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AUTUMN COURSE ON GEOMAGNETISM, THE IONOSPHERE
AND MAGNETOSPHERE

(21 September - 12 November 1982)

TROPICAL IONOSPHERE AND TROPOSPHERE

A.P. MITRA

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Hillside Road
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India

Documents available here

- CCIR Document
- Davies book on "Ionospheric Radio Propagation"
- Indian book on "Tropospheric Communication and Antenna Systems"
- Indian Atlas on Radio Refractivity
- Indian Atlas on Water Vapor
- Argentinian Document on Ionogram Analysis
- Vol 1 of Boulder Symposium
- ITS 78 Volume

Tropical Troposphere

- Frequent occurrences of ducting in some zones — S.E. Asia
- High rain rate — S.E. Asia, South America
- Desert conditions, Dust problem — Middle East
- Mountain, Knife-edge diffraction, Obstacle gain

How are Tropics Different?

1
- LOW GEOGRAPHIC LATITUDES (%)
- LOW GEOMAGNETIC LATITUDES (Appleton Anomaly Field-aligned irregularities)

But Geogr lat ↔ Geomag. lat. relation different in three zones:

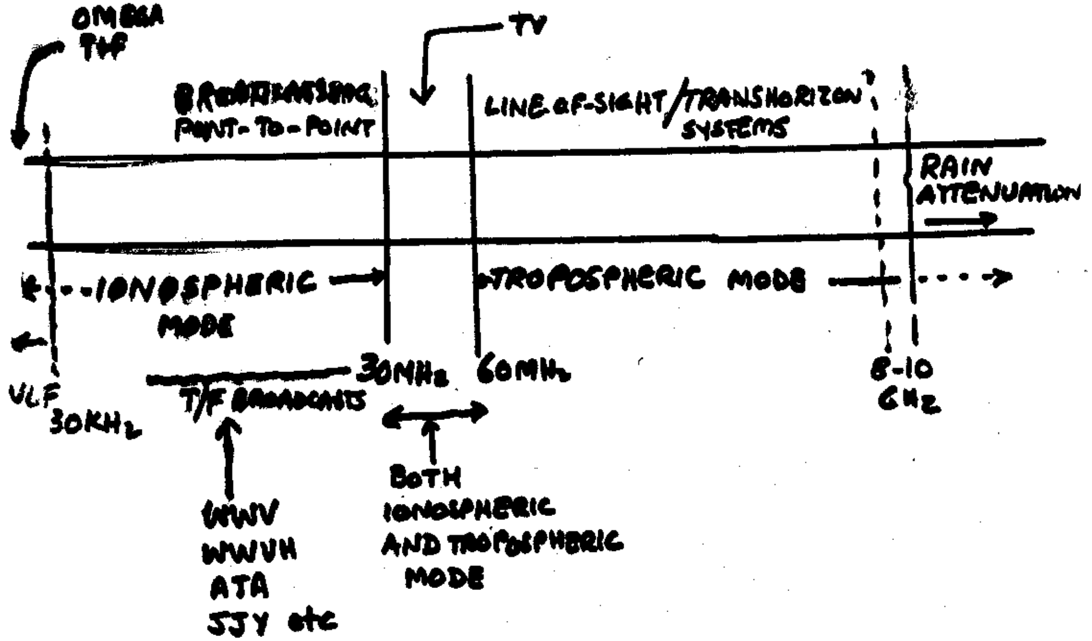
ASIAN ZONE
AFRICAN ZONE
AMERICAN ZONE

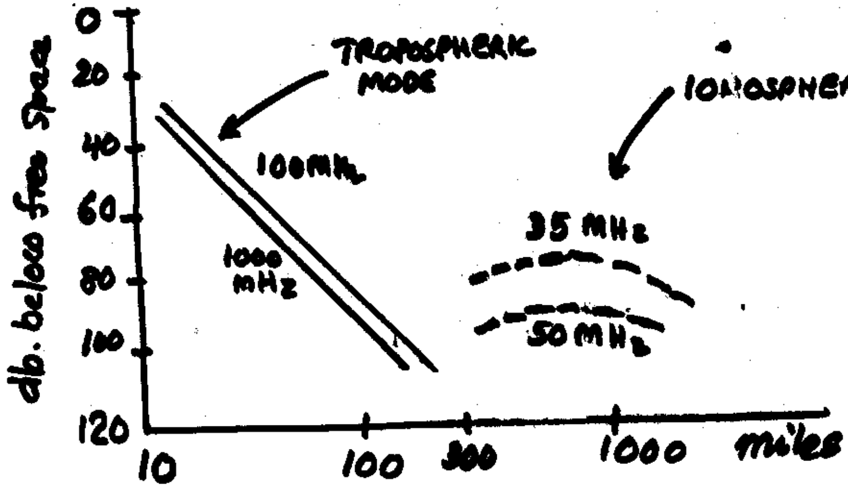
2 CONSEQUENCES

F-Region
- Generally within Appleton Anomaly belt
- High Spread-F Incidence

E-Region
: Equatorial Electrojet
Equatorial Es & Es prop. beyond MUF

D-Region
Not subject to PCA's
↑
Prop. relatively undisturbed





Some Simple Observational Techniques

