Status of GEM/NEMO

GOAPP Workshop

Ottawa ON

Jean-Marc Bélanger[1], Gregory Smith [1], François Roy [2] and Hal Ritchie[1]

 [1] Meteorological Research Division, EC

 [2] Canadian Meteorological Centre, EC

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Outline

- Background on CONCEPTS

- Previous steps

- Components of global coupled system in development

- Preliminary results from coupled model

- Summary and look ahead

Environment Canada   Environnement Canada

Canada

CONCEPTS

- An initiative for operational Canadian coupled atmosphere-ocean-ice assimilation and modelling systems

- To take advantage of improvements in ocean and ice models and real time global oceanographic data sets (Argo, altimetry,…) in order to
  - produce new ocean and ice products
  - improve weather and climate predictions

Partnerships

- For cost effectiveness, EC, DFO and DND are collaborating on this major initiative.

- We have established the Canadian Operational Network of Coupled Environmental PredicTion Systems (CONCEPTS).

- Partnering with Mercator-Océan (France) for ocean aspects (Nucleus for European Modelling of the Ocean (NEMO) system)

Previous steps

- Validation of NEMO installation at CMC, replacing ECMWF forcings by GEM forcings, sensitivity of annual NEMO simulations driven by GEM forcings

- Weekly 10-day ocean forecasts

- Initial 1 deg GEM-NEMO coupling

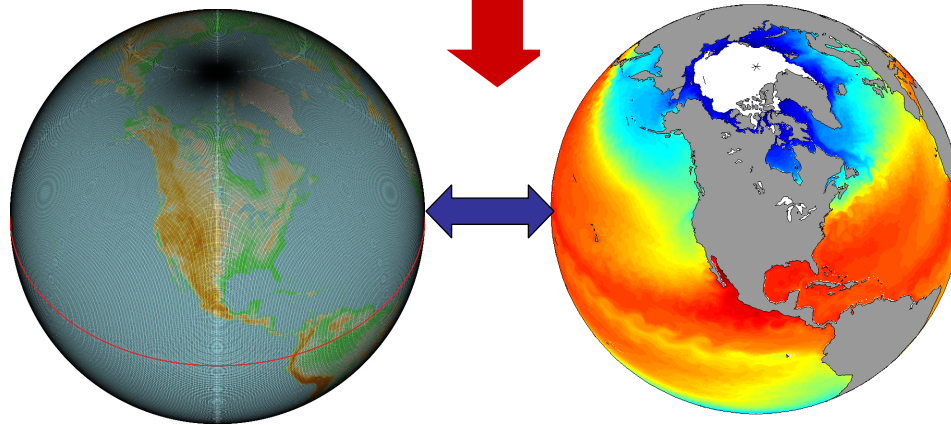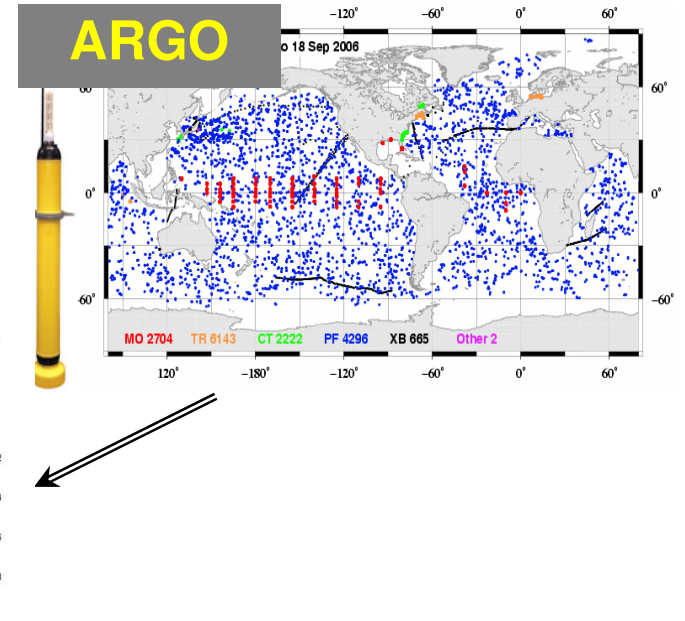- Installation of the Mercator ocean data assimilation system (SAM2) at CMC

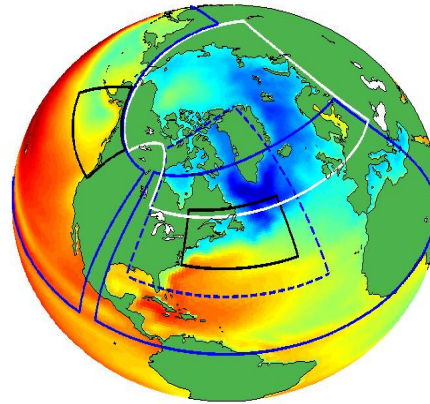Environment Canada Environnement Canada

Canada

Components of global coupled system in development

1. GEM atmospheric model (EC-GDPS)
2. 4Dvar atmospheric assimilation system (EC-GDPS)
3. NEMO-LIM2 ocean-seaice model (IPSL-Mercator)
4. SAM2v1 ocean assimilation system (Mercator)

