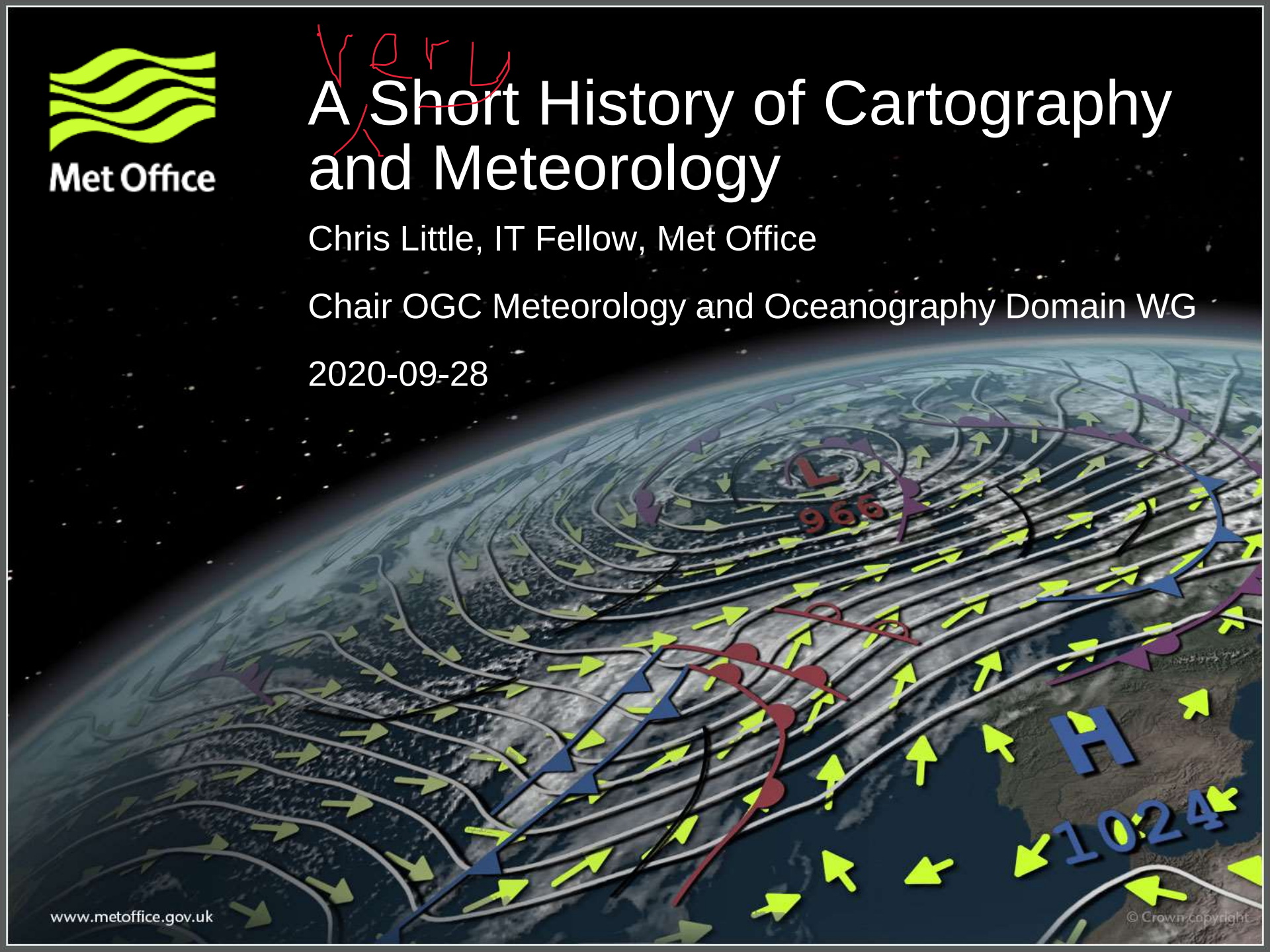
A Very Short History of Cartography and Meteorology

Chris Little, IT Fellow, Met Office

Chair OGC Meteorology and Oceanography Domain WG

2020-09-28



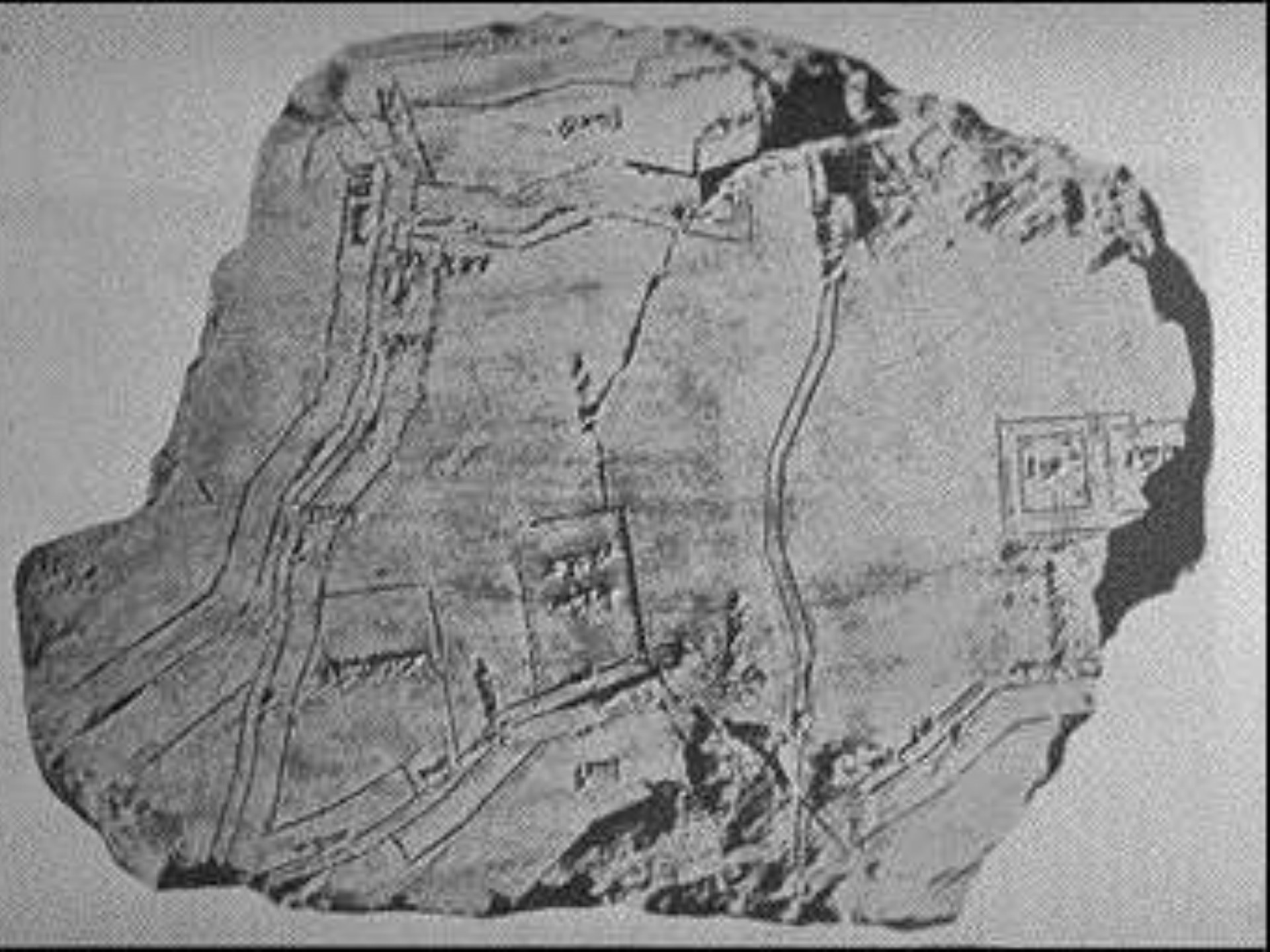
Talk Outline

Some History

Where Are We Now (± some years)

Thoughts on the Future (provocative?)

Questions & Answers (discussion?)

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CASICI CEP
INARTICLODIE LINGRESSVSENOESEMCHADETIARHET

FACTVQVEEOILVDIVQVADRAGITADIEBIS
VITAQVASVPOMSMONTES;CVQCO

ATILLAVENITADEVPOTSRAMVOLICEIORE·ETIT


Meteor + Logos - Μετεωρολογικά

Met Office

Aristotle’s 3/5 climatic zones

12th-century manuscript of Macrobius's *Commentarii in Somnium Scipionis*

ca. 1150.

