Coupled modelling of snow-atmosphere for IASI assimilation

Concordiasi Conference

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Outline

- **Objectives related to CONCORDIASI**
- **Main characteristics of ISBA-ES / Crocus, a detailed snow model for simulations in stand-alone mode or in coupled mode**
- **Stand-alone snowcover simulation over a 10-day period at Dome C**
- **Operational ARPEGE surface temperature performance and diagnostics**
- **Preliminary results using a detailed snow model in coupled mode**

Assimilation of IASI observations over snow covered areas: a new challenge for NWP

- Measured radiances are very sensitive to surface temperature
- Snow low thermal capacity and conductivity induce rapid changes of its surface temperature
- An accurate resolving of the diurnal cycle of snow surface temperature is critical

➔ **Concordiasi** : an ideal framework to investigate the sensitivity of IASI data assimilation to the complexity of snow representation in meteorological models

3 classes of snow models available at Météo-France in the externalized module SURFEX (1/2)

- 1: D95 (Douville et al., 1995) and EBA (Bazile et al., 2002) single-layer composite soil/snow models
  ➔ climate models and NWP
  ➔ most NWP models still use very simple parameterizations to represent snowcover processes

- 2 : ISBA-ES (Boone et Etchevers, 2000) multi-layer snow model including:
  - thermal diffusion, water flow, phase changes, light penetration, compaction
  - snow/soil thermal fluxes through an effective coupling
  - Invariable number of snow layers (3 to ...)
    ➔ process studies and hydrology

3 classes of snow models available at Météo-France in the externalized module SURFEX (2/2)

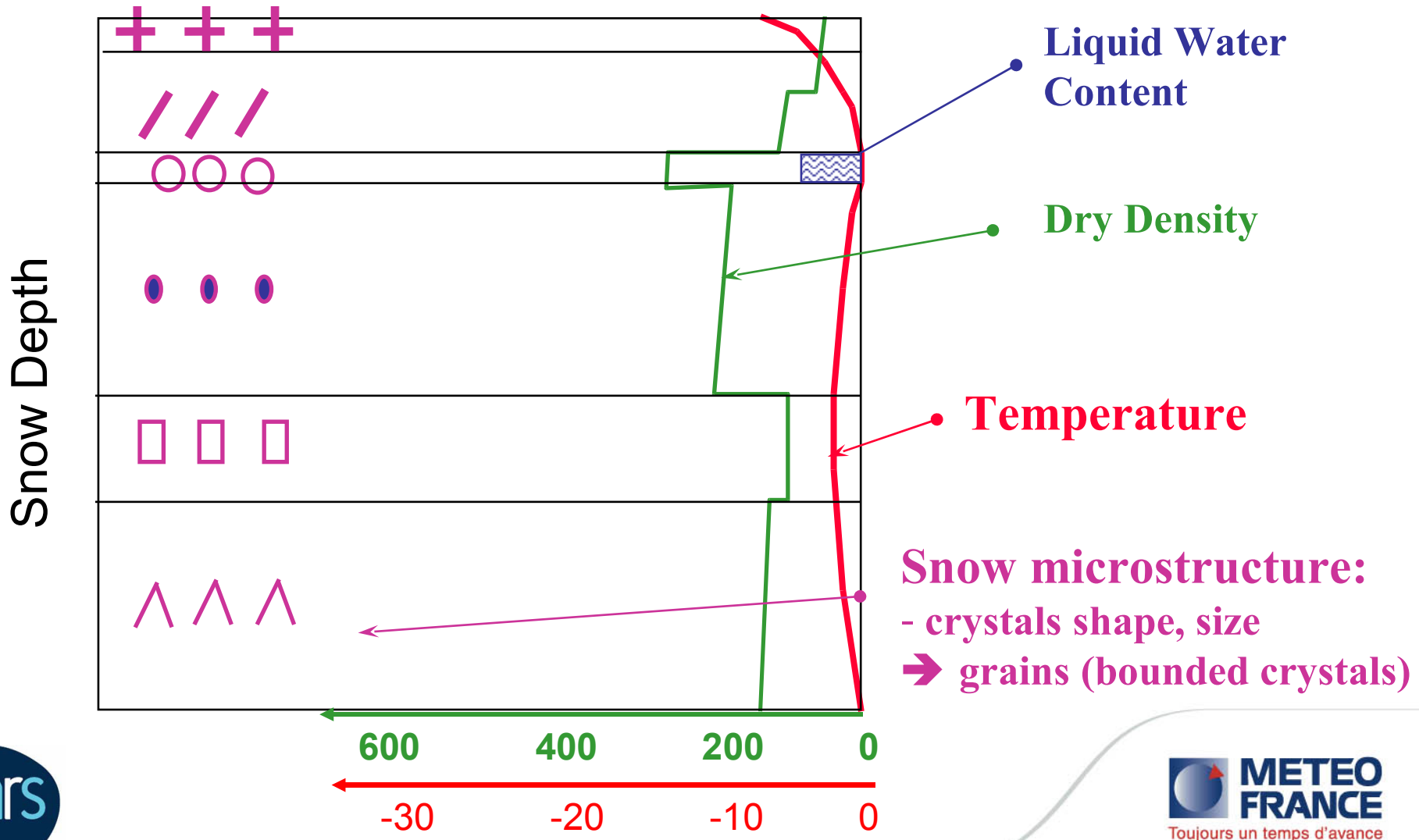
- 3 : Crocus now based on ISBA-ES + :
  - dynamical layering (layers number and depths are variable)
  - metamorphism and snow age
  - spectral albedo (3 bands) function of snow grains and age
  - wind compaction (snow drift effects)

    ➔ process studies, avalanche forecast, climate impact and hydrology

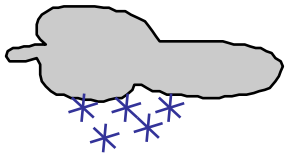
Main limitations of ISBA-ES / Crocus:

-1-D model
- no blowing snow yet (already wind compaction and V. Vionnet PhD)
- no interaction with vegetation
- no air flow inside the snowpack
- no specific adaptation to Antarctic conditions

