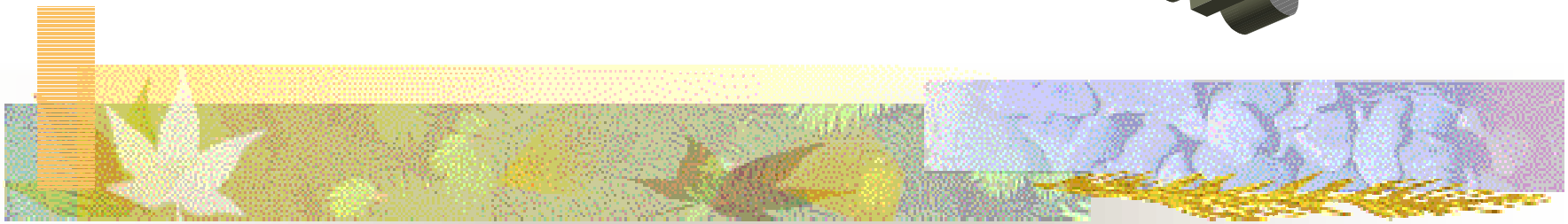
Prévision saisonnière



L'ENSO
El Niño et l'Oscillation Australe

J.P. Céron (Météo-France) et

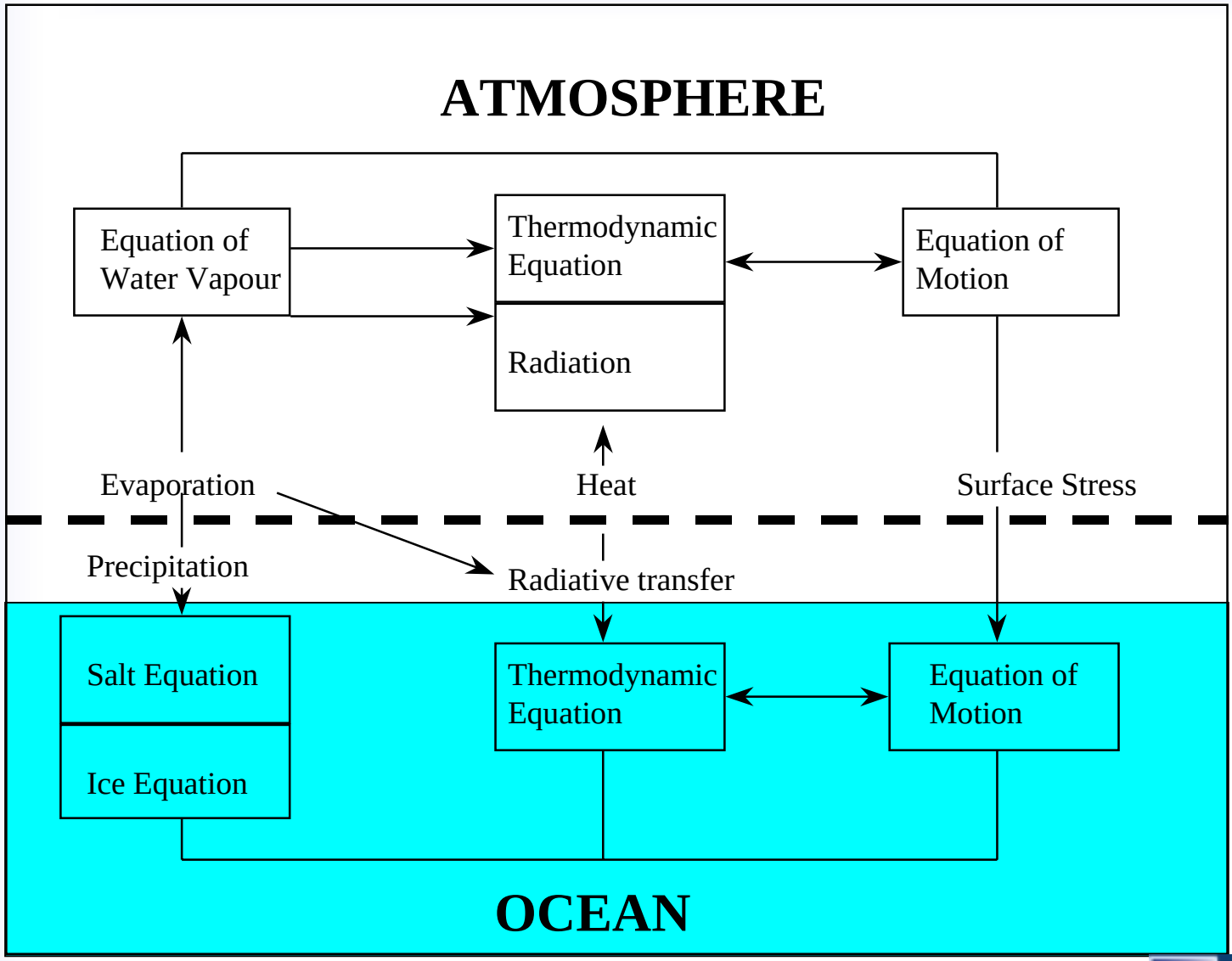
R. Washington (Université d'Oxford)

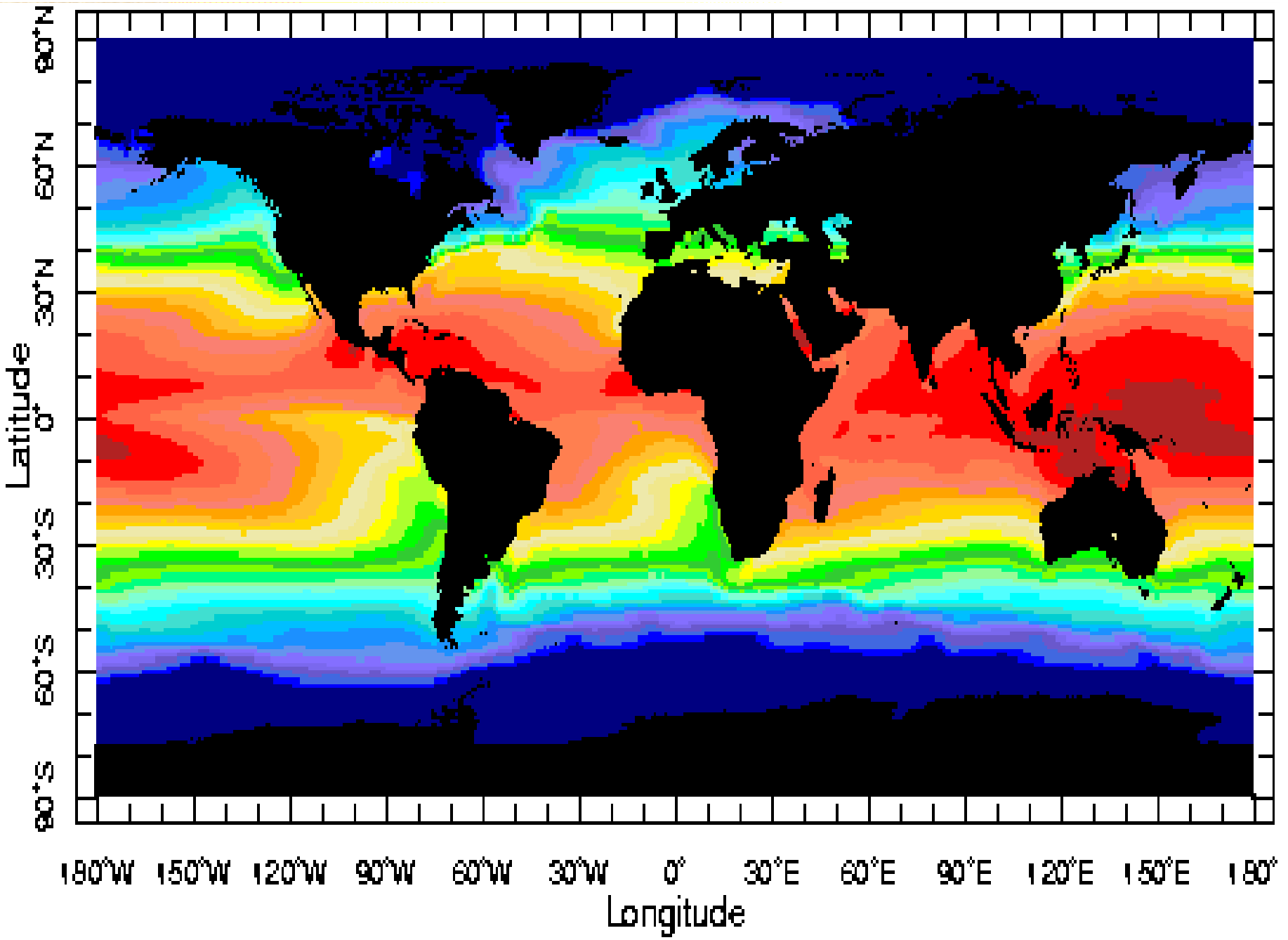
Les Principes de base (1)

