SURFEX in the climate group:

Off-line global applications
&
CNRM Earth System Model

Bertrand Decharme

Off-line global experiments

- **<u>Especially relevant to evaluate :</u>**
  - Meso-scale parameterizations from GMME
    - Hydrology
    - Snow (simple or multi-layer explicit)
    - ISBA-Ags (interactive vegetation with photosynthesis)
    - ....
  - Global parameterizations from GMGEC
    - Sub-grid hydrology
    - TRIP river routing model
    - Continental carbon cycle

- **<u>Other applications</u>**
  - Runoff/Discharge trends over the past and the future
  - Hydrological impacts of global warming
 - ....

Offline experiment design : Configuration – ISBA 3-L

Plant transpiration (E_{tr})

Canopy direct evaporation (E_c)

W_r

Soil freezing sublimation (E_{gf})

Sublimation (E_s)

Canopy dripping (R_r)

Surface runoff (Q_s)

Bare soil evaporation (E_g)

Fonte (S_m)

W_n

Soil freezing

Rooting depth (d_2)

Infiltration

Diffusion

Total soil depth (d_3)

Diffusion & drainage

Deep drainage
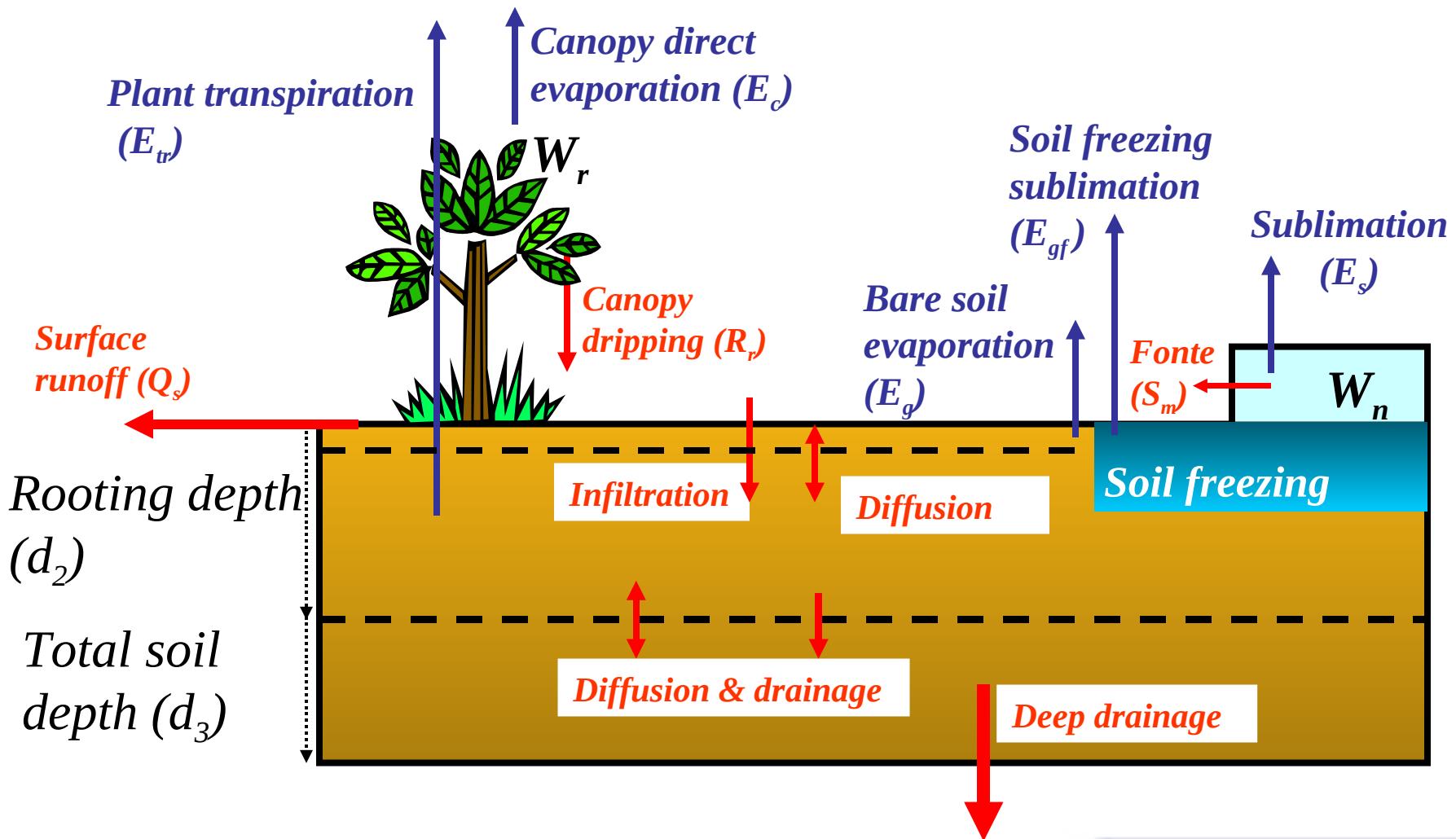
Noilhan and Planton 1989; Douville et al. 1995; Mahfouf and Noilhan 1996; Boone et al. 1999; Boone et al. 2000

Offline experiment design : Sub-Grid Hydrology

Spatial variability of hydrologic processes :

- *Precipitation*
- *Topography (TOPMODEL)*
- *Soil properties*
- *Vegetation (Tiles)*

Exponential profile of k_{sat} with soil depth

ISBA grid cell
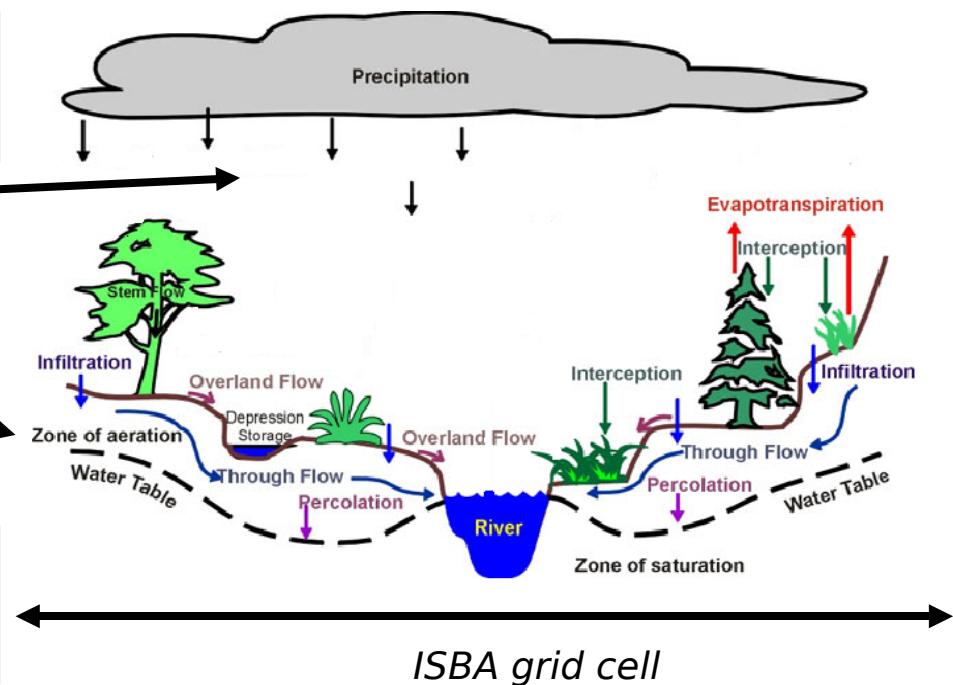
Details will be given this afternoon during specific talk about ISBA

Decharme et al. 2006 ; Decharme et Douville 2006

Offline experiment design

USER

Atmospheric forcing:

Princeton Univ. + GPCC

3-hr, 1°

SURFEX

Offline experiment: Atmospheric forcing
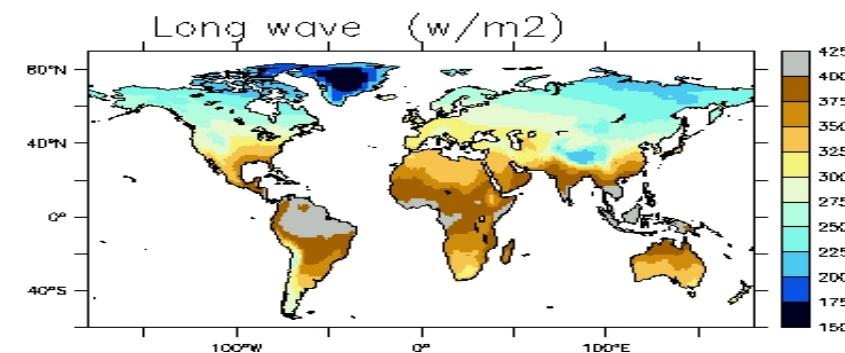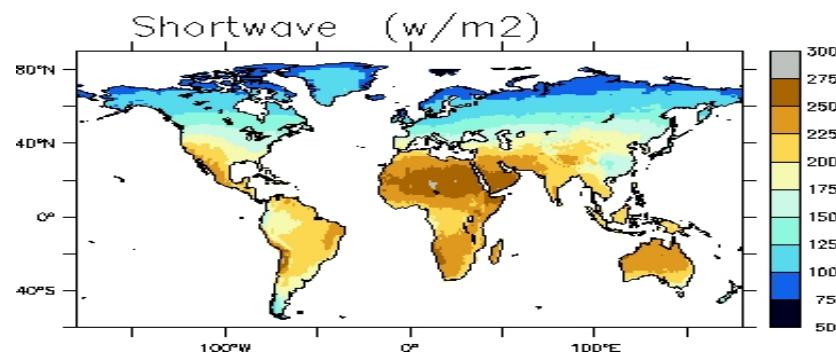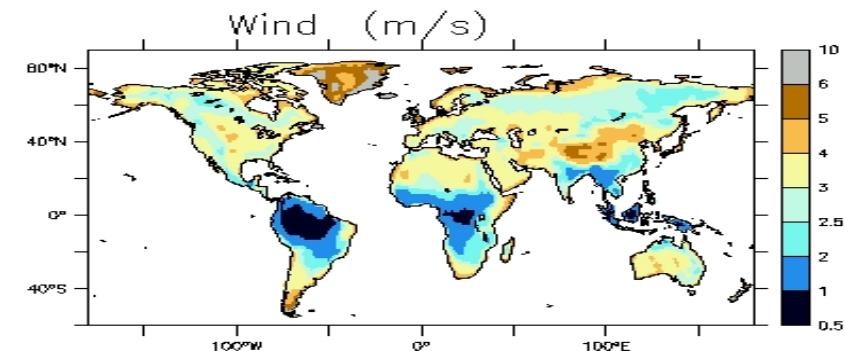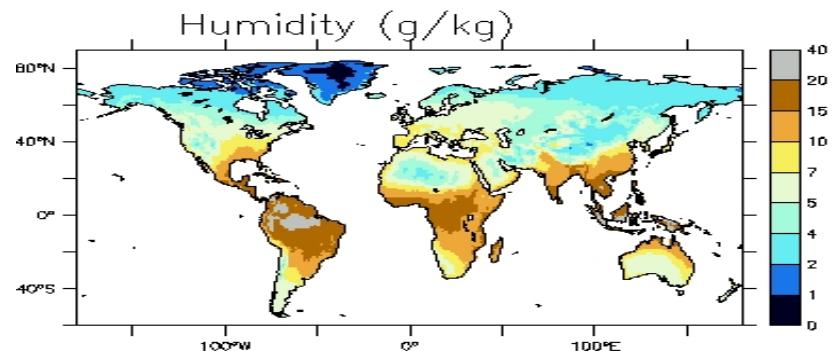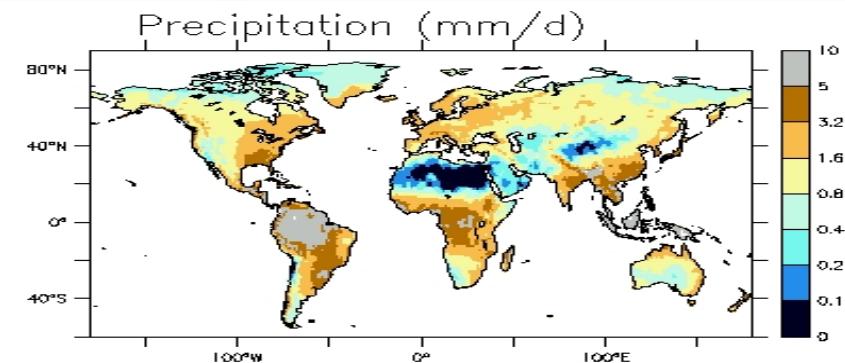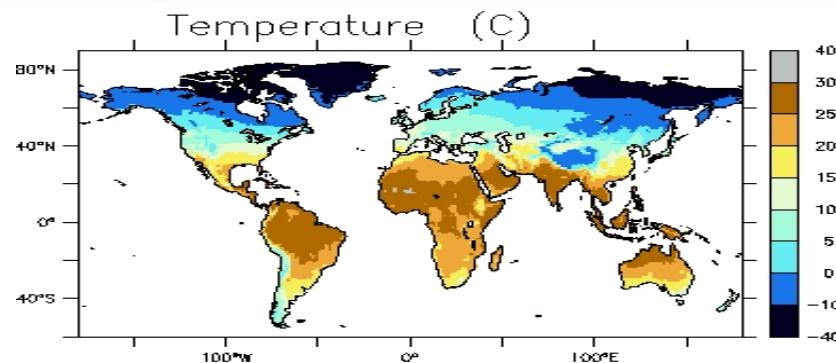
1986-2006 Average *(Princeton University)*

Offline experiment design

USER
Atmospheric forcing:
Princeton Univ. + GPCC
3-hr, 1°

PGD.exe
Sol and vegetation
parameters → **1°**
ECOCLIMAP 1km

SURFEX

Offline experiment design : __PGD.exe__

```
&NAM_FRAC              LECOCLIMAP = T          ←  .TRUE.=Use of ECOCLIMAP
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&NAM_PGD_GRID          CGRID = 'LONLAT REG'
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                       XLATMAX =   90.    ,
                       NLON    =  360     ,
                       NLAT    =  150
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                       CTOWN   = 'NONE '  ,
                       CWATER  = 'NONE '
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                        LTOWN_TO_ROCK    = T
/
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                       YFILETYPE    = 'DIRECT'        ,
                       XRM_COVER    = 0.01            ,
                       XRM_COAST    = 0.6
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                       YCLAYFILETYPE = 'DIRECT'        ,
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                       YCTIFILETYPE  = 'DIRECT'        ,
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/
&NAM_IO_OFFLINE        CSURF_FILETYPE      = 'FA   ',
                       CTIMESERIES_FILETYPE = 'FA   '
/
```

Model used (here only ISBA)

Arrange the covers:
- Marshes in vegetation type
- Town cover in Rock

1km ECOCLIMAP file to be read
- Remove covers < grid cell fraction XRM_COVER
- Remove inland coast < grid cell fraction XRM_COAST

Offline experiment design : <u>PGD.exe</u>

```
&NAM_FRAC              LECOCLIMAP = T          ◄──────  .TRUE.=Use of ECOCLIMAP
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                       XLATMIN =  -60.    ,          Grid configuration
                       XLATMAX =   90.    ,
                       NLON    =  360     ,
                       NLAT    =  150
/
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                       CSEA    = 'NONE  '  ,
                       CTOWN   = 'NONE  '  ,
                       CWATER  = 'NONE  '
/
&NAM_PGD_ARRANGE_COVER  LWATER_TO_NATURE = T ,
                        LTOWN_TO_ROCK    = T
/
&NAM_COVER             YCOVER       = 'ecoclimats_v2' ,
                       YFILETYPE    = 'DIRECT'   ,
                       XRM_COVER    = 0.01       ,
                       XRM_COAST    = 0.6
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&NAM_ZS                YZS          = 'gtopo30'     ,
                       YFILETYPE    = 'DIRECT'
/
&NAM_ISBA              YCLAY           = 'clay_fao'   ,
                       YCLAYFILETYPE = 'DIRECT'    ,
                       YSAND           = 'sand_fao'   ,
                       YSANDFILETYPE = 'DIRECT'    ,
                       YCTI            = 'topo_index' ,
                       YCTIFILETYPE  = 'DIRECT'    ,
                       XUNIF_WDRAIN  = 0.0005     ,
                       CISBA           = '3-L'       ,
                       NGROUND_LAYER = 3          ,
                       NPATCH          = 12
/
&NAM_IO_OFFLINE        CSURF_FILETYPE      = 'FA   ',
                       CTIMESERIES_FILETYPE = 'FA   '
/
```

Model used (here only ISBA)

Arrange the covers:
- Marshes in vegetation type
- Town cover in Rock

1km ECOCLIMAP file to be read
- Remove covers < grid cell fraction XRM_COVER
- Remove inland coast < grid cell fraction XRM_COAST

1km GTOPO file to be read

Offline experiment design : **PGD.exe**

1° continental topography from GTOPO30 **METEO FRANCE**

Offline experiment design : <u>PGD.exe</u>

```
&NAM_FRAC              LECOCLIMAP = T          ⟵  .TRUE.=Use of ECOCLIMAP
/
&NAM_PGD_GRID          CGRID = 'LONLAT REG'
/
&NAM_LONLAT_REG        XLONMIN = -180.    ,
                       XLONMAX =  180.    ,        Grid configuration
                       XLATMIN =  -60.    ,
                       XLATMAX =   90.    ,
                       NLON    =  360     ,
                       NLAT    =  150
/
&NAM_PGD_SCHEMES       CNATURE = 'ISBA  '  ,       Model used (here only ISBA)
                       CSEA    = 'NONE  '  ,
                       CTOWN   = 'NONE  '  ,
                       CWATER  = 'NONE  '
/
&NAM_PGD_ARRANGE_COVER LWATER_TO_NATURE = T ,      Arrange the covers:    •Marshes in vegetation type
                       LTOWN_TO_ROCK    = T                               •Town cover in Rock
/
&NAM_COVER             YCOVER          = 'ecoclimats_v2' ,   1km ECOCLIMAP file to be read
                       YFILETYPE       = 'DIRECT'    ,       •Remove covers < grid cell fraction XRM_COVER
                       XRM_COVER       = 0.01        ,       •Remove inland coast < grid cell fraction XRM_COAST
                       XRM_COAST       = 0.6
/
&NAM_ZS                YZS             = 'gtopo30'    ,       1km GTOPO file to be read
                       YFILETYPE       = 'DIRECT'
/
&NAM_ISBA              YCLAY           = 'clay_fao'   ,
                       YCLAYFILETYPE   = 'DIRECT'     ,
                       YSAND           = 'sand_fao'   ,       10km FAO (soil texture) file to be read
                       YSANDFILETYPE   = 'DIRECT'     ,
                       YCTI            = 'topo_index' ,
                       YCTIFILETYPE    = 'DIRECT'     ,
                       XUNIF_WDRAIN    = 0.0005       ,
                       CISBA           = '3-L'        ,
                       NGROUND_LAYER   = 3            ,
                       NPATCH          = 12
/
&NAM_IO_OFFLINE        CSURF_FILETYPE      = 'FA'  ,
                       CTIMESERIES_FILETYPE = 'FA'
/
```

