GEWEX SSG-29
A model & data user perspective

How satellite-based and ground-based sites observation information can support Earth surface model development?

Gianpaolo Balsamo
with contributions of several Colleagues acknowledged on the slides

Presented to 2017 GEWEX SSG-25, Sanya, People Republic of China

ECMWF, Earth System Modelling Section, Coupled Processes Team
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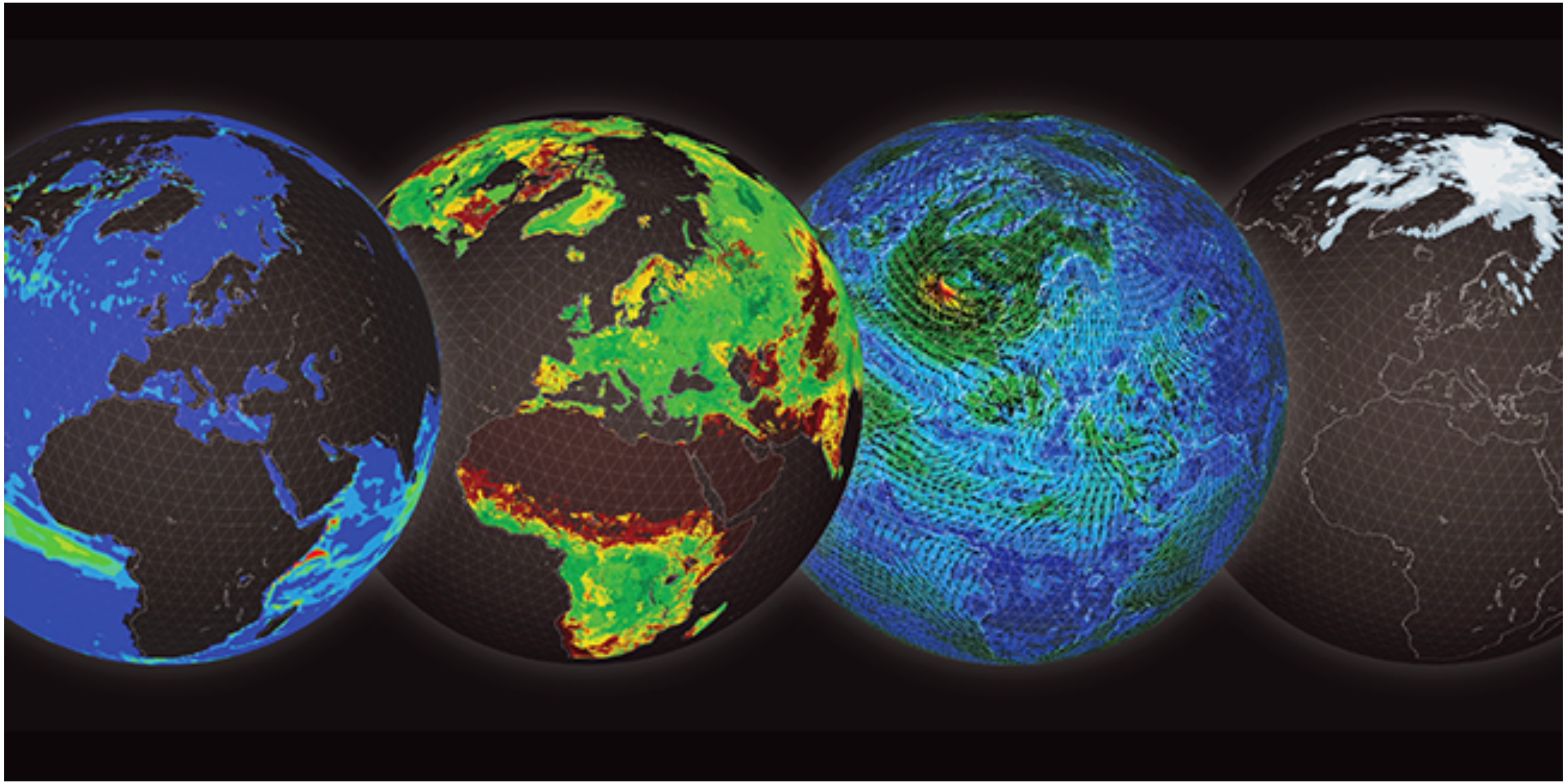
Multi-spheres concept in modelling & prediction



ECMWF 2016 Annual Seminar Earth system modelling for seamless prediction:
On which processes should we focus to further improve atmospheric predictive skill?
http://www.ecmwf.int/en/annual-seminar-2016

