UNIVERSITY OF THESSALY
SCHOOL OF SCIENCE
INFORMATICS AND COMPUTATIONAL BIOMEDICINE

WEATHER FORECAST MODELS, WITH REFERENCE TO THE BASIC PHENOMENA AND SCALES UNDER CONSIDERATION - MARINE WEATHER FORECAST ASSESSMENT BASED ON THE EX POST RECORDED WEATHER

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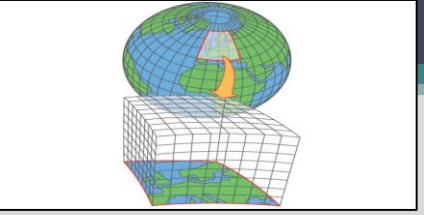


Aim of this presentation

1st Part

Reference to the basic meteorological phenomena and scales, which are observed and considered during the weather forecast.

Reference to the numerical weather prediction models, through which the forecast is currently achieved.

- Historical review
- Basic equations used
- Phases of the forecast
- Ways of data collection

Aim of this presentation

2nd Part

Assessment of the marine weather forecast by comparing predicted weather phenomena with occurrences.

Collection of forecast data, every 3 hours and for 7 days at specific coordinates, compared to actual weather phenomena.

Analysis and comparison of predictions-occurences using the IBM SPSS Statistics software.

1st Part

WEATHER FORECAST MODELS, WITH REFERENCE TO THE BASIC METEOROLOGICAL PHENOMENA AND SCALES (WHICH ARE) UNDER CONSIDERATION

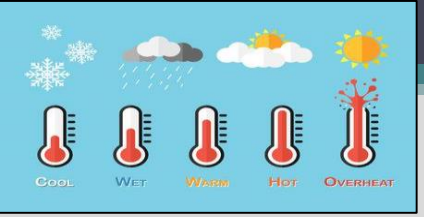
Meteorological phenomena under consideration

- The Earth's atmosphere, its composition and its structure.
- The Atmospheric pressure.
- The Air temperature.
- The Water temperature.
- The Humid air in the atmosphere.
- The Solar and Earth radiation.
- The Wind.
- The Waves.

Meteorology

Meteorology is the science that studies the atmosphere and the phenomena that occur within it.

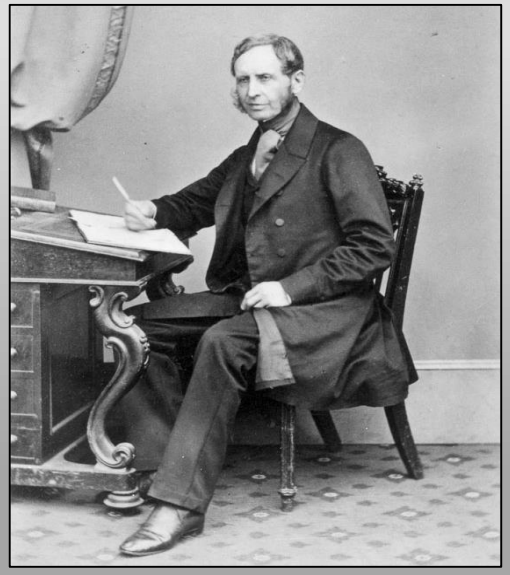
In addition to this brief definition, Meteorology can in its broadest sense be characterized as the basic atmospheric science, which has as its research objective the study of the dynamics of the atmosphere and the effects of the dynamic causes on the surface of the earth, as long as the study of the Atmospheric Physics and Atmospheric Chemistry.



The birth of the weather forecast

There was no weather forecast in 1854 when Robert FitzRoy established in Britain, what later would be called the Met Office.

The man who invented the weather forecast faced scepticism and even mockery.



FitzRoy's weather forecasts were taken up by Derby race-goers.

Atmosphere

Earth is the only planet in the solar system with an atmosphere that can sustain life. The blanket of gases not only contains the air that we breathe but also protects us from the blasts of heat and radiation emanating from the sun. It warms the planet by day and cools it at night.

According to NASA, the gases in Earth's atmosphere include:

- Nitrogen - 78 percent
- Oxygen - 21 percent
- Argon - 0.93 percent
- Carbon dioxide - 0.04 percent
- Trace amounts of neon, helium, methane, krypton and hydrogen, as well as water vapor.

