Mécanique des Fluides
2017-2018

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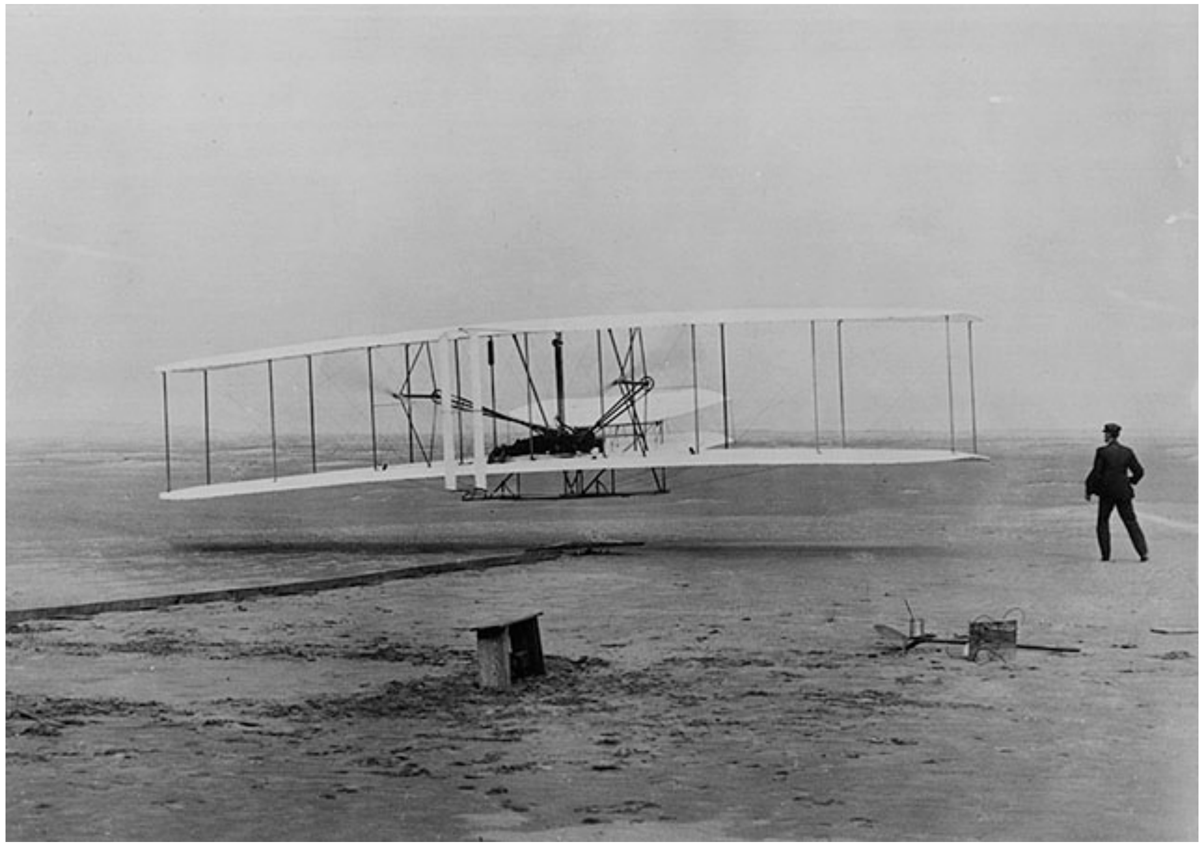
www.pmmh.espci.fr

- Y a-t-il une industrie de la mécanique des fluides ?
- Y a-t-il des industries sans mécanique des fluides ?
- Une science du $19^{\text{ème}}$ siècle, reste-t-il des questions fondamentales ?
- Mécanique des fluides, climat et énergie

L'aéronautique, une industrie de la mécanique des fluides

Otto Lilienthal 1894



vol des frères Wright 1903

Premiers succès empiriques

Une technologie aboutie ?

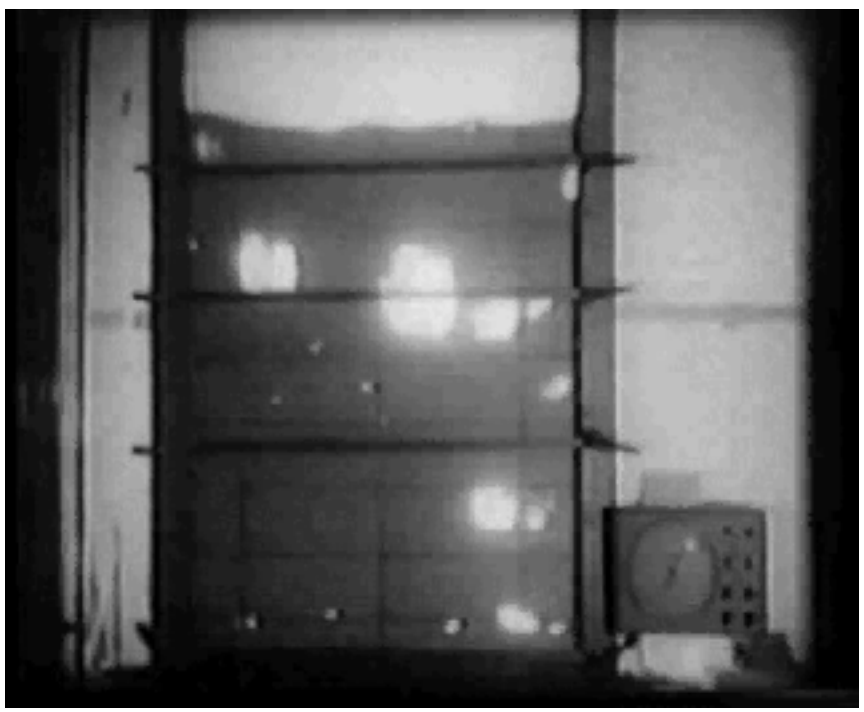
Boeing 707
1954

Northrop XB35
1946

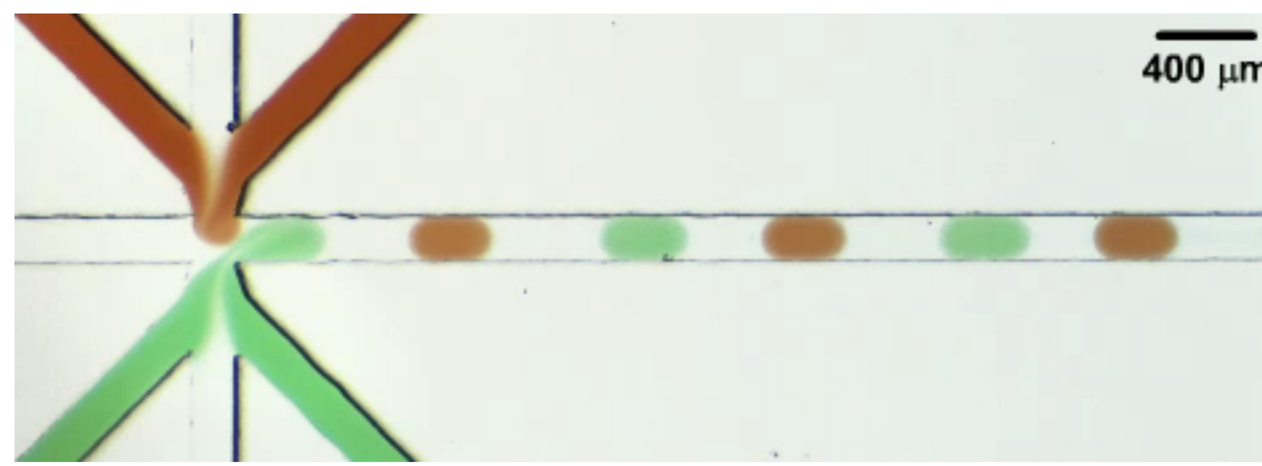
Airbus A380
2006

Des industries sans mécanique des fluides ?
Peut-être mais le mouvement des fluides est au coeur de nombreux procédés

