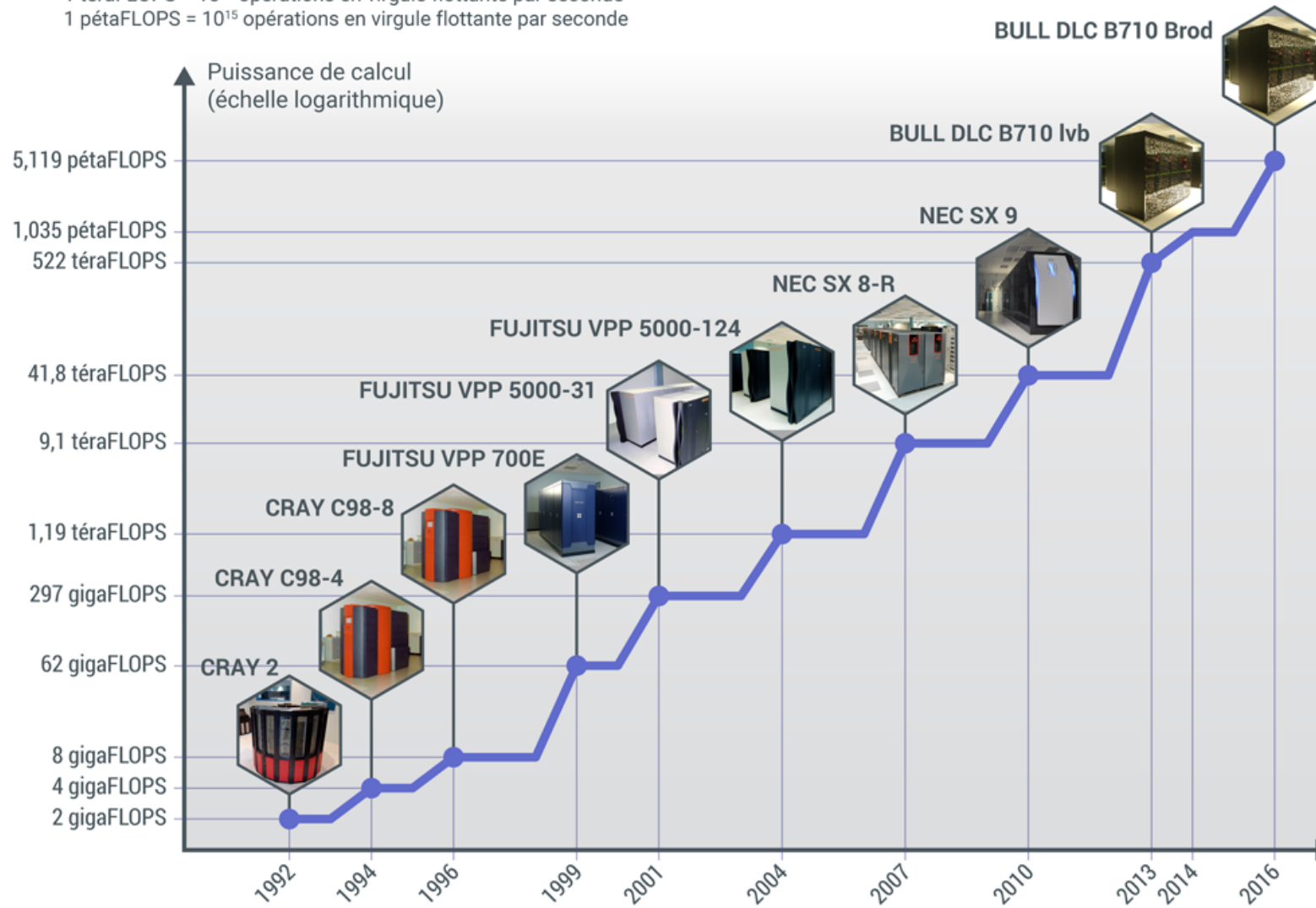# Météo-France report

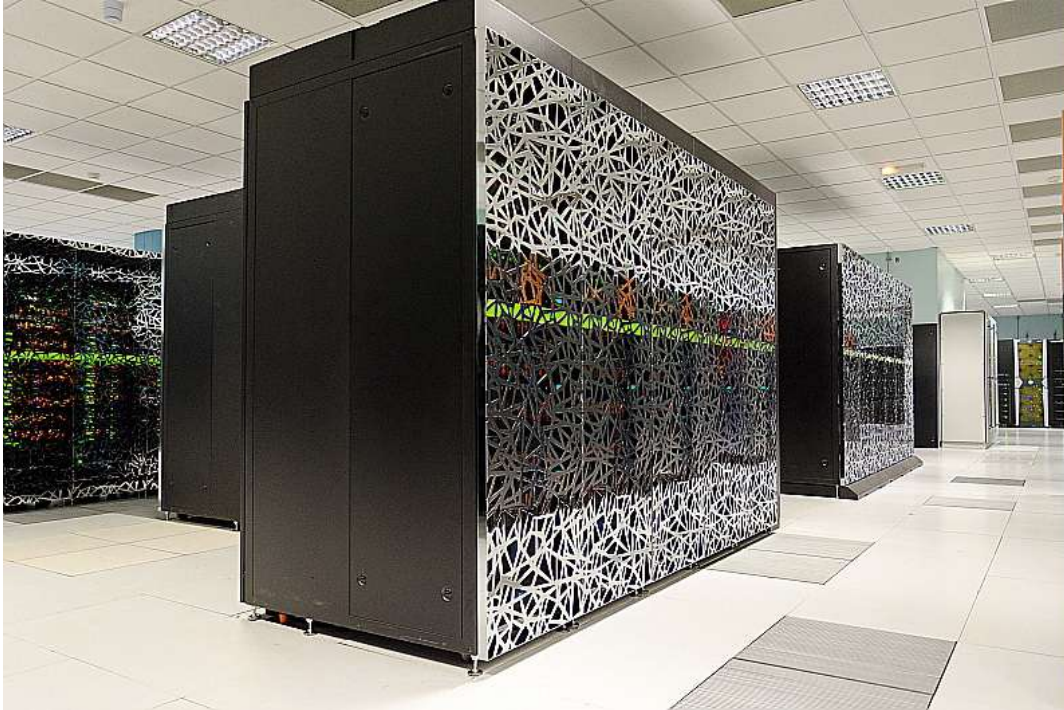*François Bouyssel*
Météo-France/CNRM

Pan-WCRP Modelling Groups Meeting, UK Met Office, Exeter, United Kingdom, 9-13 October 2017

Evolution of HPC at Météo-France

1 gigaFLOPS = 10^9 opérations en virgule flottante par seconde
1 téraFLOPS = 10^{12} opérations en virgule flottante par seconde
1 pétaFLOPS = 10^{15} opérations en virgule flottante par seconde

Puissance de calcul
(échelle logarithmique)

BULL DLC B710 Brod

BULL DLC B710 lvb

NEC SX 9

NEC SX 8-R

FUJITSU VPP 5000-124

FUJITSU VPP 5000-31

FUJITSU VPP 700E

CRAY C98-8

CRAY C98-4

CRAY 2

5,119 pétaFLOPS

1,035 pétaFLOPS
522 téraFLOPS

41,8 téraFLOPS

9,1 téraFLOPS

1,19 téraFLOPS

297 gigaFLOPS

62 gigaFLOPS

8 gigaFLOPS
4 gigaFLOPS
2 gigaFLOPS

1992   1994   1996   1999   2001   2004   2007   2010   2013   2014   2016

METEO FRANCE

Super-computers at Météo-France

Initial configuration (**2013**)
2 x 1000 nodes
1 node = 24 CPUs
Intel « Ivy Bridge »
50 000 cores / 1 Pflops