Atmosphere

Atmosphere's layers

exosphere

thermosphere

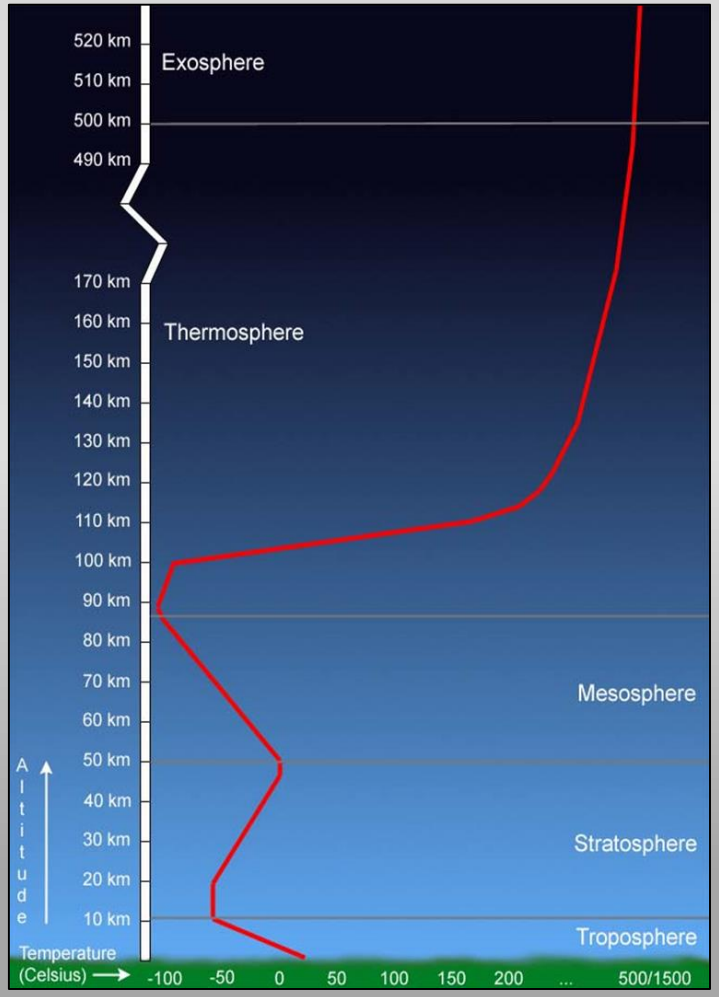
mesosphere

stratosphere

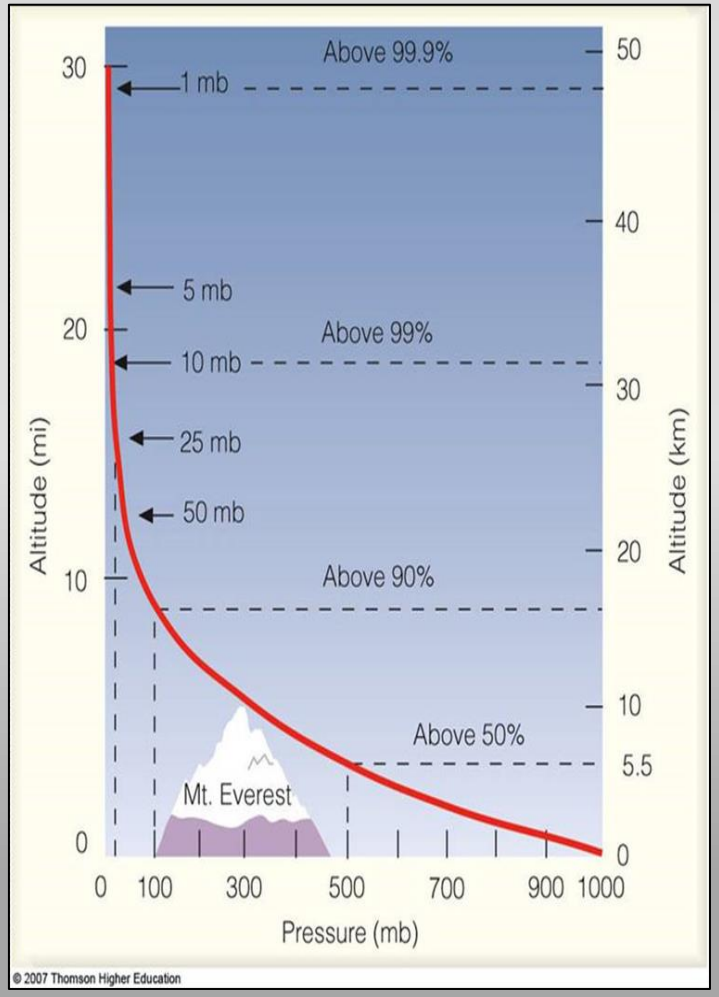
troposphere

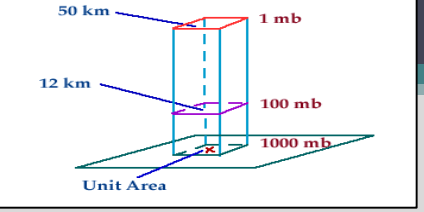
Atmosphere

Temperature



Pressure

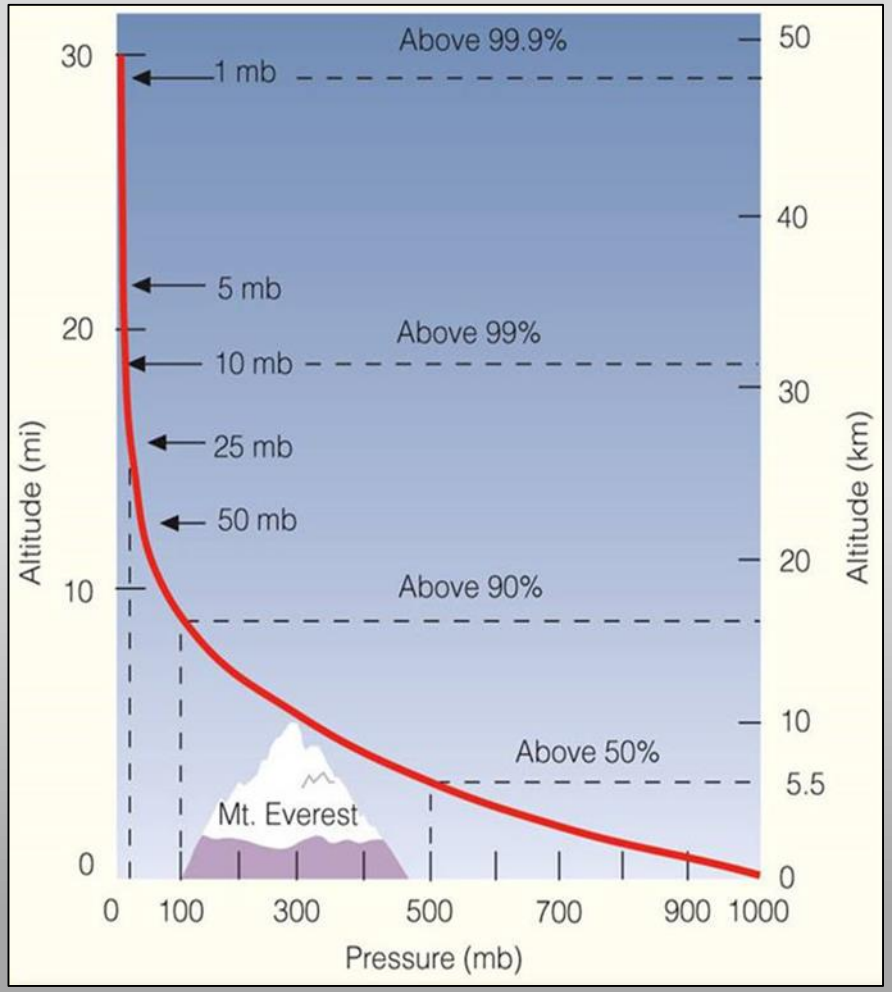


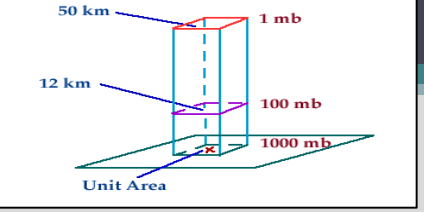


Atmospheric pressure

Atmospheric pressure is subject to significant changes in vertical and horizontal terms. The vertical change is due to the air's characteristic of being compressible. The top layers of air compress those below them, resulting in increased pressure as we approach the surface of the earth.

Horizontal pressure distribution is essential for studying wind movement.



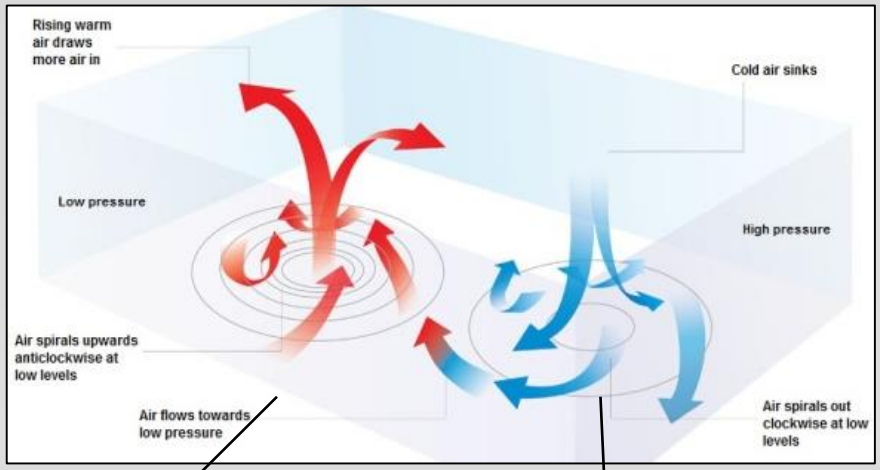


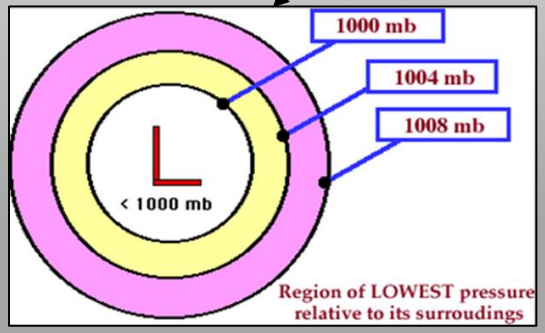
Atmospheric pressure

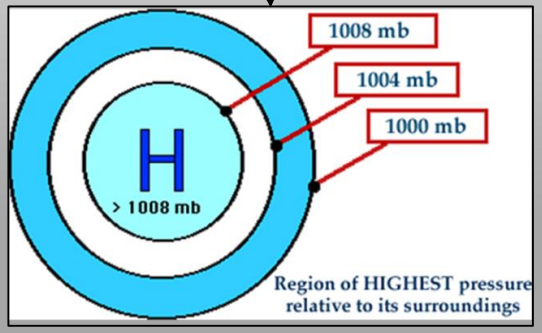
High and low pressure systems

On a weather chart, lines joining places with equal sea-level pressures are called isobars. Charts showing isobars are useful because they identify features such as anticyclones (areas of high pressure) and depressions (areas of low pressure).

Areas of high and low pressure are caused by ascending and descending air. As air warms, it ascends leading to low pressure at the surface. As air cools, it descends leading to high pressure at the surface.



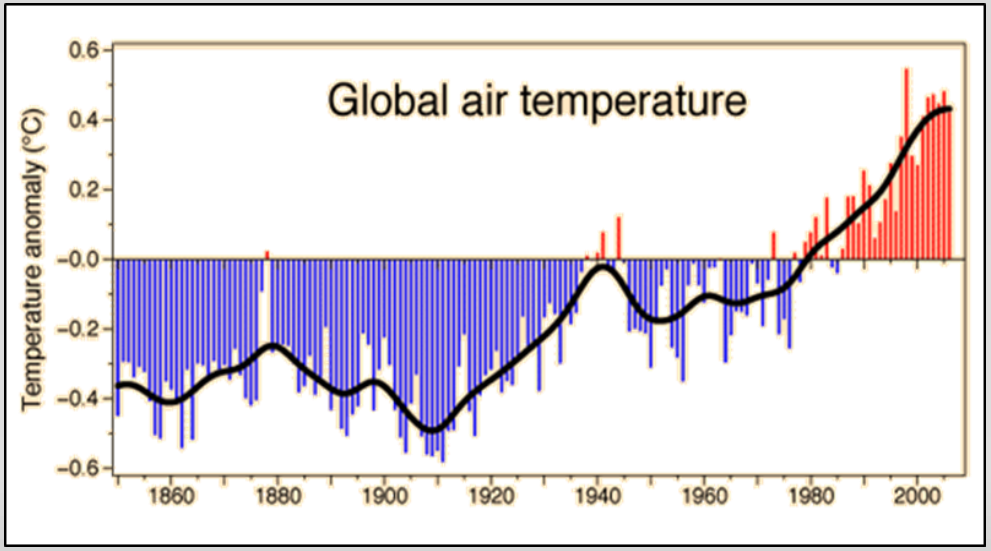




Air temperature

Earth is the only planet we know to support life. It is not very close or too far from the sun. It is in a zone that is just the right one, not too hot or too cold. The average earth temperature is about 33.6 F (0.9°C), according to NASA.

However, temperatures vary greatly throughout the world, depending on the time of year, ocean and wind currents and weather conditions. The summers tend to be warmer and the winters are colder.

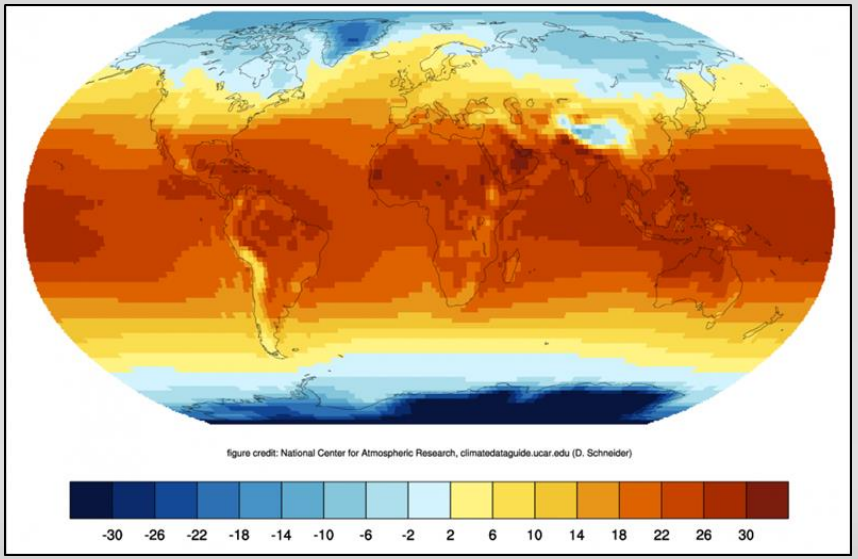


Air temperature

Air temperature is subject to normal and irregular changes.

The normal changes are due to the various movements of the earth and the irregularities in the alternation of the various weather conditions. The most important of these moves is the rotation of the earth around its axis, which takes place in one day and its passing around the sun that is completed in one year.

From the normal temperature changes, the daily and annual changes are the most important.

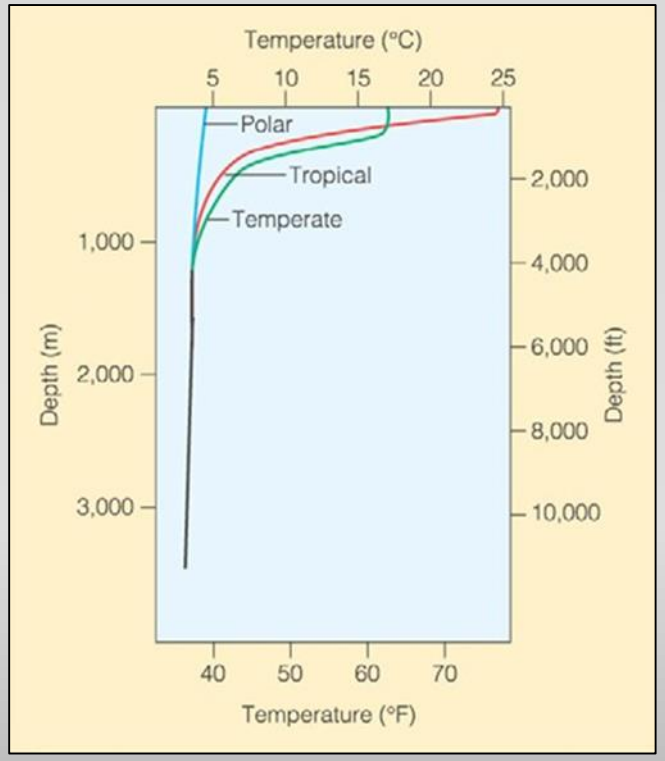


Water Temperature

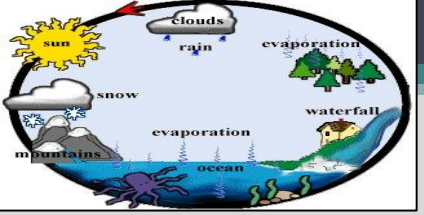
The vertical variation of water temperature is closely related to the flow of ocean currents. Generally, the way the water temperature is divided into water depths is characterized by the existence of three zones:

- the surface zone (5 - 200 m),
- the transition zone (200 - 1000 m),
- the deep zone (> 1000 m).

