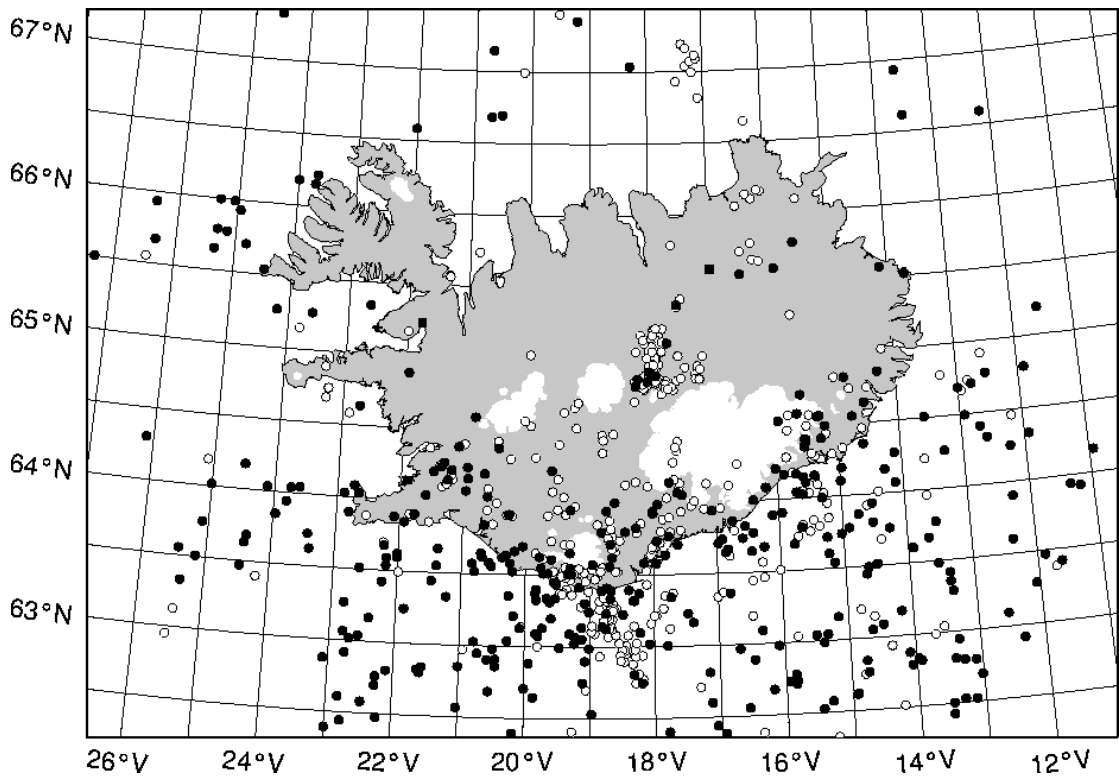
Mynd 7. *Þrumuveðrið 9. ágúst 2003*



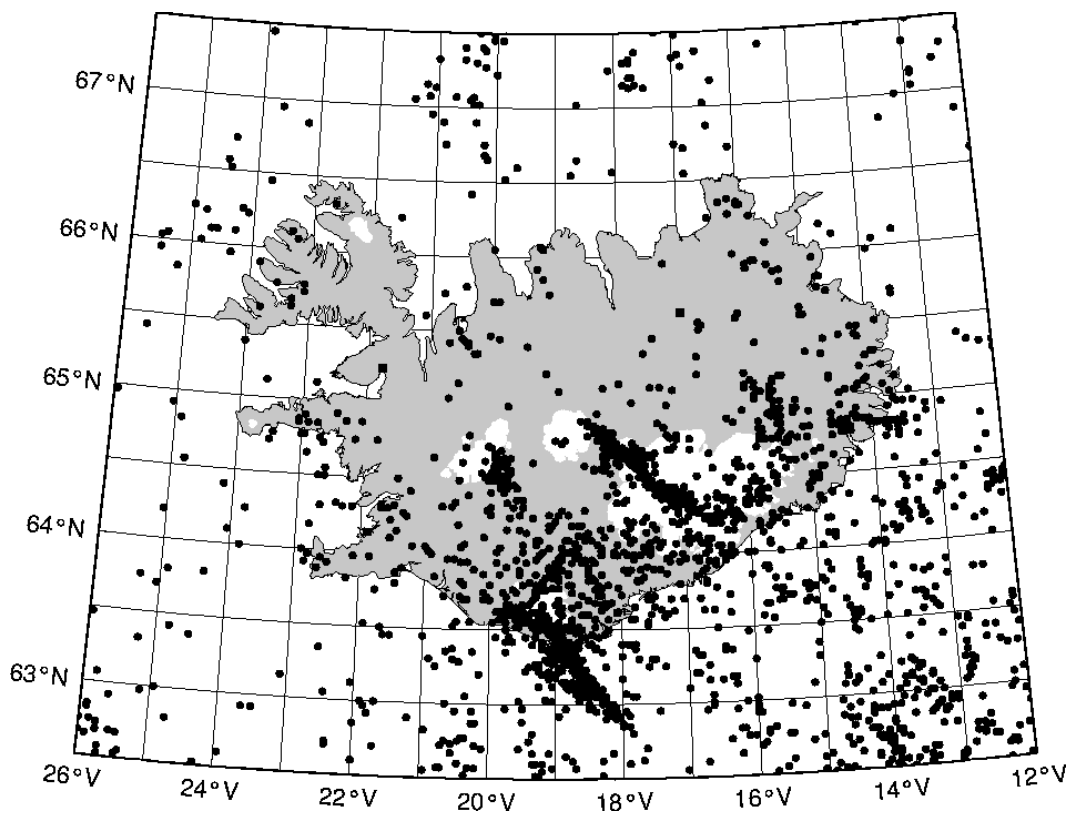
Mynd 8. *Þrumuveðrið 13. mars 2004*



Mynd 9. *Eldingar á árinu apríl 2003 til mars 2004*



Mynd 10. Skráðar eldingar með LLP-eldingamælikerfinu frá júní 1997 til mars 2004



Mynd 11. Skráðar eldingar með ATD-sferics eldingamælikerfinu frá september 1998 til mars 2004

Viðauki – ICLP greinar og EGU útdrættir

Tvær greinar eftir starfsmenn Veðurstofunnar, sem lýsa rannsóknum á þrumuveðrum á Íslandi, hafa verið sendar á ráðstefnuna *27th International Conference on Lightning Protection (ICLP 2004)*, sem haldin verður í Avignon í Frakklandi 13.-16. september 2004. Fylgir afrit þeirra hér sem viðauki.

- Þórður Arason, *Comparison of data from a lightning location system and atmospheric parameters from a numerical weather prediction model*
- Haraldur Ólafsson, Þórður Arason og Trausti Jónsson, *Seasonal and interannual variability of thunderstorms in Iceland and the origin of airmasses in the storms*

Á eftir ICLP-greinunum fylgja tveir EGU-útdrættir. Annar fyrir erindi og hinn fyrir veggspjald sem kynnt voru á ráðstefnunni *European Geosciences Union 2004, 1st General Assembly*, sem haldin var í Nissa í Frakklandi 25.-30. apríl 2004.

