POLITECNICO DI TORINO
UNIVERSITÀ DEGLI STUDI DI TORINO
Dipartimento Interateneo di Scienze, Progetto e Politiche del Territorio

Meteorology and Weather Analysis for Sailors:

Messages for Users and Coaches

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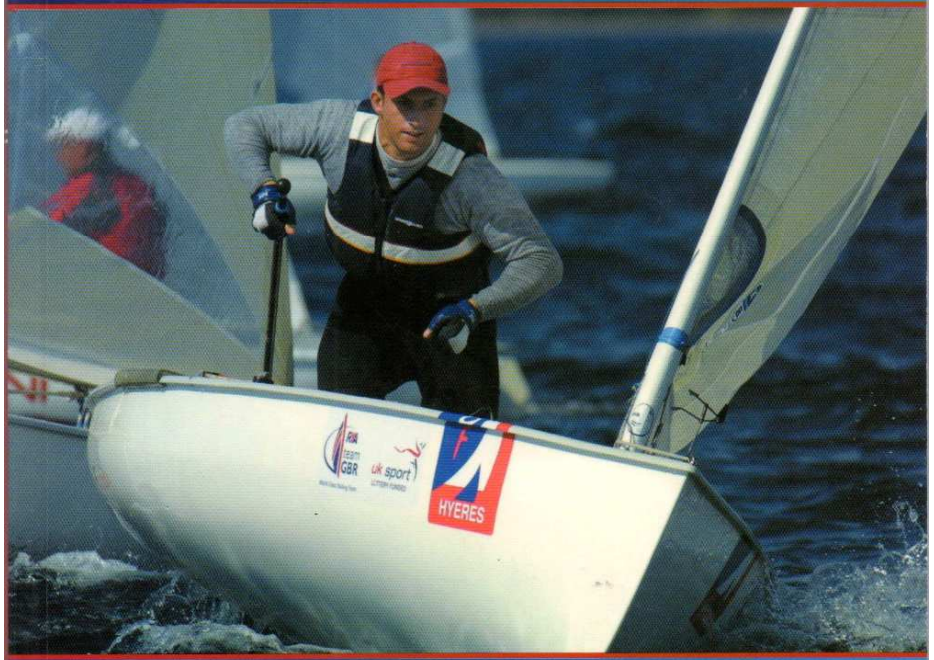
16th January 2019

fernhurst
COLOUR EDITION

Lifeboats

WIND STRATEGY

David Houghton &
Fiona Campbell



How to predict the wind on any racecourse
Analysis of popular venues
Summary sheets to take afloat

THIRD EDITION
FOR NORTHERN AND
SOUTHERN HEMISPHERES

2nd edition

HIGH PERFORMANCE SAILING

FRANK BETHWAITE

Faster Racing Techniques

BLOOMSBURY

Weather analysis: main factors

RACE PLANNING (RESTRICTED WATERS)

Things to establish before the race

*Likely **gradient** wind direction can be found from:*

- forecaster at a local weather station;
- telephone pre-recorded forecast;
- telephone fax actual and forecast charts (send by a meteorologist or found in the web);
- TV forecast that also gives current charts;
- radio forecast for inshore and offshore.

https://www.windy.com

RACE PLANNING (RESTRICTED WATERS)

Things to establish before the race

*Likely **type** of airstream:*

- unstable:
    - likely strength?
    - Strength of gusts?
    - Showers?
    - Thunderstorm?
- stable:
    - strength?
    - When will inversion break? Morning of afternoon (for the sea breeze)?
    - Any fog?

RACE PLANNING (RESTRICTED WATERS)

Things to establish before the race

*Proximity of **topography**:*

Google Earth

- local contour map;
- cliffs;
- promontories;
- valleys;
- islands (most important when airstream stable);
- bays.

RACE PLANNING (RESTRICTED WATERS)

Things to establish before the race

*Possible **local shift**:*

- shoreside shifts;
- gusts over cliffs;
- bending over islands and promontories;
- sea breeze (stable) bent when coming up against high ground;
- flow into bays;
- holes in the wind in lee of islands.

RACE PLANNING (RESTRICTED WATERS)

Things to establish before the race

***Tidal streams**:*

- state of the tide during the race;
- set of stream past marks and coastal inlets;
- streams emptying from estuaries;
- back eddies in bays;
- attention a the change of the sea temperature when the tide change (important for the sea breeze).

RACE PLANNING (RESTRICTED WATERS)

Things to establish before the race

***Fronts**, etc.:*

- any fronts likely to cross area?
- Shifting pressure systems?
- Lows…

RACE PLANNING (RESTRICTED WATERS)

Things to establish before the race

*If **frontal shifts**?*

- New wind veered to old;
- new wind quality (will there be a permanent wind shift?)…

RACE PLANNING (RESTRICTED WATERS)

Things to establish before the race

*If **sea breeze shift**?*

- Most likely new direction is 10°-20° left of directly onshore;
- consider other lesser shifts in moderate winds (oscillating wind for light sea breeze).

RACE PLANNING (RESTRICTED WATERS)

Things to establish before the race

*If very **late finish**?*

- Lose sea breeze?
- Shift back to gradient replacing sea breeze?
- Flat calm?

RACE PLANNING (RESTRICTED WATERS)

Things to establish on the spot

*Mean wind **direction and speed**:*

- measure in the sea (use handle or fixed anemometer…)

RACE PLANNING (RESTRICTED WATERS)

Things to establish on the spot

*Mean wind **mark**:*

• try to establish a sight mark in the eye of the mean wind as far away as possible;

• use as a reference for shifts.

RACE PLANNING (RESTRICTED WATERS)

Things to establish on the spot

*Type of **air stream**:*

- Cu day;
- warm, poor visibility day;
- showery day…;
- look the clouds.

RACE PLANNING (RESTRICTED WATERS)

Things to establish on the spot

***Position** of marks and **wind direction**:*

- inshore marks:
  - shoreside shifts?
  - sea breeze shifts?
- Offshore marks:
  - sea breeze shifts or calms?

RACE PLANNING (RESTRICTED WATERS)

Things to establish on the spot

***Sea breeze**:*

- possible?
- When?

RACE PLANNING (RESTRICTED WATERS)

Things to establish on the spot

*When the **sea breeze blows**:*

- what is new tactical situation?

RACE PLANNING (RESTRICTED WATERS)

Things to establish on the spot

*Review the **large scale shift timing**:*

• cannot time fronts accurately enough, so eye to windward if frontal situation passing;

• is warm front coming?

RACE PLANNING (RESTRICTED WATERS)

Things to establish on the spot

***Quality assessment**:*

- recognize normal shift day and time shift pattern;
- recognize abnormal shift pattern if it exist and time shift pattern;
- assume tacking to variables paramount and other tactical considerations secondary.

RACE PLANNING (RESTRICTED WATERS)

Things that help the day go smoothly

***Know the way the wind blows**:*

• get the forecast the night before AND in the morning. Methods are given above.

RACE PLANNING (RESTRICTED WATERS)

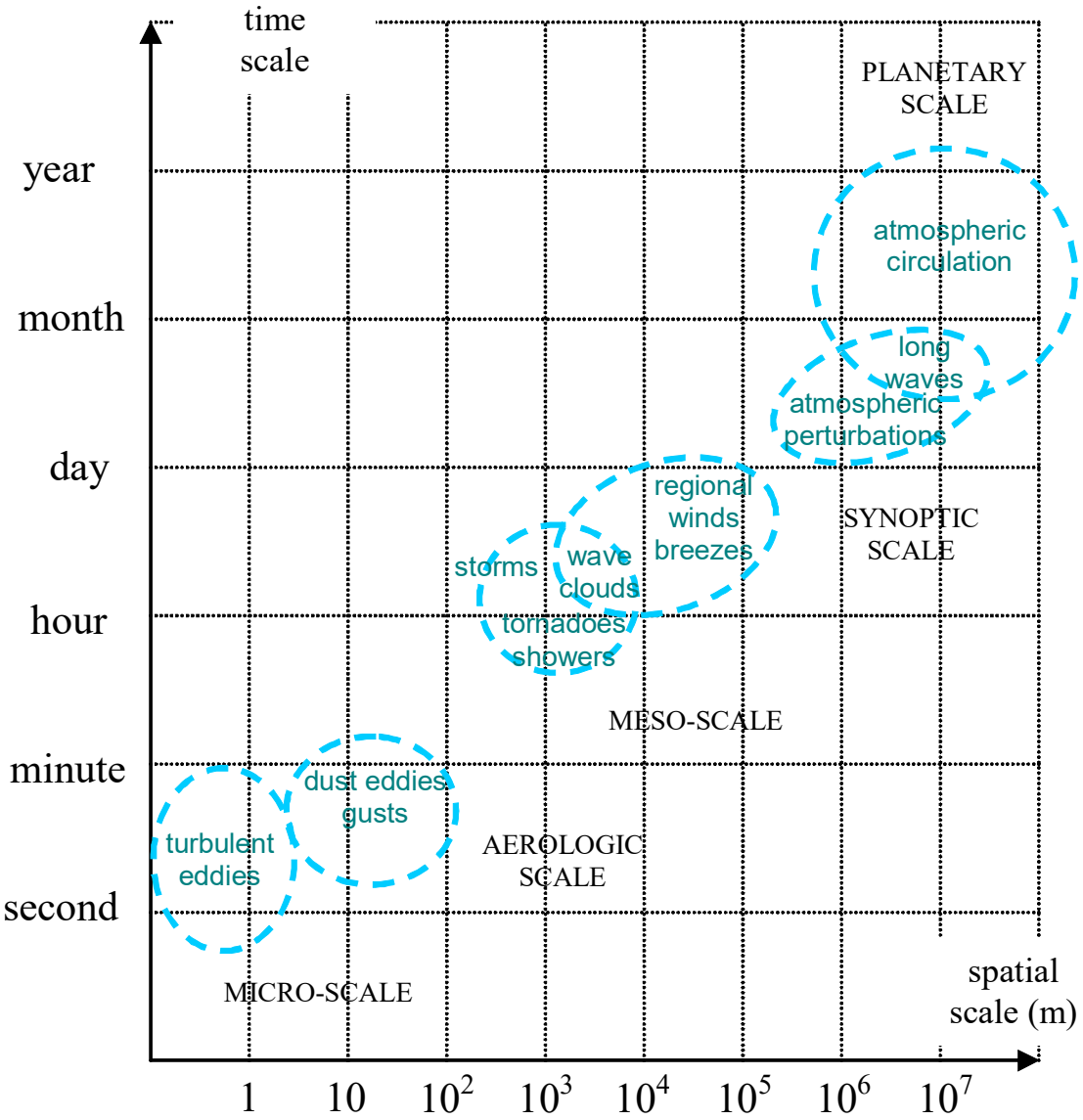
Things that help the day go smoothly

*Look for possible **trouble**:*

- forecast can be WRONG;
- search and look the signal that help you to understand if the forecast is TRUE or FALSE (pressure, sky and clouds, humidity…).