The temperature in the upper water layer, ranging from 0 to 5 m, is determined by factors independent of the ocean circulation, such as the amount of solar energy and the ocean-atmosphere thermal exchange mechanism.



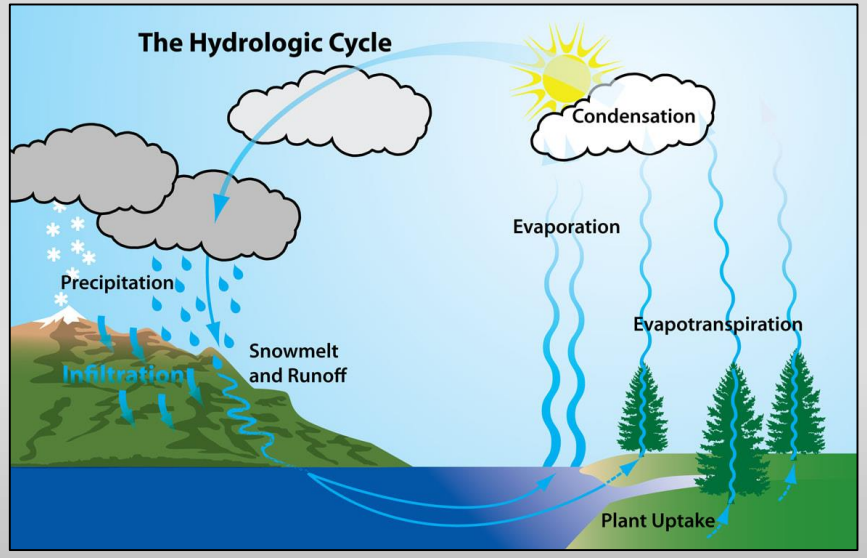
The temperature in the ocean surface layers ranges between -2 °C and 32 °C. Its distribution depends more on the latitude, the season and the currents.



Humid air in the atmosphere

Water in the atmosphere

Water is one of the main ingredients for the existence of life on earth. The concentration of water vapor in the atmosphere is not stable, but fluctuates widely, varying from 0.2% in cold dry climates to up to 5% in wet tropics.



For every first minute of the hour almost 109 tons of water are fed into the atmosphere. Most of this water comes from the evaporation that occurs in the oceans.

Humid air in the atmosphere

Humid air is called the air consisting of dry air and water vapor. The amount of water vapor in the humid air is expressed by the term **humidity**.

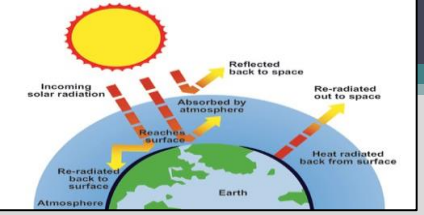
- Clouds
- Fog
- Rain and Snow
- Storms and Hail

NWS Heat Index

Relative Humidity (%) \ Temperature (°F)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger



Solar and Earth radiation

The sun is the main source of energy in the earth, which in turn affects the earth's atmosphere, setting the various meteorological systems in motion and generating various atmospheric processes in general.

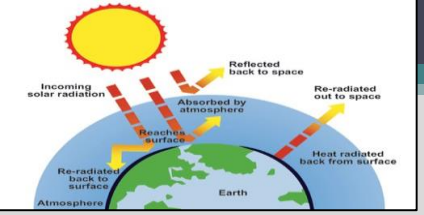
During the passage of solar radiation through the atmosphere of the earth, this radiation undergoes:

- Reflection and diffusion back in Space (25%).
- Absorption from clouds, dust and water vapor (25%).

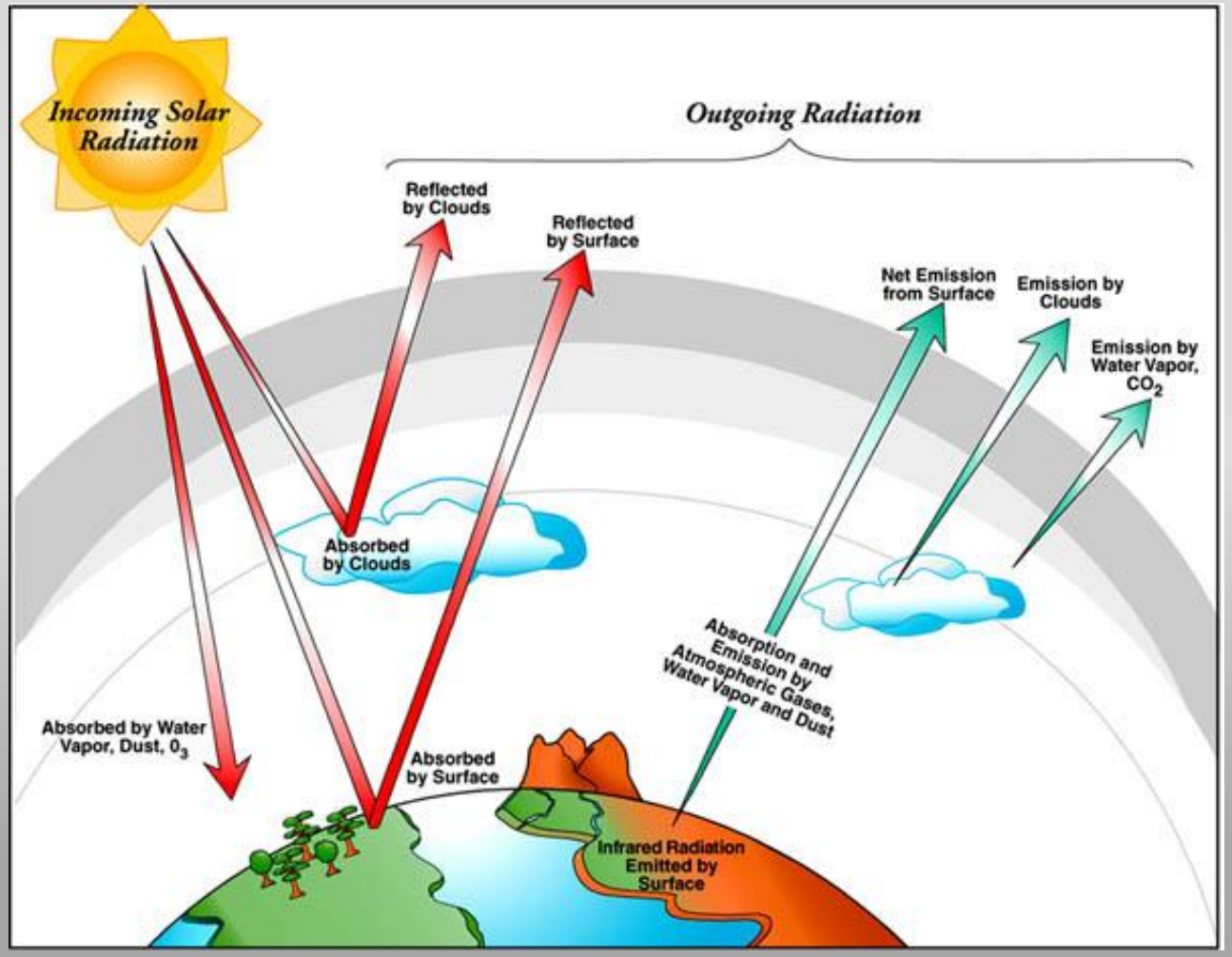
50% of solar radiation reaches the surface of the earth as direct and diffused radiation. From it,

- 5% is reflected and diffused from the surface of the earth.
- 45% is absorbed by the earth and turns into heat.

The surface of the earth emits the heat it receives in the form of radiation.



Solar and Earth radiation

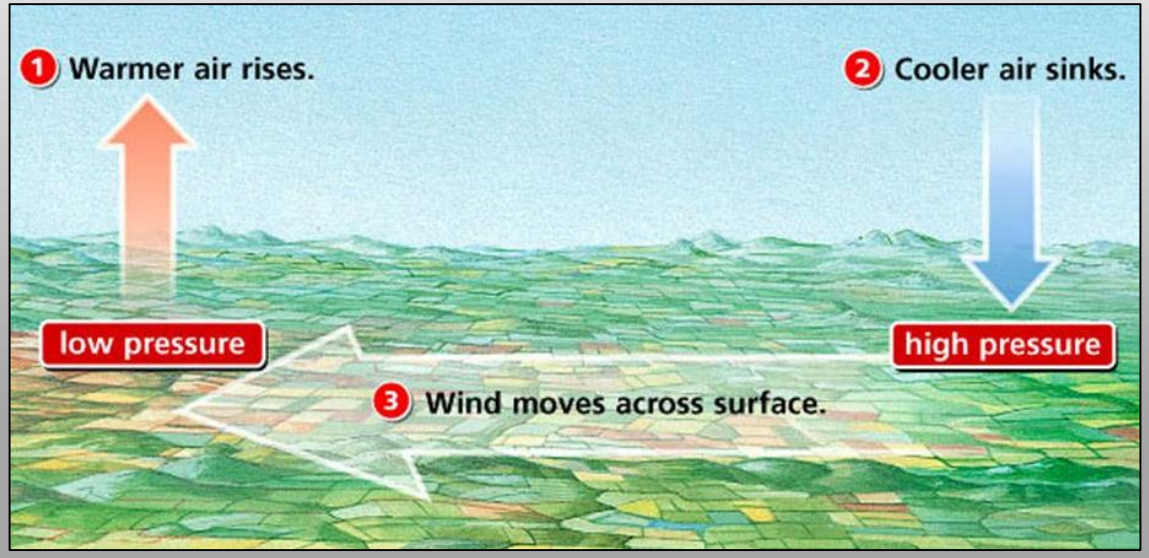


Wind

The wind is air in motion and its movements tend to balance the contrasts to the temperature, humidity and pressure in the atmosphere.

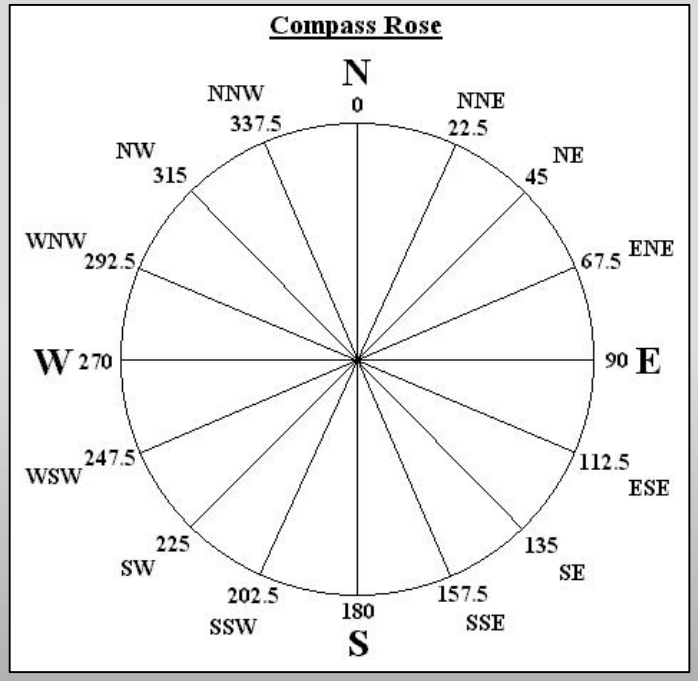
The main cause of wind formation is the spatial differentiation of atmospheric pressure, due to the uneven absorption of solar radiation on the surface of the earth.