Recent upgrade (**2016**):
2 x 1800 nodes
1 node = 40 CPUs
Intel « Broadwell IP »
**150 000 cores / 5 Pflops**

2 x BULL B710 DLC
1 cluster for operations (ECA)
1 cluster for research (CNC)

METEO
FRANCE

Global NWP systems based on ARPEGE

Systems	Characteristics
ARPEGE *Deterministic*	Tl1198c2.2 L105 (7.5km on W Europe) 4DVar (6h cycle): Tl149c1L105 & Tl399c1L105 5 forecasts per day up to 114h
AEARP *(EDA)*	Tl479c1 L105 ; 25 members 4D-Var (6h cycle): Tl149c1 L105 Background covariances averaged on 1.5 days and updated every 6h
PEARP *(EPS)*	Tl798c2.4 L90 (10km on W Europe) 35 members ; twice a day up to 108h Using 17 EDA members and singular vectors New set of 10 physical packages (with new convection scheme "PCMT")

Arpege version intervalle: 2.5km
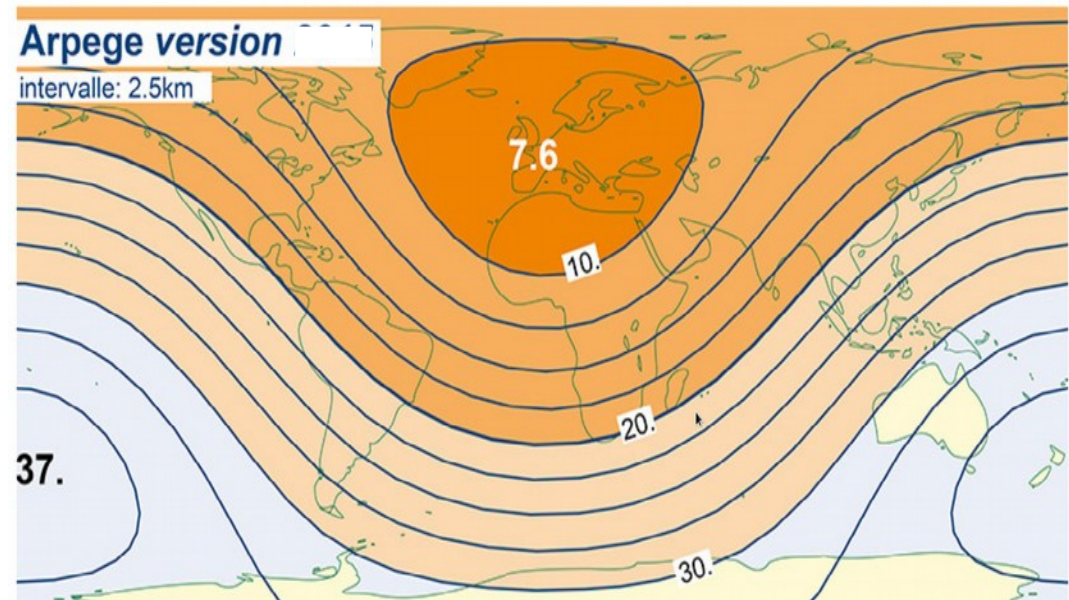
Nouvelle résolution horizontale (en km) du modèle Arpege en version « déterministe »

Ensemble Arpege intervalle : 5km
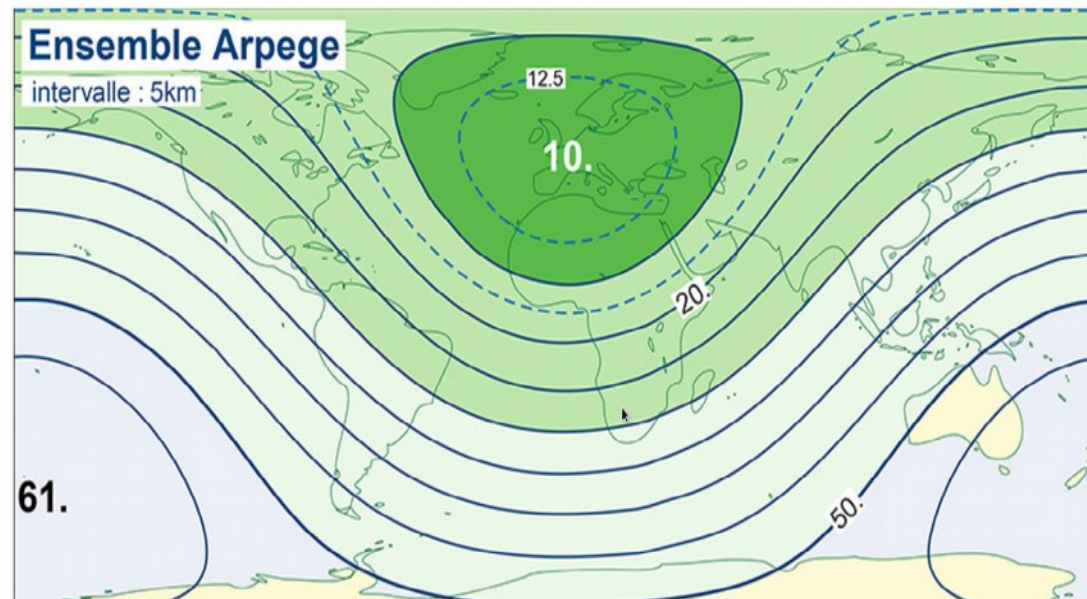
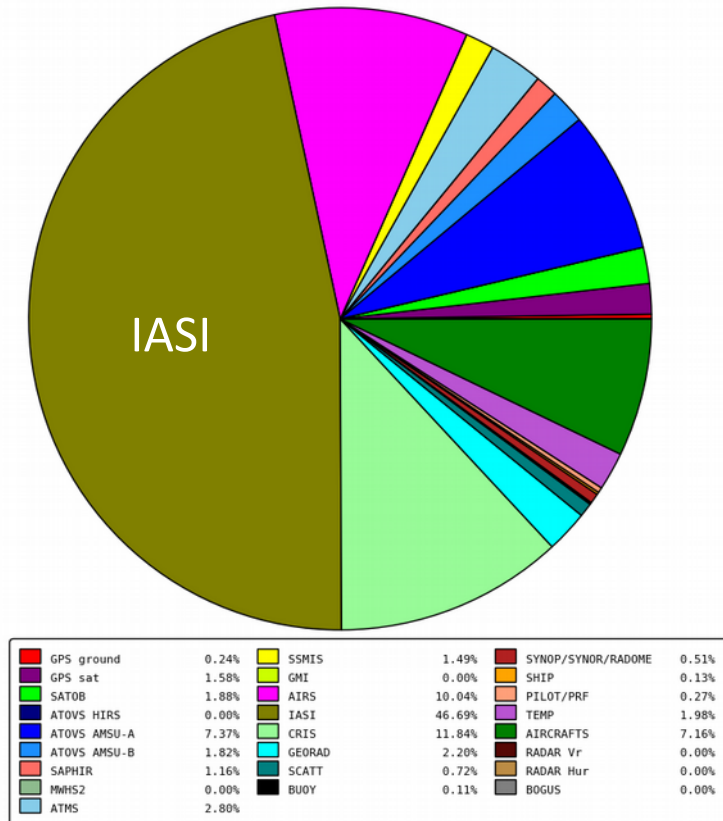*Nouvelle résolution horizontale (en km) du modèle Arpege ensemble*

