ECMWF global reanalyses: Resources for the wind energy community *(and a few myth-busters)*

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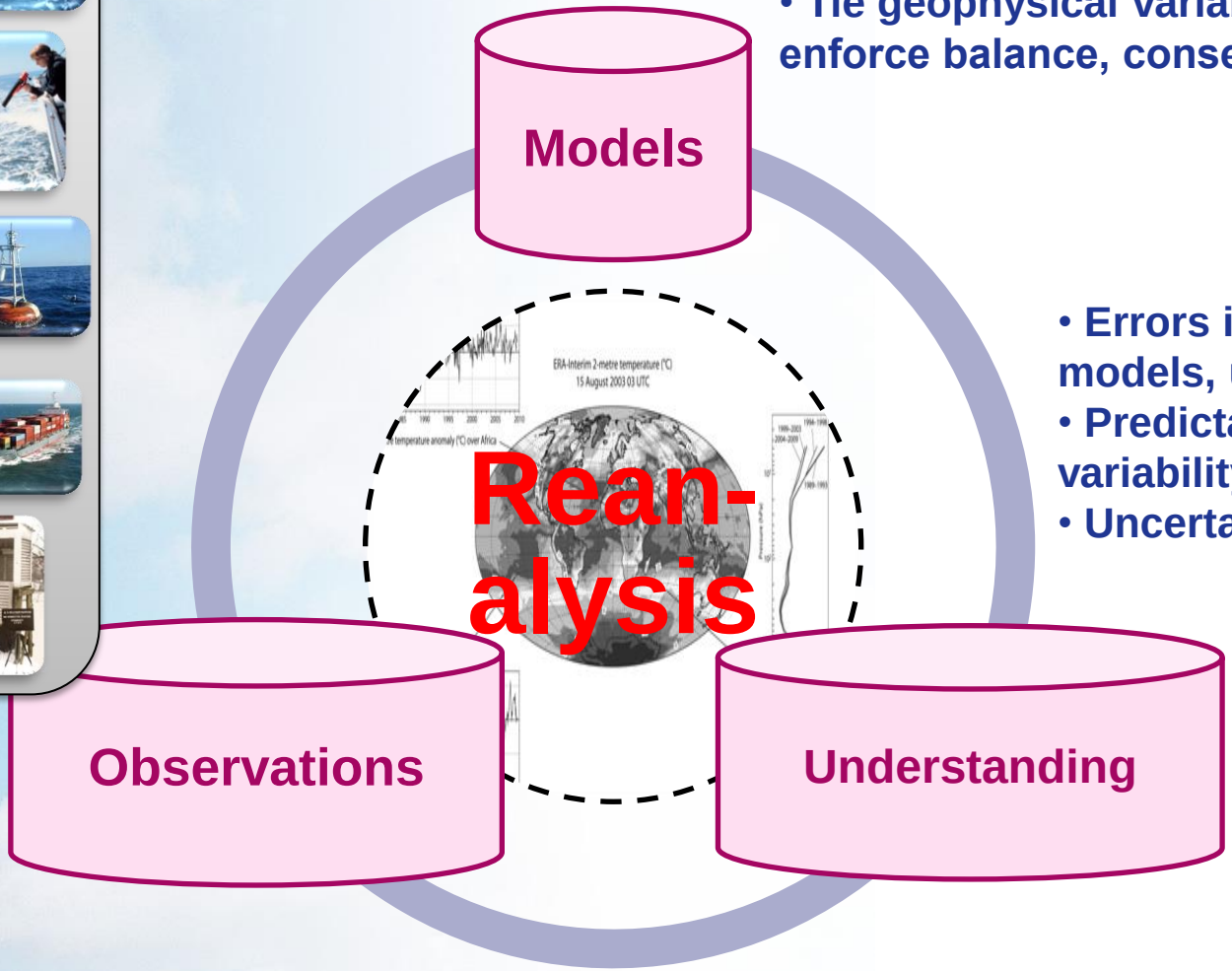
Outline

- What reanalyses are made of
- Products
- Current developments: ERA-20C
- Conclusions

The 3 pillars of Geosciences

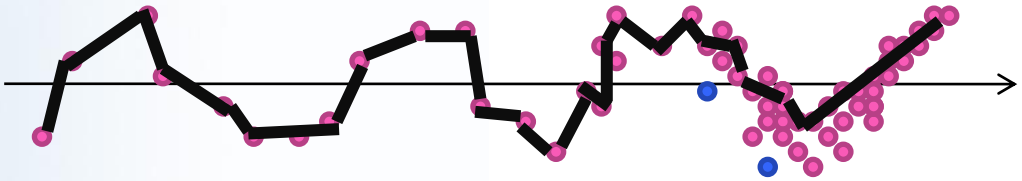
- State-of-the-art numerical schemes representing physical laws
- Tie geophysical variables together, enforce balance, conservation, …



- Errors in observations, models, understanding
- Predictability & variability
- Uncertainties

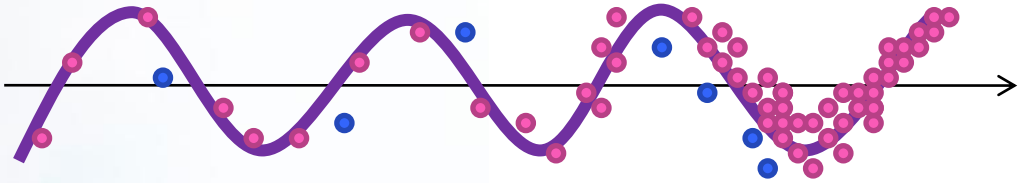
Reconstructing the past

"Observations-only"

