Surface issues for High Resolution NWP

François Bouyssel - Jean-François Mahfouf

with many contributors

"High Resolution NWP" Workshop, 17-20 May 2010, Brac, Croatia

cnrs

METEO FRANCE
Toujours un temps d'avance

Outline

- Introduction (specificities of HR-NWP)
- Coupling strategies
- Modelling aspects
- Physiographic data bases
- Data assimilation aspects

Purpose of surface schemes

- Realistic description of momentum, energy and mass (water, CO2, aerosols, …) exchanges between the Earth's surface and the atmospheric turbulent boundary layer

- Diversity of Earth's surface types that should be considered: continental surfaces including vegetation, bare soil, snow, glaciers, urban areas, fresh water (lakes, lake-ice, snow on lakes) and oceanic surfaces (open water, sea-ice, snow on sea-ice)

Specificities of HR-NWP

- Temporal scales : < ~ few days

  ⇒ the description of components with much longer time scales should focus rather on their analysis (or initialisation) than on their modelling and be limited to vertical exchanges

- Spatial scales : few hundred meters to few kms

  ⇒ some surface types cannot be neglected anymore (i.e. lakes, town, …)

  ⇒ « mosaic » approach to describe sub-grid scale variability could be less a priority ? (not sure because fractal nature of surface heterogeneities …)

Main surface types

Bare soil

Vegetation

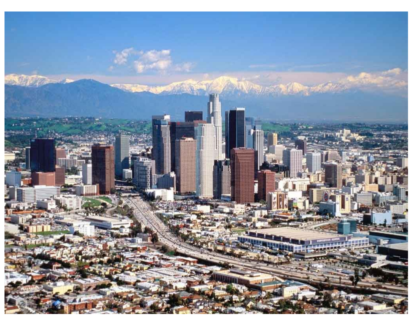
Snow

Oceans

Ice caps

Sea ice

Towns



Lakes

How to characterize surfaces ?

- A wide range of temporal scales:

  ⇒ Fast evolving components (~ 1 h): **modelling** (evolution of prognostic variables) : Land surface temperature, interception reservoir, …

  ⇒ Slow evolving components (~ 1 day) : **modelling** and **surface analyses**: soil moisture, snow parameters, sea surface temperature, lake surface temperature, …

  ⇒ Static or very slowly evolving components (~ 1 month or more): **climatological databases** or **analyses** : surface type, soil texture, land cover, vegetation fraction, leaf area index, surface albedo, …

- New informations will be necessary for HR-NWP: higher resolution physiographic databases, new parameters for lakes, towns, irrigated surfaces, crop types, harvests, …

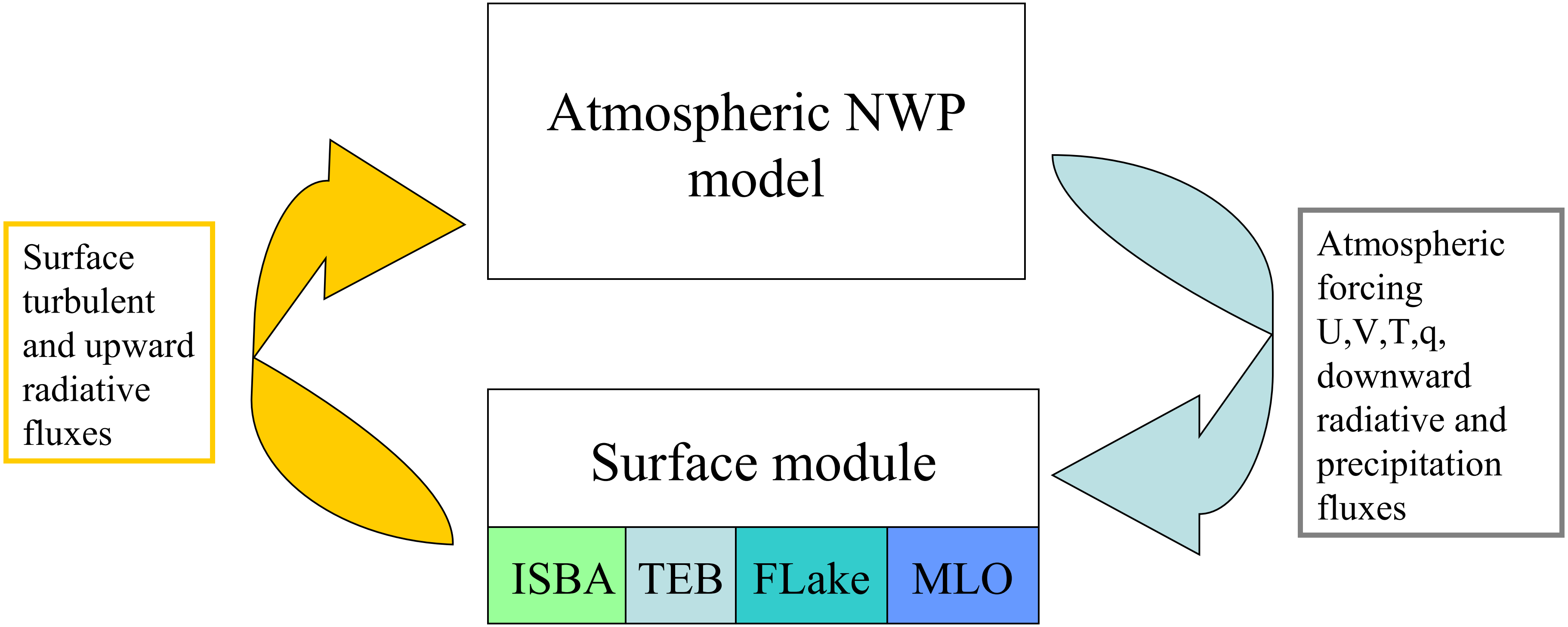
Benefits of surface externalization

- Surface models become more and more sophisticated and so their development, initialization, dataflow, diagnostics should be preferably separated from atmospheric models (will surface and atmospheric modelling communities be more and more separated in the future ?)

