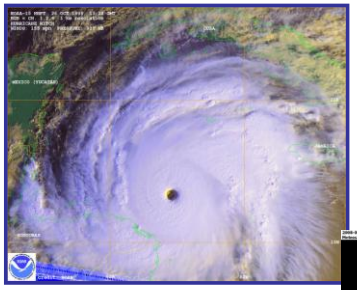
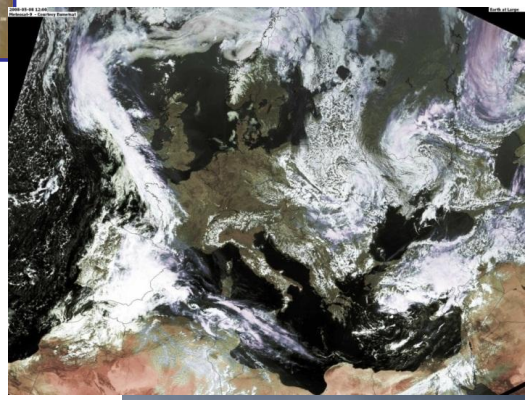
Ten-year Prospective for Numerical Weather Prediction





Gilbert Brunet
Director Meteorological Research Division, Environment Canada
Deputy Director Weather Science, UKMO

The Parameterization of Moist Processes for Next-Generation Weather Prediction Models Workshop
January 27-29, 2015

NOAA Weather and Climate Center
College Park, MD, USA

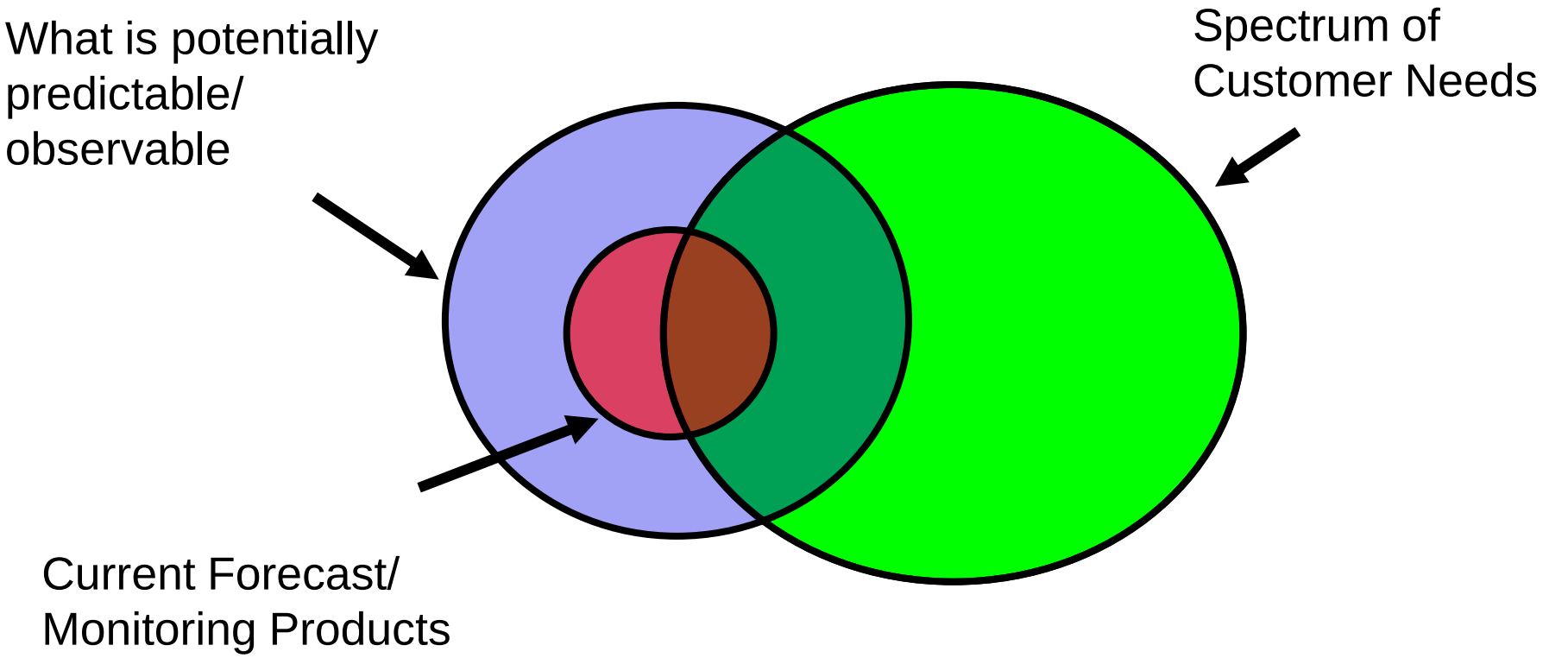
Aknowledgements: A. Brown, D. Burridge, K. Mylne, R. Reid, A. Scaife, J. Slingo, and A. Zadra

Goals of Numerical Weather Prediction (NWP) Research

- To improve public safety and economic productivity by doing research on the prediction of high-impact weather;
- To encourage the utilization of relevant advances in weather prediction systems to the benefit of users, customers and stakeholders.
- To demonstrate improvements in the prediction of weather through the exploitation of advances in scientific understanding, observational network, data assimilation and modelling techniques and information systems;
- To improve understanding of atmospheric processes and accelerate advances in NWP through national and international collaborative research programmes;

Goals of a Numerical Weather Prediction (NWP) Research Programme

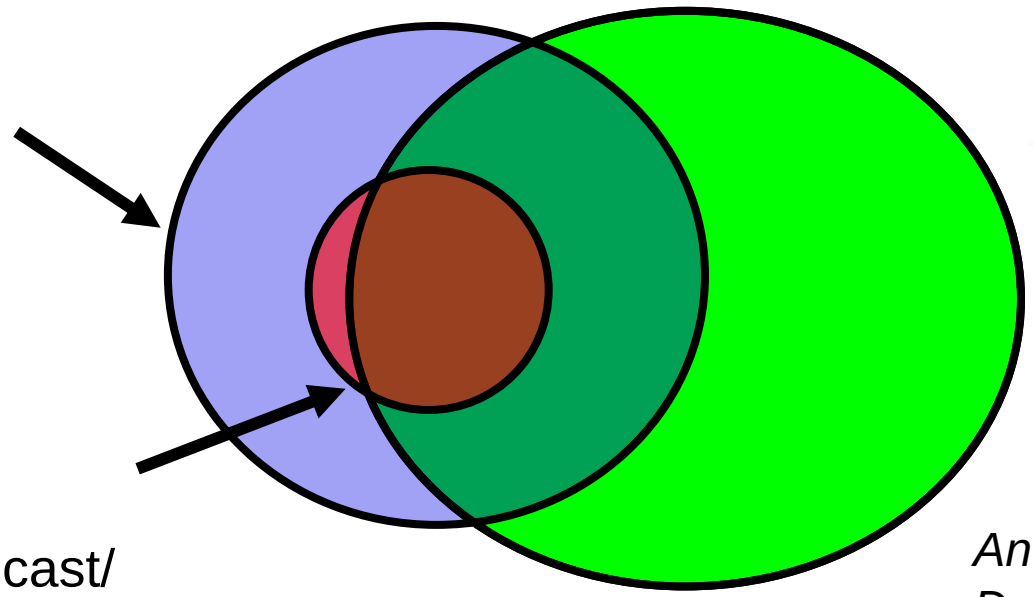
- To encourage the utilization of relevant advances in weather prediction systems to the benefit of users, customers and stakeholders.



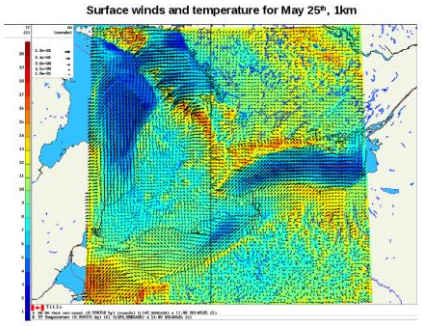
Goals of a Numerical Weather Prediction (NWP) Research Programme

- To encourage the utilization of relevant advances in weather prediction systems to the benefit of users, customers and stakeholders.

What is potentially predictable/ observable



Spectrum of Customer Needs

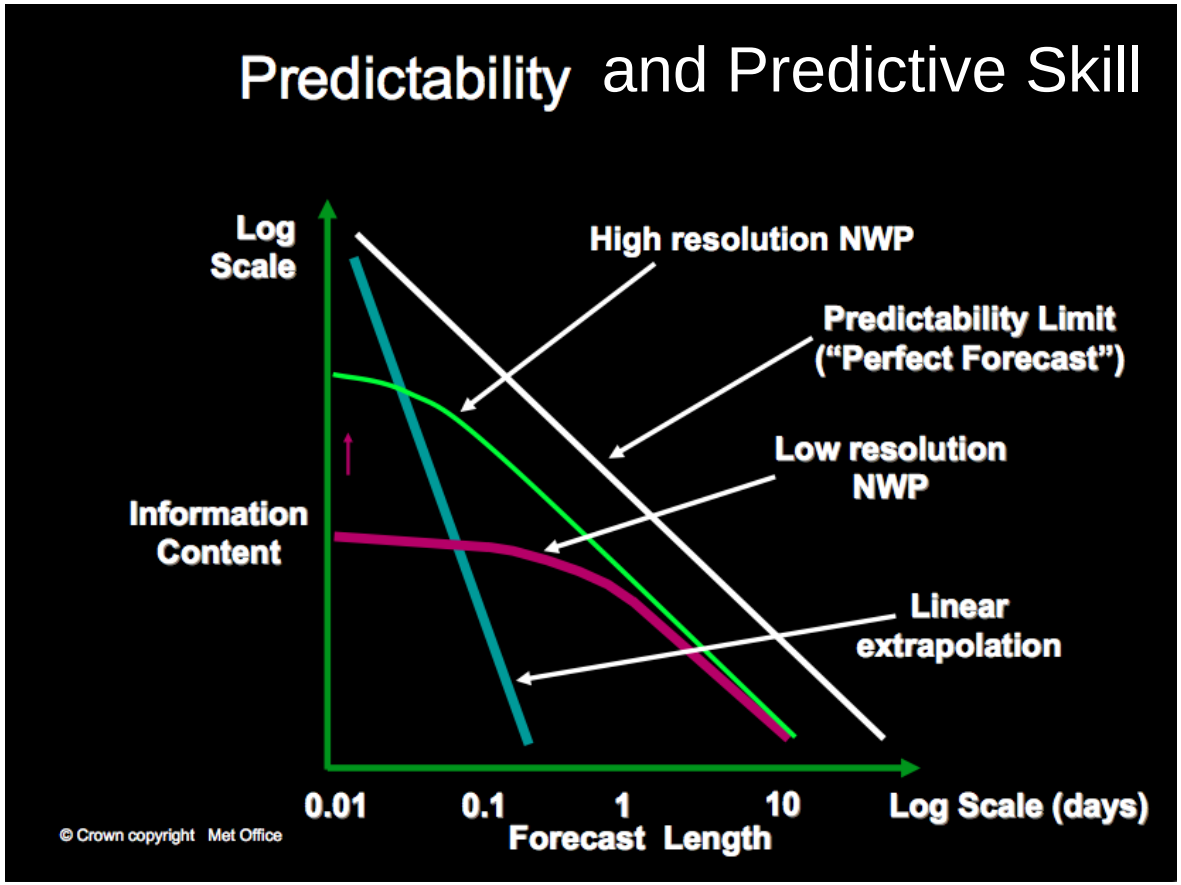


Current Forecast/ Monitoring Products

An urban Forecast Demonstration Project (FDP): Pan Am 2015 (Toronto).