- Haraldur Ólafsson, Trausti Jónsson og Þórður Arason, *The origin of airmasses in major thunderstorms in Iceland and the predictability of the storms*
- Haraldur Ólafsson, Trausti Jónsson og Þórður Arason, *Climatology of thunder in Iceland*

Comparison of Data from a Lightning Location System and Atmospheric Parameters from a Numerical Weather Prediction Model

Pórður Arason

Veðurstofa Íslands - Icelandic Meteorological Office, Bustadavegi 9, IS-150 Reykjavik, Iceland
arason@vedur.is

Abstract: This study presents a comparison between the occurrence of thunderstorms in Iceland as identified by lightning location systems and the properties of the atmosphere as analysed and predicted by a short range numerical meteorological forecast model. The purpose of the comparison is to identify thunderstorm prediction indices, suitable for Iceland. The numerical meteorological forecast model of Météo-France, Arpège, was used for this study. On the basis of output from the Arpège, the key atmospheric variables were defined in a grid. The lightning locations of the ATD sferics system of the UK Met Office and the LLP-based lightning location system of the Icelandic Meteorological Office, were used for this study. Several thunderstorm indices based on the temperature and humidity profile of the atmospheric column of each element of the forecast model were calculated. The indices that best predicted occurrences of lightnings were then used in a statistical similarity model that estimates thunderstorm probabilities. These were adjusted for annual variations and diurnal variations in the summer. The results enable the construction of probabilistic local thunderstorm forecasts for Iceland, based on output from an operational numerical weather prediction model.

Keywords: Thunderstorm prediction, Numerical weather prediction model, Thunderstorm index, ATD sferics, Iceland

1. Introduction

The ability to accurately predict thunderstorms a few days in advance is enormously important. This ability can both save lives and in some instances also prevent damage to property.

In the 1940's and 50's some fairly simple atmospheric stability indices were developed. They were designed to estimate chances of thunderstorms from a single radiosonde profile. One of the oldest indices, still in use, is the Showalter stability index, published in 1953 [1].

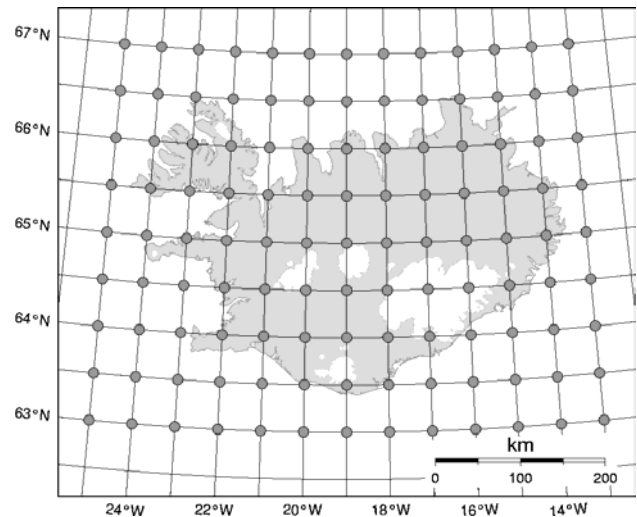


Figure 1: The grid-points of the Arpège weather prediction model over Iceland.

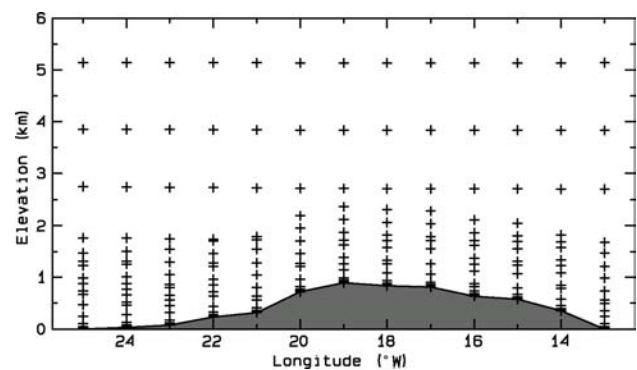


Figure 2: A sample vertical cross section at 65°N showing typical distribution of the Arpège grid-points. The three pressure levels at the highest elevation are the 500, 600 and 700 hPa isobars.

Many of the indices were developed in the pre- or early-computer era. Now, forecasters have access to powerful

computers and numerical weather prediction models. Significant advances are being made in incorporating atmospheric convection into the numerical models. However, one of the fundamental problems is that the horizontal grid size of the weather prediction models is almost an order of magnitude larger than the convection cells.

In this study we have compared several atmospheric stability indices to lightning location data in a statistical way to predict thunderstorms. Our hope is to be able to predict thunderstorms beyond what currently operational numerical weather prediction models can. One of the advances of using this statistical point of view is that several underlying, known as well as unknown, processes, properties and local phenomena will be taken into account.

In this article we outline a prototype of a statistical similarity model that seems to accurately predict thunderstorms in Iceland. Next steps will include assessing the accuracy of the predictions and making the model operational.

2. Weather prediction model

One of the operational models used at the Icelandic Meteorological Office is the output of a numerical weather prediction model, Arpège, made by Météo-France [2]. The parameters given by the Arpège output at each grid point are elevation of an air parcel above sea level, air pressure, air temperature, relative humidity, wind speed and wind direction. Output from the Arpège is received twice daily with analysis for 00:00 and 12:00 UTC. The forecast range is 0, 6, 12, 18, 24, 30, 36, 42, 48, and 54 hours.

For this study, the analysis output of Arpège was used to determine the state of the atmosphere at 00:00 and 12:00 UTC. The 6 hour forecasts at 00:00 and 12:00 were used to determine the state of the atmosphere at 06:00 and 18:00 UTC.

The horizontal spacing of the grid on which the Arpège is projected spans 1° of longitude and 0.5° of latitude. The domain of the study extends from 63°N to 67°N and 13°W to 25°W , see Figure 1. Each of these 117 horizontal elements of the study area is therefore about 47×55 km. For each areal element, the Arpège model output predicts the state of the atmosphere in 11-19 vertical layers below the 500 hPa pressure level, which is about 5 km above sea level. A sample cross section showing the vertical distribution of the Arpège grid is shown in Figure 2.

Models output at 00, 06, 12, and 18 UTC for the four years 2000-2003 are represented by 5844 time points. Two of the outputs were damaged and not used for this study. For every time point we have 117 areal elements, above which the properties of the atmospheric column are defined. Therefore, by using the Arpège model output we have an estimate of the properties of 683514 atmospheric columns above an areal element.

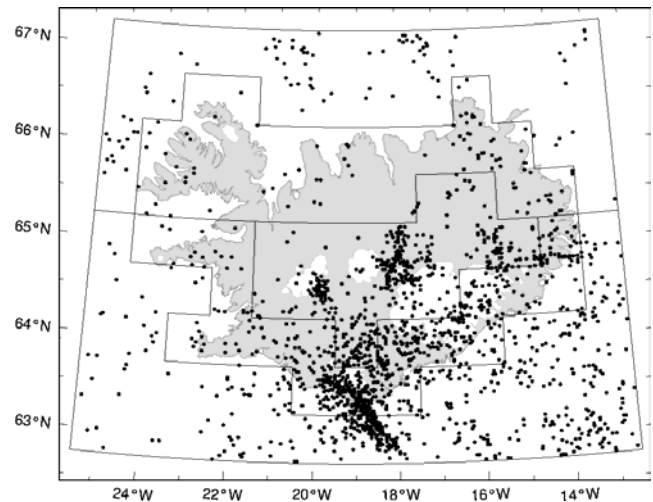


Figure 3: The study area was split into five distinct geographical regions, shown on this map along with the located lightnings 2000-2003.