Génie chimique à grande et petite échelle



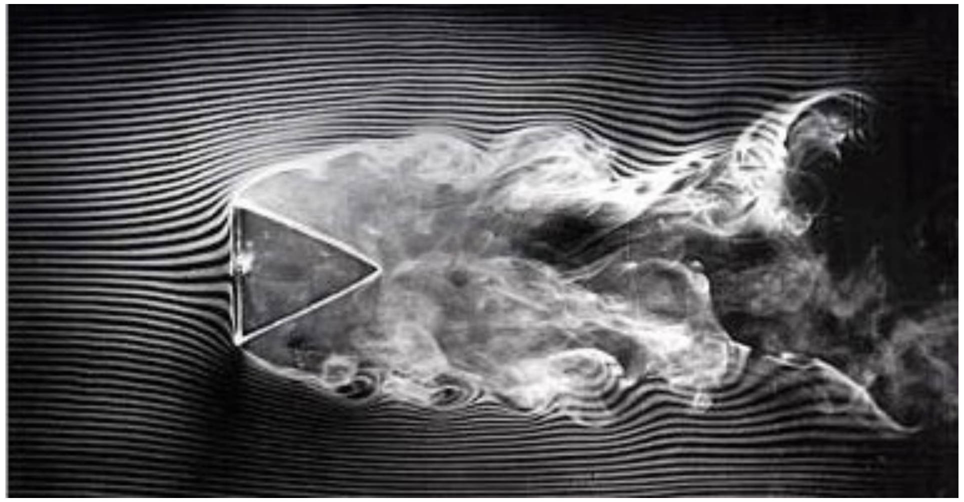
Instabilité de lit fluidisé



Production de gouttes alternées en microfluidique

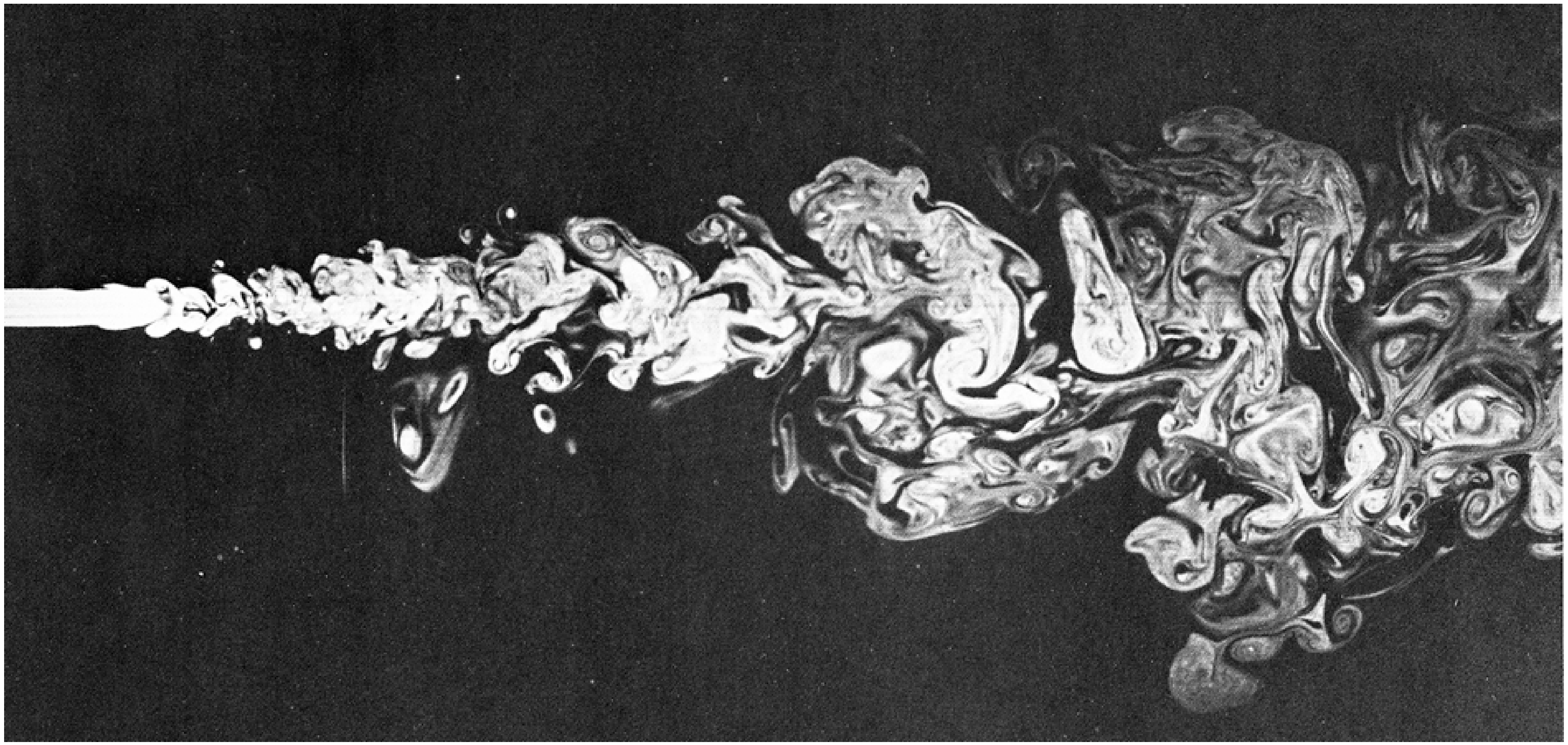
Une vieille science, mais toujours active

- 1700 : Newton Notion de frottement fluide
- 1740 : Bernoulli, Euler Mouvement de fluide parfait
- 1820 - 1845 : Navier, St Venant, Stokes Description du mouvement avec viscosité
- 1844 : Poiseuille, Hagen Ecoulement de fluide visqueux dans un tube
- 1875 : Boussinesq Premières théories sur la turbulence
- 1900 : Prandtl Notion de couche limite
  - Eiffel Souffleries
  - Marey Chronophotographie, cinéma



Quelques axes de recherche modernes

- Echelles nanoscopiques
- Turbulence et simulation numérique
- Interfaces (au sens large)
  - Biophysique, vol instationnaire
  - Géophysique externe : dynamique atmosphérique et océanique
  - Interactions fluides/grains : érosion, transport



jet turbulent

Une étude de propulsion instationnaire

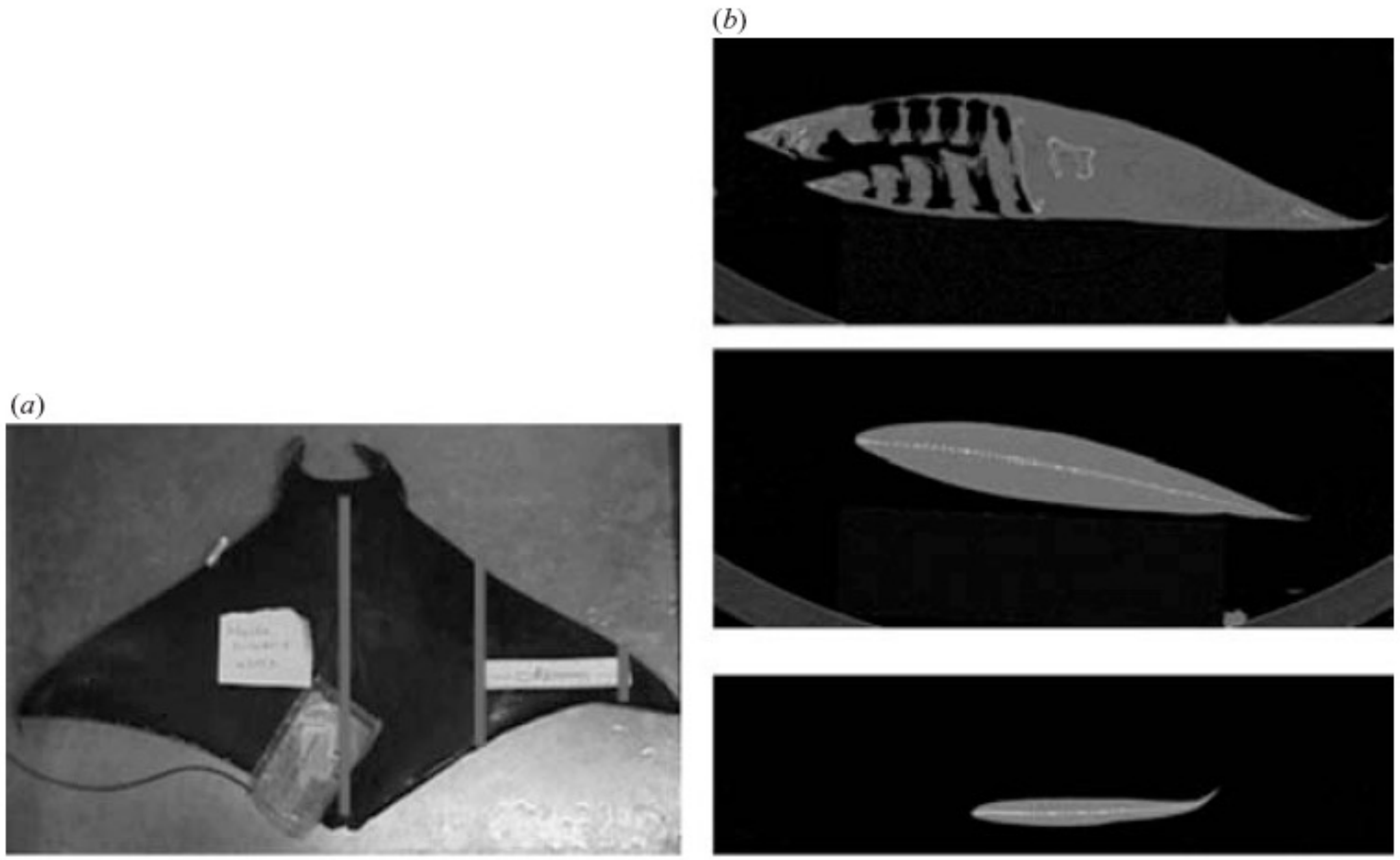


FIGURE 1. (*a*) Planform photo of a juvenile manta ray. (*b*) Catscan cross-sections at the locations shown in the planform photo. The thickness-to-chord ratio varies between 0.15 and 0.20 along the span. Images provided by Professor Frank Fish.

Clark & Smits
J. Fluid Mech. 2006

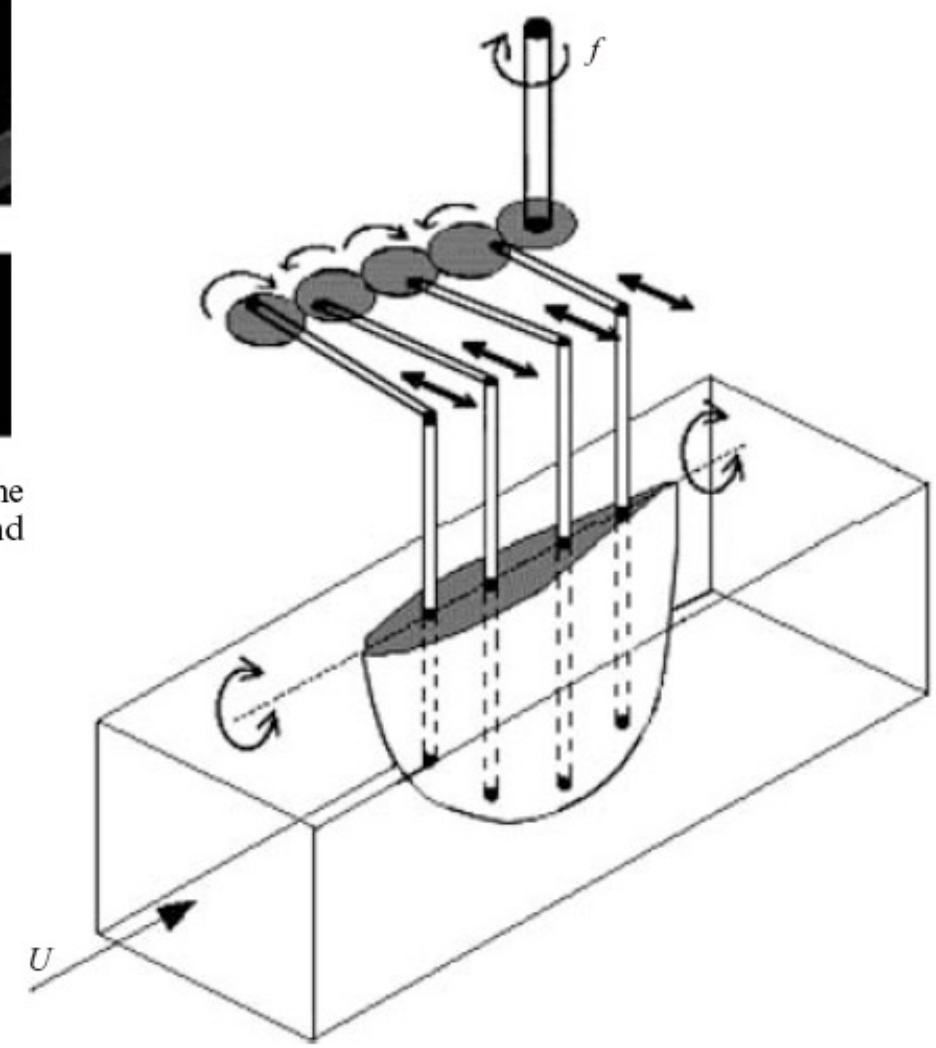


FIGURE 2. Fin actuation mechanism. A DC motor with a speed controller turns a sha
frequency f which powers a gear train. The rotation of the gears actuates rods which im
a travelling wave along the fin through rigid spars.

Une étude de propulsion instationnaire

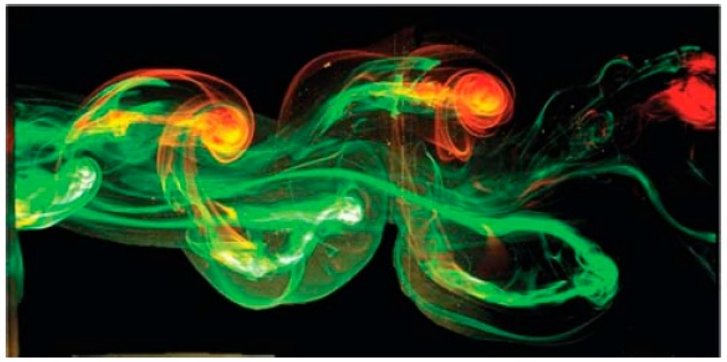


FIGURE 8. Flow visualization in the near wake of the fin at $\phi = 90°$ and $St_A = 0.15$. The green dye was injected from one side of the fin, the red dye from the other side. Flow is from left to right. View is from above, looking along the span.