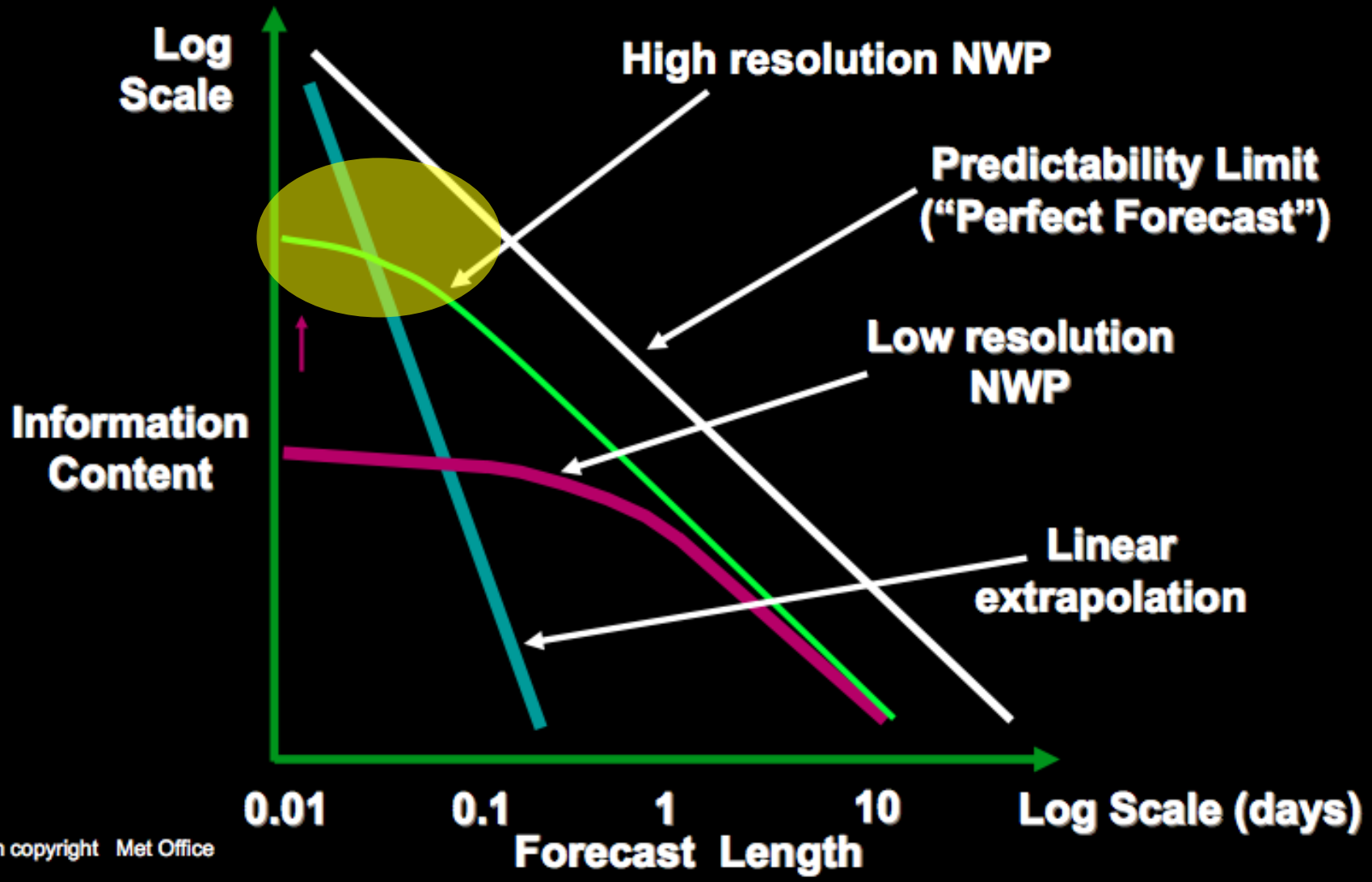
Goals of a Numerical Weather Prediction (NWP) Research Programme

- **To demonstrate improvements in the prediction of weather, with emphasis on high-impact events through the exploitation of advances in scientific understanding, observational network design, data assimilation and modelling techniques and information systems.**



Linear extrapolation, Limited Area Model (LAM) and global NWP model ...

Predictability and Predictive Skill

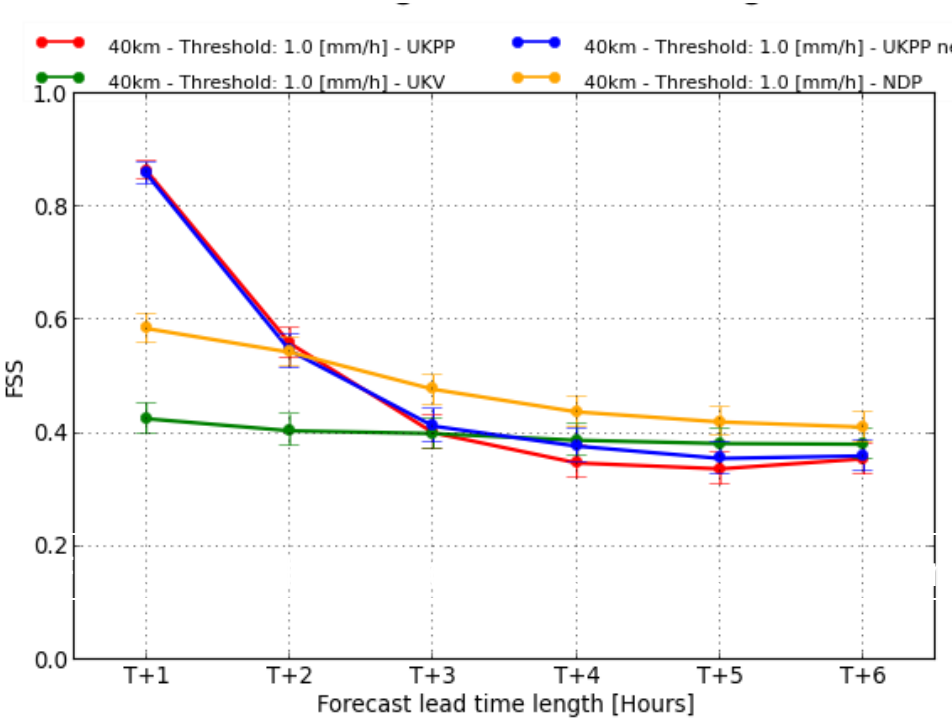


The UK Met Office Nowcasting Demonstration Project (NDP) (London Olympics 2012)

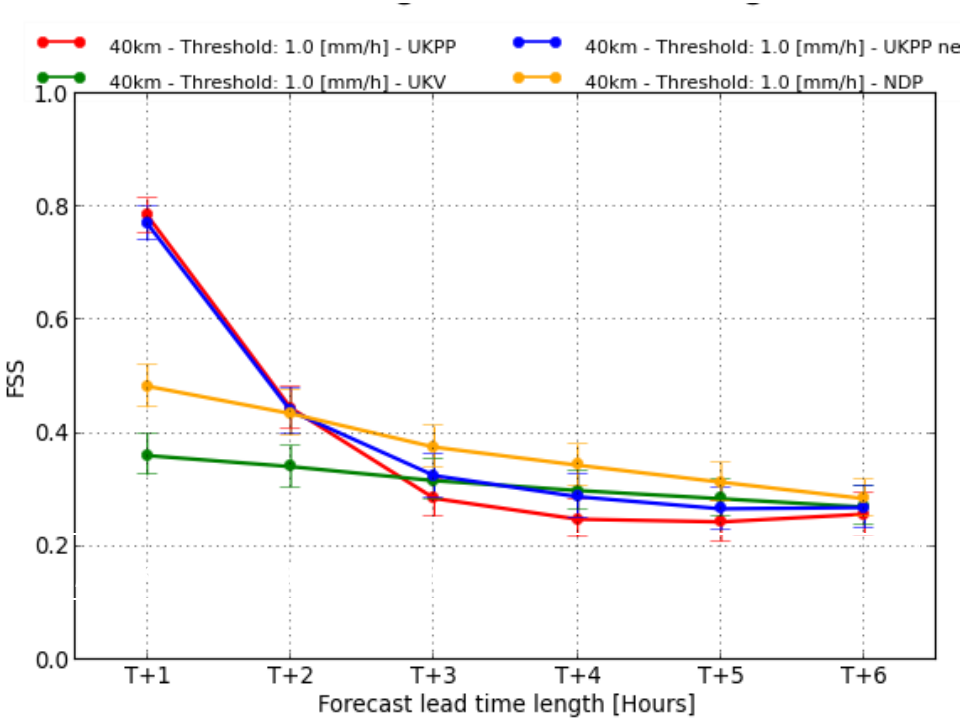
Verification of hourly precipitation forecasts against radar
Same validity time, available at same time to forecasters