Pivotal role of GEM-NEMO
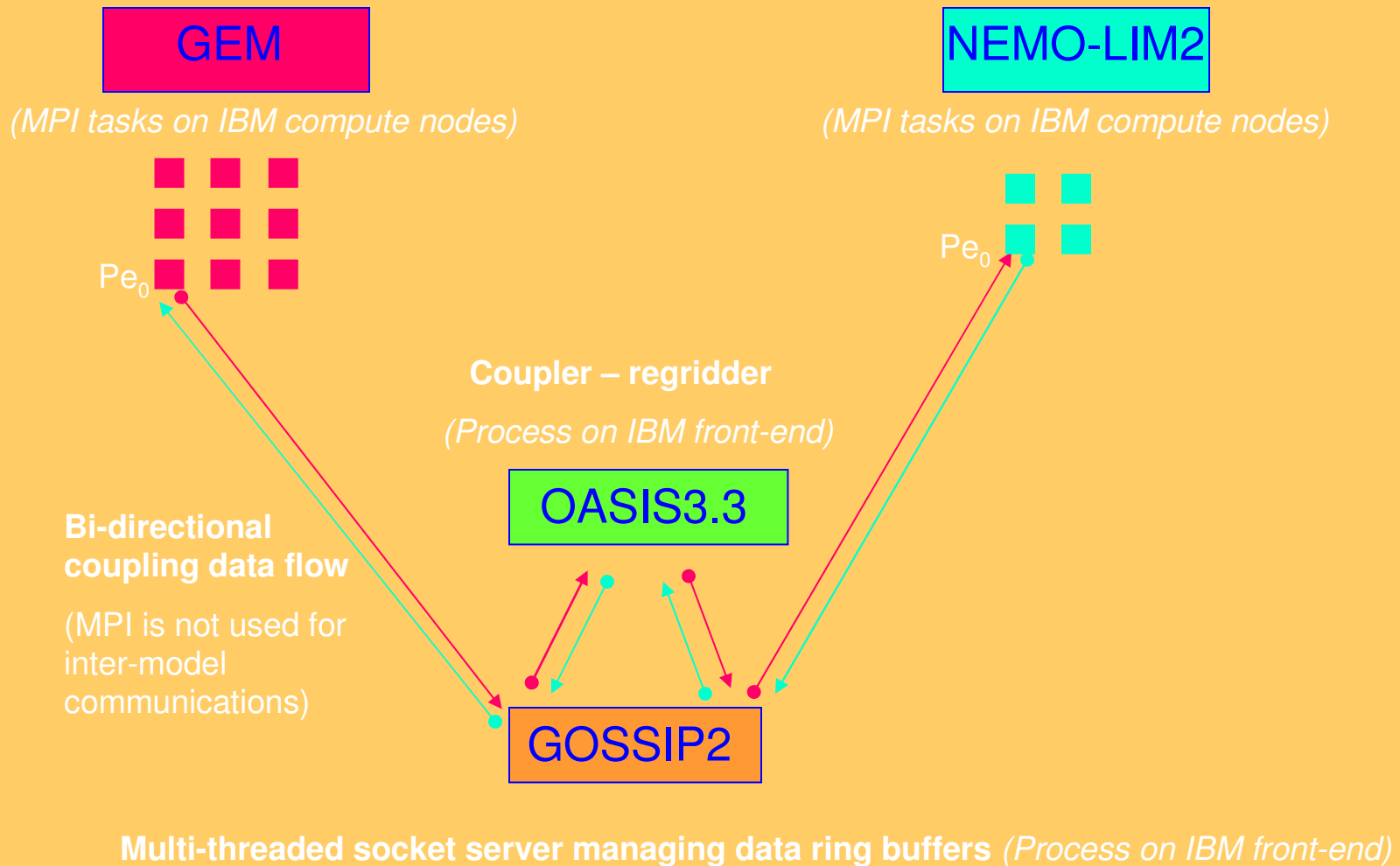
Altimeter
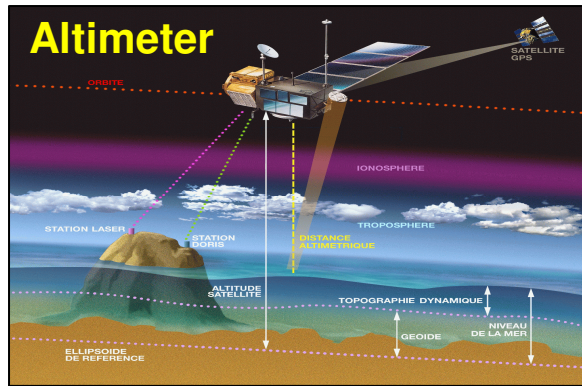
**Ocean Modelling &
Data Assimilation**

ARGO

Coupled Global GEM-NEMO

Global coupled model architecture
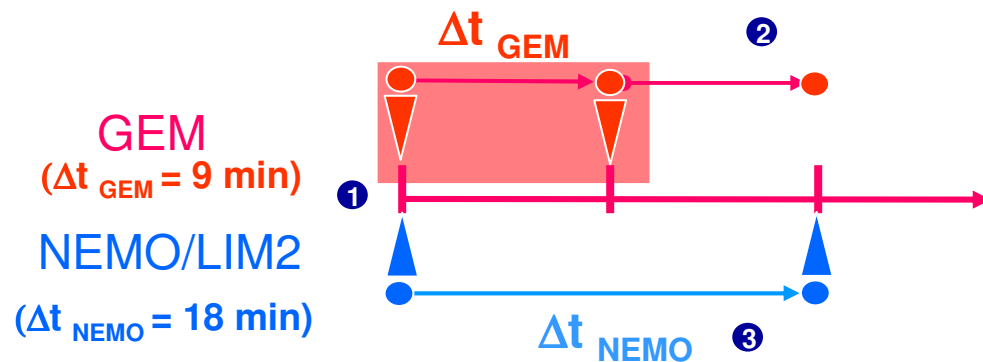
v_3.3.2 (0.3degL58)

v_3.1 (0.25degL50)

GEM

NEMO-LIM2

(MPI tasks on IBM compute nodes)

(MPI tasks on IBM compute nodes)

Pe_0

Pe_0

Coupler – regridder

(Process on IBM front-end)

OASIS3.3

**Bi-directional
coupling data flow**

(MPI is not used for
inter-model
communications)

GOSSIP2

Multi-threaded socket server managing data ring buffers *(Process on IBM front-end)*

State variable coupling

GEM
(Δt_{GEM} = 9 min)

NEMO/LIM2
(Δt_{NEMO} = 18 min)

Δt_{GEM}

Δt_{NEMO}

Bulk formulations:

RPN S.L. (GEM) / CORE (NEMO)

▼ATM → OCE

U: zonal wind component at 1st level (~50m)
V: meridional wind component at 1st level
T: air temperature at 1st level
Q: specific humidity at 1st level

p_{nk-1}: pressure at 1st level
Q_S: Incoming solar radiation at surface
Q_L: Incoming longwave radiation at surface
R: Precipitation
p_s: Surface pressure

▲OCE → ATM

SST: Sea surface temperature
Tice: seaice surface temperature
Cice: seaice concentration
Hice: seaice depth
M: binary land-sea mask

($\vec{V}o$: ocean surface current)

Preliminary results from global coupled model simulations in development

- Hi-res GEM_03 / NEMO_025
(801x600x58L uniform lat-lon grid) / (1442x1021x50L ORCA025 tripolar grid)

- Short runs (4 days) starting on 2009052000

- Hi-freq. coupling: 18 min. (Δt_{GEM}=9min./ Δt_{NEMO}=18min.)