3. Lightning location data

For this study we have used lightning locations for the four years 2000-2003 from the Icelandic lightning location system [3, 4, 5] and data from the ATD sferics system of the UK Met Office [6]. The lightning data were used to determine times and places of thunderstorms.

For comparison purposes the lightning location data were gridded in space and time in the same way as the Arpège model output, i.e. the same 117 areal elements and 6 hour time intervals. Thunderstorms occurring between 03:00 and 09:00 were set at time 06:00 UTC.

Figure 3 shows all the located lightnings during these four years 2000-2003. Volcanogenic lightnings [7] from the Hekla 2000 eruption were omitted.

4. Temporal and spatial variation

There is considerable temporal variation in the occurrence of thunderstorms in Iceland, both as an annual variation and diurnal variation during the summer. Figure 4 shows the annual variation in thunder reports from manned observations during the fifty year period 1951-2000. The figure shows the number of reported thunder days for each day of the year. Note that the graph shows a higher number than thunder days, since for example five manned stations reporting the same thunderstorm will count as five reports.

During these fifty years there has been considerable change in the number of manned stations. However, those changes should not affect the shape of the graph since there is not a seasonal variation in the number of stations.

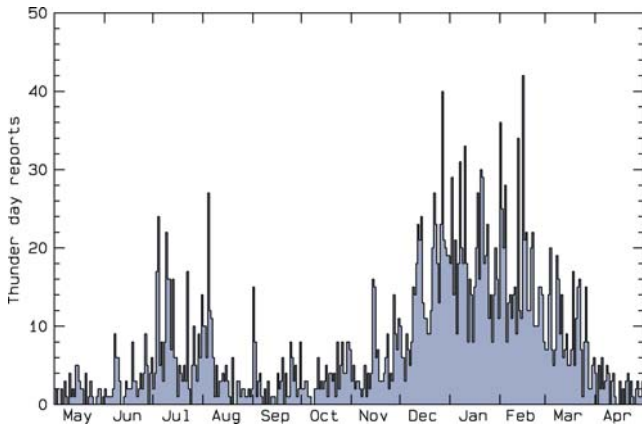


Figure 4: The number of thunder day reports for each day of the year, as determined by manned observations 1951-2000.

Clearly, Figure 4 shows the two distinct thunder seasons in Iceland. First, there is a thunder season during the summer, centered in July. Second, the main thunder season in Iceland is during the winter, from November to March. There is considerably lower activity during spring and fall.

Furthermore, previous studies have shown that there is significant difference between these two thunder seasons, both in spatial distribution, thunderstorm duration and in the lightning polarities and observed peak current [3, 4, 5].

During summer there is a strong diurnal variation in the occurrence of thunderstorms. Figure 5 shows the number of lightnings in the study area versus time of day. For this figure the data were split into the winter half (October-March) and summer half (April-September). One thunderstorm with over 200 lightnings on 2002-06-08 was omitted for this figure. During the summer there is a significant increase in lightning activity in the afternoon. In Figure 5, time of day represents UTC time, and local noon in Iceland is at 13:00 – 13:30 UTC.

Due to the temporal variations we split the data into 9 temporal groups for our calculations as shown in Table 1.

Table 1. Summary of temporal groups

No	Months	Time of day
1	November through March	00, 06, 12, 18
2	April and May	00, 06
3	April and May	12, 18
4	June, July and August	00
5	June, July and August	06
6	June, July and August	12
7	June, July and August	18
8	September and October	00, 06
9	September and October	12, 18

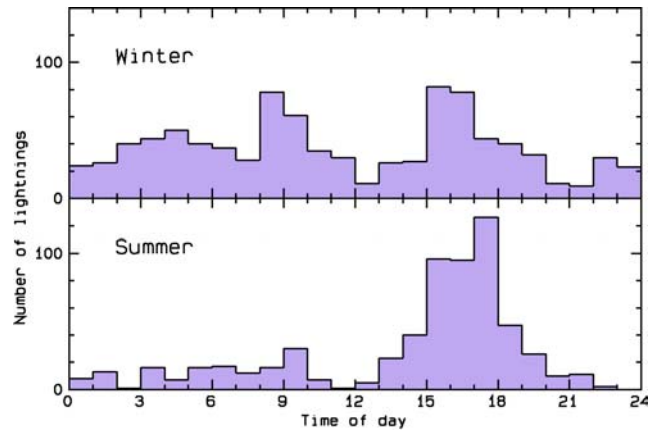


Figure 5: The diurnal variation in the occurrence of lightnings in the study area for 2000-2003. The top panel shows the winter half of the year, while the lower panel shows the diurnal variation during the summer half of the year.

Previous studies have shown significant spatial variation in thunderstorm occurrence. The frequency appears highest over the ocean south of Iceland and at the Southern coast. We split the data into five geographical regions based on thunderstorm distributions [5, 8]. These are: 1–Southern ocean; 2–Southern coast; 3–Central highlands; 4–Northern coast; 5–Northern ocean. The boundaries between the five geographical regions are shown in Figure 3.

5. Thunderstorm indices

A variety of thermodynamic and kinematic parameters have been used to indicate potential instability of the atmosphere [9].

As an example of a very simple index, the Vertical Totals Index is defined as the temperature difference between the air at 850 hPa and 500 hPa pressure levels. Some indices take into account the moisture content of the air. Some measure the temperature difference of the ambient air and the final temperature of an air parcel lifted pseudo-adiabatically from some lower level. Most of the indices only compare properties at a few distinct pressure levels.

The Convective Available Potential Energy (CAPE) index utilizes all of the temperature and moisture profile, by integrating the energy released during an ascent of an air parcel up through the atmosphere. Conventionally, CAPE is only calculated when energy is released. We have also calculated negative terms of CAPE, i.e. the total energy released or required to lift an air parcel from the surface to the 500 hPa level.

In Table 2 we have summarized the indices that we have considered for the current study. In the table the subscripts 500, 700, 850 and 1000 indicate pressure levels in hPa. Subscript *s* indicates conditions at the surface and subscript 0.5 indicates average state in the lowest 0.5 km of the

atmosphere. The symbol T stands for temperature, Td for dew point, p for pressure, u and v are wind speeds, Z and z indicate elevation, g is the acceleration of gravity and ρ_v is the density of water vapor in air. $T^*_{a \rightarrow b}$ is the terminal temperature of a moist air parcel that is lifted pseudo-adiabatically from level a to level b . θ_w and θ_s are the wet bulb potential temperature and the saturated potential temperature, respectively.