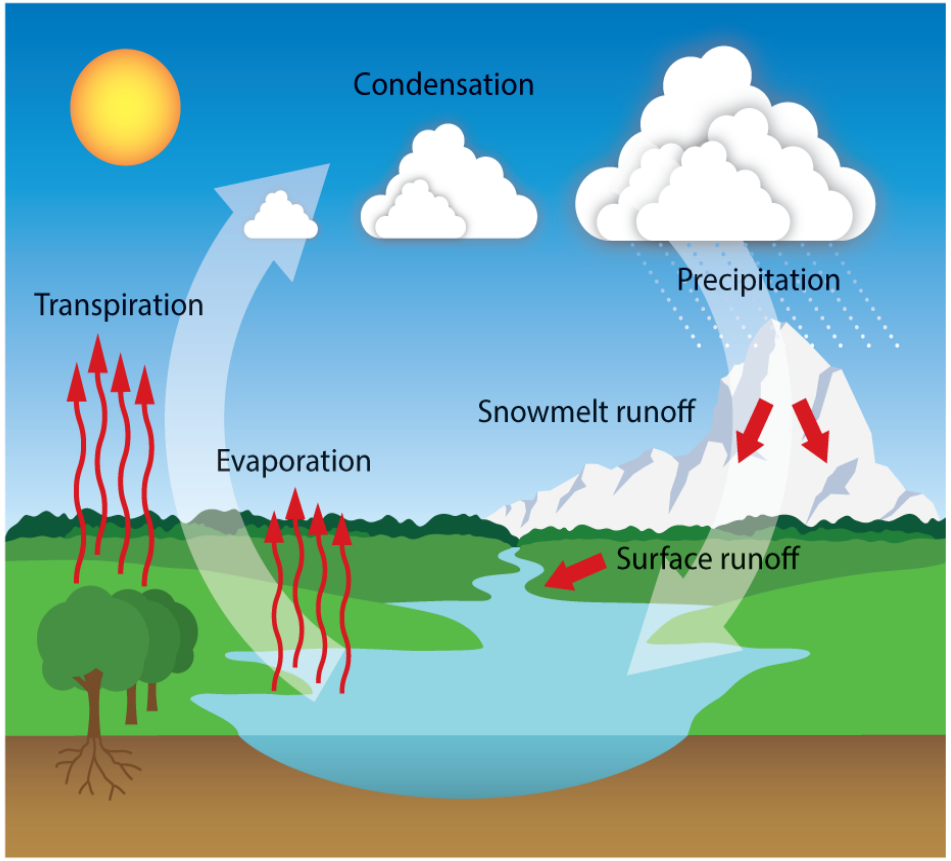
ECMWF STRATEGY 2016-2025

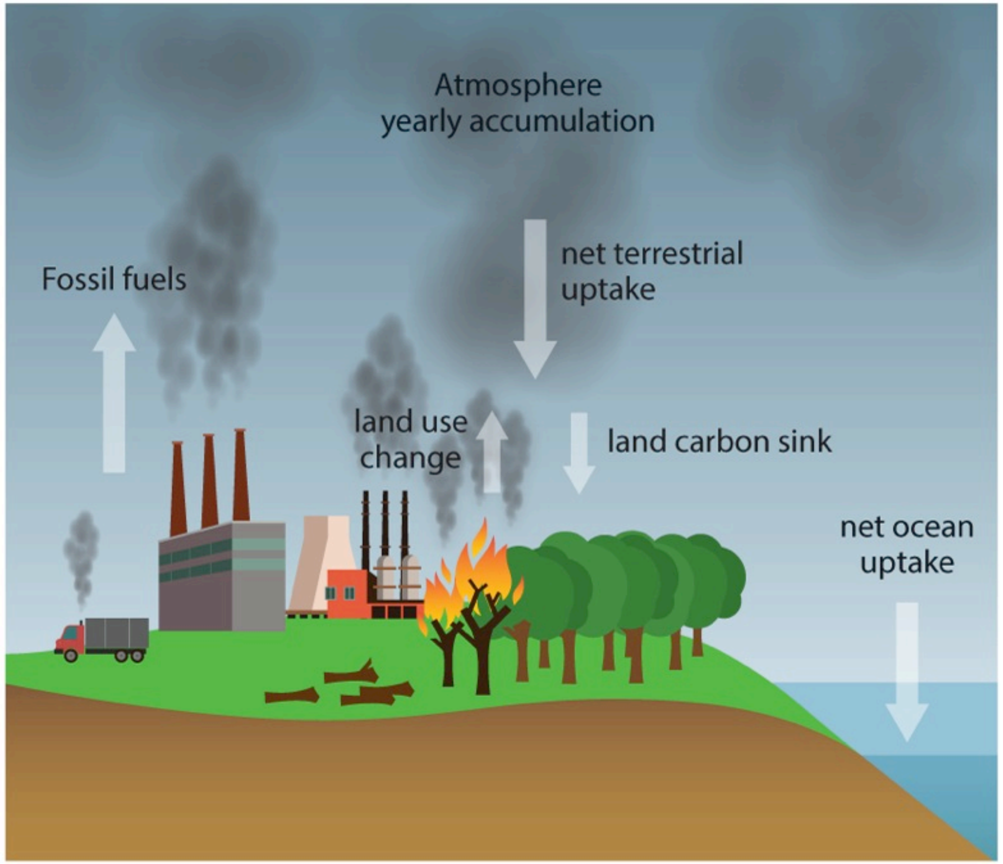
EARTH SYSTEM APPROACH

ENSEMBLE MODELLING AND ASSIMILATION. GOAL: 5KM

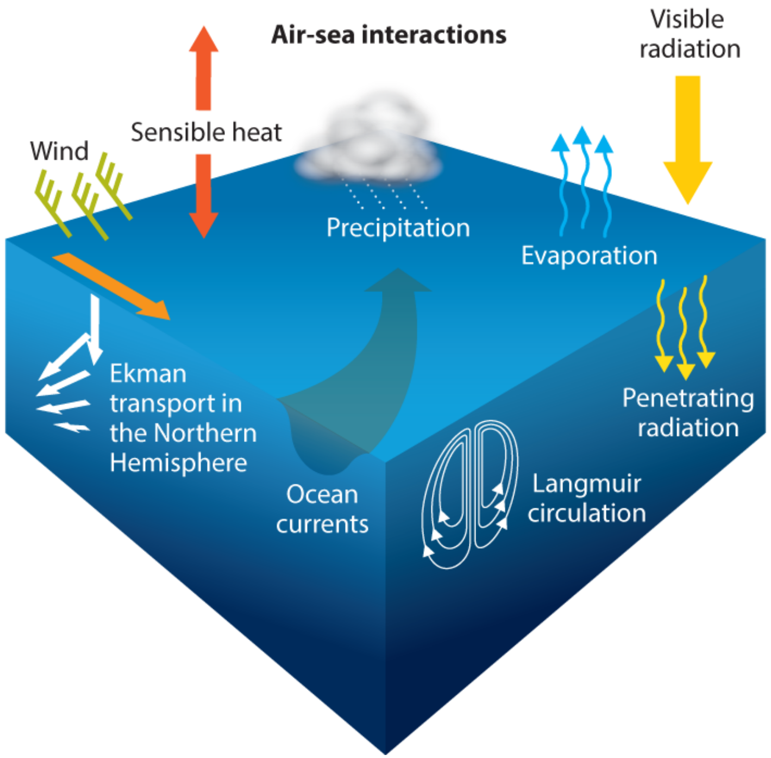
SCALABILITY ACROSS WHOLE NWP CHAIN

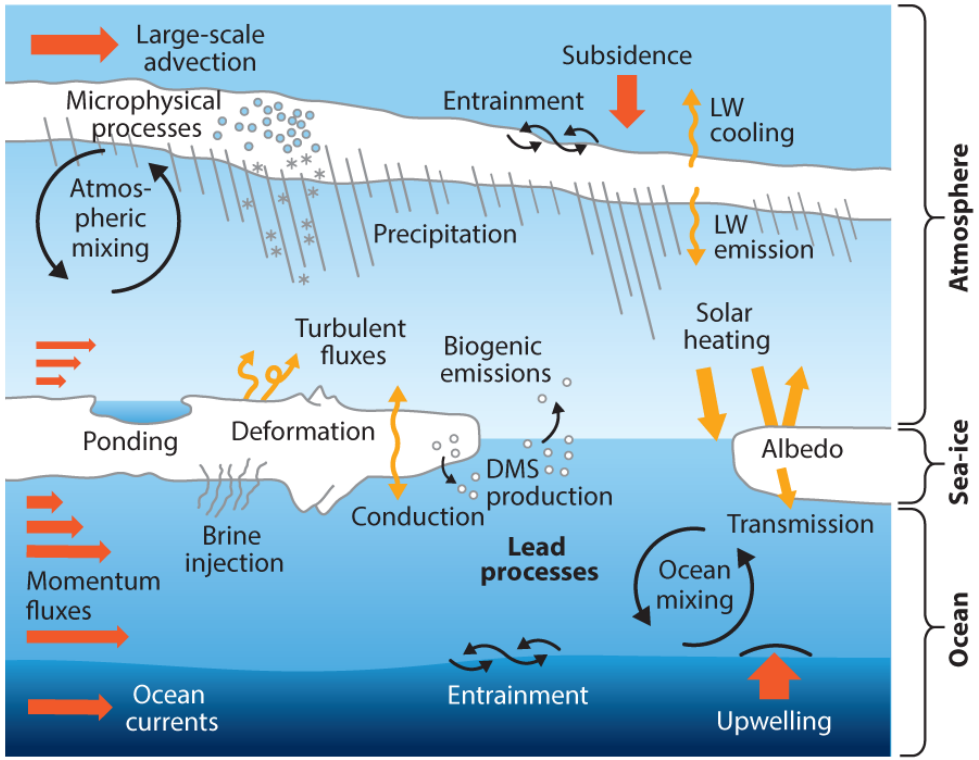
Natural Land & Human-activity @ECMWF:
How can/will natural land modelling include LUC





Oceans & marine cryosphere @ECMWF: How climate modelling fed into weather





ECMWF

Earth surface modelling components @ECMWF

- **NEMO3.4**

  NEMO3.4 (Nucleus for European Modelling of the Ocean)

  Madec et al. (2008)

  Mogensen et al. (2012)

  ORCA1_Z42: 1.0° x 1.0°

  ORCA025_Z75 : 0.25° x 0.25°

- **EC-WAM**

  ECMWF Wave Model

  Janssen, (2004)

  Janssen et al. (2013)

  ENS-WAM : 0.25° x 0.25°

  HRES-WAM: 0.125° x 0.125°

- **LIM2**

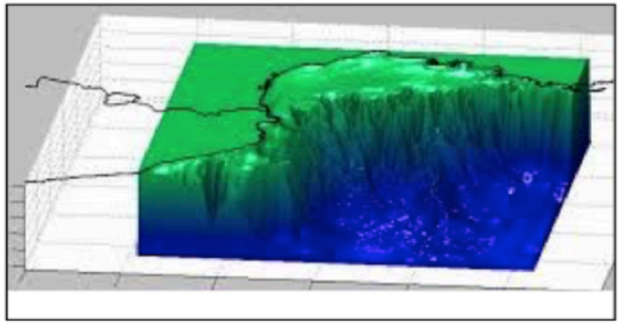
  The Louvain-la-Neuve Sea Ice Model

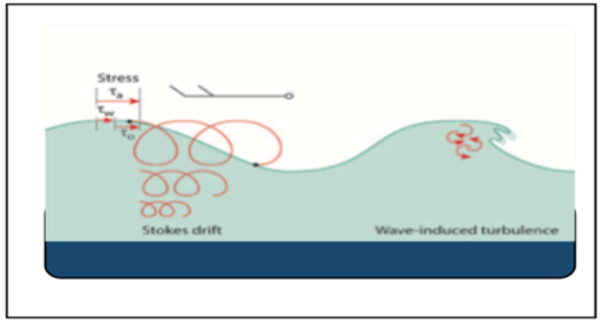
  Fichefet and Morales Maqueda (1997)

  Bouillon et al. (2009)

  Vancoppenolle et al. (2009)

  ORCA025_Z75 : 0.25° x 0.25°





Ocean 3D-Model
Surface Waves and currents, Sea-ice.

- **Hydrology-TESSEL**

  Balsamo et al. (2009) van den Hurk and Viterbo (2003)

  Global Soil Texture (FAO)

  New hydraulic properties

  Variable Infiltration capacity & surface runoff revision

- **NEW SNOW**

  Dutra et al. (2010)

  Revised snow density

  Liquid water reservoir

  Revision of Albedo and sub-grid snow cover

- **NEW LAI**

  Boussetta et al. (2013)

  New satellite-based

  Leaf-Area-Index

- **SOIL Evaporation**

  Balsamo et al. (2011),

  Albergel et al. (2012)

- **H_2O / E / CO_2**

  Integration of

  Carbon/Energy/Water

  Boussetta et al. 2013

  Agusti-Panareda et al. 2015

- **Lake & Coastal area**

  Mironov et al (2010),

  Dutra et al. (2010),

  Balsamo et al. (2012, 2010)

  Extra tile (9) to for sub-grid lakes and ice

  LW tiling (Dutra)

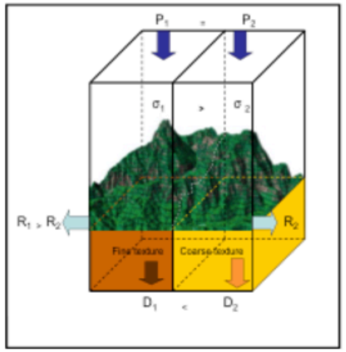
- **Enhance ML**

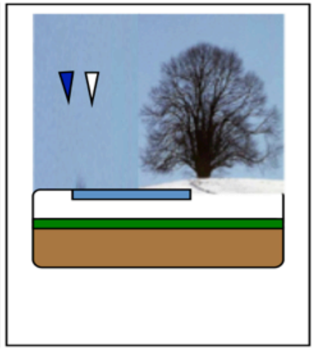
  Snow ML5

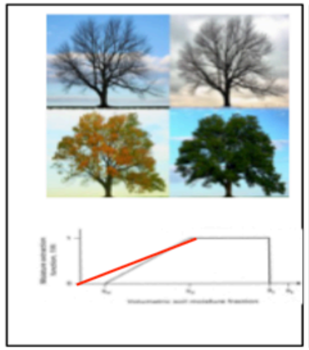
  Soil ML9

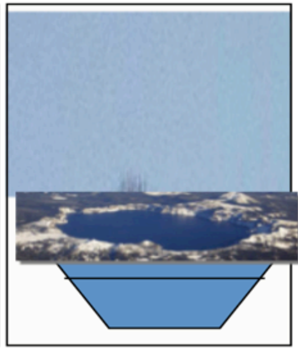
  Dutra et al. (2012, 2016)