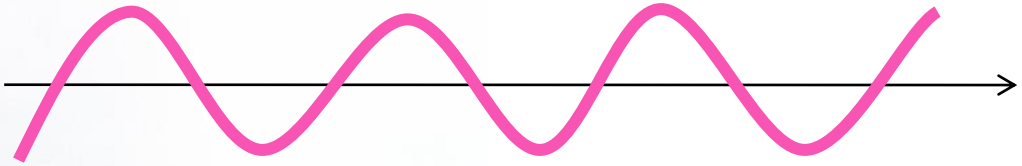


Gross exaggeration towards discontinuity

Reanalysis



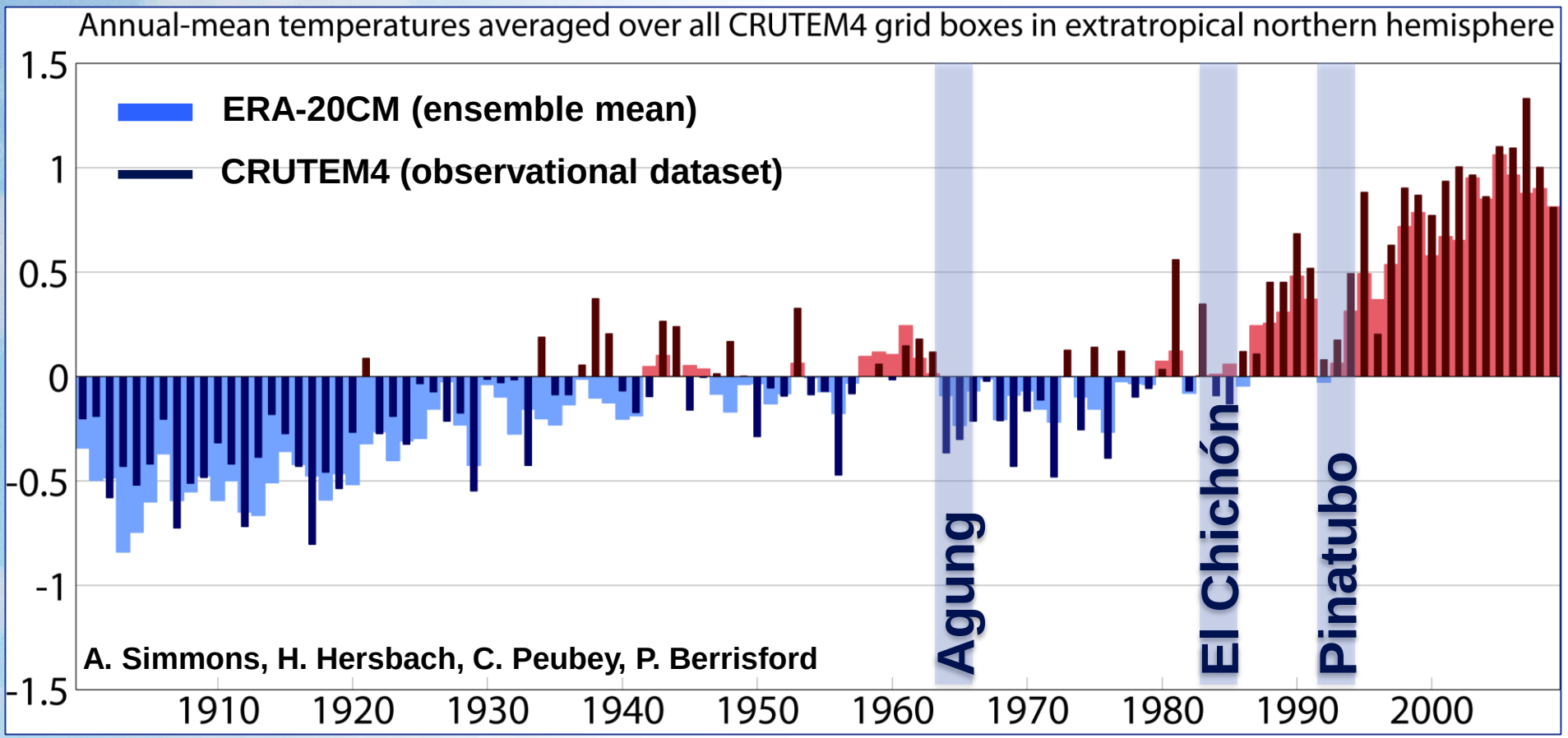
"Model only"



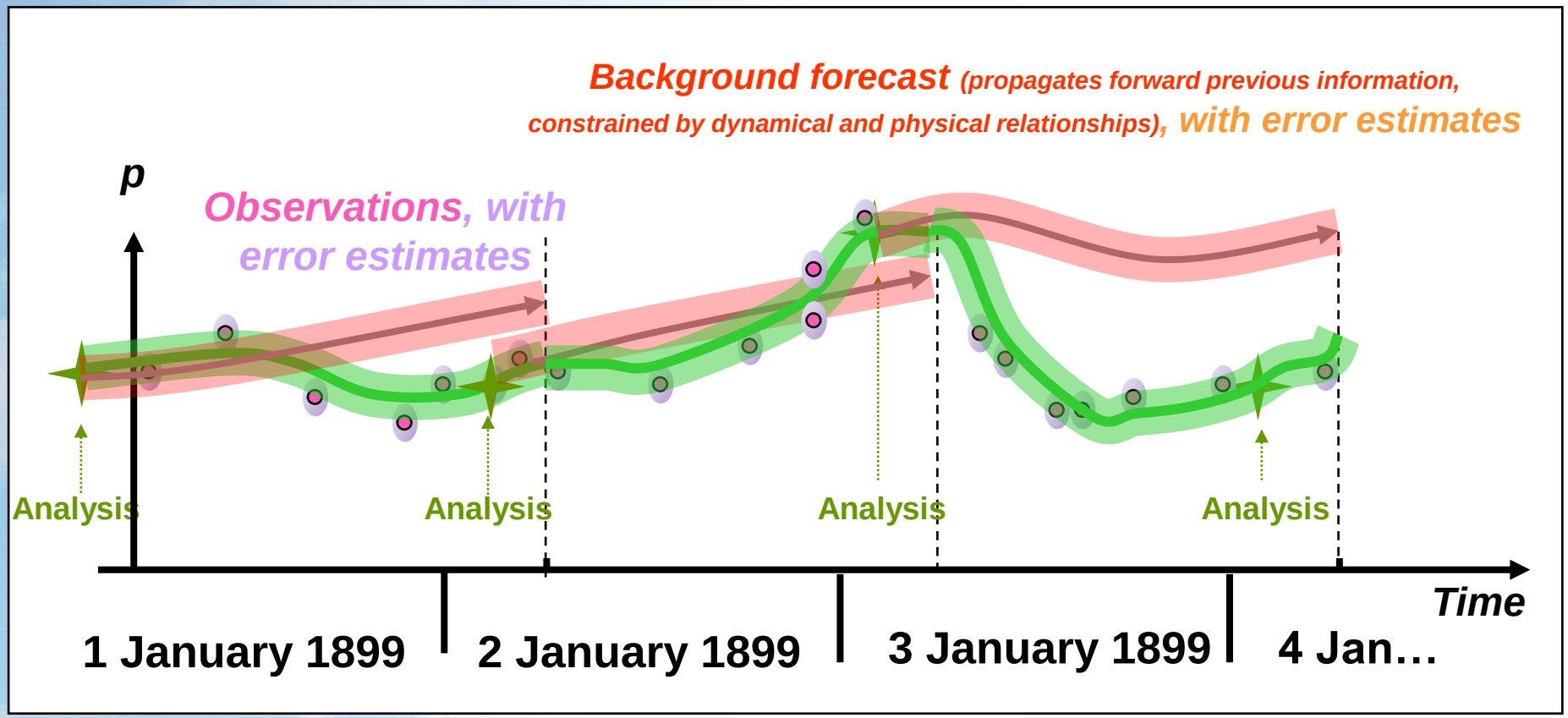
Gross exaggeration towards continuity

Model integration, without observation assimilation

- Boundary conditions: HadISST2 sea-surface temperature and ice cove
- CMIP5 forcings: Solar irradiance, Greenhouse gases, Ozone for radiation, Tropospheric aerosols, Volcanic aerosols



Combining observations and models



Strong constraint Four-dimensional variational (4DVAR) analysis

Myth #1: Reanalyses = “gridded observations”

1) Deal with missing data: no gaps

2) Consistency in horizontal and vertical

3) Consistency across geophysical variables

4) Use widest variety & amount of observations
(40,000 millions in ERA-Interim)

