IMPLICIT COUPLING BETWEEN ATMOSPHERIC AND SURFACE PHYSICS

Patrick Le Moigne

15th ALADIN Workshop: 6-10 June, Bratislava

IMPLICIT COUPLING BETWEEN ATMOSPHERIC AND SURFACE PHYSICS

- Introduction
- Externalization of Isba surface scheme from Arpege-Climat GCM
- ACSURFEX: interface to SURFEX module
- Eurocs case study using SURFEX in off-line mode within 1D Arpege-Climat model
- Conclusion / Perspectives

Introduction

Best et al., 2004 (after work of Polcher et al., 1998) propose a generalized coupling between atmospheric models and surface schemes where:

1. The atmospheric **variables** from lowest model level and their **relation** to corresponding fluxes are passed to the surface scheme.

2. Surface scheme returns the **fluxes** (used as boundary condition by the atmosphere)

In these conditions the atmosphere doesn't have to know details about surface. This coupling has been applied in Arpege-Climat model.

Externalization of Isba surface scheme from Arpege-Climat GCM

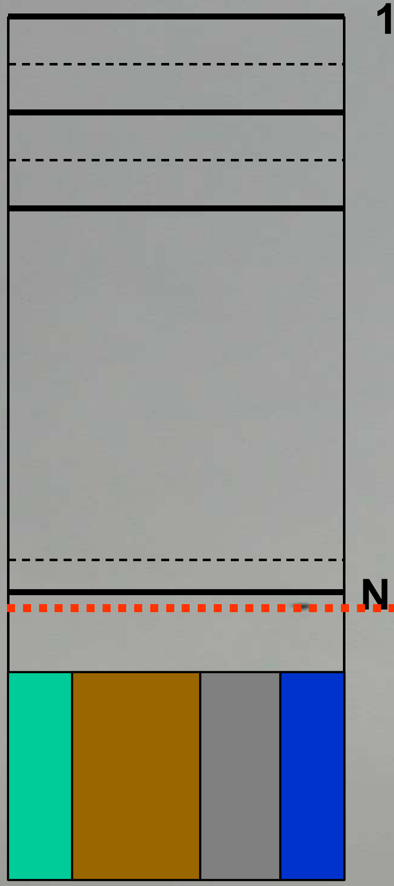
[Gibelin, 2003 and Zuurendonk, 2004]

More and more sophisticated surface parameterizations lead to externalize the LSS from Arpege-Climat GCM

Objectives:

- Easy to maintain surface parameterization surface code.
- Both coupled and forced model can be used (Intercomparison projects).
- Easy to use different surface models in the atmospheric model.
- Essential step for participating in PRISM (Project for integrated earth system modelling) project.

Coupling with the atmosphere



Vertical diffusion

$$\begin{cases} X \equiv u, v, \theta, q \\ X_i^+ - X_i^- = -\omega_{i,i}\left(X_{i+1}^+ - X_i^+\right) + \omega_{i-1,i}\left(X_i^+ - X_{i-1}^+\right) \\ F_{X,0} = 0 \end{cases}$$

Downward sweep

$$\begin{cases} X_i^+ = A^-_{X,i} X^+_{i+1} + B_{X,i} \\ A_{X,i} = f\left(\omega_{i-1,i}, \omega_{i,i}, A_{X,i-1}\right) \\ B_{X,i} = f\left(\omega_{i-1,i}, \omega_{i,i}, B_{X,i-1}, X_{X,i-1}\right) \end{cases}$$

