EAS270_Ch14_Storms_C.odp
JDW, EAS U.Alberta, last mod. 4 Dec. 2016

Hurricane & tropical cyclone

- deep, vert.-stacked, synoptic scale thermal low
- energy derives from heat & latent heat gathered from very warm (>26°C) ocean surface layer
- 60-120 kph = trop. storm; >120 kph = hurricane
- occur late summer/early fall
- originating over tropical waters, at least 5° from the equator (Coriolis force an ingredient)
- 100-1000 km radius
- packed, circular isobars, no fronts
- central pressure may fall below 900 hPa

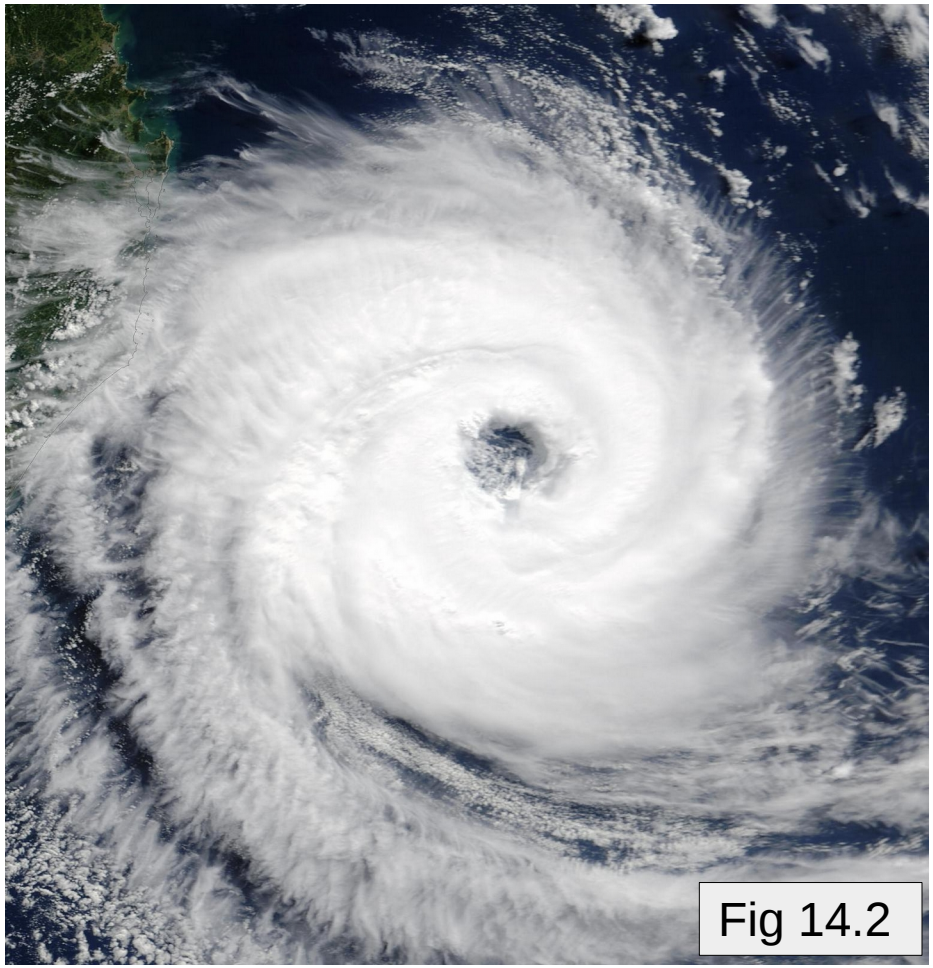


Fig 14.2

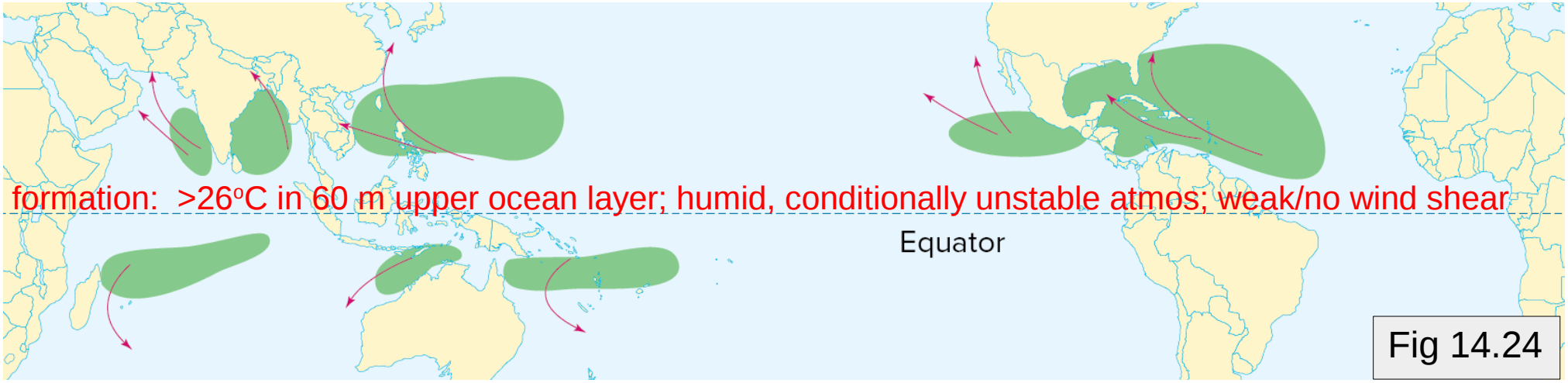
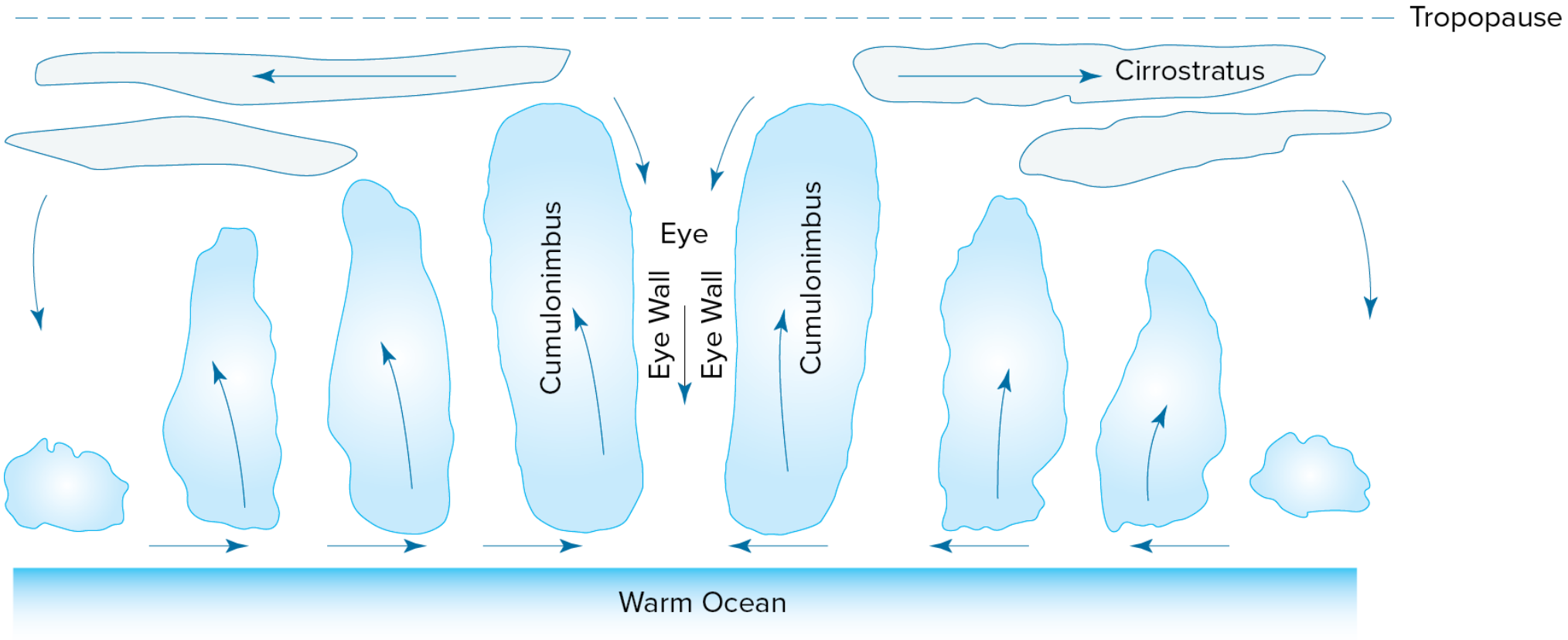