Table 2. Summary of indices considered for this study

No	Index	Definition
1	Air temperature at surface	T_s
2	Air temperature at 700 hPa	T_{700}
3	Air pressure at sea level	p
4	Westerly winds at 700 hPa	u_{700}
5	Southerly wind at 700 hPa	v_{700}
6	Elevation of the 500 hPa level	Z_{500}
7	Adedokun 1 Index	$\theta w_{850} - \theta s_{500}$
8	Adedokun 2 Index	$\theta w_s - \theta s_{500}$
9	Boyden Index	$0.1(Z_{700} - Z_{1000}) - T_{700} - 200$
10	Bradbury Index	$\theta w_{500} - \theta w_{850}$
11	Negative Convective Available Potential Energy (all terms)	$g \int (T^*_{0.5 \rightarrow z} - T)/T dz$
12	CAPE (only positive terms)	$g \int (T^*_{0.5 \rightarrow z} - T)/T dz$
13	Cross Totals Index (CT)	$Td_{850} - T_{500}$
14	Deep Convective Index	$T_{850} + Td_{850} - LI_s$
15	Jefferson Index	$1.6\theta w_{850} - T_{500} - (T_{700} - Td_{700})/2 - 8$
16	K Index (KI)	$T_{850} - T_{500} + Td_{850} - T_{700} + Td_{700}$
17	Lifted Index (from surface) (LI_s)	$T_{500} - T^*_{s \rightarrow 500}$
18	Lifted Index (0.5km) ($LI_{0.5}$)	$T_{500} - T^*_{0.5 \rightarrow 500}$
19	Showalter Stability Index	$T_{500} - T^*_{850 \rightarrow 500}$
20	S Index	$TT - (T_{700} - Td_{700}) - A$
21	Thompson Index	$KI - LI_{0.5}$
22	Total Totals Index (TT)	$CT + VT$
23	Vertical Totals Index (VT)	$T_{850} - T_{500}$
24	Integrated Water Content	$\int \rho_v dz$

6. Statistical similarity analysis

In order to estimate thunderstorm probabilities for a given place in space and time, we chose to compare the state of the atmospheric column to previous states at similar times and places. Once we have identified an adequate number of previous occurrences that are similar, we calculate the frequency of thunderstorms in our data set.

In order to assess similarity of two states of the atmosphere we calculate the distance between the 24-dimensional thunderstorm index vectors in 24-dimensional space. If two states are identified by the subscripts n and m , then we measure the distance of the i -th stability index by

$$d_{i n m} = w_i (x_{i n} - x_{i m}) / \sigma_i \quad [1]$$

where $x_{i n}$ and $x_{i m}$ are the value of the i -th stability index for state n and m , respectively, σ_i is the standard deviation of index x_i , and w_i is an empirically chosen weight for the i -th index.

The distance between two states, n and m , in the 24-dimensional space is $D_{n m}$

$$D_{n m}^2 = d_{1 n m}^2 + d_{2 n m}^2 + d_{3 n m}^2 + \dots + d_{24 n m}^2 \quad [2]$$

For a given situation, n , we calculate $D_{n m}$ for all previous situations, m , for the time group and region of n . The lowest distances in the 24-dimensional space $D_{n m}$ represent similar situations. Then we select a sufficient number, N , of similar situations and estimate the frequency of thunderstorms in our selection. We have estimated the thunderstorm frequency as the highest frequency for N in the range 200-300.

Our current choice of weights for the 24 indices in Table 2 for the similarity calculations are $w = [0.1 \ 0.1 \ 0.2 \ 0.1 \ 0.2 \ 0.1 \ 0.7 \ 0.7 \ 0.2 \ 0.2 \ 1.0 \ 0.5 \ 0.5 \ 0.1 \ 1.0 \ 0.5 \ 0.5 \ 1.0 \ 1.0 \ 0.5 \ 0.1 \ 0.5 \ 0.2 \ 0.1]$. The highest weights are assigned to Negative CAPE, Jefferson index, $LI_{0.5}$, and Showalter index. The standard deviations of the 24 indices in Table 2 were estimated from the whole data set and are $\sigma = [5.4 \ 6.1 \ 13.8 \ 8.5 \ 8.5 \ 178 \ 2.9 \ 3.7 \ 2.1 \ 2.9 \ 0.65 \ 48.0 \ 6.8 \ 11.1 \ 7.4 \ 14.1 \ 6.1 \ 5.7 \ 4.8 \ 16.9 \ 11.8 \ 10.1 \ 4.2 \ 5.3]$.

As an example of the results of our calculations we show, in Figure 6, a contour plot of the predicted thunderstorm probabilities on 20 February 2003 at 06:00 UTC. The similarity calculations indicate increased chances of thunderstorms on the SE-coast. The highest probability in a single element in this case is 2.5%.

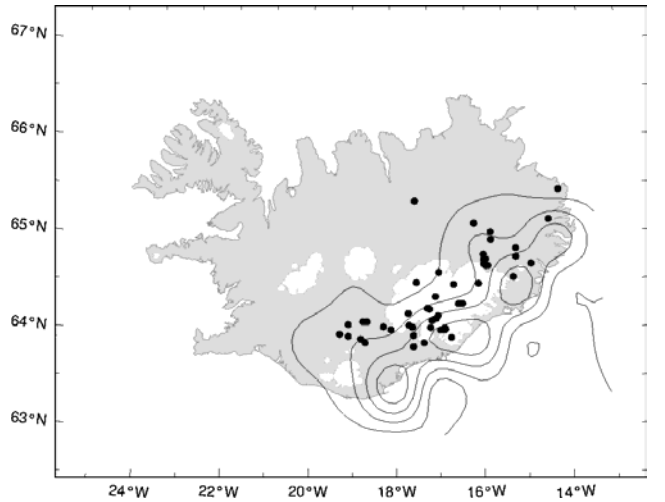


Figure 6: Estimated thunderstorm probability on 2003-02-20 at 06:00 UTC. Contour interval is 0.5%. The dots show located lightnings at the same time.

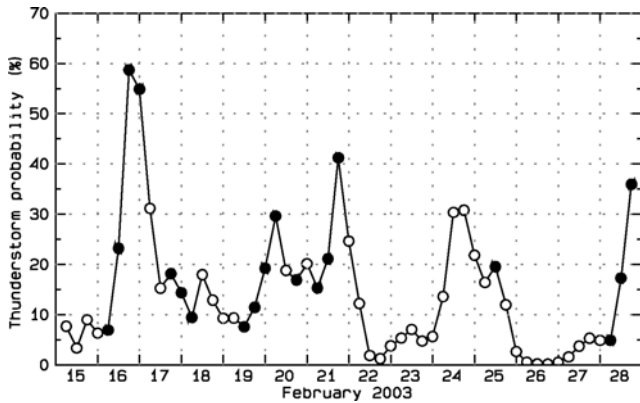


Figure 7: Estimated thunderstorm probability for 6 hour time steps for the latter half of February 2003. Filled dots indicate times with located lightnings in the study area.

Combining all the 117 elements in Figure 6, we can calculate the thunderstorm probabilities for the whole domain for the 6 hours

$$P = 1 - \prod (1 - p_i) \quad [3]$$

In the case shown in Figure 6 the probability of a thunderstorm anywhere in Iceland is estimated 30%.