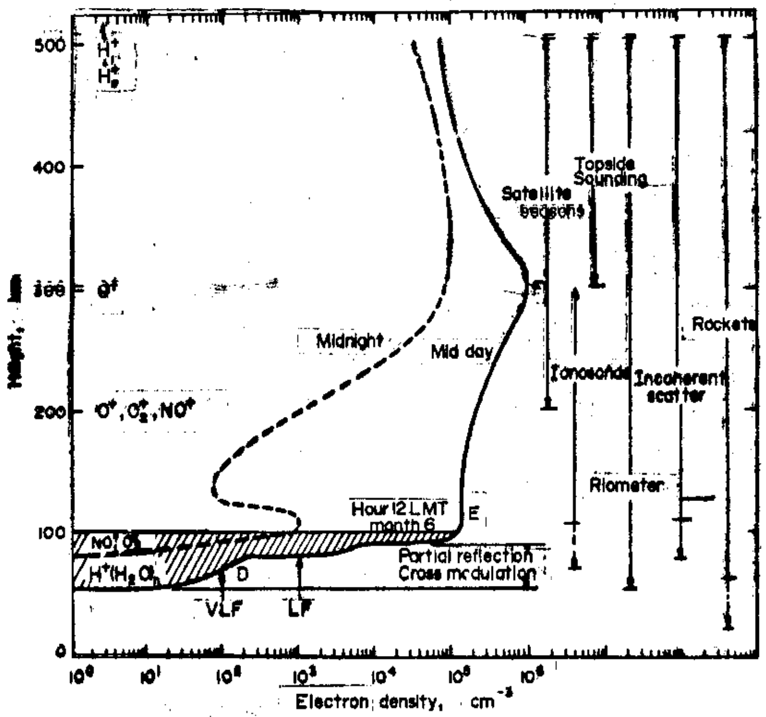
A. Ionosphere

- Radio wave field strengths
- $\boxed{\text{IONOSONDES}}$ (list distributed — note non-uniform distribution)
- $\boxed{\text{A1, A2, A3}}$
- TEC

PROFILE MODELLING
- IRI
- FROM BASIC CONSIDERATIONS

B. Troposphere

- $\boxed{\text{Radiosondes}}$
- Sodar
- Use of link data
- Radar



KVO-29-1

Parameters of Interest

R	11 years 22 years ← Hale Cycle 180 years ?
Solar constant	≤ 1% (~ 0.1%)
$F_{10.7}$	
UV	Limited period only
PCA	ΔA, ΔNO_x
SID's	ΔA (Riometer) Phase changes (VLF)
PROTON FLUXES	>10 MeV >30 MeV >60 MeV
K_p, A_p, C_i, C_p	

SOLAR RADIATION

S	$1373 \pm 20\ W m^{-2}$	• UNLIKELY TO HAVE VARIED MORE THAN 10-15% IN PAST 3 billion YEARS.		
FAR IR	10 μm – 1000 μm	4950K 10 μm 4450K ~ 150 μm 6000K ~ 1000 μm		
OPTICAL & IR	0.3 – 10 μm	99% OF TOTAL SOLAR RADIATION		
UV	1200 – 3000 Å	3000 Å	1%	
		2000 Å	5%	
		1200 Å	25%	27d. Rotation
		L_α	15%	27d
EUV	10 – 1200 Å		100%	M → MX.
			25% : 16%	B FL.
		λ>170A	CAN BE X5 FOR CORONAL LINES	
XRAYS	<10 Å	X 1000 – 100 OVER SOLAR CYCLE AND DISTURBANCES		

Ra[illegible] and Altitudes

XUV	0.1 nm	45 km.
	2.0 nm	100 Km
	20 nm	125 Km
	150 nm	80 Km
	220-280 nm	35 Km
PROTONS	1 MeV	90 Km
	100 MeV	30 Km
	1000 MeV	8 Km
α-PARTICLES	1 "	95 Km
	1000 "	25
ELECTRONS	0.02 "	90
	100 "	10
BREMSTRALLUNG	0.005 "	75 Km
	0.20 "	30
IR (≥ 700 nm)		SURFACE

VARIABILITIES

	LONG-TERM	SHORT-TERM
foE	WITH SEASON; SOL.CYCL.	DAY-TO-DAY : ±6%. FLARES: +5-10%.