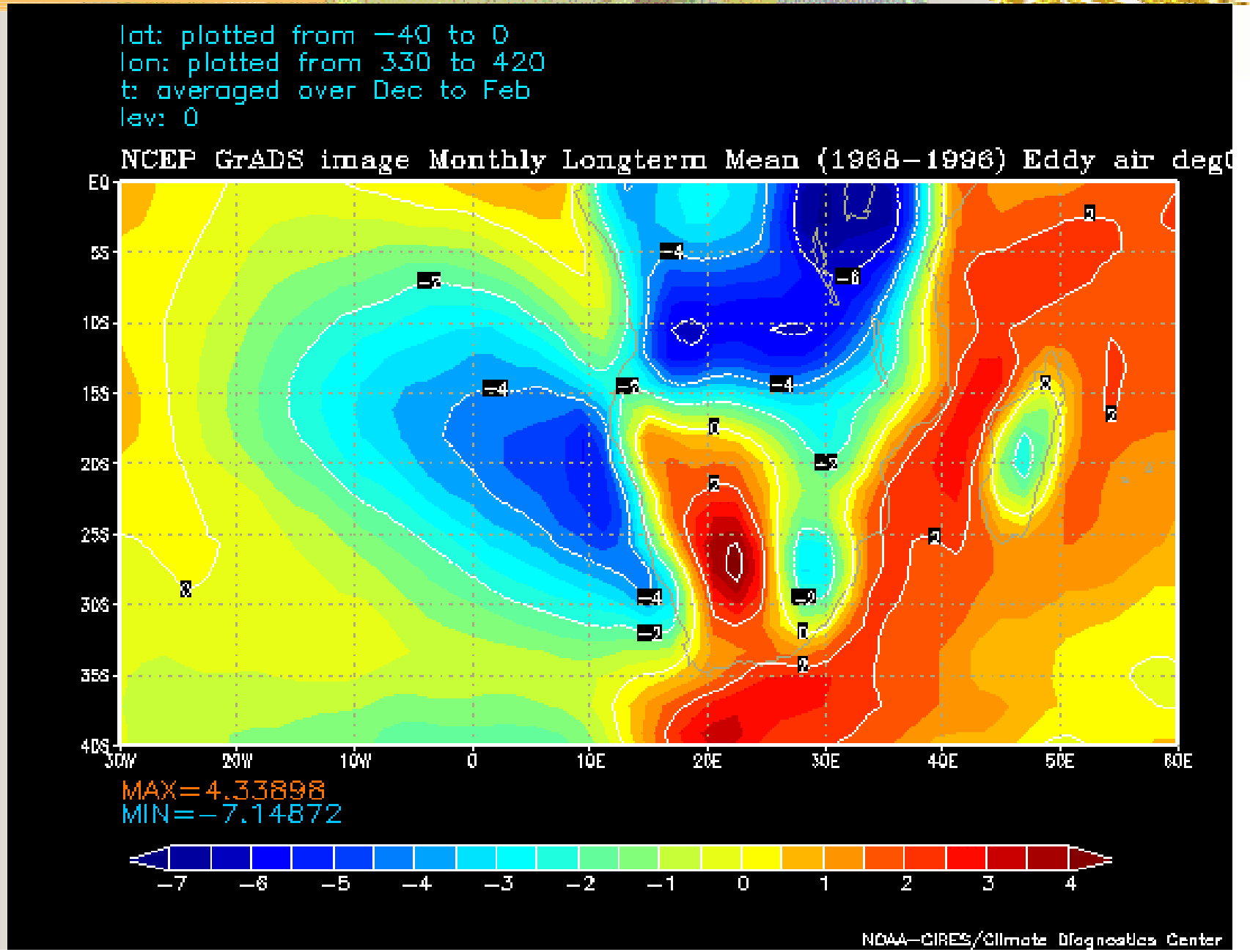
- Circulation moyenne dans les régions tropicales très fortement marquée par la convection organisée à grande échelle (circulation divergente de Hadley-Walker)
- Échanges énergétiques principalement pilotés, dans les régions tropicales par la circulation moyenne
- Circulation moyenne principalement pilotée par les conditions de surface (notamment SST mais aussi surface continentale)
- Rétroactions entre la circulation atmosphérique et les conditions de surface

Les principes de base (2)

- **Les échanges océan/atmosphère**
  - Les flux en surface (sensible, latent, quantité de mouvement)
- **Les interactions océan/atmosphère**
  - Convergences/divergences + tension du vent (dynamique couplée)
  - Transport d'Ekmann
  - Les processus couplés
- **La circulation océanique**
  - Courants de surface et de subsurface
  - Upwelling, downwelling

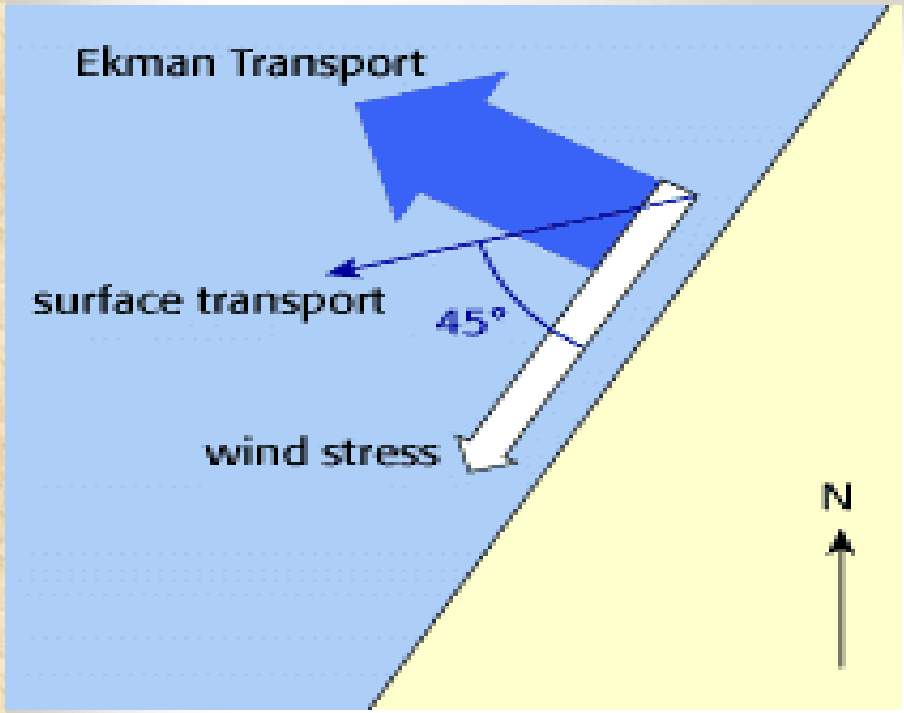

ATMOSPHERE
Equation of Water Vapour
Thermodynamic Equation
Radiation
Equation of Motion
Evaporation
Heat
Surface Stress
Precipitation
Radiative transfer
Salt Equation
Ice Equation
Thermodynamic Equation
Equation of Motion
OCEAN

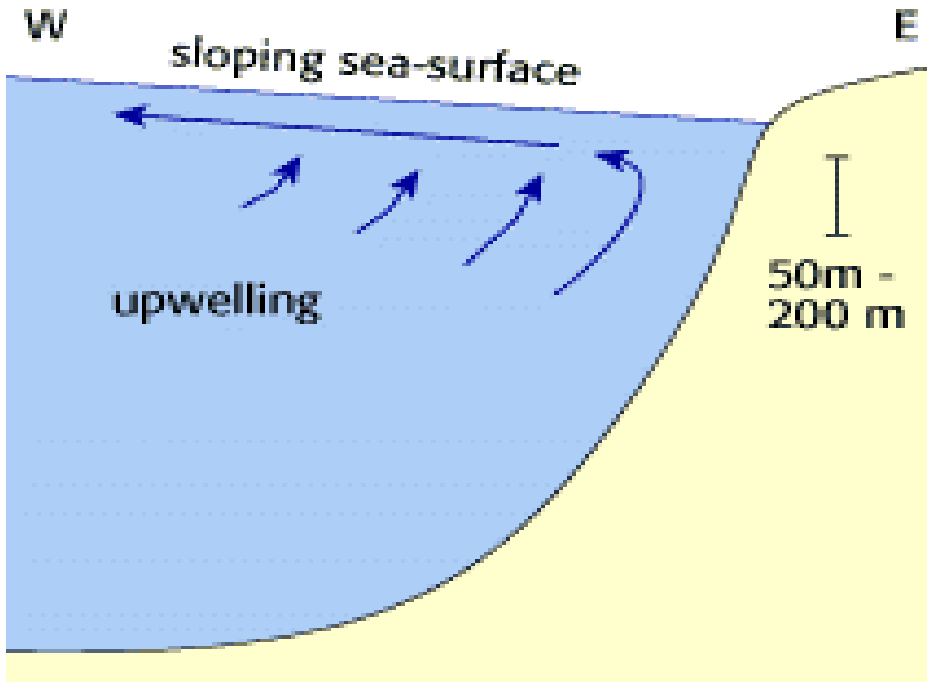

90°N
60°N
30°N
0°
30°S
60°S
90°S
Latitude
180°W
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
Longitude

