Met Office

DISPERSION MODEL INPUT PARAMETERS FROM NUMERICAL WEATHER PREDICTION OR SYNOPTIC OBSERVATIONS

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12th International Conference on Harmonisation Within Atmospheric Dispersion Modelling for Regulatory Purposes

Cavtat, Croatia 6-9 October 2008

Contents

Introduction

Regulatory dispersion modelling uses hourly met data

Previous work.

Met Office

Previous work at Harmo 11 Conference, Cambridge, July 2007 studied met data used for input to dispersion models:

OBS: Synoptic Observations.

NWP: Numerical Weather Prediction Data from UM.

- OBS, NWP-12km and NWP-60km data were compared.
- Wind speed, direction, cloud, temperature and NWP BLD.

Middleton D R (in press) IJEP

Present Work

<u>Extends</u> the study of hourly synoptic OBS versus NWP-12km and NWP-60km data from the UM.

2. Wind Speed Weibull distributions of OBS & NWP.

3. BLD from OBS (NAME III pre-processor) versus BLD from NWP (UM).

4. Stability distribution via Pasquill-Smith & Pasquill-Golder.

5. Stability maps for Monin Obukhov Length, Friction Velocity & Sensible Heat Flux.

NAME III Met Pre-Processor Input Data

- NAME III and ADMS models have similar boundary layer algorithms & inputs.
  Jones et al. (2007); Carruthers et al. (1994)
- Data for 2004 at ~50 sites in the UK.
- NWP Data were interpolated in space & time to each site location.
- NWP & Hourly Synoptic OBS data were input into NAME III met pre-processor.
- Analyse pre-processor outputs.

OBS data

OBS Synoptic Data Inputs

- Wind speed (m s^{-1})
- Wind direction (degrees)
- Cloud amount (oktas)
- Temperature (C)
- Precipitation rate (mm hr^{-1})
- Relative Humidity (%)

Calculated in NAME III Pre-Processor

- Boundary Layer Depth
- Sensible Heat Flux
- Friction Velocity
- Monin Obukhov Length

NWP data

NWP Data Inputs from UM

- Wind speed (m s^{-1})
- Wind direction (degrees)
- Cloud amount (oktas)
- Temperature (C)
- Precipitation rate (mm hr^{-1})
- Relative humidity (%)

- Sensible heat flux (W m^{-2})
- Boundary layer depth (m)

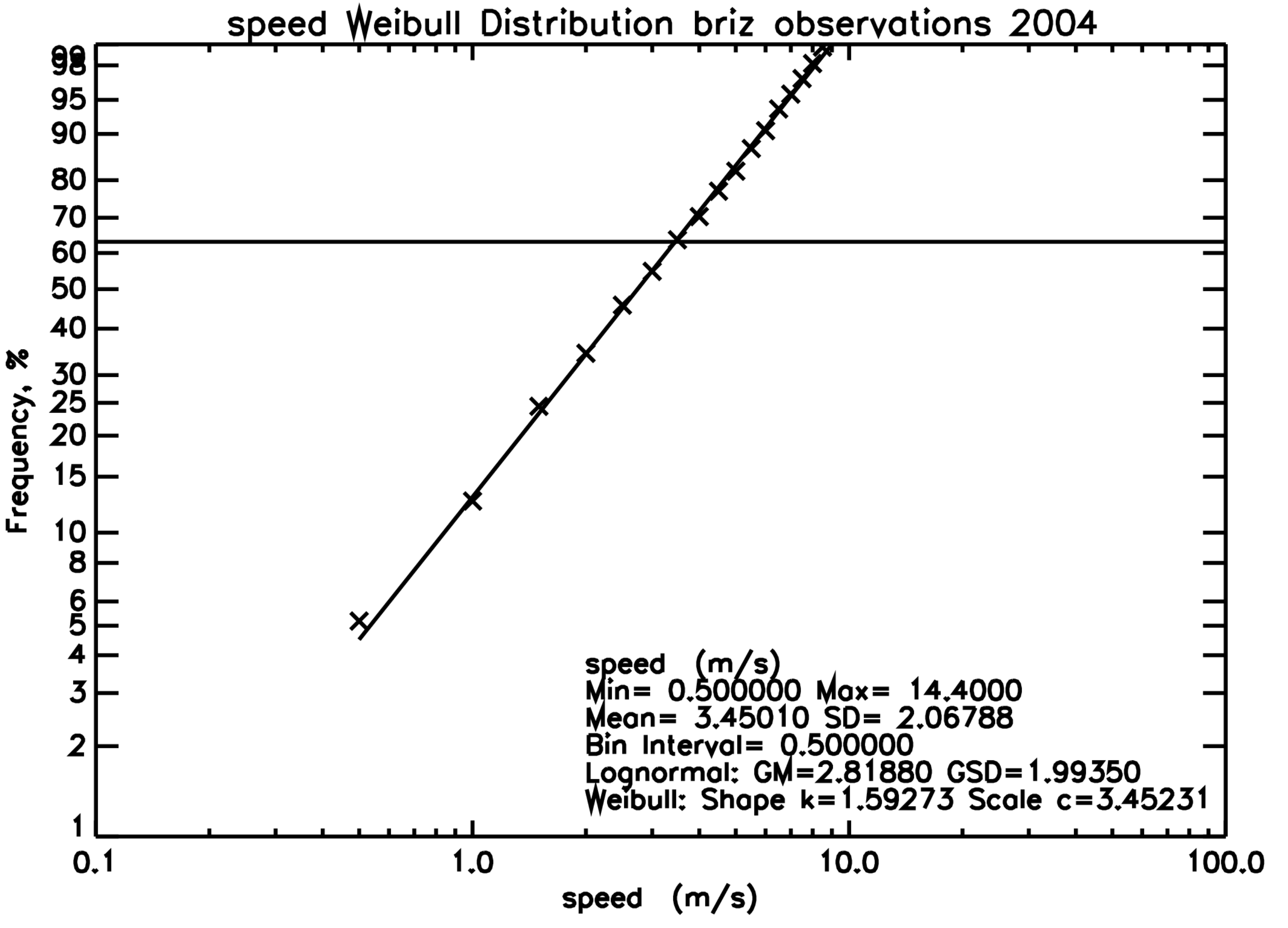
Calculated in NAME III Pre-Processor

- Friction Velocity
- Monin Obukhov Length

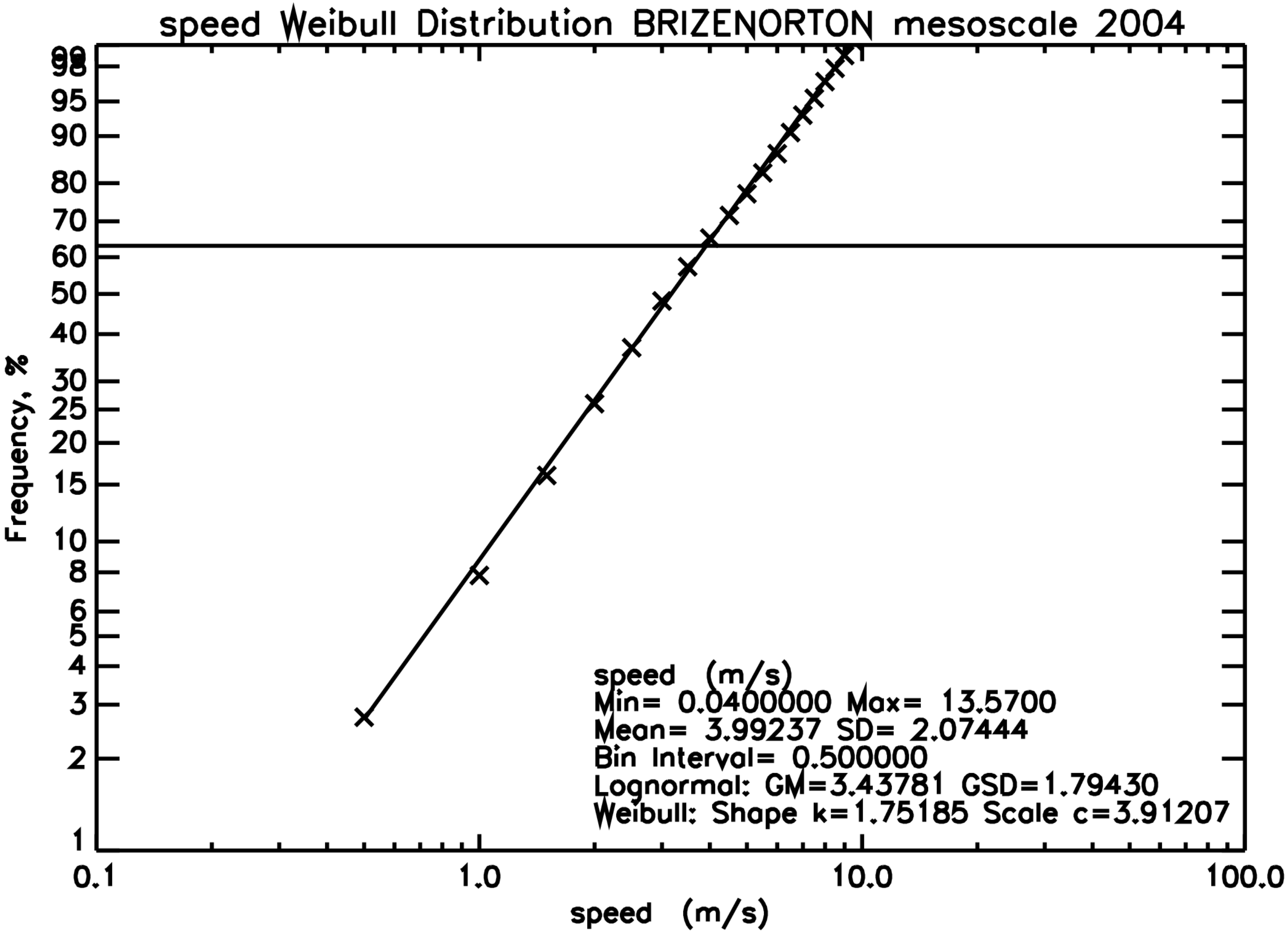
Wind Speed Weibull Distribution

Used in wind engineering

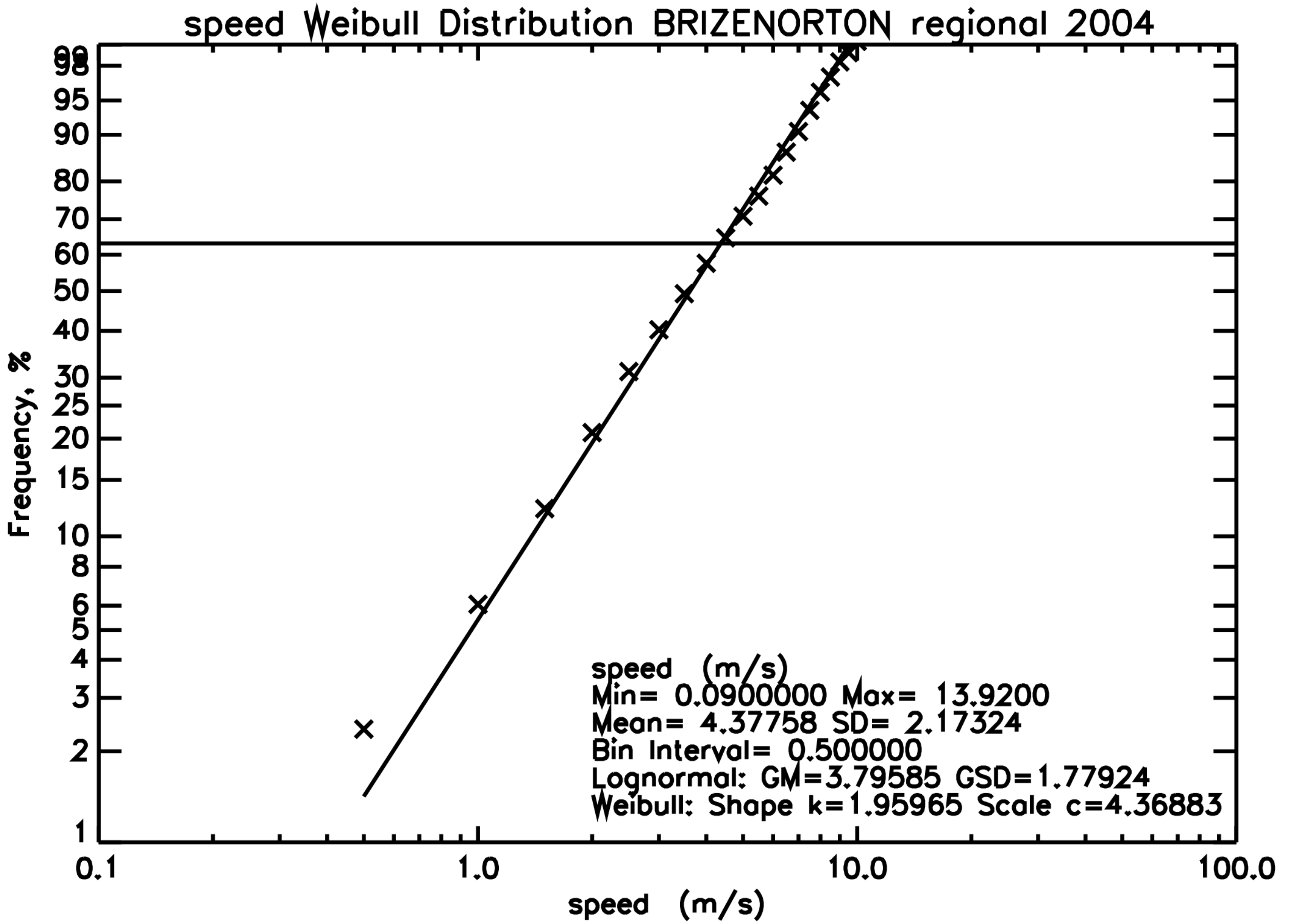
OBS Wind Speed Weibull Distribution Well Exposed Site at Brize Norton 2004