- Initial conditions: 4Dvar G2 operational analysis

  Mercator SAM2 operational analysis

- Bulk formulae : RPN S.L. physics (GEM) vs CORE (NEMO)

- Regridding:

ATM $\rightarrow$ OCE: Bicubic and Linear Interpolations from OASIS3 (EZSCINT)

OCE $\rightarrow$ ATM: Distance weighted averaging from OASIS3 (SCRIP)

Impact of coupling + SST I.C. on 96H T forecast

ΔTa(η=0.995)

5(K)

-5
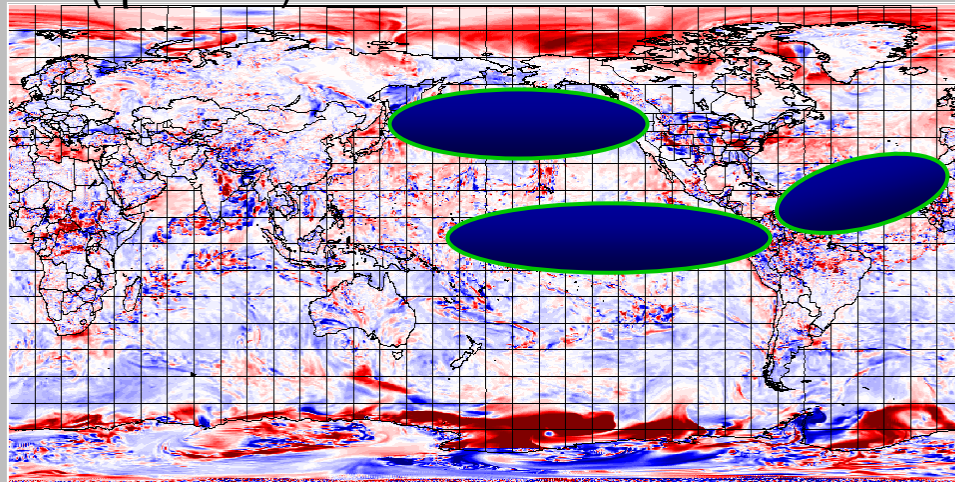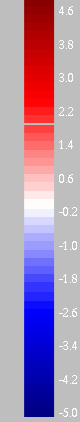
CPL –

GEM (constant CMC SST)

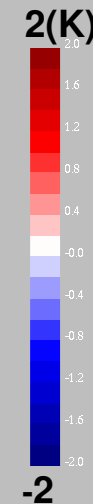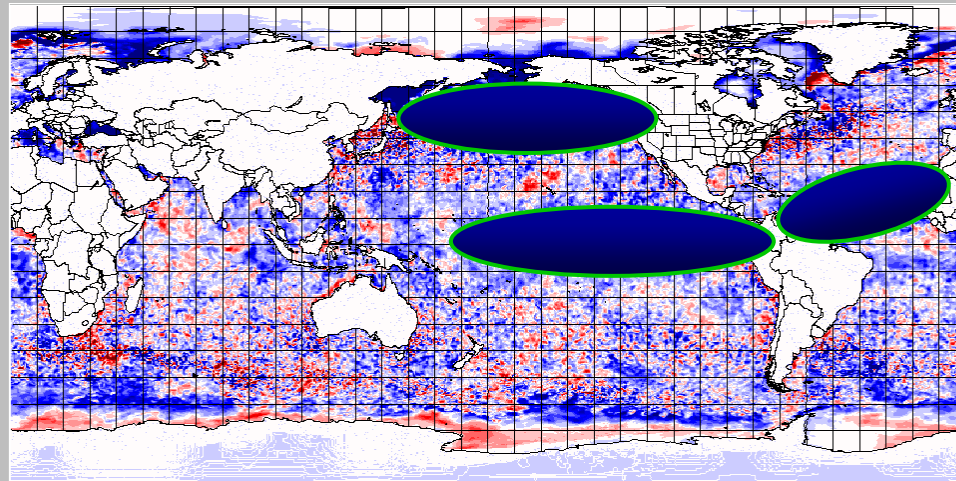ΔSST at initial time

2(K)

-2
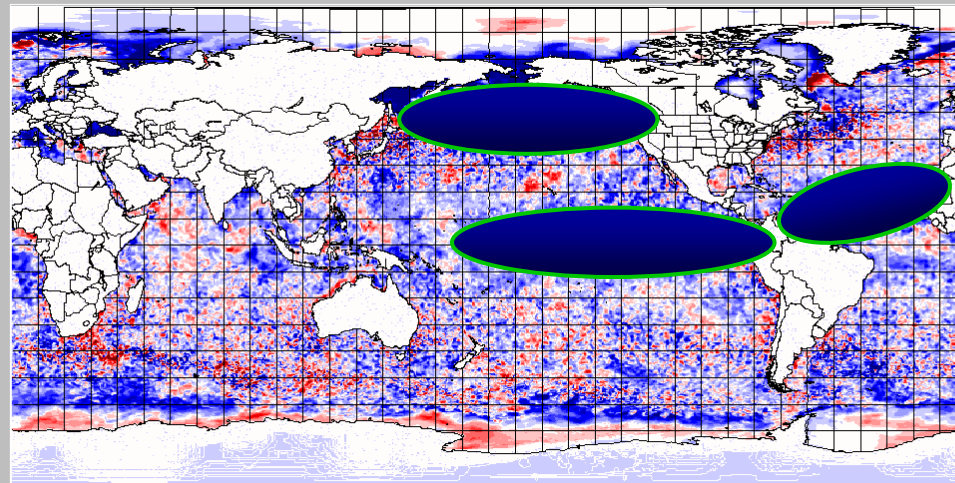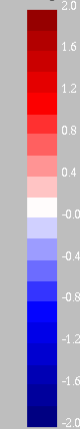
Mercator SST -