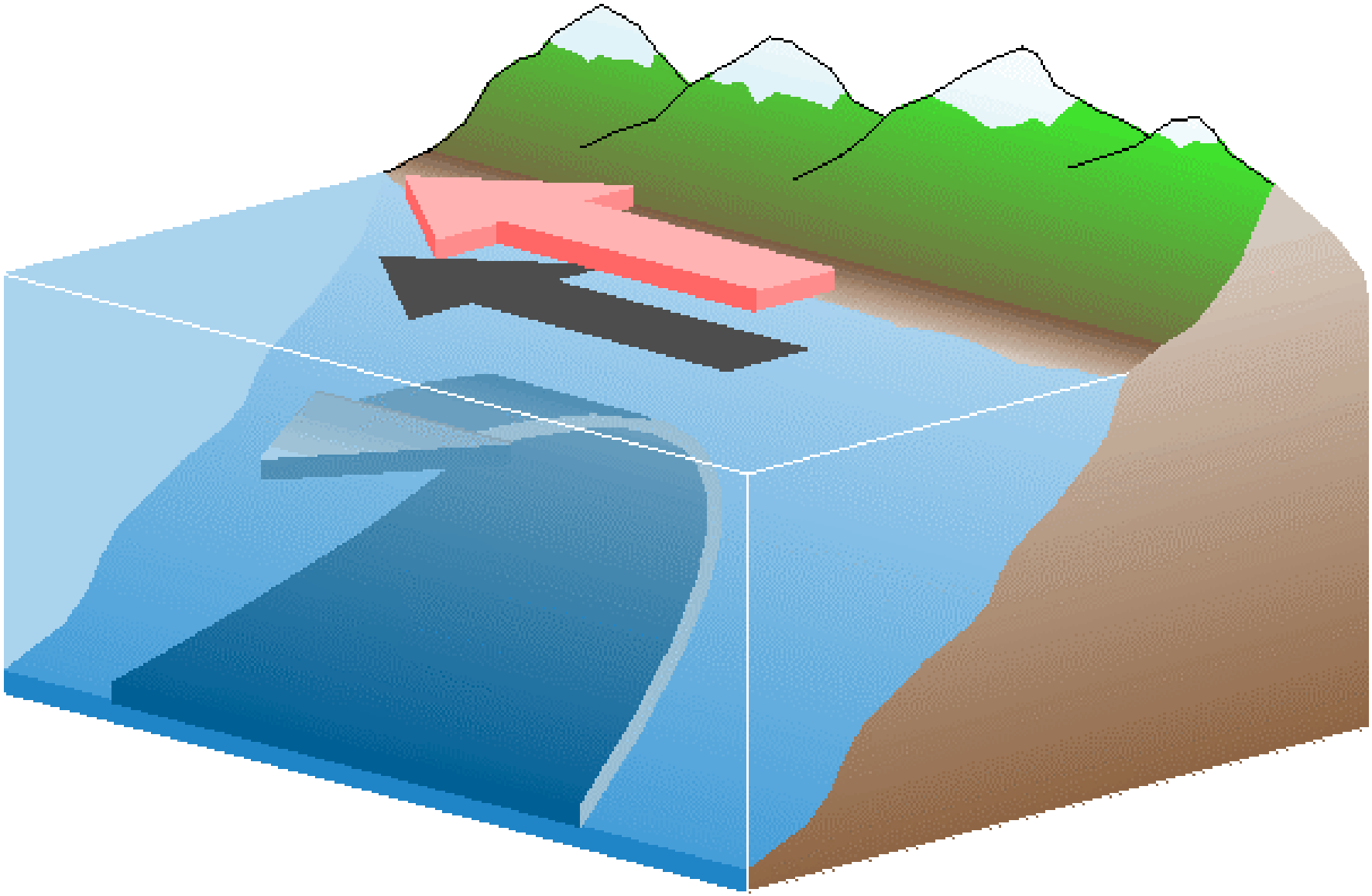

lat: plotted from -40 to 0
lon: plotted from 330 to 420
t: averaged over Dec to Feb
lev: 0
NCEP GrADS image Monthly Longterm Mean (1968-1996) Eddy air deg
EQ
5S
10S
15S
20S
25S
30S
35S
40S
30W
20W
10W
0
10E
20E
30E
40E
50E
60E
MAX=4.33898
MIN=-7.14872
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
NOAA-CIRES/Climate Diagnostics Center

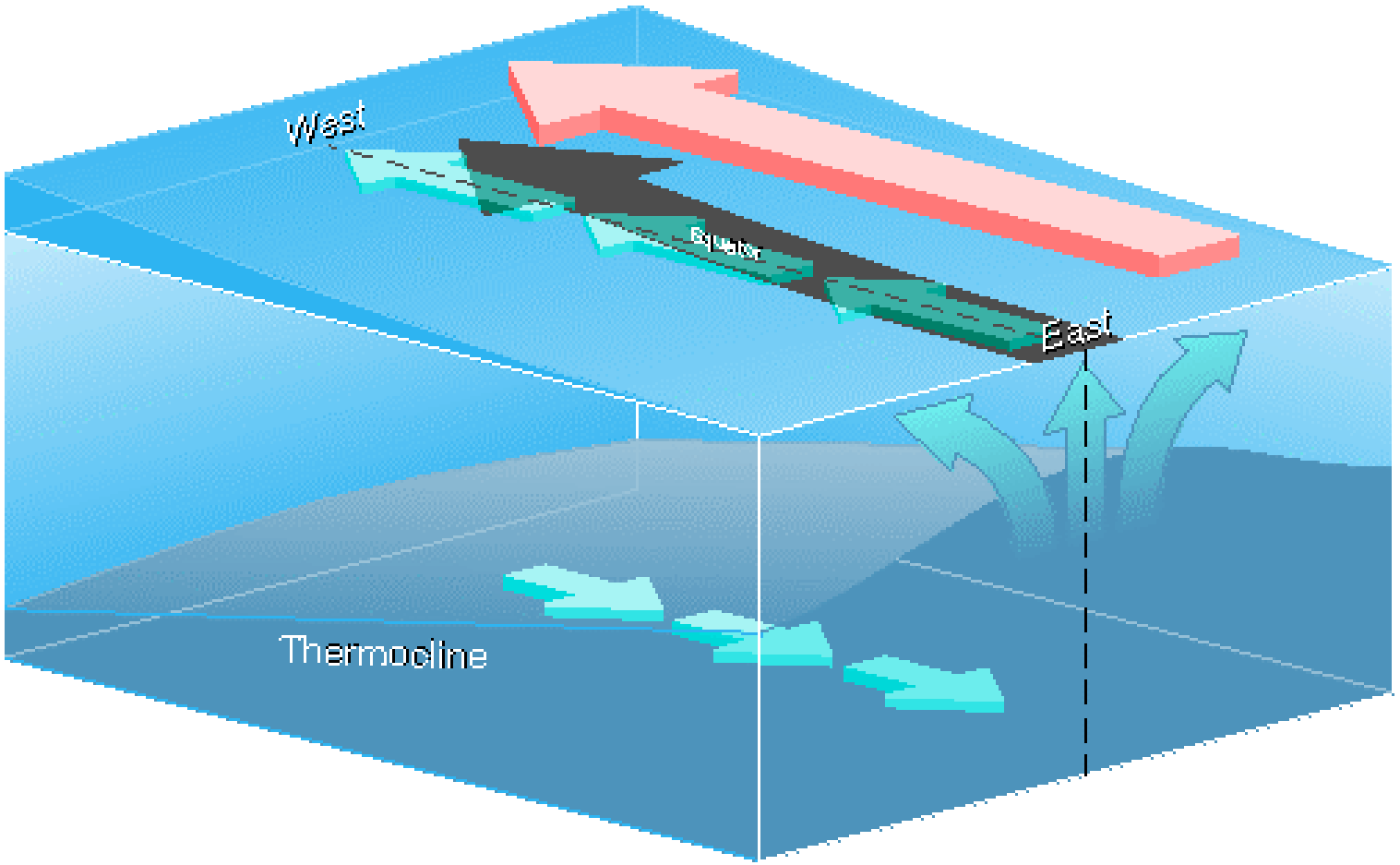
Transport d'Ekman

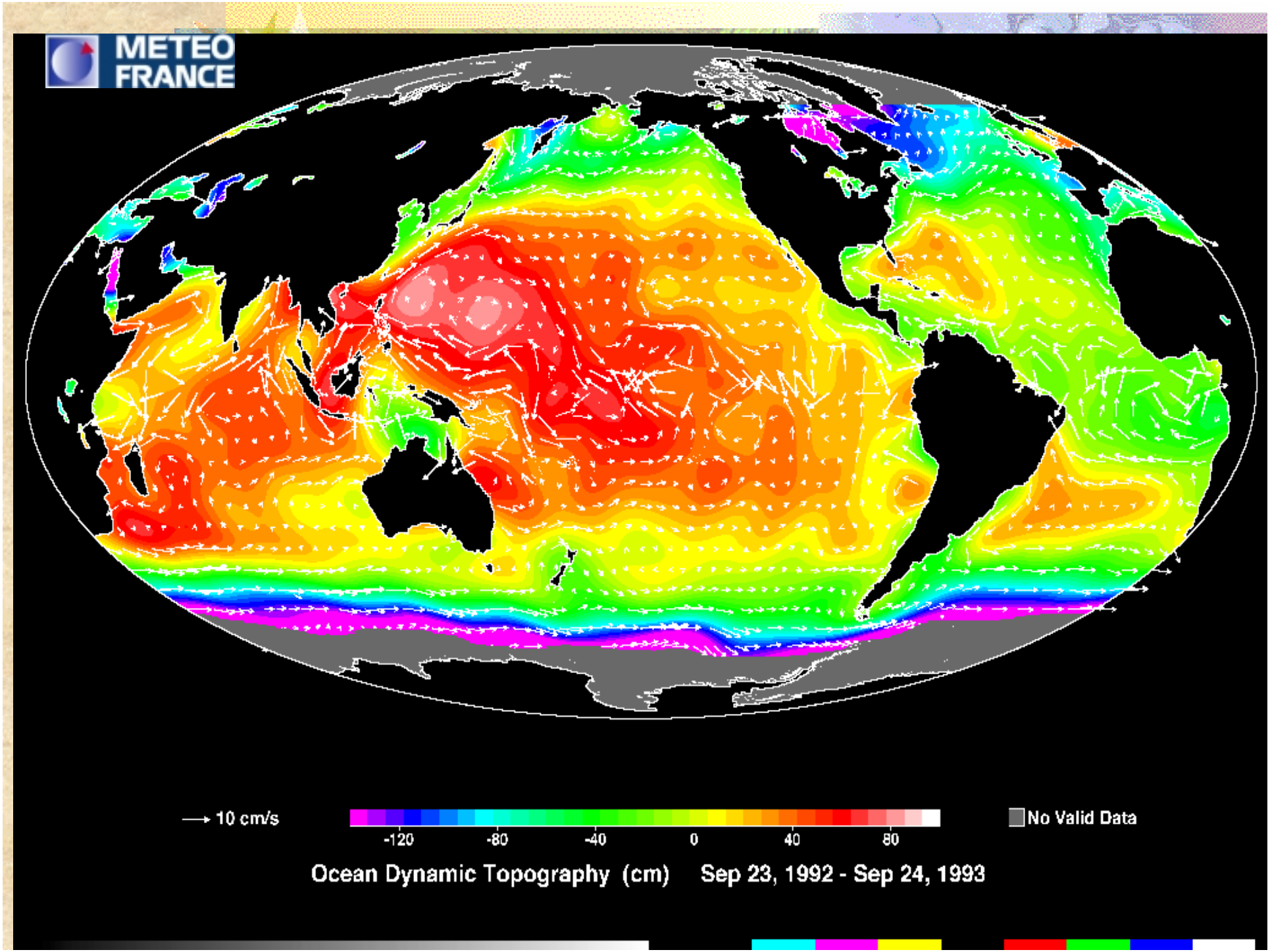
- Effet du vent en surface (tension du vent)
- Action de la force de Coriolis sur le fluide océanique
- Transport d'Ekman résultant a droite du vent dans l'hémisphère Nord et a gauche dans l'hémisphère Sud
- Couplage mouvement vertical et mouvement horizontal par l'équation de continuité