Observations in ARPEGE

21 x 10^6/day

nombres d'observations utilisees par type d'obs
s cut-off long - ARPEGE metropole oper
...vations conventionnelles et satellites
cumul du nombre d'observations utilisees sur la periode 2017011900 - 2017011918 : 21344548

GPS ground	0.24%	SSMIS	1.49%	SYNOP/SYNOR/RADOME	0.51%
GPS sat	1.58%	GMI	0.00%	SHIP	0.13%
SATOB	1.88%	AIRS	10.04%	PILOT/PRF	0.27%
ATOVS HIRS	0.00%	IASI	46.69%	TEMP	1.98%
ATOVS AMSU-A	7.37%	CRIS	11.84%	AIRCRAFTS	7.16%
ATOVS AMSU-B	1.82%	GEORAD	2.20%	RADAR Vr	0.00%
SAPHIR	1.16%	SCATT	0.72%	RADAR Hur	0.00%
MWHS2	0.00%	BUOY	0.11%	BOGUS	0.00%
ATMS	2.80%				

Fraction of observation types

Satellite observations (90 %)

-> Infra-red radiances (70 %)

-IASI (METOP-A + B)

-CrIS (Suomi-NPP) / AIRS (Aqua)

-CSR from GEO satellites

-> Microwave radiances

-AMSU-A (NOAA/Aqua/METOP)

-MHS/AMSU-B (NOAA/METOP)

-ATMS (Suomi-NPP)

-SSMI/S (DMSP F17/F18)

-SAPHIR (Megha-Tropiques)

-> GNSS-RO + Ground-based

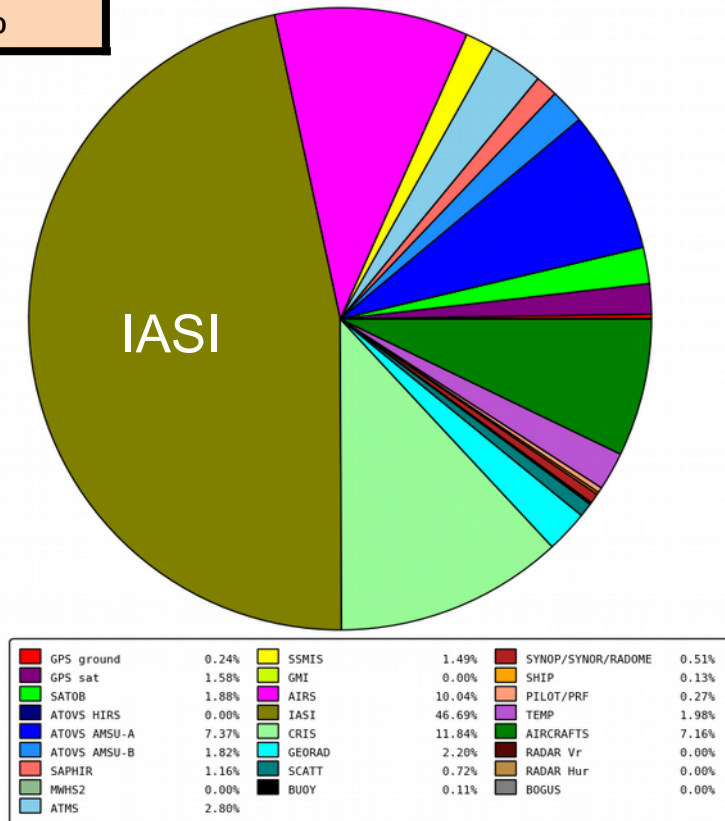-> AMVs + Scatterometer winds

Conventional observations (10 %)

-> Aircrafts, surface, RAOB

Spatial thinning of satellite obs
between 250 and 125 km
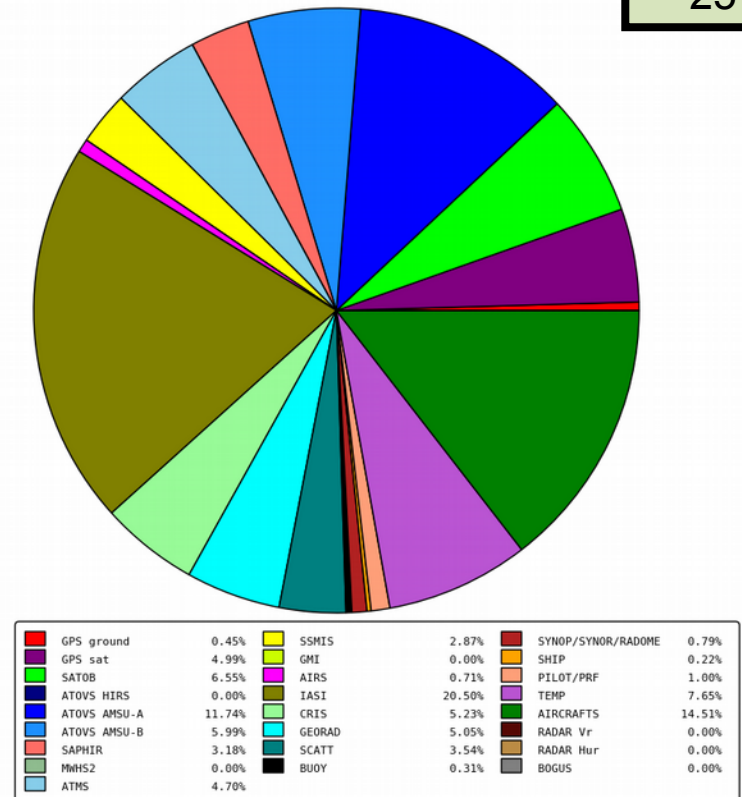
METEO FRANCE

Observations in ARPEGE

IR 70 %
MW 12%

portions des nombres d'observations utilisees par type d'obs
analyses cut-off long - ARPEGE metropole oper
observations conventionnelles et satellites
observations utilisees sur la periode 2017011900 - 2017011918 : 21344548

IASI

GPS ground	0.24%	SSMIS	1.49%	SYNOP/SYNOR/RADOME	0.51%
GPS sat	1.58%	GMI	0.00%	SHIP	0.13%
SATOB	1.88%	AIRS	10.04%	PILOT/PRF	0.27%
ATOVS HIRS	0.00%	IASI	46.69%	TEMP	1.98%
ATOVS AMSU-A	7.37%	CRIS	11.84%	AIRCRAFTS	7.16%
ATOVS AMSU-B	1.82%	GEORAD	2.20%	RADAR Vr	0.00%
SAPHIR	1.16%	SCATT	0.72%	RADAR Hur	0.00%
MWHS2	0.00%	BUOY	0.11%	BOGUS	0.00%
ATMS	2.80%				

Fraction of observation types
(conv = 10 %)

IR 25 %
MW 25%

Part des DFS par type d'obs
analyses cut-off long - ARPEGE metropole oper
observations conventionnelles et satellites
cumul du DFS sur la periode 2017011900 - 2017011918 : 464437