Figure 7 shows this total probability, P , as a function of time for a half month in February 2003, when winter-thunderstorms were quite frequent. The filled circles indicate that the lightning location systems measured some lightnings during the time period, and open circles where no lightnings were registered. Most of the high peaks are associated with observed thunderstorms, although on 24 February no lightnings were registered even though chances seem to be high.

7. Further developments

The current model is a prototype for feasibility study of the method. A systematic survey of false alarms and surprise events needs to be undertaken. Furthermore, the accuracy needs to be better quantified and any shortcomings of the method identified.

The empirical weights used in calculating similarity in the 24-dimensional space need to be further tuned. It is believed that by doing so we may significantly advance our predictions.

There are plans to make the model operational and the thunderstorm forecasts available on our web page. As time passes we will systematically add more lightning and atmospheric data into the statistical base, which will make the predictions more reliable.

This model has been developed for Iceland. The methods described can easily be applied to other places.

8. Acknowledgements

We would like to thank Mr. Eric Hibbett at the UK Met Office for supplying the ATD sferics data for this study and Météo-France for access to the Arpège numerical weather prediction model results. The author would like to thank Haraldur Ólafsson and Flosi H. Sigurðsson for constructive comments.

9. References

- [1] Showalter, A. K., "A stability index for thunderstorm forecasting", Bull. Amer. Meteor. Soc., 34, pp. 250-252, 1953.
- [2] Courtier, P., C. Freyrier, J.-F. Geleyn, F. Rabier and M. Rochas, "The Arpège project at Météo-France", ECMWF Seminar Proceedings, September 9-13 1991, Vol. 2, European Centre for Medium-Range Weather Forecasts, Reading UK, pp. 193-232, 1991.
- [3] Arason, P., "Initial results of the Icelandic lightning location system", Proceedings of the 24th International Conference on Lightning Protection, pp. 241-244, Birmingham, 1998.
- [4] Kristmundsson, G. M., and Þ. Arason, "Mælingar og skráning á niðurslætti eldinga til jarðar", Yearbook Eng. Assoc. Iceland (in Icelandic), Reykjavík, pp. 337-344, 1998.
- [5] Working Group on Lightning Research in Iceland, "Mælingar og skráning á niðurslætti eldinga til jarðar á Íslandi", Annual report 2003 (in Icelandic), Reykjavík, 31 p., May 2003.
- [6] Nash, J., E. Hibbett, G. Callaghan, P. Taylor, N. Daly, R. Burness, and M. West, "The UK Met. Office's upgraded lightning location system", Proceedings of TECO 2000, Instruments and Observing Methods, Report No. 74, WMO/TD - No. 1028, World Meteorological Organization, pp. 250-253, 2000.
- [7] Arason, P., E. Sigurðsson, G. M. Kristmundsson, H. Jóhannsdóttir and G. Júlíusson, "Volcanogenic lightnings during a sub-glacial eruption in Iceland", Conference Proceedings, Vol. A, 25th International Conference on Lightning Protection (ICLP 2000), pp. 100-102, Rhodes, 2000.
- [8] Sigurðsson, F. H., and E. Þorbjörnsson, "Fjöldi þrumudaga á Íslandi 1950-1989 (Number of thunder days in Iceland 1950-1989)", Report (in Icelandic), Icelandic Meteorological Office, Reykjavík, 3 p., 1990.
- [9] Haklander, A., "Thunderstorm predictors and their forecast skill for the Netherlands", MS Thesis, Institute of Marine and Atmospheric Research, Utrecht University, the Netherlands, 63 p., 2002.

Seasonal and Interannual Variability of Thunderstorms in Iceland and the Origin of Airmasses in the Storms

H. Ólafsson¹, Þ. Arason², T. Jónsson²

1: Háskóli Íslands (University of Iceland) and Veðurstofa Íslands (Icelandic Meteorological Office) and Rannsóknastofa í veðurfræði (Institute for Meteorological Research)
2: Veðurstofa Íslands (Icelandic Meteorological Office)

Abstract: Variability and the meteorological conditions of thunder in Iceland are explored. Most thunderstorms occur in winter, where arctic air moves rapidly from N-America over a relatively warm sea towards Iceland. A secondary maximum in the thunderstorm frequency is in summer. The summertime thunderstorms are formed within an airmass that has been advected from Britain and/or continental Europe. These thunderstorms tend to be associated with a frontal or a convergence zone. There is substantial interannual variability in the frequency of thunderstorms at the south coast of Iceland, but there is not a sign of a long-term trend.

Keywords: Iceland, seasonal cycle of thunder, origin of airmasses, variability of thunder.

1. Introduction

Although not as frequent as over the mid-latitude continents, lightnings are an important risk for power structures in Iceland. Yet, relatively little has been published on the climatology of thunder in Iceland [1] and no study has been made of the meteorological conditions leading to thunderstorms in Iceland. Here, the annual cycle of thunder reports from synoptic weather observations Iceland is explored. On the basis of the seasonal variation in the frequency of thunder, the year is divided into three seasons, summer, winter and an intermediate season. The synoptic scale meteorological conditions during the five most intensive thunderstorms of each season during a period of twenty years are studied. Trajectories are calculated at different levels in the troposphere in order to find the origin of the airmasses in the thunderstorms.

2. Seasonal variability

Figure 1 shows the sum of thunder reports from synoptic weather stations in Iceland during the period 1951-2000. In general, thunder is not very frequent in Iceland and strong and widespread individual thunderstorms appear as

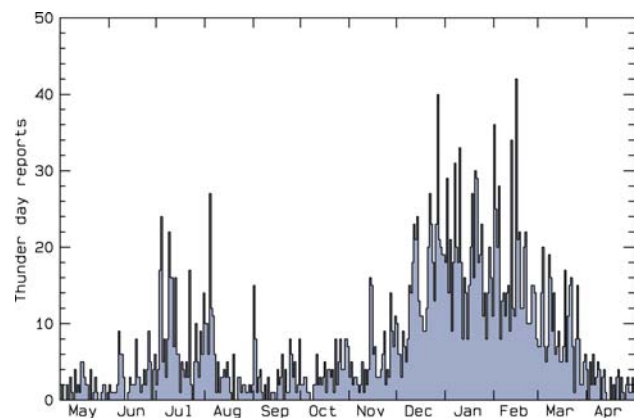


Figure 1: Seasonal cycle of the number of thunder reports from synoptic weather stations in Iceland 1951-2000.

peaks in the graph on the figure. In spite of the high relative impact of individual storms, the figure reveals significant seasonal variability in the frequency of thunderstorms. Unlike in most other countries, the maximum frequency of thunder is in mid-winter, from December to February. A secondary, but a much smaller maximum is during the warmest period of the year, in July and August. Thunder is rare during other seasons. To get a closer insight into the nature of the thunderstorms during the two peak seasons, observations from an automatic lightning detection system operated by the Icelandic Meteorological Office [2] are shown in Figures 2 and 3. In spite of the fact that thunder is rare in Iceland and that the period of automatic observations is short (1998-2003), many lightnings have been detected. The figures reveal quite different geographical distributions in the two seasons. In the winter (Fig. 2), the lightnings are almost exclusively in the southern part of Iceland, and over the ocean to the south. Usually, only a few lightnings come with each thunderstorm, so the lightnings

are not clustered. In the summer (Fig. 3), the lightnings are to a greater extent grouped in clusters and more of the lightnings are over land. The two most prominent clusters are from two distinct thunderstorms. Furthermore, there are almost as many lightnings detected in the northern part of the island, than in the southern part.