Lower atmospheric level

$$X_N^+ = A^-_{X,N} F^+_{X,S} + B^-_{X,N}$$

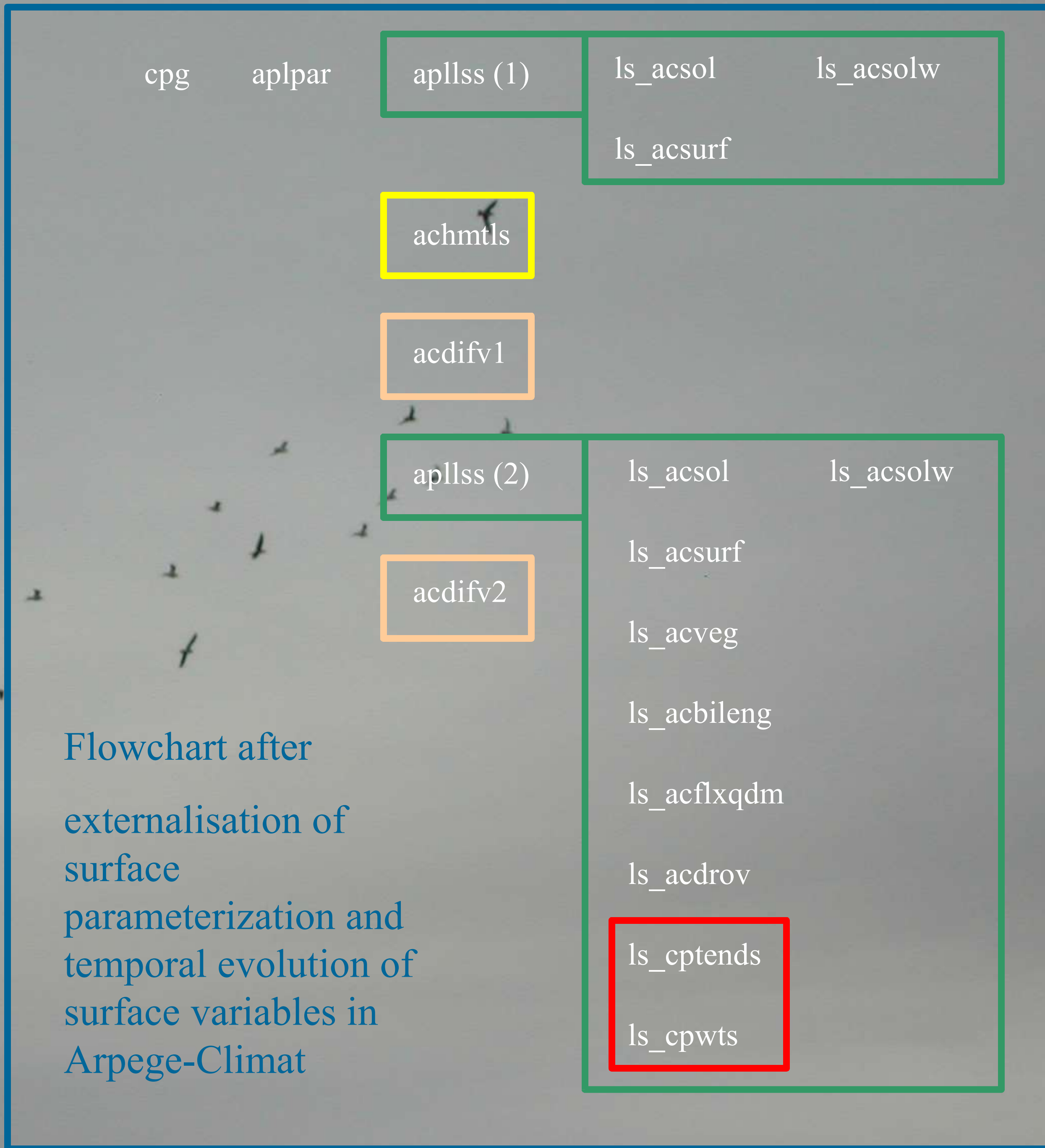
Surface Ts + Fluxes on each tiles, Average fluxes

$$\begin{cases} H^+ = \rho C_p V_N^- C_H^- \left(\beta_S T_S^+ - \beta_N T_N^+\right) \\ \dfrac{C_s}{\Delta t}\left(T_S^+ - T_S^-\right) = R_n^+ - H^+ - LE^+ - G^+ \end{cases}$$

