Forecasting Techniques and NWP

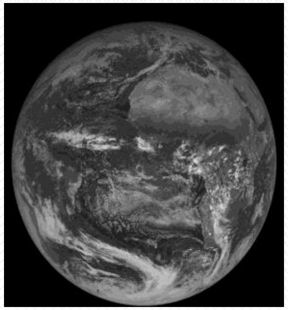
Khalifa Al Sudairi
chief of NWP
k.alsudairi@met.gov.om

Current State of the Atmosphere

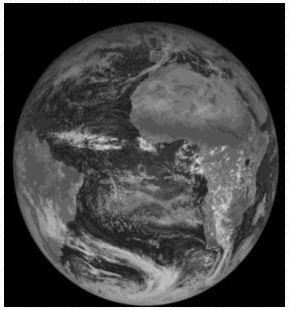
- **Get to Know the current State of the Atmosphere**
- **By Knowing the current State accurately you can do short range forecast.**

Current State of the Atmosphere

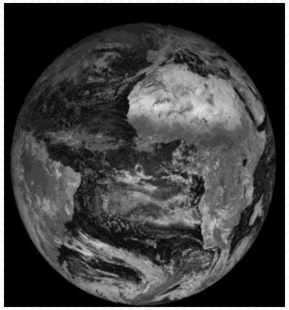
Look to different Satellites Channels



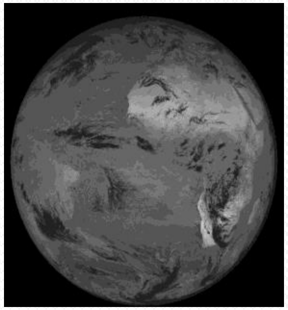
VIS 0.6



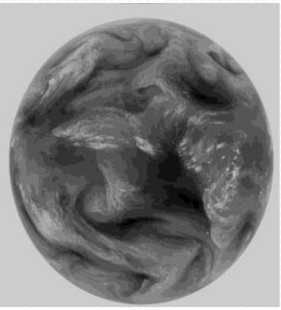
VIS 0.8



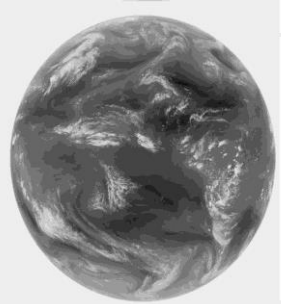
NIR 1.6



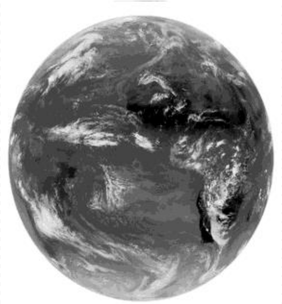
NIR 3.9



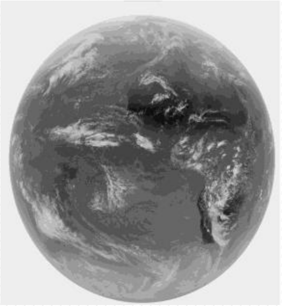
WV 6.2



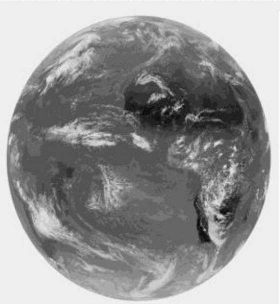
WV 7.3



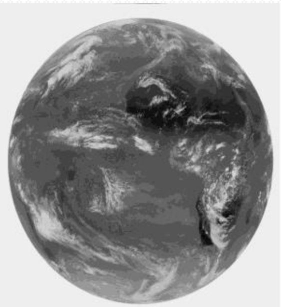
IR 8.7



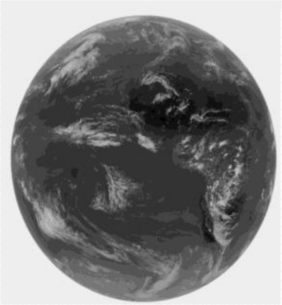
IR 9.7



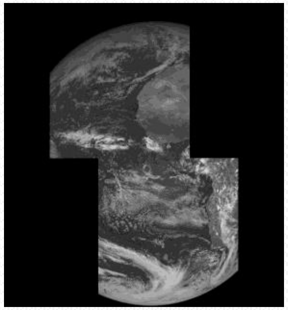
IR 10.8



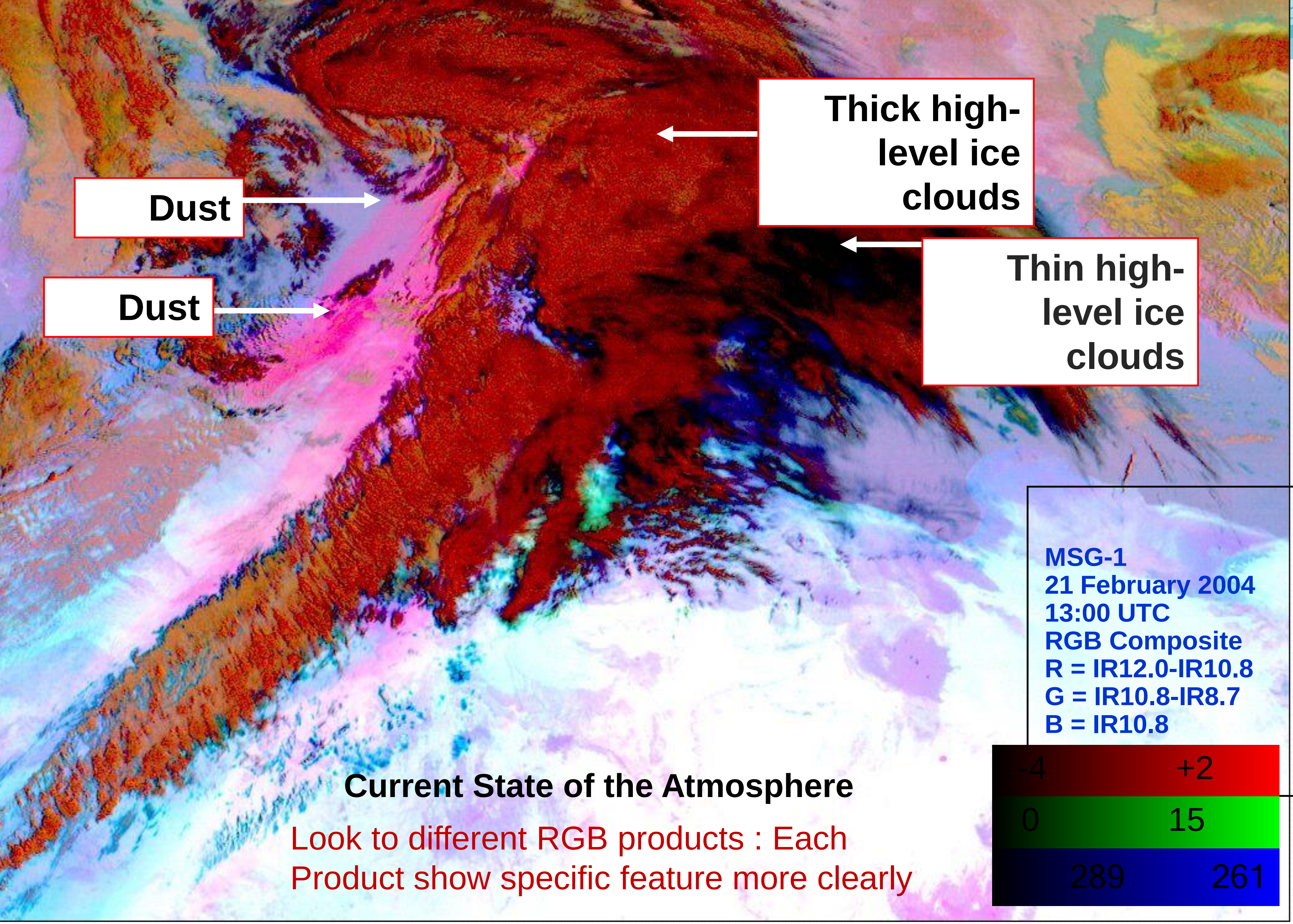
IR 12.0



IR 13.4



HRVIS



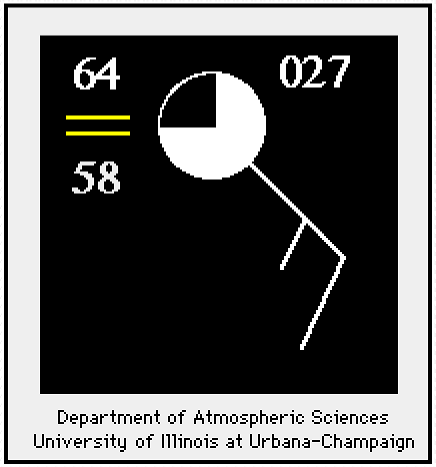
Current State of the Atmosphere

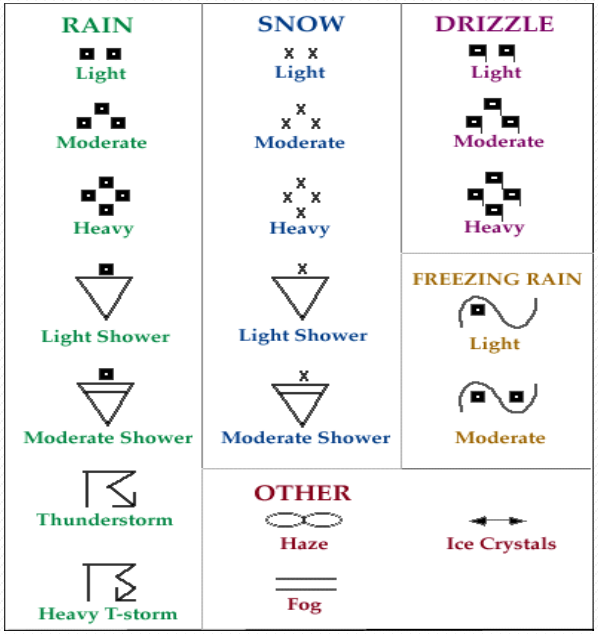
Look to different RGB products : Each Product show specific feature more clearly

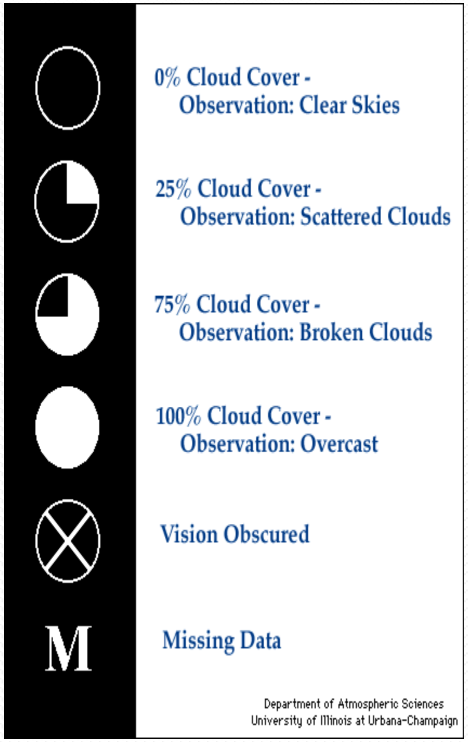
Current State of the Atmosphere

- Surface Charts
- Upper Air Charts
- Metars, Synops,(Ship, Aircraft, Police) Reports

Observe Weather Elements



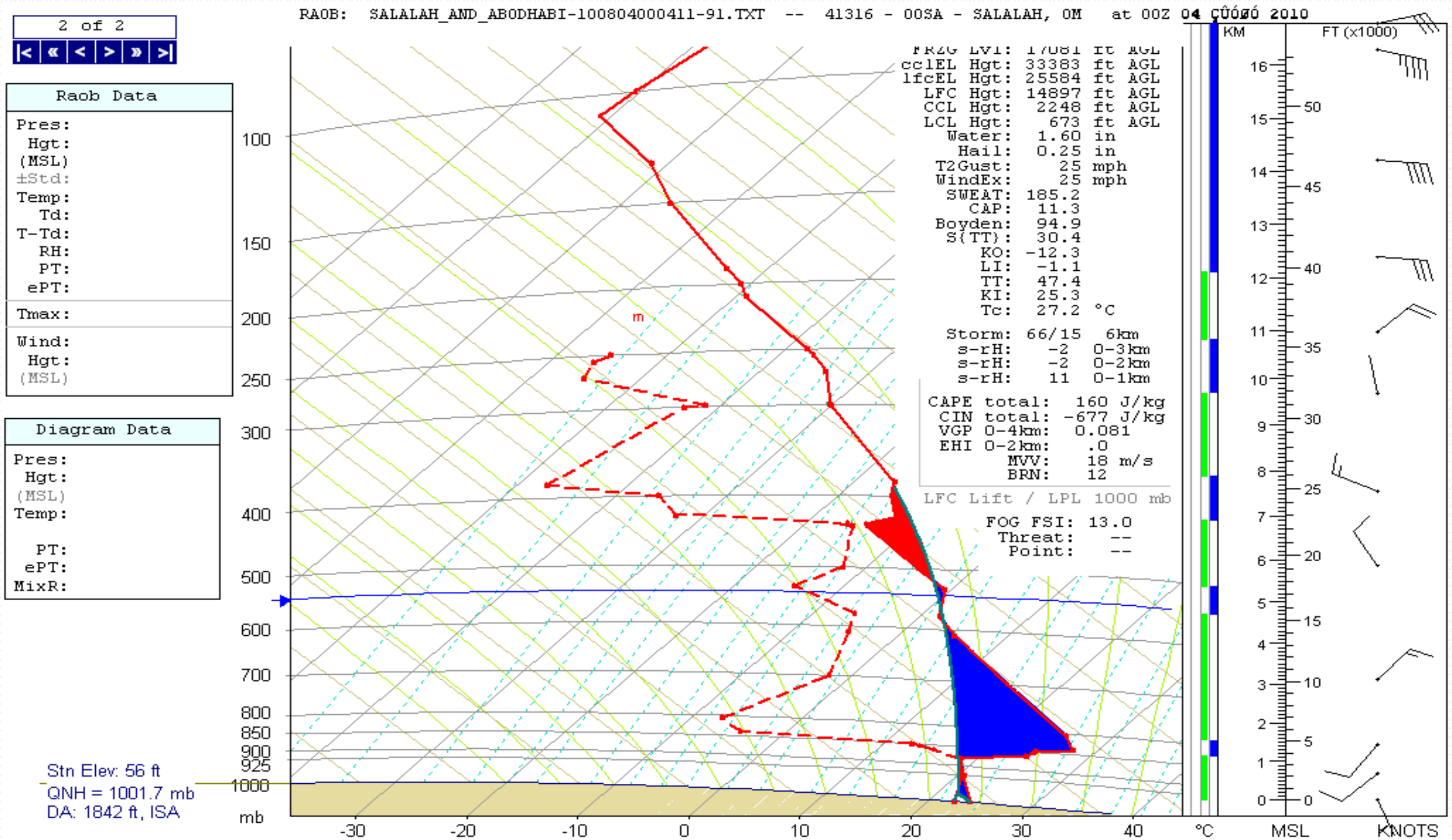


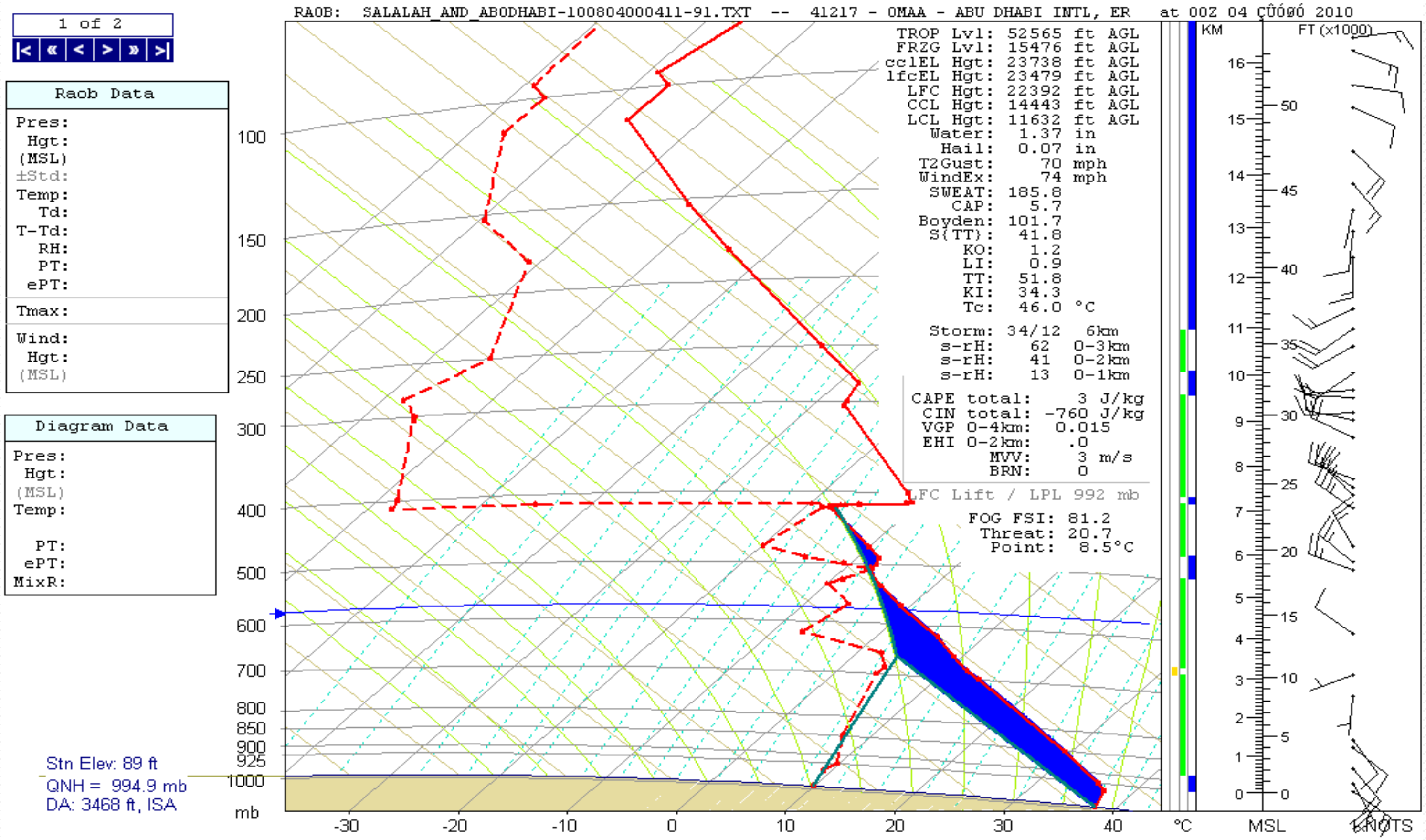


Analyze !

