

PART I

MEASUREMENT OF METEOROLOGICAL VARIABLES

PART I. MEASUREMENT OF METEOROLOGICAL VARIABLES

CONTENTS

	<i>Page</i>
CHAPTER 1. GENERAL.....	I.1-1
1.1 Meteorological observations.....	I.1-1
1.2 Meteorological observing systems	I.1-2
1.3 General requirements of a meteorological station	I.1-2
1.4 General requirements of instruments.....	I.1-6
1.5 Measurement standards and definitions	I.1-7
1.6 Uncertainty of measurements	I.1-9
Annex 1.A. Regional centres	I.1-17
Annex 1.B. Operational measurement uncertainty requirements and instrument performance	I.1-19
Annex 1.C. Station exposure description	I.1-25
References and further reading	I.1-27
CHAPTER 2. MEASUREMENT OF TEMPERATURE.....	I.2-1
2.1 General.....	I.2-1
2.2 Liquid-in-glass thermometers	I.2-4
2.3 Mechanical thermographs	I.2-10
2.4 Electrical thermometers	I.2-11
2.5 Radiation shields.....	I.2-16
Annex. Defining the fixed points of the international temperature scale of 1990	I.2-18
References and further reading	I.2-20
CHAPTER 3. MEASUREMENT OF ATMOSPHERIC PRESSURE	I.3-1
3.1 General.....	I.3-1
3.2 Mercury barometers.....	I.3-3
3.3 Electronic barometers	I.3-8
3.4 Aneroid barometers.....	I.3-11
3.5 Barographs	I.3-12
3.6 Bourdon-tube barometers	I.3-13
3.7 Barometric change	I.3-13
3.8 General exposure requirements.....	I.3-14
3.9 Barometer exposure	I.3-14
3.10 Comparison, calibration and maintenance.....	I.3-15
3.11 Adjustment of barometer readings to other levels	I.3-20
3.12 Pressure tendency and pressure tendency characteristic	I.3-21
Annex 3.A. Correction of barometer readings to standard conditions	I.3-22
Annex 3.B. Regional standard barometers.....	I.3-25
References and further reading	I.3-26
CHAPTER 4. MEASUREMENT OF HUMIDITY	I.4-1
4.1 General.....	I.4-1
4.2 The psychrometer	I.4-6
4.3 The hair hygrometer	I.4-12
4.4 The chilled-mirror dewpoint hygrometer.....	I.4-14
4.5 The lithium chloride heated condensation hygrometer (dew cell).....	I.4-17

4.6	Electrical resistive and capacitive hygrometers	I.4-20
4.7	Hygrometers using absorption of electromagnetic radiation	I.4-21
4.8	Safety	I.4-21
4.9	Standard instruments and calibration	I.4-23
	Annex 4.A. Definitions and specifications of water vapour in the atmosphere.....	I.4-26
	Annex 4.B. Formulae for the computation of measures of humidity	I.4-29
	References and further reading	I.4-30
CHAPTER 5. MEASUREMENT OF SURFACE WIND.....		I.5-1
5.1	General.....	I.5-1
5.2	Estimation of wind	I.5-3
5.3	Simple instrumental methods	I.5-4
5.4	Cup and propeller sensors	I.5-4
5.5	Wind-direction vanes.....	I.5-5
5.6	Other wind sensors	I.5-5
5.7	Sensors and sensor combinations for component resolution	I.5-6
5.8	Data-processing methods.....	I.5-6
5.9	Exposure of wind instruments.....	I.5-8
5.10	Calibration and maintenance.....	I.5-11
	Annex. The effective roughness length	I.5-12
	References and further reading	I.5-13
CHAPTER 6. MEASUREMENT OF PRECIPITATION		I.6-1
6.1	General.....	I.6-1
6.2	Siting and exposure	I.6-3
6.3	Non-recording precipitation gauges	I.6-3
6.4	Precipitation gauge errors and corrections	I.6-6
6.5	Recording precipitation gauges	I.6-8
6.6	Measurement of dew, ice accumulation and fog precipitation	I.6-11
6.7	Measurement of snowfall and snow cover	I.6-14
	Annex 6.A. Precipitation intercomparison sites	I.6-18
	Annex 6.B. Suggested correction procedures for precipitation measurements	I.6-19
	References and further reading	I.6-20
CHAPTER 7. MEASUREMENT OF RADIATION.....		I.7-1
7.1	General.....	I.7-1
7.2	Measurement of direct solar radiation.....	I.7-5
7.3	Measurement of global and diffuse sky radiation	I.7-11
7.4	Measurement of total and long-wave radiation	I.7-19
7.5	Measurement of special radiation quantities	I.7-24
7.6	Measurement of UV radiation	I.7-25
	Annex 7.A. Nomenclature of radiometric and photometric quantities	I.7-31
	Annex 7.B. Meteorological radiation quantities, symbols and definitions	I.7-33
	Annex 7.C. Specifications for world, regional and national radiation centres	I.7-35
	Annex 7.D. Useful formulae	I.7-37
	Annex 7.E. Diffuse sky radiation – correction for a shading ring.....	I.7-39
	References and further reading	I.7-40