NDP better than older UKV forecast at all ranges

NDP better than STEPS (Sydney 2000 WWRP FDP) extrapolation/merged nowcast

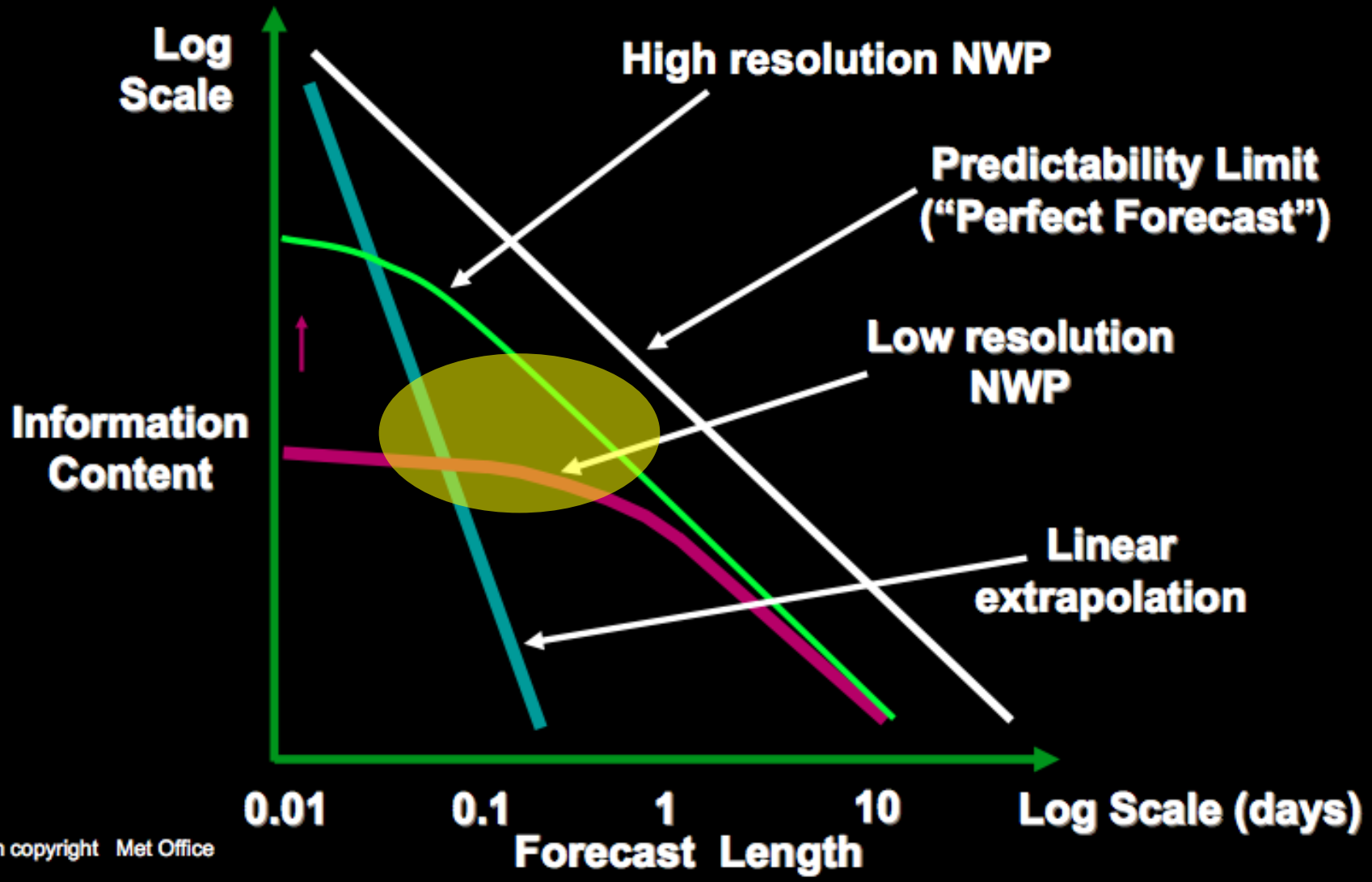


July



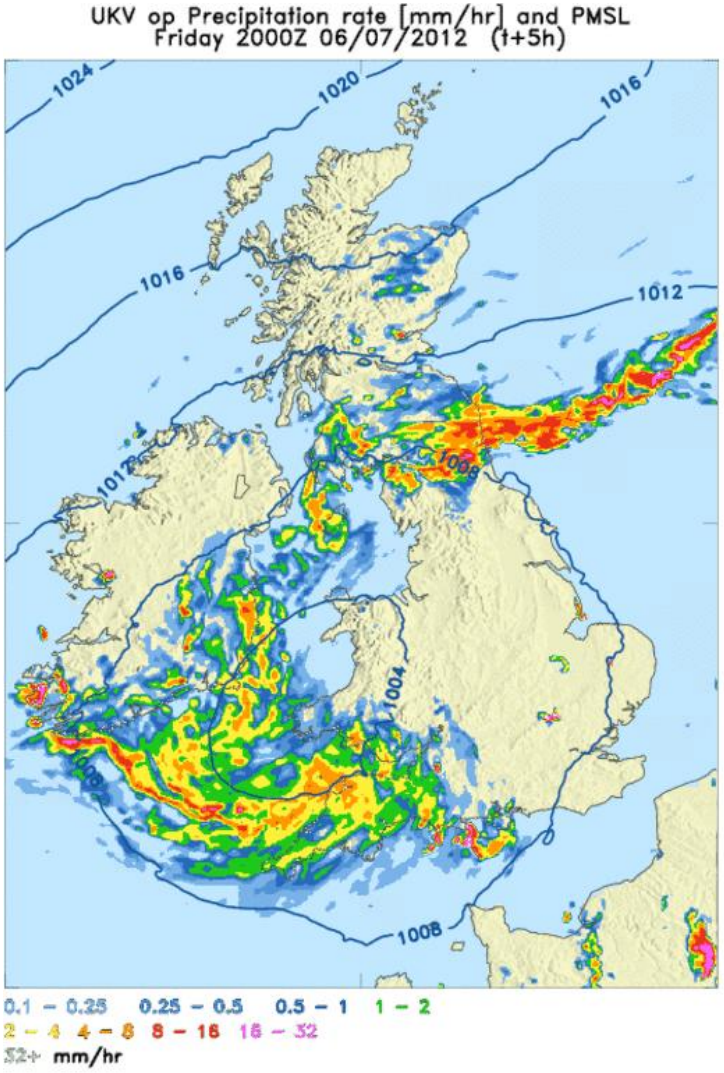
August

Predictability and Predictive Skill

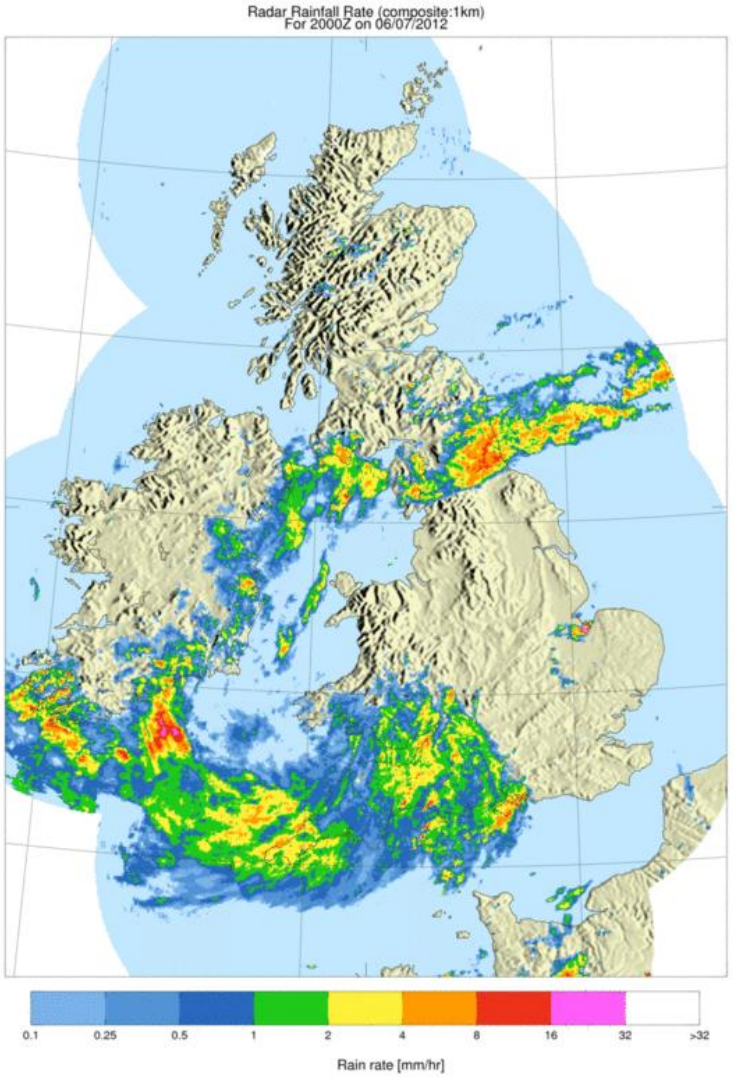


SW Floods 6th – 7th July 2012

Model Forecast



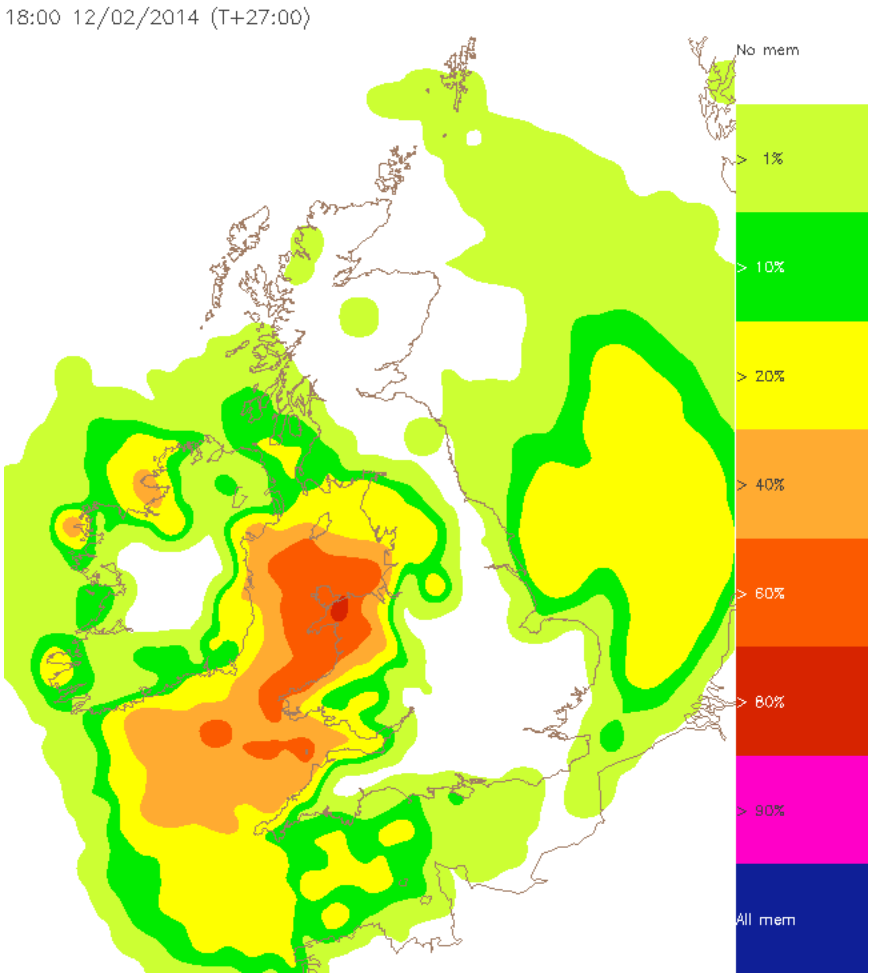
Radar



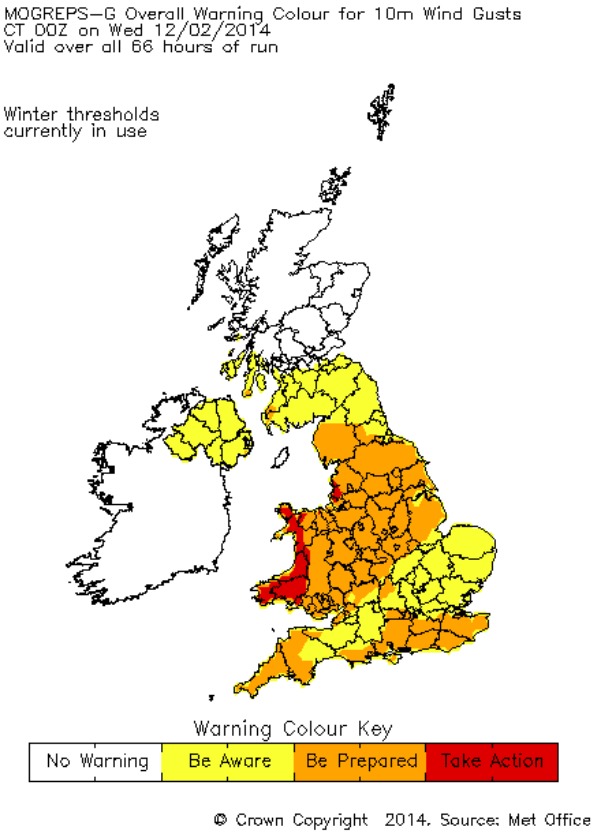
© Crown copyright Met

UKMO regional EPS

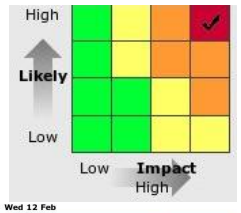
2.2km Convection-Permitting ensemble
12 members 4X per day to 36h

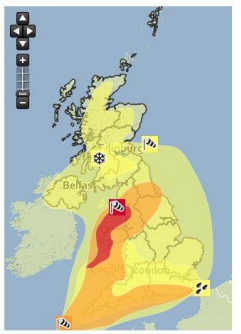


Probability Wind > 48kt

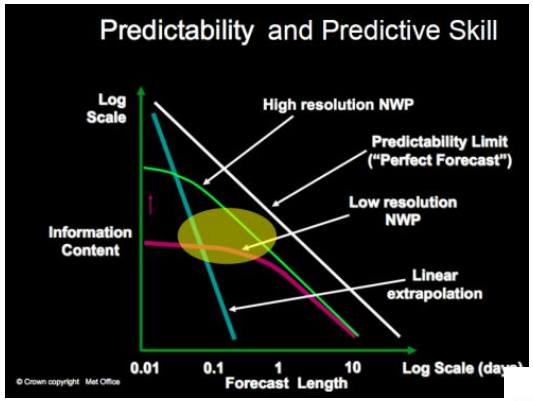


- Global ensembles (above) provides first-guess warning of severe weather up to 5 days ahead
- Regional EPS (left) adds detail for last 36h



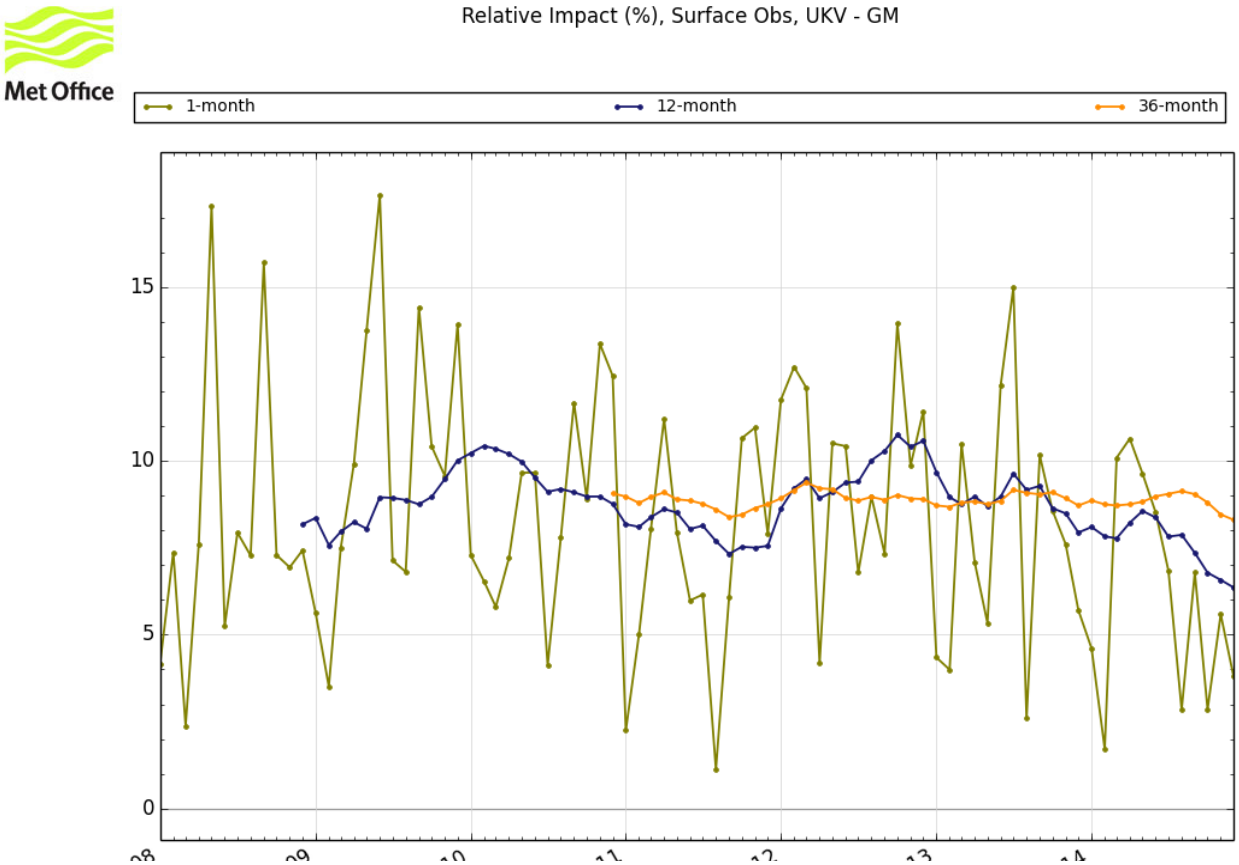


Useful guidance for risk-based warnings



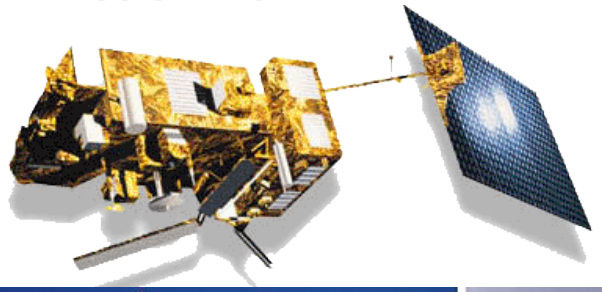
Relative benefit (%) of the UKMO deterministic regional over global NWP systems for surface variables (including precipitation and visibility).