- Easier implementation of new surface parameterizations in atmospheric models (general interface surface/atmosphere : Polcher et al. 1998)

- The use of identical surface parameterizations for « in line » and « off line » applications opens new perspectives for surface modelling and surface analysis (advanced analysis algorithms, use of analysed precipitation and radiation fluxes, …)

Internal coupling strategy (SURFEX)

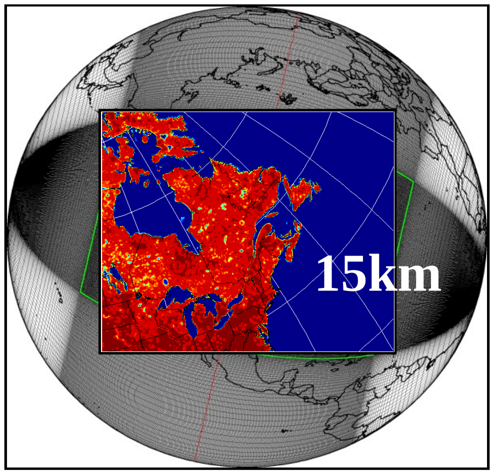


ALMA coupling norm (Polcher et al., 1998; Best et al., 2004)

External coupling strategy

Canadian environmental modelling system

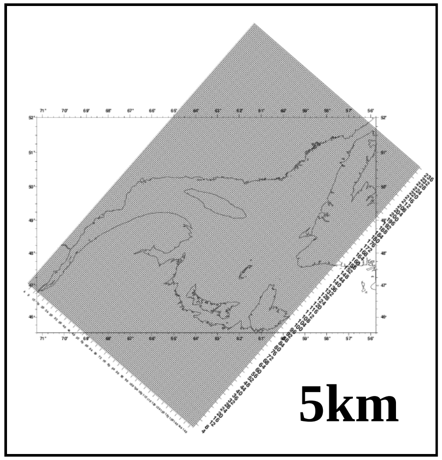
Computer 1



OASIS

External
Coupler
Interpolation
Aggregation

Computer 2



Atmospheric model

$\Delta t = 550$ s

Regional Ocean model

$\Delta t = 250$ s

[*also hydrological models*]

From P. Pellerin (MSC)

SBL representation

- Where should be done the computations between the lowest atmospheric level and the surface level (diagnostics and/or prognostic computations like CANOPY scheme)? Atmospheric part or surface part ?
- What will be the height of the lowest model level?
- If the benefit of CANOPY approach (1D turbulence non advected) is confirmed for HR-NWP, wouldn't it be useful to also include (simplified) radiation and microphysical schemes for fog simulation

Current status of operational surface schemes

- AROME description (similar complexity in others operational CSRM) :

  ⇒ Orography (GTOPO30, 1km), soil texture (FAO, 10 km), land cover, soil and vegetation parameters (ECOCLIMAP, 1 km) based on Univ. Of Maryland, Corine land cover, NDVI satellite obs., …

  ⇒ 4 tiles used (nature, sea, lake, town) : « patches » not used

  ⇒ Nature: ISBA (force-restore) 2L for T, 3L for liquid and frozen water, 1L snow scheme

  ⇒ Sea: ECUME (bulk iterative scheme) : SST constant

  ⇒ Lake: Louis + Charnock formulation : LST constant

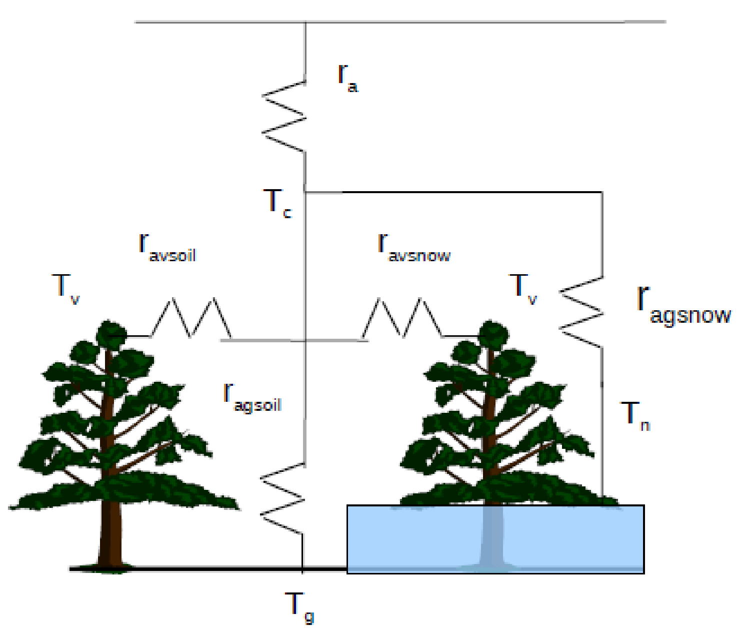
  ⇒ Town: TEB (urban canyon concept)

  ⇒ SBL: CANOPY (6 levels below lowest atm level + 1D turb scheme)