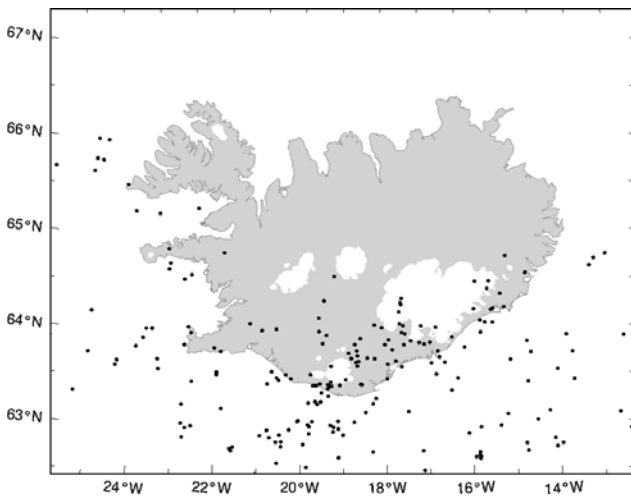


Figure 2: Lightnings detected by the automatic lightning detection system [2] Dec–Feb 1998-2003.

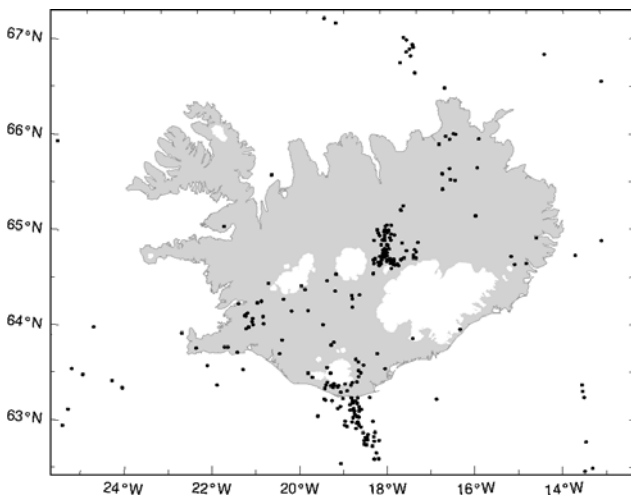


Figure 3: Lightnings detected by the automatic lightning detection system [2] Jun-Aug 1998-2003.

3. Interannual variability

For several decades, synoptic weather observations have been made regularly every 3 hours at Stórhöfði, in Vestmannaeyjar, located approximately 15 km off the south coast of Iceland. These observations can be

expected to represent the main thunder activity in Iceland, i.e. the winter peak. The yearly number of days with thunder and the mean annual temperature at Stórhöfði 1949-2003 is shown in Figure 4. Apart from the peak values in 1963 and 1964, which are associated with volcanic activity [3], there is no clear trend in the frequency of thunder. The average yearly number of thunder days (excluding 1963 and 1964) is 2.5 with a maximum of 7 days and a minimum of 0 days. There is no clear connection between the mean annual temperature and the frequency of thunder.

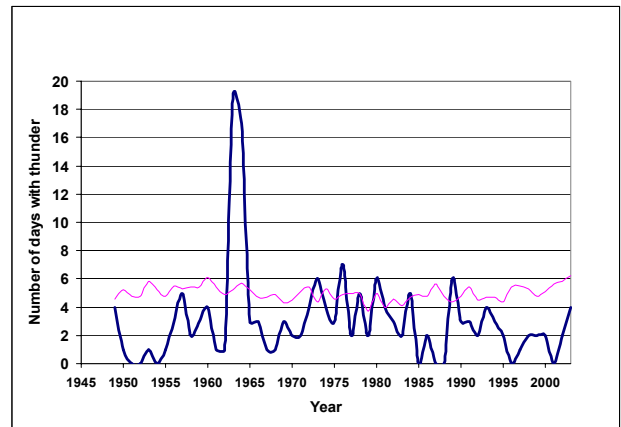


Figure 4: Annual number of days with thunder and mean annual temperature 1949-2003 at Stórhöfði, S-Iceland.

4. Comparison of thunderstorms in winter and in summer

4.1 Classification of thunderstorms

The seasonal variability of the frequency of thunderstorms calls for a further investigation of the nature of the storms in the different seasons. For this purpose, observations from all synoptic weather stations in Iceland during the period 1981-2000 have been studied. The thunderstorms have been grouped in winter events (DJFM), summer events (JJA) and intermediate season events (AM and SON). Five events leading to the greatest number of thunder reports in each group are given in Table 1. The airmasses at 500, 2000, and 6000 m.a.s.l. in each thunderstorm are traced 5 days back and the baroclinicity of the airmass is evaluated from the difference in the direction of the trajectories at 2000 m and 6000 m immediately before the thunderstorm. The table also gives information on how fast the advection of the airmass has been at 2000 m during the 24 hours preceding 12 UTC on the day of the thunderstorm.

Winter	Origin of low level airmass	Wind veering	Advection
94-01-21	N-America	0°	60 m/s
93-02-12	N-America	20° (warm advection)	40 m/s
91-01-30	N-America	10° (warm advection)	40 m/s
89-01-11	N-America	0°	10 m/s
83-12-27	N-America	0°	20 m/s
Summer			
91-08-02	Britain/Cont.Europe	0°	10 m/s
91-07-08	Britain/Cont.Europe	0°	10 m/s
88-07-10	Britain/Cont.Europe	0°	10 m/s
84-07-11	Britain/Cont.Europe	10° (warm advection)	10 m/s
82-07-03	S-Ocean	80° (cold advection)	10 m/s
Interm. Season			
99-09-05	N-America	50° (cold advection)	10 m/s
97-09-27	N-America	10° (warm advection)	30 m/s
89-10-31	N-America	0°	50 m/s
81-09-01	Britain/SE-Ocean	0°	30 m/s
81-05-14	Britain/Cont. Europe	0°	20 m/s

Table 1: Five most active thunderstorms of each of the three seasons during the period 1981-2000.

The most striking information revealed by Table 1 is the fact that the airmasses in the winter thunderstorms originate exclusively in North-America, while the airmasses in the summer thunderstorms originate close to Britain and/or over continental Europe. The thunderstorms in the intermediate season feature both sources of airmasses. There is always significant advection of the airmass prior to the thunderstorm, particularly in the winter storms. There is most often, but not always, only a very little change of wind direction with altitude, indicating limited baroclinicity.

4.2 A winter thunderstorm

A typical example of the meteorological conditions during a winter thunderstorm is given in Figs. 5-8. There is strong flow from the southwest at all levels. The airmass in which the convection develops originates in NE-Canada and has been advected over the warm Labrador Sea and the even warmer Greenland Sea between Iceland and S-Greenland. The satellite image (Fig. 8) shows well organized convection with towers reaching up through the troposphere over a large area over the ocean to the south of Iceland.

