

The Askervein Experiment (1982, 1983)



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Originated from IEA meetings about 1980

Discussions with Unsal Hassan (then with CERL),

Paul Mason (UKMO) and others.

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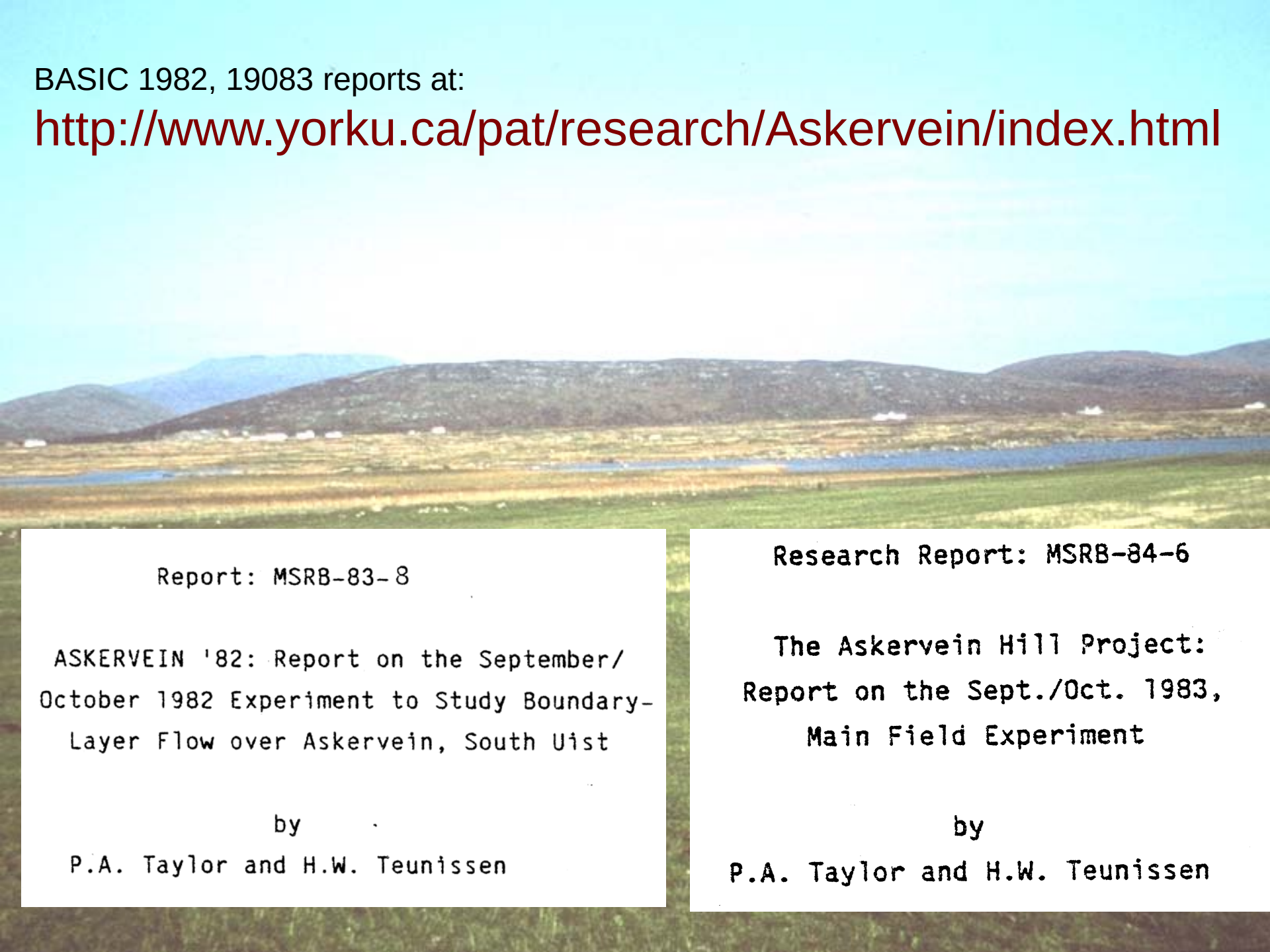
N.J. Cook
Building Research Establishment
United Kingdom

R. Delnon and R. Johnson
ERA Technology Ltd.
United Kingdom



BASIC 1982, 19083 reports at:

<http://www.yorku.ca/pat/research/Askervein/index.html>



Report: MSRB-83-8

ASKERVEIN '82: Report on the September/
October 1982 Experiment to Study Boundary-
Layer Flow over Askervein, South Uist

by

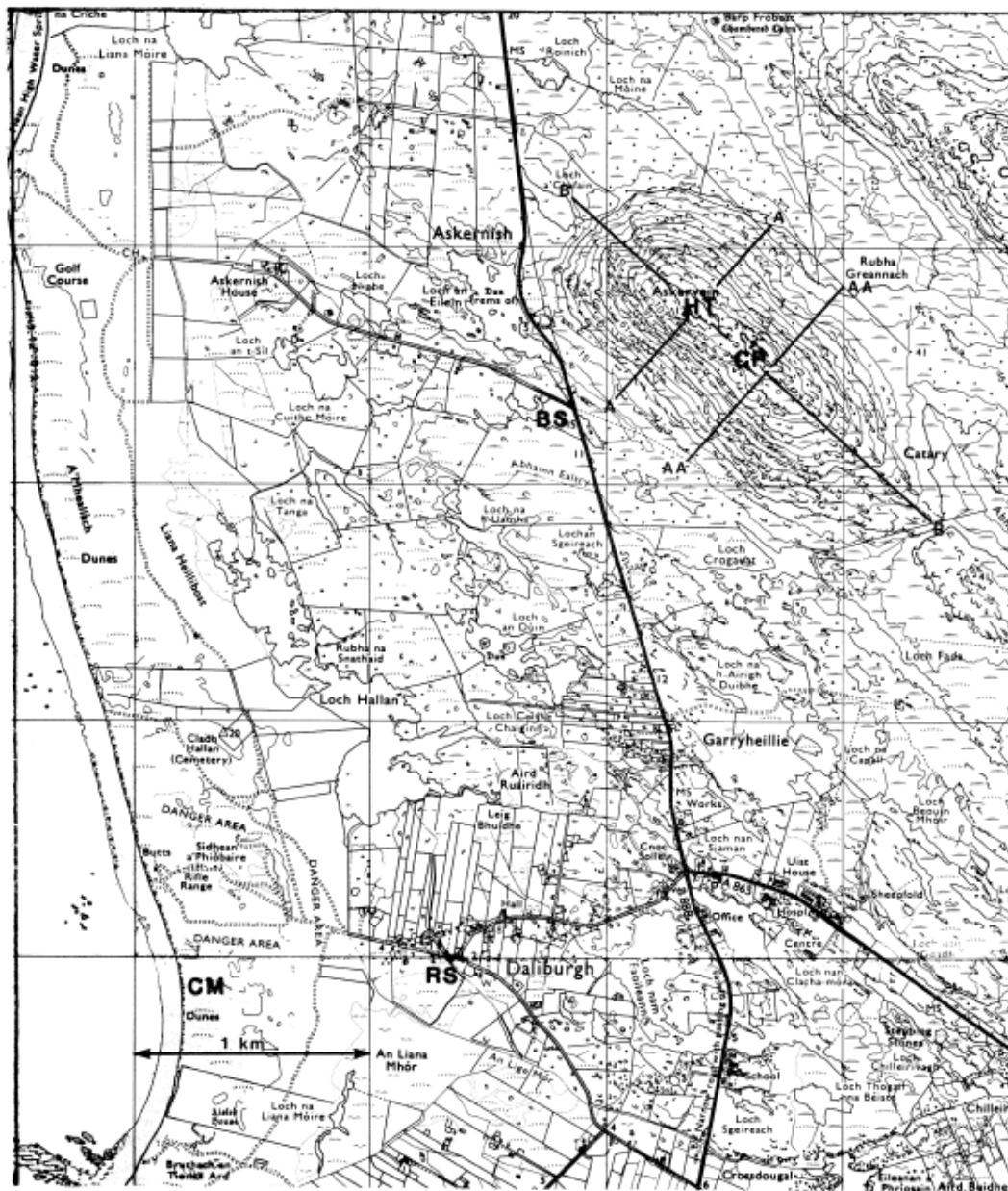
P.A. Taylor and H.W. Teunissen

Research Report: MSRB-84-6

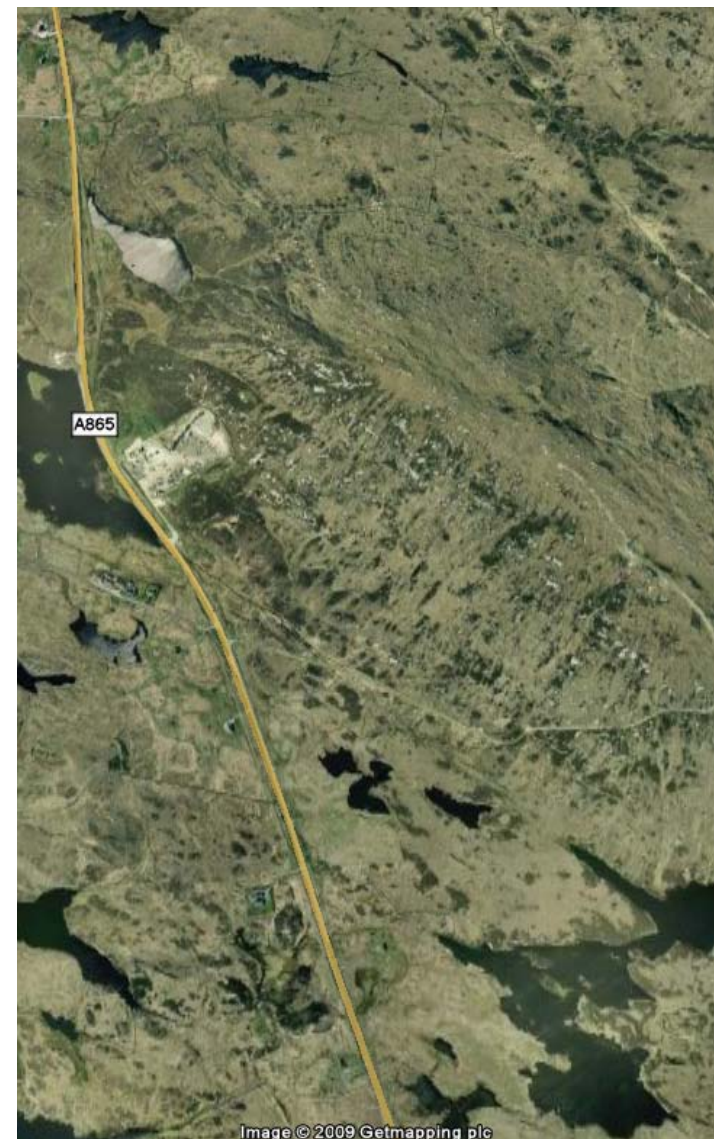
The Askervein Hill Project:
Report on the Sept./Oct. 1983,
Main Field Experiment

by

P.A. Taylor and H.W. Teunissen



Ordnance Survey Map that we had in 1982



Google Earth 2009. HT

57°11'16.63"N, 7°22'45.07"W

Askernish

HT

RS

A865 Daliburgh

B888

Image © 2009 Getmapping plc
© 2009 Tele Atlas
Image © 2009 DigitalGlobe

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57°10'10.92" N 7°23'46.94" W elev 1 m