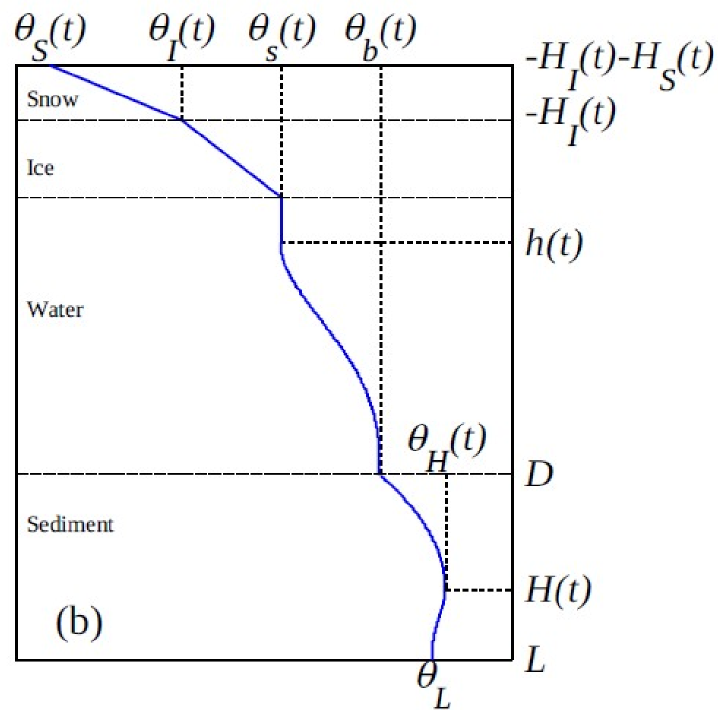
Current modelling priorities for SRNWP

- Description of missing processes in SURFEX (ALADIN/LACE) already available in HIRLAM : snow/ forest interactions (double energy balance), prognostic sea-ice
- Implementation « Flake » lake model in SURFEX

"Traditional" double energy balance



FLAKE



Transfer of research schemes towards operations

- Implicit coupling on T, Qv will not be necessary for HR-NWP, which will make easier the use of more sophisticated surface parameterizations (for instance CANOPY and TEB are in AROME and not yet in ALADIN due to numerical stability issues)

- **Explicit soil diffusion scheme** : 3 prognostic equations for each of L layers for temperature, liquid water and soil ice (improved representation of vertical gradients of temperature and soil moisture, more consistent treatment of water phase change, vertical soil texture heterogeneities)

- **Multi-layer snow scheme (ISBA-ES)**: thermal diffusion, water flow, phase changes, light penetration, compaction, snow/soil thermal fluxes

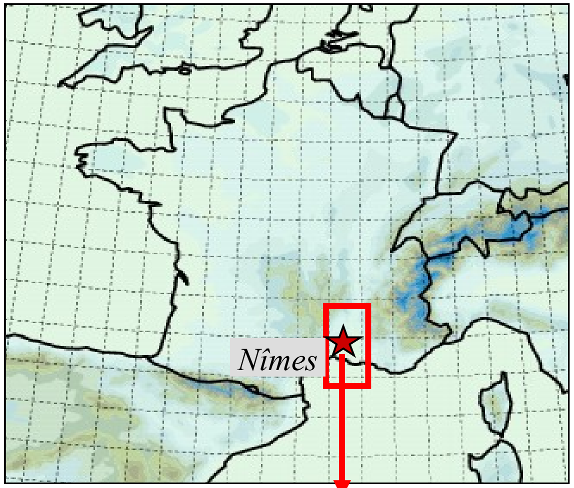
What is relevant for HR-NWP ?

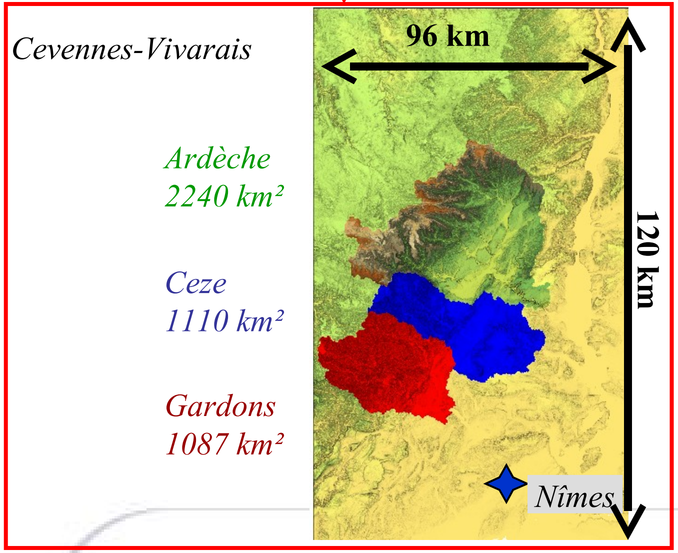
- Coupling with hydrological model ?
- Coupling with 1D ocean mixing layer model ?
- Which complexity in the vegetation scheme ?
- Aerosol and chemical emissions ?
- Which complexity in the town scheme ?
- Which complexity in the SBL scheme ?
- etc

The hydrometeorological system AROME/ISBA-TOPMODEL

(B. Vincendon)

- ISBA-TOPMODEL coupled system dedicated to Mediterranean flood simulation.
- Daily simulations during the autumn 2008 using AROME run starting from 00UTC, day D analysis
- Hourly discharge forecast up to day D+1 at 00UTC.