NWP-12km Wind Speed Weibull Distribution UM Mesoscale Data, at Brize Norton 2004



NWP-60km Wind Speed Weibull Distribution
UM Regional Data, Brize Norton 2004



Weibull Distribution

Met Office

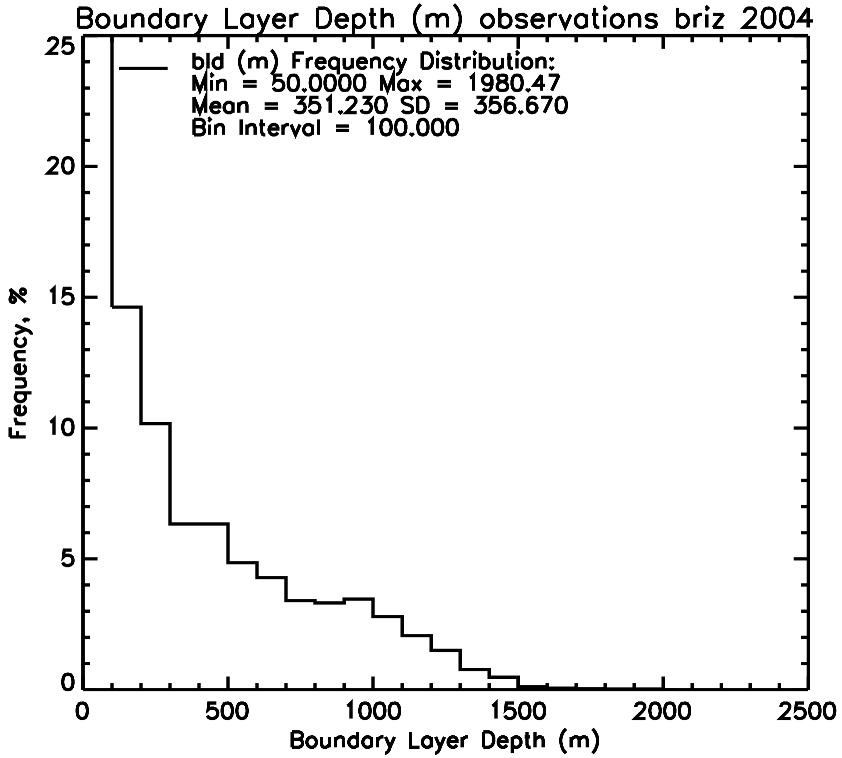
- Distribution used by wind power engineers to assess likely power output.
- Describes a skewed frequency distribution.
- Has two fitted parameters:
  Shape factor k (dimensionless)
  Scale factor c ($m\ s^{-1}$)
- OBS and NWP Wind speed data fit the Weibull cumulative frequency distribution as a straight line.
- Brize Norton 2004 Scale factor c:

OBS	NWP-12km	NWP-60km
3.45 m/s	3.91 m/s	4.37 m/s

Boundary Layer Depth

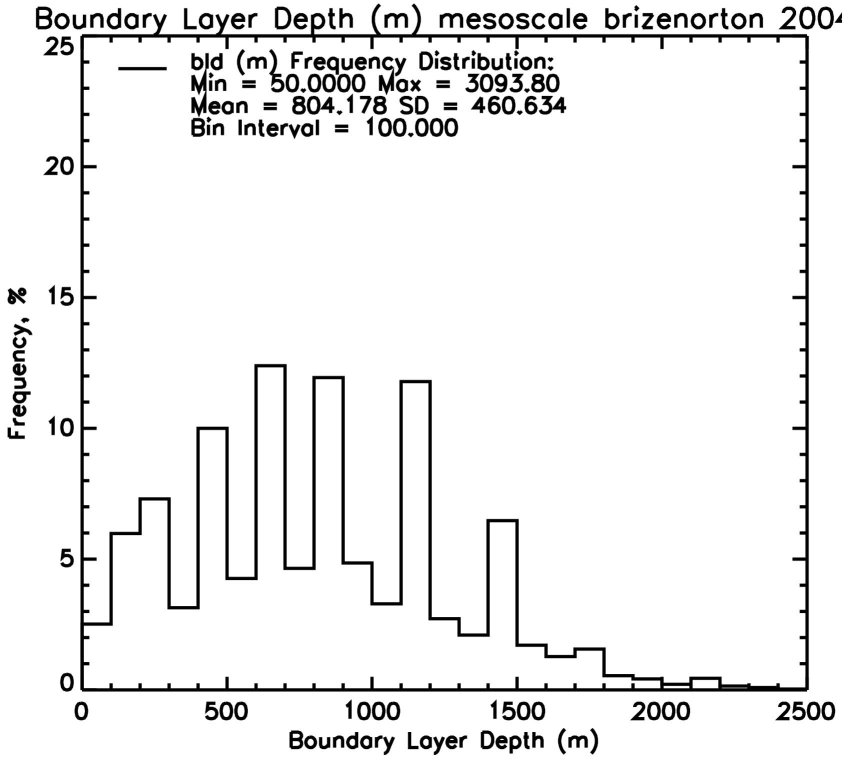
OBS: pre-processor NWP: from UM

NAME III BLD Distribution using OBS Brize Norton 2004

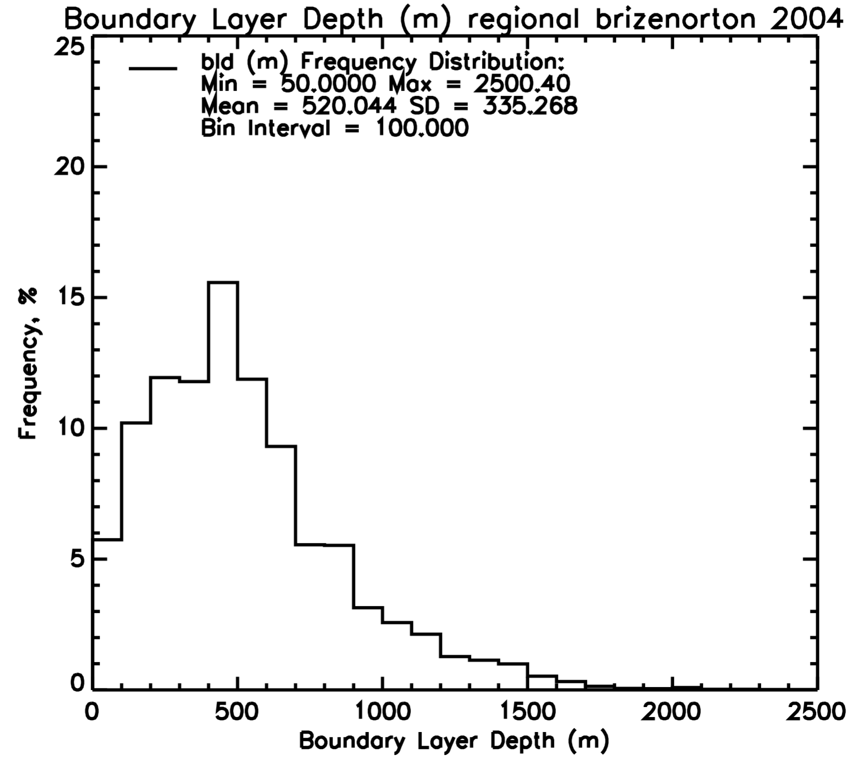


OBS Preproc

NWP BLD Distribution from UM Brize Norton 2004



NWP-12km



NWP-60km

Met Office

Atmospheric Stability

Traditional Pasquill Schemes

Pasquill Stability Schemes
Used in early dispersion models.

Empirical rapid assessment of dispersion conditions for plumes:

- Pasquill F (1961) stability classes A (unstable), D (neutral) to F (stable) were based on cloud cover, wind speed and day or night. Class G was added. Modified by Turner and by Gifford.

- Smith F B (1979) continuous stability measure from 0 (unstable) through 3.6 (neutral) to 7 (stable). NRPB-R91.

- Golder (1972) relates $L(z_0)$ to Pasquill scheme.

- Sort NAME III met pre-processor output data on Pasquill-Smith stability or Golder $L(z_0=0.1\text{ m})$.

Relating Stability for Pasquill and L
Ref: Golder D (1972) BLM 3, 47-58

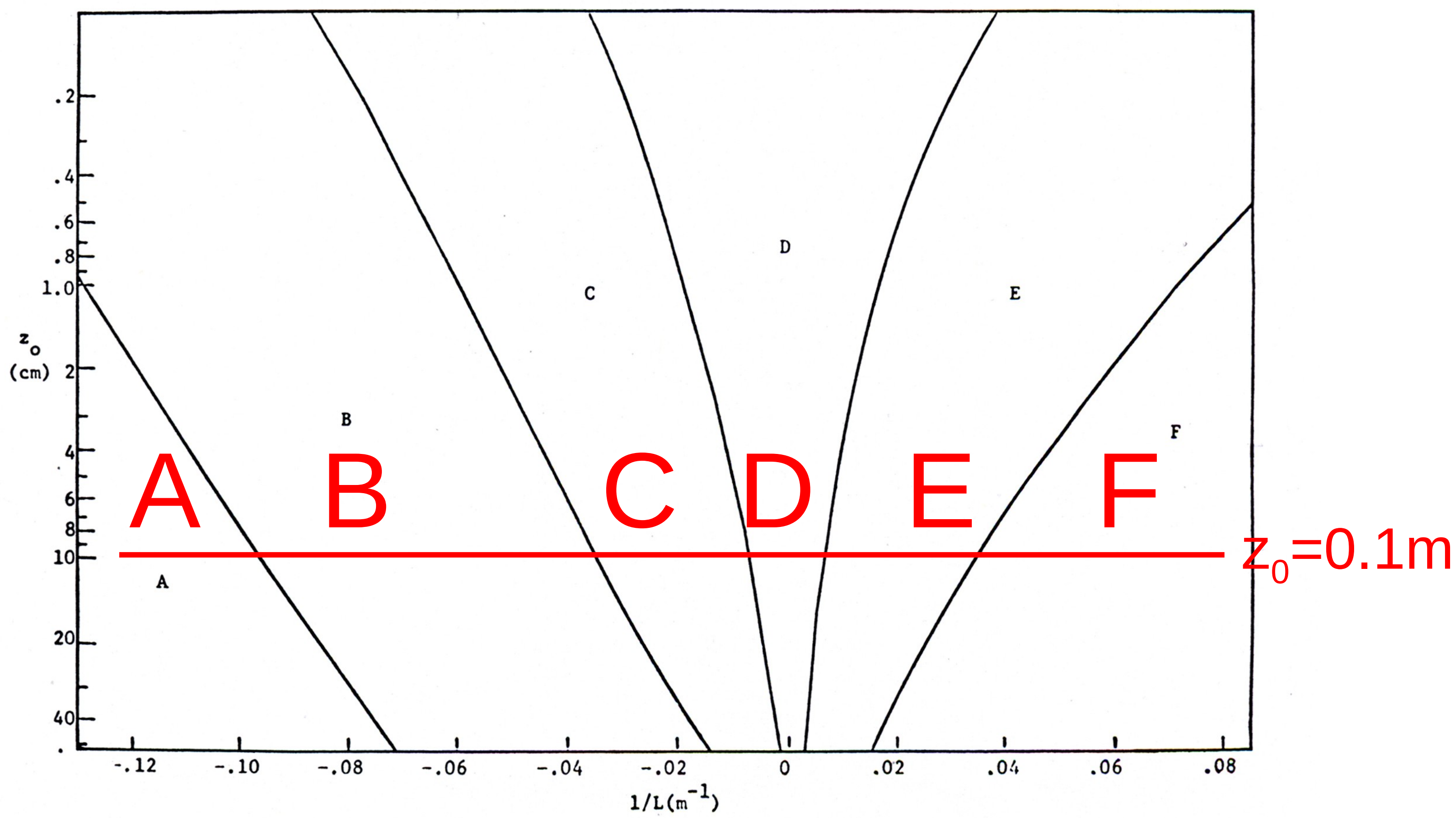
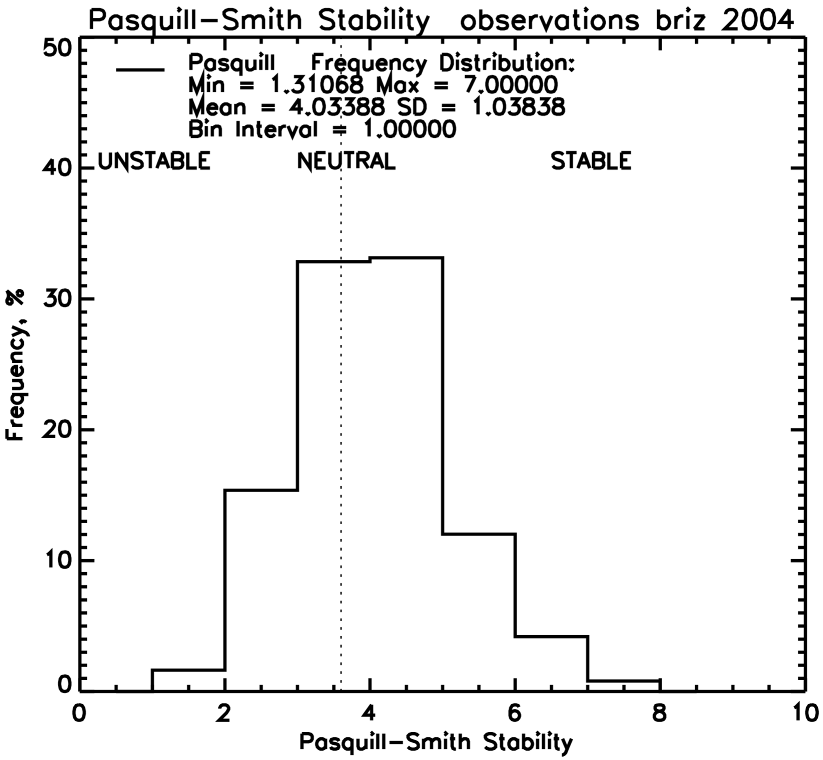


Fig. 4. $1/L$ as a function of Pasquill classes and z_0.