4.3 A summer thunderstorm

A typical example of the meteorological conditions during a summer thunderstorm is given in Figs. 9-12. There is moderate advection from the southeast at all levels and the airmass originates in continental Europe. As in the winter case, the flow is close to parallel at all levels immediately prior to the thunderstorm and the weather situation is relatively stationary with a low pressure area at all levels south of Iceland. The satellite image (Fig. 12) shows a cloud band reaching from Greenland, across the southern part of Iceland and extending towards Scotland, suggesting low level convergence on a synoptic scale.

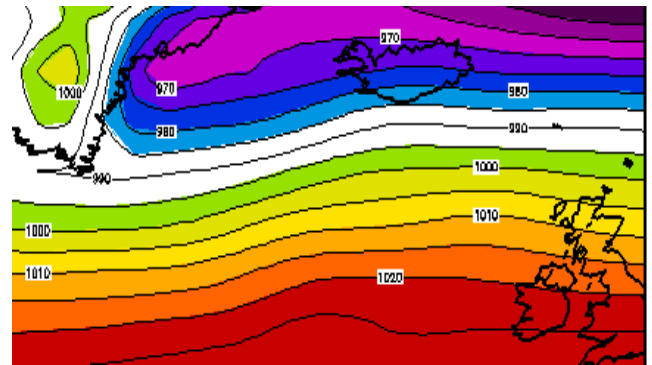


Figure 5: Mean sea level pressure on 21 January 1994 at 12 UTC. Contours with 5 hPa intervals.

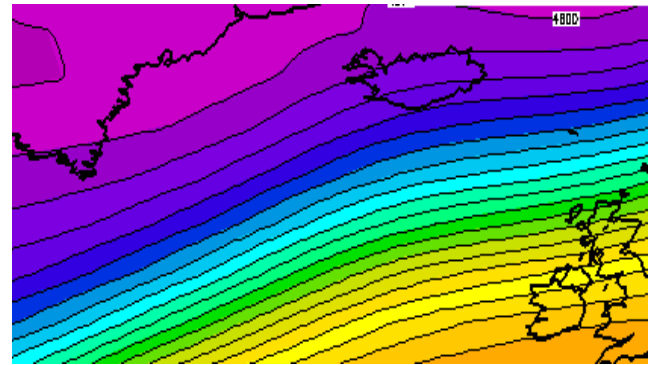


Figure 6: Height of the 500 hPa geopotential on 21 January 1994 at 12 UTC. Contours with 50 dam intervals.

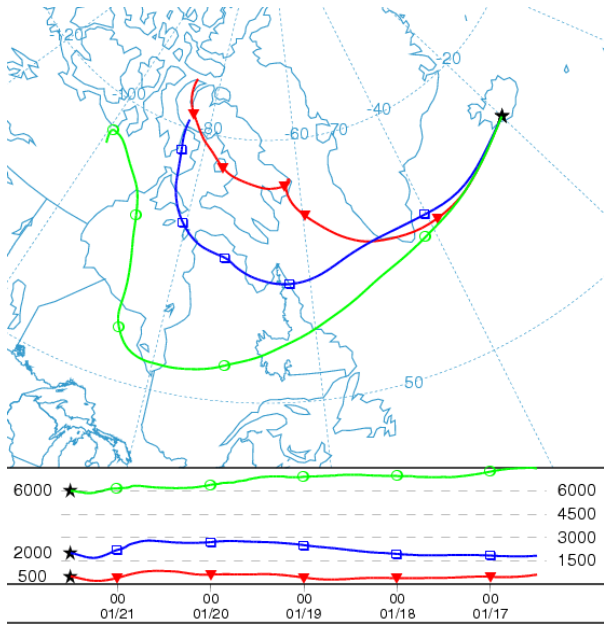


Figure 7: Trajectories at 500, 2000 and 6000 m.a.s.l. calculated backwards 5 days from 21 January 1994 at 12 UTC

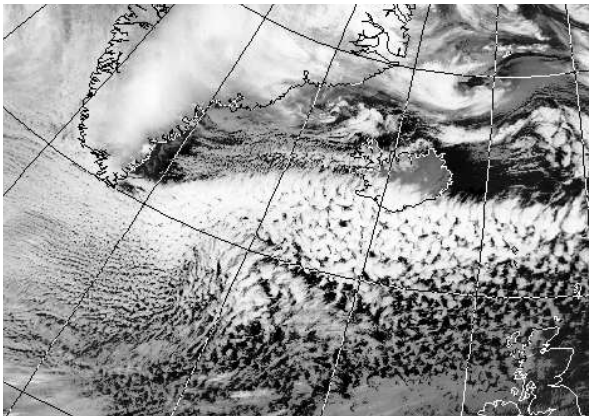


Figure 8: Infrared satellite image from 21 January 1994 at 17:07 UTC.

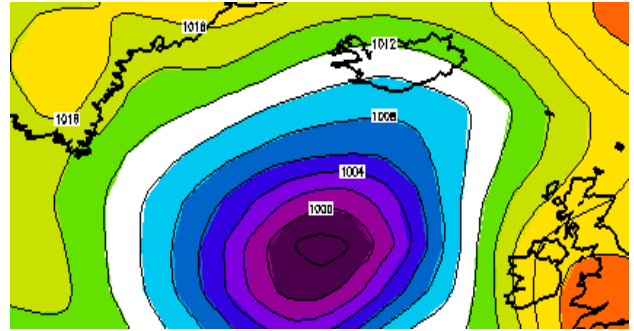


Figure 9: Mean sea level pressure on 2 August 1991 at 12 UTC. Contours with 5 hPa intervals.

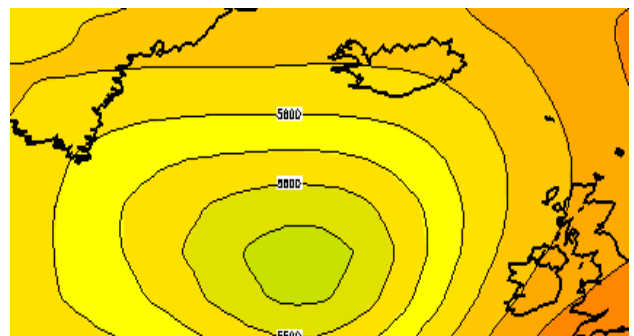


Figure 10: Height of the 500 hPa geopotential on 2 August 1991 at 12 UTC. Contours with 50 dam intervals.

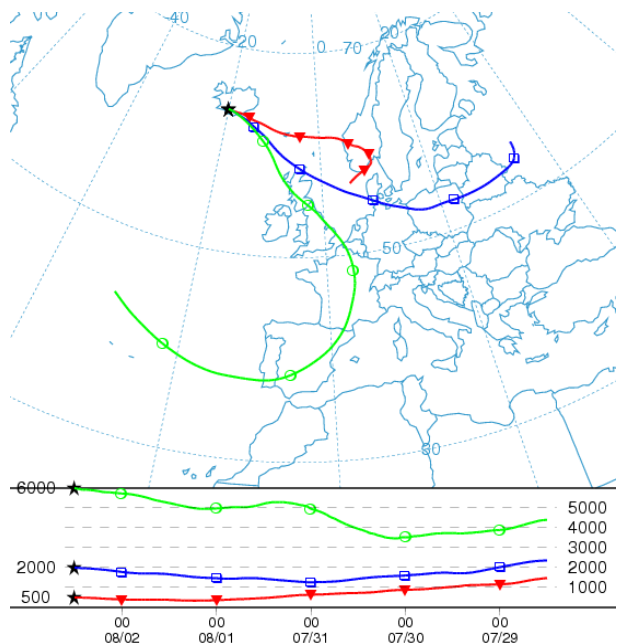


Figure 11: Trajectories at 500, 2000 and 6000 m.a.s.l. calculated backwards 5 days from 2 August 1991 at 12 UTC.