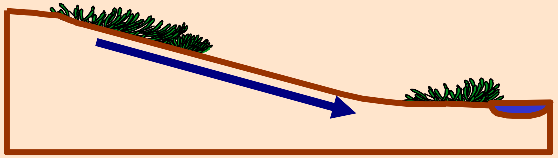


Atmospheric forcing

Cloud resolving model AROME

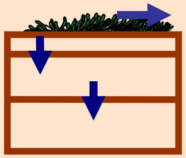
Precipitation, radiation,…

ISBA-TOPMODEL *(Vincendon et al, 2010)*



Surface scheme
ISBA

Hydrological model
TOPMODEL

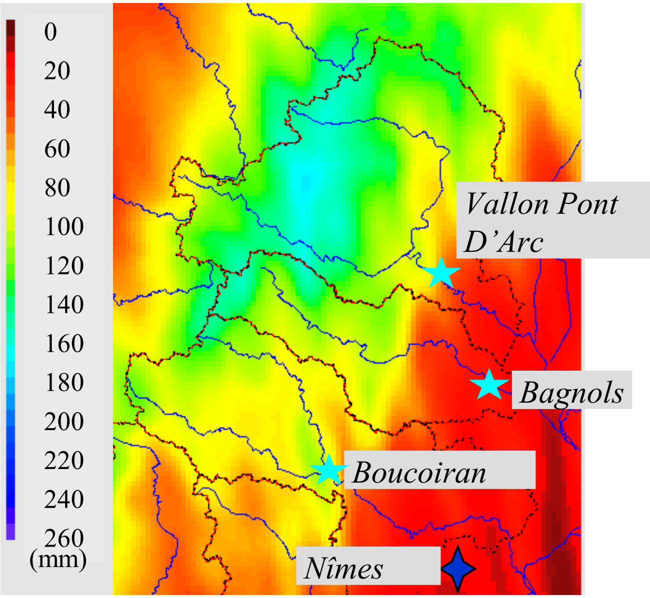


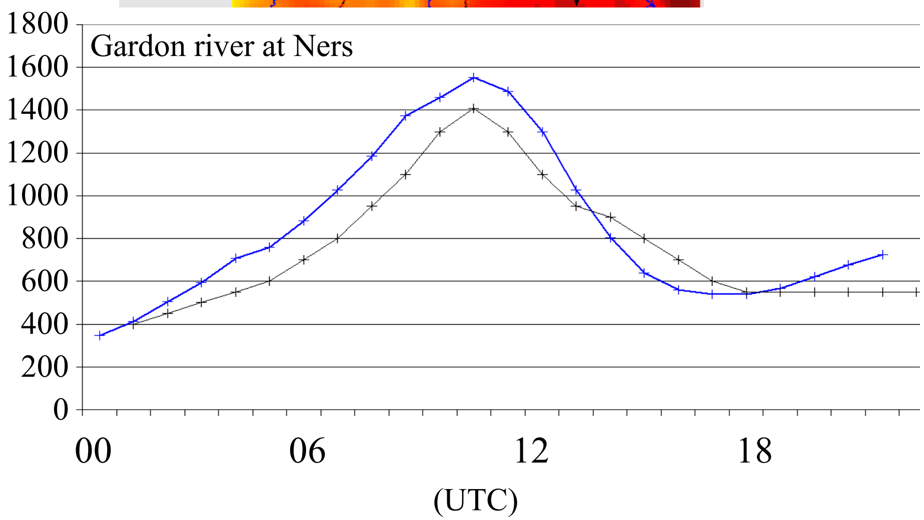
Routing

Total Discharge

Evaluation on 01-02 November 2008 case

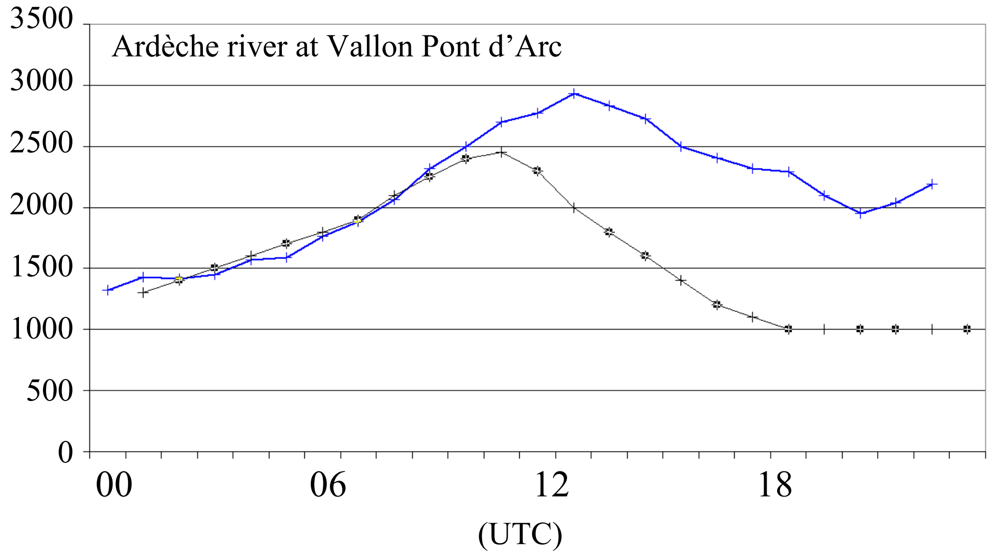
24h-accumulated rainfall (mm) from AROME run starting from 00UTC, 02 November 2008 analysis