The meteorological models and the effect of the sea breeze

Spatio – temporal scales



Very large spectrum of scales for atmospheric modelling, which can not be reproduced in a simulation :

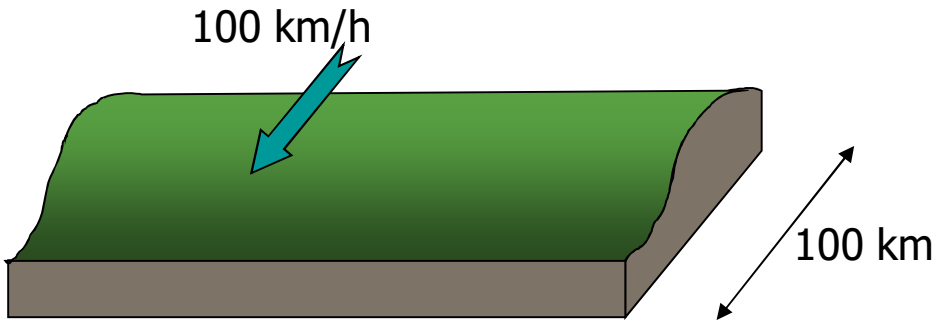
induces too large a domain or too small a grid

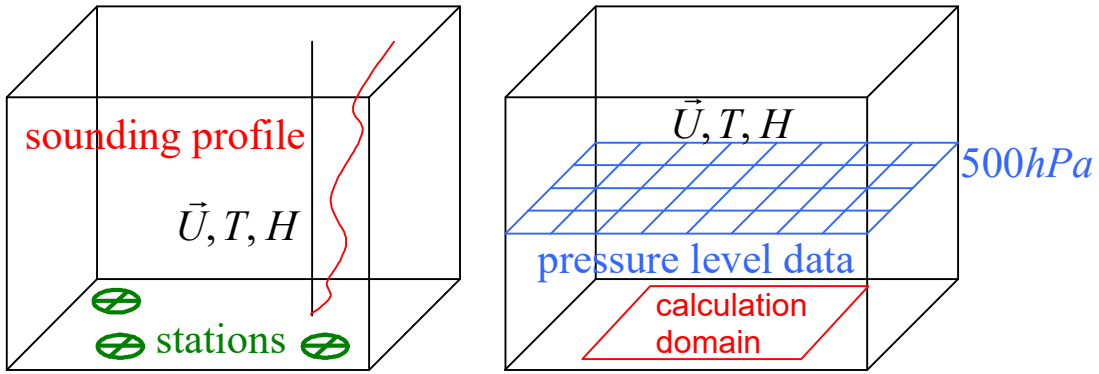
equilibrium between calculation time and precision

cannot be computed with a direct numerical simulation (DNS)

turbulence models

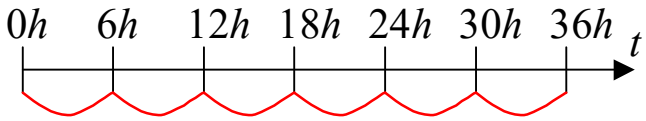
Initialisation – boundary conditions





Need to know atmospheric conditions outside the domain (synoptic conditions) :

nudging every 6 or 12 hours



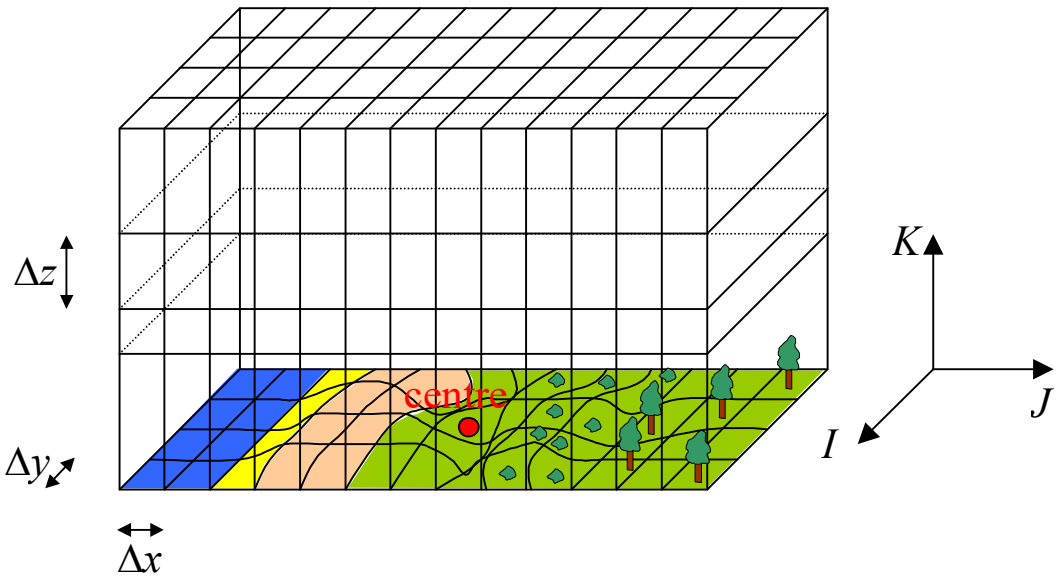
periodic boundary conditions

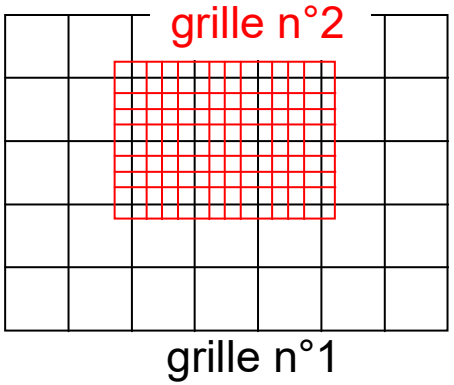
generally from experimental data or from synoptic model (ECMWF in Europe)

https://www.windy.com

Gradient wind: models ECMWF 9km and GFS 22km

Calculation domain



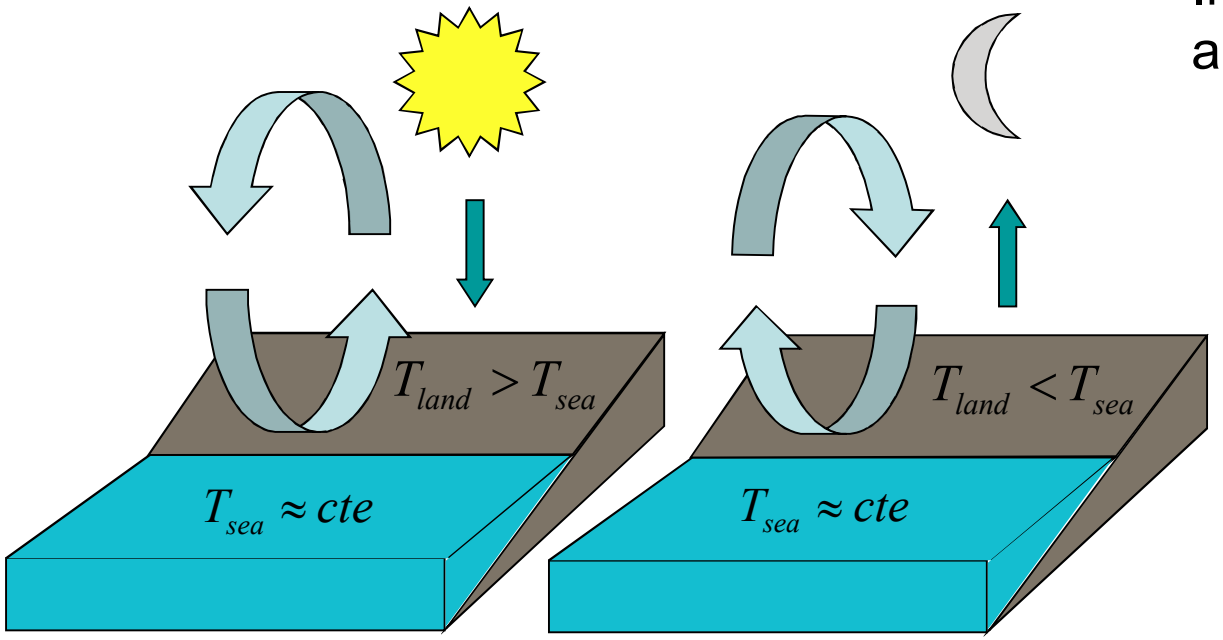


Embedded grids for local refinement

Domain parameters :

- cell number and size
  - effects on stability, precision and calculation time
- geographic location
  - effects on radiation, Coriolis force
- topography, land percentage
  - effects on flow, same precision as cells
- vegetation, soil
  - effects of roughness, evaporation, albedo
  - hard to define
- cities
  - effects of roughness, heat, albedo
  - modify boundary layer

Coastal zone specifics



sea breeze

land breeze

Interface between land and sea :

- abrupt changes in roughness, heat, albedo
- humidity and evaporation
- differences in temperatures induce changes of stability in atmospheric boundary layer
- breezes due to thermal effects
  - can modify synoptic conditions

https://www.windy.com

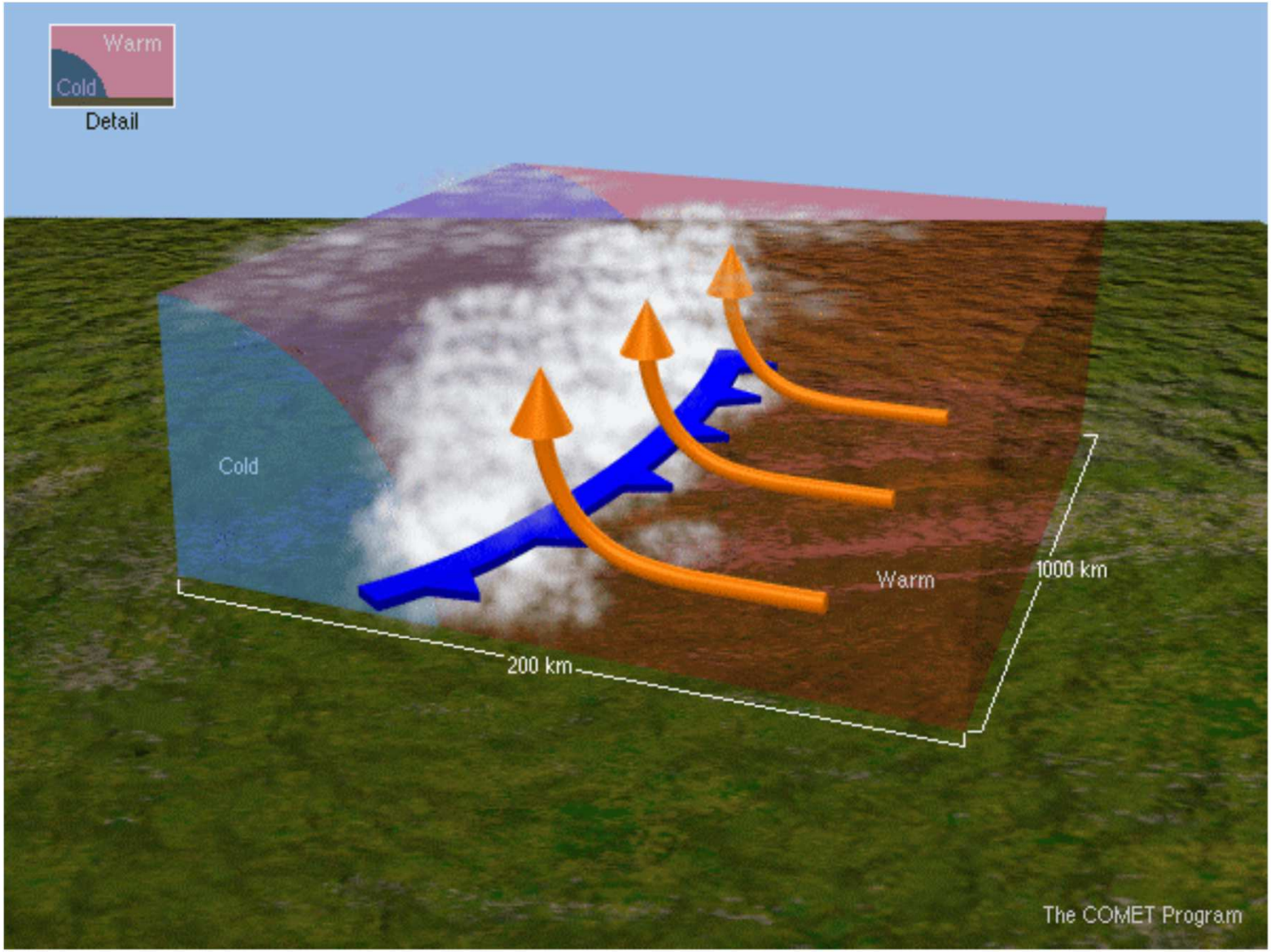
Local wind and sea breeze simulation: models NEMS 4km and ICON 7km