Fig 14.24

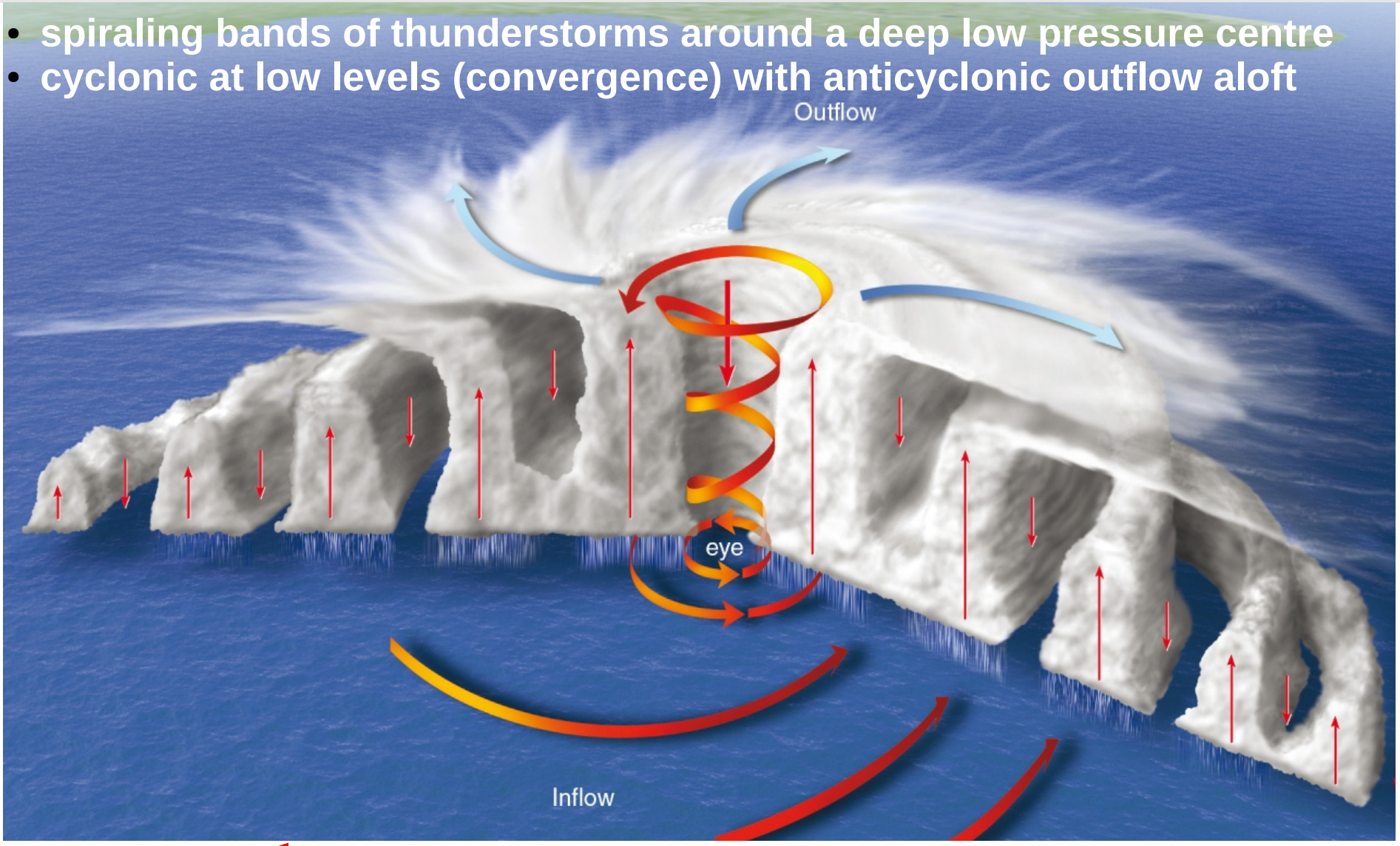
Feedback: **warm, moist** surface air ***converging*** due to cross-isobar flow (***friction*** of rough, wind-driven ocean)→ ***lift*** → release latent heat aloft → warming air aloft (warm core of air aloft) → slow $\Delta P/\Delta z$ so that upper region of hurricane has HIGH ***P*** relative to same level outside storm → anticyclonic winds & ***divergence aloft*** → reduce central surface pressure (***L***) → increase surface ***winds*** → increase surface $\boldsymbol{Q_H + Q_E}$ and increase surface convergence



- eye circa 20 - 50 km in diameter; clear, or fairweather Cu

Fig 14.26

- **spiraling bands of thunderstorms around a deep low pressure centre**
- **cyclonic at low levels (convergence) with anticyclonic outflow aloft**



<u>Feedback</u> increase wind speed → increase heat & vapour transfer off ocean & increase converging flux of air → increasing updraft volume & energy content → warmer core → lower central pressure → stronger wind

- mesoscale
- enabled by favourable synoptic scale setting
  - strong Q_H+Q_E (warm, moist boundary layer)
  - conditionally unstable airmass**
  - "airmass thunderstorms" occur away from fronts
- single cell, multicell, or supercell
- individual cells a few km in diam
- may form long-lived storm *clusters* (mesoscale convective complex) or *squall lines*

** to get an energetic cloud, must release stored potential energy (warm, moist near-ground air) over a small area – "focusing" the energy release

- in conditionally-unstable atmosphere, rising unsaturated parcels experience a restoring force… but those few that *do* rise to the LFC result in deep, energetic clouds whose updraft causes surface convergence – sucking in the energy (warm, moist air) to this "focal point"

- "trigger" process selects the updrafts which produce deep convection – trigger points may relate to unequal pattern of surface heating, to terrain slopes or irregularities, to surface convergence or (in case of "severe thunderstorm") to frontal lifting

- an elevated temperature inversion may suppress deep convection for a time, but the "potential Instability" (of moist air beneath dry) means an eventual storm is likely to be the more explosive

- convection initiated – by turbulence? by converging surface wind?
- surging plumes of rising warm, moist air reach the LCL to produce light Cu, whose evaporation humidifies the column – allowing later pulses to climb higher

- precip commences
- downdraft is negatively buoyant – chilled by evaporation (entrained dry air evaporates droplets) and weighed down by precip
- separate updraft + downdraft = "cell" (an airmass Cb may have several cells)

- rain-bearing downdraft falls into updraft, cutting off supply of buoyant air

  - *lifetime of order 1 hr*
  - *may exhibit*
    - *overshooting top (penetrating the stratosphere)*
    - *an anvil*

