Recent developments at Météo-France for converting IFS soil variables for the ISBA scheme

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Motivations

- Need to run the Météo-France models (ALADIN, AROME, ARPEGE) using ECMWF analyses and reanalyses
- Simple use of ECMWF IFS soil variables to initialize the ISBA scheme leads to poor near-surface forecast scores
- Temporary "blending" : use ECMWF for upper air fields and use "native" soil variables
- Difficulty of surface interpolation : strong model dependencies in terms of surface parameterizations and physiographic databases
- Need to include physical constraints in the interpolation procedure (e.g. flux conservation)

H-TESSEL (1)

Main features (2)

- 4-layer scheme (diffusion equations) with uniform vertical discretization and total soil depth (7cm, 21 cm, 72cm, 189 cm)
- Soil texture dependency : 5 classes (dominant class in each grid box) charaterized by different thermal and hydraulic properties - texture uniform on the vertical
- The amount of water in the soil is driven by three textural parameters (that are used to control evapotranspiration):
  - : Volumetric water content at saturation : θ_{sat} $[w_{sat}]$
  - : Volumetric water content at field capacity : θ_{cap} $[w_{fc}]$
  - : Volumetric water content at wilting point : θ_{pwp} $[w_{wilt}]$

H-TESSEL (2)

Main features (2)

- The grid box can contain : bare soil, high vegetation, low vegetation, snow below vegetation, snow on top of vegetation, water on vegetation, ice water - for each of these 7 surfaces ("tiles") a separate surface energy balance equation is solved.
- Each "tile" sees the same overlying atmosphere and the same underlying soil. Each vegetation type has its own root profile weighting the water extraction in the 4 different layers.
- Evapotranspiration controlled by a canopy resistance depending upon vegetation type (minimum value, LAI, vegetation cover) and environmental conditions (soil moisture, radiation, air temperature and humidity)

H-TESSEL (3)

The soil wetness index (SWI)

$$SWI = \frac{\theta - \theta_{pwp}}{\theta_{cap} - \theta_{pwp}} = \frac{w - w_{wilt}}{w_{fc} - w_{wilt}}$$

- When $SWI > 1$: evapotranspiration (bare soil + vegetation) takes place at potential rate
- When $0 < SWI < 1$: soil conditions control evapotranspiration
- When $SWI < 0$: evapotranspiration is negligible (soil too dry)

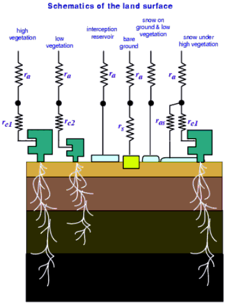
ISBA

Main features

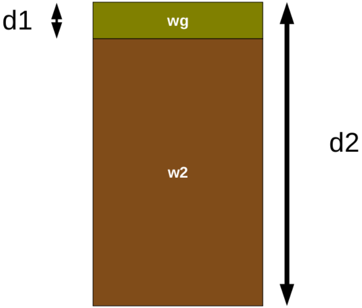
- 2-layer force-restore scheme (Deardorff, 1977) with "fixed" surface layer of 1 cm and a variable total soil depth (depending surface types) - Plants can extract water over the whole soil depth - No physical depths for soil temperatures (implicit definition in terms of time scales).
- Soil texture defined by a continuous formulation depending upon the fraction of SAND and of CLAY (Noilhan and Mahfouf, 1996)
- One single surface energy balance : same surface temperature for vegetation, bare soil and snow.
- Surface evapotranspiration = bare soil evaporation (relative humidity formulation) - vegetation evapotranspiration (canopy resistance depending upon *SWI* and environmental quantities)

Schematic structure of the land schemes

IFS-TESSEL



ISBA-2L



Importance of the conversion according to the various prognostic variables

- Root zone soil moisture content (liquid+solid)
- Snow water content
- Deep soil temperature(s)
- Superficial soil moisture content
- Surface temperature