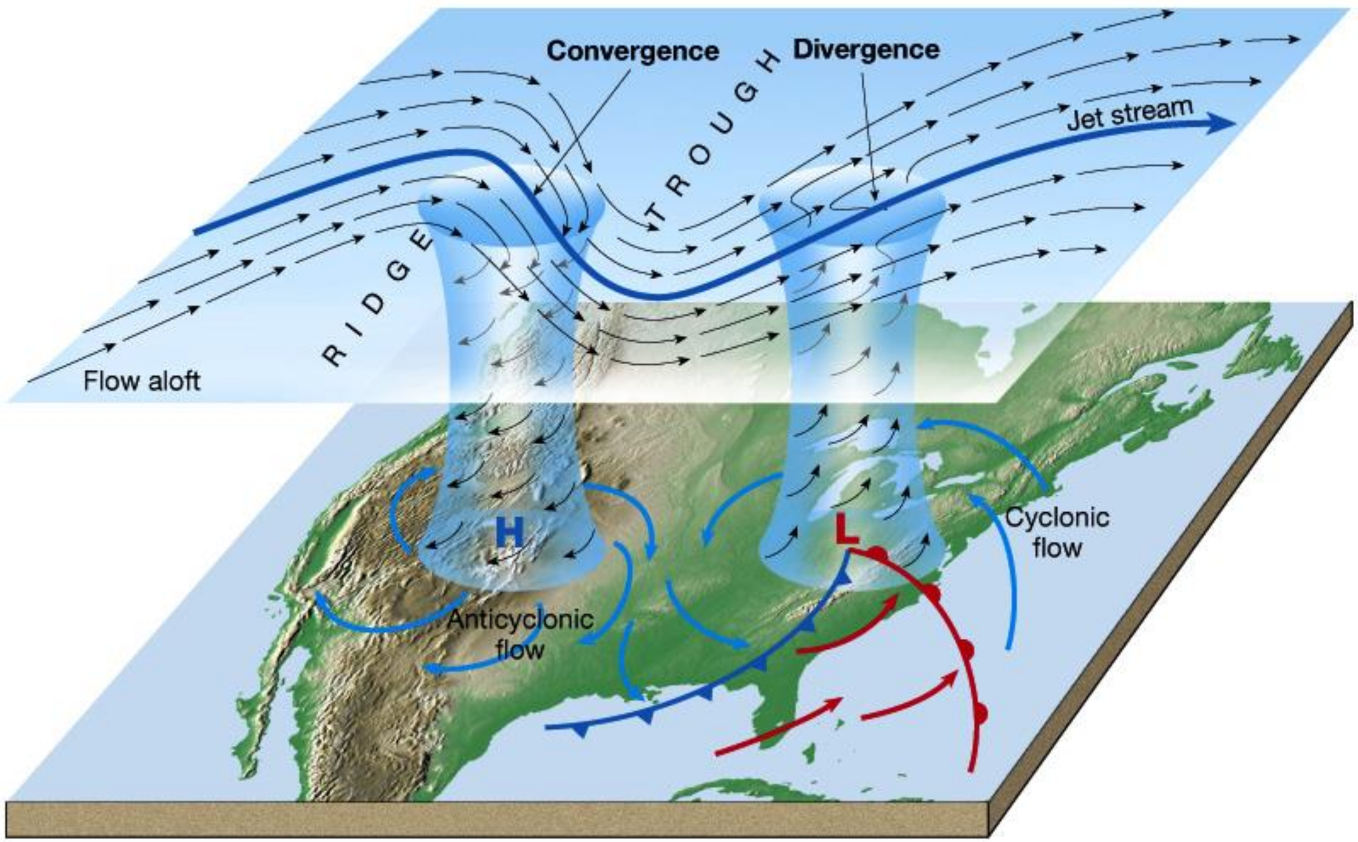
- Types of analyses performed :
- **Isobaric analysis**
- An isobaric analysis involves the construction of lines of equal mean sea level pressure on a geographic map
- **Isotherm analysis**
- Isotherms are lines of equal temperature drawn on weather maps

Fog over salalah




1 of 2
RAOB: SALALAH_AND_ABODHABI-100804000411-91.TXT -- 41217 - OMAA - ABU DHABI INTL, ER at 00Z 04 2010
Raob Data
Pres:
Hgt:
(MSL)
±Std:
Temp:
Td:
T-Td:
RH:
PT:
ePT:
Tmax:
Wind:
Hgt:
(MSL)
Diagram Data
Pres:
Hgt:
(MSL)
Temp:
PT:
ePT:
MixR:
TROP Lvl: 52565 ft AGL
FRZG Lvl: 15476 ft AGL
cclEL Hgt: 23738 ft AGL
lfcEL Hgt: 23479 ft AGL
LFC Hgt: 22392 ft AGL
CCL Hgt: 14443 ft AGL
LCL Hgt: 11632 ft AGL
Water: 1.37 in
Hail: 0.07 in
T2Gust: 70 mph
WindEx: 74 mph
SWEAT: 185.8
CAP: 5.7
Boyden: 101.7
S(TT): 41.8
KO: 1.2
LI: 0.9
TT: 51.8
KI: 34.3
Tc: 46.0 °C
Storm: 34/12 6km
s-rH: 62 0-3km
s-rH: 41 0-2km
s-rH: 13 0-1km
CAPE total: 3 J/kg
CIN total: -760 J/kg
VGP 0-4km: 0.015
EHI 0-2km: .0
MVV: 3 m/s
BRN: 0
LFC Lift / LPL 992 mb
FOG FSI: 81.2
Threat: 20.7
Point: 8.5°C
Stn Elev: 89 ft
QNH = 994.9 mb
DA: 3468 ft, ISA
mb
-30 -20 -10 0 10 20 30 40 °C
KM MSL
FT (x1000)
KNOTS

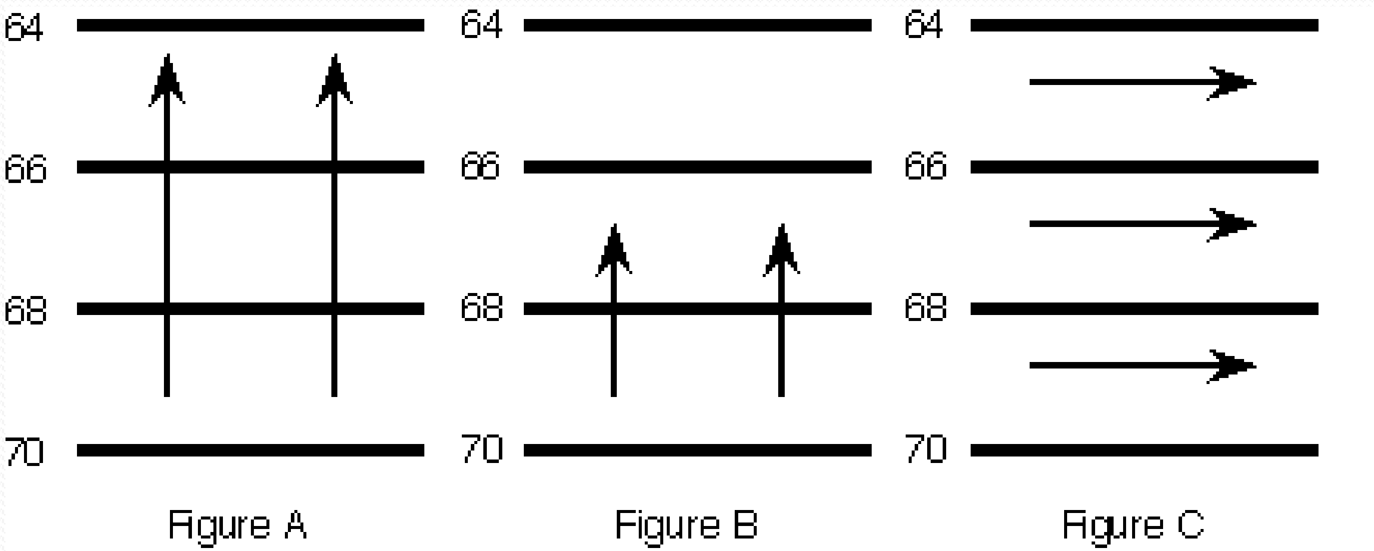
Upper air trough



Advection

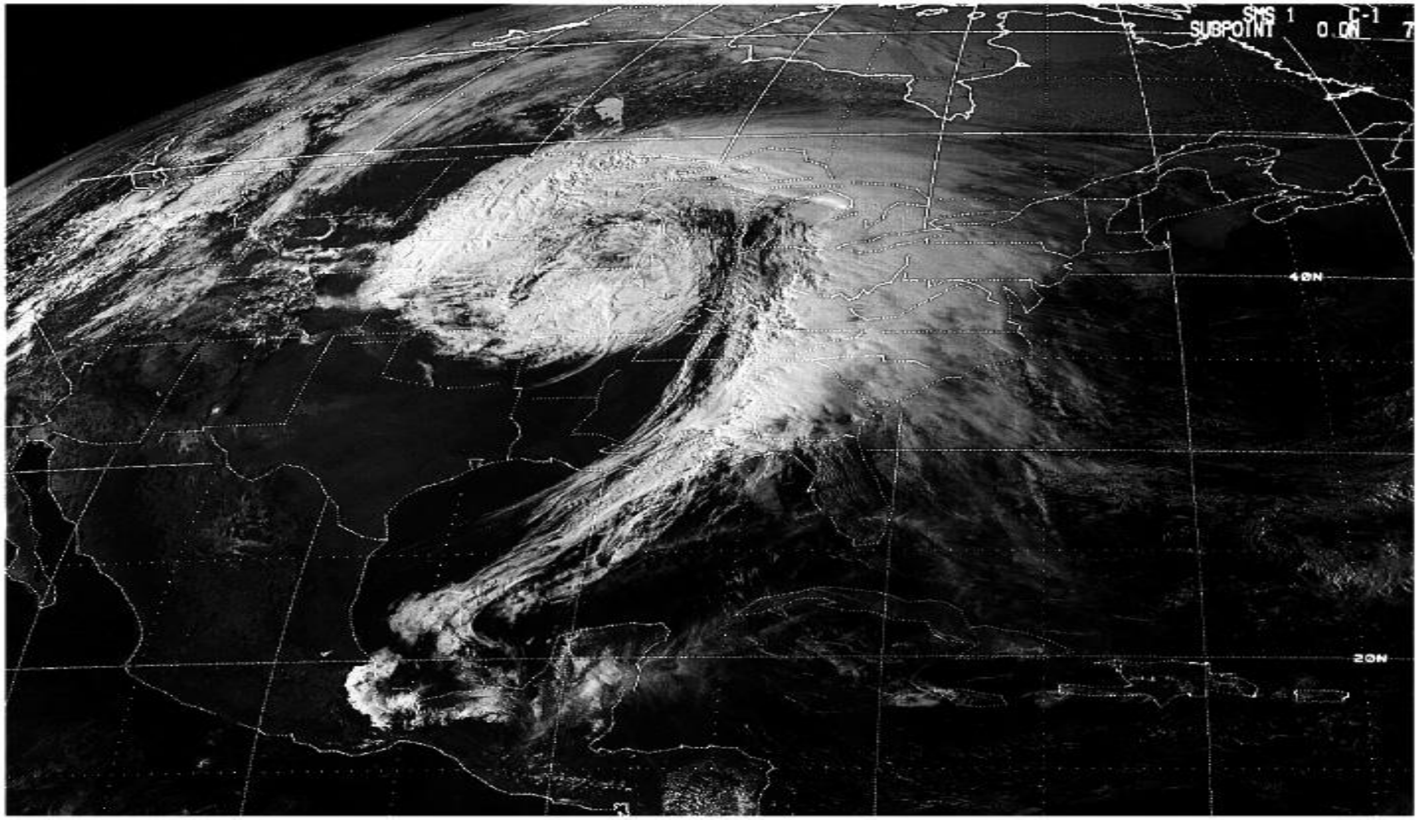
The term advection refers to the transport of something from one region to another. Meteorologists are most interested in the advection of variables like temperature, and moisture .

- The arrows are wind vectors and the horizontal lines are isotherms (lines of constant temperature) in degrees Fahrenheit. Maximum advection when winds perpendicular to line, and zero advection when parallel



(Temperature is Fahrenheit)

Fronts



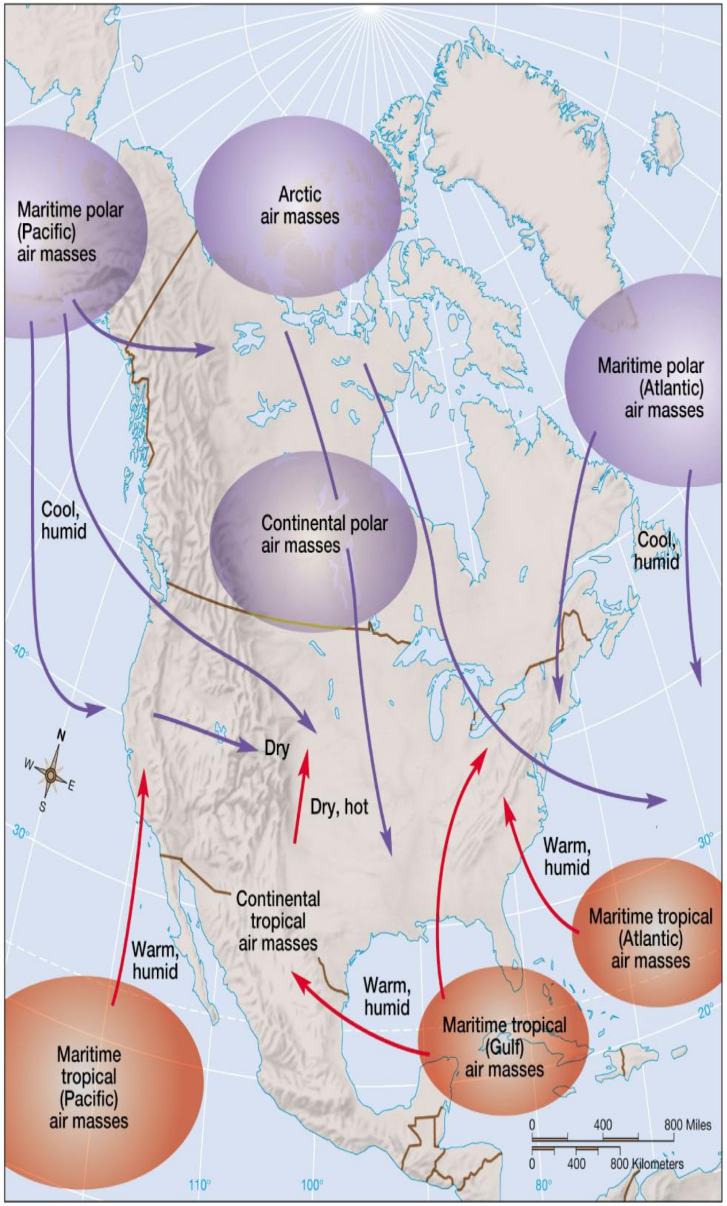
Air Masses

Very large bodies of air with fairly uniform temp and humidity characteristics

Form in high and low latitudes, not mid-latitudes

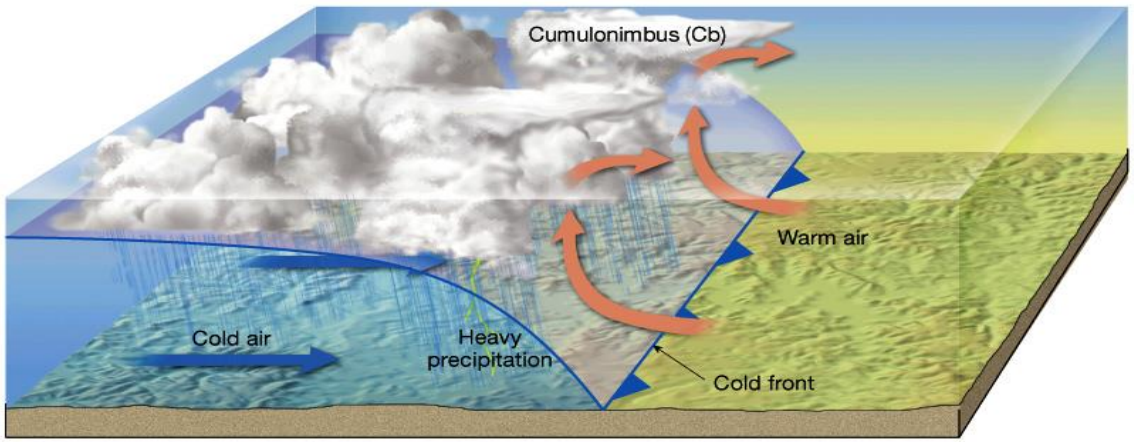
Air takes on the characteristics of the *source region*