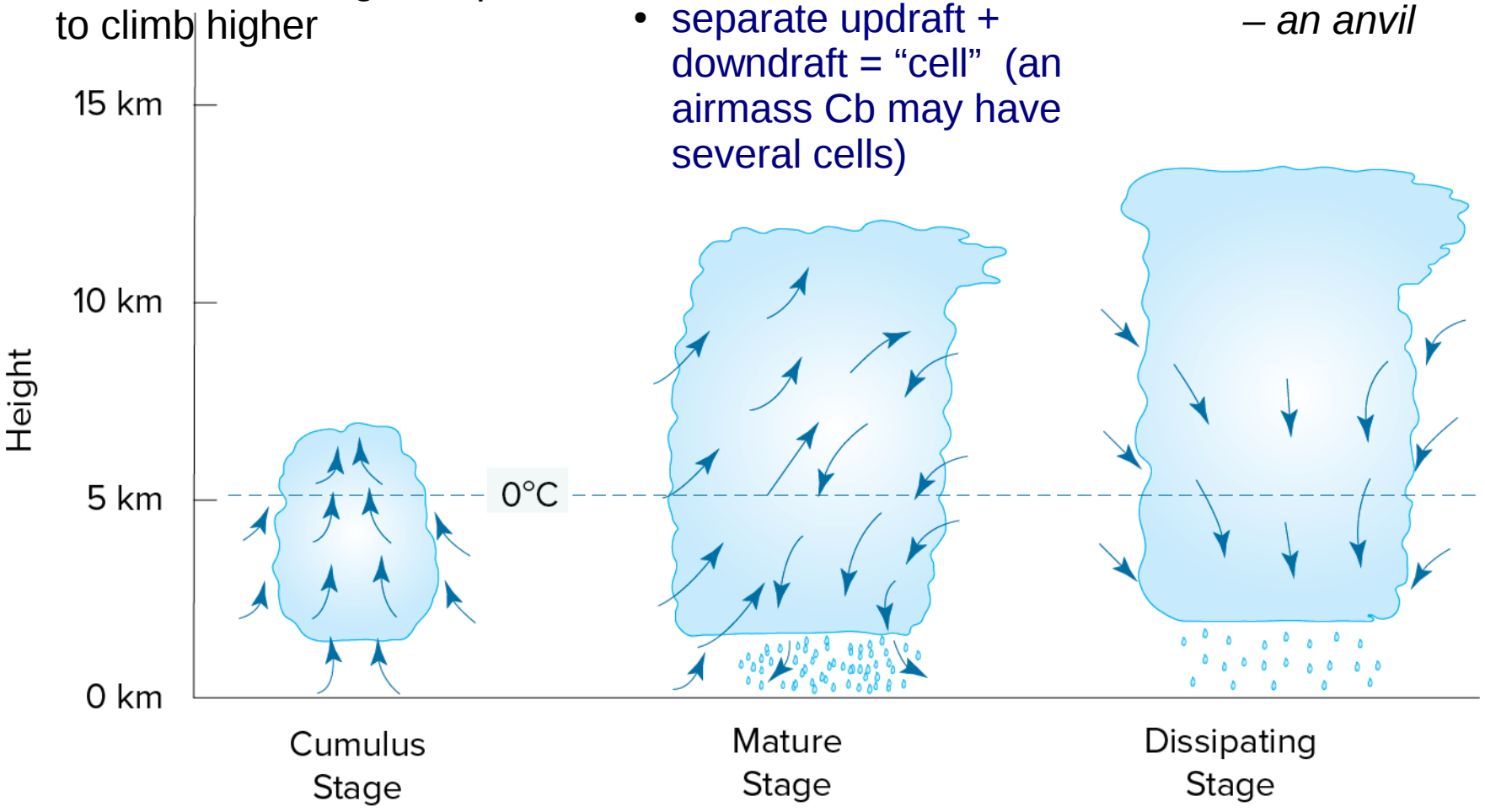


Fig 14.30

- form in environments where horizontal wind speed varies with height (wind "shear")
- wind shear causes storm tilt, keeping updraft and downdraft separate
- several cells, in different stages of development
- circulation induced by one cell (esp. gust front) serves as trigger for another

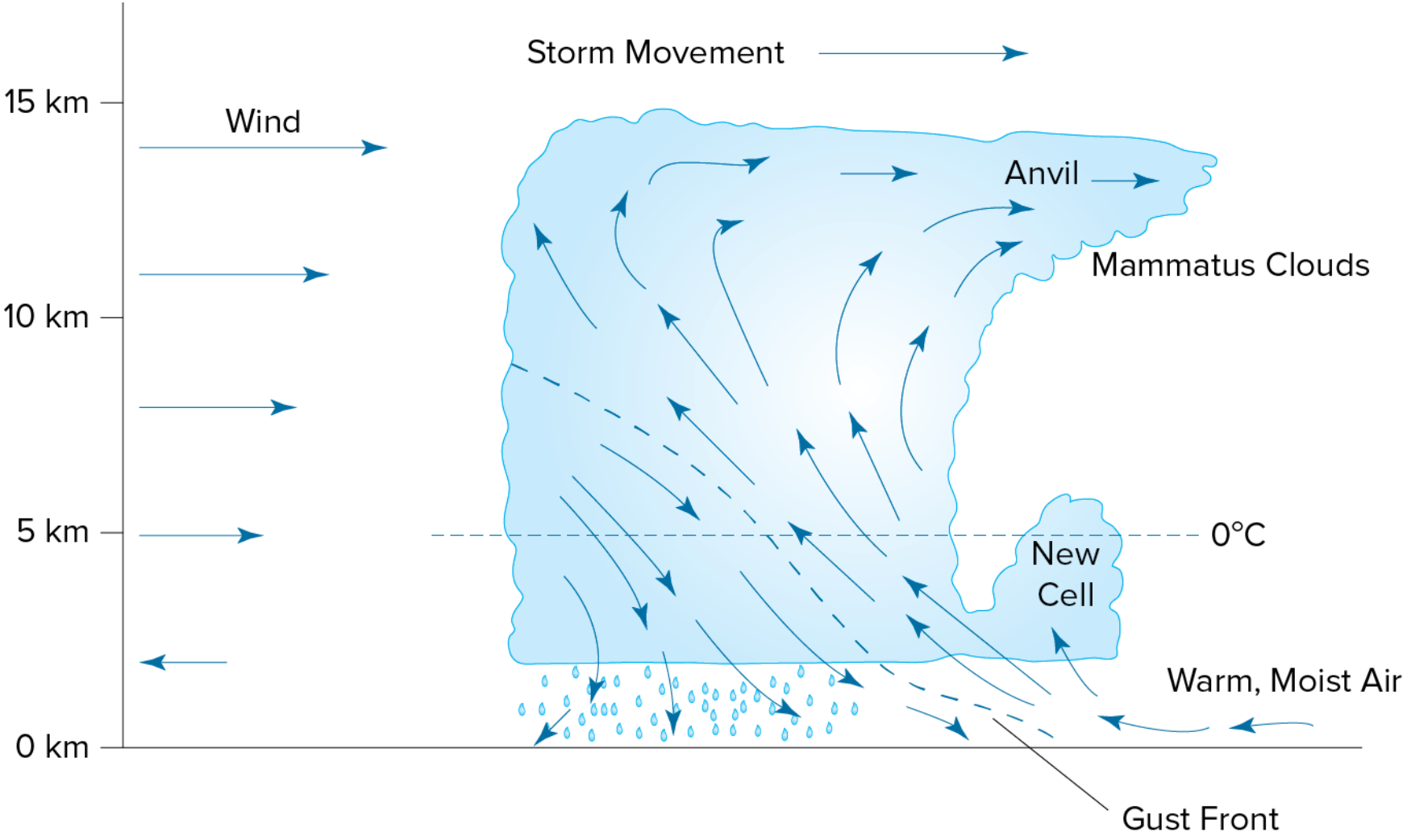


Fig 14.32

- much larger than single-cell storms (diam up to 50 km, depth up to 20 km)
- (recall our "back-of-envelope" calculation, which linked violence of updraft to cloud depth)
- forms in an environment with strong shear in speed and direction
- shear spawns a rotating updraft (mesocyclone), recognizable on radar
- stretched, an upright vortex thins and spins faster – may form tornado