1-D snowcover description



External processes taken into account

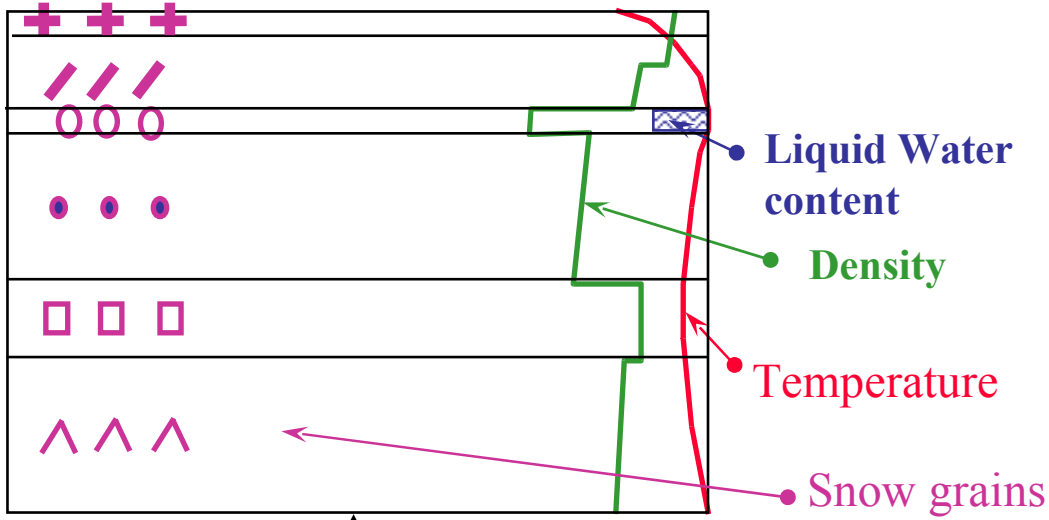


Snow /rain precipitation

Radiative balance (short and long-wave)

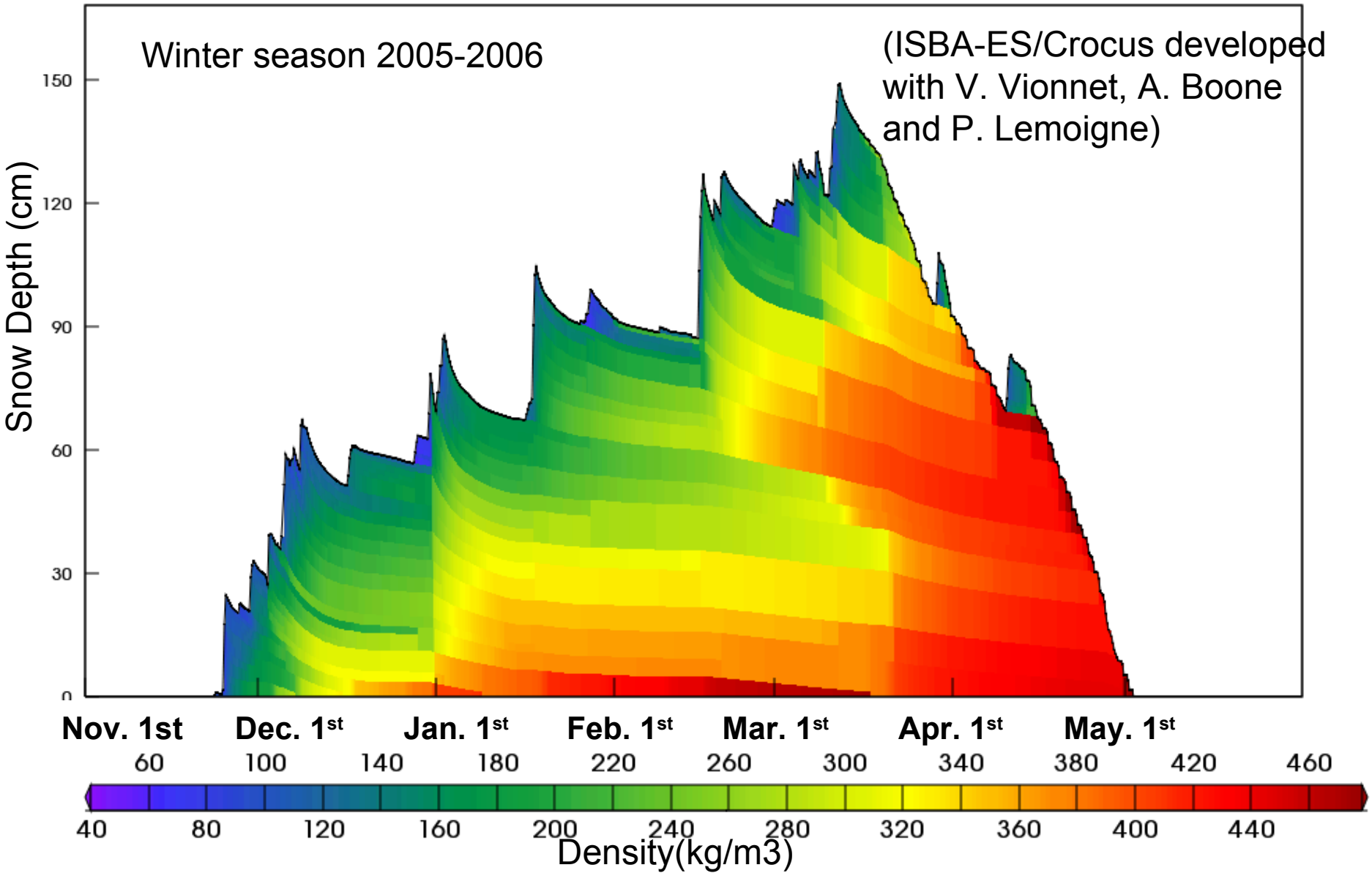
turbulent fluxes
(sensible and latent heat)

wind compaction



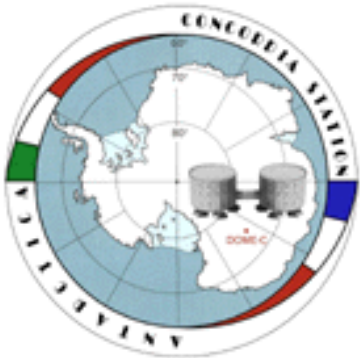
Ground thermal flux
Water run-off

An example of density simulation from observed forcing data (Col de Porte, 1320 m a.s.l)



Dome C / Concordia : a very convenient site to study snow-atmosphere interactions

- Flat, horizontal and quasi-infinite terrain
- Relatively homogeneous snow surface (scale dependant)
- No vegetation
- Moderate wind velocity
- Sophisticated instrumentation at Concordia base:
  - BSRN radiation observations
  - LGGE/IPEV and PNRA boundary layer and surface observations
  - LGGE continuous snow temperature profiles
  - LGGE detailed density, temperature and SSA profiles in Summer
  - Radio-soundings
  - .....
- Differences with South Pole station:
  - high diurnal cycle ➔ more challenging
  - under IASI swath !