Air masses migrate from their source regions, bringing changes in weather to other places



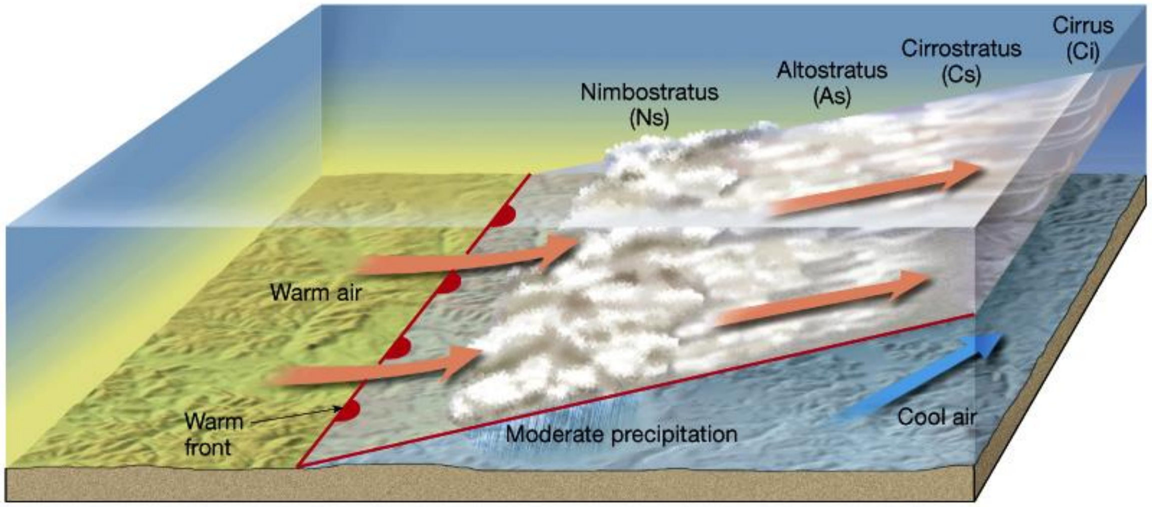
Cold Front

- Cooler air displacing warmer air
- Fastest moving of fronts
- Steep frontal surface marked by cumuliform clouds
- Can produce short-lived heavy precip, t-storms

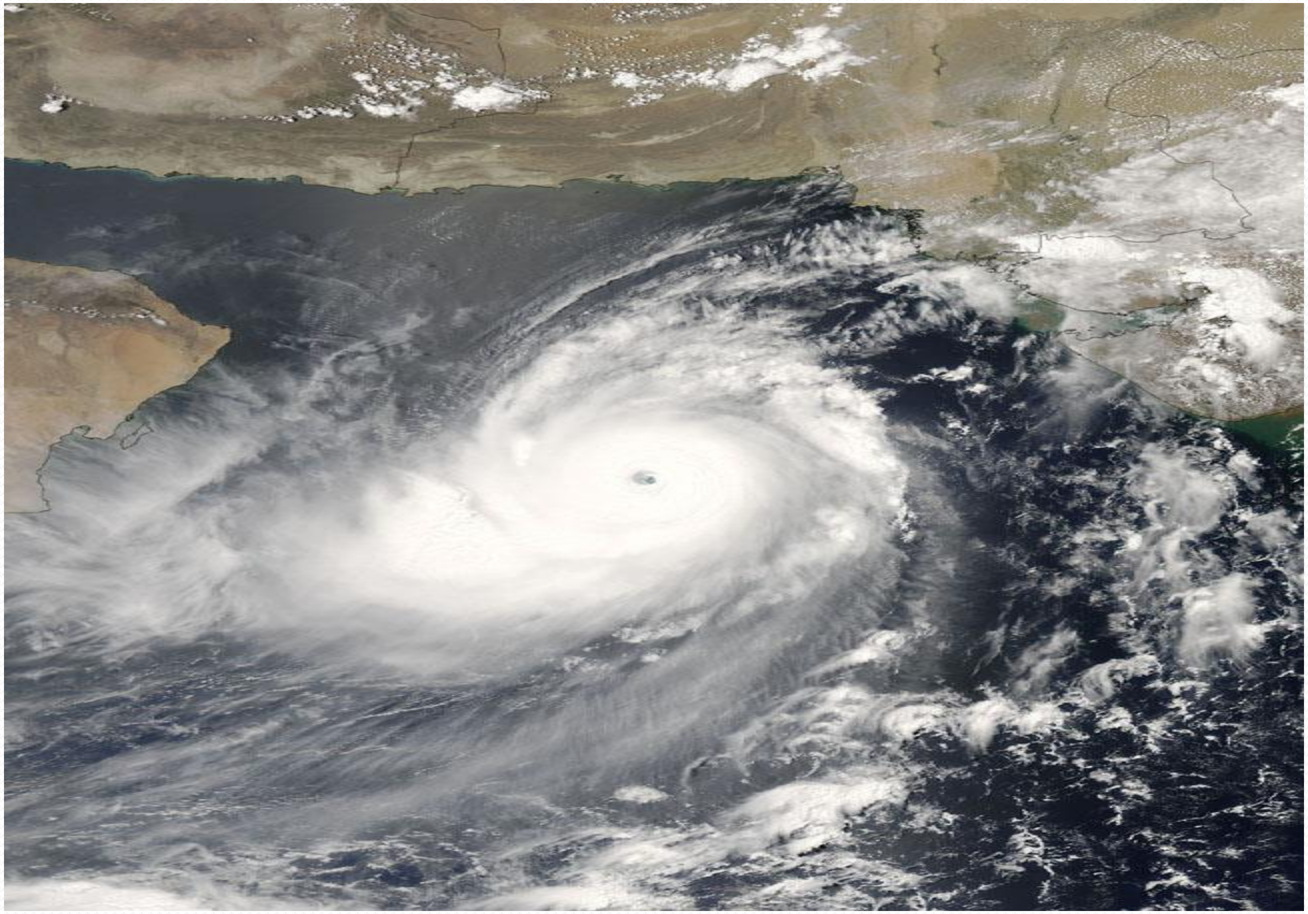


Warm Front

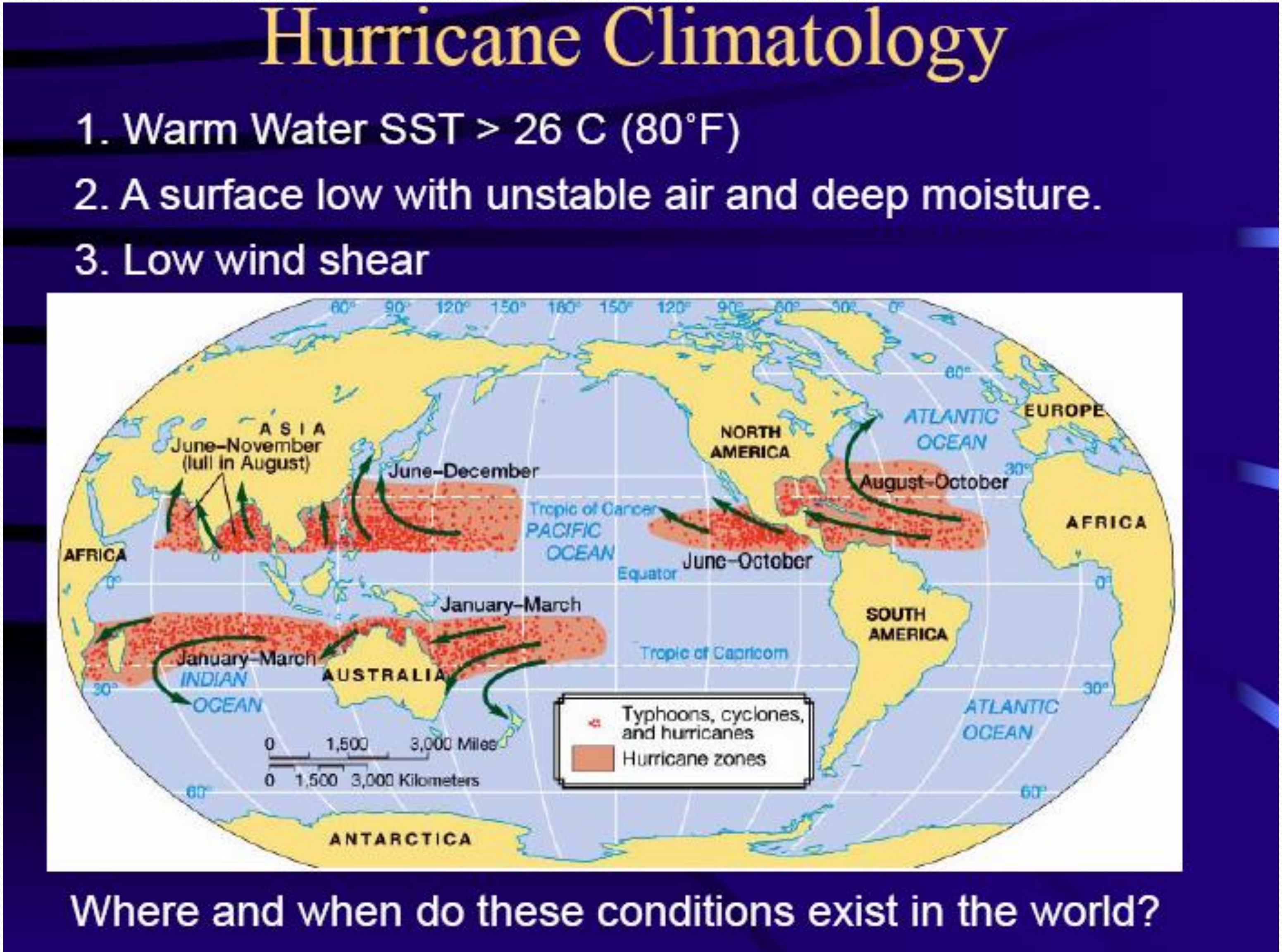
- Warmer air displacing cooler air
- Move slower than cold fronts
- Gently sloping surface marked by stratus-type clouds
- Can produce extended periods of precip



Tropical cyclone

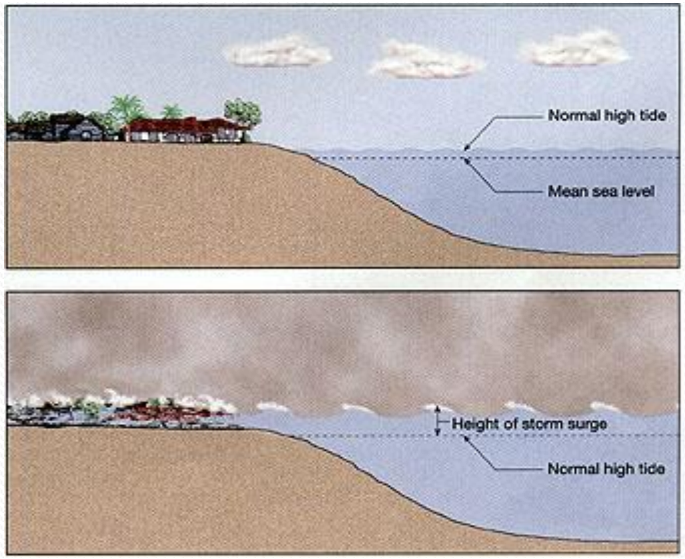


Tropical cyclone oman



Weather associated with tropical cyclone

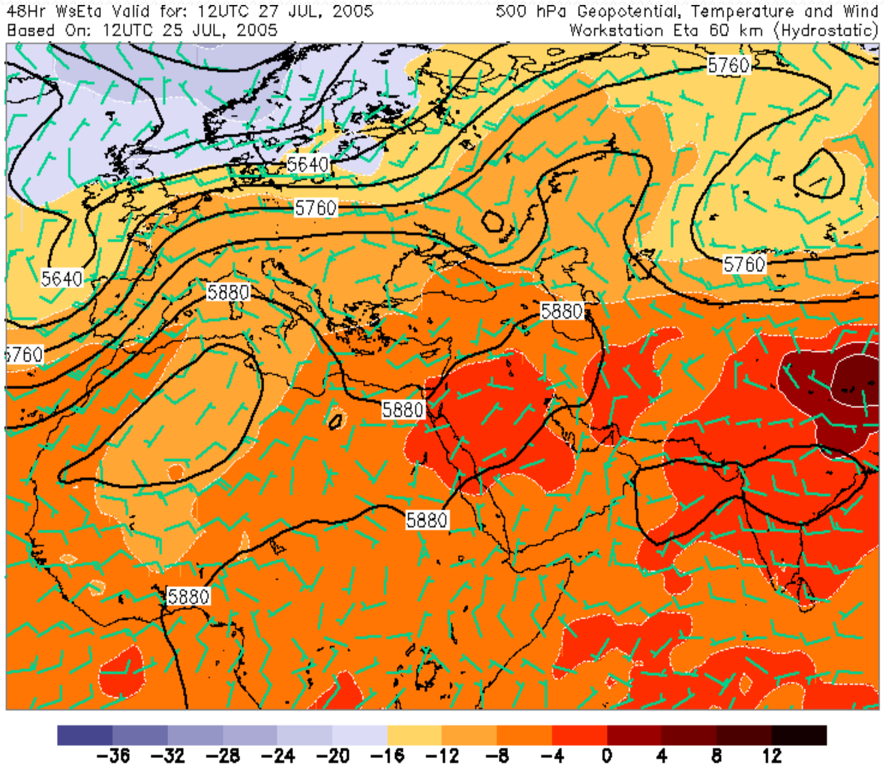
- Floods
- Strong wind
- Storm surge

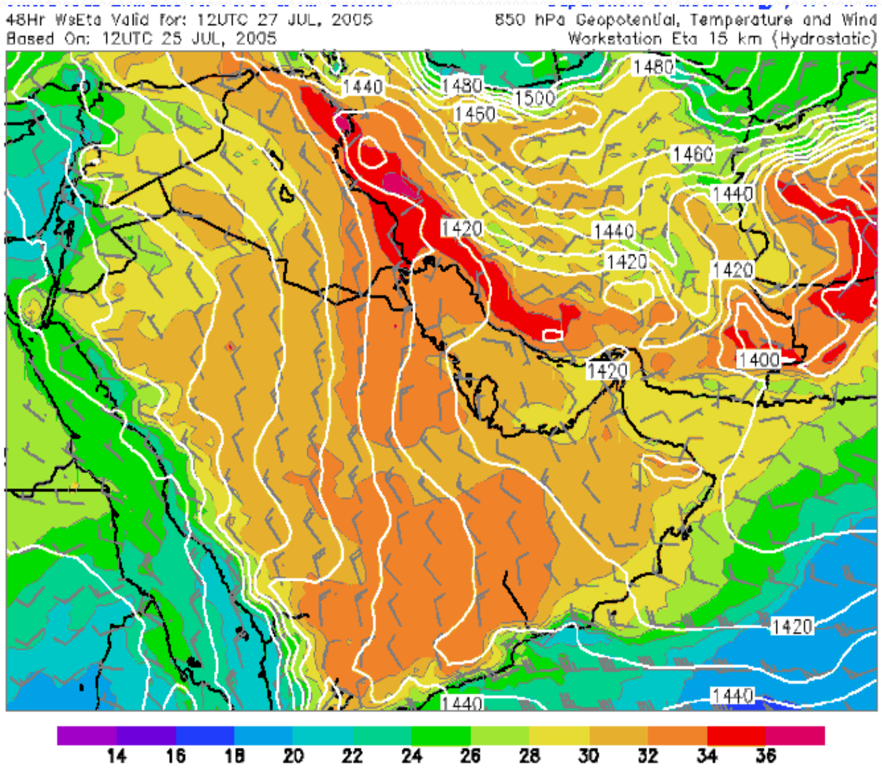


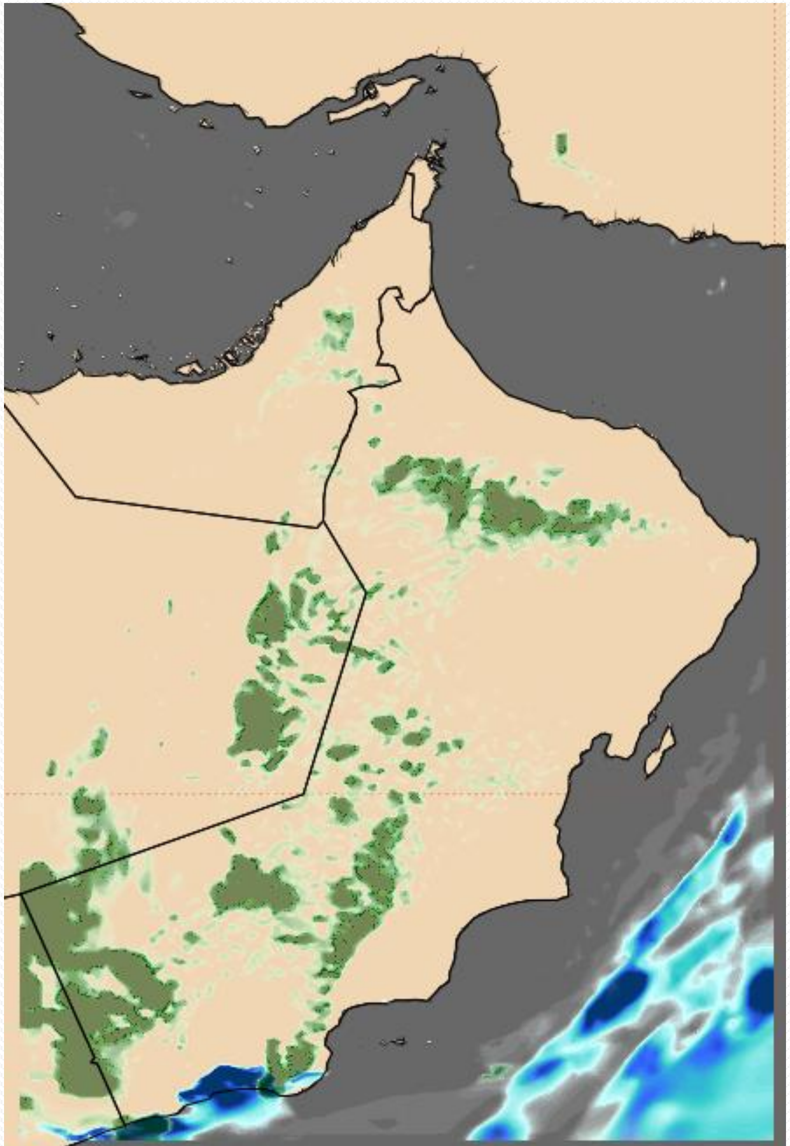
Numerical Weather Prediction
The modern way to forecast the weather