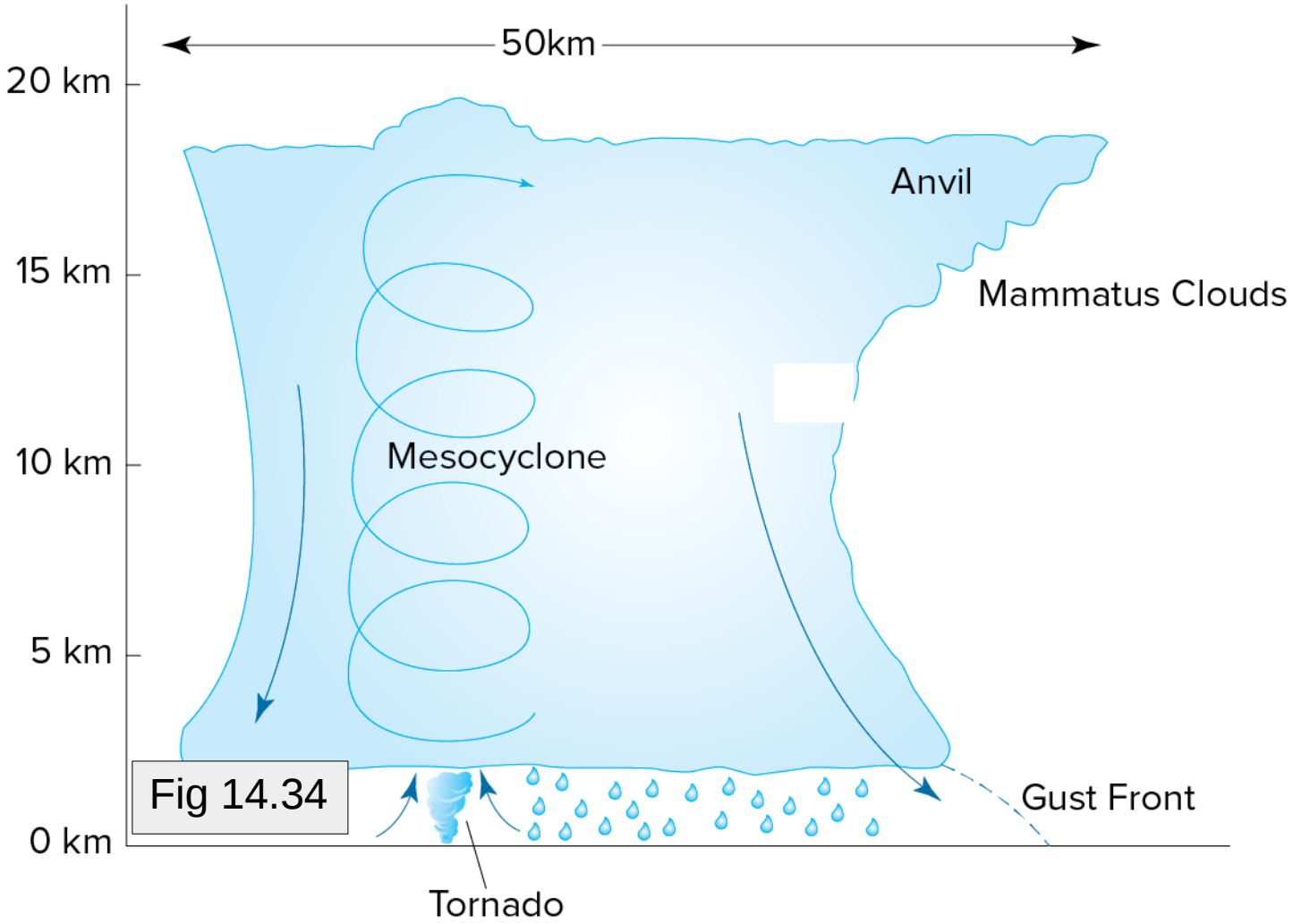


Fig 14.34

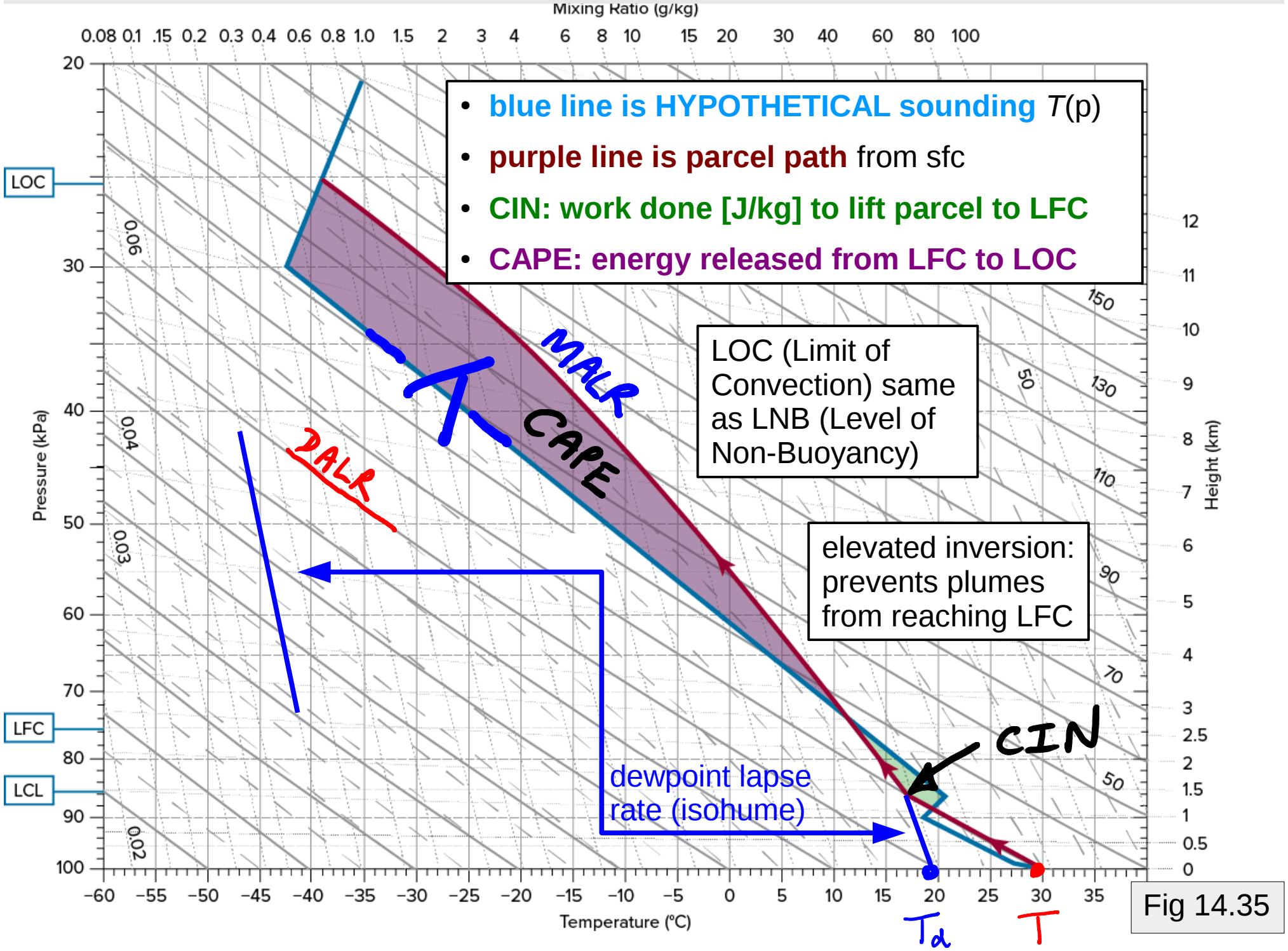
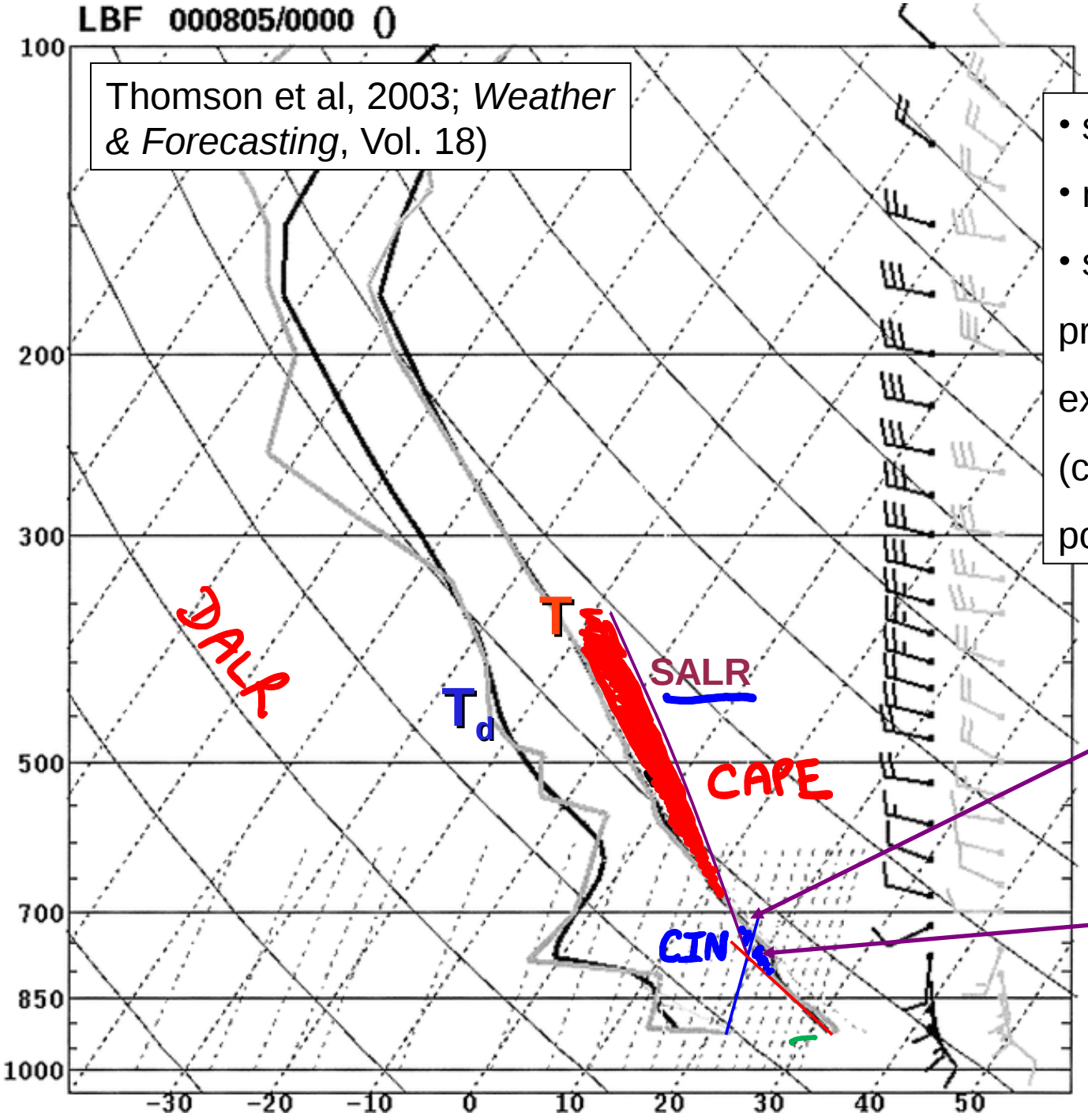