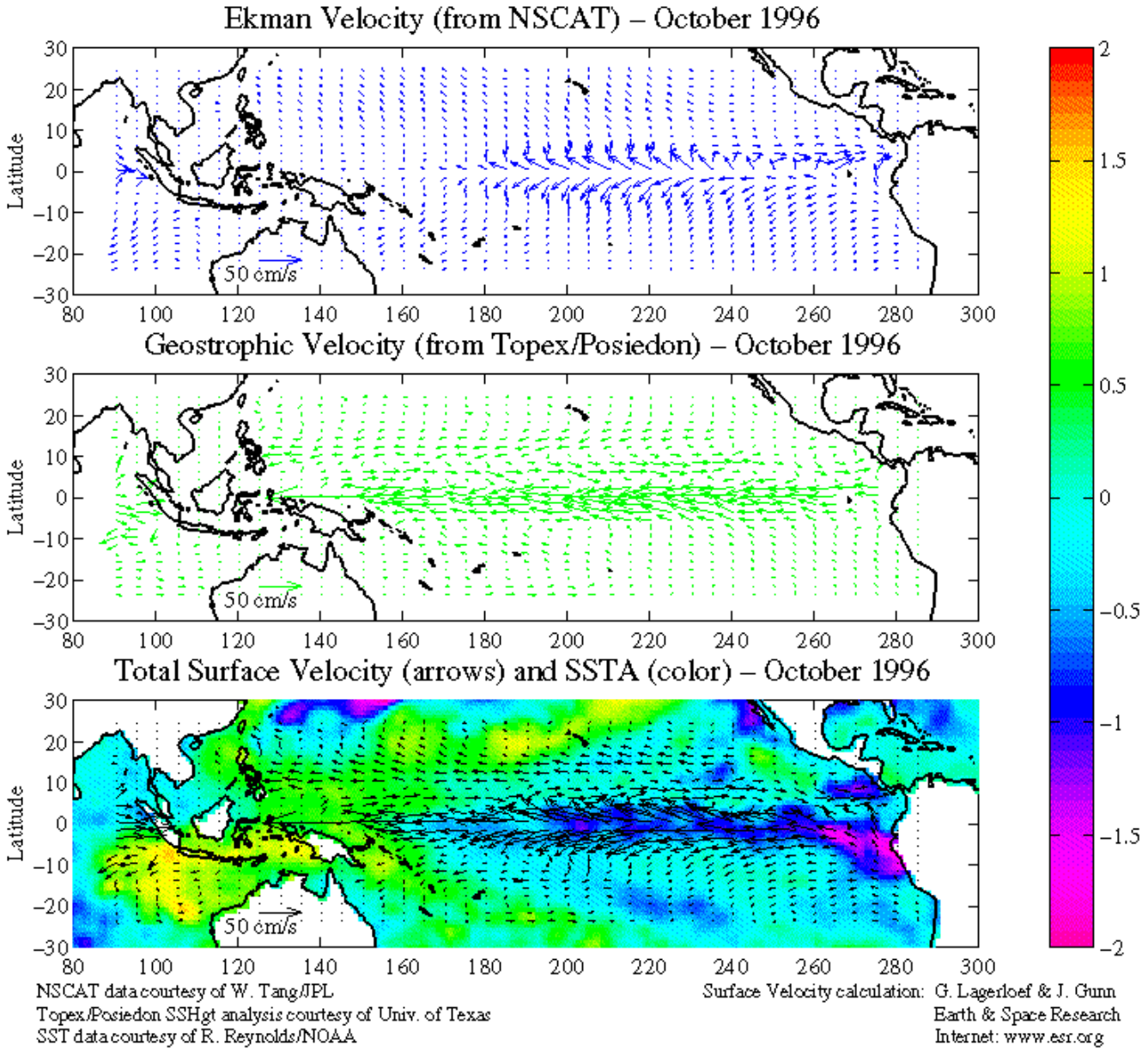

Ekman Transport
surface transport
45°
wind stress
N


W
sloping sea-surface
E
upwelling
50m -
200 m



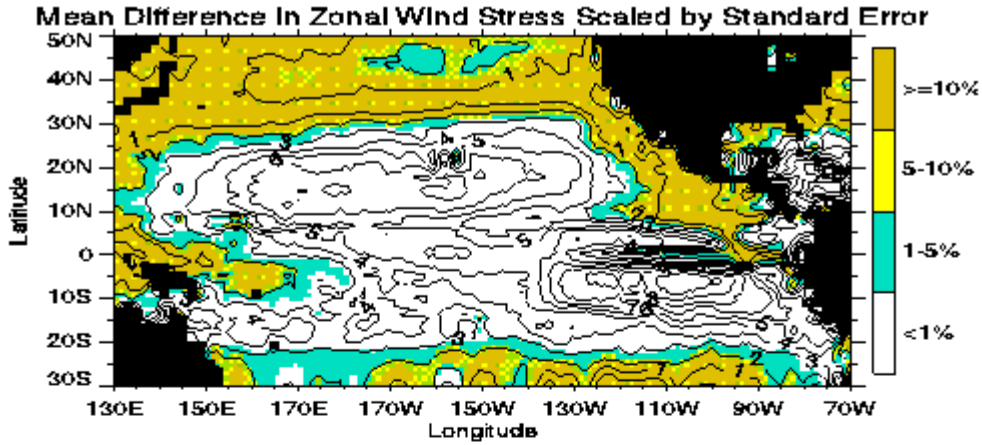

West
East
Thermocline

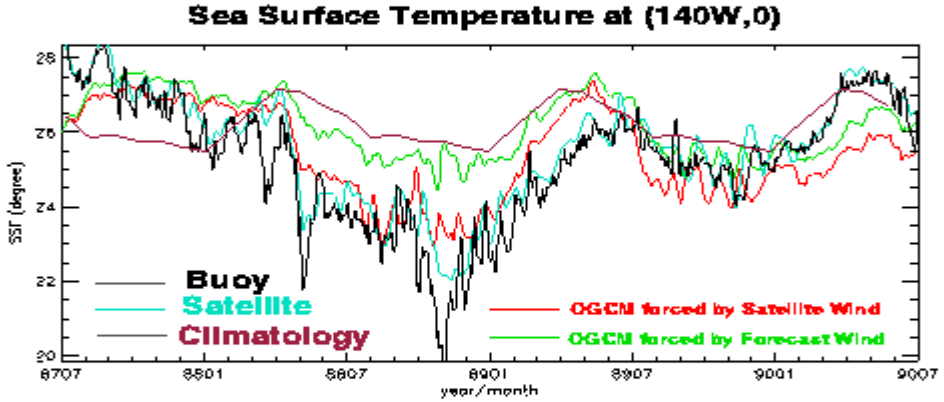

METEO FRANCE
10 cm/s
-120
-80
-40
0
40
80
No Valid Data
Ocean Dynamic Topography (cm) Sep 23, 1992 - Sep 24, 1993

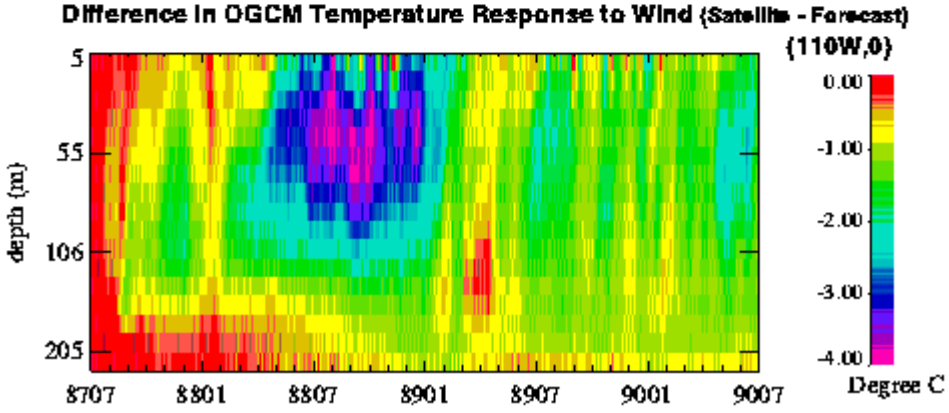


NSCAT data courtesy of W. Tang/JPL
Topex/Posiedon SSHgt analysis courtesy of Univ. of Texas
SST data courtesy of R. Reynolds/NOAA