Eye alt 3.82 km



Askervein Map B Master Grid

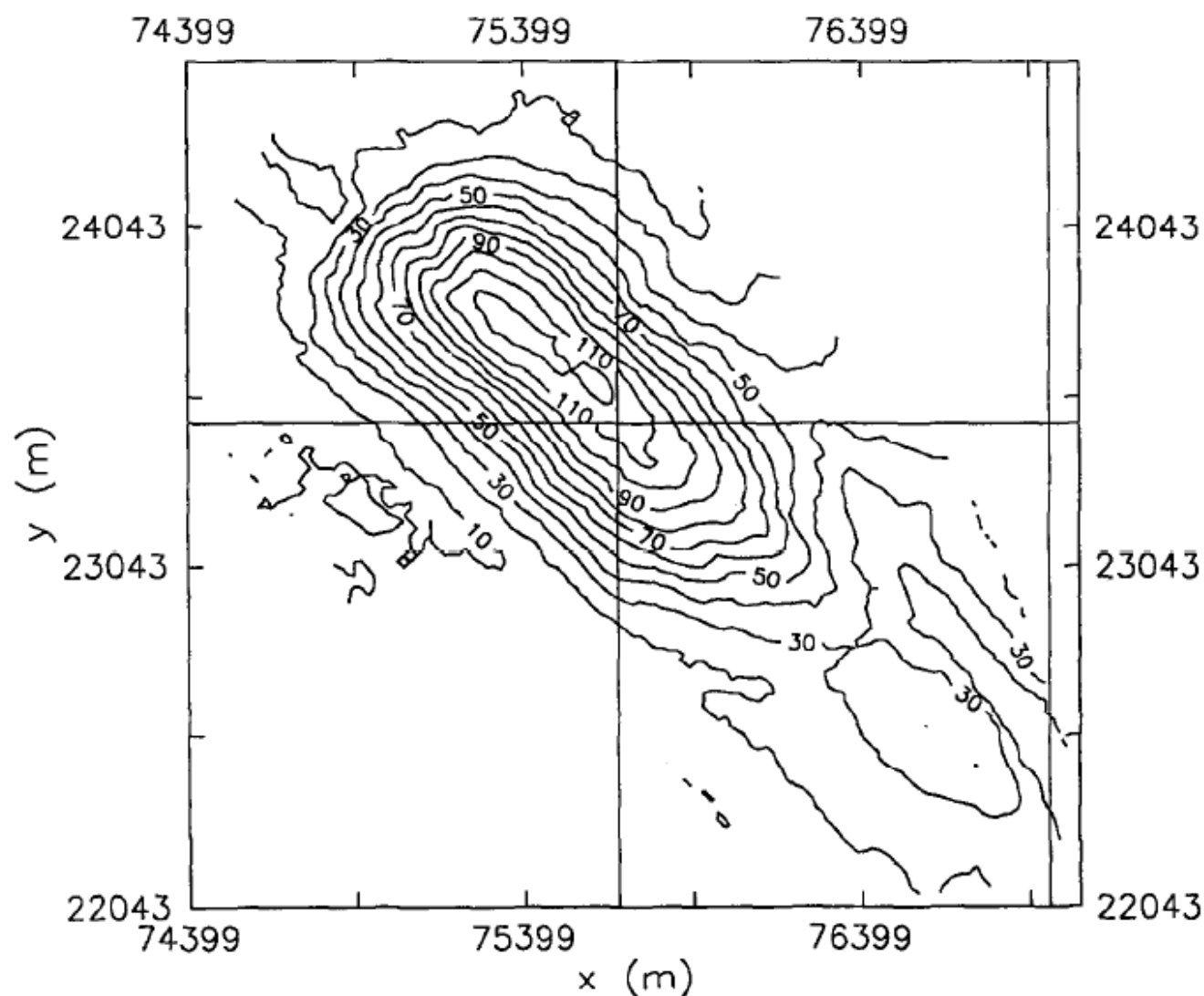
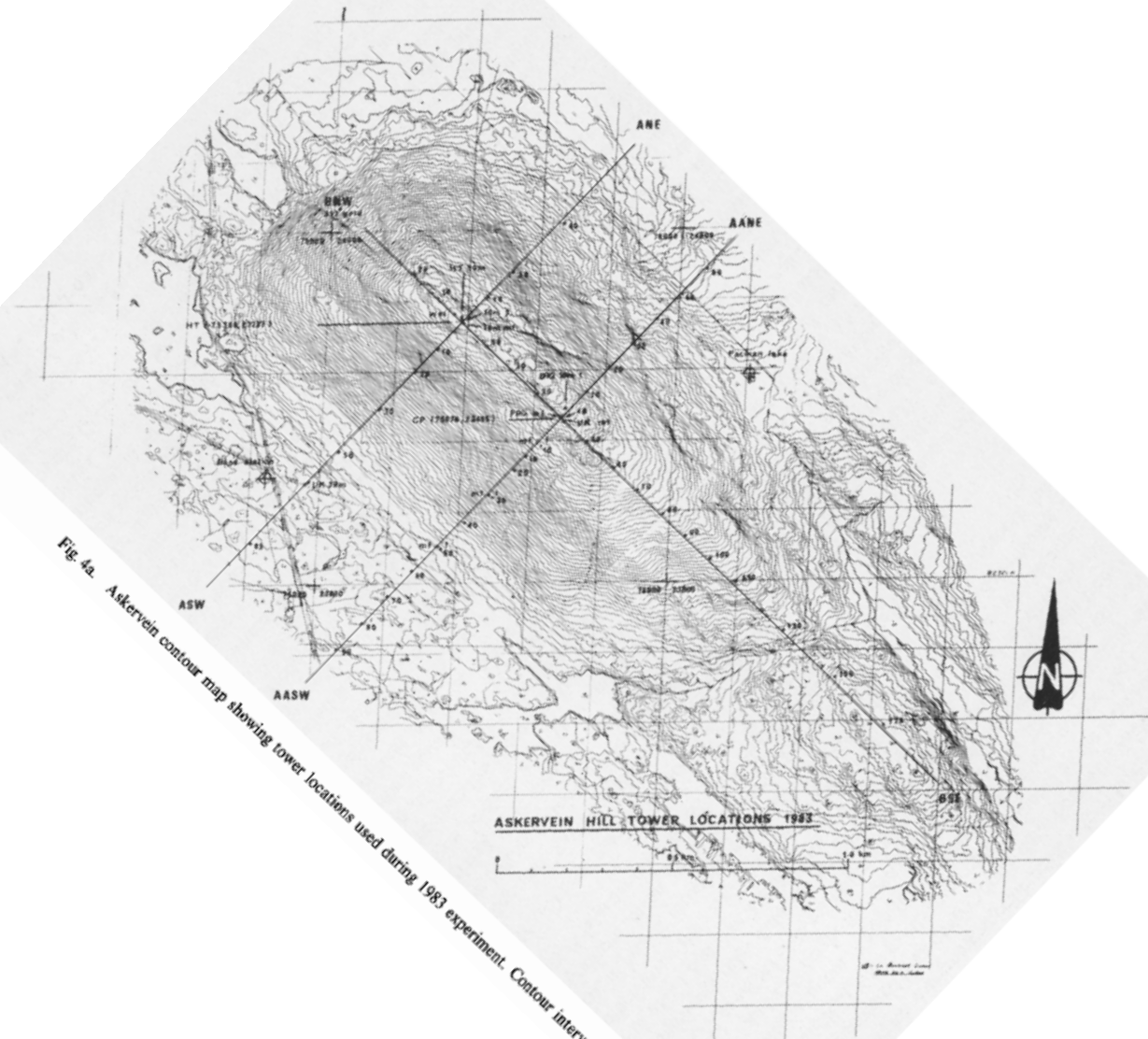


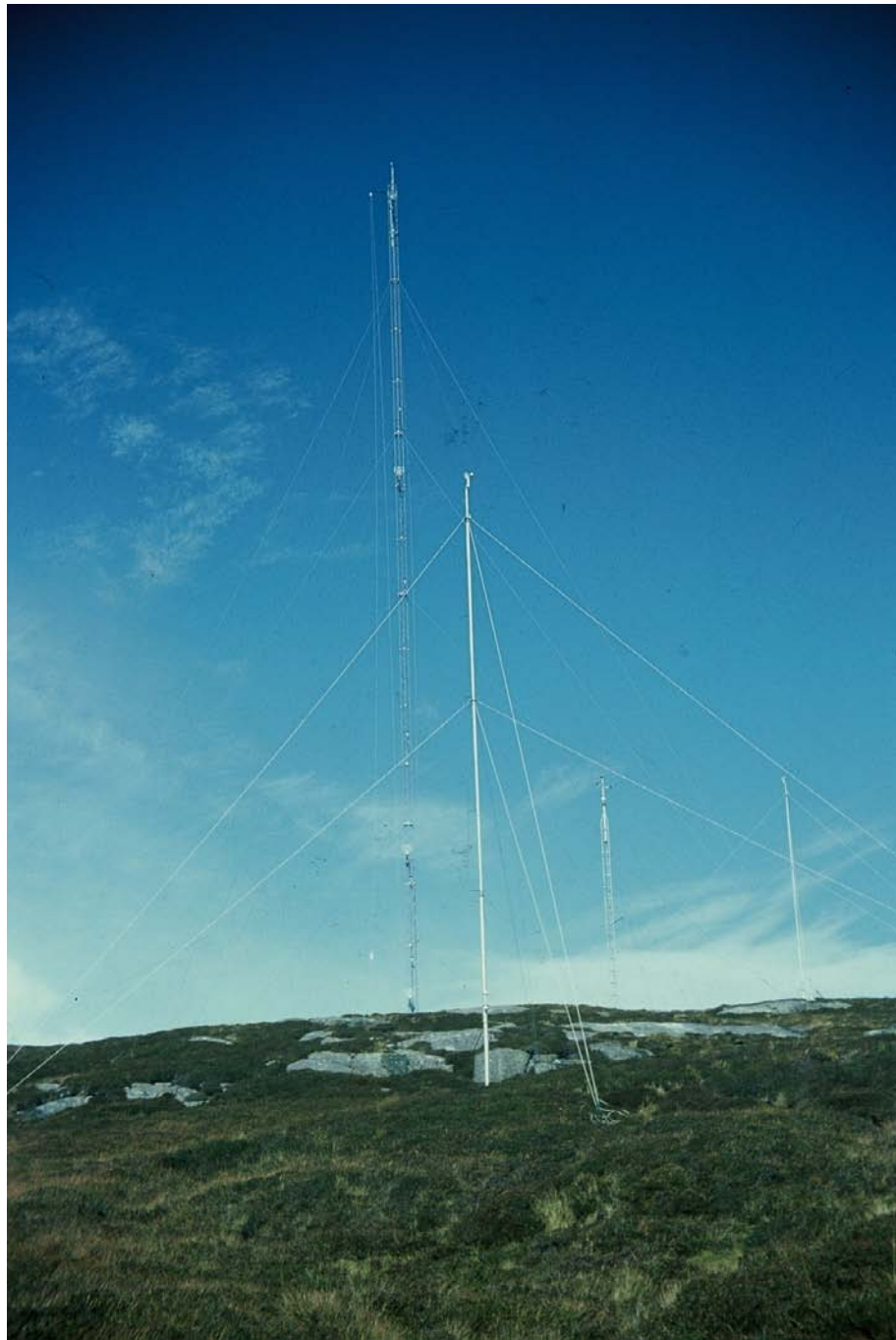
Figure 2. Same as Figure 1 except the area covered is referred to in the text as *Map B* and the original contour map was specially prepared for the Askervein study at a scale of 1:5 000; see text for further details. Heights are in metres above sea level and the contour interval is 10 m. Topographic features to the north and east of Askervein have been blanked out as they were incomplete on the original map.

Fig. 4a. Askervein contour map showing tower locations used during 1983 experiment. Contour interval 2 m.



I should have a better copy somewhere!!!





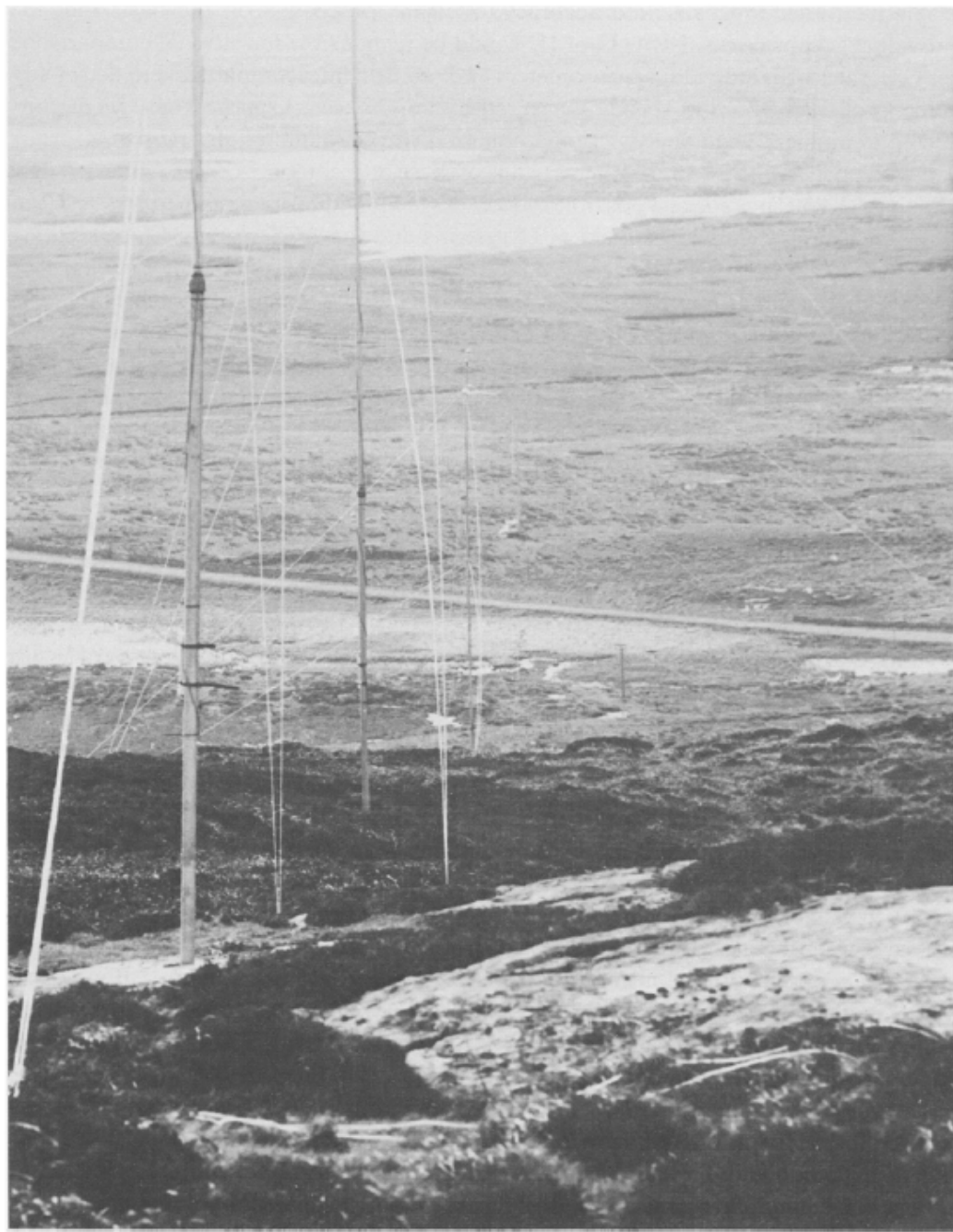


Fig. 1. Photograph of 10 m mean flow posts deployed along the A line during the Askervein '82 experiment.