Mixing Ratio (g/kg)
0.08 0.1 .15 0.2 0.3 0.4 0.6 0.8 1.0 1.5 2 3 4 6 8 10 15 20 30 40 60 80 100
Pressure (kPa)
20 30 40 50 60 70 80 90 100
Height (km)
12 11 10 9 8 7 6 5 4 3 2.5 2 1.5 1 0.5 0
Temperature (°C)
−60 −55 −50 −45 −40 −35 −30 −25 −20 −15 −10 −5 0 5 10 15 20 25 30 35
LOC
LFC
LCL
0.06
0.04
0.03
0.02
150
130
110
90
70
50
50
• blue line is HYPOTHETICAL sounding T(p)
• purple line is parcel path from sfc
• CIN: work done [J/kg] to lift parcel to LFC
• CAPE: energy released from LFC to LOC
MALR
CAPE
DALR
LOC (Limit of Convection) same as LNB (Level of Non-Buoyancy)
elevated inversion: prevents plumes from reaching LFC
CIN
dewpoint lapse rate (isohume)
Td
T

Fig 14.35



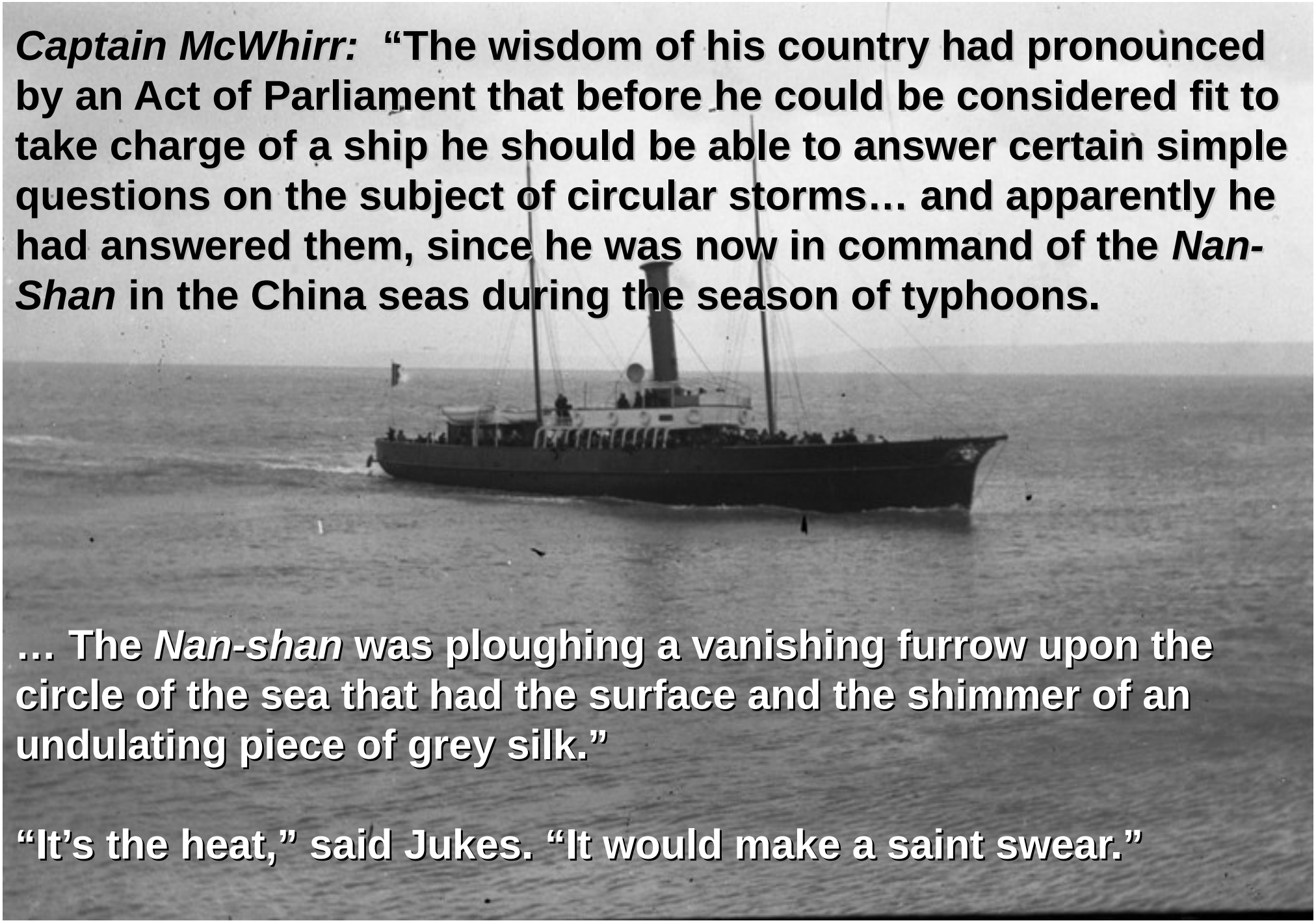
Thomson et al, 2003; *Weather & Forecasting*, Vol. 18)

- sounding near a supercell
- note wind shear
- saturated ascent would produce large temperature excess, ie. much "CAPE" (convectively available potential energy)

LFC (parcel following moist adiabat warmer than environ.)

LCL (intersection of dry adiabat thru sfc T with dewpoint lapse rate line thru T_d)

Non-examinable: excerpt from Joseph Conrad's “Typhoon” (short story, published 1904)

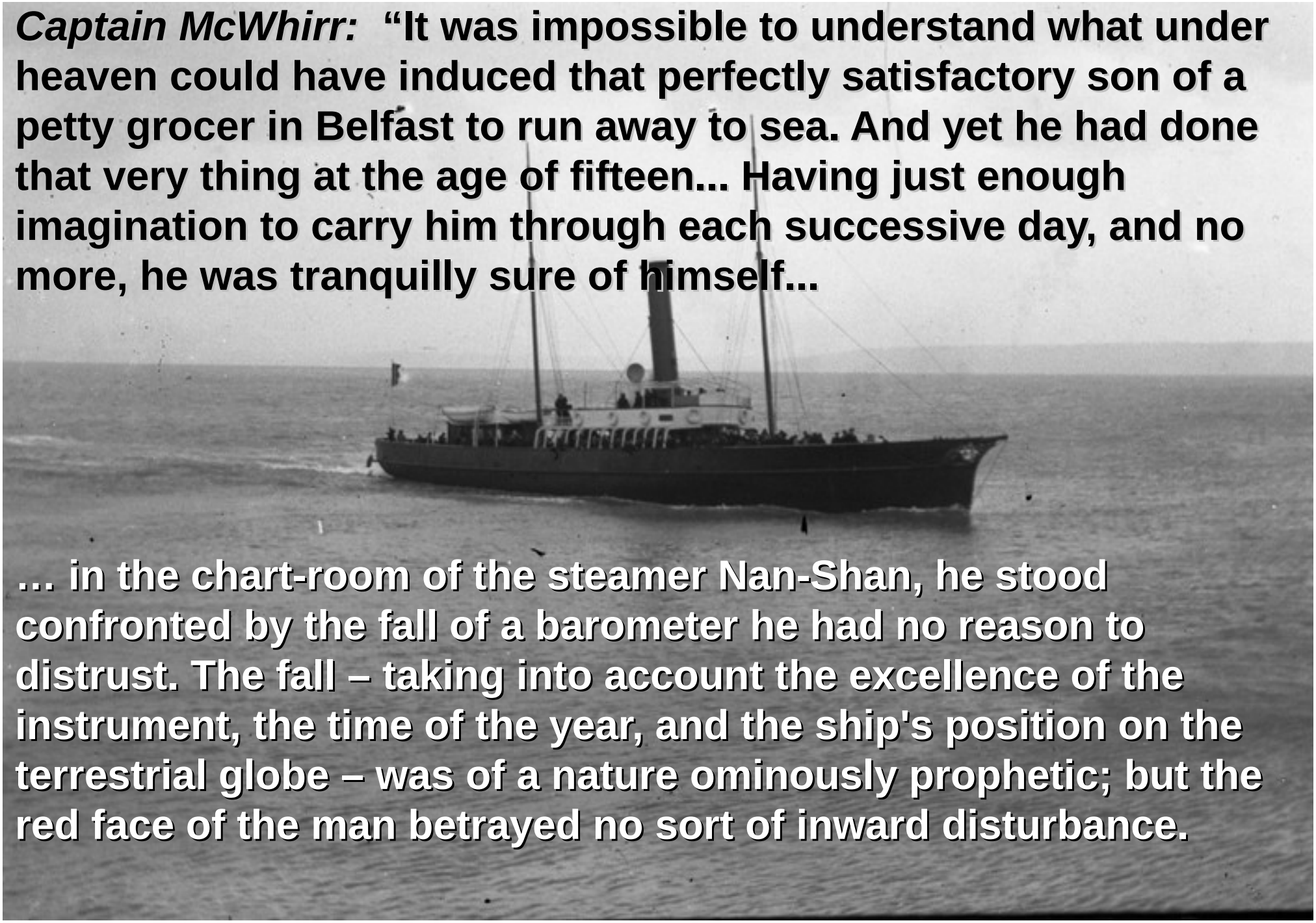


Captain McWhirr: **“The wisdom of his country had pronounced by an Act of Parliament that before he could be considered fit to take charge of a ship he should be able to answer certain simple questions on the subject of circular storms… and apparently he had answered them, since he was now in command of the *Nan-Shan* in the China seas during the season of typhoons.**

… The *Nan-shan* was ploughing a vanishing furrow upon the circle of the sea that had the surface and the shimmer of an undulating piece of grey silk.”

