050 Meteorology

050-01 The Atmosphere

050-01-01 Composition, extent, vertical division

Troposphere	0 – 11 km	15° to -56.5°
Stratosphere	11 – 50 km	-56.5° to 0°
Mesosphere	50 – 85 km	0° to -90°
Thermosphere	85 – 600 km	-90° to >1500°
Exosphere	600 – 10000 km	

Troposphere

Latitude	**Winter**	**Summer**	**Temperature**
60° N	25000 ft	30000 ft	-50°
50° N	28000 ft	35000 ft	-55°
30° N	?	38000 ft	-55°
0° N	50000 ft	60000 ft	-60° to -80°

050-01-02 Air temperature

°C = 5/9 * (°F – 32)
°F = 9/5 * °C + 32
K = °C + 273

- solar radiation
- terrestrial radiation
- conduction
- convection
- condensation

050-01-03 Atmospheric pressure

hPa	**ft**	**density**
1013	Sea level	1.225 kg/m³
850	5000	1.055 kg/m³
700	10000	0.904 kg/m³
600	14000	0.796 kg/m³
500	18000	0.698 kg/m³
400	24000	0.569 kg/m³
300	30000	0.459 kg/m³
250	34000	0.395 kg/m³
200	39000	0.317 kg/m³
150	45000	0.238 kg/m³

27 ft/hPa	MSL
36 ft/hPa	10000 ft
50 ft/hPa	18000 ft
60 ft/hPa	25000 ft
73 ft/hPa	30000 ft
216 ft/hPa	49000 ft

H = 96 * T / P

H .. change in height (ft/hPa)
T .. temperature (K)
P .. pressure (hPa)

050-01-05 ICAO Standard Atmosphere (ISA)

MSL 15 °C, 1013.25 hPa, 1225 g/m^3, 1.98 °C per 1000 ft, Tropopause: 36090 ft, -56.5 °C

050-01-06 Altimetry

- QFF is QFE reduced to MSL with actual temperature and isothermal between MSL and SFC
- altimeter setting: 1 in → 1000 ft

cold	**warm**
true **<** indicated	true **>** indicated

FL 27ft/hPa **QNH** 4%/10°C **TRUE**

QFF vs QNH	cold	warm
above SL	**+**	**-**
below SL	**-**	**+**

050-02 Wind

050-02-01 Definition and measurement of wind

geostrophic wind: PGF, CoriolisF, parallel to isobars

gradient wind: PGF, CoriolisF, CentrifulgalF, NH LOW: gradient < geostrophic

050-02-02 Primary cause of wind

surface vs 2000 ft	speed	direction
LAND NIGHT	25%	45°
LAND DAY	50%	30°
SEA	70%	10°

050-02-03 General global circulation

warm anticyclone → intensity increases with altitude

cold anticyclone → intensity decreases with altitude

050-02-04 Local winds

sea breeze	day, 10kts, 1000-3000ft, 8-15 nm
land breeze	night, 5kts, 1000ft, 5nm
anabatic	up-slope, valley wind, day, 5kts
katabatic	down-slope, MTN wind, night, 10kts

050-02-06 Turbulence

LGT	< 0.5 g	
MOD	0.5–1 g	positive control at all times
SEV	> 1 g	maybe out of control temporarily

050-02-07 Jet streams

name	direction	season	core altitude	position	speed
Arctic	westerly	winter	FL200-FL250	60°N (50°N in USA)	200kts
Polar Front	westerly	all year	FL300-FL350	50°N (winter) 60°N (summer)	125-140kts
Polar Night	westerly	winter	>FL500		150kts
Subtropical	westerly	all year	FL400	25°N (winter) 45°N (summer)	70-200kts
Equatorial	easterly	summer	FL450-FL500	15°N	60kts