GPS ground	0.45%	SSMIS	2.87%	SYNOP/SYNOR/RADOME	0.79%
GPS sat	4.99%	GMI	0.00%	SHIP	0.22%
SATOB	6.55%	AIRS	0.71%	PILOT/PRF	1.00%
ATOVS HIRS	0.00%	IASI	20.50%	TEMP	7.65%
ATOVS AMSU-A	11.74%	CRIS	5.23%	AIRCRAFTS	14.51%
ATOVS AMSU-B	5.99%	GEORAD	5.05%	RADAR Vr	0.00%
SAPHIR	3.18%	SCATT	3.54%	RADAR Hur	0.00%
MWHS2	0.00%	BUOY	0.31%	BOGUS	0.00%
ATMS	4.70%				

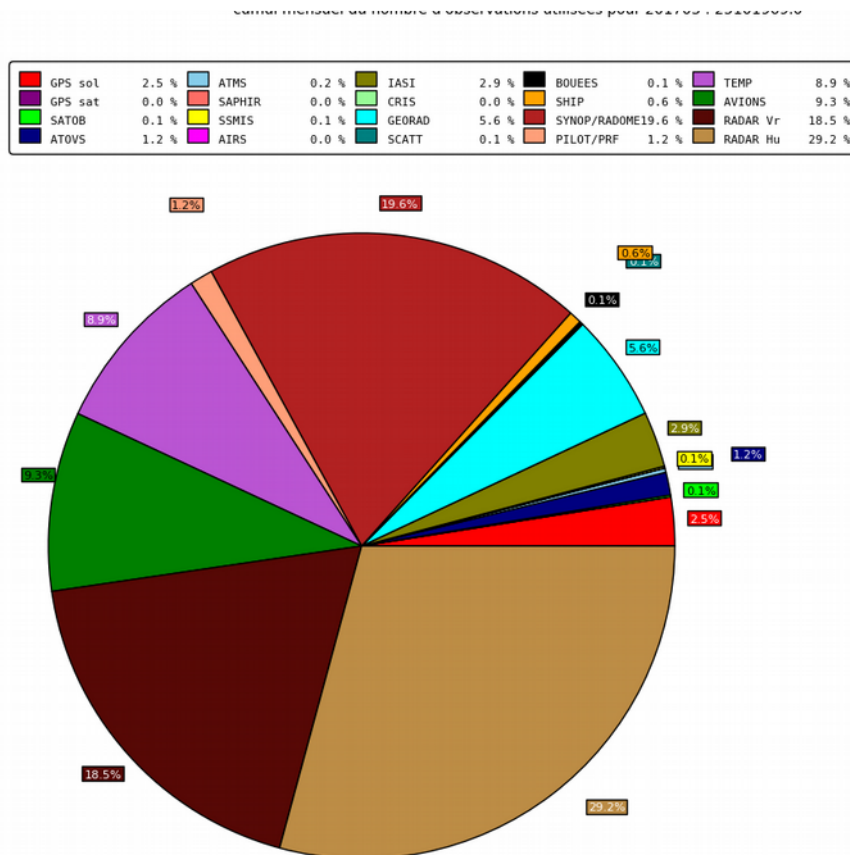DFS: information content
(conv = 25%)

METEO FRANCE

Regional NWP systems based on AROME

Systems	Characteristics
AROME *Deterministic*	1.3km (1536 x 1440 pts) L90: from 5m to 10hPa 3DVar (1h cycle) 5 forecasts per day up to 42h
AROME Nowcasting	1.3km (1536 x 1440 pts) L90: from 5m to 10hPa 3DVar (no cycling – 10' cut-off) 24 forecasts per day up to 6h
AROME-EPS	2.5km L90 12 members Twice per day up to 45h Initial and boundary conditions from PEARP
AROME Overseas (5 domains)	2.5km L90 – Dynamical adaptation of IFS (altitude) and Arpege (surface) 4 forecasts per day up to 42h
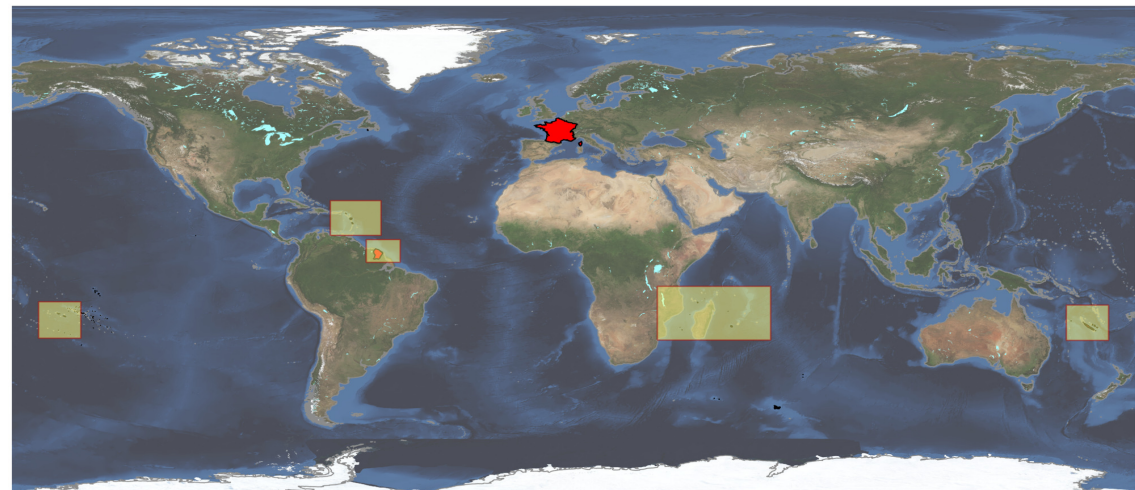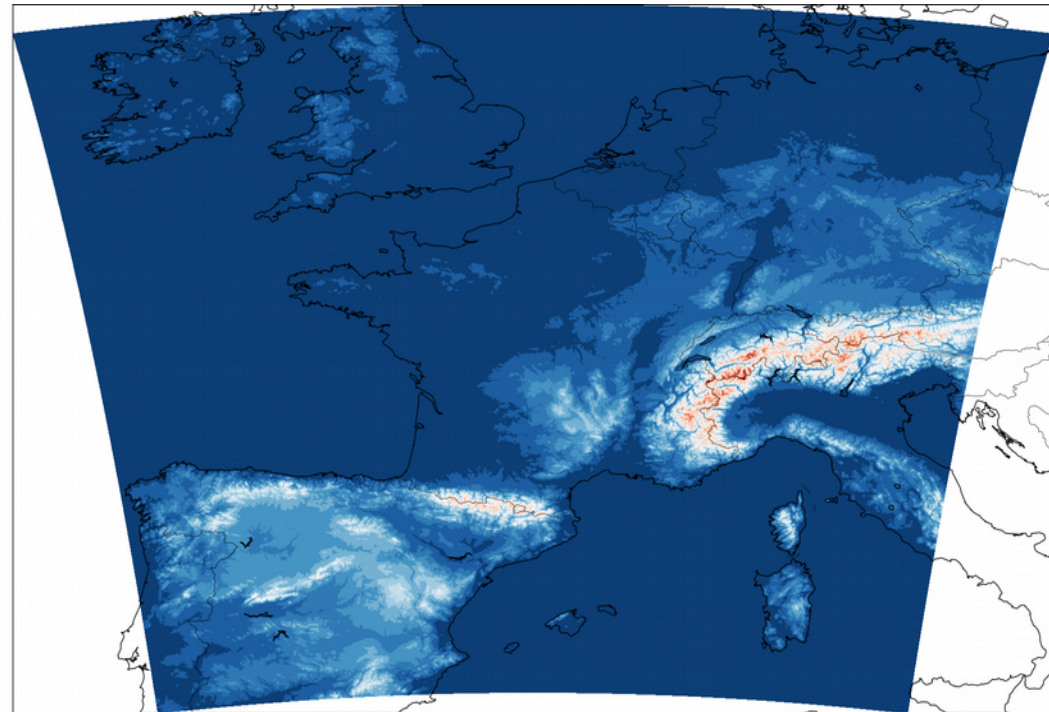
Observations in AROME 3D-Var