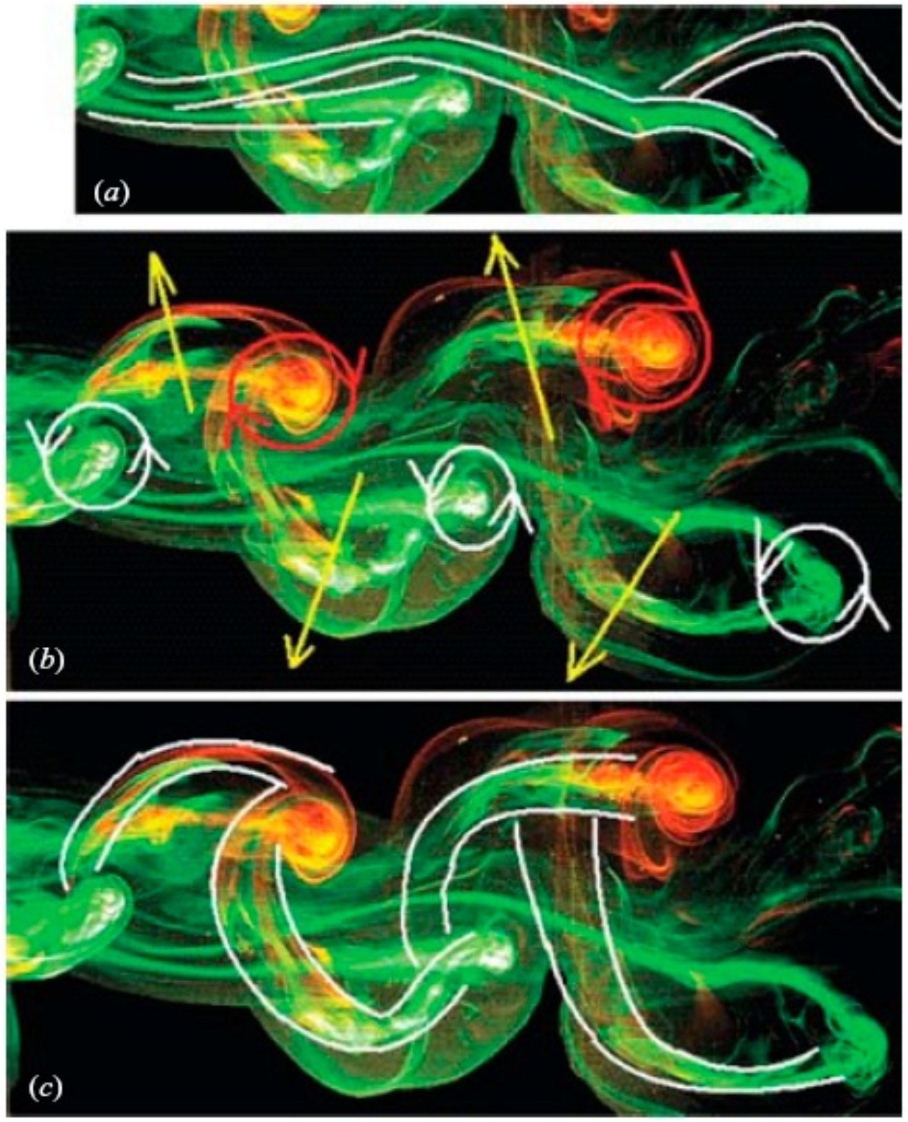


FIGURE 9. Features of the wake shown in figure 8. (*a*) Long vortex 'tails' found in the region of the wake near the fin root. (*b*) Vortex cores of alternating sign found in the wake in the region near the mid-span. The arrows show the direction of the induced velocities. (*c*) Connections between vortex cores found in the region of the wake near the fin tip.

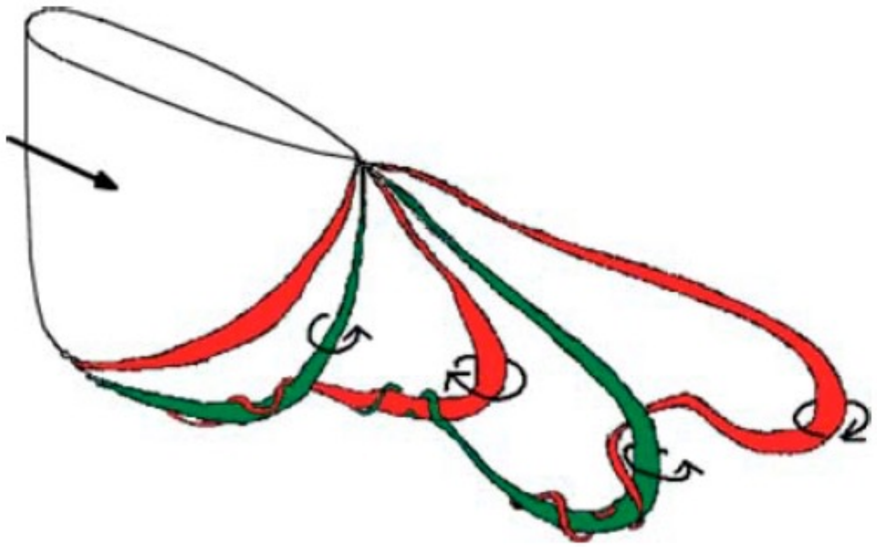
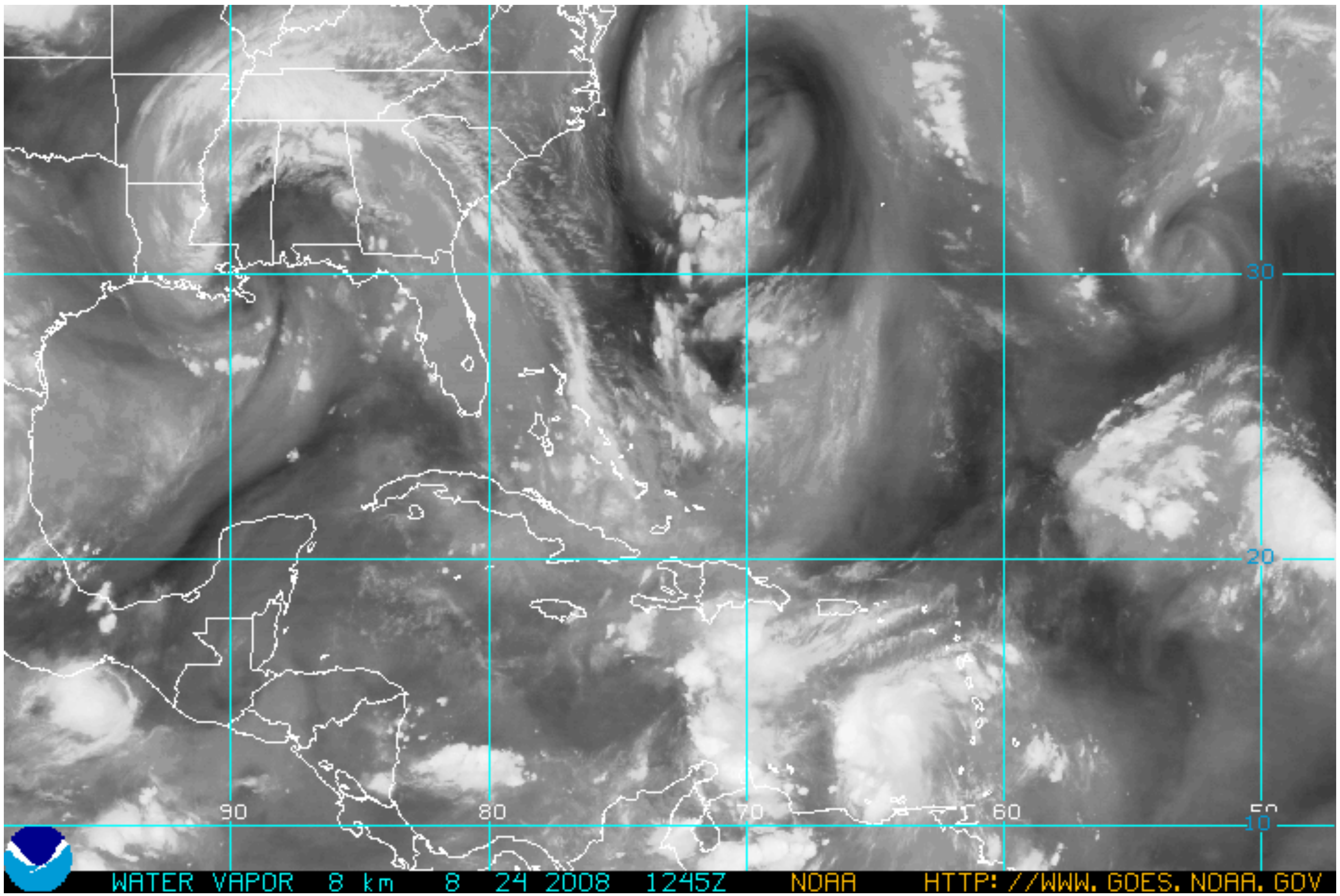


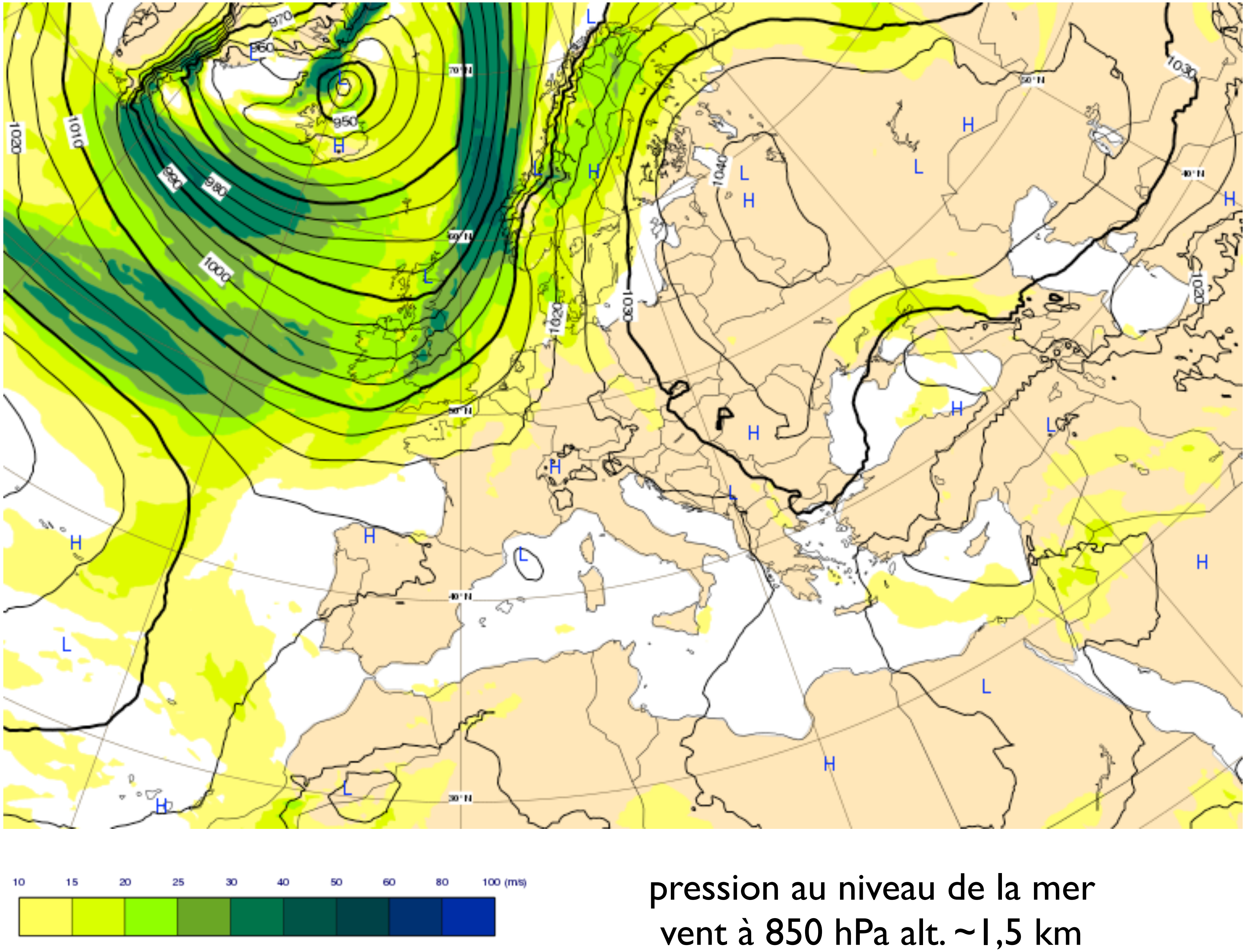
FIGURE 11. The vortex model proposed for $St_A = 0.15$ at the time when the trailing edge vortex is about to shed. The colors indicate the sign of the circulation, also illustrated by the arrows.