CMC SST

Impact of SST I.C. only on 96H T forecast

$\Delta Ta(\eta=0.995)$
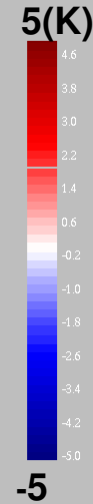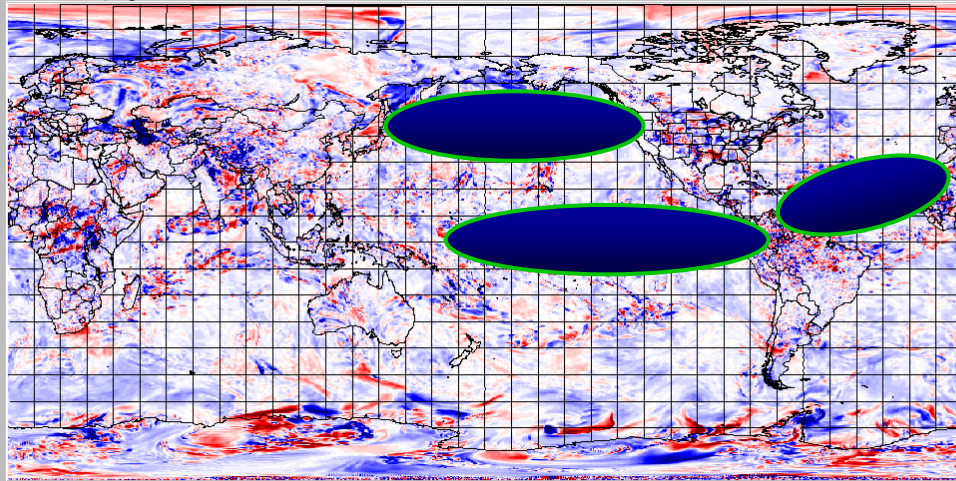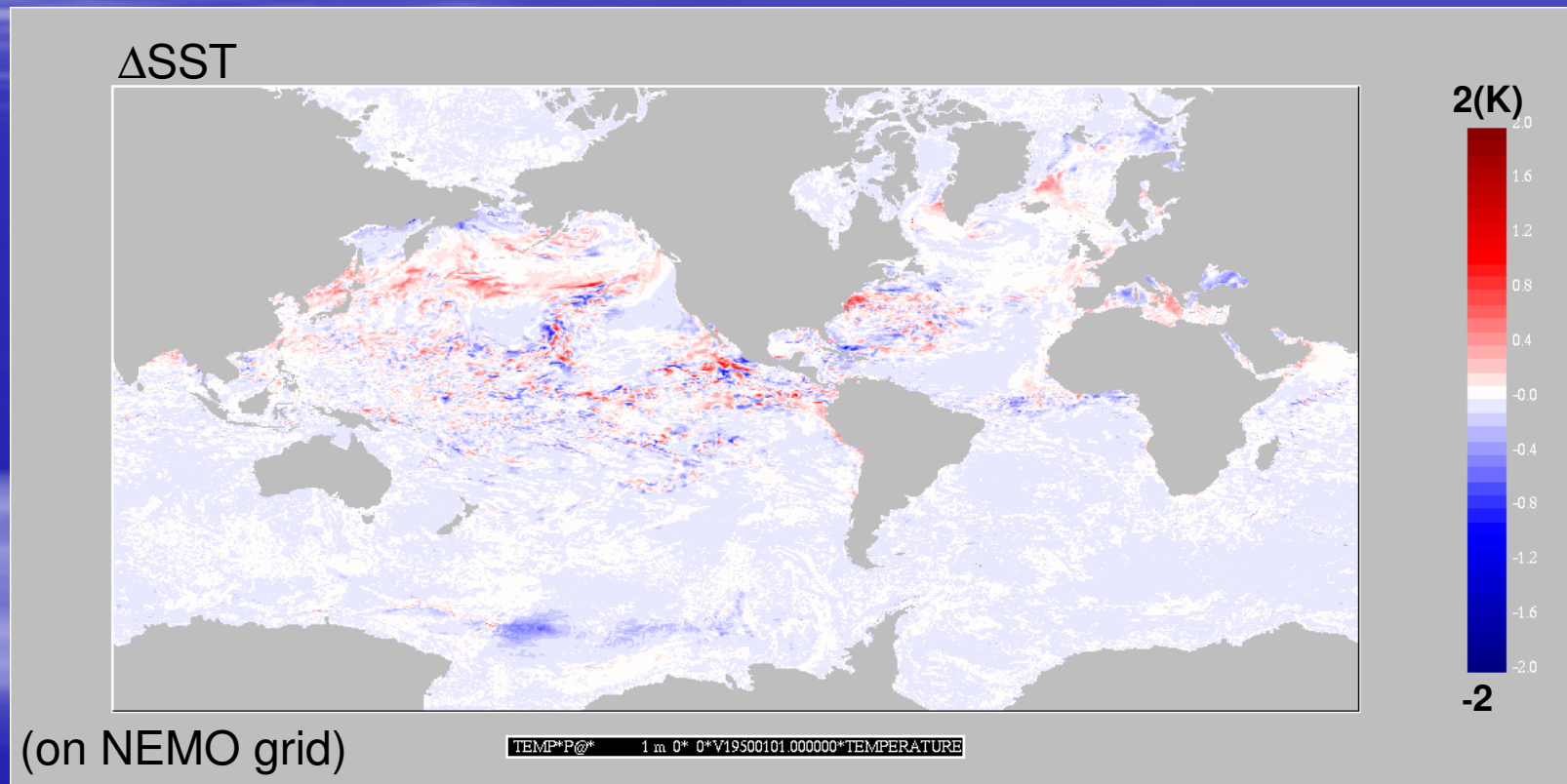
GEM (Mercator SST) -

GEM (CMC SST)

(constant SST runs)

ΔSST at initial time

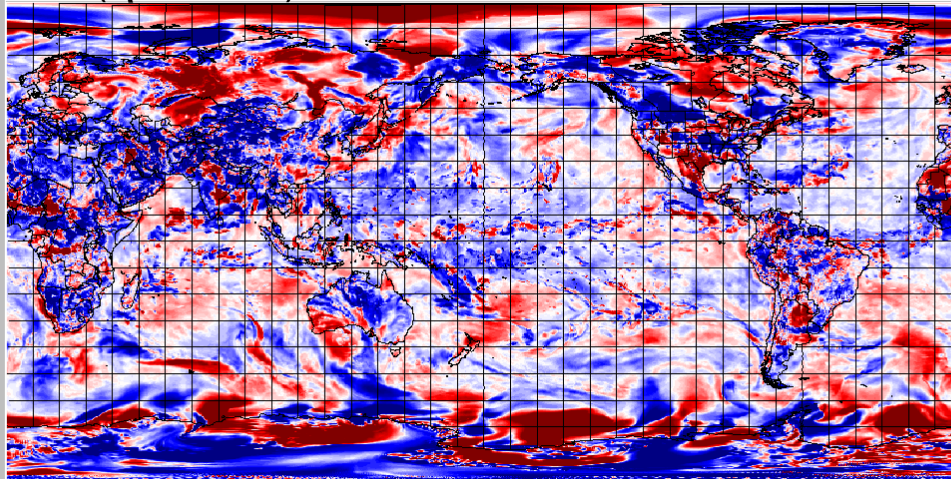Mercator SST -

CMC SST

(repeated)