5) Consistent quality control of observations

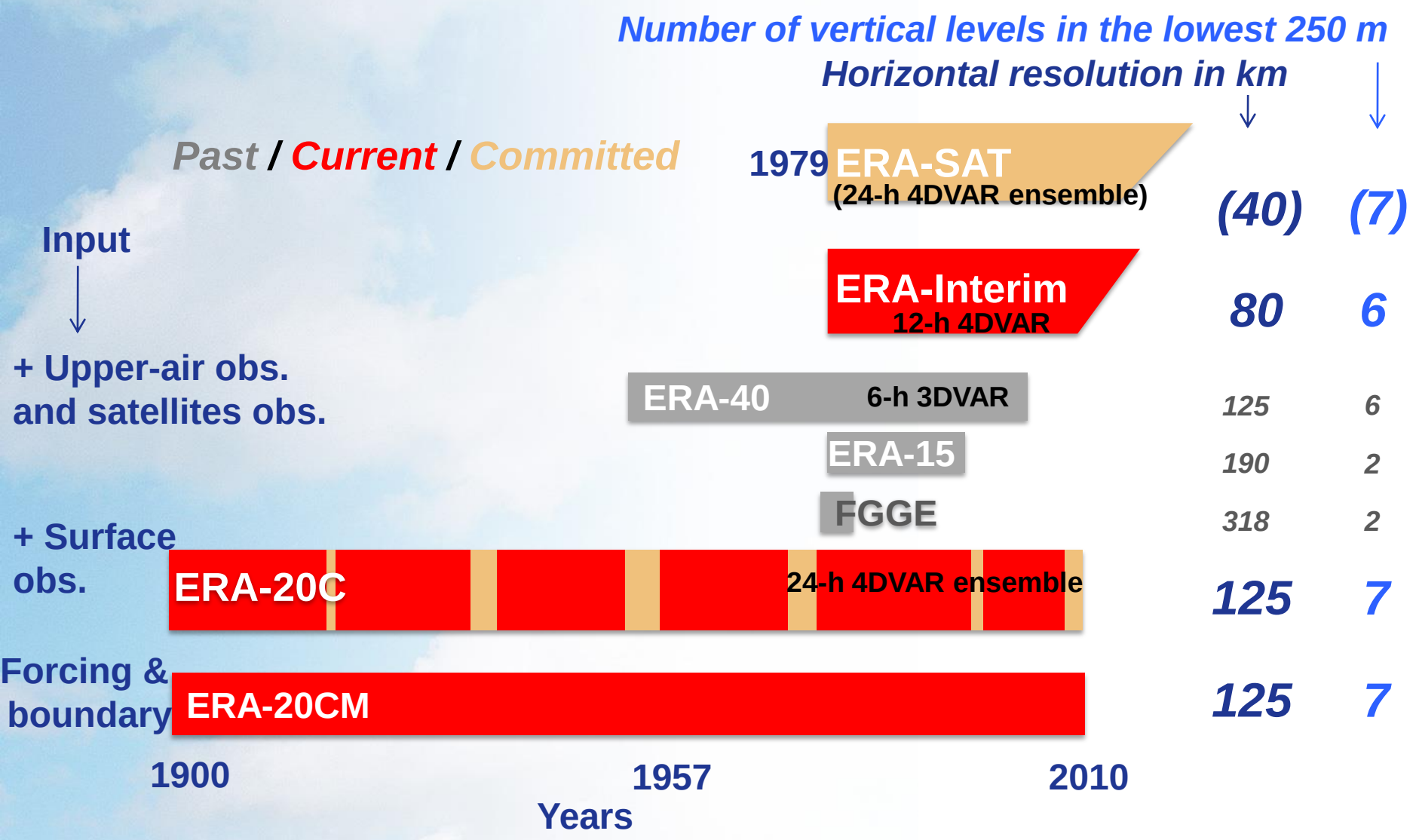
6) Account for observation changes over time with data assimilation

NEW

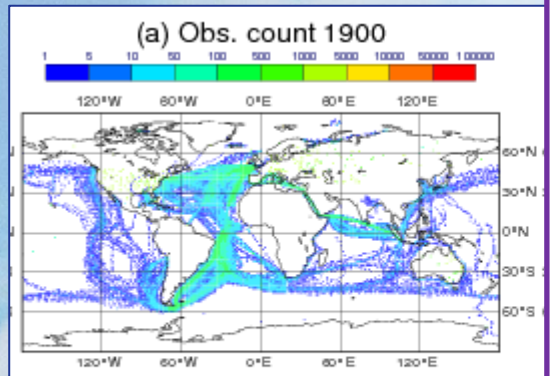
7) Uncertainty estimates and ensemble of solutions to drive applications

NEW

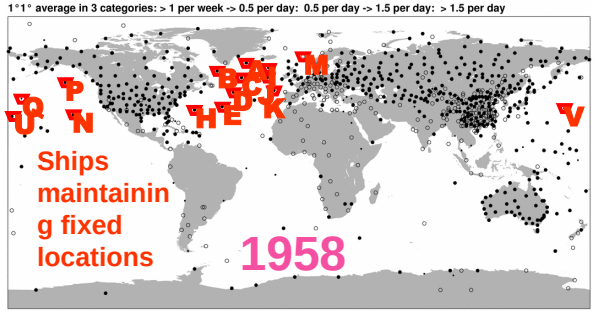
ECMWF global atmospheric reanalyses



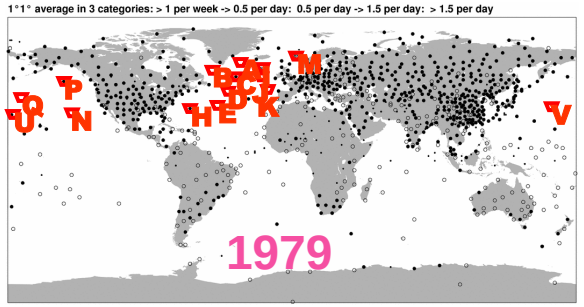
In situ observations during the 20th century (a selection)