Surface Velocity calculation: G. Lagerloef & J. Gunn
Earth & Space Research
Internet: www.esr.org



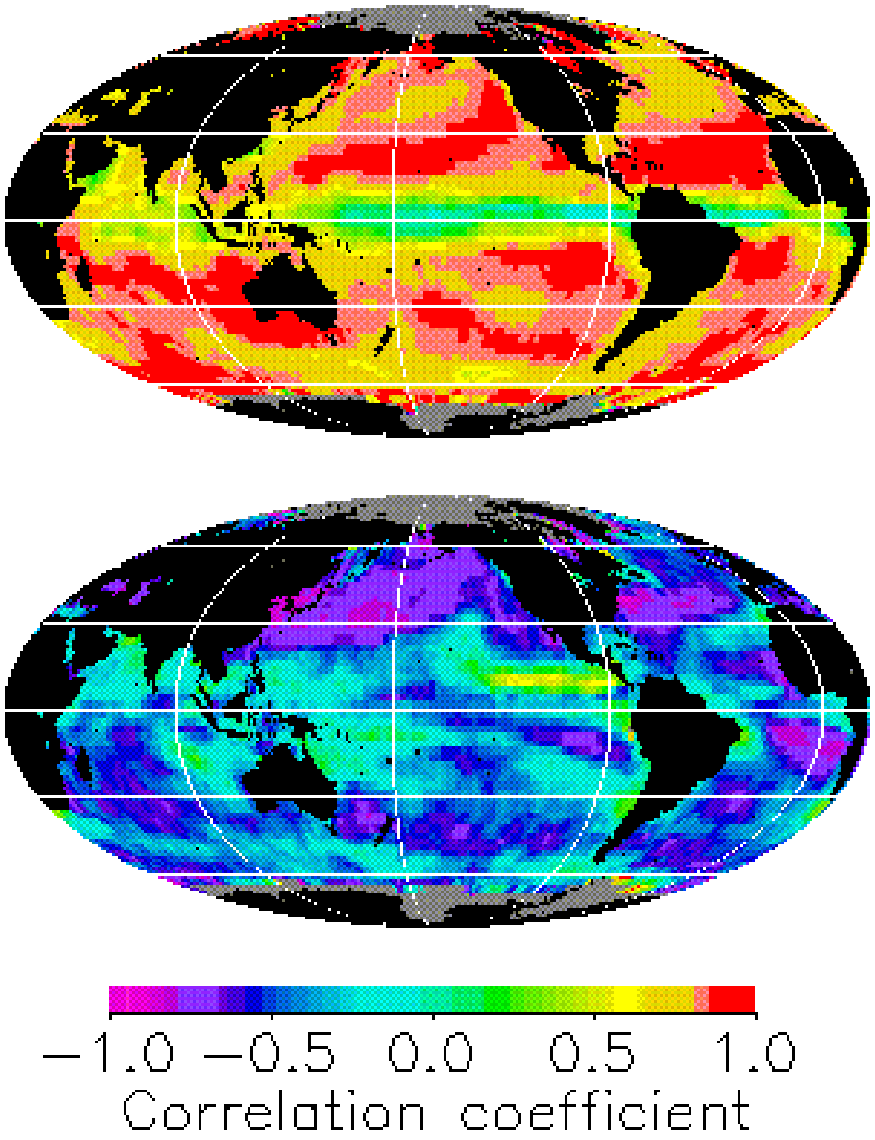




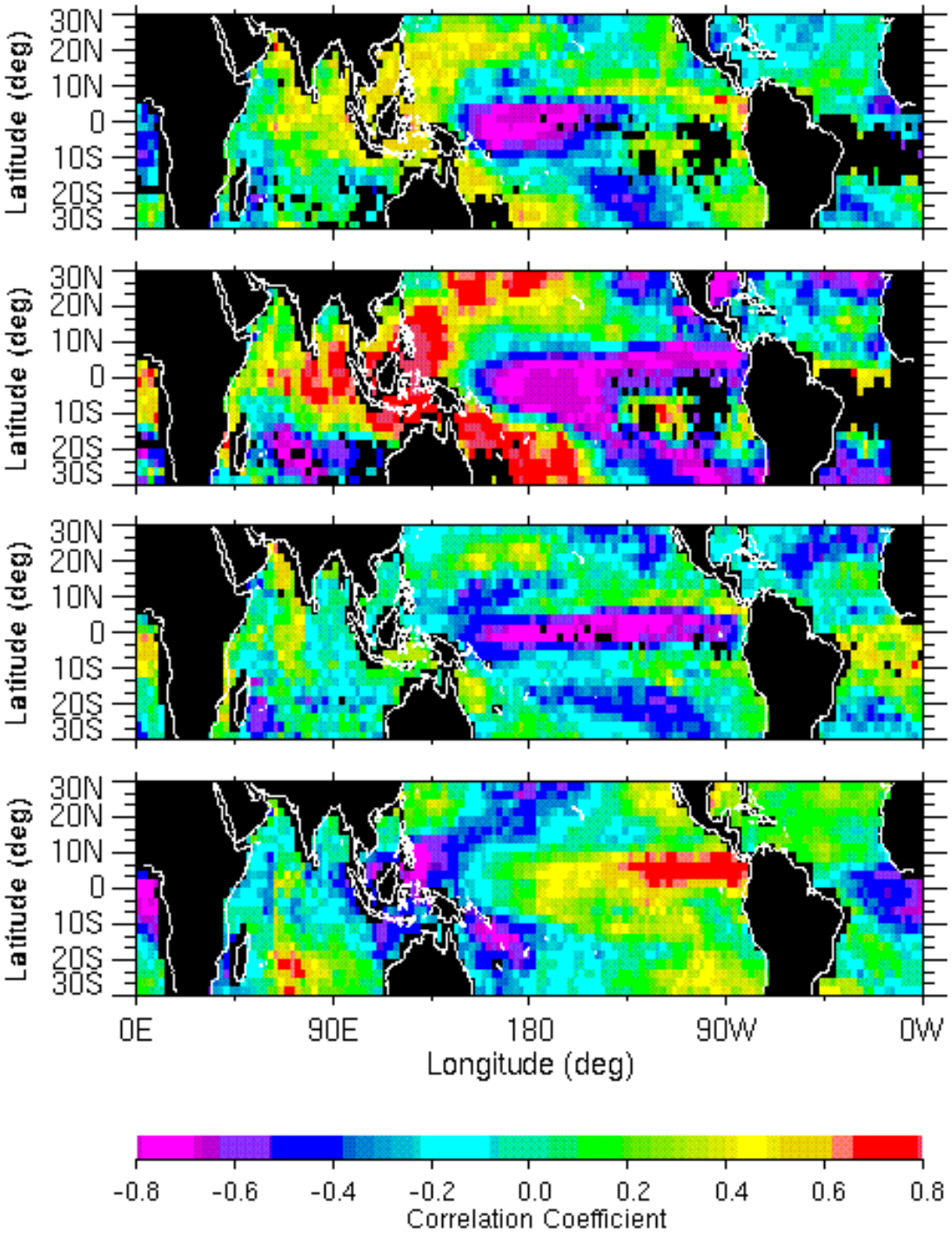
Liu, Tang & Atlas

Le forçage lié au vent

METEO FRANCE



Le forçage solaire et du flux d'évaporation



Le forçage des SST et les nuages

METEO FRANCE

Historique

- **Opposition de phase sur la pression Sydney – Buenos Aires (Hildebrandsson – 1897)**
- **Oscillation Australe (P,T,RR) – G. Walker (~1920)**
- **Lien entre SST Pacifique et OA (Bjerkness – 1966, 1969) – Apparition de la notion de Téléconnexion**
- **« Build-up » de Wyrtki (1975-1979)**
- **Niño composite et verrouillage sur le cycle saisonnier – Rasmusson et Carpenter (1982)**
- **Modélisation océan/atmosphère couplée (1980 ….)**
- **Développements théoriques (1980 …)**

Développements théoriques

- « Build-up de Wyrtki
  - Pilotage de l'océan par l'atmosphère (relaxation des alizés – redistribution des eaux chaudes de l'Ouest vers l'Est)
- L'Oscillateur retardé
  - Réflexion des ondes de Rossby en onde de Kelvin (bord Ouest) générant un approfondissement de la thermocline. Réflexion des ondes de Kelvin (bord Est). Alternance d'anomalies chaudes (kelvin «downwelling») et froides (kelvin «upwelling»).
- Instabilités couplées
  - Relation SST - thermocline (couplage positif avec une convergence du vent en surface)
  - Mode couplé instable basse-fréquence (périodes 3à 4 ans et 6 mois)
  - «SST mode» - advection de gradient moyen zonal de SST par les perturbation du courant – advection du gradient moyen vertical de température par les perturbation de la vitesse verticale – modulation de l'advection verticale par l'upwelling equatorial moyen
  - Barrière de sel – déplacement du bord Est de la Warmpool – rôle de l'advection zonale du gradient de SST

L'ENSO

- Phénomène couplé Océan/Atmosphère
- ENSO principale source de variabilité du système climatique aux échelles de temps interannuelles
- Manifestation océanique « El Niño/La Niña » dans le Pacifique, en surface mais aussi en profondeur.
- Périodes caractéristiques 3 à 7 ans et « alternances» Niño/ Niña.
- Influence planétaire via les modifications de la circulation générale. Télé connexions.
- Phénomène océanique partiellement prévisible (causes du déclenchement?)
- Interactions ENSO/PDO, ENSO/MJO, MJO/Synoptique