Offline experiment design : __PGD.exe__

sand

Min 0.154733   Max 0.92

Clay

Min 0.03   Max 0.58

Not know so SURFEX performs an interpolation (Nearest grid points)

1° sand and clay fractions from FAO

Offline experiment design : __PGD.exe__

```
&NAM_FRAC                 LECOCLIMAP = T          ◄──── .TRUE.=Use of ECOCLIMAP
/
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                          XLONMAX =  180.    ,
                          XLATMIN =  -60.    ,         Grid configuration
                          XLATMAX =   90.    ,
                          NLON    =  360     ,
                          NLAT    =  150
/
&NAM_PGD_SCHEMES          CNATURE = 'ISBA '  ,
                          CSEA    = 'NONE '  ,
                          CTOWN   = 'NONE '  ,
                          CWATER  = 'NONE '
/
&NAM_PGD_ARRANGE_COVER    LWATER_TO_NATURE = T ,
                          LTOWN_TO_ROCK    = T
/
&NAM_COVER                YCOVER      = 'ecoclimats_v2' ,
                          YFILETYPE   = 'DIRECT'    ,
                          XRM_COVER   = 0.01        ,
                          XRM_COAST   = 0.6
/
&NAM_ZS                   YZS         = 'gtopo30'   ,
                          YFILETYPE   = 'DIRECT'
/
&NAM_ISBA                 YCLAY          = 'clay_fao'   ,
                          YCLAYFILETYPE  = 'DIRECT'     ,
                          YSAND          = 'sand_fao'   ,
                          YSANDFILETYPE  = 'DIRECT'     ,
                          YCTI           = 'topo_index' ,
                          YCTIFILETYPE   = 'DIRECT'     ,
                          XUNIF_WDRAIN   = 0.0005       ,
                          CISBA          = '3-L'        ,
                          NGROUND_LAYER  = 3            ,
                          NPATCH         = 12
/
&NAM_IO_OFFLINE           CSURF_FILETYPE      = 'FA   ',
                          CTIMESERIES_FILETYPE = 'FA   '
/
```

Model used (here only ISBA)

Arrange the covers:
- Marshes in vegetation type
- Town cover in Rock

1km ECOCLIMAP file to be read
- Remove covers < grid cell fraction XRM_COVER
- Remove inland coast < grid cell fraction XRM_COAST

1km GTOPO file to be read

10km FAO (soil texture) file to be read

1km Topo indexes (TOPMODEL)

Offline experiment design : PGD.exe

In ISBA, the TOPMODEL based approach used Topo index statistics (*min, max, mean, std and skewness*) to simulate surface runoff in each 1° grid-cells.

Min 16.37   Max 32.89
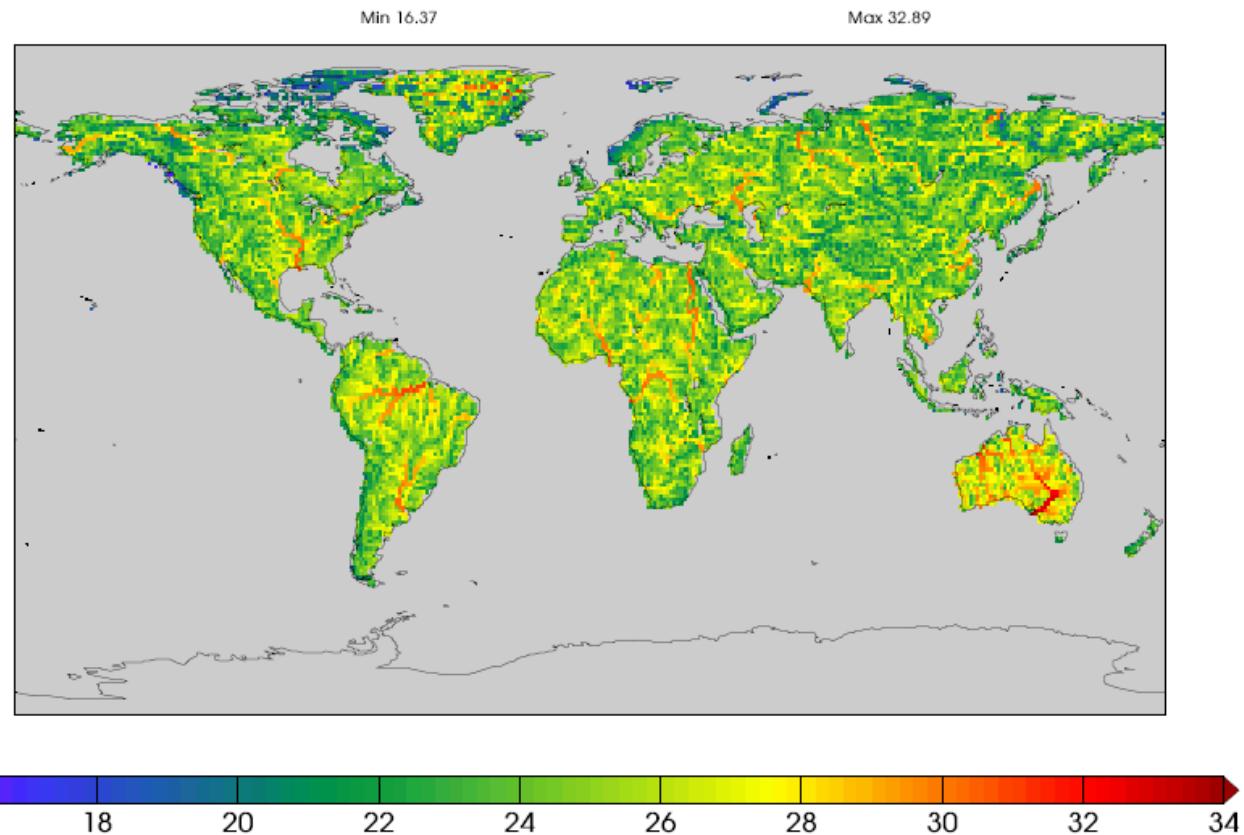
1° Topo index (max) used by TOPMODEL

Offline experiment design : <u>PGD.exe</u>

```
&NAM_FRAC              LECOCLIMAP = T        ← .TRUE.=Use of ECOCLIMAP
/
&NAM_PGD_GRID          CGRID = 'LONLAT REG'
/
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                       XLONMAX =  180.    ,
                       XLATMIN =  -60.    ,  ← Grid configuration
                       XLATMAX =   90.    ,
                       NLON    =  360     ,
                       NLAT    =  150
/
&NAM_PGD_SCHEMES       CNATURE = 'ISBA  ' ,
                       CSEA    = 'NONE  ' ,
                       CTOWN   = 'NONE  ' ,
                       CWATER  = 'NONE  '
/
&NAM_PGD_ARRANGE_COVER LWATER_TO_NATURE = T ,
                       LTOWN_TO_ROCK    = T
/
&NAM_COVER             YCOVER       = 'ecoclimats_v2' ,
                       YFILETYPE    = 'DIRECT'    ,
                       XRM_COVER    = 0.01        ,
                       XRM_COAST    = 0.6
/
&NAM_ZS                YZS          = 'gtopo30'   ,
                       YFILETYPE    = 'DIRECT'
/
&NAM_ISBA              YCLAY          = 'clay_fao'   ,
                       YCLAYFILETYPE  = 'DIRECT'     ,
                       YSAND          = 'sand_fao'   ,
                       YSANDFILETYPE  = 'DIRECT'     ,
                       YCTI           = 'topo_index' ,
                       YCTIFILETYPE   = 'DIRECT'     ,
                       XUNIF_WDRAIN   = 0.0005       ,
                       CISBA          = '3-L'        ,
                       NGROUND_LAYER  = 3           ,
                       NPATCH         = 12
/
&NAM_IO_OFFLINE        CSURF_FILETYPE      = 'FA ' ,
                       CTIMESERIES_FILETYPE = 'FA '
/
```

Model used (here only ISBA)

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1km GTOPO file to be read

10km FAO (soil texture) file to be read

1km Topo indexes (TOPMODEL)