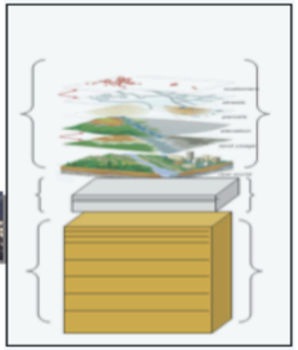
  Balsamo et al. (2016)









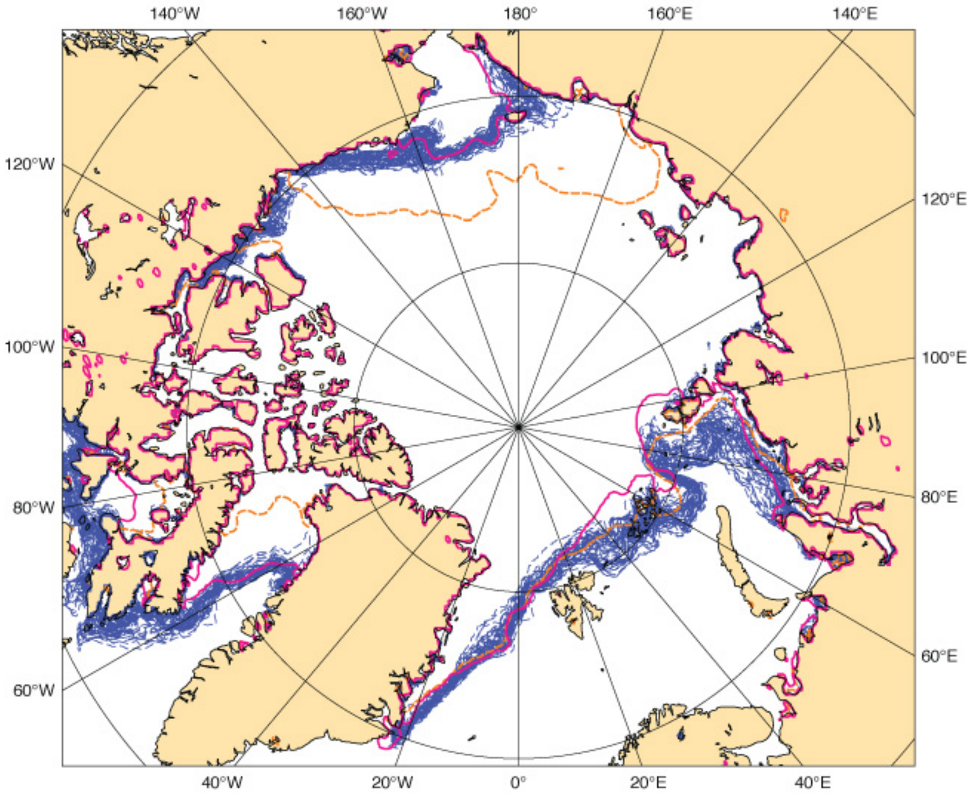


Land surface 1D-model soil, snow, vegetation, lakes and coastal water (thermodynamics only).

Ingredients of the ECMWF operational sea-ice model

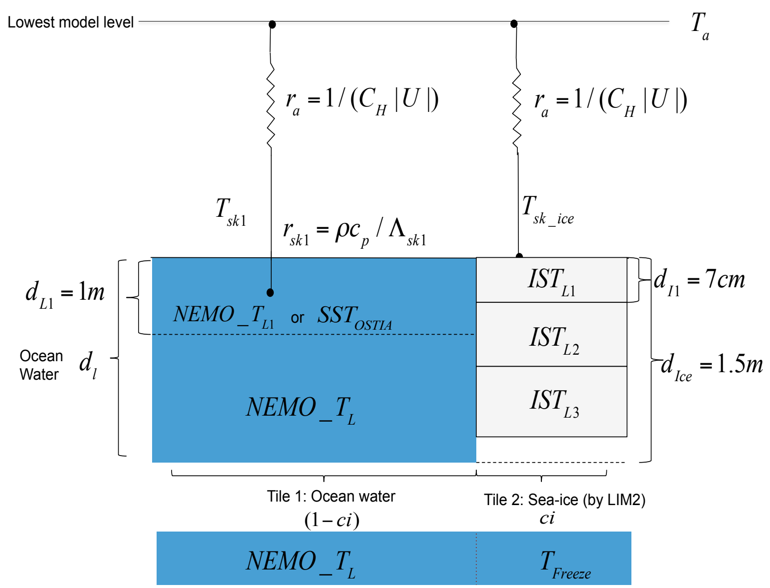
- **INTERACTIVE Dynamical SEA-ICE since NOVEMBER 2016**