ALADIN *SWI* on 15 July 2008

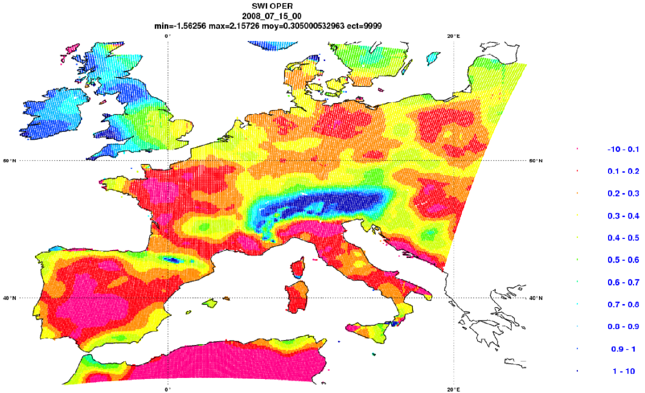
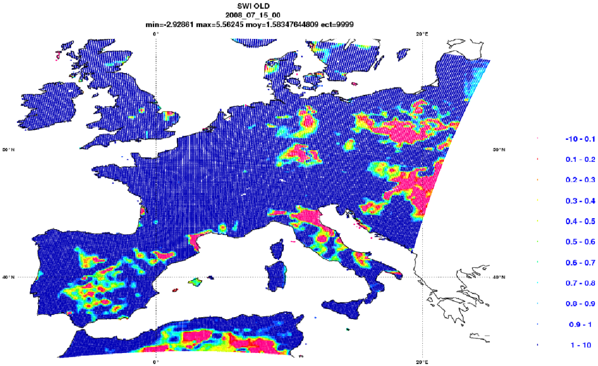


Fig.3 – ALADIN OPER SWI for the 15th of July 2008 at 00UTC

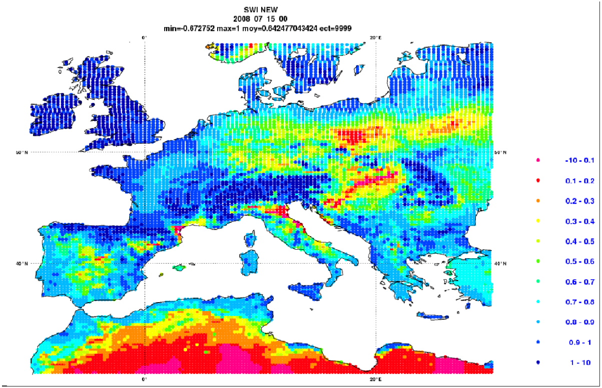
Conversion in fraction of saturation

$$\left(\frac{w_2}{w_{sat}}\right)_{ISBA} = \left(\frac{\sum_{i=1}^{4}\alpha_i\theta_i}{\theta_{sat}}\right)_{IFS}$$



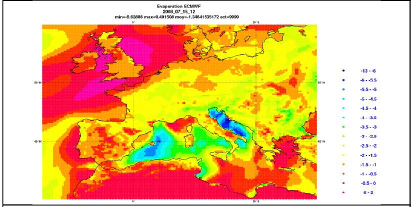
Conversion in *SWI*

$$\left(\frac{w_2 - w_{wilt}}{w_{fc} - w_{wilt}}\right)_{ISBA} = \left(\frac{\sum_{i=1}^{4} \alpha_i \theta_i - \theta_{pwp}}{\theta_{cap} - \theta_{pwp}}\right)_{IFS}$$