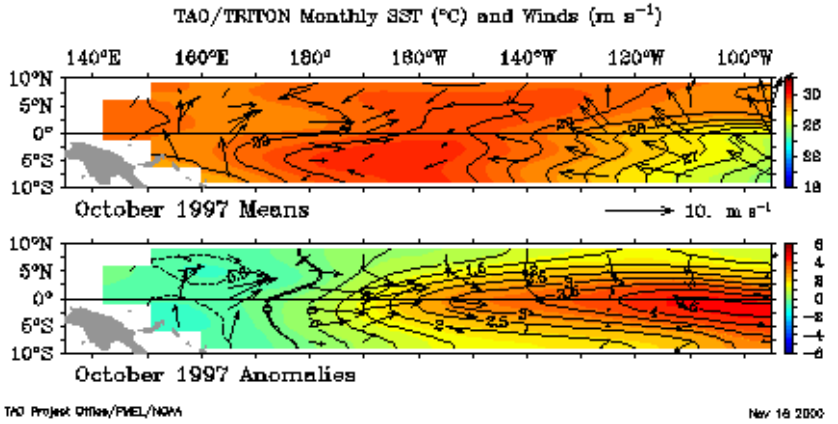
L'ENSO (1)

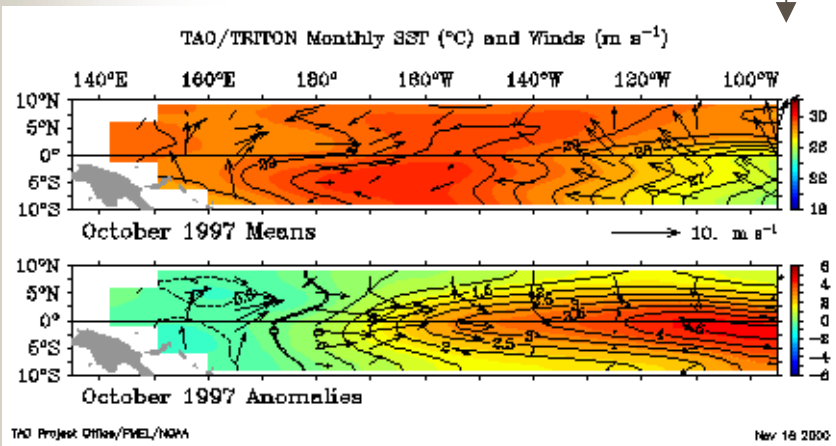
El Niño 97

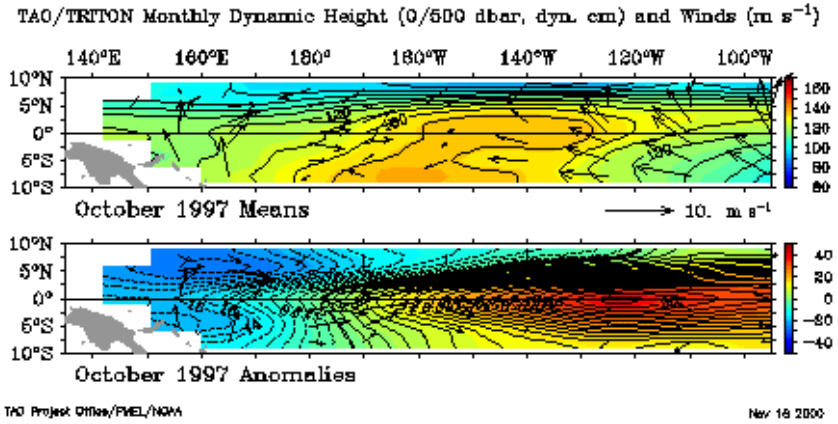
Température de surface

Hauteur dynamique

Profondeur de la thermocline

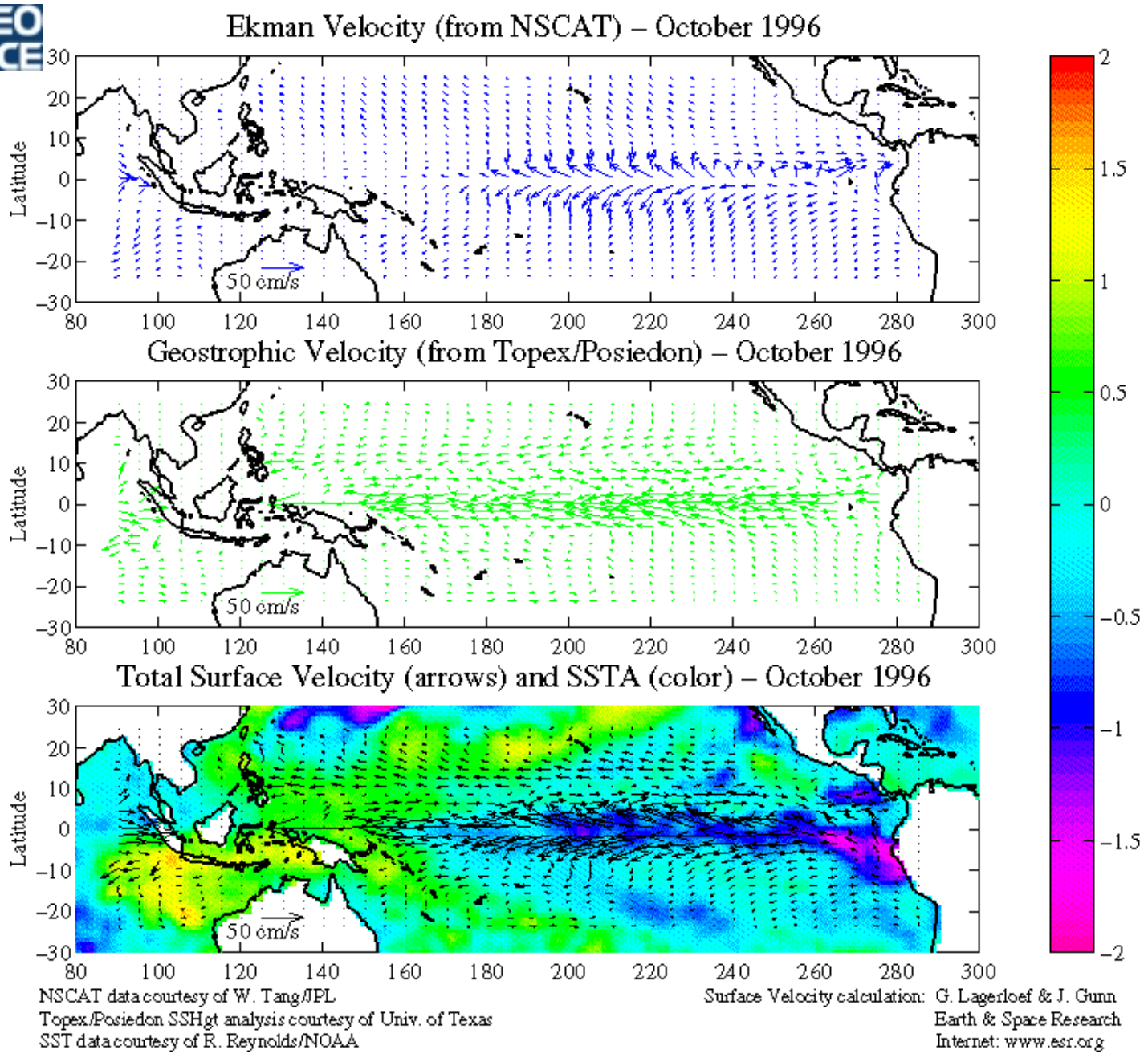






L’ENSO (2)

- Les courants océaniques de surface

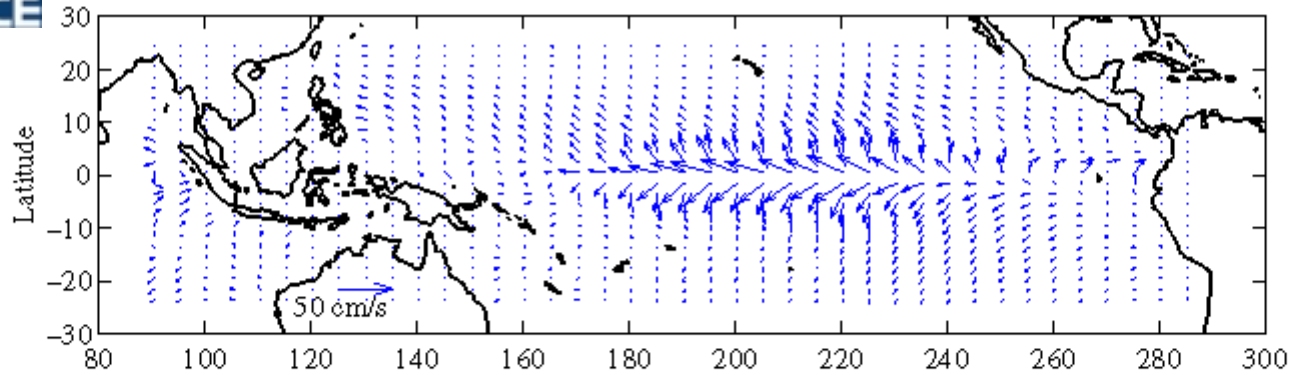


NSCAT data courtesy of W. Tang/JPL
Topex/Posiedon SSHgt analysis courtesy of Univ. of Texas
SST data courtesy of R. Reynolds/NOAA