Surface pressure network

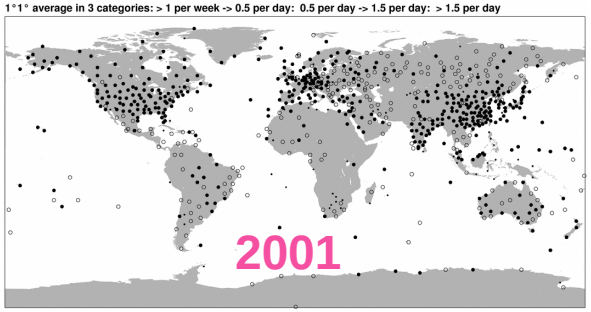


1609 soundings/day



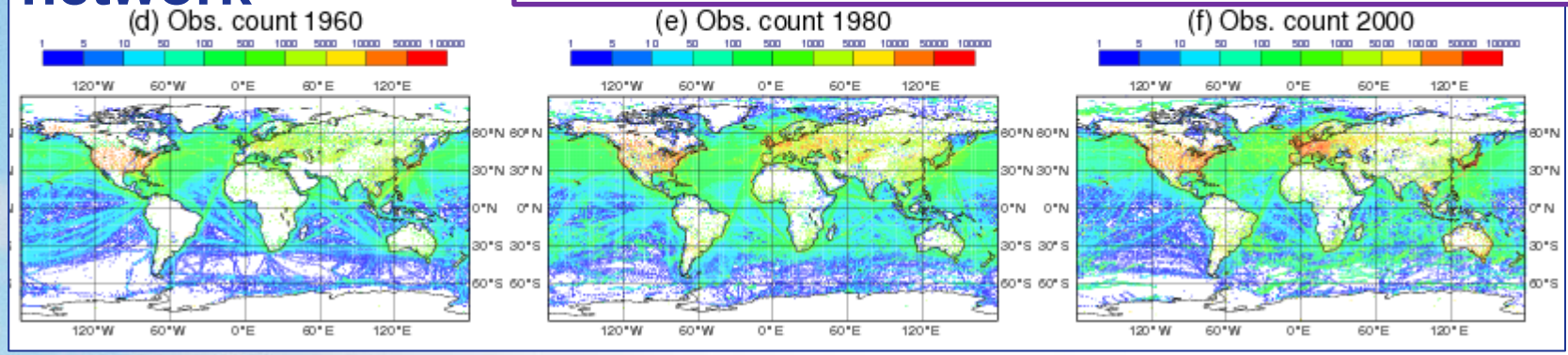
1626 soundings/day

Radiosonde network



1189 soundings/day

S. Uppala



Wind observations used in ERA-Interim reanalysis

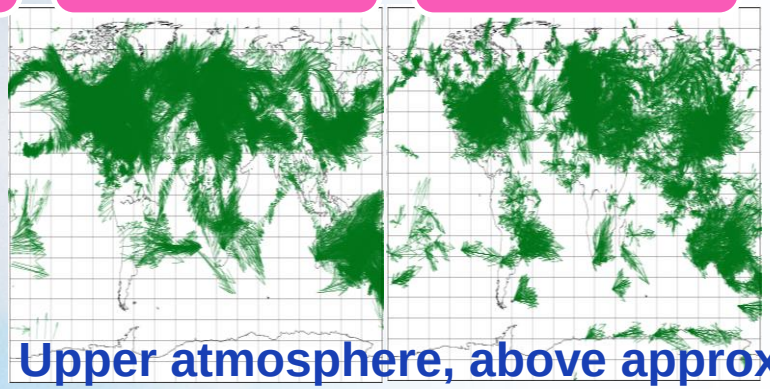

Stations/ Ships/ Buoys

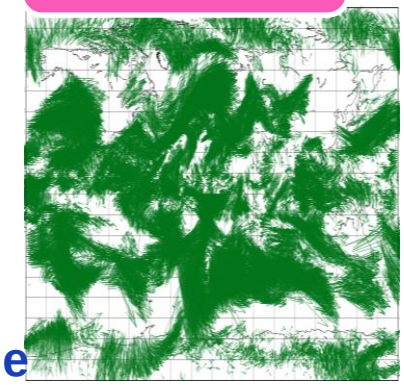

Aircraft


Balloons/ Sondes/ Profilers


Satellite scattero-meters

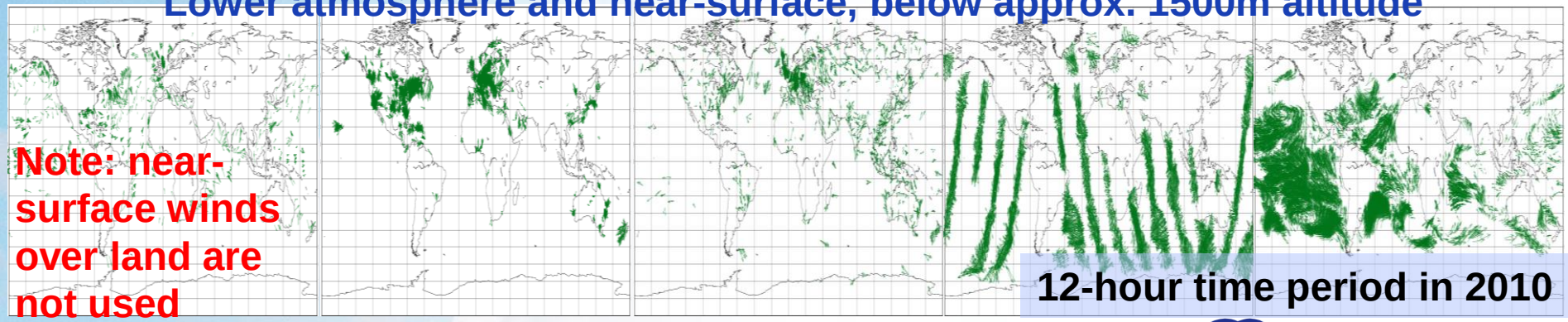

Satellite imagers





Upper atmosphere, above approx. 1500m altitude

Lower atmosphere and near-surface, below approx. 1500m altitude

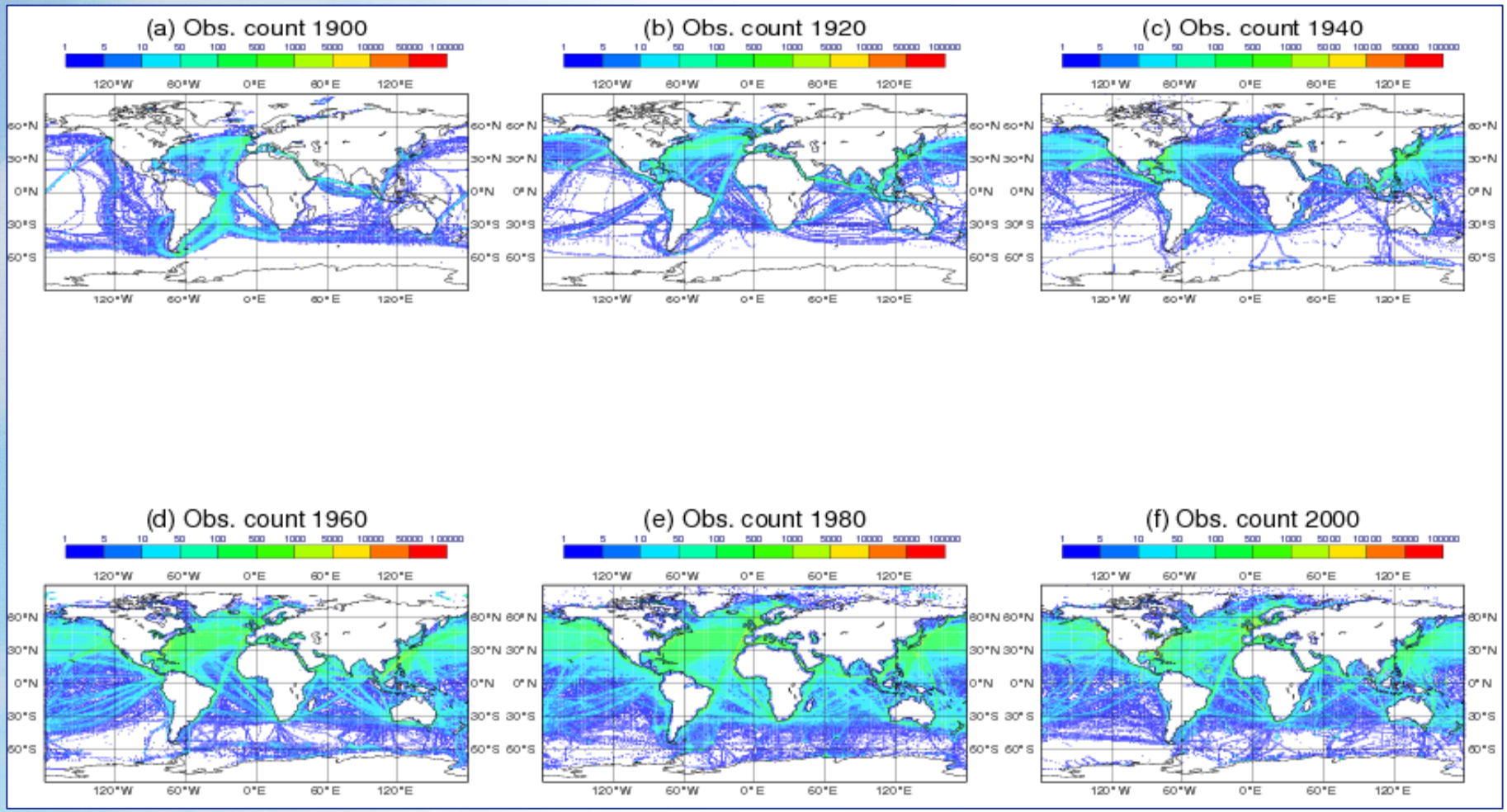


Note: near-surface winds over land are not used

12-hour time period in 2010

Observations input to ERA-20C reanalysis

- Surface pressures from land and ocean, and
- **10-meter wind above ocean. Coverage below:**