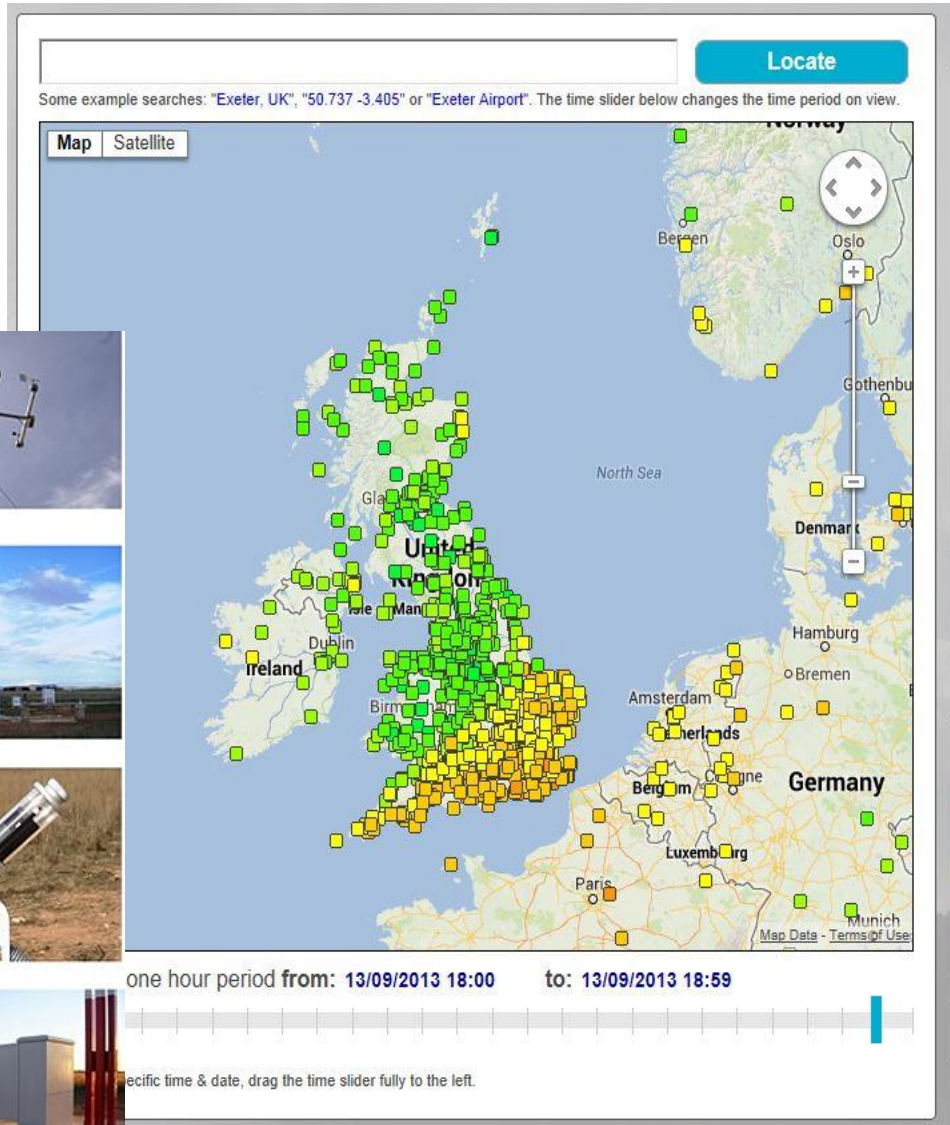
- Added value of ~9% from UKV, representing 5 – 10 yrs lead over the Global NWP system.
- Resolution and DA important, but advances in physics are needed



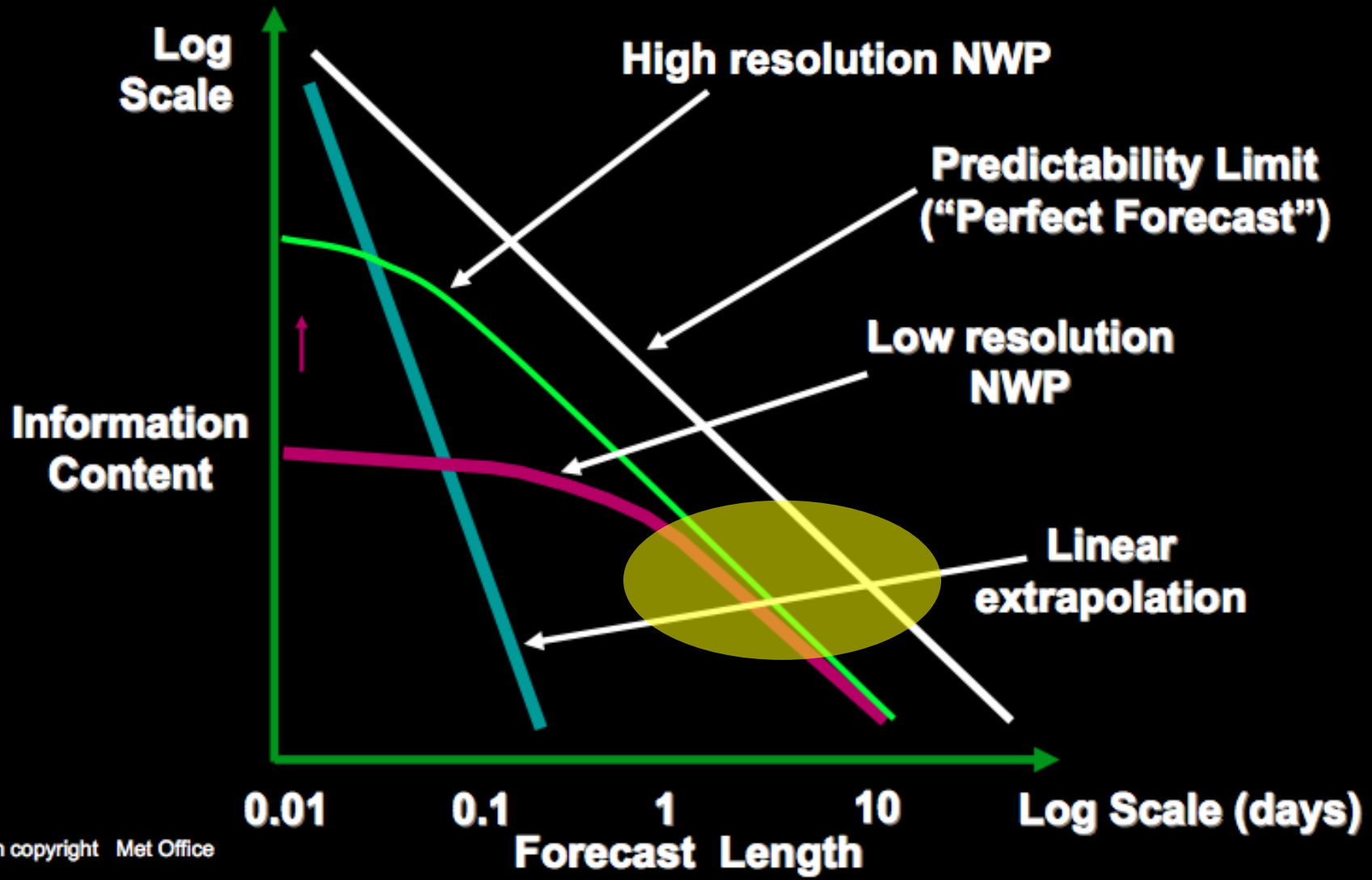
Observing Systems: Keeping Pace with the Models

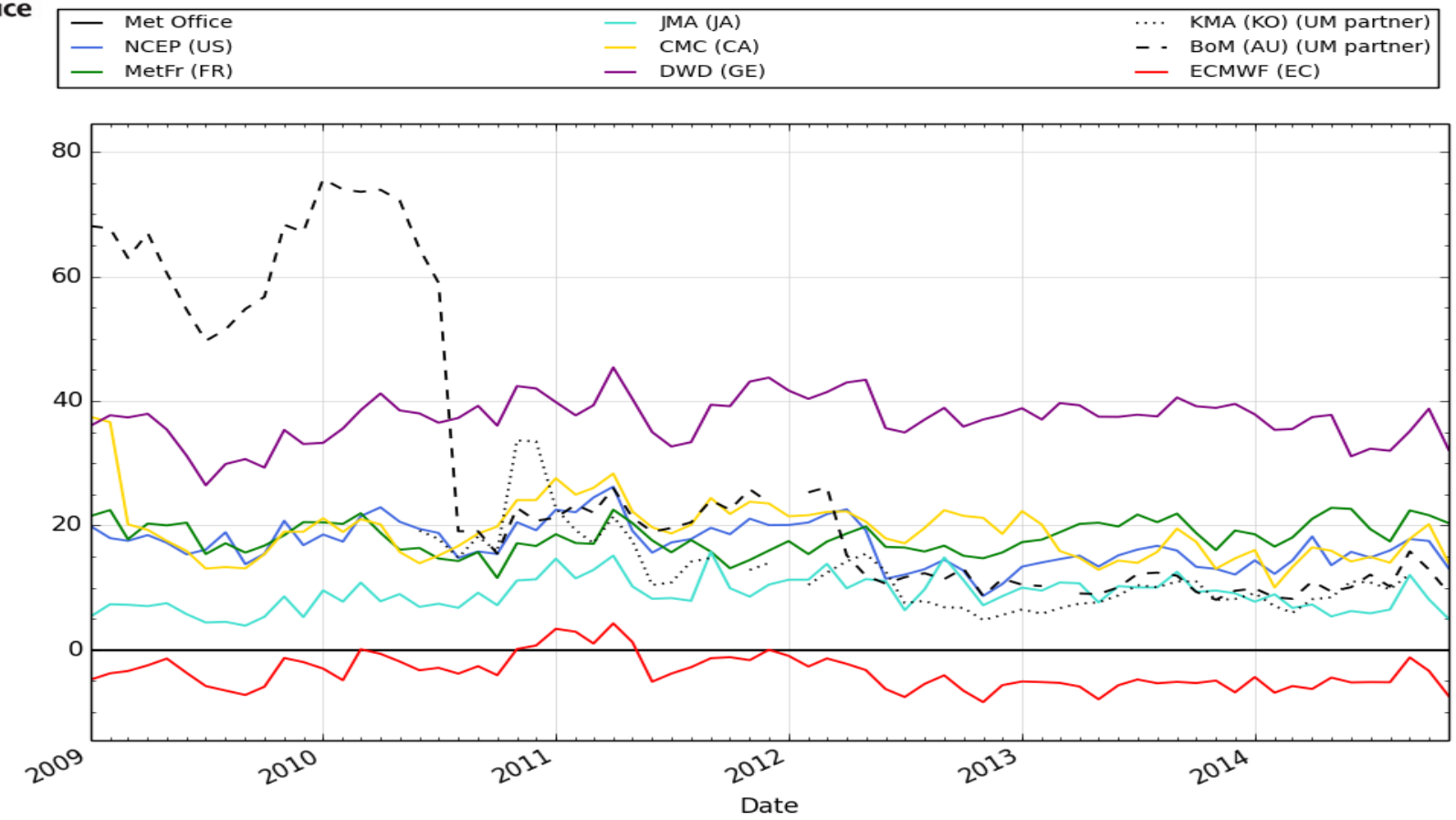
Met Office





Predictability and Predictive Skill





- How to explain the differences? (resolution, data assimilation and physics);
- Precipitation is not part of this metric.

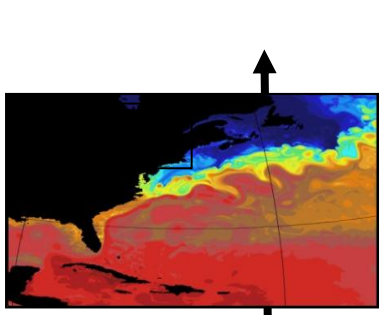
Goals of Numerical Weather Prediction (NWP) Research

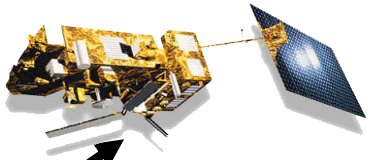
To demonstrate improvements in the prediction of weather through the exploitation of advances in scientific understanding, observational network, data assimilation and modelling techniques and information systems.