Fronts

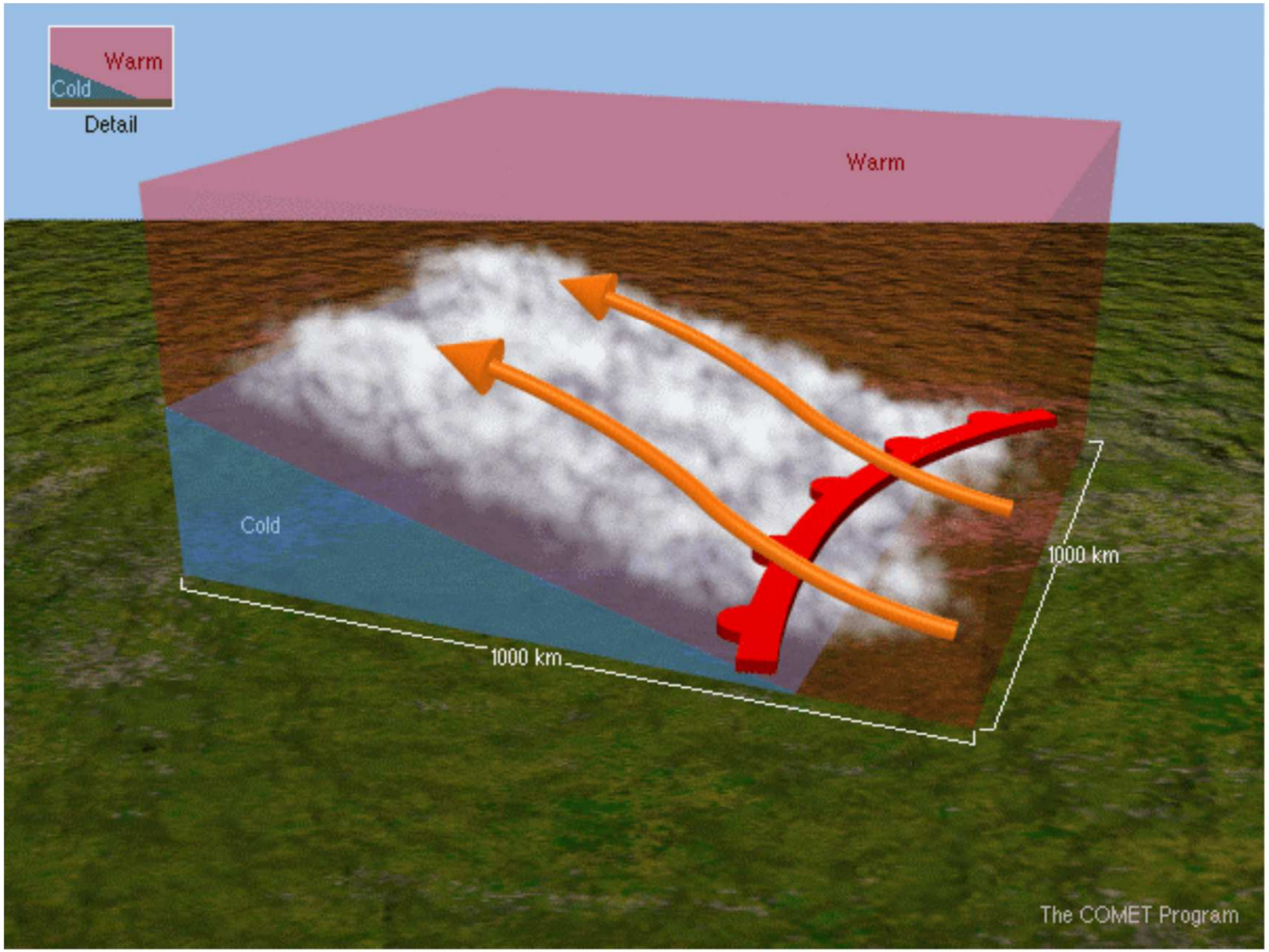
Fronts and Air masses

- A **front** is a transition zone between air masses of different densities.
- Frontal types:
  - Cold front
    - Zone where colder air is replacing warmer air
  - Warm front
    - Zone where warmer air is replacing a retreating colder air mass.
  - Stationary front
    - Zone that has little or no movement.
  - Occlusions
    - 2 types: Warm and Cold
    - Occur during mature phase of storm development

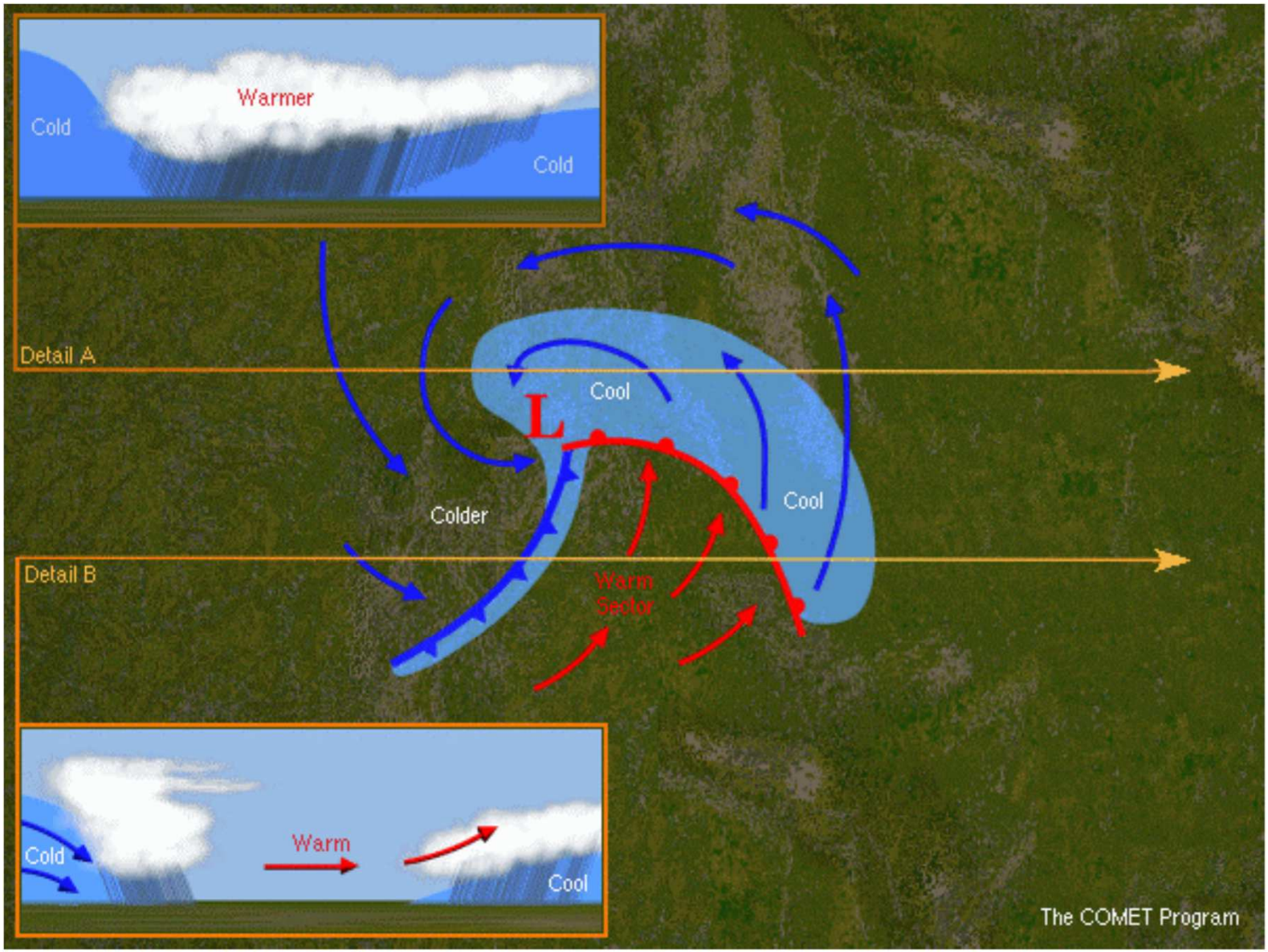
Cold front structure



Warm front structure



3-D Frontal Structure



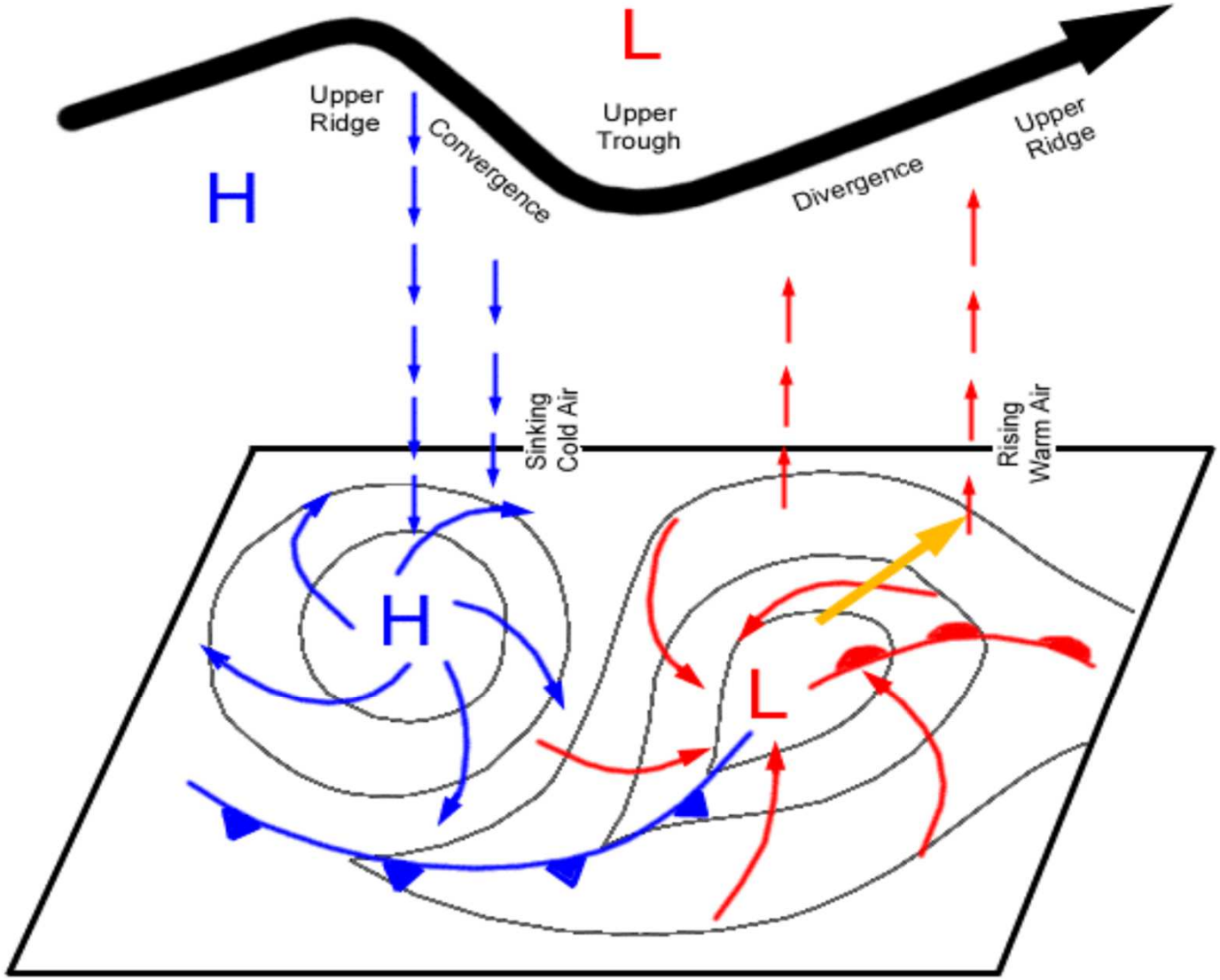
Typical sequence of weather associated with a warm front in North Hemisphere

	Front approching	As it passes	In warm sector
wind	increases&backs	veers	direction steady
cloud	sequence of Ci, Cs, As, Ns, St	Ns	St, Sc
rain	become heavier&more continuous	stops or turn to drizzle	light rain
visibility	deteriorate slowly	deteriorates	moderate or poor
pressure	falls at increasing rate	stops falling	falls if depression deepening, otherwise steady
dewpoint	little change	rises	little change