... meanwhile in the ocean ...
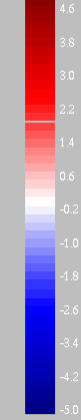
96H SST forecast difference (CPL – FORCED)

96H forecasts verification against CMC analysis
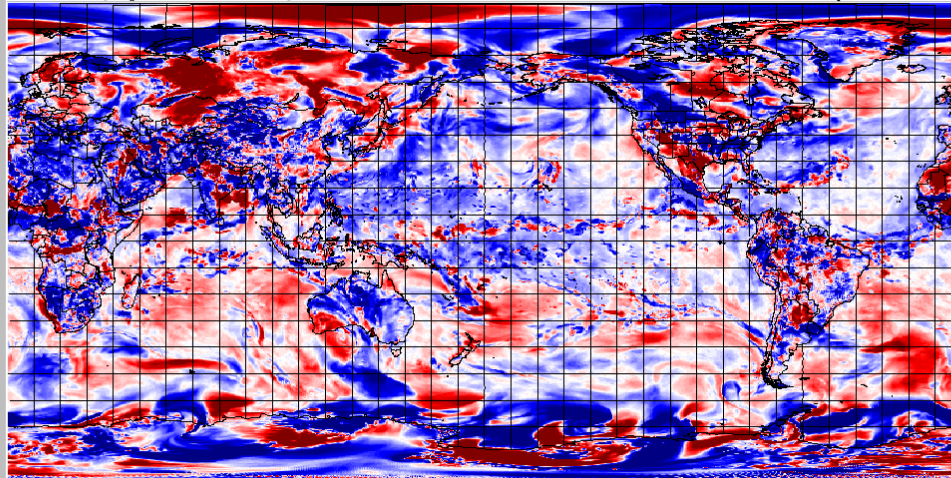

ΔTa(η=0.995)   Initial SST from Mercator

5(K)

-5

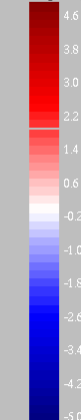TT*[P-A]* 0.9950 sg[96- 0]* 0*V20090524.000000*[ETIKET-G233K4DN]

CPL –

4Dvar analysis

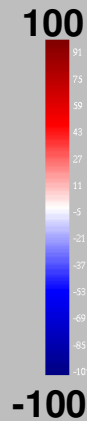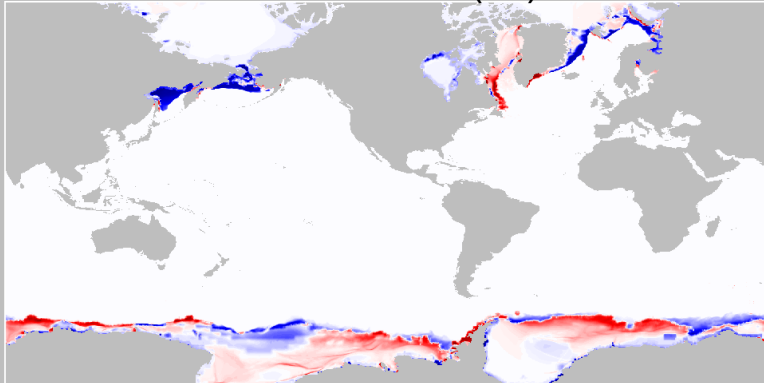ΔTa(η=0.995)   Constant SST (CMC)

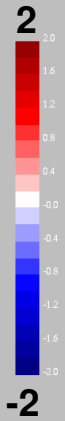5(K)

-5

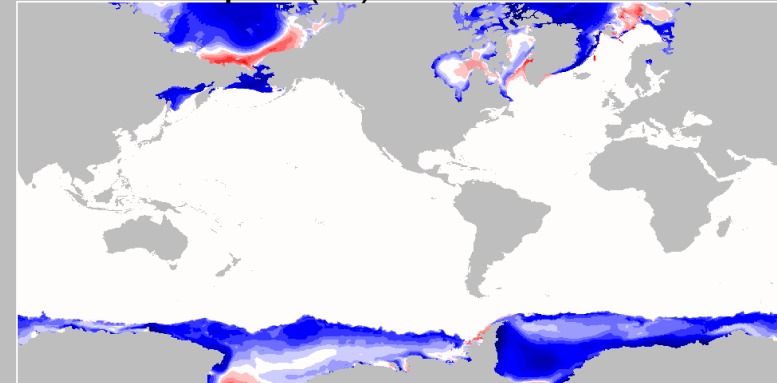TT*[P-A]* 0.9950 sg[96- 0]* 0*V20090524.000000*[G133K58N-G233K4DN]