Instrumentation

- Lots of cup anemometers, mostly on about fifty 10-m posts – Gill, Casella, Vector, Friedrichs
- Gill UVW propeller anemometers – signal conditioning problems. RM Young windmonitor
- TALA kites, single (Peter Taylor et al) and multiple (Nick Cook)
- Sonics (Risø + AES, Hans Teunissen)
Radiosondes
- 50-m towers at HT and RS, 30-m tower near upwind base of hill.
- Data acquisition! Computers and lots of magnetic tape in hilltop caravan and Reference station shed. Sea Data tape loggers. Pulse counters, electronic and mechanical (Casella anemometers)

a)

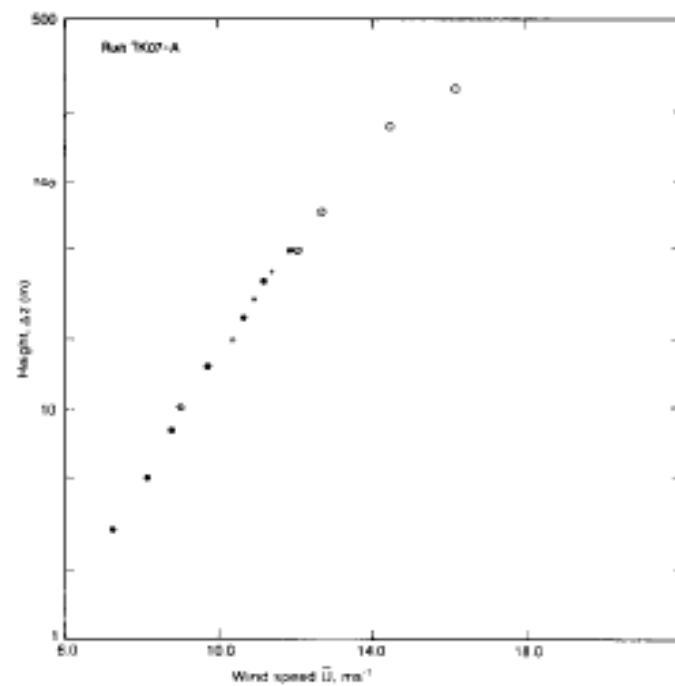
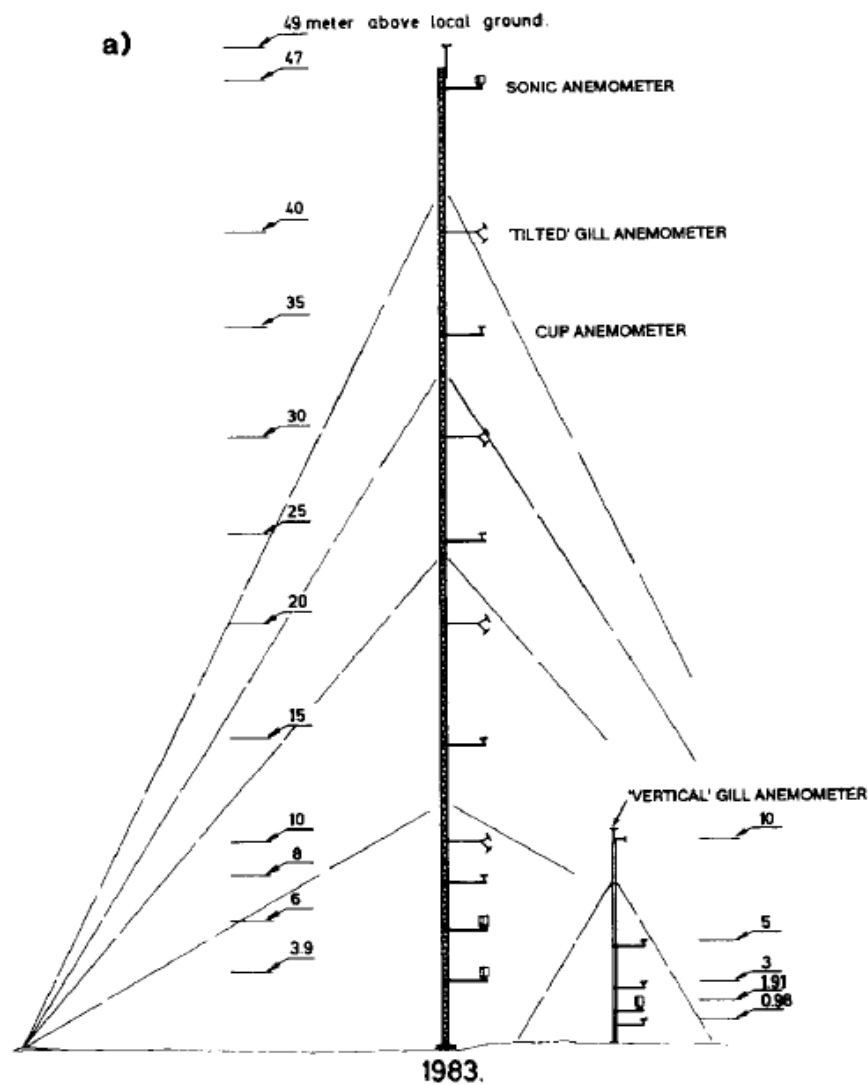


Fig 2d.

RS profile, with TALA kite data

Boundary-Layer Meteorology: Search, Askervein – 31 papers

BOUNDARY-LAYER FLOW OVER TOPOGRAPHY: IMPACTS OF THE ASKERVEIN STUDY

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(Received in final form 20 October, 1995)

Abstract. One of the objectives of the Askervein Hill Project was to obtain a comprehensive and accurate dataset for verification of models of flow and turbulence over low hills. In the present paper, a retrospective of the 1982 and 1983 Askervein experiments is presented. The field study is described in brief and is related to similar studies conducted in the early 1980s. Data limitations are discussed and applications of numerical and wind-tunnel models to Askervein are outlined. Problems associated with model simulations are noted and model results are compared with the field measurements.

27. Article [The Askervein Hill project: Overview and background data](#)
[P. A. Taylor](#) and [H. W. Teunissen](#)

The Askervein Hill project was a collaborative study of boundary-layer flow over low... [Volume 39, Numbers 1-2 / April, 1987](#) [PDF \(4.8 KB\)](#)

26. Article [The Askervein Hill Project: Mean wind variations at fixed heights above ground](#) [J. R. Salmon](#), [A. J. Bowen](#), [A. M. Hoff](#), [R. Johnson](#), [R. E. Mickle](#), [P. A. Taylor](#), [G. Tetzlaff](#) and [J. L. Walmsley](#)

This is one of a series of papers on the Askervein Hill Project. It presents results on the variations in mean wind speed...[Volume 43, Number 3 / May, 1988](#) [PDF \(1.9 MB\)](#)

28. Article [The Askervein Hill Project: Vertical profiles of wind and turbulence](#) [R. E. Mickle](#), [N. J. Cook](#), [A. M. Hoff](#), [N. O. Jensen](#), [J. R. Salmon](#), [P. A. Taylor](#), [G. Tetzlaff](#) and [H. W. Teunissen](#)

This is one of a series of papers on the Askervein Hill Project. It presents results from the Askervein 1982 and 1983 experiments...
[Volume 43, Numbers 1-2 / April, 1988](#) [PDF \(1.6 MB\)](#)

BOUNDARY-LAYER FLOW OVER LOW HILLS

(A Review)*

Boundary-Layer Meteorology **39** (1987) 107–132.
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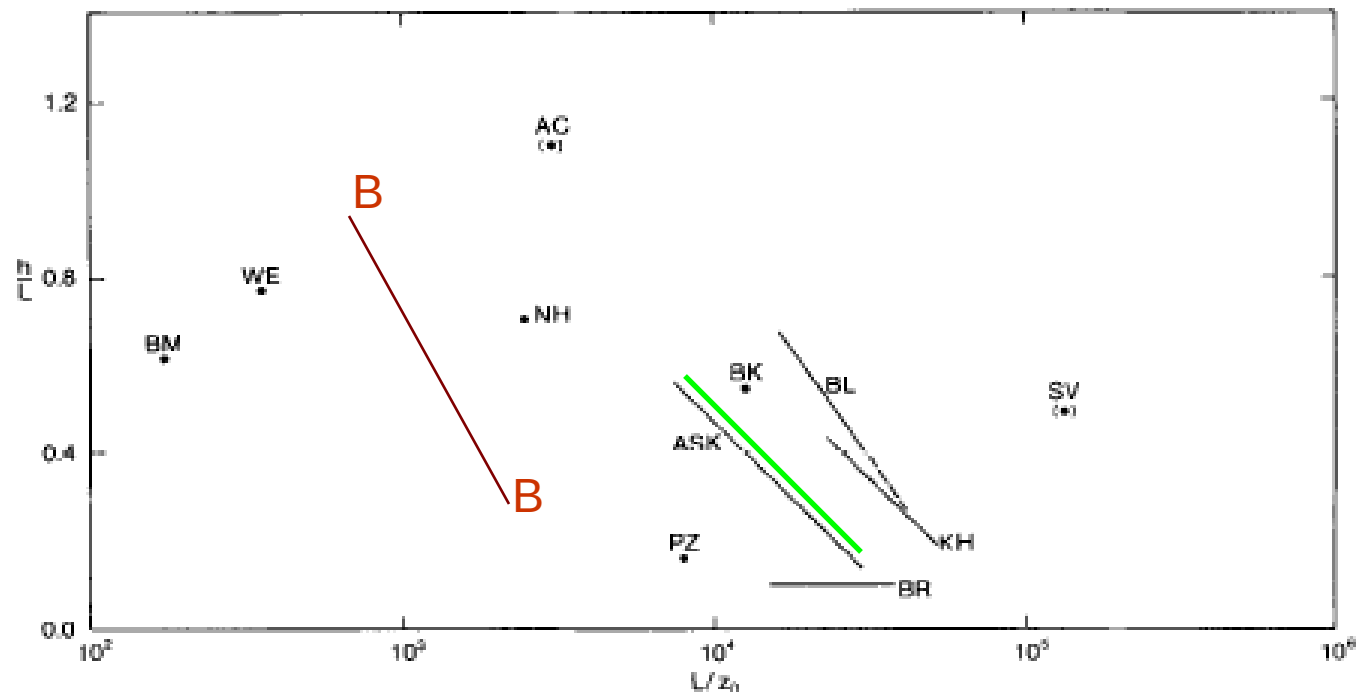


Fig. 3. Parameter space diagram – field studies of boundary-layer flow over hills. See Table I for additional details.

Bolund, $L/z_0 = 0.73-3.7 \times 10^3$: $h/L = 1.0-0.2$; $h = 10.9$ m, L was not well defined – not the simple hill we had looked for in 1980s: Note that L is upwind distance to point where $z_s = h/2$.

Run TU-03B, $\Phi = 210$, October 1983

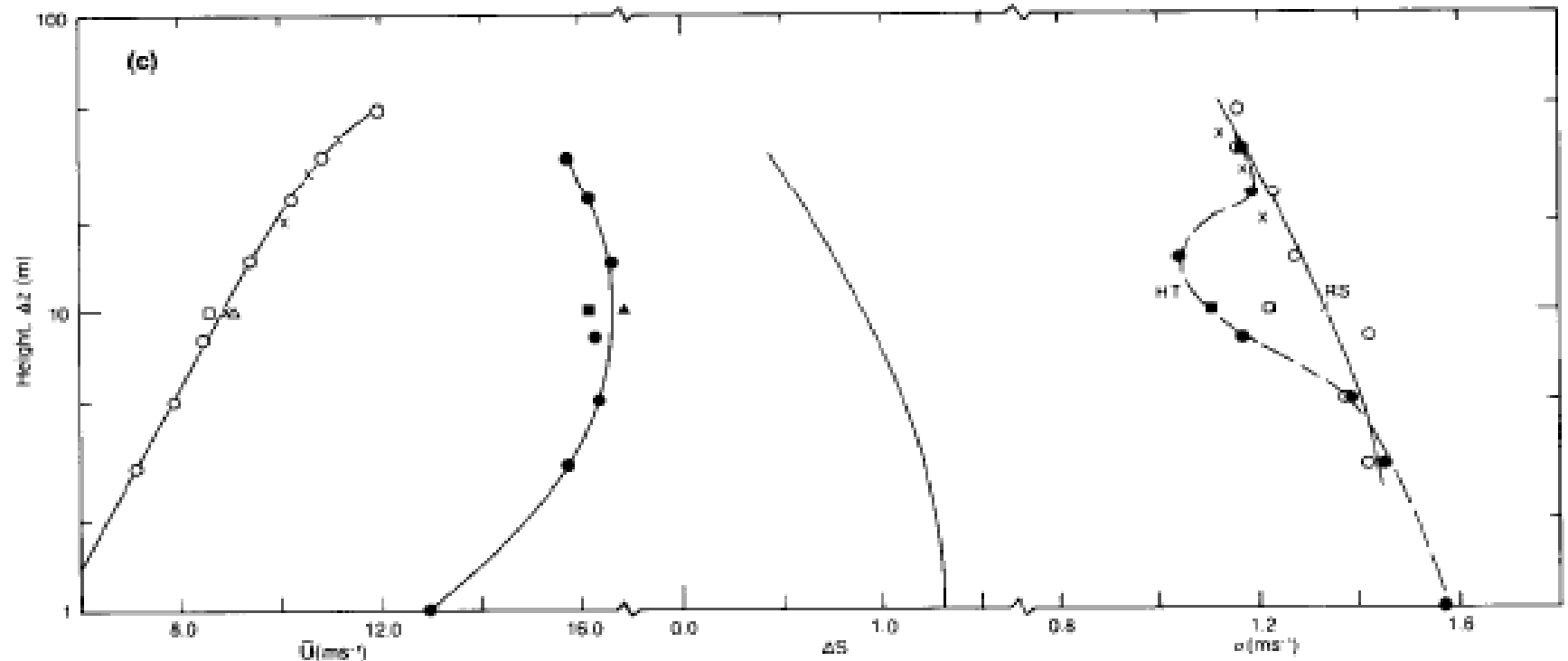


Fig. 6c.