Upward sweep

Principle of externalization in climate version of Arpege

Original flowchart

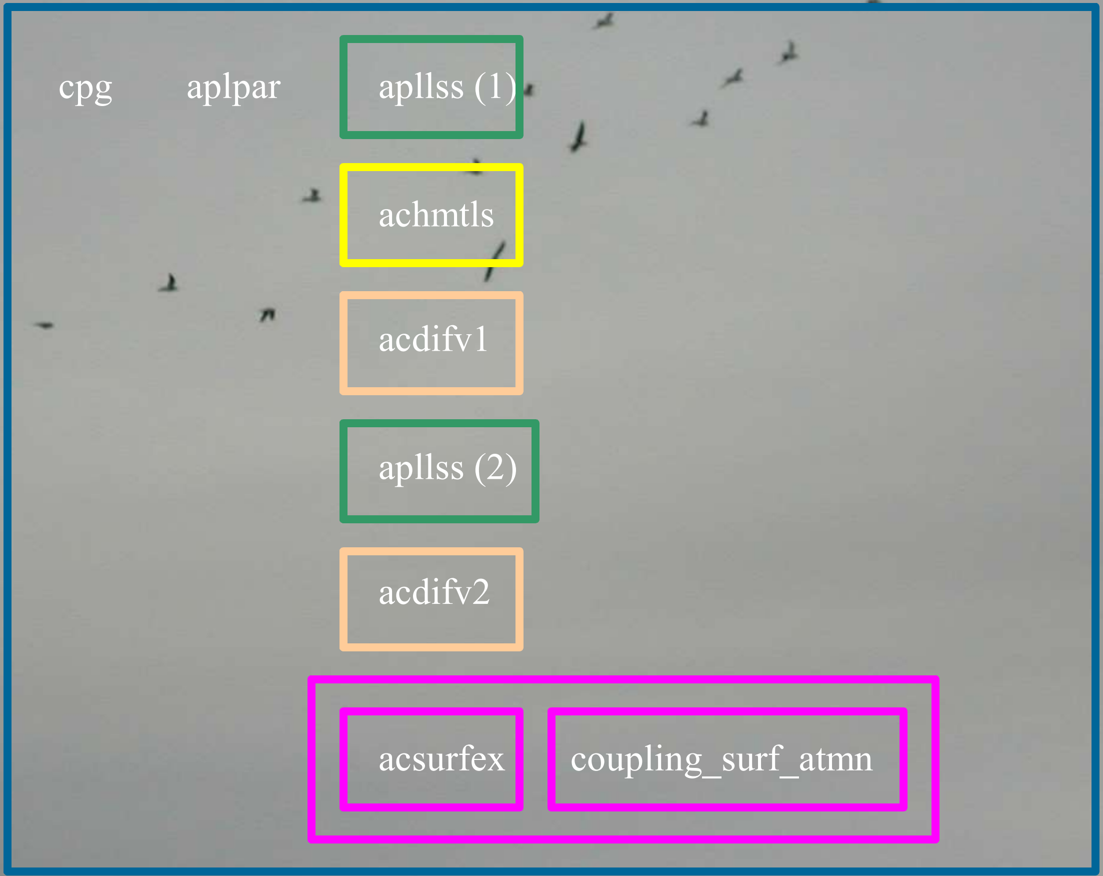


Flowchart after externalisation of surface parameterization and temporal evolution of surface variables in Arpege-Climat

ACSURFEX interface to SURFEX

[P. Marquet, April 05]

acsurfex is the interface between **aplpar** (Arpege) and **coupling_surf_atmn** (Surfex) where Arpege fields are transformed to feed the surface module:



1. Variables defined during surface setup

INPUT

Name of the variable	SURFEX	ARPEGE
Time step of the physics (s)	ZTSTEP_ISBA	PDTPHY
Year	IYEAR	NINDAT/10000
Day	IDAY	MOD(NINDAT,100)
Month	IMONTH	MOD((NINDAT-IDAY)/100,100)
Seconds from start	ZTIME	RSTATI
Horizontal space dimension	INI	KLON=1
Forcing height of T and q (m)	XZREF	(PAPHIF(1,KLEV)-PAPHI(1,KLEV)) / RG
Forcing height of wind (m)	XUREF	(PAPHIF(1,KLEV)-PAPHI(1,KLEV)) / RG
Orography (m)	XZS	PAPHI(1,KLEV) / RG
Surface pressure (Pa)	XPS	PAPRS(1,KLEV)