Wind moves from an area of high pressure to an area of low pressure



Wind

Direction



Speed

Expressed in m/sec,
km/h, mi/h, knots

+

Beaufort scale

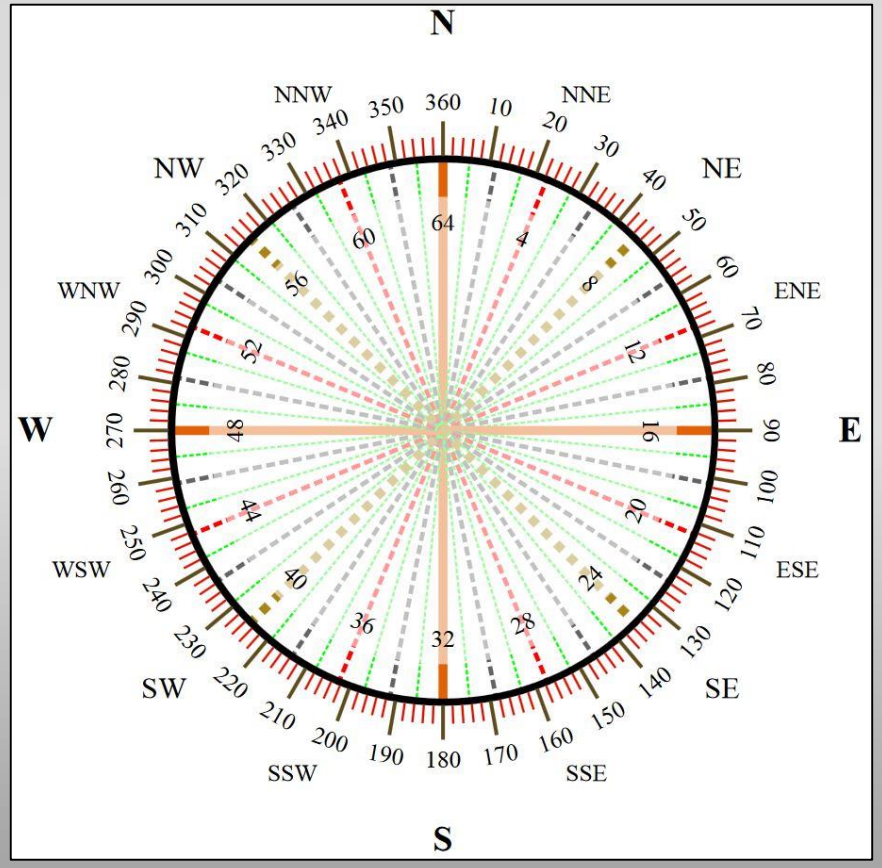
Wind Speed

The Beaufort scale classifies winds in 13 categories based on their intensity. There are exactly twelve values and in addition zero, which corresponds to apnea.

Beaufort Scale

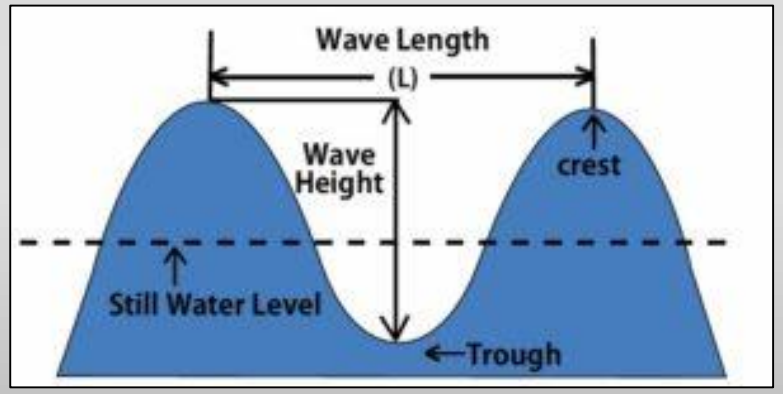
Wind Direction

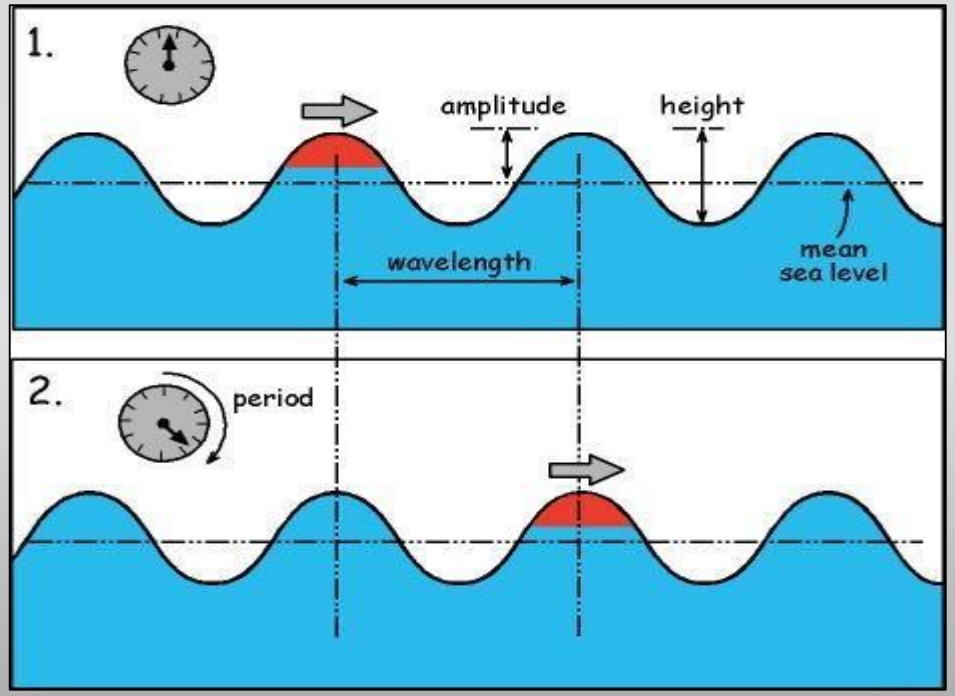
The direction of the wind is expressed either in degrees, beginning at the magnetic north, either with wind symbols or nominal.



Waves

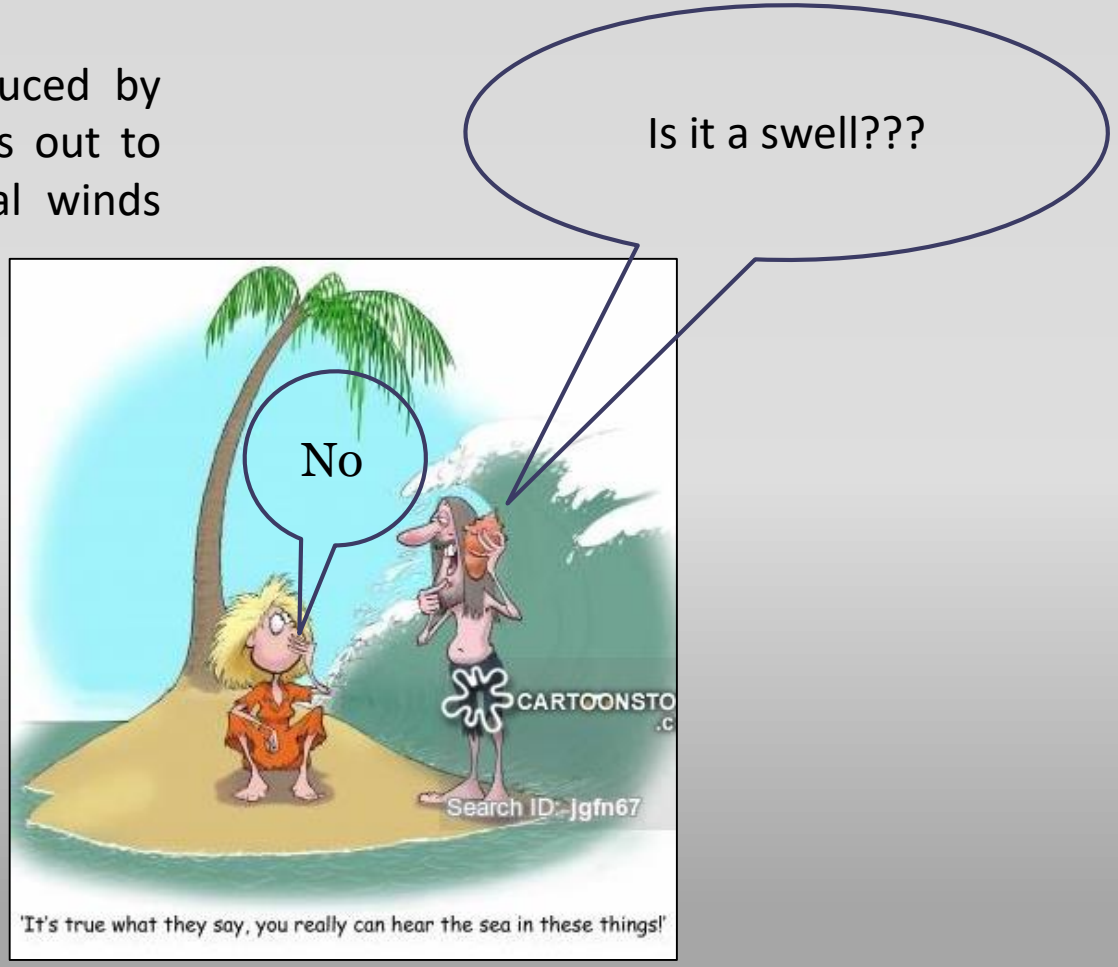
Characteristics

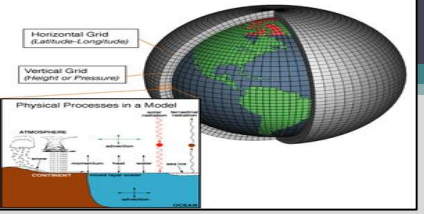




Swells

Swells are collections of waves produced by storm winds raging hundreds of miles out to sea, rather than the product of local winds along beaches.