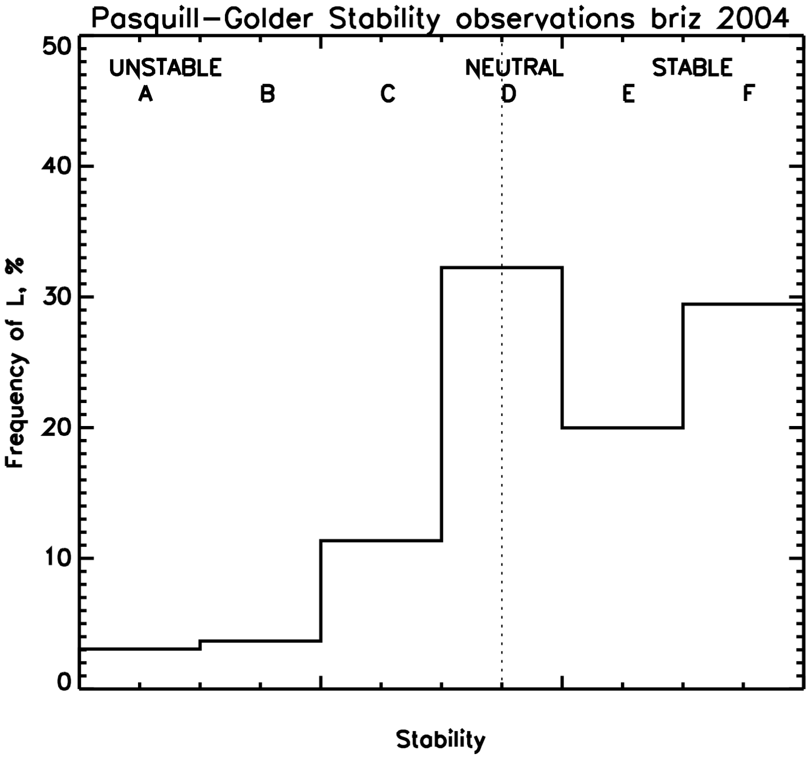
L for Sorting Stability data.
Ref: Golder D (1972) BLM 3, 47-58

Pasquill Class	Range of $L(z_0=0.1$ m$)$
A Strongly Unstable	0.0 to -10.4
B Unstable	-10.4 to -28.0
C Weakly Unstable	-28.0 to -142.2
D Neutral	-142.2 to - ∞ and + ∞ to 151
E Stable	151.0 to 29.0
F Strongly Stable	29.0 to 0.0

Stability Distributions: OBS
Well Exposed Site at Brize Norton 2004

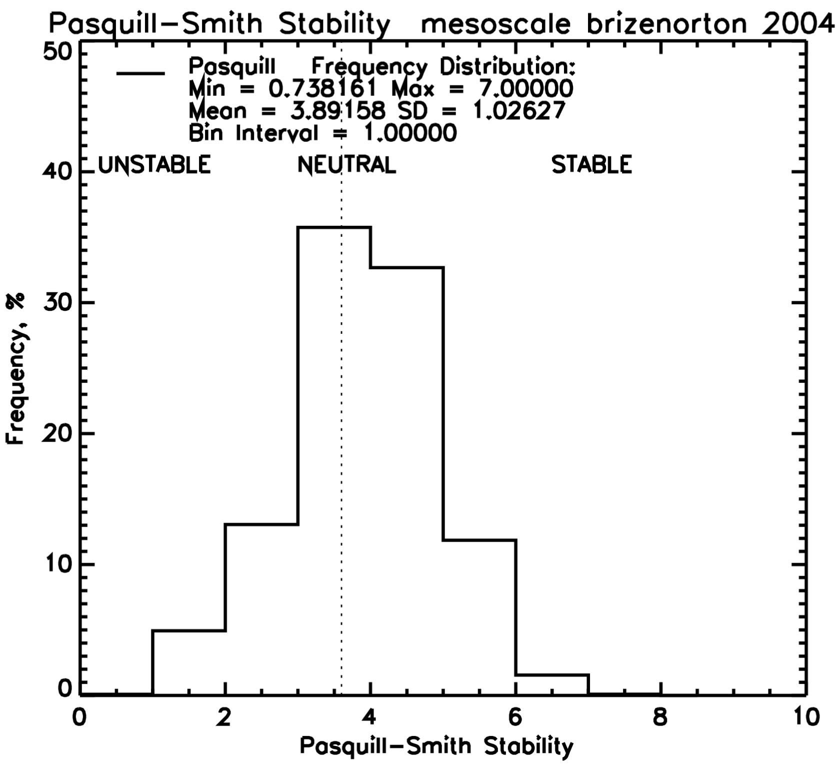


Pasquill-Smith
R-91

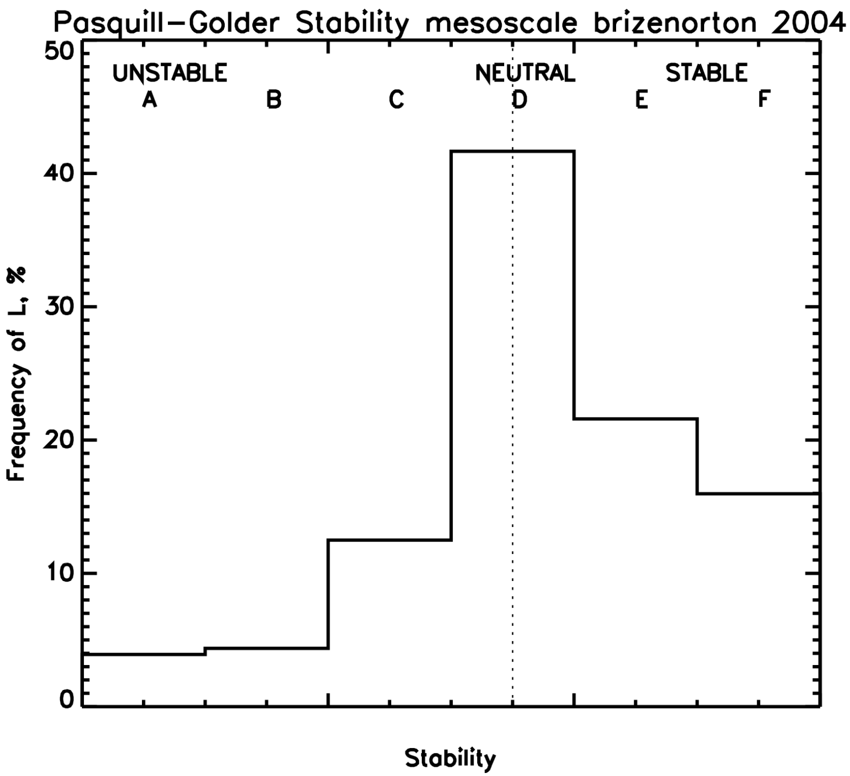


Pasquill-Golder
BLM (1972)

Stability Distribution: NWP-12km
Well Exposed Site at Brize Norton 2004

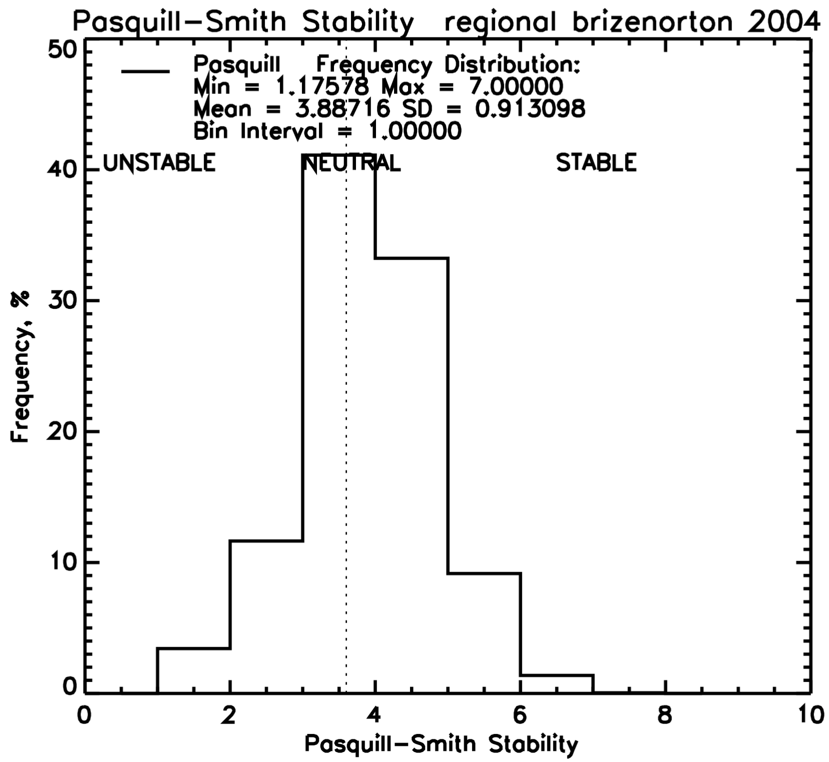


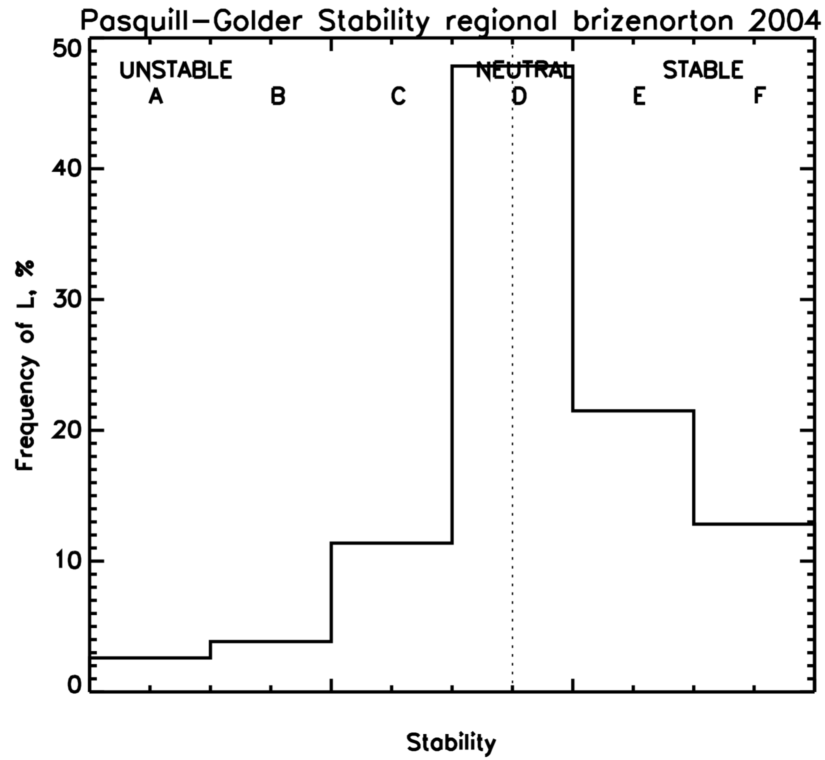
Pasquill-Smith
R-91



Pasquill-Golder
BLM (1972)

Stability Distributions: NWP-60km Well Exposed Site at Brize Norton 2004





Pasquill-Smith
R-91

Pasquill-Golder
BLM (1972)

Summary: u, BLD, Pasquill schemes

- Wind speed frequencies described by Weibull distribution for OBS and NWP data.
- BLD from OBS NAME III pre-processing: Most frequent values were BLD <100m.
- BLD from NWP-12km from UM: Most frequent values were BLD 600-700m, with a lot of scatter.
- BLD from NWP-60km from UM: Most frequent values were BLD 400-500m.
- Pasquill-Smith and Pasquill-Golder stabilities were mostly neutral stability for OBS & NWP data. In OBS results, stable also frequent in Pasquill-Golder.

Stability Maps – Heat Flux & Friction Velocity – Monin Obukhov Length

$L(u_*,H)$ is used in current regulatory models

Monin Obukhov Length $L(u_*,H)$ Measure of stability

- L depends on Sensible Heat Flux H and Friction Velocity u_*.

- Either parameter…
  Can influence the diagnosis of stability.
  May differ in NWP derived estimates compared to OBS.

- Need a sensitive method that reveals differences in the distributions of H , u_* , and hence in L .

- Present a simple method that plots "stability maps".

- Scatter plot of hourly data for 1 year on a graph of H versus u_* or H versus u_*^3 . Draw lines of constant L.

Isopleths of constant L

$$L = -\frac{\rho C_p T}{\kappa g} \frac{u_*^3}{H}$$

Inserting constants,

$$L = -91065.6 \frac{u_*^3}{H}$$

Rearrange & Solve for u_* at a series of H values with fixed L.

Plot positions H, u_* or H, u_*^3 to draw isopleths of L.