ISBA configuration

I/O Format

Offline experiment design

USER

<u>Atmospheric forcing:</u>

Princeton Univ. + GPCC

3-hr, 1°

SURFEX

PGD.exe

<u>Sol and vegetation</u>
<u>parameters</u> ➡ **1°**

ECOCLIMAP 1km

PREP.exe

<u>Initialization of prognostic variabl</u>

ARPEGE GRIB file ➡ **1°**
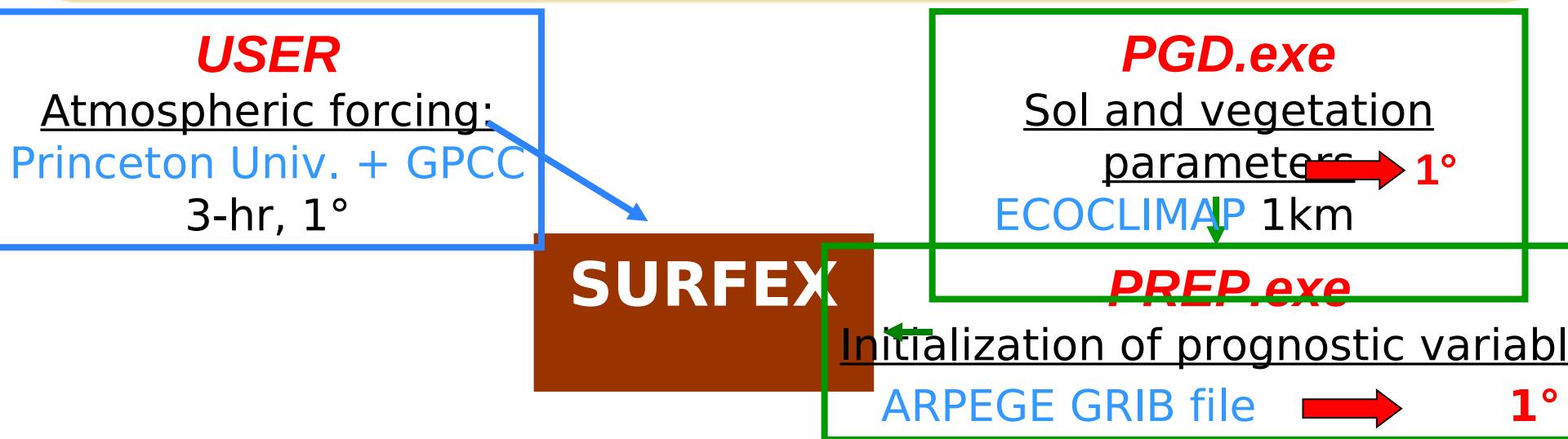
Offline experiment design : <u>PREP.exe</u>
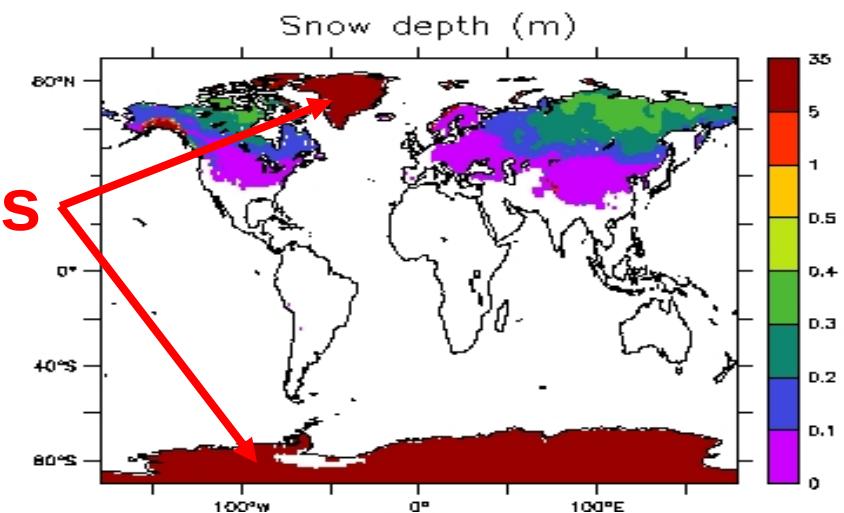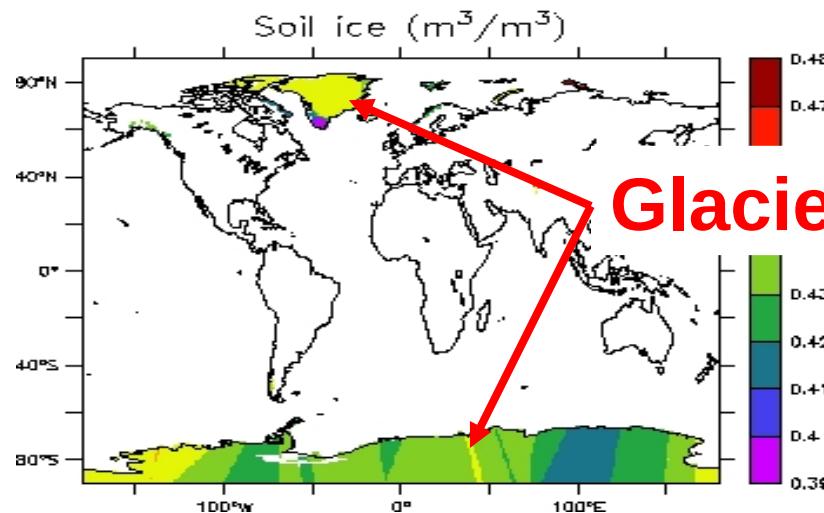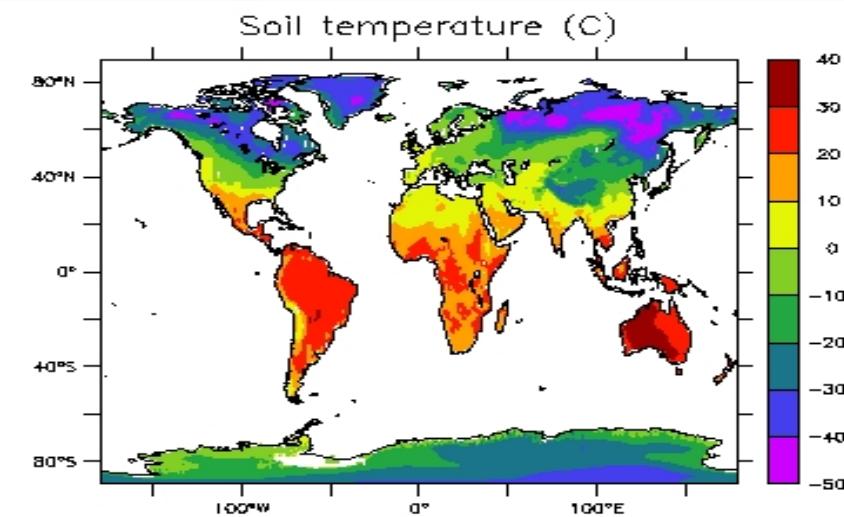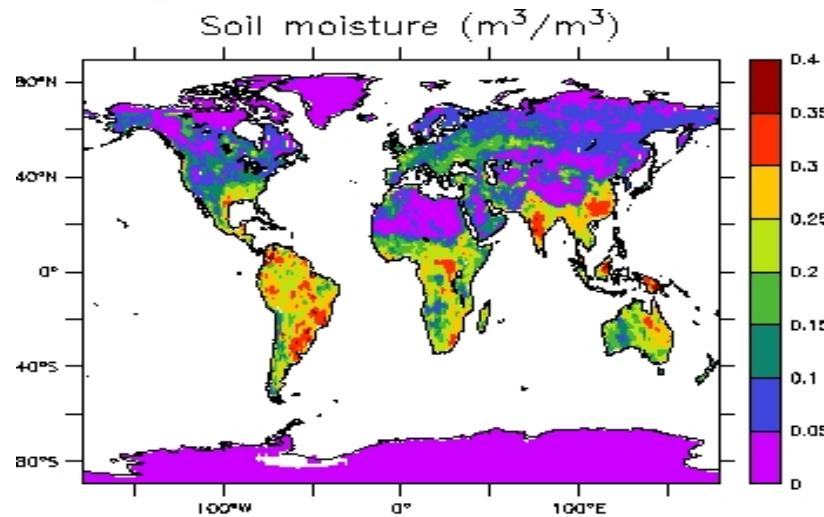
<u>1° prognostic variable</u>

Offline experiment design

USER
Atmospheric forcing:
Princeton Univ. + GPCC
3-hr, 1°

PGD.exe
Sol and vegetation parameters ➡ **1°**
ECOCLIMAP 1km

SURFEX

PREP.exe
Initialization of prognostic variabl
GRIB file ➡ **1°**

OFFLIN.exe

Runoff

Evaporation

Soil moisture, snow, free water climatology

TRIP
1° or 0.5°

GRACE observations

Discharge

in situ observations
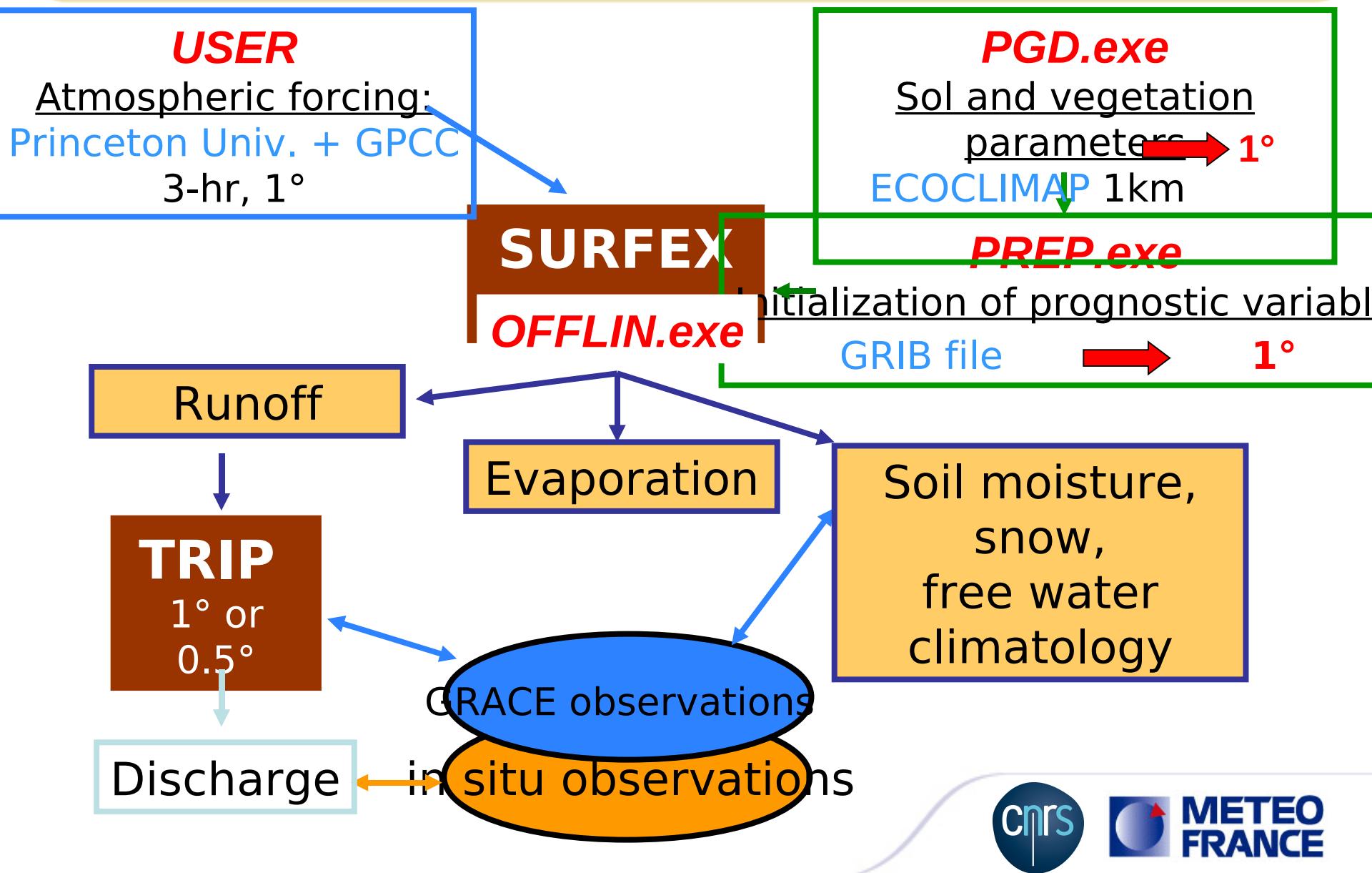
SURFEX-TRIP vs. GRACE : 2003-2006