PRED. METHOD: a. MUGGLETON (1975) ← f(F, L, [illegible]).
1944-1973 data 55 observations

b. LEFTIN (1976) ← f(R, M, UT, L, LONG).

C. Nighttime (Wakai, NTN)

F-REGION

foF1 : DU CHARME ET AL (1973)
ROISCH AND JONES (1973)

foF2 :
- CCIR ATLAS (CCIR 340-3) COEFFICIENTS FROM JONES et al (1968)
- hmF2 from M3000F2
- LONGTERM PRED. OF M3000F2 AVAILABLE THROUGH COEFF IN ITS-78 PROGRAMME

DAY-TO-DAY : AS MUCH AS 15-20%.

PREDICTIONS
- SRI MODEL
- AIRFORCE GLOBAL WEATHER CENTRE CCIR → UPDATED WITH NEAR REALTIME IONOSONDES AND TEC.

Propagation by Es

1. ZONES

AURORAL ZONE	:	NIGHTTIME, LITTLE SEASONAL VARIATION
MIDLATITUDE	:	BOTH DAY/NIGHT, SUMMER
EQUATORIAL	:	DAYTIME, FREQUENT

2. Role of Es in Communication

- Extension of role/range of usable HF radio waves - particularly imp. at s.min. when range limited
- May increase multipath problems for high HF rate system.
- Provide prop. of interfering signals to a larger extent
  eg. TV ⇐ >600 Km Es, <600 Km TROPOSPHERE

3. Global/Regional Distr.

LEFTIN ET AL (1968) :
- SOLAR CYCLE MAX & MIN.
- IN TERMS OF A MODIFIED LATITUDE COORDINATE

Es-MUF $= (f_{Es} - 4\ \text{MHz}) \sec i$

SMITH (1981) $\log_{10}\left(\frac{P_1}{P_2}\right) = b(f_1 - f_2)$

$b \sim 0$

SAXENA
IZMIRAN (1964)

FOR IN &
GLOBAL

D-Region Problem

1. Communication and broadcasting
   Those using MF and HF bands.
   Depend upon acceptable signal-to-noise ratio

2. Users of ELF/VLF or LF navigation Systems
   eg. Omega
   Depend upon stability of reflection region for time and position determination

3. T&F Systems
   One of the most vital way of calibrating atomic clocks ⇒ through VLF transmissions.

LOW LATITUDE PROBLEM

- Essentially no data to predict propagation of OMEGA and other VLF signals in this zone - however improving
- Very few authentic pulse absorption equipment - practically dependent on IGY/IQSY data
  the reality of absorption anomaly ?
- However, simpler to model

TRANS-IONOSPHERIC PROPAGATION

TEC → ← IONOSPHERE MODELS (RAY TRACING)

TIME DELAY

PREDICTION: ± 20% of TEC MONTHLY MEAN (DAYTIME)
± 30-35% AT NIGHT

↓

a) LUNAR TIDAL EFFECTS $I(t) = S(t)\{1 + m\,C(t)\}$

b) Improved : Solar flux EUV (?)

c) Geomag. : Storm effects Mendillo-Klobuchar (STP, 1979)

SCINTILLATIONS

$$S_4 = \left\{ \frac{\langle I^2\rangle - \langle I\rangle^2}{\langle I\rangle^2} \right\}^{1/2}$$

PROVEN TO BE MOST USEFUL FOR THEORETICAL ANALYSIS AND MODELLING

PARAMETERS NEEDED TO DEFINE PERFORMANCE CHARACTERISTICS:

- S_4
- τ_c (COHERENCE TIME)
- COHERENCE BANDWIDTH,

MODELS: RINO (RADIO SCIENCE, 1979)
FREEMOW-RINO, AGARD CONF 238 (1978)