Copenhagen, Det Kongelige Bibliotek

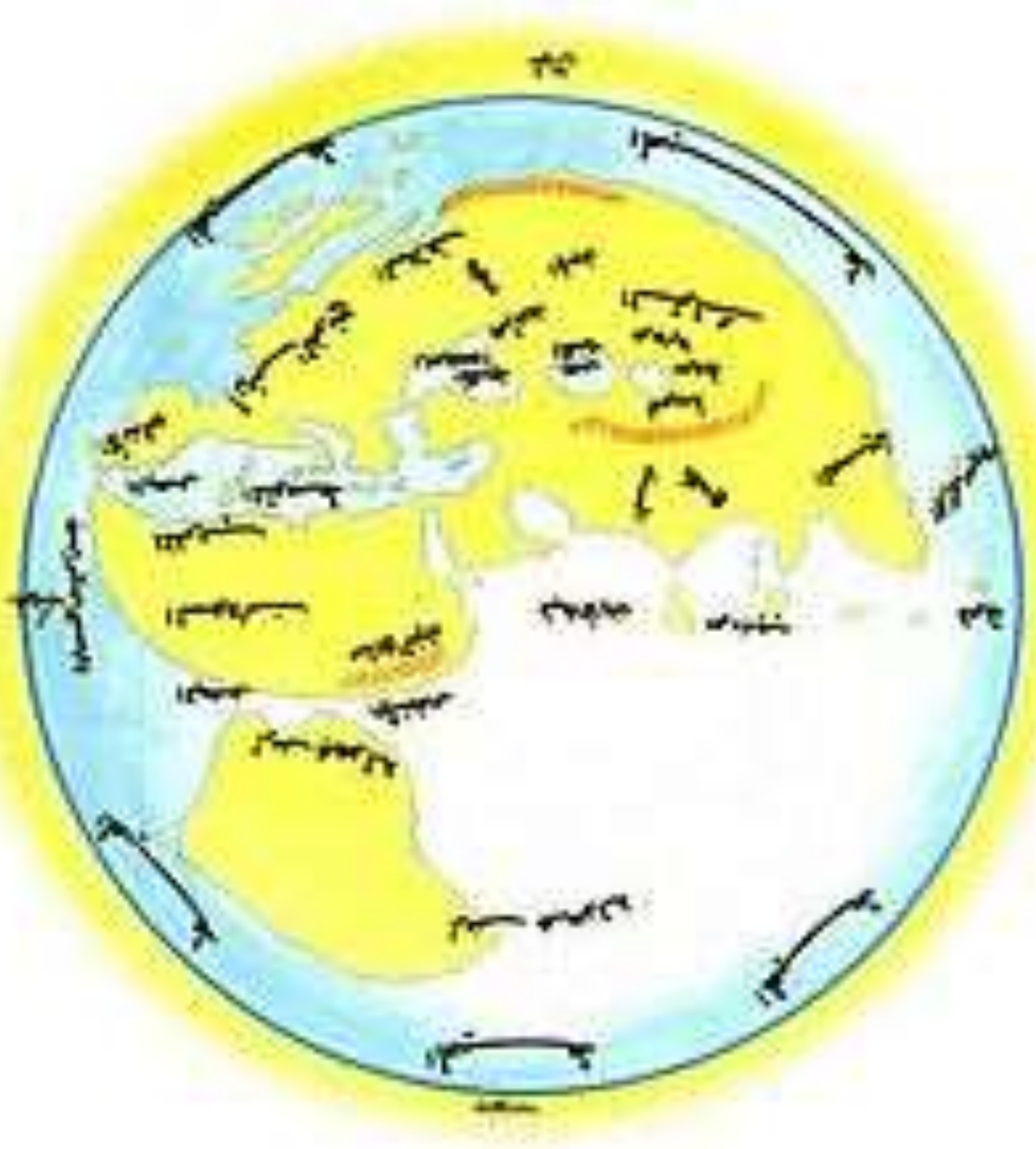
Met Office

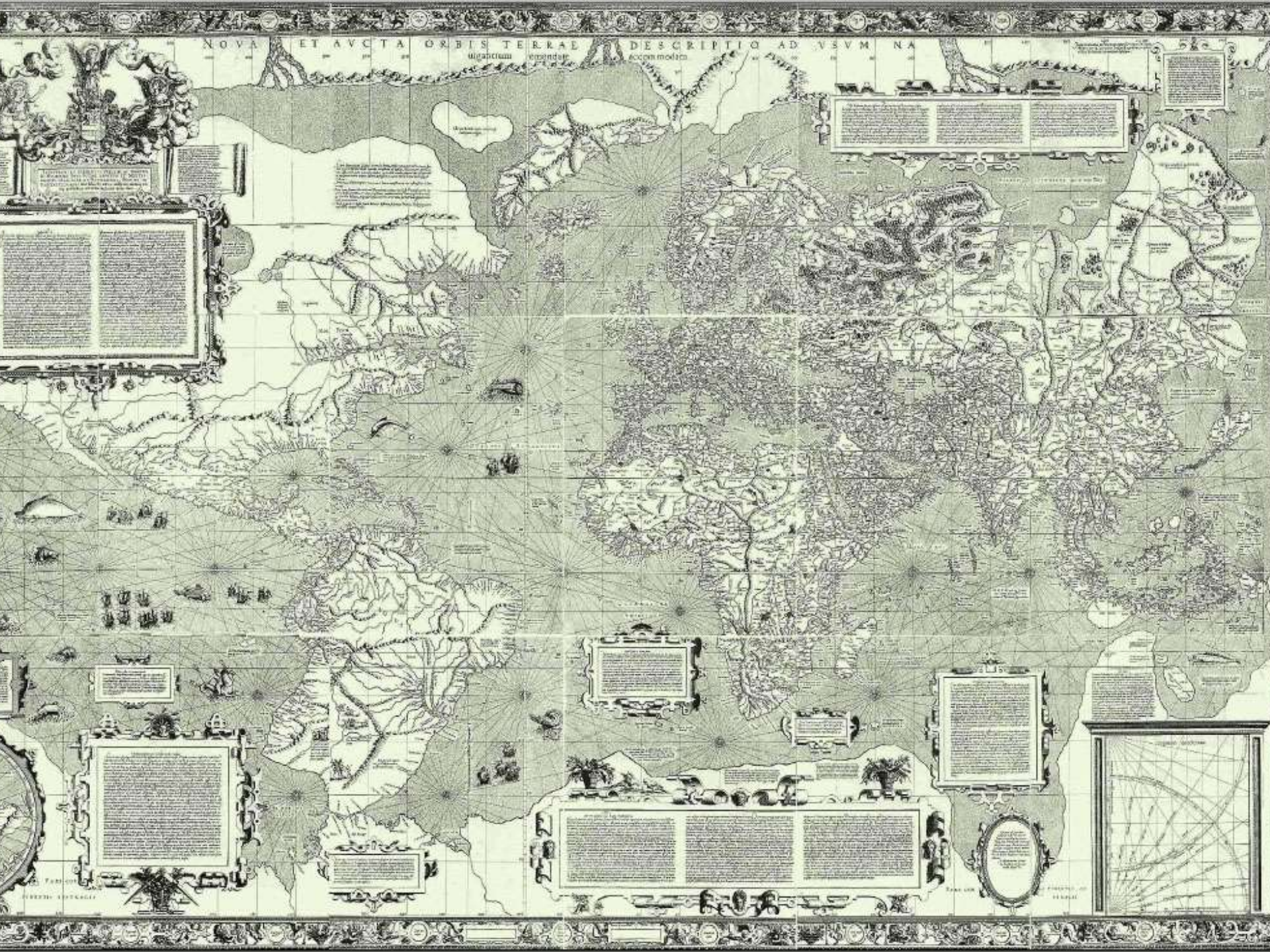
Al-Masudi

947CE

The Meadows of Gold and Mines of Gems

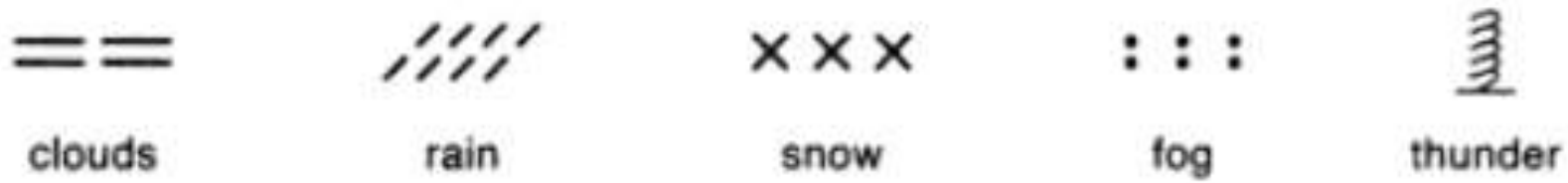
(مروج الذهب ومعادن الجواهر ,*Muruj adh-dhahab wa ma'adin al-jawhar*)




NOVA ET AVCTA ORBIS TERRAE DESCRIPTIO AD VSVM NA

Halley's Trade Wind Map 1656

J. H. Lambert, 1771



Meteorological Society of the Palatinate, 1781–1792

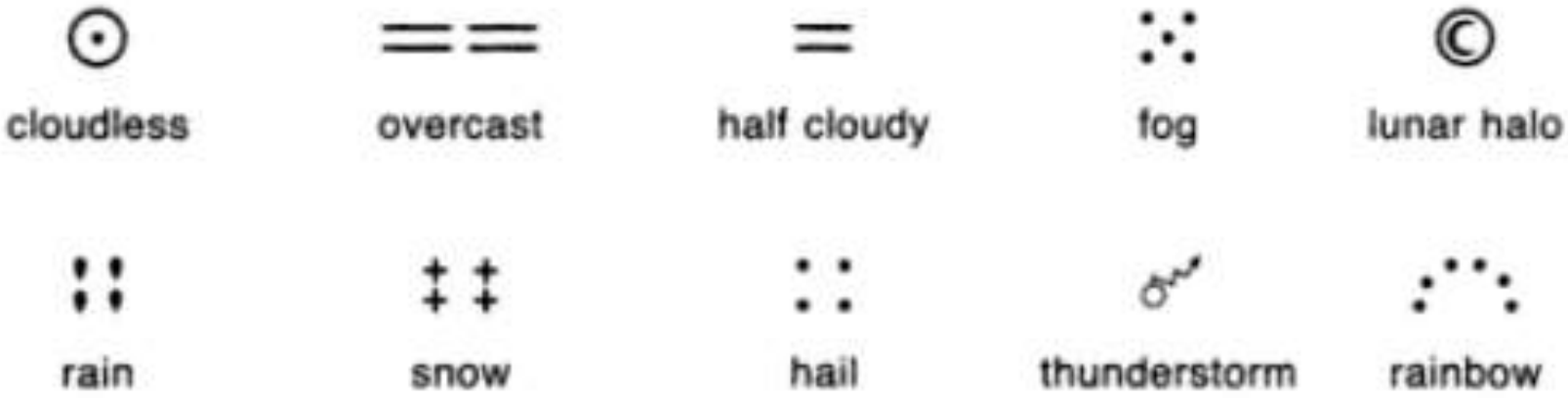
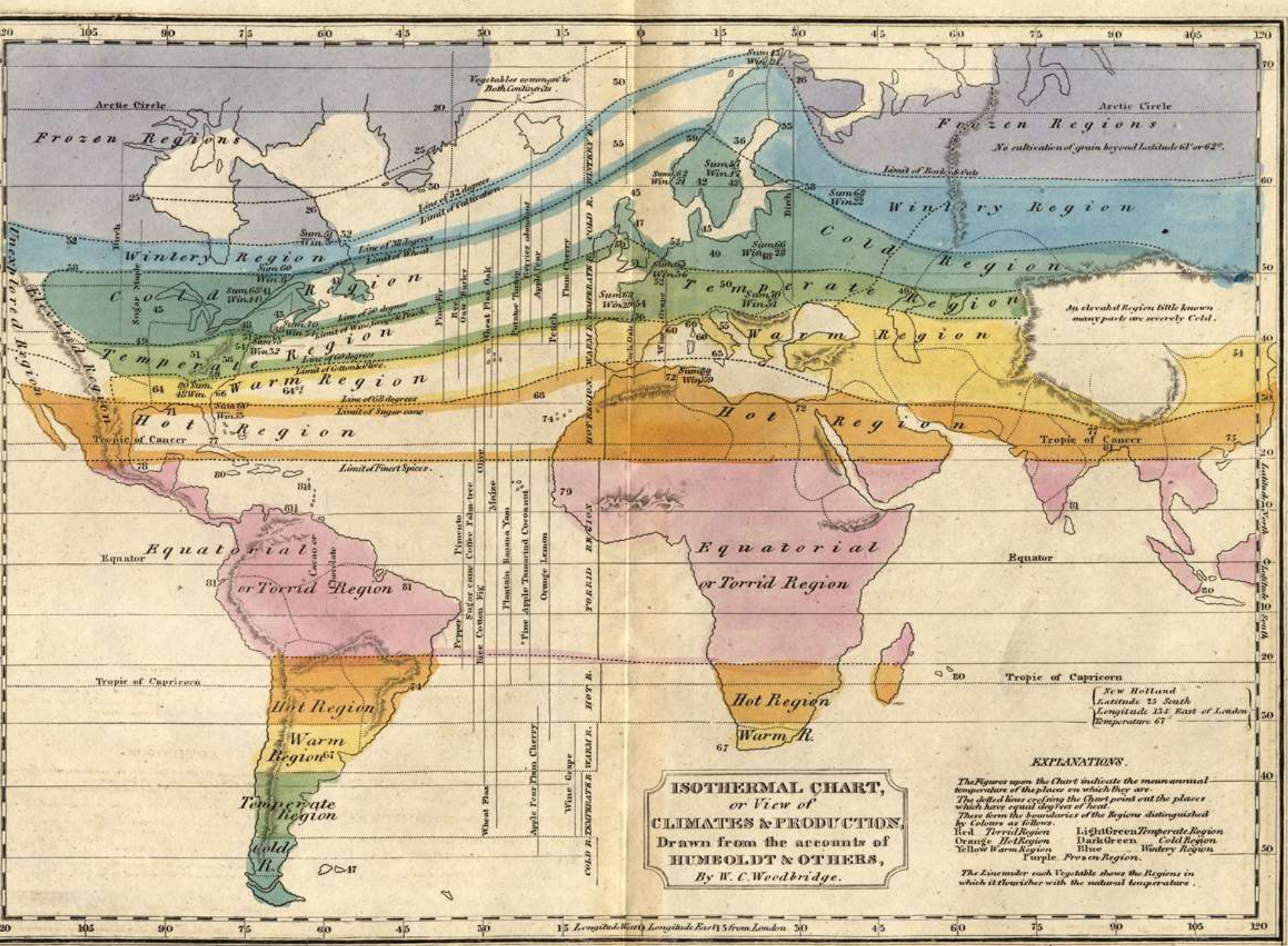


Fig. 12.4. Weather glyphs devised by Lambert in 1771 (upper row) and the Meteorological Society of the Palatinate between 1781 and 1792 (lower rows). Compiled from C. Fitzhugh Talman, "Meteorological Symbols," *Monthly Weather Review* 44 (1916): 265.


New York
Washington
San Francisco
Atlanta
New Orleans
Havanna
Atlantik
Mexiko-Stadt
Veracruz
Karibik
Managua
Cartagena
Caracas
Orinoco
Bogotá
Galapagos
Chimborazo
6310 m
Quito
Belém
Amazonas
Recife
Pazifik
Lima
Salvador




Luftdruck-Vertheilung
nach Brandes
6. März 1783.

Beaufort's Weather Code
1820-1825 version

b. Blue sky

c. Clear, transparent atmosphere

ci. Cirrus clouds

cl. Cloudy

cu. Cumulus clouds

d. Mist (damp air)