Values of *L* for counting frequency

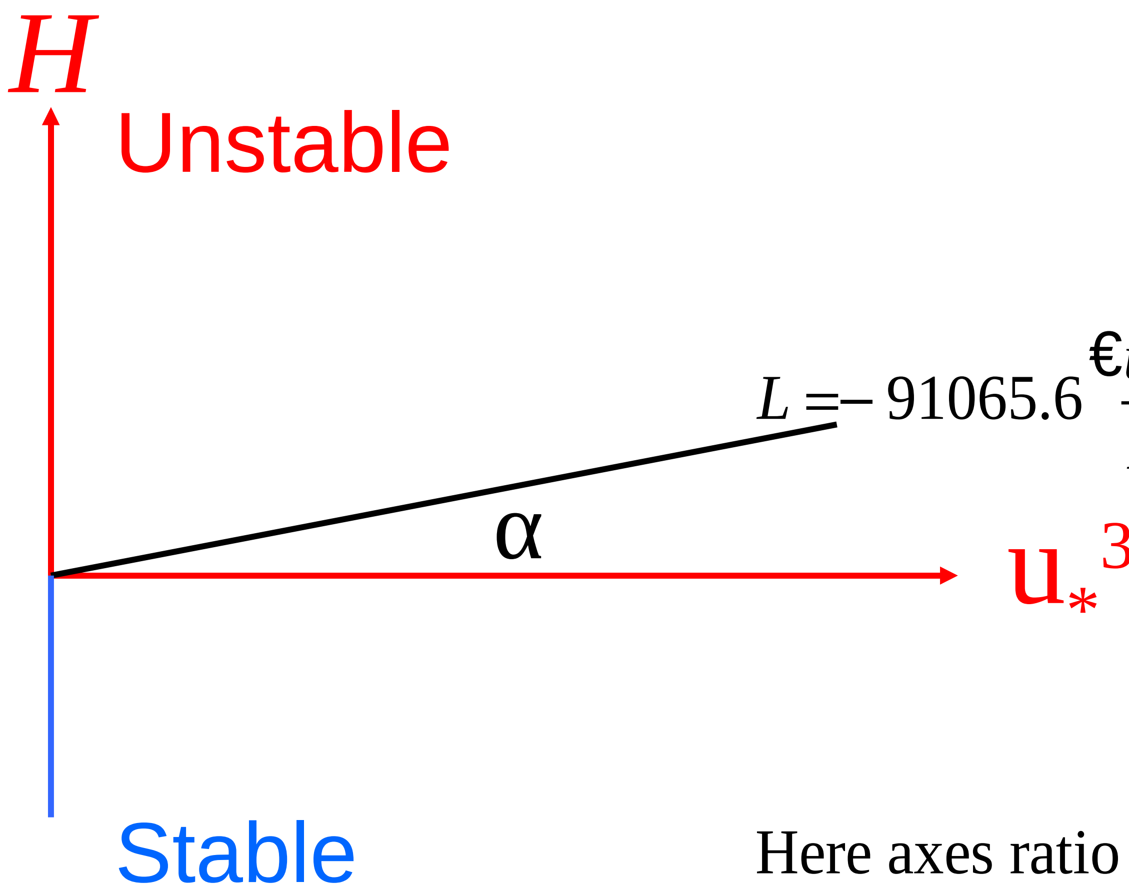
- Frequency distribution of *L* over 1 year describes the stability regime at a site, as seen in OBS or NWP data.
- *H* versus u_* gives *curved* isopleths for *L*.
- *H* versus u_*^3 gives *linear* isopleths for *L*.
- Count points between isopleths.

Stepping from Stable to Unstable

- Define a series of *straight line* isopleths for L marking out equi-angular sectors on the graph of H versus u_*^3.

- Simple geometry defines values of L on each sector for sorting.

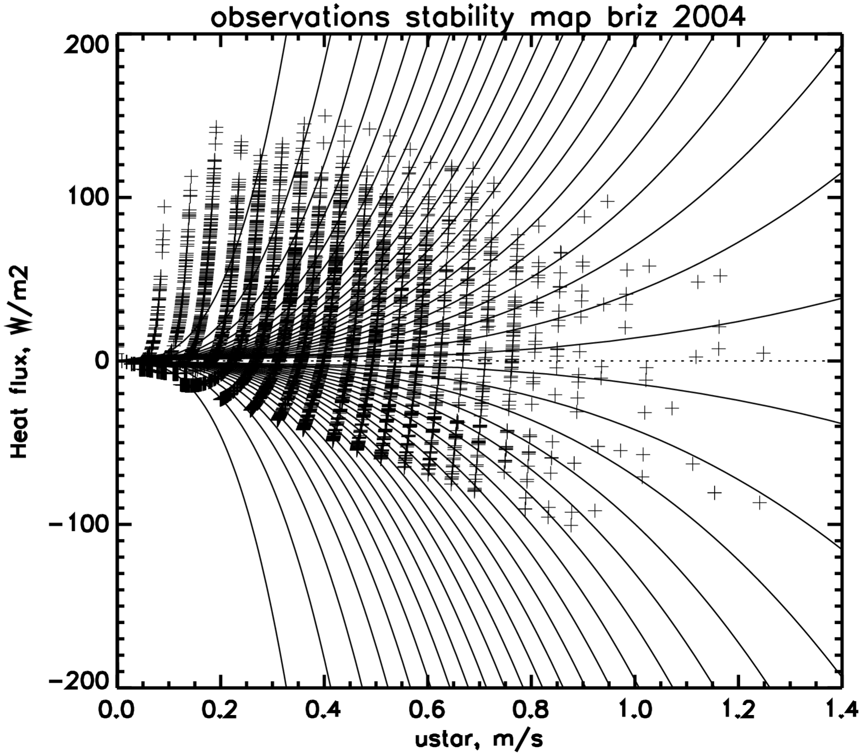
Stepping L



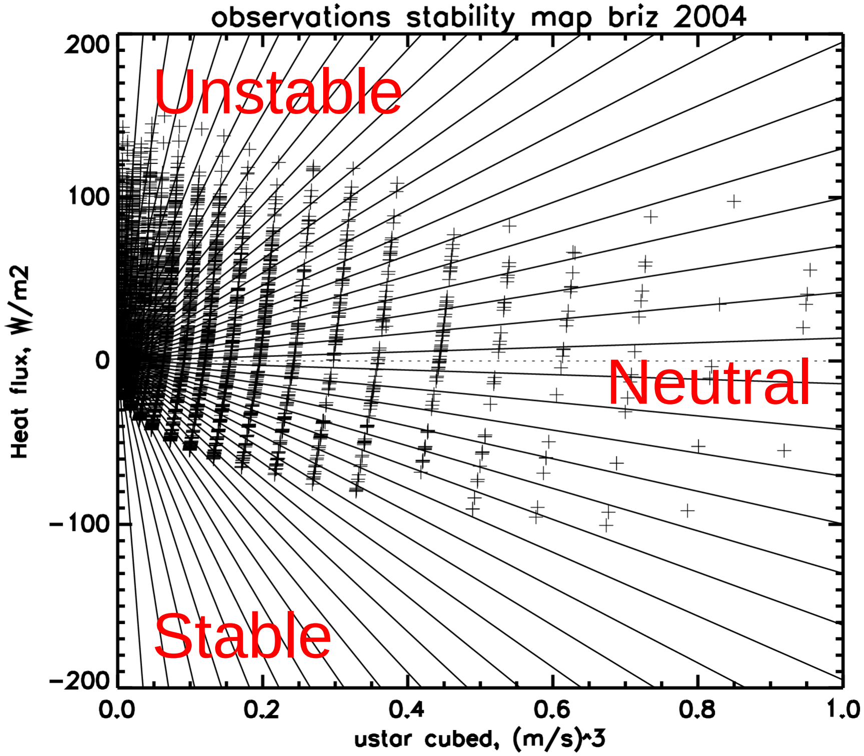
$$L = -91065.6\left(\frac{u_*^3}{H}\right) = \frac{-91065.6}{f\tan\alpha}$$

Here axes ratio $f = \Delta H / \Delta u_*^3 = 400$

Curved and Linear Isopleths of *L*



H versus *u**



H versus *u*3*
Equi-angular 2° sectors

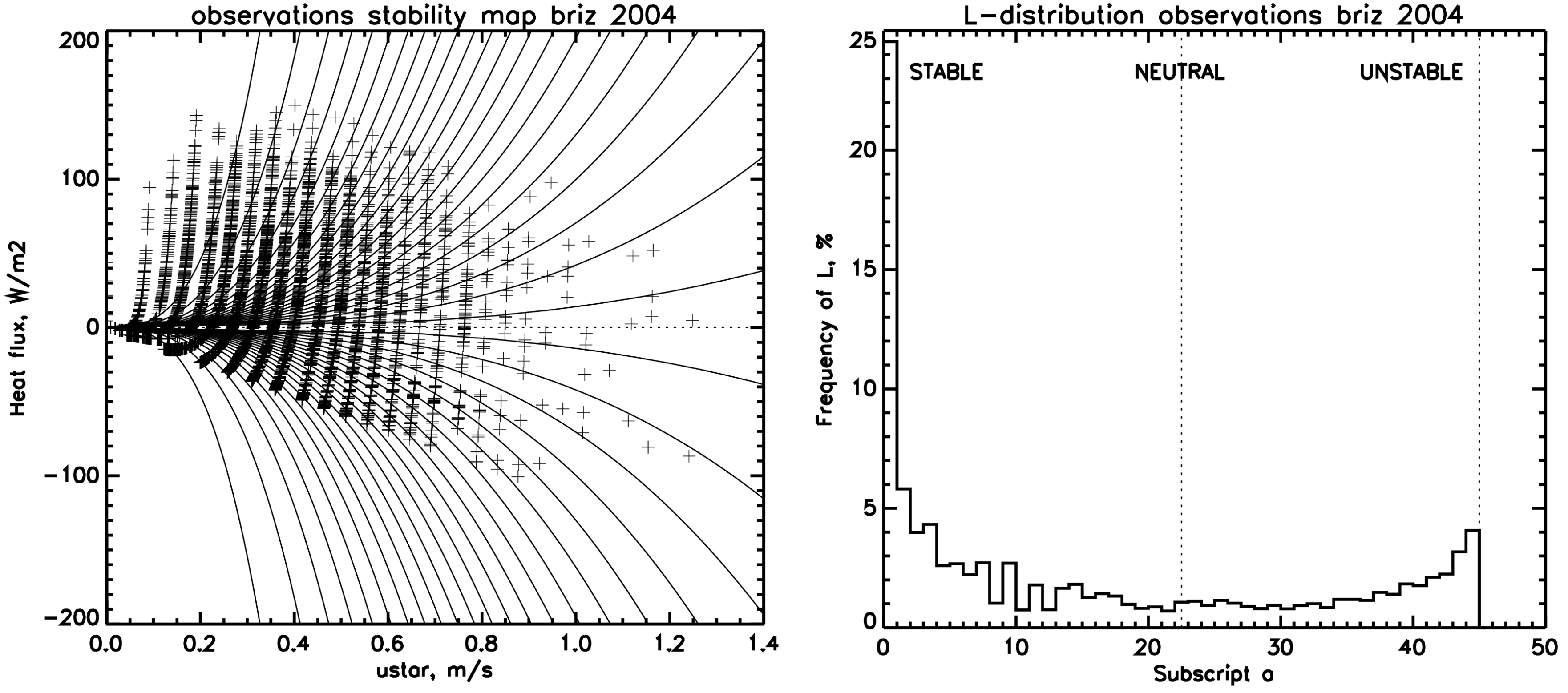
Sites

Character	NWP Site	Latitude	Longitude	OBS Station	Location
Inland	Brize Norton	-1.5833	51.750	Brize Norton	Open country side
Complex terrain	Aviemore	-3.8333	57.200	Aviemore	Valley in Scottish Highlands
Coastal	Valley	-4.5333	53.250	Valley	West coast of Anglesey
Estuary Head	Abbotsinch	-4.4333	55.866	Glasgow Bishopton	Inland head of Estuary