For the first-time the ice is evolved along the Ensemble Forecast System

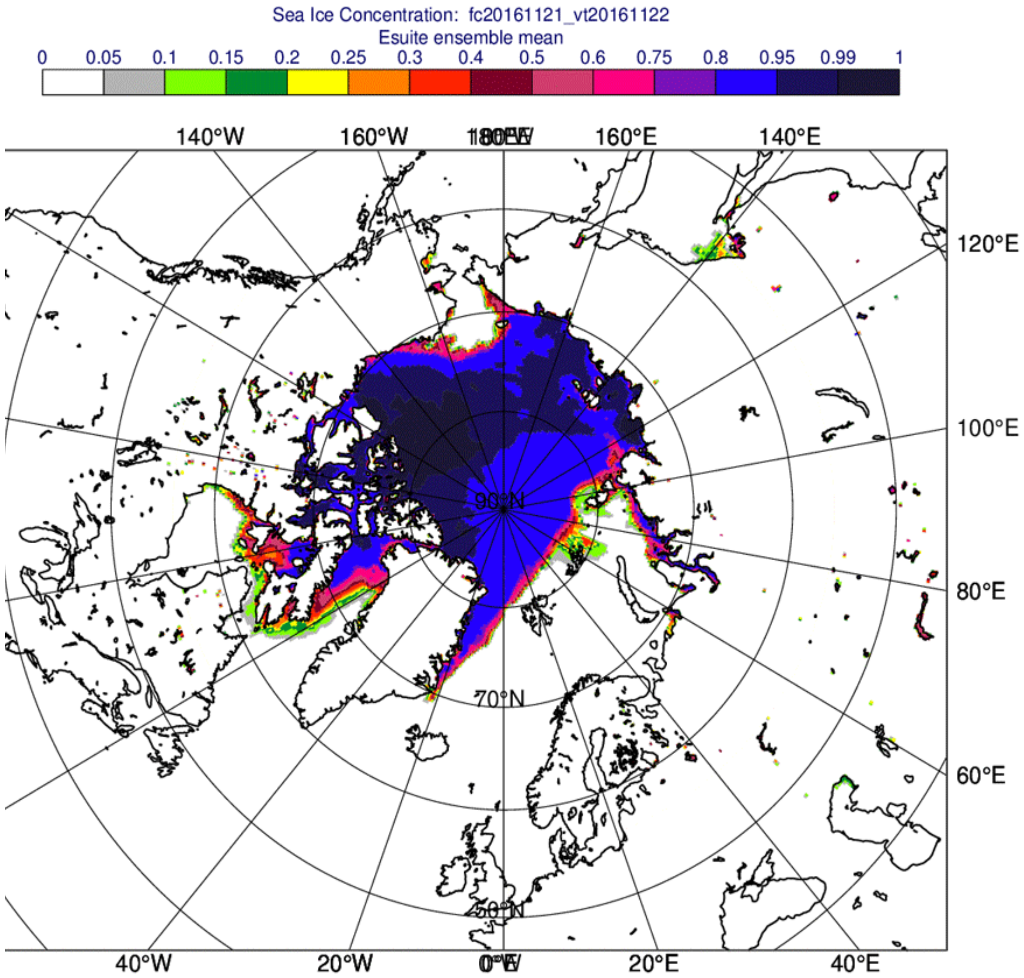


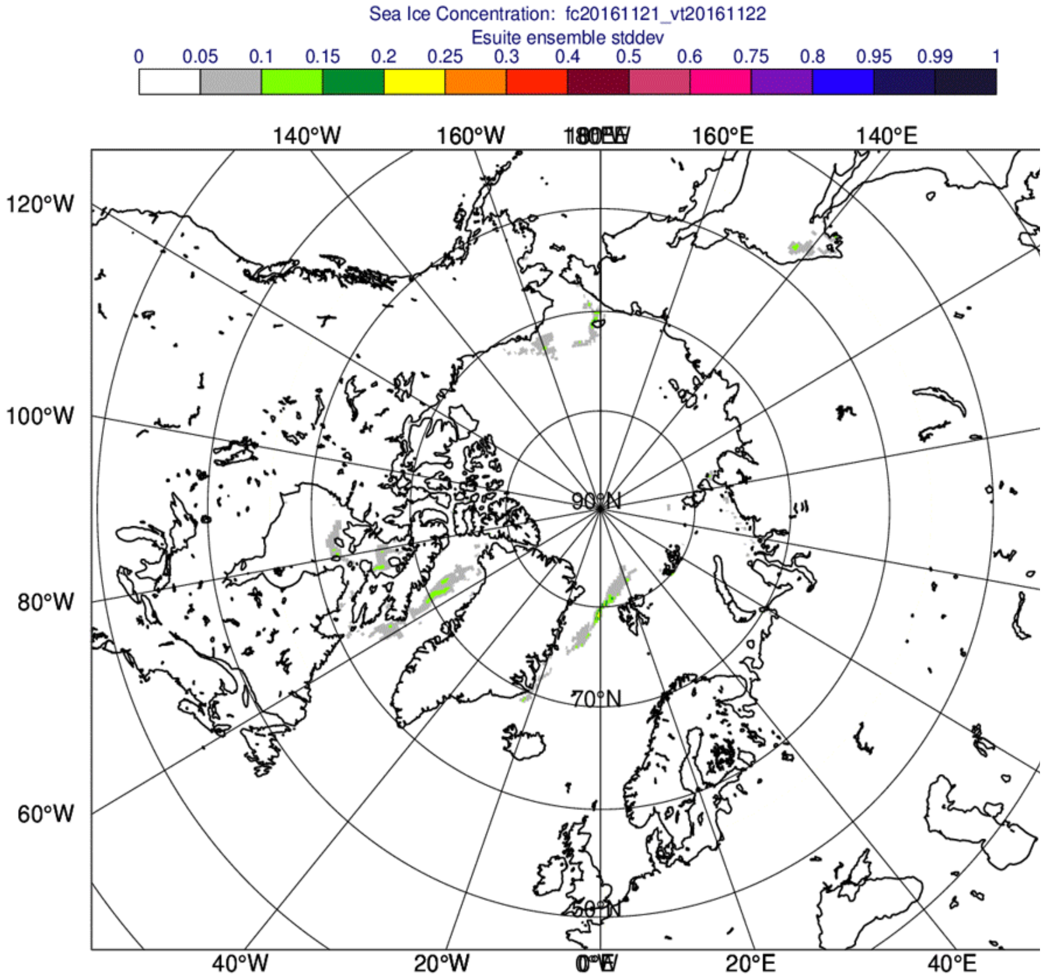
- **INTEGRATED within the TILING approach**

Fractional ice cover benefit from a tiled energy balance for water/ice



Sea-ice cover in the Ensemble Forecasting System





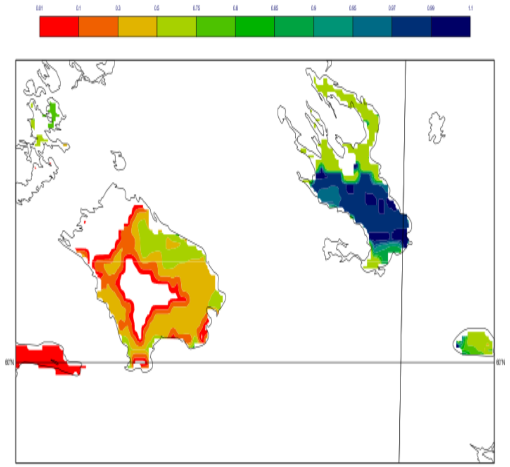
ECMWF

Lakes 3M Challenges Mapping, Monitoring, and Modelling for Prediction

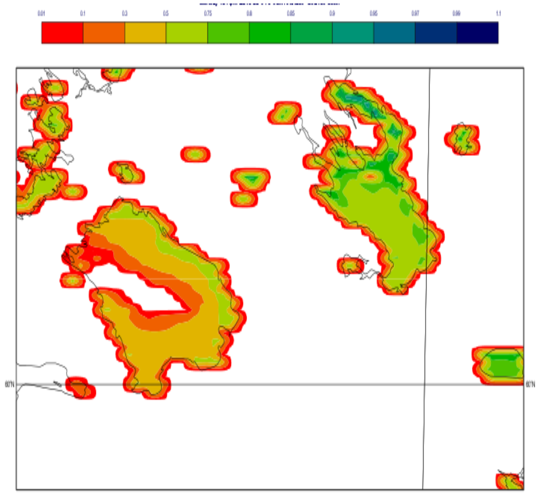
Interactive lakes became operational at ECMWF
On May 2015 in every day Forecasts

Here a case Study of 18 April 2016: The Largest European Lakes: Lake Lagoda & Lake Onega

OSI-SAF Satellite Ice cover 18 April 2016



ECMWF IFS Lake Ice Cover (Ladoga melting faster)



NEWS

ECMWF Newsletter No. 150 – Winter 2016/17

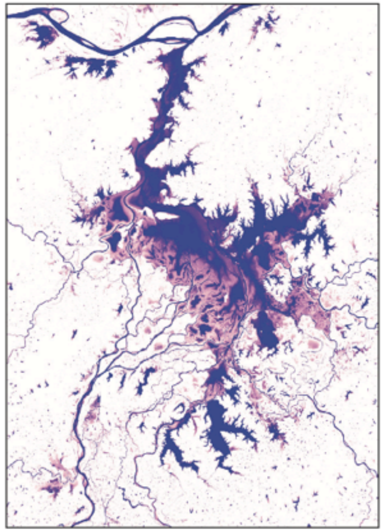
Lakes in weather prediction: a moving target

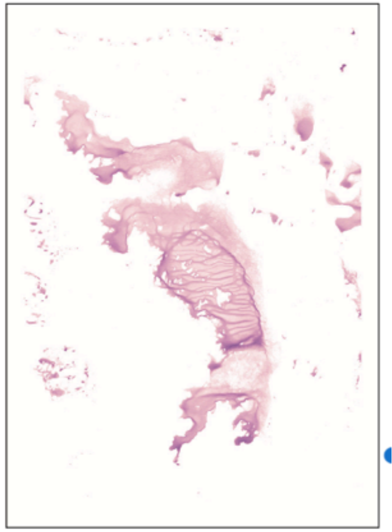
GIANPAOLO BALSAMO (ECMWF),
ALAN BELWARD
(Joint Research Centre)

Lakes are important for numerical weather prediction (NWP) because they influence the local weather and climate. That is why in May 2015 ECMWF implemented a simple but effective interactive lake model to represent the water temperature and lake ice of all the world's major inland water bodies in the Integrated Forecasting System (IFS). The model is based on the version of the FLake parametrization developed at the German National Meteorological Service (DWD), which uses a static dataset to represent the extent and bathymetry of the world's lakes.

However, new data obtained from satellites show that the world's surface water bodies are far from static. By analysing more than 3 million satellite images collected between 1984 and 2015 by the USGS/NASA Landsat satellite programme, new global maps of surface water occurrence and change with a 30-metre resolution have been produced. These provide a globally consistent view of one of our planet's most vital resources, and they make it possible to measure where the world's surface water bodies really can be found at any given time.

As explained in a recent *Nature* article (doi:10.1038/nature20584), the maps show that over the past three decades almost 90,000 km^2 of the lakes and rivers thought of as permanent have vanished from the Earth's surface. That is equivalent to Europe losing half of its lakes. The losses are linked to drought





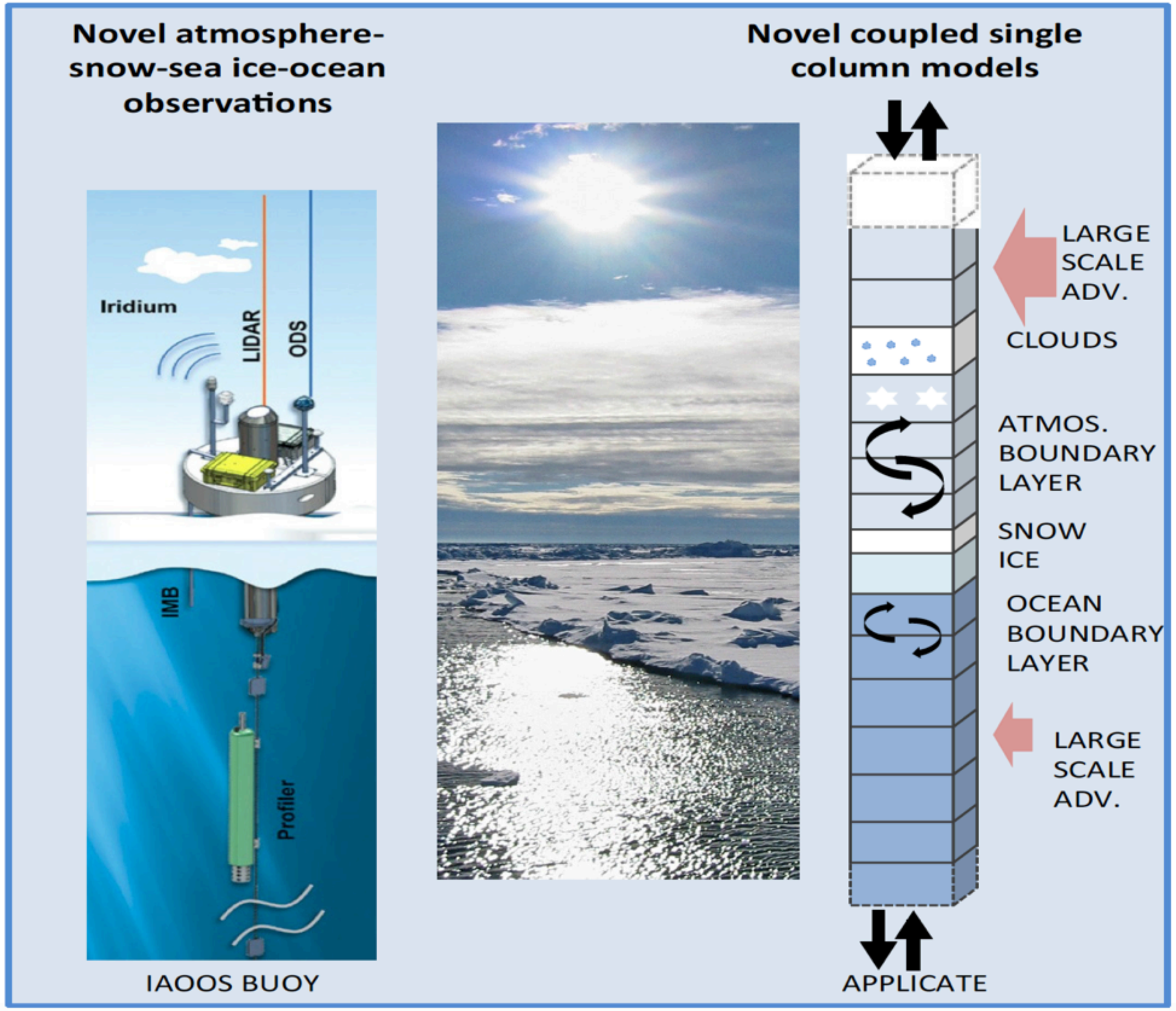
Dynamic lakes. The size of Poyang Lake (left), one of China's largest lakes, fluctuates dramatically between wet and dry seasons each year while overall decreasing. Lake Gairdner in Australia (right), which is over 150 km long, is an ephemeral lake resulting from episodic inundations. Both maps show the occurrence of water over the past 32 years: the lighter the tone the lower the occurrence. (*Images: Joint Research Centre/Google 2016*)