Dk Dark weather but atmosphere clear

f. Foggy

f: Dense Fog

g. Gloomy weather

h. Haze

m. Mist in valley

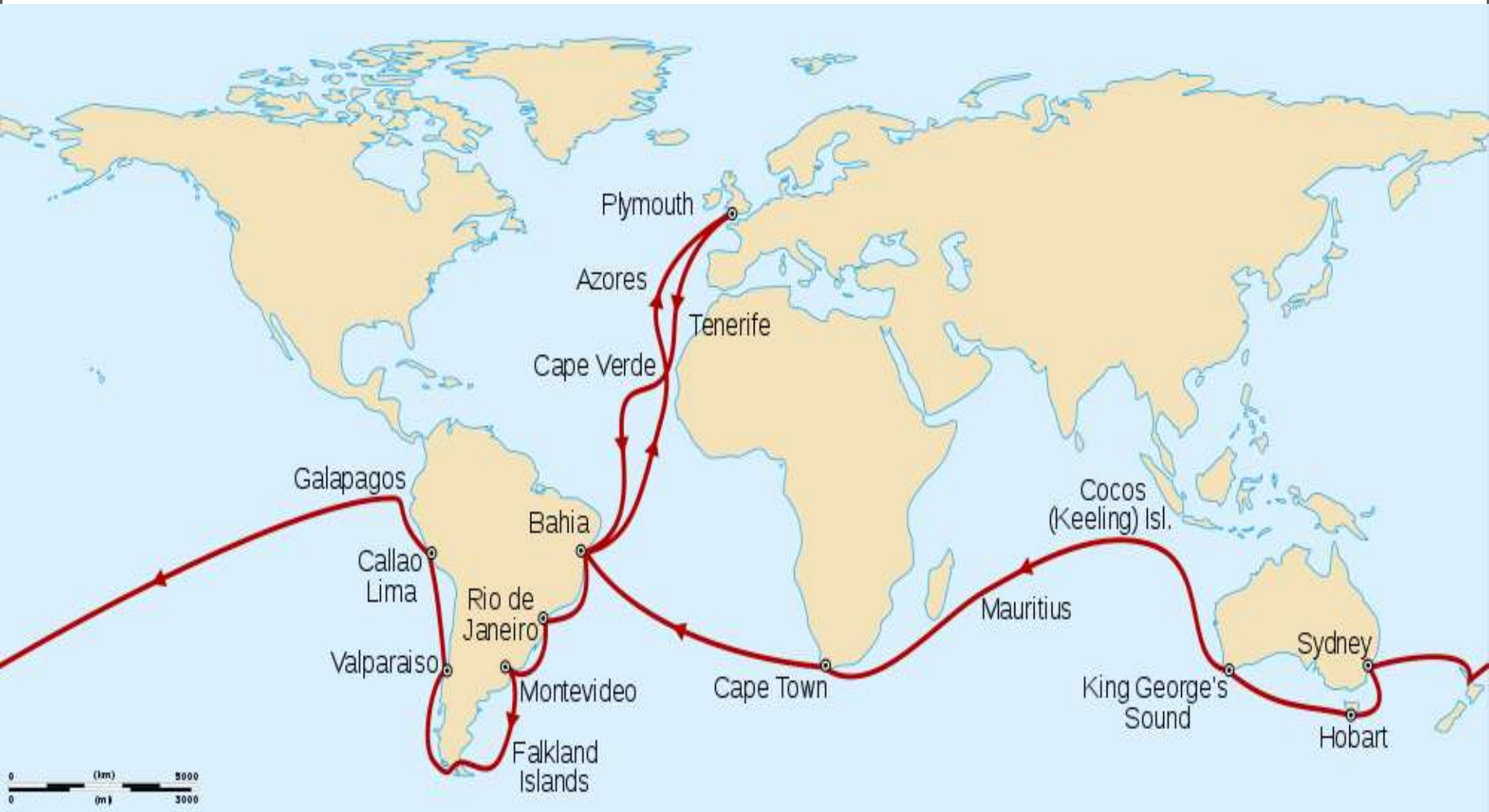
p. Passing cloud

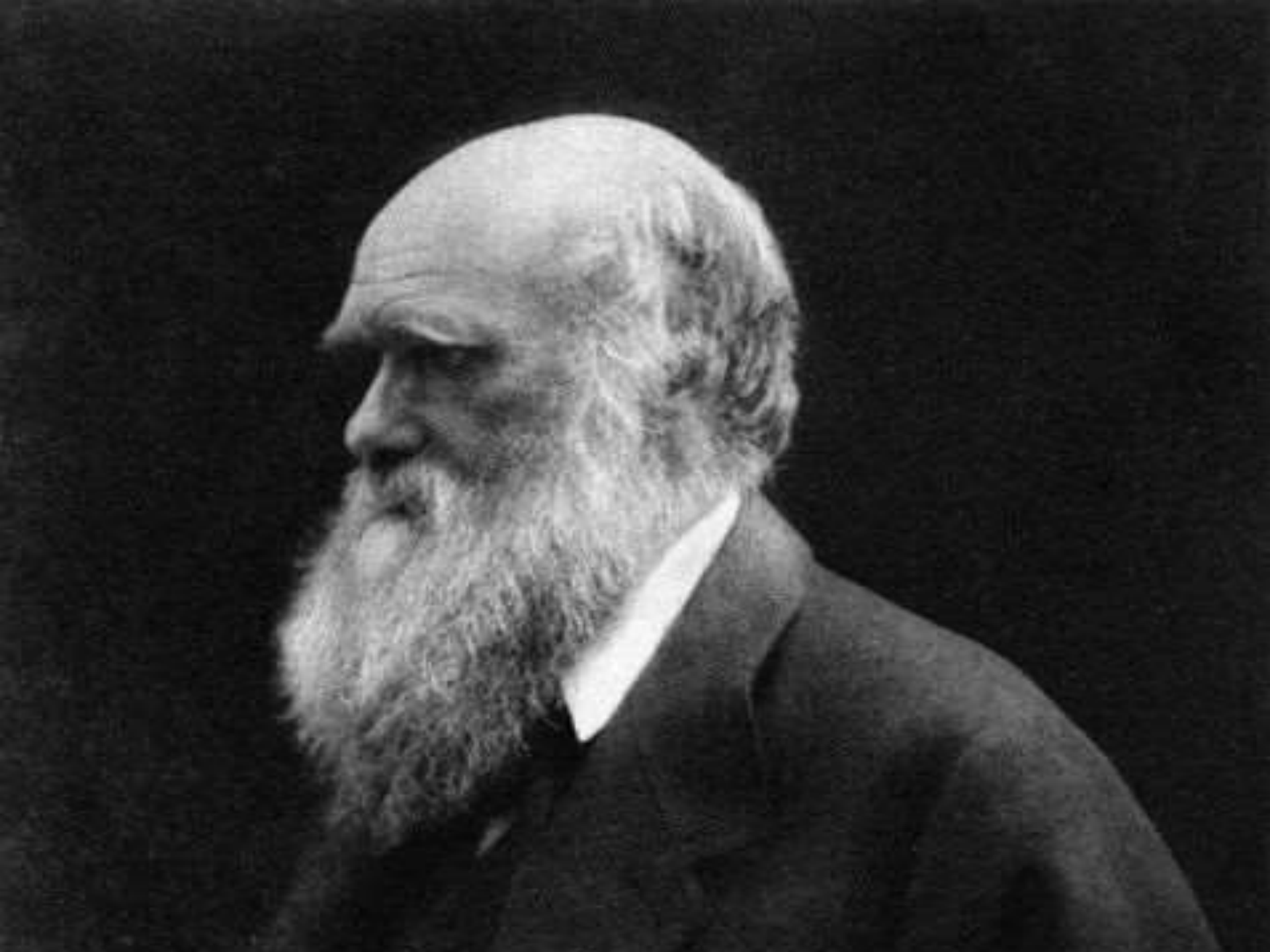
r. Rain

1831 Beaufort Wind Force Scale

0	Calm	
1	Light Air	Or just sufficient to give steerage way
2	Light Breeze	Or that in which a man-of-war with all sail set, and clean full would go in smooth water from.1 to 2 knots
3	Gentle Breeze	3 to 4 knots
4	Moderate Breeze	5 to 6 knots
5	Fresh Breeze	Or that to which a well-conditioned man-of-war could just carry in chase, full and by. Royals, etc
6	Strong Breeze	Single-reefed topsails and top-gallant sail
7	Moderate Gale	Double reefed topsails, jib, etc
8	Fresh Gale	Treble-reefed topsails etc
9	Strong Gale	Close-reefed topsails and courses
10	Whole Gale	Or that with which she could scarcely bear close-reefed main-topsail and reefed fore-sail
11	Storm	Or that which would reduce her to storm staysails
12	Hurricane	Or that which no canvas could withstand

Voyage of HMS Beagle





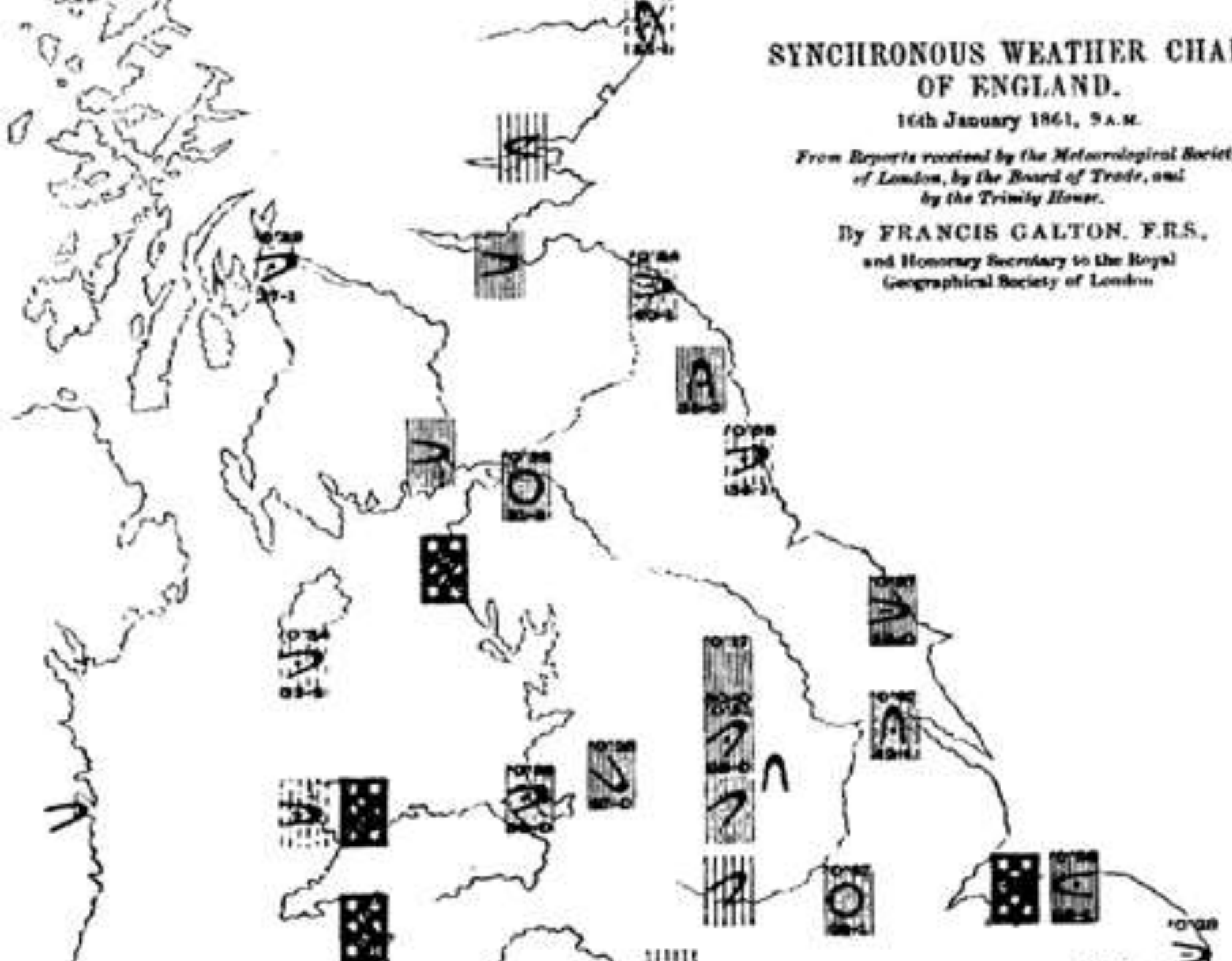

NEWFOUNDLAND
GRAND BANK
NOVA SCOTIA
Boston
New York
Philadelphia
C. Charles
C. Hatteras
UNITED STATES
FLORIDA
New Orleans
Tampico
CUBA
HAYTI
BERMUDAS
AZORES
Straits of Gibraltar
MADEIRA
CANARY ISLANDS
CAPE VERD ISLANDS
AFRICA
Bay of Panama
Amazon R.
SOUTH AMERICA
1000 fathoms
2000 "
3000 "
4000 "

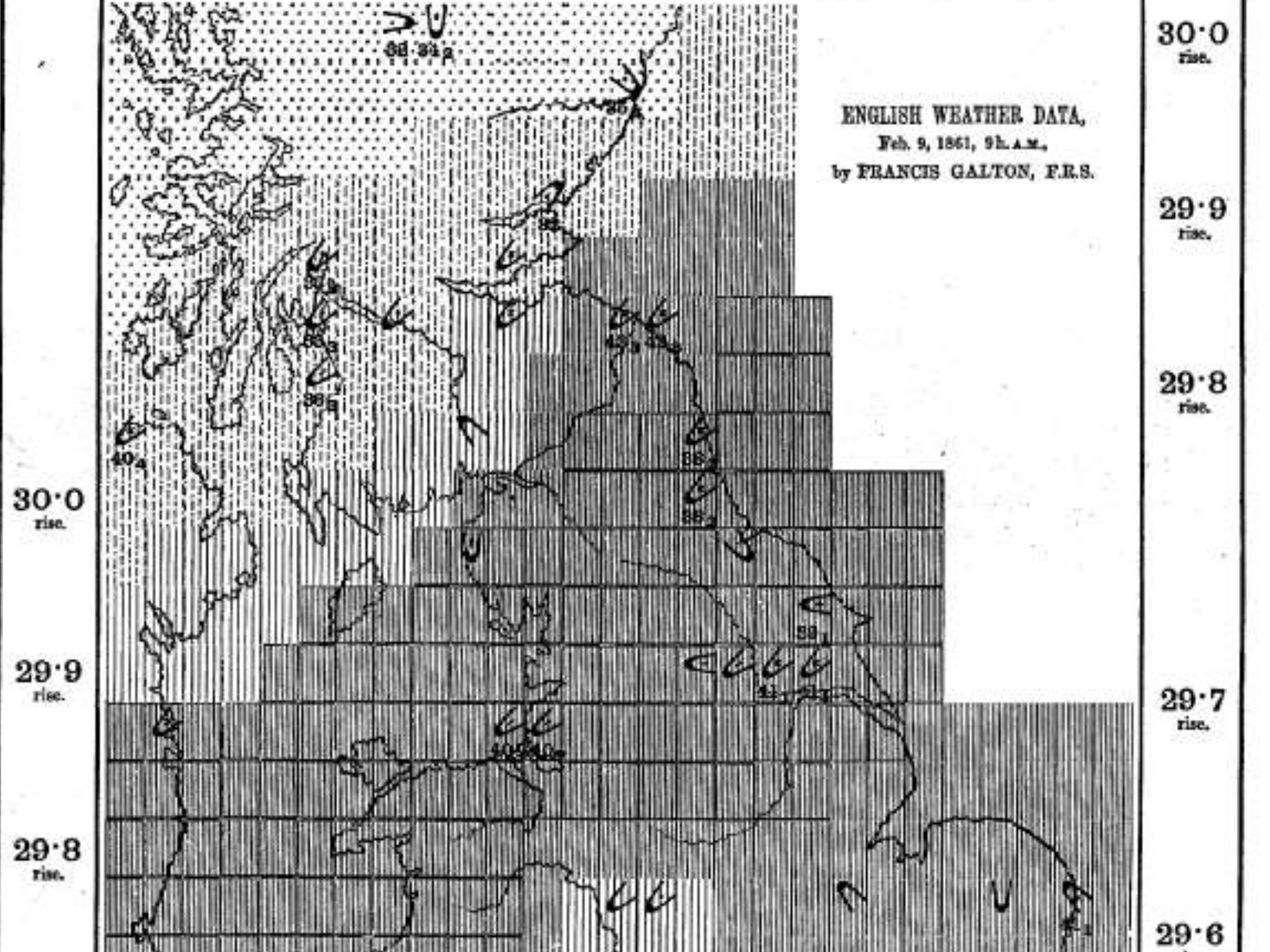
SYNCHRONOUS WEATHER CHART OF ENGLAND.

16th January 1861, 9 A.M.

From Reports received by the Meteorological Society of London, by the Board of Trade, and by the Trinity House.