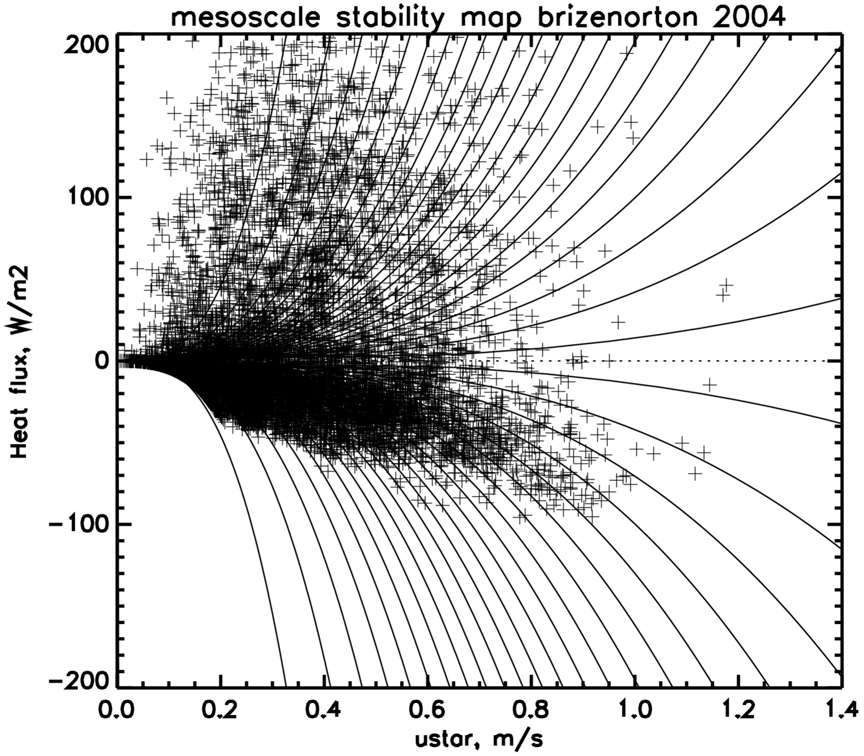
1. Inland

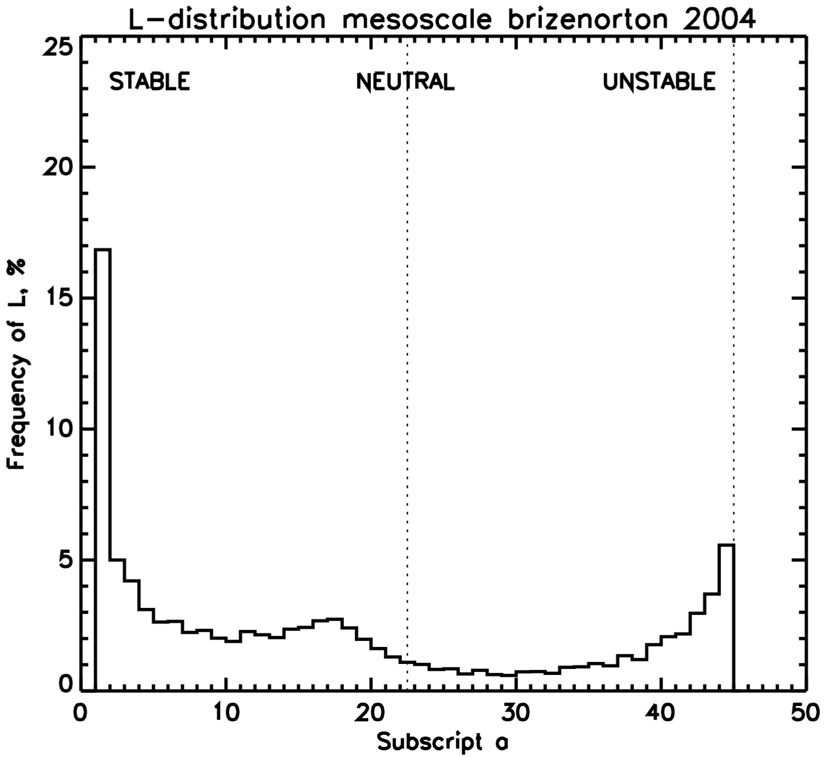
Brize Norton, Oxfordshire

OBS Inland
Brize Norton 2004

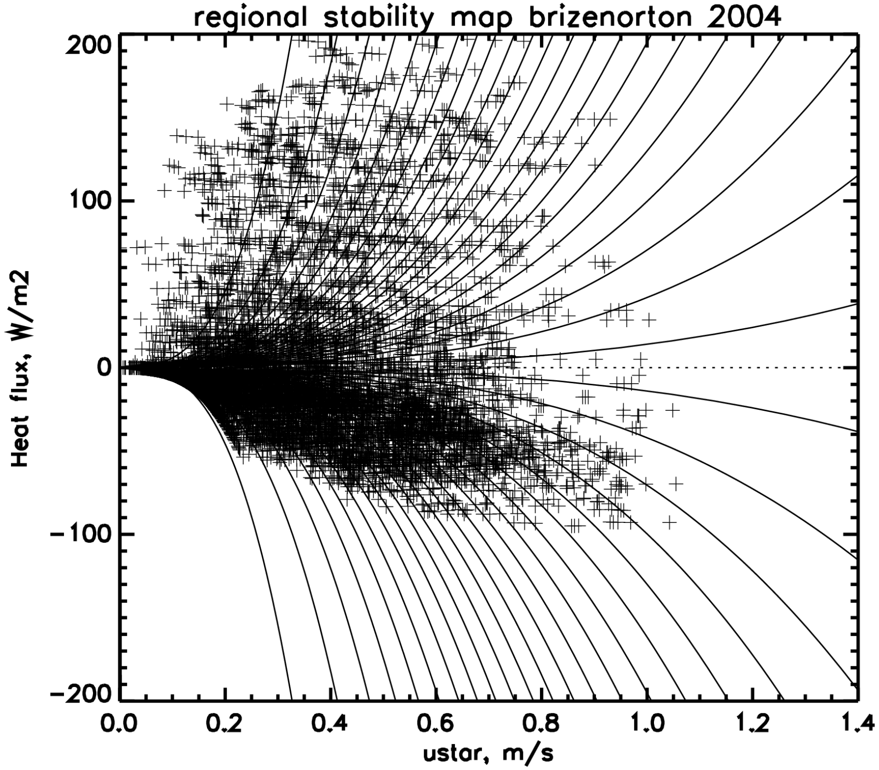


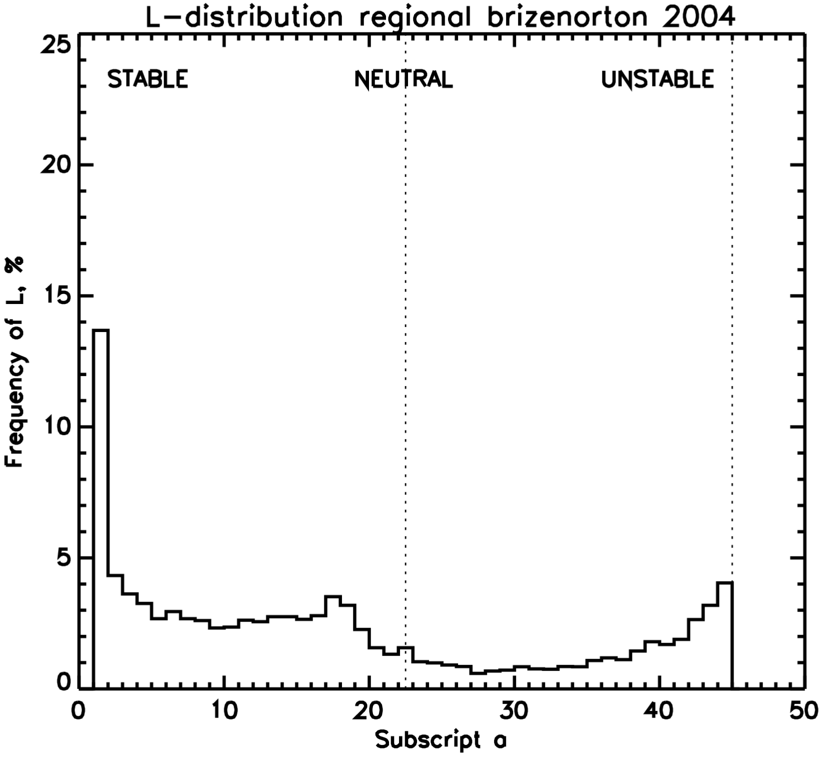
NWP-12km Inland
Brize Norton 2004





NWP-60km Inland
Brize Norton 2004

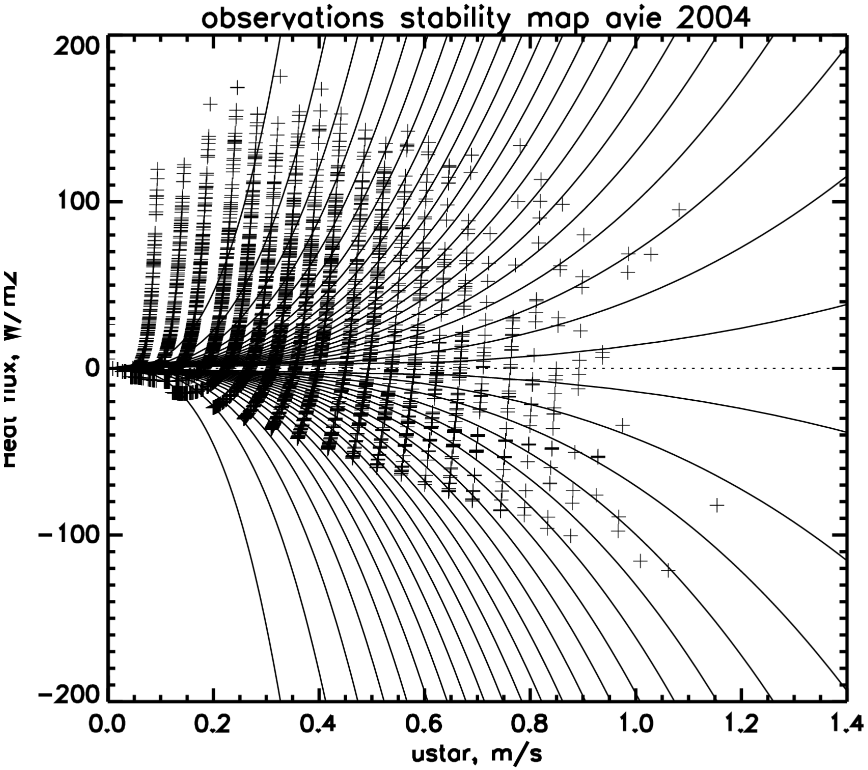


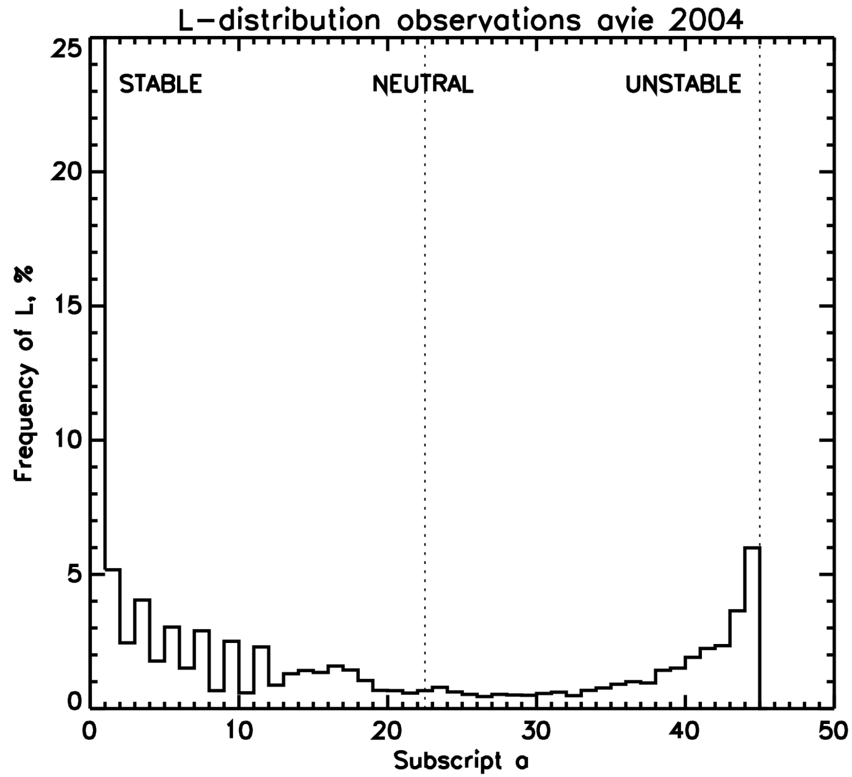


2. Complex Terrain

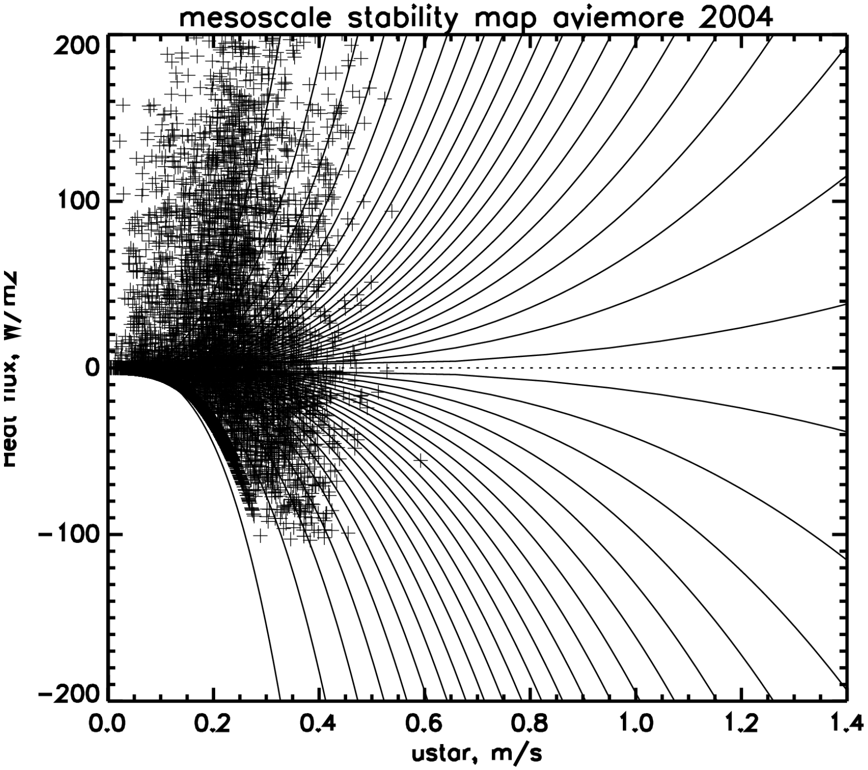
Aviemore, Scottish Highlands

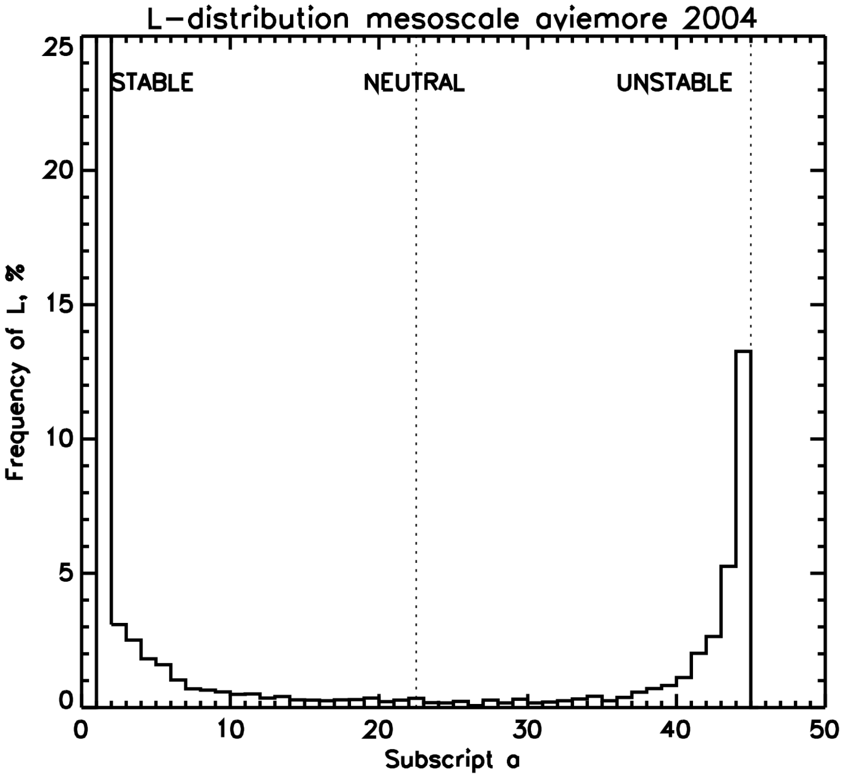
OBS Complex Terrain Aviemore 2004



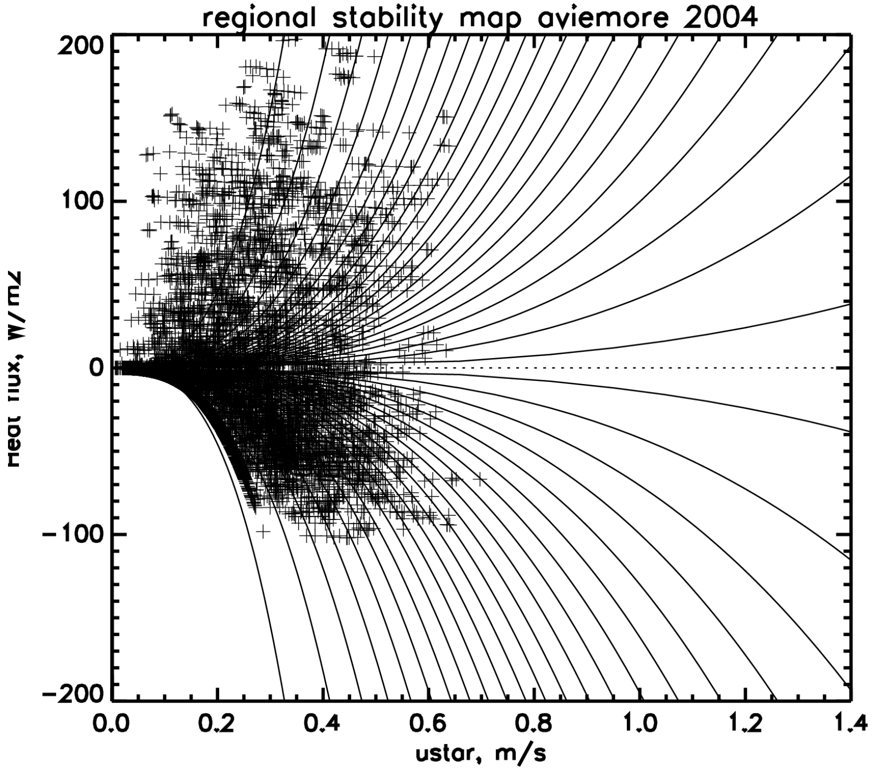


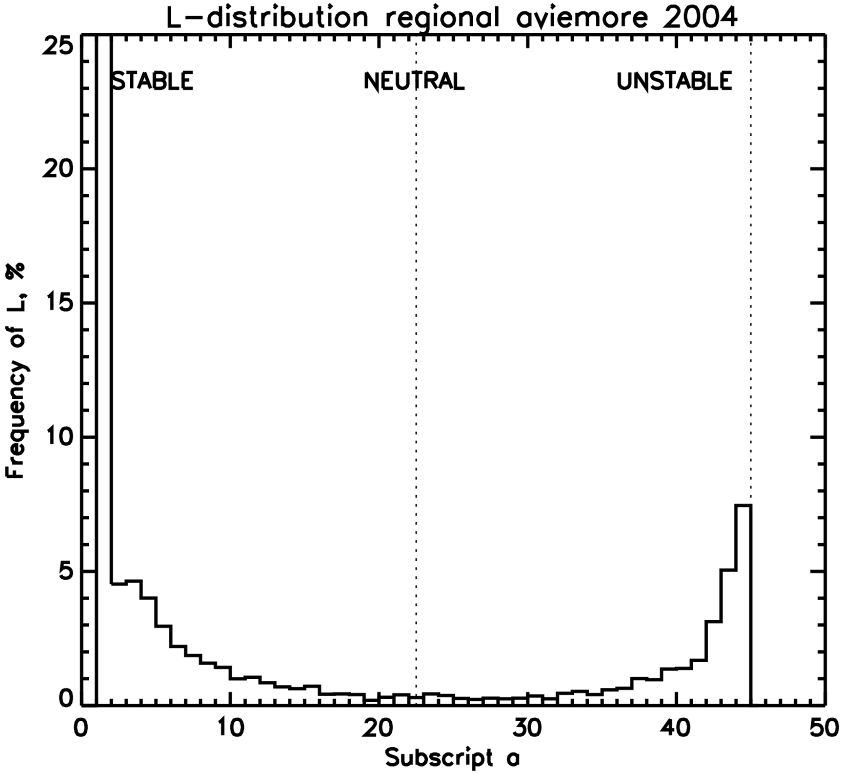
NWP-12km Complex Terrain Aviemore 2004





NWP-60km Complex Terrain Aviemore 2004

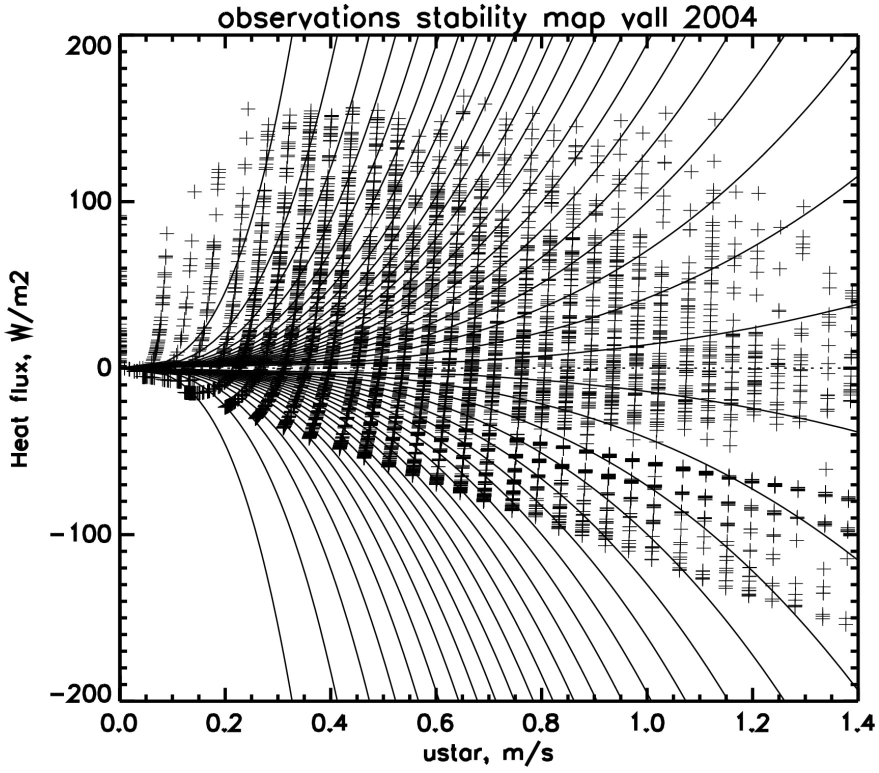


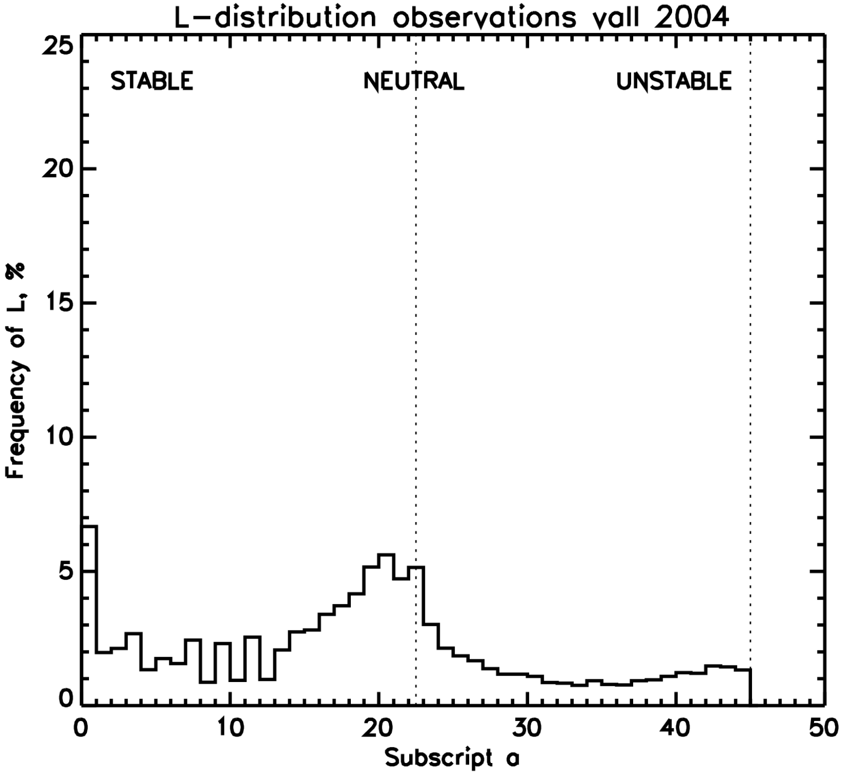


3. Coastal

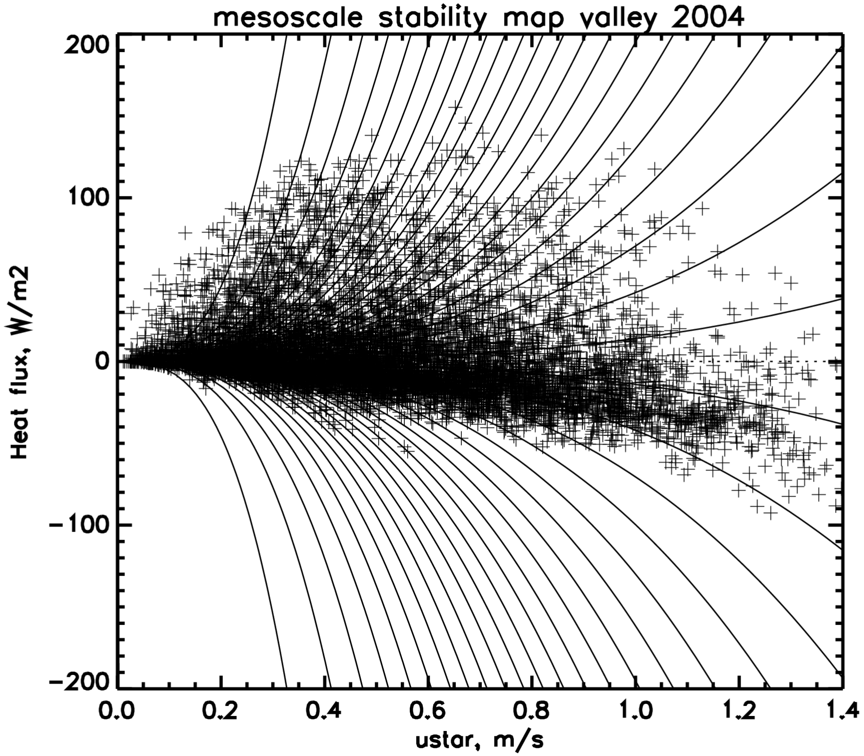
Valley, Anglesey

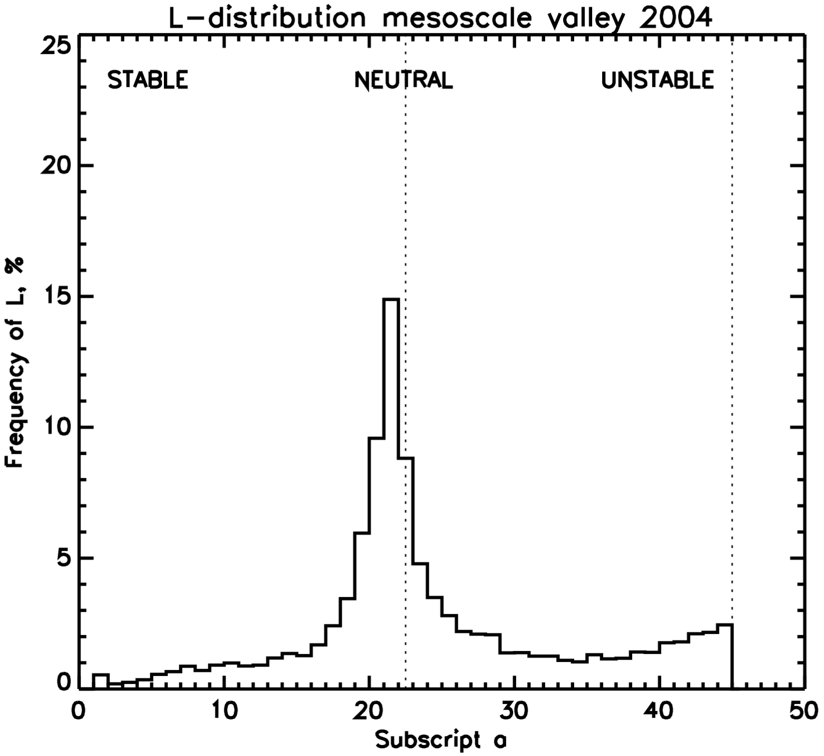
OBS Coastal Valley 2004



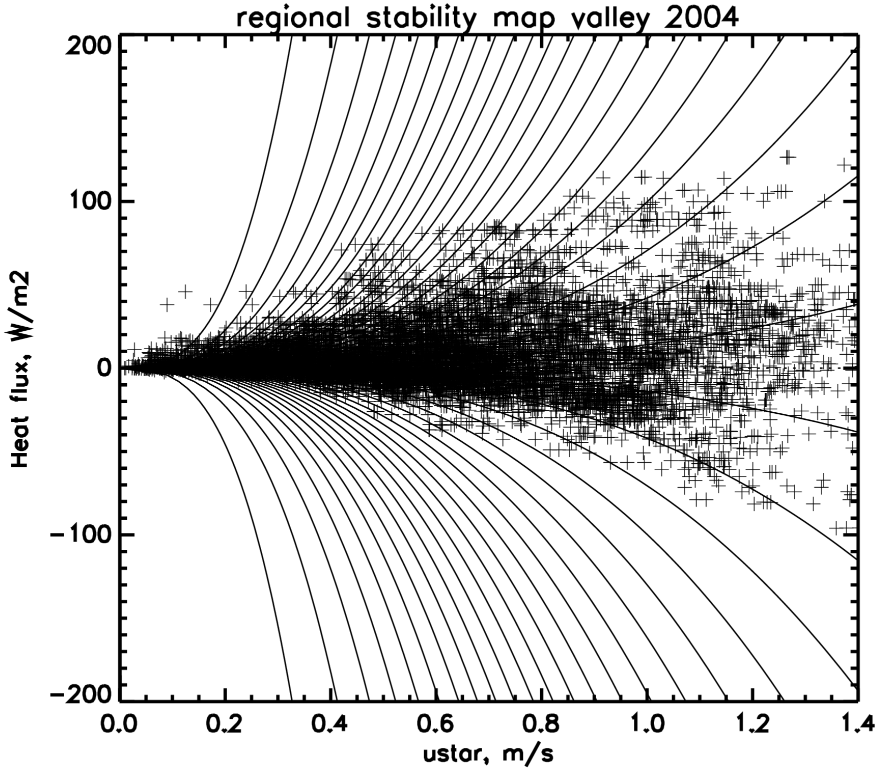


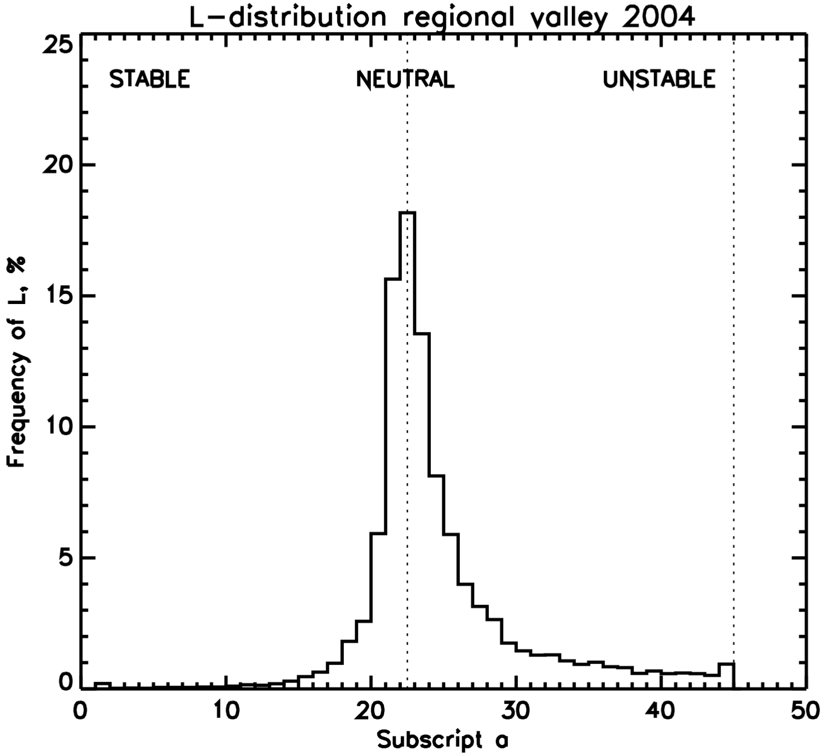
NWP-12km Coastal Valley 2004





NWP-60km Coastal Valley 2004

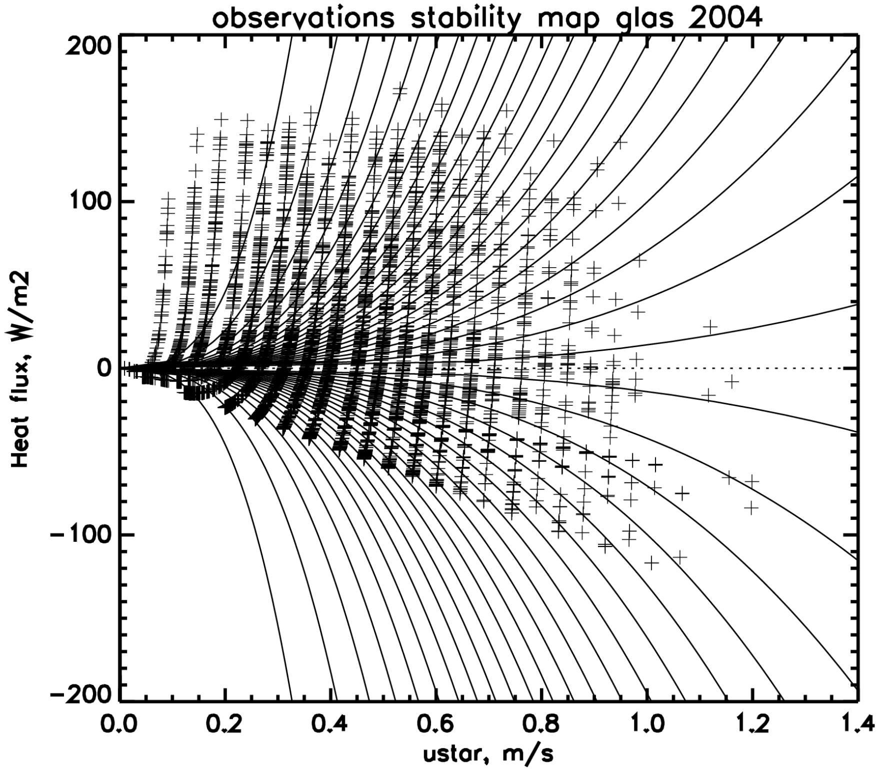


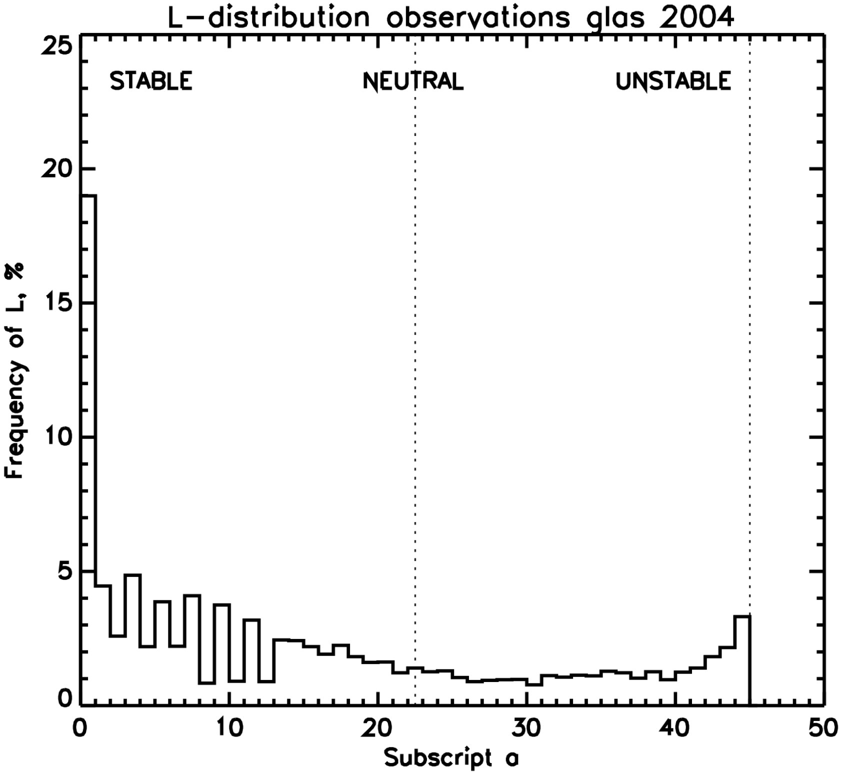