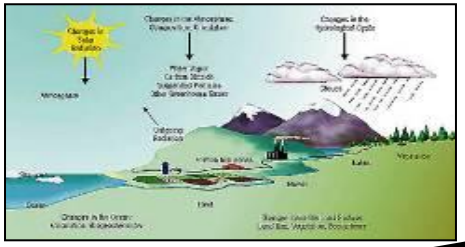
The Way Forward

Making the most of resources

"Model development taking account of all these aspects and the balance at every time-scale between model breadth, complexity and resolution and ensemble size will require clarity of thinking and leadership"







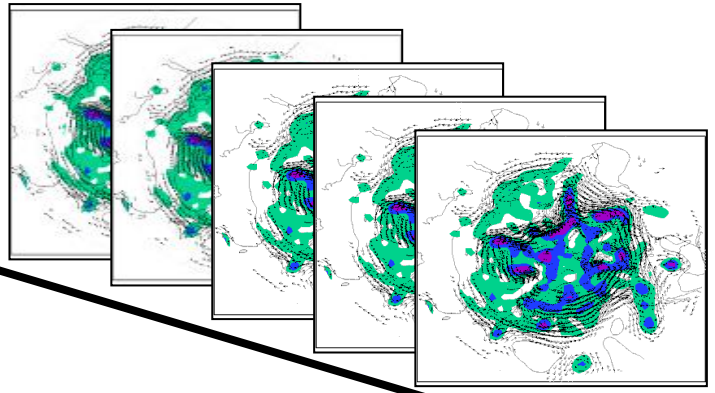
Earth Observation

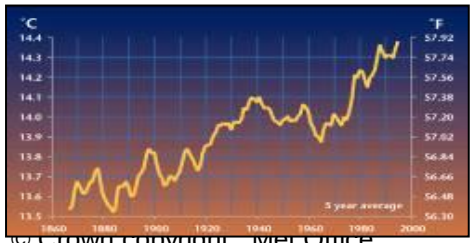
Resolution

Computing Resources

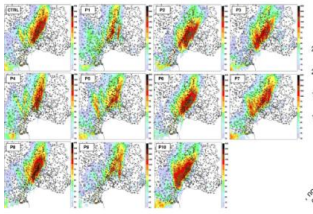
Complexity

Duration and/or Ensemble size

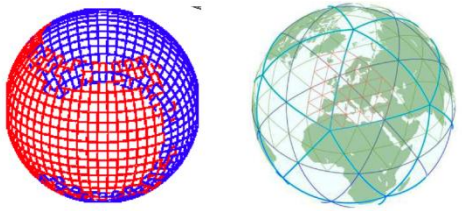




Trends for NWP systems

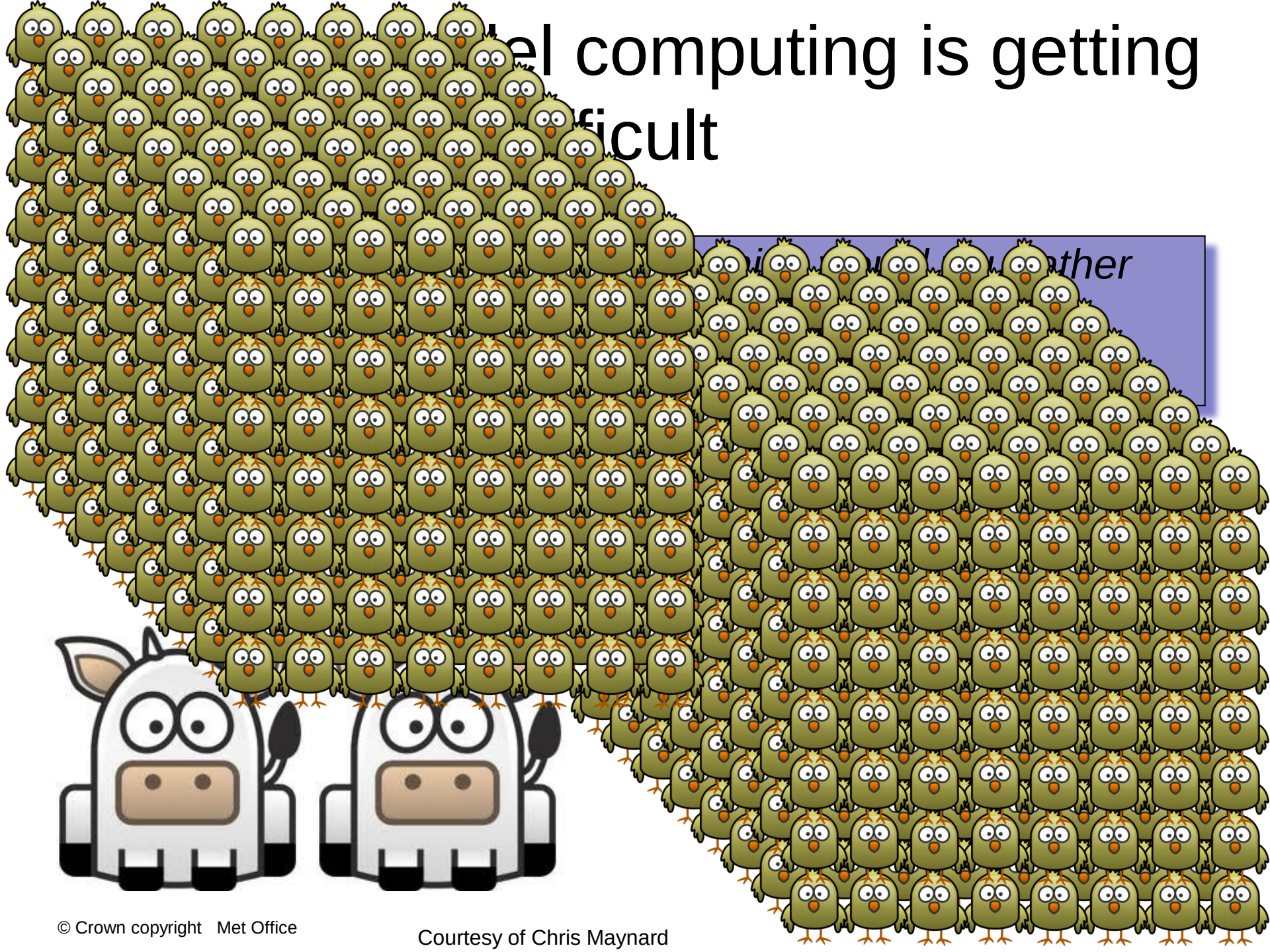


- Integrated NWP systems (for efficiency);
- Seamless forecasts: from minutes to months and beyond to climate;
- Toward coupled NWP with ocean, sea-ice, waves, chemistry and hydrology;
- Generalization of ensembles to impact models;



- Continued trend in increased resolution;
- Revisiting the basic equations for non-hydrostatic dynamics;
- Towards unstructured grids to better represent steep orography (like in ocean models);
- More scalable dynamical cores, optimizing the data flux between processor (crucial for next generation of HPCs).

el computing is getting ficult



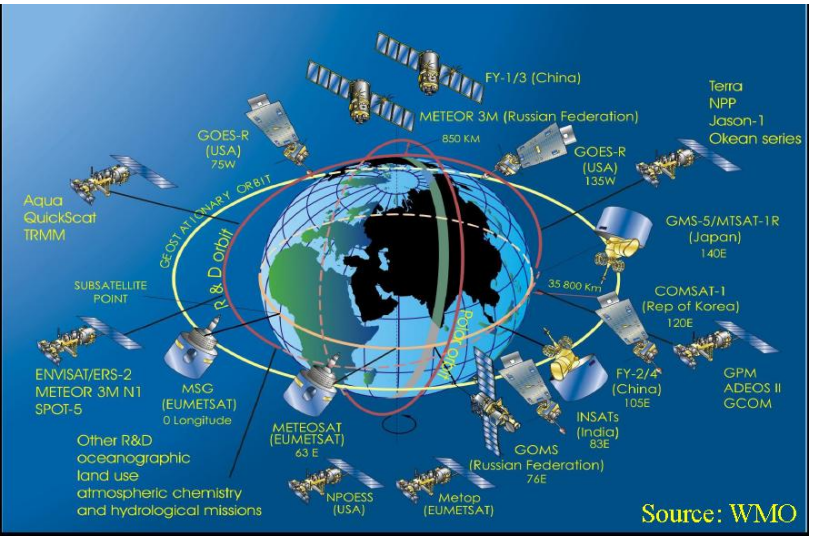
Courtesy of Chris Maynard

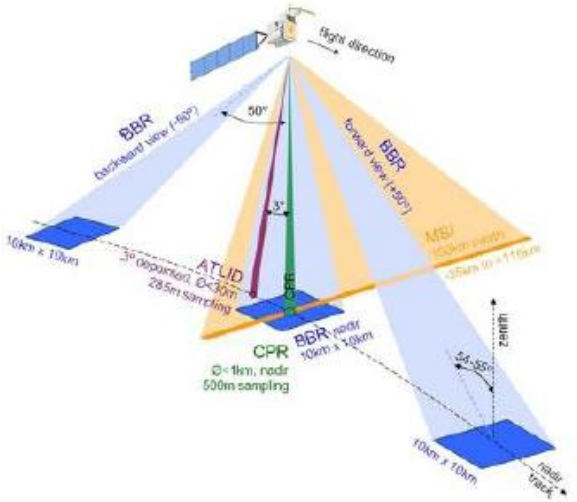
How to solve the weather prediction equations efficiently and accurately on massively // HPC?

International collaboration and partnership will be crucial!

New Observations

- High spectral resolution IR sounders on geostationary satellites (MTG in 2020);
- Space wind lidars (Aeolus in 2015);
- Advanced usage of met radars; ground based remote sensing;
- New types of observations (e.g EarthCare).





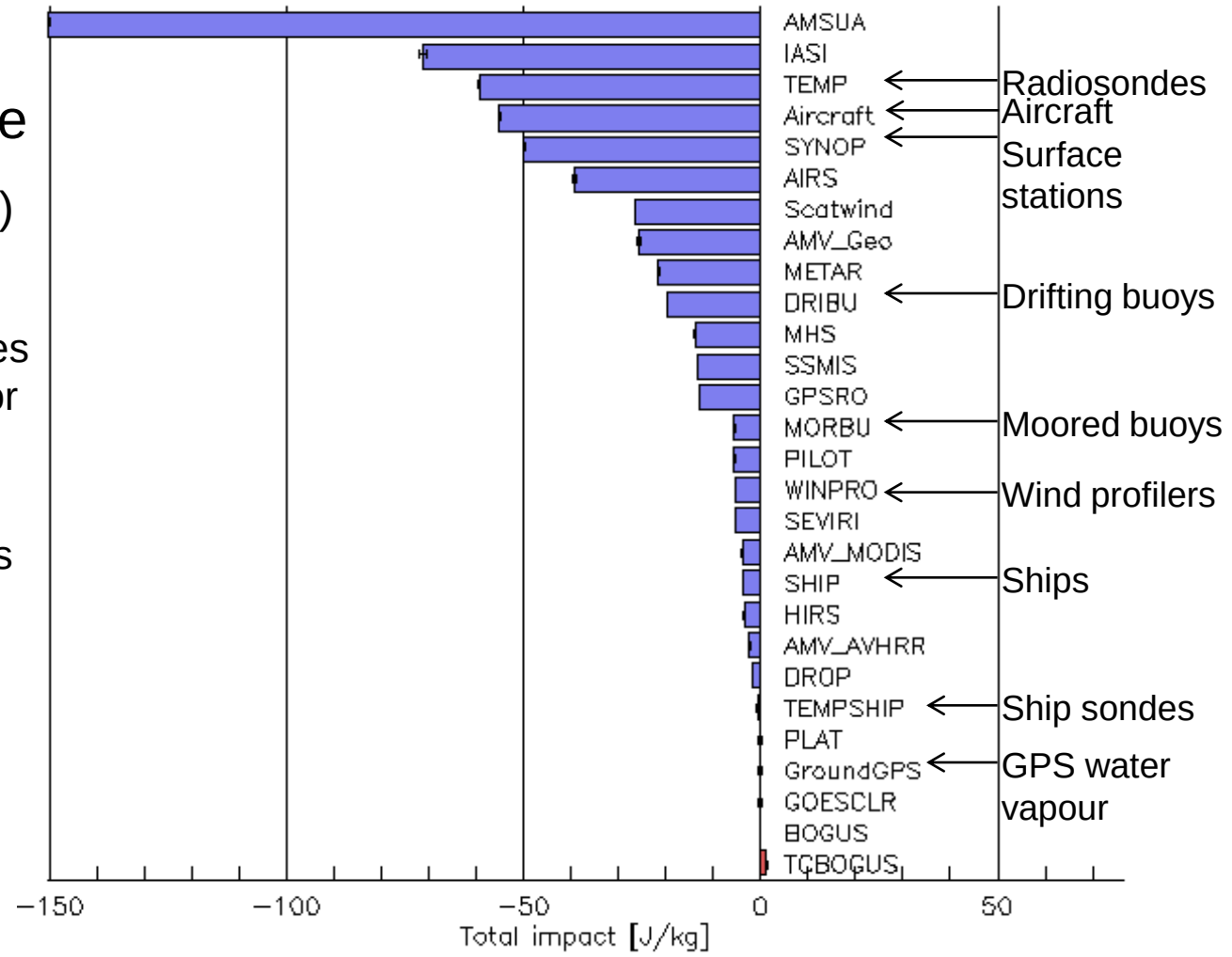
Forecast Sensitivity to Observations (FSO) impacts

Total impact of observations by type

(January – March 2012)

- Beneficial impacts are indicated by negative values – they reduce forecast error (shown in blue)
- Detrimental impacts are indicated by positive values – they increase forecast error (shown in red)