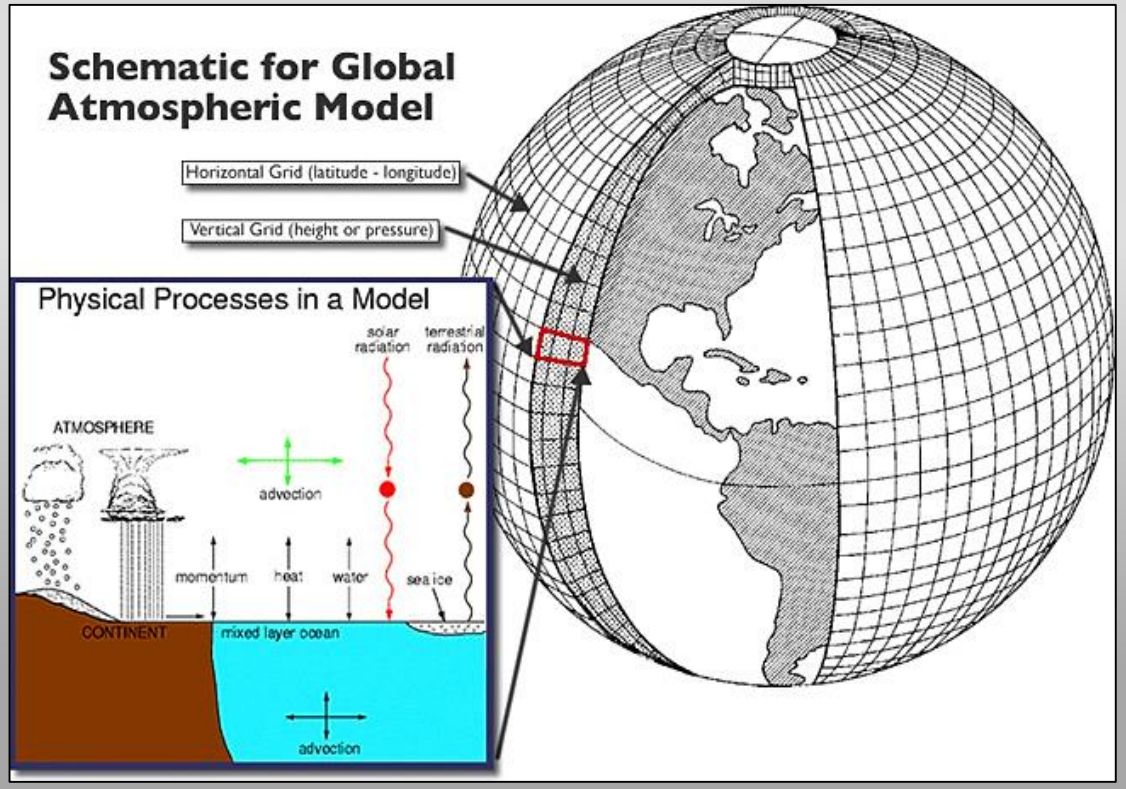


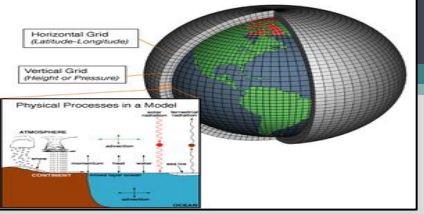


Numerical Weather Prediction Models

Numerical weather prediction models are continuously fueled with information on various atmospheric conditions such as atmospheric pressure, temperature, humidity, etc. from meteorological stations established by each country's meteorological services on land and at sea.

They are also powered by information about points of the atmosphere at specific altitudes even at points of the upper atmosphere.

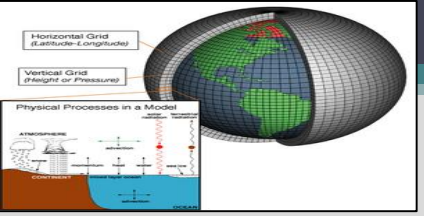




Numerical Weather Prediction Models

Numerical models run algorithms and equations that simulate the physical processes taking place in the atmosphere, giving results on how the atmosphere will work in the next few hours.

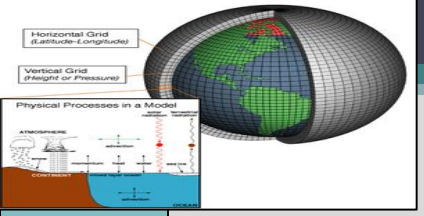
- Global and regional numerical models are the basis for weather prediction
- Initialized with observations, most models are run on 3D grids that encompass hundreds of thousands or millions of points.
- They produce hundreds of terabytes of model output per day.



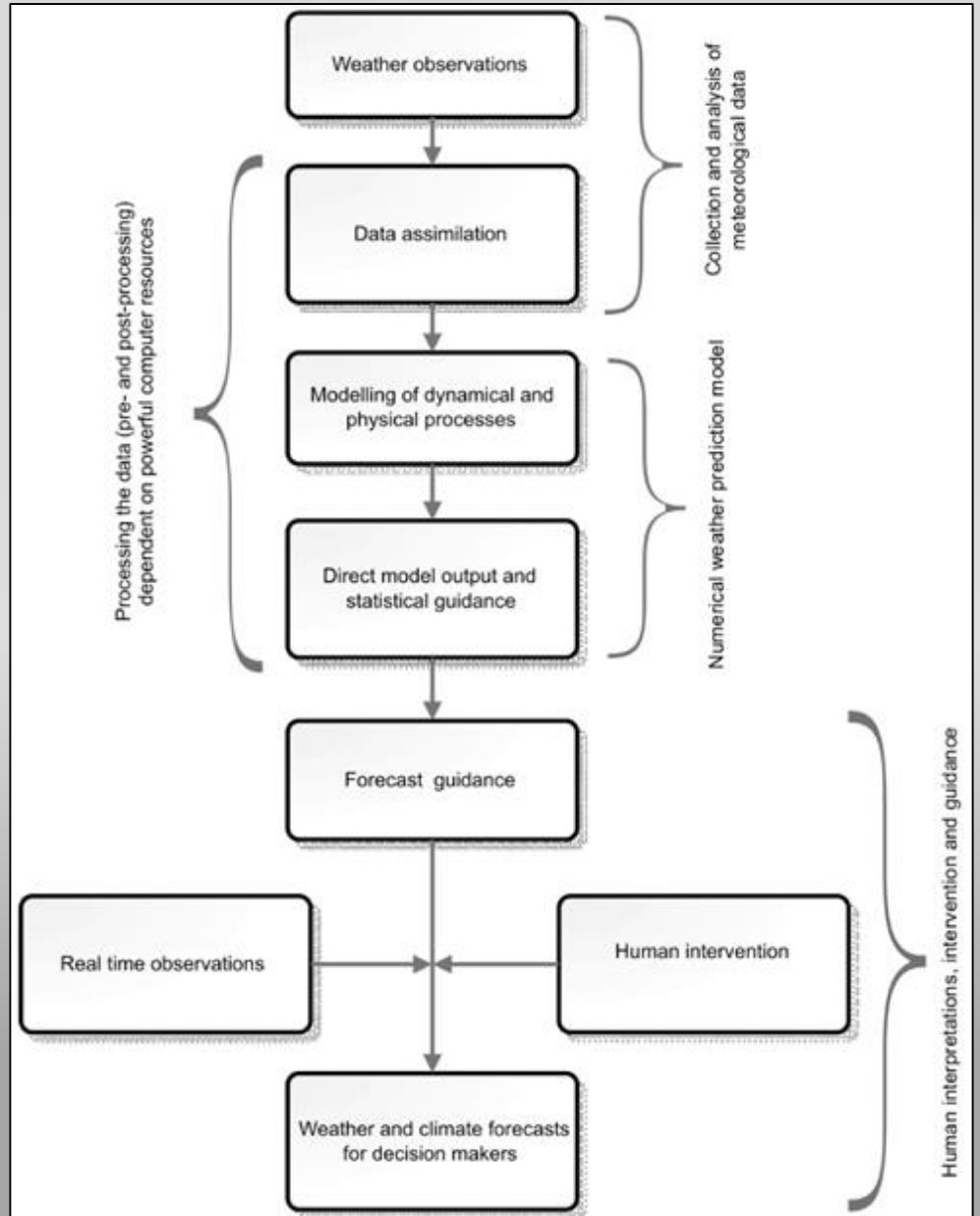
Phases of weather forecasting through numerical models

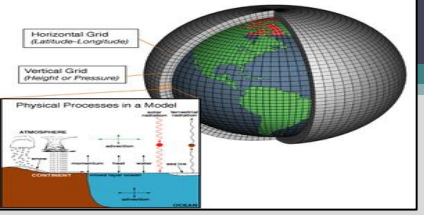
The weather forecast includes the conversion of data from observations into forecasts, through a numerical model, into **three basic phases**:

- The **first phase** is the collection and analysis of meteorological data to determine the initial conditions of the model.
- The **second phase** requires the use of deterministic numerical prediction models, based on dynamic and natural atmospheric processes, to visualize the initial conditions of the system in future situations.
- The **third phase** concerns the conversion of the outputs produced from numerical models into practical valuable information for users.



Phases of weather forecasting through numerical models





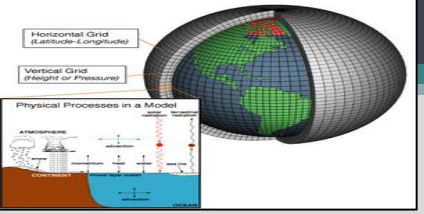
Numerical Weather Prediction Models

Global Forecast Models

ECMWF
GFS
NOGAPS or NAVGEM
GEM
UKMO
GM
JMA
NWS
USAF

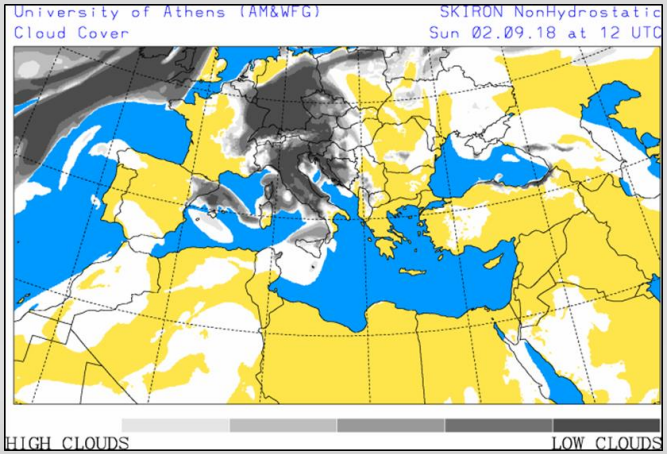
Regional (Greek) Forecast Models

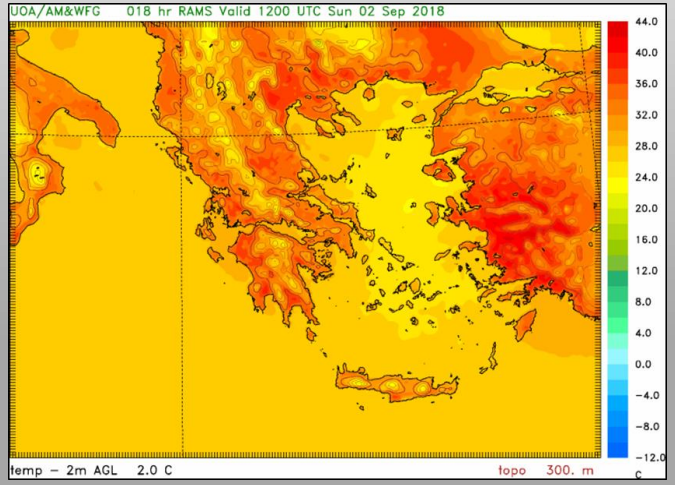
Bolam and MM5
COSMO-from Hellenic National Meteorological Service (EMY)
SKIRON/ETA (Poseidon)
Αίολος (WRF-ARW)
SuperForecast