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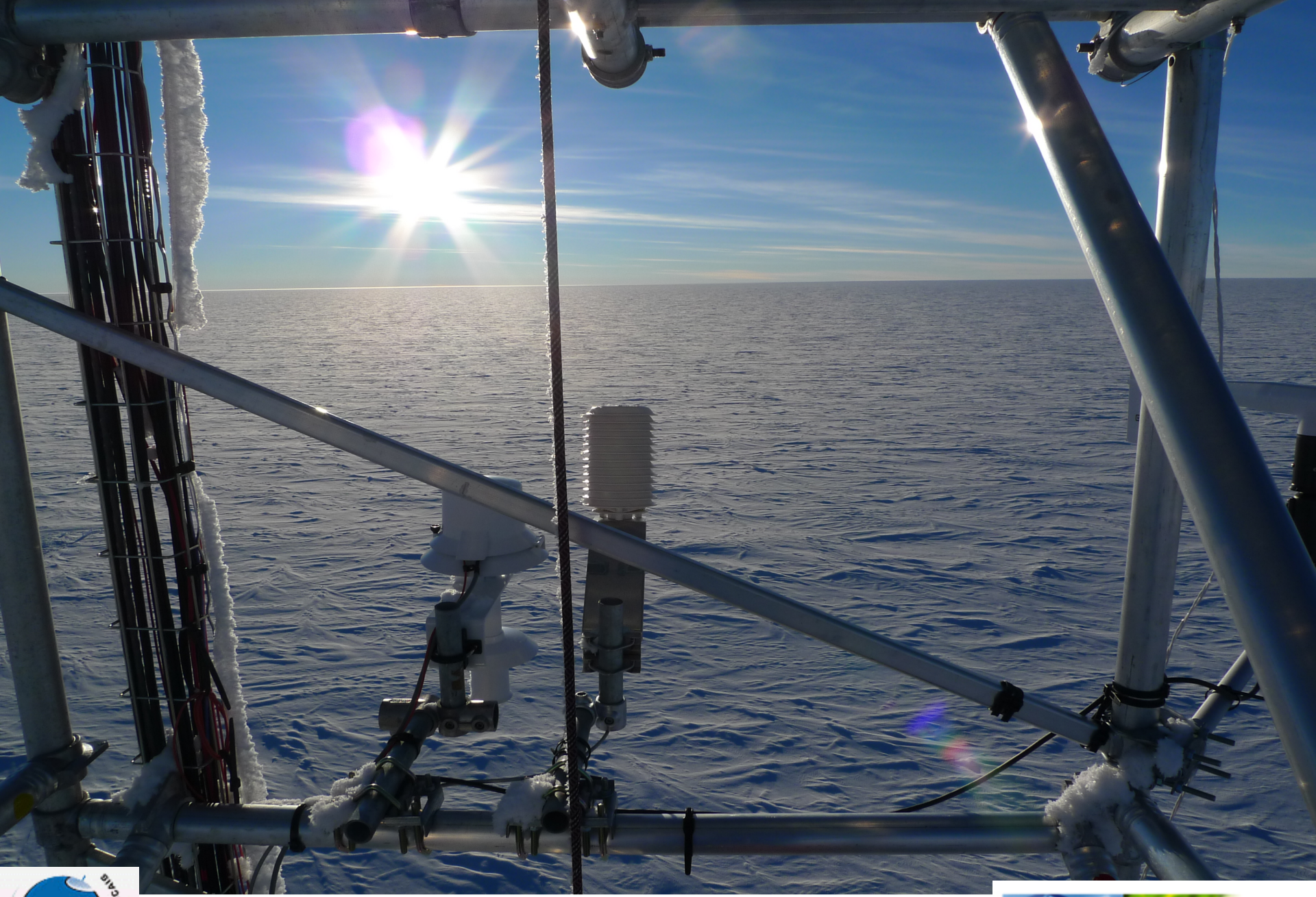
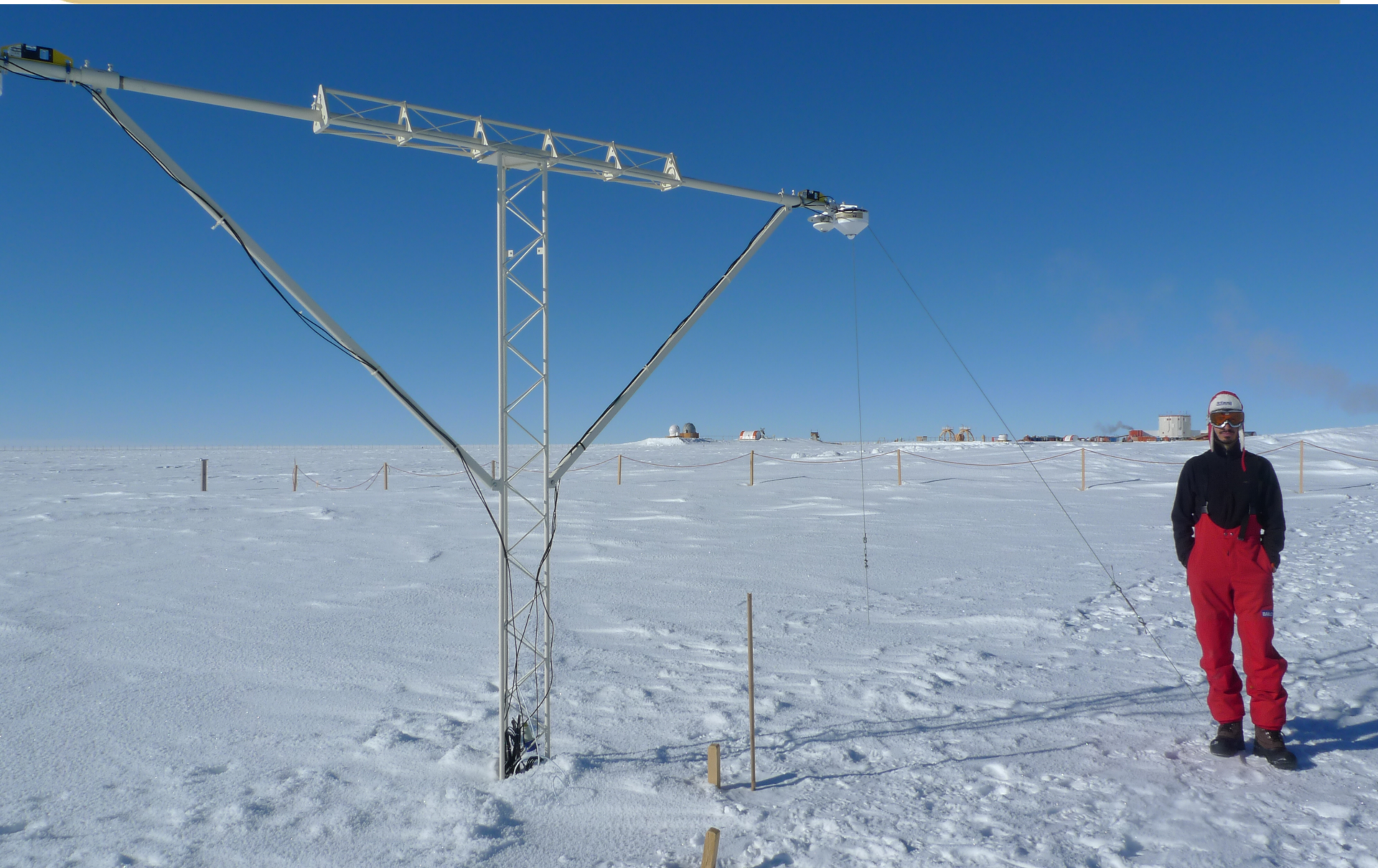