“It’s the heat,” said Jukes. “It would make a saint swear.”

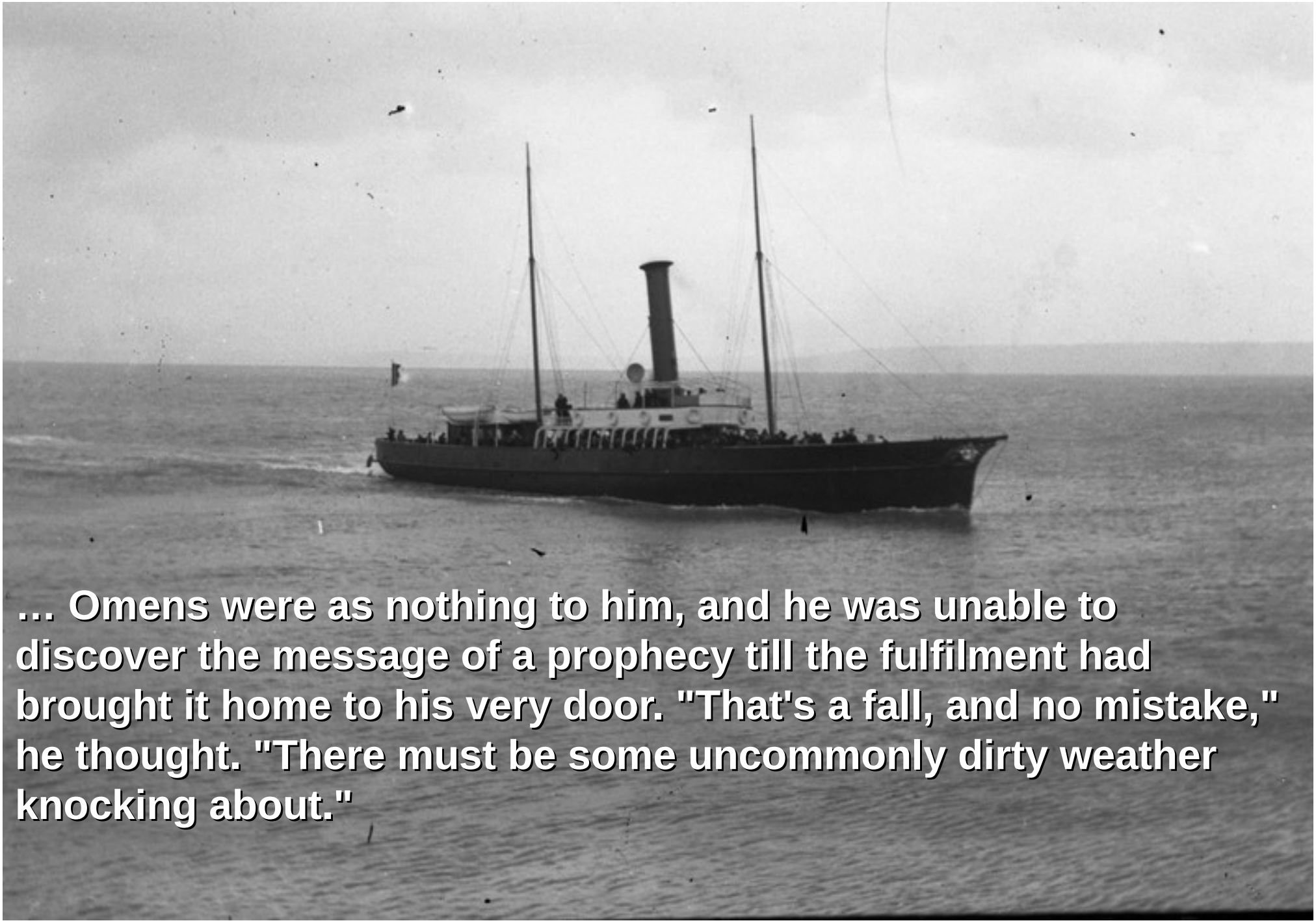
Excerpts from Joseph Conrad's “Typhoon” (short story, published 1904)



Captain McWhirr: **“It was impossible to understand what under heaven could have induced that perfectly satisfactory son of a petty grocer in Belfast to run away to sea. And yet he had done that very thing at the age of fifteen... Having just enough imagination to carry him through each successive day, and no more, he was tranquilly sure of himself...**

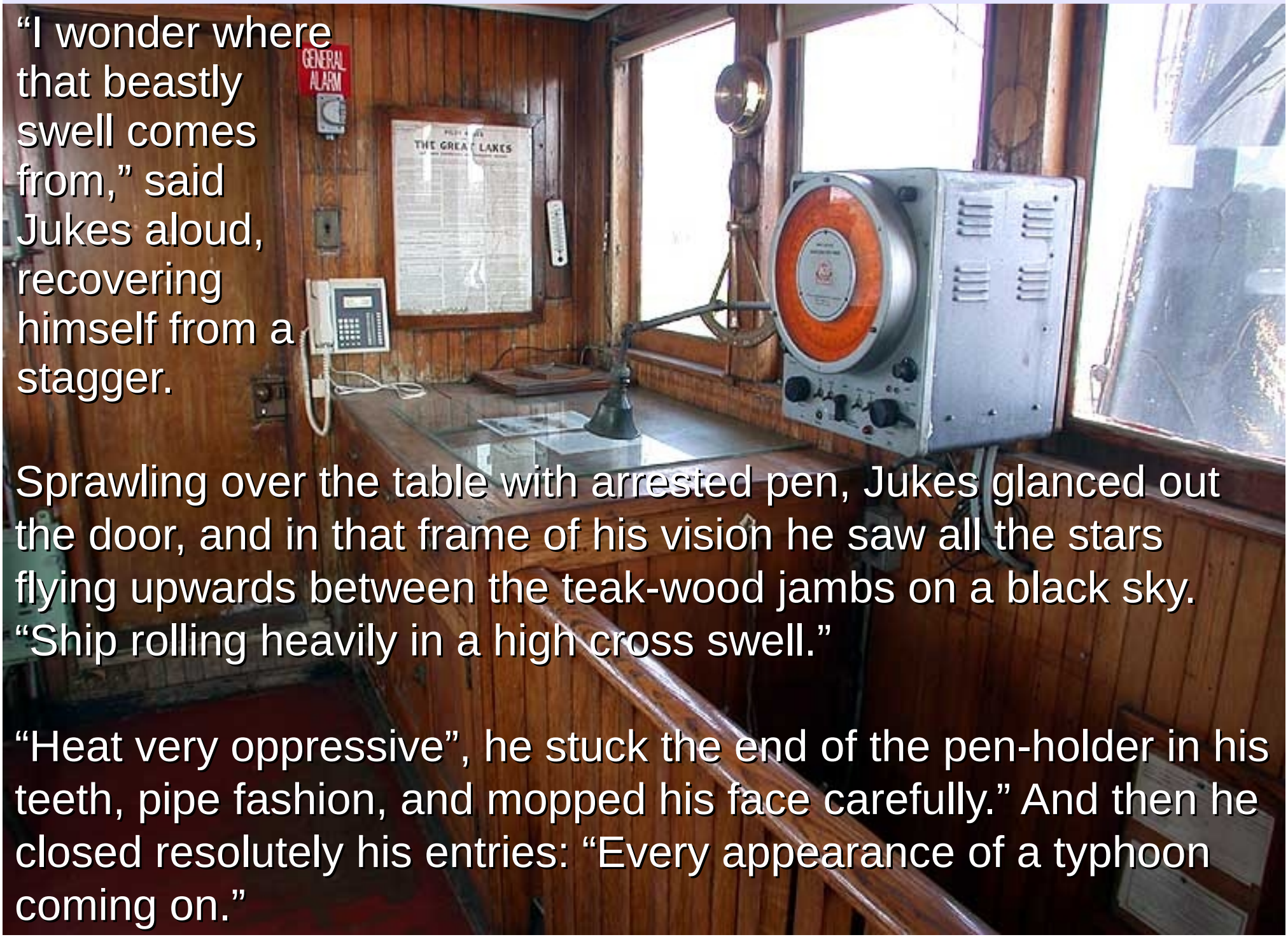
… in the chart-room of the steamer Nan-Shan, he stood confronted by the fall of a barometer he had no reason to distrust. The fall – taking into account the excellence of the instrument, the time of the year, and the ship's position on the terrestrial globe – was of a nature ominously prophetic; but the red face of the man betrayed no sort of inward disturbance.