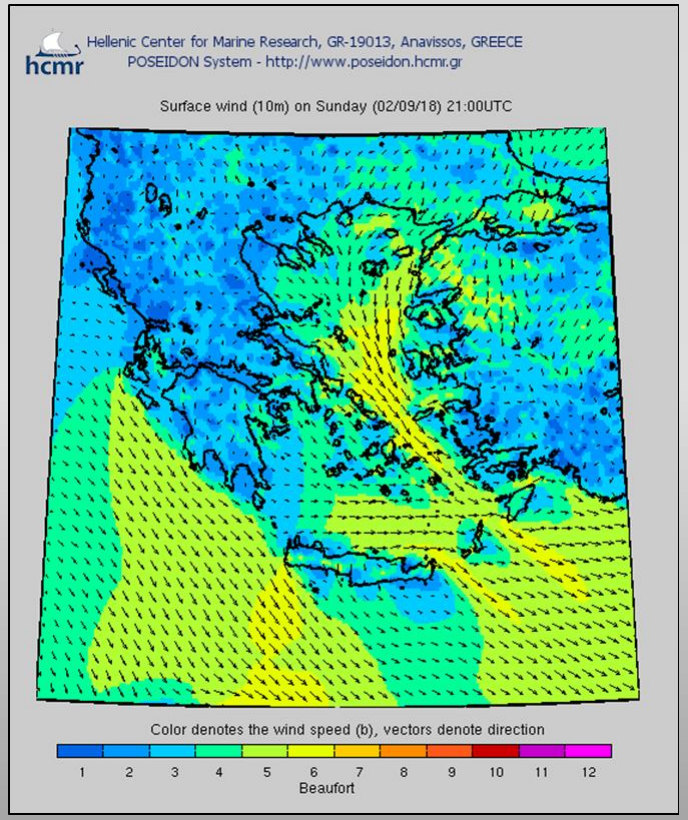
Outputs of Numerical Weather Prediction Models

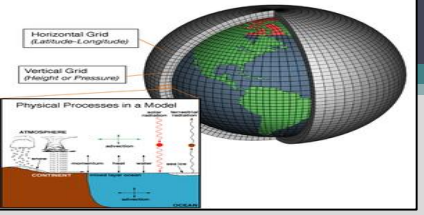
Cloud cover-Air temperature (SKIRON)





Surface wind(10m) (POSEIDON)



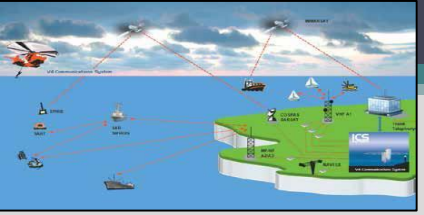


The future of Numerical Weather Prediction Models

The accuracy and reliability of operational NWP systems improved significantly during the last years. These advances were achieved primarily by the refinement of data-assimilating processes, the introduction of new or improved types of observation, the enhancement of the physical parameterisation procedures, and also the superior vertical and horizontal resolutions of the models. Further advances in the quality of forecast guidance during the next ten years are likely and should be achieved by increasing the spatial and temporal resolution of surface observations in data-sparse areas.

2nd Part

MARINE WEATHER FORECAST ASSESSMENT BASED ON THE EX POST RECORDED WEATHER

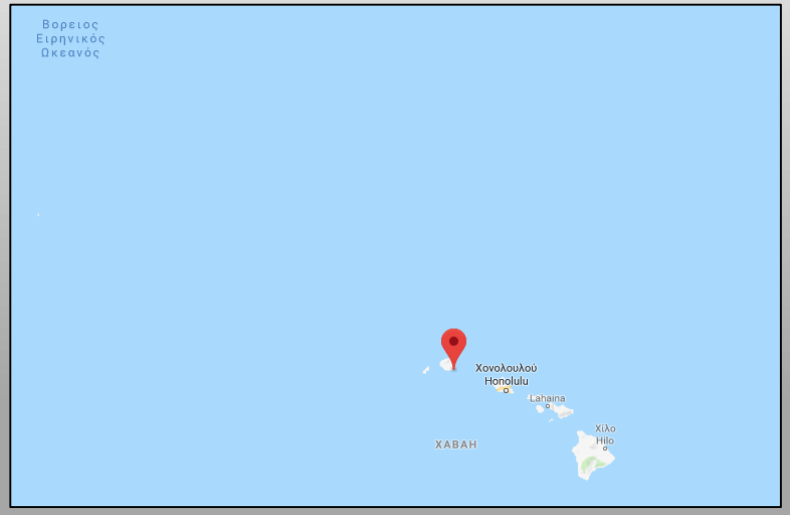


Marine Weather Forecast Assessment

Data collected

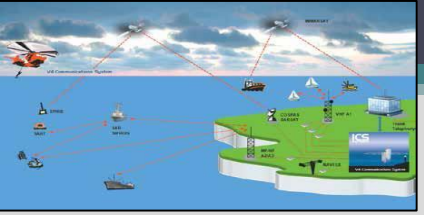
21.80N και 159.35W

- Wind Speed
- Wind Direction
- Air Temperature
- Water Temperature



21.297N και 157.959W

- Wave Height
- Significant Wave Height
- Swell Height
- Swell Direction
- Swell Period

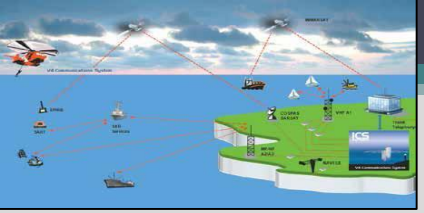


Marine Weather Forecast Assessment

Variables created

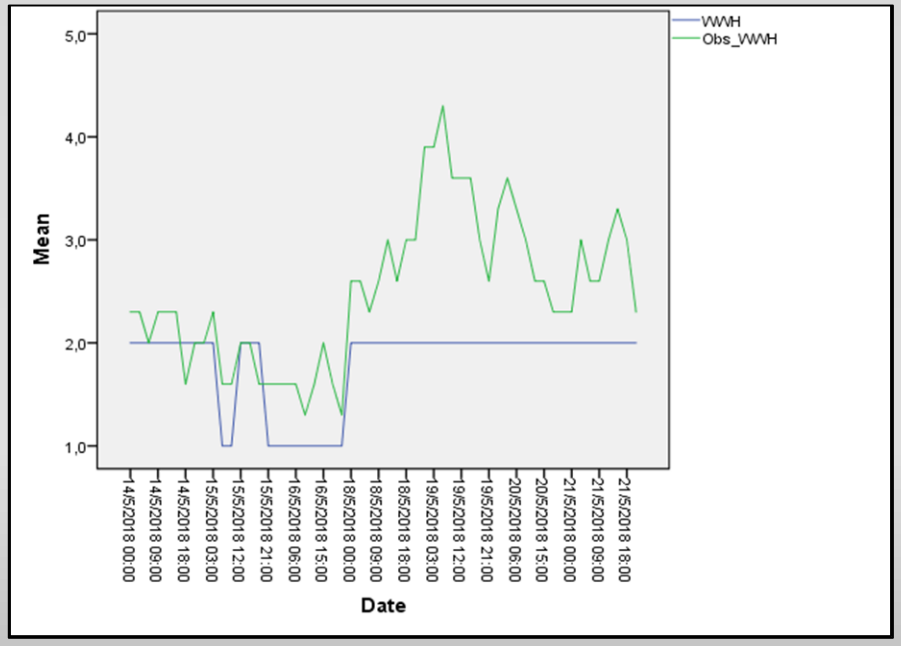
- Wind Speed: W_Sp
- Wind Direction: W_Dir
- Air Temperature: Temp
- Water Temperature: Wtemp
- Wave Height: WWH
- Significant Wave Height: SWVHT
- Swell Height: SWELL_H
- Swell Direction: SWELL_D
- Swell Period: SWELL_P

The values of the variables were recorded for 7 days, every 3 hours, from 14/5/2018 00:00 to 16/5/2018 21:00 and from 18/5/2018 00:00 to 21/5/2018 21:00.



Marine Weather Forecast Assessment

Wave Height



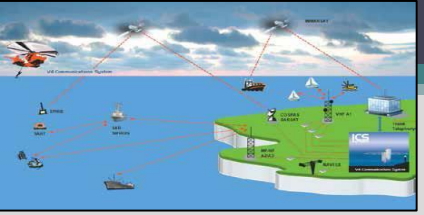
Correlations

		WWH	Obs_WWH
WWH	Pearson Correlation	1	,628**
	Sig. (2-tailed)		,000
	N	56	56
Obs_WWH	Pearson Correlation	,628**	1
	Sig. (2-tailed)	,000	
	N	56	56

**. Correlation is significant at the 0.01 level (2-tailed).

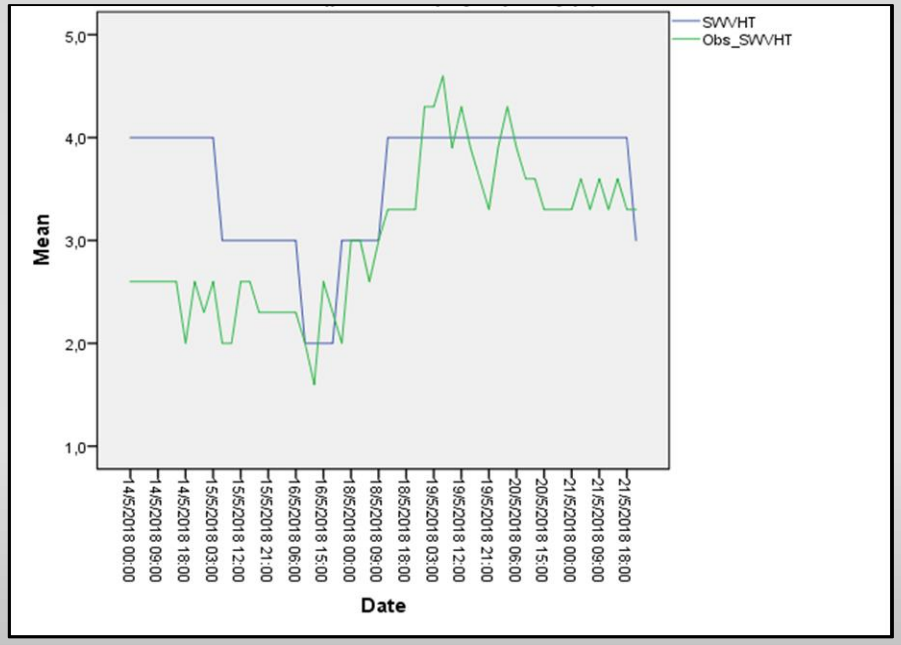
Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
WWH	56	1,0	1,0	2,0	1,804	,4009
Obs_WWH	56	3,0	1,3	4,3	2,495	,7252
Valid N (listwise)	56					