De la météo au climat

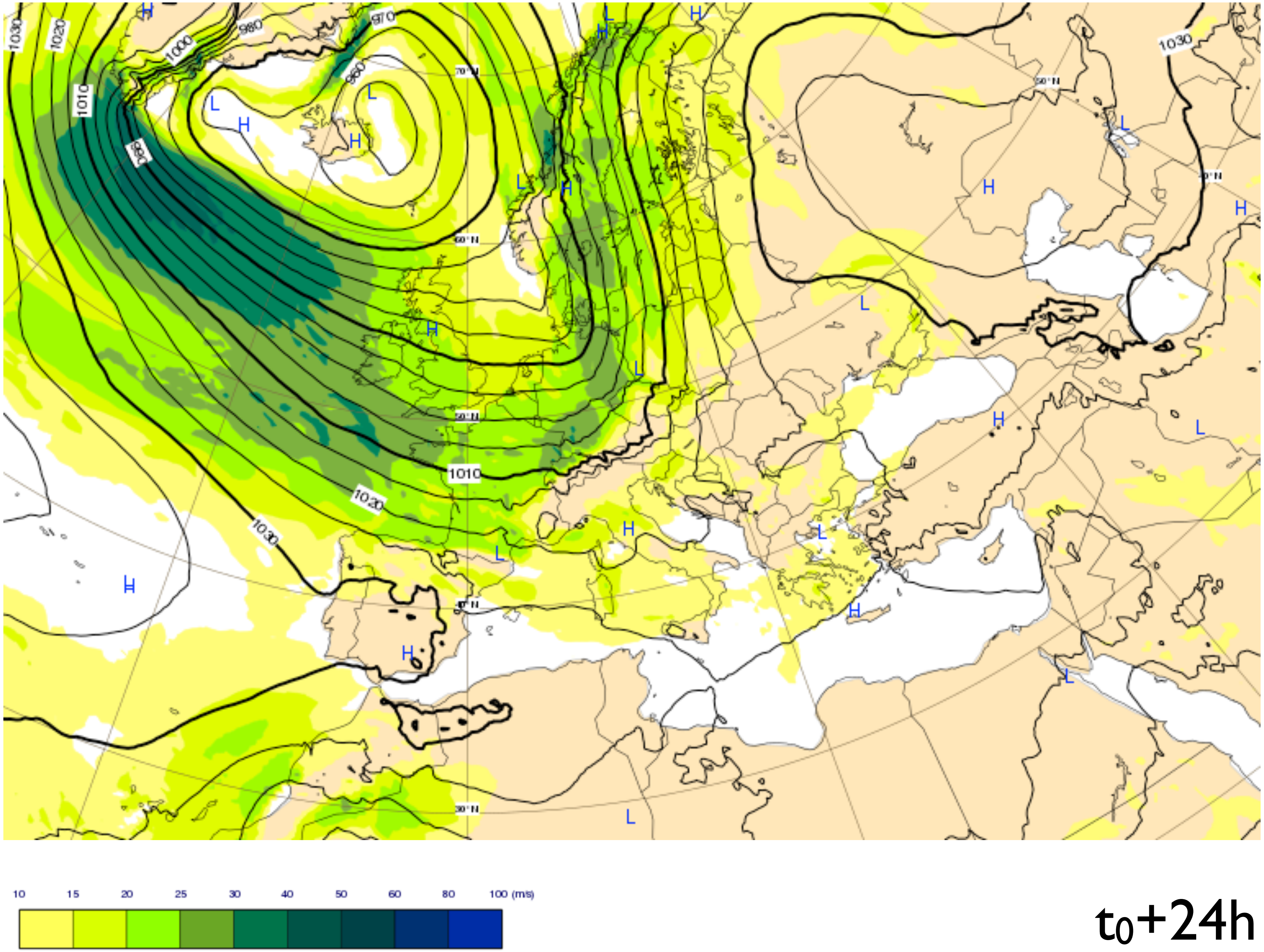


Prévisions à moyen terme

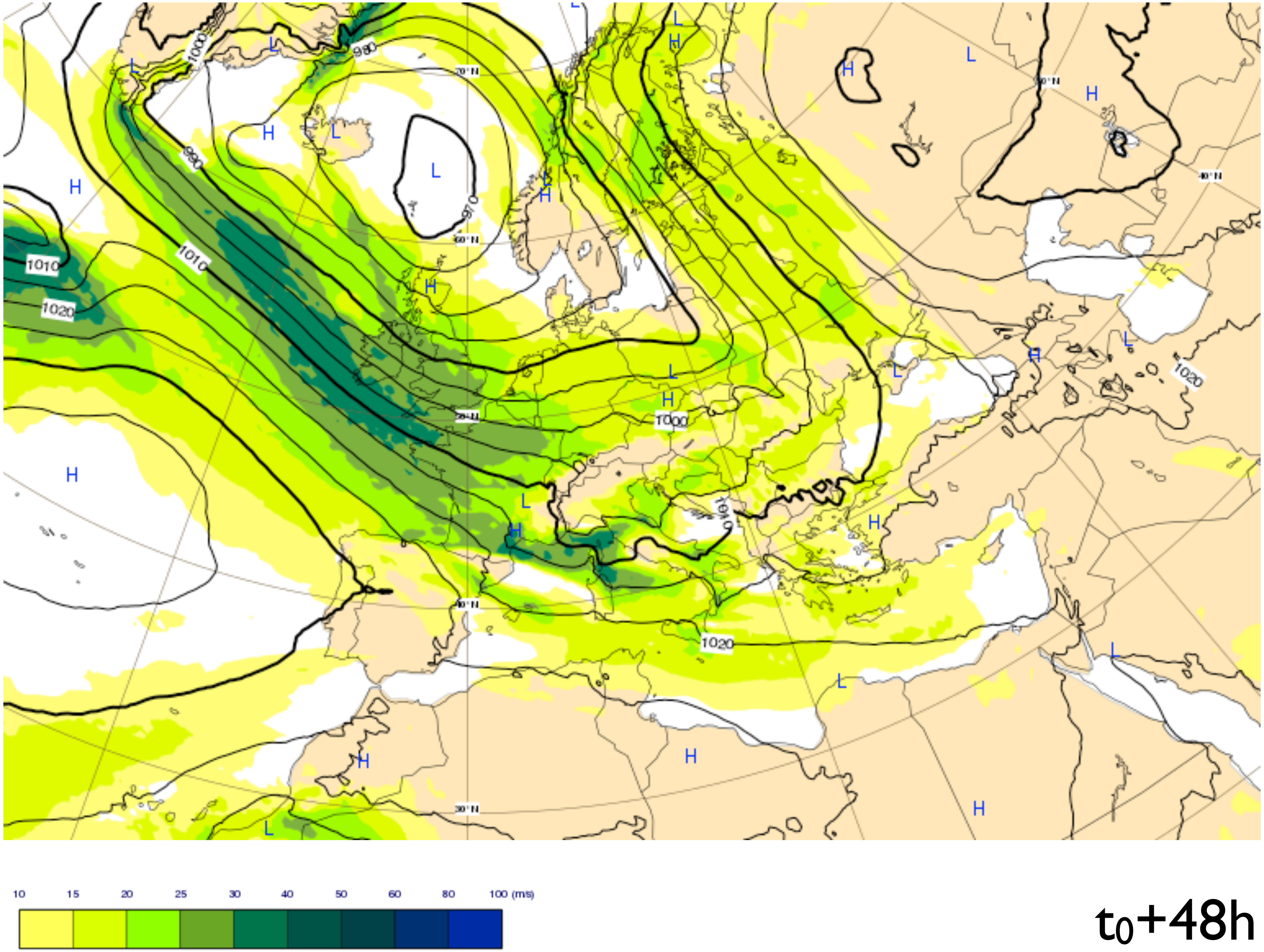
Centre Européen de Météorologie http://www.ecmwf.int/