2. Atmospheric forcing at lowest model level

INPUT

Name of the variable	SURFEX	ARPEGE
Zonal wind (m/s)	XU	PU(1,KLEV)
Meridian wind (m/s)	XV	PV(1,KLEV)
Temperature (K)	XTA	PT(1,KLEV)
Pressure (Pa)	XPA	PAPRSF(1,KLEV)
Density (Kg/m3)	XRHOA	XPA / XTA / PR(1,KLEV)
Specific humidity (kg/m3)	XQA	PQ(1,KLEV) * XRHOA
Liquid precipitation rate (Kg2/m/s)	XRAIN	0.
Solid precipitation rate (Kg/m2/s)	XSNOW	0.
Downward longwave radiation (W/m2)	XLW	PFRTHDS(1) / PEMIS(1)
Downward diffuse solar radiation (W/m2)	XSCA_SW	PFRSO(1,KLEV) / (1.-PALB(1)) * PFRSOPS(1) / (PFRSODS(1) + PFRSOPS(1))
Downward direct solar radiation (W/m2)	XDIR_SW	PFRSO(1,KLEV) / (1.-PALB(1)) * PFRSODS(1) / (PFRSODS(1) + PFRSOPS(1))

3. Tri-diagonal matrix substitution coefficients

INPUT

Name of the variable	SURFEX	ARPEGE
A_u	XPEW_A_COEF	PCFAU(1,KLEV)
A_theta	XPET_A_COEF	PCFATH(1,KLEV)
A_q	XPEQ_A_COEF	PCFAQ(1,KLEV)
B_u	XPEW_B_COEF	SQRT(PCFBU(1,KLEV)**2+PCFBV(1,KLEV)**2)
B_theta	XPET_B_COEF	PCFBTH(1,KLEV)
B_q	XPEQ_B_COEF	PCFBQ(1,KLEV) * XRHOA

Only one coefficient for wind since surface treats wind speed and not u and v components.

Not a problem if atmospheric and surface grids are the same

call to SURFEX module

OUTPUT

Name of the variable	SURFEX	ARPEGE
Latent heat flux (W/m2)	XSFTQ	PFEV = - XSFTQ
Sensible heat flux (Kg/m2/s)	XSFTH	PFCS = - XSFTH
Zonal momentum flux (m/s)	XSFU	PFMDU = XSFU
Meridian momentum flux (m/s)	XSFV	PFMDV = XSFV
Radiative temperature (K)	XTSRAD	PTSN = XTSRAD
Direct albedo for each band	XDIR_ALB	
Diffuse albedo for each band	XSCA_ALB	PALB = (XDIR_ALB + XSCA_ALB) / 2.
Emissivity	XEMIS	PEMIS = XEMIS

Eurocs case study using SURFEX in off-line mode within 1D Arpege-Climat model

[P. Le Moigne and E. Martin, May 2005]

First run in **off-line** mode using **implicit** formulations with the following options:

•ISBA FR 2L for both LSS

•Surface parameters are derived from ECOCLIMAP (integrated in SURFEX) and imposed in Arpege initial file:

- percentage of sand and clay, soil depth
- fraction of vegetation, LAI, minimal stomatal resistance, roughness length
- albedo, emissivity