Typical sequence of weather associated with a cold front in North Hemisphere

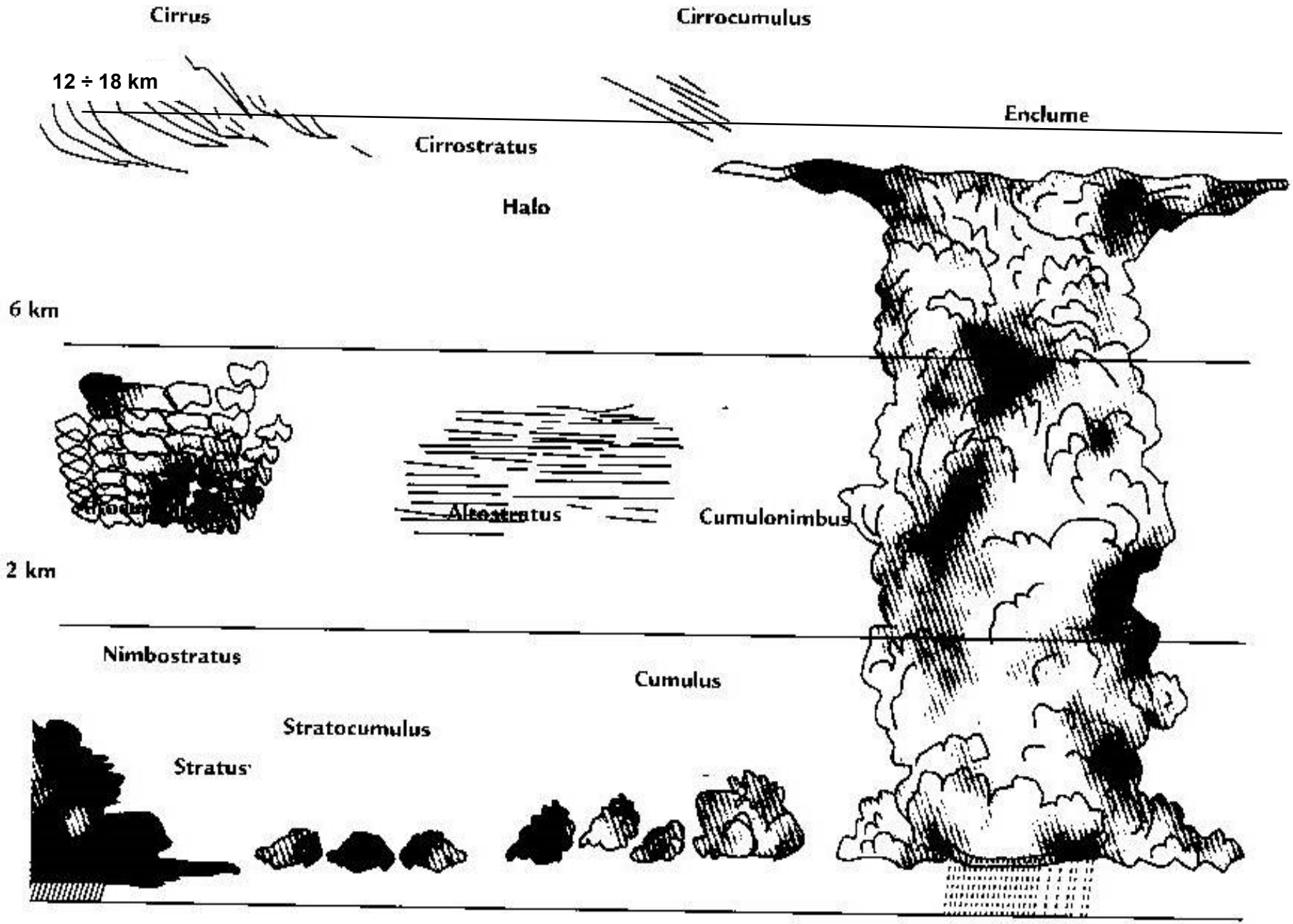
	Front approching	As it passes	In cold air behind it
wind	backs&increases close to front	sudden veer often with squall	probably backs a little then steady; gusty&strong
cloud	St&Sc thickening Ns	Cb	often total clearance, Cu
rain	heavy rain near front	heavy rain, peraphs hail&tunder	usually fine for 1-2hours, then showers
visibility	moderate to poor	poor in rain	very good
pressure	falls near front	sudden rise	rise gradually levels off
dewpoint	little change	sudden fall	little change

Flow associated with developing Low

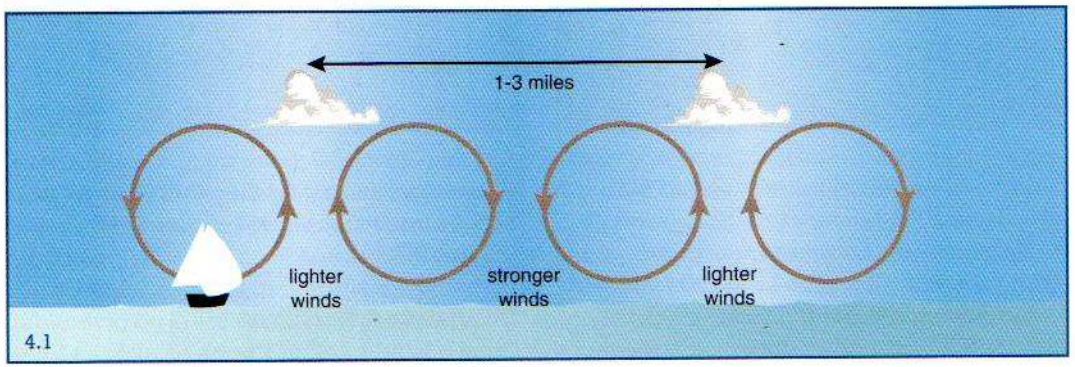


The COMET Program

Winds near clouds

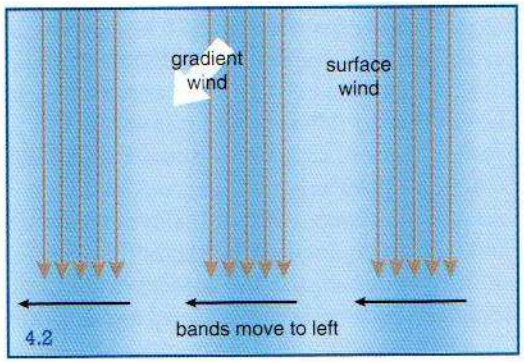

Cirrus
Cirrocumulus
12 ÷ 18 km
Enclume
Cirrostratus
Halo
6 km
Altostratus
Cumulonimbus
2 km
Nimbostratus
Cumulus
Stratocumulus
Stratus

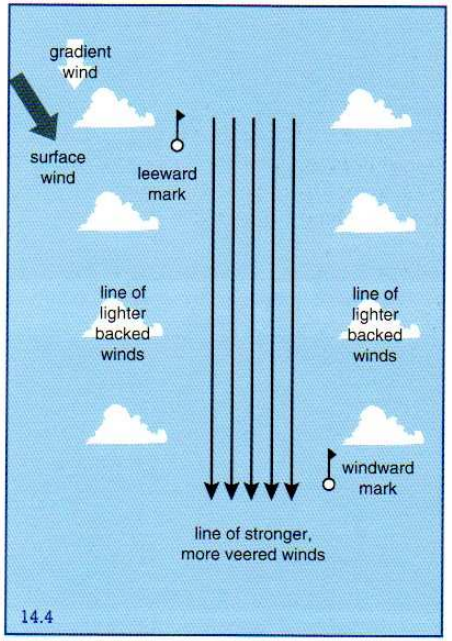
ROLL CLOUDS (1)



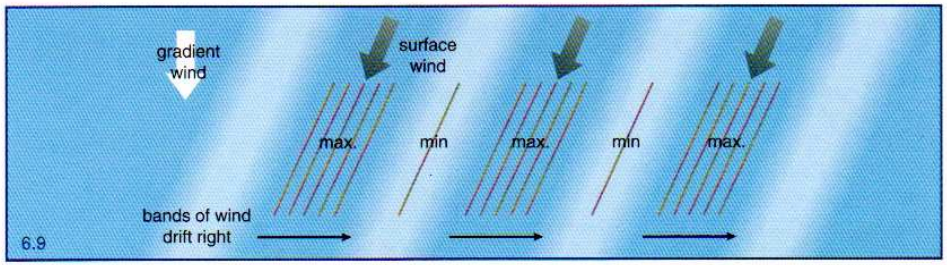
ROLL CLOUDS (2)

Northern Hemisphere

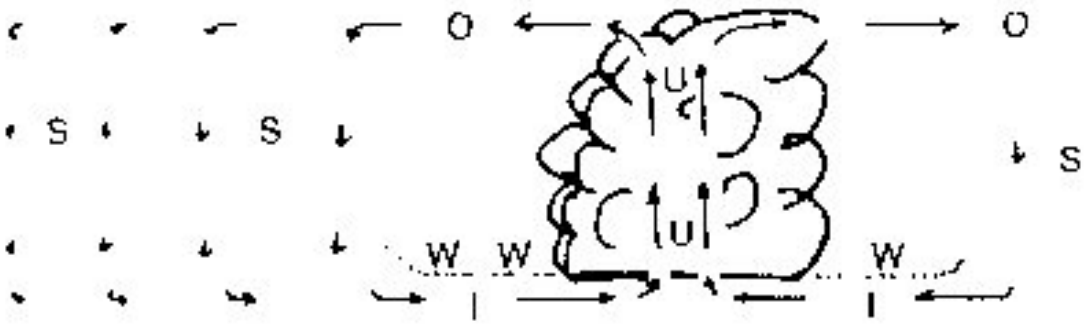




Southern Hemisphere



CUMULUS CLOUDS – NON RAINING (1)

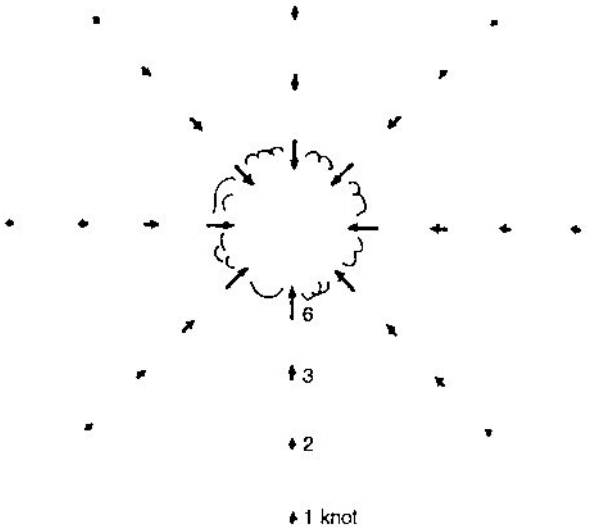


U = Updraught as warmed air rises
O = Outflow at cloud top level
S = Gentle subsidence over wide area
| = Inflow at and below cloud base level
W= Wisps of cloud sometimes form when inflow is strong enough to create turbulence.

Fig 8.4 Circulation around and below non-raining cloud

CUMULUS CLOUDS – NON RAINING (2)

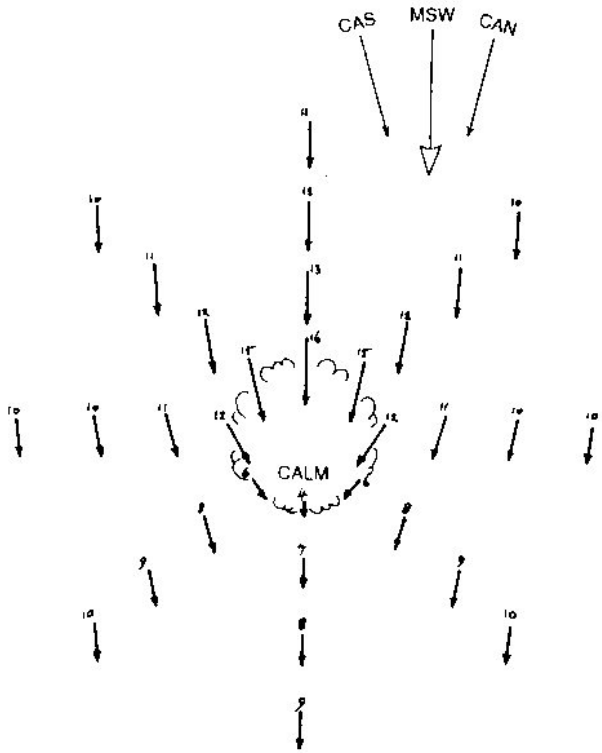
Steady clouds…



Speeds suggested are typical, and indicate change of speed with increasing distance from cloud edge.

Fig 8.5 View from above of surface wind pattern under low-based, non-raining cumulus cloud.