By FRANCIS GALTON, F.R.S.,
and Honorary Secretary to the Royal Geographical Society of London

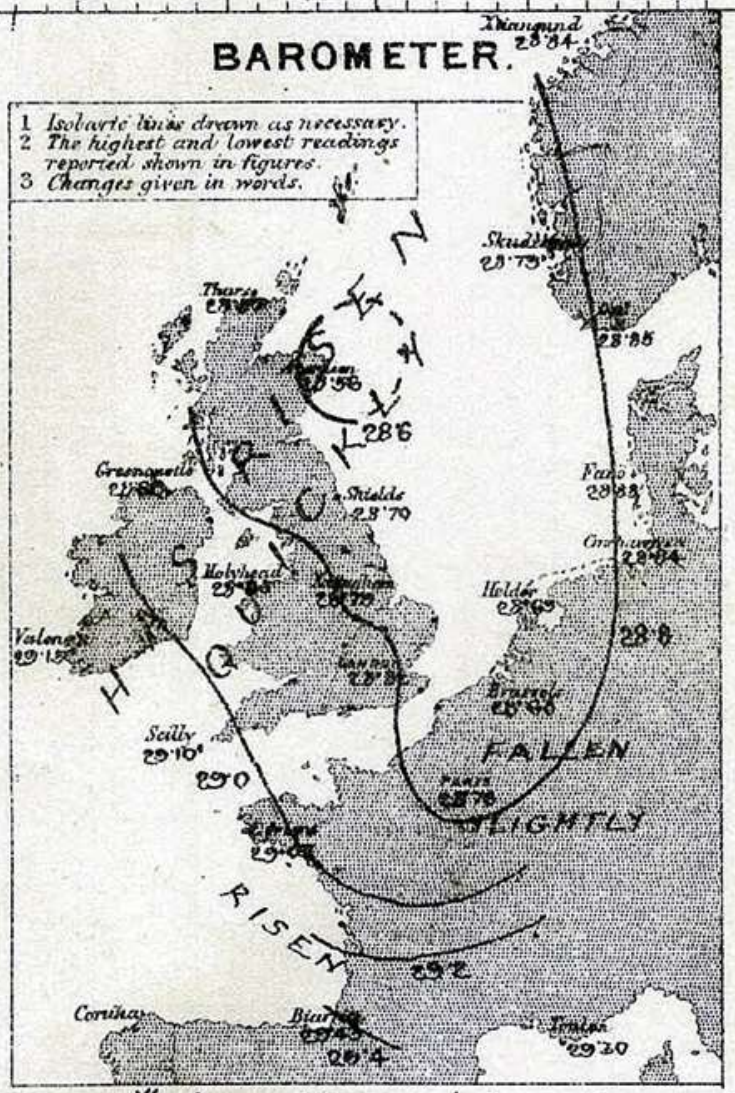



ENGLISH WEATHER DATA,
Feb. 9, 1861, 9h. A.M.,
by FRANCIS GALTON, F.R.S.
30·0
rise.
29·9
rise.
29·8
rise.
29·7
rise.
29·6
30·0
rise.
29·9
rise.
29·8
rise.

TUESDAY 21ST JANY 1873 AT 8 A.M.

BAROMETER.

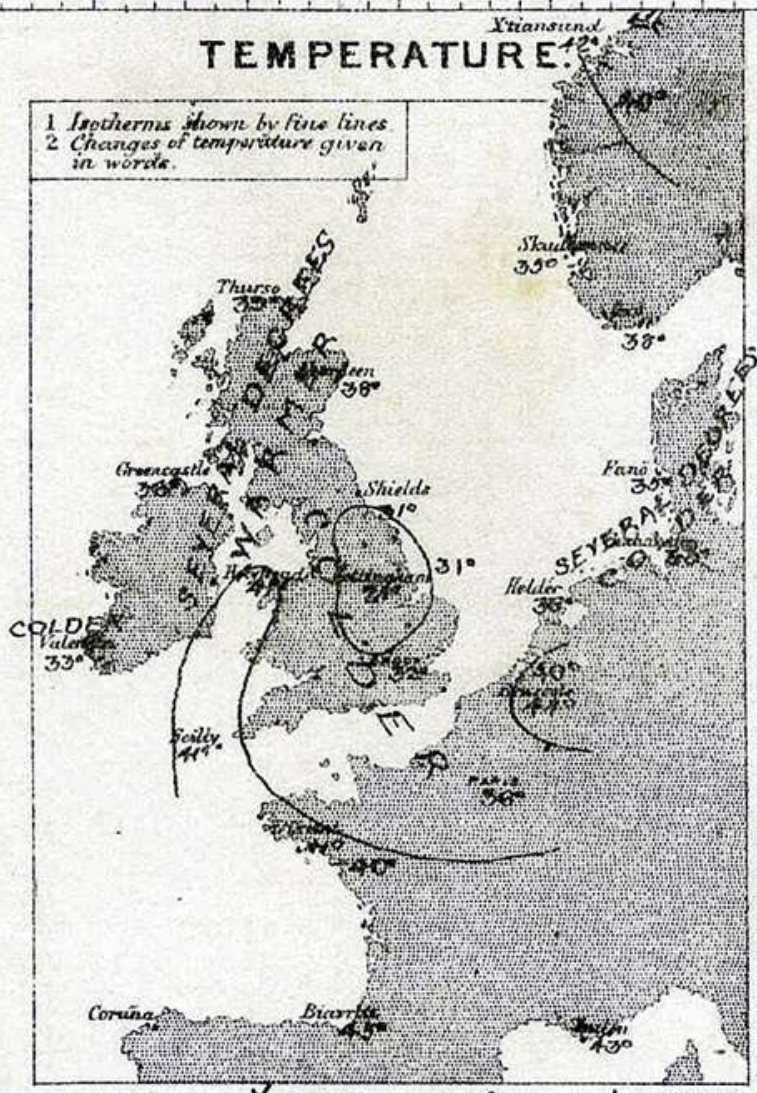
1 Isobaric lines drawn as necessary.
2 The highest and lowest readings reported shown in figures.
3 Changes given in words.



The barometer remained very low and was unsteady in the south east of England till last evening, though a recovery had commenced in the west and north. During the night this recovery has been general except in the east of France, and is most marked on the western and northern coasts. There is now a gradient of 0·06 in. per 30 miles from Valencia to Aberdeen.

TEMPERATURE.

1 Isotherms shown by fine lines
2 Changes of temperature given in words.



Temperature has again fallen at the eastern and southern stations and a sharp frost prevails over the centre and east of England. At York the temperature in the shade fell to 18° last night.

Where are we now?

The Primitive Equations of Meteorology – p, T, (u, v) and q

$$p = \rho RT$$

Ideal Gas Law (Equation of State)

$$\Delta T = \Delta q / c_p + (1/\rho)\Delta p$$

First Law of Thermodynamics

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

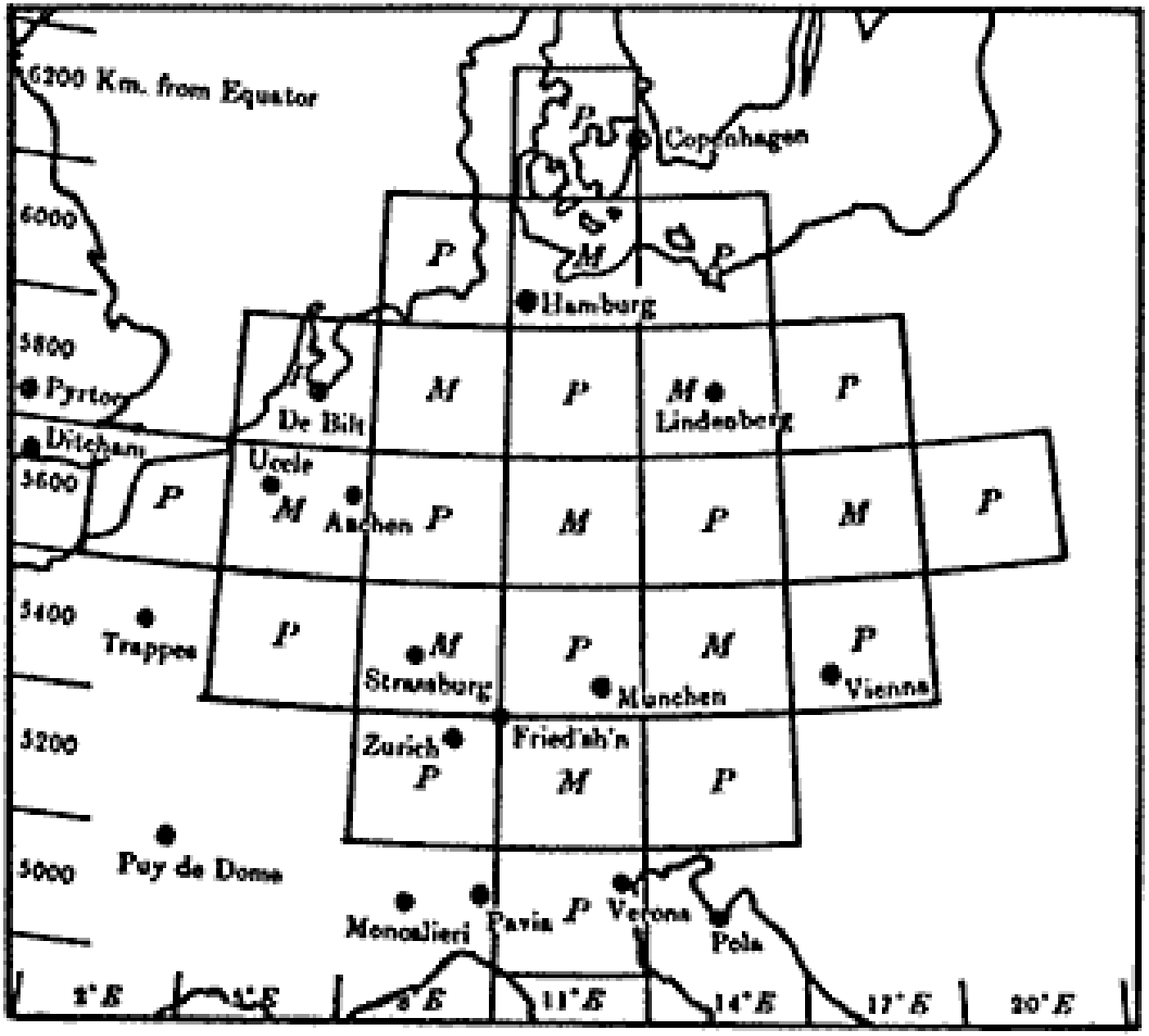
Hydrostatic Law

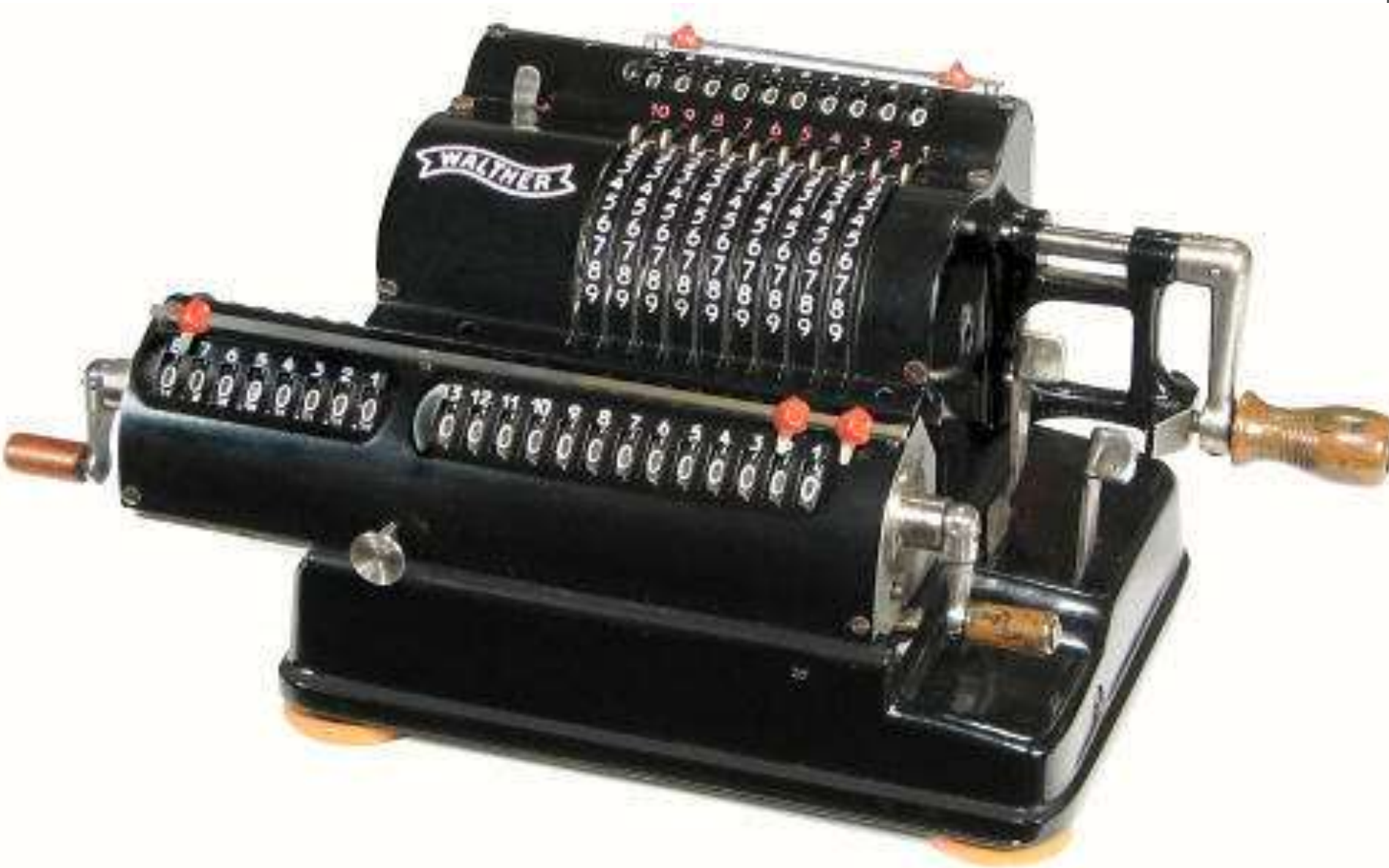
$$\vec{a}_h = \sum \left(\vec{F}_h / m \right)$$