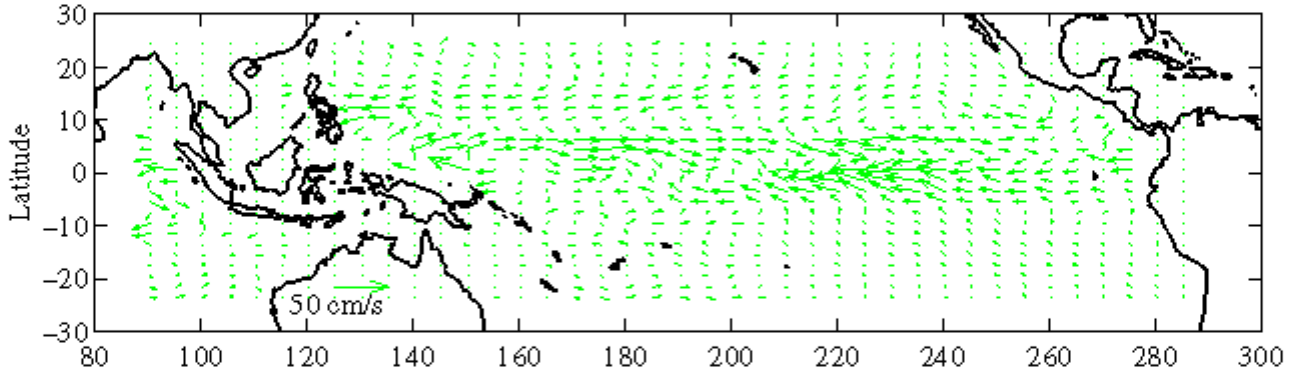
Surface Velocity calculation: G. Lagerloef & J. Gunn
Earth & Space Research
Internet: www.esr.org

METEO FRANCE

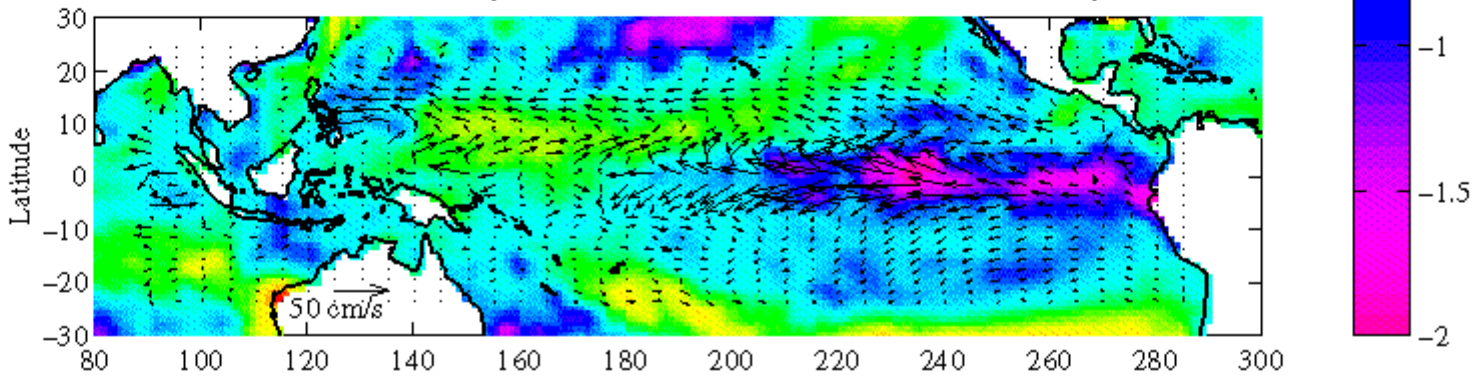
Ekman Velocity (from NSCAT) – January 1997



Geostrophic Velocity (from Topex/Posiedon) – January 1997



Total Surface Velocity (arrows) and SSTA (color) – January 1997



NSCAT data courtesy of W. Tang/JPL
Topex/Posiedon SSHgt analysis courtesy of Univ. of Texas
SST data courtesy of R. Reynolds/NOAA

Surface Velocity calculation: G. Lagerloef & J. Gunn
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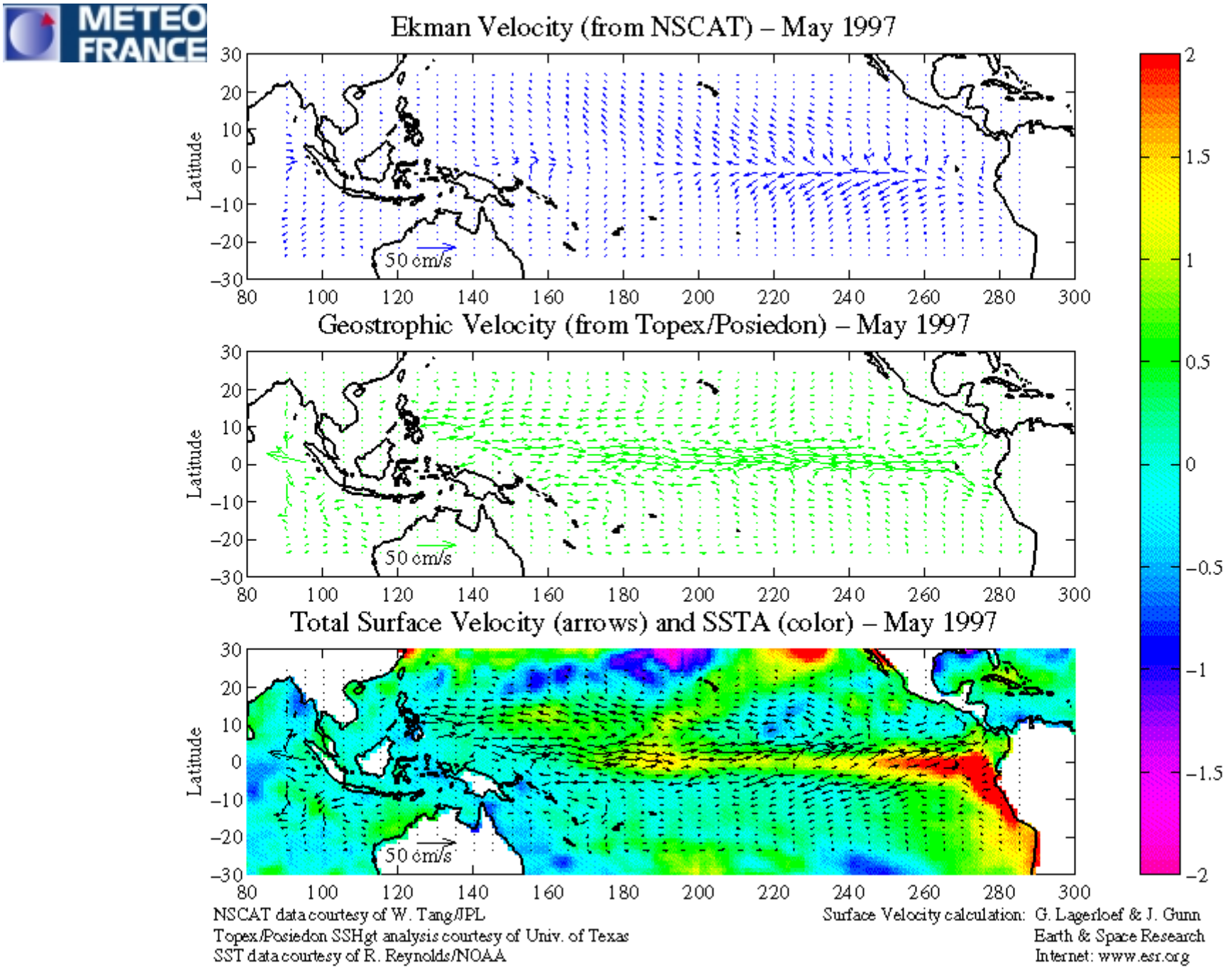
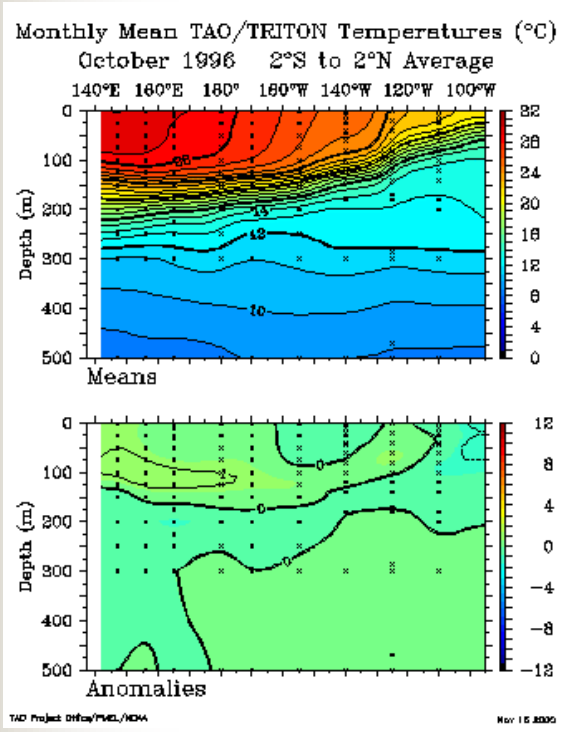
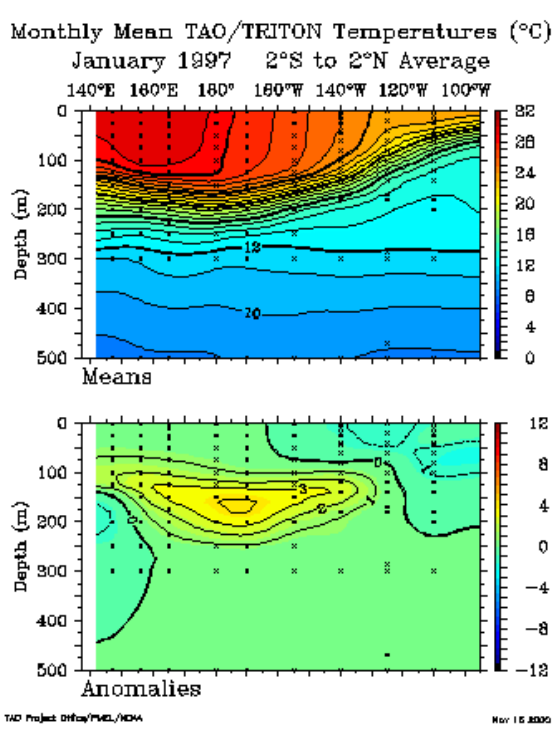
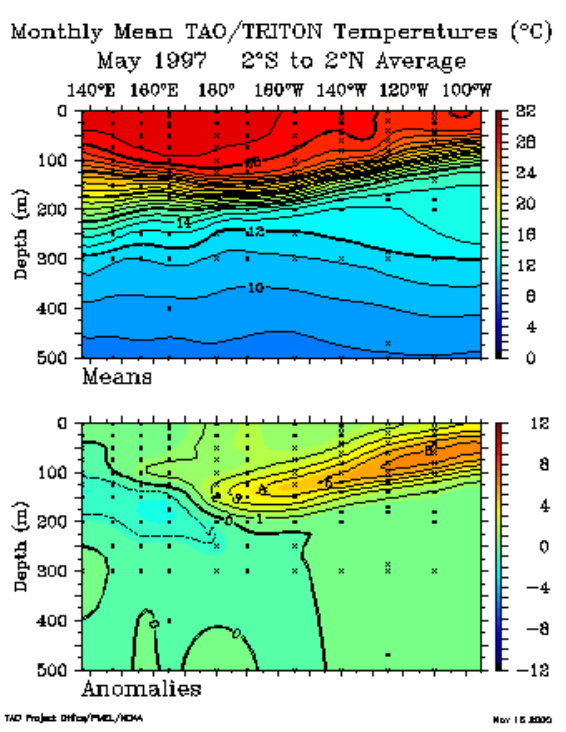