Marine Weather Forecast Assessment

Significant Wave Height



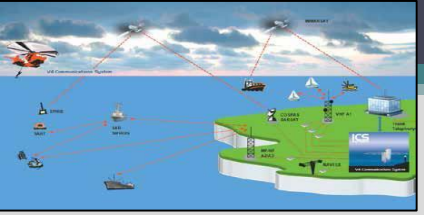
Correlations

		SWVHT	Obs_SWVHT
SWVHT	Pearson Correlation	1	,615**
	Sig. (2-tailed)		,000
	N	56	56
Obs_SWVHT	Pearson Correlation	,615**	1
	Sig. (2-tailed)	,000	
	N	56	56

**. Correlation is significant at the 0.01 level (2-tailed).

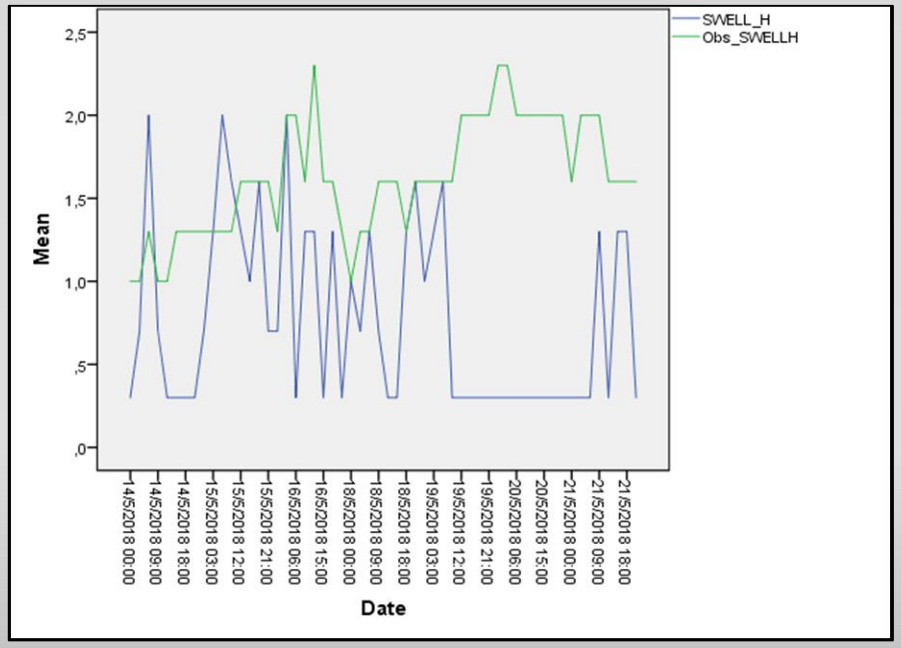
Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
SWVHT	56	2,0	2,0	4,0	3,589	,6260
Obs_SWVHT	56	3,0	1,6	4,6	3,032	,7153
Valid N (listwise)	56					



Marine Weather Forecast Assessment

Swell Height

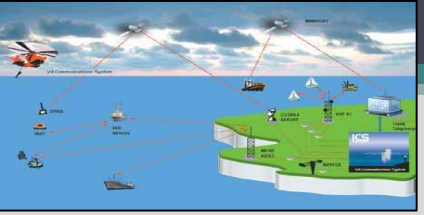


Correlations

		SWELL_H	Obs_SWELLH
SWELL_H	Pearson Correlation	1	-,220
	Sig. (2-tailed)		,103
	N	56	56
Obs_SWELLH	Pearson Correlation	-,220	1
	Sig. (2-tailed)	,103	
	N	56	56

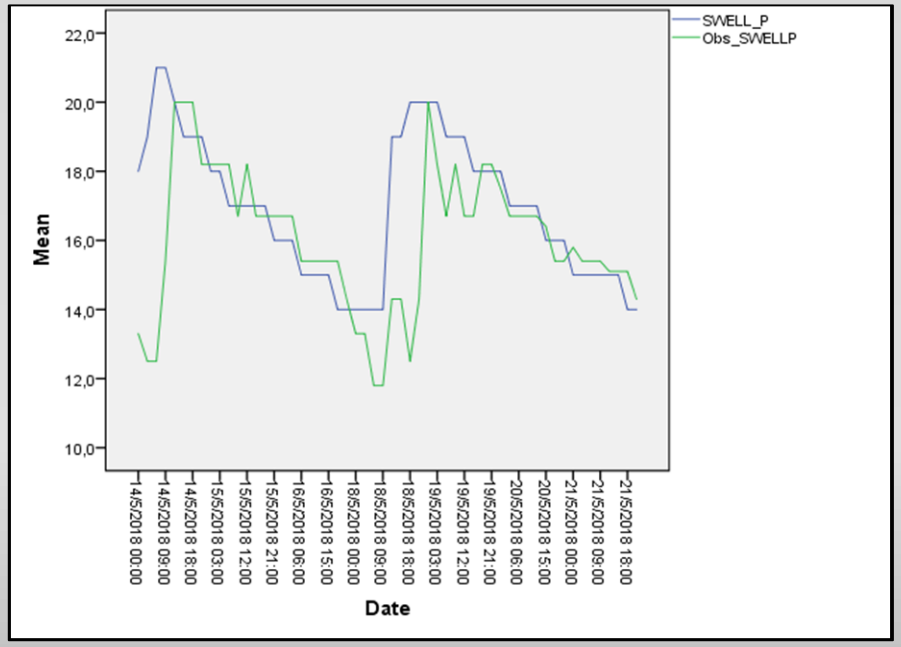
Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
SWELL_H	56	1,7	,3	2,0	,768	,5521
Obs_SWELLH	56	1,3	1,0	2,3	1,621	,3520
Valid N (listwise)	56					



Marine Weather Forecast Assessment

Swell Period



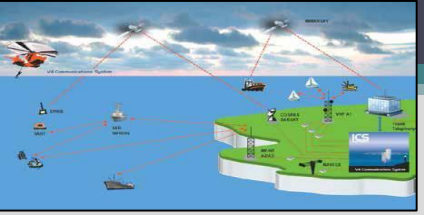
Correlations

		SWELL_P	Obs_SWELLP
SWELL_P	Pearson Correlation	1	,375**
	Sig. (2-tailed)		,004
	N	56	56
Obs_SWELLP	Pearson Correlation	,375**	1
	Sig. (2-tailed)	,004	
	N	56	56

**. Correlation is significant at the 0.01 level (2-tailed).

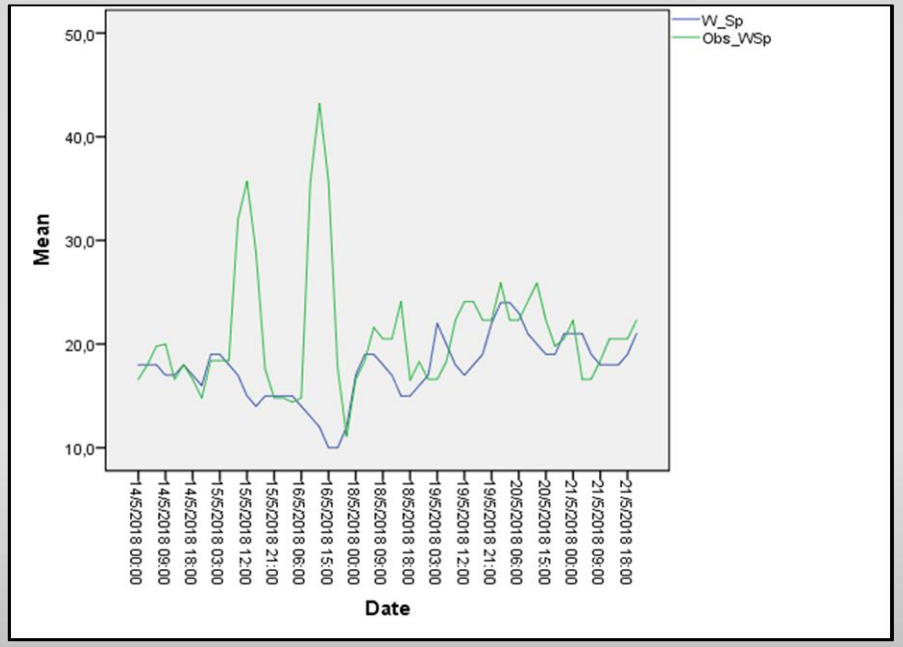
Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
SWELL_P	56	7,0	14,0	21,0	16,964	2,0799
Obs_SWELLP	56	8,2	11,8	20,0	16,032	2,0497
Valid N (listwise)	56					



Marine Weather Forecast Assessment

Wind Speed

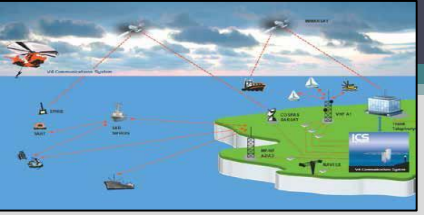


Correlations

		W_Sp	Obs_WSp
W_Sp	Pearson Correlation	1	-,165
	Sig. (2-tailed)		,225
	N	56	56
Obs_WSp	Pearson Correlation	-,165	1
	Sig. (2-tailed)	,225	
	N	56	56