050-03 Thermodynamics

050-03-01 Humidity

$$RH(\%) = \frac{actual\ water\ vapor\ (g/kg)}{maximum\ water\ vapour\ (g/kg)}$$

0.1g/m³ at the poles

25 g/m³ at the equator

mixing ratio: g of water vapour per kg of dry air

050-03-03 Adiabatic processes

SALR	1.8 °C / 1000 ft	0.6 °C / 100 m
ELR	2 °C / 1000 ft	0.65 °C /100 m
DALR	3 °C / 1000 ft	1 °C / 100 m

absolute stability	ELR < SALR < DALR
absolute instability	SALR < DALR < ELR
conditional instability	SALR < ELR < DALR

Cloud base = Spread x 400

050-04 Clouds and Fog

050-04-01 Cloud formation and description

	name	cat	height (ft)	turb	ice	precip
ST	Stratus	low	0-6500	no	lgt/mod	DZ, FZDZ, SG, IC
SC	Stratocumulus	low	0-6500	lgt/mod	lgt/mod	RA-, SN
AC	Altocumulus	mid	6500-23000	lgt/mod	lgt/mod	
AS	Altostratus	mid	6500-23000	lgt/mod	lgt/mod	
CI	Cirrus	high	16500-45000	no	no	
CS	Cirrostratus	high	16500-45000	no	no	
CC	Cirrocumulus	high	16500-45000	no	no	
CU	Cumulus		0-25000	mod/sev	mod/sev	
CB	Cumulonimbus		0-45000	mod/sev	mod/sev	SH*
NS	Nimbostratus		0-6500	mod	mod/sev	RA+, SN+

050-04-02 Fog, mist, haze

- radiation fog
- advection fog
- frontal fog, mixing fog
- orographic fog
- shallow fog
- steam fog (arctic smoke) (<500ft)

050-05 Precipitation

050-05-01 Development of precipitation

- coalescence (collision-coalescence process), drizzle, -RA
- Bergeron-Findeisen (ice crystal) process, mixed phase, TS

050-05-02 Types of precipitation

ice pellets	transparent, translucent balls of ice, <5mm, bounce on ground
DZ	small water droplets (0.2-0.5mm)
RA	water droplets (0.5-5.5mm)
SN	grains, pellets or flakes
GR	hail, frozen water (up to 1kg)

050-06 Air Masses and Fronts

050-06-01 Air masses

- Arctic (A), Polar (P), Tropical (T), Equatorial (E)
- maritime (m), continental (c)
- warm air mass over cold surface → stable
- cold air mass over warm surface → unstable

050-06-02 Fronts

cold front	before	during	after
wind	backing, increase, squally	sharp veers, strong gusts	veer, decrease, stabilize
temp	steady, then falling rapidly	sudden decrease	steady (cold)
press	steady decrease	lowest value	slow increase
cloud	SKC or ST/SC then NS/CB	BKN/OVC with CU/CB	AC/AS, some CU/CB
precip	DZ, RA- then SHRA	RA+, TS	no precip, later SHRA
vis	fair to poor, maybe DZ, BR	poor in precip, then good	very good, except in SHRA

warm front	before	during	after
wind	backing, increase	sharp veer	stabilizes
temp	steady, slow increase	sudden increase	steady
press	steady decrease	lowest value	slight rise, then steady or fall
cloud	gradual increase	ovc, low bases	ovc, low bases
precip	continuous	continuous, mod/heavy	DZ, RA-
vis	reducing to poor	poor	poor

occlusion	before	during	after
wind	south-eastern	variable	west/north-west
temp (cold occ)	cold to cool	decreasing	colder
temp (warm occ)	cold	increasing	milder
press	steady decrease	lowest value	gradual increase
cloud	CI, CS, AS, NS	NS, sometimes TCU/CB	NS, AS
precip	light to heavy	light to heavy	light to mod, then clear
vis	poor in precip	poor in precip	improving

quasi-stationary fronts:

- polar frnt (summer 50-65°N, winter 40-50°N)
- arctic front
- ITCZ front
- Mediterranean front (only winter)

warm front occlusion, in europe during winter

cold front occlusion, in europe during summer

050-07 Pressure Systems

050-07-01 The principal pressure areas

polar cell, ferrel cell, hadley cell

sub tropical high pressure belt

azore high (SE USA, SW EU in summer , S EU, N Africa in winter)

polar lows (iceland, southern greenland), weaker in summer

mediterranean low (polar air reaches warm water), typical in winter

dynamic = cold low (deepening at altitude, winds increasing)

thermal = warm low (low is weakening aloft and turns into high pressure)

subtropical highs (warm anticyclones)

continental highs (cold anticyclones)

050-07-02 Anticyclone

cold temporary anticyclone (between two polar front depressions)

blocking high (warm anticyclone which converts west-east movement of polar front to meridional flow)

subsidence inversion

050-07-03 Non frontal depressions

Thermal Depressions – warm LOW pressure areas, air moves over warm earth, typically over land in summer
dynamic lows – cold LOW pressure areas, air in centre of low is colder than surroundings, stronger in winter

050-07-04 Tropical revolving storms

Tropical Storm <= 64kt

Tropical revolving Storm >64kt

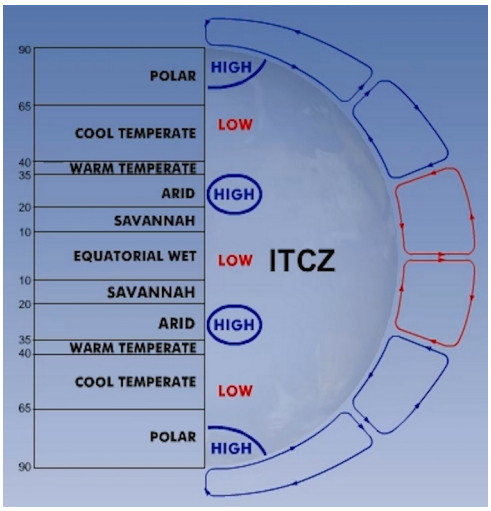
Hurricane	N Hemisphere	Jul-Nov	17.7 per year
Cyclone	Indian Ocean	Apr-May, Oct-Nov	12 per year
Cyclone	coast of East Africa	Dec-Apr	occasionally
Cyclone/Willy-Willy	Australia	Dec-Apr	occasionally
Typhoon	Asia	Jun-Nov	20 per year

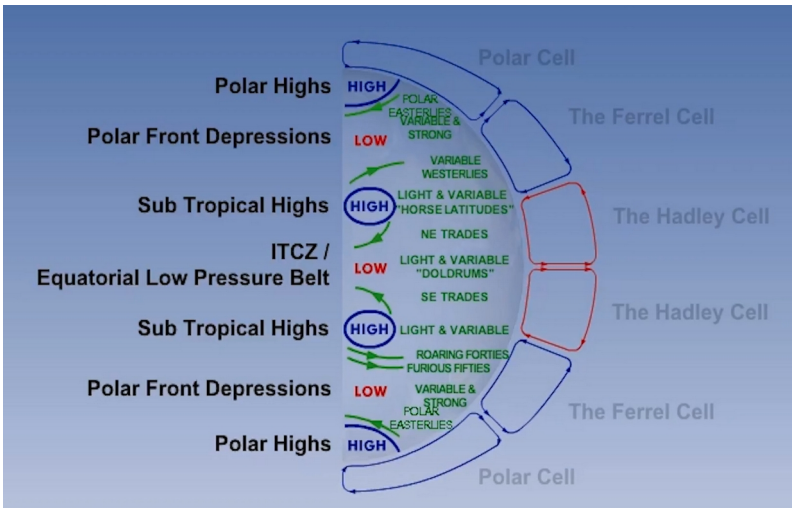
TRS per year WEST of Darwin	5
TRS per year EAST of Darwin	2
TRS per year Bay of Bengal	12
Hurricanes per year in the Atlantic	6
TRS per year in Philipines	9