4. Estuary

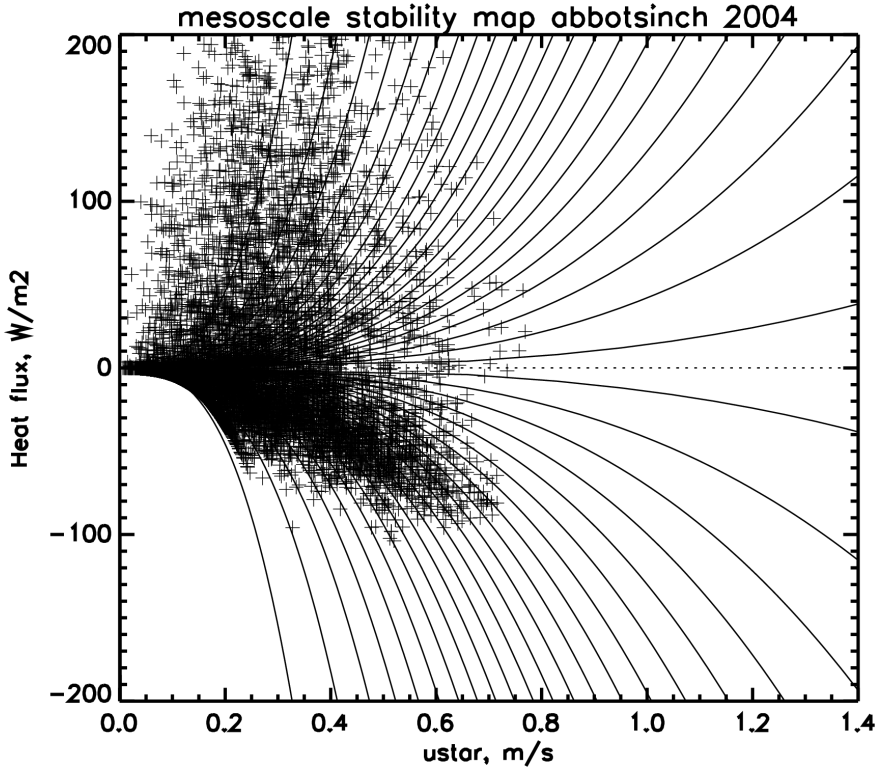
Glasgow Abbotsinch, Scotland

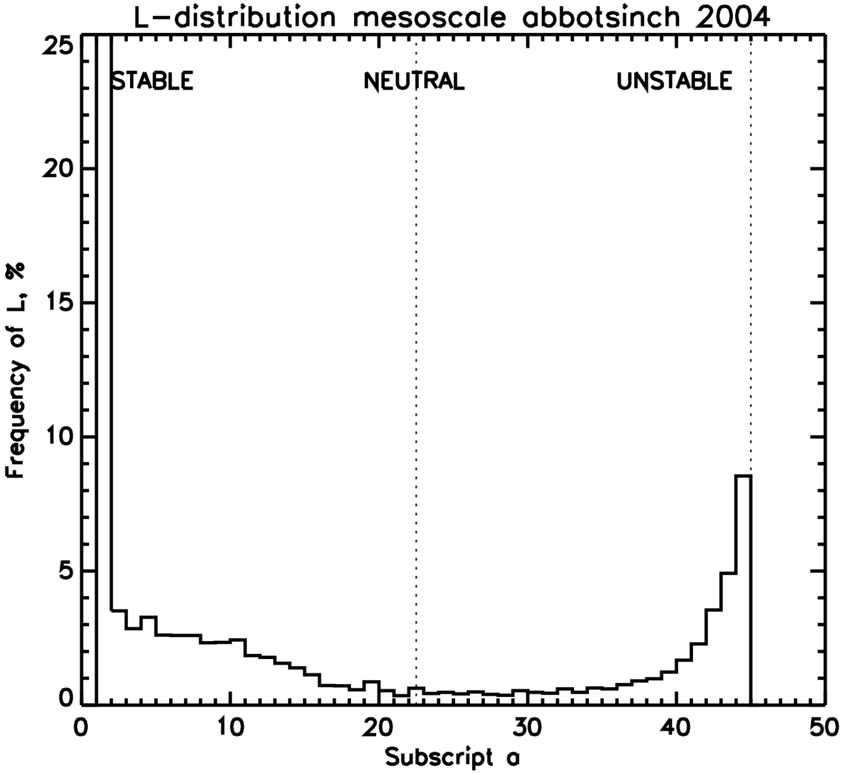
OBS Estuary
Glasgow Abbotsinch 2004



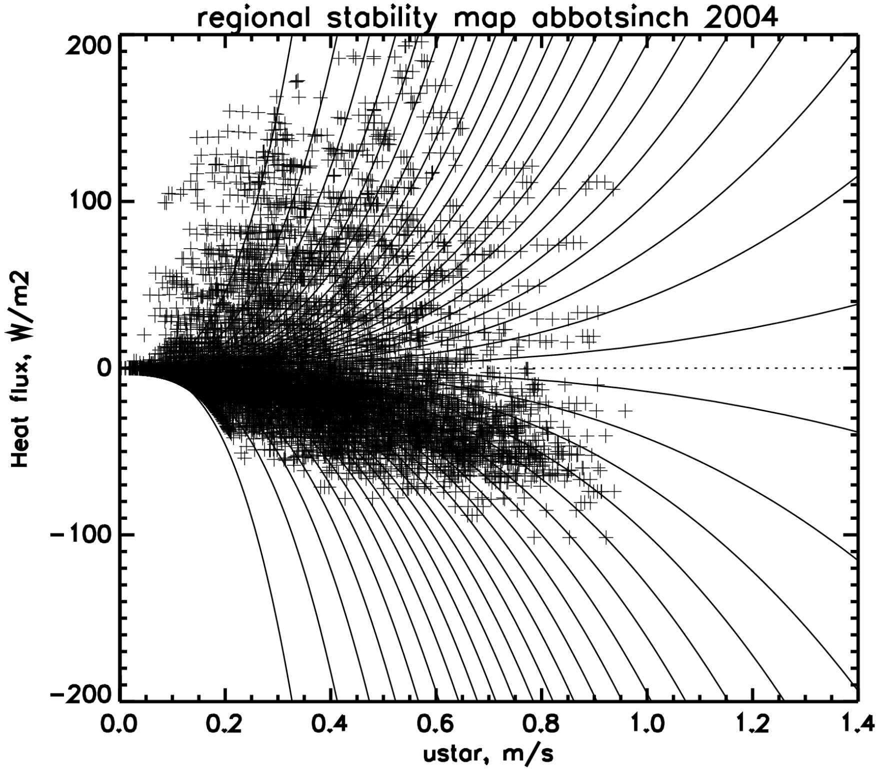


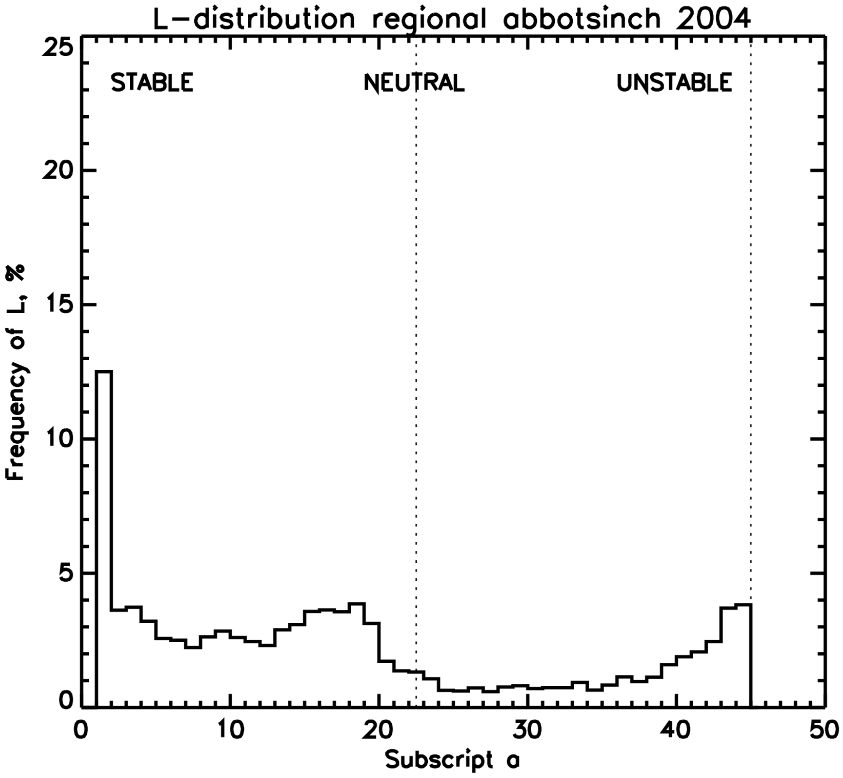
NWP-12km Estuary Abbotsinch 2004





NWP-60km Estuary Abbotsinch 2004





Summary: Stability Maps & L-Distribution

- To interpret differences in the stability distribution from NWP or OBS data sets at different types of sites a new sensitive graphical tool was used.
- Stability map is a plot of H versus u_*^3 with regular isopleths of L stepped from stable to unstable.
- Corresponding values of L are used in counting frequency.

Summary: Site sensitivity results

- Inland: NWP-12km or NWP-60km adequately represent the stability regime, similar to OBS.
- Complex terrain: Behaves largely as inland, except orographic drag slows NWP wind speed & NAME III gives <u>smaller friction velocity u_*</u> .
  (NWP is not designed to fully cope with this terrain.)
- Coastal: Coarser NWP-40km were less representative, with <u>reduced dynamic range in heat flux *H*</u> over a sea-surface grid square.