Boundary layer observation (LGGE)
for stand-alone simulations and models evaluation

IPEV INSTITUT POLAIRE FRANÇAIS Paul Emile Victor

L G G E
Laboratoire de Glaciologie et Géophysique de l'Environnement

BSRN (ISAC-CNR) radiation data for stand-alone snow simulations and models evaluation



Applied methodology to investigate the sensitivity of NWP outputs at Dome C to the snow scheme

- Stand-alone simulation ISBA-ES/Crocus during a 10-day period:
  - Observed meteorological forcing: BSRN data and LGGE (D. Six)
  - Initialization from an observed temperature profile (L. Arnaud) and an observed density profile (G. Picard)

- Evaluation of the ARPEGE operational forecast (EBA snow model)
  - Surface temperature
  - Radiative fluxes
- Stand-alone ISBA-ES/Crocus simulations with ARPEGE forcing

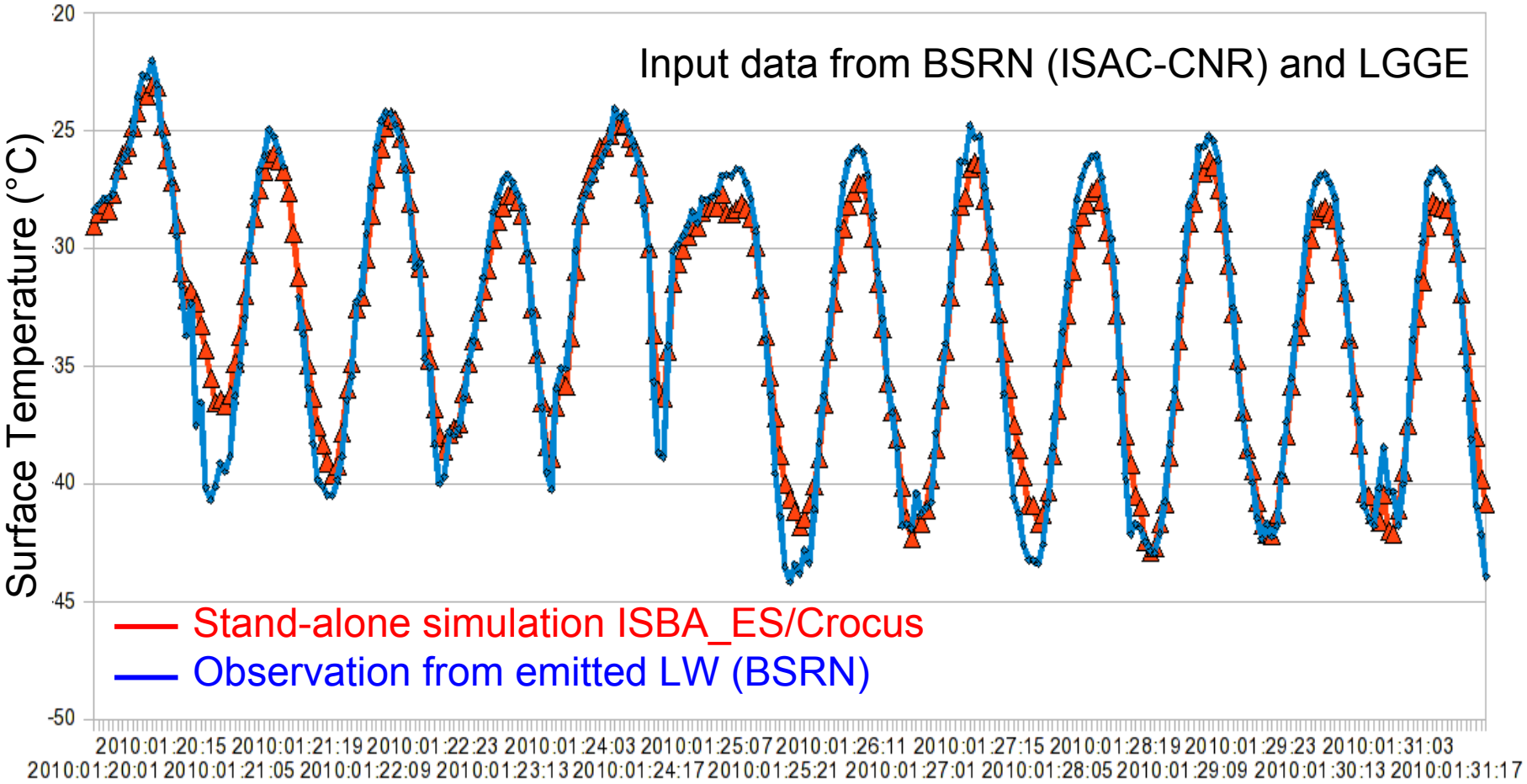
- AROME simulations (NWP LAM) with ISBA-ES/Crocus model
  Lateral Boundary conditions : Antarctic ARPEGE (A. Bouchard)
  ➔ ongoing work and only preliminary results