Moving clouds…

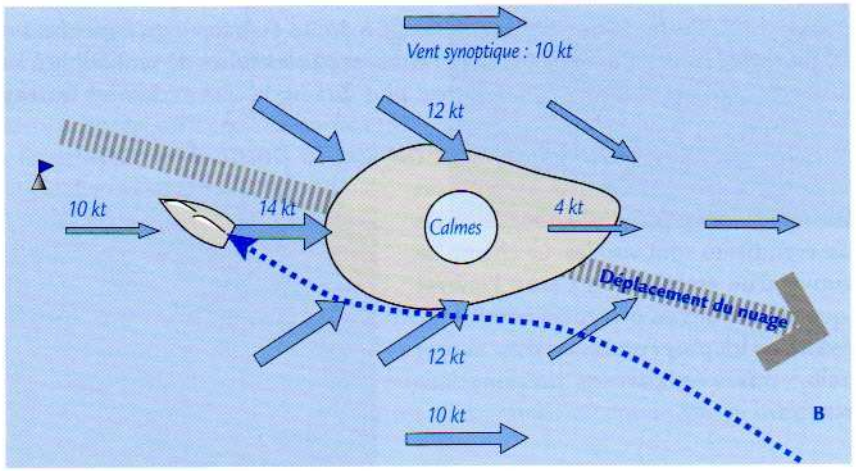


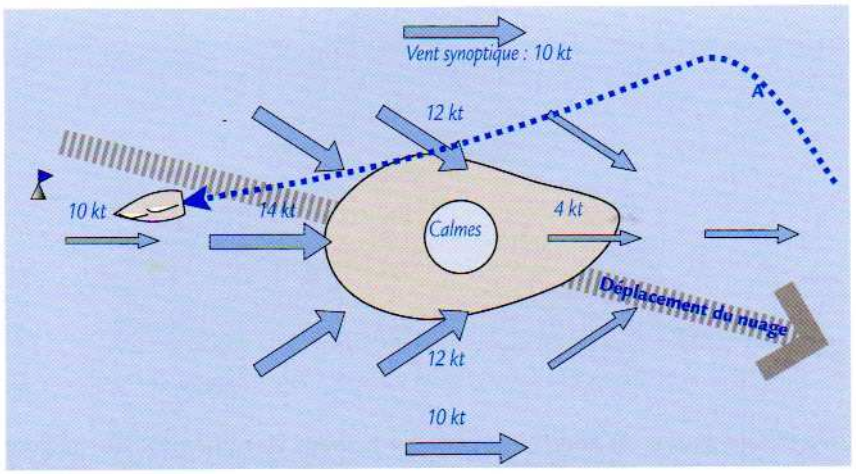
Surface wind pattern in 10 knot breeze near and under low-based, non-raining Cumulus cloud.

Note:
You sail in the surface wind -
but the cloud is steered by the gradient wind aloft - so
MSW = Mean direction of surface wind
CAS = Cloud approach, southern hemisphere
CAN = " " northern "

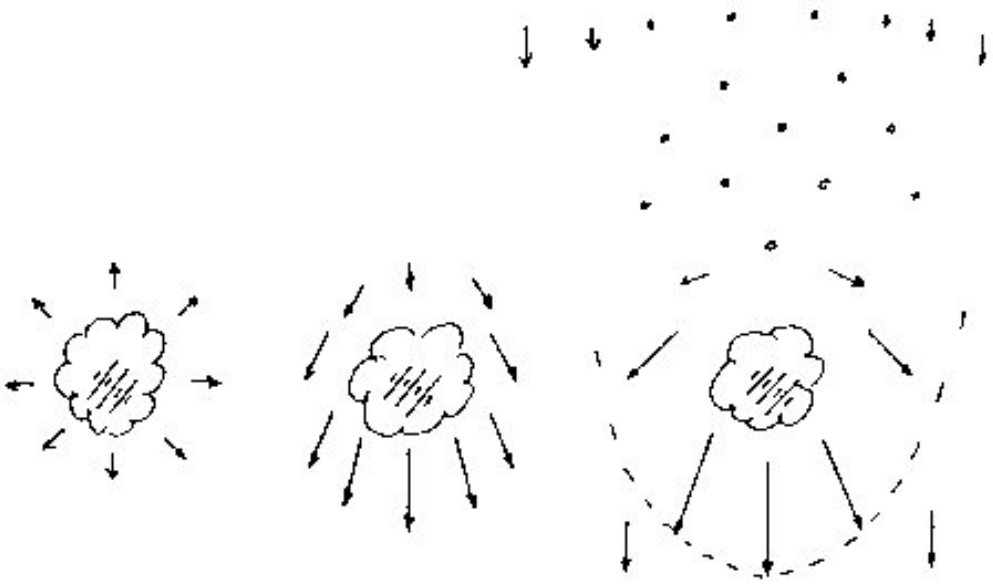
Fig 8.6 Surface wind pattern near non-raining cloud

CUMULUS CLOUDS – NON RAINING (3)





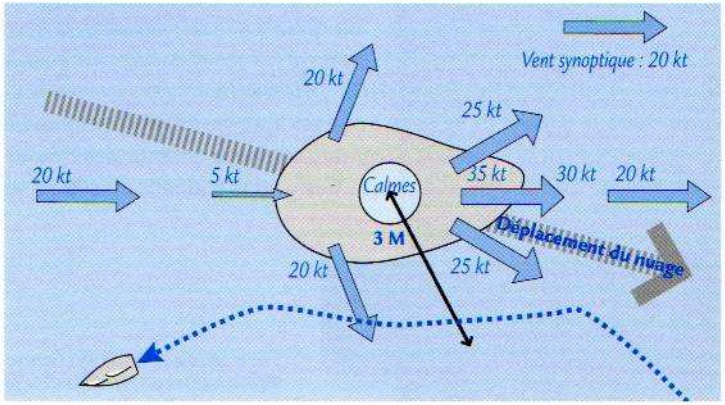
CUMULUS CLOUDS – RAINING (1)

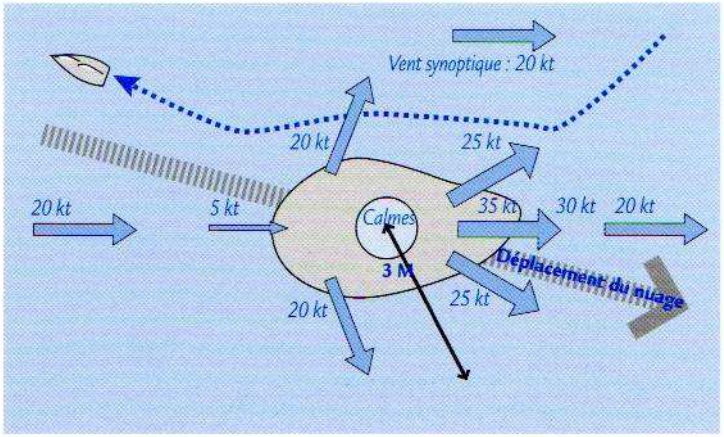


(a)	(b)	(c)
Small cloud Raining Calm Outflow 5 knots	Small cloud Raining Wind 10 knots Outflow 5 knots Simple pattern No calm area.	High based cloud Raining Wind 10 knots Outflow 10 knots, and cold Complex pattern Extensive calm area

Fig 8.8 Surface wind patterns near raining clouds

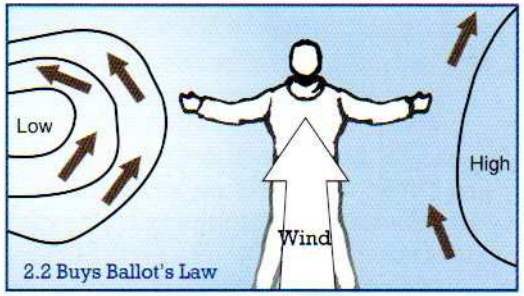
CUMULUS CLOUDS – RAINING (2)

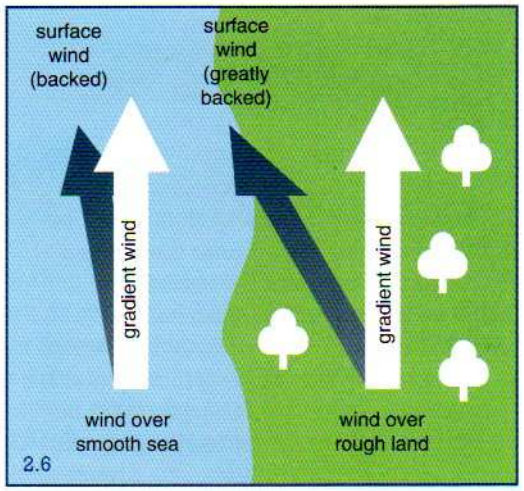




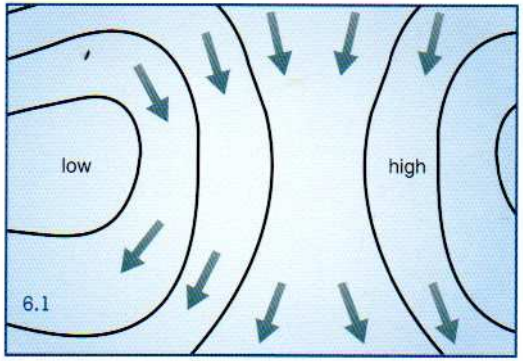
Wind facts

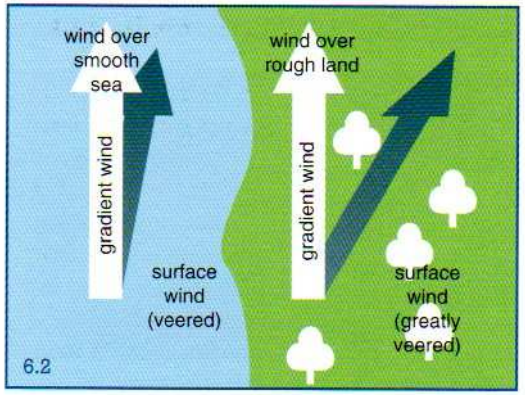
Northern Hemisphere



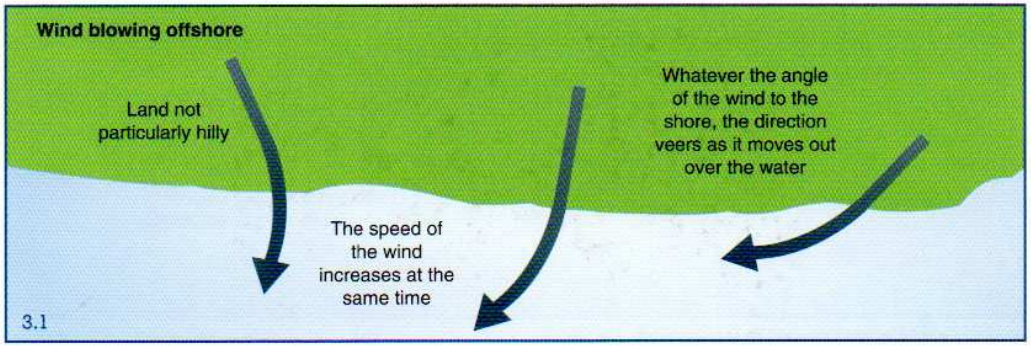


Southern Hemisphere

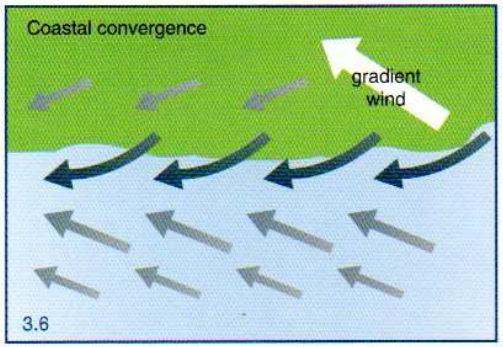




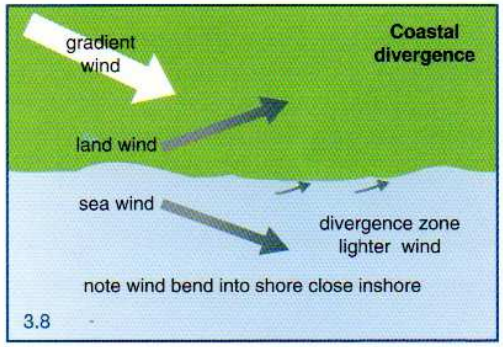
Northern Hemisphere: winds near coasts



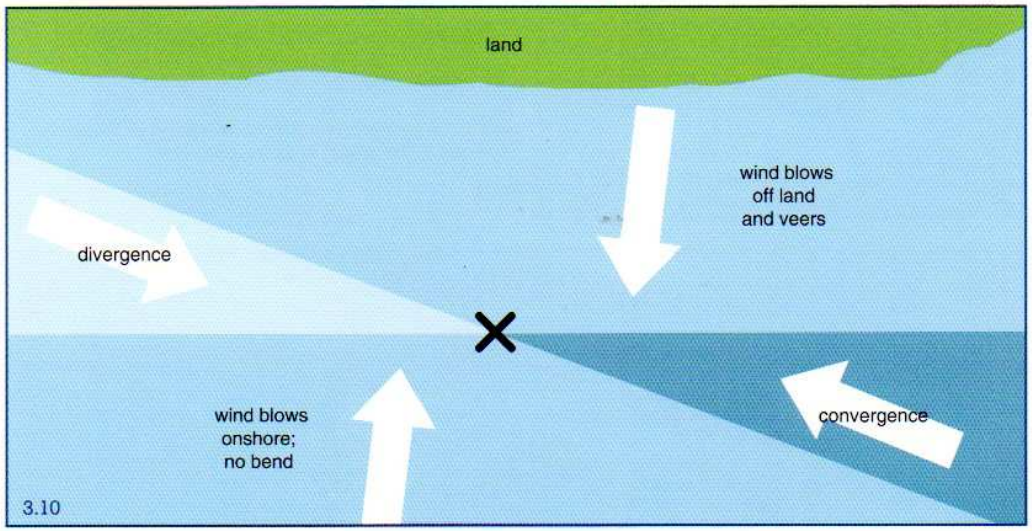
3.1 Above: with the wind blowing off the shore the wind veers and increases. On a gusty day the changes are most apparent in the lulls.