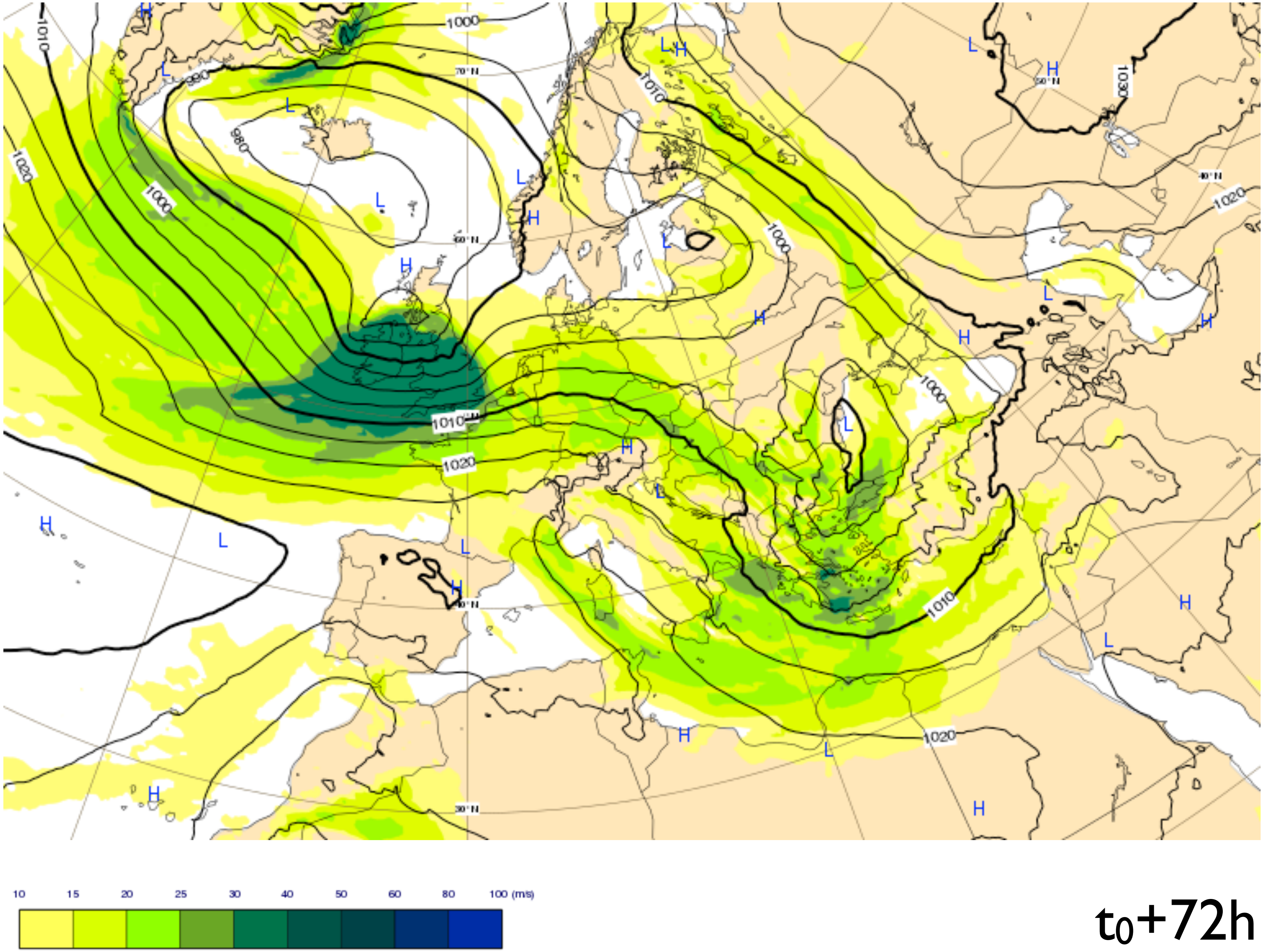
pression au niveau de la mer
vent à 850 hPa alt. ~1,5 km


10 15 20 25 30 40 50 60 80 100 (ms)
1030
1020
1010
1000
990
980
970
960
L
H

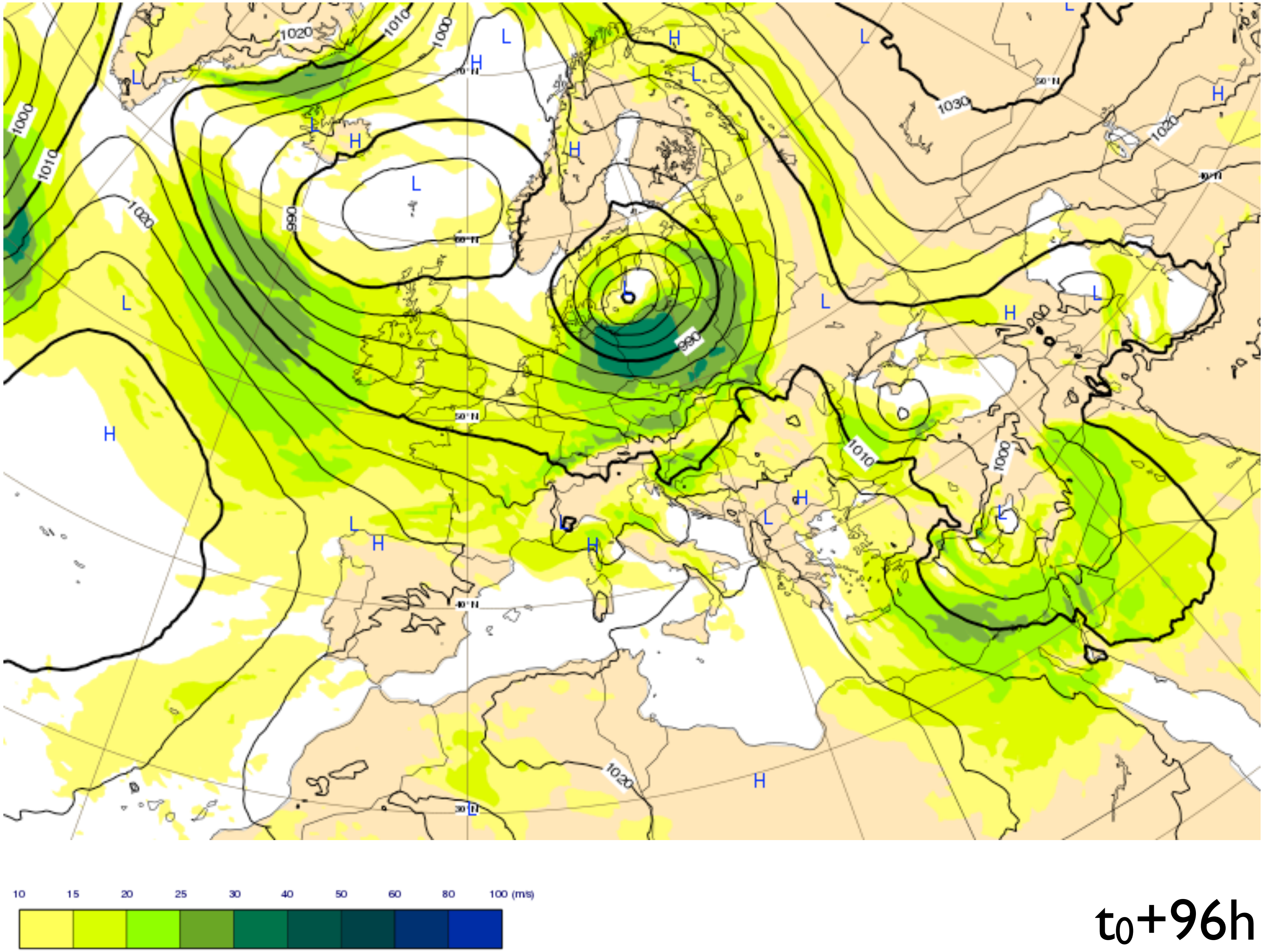
t_0+24h



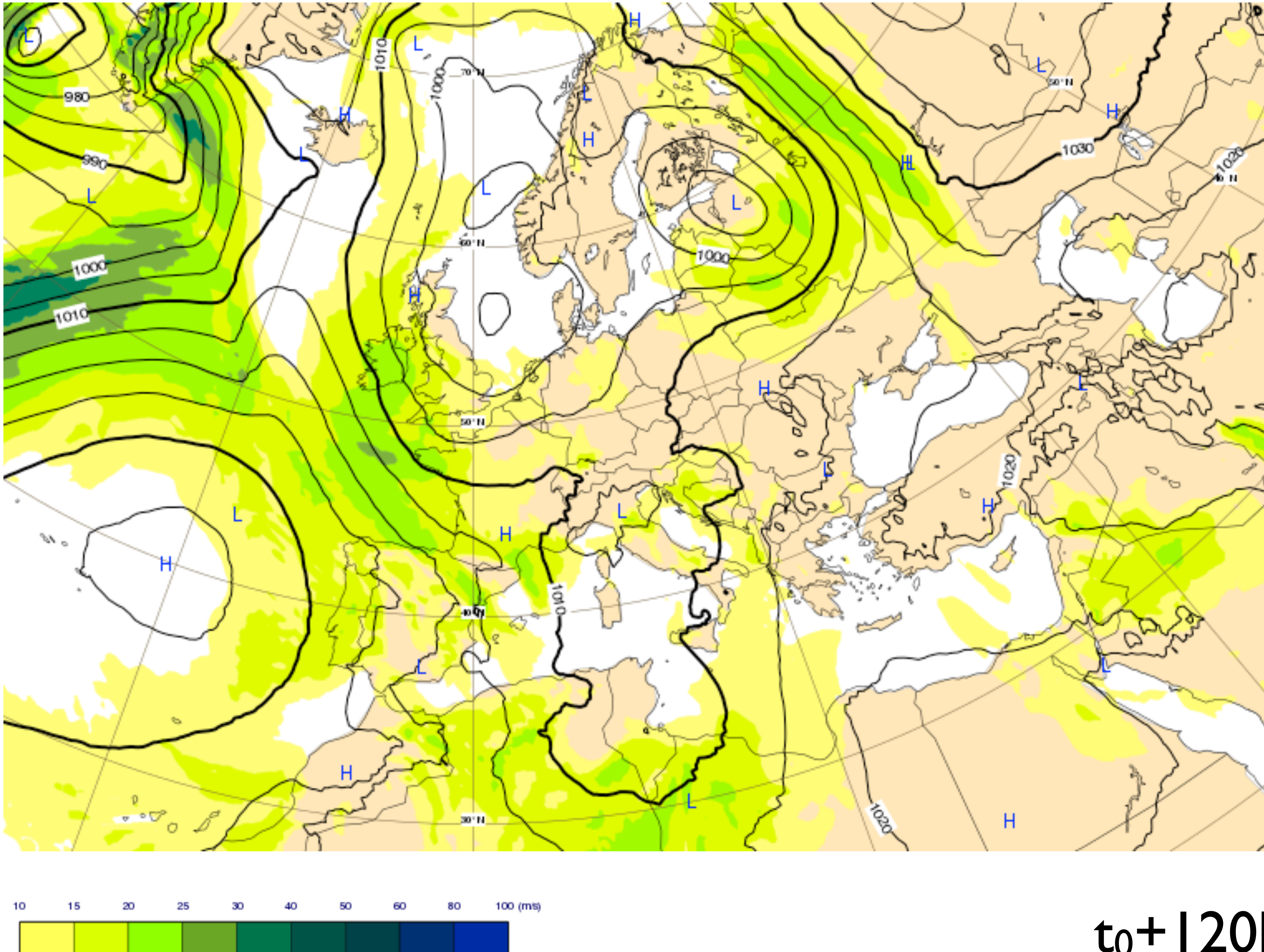
t_0+48h


1000
990
980
1010
1020
1000
1010
1000
1030
1020
1000
1010
1020
1010
1020
10 15 20 25 30 40 50 60 80 100 (ms)