Adaptation of the snow model to Antarctic conditions

- ISBA-ES/Crocus has been designed only for seasonal snow:
  - Conductivity and capacity should be OK, provided density is realistic
  - Snow roughness should take into account the sastruggis
  - Compaction rates should differ but are OK for short-range simulations
  - Metamorphism laws should differ but are OK for short-range simulations
  - Albedo derivation from snow grains size, type, age should differ
  - Light penetration rate should take into account the high solar incidence

- Snow model changes (roughness, light penetration, ageing):
  ➔ reasonable for short-range simulations (i.e <= 1 month duration)
  ➔ not convenient for long-term simulations

Performance of ISBA-ES/Crocus in stand-alone mode: snow surface temperature



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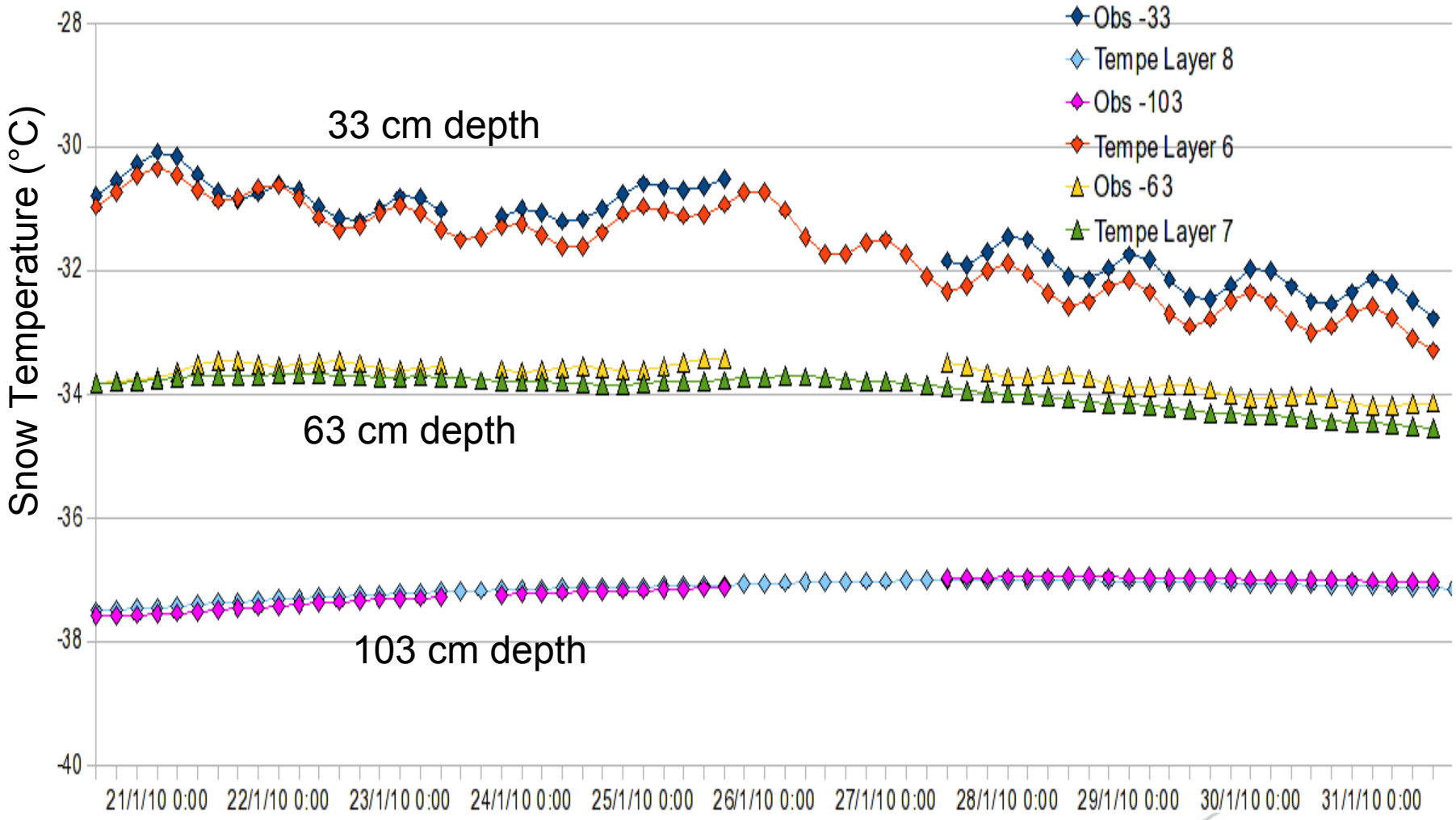
Performance of ISBA-ES/Crocus in stand-alone mode: deep snow temperature



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Observed snow temperature profile from Laurent Arnaud