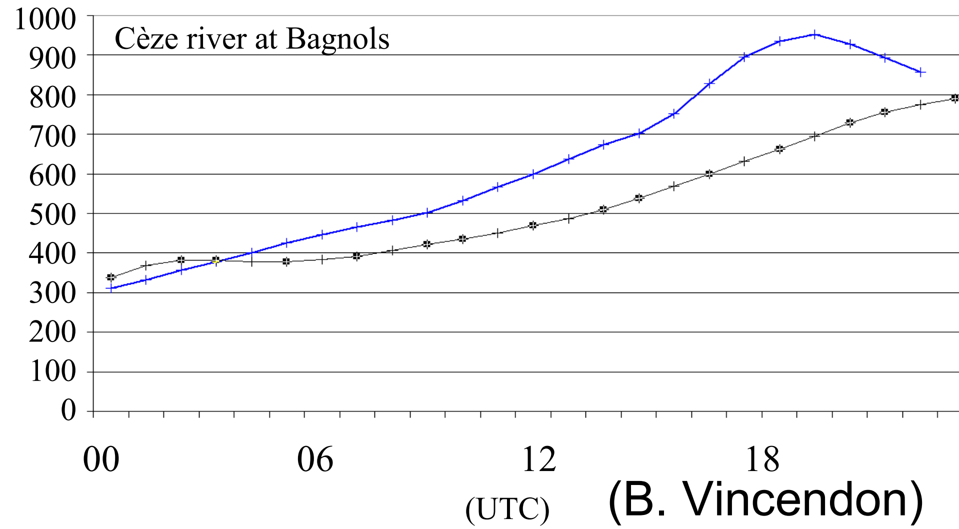




Observed and simulated discharges, 02 November 2008

Forecast
Observation





(B. Vincendon)

Coupling Atmosphere and 1D-Ocean with SURFEX

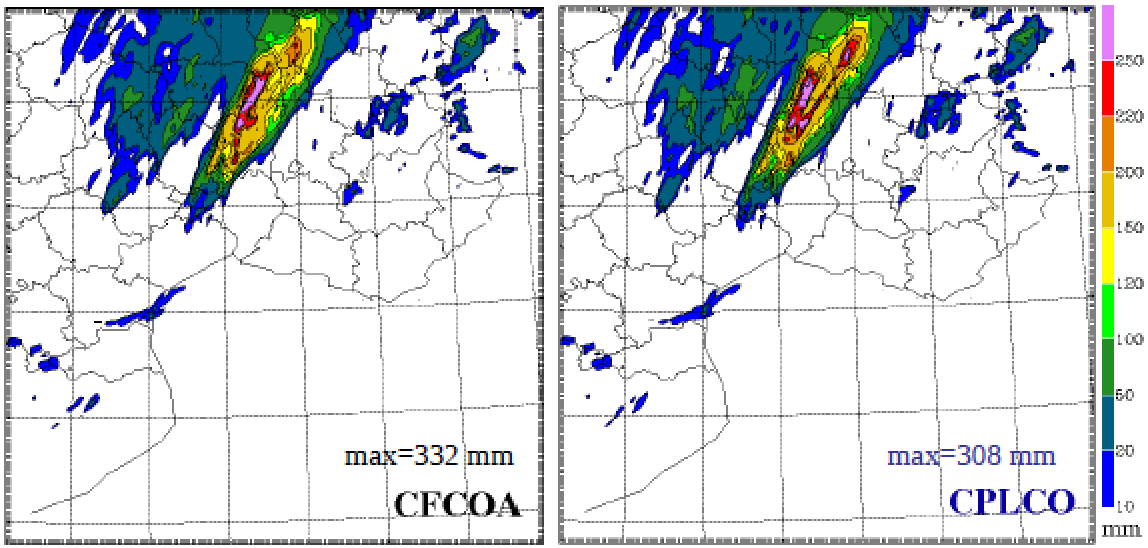
Extreme mediterranean rain event 8-9 sept. 2002

(from C. Lebeaupin-Brossier, 2007)

Principle: Oceanic vertical mixing represented according to the parametrisation of turbulence from Bougeault et Lacarrère [1989] adapted to the ocean