Newton's Second Law of Motion

$$\frac{1}{\rho} \Delta\rho / \Delta t = -DIV$$

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

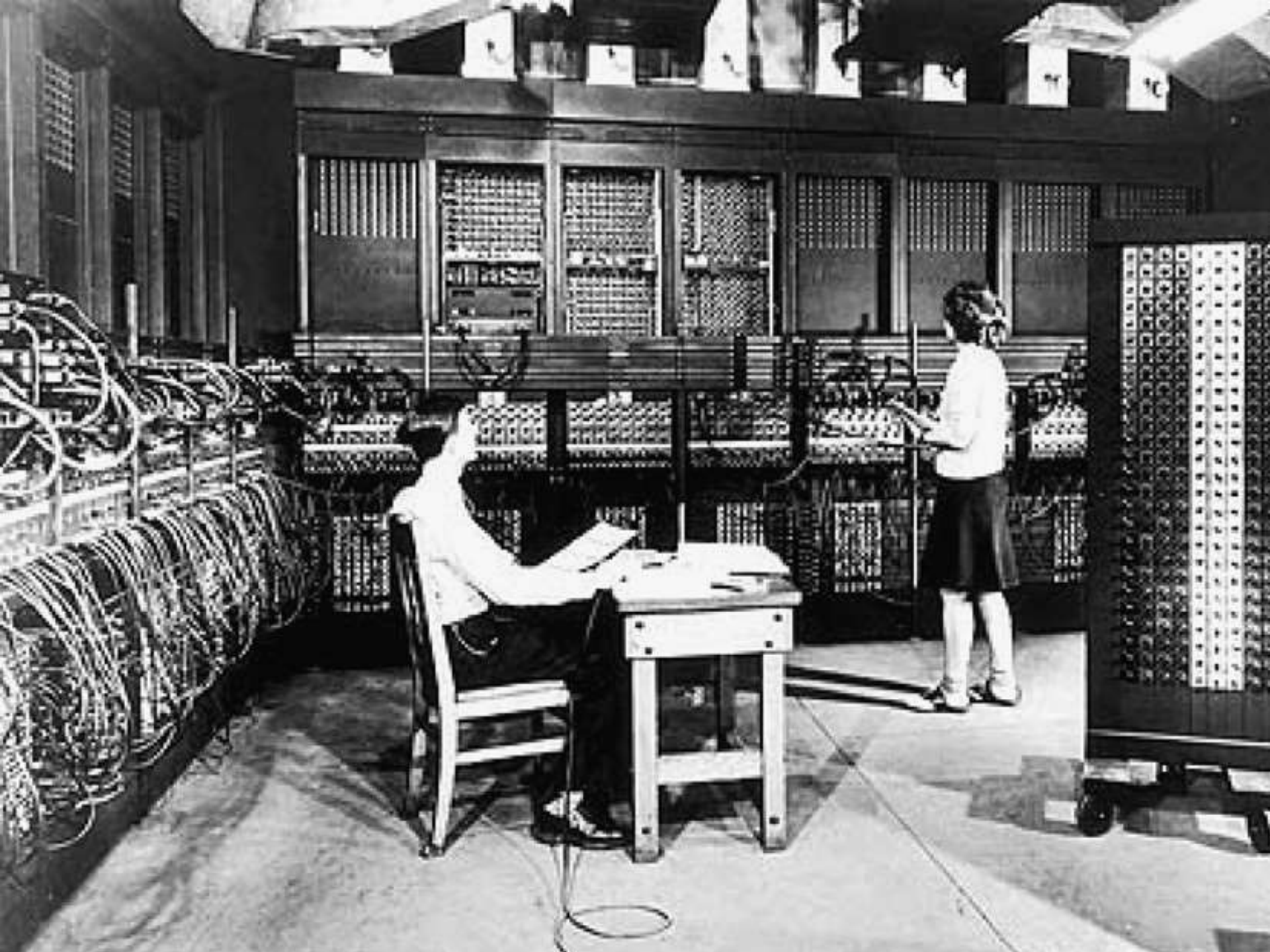




Quasi-Geostrophic Vorticity Equation

$$q = \left(\frac{1}{f_o}\nabla^2\Phi + f + \frac{\partial}{\partial p}\left(\frac{f_o}{\sigma}\frac{\partial\Phi}{\partial p}\right)\right)$$

Baroclinic Instability Theory



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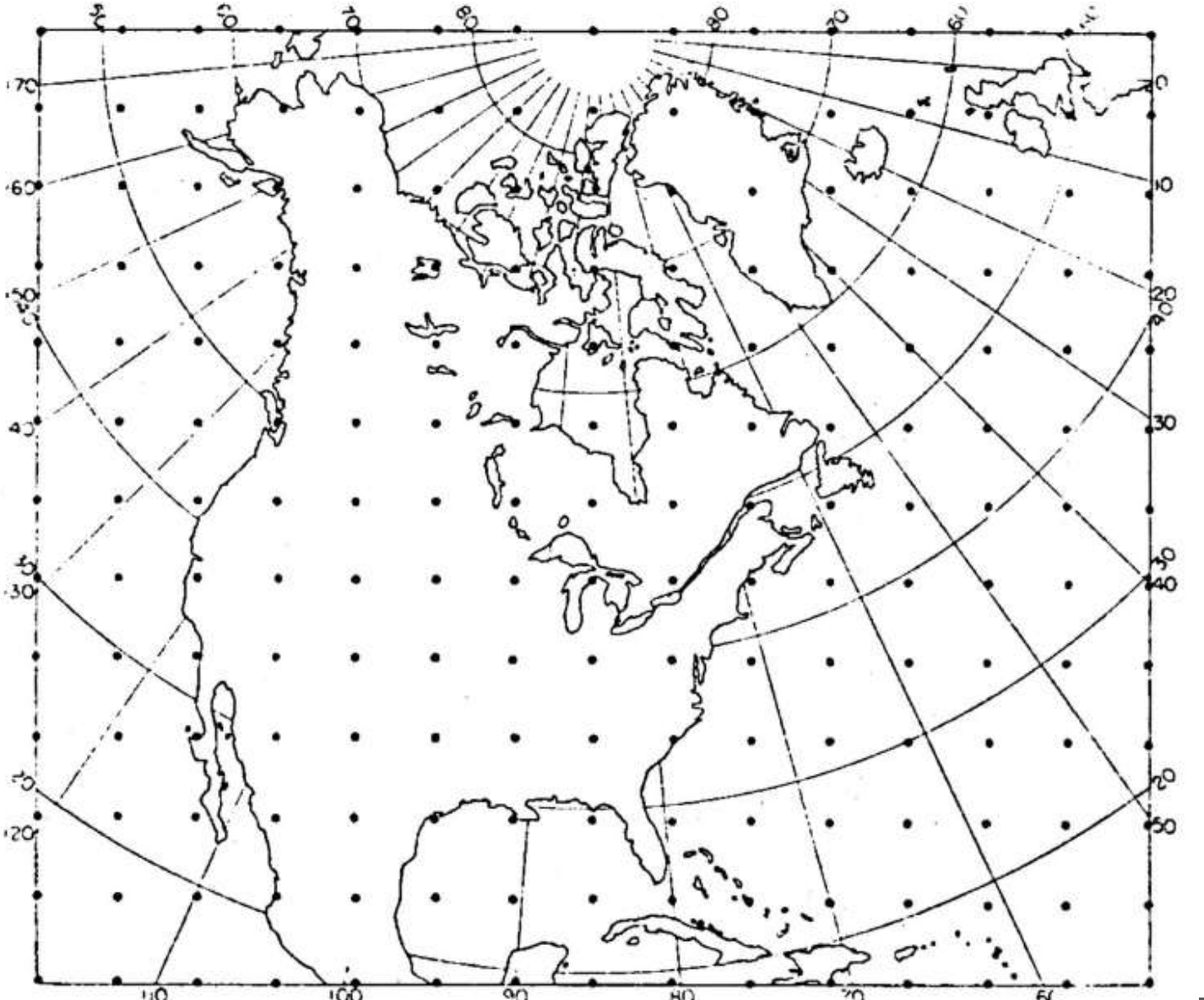
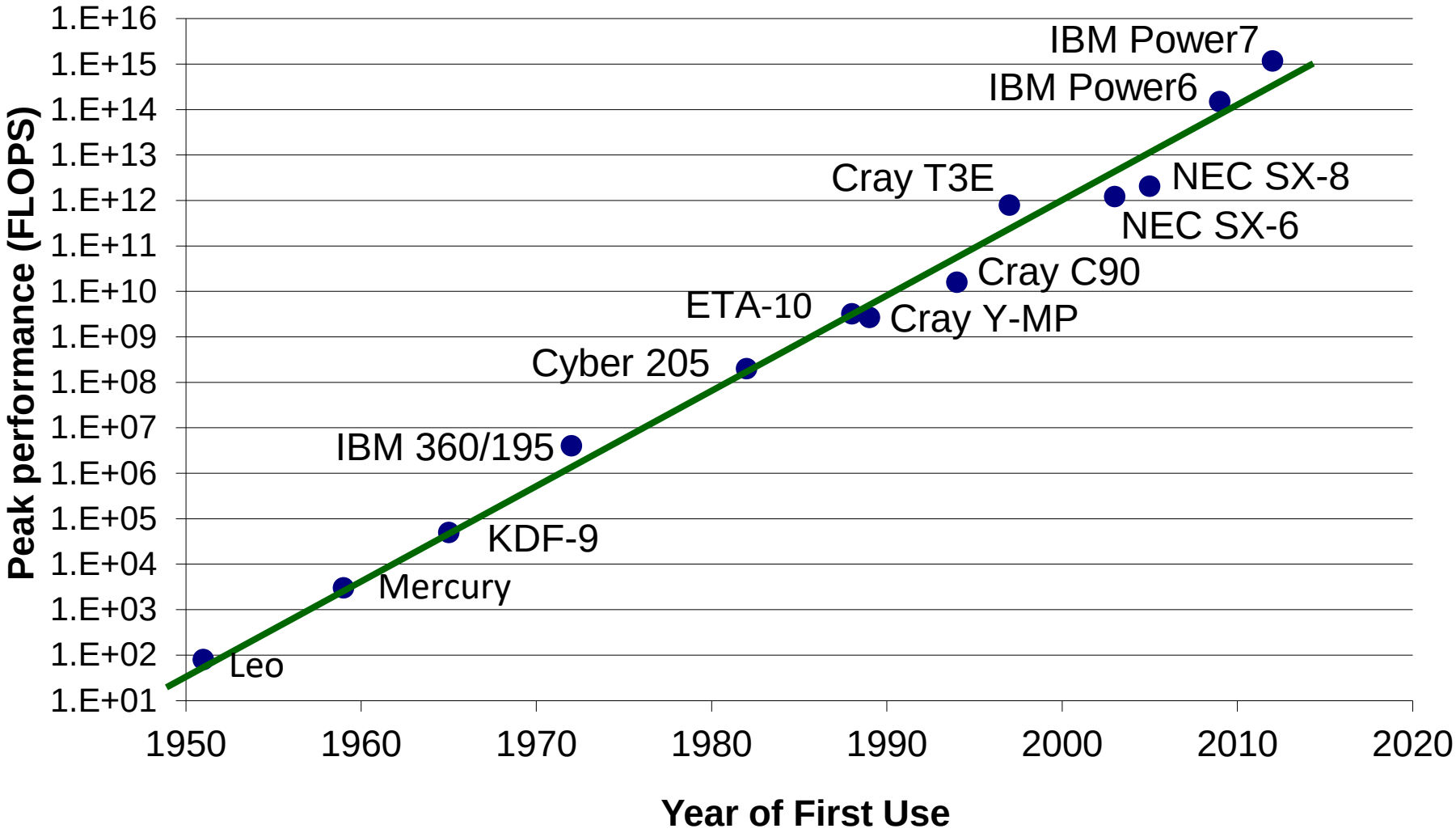
- ENIAC 24 hour forecast grid