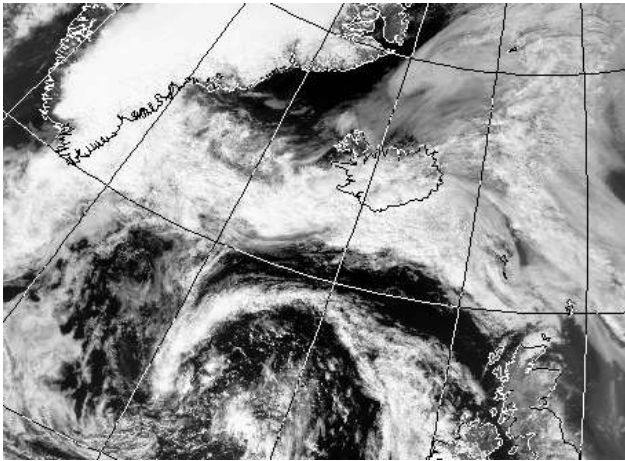


Figure 12: Visible-light satellite image from 2 August 1991 at 15:00 UTC.

5. Discussion

The differences between the winter and summer thunderstorms calls for a discussion on the dynamics of the storms. The well organized convection over the ocean in the winter storms and low static stability of the airmass (not shown) indicate that the flux of heat and moisture from the sea is of primary importance in creating the thunderstorms. The wind speed is very high in some of the cases and mixing through mechanical turbulence may therefore also play a role. Most of the summer thunderstorms are associated with synoptic scale convergence in southeasterly flow. In these storms, forcing from the surface may be of a smaller importance than in the winter storms. This would be in agreement with the fact that the relatively cold ocean has in general a stabilizing effect on the lowest part of the troposphere in this region in summer. Heat flux from the land surface may however play a role, and the fact that the summer thunderstorms are more frequent over land than over the sea supports this. With substantial winds in all cases, a positive effect on precipitation and thunder activity from topographic lifting should be expected [4]. In the winter storms this effect appears clearly in SE-Iceland, where the lightnings are no less frequent over the snow covered mountains with small surface fluxes than over the sea, where the surface fluxes feeding the storms are present and strong. In the summer, there are lightnings in the central highlands where the airmasses have been submitted to topographically forced lifting.

6. Conclusion

An investigation of observations of thunder and lightnings from manned weather stations and an automatic lightning detection system show that

- There is large seasonal variability in the frequency of thunder in Iceland. Most thunderstorms occur in mid-winter, but a secondary maximum is in July and August.
- There are indications that lightnings are more clustered in summer, than in winter and a higher proportion of lightnings are detected in the central and northern part of Iceland in summer than in winter.
- The winter thunderstorms are formed in an arctic airmass that has been advected rapidly from N-America over the warm N-Atlantic Ocean, while the summer thunderstorms tend to be associated with a front or a convergence zone extending from Iceland to the southeast or east. The low level airmasses in the summertime thunderstorms have been advected from the southeast, mainly from Britain and continental Europe.
- Most of the thunderstorms form in the absence of strong baroclinicity in the lower troposphere, including the storms in the summer season.
- There is significant interannual variability in the frequency of thunderstorms at the south coast of Iceland, but no sign of a long-term trend.

7. Acknowledgements

The trajectories are based on NCEP/NCAR reanalysis data using the HYSPLIT numerical model provided by NOAA/ARL. The satellite images are from NOAA, provided by the Dundee Satellite Station and the weather maps are provided by NOAA-CIRES/CDC.

8. References

- [1] Jónsson, T.: Sveiflur III. *Árstíðasveiflur á Íslandi*. (The Seasonal Cycle in Iceland) Tech. Rep. (in Icelandic), Veðurstofa Íslands (Icelandic Meteorological Office), VI-02033, 21 p.
- [2] Arason, P.: "Initial results of the Icelandic lightning location system", In Proc. of the 24th Int. Conf. on Lightning Protection (ICLP1998), 14-18 September 1998, Birmingham, UK.
- [3] Arason, P., E. Sigurdsson, G. M. Kristmundsson, H. Johannsdóttir and G. Juliusson: "Volcanogenic lightnings during a sub-glacial eruption in Iceland", In Proc. of 25th Int. Conf. Lightning Protection (ICLP 2000), 18-22 September 2000, Rhodos, Greece.
- [4] Rögnvaldsson, Ó., P. Crochet and H. Ólafsson: "Mapping of precipitation in Iceland using numerical simulation and statistical modeling.", To appear in Meteorol. Zeitschrift, 2004.



THE ORIGIN OF AIRMASSES IN MAJOR THUNDERSTORMS IN ICELAND AND THE PREDICTABILITY OF THE STORMS

H. Ólafsson (1), T. Jónsson (2) and P. Arason (2)

(1) University of Iceland Icelandic Meteorological Office and Institute for Meteorological Research (2) Icelandic Meteorological Office

The evolution of the atmosphere prior to major thunderstorm events in Iceland is studied by tracing the airmasses back in time. The backtracing reveals large seasonality in the trajectory pattern: In wintertime, both low level as well as upper level tropospheric airmasses originate from N-America and they are highly influenced by the blocking effect of Greenland. Airmasses in summertime thunderstorms originate on the other hand from the south or southeast (Europe) at low levels, while cold air at at upper levels is brought in by westerly winds.

Thunderstorm events are simulated and the predictability of the storms is evaluated, using atmospheric thunder indices. The simulations reveal reasonable accuracy in the short range forecasts. The sensitivity of the forecasts is discussed in view of the THORPEX campaign on atmospheric predictability.



CLIMATOLOGY OF THUNDER IN ICELAND

H. Ólafsson (1), T. Jónsson (2) and P. Arason (2)

(1) University of Iceland, Icelandic Meteorological Office and Institute for Meteorological Research (2) Icelandic Meteorological Office

The climate of Iceland is characterized by stable and cool airmasses, both in winter and summer. Severe thunderstorms that cause damage on structures do however occur.

Fifty years of meteorological observations are studied and the data reveals large seasonality in thunderstorm frequency, with two maxima, one in summer and one in mid-winter. The summer maximum is smaller than the winter-maximum and summertime thunderstorms are related to systems that develop over land, while the wintertime thunderstorms develop over the ocean and are advected over land. The summertime thunderstorms form in weak ambient winds, whereas the wintertime thunderstorms only occur in strong ambient winds. There is significant interannual variability in the occurrence of thunder. This can be attributed to variability in the general atmospheric circulation, and can be linked to similar variability elsewhere in the N-Hemisphere.