Terrestrial Water Storage= soil moisture + snow + river + plant interception
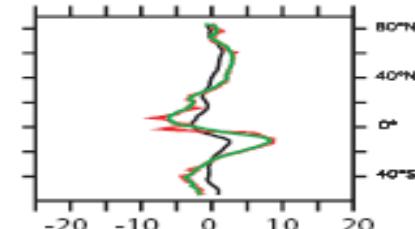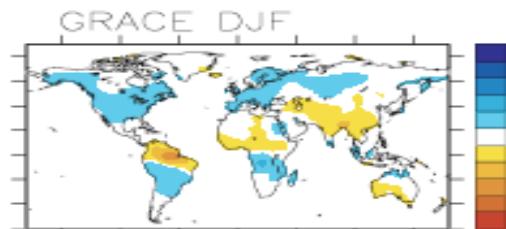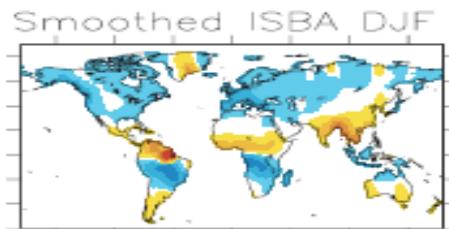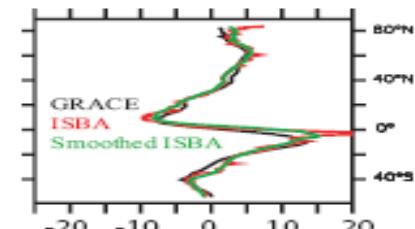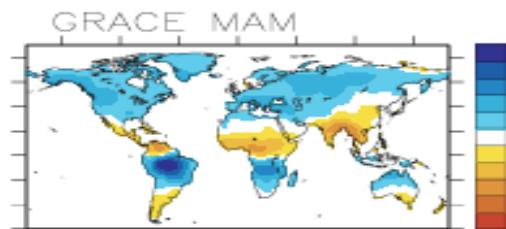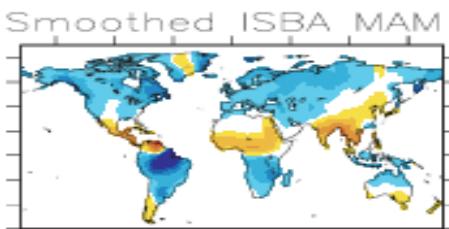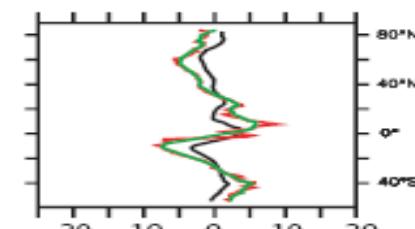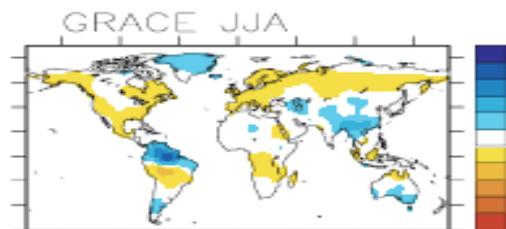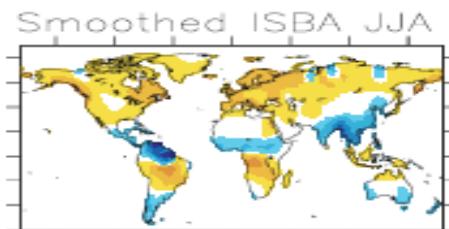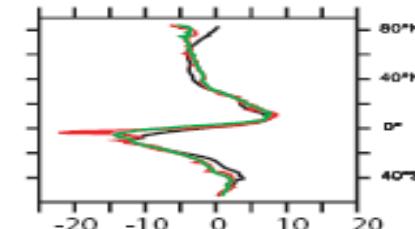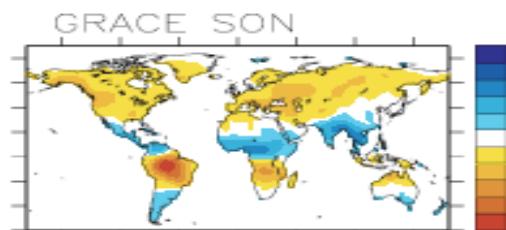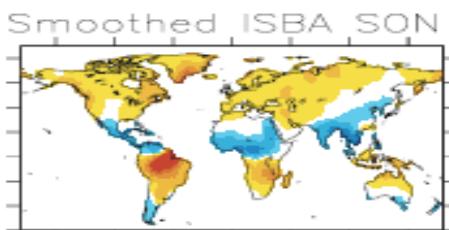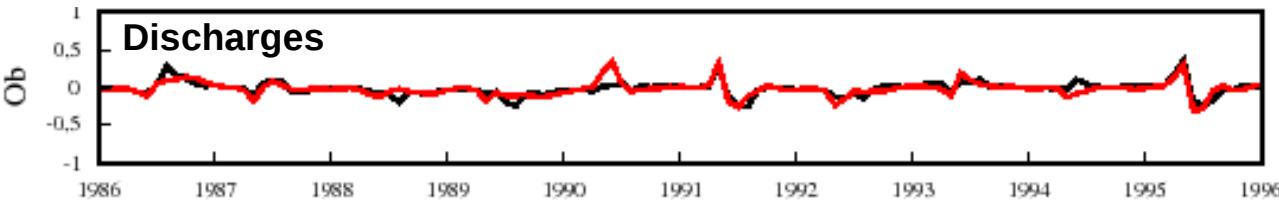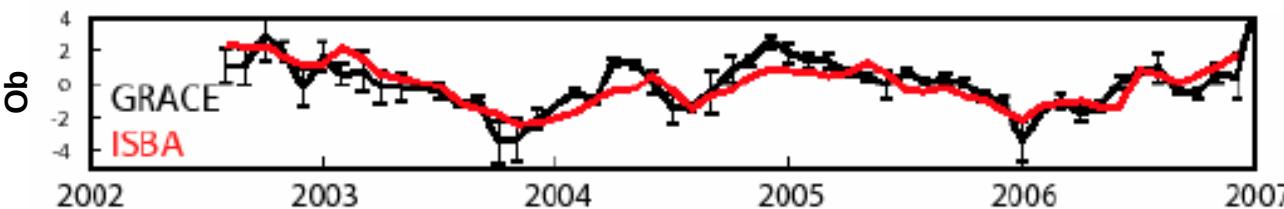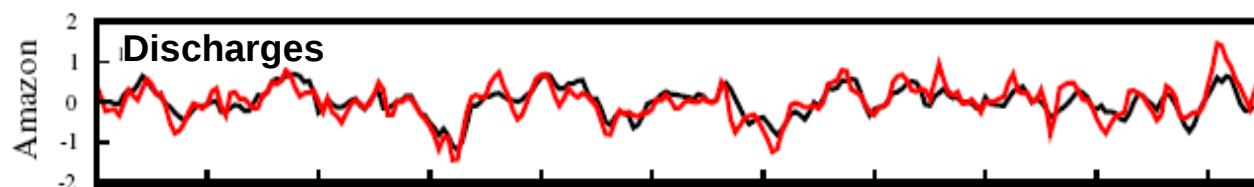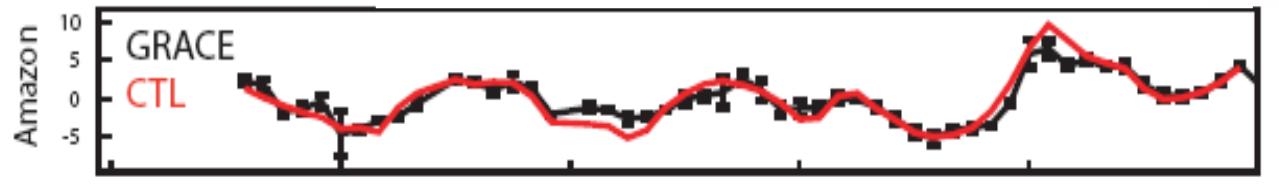
SURFEX-TRIP vs. GRACE and Discharges