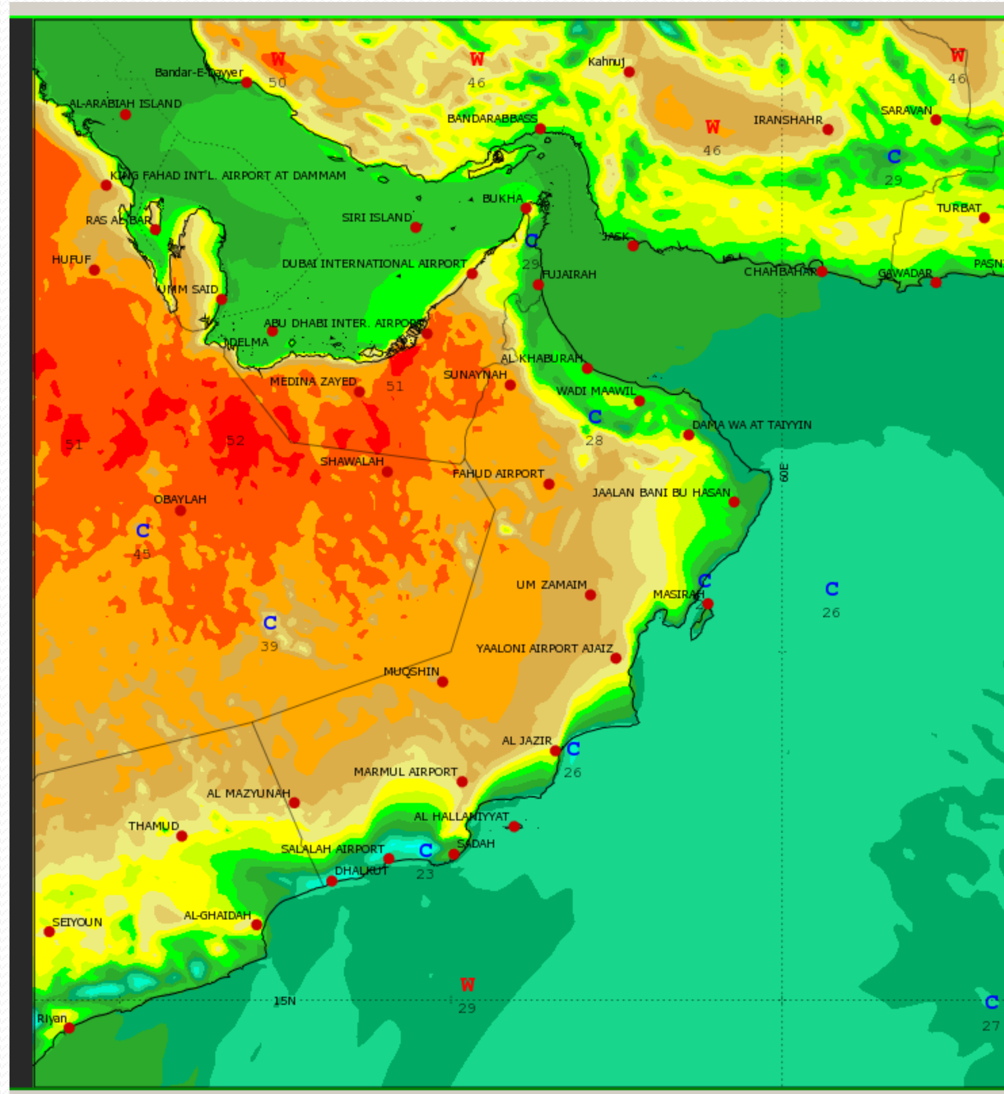
General Concepts

NWP model Products



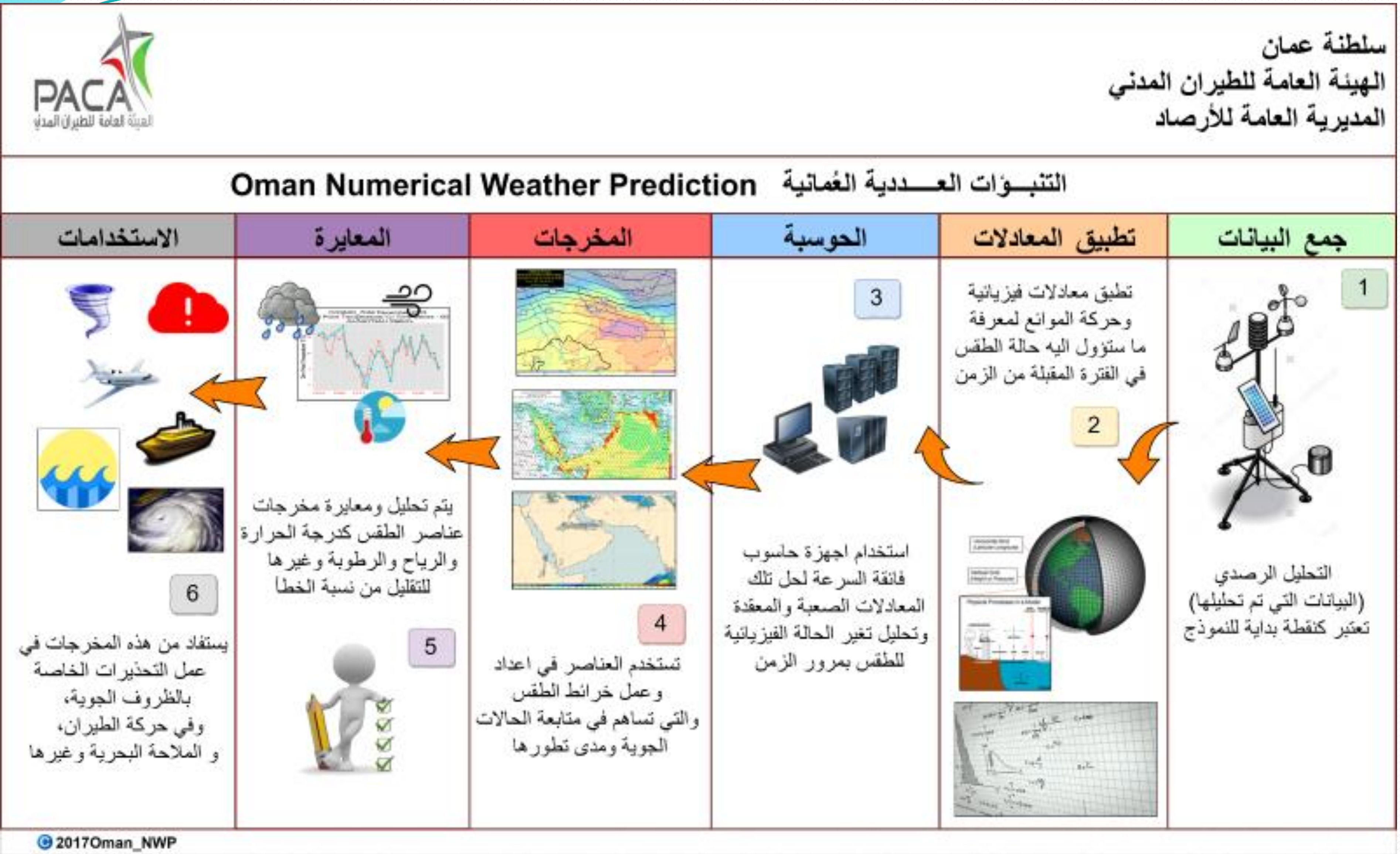





Bandar-E-Dayyer
W 50
W 46
Kahnuj
W 46
AL-ARABIAH ISLAND
BANDARABBASS
IRANSHAHR
SARAVAN
C 29
KING FAHAD INT'L. AIRPORT AT DAMMAM
BUKHA
TURBAT
RAS AL BAR
SIRI ISLAND
JASK
HUFUF
DUBAI INTERNATIONAL AIRPORT
FUJAIRAH
CHAHBAHAR
GAWADAR
PASNI
UMM SAID
ABU DHABI INTER. AIRPORT
DELMA
AL KHABURAH
MEDINA ZAYED
51
SUNAYNAH
WADI MAAWIL
C 28
DAMA WA AT TAIYYIN
52
SHAWALAH
FAHUD AIRPORT
JAALAN BANI BU HASAN
60E
OBAYLAH
C 45
UM ZAMAIM
MASIRAH
C 26
C 39
YAALONI AIRPORT AJAIZ
MUQSHIN
AL JAZIR
C 26
MARMUL AIRPORT
AL MAZYUNAH
AL HALLANIYYAT
THAMUD
SALALAH AIRPORT
SADAH
C 23
DHALKUT
SEIYOUN
AL-GHAIDAH
W 29
15N
Riyan
C 27

What is NWP Model?

- **Take the equations that describe atmospheric processes.**
- **Convert them to a form where they can be programmed into a large computer.**
- **Let the computer to solve them**
- **This is called a “model” of the atmosphere**


سلطنة عمان
الهيئة العامة للطيران المدني
المديرية العامة للأرصاد
PACA
الهيئة العامة للطيران المدني
Oman Numerical Weather Prediction التنبـــؤات العـــددية العُمانية
جمع البيانات
تطبيق المعادلات
الحوسبة
المخرجات
المعايرة
الاستخدامات
1
التحليل الرصدي
(البيانات التي تم تحليلها)
تعتبر كنقطة بداية للنموذج
تطبق معادلات فيزيائية
وحركة الموائع لمعرفة
ما ستؤول اليه حالة الطقس
في الفترة المقبلة من الزمن
2
3
استخدام اجهزة حاسوب
فائقة السرعة لحل تلك
المعادلات الصعبة والمعقدة
وتحليل تغير الحالة الفيزيائية
للطقس بمرور الزمن
4
تستخدم العناصر في اعداد
وعمل خرائط الطقس
والتي تساهم في متابعة الحالات
الجوية ومدى تطورها
يتم تحليل ومعايرة مخرجات
عناصر الطقس كدرجة الحرارة
والرياح والرطوبة وغيرها
للتقليل من نسبة الخطأ
5
6
يستفاد من هذه المخرجات في
عمل التحذيرات الخاصة
بالظروف الجوية،
وفي حركة الطيران،
و الملاحة البحرية وغيرها
© 2017Oman_NWP

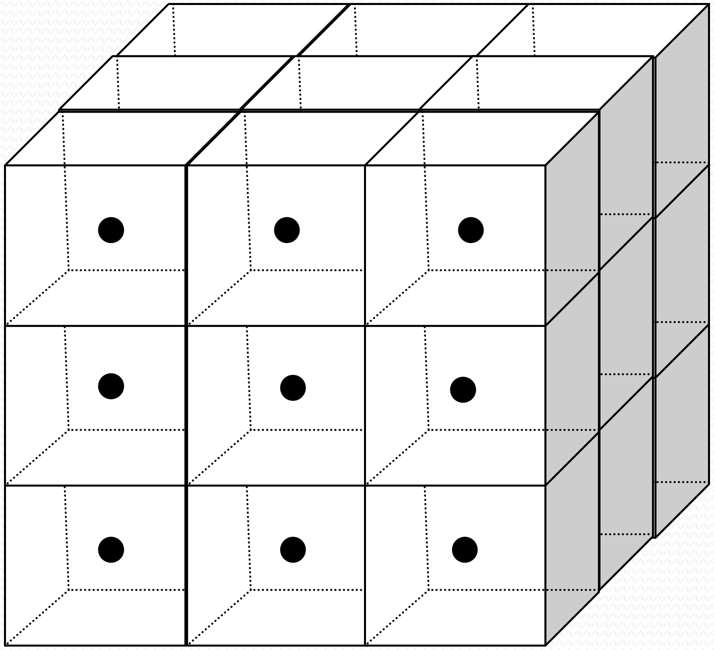
What do we mean by "solve the equations"

- **The equations describe how the atmosphere changes with time.**
- **For example, one equation would be**

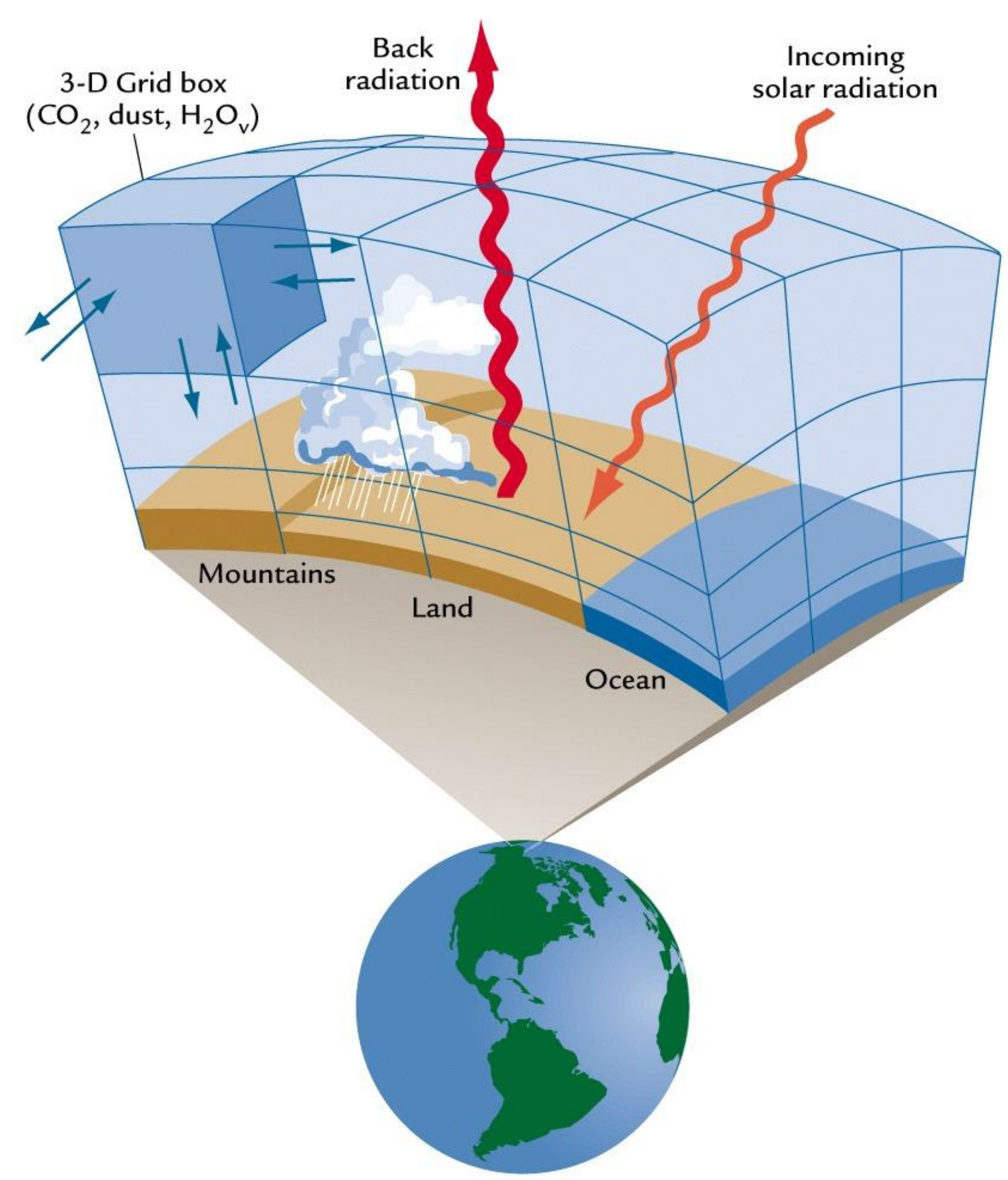
$$\frac{T\,Change}{Time} = Solar + Condensation + Convection$$
$$+ Evaporation + Advection + \ldots\ldots$$