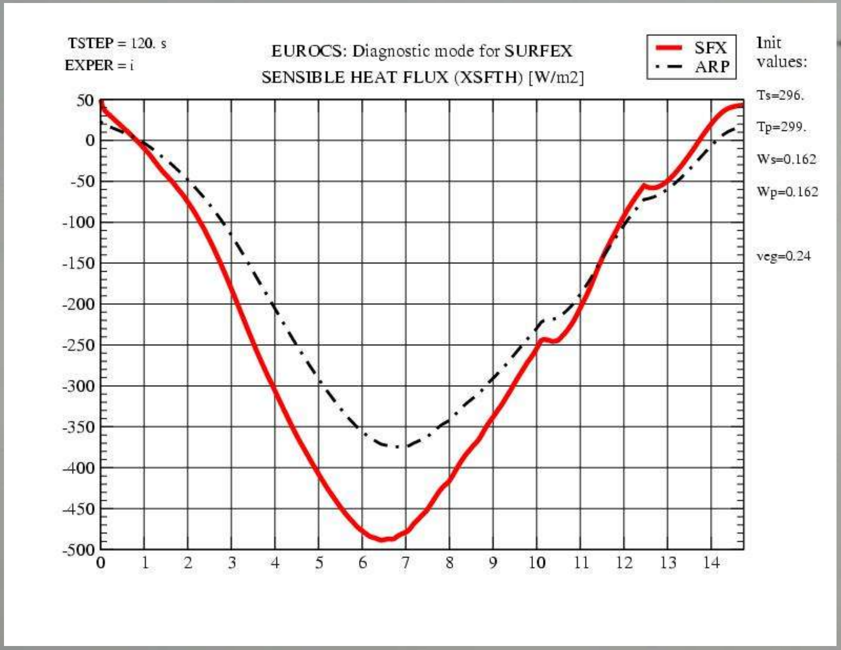
thermal conductivities for soil and vegetation (C_G and C_V) and orography are imposed

Eurocs case study using SURFEX in off-line mode within 1D Arpege-Climat model

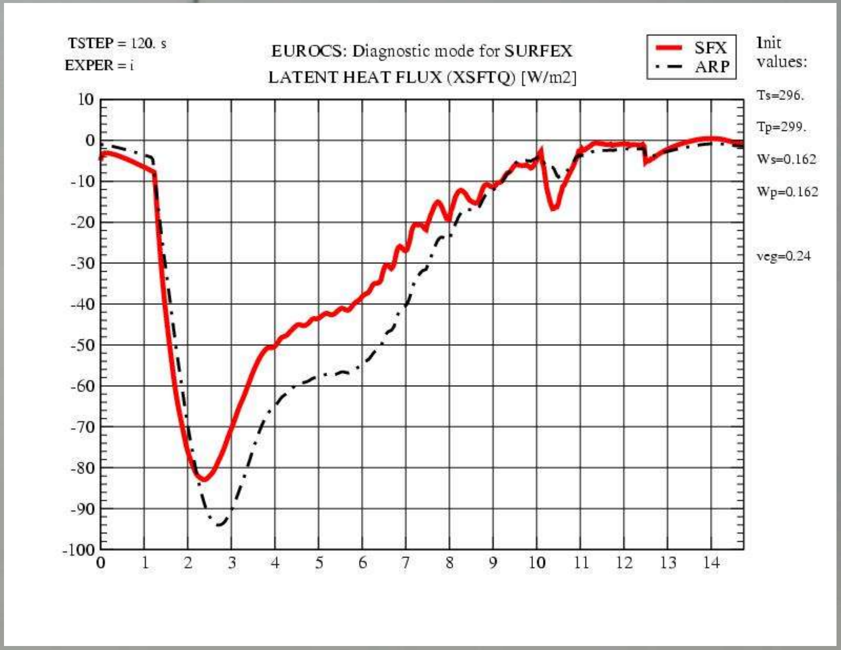
[P. Le Moigne and E. Martin, May 2005]

ΔH_{MAX} ~ 120 W/m2

ΔLE_{MAX} ~ 15 W/m2



H



LE

Several possibilities to explain these differences:

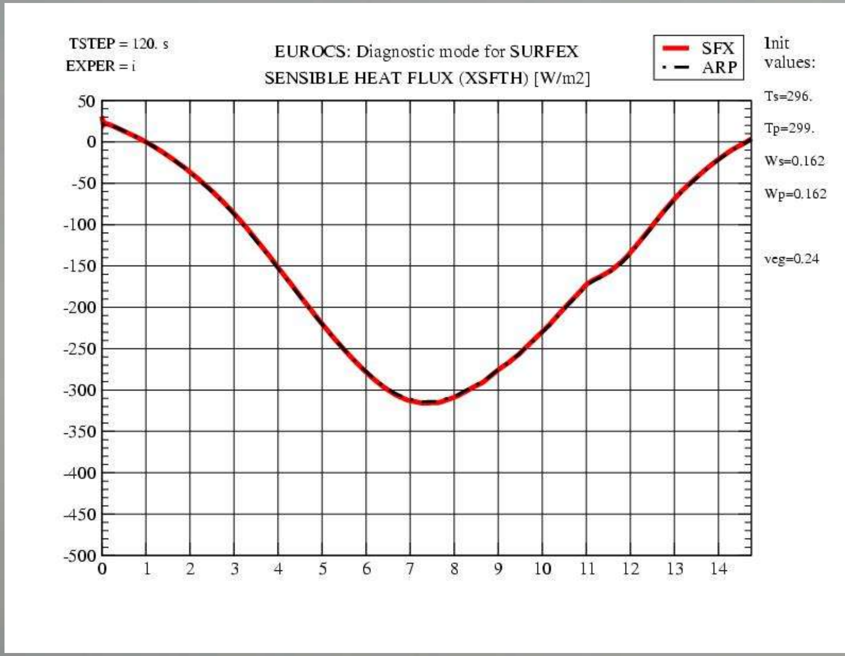
- Ch, Cd, Cdn: exchange coefficients are not the same between atmosphere and surface
- L: latent heat is kept constant in SURFEX while it should depend on T as in Arpege
- Cp: specific heat doesn't depend on q in SURFEX

1. Ch, Cd and Cdn are imposed in achmtls and in drag
2. L becomes constant
3. Dependancy on q is eliminated for Cp (accoefk, acdifv2, achmtls and ls_acbileng)

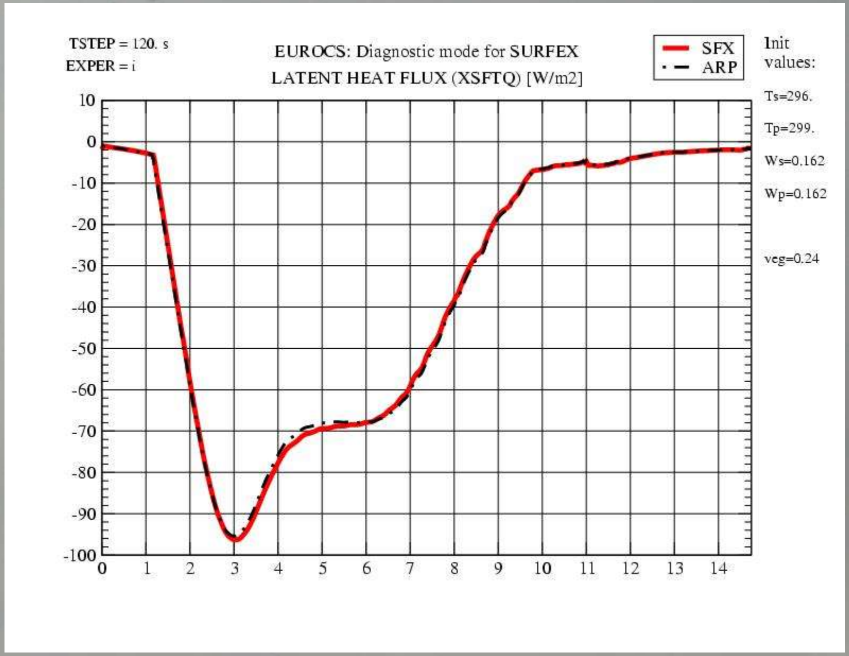
Eurocs case study using SURFEX in off-line mode within 1D Arpege-Climat model

[P. Le Moigne and E. Martin, May 2005]