t_0+72h

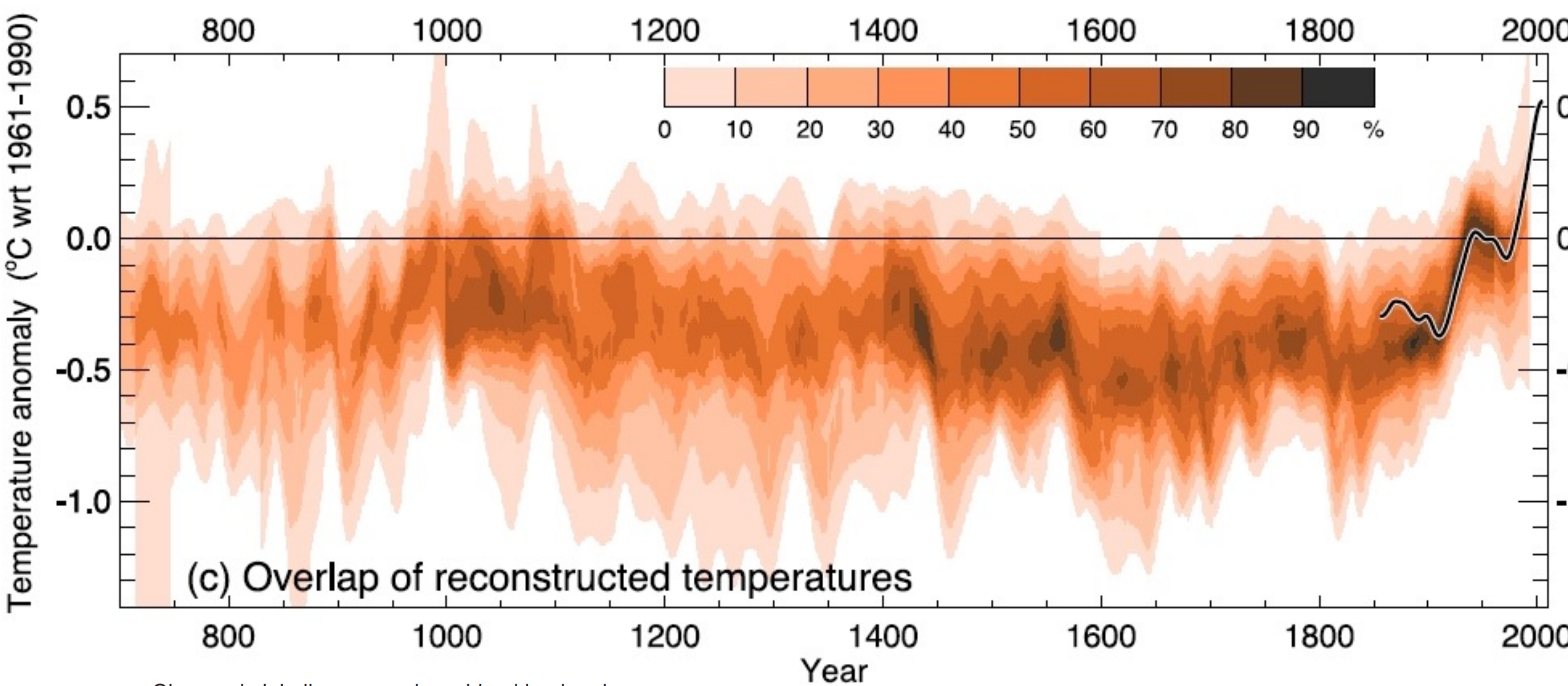


t_0+96h

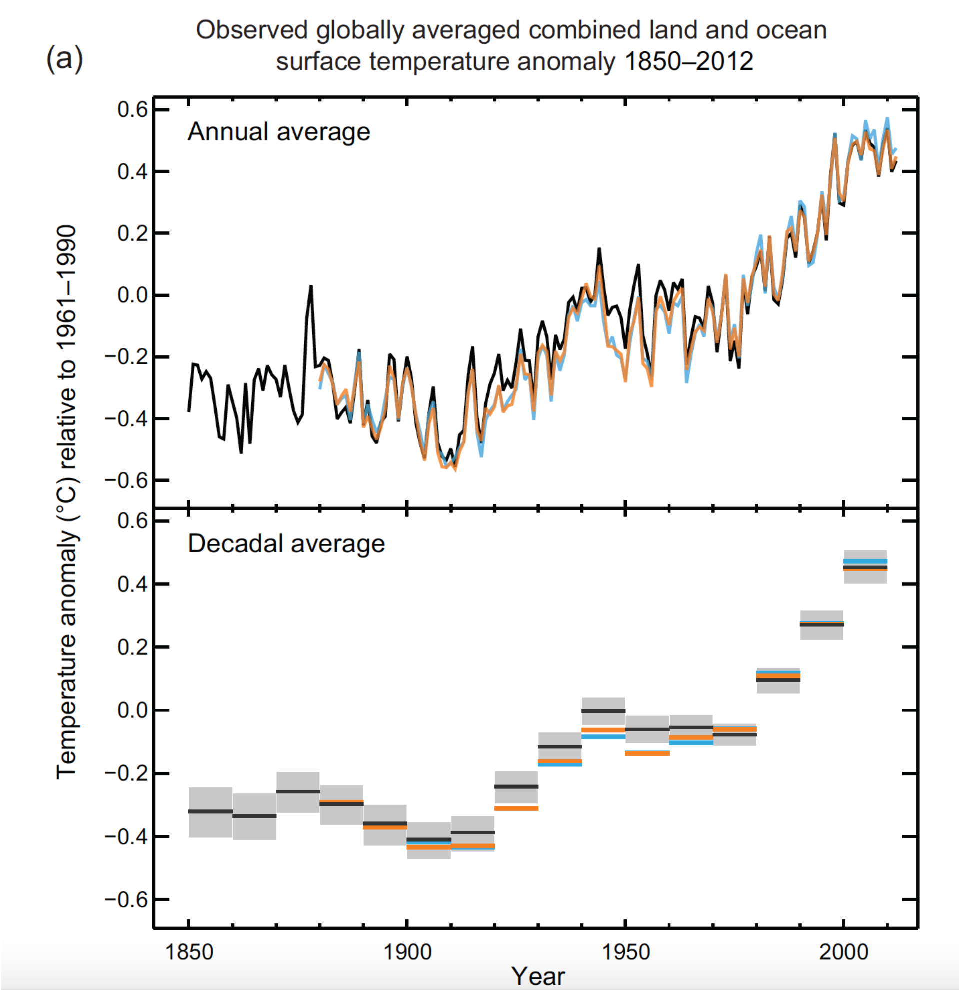


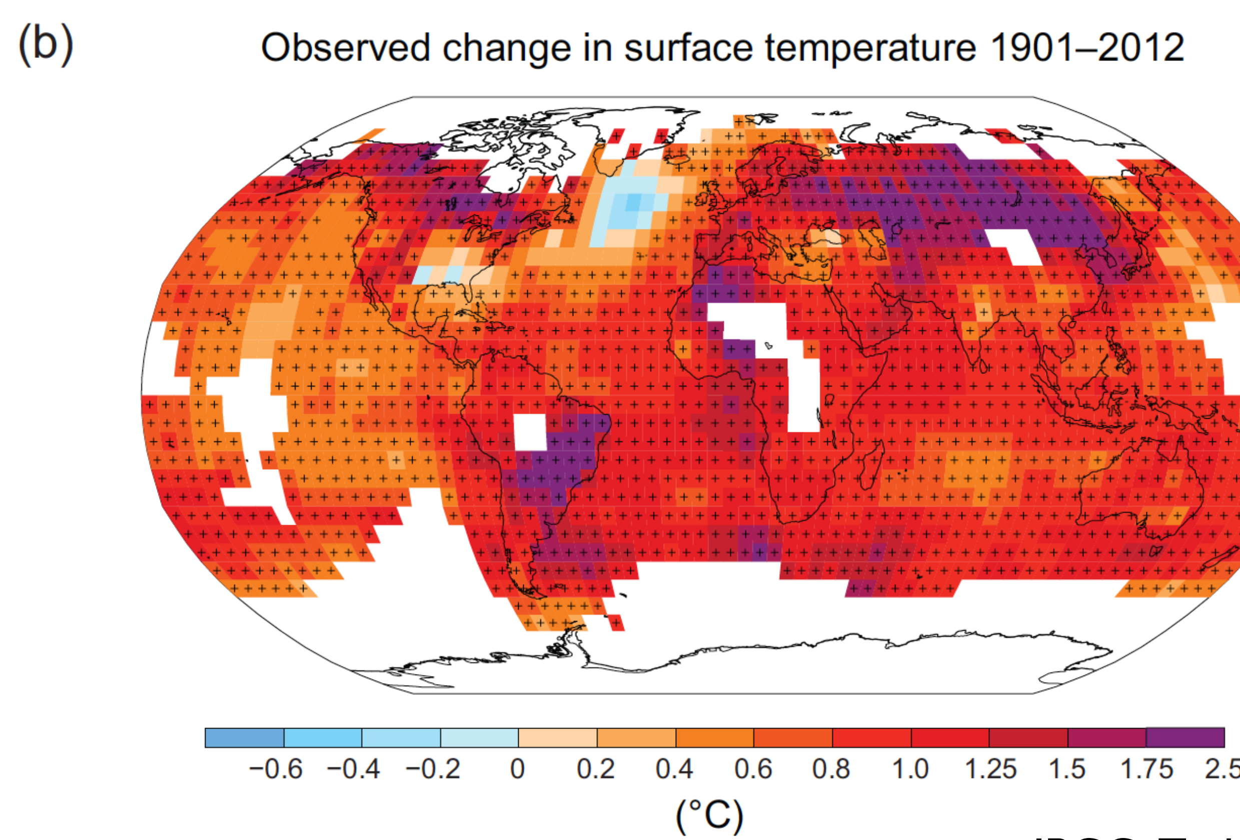
t_0+120h

Comprendre et prédire le climat ?



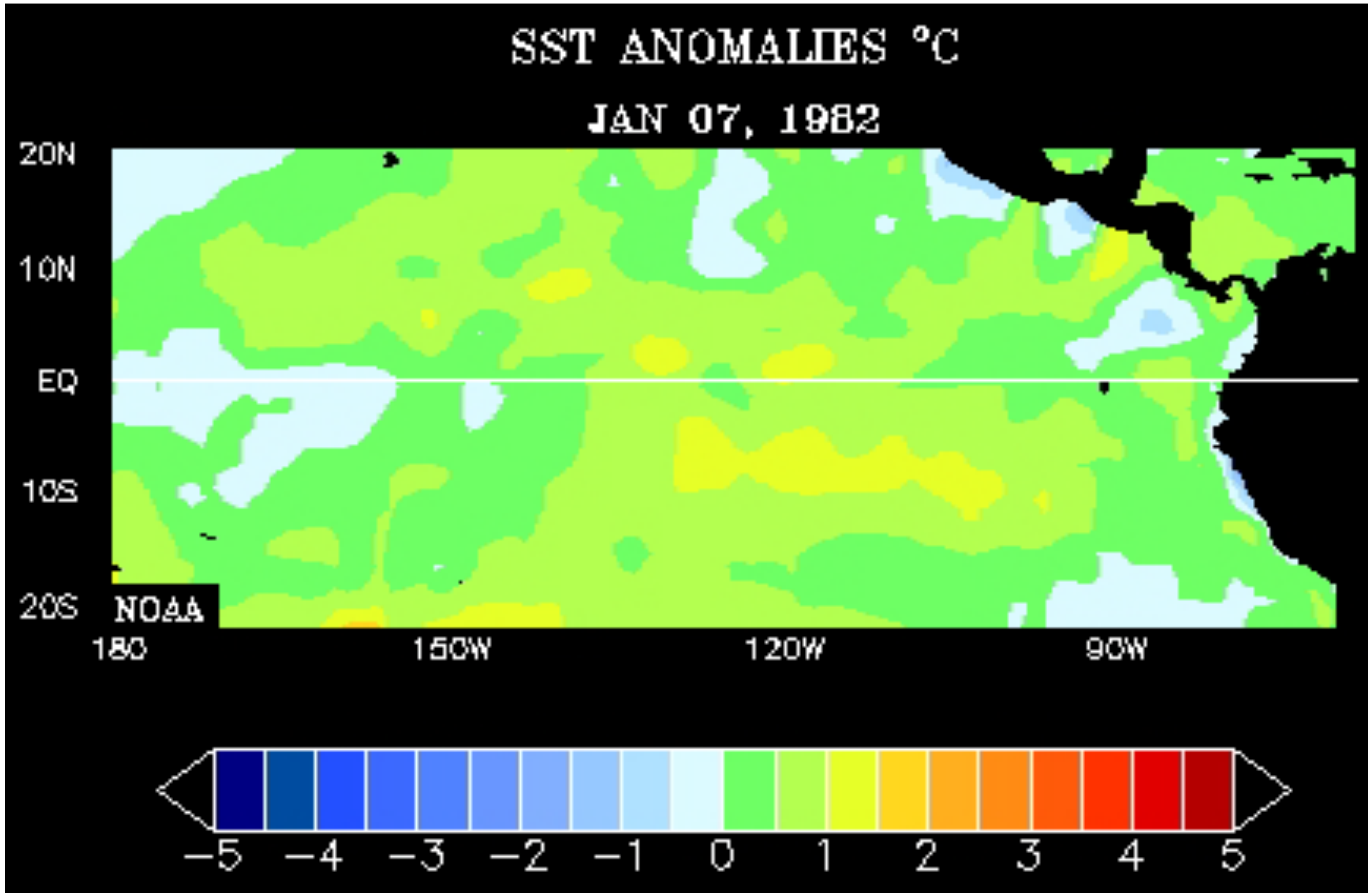
IPCC (GIEC) Technical report 2007
www.ipcc.ch