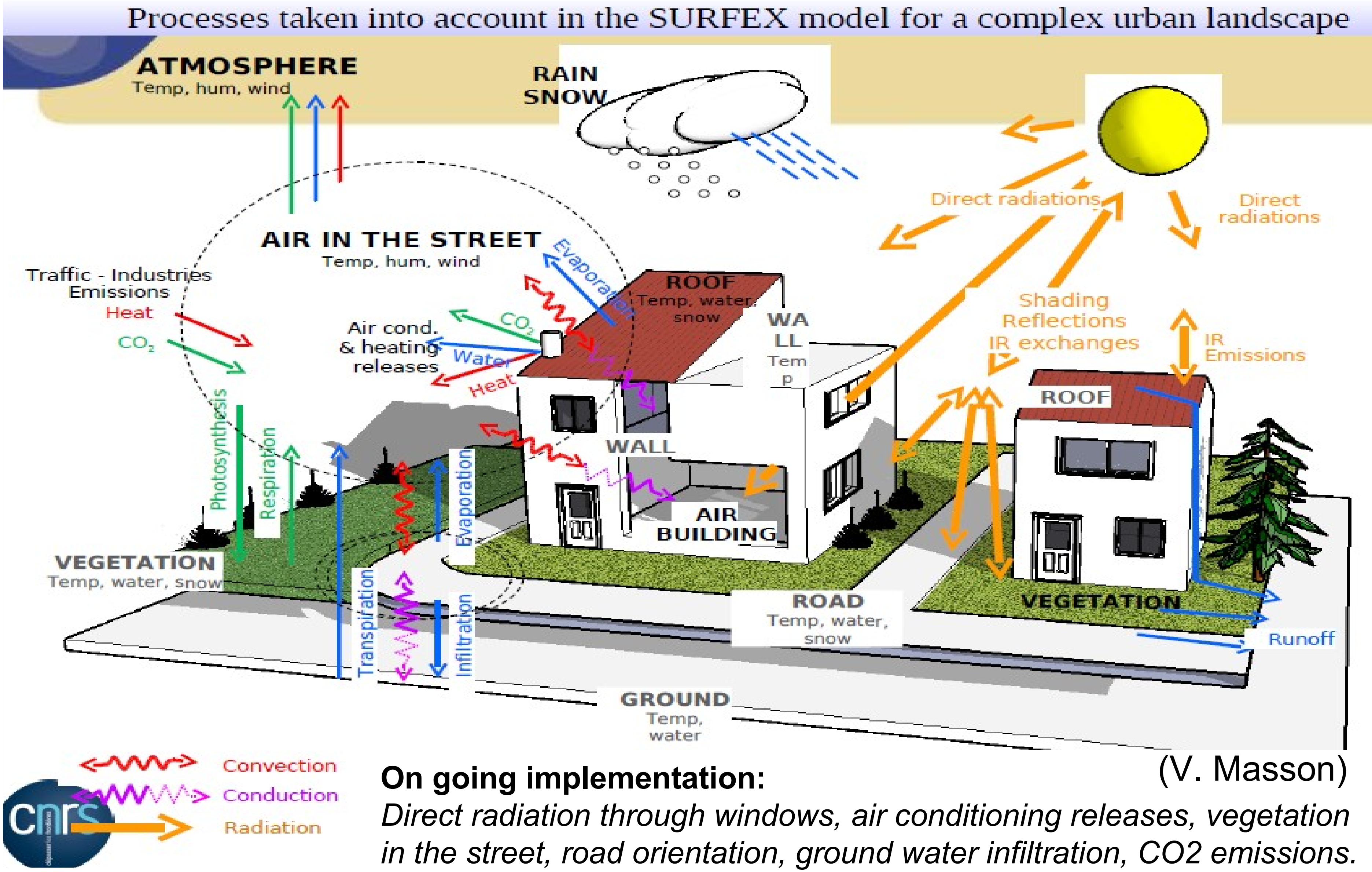
Prognostic equations for: Temperature, Salinity, Current, TKE

CFCOA : Atmosphere forced by 1D-Ocean
CPLCO : Coupled Atmosphere-Ocean



Accumulated precipitation over 24h *(mm)*

Town model complexity



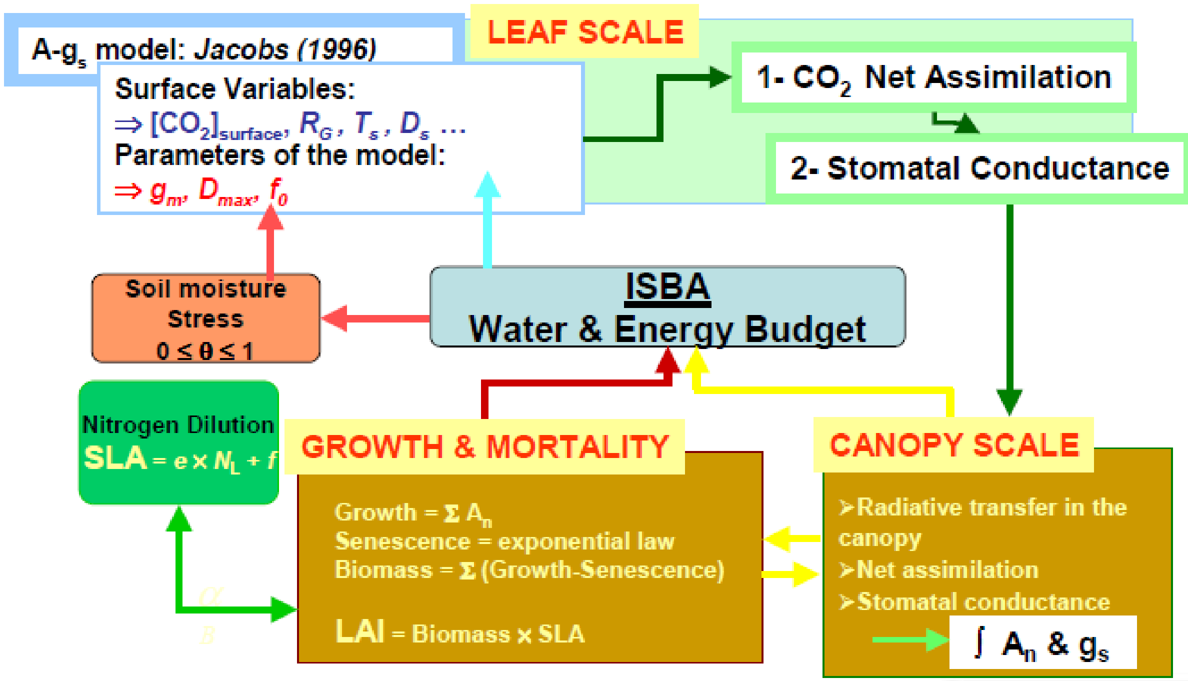
(V. Masson)

On going implementation:
Direct radiation through windows, air conditioning releases, vegetation in the street, road orientation, ground water infiltration, CO2 emissions.