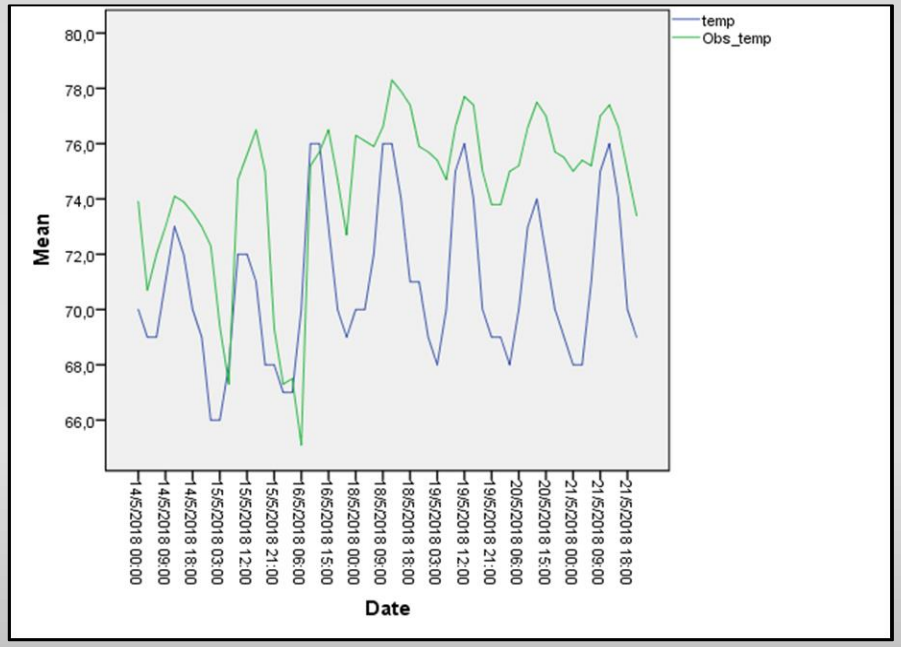
Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
W_Sp	56	14,0	10,0	24,0	17,625	3,0722
Obs_WSp	56	32,1	11,1	43,2	20,996	6,0120
Valid N (listwise)	56					



Marine Weather Forecast Assessment

Air Temperature



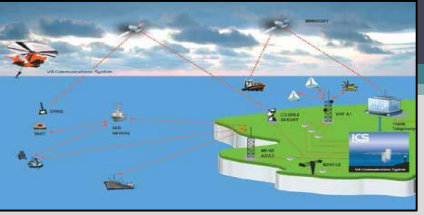
Correlations

		temp	Obs_temp
temp	Pearson Correlation	1	,629**
	Sig. (2-tailed)		,000
	N	56	56
Obs_temp	Pearson Correlation	,629**	1
	Sig. (2-tailed)	,000	
	N	56	56

**. Correlation is significant at the 0.01 level (2-tailed).

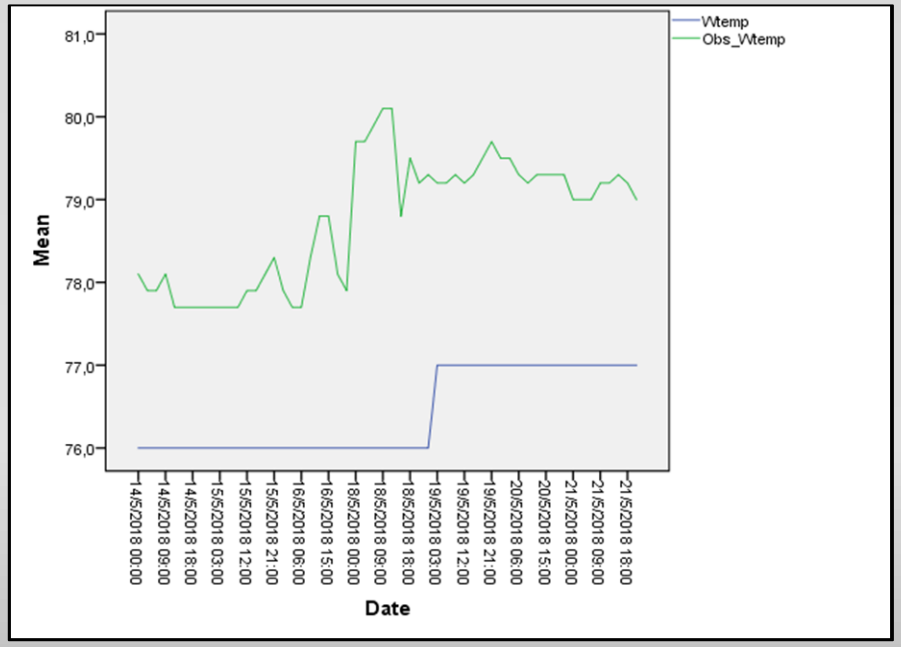
Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
temp	56	10,0	66,0	76,0	70,875	2,7835
Obs_temp	56	13,2	65,1	78,3	74,480	2,8943
Valid N (listwise)	56					



Marine Weather Forecast Assessment

Water Temperature



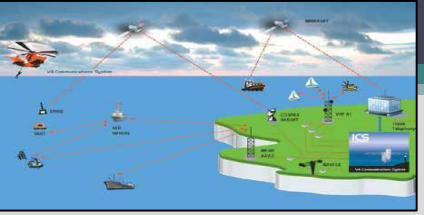
Correlations

		Wtemp	Obs_Wtemp
Wtemp	Pearson Correlation	1	,558**
	Sig. (2-tailed)		,000
	N	56	56
Obs_Wtemp	Pearson Correlation	,558**	1
	Sig. (2-tailed)	,000	
	N	56	56

**. Correlation is significant at the 0.01 level (2-tailed).

Descriptive Statistics

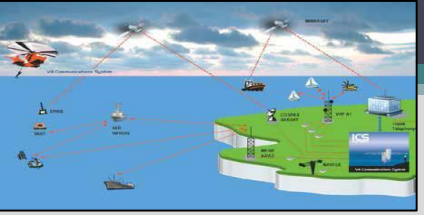
	N	Range	Minimum	Maximum	Mean	Std. Deviation
Wtemp	56	1,0	76,0	77,0	76,411	,4964
Obs_Wtemp	56	2,4	77,7	80,1	78,755	,7625
Valid N (listwise)	56					



Marine Weather Forecast Assessment

Wave Height

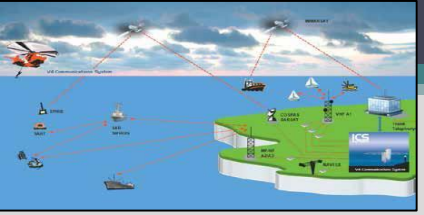
- Short-term forecasts are quite satisfactory and do not differ greatly from the occurrences.
- Long-term forecasts are not as satisfactory and the prediction-observation gap is growing.
- Forecast and observation follow a similar trend (upward or downward) mainly for short-term forecasts.
- The difference in the mean between forecast and observation is about 0.7 ft.
- The observations show a wider range and a greater standard deviation (differentiation) than forecasts.
- The correlation between the two variables is good enough (0.628).



Marine Weather Forecast Assessment

Significant Wave Height

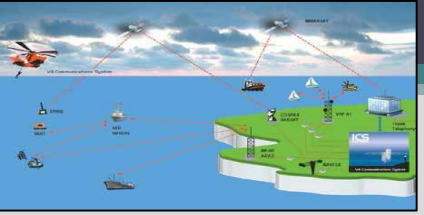
- The match between forecast and observation is good enough, both in the short and long term. There are some instances where the difference is great, but in the larger part the values are very close.
- The trend followed by forecast and observation is largely the same.
- The difference in the mean between forecast and observation is about 0.5 ft.
- The observations here also show a wider range and a greater standard deviation than forecasts, but to a lesser extent than in the wave height.
- The correlation here is pretty good (0.615).



Marine Weather Forecast Assessment

Swell Height

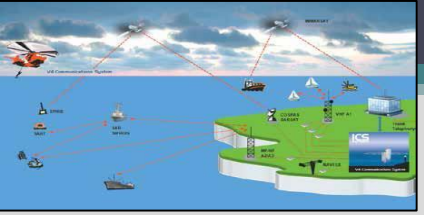
- In the short to medium term there is value convergence, but in the long run the gap is high.
- The trend followed by forecast and observation is similar in some cases, but totally opposite in others.
- The difference between the average predicted and observed value is about 0.9 ft.
- The observations here show a smaller range and a smaller standard deviation than forecasts, but the difference is small.
- The correlation is not good (-0.22).



Marine Weather Forecast Assessment

Swell Period

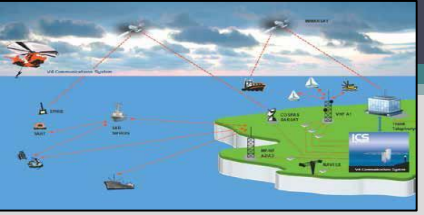
- The match between forecast and observation, with the exception of very few cases, is good enough, both in the short and long term.
- The trend followed by forecast and observation is very similar.
- The difference in the mean between forecast and observation is about 0.9 sec.
- Observations show a wider range than forecasts, but the difference is small. The standard deviation is almost the same.
- The correlation coefficient is not good (0.375), which may be due to few values that are very far apart.



Marine Weather Forecast Assessment

Wind Speed

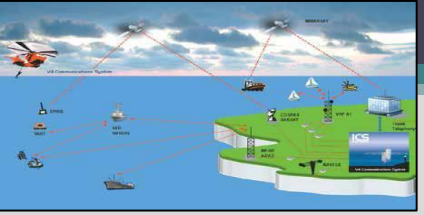
- The match between forecast and observation is relatively good, both in the short and the long term, with the exception of some cases. This is probably because of very strong wind gusts.
- The trend followed by forecast and observation is very similar here.
- The difference between the average forecast and observation is about 3.3 km/h.
- The observations show a wider range than forecasts, as well as a larger standard deviation.
- The correlation coefficient is not good (-0.165).
- There is a general ratio between prediction and observation, but due to the fact that the wind constantly changes its intensity, there can be no absolute value matching.



Marine Weather Forecast Assessment

Air Temperature

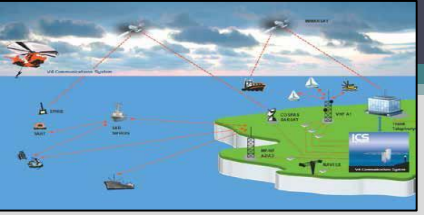
- The match between forecast and observation is not very good, especially in the long term. For the most part there is a difference between forecast and observation.
- In the short term though, even though there is some difference, values are close enough.
- The trend followed by forecast and observation is very similar, so the correlation coefficient is quite good (0.629).
- The difference between the average predicted and observed value is about 3.6 ° F.
- Observations show a wider range than forecasts but a similar standard deviation.



Marine Weather Forecast Assessment

Water Temperature

- The match between forecast and observation is not very good and there is a difference between them.
- The trend followed by forecast and observation is largely the same, so the correlation coefficient is good (0.558).
- The difference between the mean forecast and observation is about 2.3 ° F.
- The observations show a wider range than forecasts and a larger standard deviation.
- Generally, there is a forecast-observation ratio but with a constant difference of about 2 ° F.



Marine Weather Forecast Assessment

Swell Direction-Wind Direction

- In regard to swell direction, observations are different from forecasts in 100% of the cases. The difference, however, is very small, e.g. NA-N or ANA-NNA.
- Regarding wind direction, we have a forecast-observation match in 25% of cases. Very few are the cases in which there is a big difference, while in most of them, the values are very close, e.g. ABA-BA.

Thank you for your attention