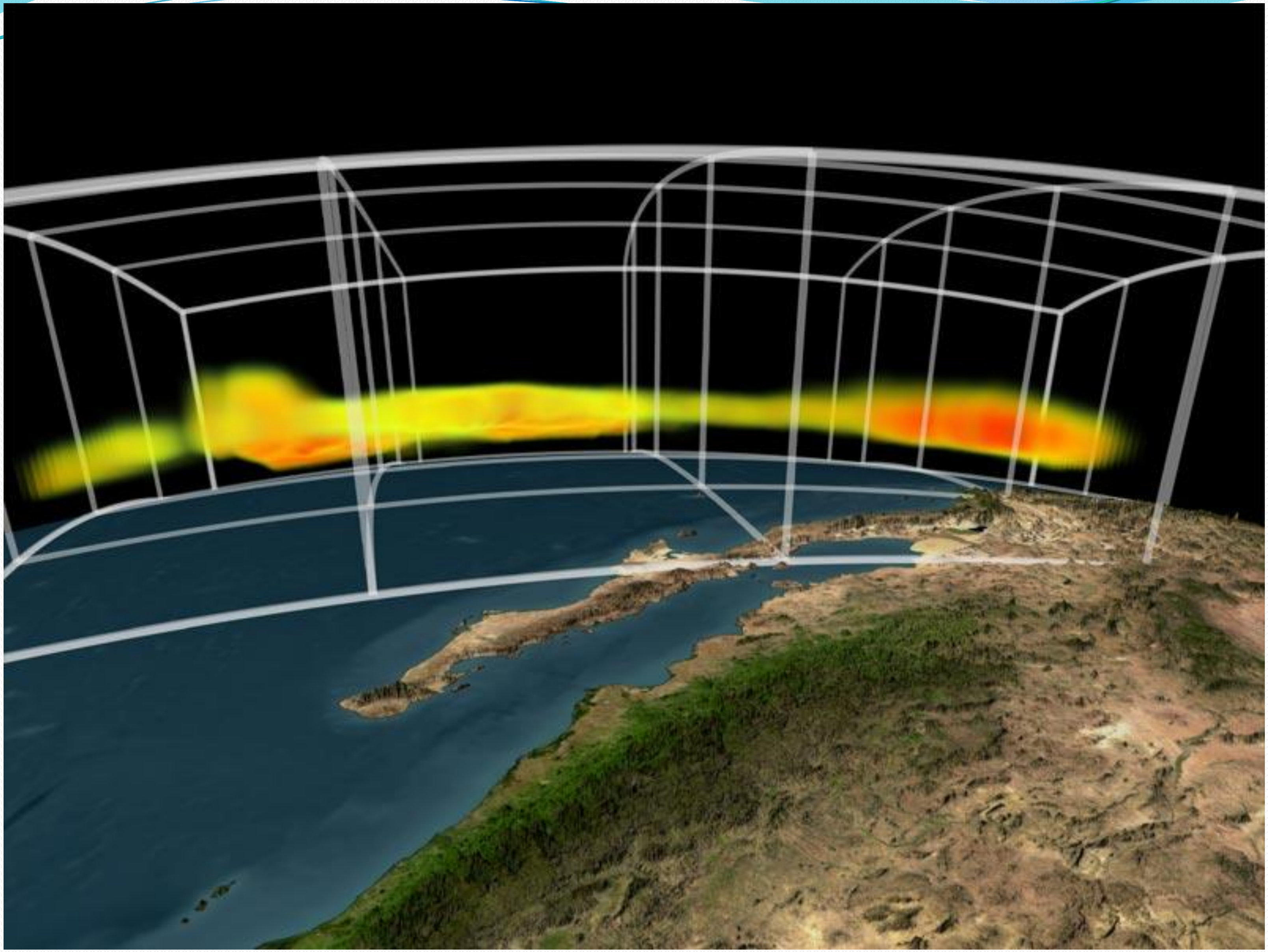
NWP Concept: General overview

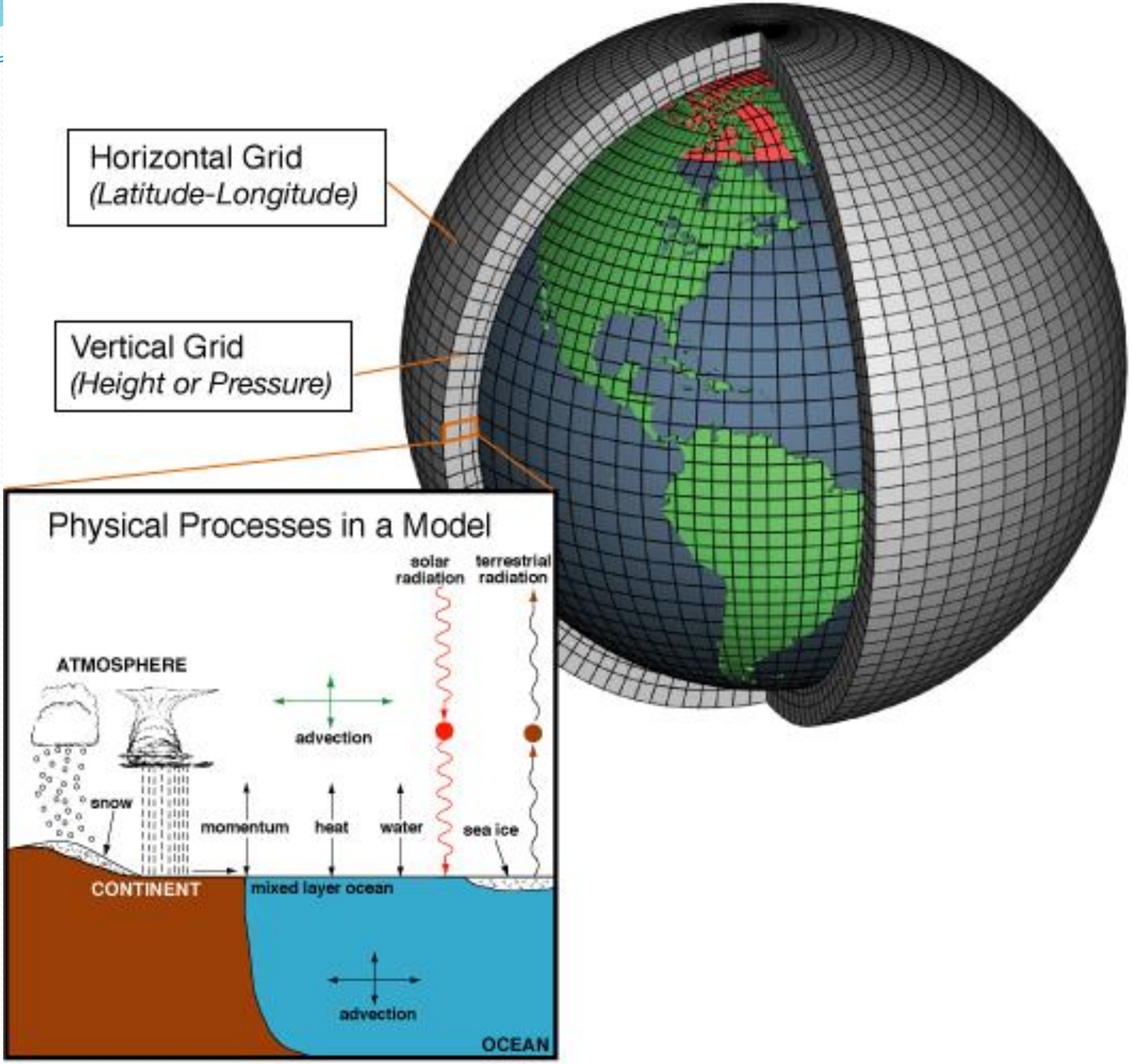
- **NWP consists in :**
  - **Subdividing a chosen geographic 3D area in thousands (or millions) of little cubes.**

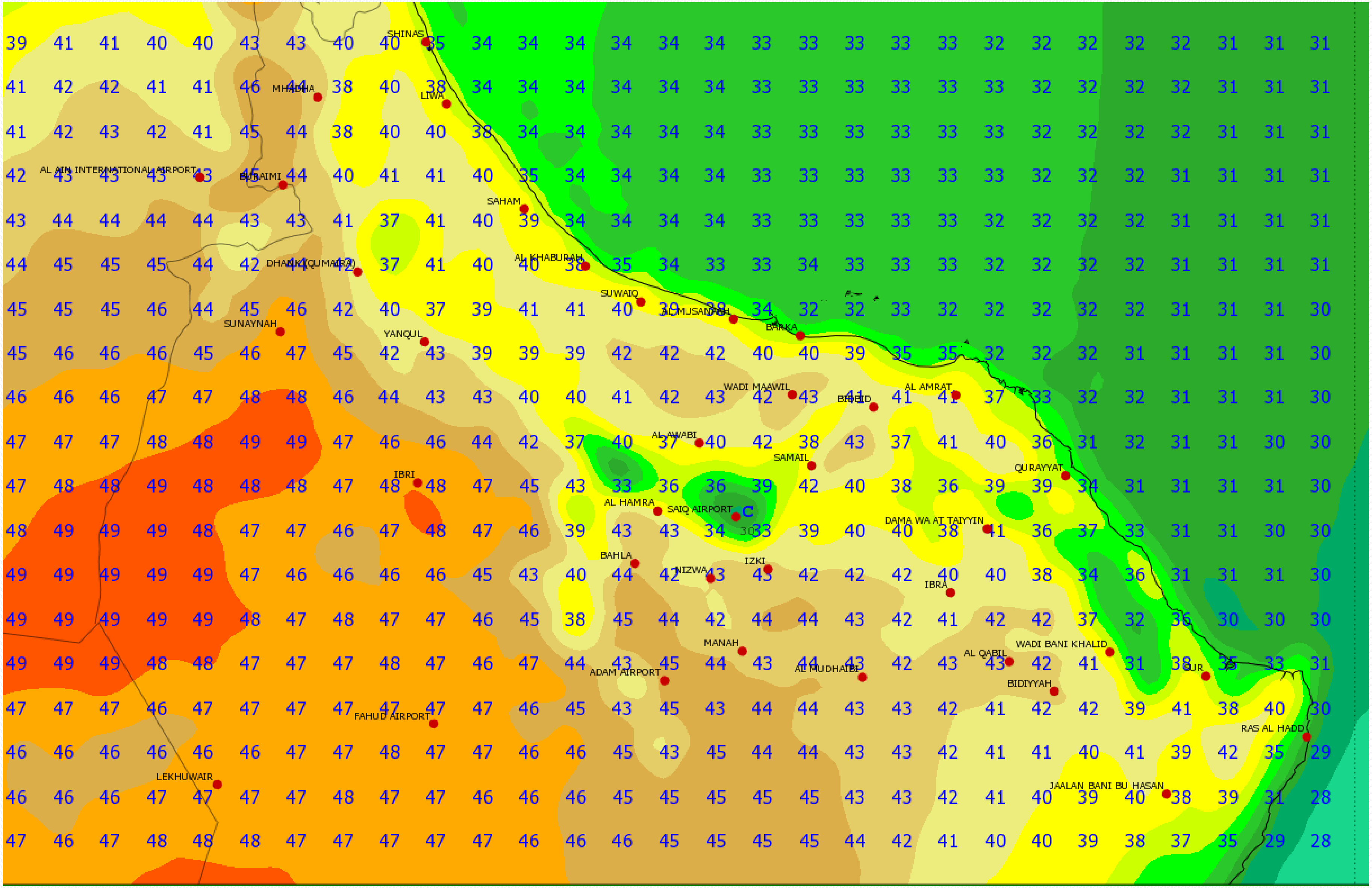


3D cubes of the atmosphere used by NWP models


Back radiation
Incoming solar radiation
3-D Grid box (CO_2, dust, H_2O_v)
Mountains
Land
Ocean




Horizontal Grid
(Latitude-Longitude)
Vertical Grid
(Height or Pressure)
Physical Processes in a Model
solar radiation
terrestrial radiation
ATMOSPHERE
advection
snow
momentum
heat
water
sea ice
CONTINENT
mixed layer ocean
advection
OCEAN


SHINAS
MAHDHA
LIWA
AL AIN INTERNATIONAL AIRPORT
BURAIMI
SAHAM
AL KHABURAH
SUWAIQ
AL MUSANAAH
BARKA
SUNAYNAH
YANQUL
WADI MAAWIL
BIDBID
AL AMRAT
AL AWABI
SAMAIL
QURAYYAT
IBRI
AL HAMRA
SAIQ AIRPORT
DAMA WA AT TAIYYIN
BAHLA
NIZWA
IZKI
IBRA
MANAH
WADI BANI KHALID
AL QABIL
ADAM AIRPORT
AL MUDHAIBI
SUR
BIDIYYAH
FAHUD AIRPORT
RAS AL HADD
LEKHUWAIR
JAALAN BANI BU HASAN

NWP

Zonal wind u

$$\frac{\partial u}{\partial t} - (\varsigma + f)v + \dot{\eta}\frac{\partial u}{\partial \eta} = -\frac{1}{a\cos\varphi}\frac{\partial}{\partial \lambda}(\Phi + K) - \frac{RT_v}{a\cos\varphi}\frac{\partial}{\partial \lambda}(\ln p) + \left(\frac{\partial u}{\partial t}\right)_{sub} - K_4\nabla^4 u - \mu_{\mathrm{lbc}}(u - u_{lbc})$$

Meridional wind v

$$\frac{\partial v}{\partial t} + (\varsigma + f)u + \dot{\eta}\frac{\partial v}{\partial \eta} = -\frac{1}{a}\frac{\partial}{\partial \varphi}(\Phi + K) - \frac{RT_v}{a}\frac{\partial}{\partial \varphi}(\ln p) + \left(\frac{\partial v}{\partial t}\right)_{sub} - K_4\nabla^4 v - \mu_{lbc}(v - v_{lbc})$$

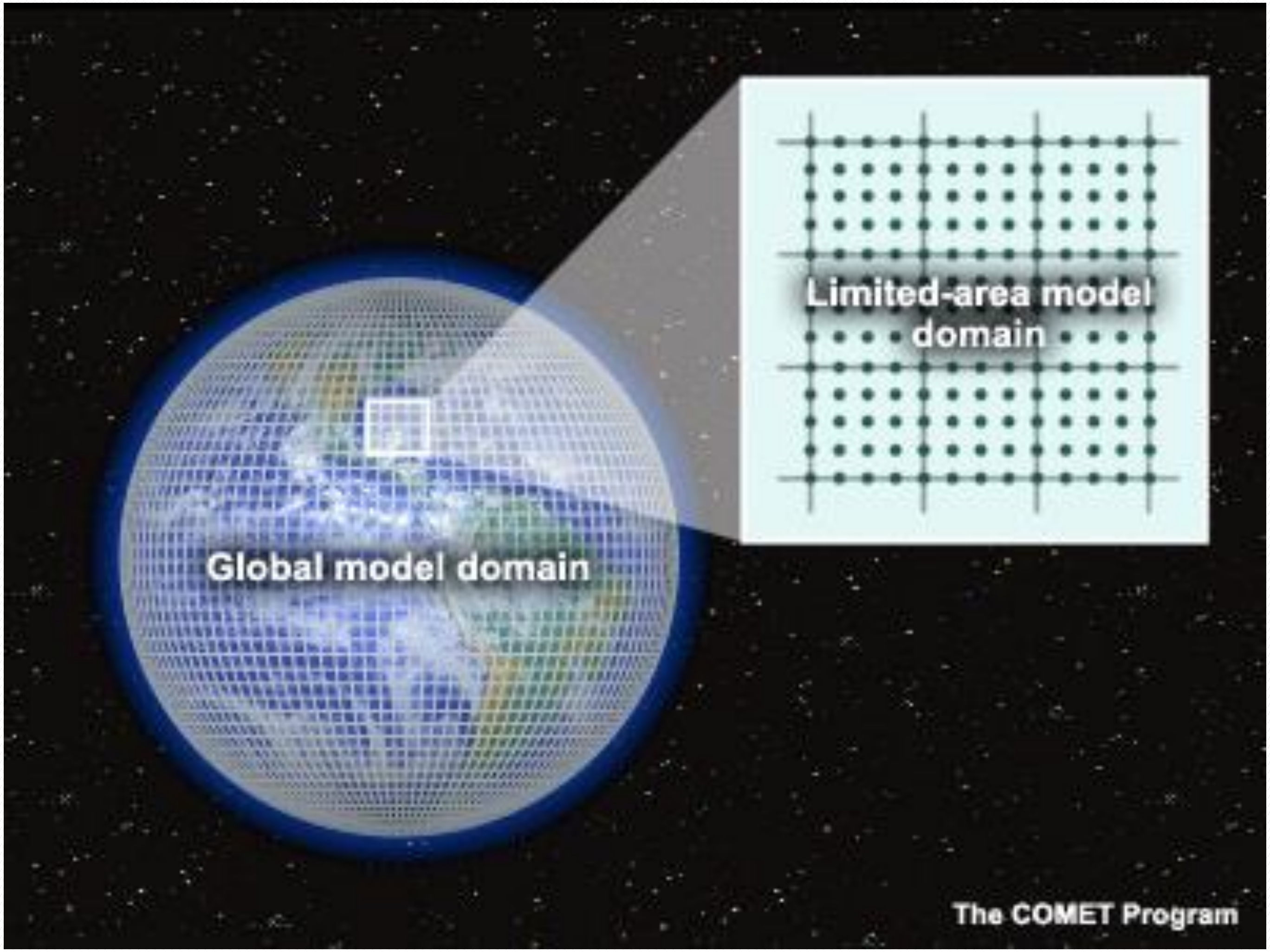
Temperature T

$$\frac{\partial T}{\partial t} + \frac{1}{a\cos\varphi}\left(u\frac{\partial T}{\partial \lambda} + v\cos\varphi\frac{\partial T}{\partial \varphi}\right) + \dot{\eta}\frac{\partial T}{\partial \eta} = \frac{\alpha\omega}{c_p} + \frac{L_v}{c_p}C_{vc} + \left(\frac{\partial T}{\partial t}\right)_{sub} - K_4\nabla^4(T - T_{ref}) - \mu_{\mathrm{lbc}}(\mathrm{T} - \mathrm{T}_{\mathrm{lbc}})$$

Surface pressure p_s

$$\frac{\partial p_s}{\partial t} = -\frac{1}{a\cos\varphi}\int_0^1 \left\{\frac{\partial}{\partial \lambda}\left(u\frac{\partial p}{\partial \eta}\right) + \frac{\partial}{\partial \varphi}\left(v\cos\varphi\frac{\partial p}{\partial \eta}\right)\right\} d\eta - \mu_{\mathrm{lbc}}(p_s - p_{s,lbc})$$

NWP concepts : Global & LAM models.