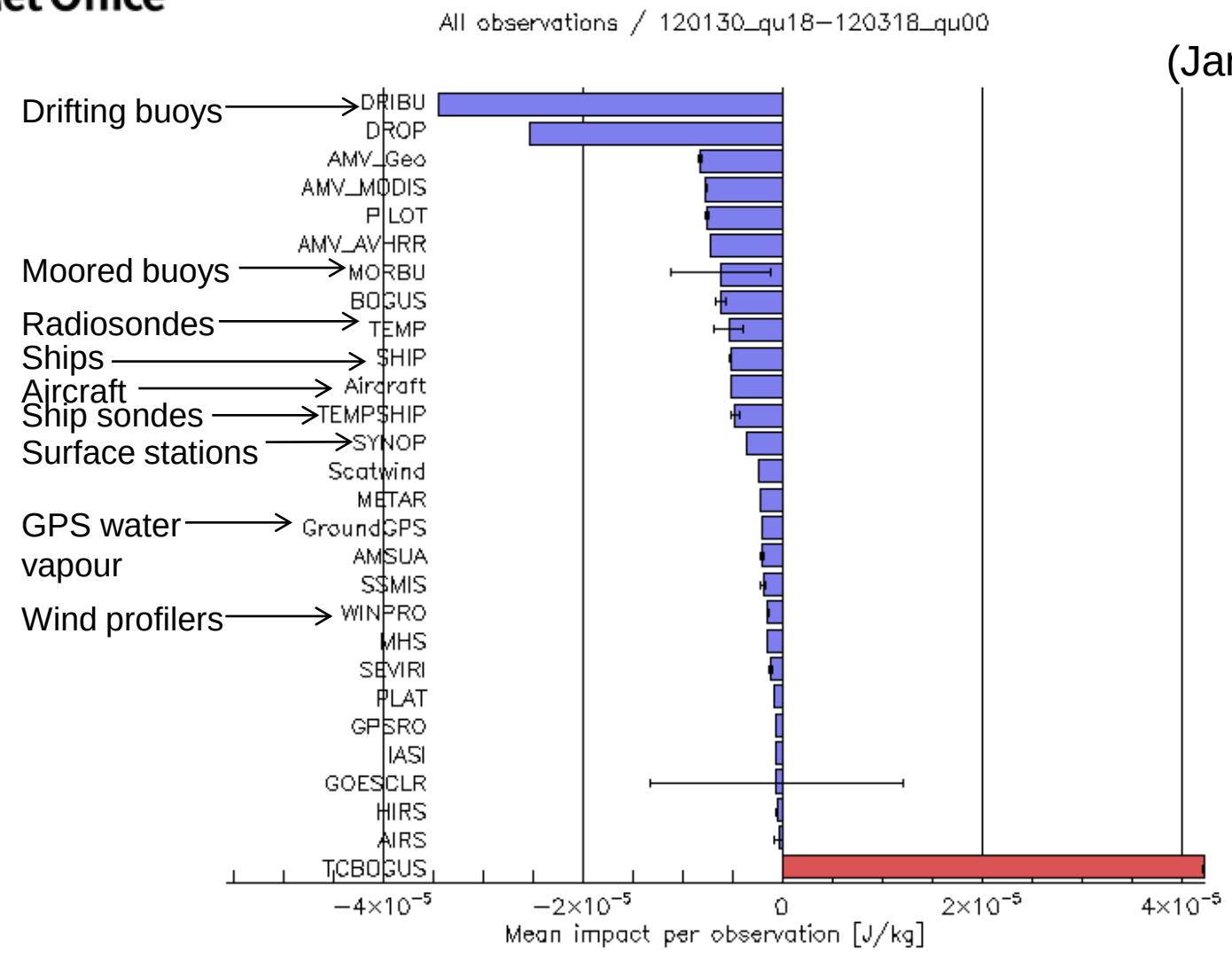
Impacts require careful interpretation



FSO impacts

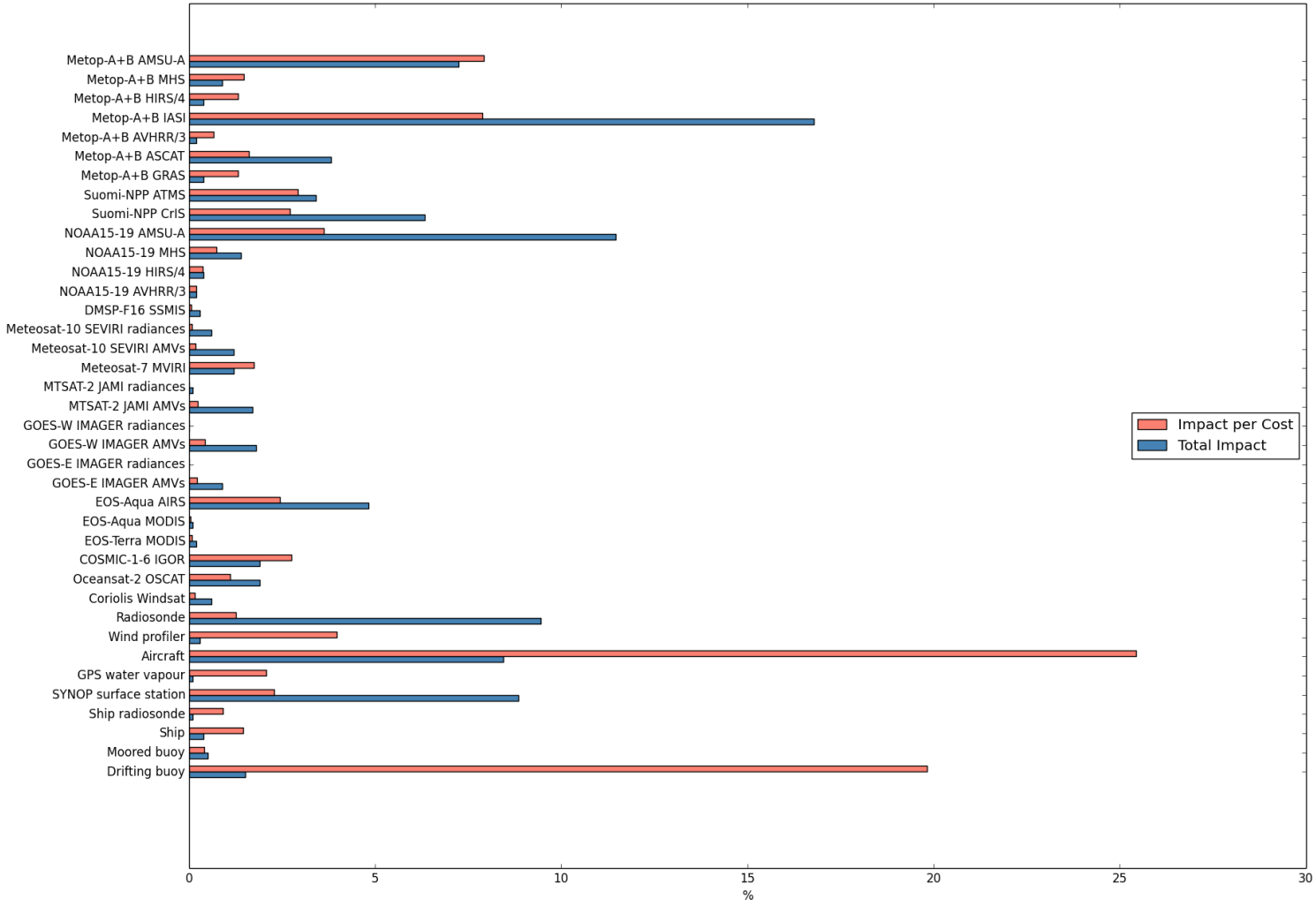
Mean impact of observations by type

(January – March 2012)

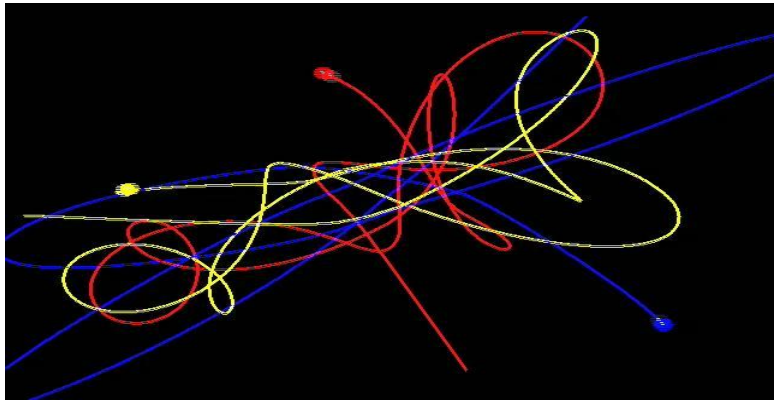


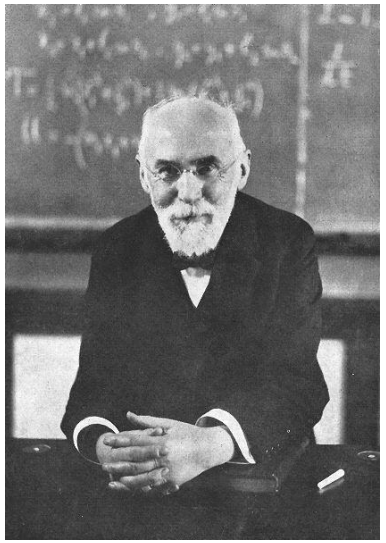
FSO impacts

Impact per cost (red) and Total impact (blue) by type (January – March 2012)



Chaos: an old problem



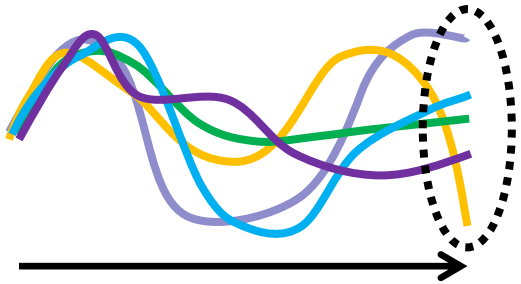


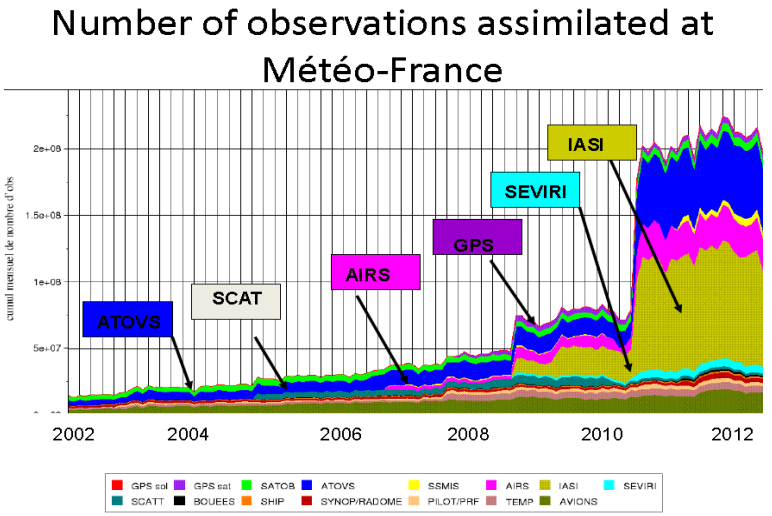
Henri Poincaré (1854-1912)

"A small error in the former will produce an enormous error in the latter...The meteorologists see very well that the equilibrium is unstable, that a cyclone will be formed somewhere, but exactly where they are not in a position to say; a tenth of a degree more or less at any given point, and the cyclone will burst here and not there, and extend its ravages over districts it would otherwise have spared."

***Science and Method*, 1908, Henri Poincaré**

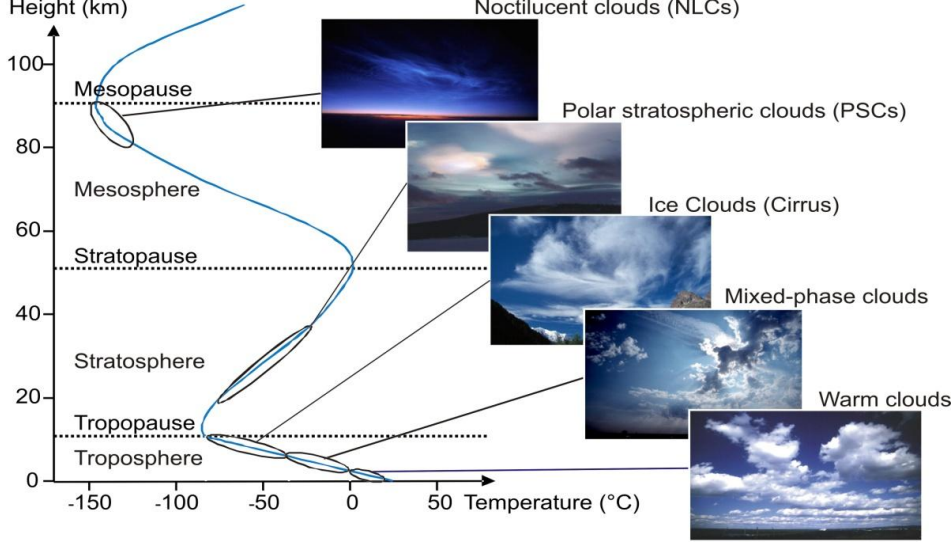
Data assimilation and ensemble techniques





- Work on improving description of both initial conditions and models uncertainties;
- Evolution driven by both progress in science and constraints from massively parallel machine architectures;
- Increasingly hybrid methods (ensembles-variational);
- Develop suitable verification techniques (deterministic, probabilistic, ensemble and high-resolution).