Satellite observations = 10 %

DirOP/COMPAS 02-avril-2017

- **Radar DOW + Z (RH)**
- **Surface (SYNOP + RADOME)**
- **Radiosoundings (BUFR HR)**
- **Aircrafts**
- **GEO radiances (METEOSAT)** *with* T_s *inversion (5 channels)*
- **LEO satellites (IASI, AMSU, AMVs, SCAT)**
- **Ground based GNSS (ZTD)**
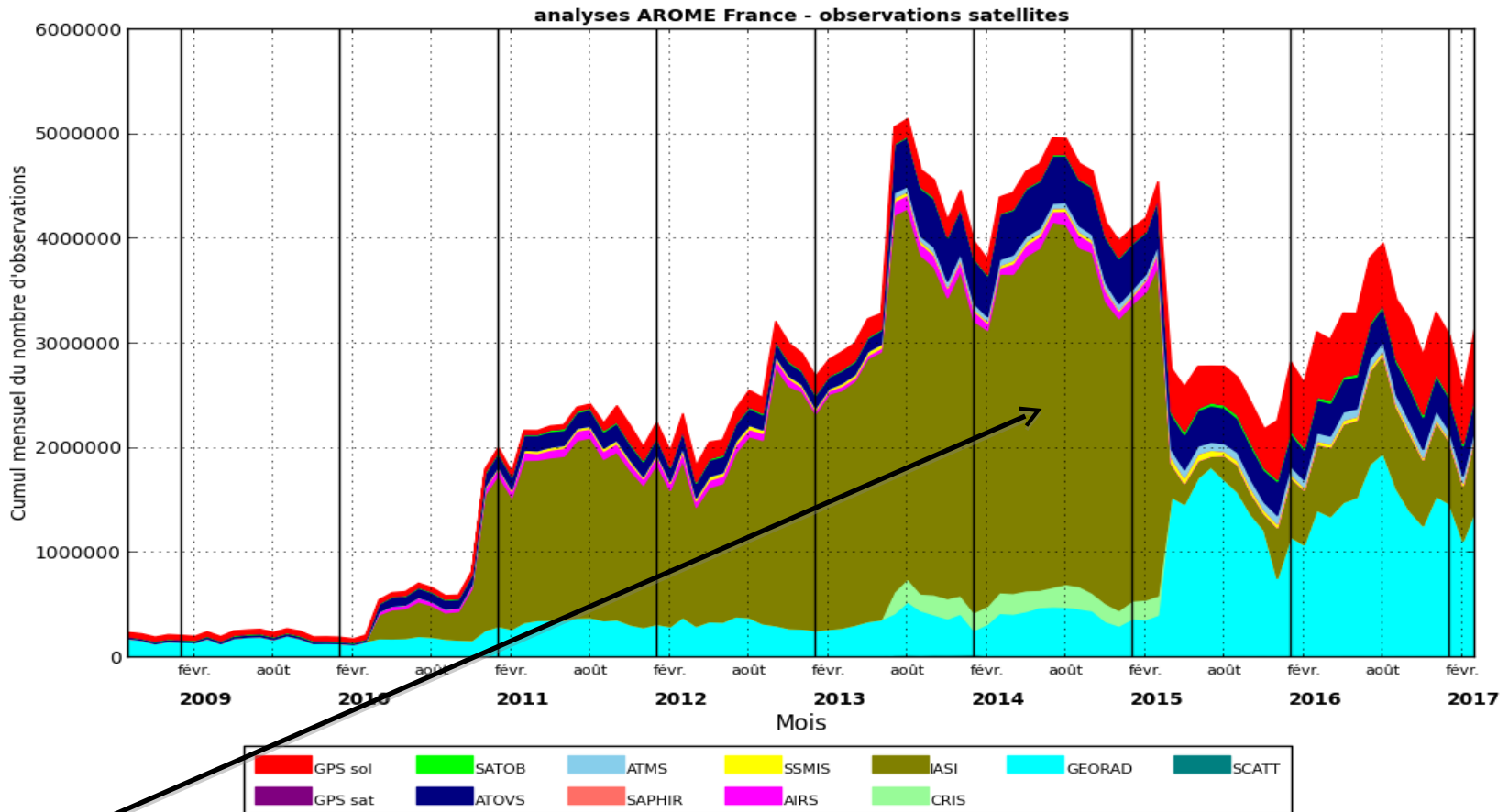
Spatial thinning of satellite obs between 80 and 125 km

Data availability for AROME-NWC : radar, surface, IASI, AMSU-A/MHS radiances (from Lannion) and ASCAT winds (from EARS)

Satellite observations in AROME 3D-Var

Evolution des cumuls mensuels de nombre d'observations utilisées par type d'observation
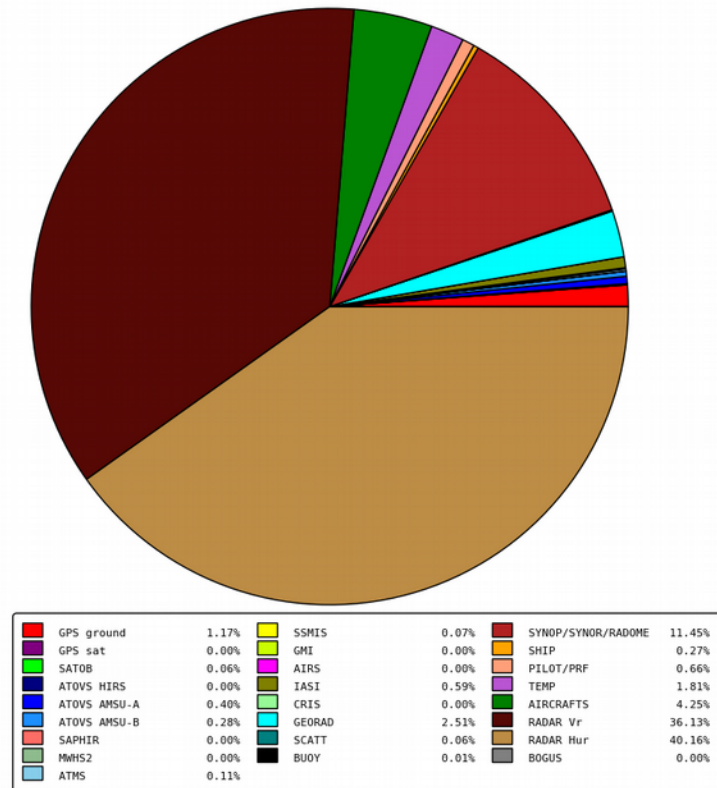
analyses AROME France - observations satellites