NWP concepts : Global models

- **Global models resolve atmospheric equations on the whole glob.**
- **They can not use very fine resolution because of computers limitations.**
- **Because of their weak resolution, they can not detect small scale phenomena.**
- **The most popular global models are :**
  - **ECMWF/IFS (partially public and received on MDD) : http://www.ecmwf.int**
  - **NCEP/GFS (completely public) : http://www.ncep.noaa.gov.**
  - **Météo-France/ARPEGE (not available on the net).**
  - **German DWD global model.**
  - **METOFFICE/UKMO Unified Model.**
  - **Japan Meteorological Agency JMA Global Model.**

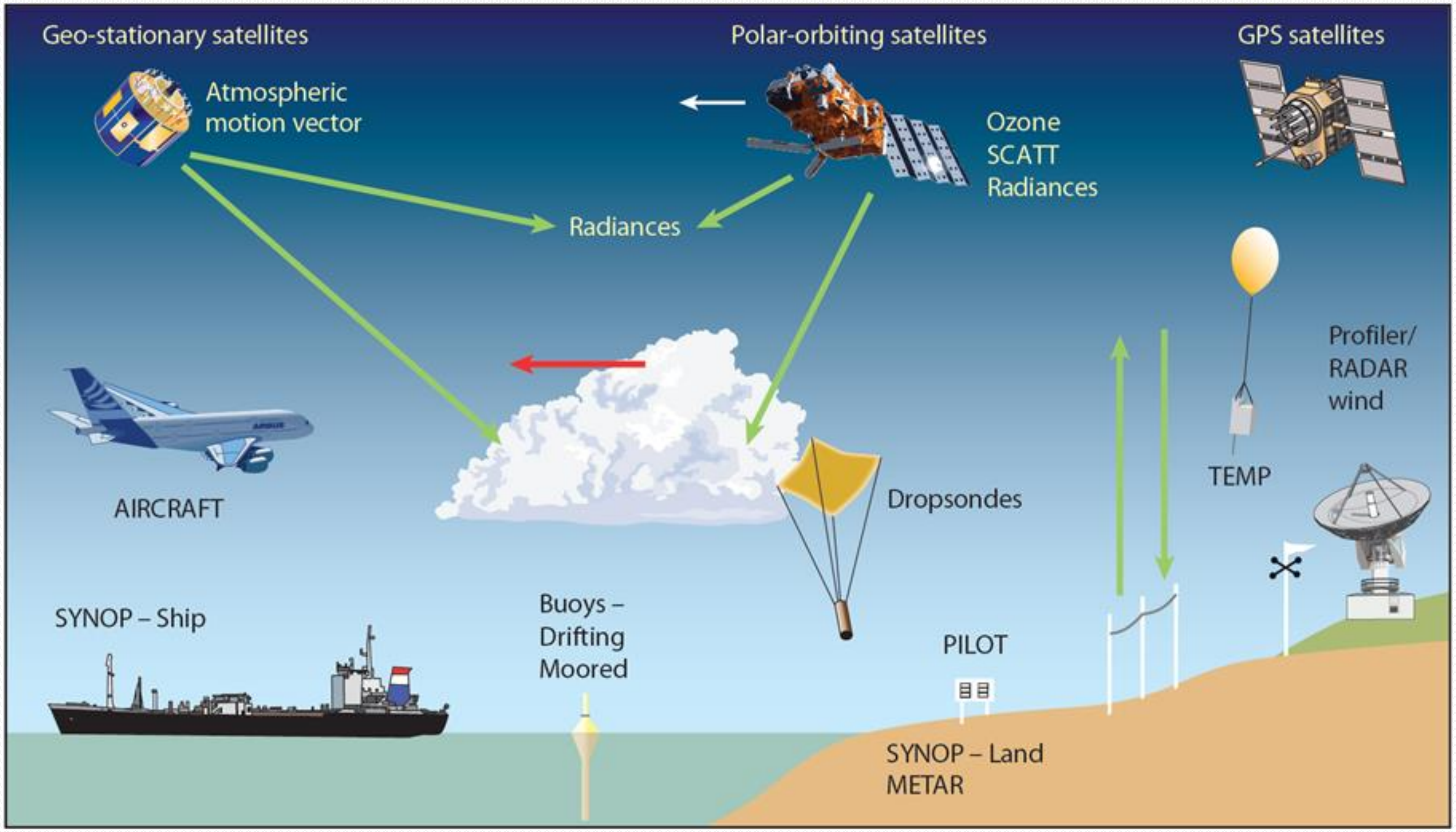
- **Global models are used to forecast general synoptic circulation and to provide Initial and Lateral Boundary Data for Limited Area models.**

NWP Concepts : Limited Area Models (LAM).

- **They are widely used by Weather Centers over the world.**
- **The most popular LAMs are:**
  - **HRM (used in more than 30 Centers and universities)**
  - **ETA (used in more than 50 Centers and Universities).**
  - **MM5 (AFWA and more than 20 centers over the world).**
  - **ALADIN (Private Consortium guided by Meteo-France : 15 European and north African countries)**
  - **COSMO / LM (COnsortium for Small scale MOdeling guided by DWD).**
  - **HIRLAM (Private Consortium : Scandinavian countries and Spain).**
  - **NMM / WRF (the next generation LAM model taking advantage from both ETA and MM5).**
  - **COAMPS, RAMS, RUC, …etc.**

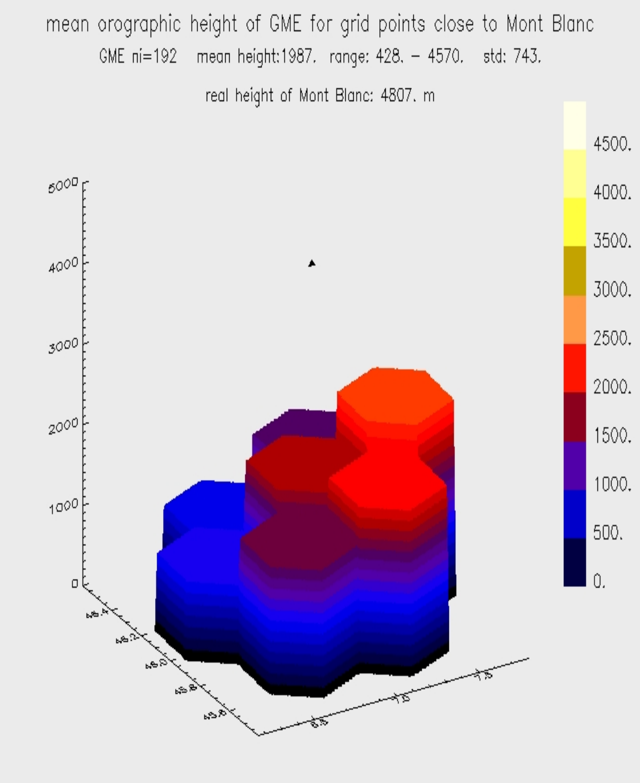
NWP Concepts : Initial Data.

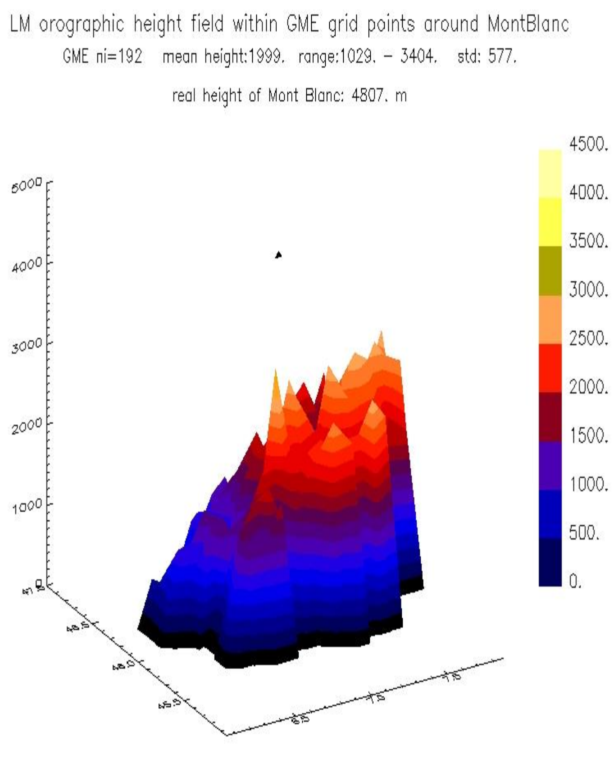
- The **actual situation** used by the model to start integrate equations.
- It is created by techniques called **data assimilation**.
- The information used to create initial data are:
  - **GTS data** (Conventional observations) : **SYNOP, SHIP, BUOY, SYNOR, TEMP, PILOT, AIREP, AMDAR, ACAR, SATEM, SATOB**).
- The process of initial data creation (analysis and data assimilation) is more **complicate** than the forecast model itself, and more **consumer in term of CPU time**.

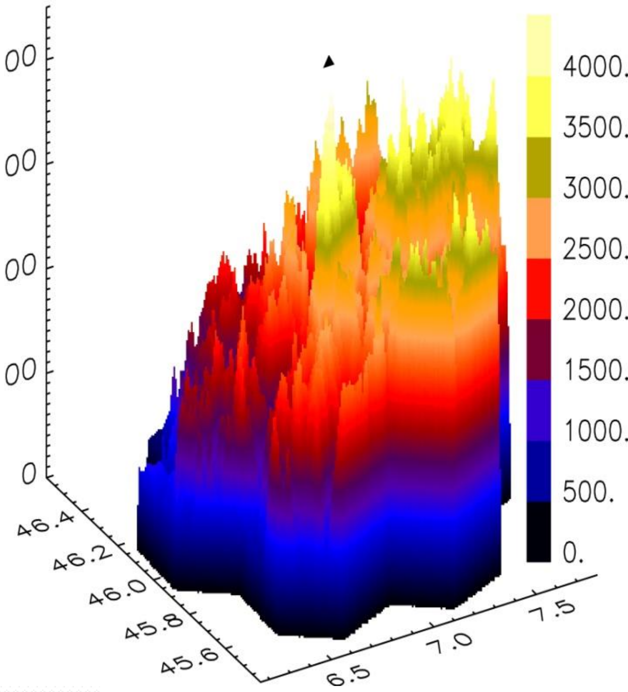


Geo-stationary satellites
Polar-orbiting satellites
GPS satellites
Atmospheric motion vector
Ozone
SCATT
Radiances
Radiances
Profiler/
RADAR
wind
AIRCRAFT
TEMP
Dropsondes
SYNOP – Ship
Buoys –
Drifting
Moored
PILOT
SYNOP – Land
METAR

Orography (m)





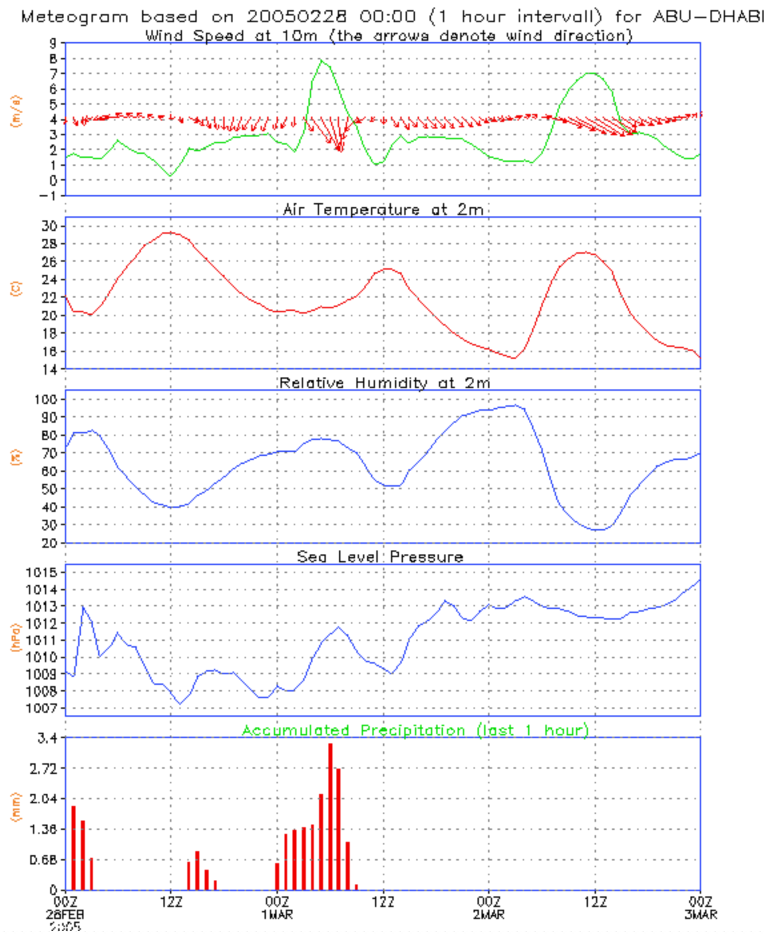


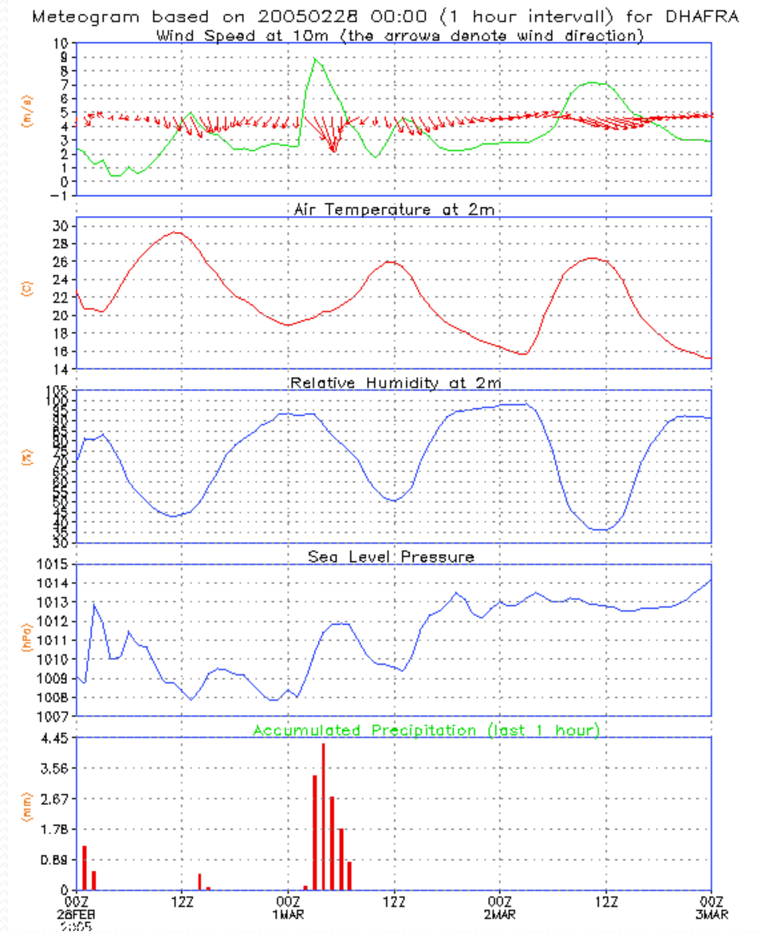
Aggregated to 40-km GME;
grid element area: 1384 km^2