Date	Run number	Time (BST)	Duration (hr)	Mean wind at RS ^a	RS profile data ^b		Ri ^c	$z/\mathcal{L}^d$
					u_* (m s ⁻¹)	z_0 (m)		
Mon03	TU03-A	1200-1300	1.0	210/9.8	0.63	0.022	-0.0038	-0.015
	-B	1400-1700	3.0	210/8.9	0.57	0.020	-0.0074	-0.004

Raw Data – Mean Flow

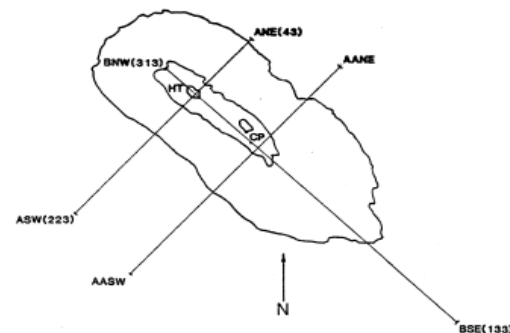
Table 3.1 Designated mean flow (MF) runs during Askervein '83 and directional grouping.

(a) Run Details

Date	Run Number	Time BST	Mean* Velocity, ms^{-1}	Mean* Direction °Grid $\pm 5^\circ$	Ri ⁺	Duration, Hours
Sept. '83						
Sun 25	MF25	(1600-2130)	5.0	210	0.0098 ³	5.5
Mon 26	MF26-A	(0000-0500)	6.0	180	0.0161	5.0
	MF26-B	(0900-1000)	8.0	210	0.0043	1.0
	MF26-C	(1900-2100)	7.8	220	0.0097	2.0
	MF26-D	(2100-0200)	7.1	225	0.0110	5.0
Tue 27	MF27-A	(0300-0430)	6.1	235	0.0126	1.5
	MF27-B	(0430-0700)	5.9	245	0.0134	2.5
Wed 28	MF28-A	(0400-0600)	6.8	090	0.0078	2.0
	MF28-B	(0600-0800)	6.5	095	0.0109	2.0
	MF28-C	(0800-1000)	7.2	100	0.0133	2.0
	MF28-D	(2000-1000)	6.0	105	0.0167	14.0
Fri 30	MF30-A	(1600-1900) ¹	12.0	130	0.0084	3.0
	MF30-B	(1900-0200)	12.5	135	0.0103	7.0
Oct. '83						
Sat 01	MF01-A	(0200-0500)	13.0	140	0.0091	3.0
	MF01-B	(0500-0900)	14.8	145	0.0059	4.0
	MF01-C	(1030-1200)	10.2	170	0.0028 ³	1.5
	MF01-D	(1400-1600)	9.0	180	-0.0205 ³	2.0
	MF01-E	(1700-1830)	7.5	185	0.0103	1.5
	MF01-F	(2100-2400)	8.0	210	0.0141	3.0
Sun 02	MF02-A	(0200-0700)	6.8	210	0.0166	5.0
	MF02-B	(1400-1600)	10.0	165	0.0026	2.0
	MF02-C	(1600-2000)	11.0	165	0.0074	4.0
Mon 03	MF03-A	(0200-0600)	10.5	205	0.0131	4.0
	MF03-B	(0700-1000)	10.0	210	0.0116	3.0
	MF03-C	(1130-1300)	10.0	210	-0.0017	1.5
	MF03-D	(1400-1700)	8.9	210	-0.0110	3.0
Tue 04	MF03-A	(1000-1300)	7.0	180	0.0090	3.0
	MF03-B	(1830-1930)	11.0	285	0.0067	1.0
	MF03-C	(2300-2400)	10.0	270	0.0132	1.0
Wed 05	MF05-A	(0000-0200)	10.0	258	0.0133	2.0
	MF05-B	(0300-0700)	10.0	263	0.0123	4.0
	MF05-C	(0800-0900)	12.0	268	0.0079	1.0
	MF05-D	(1030-1130)	9.5	285	-0.0011	1.0
	MF05-E	(1330-1700)	7.8	305	-0.0092	3.5

Table 3.1 (Continued)

Date	Run Number	Time BST	Mean* Velocity, ms^{-1}	Mean* Direction °Grid $\pm 5^\circ$	Ri ⁺	Duration, Hours
Fri 07	MF07-A	(0230-0500)	8.5	260	0.0046	2.5
	MF07-B	(1200-1400) ²	9.0	240 ⁴	0.0004	2.0
	MF07-C	(1400-1600)	10.0	255 ⁴	0.0005	2.0
	MF07-D	(2200-2300)	11.0	270	0.0029	1.0
Sat 08	MF08	(0200-0400)	9.0	280	0.0045	2.0
Sun 09	MF09-A	(1800-1900)	11.0	275	0.0025	1.0
	MF09-B	(1930-2030)	10.2	283	0.0038	1.0
	MF09-C	(2130-2230)	9.1	268	0.0034	1.0
Mon 10	MF10-A	(0030-0200)	9.0	263	0.0045	1.5
	MF10-B	(0230-0330)	8.8	265	0.0040	1.5



* based on run-averaged wind monitor data from RS

+ Based on temperature and velocity differences (4.9m-16.9m) on RS 17m post

¹ Anemometer #30 moved during run

² Reference data available only 1300-1400

³ Quite variable during these runs

⁴ Direction somewhat unsteady

Askervein '83, Raw Data – Tala Kites and Turbulence Runs

Table 3.2 ASKERVEIN '83 – TALA Kite Profile Runs (BRE and AES)

Date	Run No.	Duration	ϕ_{RS}^+	Ri_{10}	Locations	Comments
01 Oct.	a) TK01-A	15:00-16:00	180°	-0.0142	Coastal Site*	6 Standard Kites (BRE)
	b) TK01-B	16:30-17:30	180°	+0.0104	Coastal Site*	6 Standard Kites (BRE) - data from 4 kites avail. 14:20-18:10
		16:30-18:00	180°		Approx. midway between HT & CP	Single kite (CAN) with data normalized wrt 10m winds at HT
02 Oct.	a) TK02-A	12:30-14:00		-0.0128	Near HT	Single Kite (CAN).
	b) TK02-B	13:30-15:30	165°	-0.0017	Coastal Site*	6 Standard Kites (BRE), Data available 13:00-15:50
03 Oct.	TK03	15:00-17:00	205°	-0.0040	Coastal Site*	6 Standard Kites (BRE)
		15:15-17:15	205°		On downwind hillside	Single Kite (CAN)
05 Oct.	TK05	14:45-16:45	305°	-0.0105	ASW85	Single Kite (CAN)
		15:15-16:45	305°		Between HT & CP	Single Kite (CAN)
07 Oct.	a) TK07-A	13:00-14:00	240°	+0.0013	Coastal Site*	4 Standard Kites (BRE) - variable winds. Data also available 14:00-14:30
	b) TK07-B	16:15-17:30	260°	+0.0011	ASW85	Single Kite (CAN)
		16:15-17:30	260°		Between HT & CP	Single Kite (CAN)
10 Oct.	TK10	10:15-11:45	260°	+0.0003	ASW85	Single Kite (CAN)
		10:15-11:45	260°		Between HT & CP	Single Kite (CAN) - no HT normalizing data.

+Based on Windmonitor strip chart.

*Coastal Site kite profiles combined with RS tower data to give single upstream profile.

TABLE 4.7 DESIGNATED 'TURBULENCE' (TU) RUNS OBTAINED DURING ASKERVEIN '83 AND DIRECTIONAL GROUPING

(a) Run Details

DATE	RUN NUMBER	TIME (BST)	DURATION (HRS)	MEAN WIND AT RS (1)	(2) RS PROFILE DATA		(3) Ri	(4) Z/L
					u_*, ms^{-1}	Z_o, m		
Sept. '83								
Sun 25	TU25	1600-1700	1.0	210/5.5	0.37	0.024	-0.0083	-0.029
Mon 26	TU26	1000-1400	4.0	220/7.0	0.49	0.026	-0.0116	-
Fri 30	TU30-A -B	1130-1300	1.5	135/7.8	0.54	0.030	+0.0005	-0.005
		1600-1700	1.0	130/13.0	0.85	0.028	+0.0051	-
Oct. '83								
Sat 01	TU01-A	1200-1400	2.0	170/9.2	0.63	0.023	-0.0228	-0.030
	-B	1400-1600	2.0	180/9.0	0.55	0.013	-0.0205	-0.026
	-C	1700-1830	1.5	185/7.5	0.49	0.022	+0.0103	+0.001
	-D	1930-2000	0.5	200/7.5	0.49	0.017	+0.0205	+0.008
Sun 02	TU02	1400-1600	2.0	165/10.0	0.69	0.029	-0.0026	-
Mon 03	TU03-A -B	1200-1300	1.0	210/9.8	0.63	0.022	-0.0038	-0.015
		1400-1700	3.0	210/8.9	0.57	0.020	-0.0074	-0.004
Wed 05	TU05-A -B -C -D	1030-1130	1.0	285/9.5	0.64	0.020	-0.0011	-0.016
		1330-1530	2.0	305/7.8	0.51	0.014	-0.0073	-0.012
		1530-1700	1.5	300/7.5	0.45	0.009	-0.0118	-0.016
		1800-2100	3.0	300/5.0	0.38	0.039	+0.0461	-
Thu 06	TU06-A -B	1430-1600	1.5	212/11.0	0.75	0.021	+0.0002	-
		1700-1800	1.0	228/9.2	0.64	0.024	+0.0011	-
Fri 07	TU07-A -B	1200-1400	2.0	240/9.0	0.63	0.027	+0.0004	-
		1530-1700	1.5	260/10.0	0.66	0.022	+0.0009	-0.008

(1) From AES Wind Monitor at $\Delta Z = 10$ m ($^{\circ}\text{Grid}/\text{ms}^{-1}$)

(2) From Lowest ~10 m of Profiles Plotted in Figs. 4.1

(3) Based on temperature and velocity differences (4.9 m - 16.9 m) on RS 17 m tower

(4) Ratio of height (10 m) to Monin-Obukhov length (L) from sonic anemometer at $\Delta Z = 10$ m at RS.