050-08 Climatology

050-08-01 Climatic zones

0°-10°	Equatorial	high temps, high humidity, TS, CB, RA+, doldrums, two rainy seasons (sept & march)
10°-20°	Savannah/Tropical	dry trade winds in winter, rainy in summer
20°-35°	Steppe/Arid Sub-tropical	deserts, horse latitudes
35°-40°	Warm Temperate	Mediterranean
40°-65°	Disturbed (cold) Temperate	
65°-90°	Polar	tundra, avg <0°, max 10°, dry winter (highs), little precip in summer

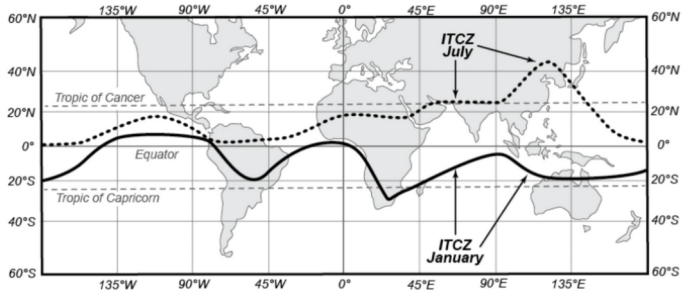




India: moist SW Monsoon in July, dry NE Monsoon in Winter

Darwin: SE winds & dry in July, NW & TS in January

050-08-02 Tropical climatology



050-08-04 Local winds and associated weather

BORA	N, NE	winter	cold strong katabatic wind on northern adriatic coast, strong violent gusts
MISTRAL	N	winter, spring	cold strong katabatic wind from rhone-valley in france to mediterranean, very gusty
PAMPEROS	S	winter	cold strong wind from antarctica to south america
HARMATTAN	NE	winter	sahara monsoon, dry & dusty
SIMOOM	S, SE	spring, summer	very hot, dry, dusty over african/arabic deserts
SIROCCO	S, SE	winter	strong, dust, sand from africa to mediterranean
GHIBLI	S	late summer	warm wind affecting libya
KHAMSIN	S	winter, spring	from egypt over eastern mediterranean
HABOOB		summer	egypt, sudan, sandstorms
SHAMAL	NW	summer	Iraq, Persian Gulf, sandstorms
CHINOOK			föhn in the rockies
FÖHN			warm katabatic wind in alps

050-09 Flight Hazards

050-09-01 Icing

large super-cooled droplets

- CU and CB 0°C to -20°C
- NS 0°C to -10°C (to -20°C if NS formed orographically)

small super-cooled droplets

- tops of NS -10°C to -40°C
- tops of CU/CB -20°C to -40°C
- ST/SC/AS 0°C to -15°C (but light icing up to -30°C)

050-09-02 Turbulence

	g	**ias change**	**derived gust**	
LGT	< 0.5g	5-10 kts	300-1199 ft/min	
MOD	0.5-1.0g	15-25 kts	1200-2099 ft/min	positive control at all times
SEV	>1.0g	>25 kts	>2100 ft/min	maybe out of control temporarily

050-09-04 Thunderstorms

	duration	**precip**	
initial	15-20 min	none	only updraughts, TCU growing into CB, congestus
mature	20-30 min	heavy	up & downdraughts, CB/TS, lightning, hail, microbursts, etc.
dissipating	30 min – 3 hrs	continued	only downdraughts, anvil at the top of CB, capillatus

050-09-05 Tornadoes

100-150 m diameter, < 30 min, <300 kts, spring & summer

050-09-09 Visibility reducing phenomena

FG	<1000 m
+SN	50-200m
DZ	500-3000m
+RA	<1000m
SN	1000m
BR	1000-5000m
RA	3000-5000m
HZ	<5000m

050-10 Meteorological Information

050-10-01 Observation

AIREP – routine weather, automated, wind, temperature, less significant weather phenomena