Aggregated to 7-km HRM;
grid element area: 49 km^2

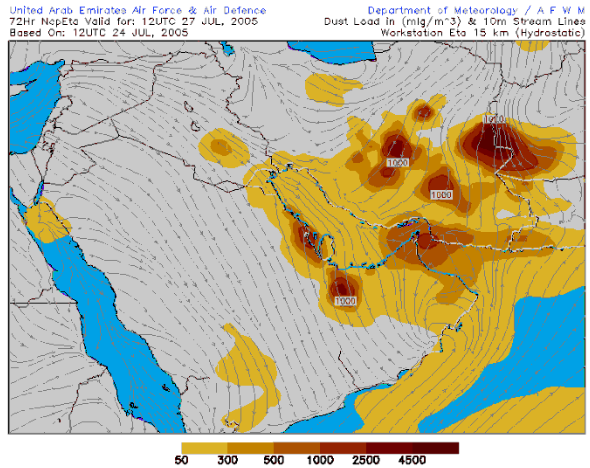
1 km x 1 km raw data

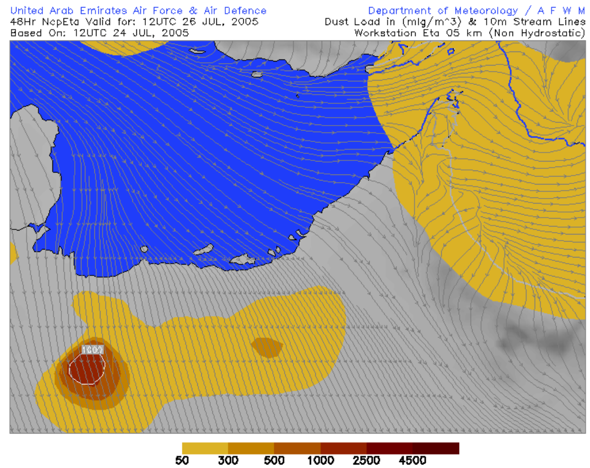
NWP Concepts : Meteograms

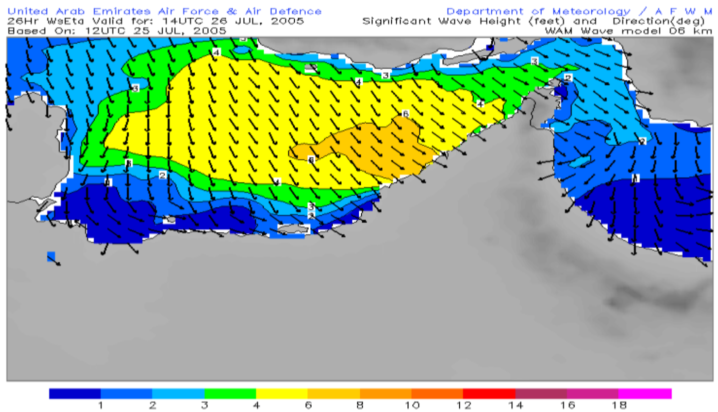


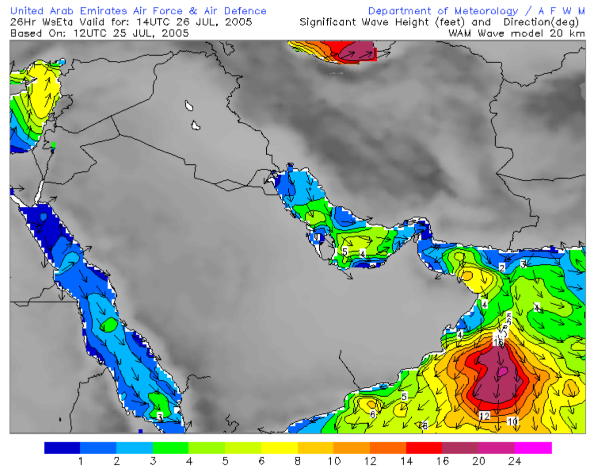


NWP Concepts: Off-line Driven Models.









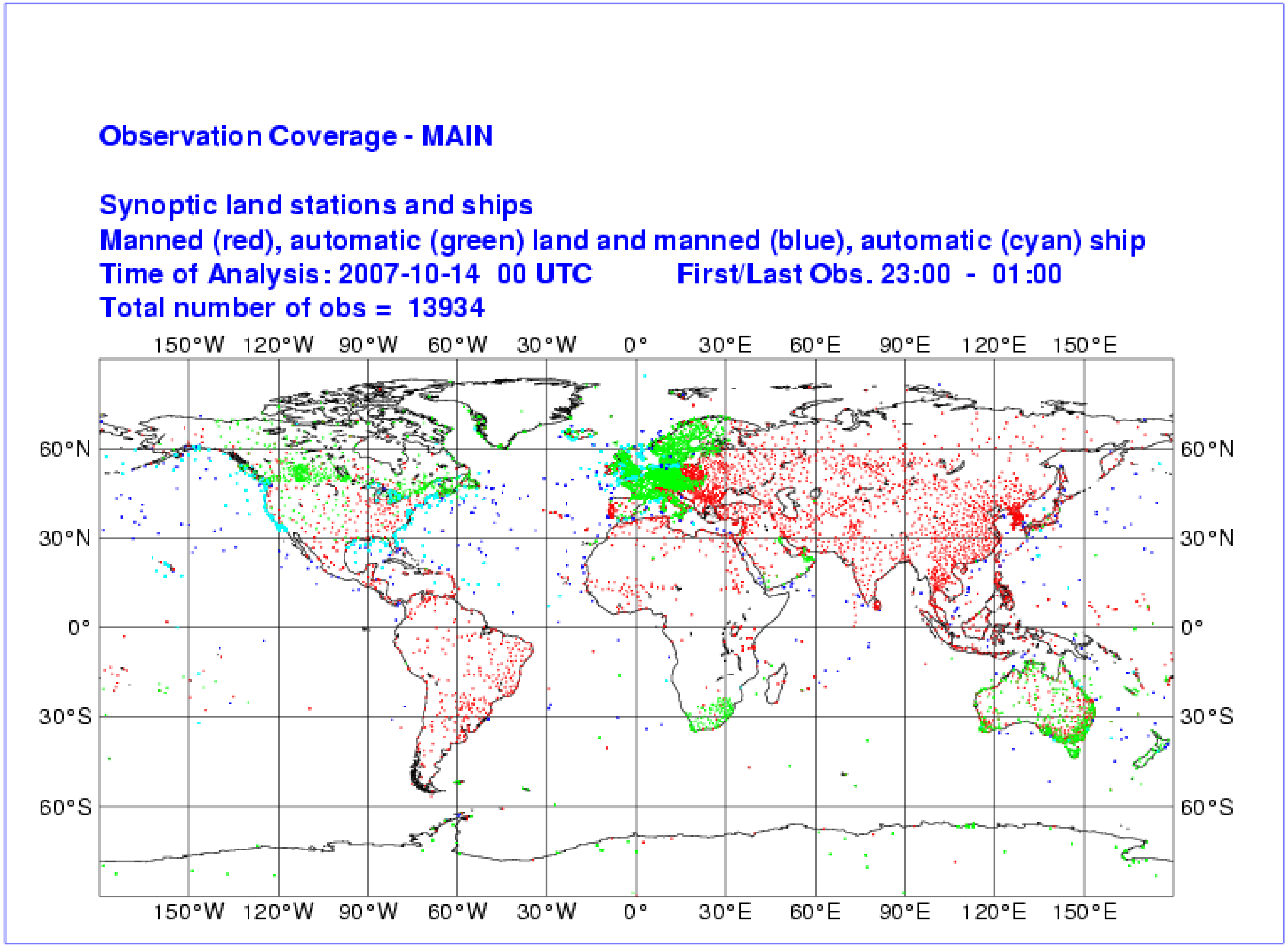
Guidance in Using NWP

1- Verify each of the models you are intended to use
2- Use different NWP sources, as many as you could
3- Remember the error margin when you do the forecast

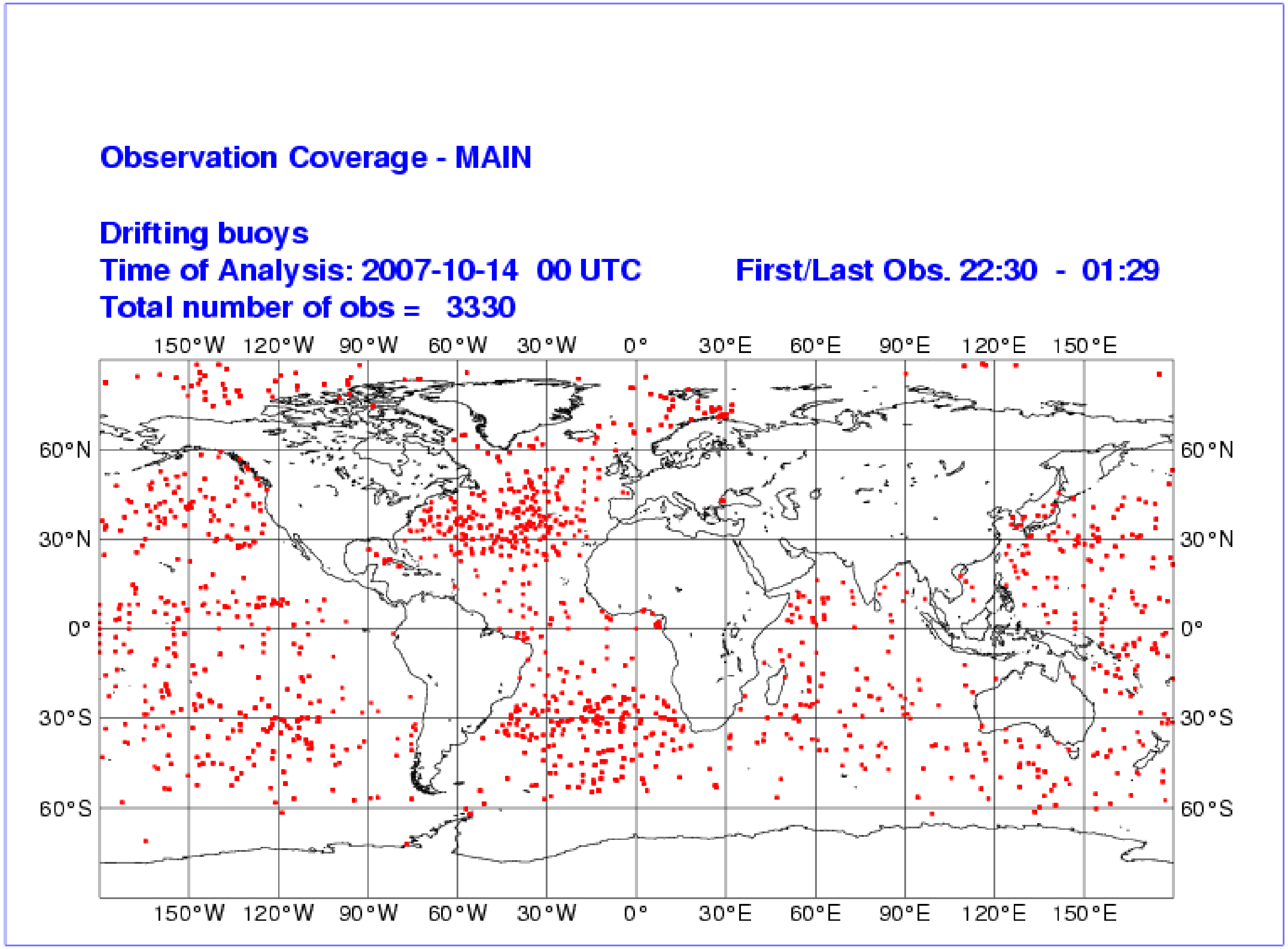
Errors of the NWP

- Due to model formulation.
- Due to uncertainty in the initial state.
- Due to errors in lateral boundary conditions.
- Due to uncertainties in soil fields (soil temperature and soil water content, …).

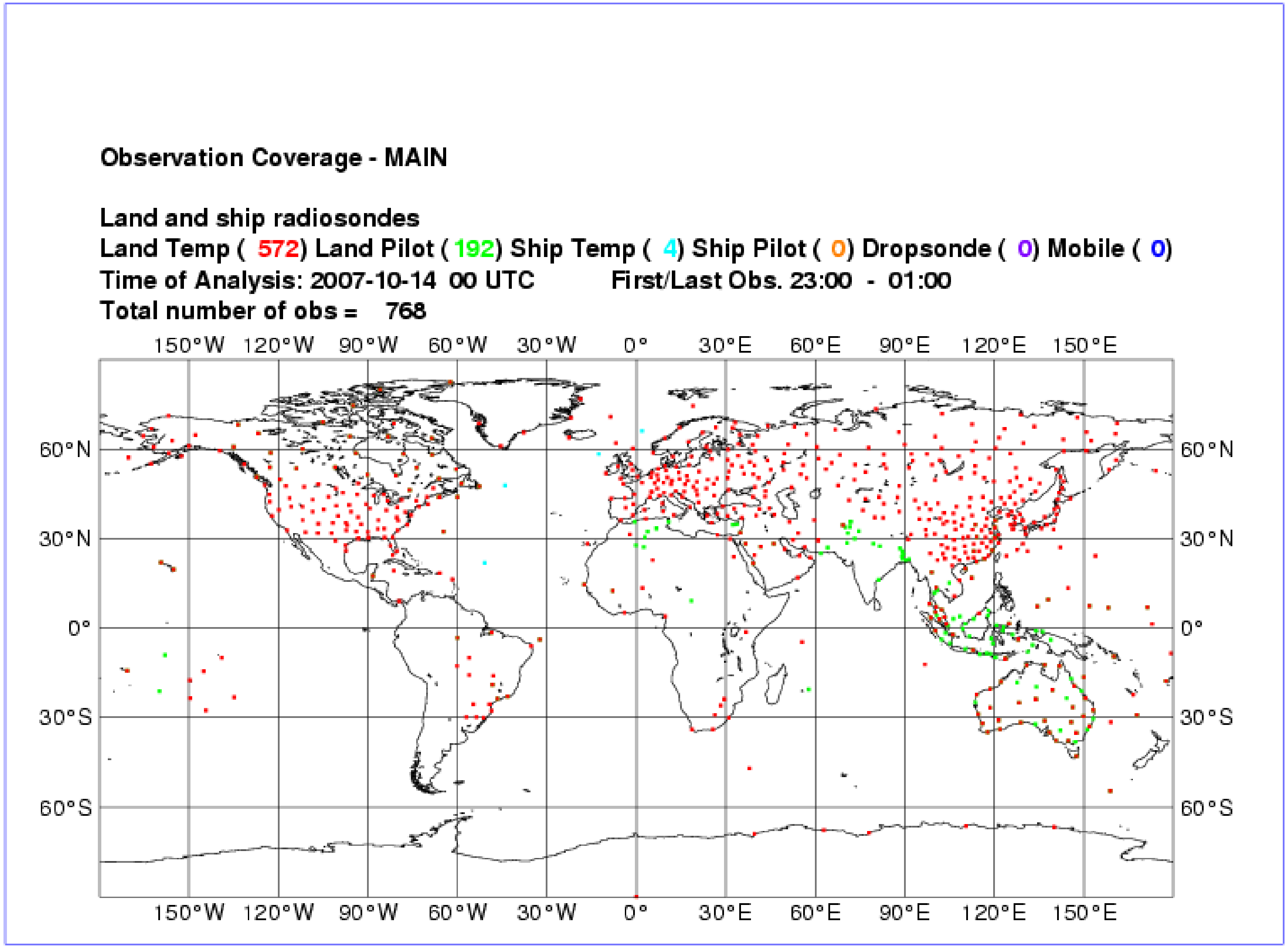
SYNOP stations and ships



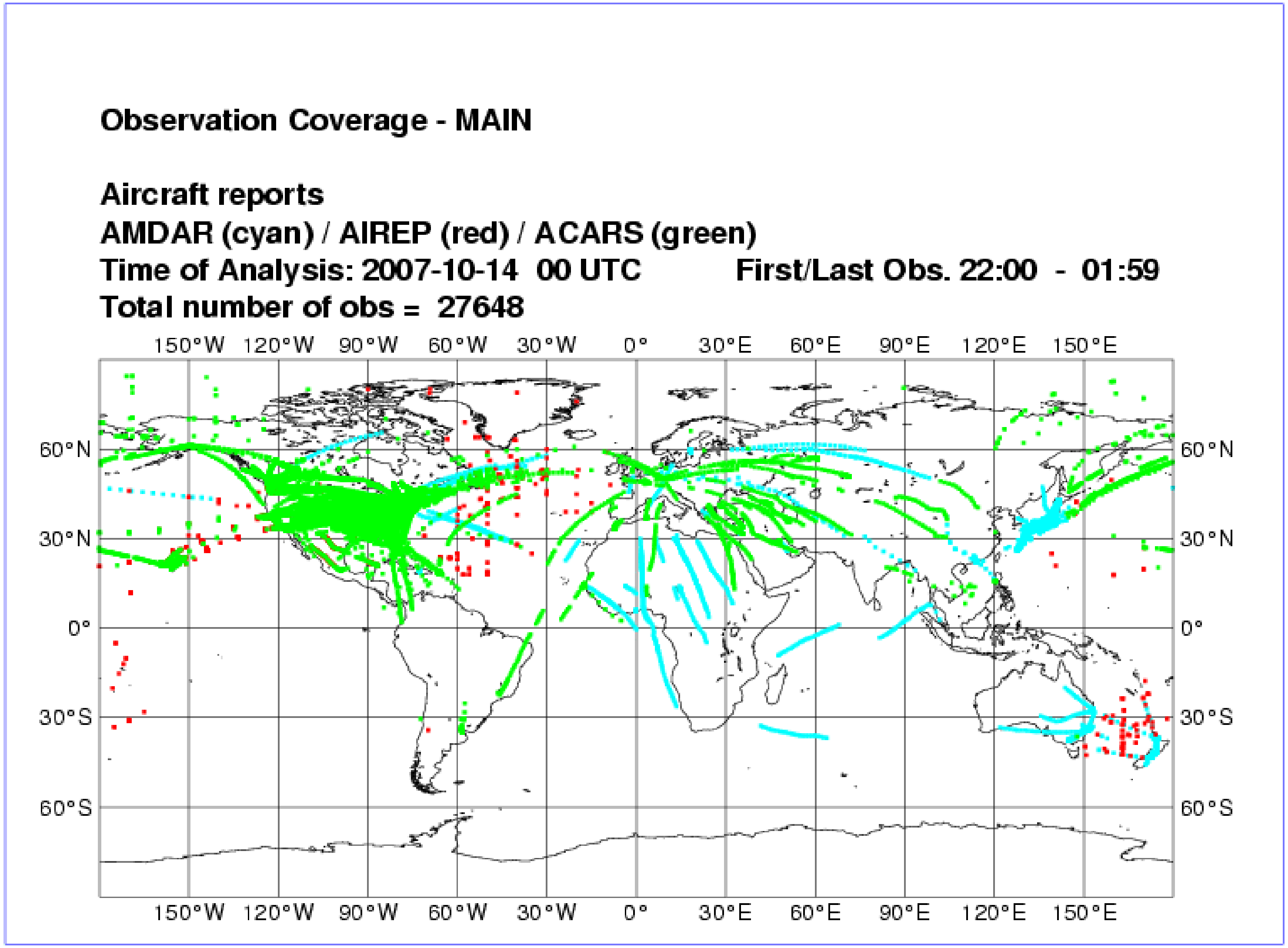
Buoys (moored and drifting)