CMC operational G1-
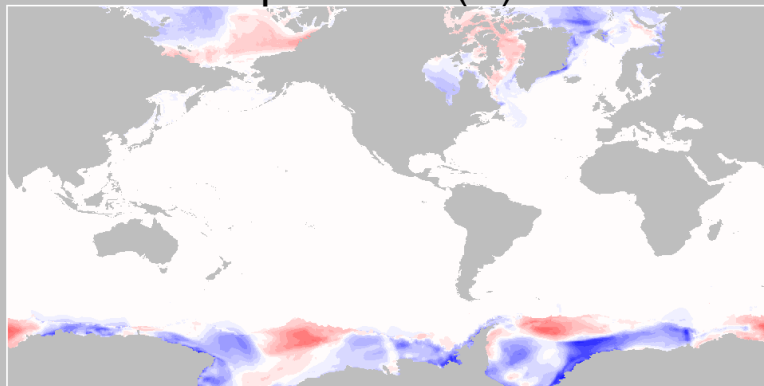
4Dvar analysis

Seaice initial conditions (CMC – Mercator)
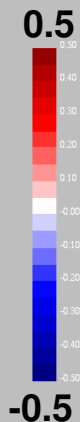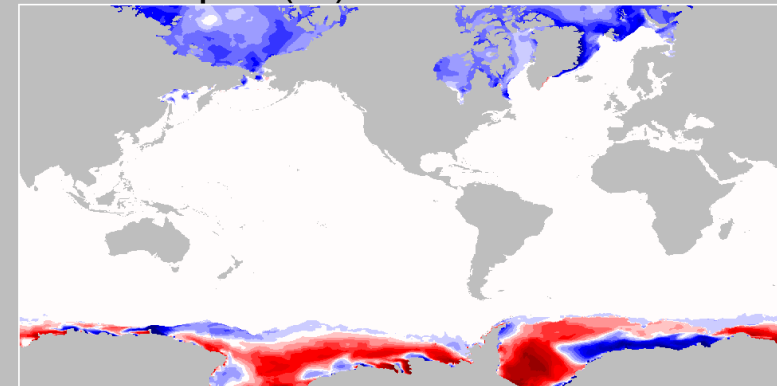
Impact of seaice I.C.s on CPL 96H forecast
(CMC – Mercator)
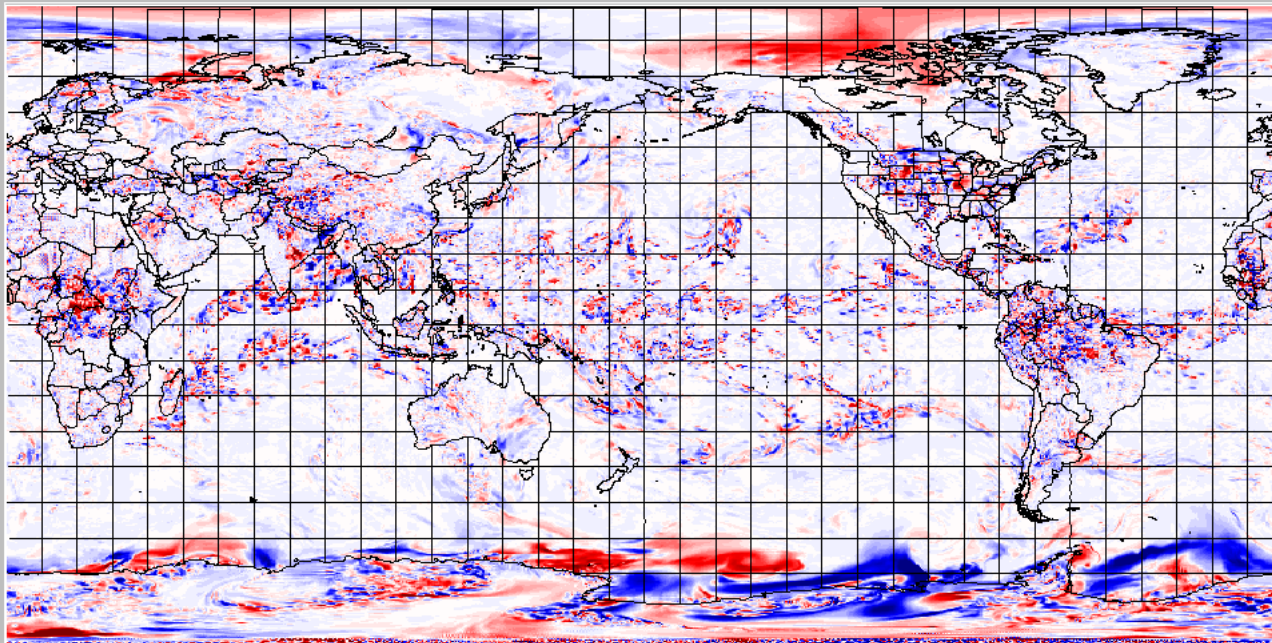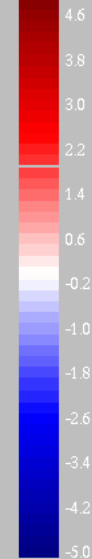

ΔTa(η=0.995)

5(K)

-5

TT*P* 0.9950 sg 96* 0*V20090524.000000*[ETIKET-CPL03]

SUMMARY

- Much effort spent on technical aspects.
  Results from first verification are encouraging.
- Further developments of prototype system:
      - use same bulk formulae / flux coupling
      - review regridding and land-sea mask coherence
      - spatial aggregation from oce $\rightarrow$ atm (SCRIP)
      - perfect restart
- Evaluation and tuning on multiple cases and longer runs (10 days and longer)

Look ahead : coupling in CONCEPTS

- Complete prototype system (this work)
- Test in long-range forecasts (monthly, seasonal)
- Development of GEM-NEMO Great lakes (Fortin et al.)
- Development of GEM-NEMO NW Atl
- Extend to Arctic region
- Oceanic and seaice initial conditions:
  $\rightarrow$ SST (G. Smith talk), polar regions (Buehner & Caya)
- Coupled data assimilation initiative (Skachko & Gauthier)