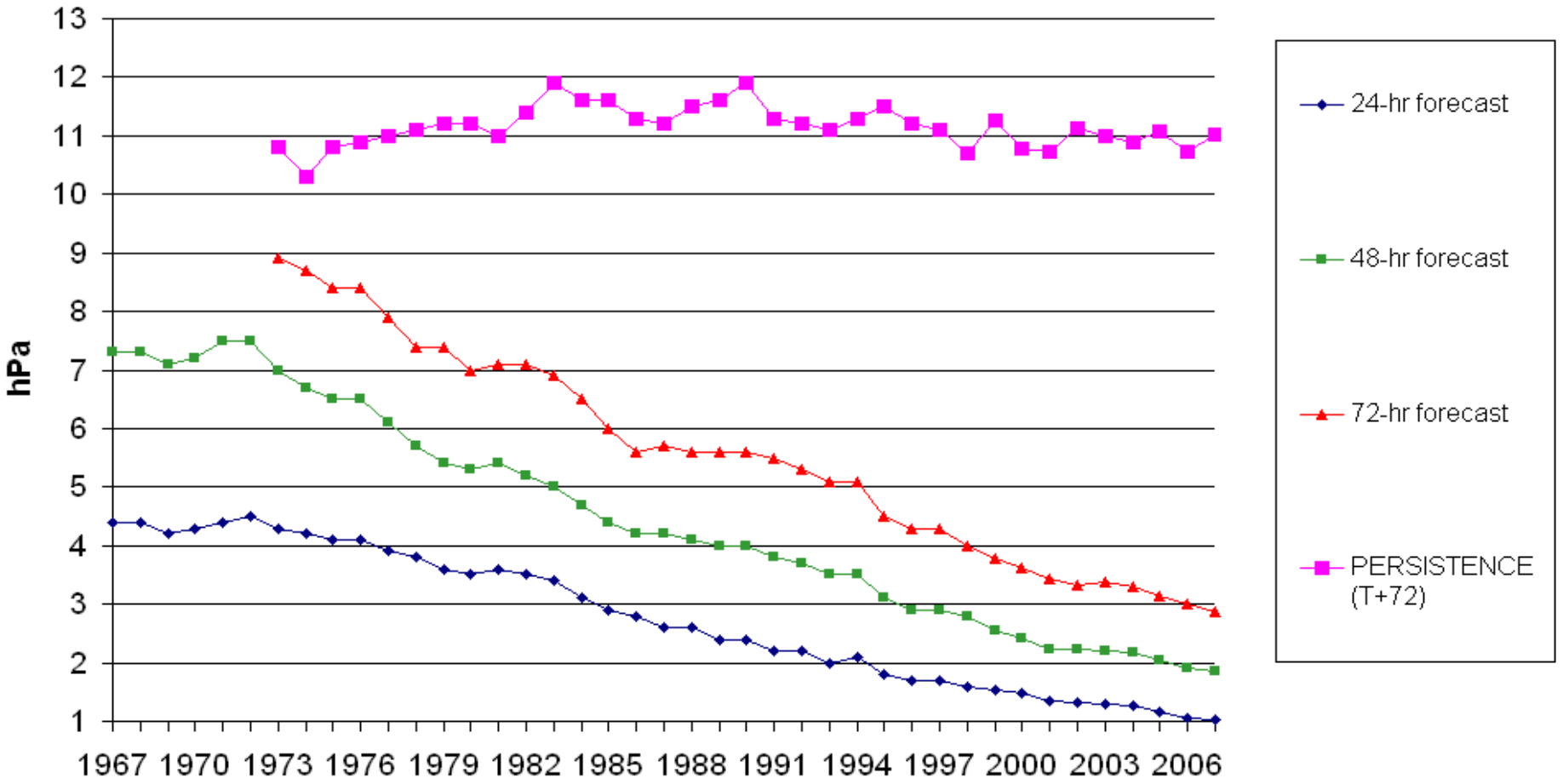
Met Office

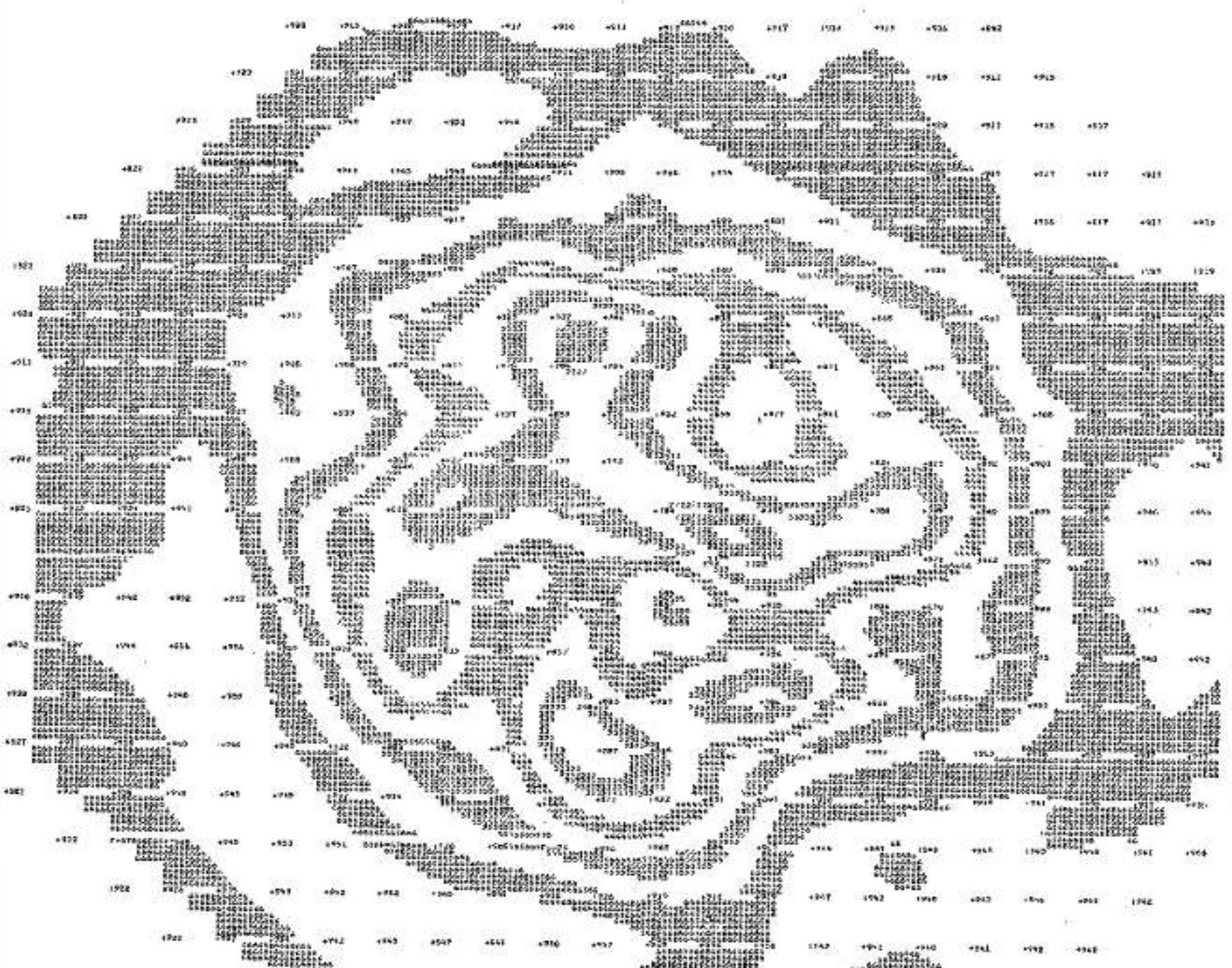
Computers Used for Weather and Climate Prediction