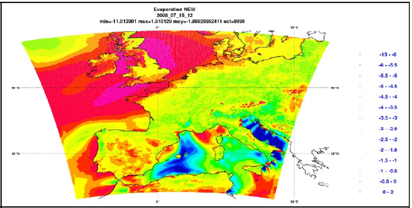
Surface evaporation

IFS

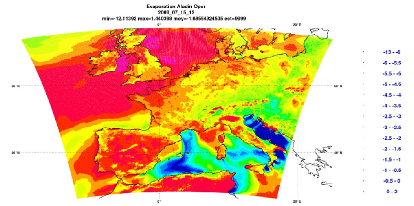


ECMWF H+12 Evaporation

ISBA with IFS *SWI*

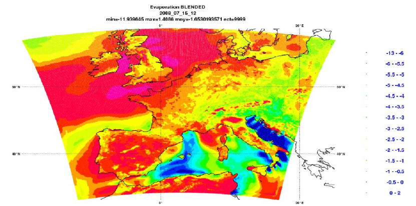


NEW H+12 Evaporation



ALADIN OPER H+12 Evaporation

ISBA

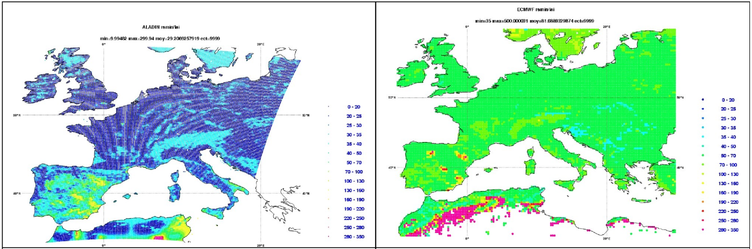


BLENDED H+12 Evaporation

ISBA blended

Scaling using R_{smin}/LAI

- Vegetation transpiration is proportional to LAI/R_{smin}
- Valid when : aerodynamical resistance is lower than canopy resistance, surface temperatures are similar



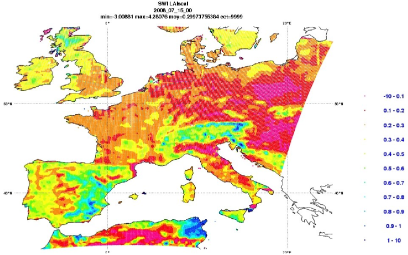
ISBA Rsmin/LAI | IFS Rsmin/LAI

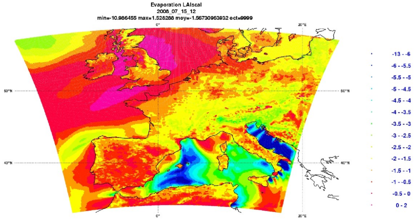
Fig.8 – ISBA and IFS Rsmin/LAI for the 15th of July 2008 at 12h UTC

ISBA | IFS

SWI conversion with R_{smin}/LAI scaling

SWI and Surface evaporation





Problem of bare soil evaporation formulations

ISBA

$$E_g = (1 - veg)\rho \frac{h_u q_{sat}(T_s) - q_a}{R_a}$$

with $h_u = h_u(w_g)$ $[h_u(0) = 0$ and $h_u(w_g > w_{fc}) = 1]$

H-TESSEL

$$E_g = (1 - c_H - c_L)\rho \frac{q_{sat}(T_s) - q_a}{R_a + R_{soil}}$$

with $R_{soil} = R_{soil}(\theta_1)$ $[R_{soil}(\theta_1 < \theta_{pwp}) = 0$ and $R_{soil}(\theta_1 > \theta_{cap}) = 1]$

Current conversion:

$$\left(\frac{w_g}{w_{fc}}\right)_{ISBA} = \left(\frac{\theta_1}{\theta_{cap}}\right)_{IFS}$$

Revised scaling for root-zone soil moisture

Low and high vegetation SWI (SWI_L and SWI_H) from :

$$\overline{\theta_H} = \sum_i fr_{Hi}\theta_i \qquad \overline{\theta_L} = \sum_i fr_{Li}\theta_i$$

Bare soil SWI (SWI_{bs}) from θ_1

Mean IFS SWI

$$SWI_{IFS} = \frac{c_H SWI_H + c_L SWI_L + (LSM - c_H - c_v)SWI_{bs}}{LSM}$$

where LSM is the land sea mask

Mean ISBA SWI

$$SWI_{ISBA} = veg \times \frac{w_2 - w_{wilt}}{w_{fc} - w_{wilt}} + (1 - veg)\frac{w_2}{w_{fc}}$$

Conclusions (1)

- Soil moisture contents are "model dependent". There is a need for rescaling such that turbulent fluxes (evapotranspiration) is preserved (from native model)
- The conversion in SWI is more satisfactory than in θ/θ_{sat} (more directly linked to evapotranspiration)
- Including additional information in the scaling provides improvements (use of R_{smin}/LAI)
- Additional information has been used in more recent experiments :
  - Include the vegetation fraction in the SWI scaling
  - Use the root weighting in order to define the mean IFS SWI instead of soil layer depths

Conclusions (2)

- Examine winter situations (frozen soils) - irrelevance of R_{smin}/LAI scaling
- The IFS *SWI* includes both liquid and frozen soil water contributions - use of soil temperature to split each component.
- Current proposal for deep soil temperature :ISBA (assumed representative of 50 cm) = average of IFS layers 2 and 3