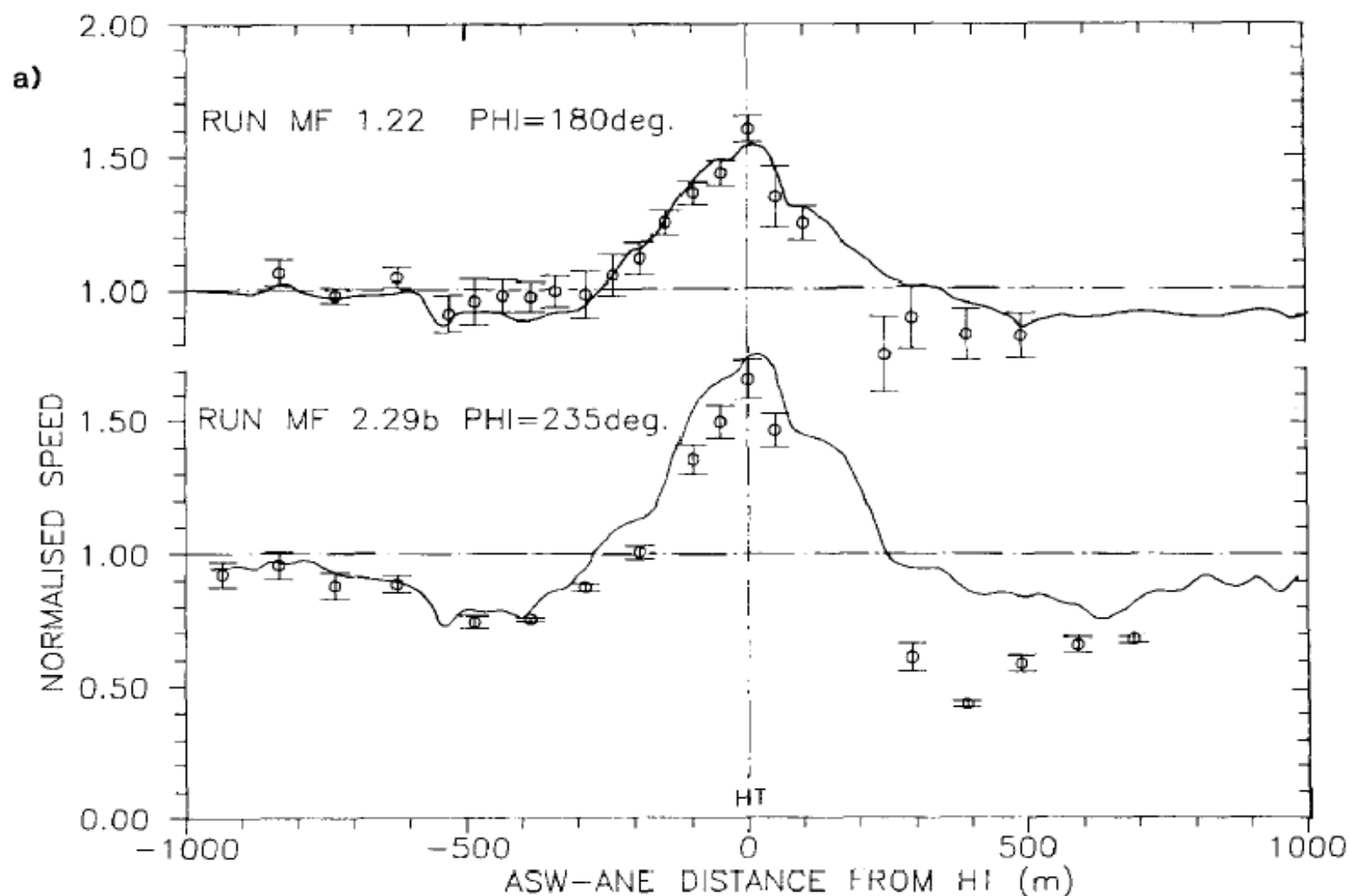
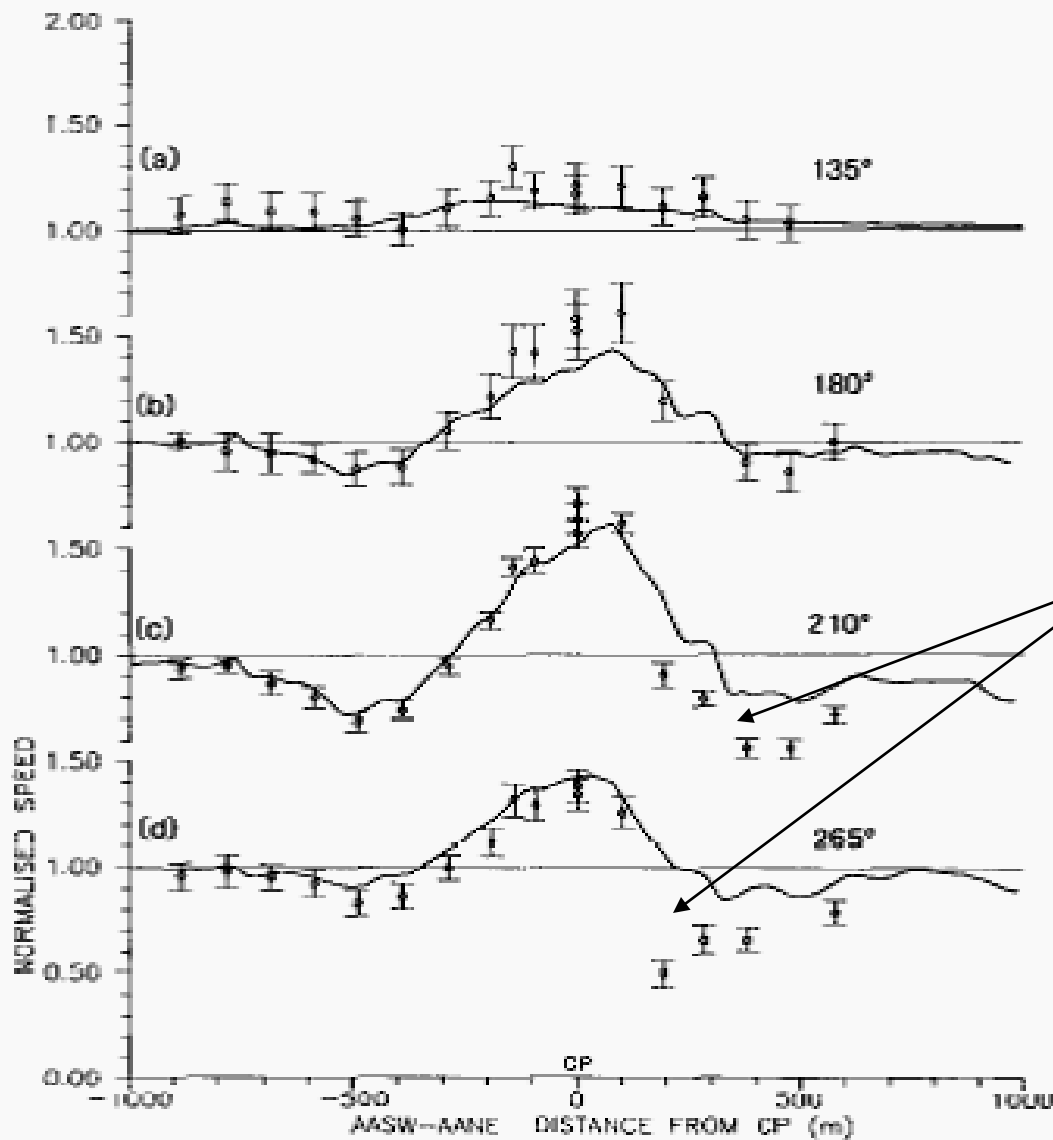


Fig. 6a.

Fig. 6. Sample plots of normalized wind speed at $\Delta z = 10$ m along A and B lines, Askervein '82. (a) A line; (b) B line. $\bar{x}$ mean of 30 min values, error bars denote one standard deviation; () questionable data; — MS3DJH/3 model results.



MS3DJH does well on upstream side of the hill but not in lee of the hill when intermittent separation occurs

Fig. 10. Normalized wind speed at $Az = 10$ m along AA line for selected wind directions and comparisons with MS3DJH/3 model results. Data are based on averages for the direction groups listed in TT87, Table 7b excluding runs with $|Ri| > 0.015$. Upstream wind directions: (a) 135° ; (b) 180° ; (c) 210° ; (d) 265° . $\bar{x}$ mean of 10 min values, error bars denote one standard deviation; — MS3DJH/3 model results.

Simple Guidelines estimates, GLW: A=3.5 - 4, B=1.8 - 1.6

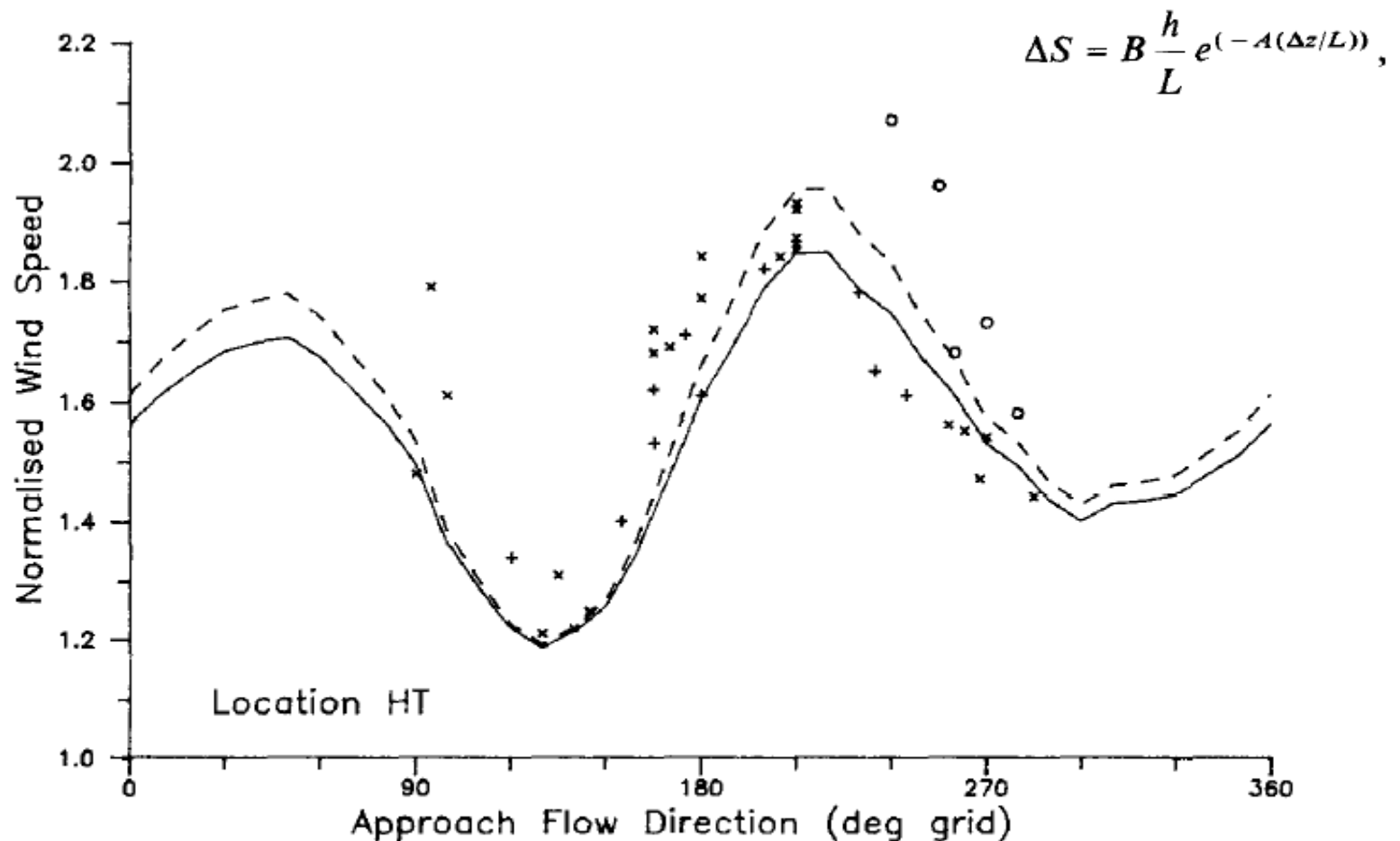


Fig. 2. Normalized wind speeds at HT as a function of ϕ , the wind direction at RS: — guidelines estimate, $\Delta z = 10$ m; - - - guidelines estimate, $\Delta z = 3$ m; + Askervein '82 runs, $\Delta z = 10$ m; x Askervein '83 runs, $\Delta z = 10$ m; O Askervein '83 runs, $\Delta z = 3$ m.