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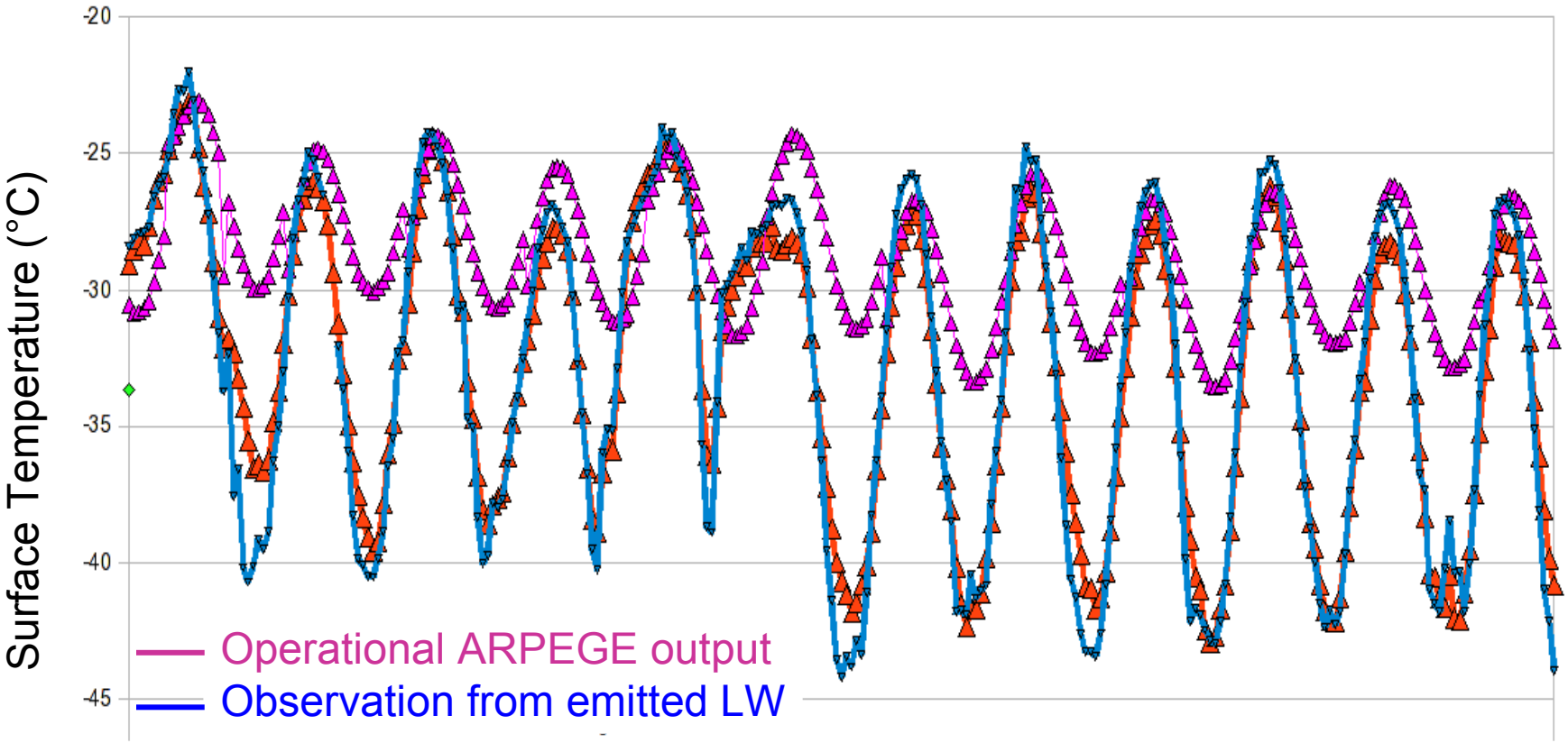
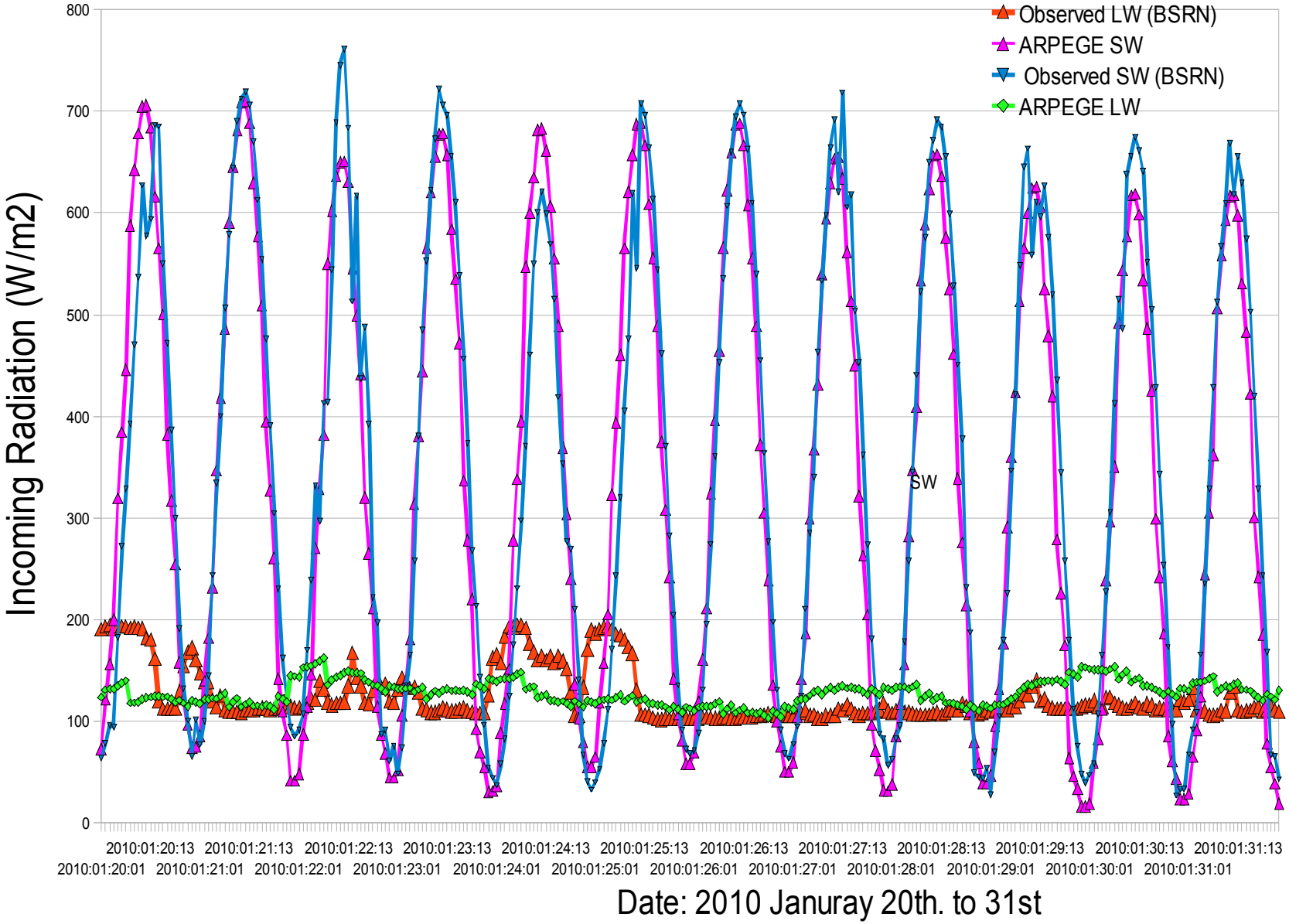
... but limited performance of ARPEGE snow surface temperature forecast ...