Lake Victoria. Lakes in tropical areas are linked with high-impact weather by contributing to the formation of convective cells. (*Photo: MHGALLERY/iStock/Thinkstock*)

Using models as tool for process understanding: The need of observations for validation

(from APPLICATE Courtesy of Peter Bauer and Thomas Jung)

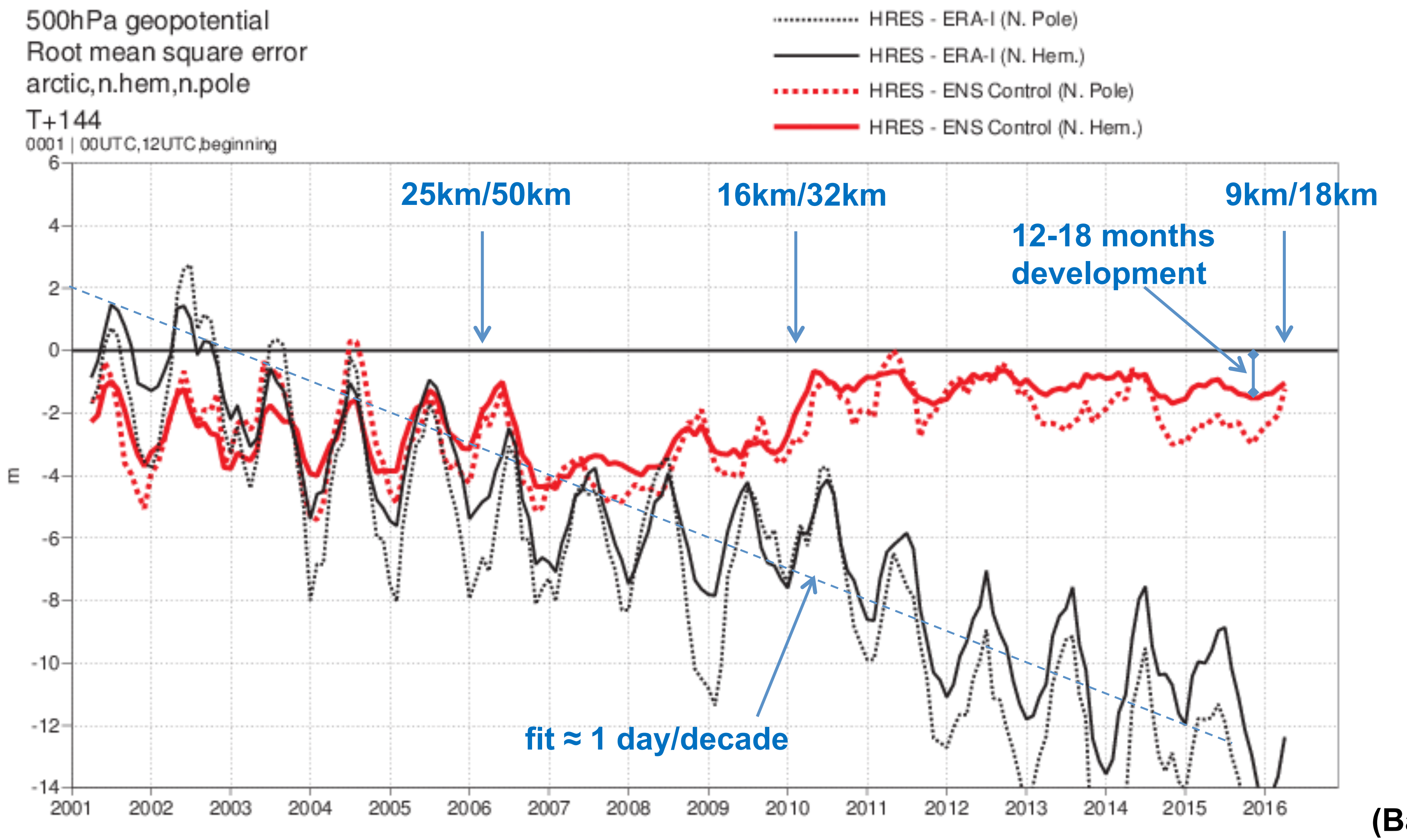
Coupled Single Column Modelling



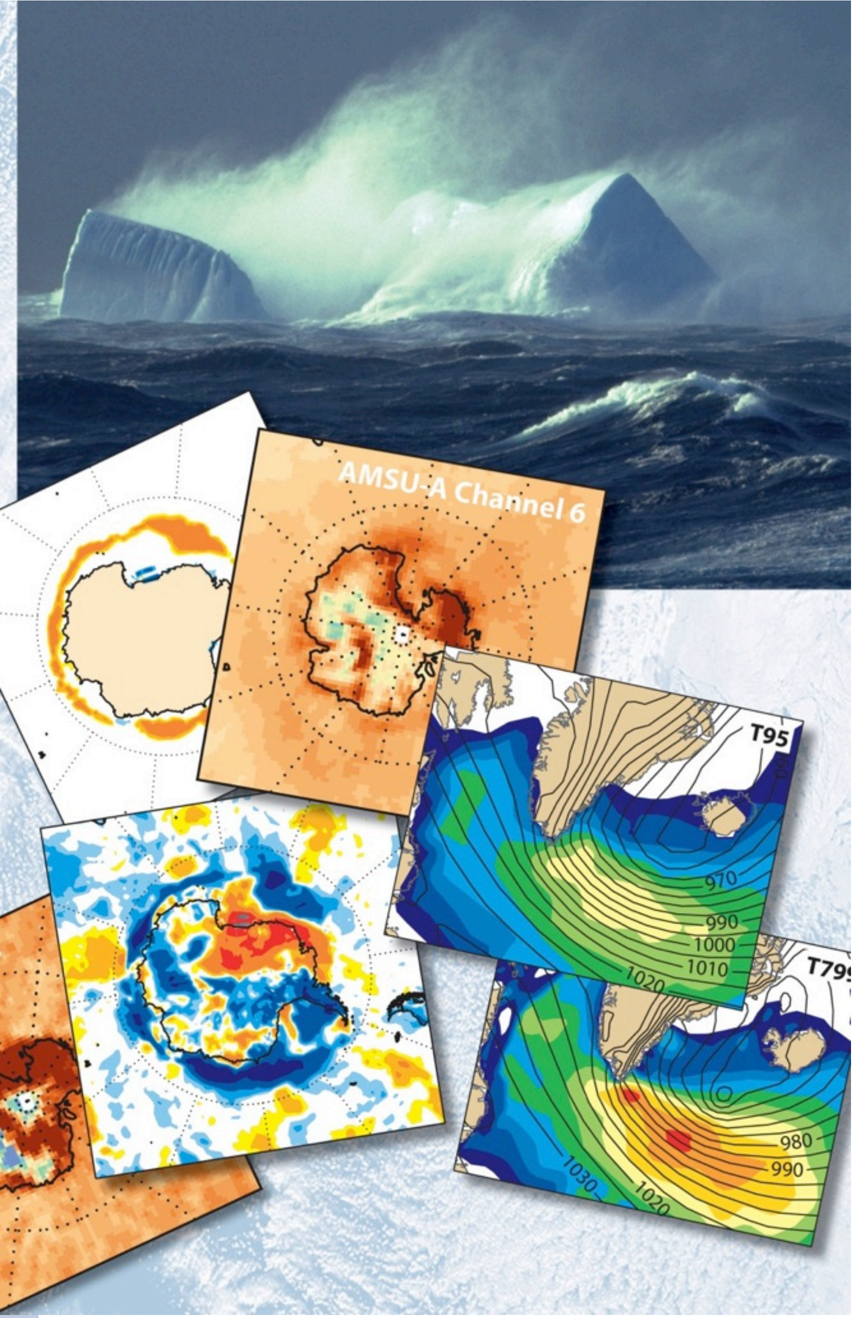
Observation Towers (e.g. Dome-C)