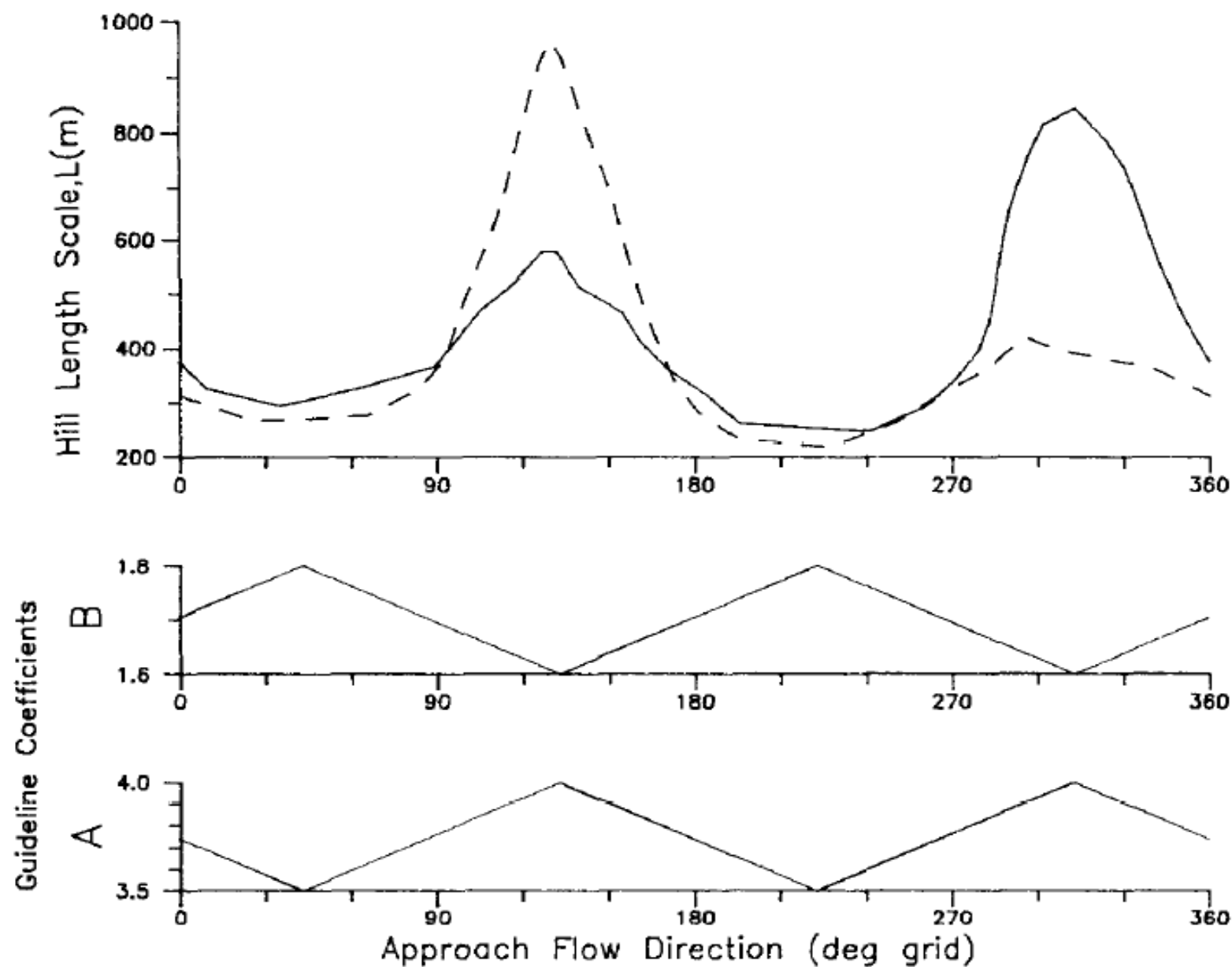
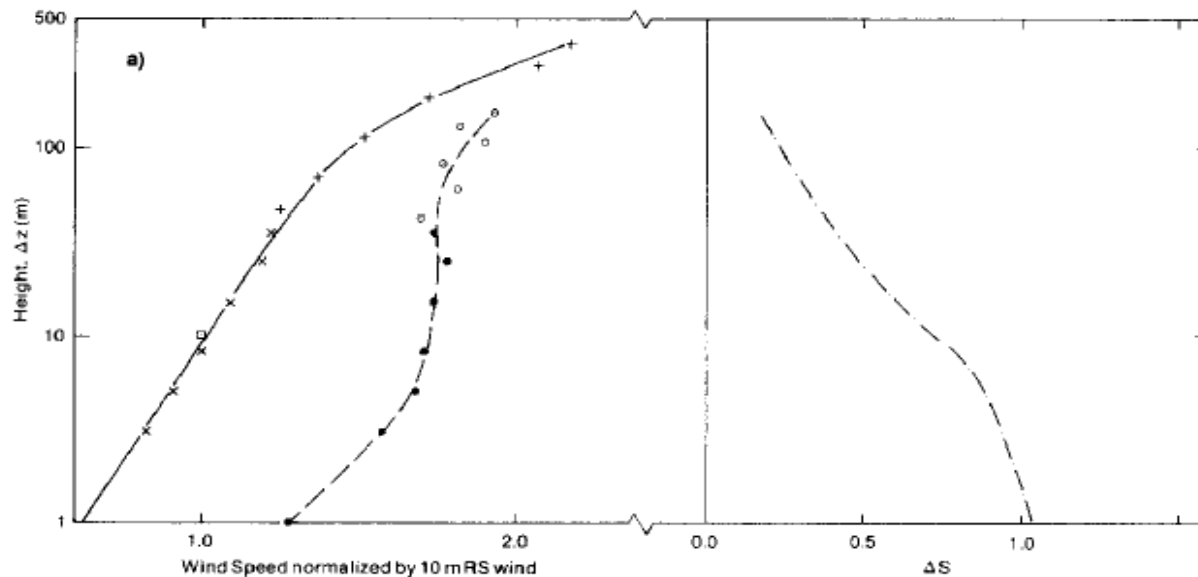
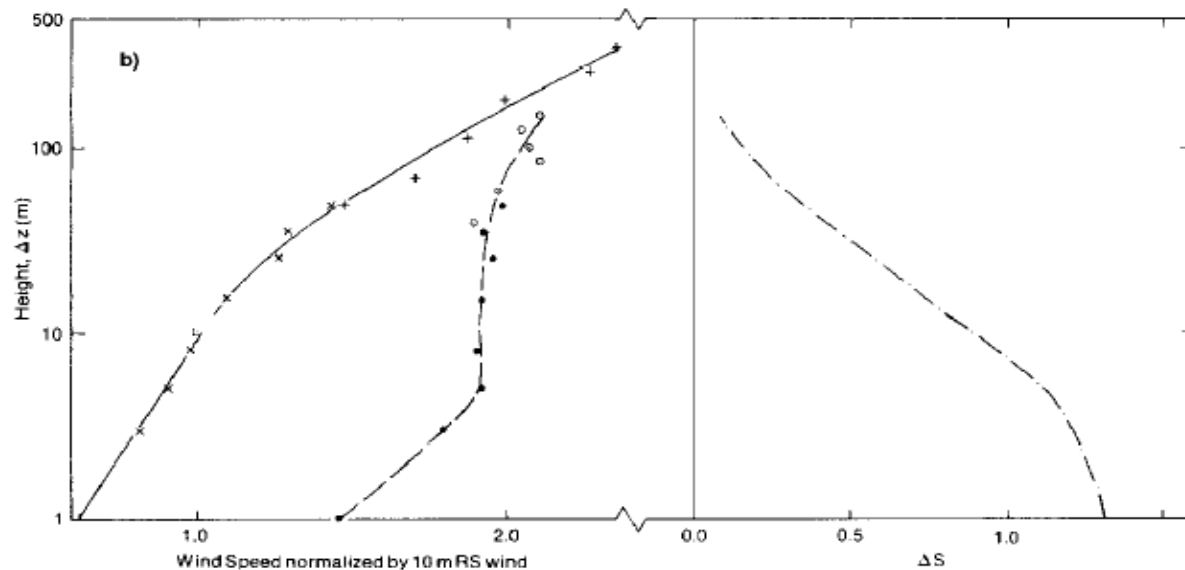


Fig. 4. L , A , and B as functions of direction: — HT; ---- CP.

Sample hilltop profiles, with kite and tower data



$\theta = 165^\circ$



$\theta = 180$

HT Profile contours

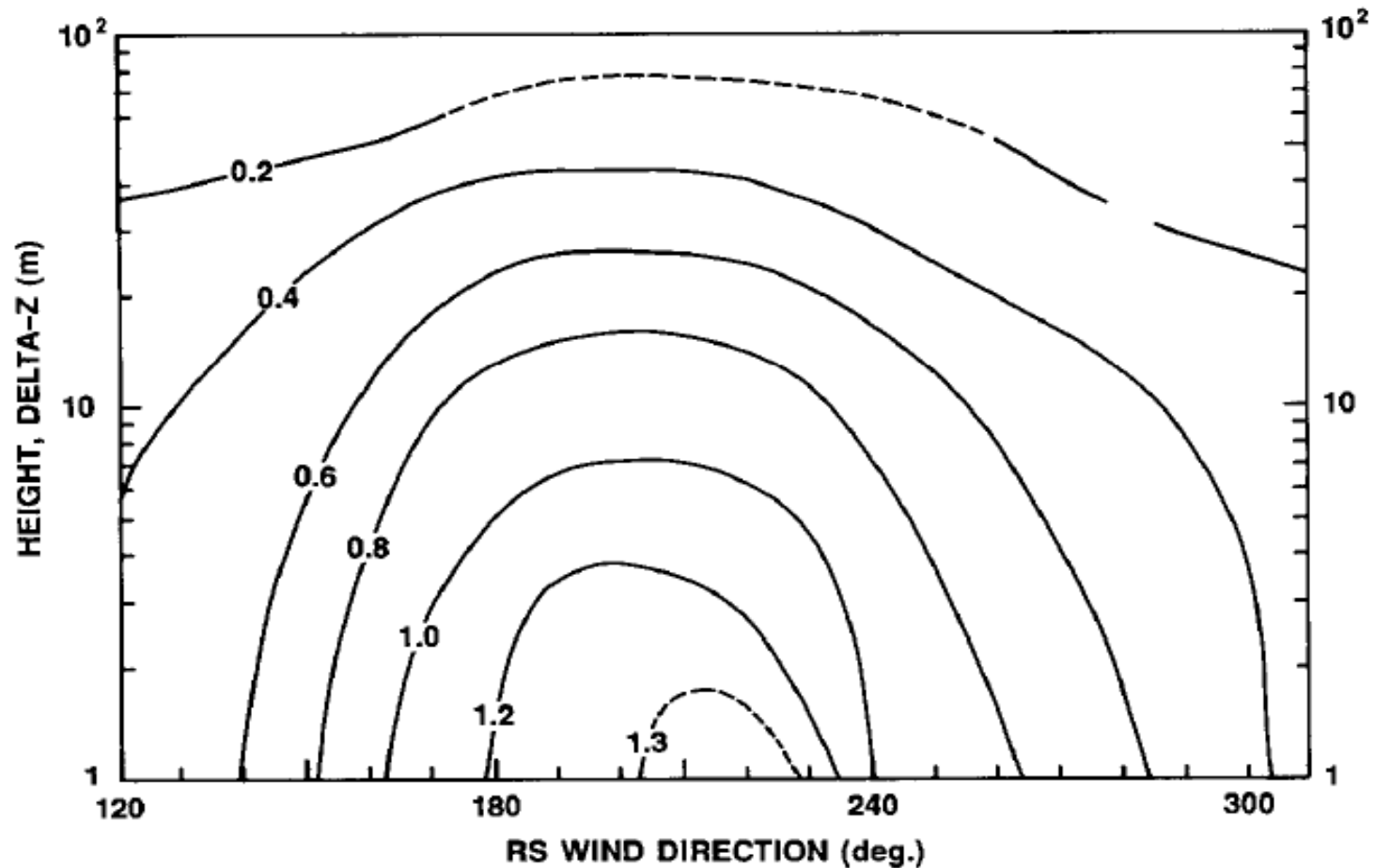


Fig. 7. Contour plot of fractional speed-up ratio, ΔS , at HT as a function of height, Δz , and RS wind direction, ϕ . Based on data from 1982 and 1983 experiments. The dashed portion of the 0.2 contour indicates an area with limited data. The 1.3 contour is dashed to indicate a different contour interval.

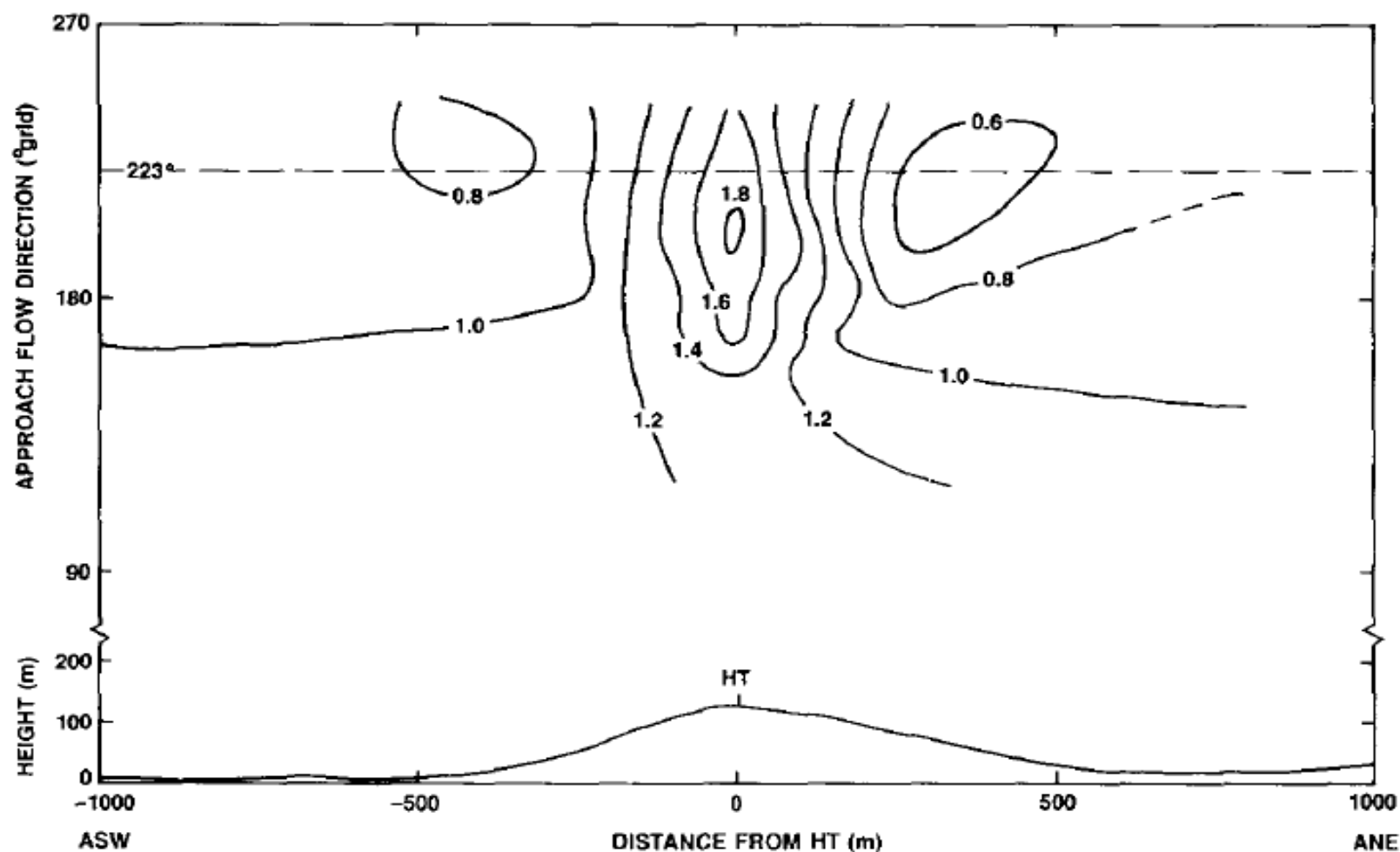


Fig. 7. Contour plot of normalized wind speed at $\Delta z = 10$ m along A line for different wind directions, Askervein '82. Topographic cross-section also shown. Run 1.23a (low wind speed) and 2.29a (direction change during the run) have been excluded.