IPCC Technical report 2013

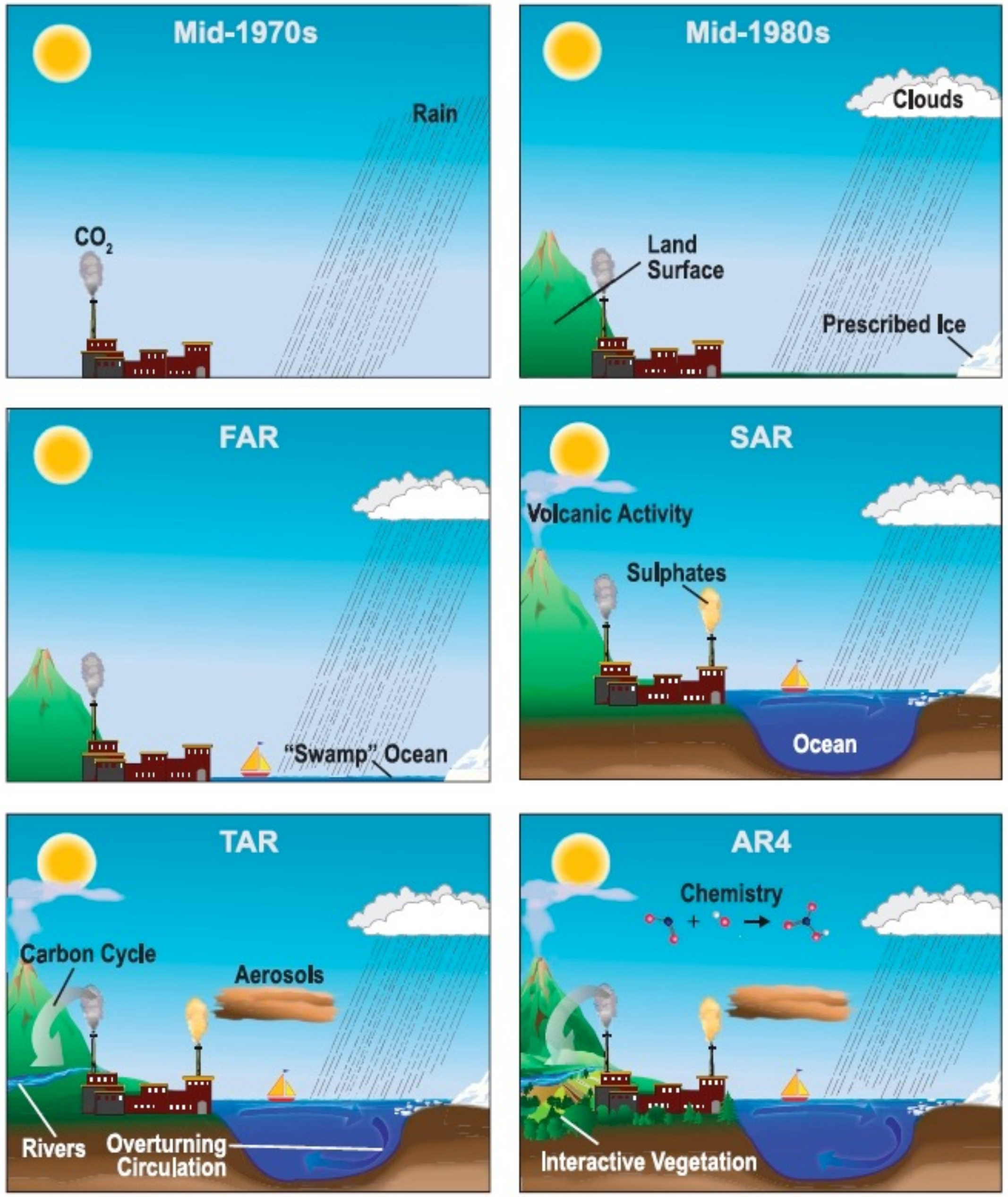
Des fluctuations naturelles

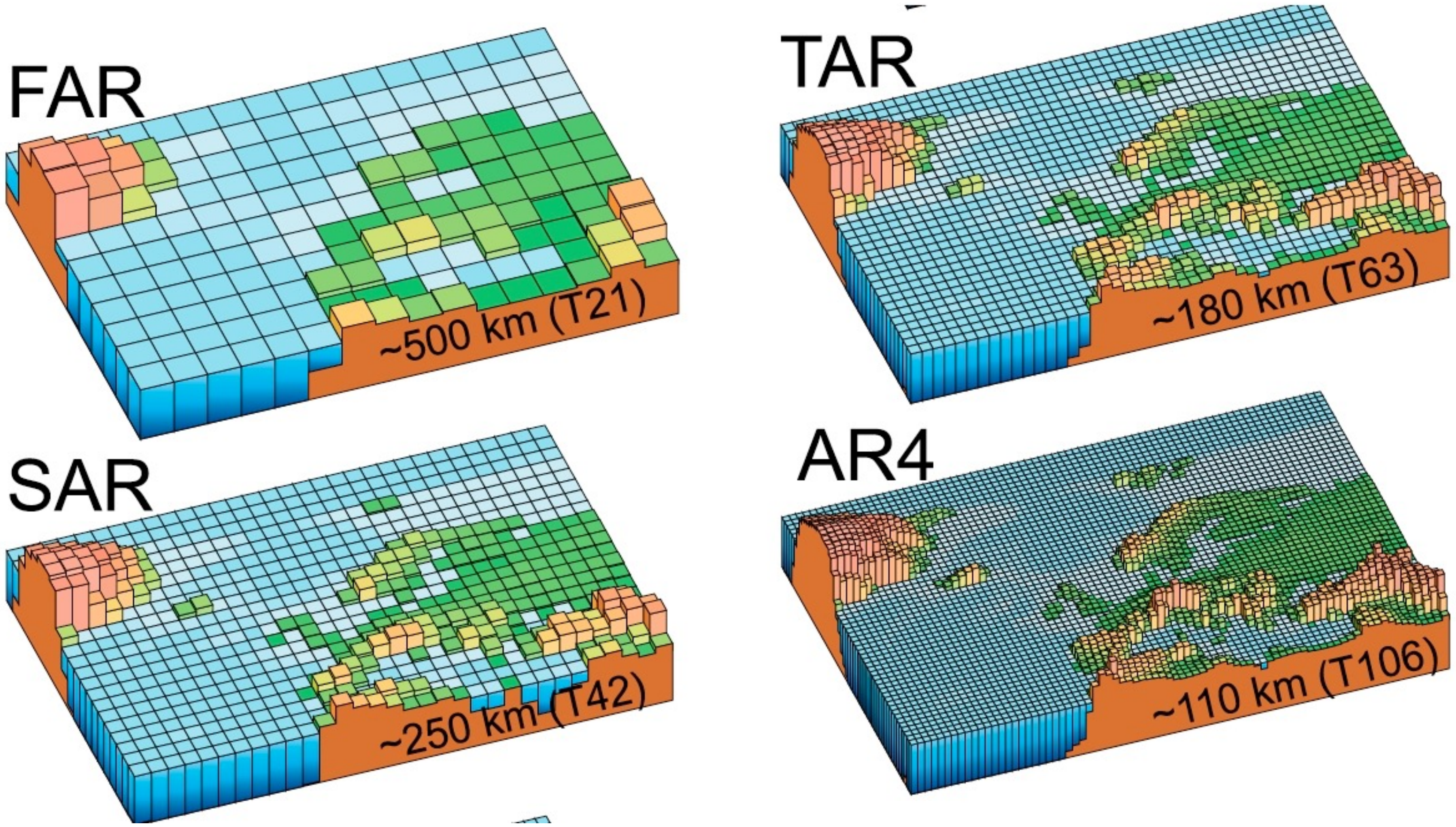


El Niño Southern Oscillation 1982-83

Documents NOAA

Modèles climatques

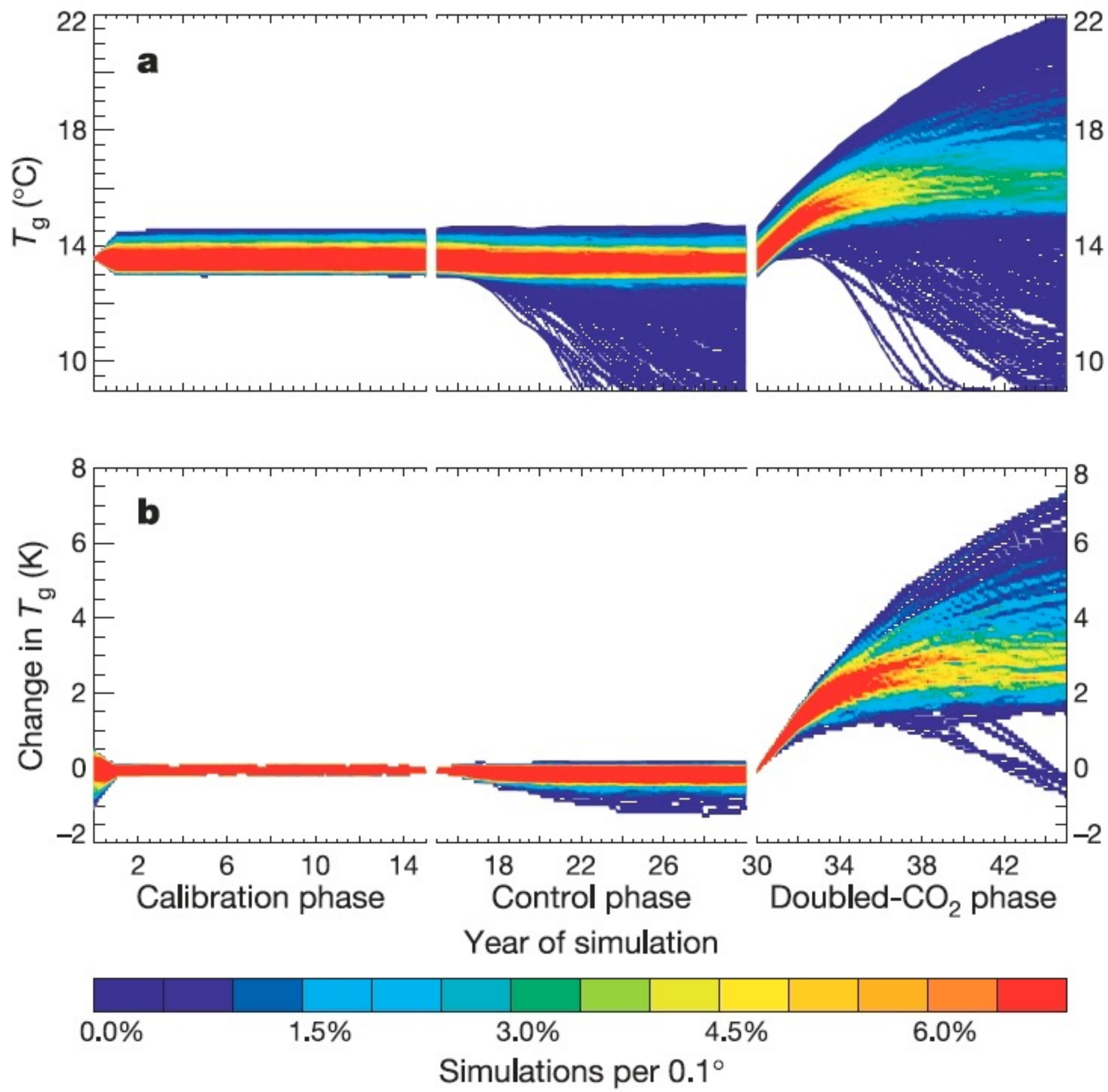




Intégrer tous les phénomènes couplés

Améliorer la résolution spatiale

Des prévisions encore incertaines mais inquiétantes



Projet
climateprediction.net

Etude paramétrique d'un modèle climatique

Calculs distribués

Des véhicules plus efficaces ?

$T = \rho V^2 S C_x$ 50 km/h en ville
25l /100 km

C_x = 0,26
50 km/h en ville
4l /100 km

Projet Loremo Cx = 0,20
50 km/h en ville
< 2l/100km

Assez d'énergie dans le vent ?

Energie cinétique :

$$\frac{1}{2}\rho_{air}V^2$$

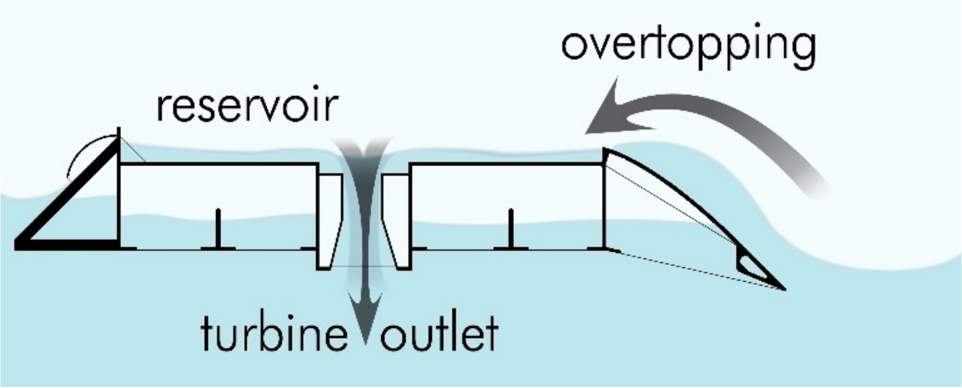