Excerpts from Joseph Conrad's “Typhoon” (short story, published 1904)



… Omens were as nothing to him, and he was unable to discover the message of a prophecy till the fulfilment had brought it home to his very door. "That's a fall, and no mistake," he thought. "There must be some uncommonly dirty weather knocking about."

Excerpts from Joseph Conrad's “Typhoon” (short story, published 1904)



“I wonder where that beastly swell comes from,” said Jukes aloud, recovering himself from a stagger.

Sprawling over the table with arrested pen, Jukes glanced out the door, and in that frame of his vision he saw all the stars flying upwards between the teak-wood jambs on a black sky. “Ship rolling heavily in a high cross swell.”

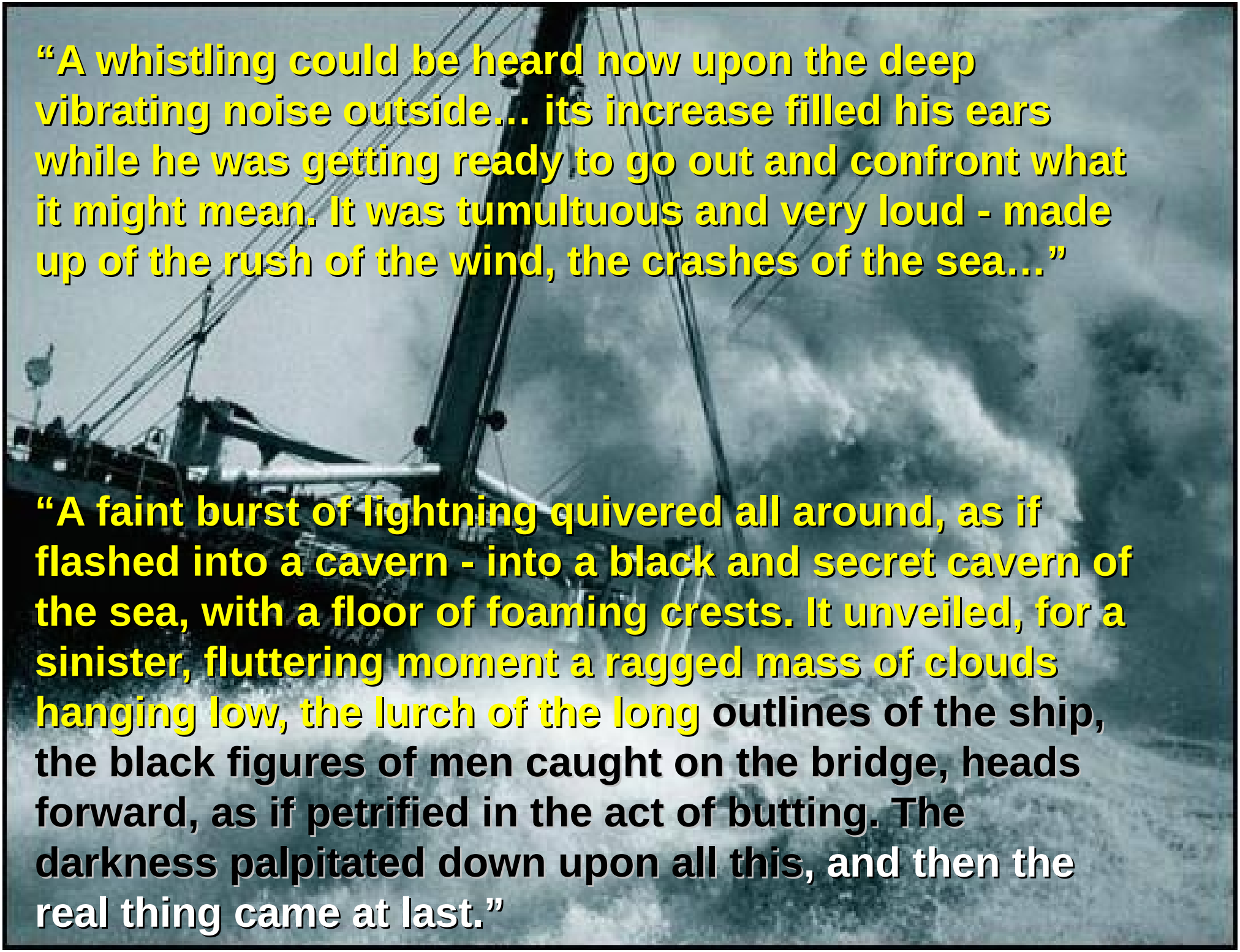
“Heat very oppressive”, he stuck the end of the pen-holder in his teeth, pipe fashion, and mopped his face carefully.” And then he closed resolutely his entries: “Every appearance of a typhoon coming on.”

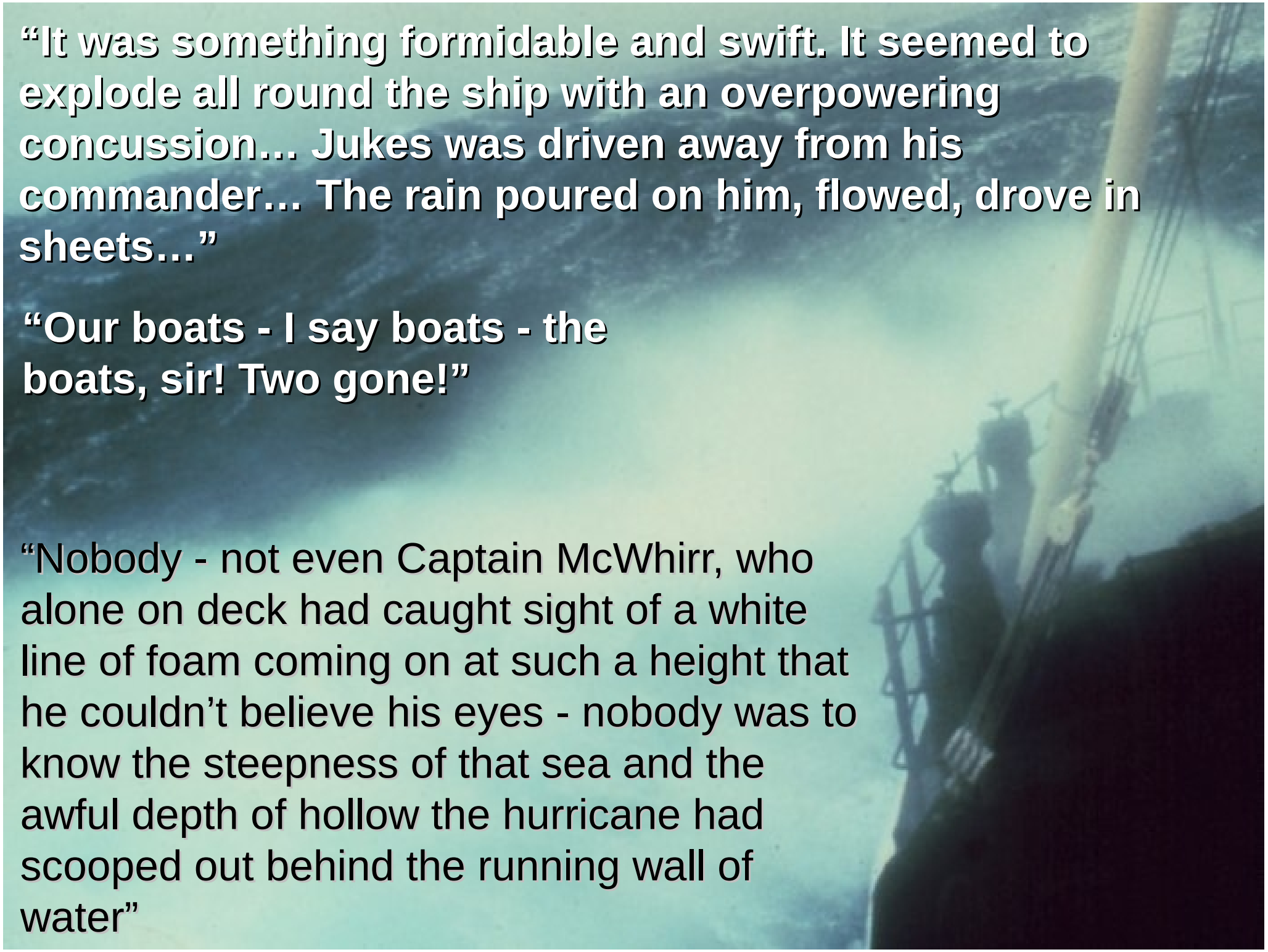
Excerpts from Joseph Conrad's “Typhoon” (short story, published 1904)

“A gale is a gale, Mr. Jukes,” resumed the captain, “and a full-powered steamer has got to face it.”