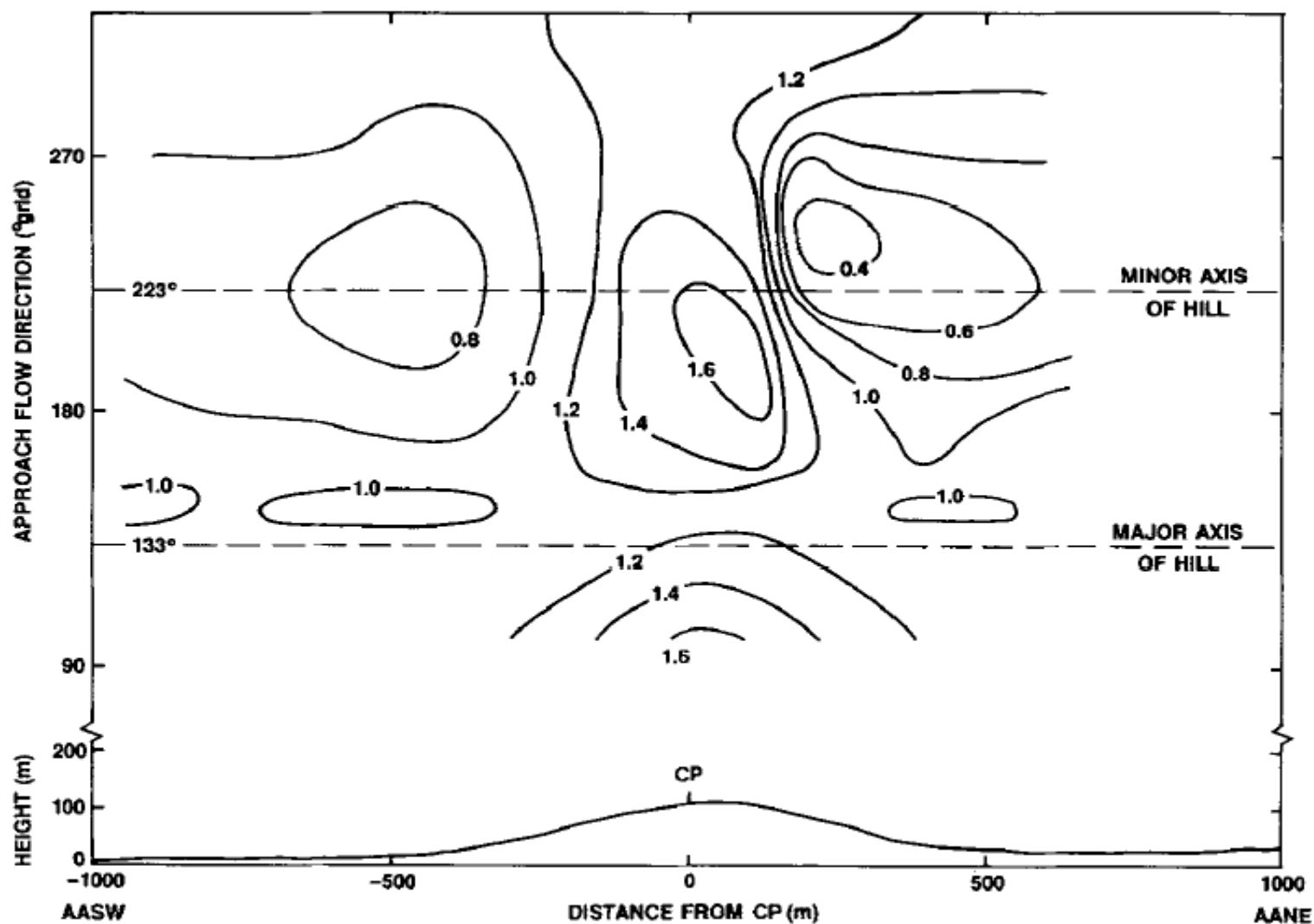


Fig. 12. Contour plots of normalized wind speed data at $\Delta z = 10$ m along AA line for different wind directions, Askervein '83. Data based on averages for the directional groups.

Sample turbulence statistics, RS + upwind hill foot

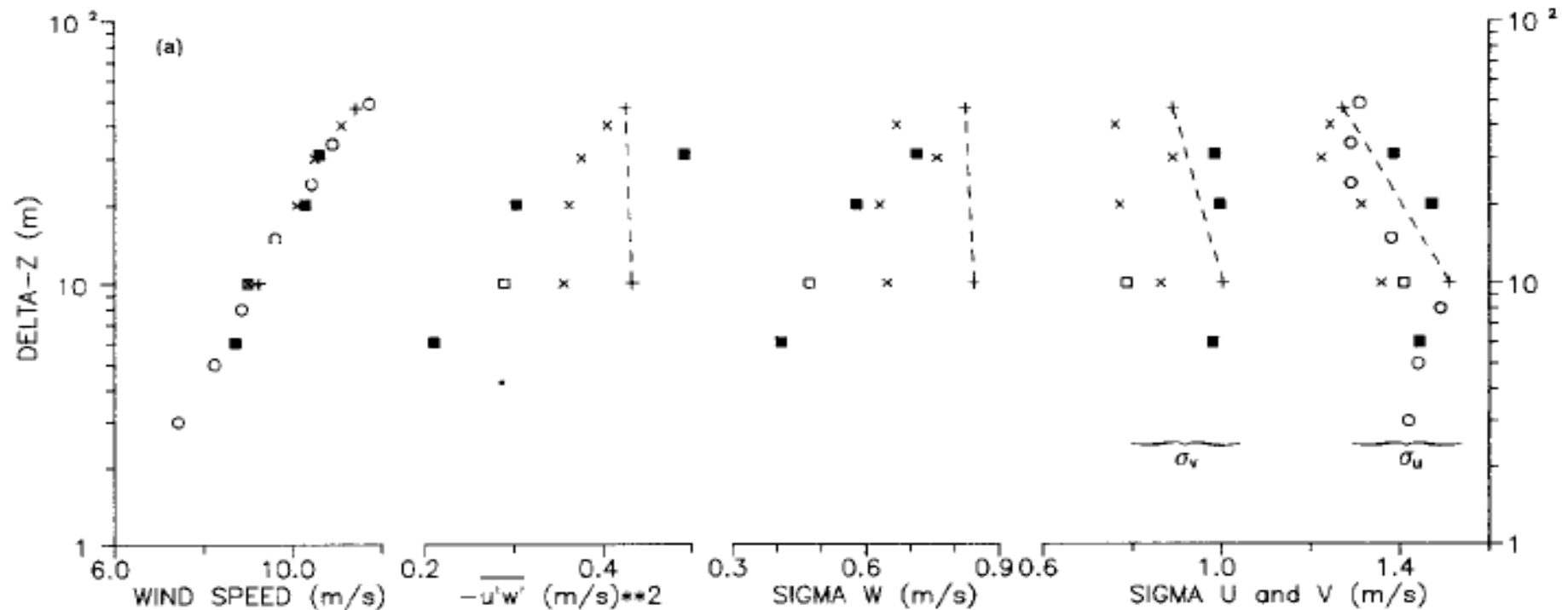
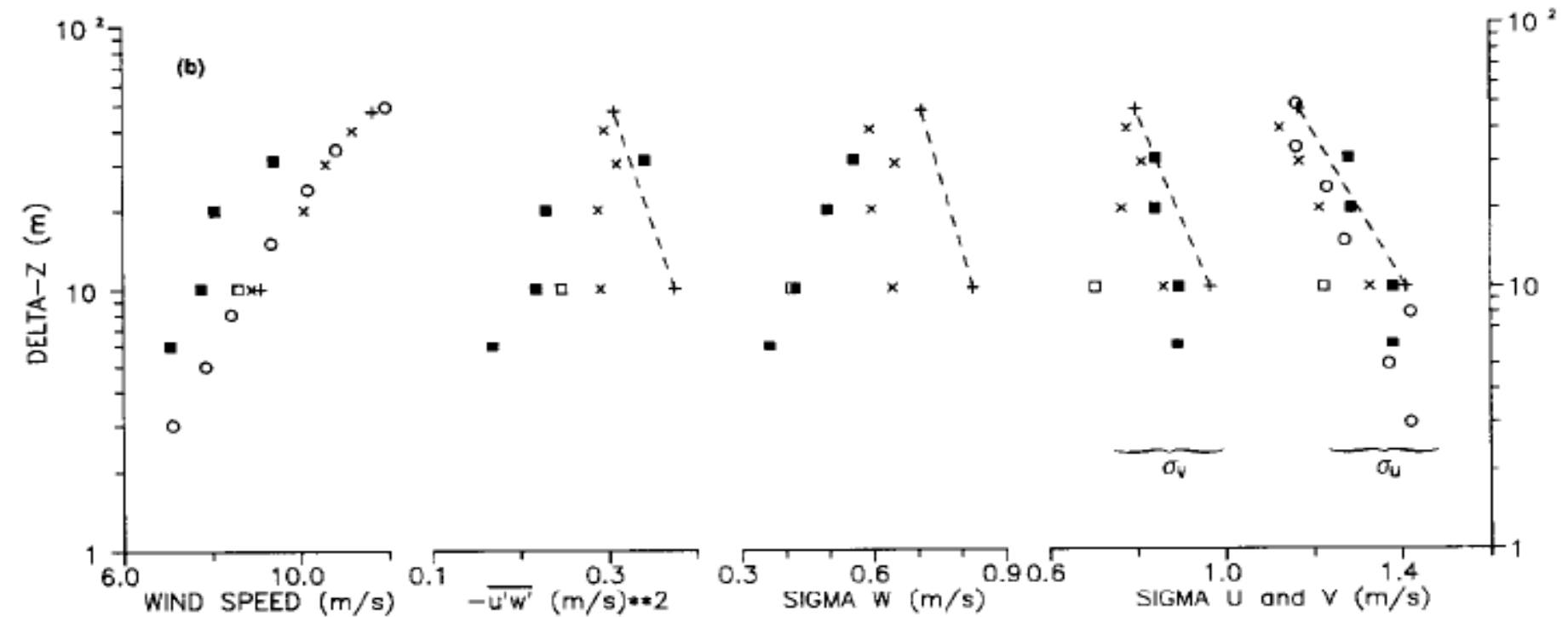


Fig. 4a.

Fig. 4. Profiles of wind speed and integral turbulence statistics at RS and ASW60. (a) Run TU01-B, $\varphi = 180^\circ$. (b) Run TU03-B, $\varphi = 210^\circ$.

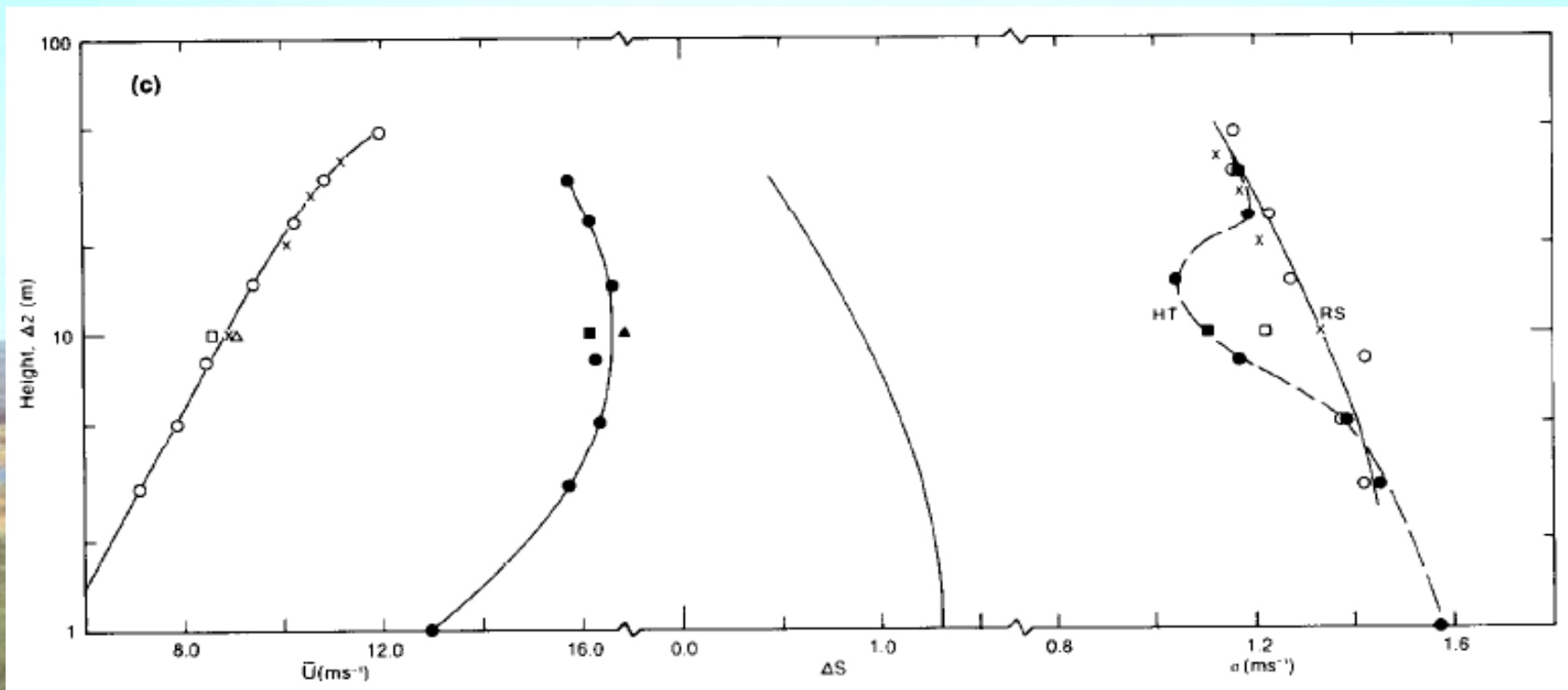
RS data: $\circ$ Cup anemometers; $+$ Sonic anemometers; $\times$ Tilted Gill UVW anemometers; $\square$ Vertical Gill UVW (10 m). ASW60 data: $\blacksquare$ Vertical Gill UVW.