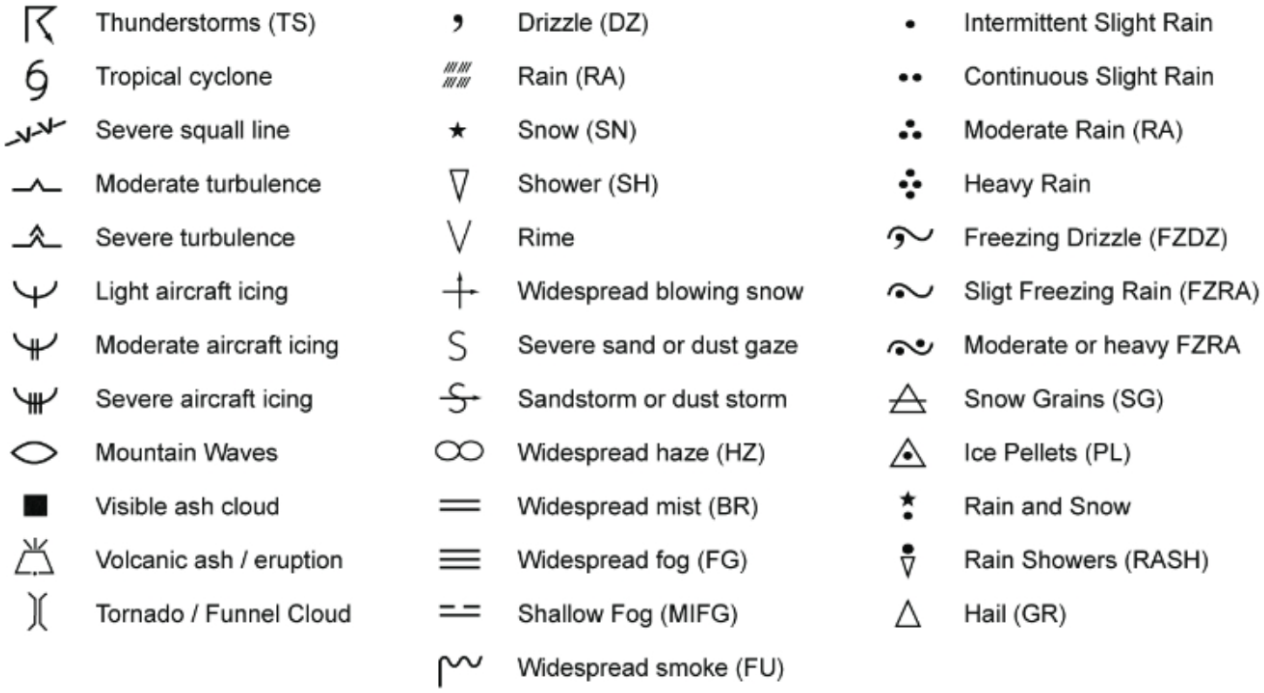
PIREP (special air report) – significant or hazardous weather

only severe icing & severe turbulence

when trans/supersonic: also moderate turbulence, hail & CBs

050-10-02 Weather charts

Distance (nm) = cos(latitude) * change in longitude * 60



ISOL	Individual Cbs
OCNL	well separated Cbs
FREQ	Cbs with little or no separation
EMBD	thunderstorm clouds contained in layer of clouds

050-10-03 Information for flight planning

CAVOK – 9999, no clouds below 5000‘ or MSA, no CBs, no significant weather

VOLMET – recorded METARs for multiple airports

SIGMET

QNH rounded down, temp/dewpoint rounded up (warmer)

LLWAS – Low Level Windshear Avoidance System

SPECI – significant changes to METAR (temp >2°, wind >60°/10kts, vis changes, rvr changes, ...)

SPECIAL – summary of SPECI in plain language, available to ATSU and ATIS

MET-REPORT - kind of a „summary“ of a METAR, issued by local ATS & ATIS

050-10-04 Meteorological services