Model physics



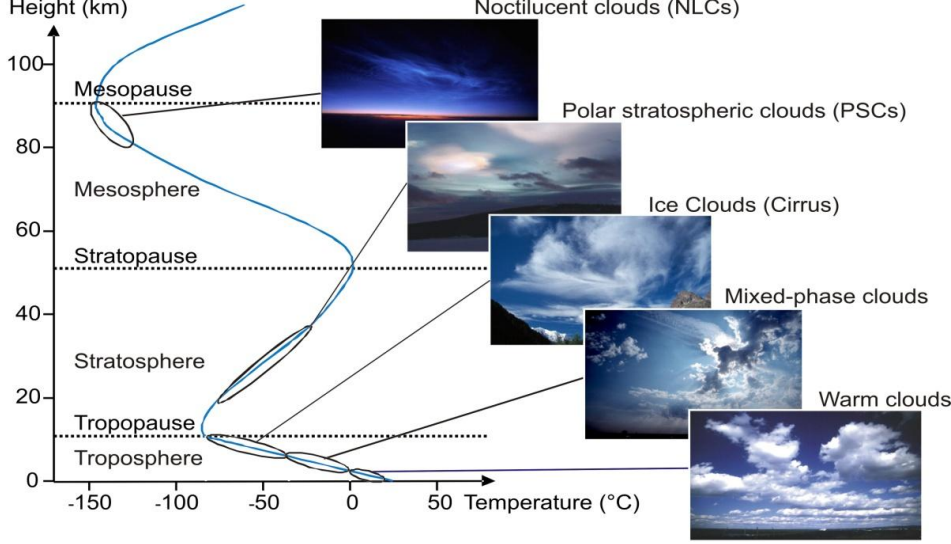
The new WCRP/WWRP International Prize for Model Development

Peter H. Lauritzen, NCAR, has been awarded the prize in 2014.

The important challenges are:

- Towards more conservative variables (e.g. chemistry);
- More advanced microphysics;
- Accounting for horizontal exchanges by turbulence and radiation for grid cells < 1km (e.g. urban NWP);

Model physics



The important challenges are:

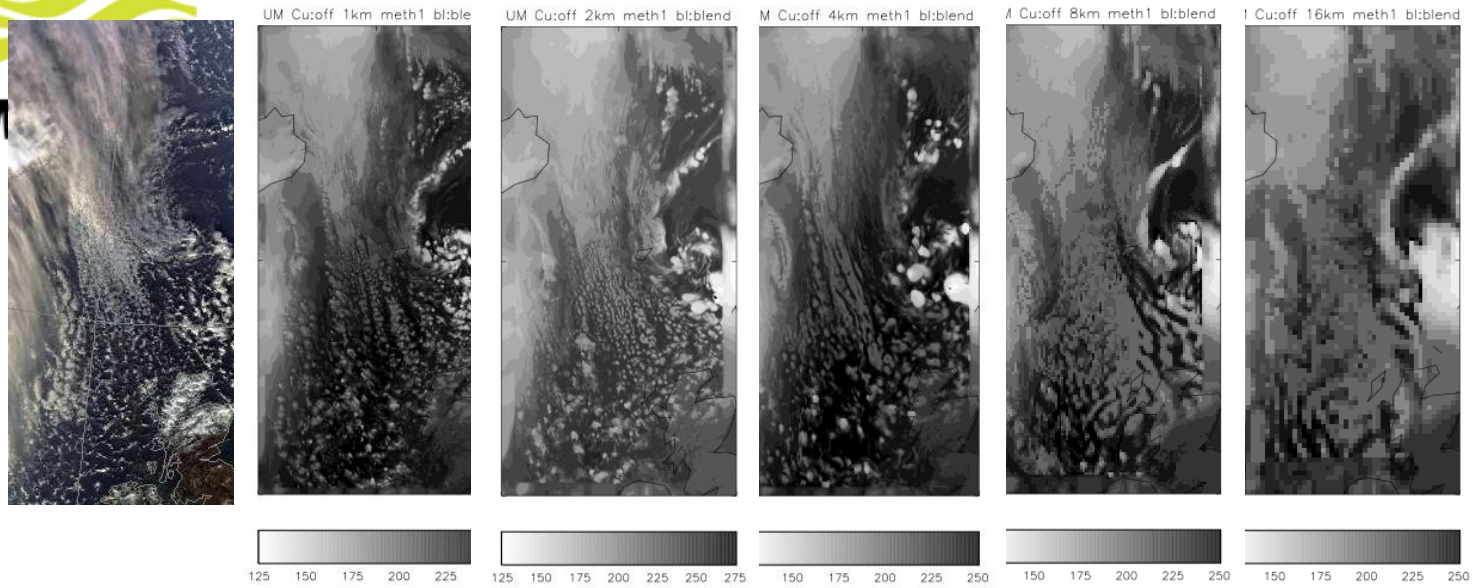
- Parametrization of convection remains a difficult problem for grid cells > 5km;
- Better representation of land surface – atmosphere interaction;
- More « grey zone » problems as the integrated forecasts systems will be used at various resolutions;

Working Group on Numerical Experimentation (WGNE): Grey Zone Project

- To systematically explore convective transport and cloud processes in weather and climate models at various resolutions;
- Exploring models with and without convective parameterizations through the so-called grey zone:
  - *What are the relative contributions of the parameterized versus the resolved contributions to the convective transport?*
  - *How well do models operate in the grey zone without an explicit convection parameterization?*
  - *How well do models operate in the grey zone with a convection parameterization?*
  - *How should scale-aware convection parameterizations behave in the grey zone?*
- The Grey Zone project aims to apply this methodology on a number of different types of moist convective systems.
- The type of moist convection considered here is a cold air outbreak.
- 3 components – Global (MPI led), LAM (UKMO led), LES (TUD led)

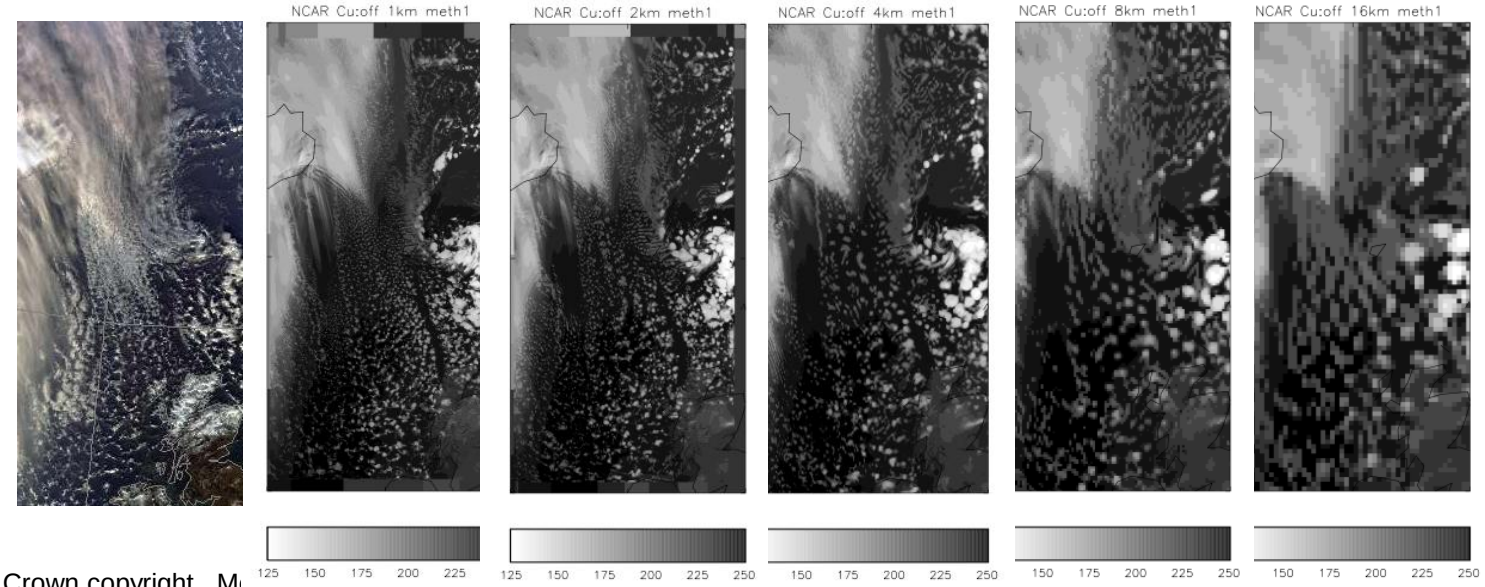
LAM contributors: NCAR, NOAA, CHMI, CNRS, UKMO, JMA and EnvCan.

MODIS 1km 2km 4km 8km 16km



UM
No
convection

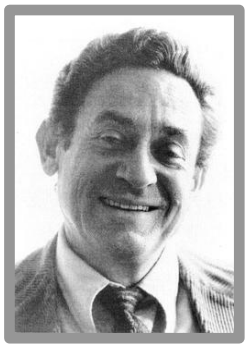
LW



WRF
No
convection

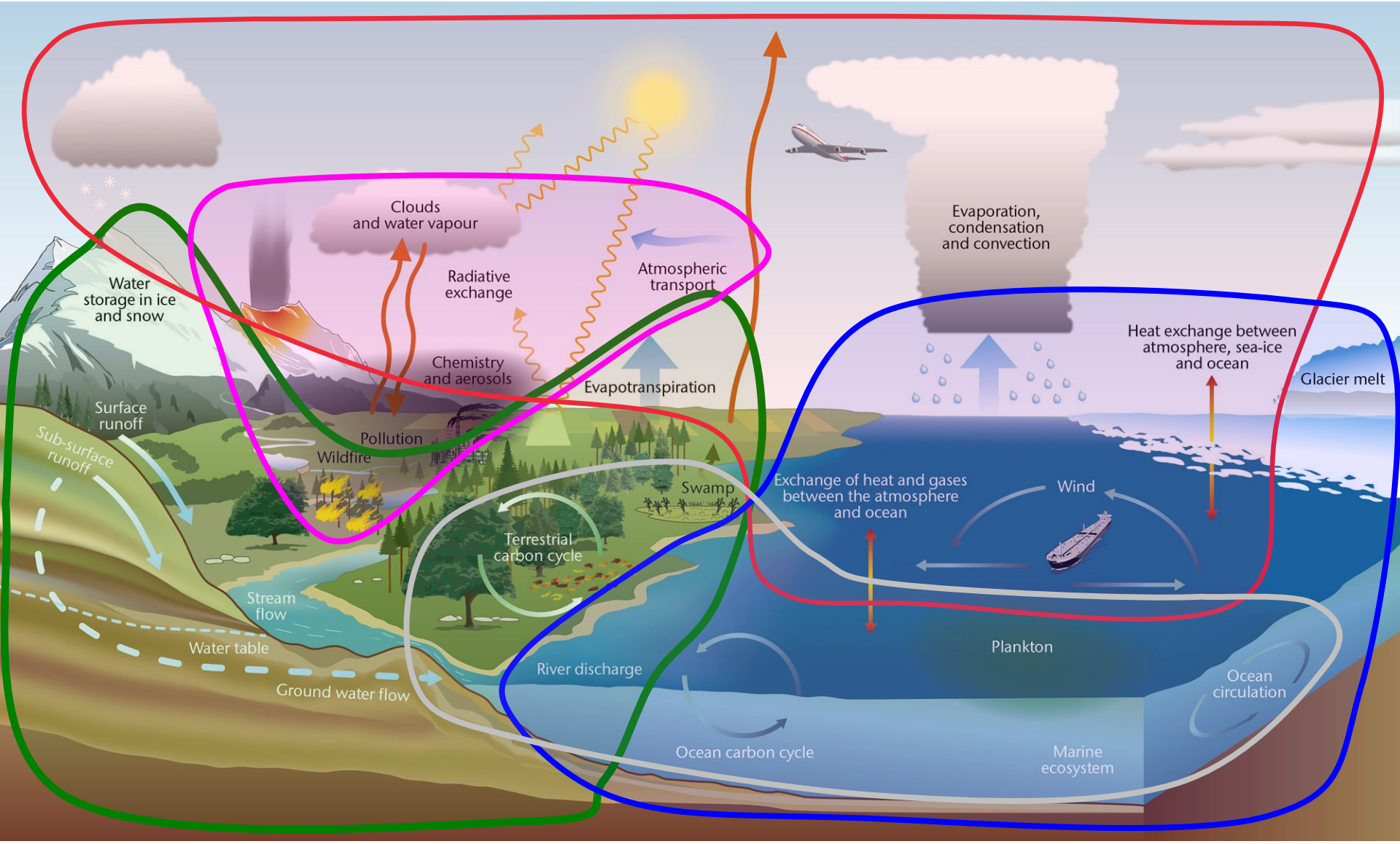
Goals of Numerical Weather Prediction (NWP) Research

To improve understanding of atmospheric processes and accelerate advances in NWP through national and international collaborative research programmes.