Interannual variability   *Annual Cycle*
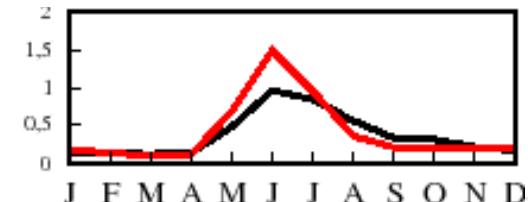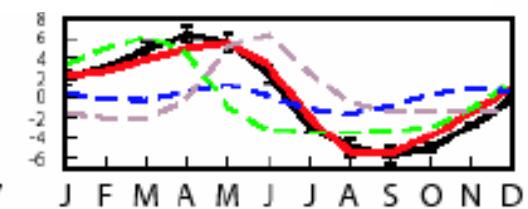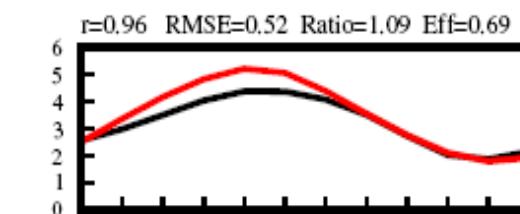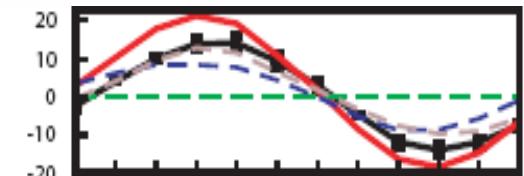
(Alkama et al. 2009, J. Hydromet, submitted)

SURFEX-TRIP vs. GRACE and Discharges
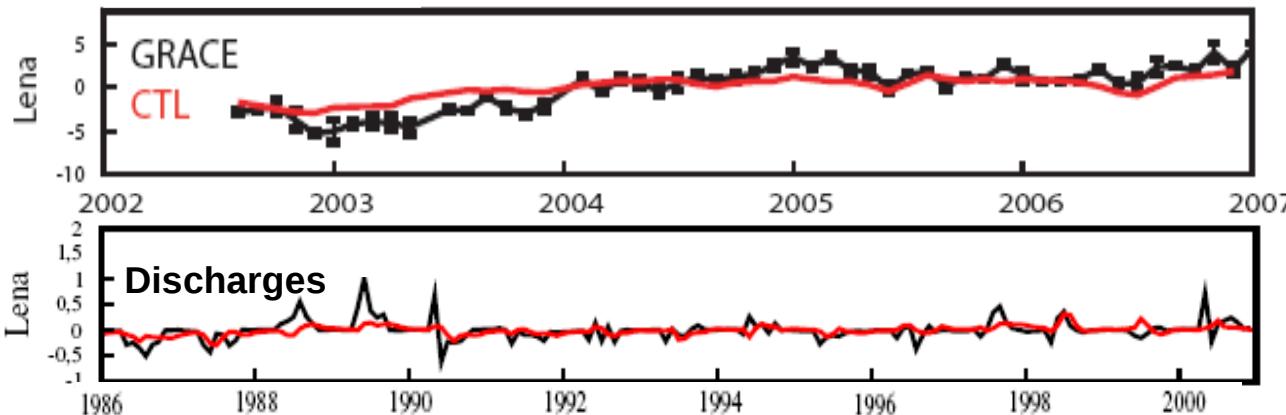
Interannual variability · *Annual Cycle*
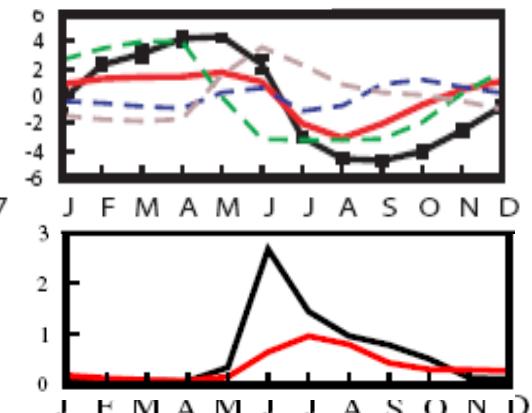
Variable flow velocity in TRIP (Manning formula)
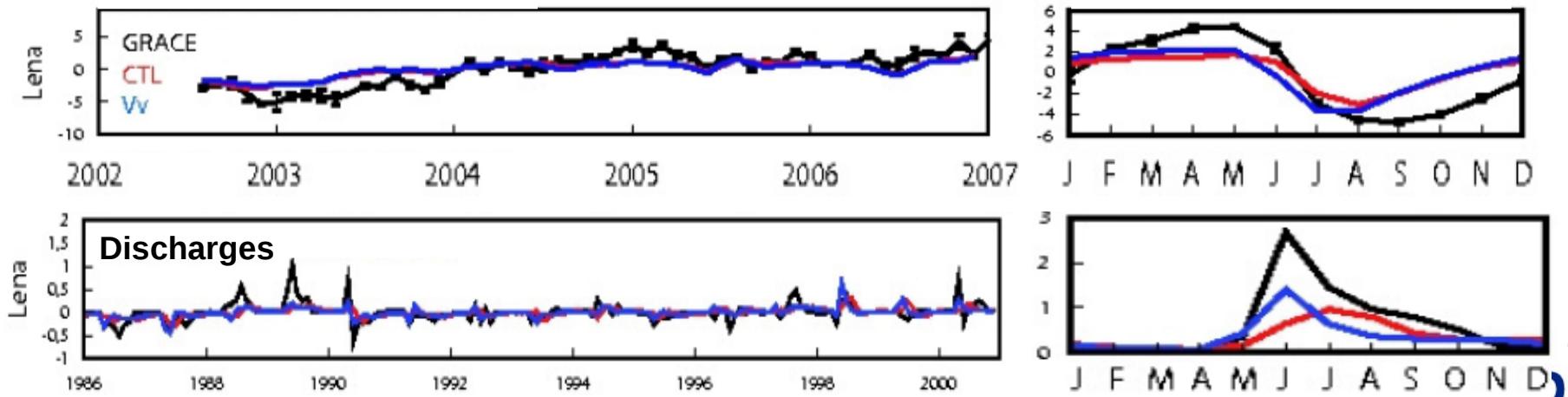
(Decharme et al. 2009, J. Hydromet, submitted)

Annual cycle of snow fractions
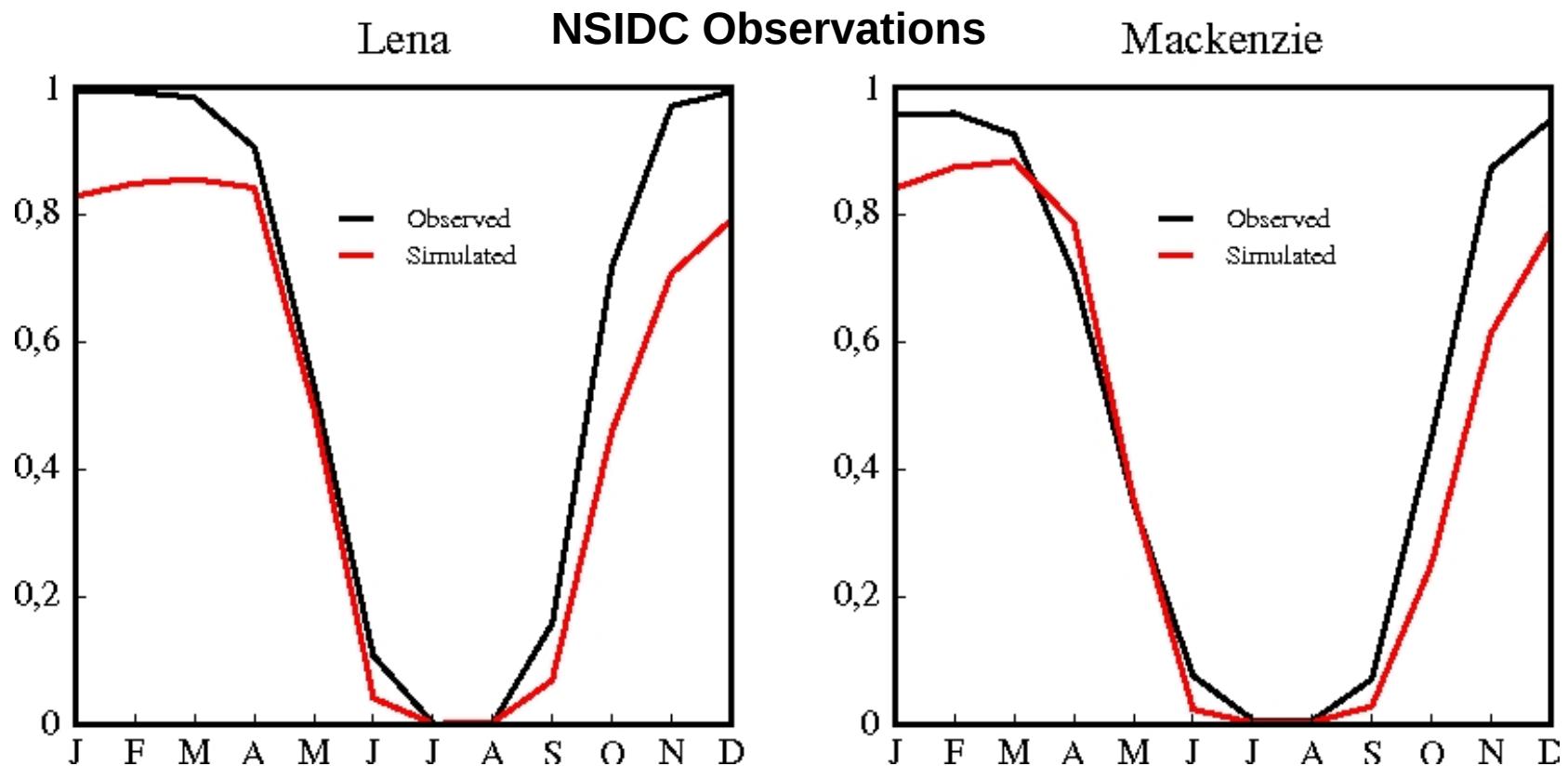
(Alkama et al. 2009, J. Hydromet, submitted)

Prospect

Prospect: Floodplains

Satellite-derived wetland estimates from Prigent et al. (2007, JGR).