ASSOCIATION

Medium-range predictive skill: a cryosphere perspective



(Bauer et al. 2014)



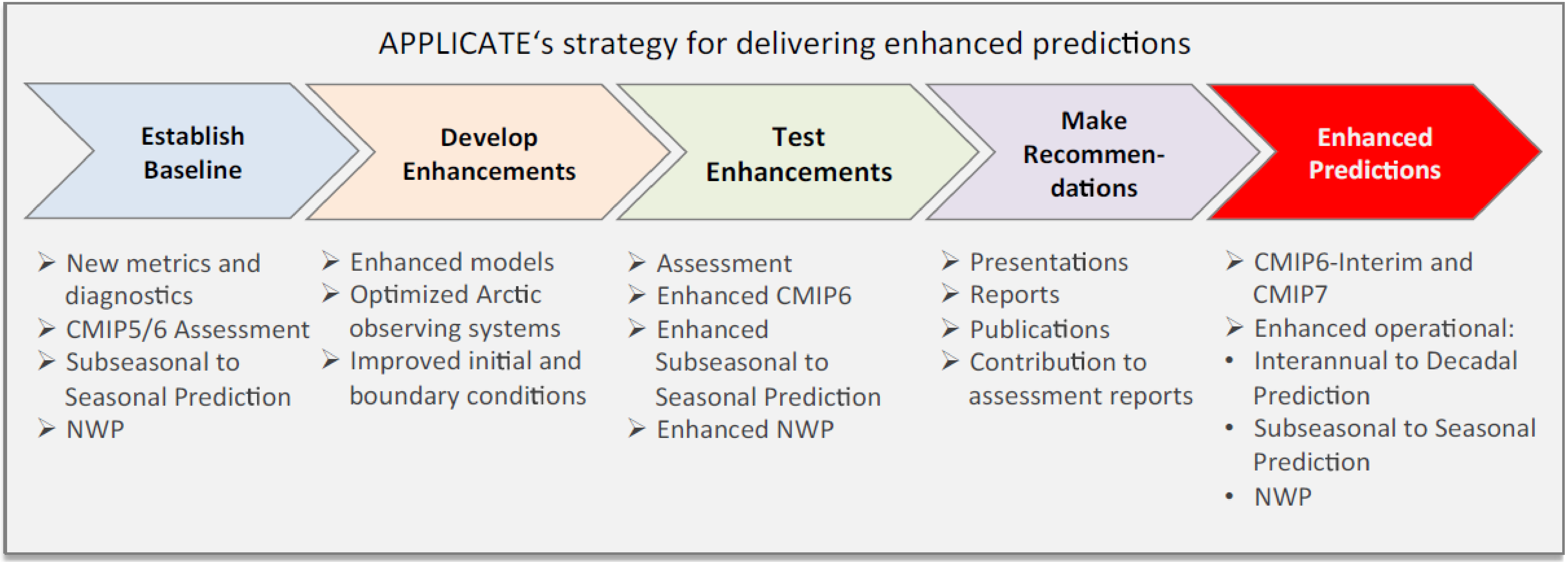
Cryosphere focus in the YOPP core-phase

P. Bauer and T. Jung

YOPP
YEAR OF POLAR PREDICTION

From Observations to Predictions: An example in APPLICATE

APPLICATE H2020 basic developments to more skilful prediction systems:



(from APPLICATE Project PI, Thomas Jung, AWI)

ECMWF

Cryosphere: a fragile element of the climate system affecting weather

- A larger use of meteorological and cryosphere data can now provide a more comprehensive understanding cryosphere changes. The snow (& sea-ice) are “climate switches” (Betts et al 2016)
- The year 2016 has been an extreme example in this context with the annual-mean global surface temperature reaching a warming level of 1.3°C above pre-industrial times (based on reanalyses) as highlighted by the Copernicus Climate Change Services press-release of 5th January 2017.
- Similarly, an exceptional reduction in global sea-ice extent has been observed in 2016, encompassing both Arctic and Antarctic, and for this the European Copernicus programme will provide dedicated monitoring via Sentinel satellites:
- https://sentinel.esa.int/web/sentinel/thematic-areas/marine-monitoring-content/-/article/sentinel-1-data-advance-sea-ice-monitoring
- Recent sea-ice studies and datasets highlight the robustness of the trends of the marine cryosphere (e.g. Tonboe et al. 2016, documenting OSI-SAF dataset).
- Good timing for the APPLICATE project http://applicate.eu
- Good synergy with PPP (Polar Prediction Panel) programs and YOPP (Year of Polar Prediction)

Water cycle: natural and anthropogenic pathways

- Water cycle improvement is an evergreen problem for NWP model are not yet capable to reproduce tropical weather (e.g. diurnal cycle and links with ITCZ)
- Water cycle is not ruled by nature only but also by economic and societal interests (in the Anthropogenic era)
- Extreme events and disruption of the water cycle have enormous amount of consequences
- Droughts and heat waves are directly health and life threatening extremes, but their teleconnections are beyond local and medium-range.

Carbon cycle: natural and anthropogenic pathways

- CO2 forecasts (and other Carbon & other Compounds) are part of the Copernicus Atmospheric Monitoring Services and Copernicus Climate Change Services operated at ECMWF.
- Several links possible with GEWEX Grand Challenges and Core Science
- GEWEX is perceived as having a key role in leveraging research priorities

Modelling atmospheric CO2 in C-IFS

courtesy of Anna Agustì-Panareda

Transport
IFS model

Fluxes
Vegetation (CTESSEL model)

Source ○

Sink ○

Fires (GFAS) △

Ocean (Takahashi et al 2009)

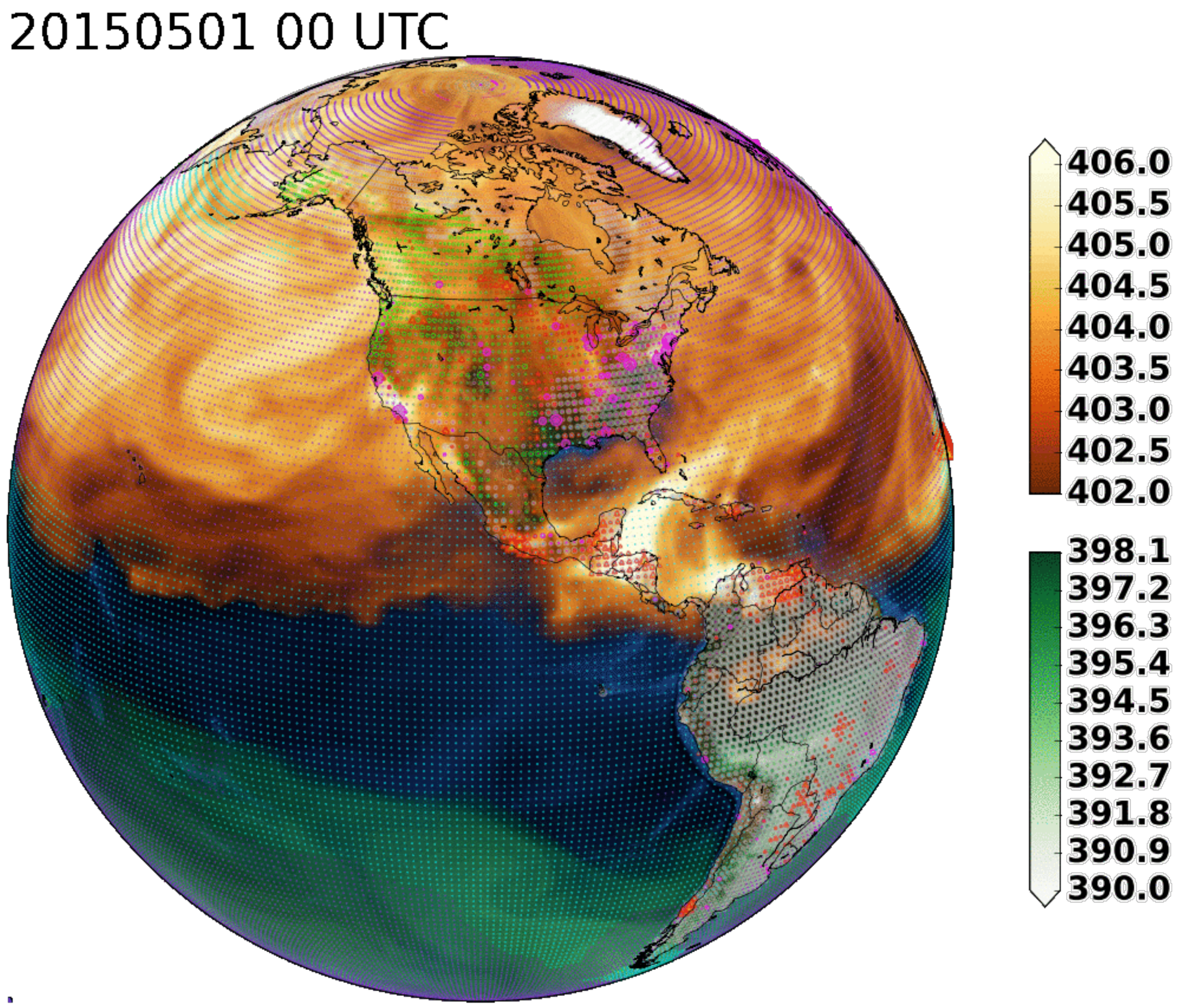
Source ○

Sink ○

Anthropogenic ●
(EDGAR v4.2)