- Charney's thinking on weather and climate prediction was visionary (GARP, 1969; Carbon dioxide and climate, 1979);
- THORPEX (2005-14): "Accelerating improvements in the accuracy of one-day to two weeks high-impact weather forecasts for the benefit of society, economy and environment."

THORPEX
A World Weather Research Programme



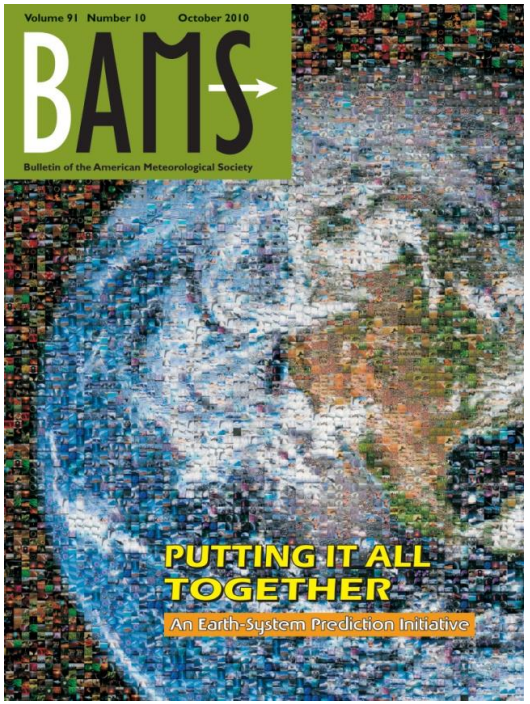
COMPOSITION ATMOSPHERE SURFACE MARINE ECOSYSTEMS

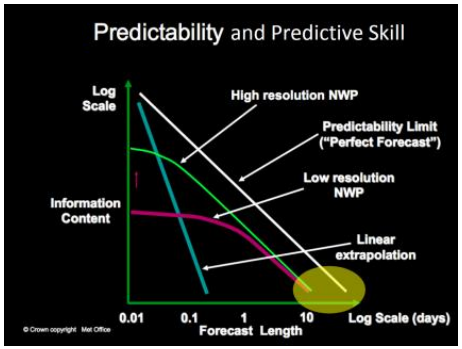
- Interactions between sub-systems (e.g. water cycle budget);
- Prediction of the Earth system: putting it all together.

Putting it All Together

World Meteorological Organization (WMO), World Weather Research Programme (WWRP), World Climate Research Programme (WCRP), International Geosphere-Biosphere Programme (IGBP), Global Climate Observing System (GCOS), and natural-hazards and socioeconomic communities.

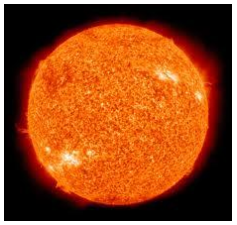
- An Earth-System Prediction Initiative for the Twenty-First Century (Shapiro et al.,)
- Addressing the Complexity of the Earth System (Nobre et al.)
- Collaboration of the Weather and Climate Communities to Advance Subseasonal-to-Seasonal Prediction (Brunet et al.)

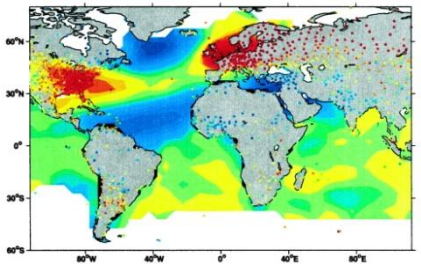


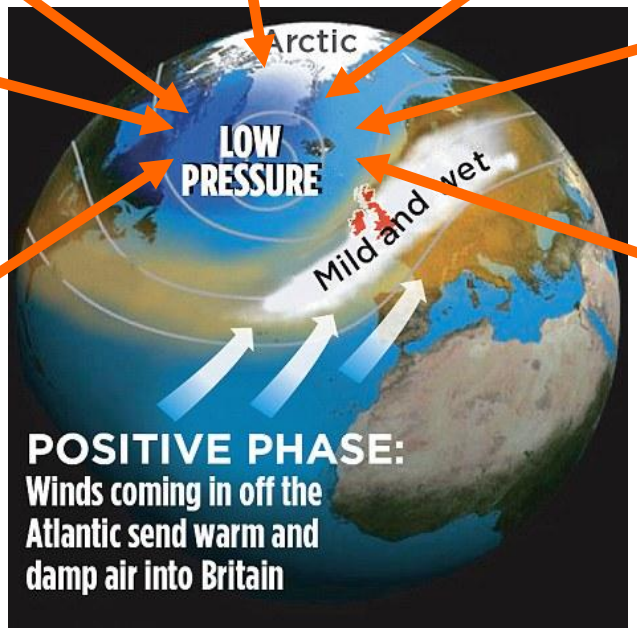


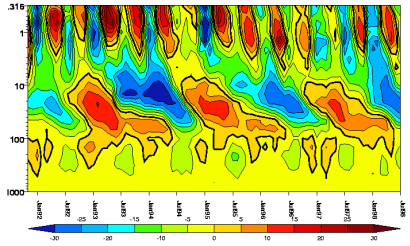
Several factors trigger variability in Atlantic winter climate

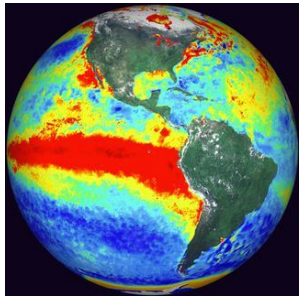
(A number of which are stratosphere related)

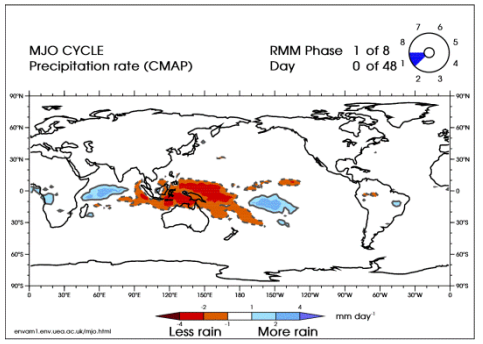




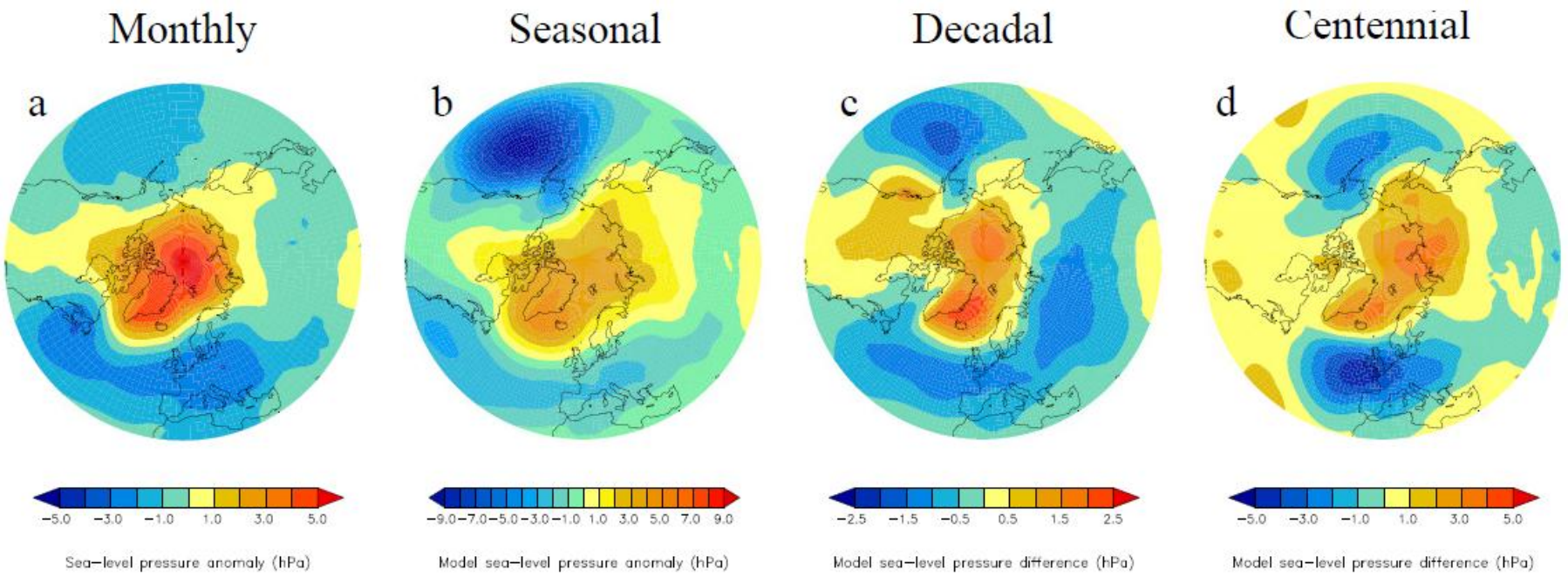








Stratospheric changes give the same response across timescales



SSW **ENSO** **Solar** **Climate Change**

All stratospheric – all show same response in troposphere

A similar response occurs in the southern hemisphere

Kidston et al, submitted.

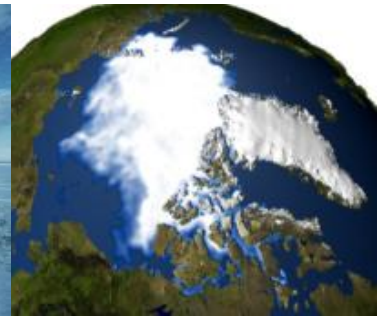
Goals of Numerical Weather Prediction (NWP) Research

WWRP projects to advance the science of seamless prediction:

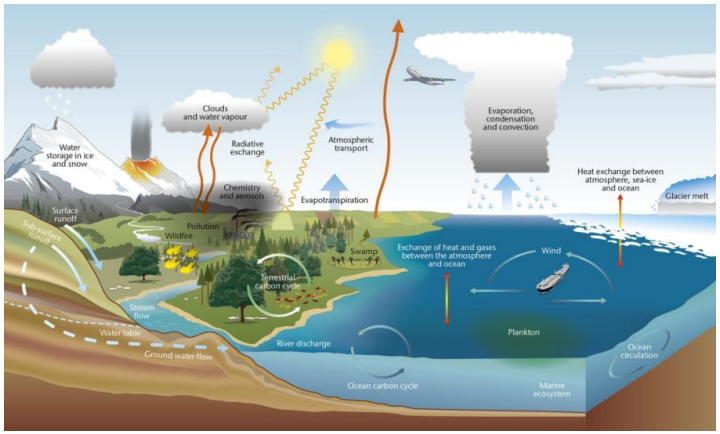
- the Sub-seasonal TO Seasonal (S2S) project (jointly with WCRP);
- HIgh-impact Weather (HIWeather) project;
- Polar Prediction Project (PPP) with joint WCRP activities (reanalyses, predictability, model error).







WMO/WWRP/THORPEX World Weather Open Science Conference, Montreal, August 2014

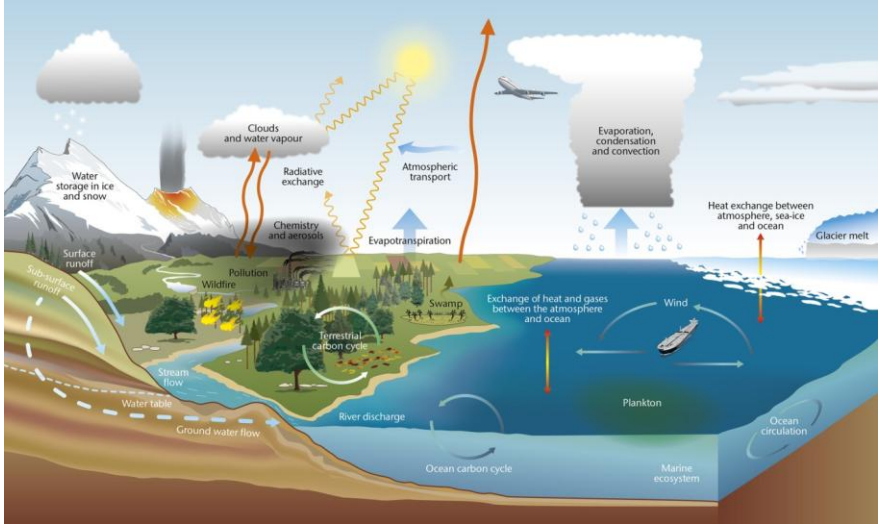


Seamless Prediction of the Earth System: from minutes to months

The scientific program was organized around five science themes:

- Data Assimilation and Observations;
- Predictability and Dynamical/Physical/Chemical Processes;
- Interactions between sub-systems;
- Prediction of the Earth system: putting it all together;
- Impacts of weather and climate events.

Toward a book



***Title*: Seamless Prediction of the Earth System: from minutes to months**

***Purpose*:** Provide a reference of current state and future challenges of NWP Science. It will cover the five themes in 25 chapters.

- Aiming to be published in summer 2015.
- It will be freely available on the WMO website

Questions & answers