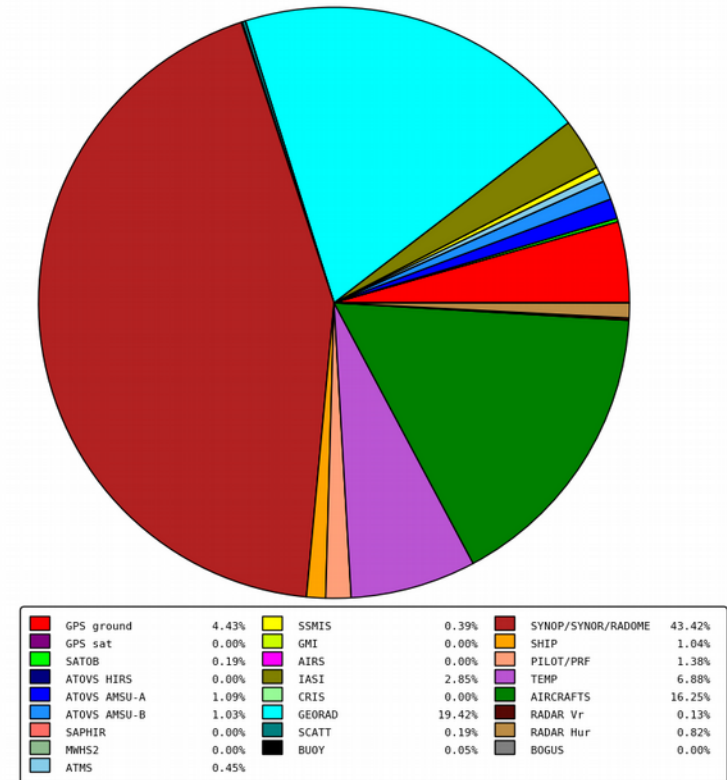3D-Var with hourly cycling + Model top at 10 hPa

Information content of observations

Part des DFS par type d'obs
analyses cut-off AROME - AROME France oper
observations conventionnelles et satellites
cumul du DFS sur la periode 2017020400 - 2017020423 : 433792

GPS ground	1.17%	SSMIS	0.07%	SYNOP/SYNOR/RADOME	11.45%
GPS sat	0.00%	GMI	0.00%	SHIP	0.27%
SATOB	0.06%	AIRS	0.00%	PILOT/PRF	0.66%
ATOVS HIRS	0.00%	IASI	0.59%	TEMP	1.81%
ATOVS AMSU-A	0.40%	CRIS	0.00%	AIRCRAFTS	4.25%
ATOVS AMSU-B	0.28%	GEORAD	2.51%	RADAR Vr	36.13%
SAPHIR	0.00%	SCATT	0.06%	RADAR Hur	40.16%
MWHS2	0.00%	BUOY	0.01%	BOGUS	0.00%
ATMS	0.11%				

Part des DFS par type d'obs
analyses cut-off AROME - AROME France oper
observations conventionnelles et satellites
cumul du DFS sur la periode 2017011900 - 2017011923 : 138321

GPS ground	4.43%	SSMIS	0.39%	SYNOP/SYNOR/RADOME	43.42%
GPS sat	0.00%	GMI	0.00%	SHIP	1.04%
SATOB	0.19%	AIRS	0.00%	PILOT/PRF	1.38%
ATOVS HIRS	0.00%	IASI	2.85%	TEMP	6.88%
ATOVS AMSU-A	1.09%	CRIS	0.00%	AIRCRAFTS	16.25%
ATOVS AMSU-B	1.03%	GEORAD	19.42%	RADAR Vr	0.13%
SAPHIR	0.00%	SCATT	0.19%	RADAR Hur	0.82%
MWHS2	0.00%	BUOY	0.05%	BOGUS	0.00%
ATMS	0.45%				

Rainy period   Dry period

AROME-France-EPS operations ('PEArome' in French)

in operational production since Oct 2016

2017 operational setup :

- model : AROME-France, **dx=2.5km** (dx=1.3km in AROME-F déterministic) grid=750x800, 90 levels
- base : **9/21utc** (coupling is 3h older)
- production : **12 members up to 45h range**

Perturbations :

- **lateral boundaries:** clustered global PEARP ensemble
- **initial**: global PEARP ensemble + centering on 3DVar analysis of AROME-France (dx=1.3km)
- **surface:** initial & constant perturbations
- **model:** stochastic perturbations of physics tendencies (SPPT)

Plans (2018):

- 6-hourly productions
- ensemble data analysis (EDA) initial perturbations
- (later : increase ensemble size & resolution)

AROME-France-EPS domain

base 21h —— Arome EPS —— J+1 18h ——▶ 45h range

base 0h —— Arome —— ——▶ 42h range
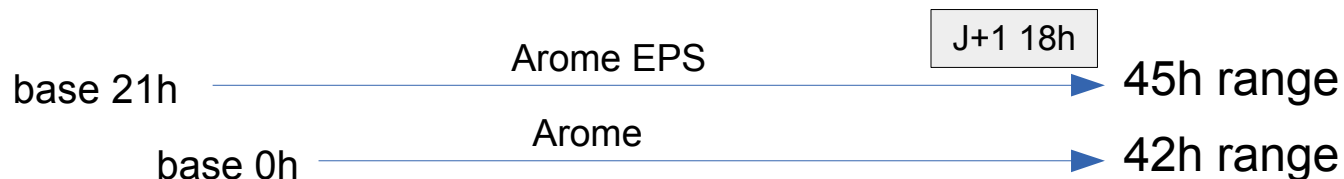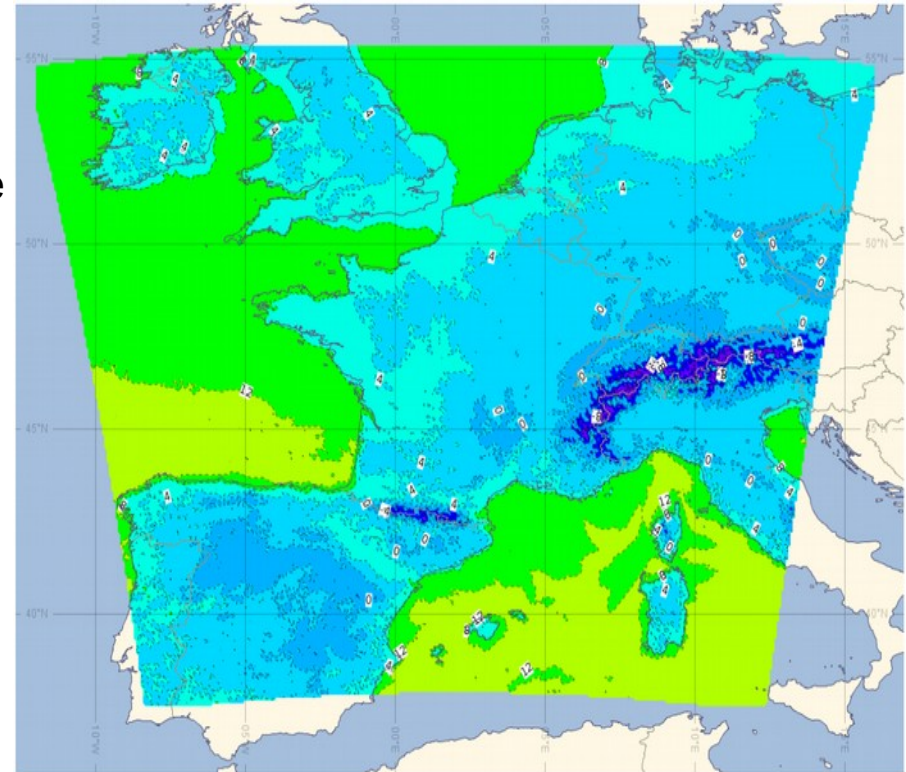
"Recent" evolutions of operational suite

December 2015 : Operational switch on 41T1_op1 : latest scientific evolution of NWP operational systems ARPEGE, ARPEGE-EPS, AROME, etc.