$\emptyset = 210$, note blocking at ASW 60



= ASW 60

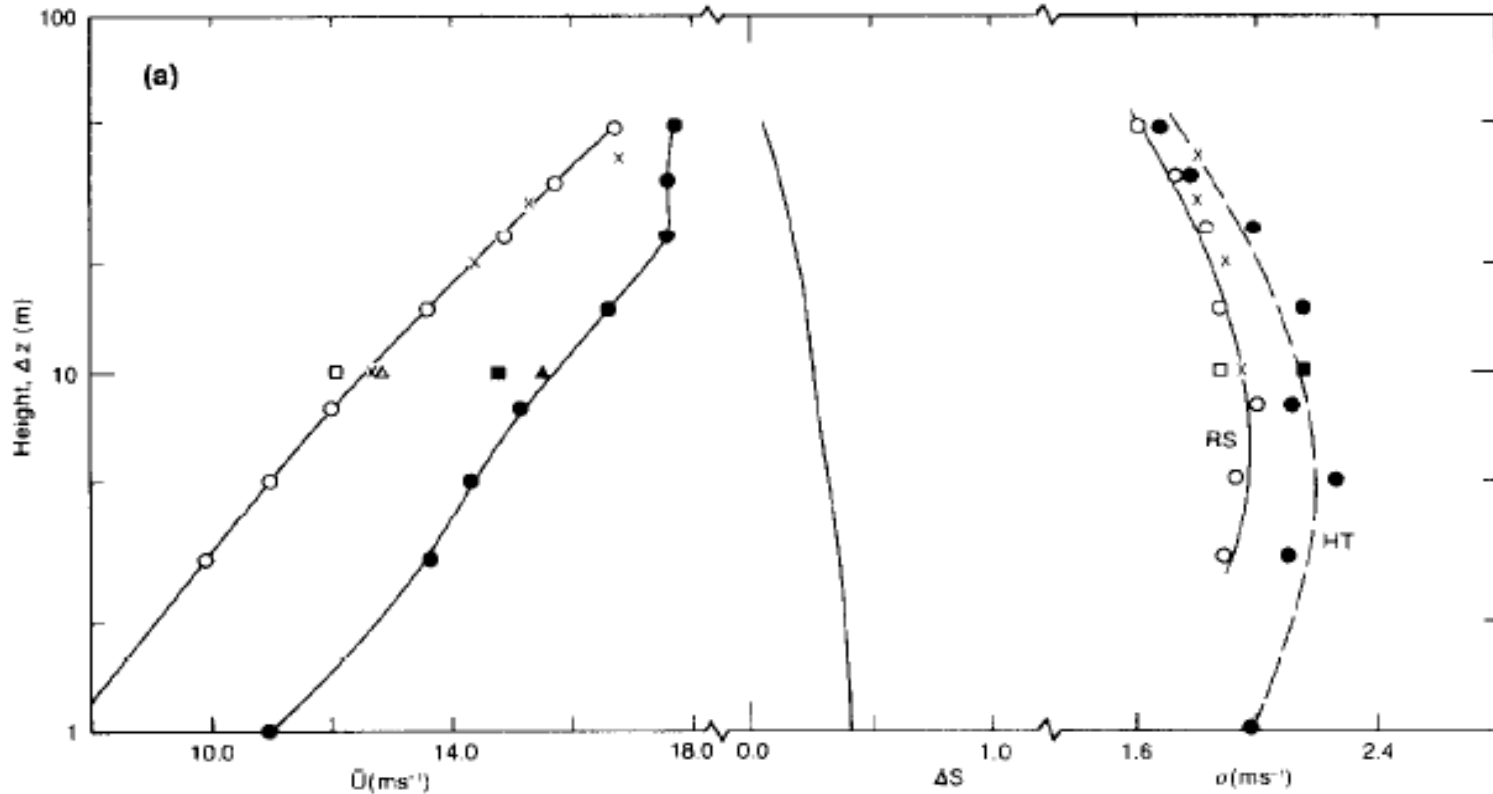
Hilltop (HT) turbulence



Flow from 210 degrees, normal to ridge, σ is based on cup anemometer variance and 3-cpt Gill at 10m.

The main limitation of the Askervein dataset at the time of writing is the lack of more extensive published turbulence data for hilltop locations. Work is presently in hand at Risø to rectify this limitation. It would be interesting to run a third experiment at the site to obtain additional turbulence data, and perhaps to add surface pressure measurements.

Hilltop (HT) turbulence



Inner Layer Depths

The formulae to be considered (JH, JEN and CL, respectively) are:

$$(\ell/L) \ln(\ell/z_0) = 2\kappa^2,$$

$$(\ell/L) \ln^2(\ell/z_0) = 2\kappa^2,$$

$$(\ell/L) \ln(\ell/z_0) = \text{constant}.$$

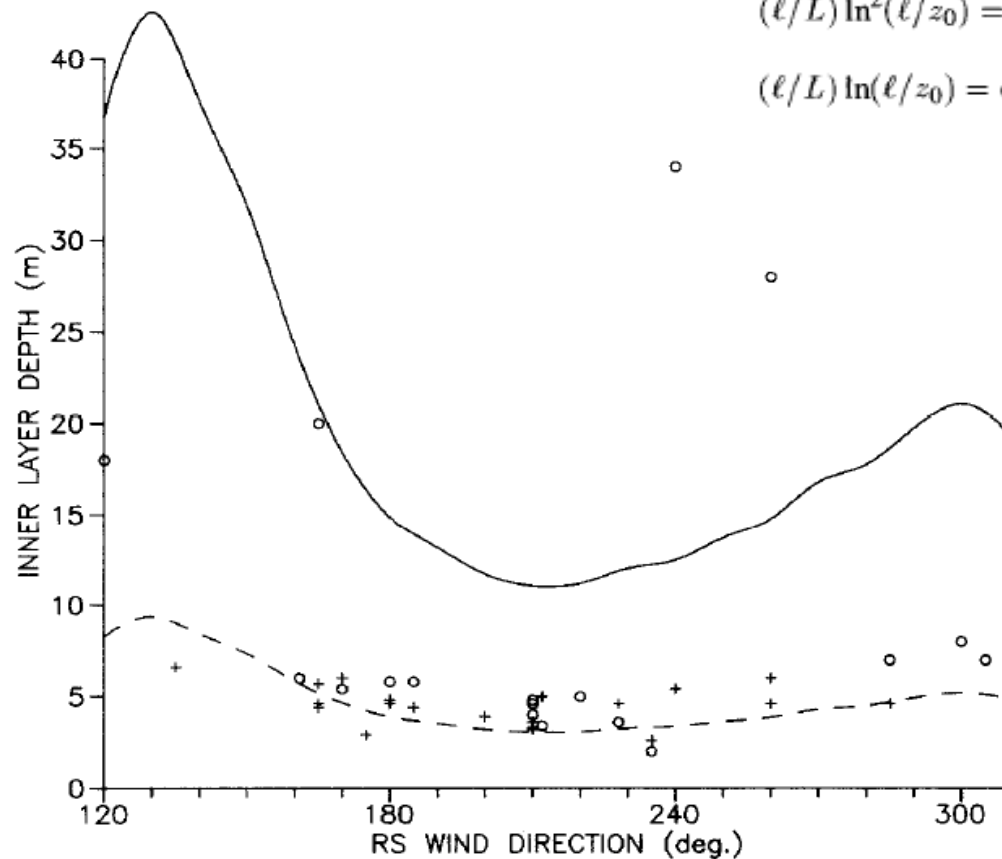


Fig. 8. Estimates and observations of inner-layer depth as functions of wind direction. Askervein hilltop (HT). + observed height of $\Delta U_{\max}$; $\circ$ observed height at which $\Delta\sigma_u = 0$; — Jackson-Hunt estimate (TT87, equation (4)); - - - - Jensen estimate (TT87, Equation (55)).



The roughness length anomaly

Table 3.7: Profile-derived z_0 and u_* values at CP and BSE10 during selected MF runs, Oct. 7-10, 1983.*

Run	CP		BSE 10	
	z_0 (m)	u_* (ms ⁻¹)	z_0 (m)	u_* (ms ⁻¹)
MF07-A	0.0003	0.43	.0011	0.55
MF07-D	-	-	.0010	0.68
MF08	-	-	.0009	0.53
MF09-A	0.0012	0.64	.0006	0.58
MF09-B	0.0017	0.65	.0013	0.60
MF09-C	0.0007	0.56	.0009	0.59
MF10-A	0.0006	0.54	.0011	0.62
MF10-B	0.0007	0.53	.0008	0.56

Based on winds measured at 0.5m and 3m levels.

*see discussion in text with regard to the interpretation of these values

(2) RS PROFILE DATA	
u_* , ms ⁻¹	z_0 , m
0.37	0.024
0.49	0.026
0.54	0.030
0.85	0.028
0.63	0.023
0.55	0.013
0.49	0.022
0.49	0.017
0.69	0.029
0.63	0.022
0.57	0.020
0.64	0.020
0.51	0.014
0.45	0.009
0.38	0.039
0.75	0.021
0.64	0.024
0.63	0.027
0.66	0.022

Note : Hilltop area appears rougher than $z_0 = 1$ mm.

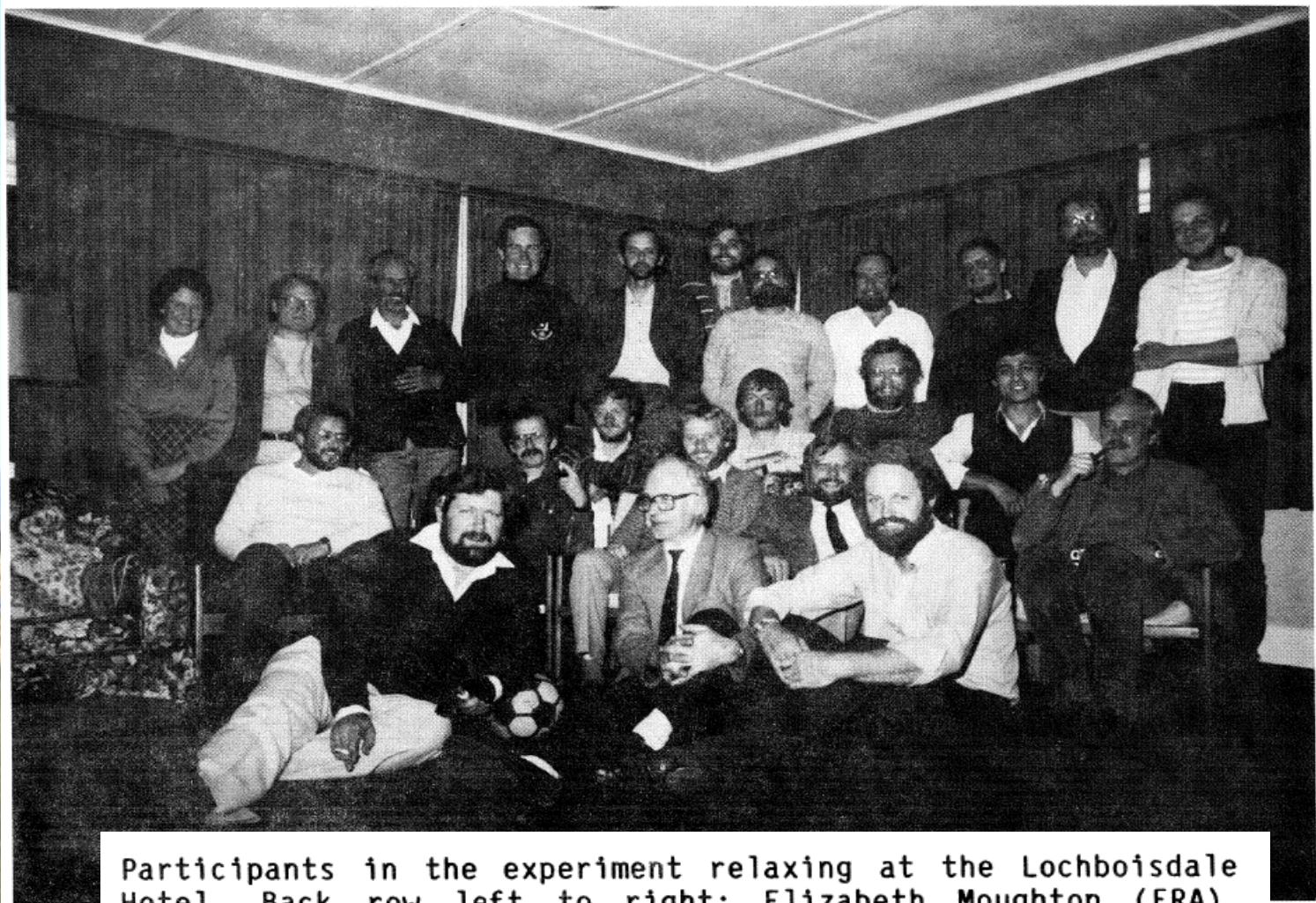
Should look at other ways to estimate z_0 and u_*

Some Conclusions

- Simple, linear models (MS3DJH, MSFD) appear to predict speed-up well on upwind side of the hill, and at hilltop locations.
- Good speed-up near the ground, $\Delta S \approx 1$ but at 100m, $\Delta S \approx 0.1-0.2$. Still an advantage for wind energy.
- Limited success with turbulence measurement, sonics and tilted Gills.
- RDT predictions of turbulence reductions (σ_s) above the hilltop were validated.
- A good data set for model validations – widely used.

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- University of Canterbury (New Zealand)



Participants in the experiment relaxing at the Lochboisdale Hotel. Back row left to right: Elizabeth Moughton (ERA), Peter Taylor (AES), David Redfern (BRE), Tony Bowen (U. of Calgary), Nick Cook (BRE), Rob Johnson (ERA), Jim Arnold (AES), Finn Hansen (Risø), Mogens Nielsen (Risø), Bob Mickle (AES), Thomas Burger (U. of Hannover). Seated: Karl Vanek (AES), Hans Teunissen (AES), Kurt Pengel (U. of Hannover), Jim Salmon (CAN.), Masood Nourshargh (ERA), Niels Otto Jensen (Risø). Seated on floor: Wes Kobelka (AES), Gunnar Dalsgaard (Risø), John Deary (AES). Not in photo: Bob Delnon (ERA), Doug Warne (ERA), Martin Shaw (BRE)

Canterbury!