	<i>Page</i>
CHAPTER 8. MEASUREMENT OF SUNSHINE DURATION	I.8-1
8.1 General.....	I.8-1
8.2 Instruments and sensors.....	I.8-3
8.3 Exposure of sunshine detectors	I.8-7
8.4 General sources of error	I.8-7
8.5 Calibration	I.8-7
8.6 Maintenance	I.8-9
Annex. Algorithm to estimate sunshine duration from direct global irradiance measurements	I.8-10
References and further reading.....	I.8-11
 CHAPTER 9. MEASUREMENT OF VISIBILITY	 I.9-1
9.1 General.....	I.9-1
9.2 Visual estimation of meteorological optical range.....	I.9-5
9.3 Instrumental measurement of the meteorological optical range.....	I.9-8
References and further reading.....	I.9-15
 CHAPTER 10. MEASUREMENT OF EVAPORATION.....	 I.10-1
10.1 General.....	I.10-1
10.2 Atmometers.....	I.10-2
10.3 Evaporation pans and tanks	I.10-3
10.4 Evapotranspirometers (lysimeters)	I.10-6
10.5 Estimation of evaporation from natural surfaces	I.10-7
References and further reading.....	I.10-10
 CHAPTER 11. MEASUREMENT OF SOIL MOISTURE.....	 I.11-1
11.1 General.....	I.11-1
11.2 Gravimetric direct measurement of soil water content	I.11-3
11.3 Soil water content: indirect methods	I.11-4
11.4 Soil water potential instrumentation	I.11-6
11.5 Remote sensing of soil moisture.....	I.11-8
11.6 Site selection and sample size.....	I.11-9
References and further reading.....	I.11-10
 CHAPTER 12. MEASUREMENT OF UPPER-AIR PRESSURE, TEMPERATURE AND HUMIDITY	 I.12-1
12.1 General.....	I.12-1
12.2 Radiosonde electronics	I.12-6
12.3 Temperature sensors.....	I.12-7
12.4 Pressure sensors.....	I.12-9
12.5 Relative humidity sensors.....	I.12-12
12.6 Ground station equipment.....	I.12-15
12.7 Radiosonde operations.....	I.12-16
12.8 Radiosondes errors	I.12-18
12.9 Comparison, calibration and maintenance.....	I.12-28
12.10 Computations and reporting.....	I.12-31
Annex 12.A. Accuracy requirements (standard error) for upper-air measurements for synoptic meteorology, interpreted for conventional upper-air and wind measurements	I.12-34

Annex 12.B. Performance limits for upper wind and radiosonde temperature, relative humidity and geopotential height	I.12-35
Annex 12.C. Guidelines for organizing radiosonde intercomparisons and for the establishment of test sites	I.12-40
References and further reading	I.12-44
CHAPTER 13. MEASUREMENT OF UPPER WIND	I.13-1
13.1 General.....	I.13-1
13.2 Upper-wind sensors and instruments.....	I.13-4
13.3 Measurement methods	I.13-10
13.4 Exposure of ground equipment.....	I.13-12
13.5 Sources of error	I.13-13
13.6 Comparison, calibration and maintenance.....	I.13-18
13.7 Corrections.....	I.13-19
References and further reading.....	I.13-21
CHAPTER 14. PRESENT AND PAST WEATHER; STATE OF THE GROUND.....	I.14-1
14.1 General.....	I.14-1
14.2 Observation of present and past weather.....	I.14-2
14.3 State of the ground	I.14-5
14.4 Special phenomena.....	I.14-5
Annex. Criteria for light, moderate and heavy precipitation intensity	I.14-7
References and further reading.....	I.14-8
CHAPTER 15. OBSERVATION OF CLOUDS	I.15-1
15.1 General.....	I.15-1
15.2 Estimation and observation of cloud amount, height and type.....	I.15-3
15.3 Instrumental measurements of cloud amount.....	I.15-5
15.4 Measurement of cloud height using a searchlight	I.15-5
15.5 Measurement of cloud height using a balloon.....	I.15-7
15.6 Rotating-beam ceilometer.....	I.15-7
15.7 Laser ceilometer	I.15-8
References and further reading.....	I.15-11
CHAPTER 16. MEASUREMENT OF OZONE.....	I.16-1
16.1 General.....	I.16-1
16.2 Surface ozone measurements.....	I.16-3
16.3 Total ozone measurements	I.16-4
16.4 Measurements of the vertical profile of ozone	I.16-11
16.5 Corrections to ozone measurements	I.16-16
16.6 Aircraft and satellite observations	I.16-17
Annex 16.A. Units for total and local ozone	I.16-18
Annex 16.B. Measurement theory	I.16-20
References and further reading.....	I.16-22
CHAPTER 17. MEASUREMENT OF ATMOSPHERIC COMPOSITION	I.17-1
17.1 General.....	I.17-1
17.2 Measurement of specific variables	I.17-1
17.3 Quality assurance.....	I.17-10
References and further reading.....	I.17-12