ISBA-TRIP floodplains simulation

Difference
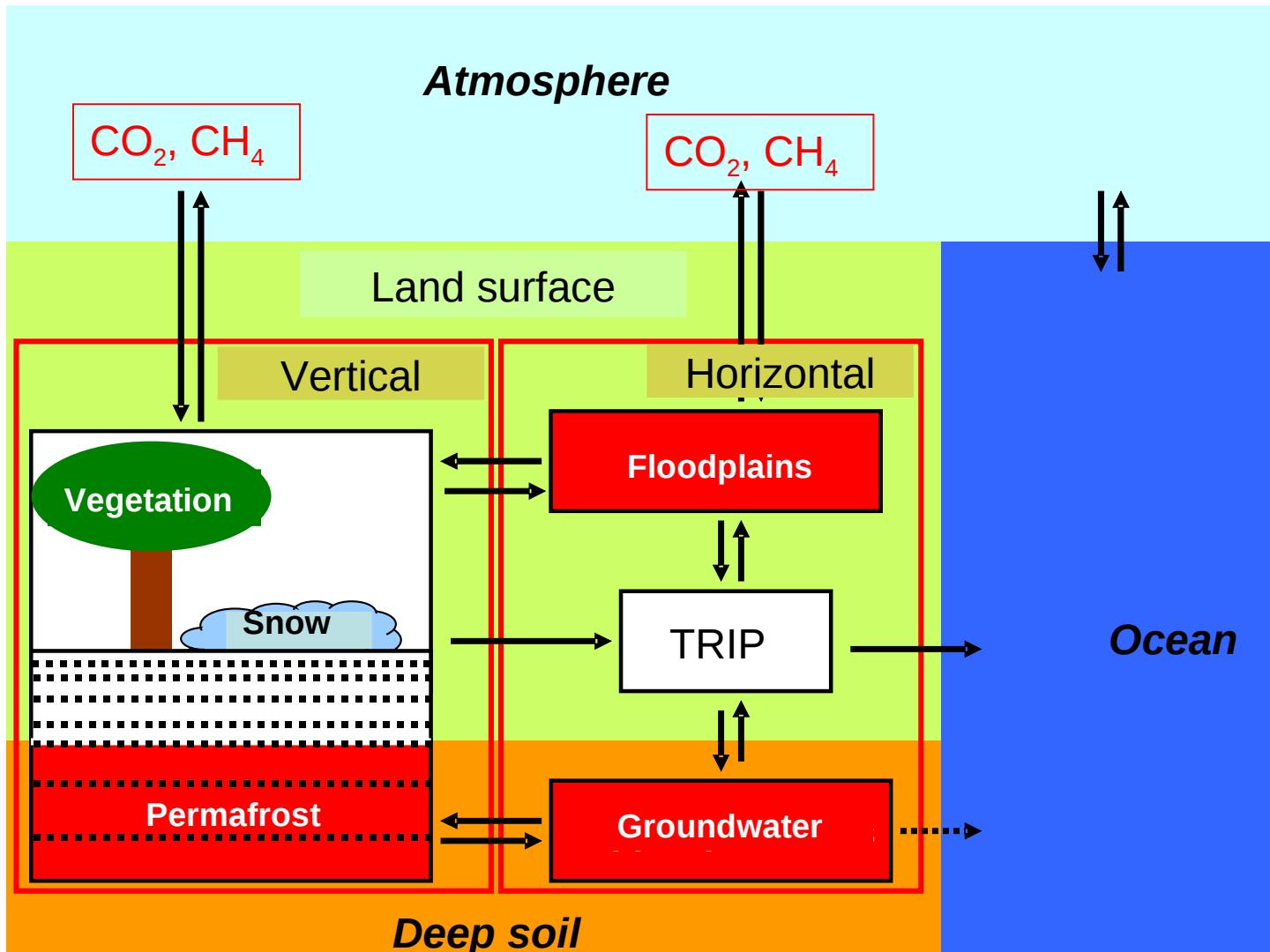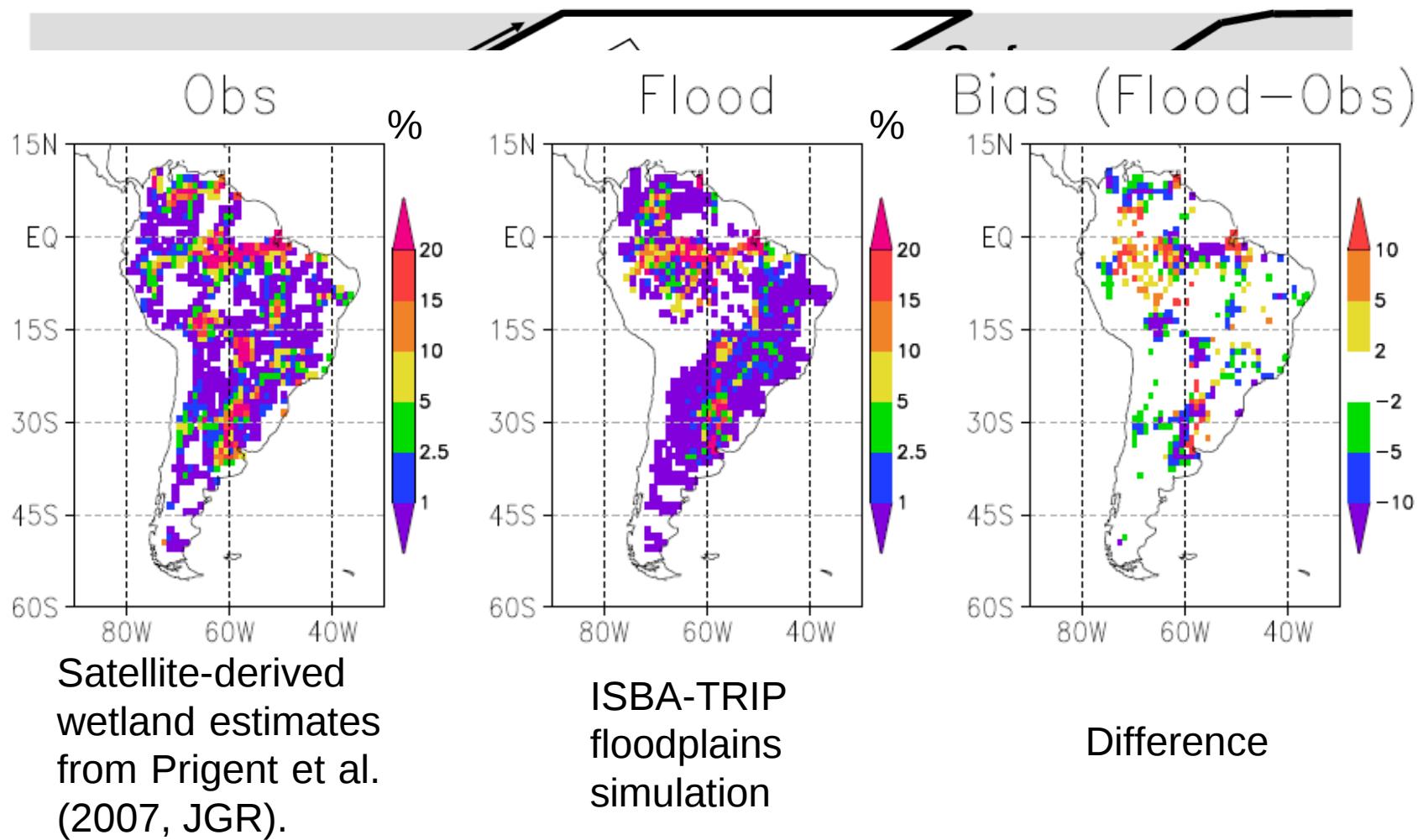
(Decharme et al. 2008, JGR, 113)

SURFEX in Earth System Model

ARPEGE V5 (T127 ~1.4°)

SURFEX V5 (T127 ~1.4°)

Coupling

OASIS

- **To SURFEX:**
  - Sea/ice fraction
  - SST (sea/ice)
  - Albedo ice
- **From SURFEX**
  - Fluxes (sea/ice)

- **From SURFEX**
  - Runoff
  - Drainage

TRIP (1°)

GELATO (1°)

NEMO (1°)