Merci / Thank you

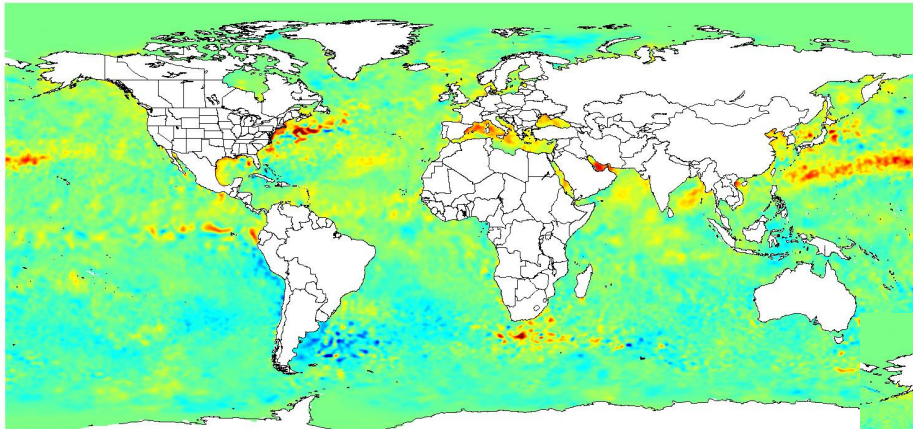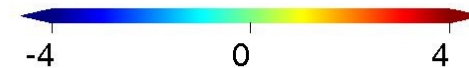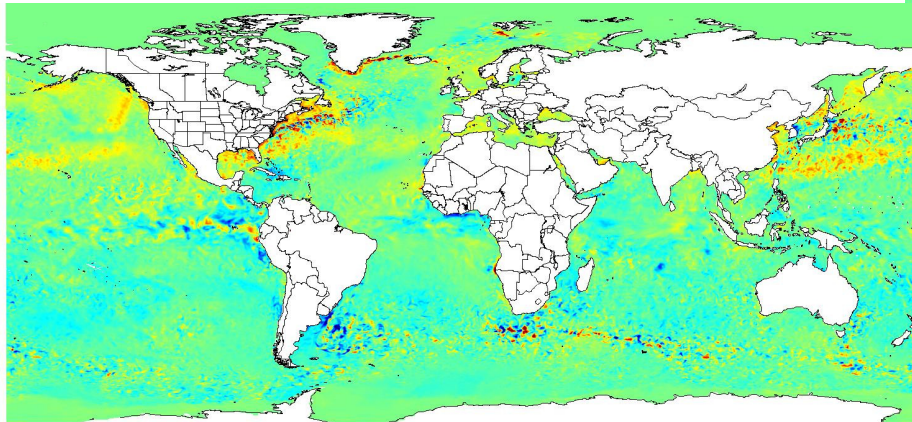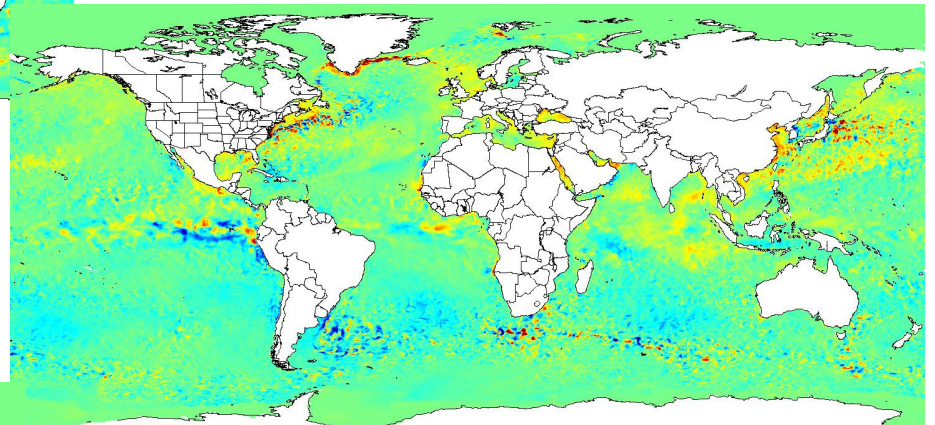Environment Canada

Environnement Canada

Canada

Forecast simulation
SST trend over 10 days (April 19-28, 2007)

CMC analysis based on satellite observations

PSY3V2 forecast (Mercator)

Forecast with 3-hourly GEM forcing
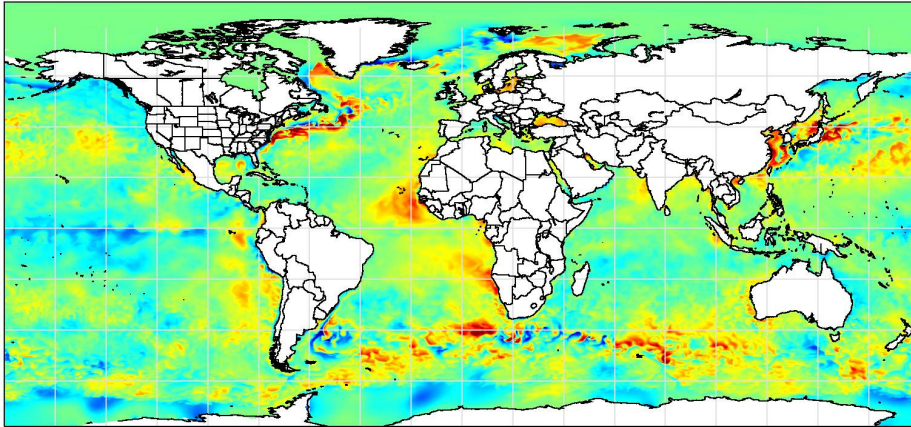
Weekly 10-day forecasts now at CMC

-4   0   4

NEMO yearly simulations: verification with CMC analysis
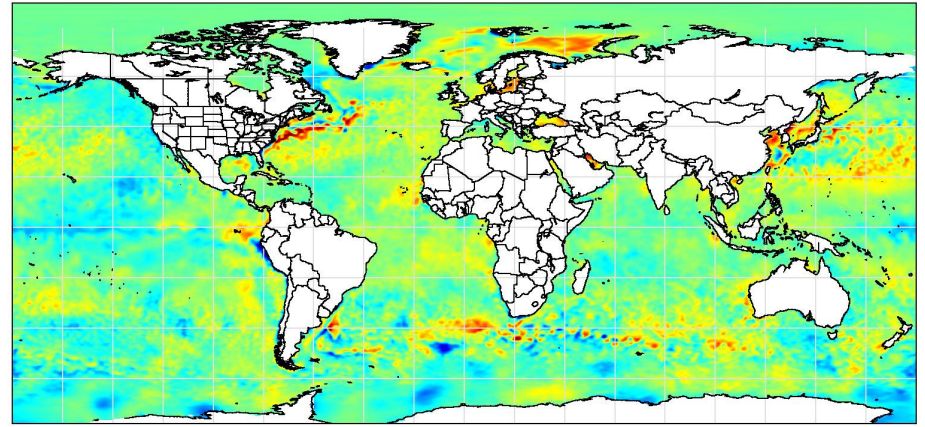
After 1 year: April 18 2008

SST anomaly based on Levitus monthly climatology
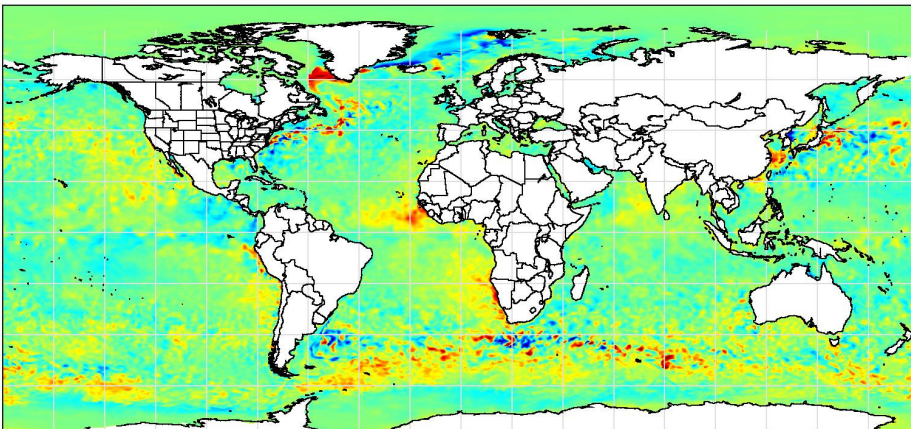