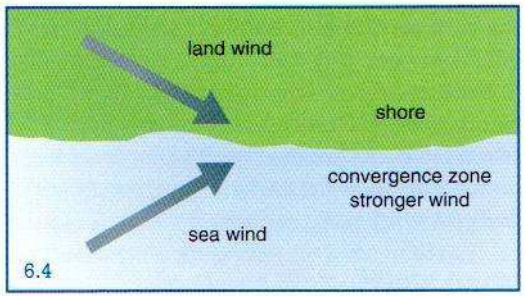
3.6 Above: with the wind blowing along the shore and the land up on your left (facing the wind) expect a band of up to 25% stronger wind 1-5 km offshore.

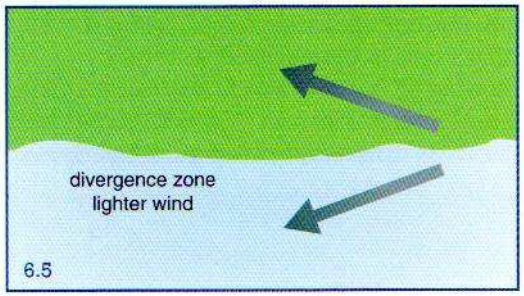


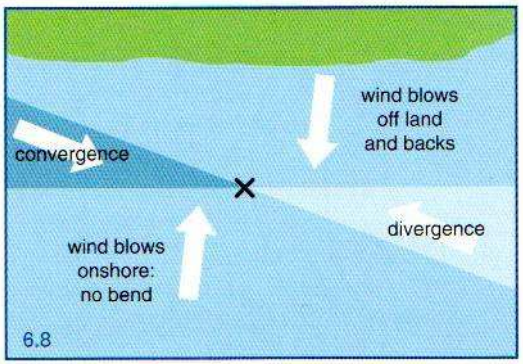
3.8 Above: with an alongshore wind and land on your right (facing the wind) expect lighter winds within 5 km of the shore, except on a sunny afternoon. Below: summary of costal effects on wind.



Southern Hemisphere: winds near coasts





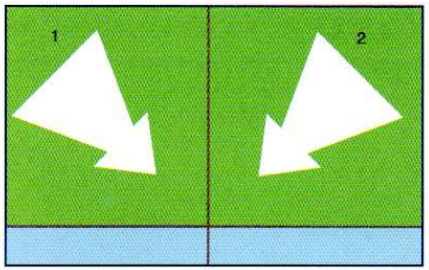


Northern Hemisphere: the sea breeze with gradient wind

The sea breeze

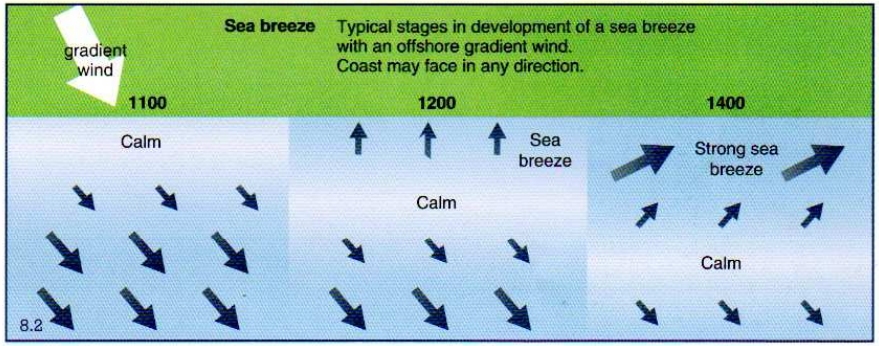
Summary and signs

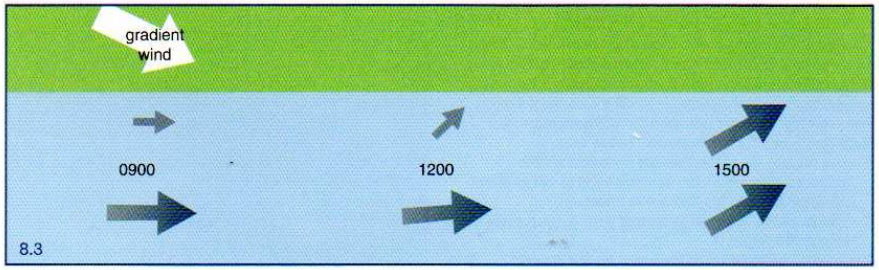
- Clear morning sky, or thin cloud.
- Temperature over land rises above sea temperature.
- Cloud offshore begins to dissolve.
- Initial offshore wind, if any, dies inshore.
- Gentle drift starts onto shore.
- Breeze builds and extends seawards, preceded by calm zone separating initial wind and sea breeze.
- Cloud over land, if any, more cumuliform.
- Breeze veers some 40 degrees in first hour then more slowly until 20 degrees back from shoreline.
- Strength increases; maximum Force 4 or 5 always near the shore.
- Breeze dies towards sunset.

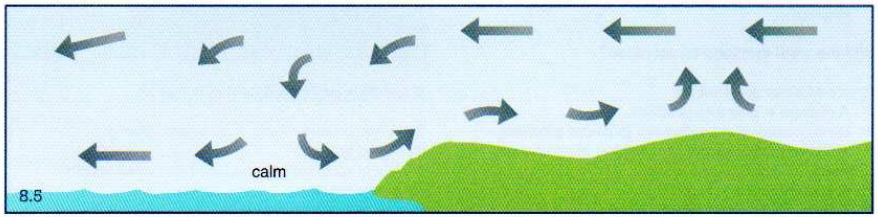


Above: The sea breeze Quadrants 1 and 2.

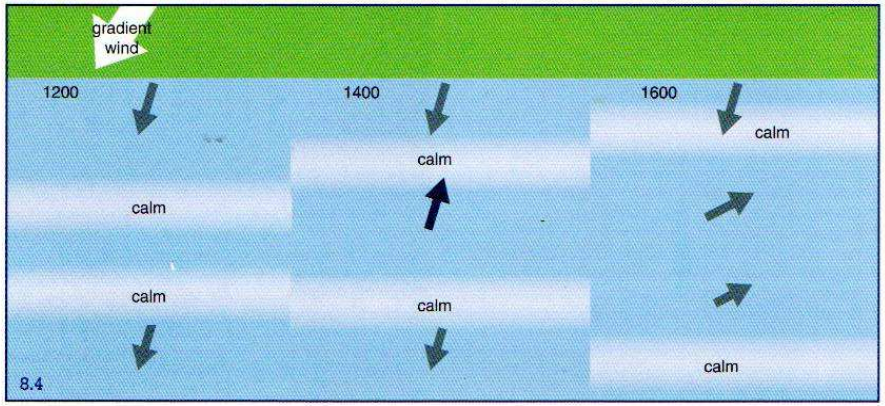
Below: the development of the sea breeze with a Quadrant 1 gradient wind. Quadrant 2 is shown overleaf.

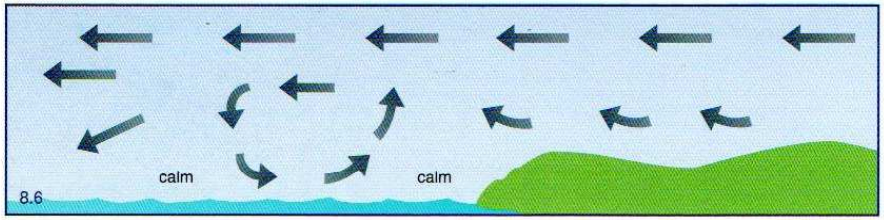






The sea breeze with a Quadrant 2 gradient wind





Afternoon wind with gradient wind onshore

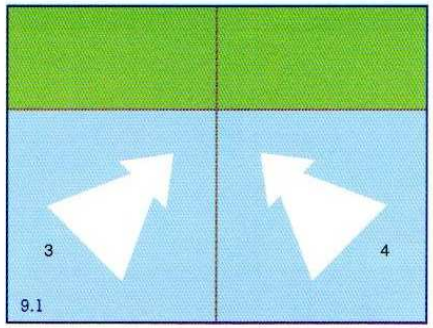
Heating of the land causes a fall of pressure which adds a component of wind of 4 or 5 knots parallel to the coast. This augments a Quadrant 3 wind especially if it is nearly parallel to the coast, but tends to kill a Quadrant 4 wind. The major differences between the enhancement of a Quadrant 3 wind and a true sea breeze are:

- The full benefit of the thermal enhancement is achieved only when the morning wind is within about 20 degrees from the line of the coast.
- The increase in speed is spread over a zone several kilometres wide.
- The change in direction depends on the strength and direction of the initial wind. It may only be a few degrees.

Will the wind increase or decrease?

Check whether there will be:

- A change in pressure gradient.
- Development of a sea breeze (offshore gradient).
- Thermal enhancement or reduction of an onshore wind.
- A change in tide.
- A band of stronger or lighter wind.

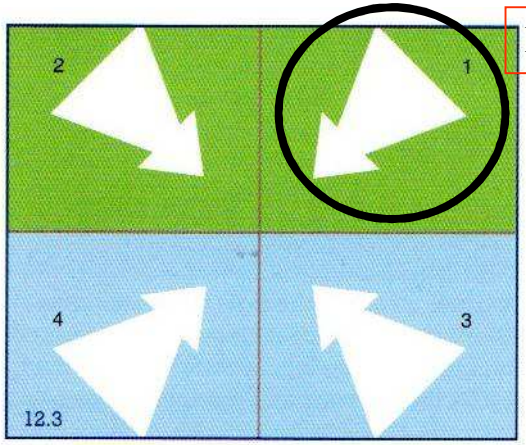


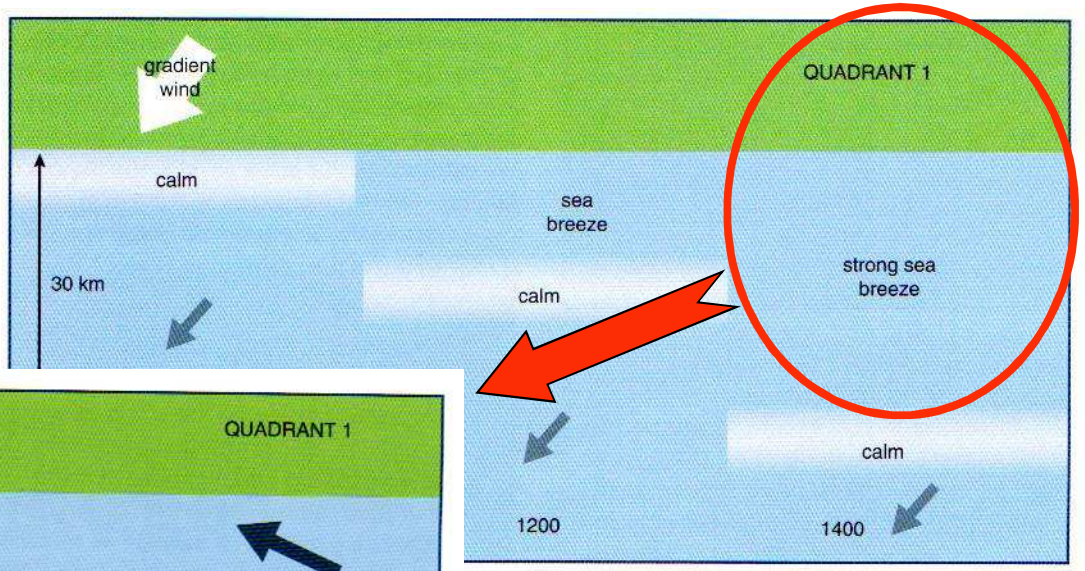
If one side pays on a beat is it due to:

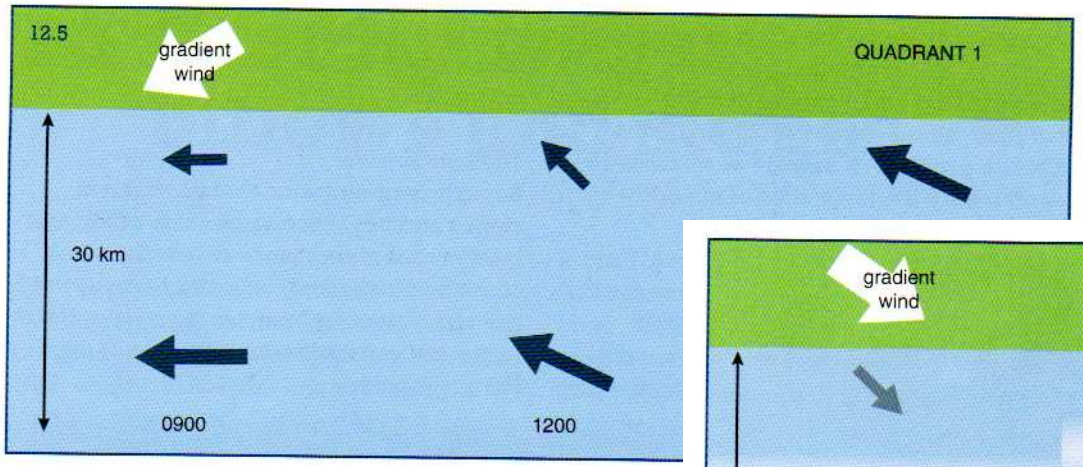
- A feature of the land or an island upwind.
- A sea breeze.
- Water temperature variations across or upwind of the course
- Current or tide variations.