"I’ve been reading the chapter on the storms there… you would think an old woman had been writing this. It passes me. If that thing means anything useful, then it means that I should at once alter the course away, and come booming down on Fu-chau from the northward at the tail of this dirty weather that’s supposed to be knocking about in our way. From the north. Do you understand, Mr. Jukes? Three hundred extra miles to the distance, and a pretty coal bill to show…"

"Suppose I went swinging off my course and came in two days late and they asked me: ‘Where have you been all that time Captain?’ What could I say to that? ‘Went round to dodge the bad weather,’ I would say. ‘It must’ve been damn bad,’ they would say. ‘Don’t know,’ I would have to say; ‘I’ve dodged clear of it.’ See that, Jukes?"


“A whistling could be heard now upon the deep vibrating noise outside… its increase filled his ears while he was getting ready to go out and confront what it might mean. It was tumultuous and very loud - made up of the rush of the wind, the crashes of the sea…”
“A faint burst of lightning quivered all around, as if flashed into a cavern - into a black and secret cavern of the sea, with a floor of foaming crests. It unveiled, for a sinister, fluttering moment a ragged mass of clouds hanging low, the lurch of the long outlines of the ship, the black figures of men caught on the bridge, heads forward, as if petrified in the act of butting. The darkness palpitated down upon all this, and then the real thing came at last.”



“It was something formidable and swift. It seemed to explode all round the ship with an overpowering concussion… Jukes was driven away from his commander… The rain poured on him, flowed, drove in sheets…”

“Our boats - I say boats - the boats, sir! Two gone!”

“Nobody - not even Captain McWhirr, who alone on deck had caught sight of a white line of foam coming on at such a height that he couldn’t believe his eyes - nobody was to know the steepness of that sea and the awful depth of hollow the hurricane had scooped out behind the running wall of water”

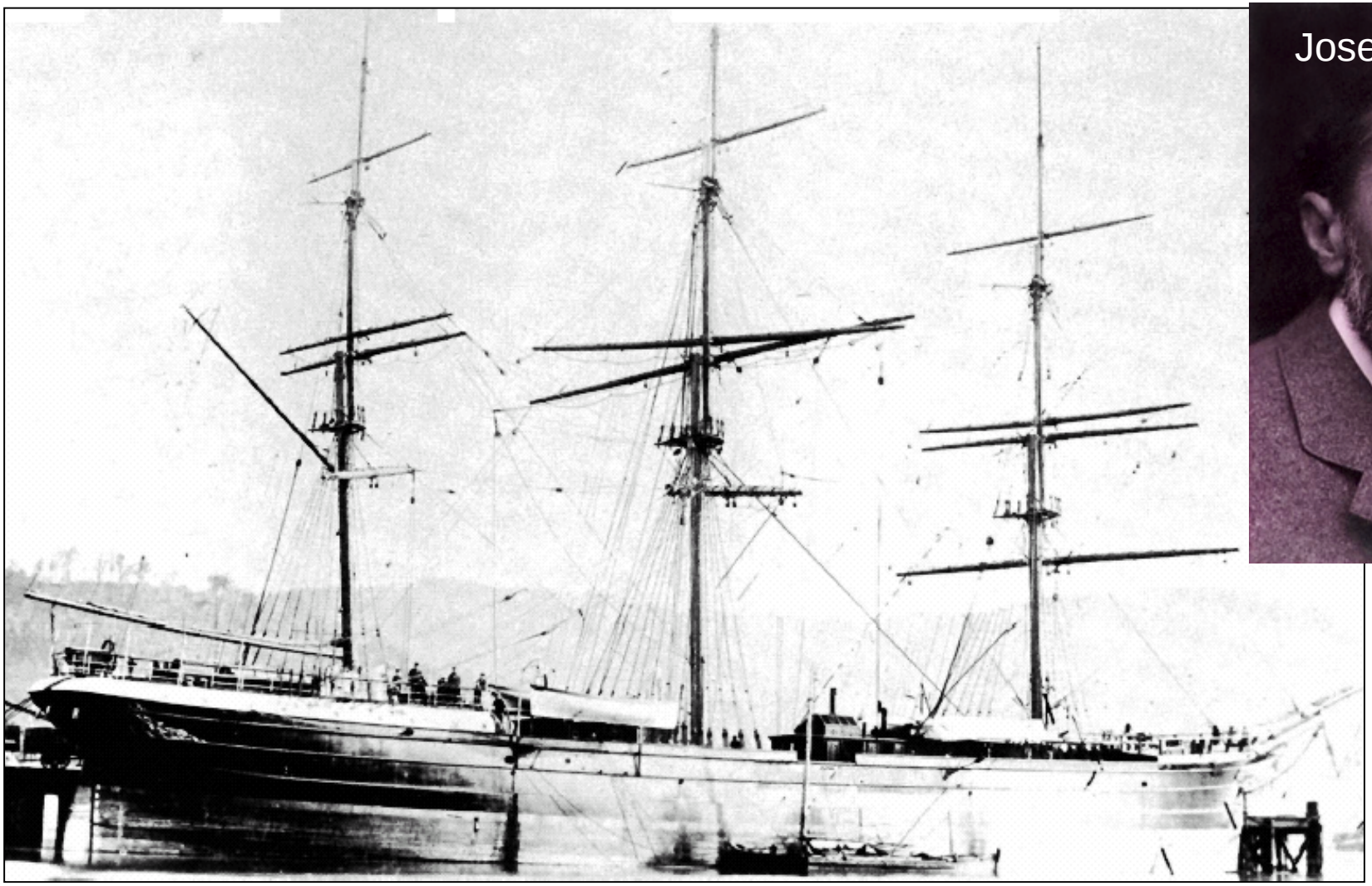
Excerpts from Joseph Conrad's “Typhoon” (short story, published 1904)

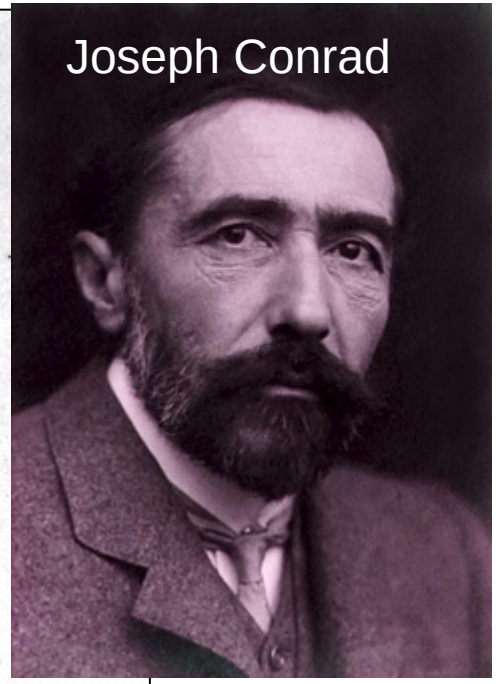
“There was no wind, not a breath, except the faint currents created by the lurches of the ship. The smoke tossed out of the funnel was settling down upon her deck.
“We have done it, sir,” Jukes gasped.”

(but then they steamed out of the eye back into the typhoon...)

“On a bright, sunshiny day, with the breeze chasing her smoke far ahead, the *Nan-Shan* came into Fu-chau”. Her arrival was at once noticed on shore, and the seamen in harbour said: "Look! Look at that steamer. Siamese -- isn't she? Just look at her!

She seemed, indeed, to have been used as a running target for the secondary batteries of a cruiser.”





Wikipedia

Joseph Conrad** was captain of this vessel, the barque “Otago” seen here moored at Port Chalmers (Dunedin, New Zealand). Photo from N.Z. Geographic No.78, 2006.

**Józef Teodor Konrad Korzeniowski, author of *Lord Jim, The Secret Agent, An Outcast of the Islands, The Rover, The Shadow Line, Heart of Darkness, Nostromo, Almayer's Folly, Under Western Eyes,...*