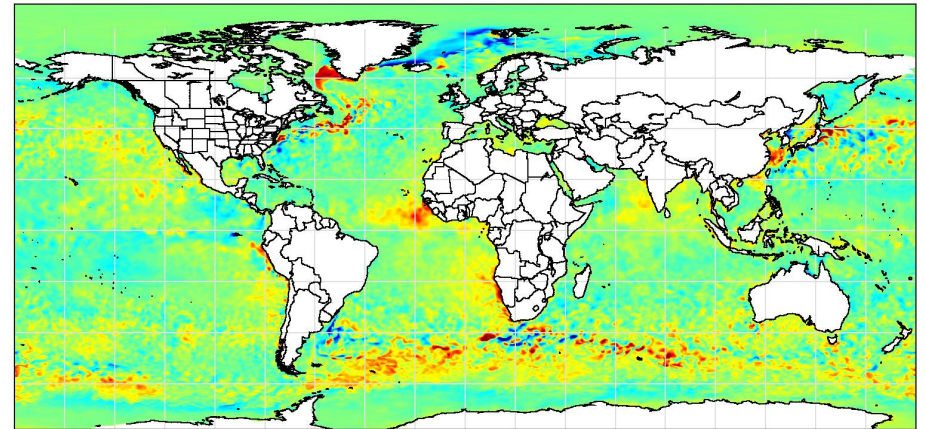Warm bias decreasing in the southern hemisphere …

SAM2v1 Assimilation System

- Reduced-order Extended Kalman Filter (SEEK)
- Error covariance matrix is represented by an ensemble of anomalies from a reference simulation:
  - ~350 multivariate modes with SSH, T, S, U, V
- Adaptivity:
  - Background error variance adjusted at each assimilation cycle to be consistent with innovation statistics (Talagrand, 1998)
- Localization applied
  - e.g. Houtekamer and Mitchell, 2001
  - Spatially-varying decorrelation radii used
- SAM2 has been extensively tested and is used operationally by Mercator

Observations assimilated

- **Sea level anomalies :**
  - AVISO SSALTO/DUACS
   - Jason (2cm), ENVISAT and GFO (3.5cm)
    - Near-coast representivity error
    - Mean dynamic topography used:
      - Rio et al., 2005 (~5cm rms error)
- **Sea surface temperature :**
  - NCEP SST RTG (~0.7C)
- **In situ profile T and S data :**
  - E.g. Argo, XBT, TAO, CTD, …
  - CORIOLIS (Brest)
  - Quality Controlled by CLS (Toulouse)

Incréments d'analyse de la SST valide le 20080227 (cycle de 7 jours)
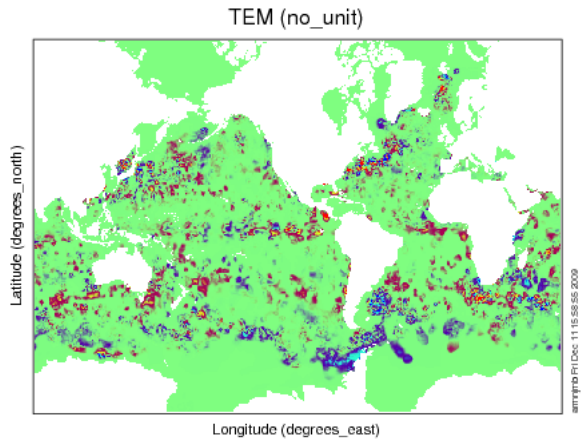
TEM (no_unit)

netcdf file from correction_1.cmx
Range of TEM: -2 to 2 no_unit
Range of Longitude: 72.75 to 73 degrees_east
Range of Latitude: -77.0105 to 49.9955 degrees_north
Current Depth: 1 m
Frame 1 in File correction_1.cdf_bench_mercator
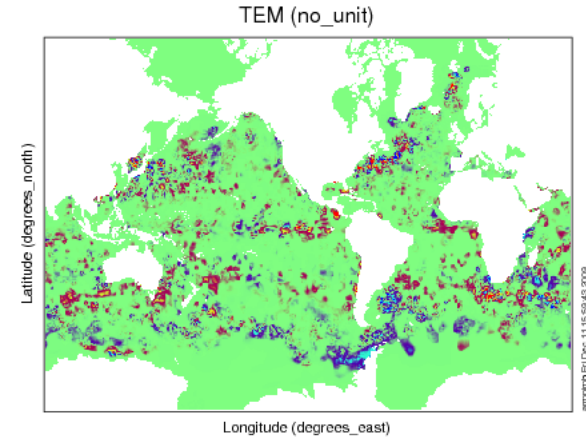
TEM (no_unit)

netcdf file from correction_1.cmx
Range of TEM: -2 to 2 no_unit
Range of Longitude: 72.75 to 73 degrees_east
Range of Latitude: -77.0105 to 49.9955 degrees_north
Current Depth: 1 m
Frame 1 in File correction_1.cdf_jmb

Benchmark Mercator:

1 nœud du Nec SX8:

Configuration (cpus):

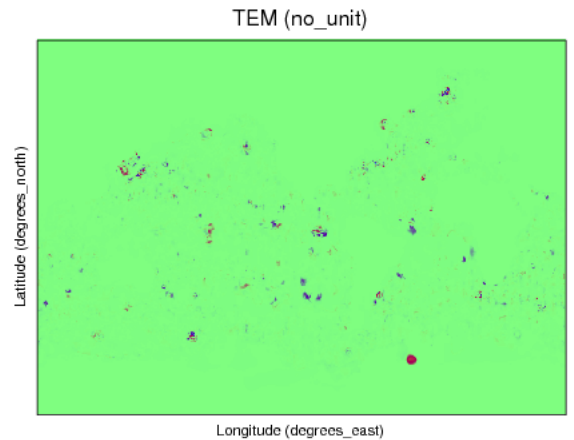1 (driver palm) + 7 (SAM2)

TEM (no_unit)

netcdf file from correction_1.cmx
Range of TEM: -2 to 2 no_unit
Range of Longitude: 72.75 to 73 degrees_east
Range of Latitude: -77.0105 to 49.9955 degrees_north
Current Depth: 1 m
Frame 1 in File diff_correction_1.cdf_jmb_mercator

Dorval:

8 noeuds IBM p5+:

Configuration (cpus):

1 (driver palm) + 127 (SAM2) + 16 (dtm)