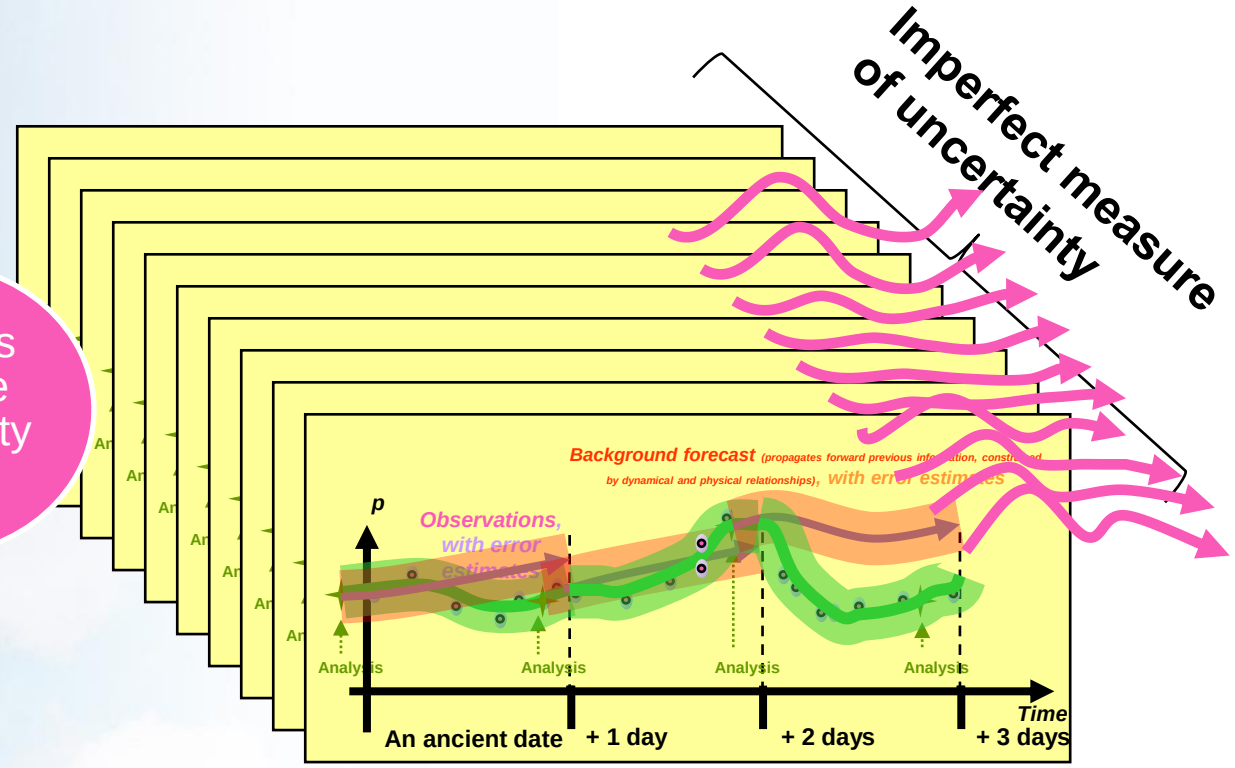
ERA-20C uses an ensemble of data assimilations to construct a (limited) PDF of the possible solutions

Forcing (HadISST2 realizations)

Model stochastic physics

Observation errors

Members span the uncertainty space



Benefits

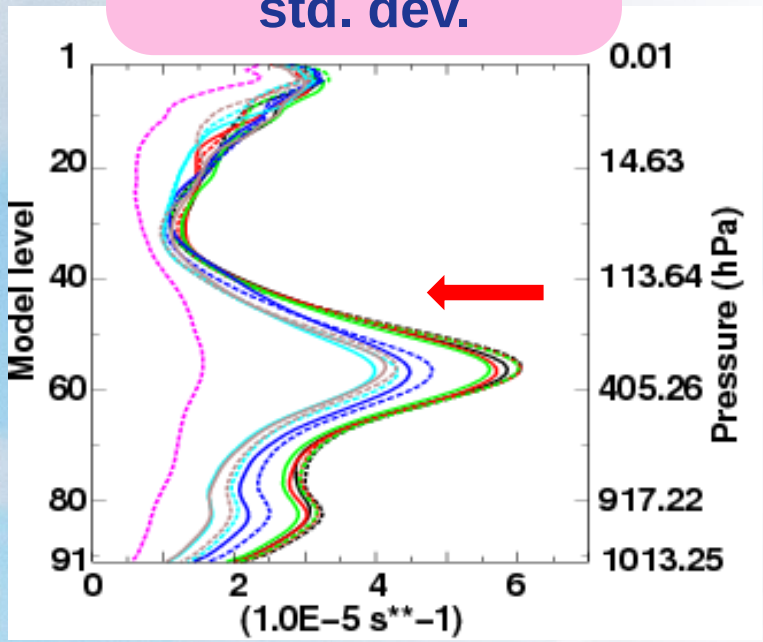
1. Estimate and update automatically our **background errors**
2. Provide users with **uncertainty estimates**
3. *Advanced users* can use **ensemble solutions for ensemble applications**

(Caveat: this is not yet perfect, but still … better than nothing)

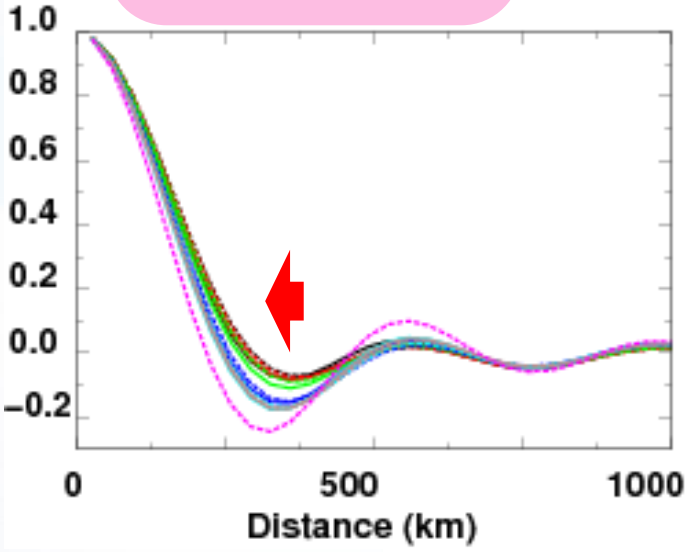
ERA-20C estimates background error covariances

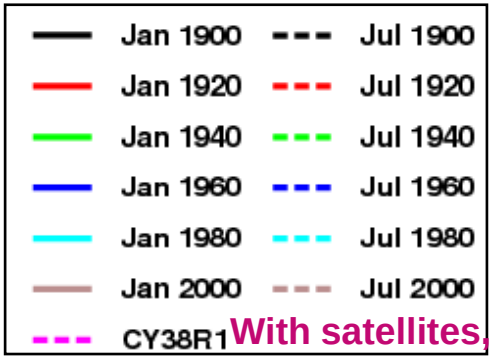
- Reminder: observation density increases by 50x in 100 years
- Update / new estimate every 10 days, based on past 90 days

Vertical profile of vorticity background error std. dev.