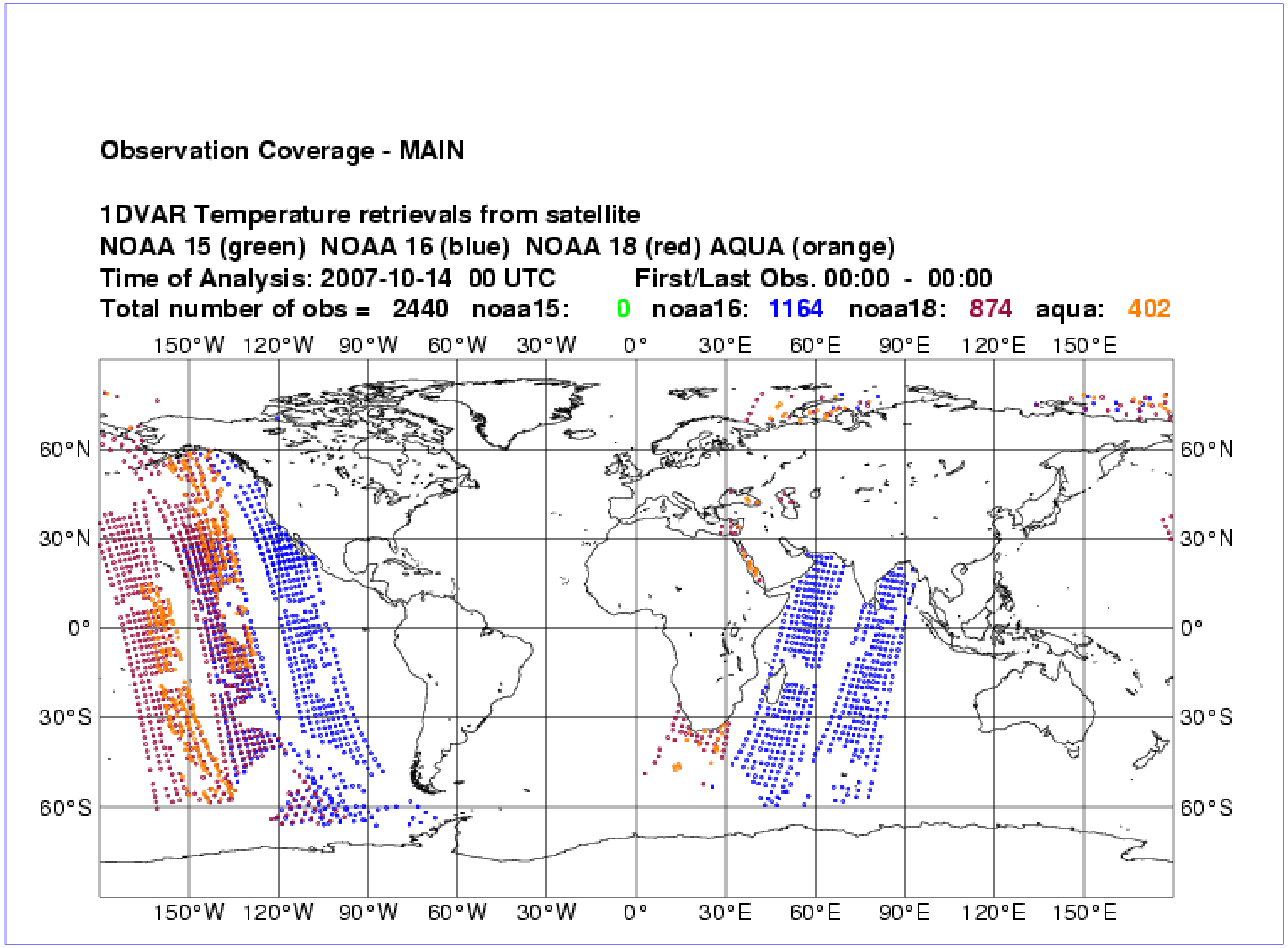
TEMP stations



Aircraft measurements (AMDAR)



ATOVS from polar orbiting satellites



"Primitive" Weather Forecasting Equations

$p = \rho R T$ *Ideal Gas Law* (Equation of State)

$$\vec{a}_h = \sum\left(\vec{F}_h / m\right)$$ *Newton's Second Law of Motion*

$\Delta p = -\rho g \Delta z$

$(PGA)_v = g$

$$\vec{a}_v = \sum(\vec{F}_v / m) = (\vec{P}\vec{G}\vec{A})_v - \vec{g}$$

Hydrostatic Law (Obtained from the Equation of Vertical Motion)

$\Delta T = \Delta q / c_p + (1/\rho)\Delta p$ *First Law of Thermodynamics*

$(1/\rho)\Delta\rho/\Delta t = -DIV$

Conservation of Mass Applied to the Atmosphere (Equation of Continuity)

Zonal wind:

$$\frac{\partial u}{\partial t} = \eta v - \frac{\partial \Phi}{\partial x} - c_p\theta\frac{\partial \pi}{\partial x} - z\frac{\partial u}{\partial \sigma} - \frac{\partial(\frac{u^2+v^2}{2})}{\partial x}$$

Meridional wind:

$$\frac{\partial v}{\partial t} = -\eta\frac{u}{v} - \frac{\partial \Phi}{\partial y} - c_p\theta\frac{\partial \pi}{\partial y} - z\frac{\partial v}{\partial \sigma} - \frac{\partial(\frac{u^2+v^2}{2})}{\partial y}$$

Temperature:

$$\frac{\delta T}{\partial t} = \frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z}$$

Precipitable water:

$$\frac{\delta W}{\partial t} = u\frac{\partial W}{\partial x} + v\frac{\partial W}{\partial y} + w\frac{\partial W}{\partial z}$$

Pressure thickness:

$$\frac{\partial}{\partial t}\frac{\partial p}{\partial \sigma} = u\frac{\partial}{\partial x}x\frac{\partial p}{\partial \sigma} + v\frac{\partial}{\partial y}y\frac{\partial p}{\partial \sigma} + w\frac{\partial}{\partial z}z\frac{\partial p}{\partial \sigma}$$

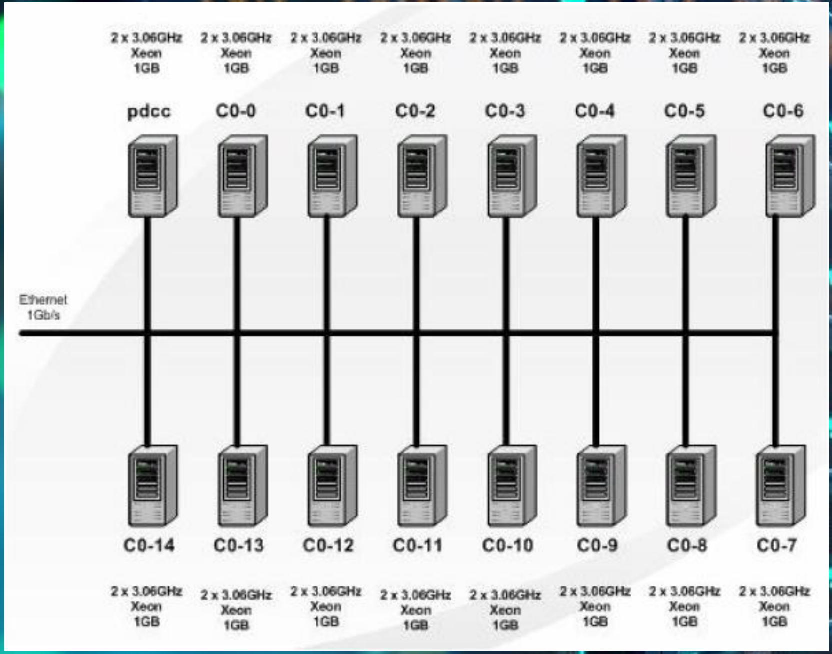
$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + \omega\left(\frac{\partial T}{\partial p} + \frac{RT}{pc_p}\right) = \frac{J}{c_p}$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \omega}{\partial p} = 0$$

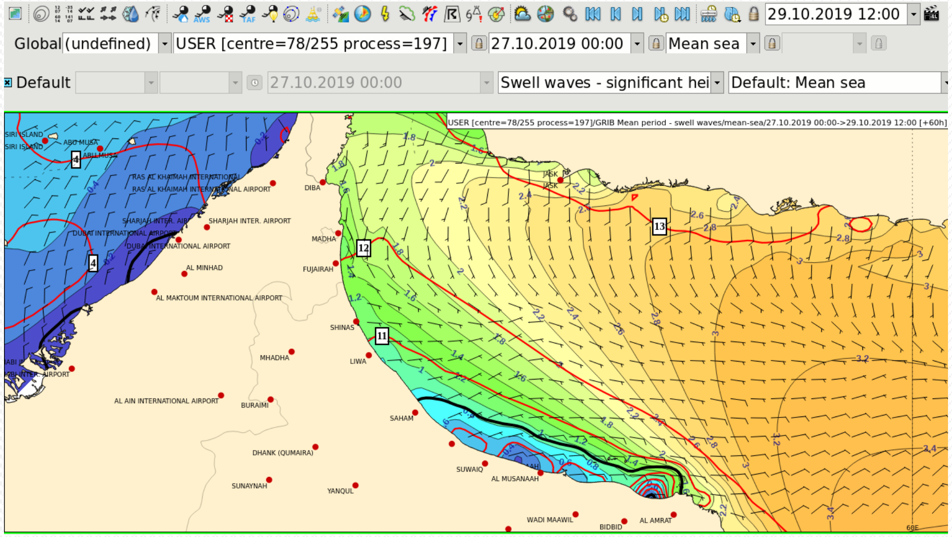
$$0 = -\frac{\partial \phi}{\partial p} - \frac{RT}{p}$$

Pc cluster

A set of computers that work together so that they
can be viewed as a single system.
Unlike grid computers, computer clusters have each node set to perform the same task, controlled and scheduled by software.

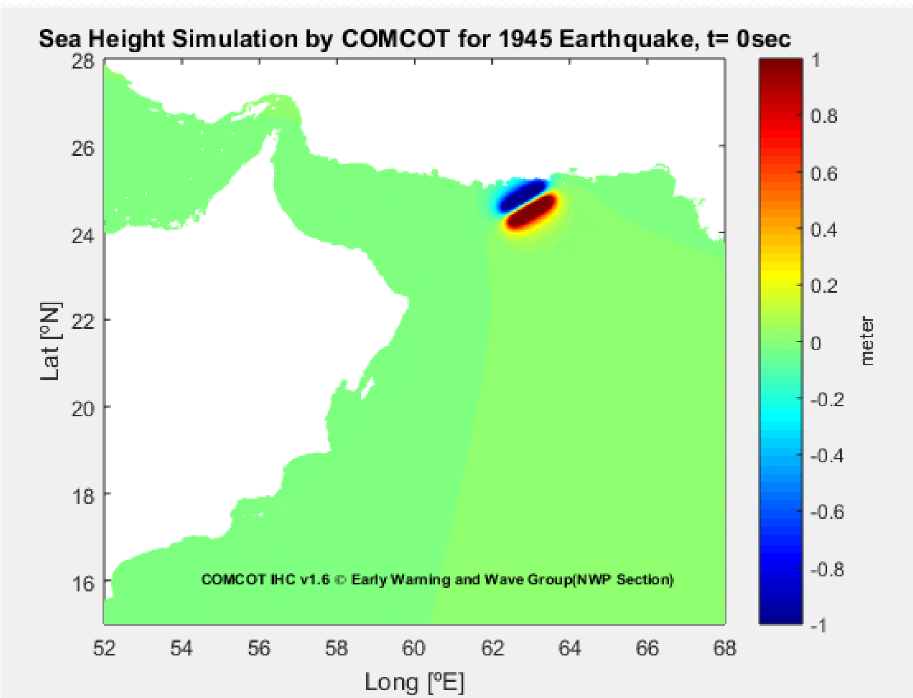


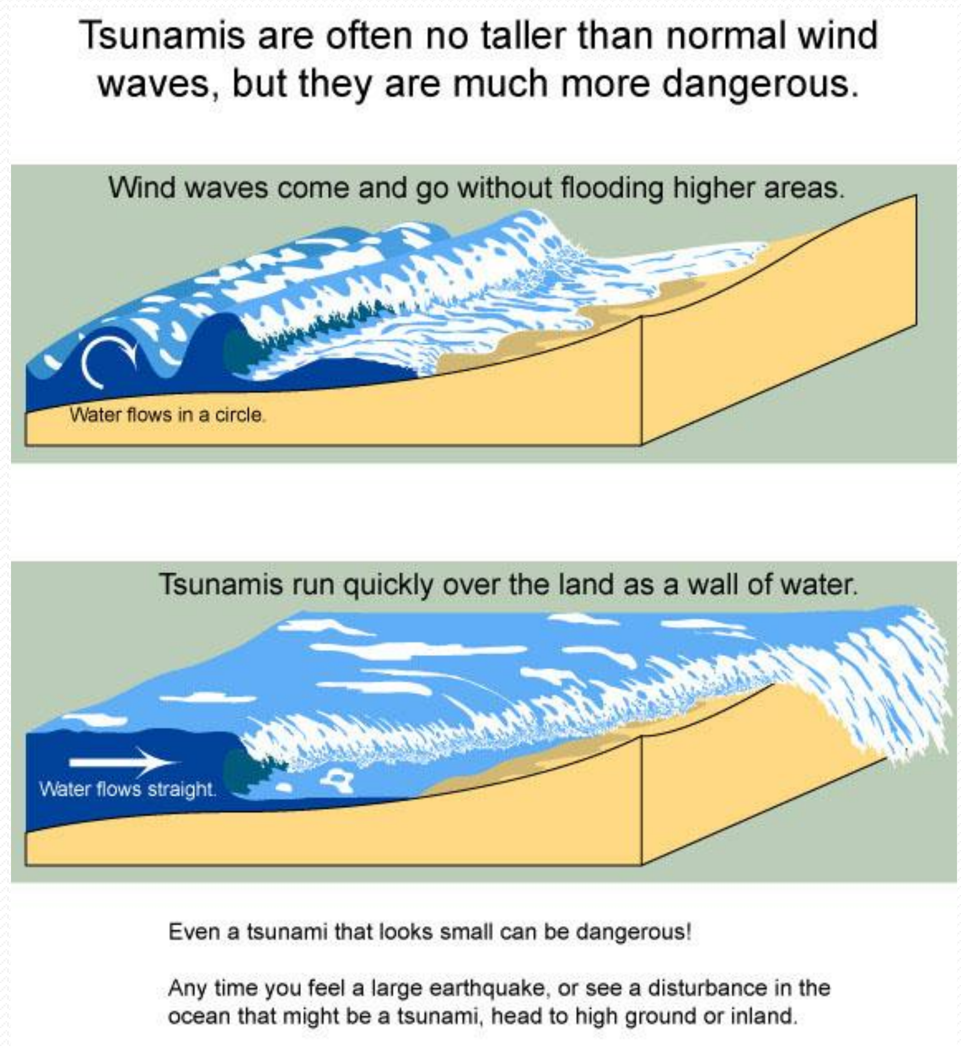
NWP Wave



29.10.2019 12:00
Global (undefined)
USER [centre=78/255 process=197]
27.10.2019 00:00
Mean sea
Default
27.10.2019 00:00
Swell waves - significant hei
Default: Mean sea
USER [centre=78/255 process=197]/GRIB Mean period - swell waves/mean-sea/27.10.2019 00:00->29.10.2019 12:00 [+60h]
DIBA
MADHA
FUJAIRAH
SHINAS
LIWA
MHADHA
SAHAM
BURAIMI
AL AIN INTERNATIONAL AIRPORT
AL MAKTOUM INTERNATIONAL AIRPORT
SHARJAH INTER. AIRPORT
AL MINHAD
DHANK (QUMAIRA)
SUNAYNAH
YANQUL
SUWAIQ
AL MUSANAAH
WADI MAAWIL
BIDBID
AL AMRAT

Tsunami models





Thank you

رابط تقييم المحاضرة