Second try: $\Delta H < 1$ W/m2, $\Delta LE < 2$ W/m2, $\Delta Ts < 0.4$ K

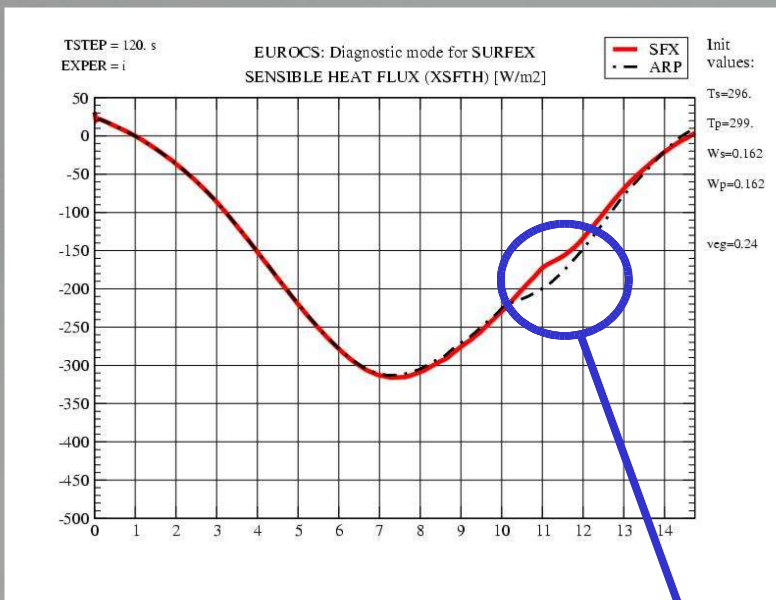


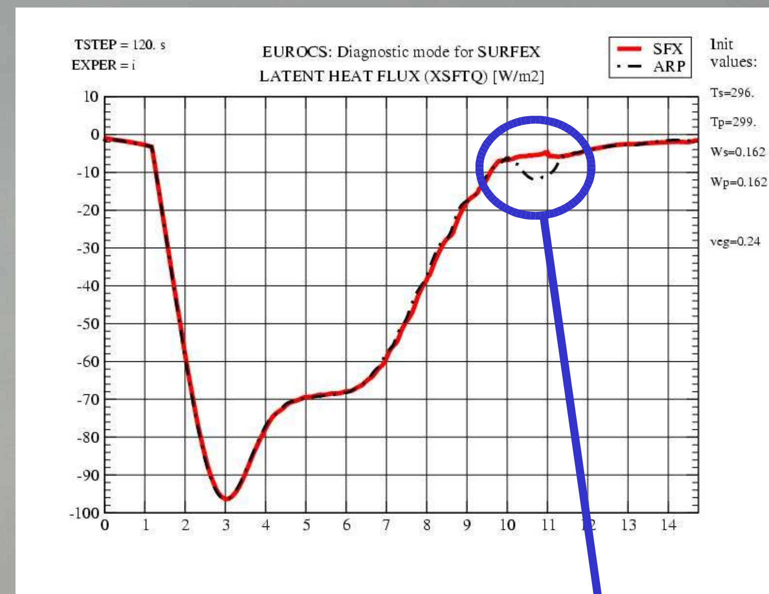
H



LE

Influence of difference of Cp between Arpege and SURFEX: Exchange coefficients and L are kept constant





H 20 W/m2

LE 5 W/m2

One way to cure this problem could be to have an explicit dependance on q for C_p

CONCLUSION / PERSPECTIVES

- 1D Arpege model is good tool to start studying the coupling between atmosphere and surface
- Surfex is able to reproduce correctly the turbulent fluxes, temperature and soil water content under certain conditions in forced mode
- There are potential problems linked to Cp, L, Ch (if they are not imposed, fluxes are different (not for L in this test))

CONCLUSION / PERSPECTIVES

- Consistency between SURFEX and existing Arpege LSS
  - Possibility to introduce the dependancy on q for Cp in surfex
  - Possibility to take into account the dependancy on T for latent heat in surfex
  - Study more carefully the Ch formulation
  - …
- Flow of information between SURFEX and Arpege
  - albedo (direct and diffuse) and emissivity are computed in surfex and Arpege radiation scheme should take them into account
  - Initialization of surface fields, I/O, …
  - …
- Start the work of **on-line implicit** coupling between Arpege and surfex (interaction atmosphere /surface)