METEO FRANCE
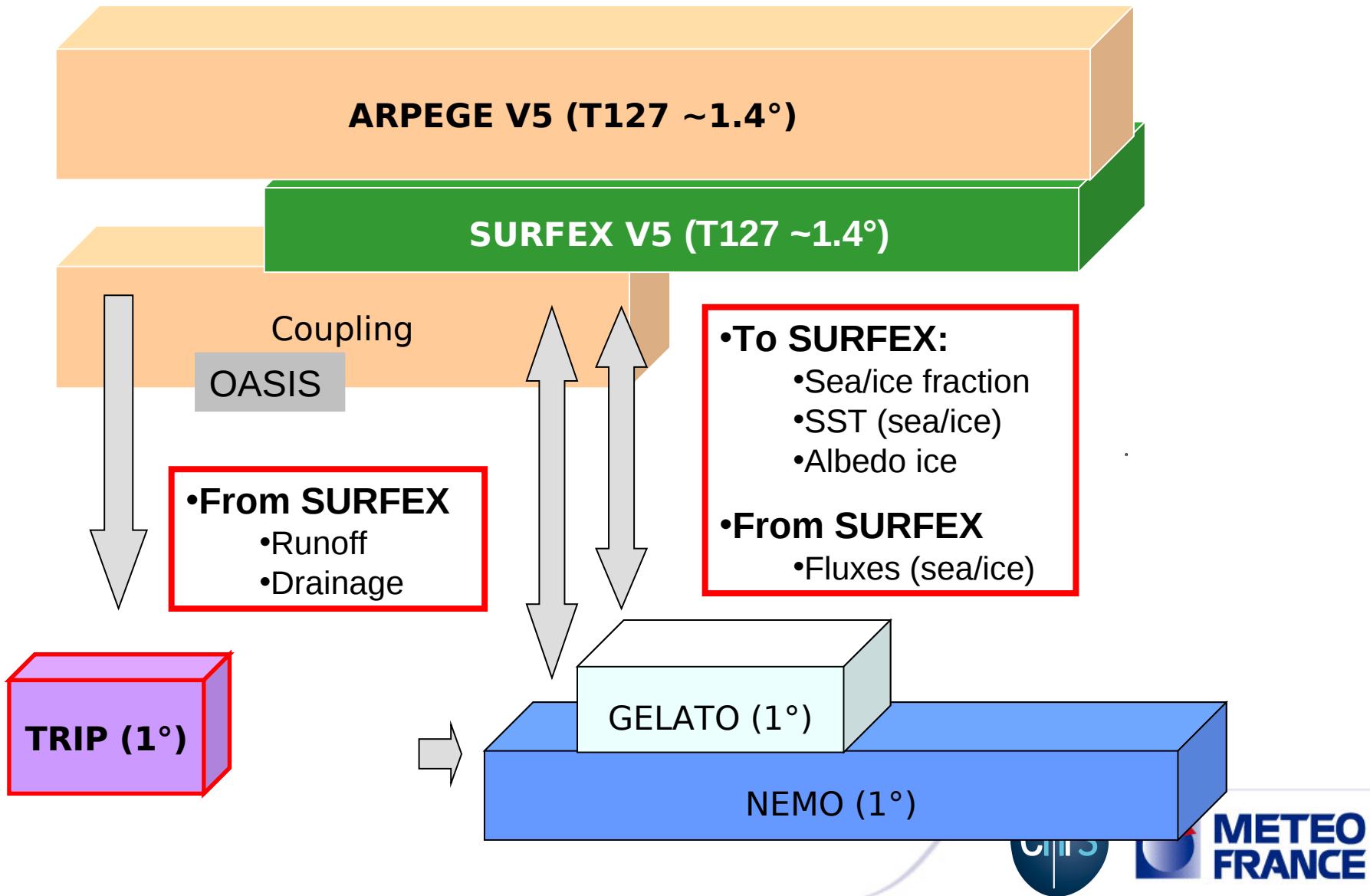
Test in SST (ERA-40) forced mode (1990-1999): 2m Air Temperature bias to CRU2

Without SURFEX
(Very simple ISBA)
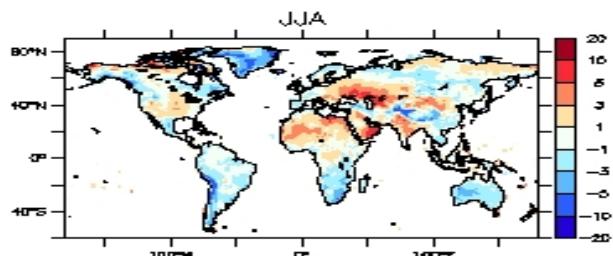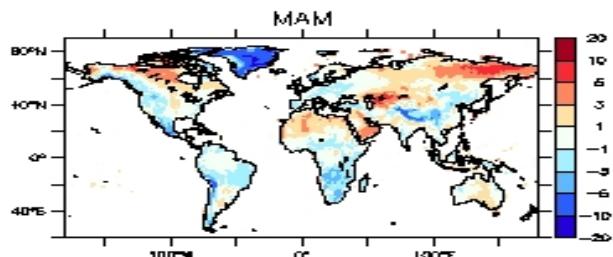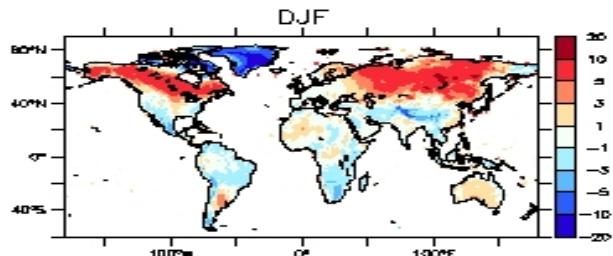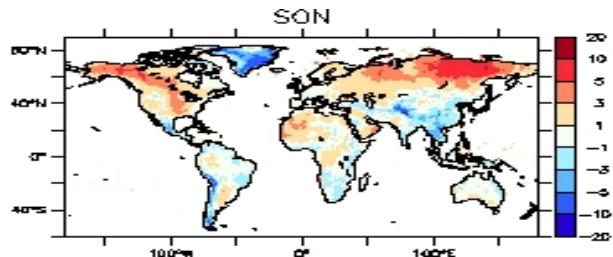
SURFEX but same
previous hydrology
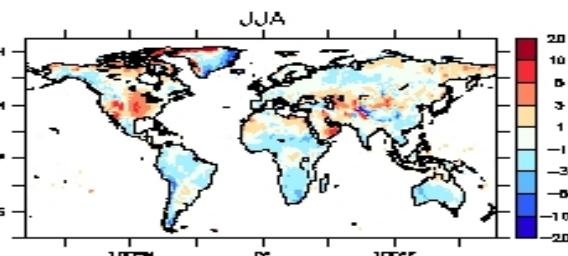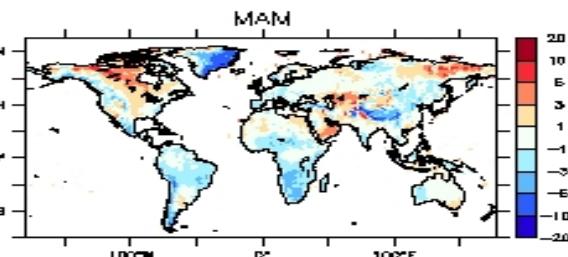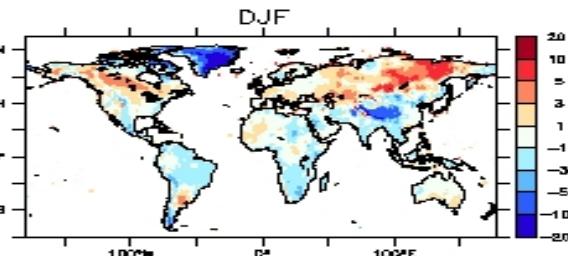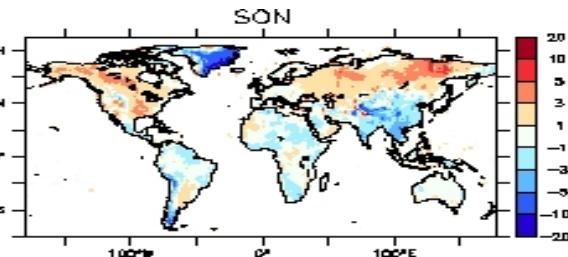
SURFEX with same
"off-line" hydrology
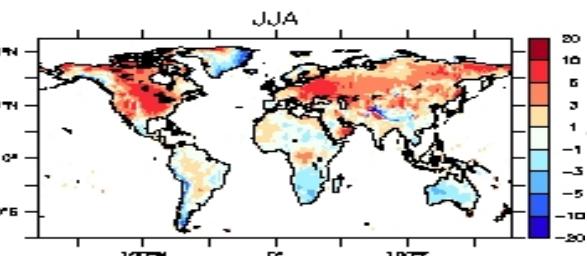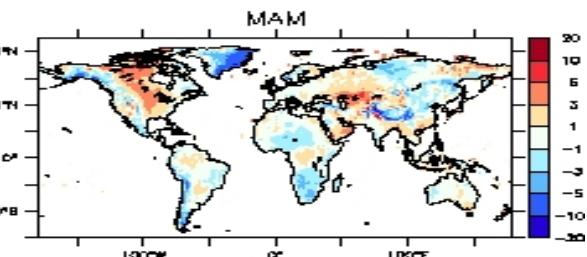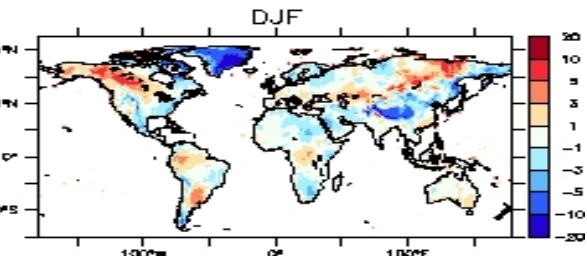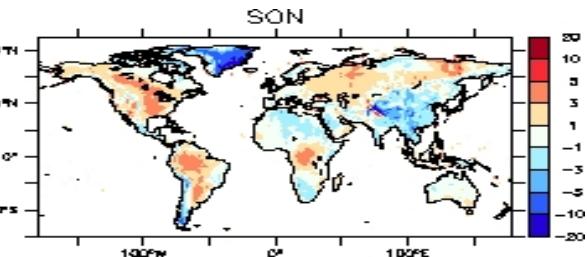
SURFEX in Earth System Model

- **Especially relevant to study climate sensibility to :**
  - Continental processes :
    - Hydrology
    - Snow
    - Carbon cycle
    - Land use
  - Ocean fluxes parameterizations :
   - Simple (Louis)
    - ECUME
    - ....

- **Important applications (CNRM/CERFACS)**
  - IPCC (Starting debut 2010)
  - Seasonal and ten-years forecast
  - ....

Test in SST (ERA-40) forced mode (1990-1999): Precipitation bias to GPCC

Without SURFEX

SURFEX but same previous hydrology

SURFEX with same "off-line" hydrology