Puissance disponible :

$$\frac{1}{2}\rho_{air}V^2SV$$

$$V \approx 10\mathrm{m/s},\ S \approx 7500\mathrm{m}^2,\ \rho_{air} \approx 1\mathrm{kg/m}^3$$

P = 3 MW = 2000 fers à repasser

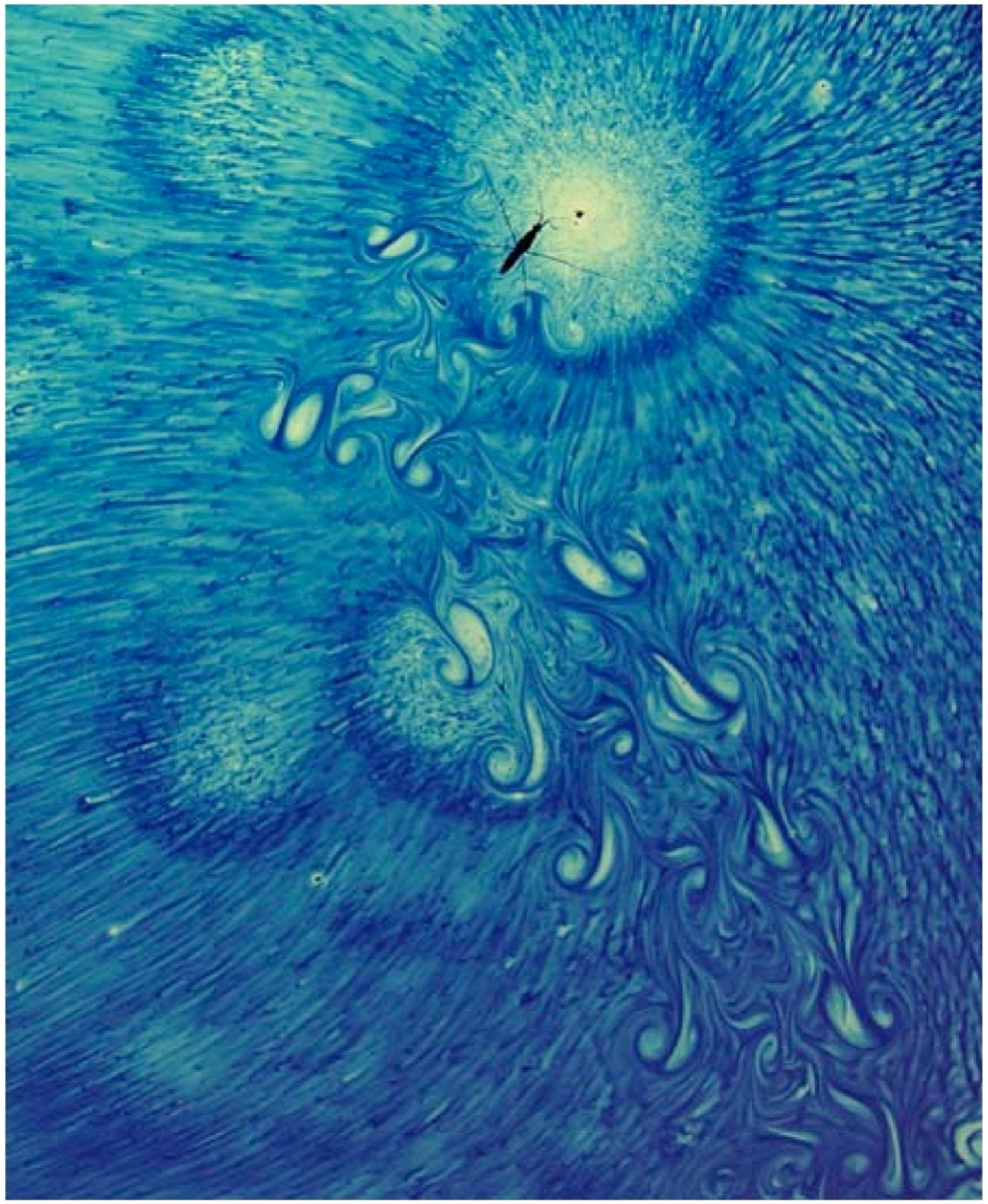
ou dans les vagues ?



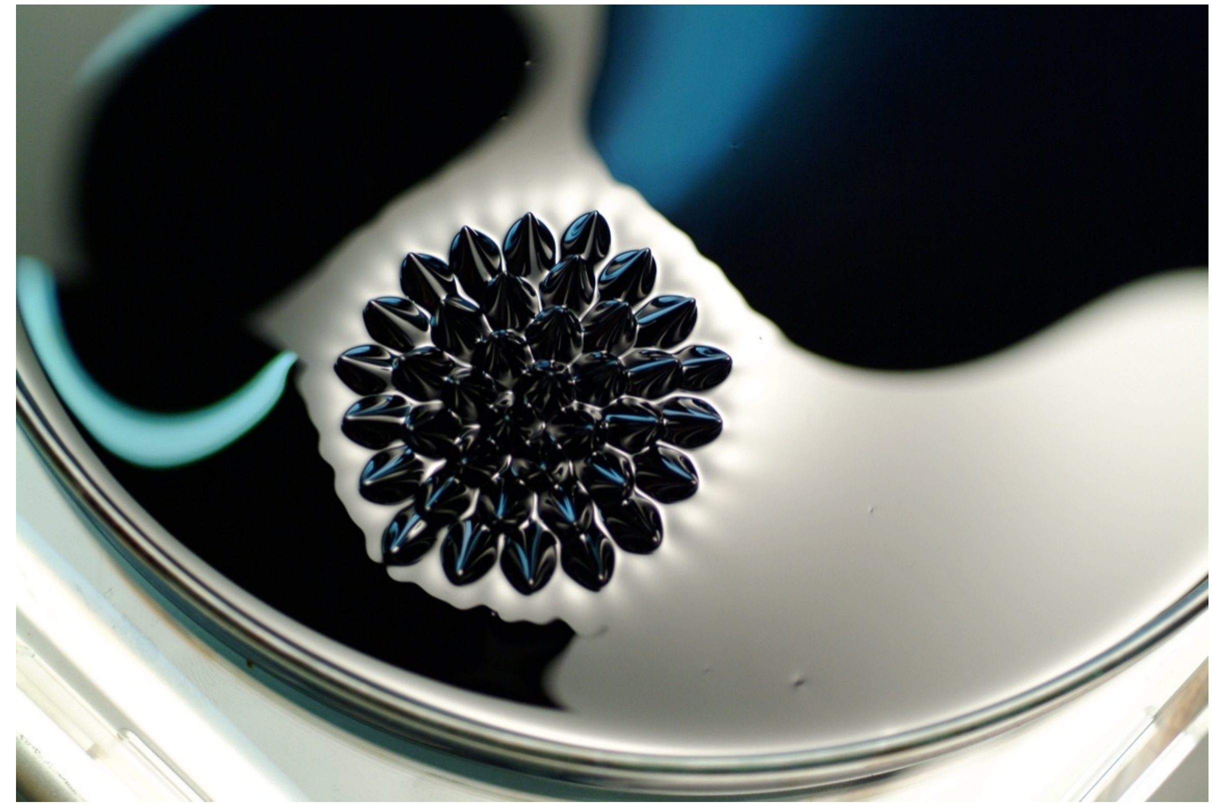
Projet danois WaveDragon

Projet britannique Pelamis

utile mais aussi esthétique ...



J. Bush MIT



J. Bico ESPCI

... et amusant


VOLVO
OCEAN
RACE
SCA


MACH 2
McDOUGALL
McCONAGHY
160
zhik
ka.
ka.sail. MACH 2
RONSTAN

Des références :

Guyon, Hulin, Petit « Hydrodynamique physique »

Batchelor « An introduction to fluid dynamics »

Tritton « Physical fluid dynamics »

Films du National Committee for Fluid Mechanics Films
http://web.mit.edu/hml/ncfmf.html

Gallery of Fluid Motion https://gfm.aps.org/