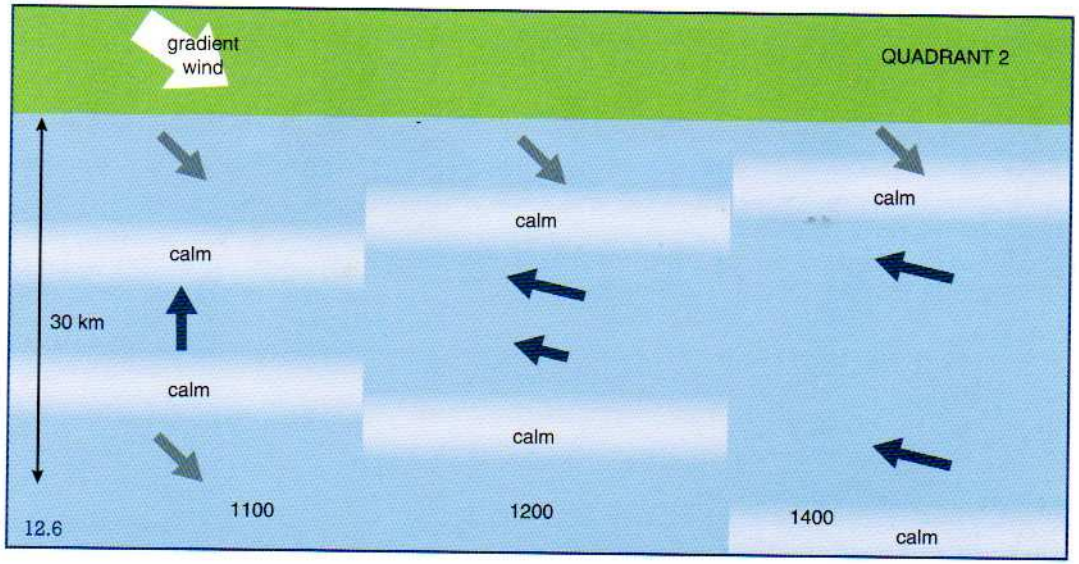
Southern Hemisphere: the sea breeze with gradient wind

Best gradient wind…









THE TWO SURFACE WINDS…

- **Light air**
- **Breeze**

Light air: the **light airs** are those winds with an average speed of about 5kts or less. Their primary characteristic is that the flow speed is feeble near the surface and increases steadily with increasing height up to above 10m in 5kts but less in lighter airs. The weather forecasts is **not reliable** in the **light airs**…

Breeze: the **breezes** are those winds which have the properties of a turbulent boundary layer. The **breezes** are winds with average speeds of about 6kts or more. Their primary characteristic is that the change of speed with height is confineed almost entirely to the one to two meters closes the surface. The weather forecasts is **realiable** when the **wind speed is included between 7-8kts to 20-22kts**. **Up to 20-22kts** we have to expect an **underestimation in the forecast of the wind speed**…

- **Light air** patterns: *steady, unsteady, pulsing, oscillating, ribboning*
- **Breeze** patterns: *steady, wandering, pulsing, convergent/divergent, channeling, gusty*

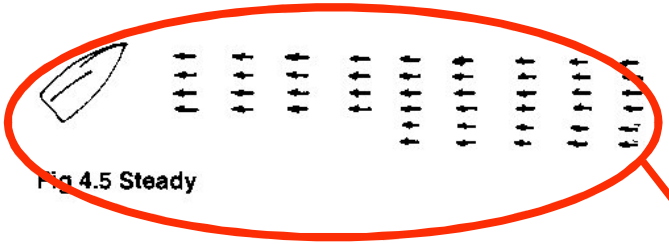


Fig 4.5 Steady

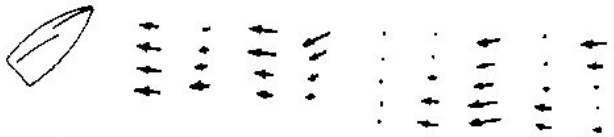


Fig 4.6 Unsteady

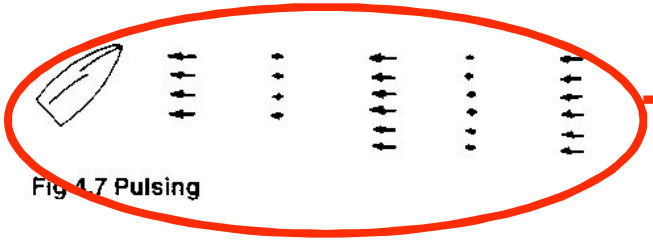


Fig 4.7 Pulsing

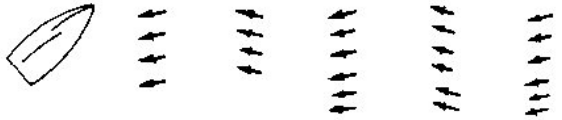


Fig 4.8 Oscillating

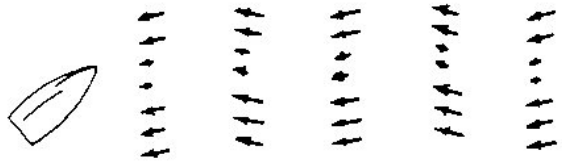


Fig 4.9 Ribboning

Arrow lengths indicate wind speed ← = 5 knots
Arrow directions suggests wind direction • = calm
Spacing of changes is typically 100 - 200 metres

Figs 4.5 to 4.9
Helmsman's visualisation of approaching air

Light air patterns: ***steady, unsteady, pulsing, oscillating, ribboning***

Breeze pattern: *steady*

Breeze pattern: *pulsing*

Breeze pattern: *convergent/divergent* (see the following slides…)

Breeze pattern: *wandering*

The **wandering breeze** will form on days when the air is heated strongly from the sea, the wind speed is beetween 6kts and 9kts and a Low pressure is dominant. The mechanism, circulation and surface winds which result are indentical in principle to that of *unsteady light air*…

Fig 4.6 Unsteady

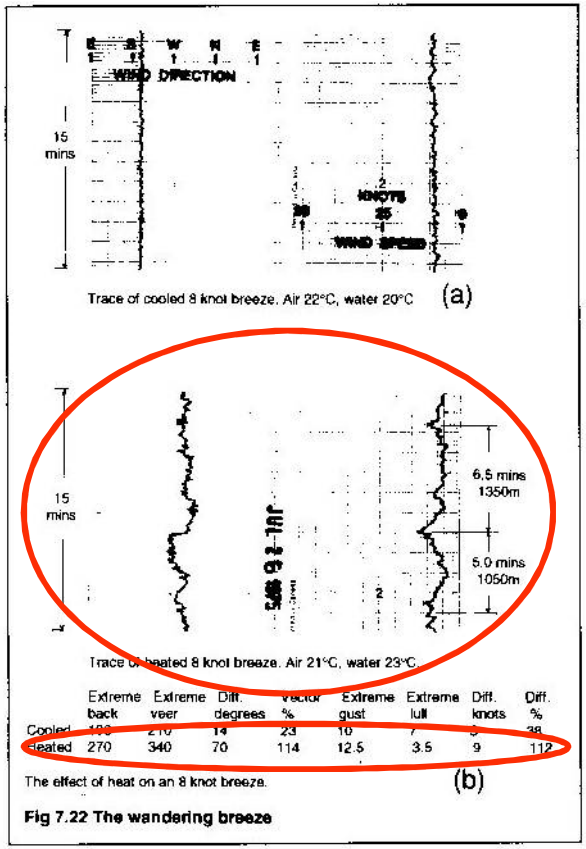


Fig 7.22 The wandering breeze

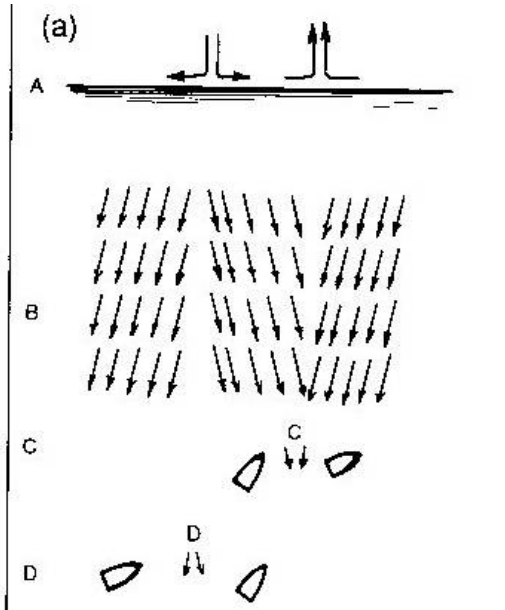
• Remember (in this pattern): ***"The gusts which don't come towards you"***. In fact they do, but much more slowly than one would expect. Normal technique is to sail to them and then to sail to remain in them. When there is a choice when you are sailing crosswind, sail to the upwind gust, otherwise your advantage will probably short-lived because the calm in the middle of the cell is likely to catch you later…

• On the assumption that you will experience two changes of wind speed and two changes of wind direction as you sail through each cell, when you sail upwind you can expect that there will be a significant change of something about every 200m or 2' on average… **It is as well to keep this in mind!!!**

• I have dealt to fairly thoroughly with the **wandering breeze**, because it is one of the commonest winds in which we race. It is also one of the most challenging to handle intelligently…

Breeze pattern: *channelling*

The **channelling breeze** can form when the heating becomes more intense. It is similar to *ribboning light air*, but occurs in stronger breezes and at about ten times the scale.



Cross wind convergence/divergence due to heat. Mechanism: strong heating causes lines of rising and descending air.

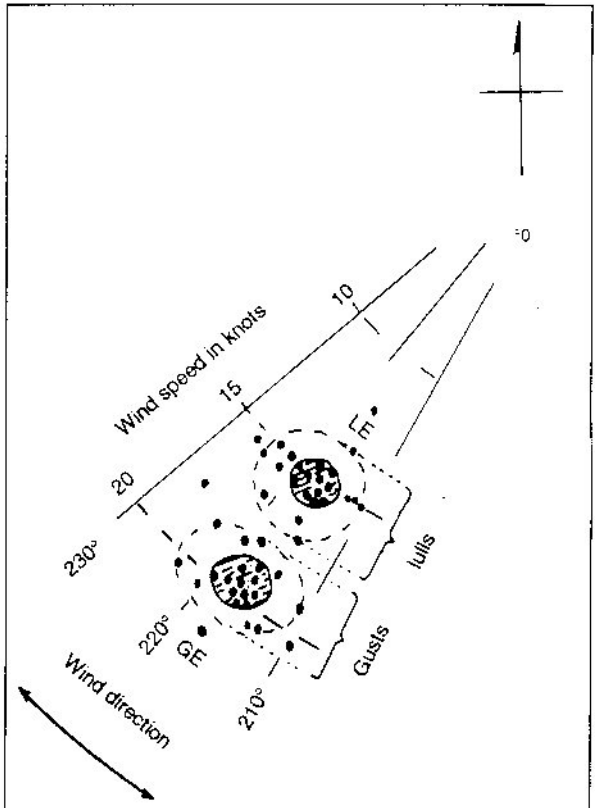
A = View looking upwind.
B = View of surface flows from above.
C = Windward boat gains in convergent situation.
D = Leeward boat gains in divergent situation.