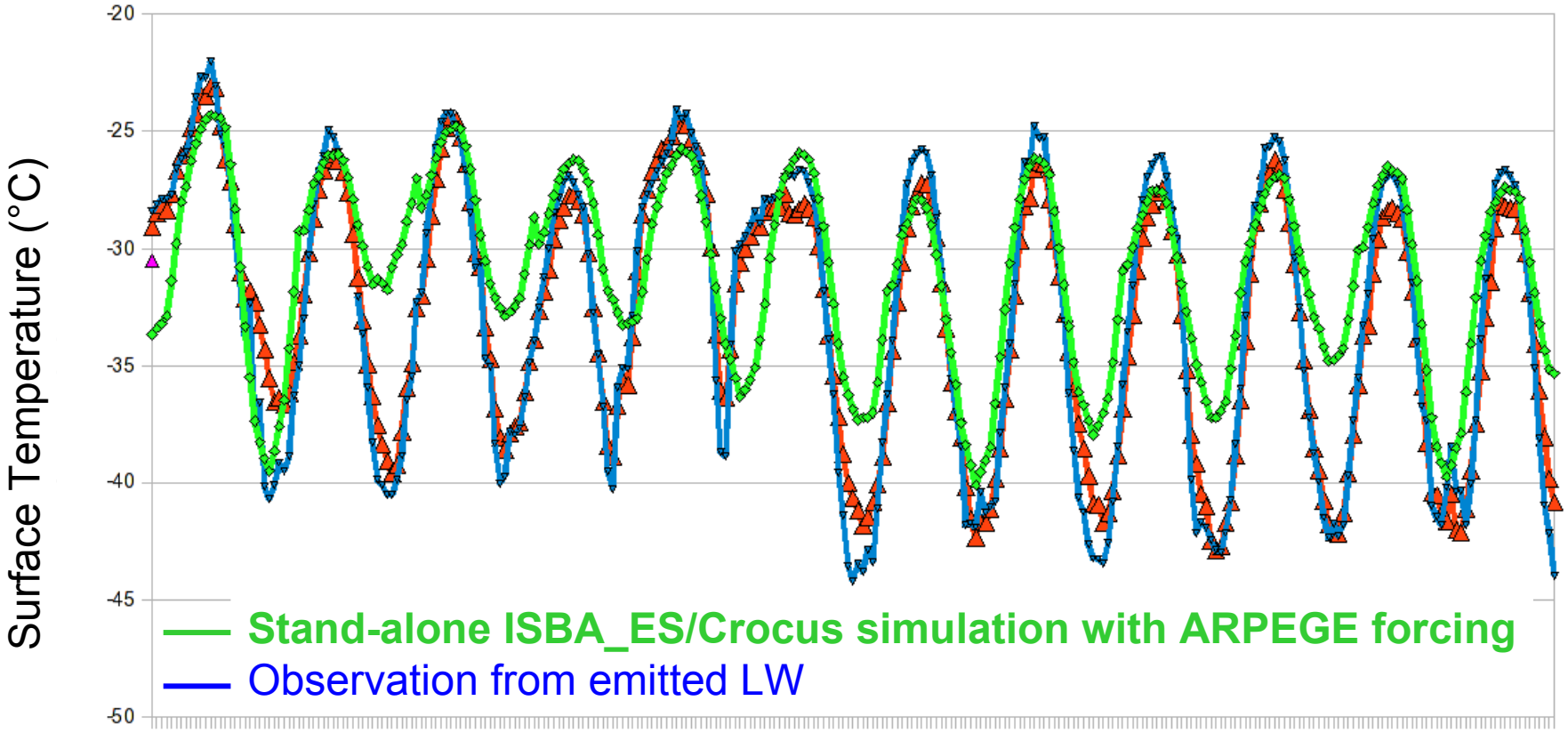
- too warm
- too weak diurnal cycle

atmospheric problems?
snow scheme problems?
coupling problems ?

Evaluation of ARPEGE downward radiation fluxes



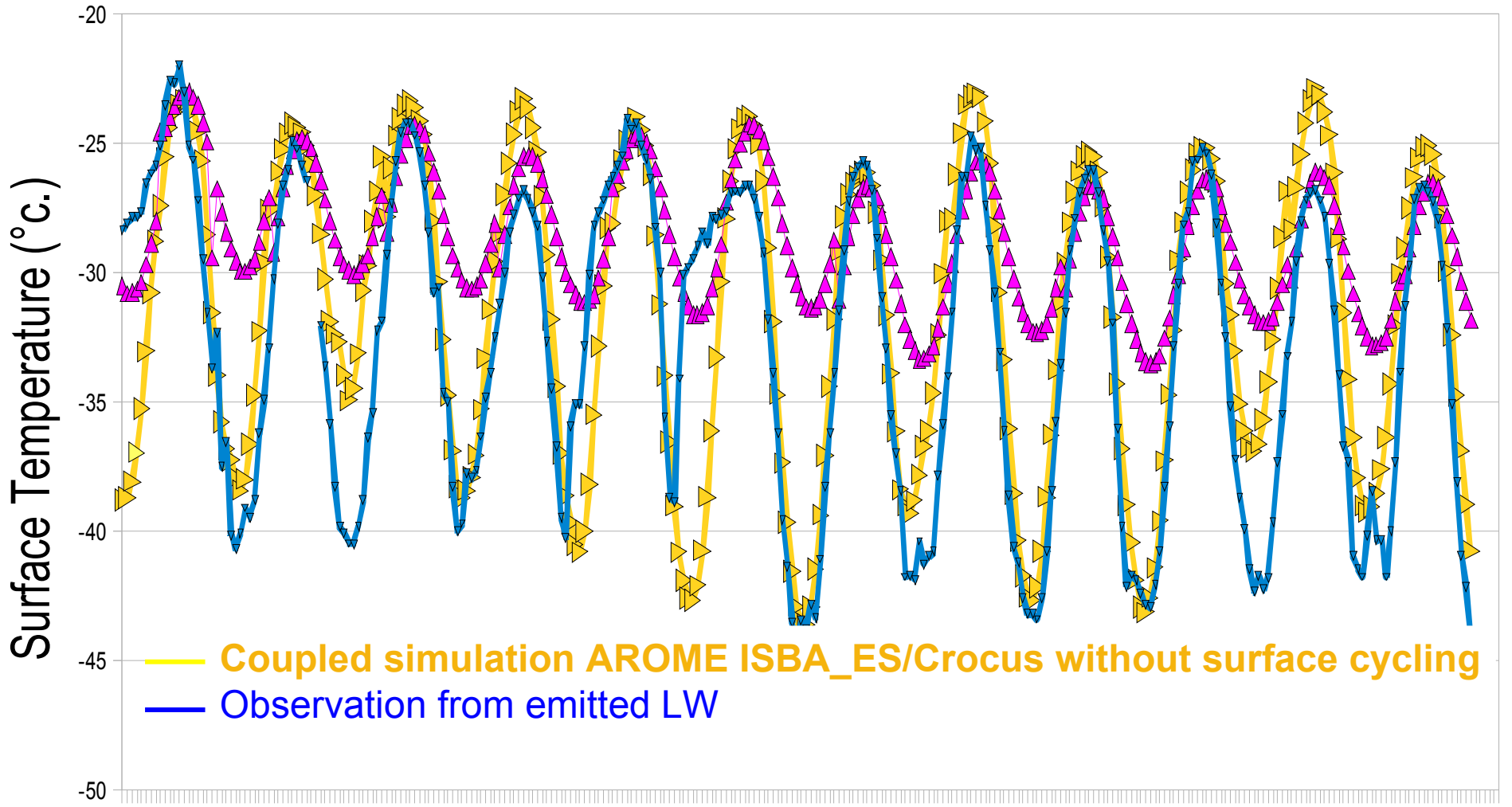
Much more realistic results when forcing the detailed model with forcing data from NWP outputs