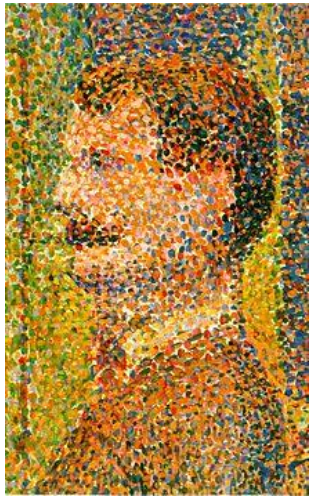


Horizontal correlation of vorticity background errors





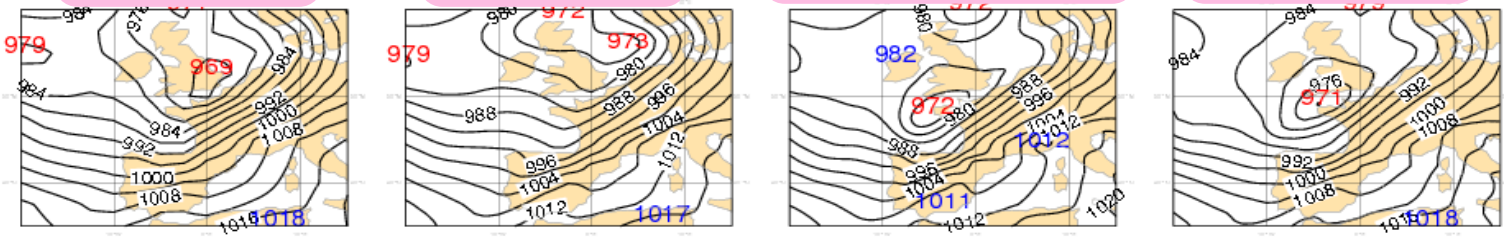
With satellites, radiosondes,… for comparison



Myth #2: "Higher resolution improves extremes representation"

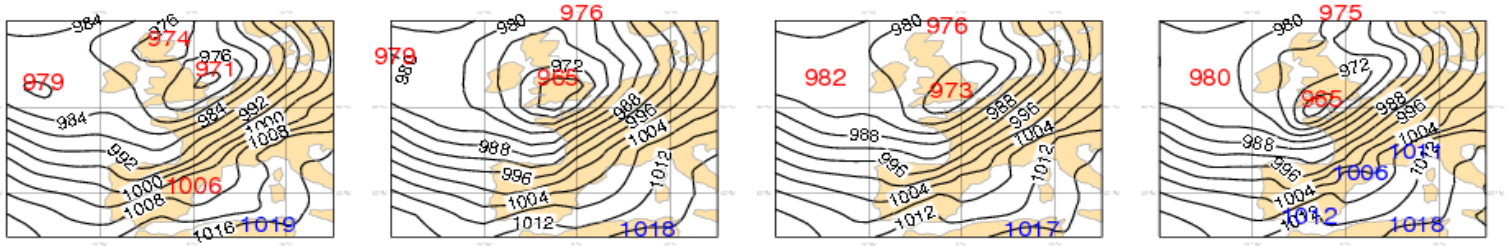
ECMWF Operations in 1987 (300 km)	ERA-15 (190 km)	ERA-40 (125 km)	ERA-Interim (80 km)	ERA-20C (125 km)