Symbol size reflects the relative flux intensity
(Note that fires have been re-scaled by a factor of 10)

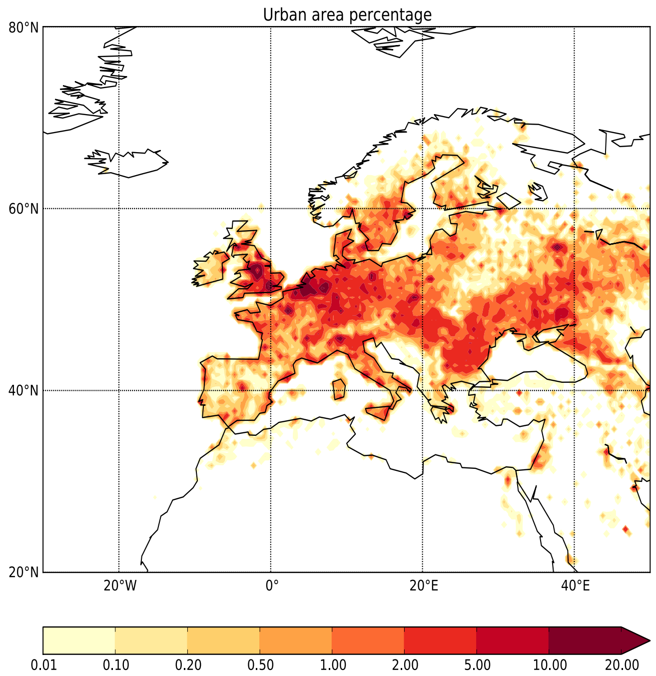
CO_2 surface fluxes & column-averaged dry-air mole fraction of CO_2 [ppm]



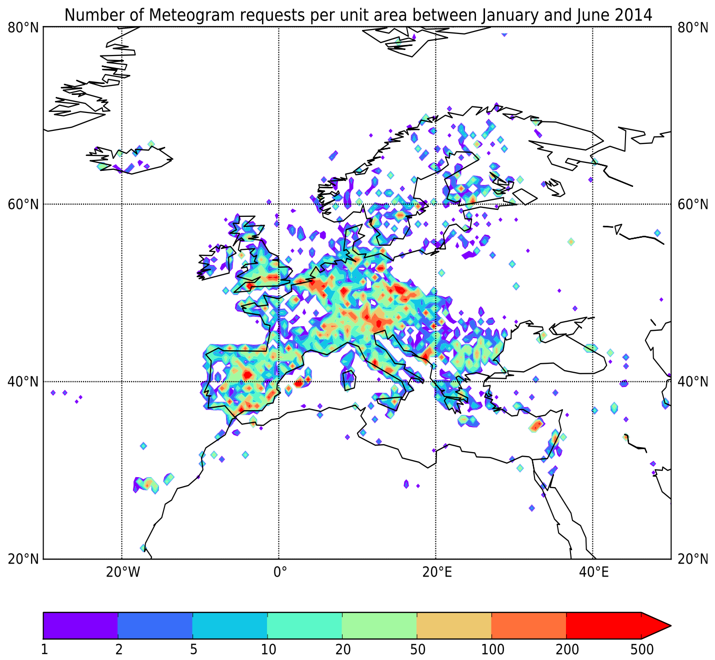
Agusti-Panareda et al. ACP 2014

Motivation for enhancing urban modelling @ECMWF

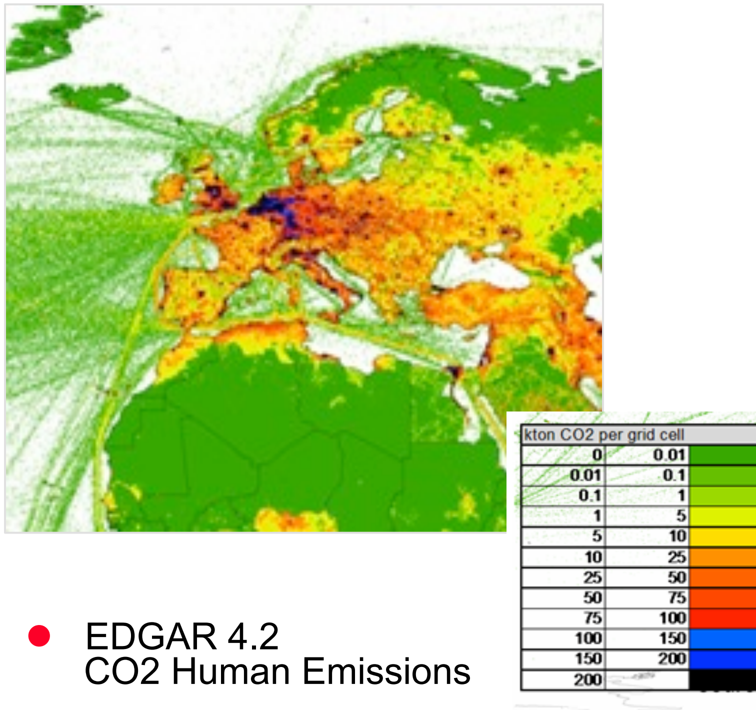
- Urban areas are important for the accurate prediction of extreme events such as heatwaves and urban flooding and need to be represented in ECMWF model.
- Best and Grimmond (2015) suggested that simple models may be well adapted to global applications
- Users lives urban areas and look at the forecast for urban locations.
- Urban maps combined with emission factors can provide first guess CO2 anthropogenic fluxes



- Urban area (a, in %, from ECOCLIMAP, Masson et al., 2003)



- Number of ECMWF Meteograms product requests from Member-States



- EDGAR 4.2 CO2 Human Emissions

ECMWF

Summary and outlook

- Joining GEWEX SSG in 2017: a responsibility and a honor
- Supporting with information from ECMWF & its Member-States Research
- Supporting and Providing links to
  - The WCRP Grand Challenge on Near-Term Climate Prediction GC-NTCP
  - The WMO Global Cryoshere Watch WMO-GCW

- Numerical Weather Prediction moving towards Environmental & Extended-range
  - New set of Challenges to include relevant processes provided they are observable
  - With All Traditional Challenges still Valid and increasing with System's complexity
  - Data & User Driven Research to push innovation uptake for improved Services
  - Large Collaborative Efforts (@ECMWF and within the NWP & Climate community)

Extra-slide for Q&A and further reading

FOUR YEAR PROGRAMME 2017-2020

FOUR YEAR PROGRAMME 2017-2020

ECMWF MISSION

TO DEVELOP A CAPABILITY FOR MEDIUM-RANGE WEATHER FORECASTING AND TO PROVIDE MEDIUM-RANGE WEATHER FORECASTS TO THE MEMBER AND CO-OPERATING STATES

FOUR YEAR PROGRAMME 2017-2020

ECMWF STRATEGY 2016-2025

EARTH SYSTEM APPROACH

ENSEMBLE MODELLING AND ASSIMILATION. GOAL: 5KM

SCALABILITY ACROSS WHOLE NWP CHAIN

FOUR YEAR PROGRAMME 2017-2020

FOUR YEAR PROGRAMME 2017-2020:
5 THEMES
10 STREAMS

Advancing weather science

1 Earth system modelling
2 Earth system assimilation and predictability

Delivering global predictions

3 The integrated ensemble system
4 The quality of our forecasts

Sustaining high-performance computing

5 Scalability
6 High-performance computing

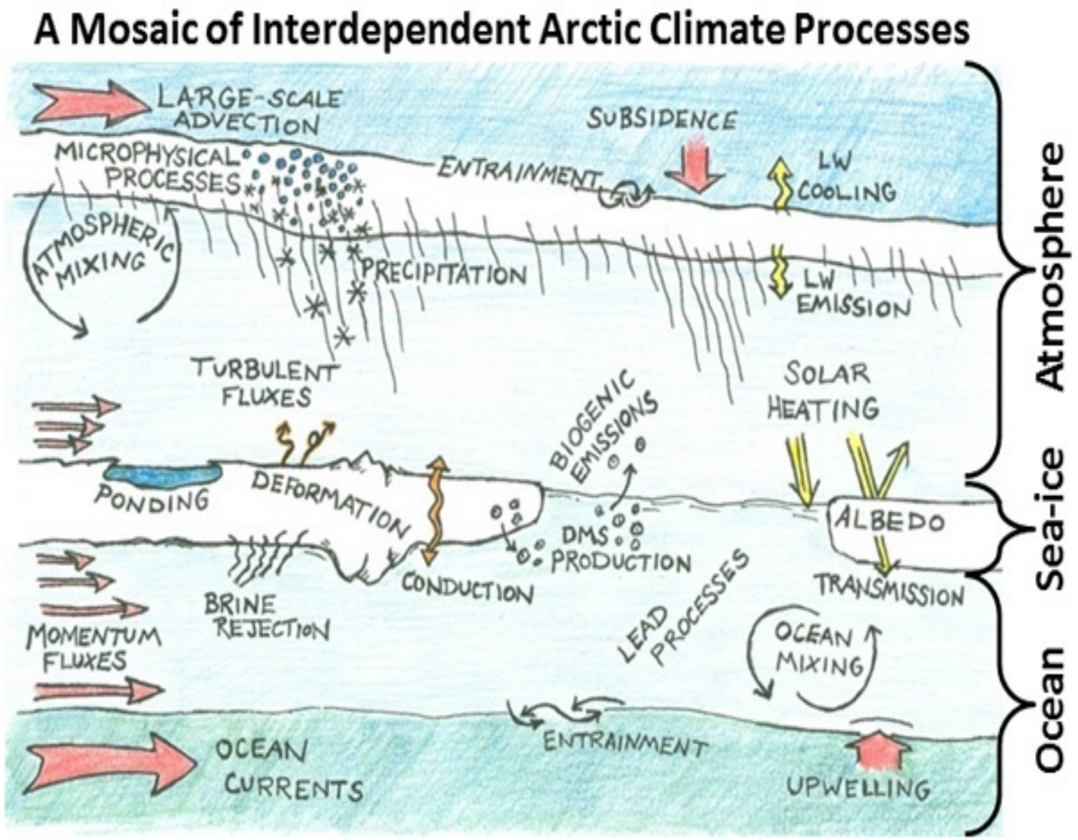
Supporting ECMWF

7 Funding and people
8 ECMWF’s accommodation

Serving Member and Co-operating States

9 Making deliverables and expertise available
10 Delivering environmental information

How complex are the coupled Processes over land and ocean/sea-ice?