Vegetation carbon cycle

The ISBA-A-gs model:

- Photosynthesis (Jacobs et al. 1996)
- Meta-analysis of the response to drought (Calvet 2000, Calvet et al. 2004)
- Plant growth (LAI evolution)



It might improve:

- simulation of vegetation evapotranspiration
- assimilation of soil moisture and LAI

(J.C. Calvet)

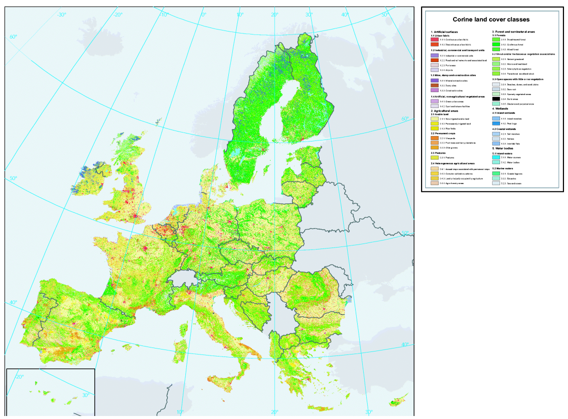
Physiographic databases

- Resolution issues : soil texture global products (FAO) at 10 km $\Rightarrow$ Harmonized World Soil Database HWSD (LUC & FAO) ~1km
- Availability of high resolution land cover maps over Europe : CORINE2000 (100 m)
- Interest for regional data sets vs global data sets (LAM outside Europe) ?
- Land cover maps = climatologies => use of real-time satellite products
- Databases for new surface types : towns, lakes ?

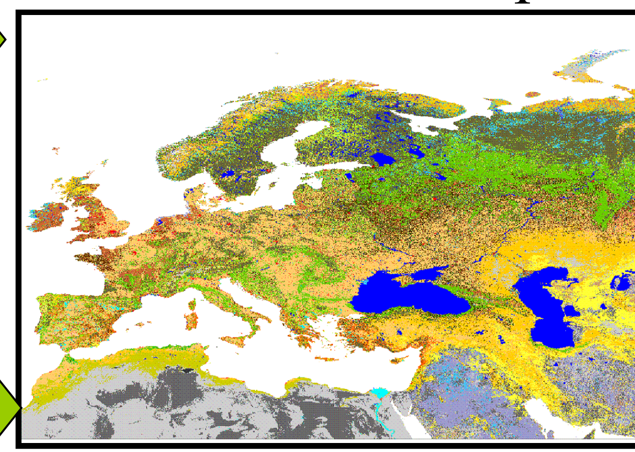
ECOCLIMAP 2

- Revised land cover climatology at Météo-France
- Higher resolution and improved quality of land cover maps
- Multi-year data availability
- Improved method for ecosystem classification

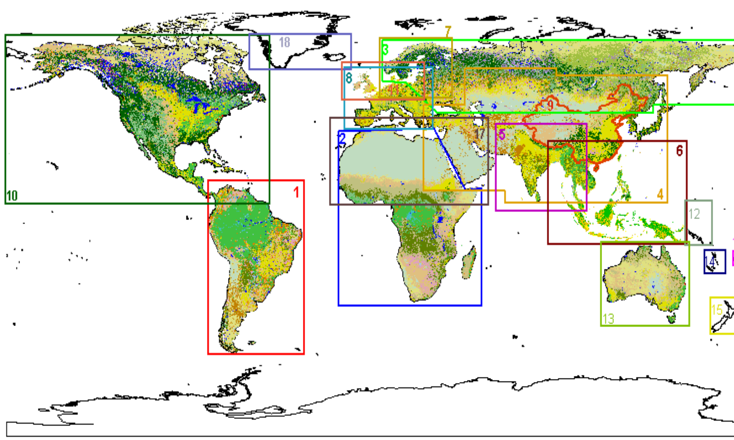
CORINE2000
(100m)



1-km merged
land cover map



GLC2000
(1 km)



(J.L. Roujean)

Data assimilation aspects (1)

- Better usage of remote-sensing data (available over Europe)
- SST and Sea-ice : OSI-SAF – MERSEA - OSTIA
- Snow analysis : snow cover / snow water equivalent (LandSAF, MODIS)
- Soil moisture analysis : satellite derived products (ASCAT, AMSR-E, SMOS)
- Vegetation properties : albedo – LAI (LandSAF, MODIS)
- Radiative forcing : downward fluxes (LandSAF)
- Precipitation forcing : radar networks (OPERA)

Data assimilation aspects (2)

- Improved land data assimilation systems :
  - EKF : SURFEX, MSC, ECMWF
  - EnKF : NILU (Met.No), US community, MSC, JMA
- Improved 2D analysis systems (SST, snow cover, screen-level variables) : OI accounting for anisotropy effects (e.g. wavelet structure functions)

Land albedo analysis

LandSAF
Total albedo

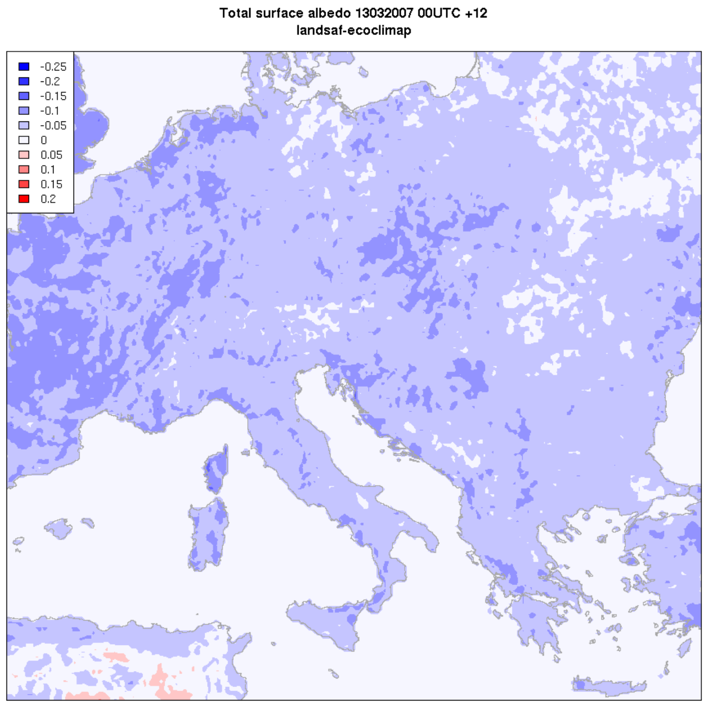
ECOCLIMAP
Albedos (soil,veg)