24-hour fcst

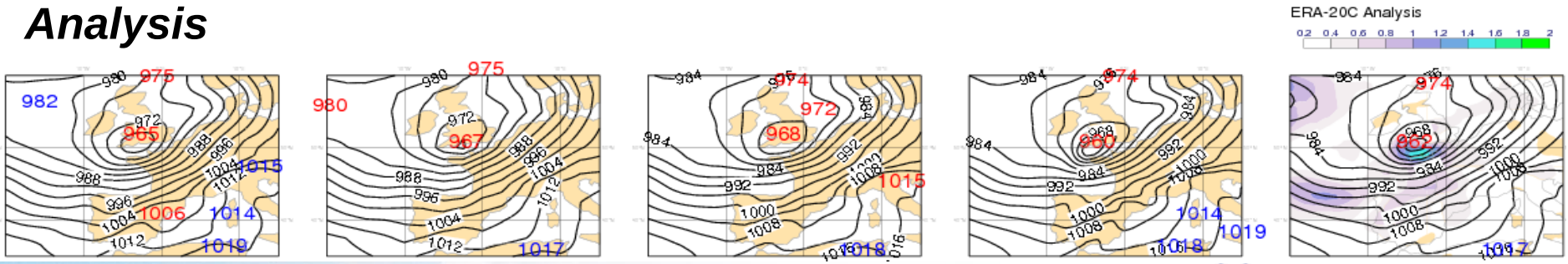


12-hour fcst

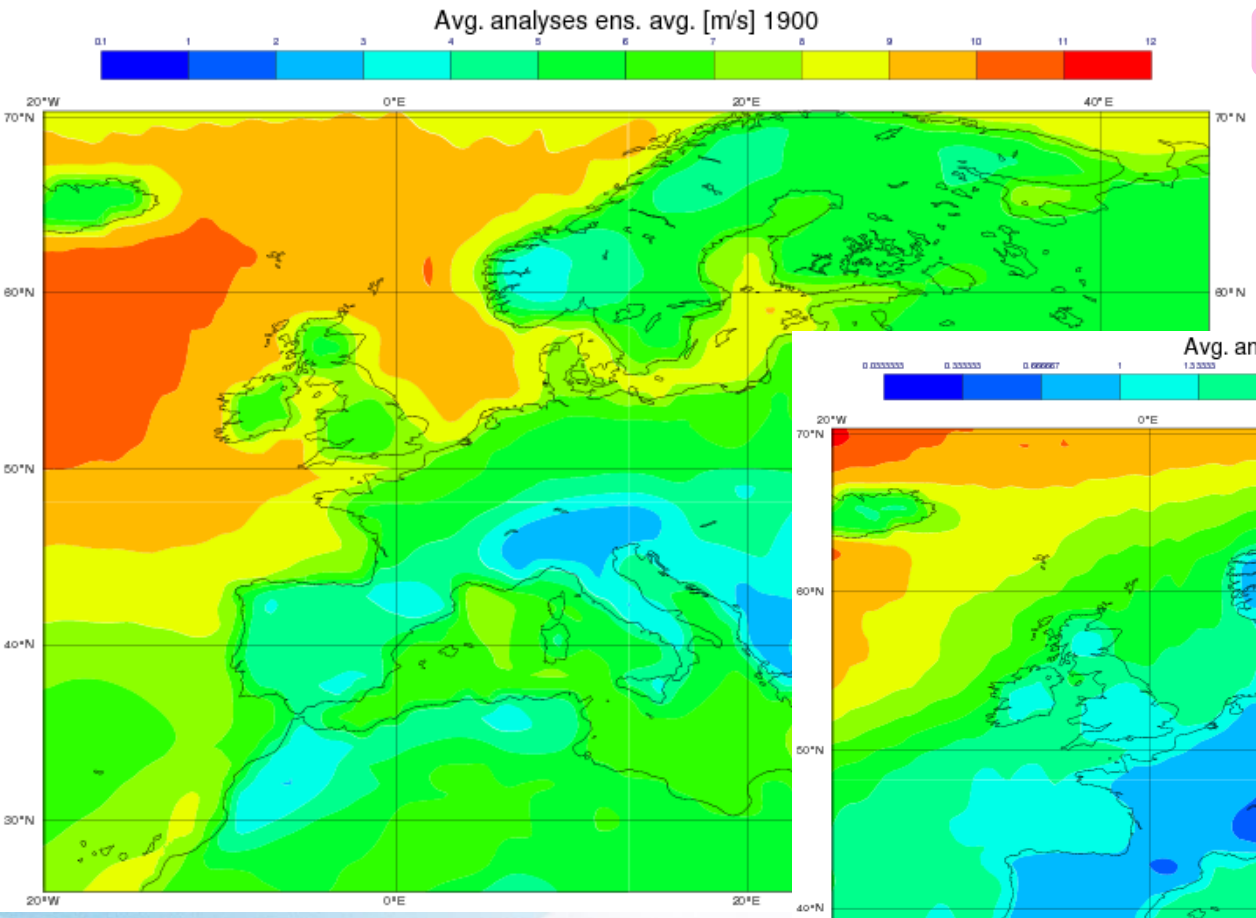
All maps valid on 19871016, 00 UTC



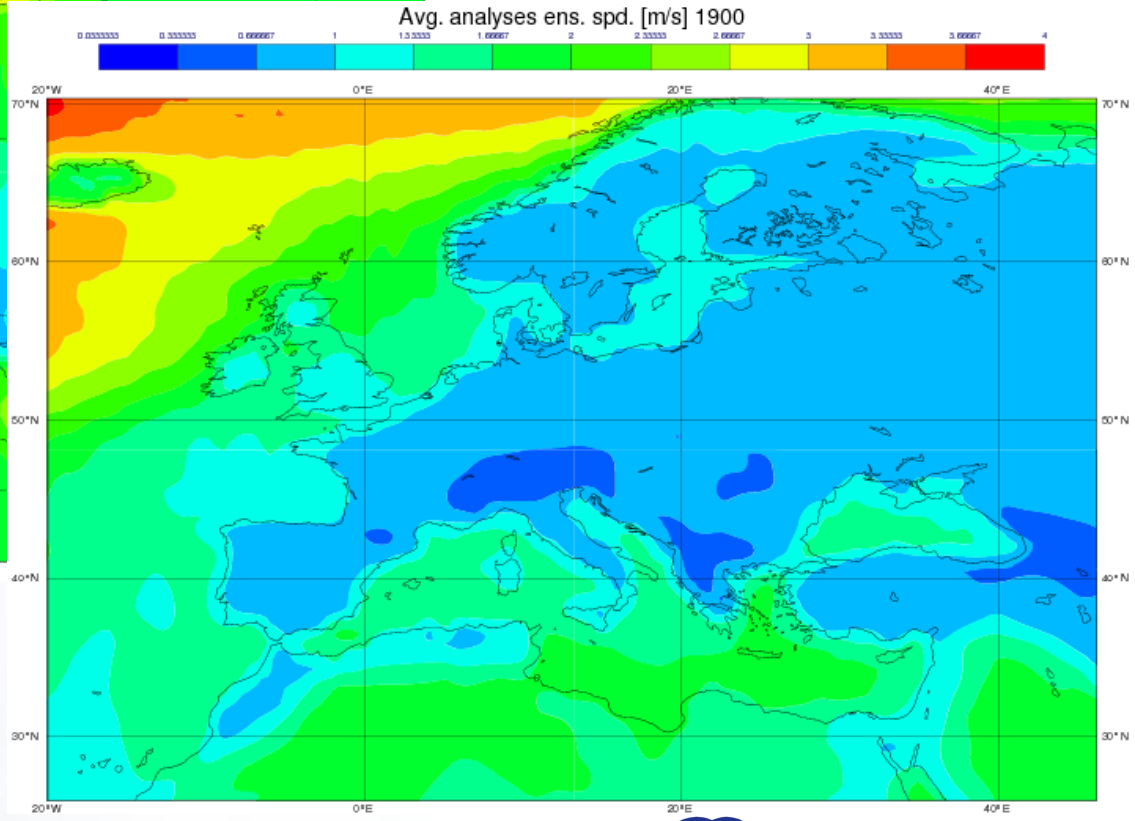
Analysis



ERA-20C 100-meter wind speed over Europe in 1900



Average



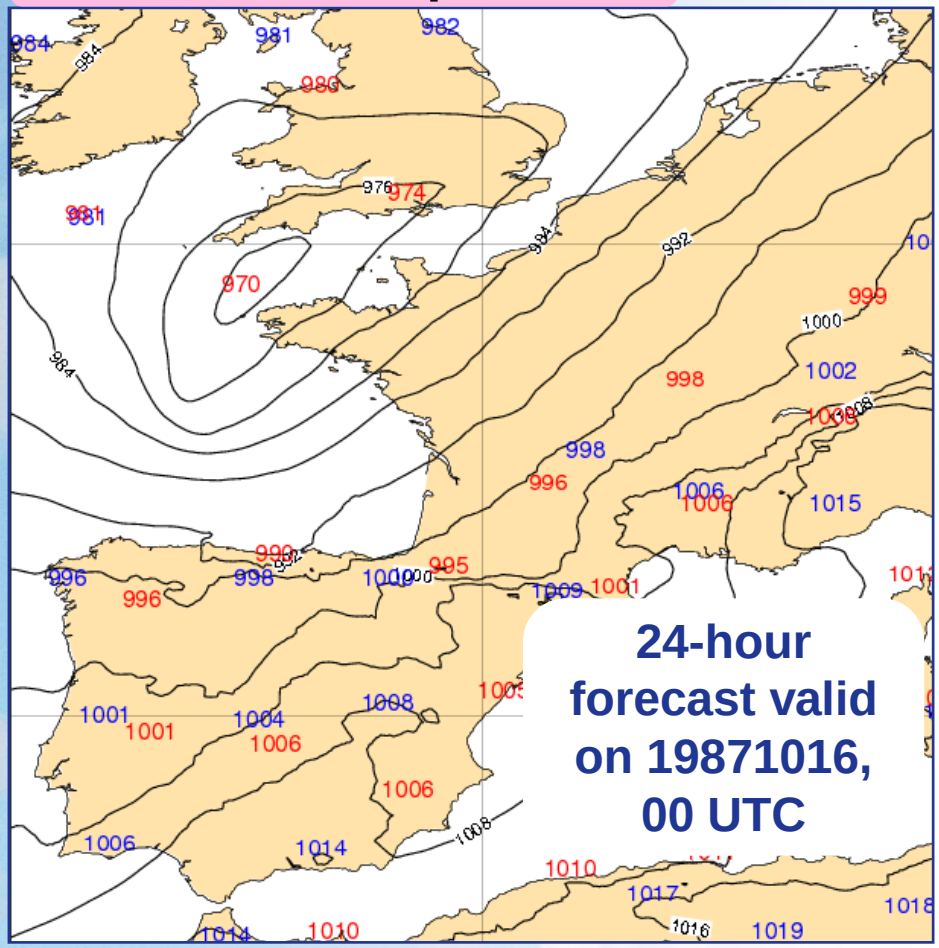
Ensemble spread

Myth #3: “Global reanalyses are necessarily low resolution”