➔ A part of the problems comes from the snow scheme in ARPEGE:

- too weak albedo (0,71 due to very weak snowfalls)
- too high thermal capacity
- too high thermal conductivity
- too low snow roughness ?

Preliminary results in coupled mode
10 consecutive day AROME ISBA-ES/Crocus



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Conclusions and perspectives

Ongoing and future work:

- Impact of snowcover cycling on the results in coupled mode

- Evaluation of AROME performance with the D95 and original ISBA-ES models

- Impact of the detailed snow model on the boundary layer

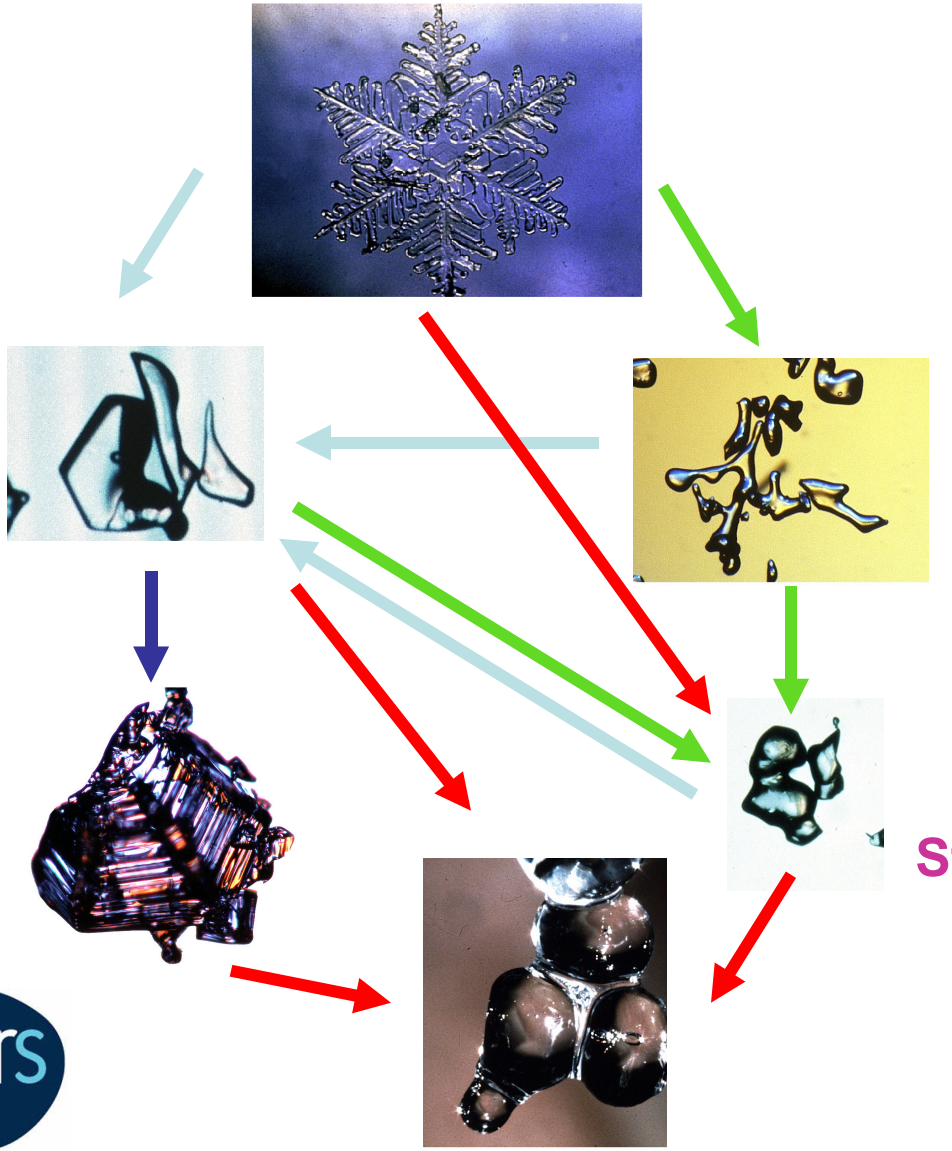
- Impact of the detailed snow model on IASI assimilation (AROME / ARPEGE)

- Extension to other key periods : mid-Winter, early Spring, IASI campaigns

Conclusions:

- Improvements should be expected from an evolution of snow schemes over the Antarctic Plateau in operational ARPEGE and probably in many NWP and climate models

Snow metamorphism (seasonal snow cover only!)



Weak temperature gradient
(0 to 5 °C./m)

Medium temperature gradient
(5 to 15 °C./m)

High temperature gradient
(> 15 °C./m)

Wet conditions
(LWC > 1% mass)

Strong influence on albedo, light penetration, viscosity, conduction, water flow

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