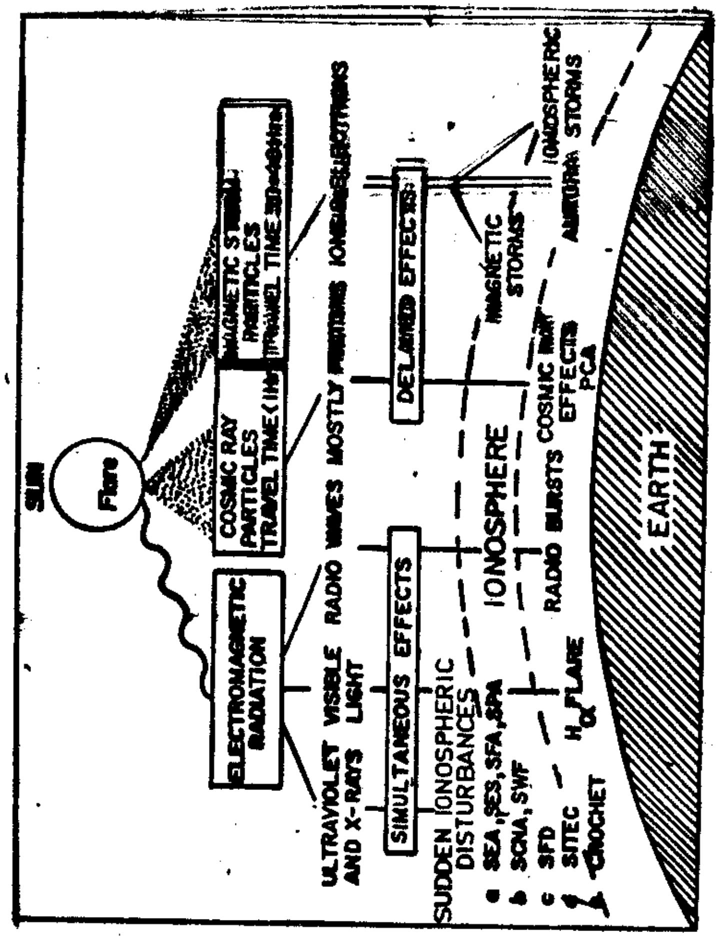
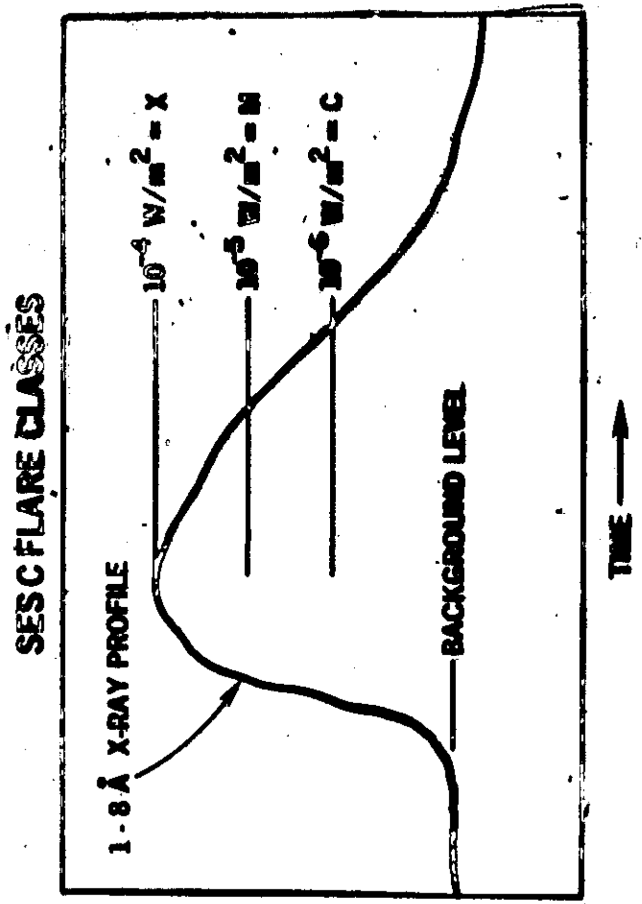


Fig. 1. An illustrative sequence of ionospheric effects associated with solar flares.