Two open-water convergent/divergent situations.

ce.

- In appearance, the wind blows in upwind/downwind channels wich can last almost indefinitely. Between them are intervening channels of much lighter wind.
- The whole pattern usually moves crosswind slowly…
- The speed difference is so great as to be visually obvious…
- Typical dimension would be that the stronger-wind channels would be 200m to 300m across, while the intervening light-air channels would be perhaps twice that width.
- Note particularly that the stronger-wind channels are also zones of **diverging** air… Because of this, it is normal to find, when tacking upwind along the stronger-wind channel, that: ***"The boat won't point when approaching the core, but will point beautifully when through it"***…

Breeze pattern: *gusty*



50% of gusts and lulls fall within the shaded circles.
90% " " " " " " " dashed "
GE= Extreme gust
LE= Extreme lull
(Plots of average speeds and directions of 23 gusts and 24 lulls during one 30 minute period of breeze without heat.)

Fig 5.7 Plots of gusts and lulls

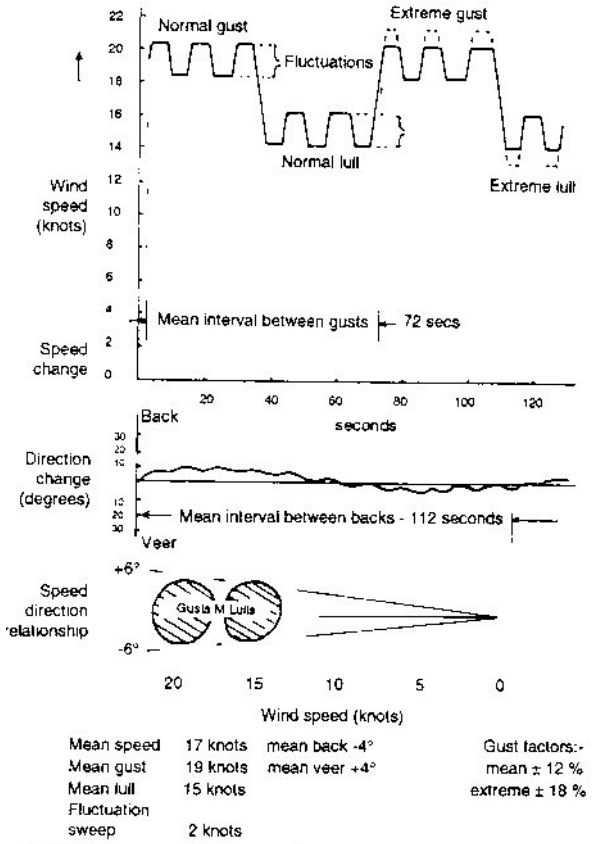


Fig 5.8 Signature of breeze without heat

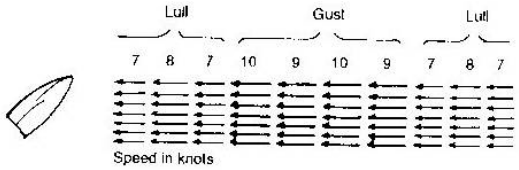
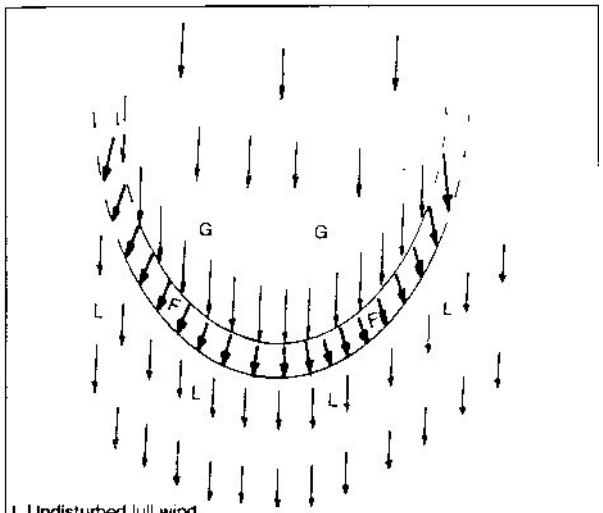


Fig 5.9 Helmsman's visualisation of a cool breeze

Breeze pattern: *gusty* (*the Fan*)

As the mass of each gust advances, it undercuts and pushes aside the slower air ahead of it. The air just ahead of each advancing shoulder of the gust is moved forcefully at almost the speed of the gust in a direction angled outwards from the gust's direction. This is the **Fan**…



L Undisturbed lull wind.

G Gust wind which undercuts the lull wind.

F The 'fan', a fringe of air 25 to 50 feet wide which is displaced outwards by the advancing gust, in a direction away from the gust edge.

The fan passes over the water too quickly to form wind lanes.

Fig 5.14 The fan

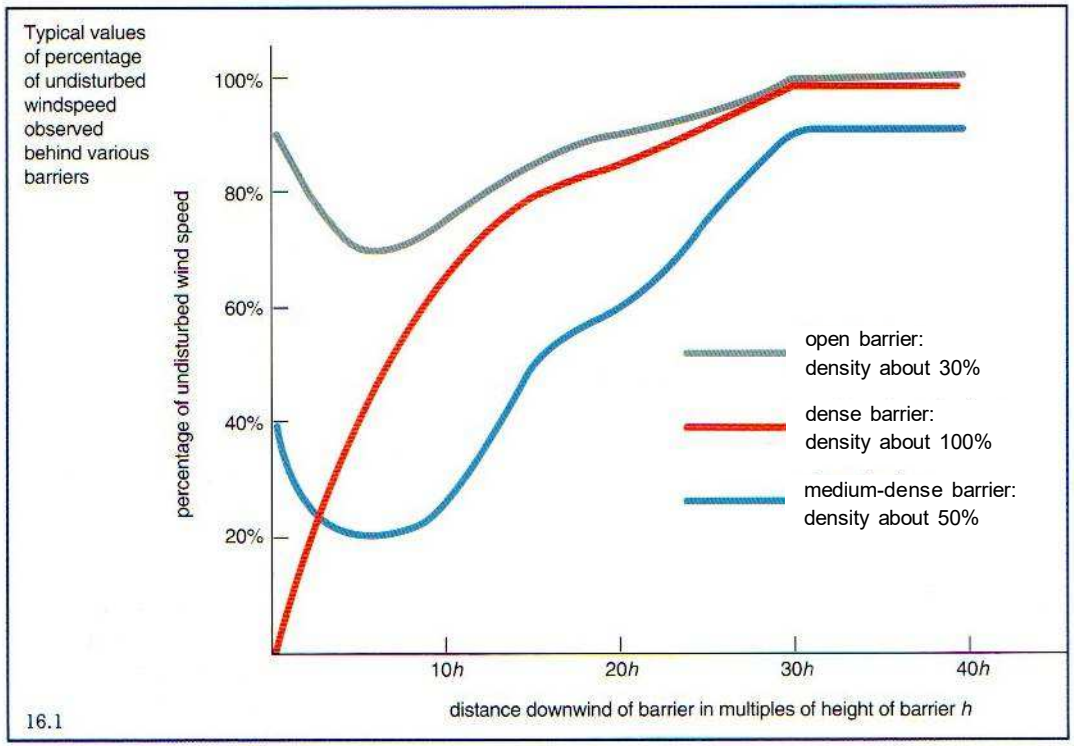
- The **Fan** passes over each part of the water surface so quickly, it makes no visible wind lanes.
- A helmsman ahead of an approaching gust will be able to see the wind lanes around him in the lull and also the wind lanes within the gust. Between the two there will be the **Fan**…
- This will appear to the helmsman as a wind of a different direction which has a dimension of two or three lenghts of a small boat!!!
- **ALERT**: crews who are aware of the fan can use this to free sheets, flick their boat onto a plane and steer along the fan at greatly increased of the VMG.
- **ALERT**: it is downwind that "riding the fan" really comes into its own. Crews of high-performance, planing, downwind tacking dinghies, or fast catamarans, can steer to intercept the fan and then bear away to accelerate in it and steer to stay in it…

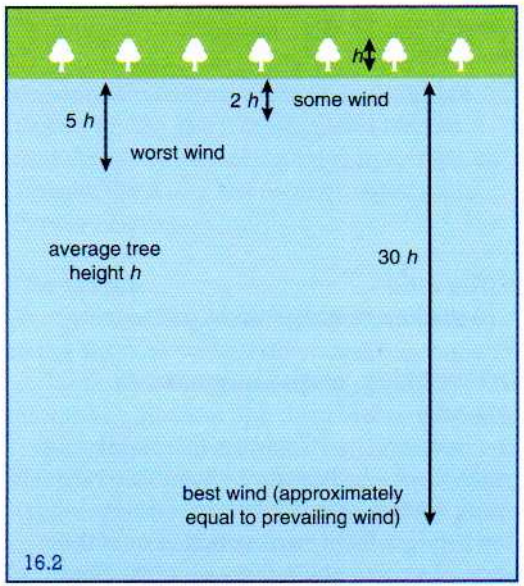
Obstacles in the wind

OBSTACLES IN THE WIND (1)

There are many types and densities of barrier: buildings, trees, forests, walls, fences and boats. Some are short, some tall, but their **influence on the wind** is a **function** primarily of the **height** and **average density** barrier.

Density might be loosely defined as *the amount of daylight that a barrier lets through*. Thus a brick wall has a density of 100%, a well spaced row of trees has a density about 30%...





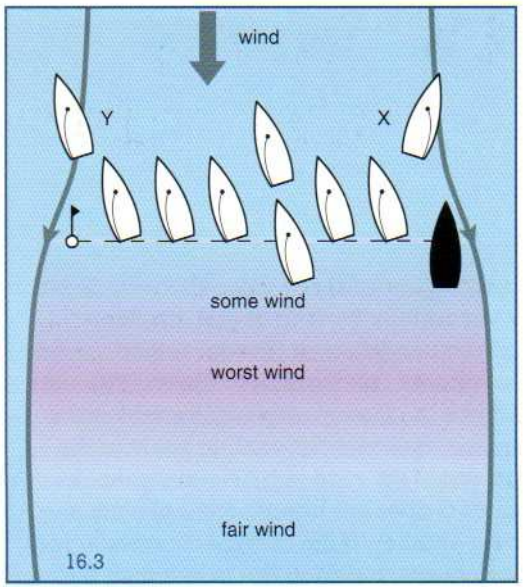
Open barrier

OBSTACLES IN THE WIND (2)

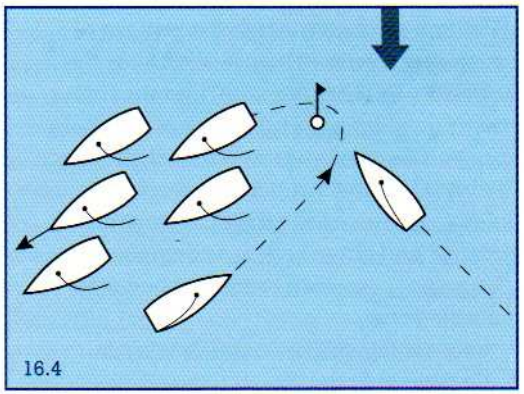
For all but the most solid barrier there is a zone of lowes wind speed about 5 times the height of the barrier downwind from it…

A medium to dense barrier is a much more effective obstacle to the wind than a dense one such as a brick wall or a thick hedge…

For most barriers other than the medium-dense variety, the wind recovers to 75% of its original average speed at a distance roughly 10 times the height of the barrier downwind…



A massed start of 100 or so boat could be described as a medium-dense barrier and it is likely to disturb the wind for a distance of 30 to 40 times its height downwind. The fleet a the start not only interferes with the wind but causes it to bend around the edges



You have to point up the dangers of approaching the windward mark on port tack if you are fairly well down to the fleet. The boats already on the reach will form a medium-dense barrier to the wind in which it will be almost impossible to sail…

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Dipartimento Interateneo di Scienze, Progetto e Politiche del Territorio

Sport Meteo

European Sailing Federation
EUROSAF

Meteorology and Weather Ana r Sailors:

Messages for U d Coaches

Thanks for your attention!!!

ndro Pezzoli, Ph.D.

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16th January 2019