24-hour model integration at T2047 or approx. 10 km

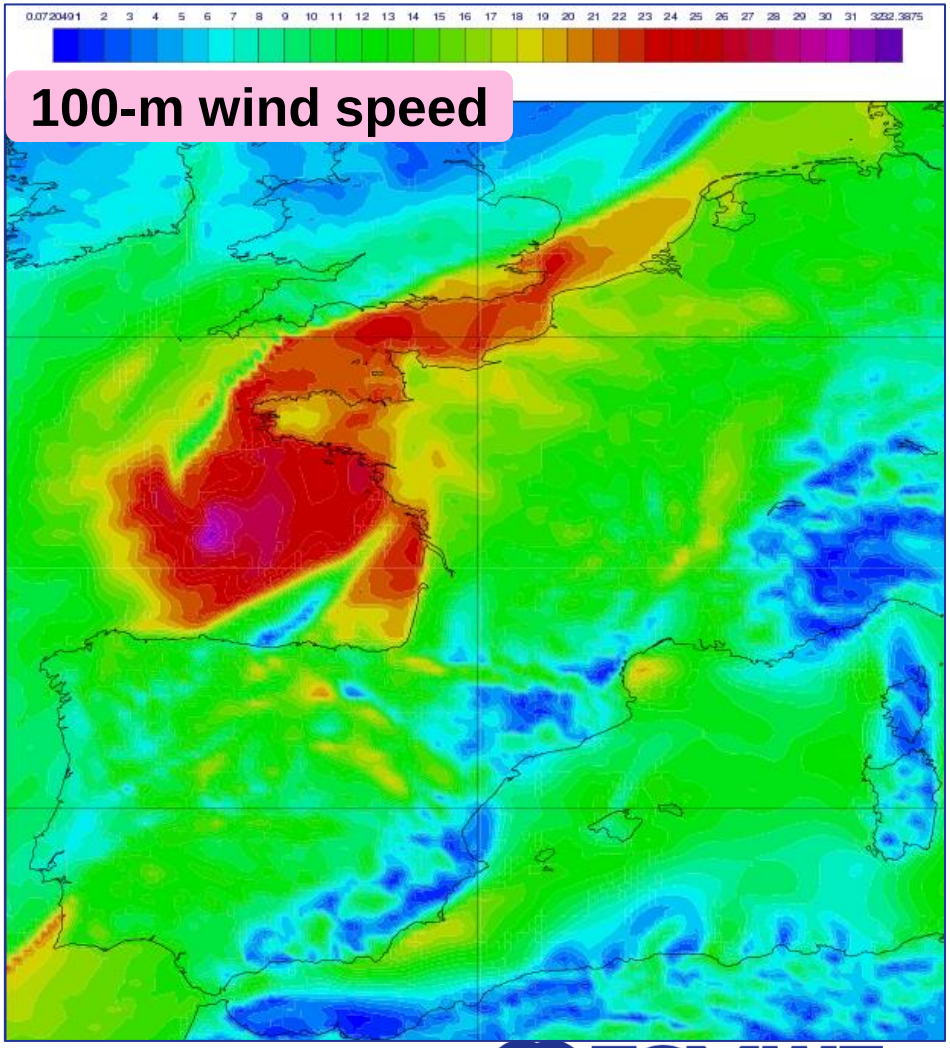
CPU cost is about the same as 1 day of ERA-20C assimilation with 10 members

Mean sea-level pressure



24-hour forecast valid on 19871016, 00 UTC

100-m wind speed



Conclusions and Questions

- **ERA-Interim continues; to be replaced at some point**
  - New product probably ~40 km resolution

- **ERA-20C: 1900-2010, 3-hourly output, 125 km resolution**
  - Around 700 Tb of archive, produced in about 8 months.
  - Ensemble of 10 solutions for all fields
    Yield: ~200 days/day, ~3.5 Tb/day, ~350 million of meteorological fields/day.
    Involves ~2000 4DVAR assimilations daily.

- Questions, to improve exchanges /understanding of needs with wind energy community:
  - **How do you procure reanalysis data for km-scale applications?**
  - **Which observations could you share with everyone?**
  - **Towards European Climate Services: what are your needs from global reanalysis?**

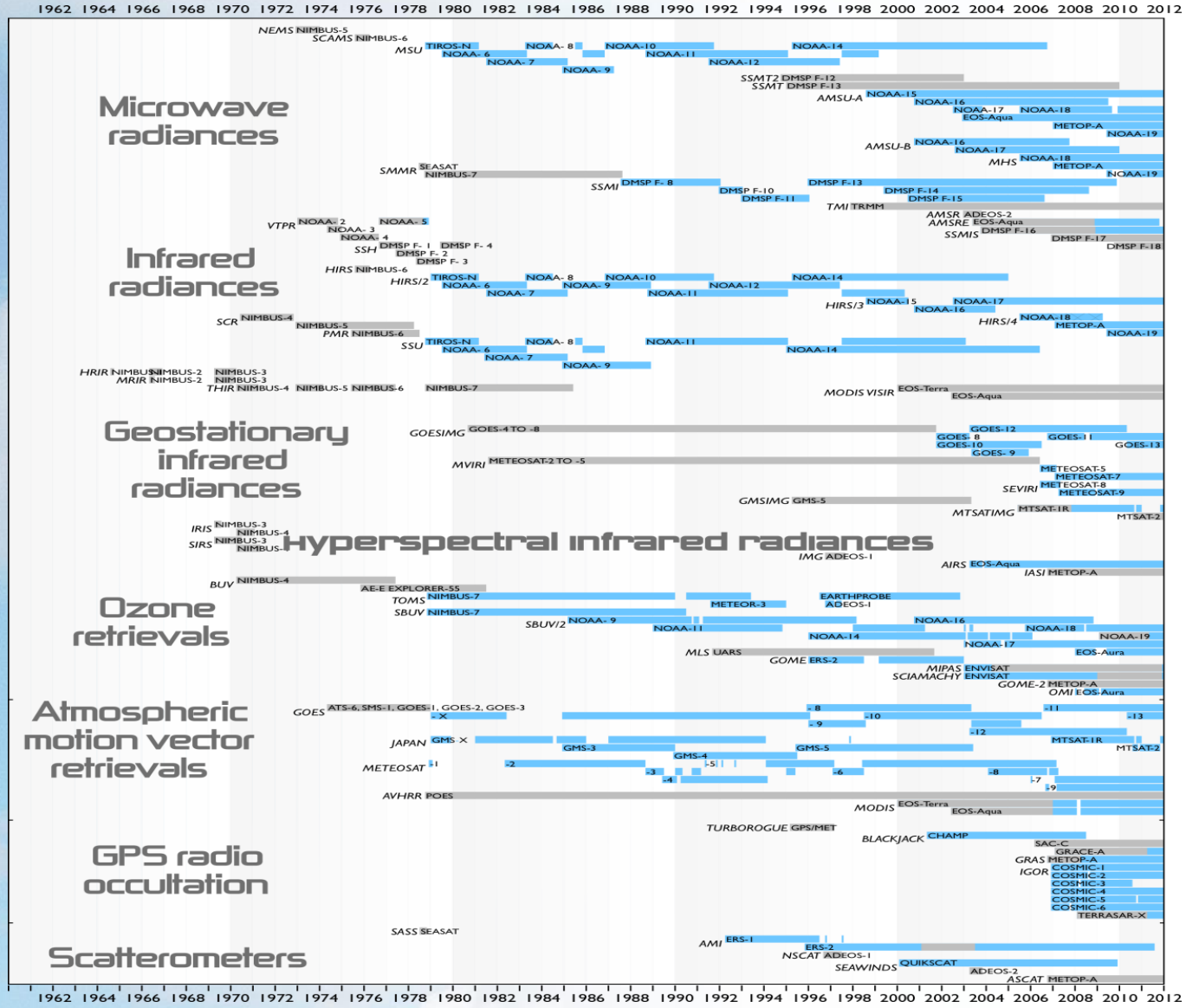
Thank you!

All ERA products: http://apps.ecmwf.int/datasets/
Questions: paul.poli {at} ecmwf.int

ECMWF reanalysis products contents

- Four-dimensional representation of the atmosphere, land-surface, and ocean-surface wave
- More than **100** geophysical variables for the *surface*:
  - E.g. 10-meter zonal and meridional wind (as well as 100-meter), 2-meter temperature, mean sea-level pressure, …
- More than **30** geophysical variables for the *ocean waves*:
  - E.g. coefficient of drag with waves, maximum individual wave height, mean direction of total swell, mean direction of wind waves, …
- More than **20** geophysical variables *vertically resolved*:
  - E.g. zonal (and meridional) component of wind, temperature, cloud cover, downdraught mass flux, geopotential, ozone mass mixing ratio, specific cloud ice water content, tendency of zonal (and meridional) component of wind due to physics, turbulent diffusion coefficient for heat, …

Satellite observations of the atmosphere since the 1960s



In blue: data assimilated in ERA-Interim

In grey: data for future reanalyses…