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DISTURBANCES

	S. MAX	S. MIN	Typical duration	Longpath VLF/LF Phase	Ampl
SID	2/WEEK	2/YEAR	3/4 hr	5-30 Cec	-1 to +5 db
PCA	1/mo	0	3d	40 dec	
STORM (MAG).	26/yr	82/yr	days	10-20 cec	5-10 db fade
W.A.	20/yr	20/yr	days	usually phase advance	5-10db fade
STRATWARM	2/yr	2/yr	weeks	unknown	unknown

Cec = Centicycles ; At 10KHz, 1Cec = 1ms in time
≃ 0.1 mile

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CHARACTERISTICS OF MAJOR T+F SYSTEMS

		ACCURACY (FREQ. SYNCHR.)	ACCURACY (TIME TRANSFER)	AMBIGUITY	COVERAGE
VLF :	GBR, NBA, OMEGA etc	1×10^{-11}	ENVELOPE 1–10ms	1 cycle	NEARLY GLOBAL
LF :	STAND. FREQ. BROADCAST	1×10^{-11}	ENVELOPE 1–10 ms	DAY OF YEAR	USA-LIMITED (WWVB)
HF/MF :	STAND. FREQ. BROADCAST (eg. WWVB, ATA)	1×10^{-11}	1000 μs	CODE – DAY OF YEAR	HEMISPHERE
TV (VHF/UHF) :	PASSIVE LINE-10	1×10^{-11}	1 μs	33 ms	NET
	COLOUR SUBCARRIER	1×10^{-12}	N/A	NA	COVERAGE
PORTABLE CLOCKS :	PHYSICAL TRANSPORT	1×10^{-13}	100 ns	NONE	LIMITED BY TRANSPORTATION

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DISTRIBUTION OF SESC SERVICES

TYPE	TIME OF APPLICABILITY	PHENOMENA OF INTEREST
FORECAST	10 YEARS 6 MONTHS, 7 and 27 DAYS	SUNSPOT NUMBER GENERAL LEVEL OF SOLAR and GEOMAGNETIC ACTIVITY
FORECAST	1, 2, 3 DAYS FORECAST	FLARES, PROTON EVENTS, GEOMAGNETIC INDICES, SOLAR FLUX INDEX
FORECAST	30 MINUTES	FLARES
ALERT	IMMEDIATE	X-RAY, RADIO, OPTICAL EMISSION FROM FLARES
FORECAST	30 MINUTES - 100 HOURS	PROTON EVENT, GEOMAGNETIC STORM, SUBSTORMS
ALERT	IMMEDIATE	PROTON EVENT, GEOMAGNETIC STORM, SUBSTORMS
DATA (REAL-TIME)	REAL-TIME	ALL DATA
DATA (SUMMARIES)	DAILY and WEEKLY	SELECTED DATA

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INSTITUTIONS REQUIRING T&F SERVICES IN INDIA

P+T	IN FUTURE FEW ms	1×10^{-13} (HAVE OWN Cs STANDARD)
ITI	FEW μs	1×10^{-12} (OWN Cs STANDARD)
R.A	FEW μs	1×10^{-11}
ISRO Sat. Tracking	Few μs	1×10^{-10}
		1×10^{-11}
LIGHTHOUSE	NOMINAL	1×10^{-8}
BROADCASTING	GET TIME-PIP CALLER: DIRECTLY FROM ATA	

Some Important Parameters in Tropospheric Propagation

- $N \left(= \frac{77.6\, p}{T} + \frac{373{,}000\, e}{T^2}\right) \simeq 1.0003$

  N_{dry} N_{wet} $N = (n-1)\times10^{6}$, 300–400 units

- $\frac{dN}{dh}$
  - 0 to $-40N$ Subrefr.
  - -40 to $-157N$ Super ref.
  - $\geq -157N$ Ducting
- C_N^2
- $a' = ka$

$$k = \frac{1}{1+\frac{a}{n}\frac{dn}{dh}\cos\theta} \qquad \theta = 0^\circ$$

Standard air: $k = \frac{4}{3}$

N-Kinks

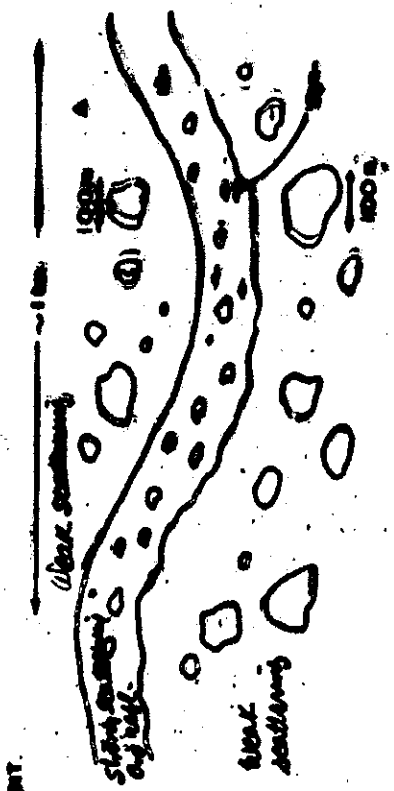
Very short	Ducting
Long	Refl.
Longer	Random Reflection