- Estuary: Mixed mode behaviour, probably depends on proximity to water surface.
- Urban: Not studied - Need urban NWP data

Conclusions

Conclusions

- Wind speeds fitted by Weibull distribution.
- OBS pre-processor BLD had high abundance <100m; NWP BLD had small frequency of the shallowest depths.
- Pasquill-Smith scheme had preponderance of neutral stabilities; P-Golder also had raised stable frequencies.
- Stability map and L-distribution plots are a sensitive tool for comparing stability distributions in OBS versus NWP grid scale at differing sites. Maps show if H or u_* is influencing the results in L.
- With coarse 60 km grid, coastal stability was more often neutral, (reduced H range). Mesoscale data seem better.

References

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Acknowledgements

- This work is part of the Met Office PWS Research Programme
- I thank my colleagues for help in retrieving data and useful discussions.

Support Material

Stepping L_a from Stable to Unstable

Regularly spaced straight line isopleths of L,

Centre at the origin on graph of H versus u_*^3 .

Lines of constant stability have slope proportional to $1/L$.

Angle $\alpha = -\pi/2 + a\pi/n$ stepping from $-\pi/2$ to $\pi/2$.

Subscript a goes from 0 to $n = 45$.

Frequency distribution:

Count number of times L falls in each sector L_a to L_{a}.

Intervals for sorting L

Plot H vertically from H_1 to H_2

and u_*^3 horizontally from 0 to $\left(\mathrm{u}_*^3\right)_2$.

The ratio of the scales is

$f = \left(H_2 - H_1\right) / \left(\mathrm{u}_*^3\right)_2$.

At each angle α, with isopleth having slope $f \tan\alpha$,

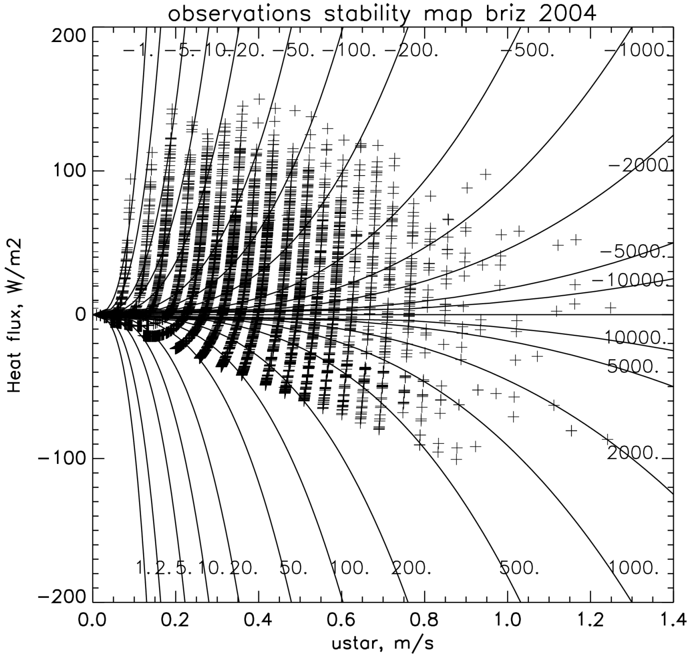
The value of L is given by $L = -\dfrac{91065.6}{f \tan\alpha}$.

Subscript a is increased to vary angle α and calculate bin intervals L_{a-1} to L_a.

Hourly values of Monin Obukhov length are counted into each bin.

Met Office

OBS



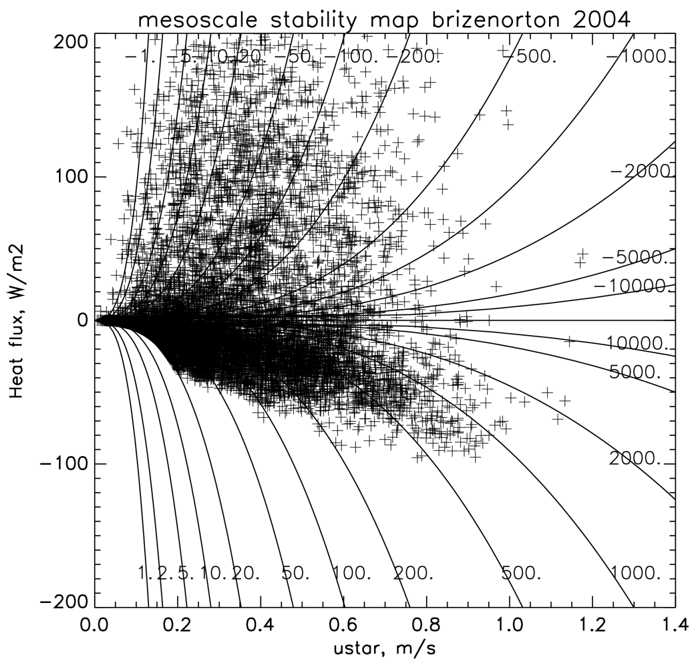
Plot H versus u_*

Arbitrary Isopleths at

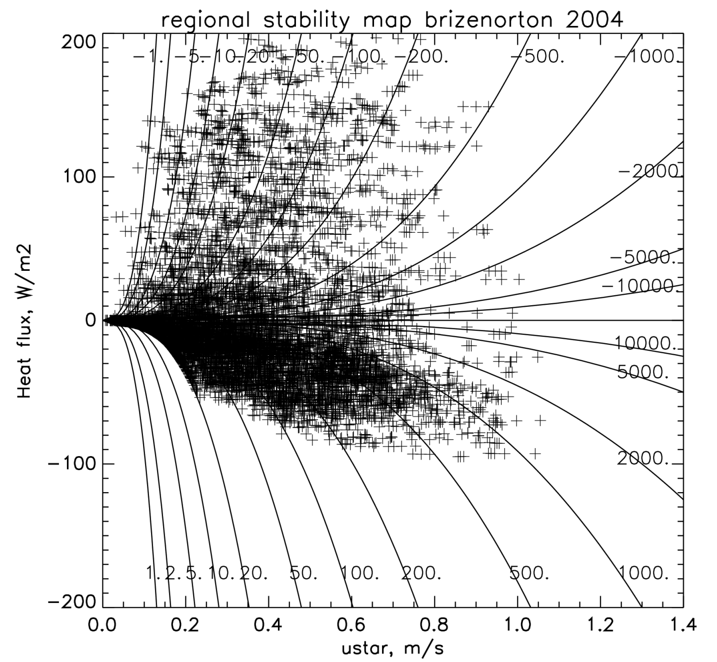
L = 1, 2, 5, 10 … m

L= … -10,-5,-2,-1 m

NWP-12km



NWP-60km



Met Office

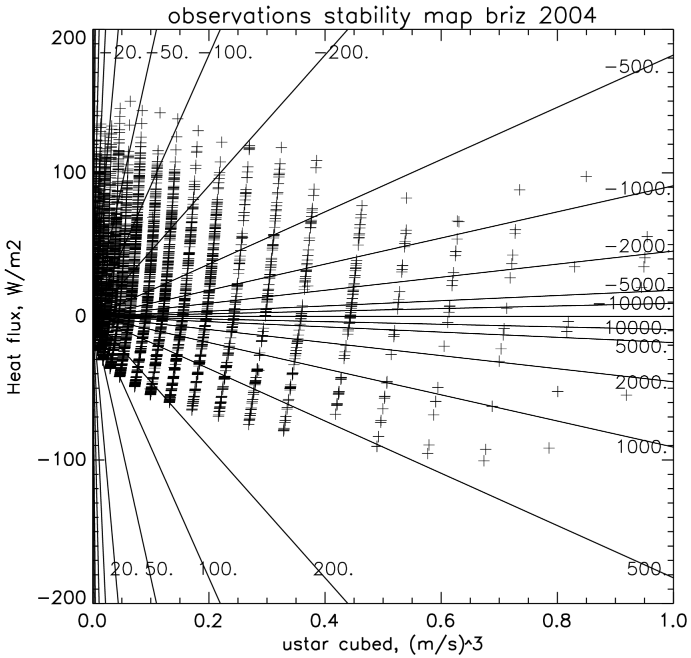
Plot H versus u_*^3

Arbitrary Isopleths at

L = 1, 2, 5, 10 … m

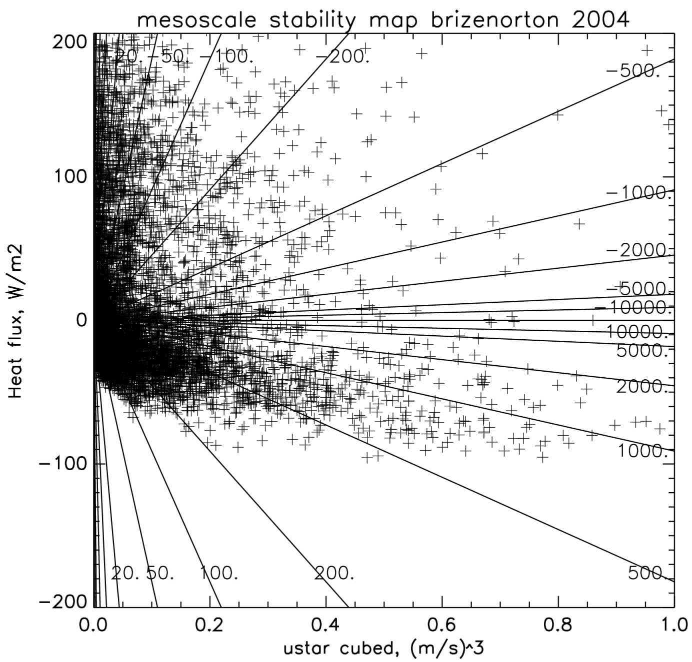
L= … -10,-5,-2,-1 m

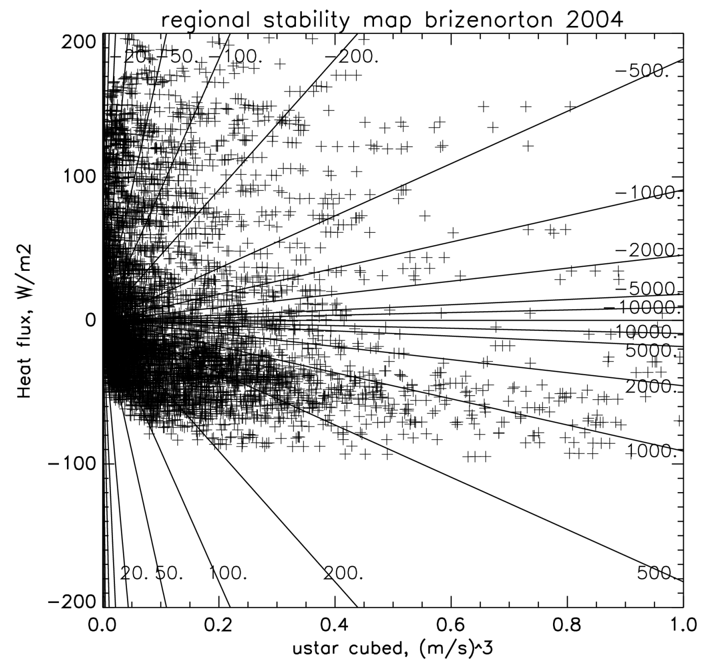
OBS



NWP-60km

NWP-12km





L isopleths for Pasquill-Golder