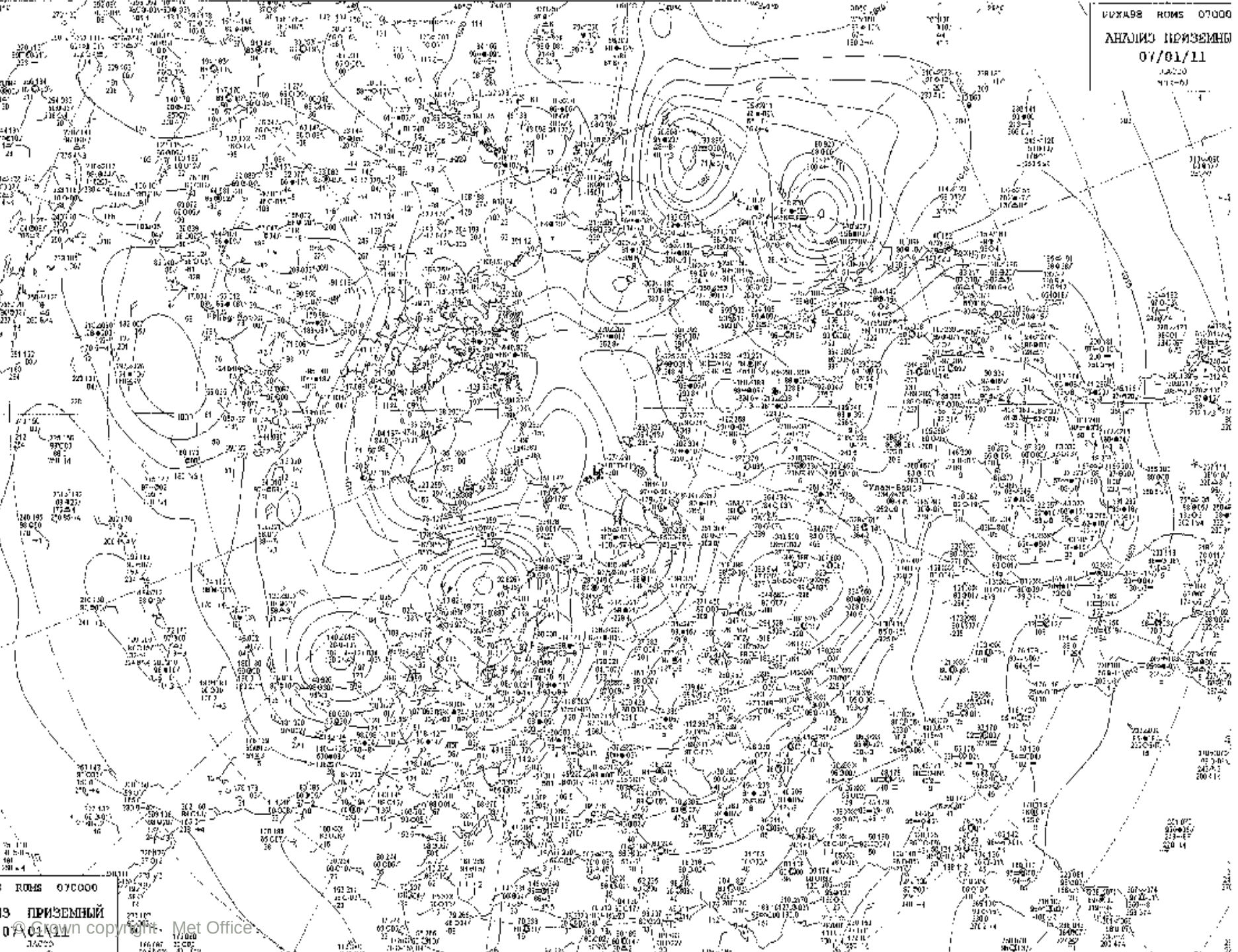


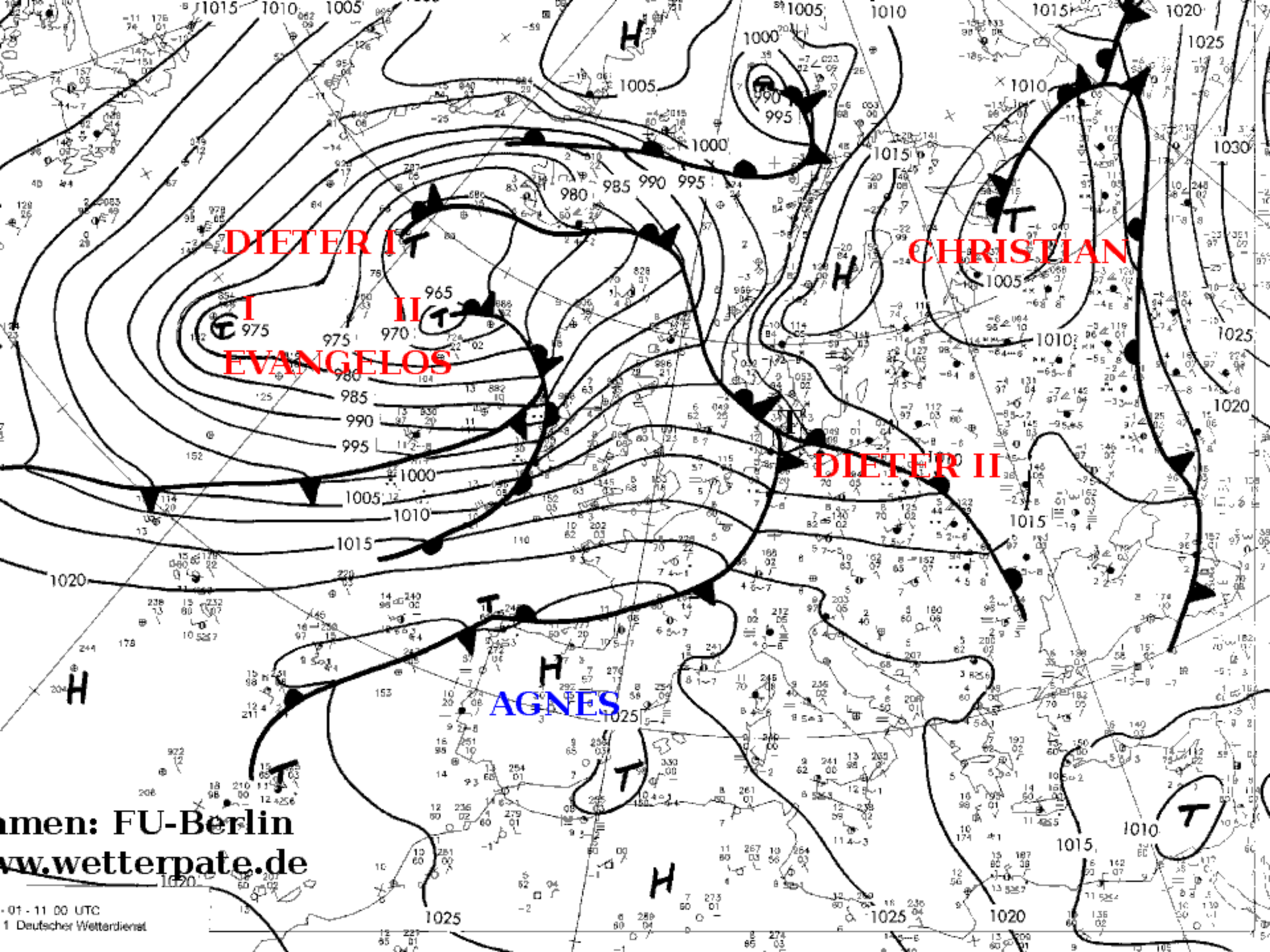
Improving accuracy: Pmsl

RMS surface pressure error over the NE Atlantic








DIETER I
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EVANGELOS
CHRISTIAN
DIETER II
AGNES
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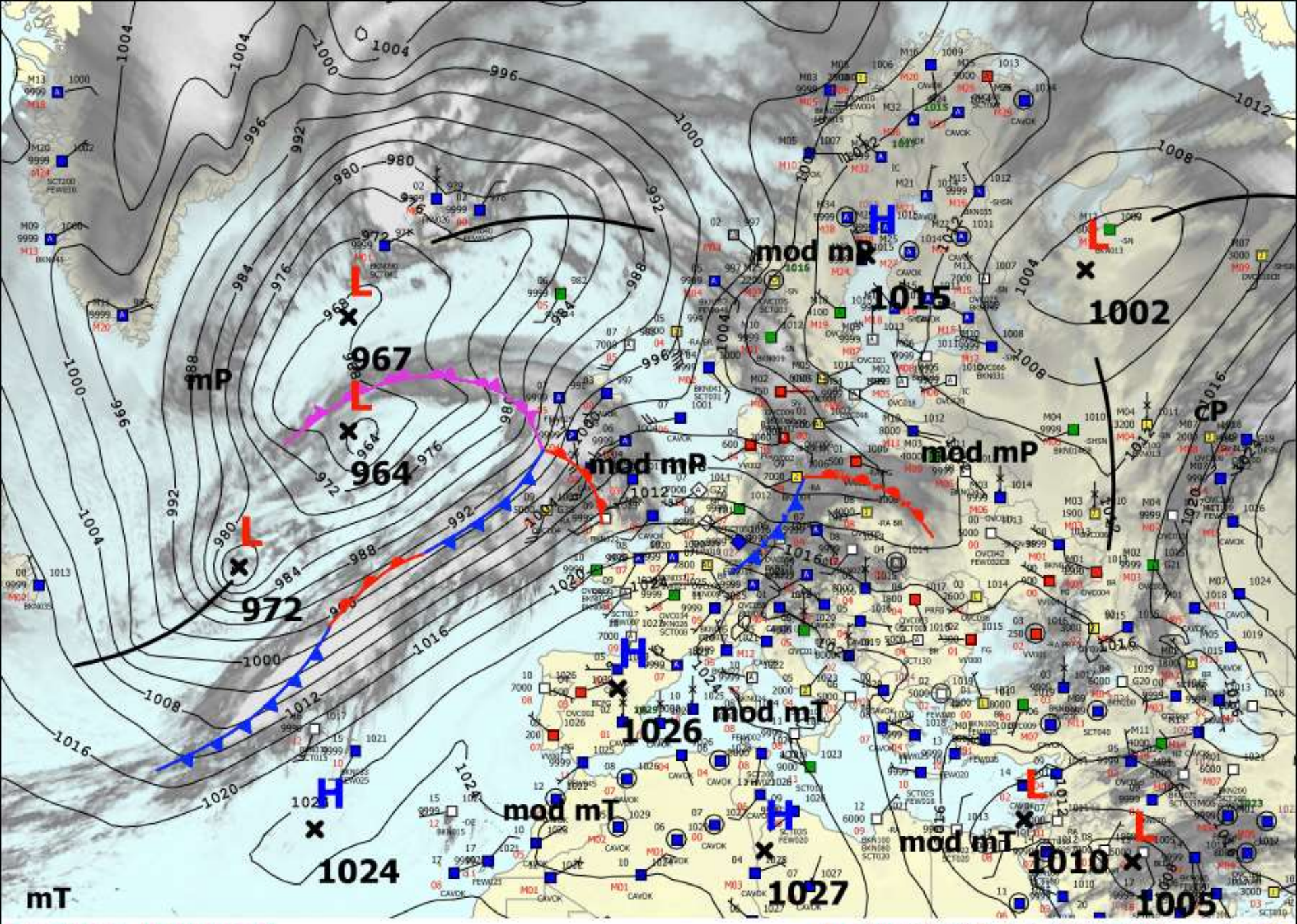
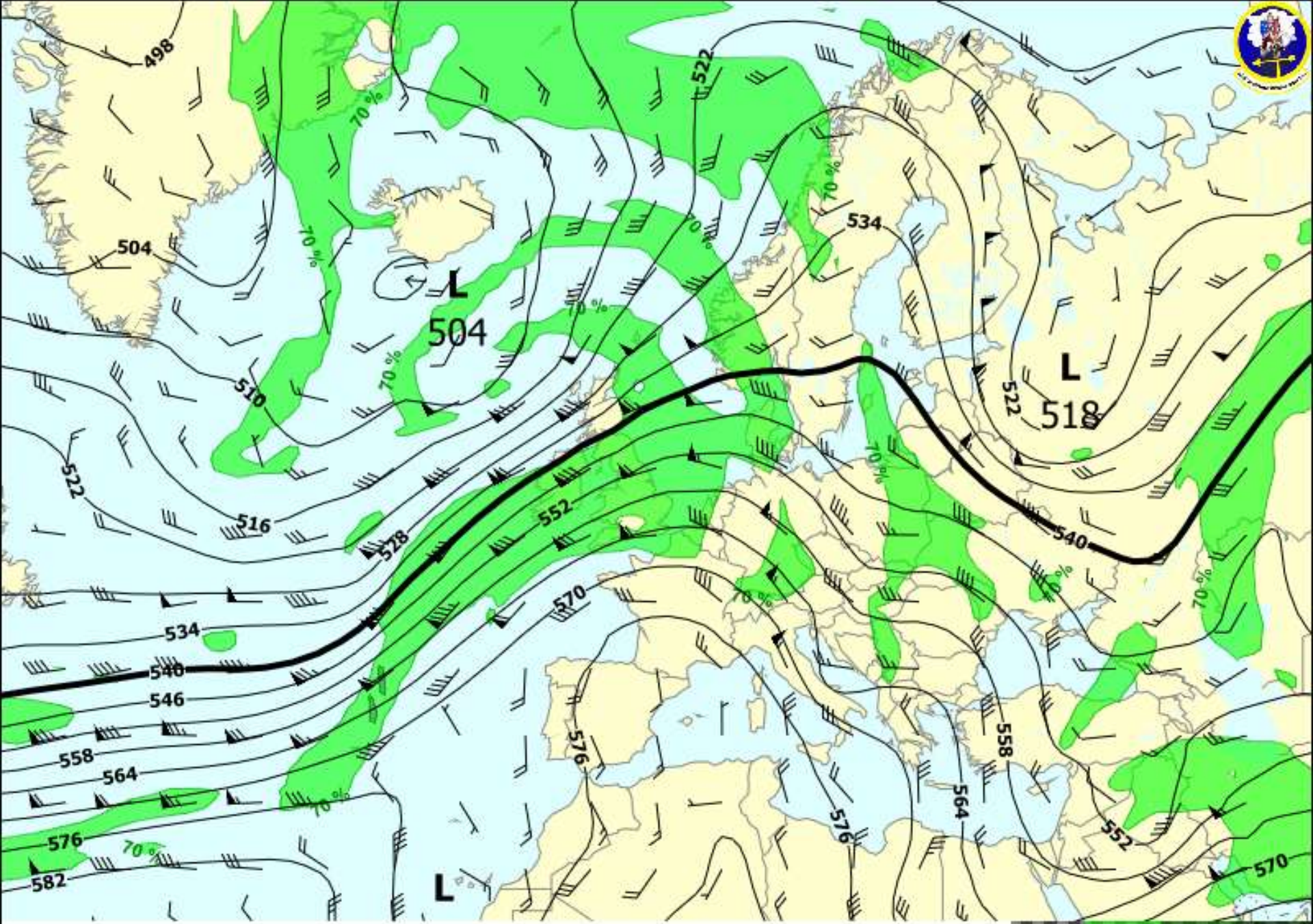


SURFACE ANALYSIS

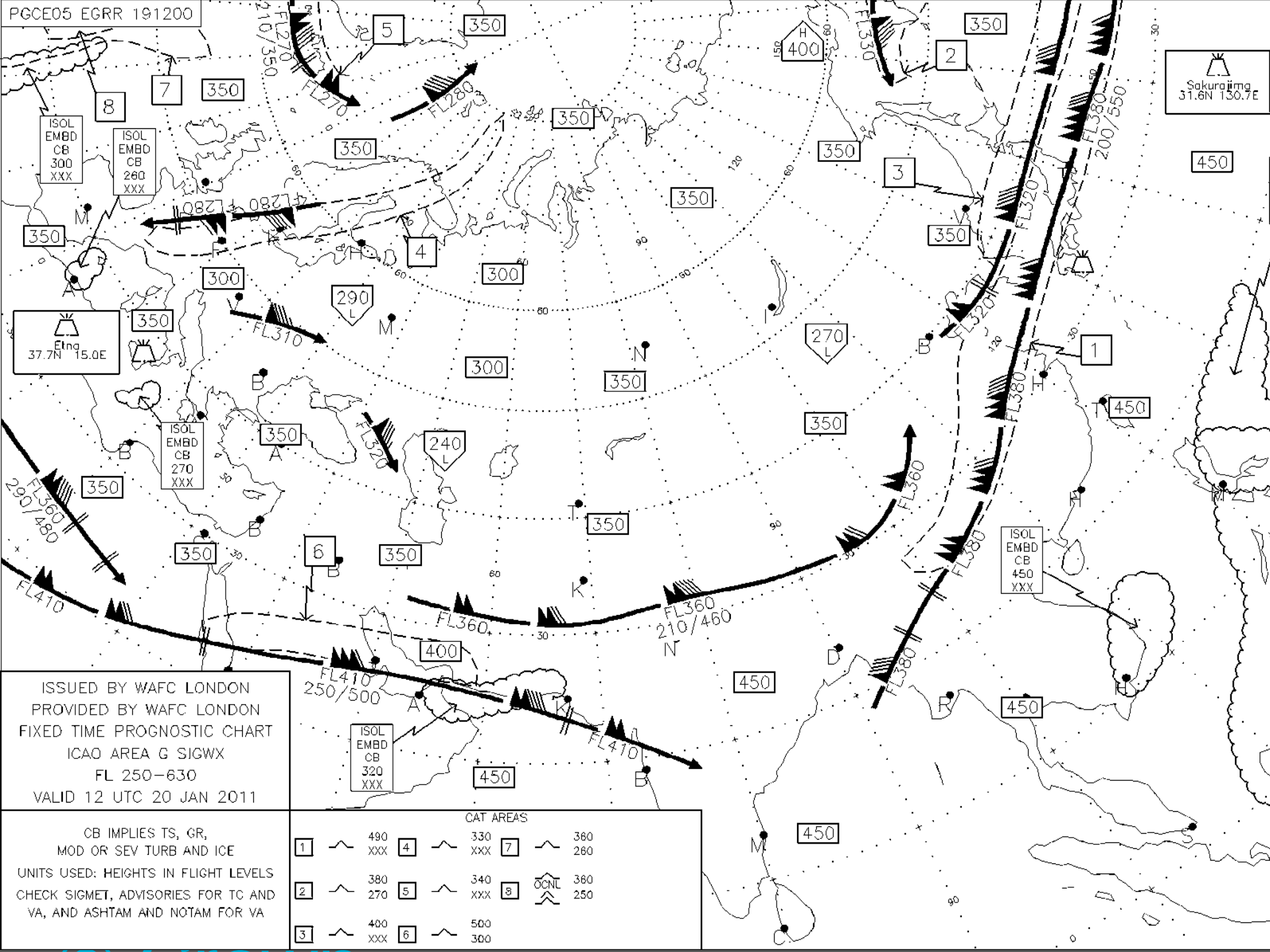
VT: 15 JAN 007 POSTED AT: 15/00387

L - LOW PRESSURE — COLD FRONT

H - HIGH PRESSURE — STATIONARY FRONT



500MB GPH | RH | WINDS VT: SAT 15 JAN 12Z (T+12)
UKMO GLOBAL MODEL 15/00Z


PGCE05 EGRR 191200
ISSUED BY WAFC LONDON
PROVIDED BY WAFC LONDON
FIXED TIME PROGNOSTIC CHART
ICAO AREA G SIGWX
FL 250–630
VALID 12 UTC 20 JAN 2011
CB IMPLIES TS, GR,
MOD OR SEV TURB AND ICE
UNITS USED: HEIGHTS IN FLIGHT LEVELS
CHECK SIGMET, ADVISORIES FOR TC AND
VA, AND ASHTAM AND NOTAM FOR VA
CAT AREAS
1 490 XXX
2 380 270
3 400 XXX
4 330 XXX
5 340 XXX
6 500 300
7 360 260
8 OCNL 360 250
ISOL EMBD CB 300 XXX
ISOL EMBD CB 260 XXX
ISOL EMBD CB 270 XXX
ISOL EMBD CB 320 XXX
ISOL EMBD CB 450 XXX
Etna 37.7N 15.0E
Sakurajima 31.6N 130.7E
FL270/350
FL280/360
FL280
FL310
FL320
FL330
FL360
FL380
FL410
FL360 290/480
FL380 200/550
FL360 210/460
FL410 250/500
290 L
240 L
270 L
H 400
350
300
400
450

Meteorology meets GIS

1980s: GIS not feasible

1990s: Niche GIS use for specific products for limited customers

2000s: Nicer niche products and prettier backgrounds

2007: Regular Met Conference: recommended GIS workshop

2008-2009: Workshop on GIS/OGC Standards in Meteorology:

- Recommended OGC involvement and establish Met DWG
- Proposed work: **WMS interoperability for Nat. Met. Services**
- MoU between OGC & WMO and IOC/WMO JCOMM
- Covers meteorology, climatology, hydrology, oceanography
- OGC Met Ocean Domain WG established

2009-2013: Three more Workshops, ~ 10 NMS joined OGC

- Work extended to **conceptual modelling, WCS**

2014-2018 OGC and W3C: SDWBP, Time, CRS, graphics, etc

2018-2020 Weather on the Web (WotW) APIs

-> OGC API – Environmental Data Retrieval (EDR)

Thoughts on Future Possibilities

Meteorology has a history of inventing/tailoring technologies

☒ Operating Systems

☒ Programming Languages

☒ Telecoms Protocols

☒ Telecom computers (message switching)

? Data Formats

☑ Visualisations

☑ Semantics

GIS domain!

Challenges for Mapping in Meteorology

Met Office

Long history of interoperability at human/paper level

Significant ‘Objects’, features of interest

Not Mbytes or GB, but TB and PetaBytes of data daily

Spatial & Temporal, 2D, 3D, 4+D, constantly changing

- Multiple Time attributes
- Irregular time intervals
- Timescales: hours,.., seasons,.., centuries, + & -

Vertical coordinates

- Cross-sections, height-time diagrams, T/φs, etc

‘Regular’ grids are not always regular

Continual change of coordinate systems & projecting

- Eulerian versus Lagrangian viewpoints

Ensembles: probabilistic distributions

Technology Trends

NWP resolutions from 500km -> 1km -> 0.3km -> ?

More blending of our data with customers/users:

- Met, Ocean, Hydro, Space, Ecology, Earth Systems

Likely evolution / interactions

- WMO Formats -> general Scientific Formats (netCDF, Zarr, ..)
- -> Geospatial standards ?
- Visualisations -> general graphics tech (SVG, OpenGL, …)
- -> Geospatial standards (SLD/SE?)

2D Maps & Layers ‘broken’

2D Maps and Layers - cartography

3D or 4D data breaks ‘Layers’ paradigm

- Suppose data have 10 levels x 10 times: ->
- 100 layers – choose from a menu?

But

- 100 levels, 100 times, 100 ensembles: ->
- 1 000 000 layers?
- X 100s of parameters of interest

Geospatial is Changing

Other 3D activities in OGC:

- CDB simulation
- Gaming
- UxVs
- Underground
- CityGML
- 3D Portrayal

None of these based on traditional 2D cartography

Start from 3/4D assumption

- Lots of 3D support in h/w (GPUs)
- Derive 2D by restriction of 3/4D work
- Could support other visualisations: cross sections (“vertical maps”), graphs

Generic containers, managed APIs, RESTful

Moving away from Schemas to ‘schema-less’

Future possibilities?

- 5 years: No specialized meteorological visualization software, all done in generic geospatial software with meteorological style sheets?
- 10 years: No specialized geospatial software, all done in ‘browsers’?
- Real 3D displays when?
- Virtual Reality/Augmented Reality/Head-Up Displays make 3D easier?