Source: Mosaic project

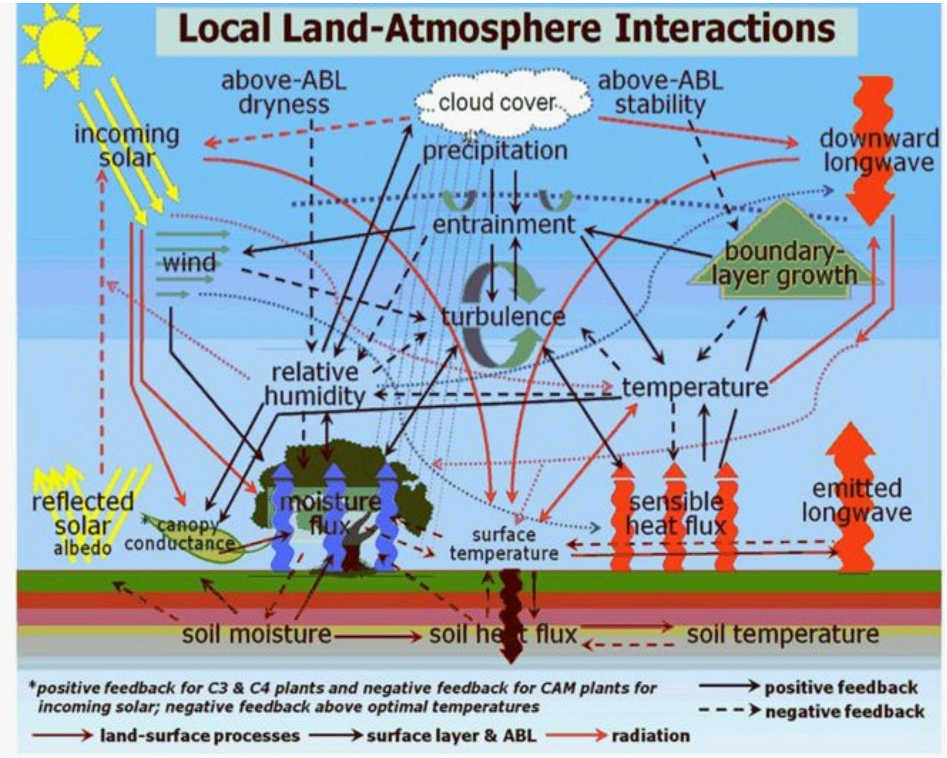
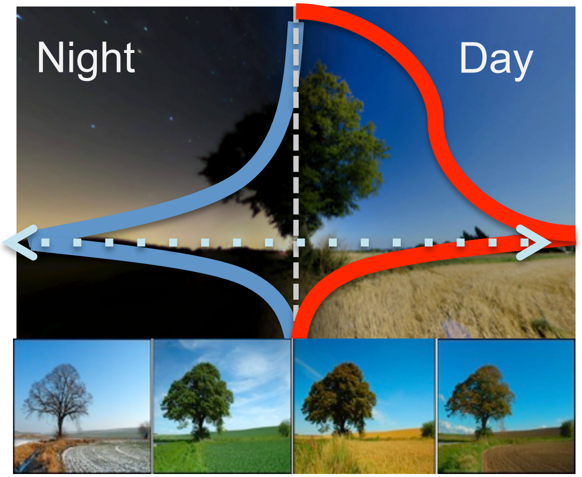


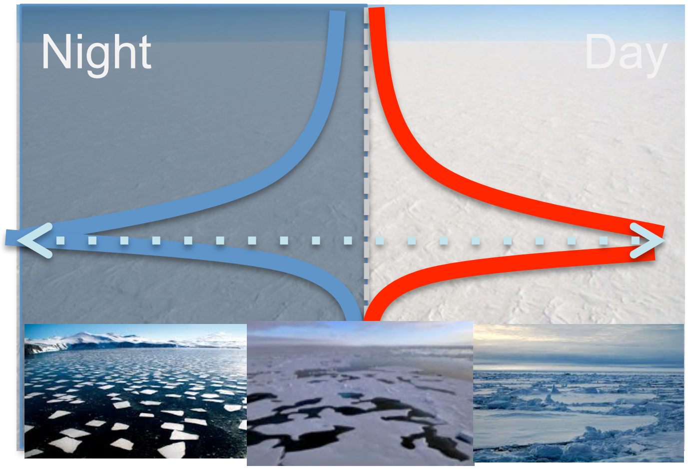
Fig. 3.1. Schematic of the complex interactions between the land surface, atmospheric boundary layer (ABL), and radiation via many variables (temperature, relative humidity, wind and associated turbulence, cloud cover, etc). Adapted from Ek and Holtslag (2004 *J. Hydromet.*, 5, 86-99), courtesy Mike Ek and Kevin Trenberth. 6

Source: GEWEX imperatives, Courtesy of Mike Ek

Coupled Processes at the surface interface: What are the challenges?

- The processes that are most relevant for near-surface weather prediction are also those that are most interactive and exhibit positive feedbacks or have key role in energy partitioning





Over Land

- Snow-cover, ice freezing/melting are in a positive feedback via the albedo
- Vegetation growth and variability and interaction with turbulence
- Vertical heat transport in soil/snow

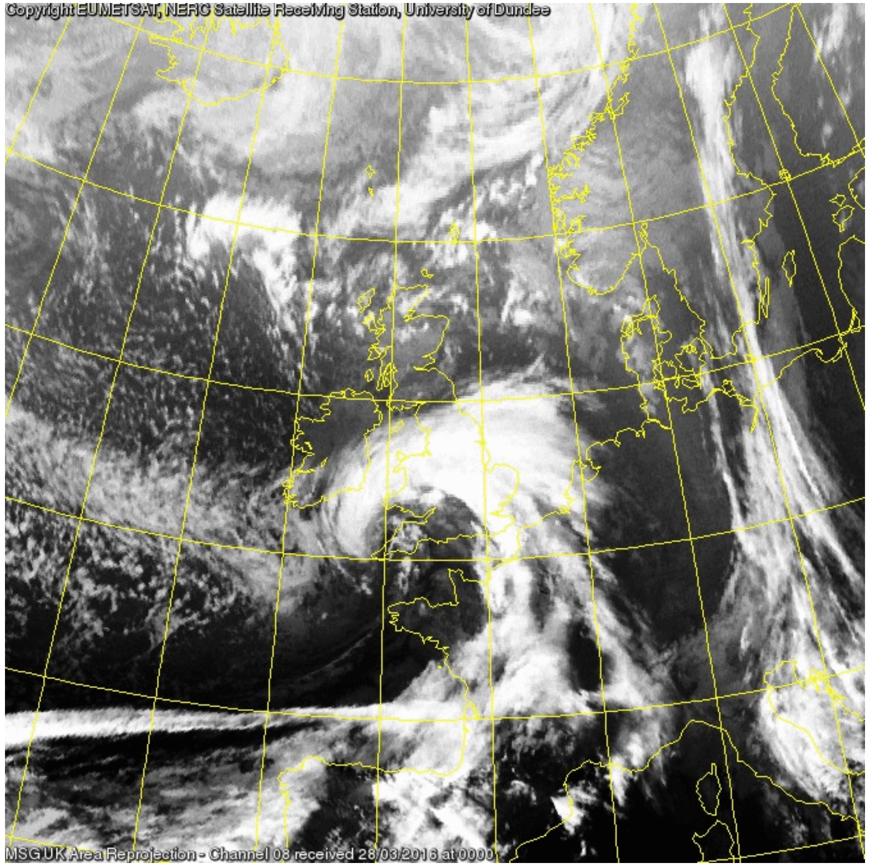
Over Ocean/Cryosphere

- Transition from open-sea to ice-covered conditions
- Sea-state dependent interaction wind induced mixing/waves
- Vertical transport of heat

- Studying and constraining positive feedback processes is key to advance seamless forecasting, embracing a larger amount of physical processes while still maintaining model realism

A nice example of an experimental global HRES dataset

… ECMWF’s first global forecast at 1.25 km resolution



(Courtesy N. Wedi)