↓

Kalman
Filter

↓

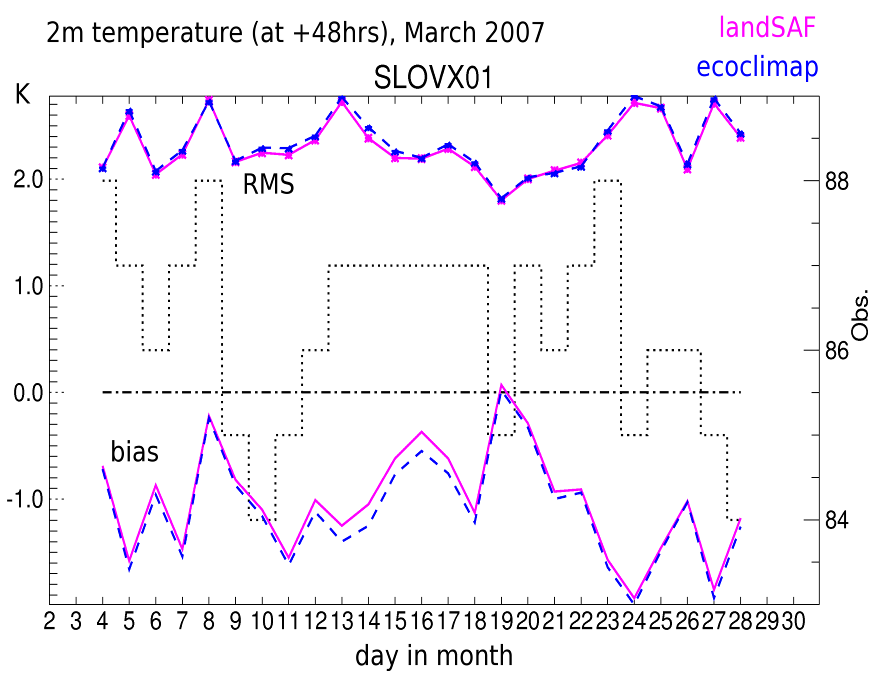
Analysed
Albedos (soil,veg)



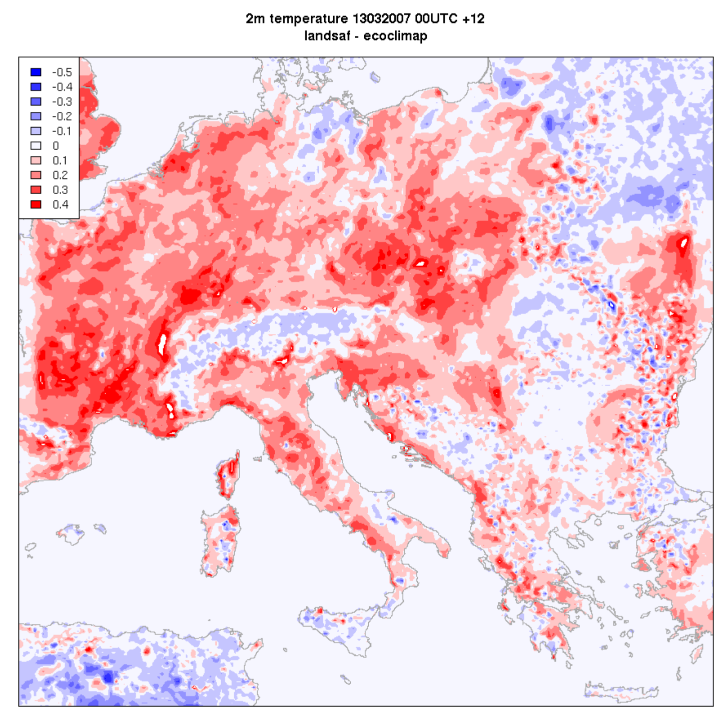
Difference (ANA – ECO) – 13/03/2007

(J. Cedilnik)

Impact on forecasts



T2m forecast scores in March 2007



Differences in T2m FC+12
13 March 2007

(J. Cedilnik)

Conclusions / Questions (1)

- Keep flexibility to do off-line and in-line surface simulations
- Internal or external coupling? SBL modelling?
- Towards operational use : lake and sea-ice models, double energy balance, soil diffusion scheme, multi-layers snow scheme, …
- Which new components will be relevant for HR-NWP? Evaluation of hydrological model, 1D ocean mixing layer model, interactive vegetation, aerosol and chemical, … ?

Conclusions / Questions (2)

- Need of higher resolution database? New parameters needed?
- Better usage of remote-sensing data (available over Europe)
- Improved analysis algorithms (real time background error and observation error statistics, anisotropy, etc)
- Efficiency, Portability, Modularity, Readability will remain of primary importance for the surface model as well as for the atmospheric model

Thank you

for your attention