2016 : new operational NWP systems :

- AROME-NWC: a nowcasting regional system over France with hourly analysis with 10' cut-off plus 6h short-range forecast with the same 1.3 km configuration than AROME-France,

- AROME-OM: five regional systems over overseas territorial collectivities with AROME configurations at 2.5 km running four times par day up to 48h range.

- AROME-EPS: a regional ensemble prediction system over France. The configuration is based on 12 perturbed forecasts of the AROME-France model with a 2,5km horizontal resolution and 90 vertical levels, coupled with the ARPEGE ensemble prediction system. The AROME-EPS system runs twice a day, at 09 and 21 UTC, to provide forecasts up to a 45h range.

June 2016 : upgrade of the BULL HPC (phase 2)

December 2017: Operational switch on 42_op2 : latest scientific evolution of NWP operational systems ARPEGE, ARPEGE-EPS, AROME, etc.

CY42_op2

- **Description for ARPEGE / AEARP (EDA) / PEARP (EPS)**
- SURFEX model (surface parameterizations)
- AEARP: resolution increase for the computation of background error variances
- AEARP: normalisation of variances induced by wavelet modelling of correlations
- Revised "white list", "sigmaO", "quality check" on ground GPS observations
- 2 water vapour channels (183GHz) of GMI onboard GPM-Core
- 3 water vapour channels (183GHz) of MWHS-2 onboard FY3-C
- Higher density of GEORAD (from 250 to 125km) + using Meteosat-8 (CSR+AMV)
- Assimilation of window SEVIRI channels (4, 6, 7, 8 over sea)
- Higher spatial horizontal sampling (from 125 to 100km) and 5 new channels (ozone) for IASI
- New physics in PEARP (ARPEGE EPS)
- Optimisations (new compiler version, etc.)
- New diagnostics (domain, variables, etc.)

- **Description for AROME**
- Same modifications as in ARPEGE for observations
- New version of Incremental Analysis Update
- New cloud optical properties
- New autoconversion threshold for transformation of cloud droplets into rain
- Ocean mixing layer scheme in AROME-Overseas
- Optimisations (new compiler version, server for production of AROME-EPS coupling files)
- New diagnostics (domain, variables, etc.)

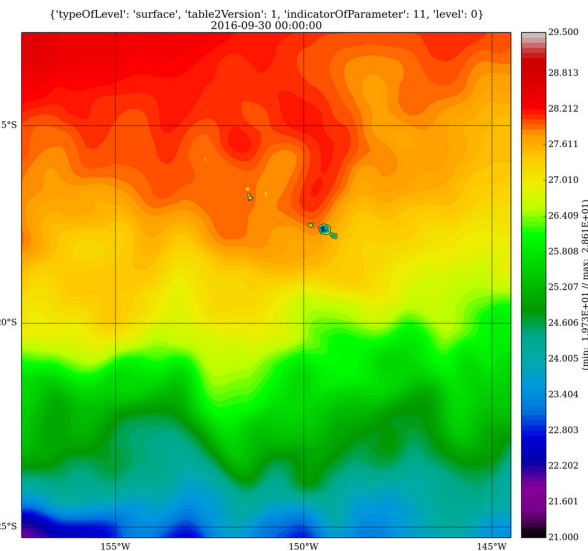# Ocean mixed layer 1D model in Arome Overseas
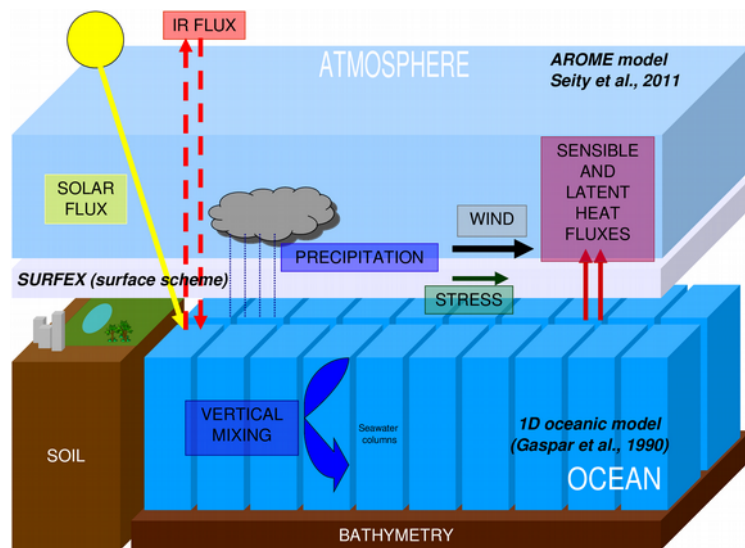
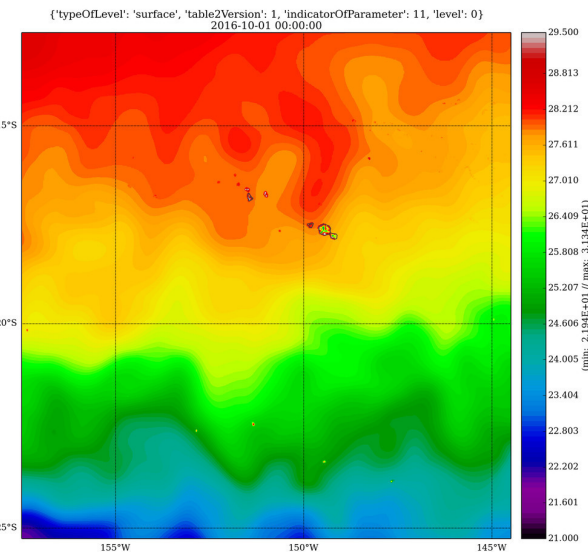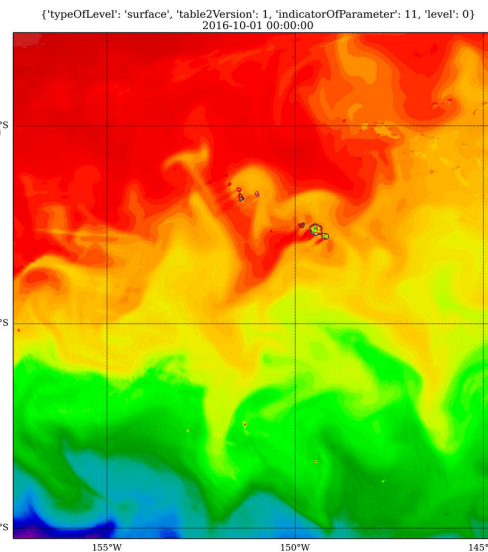- Daily initial conditions from Mercator PSY4 operational ocean model