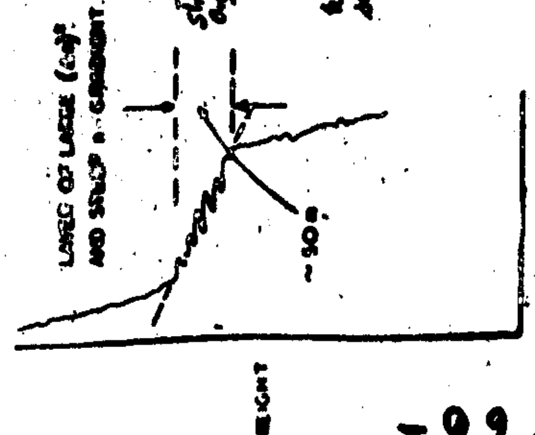
$$d = 113\, \lambda_{max}^{2/3}$$

$$= 20 =$$

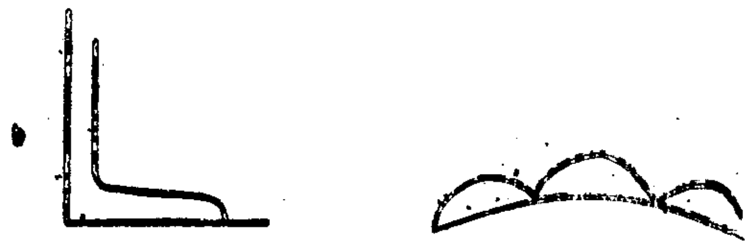
Characteristics of Climatic Types

	ANNUAL MEAN N_s	ANNUAL RANGE	GEOGRAPHICAL AREAS
1. CONTINENTAL TEMPERATE	~320	20-40 (40-50 in E. COAST U.S.A)	± 30-60° EXTREMES OF TEMP. IN A LARGE LAND MASS
2. MARITIME TEMPERATE OVER LAND	~320	SMALL 20-30	± 20-56° NEAR THE SEA WHERE PREVAILING WIND UNOBSTRUCTED BY MOUNTAINS CARRY MOIST MARITIME AIR. U.K., COASTS OF USA, EUROPE, AFRICA
3. MARITIME TEMPERATE OVER SEA	AS IN (2) BUT DUCTING COMMON		DUCTING COMMON BETWEEN UK-EUROPE, WESTCOAST OF USA-MEXICO
4. MARITIME SUBTROPICAL OVER LAND	~370	30-60	± 10-30° LOW LANDS NEAR SEA WITH DEFINITE RAINY AND DRY SEASONS
5. " OVER SEA	AS IN 4		COASTAL AREAS
6. DESERT SAHARA	~280	20-80	ROUND-THE-YEAR SEMI-ARID CONDITIONS
7. EQUATORIAL	~360	0-30	MARITIME CLIMATE 20°N-20°S MONOTONOUS HEAVY RAINS HIGH AV. SUMMER TEMP.
8. CONTINENTAL SUBTROPICAL	~320	60-160	HOT, SEASONAL EXTREMES IN RAIN. 20-40°N LAT

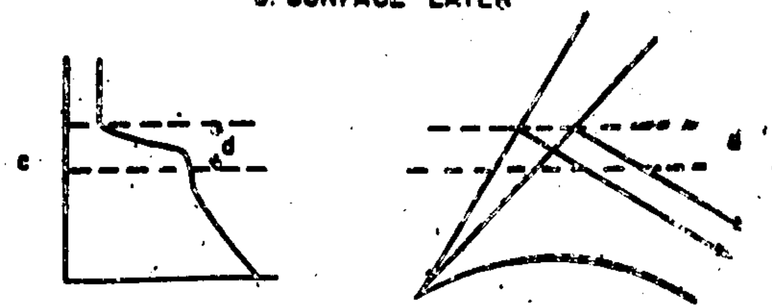




a. HOMOGENEOUS ATMOSPHERE



b. SURFACE LAYER



c. ELEVATED LAYER