Consequential suggestions:

0. Make Z & T ‘first class CRS citizens’
1. Codify and expose meteorological styles
2. Expose meteorological symbols and their semantics
   - Try to put into Unicode
3. Move away from existing rigid layout of WMO symbols/semantics of artificial 10x10 structure imposed by telegraphic codes
4. ‘Abstract’ symbols powerful. C.f. SigWx chart

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Questions & Answers

WMO Present Weather Symbols

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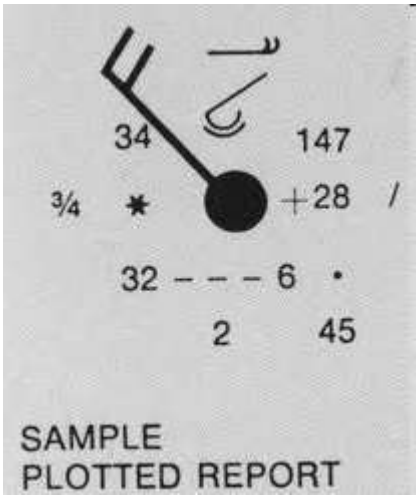

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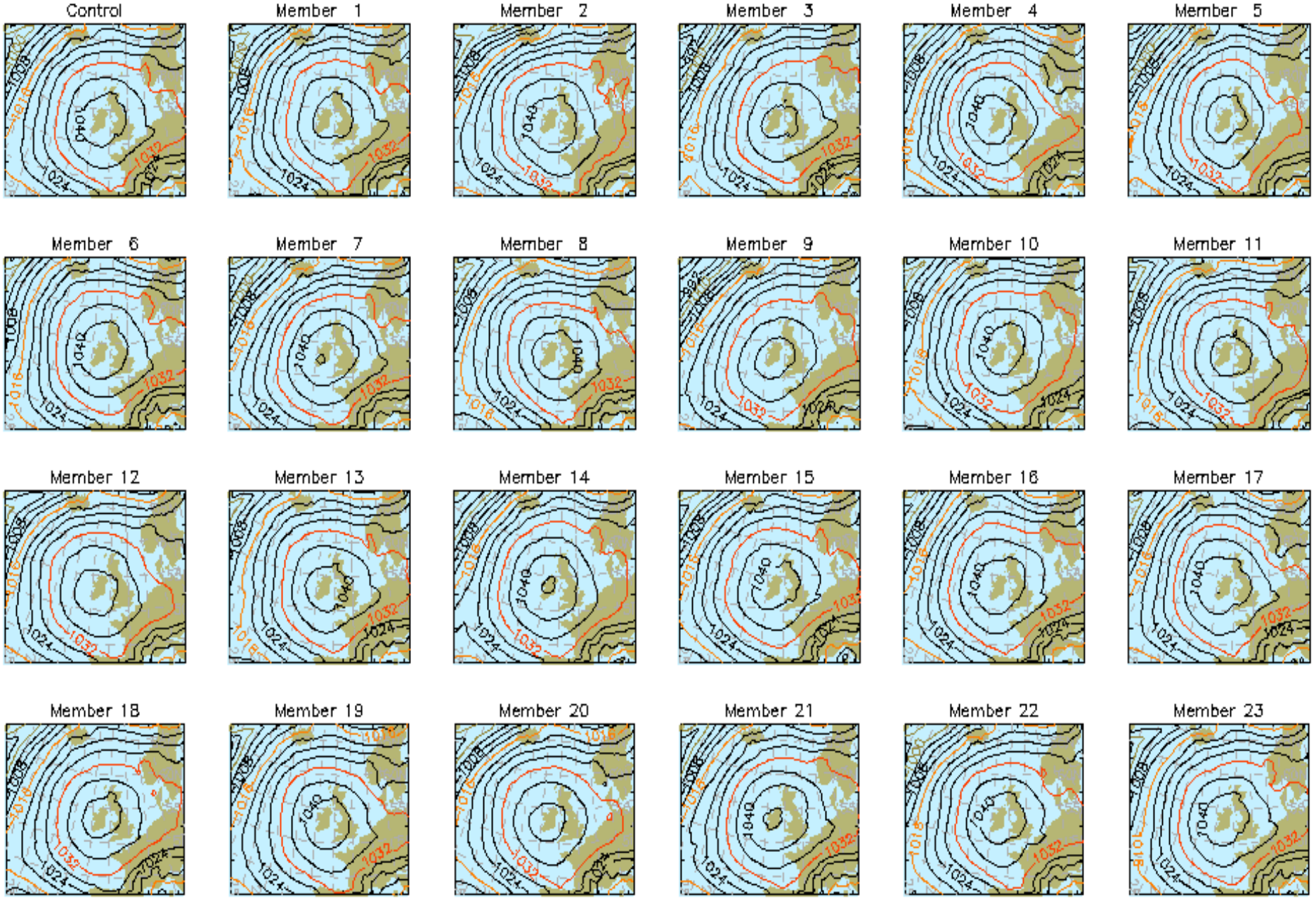
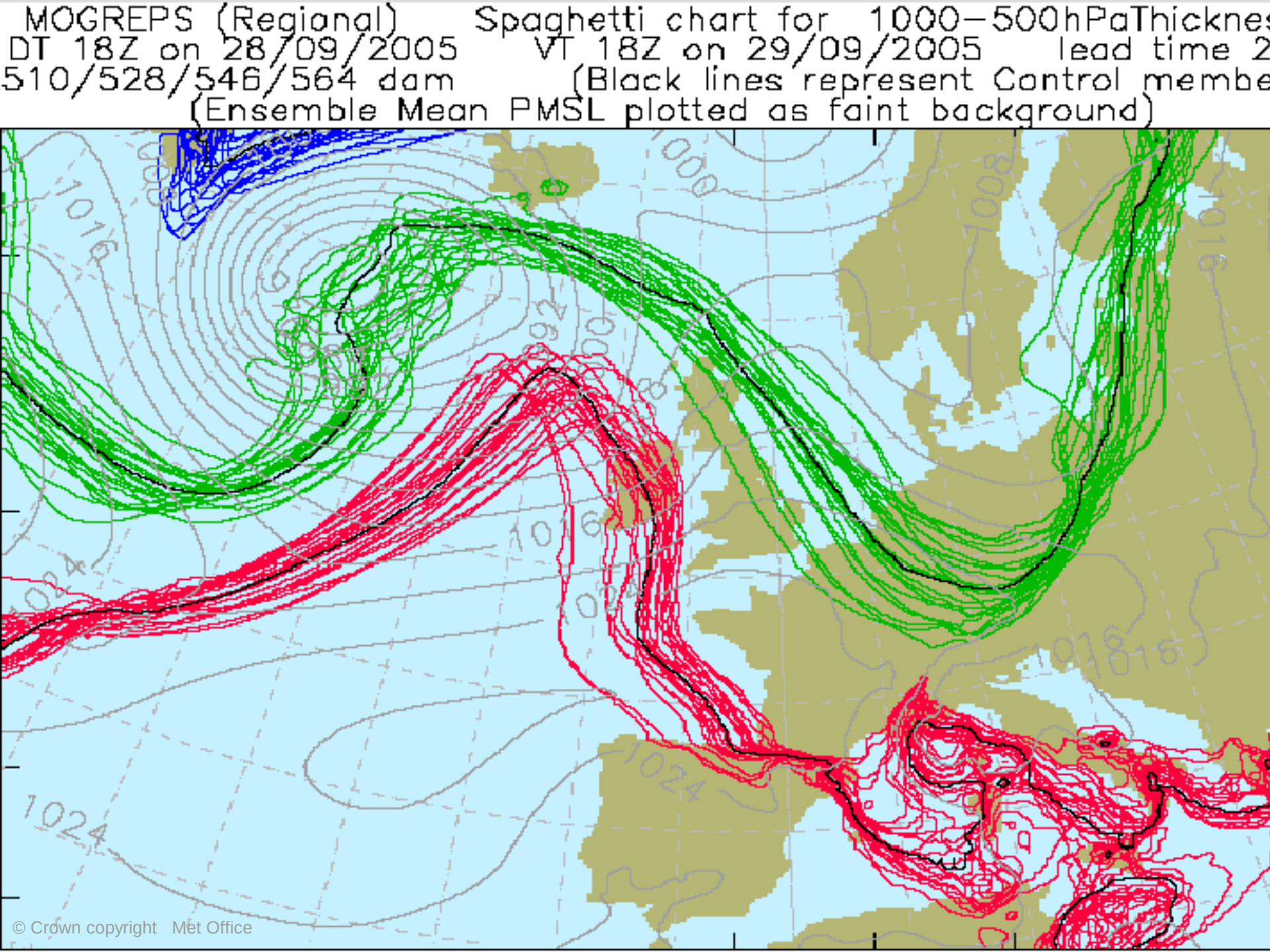
C_L									
C_M									
C_H									

MOGREPS (Regional) PMSL (hPa)

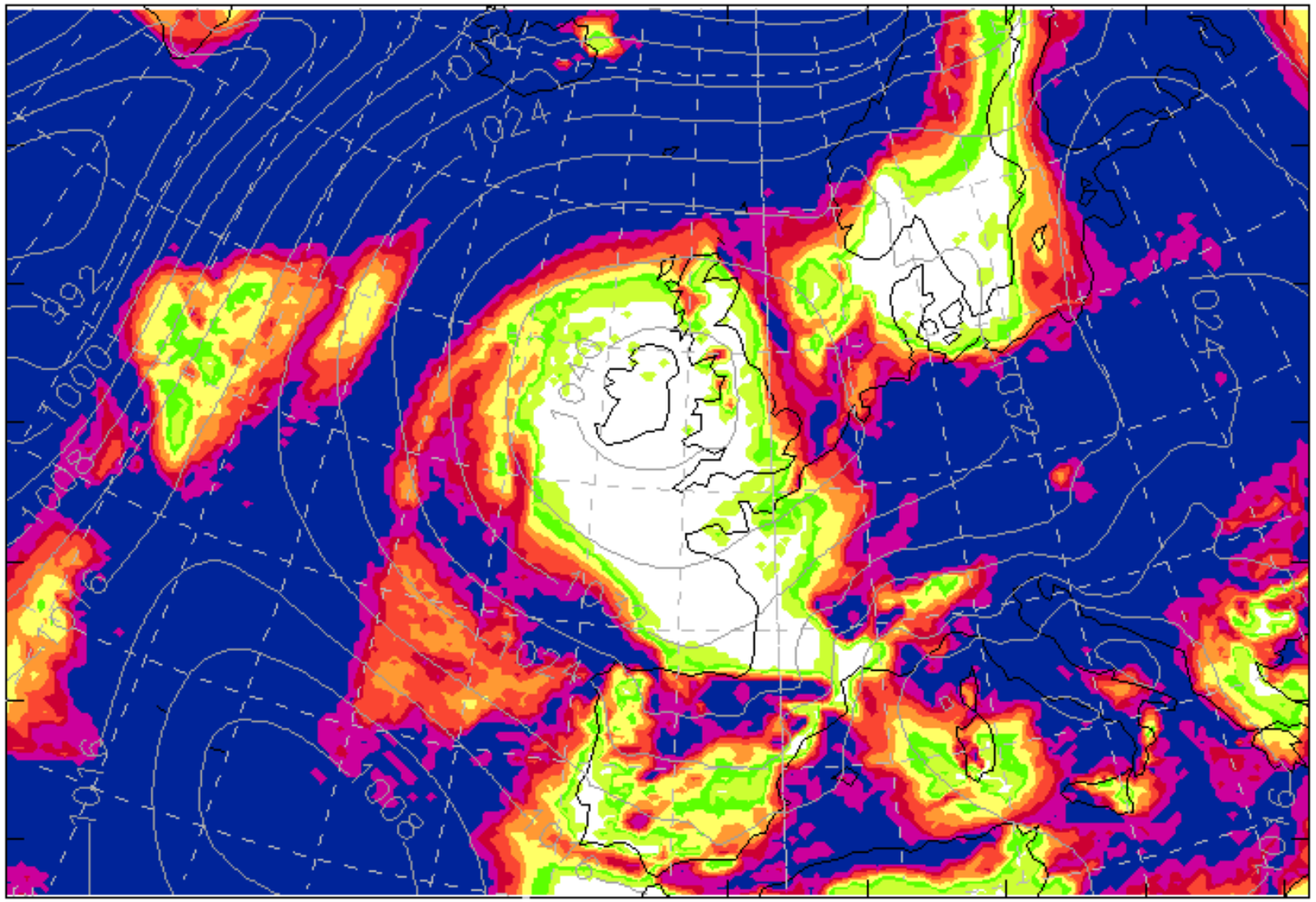
T+54h

DT 06Z on Wed 19/01/2011
VT 12Z on Fri 21/01/2011




MOGREPS (Regional) Spaghetti chart for 1000-500hPaThicknes
DT 18Z on 28/09/2005 VT 18Z on 29/09/2005 lead time 2
510/528/546/564 dam (Black lines represent Control membe
(Ensemble Mean PMSL plotted as faint background)
1000
1008
1016
1024
© Crown copyright Met Office

MOGREPS (Regional) Probability map for 48HourPrecip > 0.5mm
DT 06Z on Wed 19/01/2011 VT 06Z on Fri 21/01/2011 lead time 48h
(Ensemble Mean PMSL plotted as faint background)



No Members 0.01 0.1 0.2 0.4 0.6 0.8 0.9 0.99 All Members

Summary - Forecasting

Big Data getting bigger despite electricity costs

Forecasts need supercomputers, not ‘cloud computing’

Meteo and Ocean forecasts too big & volatile to move

- Global enterprise involving all 193 countries.

“Moving data costs, calculations are free”

1. Move apps to the data, but how?
   - Merging authoritative & unreliable info
   - Need federated security architecture
2. Defining ‘Convenience APIs’
   - Get just the data needed for the application
   - Use scalable Web architectural style ‘RESTful’
   - Cache retrieved API data with URI for re-use

Summary - Data

Cross-domain information becoming the norm, BUT

domain specific (big) data formats here to stay:

- (NetCDF, HDF, GRIB, BUFR, FITS, BAM, VCF, GF3, …)
- Binary, efficient, optimised
- Established eco-systems of access software & tools
- Established domain expertise, controlled vocabularies

Generic data formats have no traction, BUT

Web friendly transfer formats for browsers and apps

- (CSV, JSON, XML)
- More verbose – small amounts OK

Summary - Metadata

Metadata should be cross-domain for discovery

- Metadata fixed format/containers a good start
- Only for discovery, not usage and management
- Metadata is open-ended, not in containers/catalogues/portals

Controlled Vocabularies -> Taxonomies -> Ontologies

Semantic Web / Web 2.0

- Highly scalable
- Highly flexible

Resolvable registries of controlled vocabularies happening

Conceptual models can be stored as ontologies

Ontologies allow valid machine reasoning

Semantic formats much too verbose for most data