SST with coupling (e-suite)
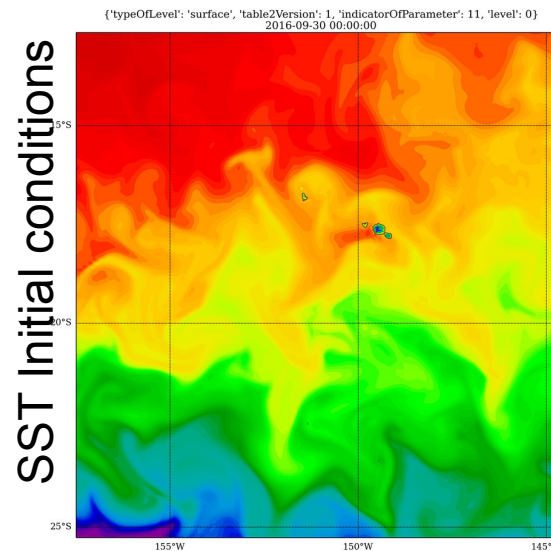
SST without coupling (oper)

SST Initial conditions

SST after 24h integration

Physical packages

	Targeted physics for hydrostatic scales (ARPEGE NWP and Climat)	Operational physics of convective scale model (AROME NWP and Climat)
Surface	SURFEX (Masson et al., 13): surface modelling platform	
Radiation	RRTM (Mlawer, 97) + SW6* (Fouquart 80, Morcrette 01)	
Turbulence	1.5 order scheme prognostic TKE (Cuxart et al., 00)	
Mixing length	Non local, buoyancy based (Bougeault-Lacarrère, 89)	
PBL thermals	New scheme PCMT (5 prog. var) (Piriou et al., 07) and (Gueremy, 11)	PMMC09 (Pergaud et al., 09)
Clouds	PDF based: (Smith, 90) **or** (Bougeault, 82)	
Microphysics	Bulk scheme with 4 prog. var. (Lopez, 02)	Bulk scheme** 5 prog. var. (Pinty and Jabouille, 98)
Convection	Bougeault (1985),	×
Subgrid orographic effects (GWD, blocking, etc.)	Catry-Geleyn (08)	×

Surface

"SURFEX", an "externalized" surface model, is progressively used.

Same physiography and surface schemes are currently used all systems : ECOCLIMAP database, ISBA soil/vegetation/ hydrology, D95 snow scheme, ECUME sea surface fluxes, except Town Energy Model used only in convective scale model
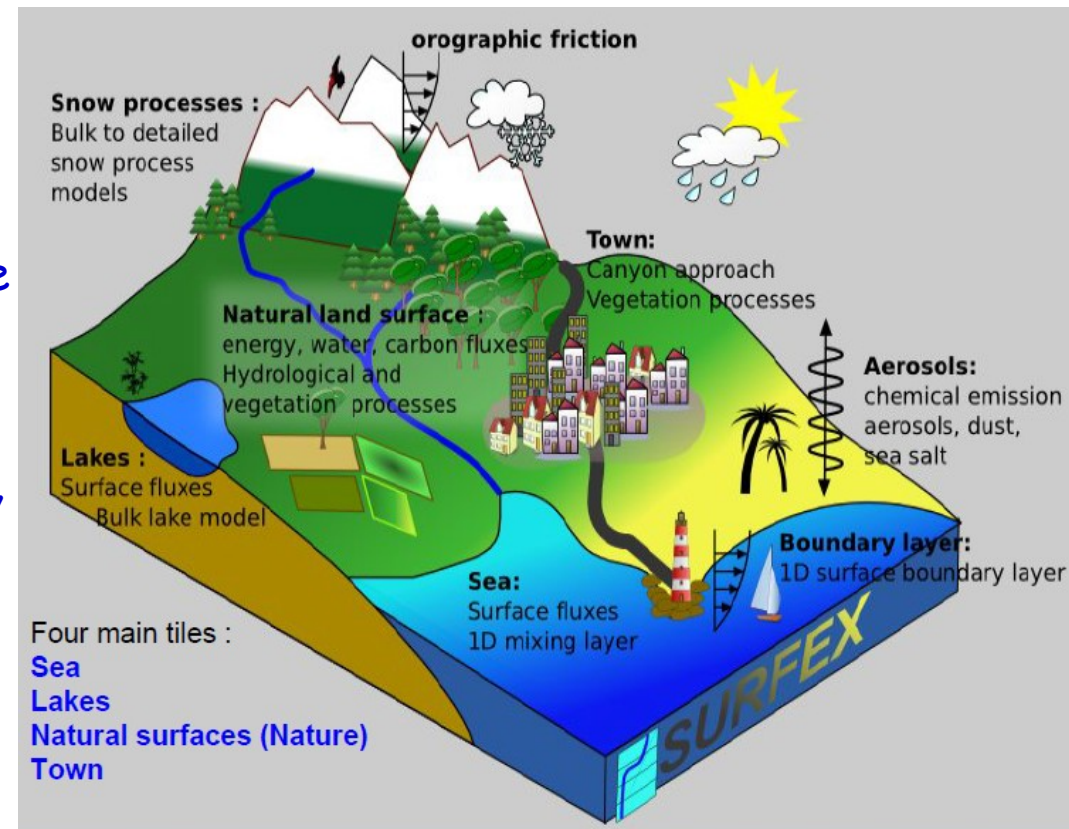
New surface parameterizations developed simultaneously for LAM and global NWP and Climat systems : Explicit soil diffusion scheme (ISBA-DIF), Explicit snow scheme (ISBA-ES), Multi-Energy balance (MEB), Carbon options (ISBA-A-gs)

(Masson et al., 2013)

LIMA: Liquid Ice Multiple Aerosols

- 2-moment, mixed-phase microphysical scheme

Droplets	Drops	Ice	Snow	Graupel	Hail
r_c N_c	r_r N_r	r_i N_i	r_s	r_g	r_h
r: mass mixing ratio (kg.kg^{-1})			N: number conc. (#.kg^{-1})		

- Derived from ICE3, with improved representation of some processes

  – Explicit deposition of water vapour on ice crystals

  – Improved pristine ice → snow conversion

- Vié *et al.*, 2016: *LIMA (v1.0): a two-moment microphysical scheme driven by a multimodal population of cloud condensation and ice freezing nuclei*, GMD, doi:10.5194/gmd-9-567-2016.

Short term plans

➢ Next E-suite : CY43T2 (?)

Scheduled from beginning 2018 to autumn 2018

Migration to VORTEX (Python toolbox) for ARPEGE 4DVar, EDA and AROME 3DVar

Migration to GRIB2 format

New horizontal resolutions for global systems (deterministic, EDA, EPS)

- ARPEGE: ~5km over France (T_l1798c2.2L105), 2 minimisations in T_l224c1L105 and T_l499c1L105

- EPS: 35 members (unchanged) at ~7.5 over France (~T_l1198c2.2L90) and four times per day

- EDA: 50 members in T_l499c1L105

➢ AROME-EPS and ARPEGE-EPS: 4 times per day

➢ Implementation of new system AROME-EDA

➢ Many uncertainties for the next HPC