METEO FRANCE
Ekman Velocity (from NSCAT) – May 1997
Geostrophic Velocity (from Topex/Posiedon) – May 1997
Total Surface Velocity (arrows) and SSTA (color) – May 1997
Latitude
50 cm/s
30
20
10
0
−10
−20
−30
80
100
120
140
160
180
200
220
240
260
280
300
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
NSCAT data courtesy of W. Tang/JPL
Topex/Posiedon SSHgt analysis courtesy of Univ. of Texas
SST data courtesy of R. Reynolds/NOAA
Surface Velocity calculation: G. Lagerloef & J. Gunn
Earth & Space Research
Internet: www.esr.org

L'ENSO (2)

- La structure océanique profonde et son évolution

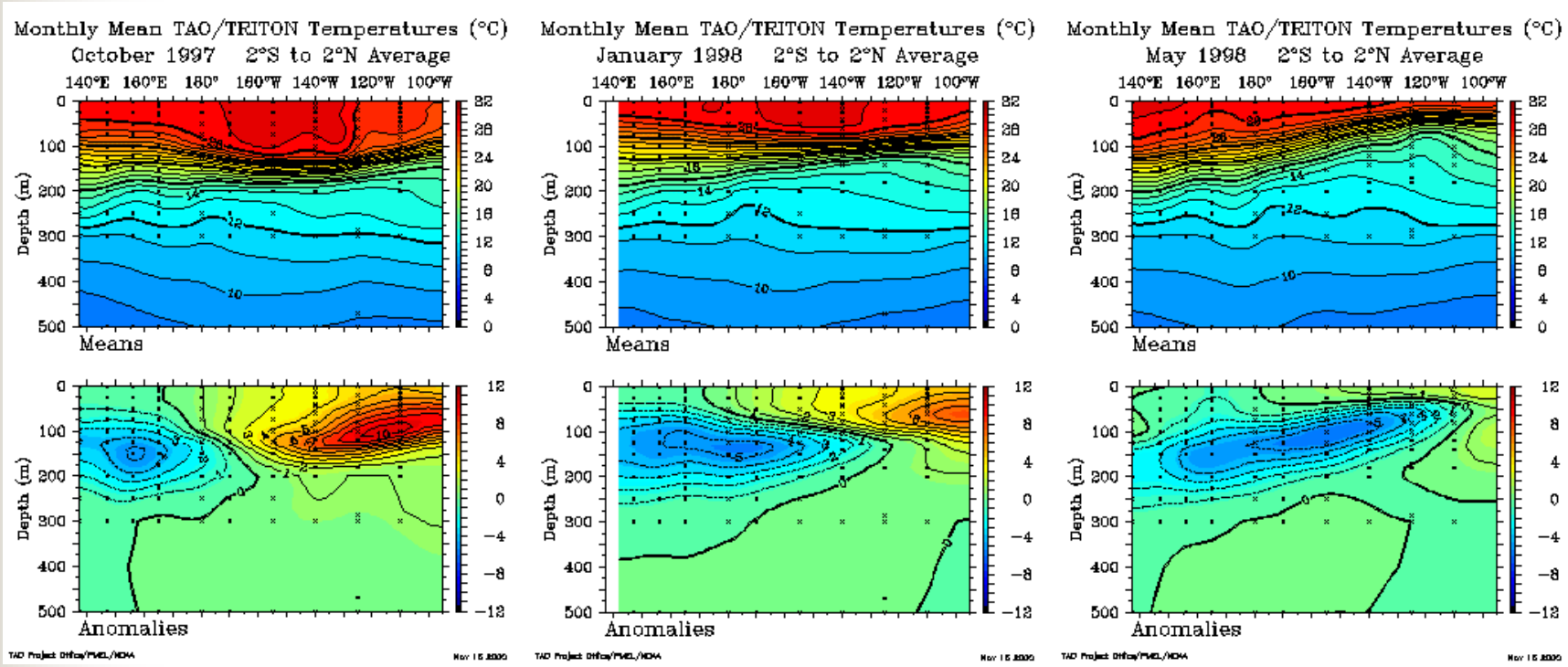






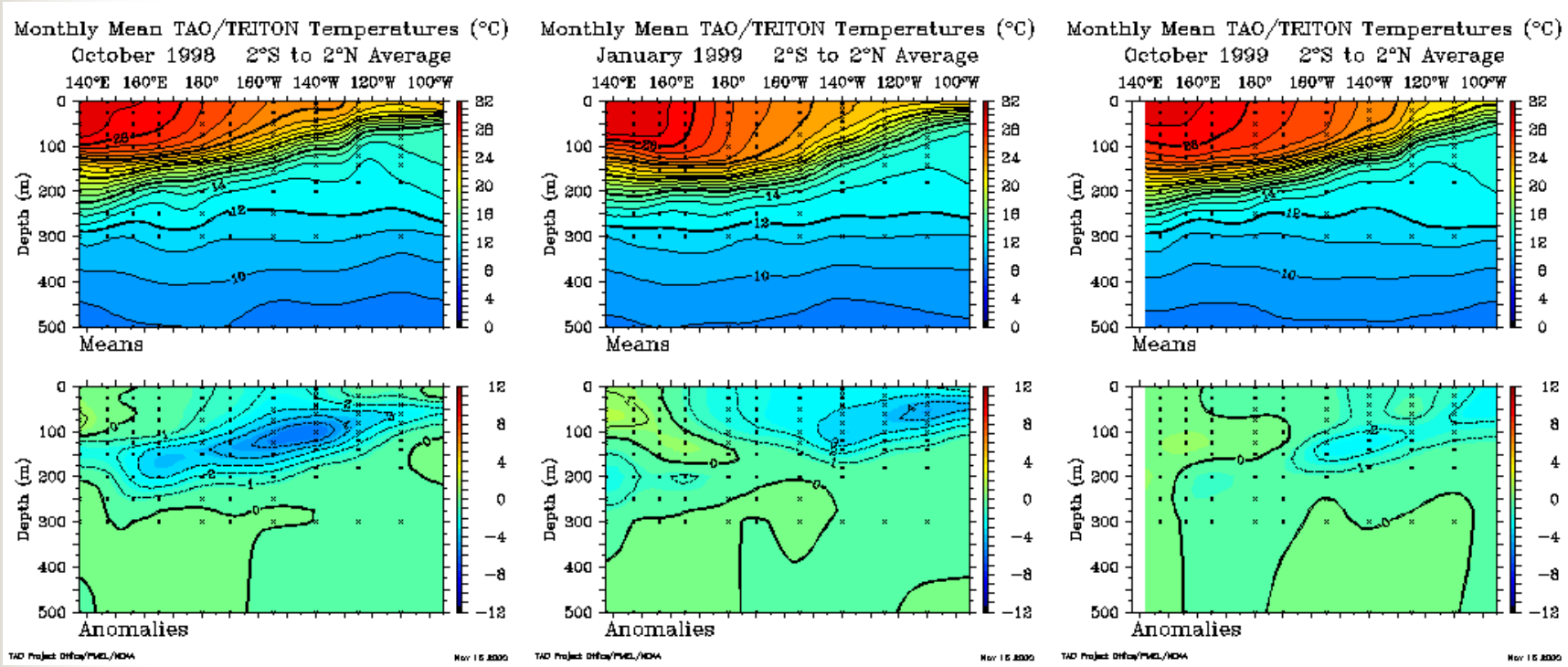
L'ENSO (3)

- La structure océanique profonde et son évolution



L'ENSO (3)

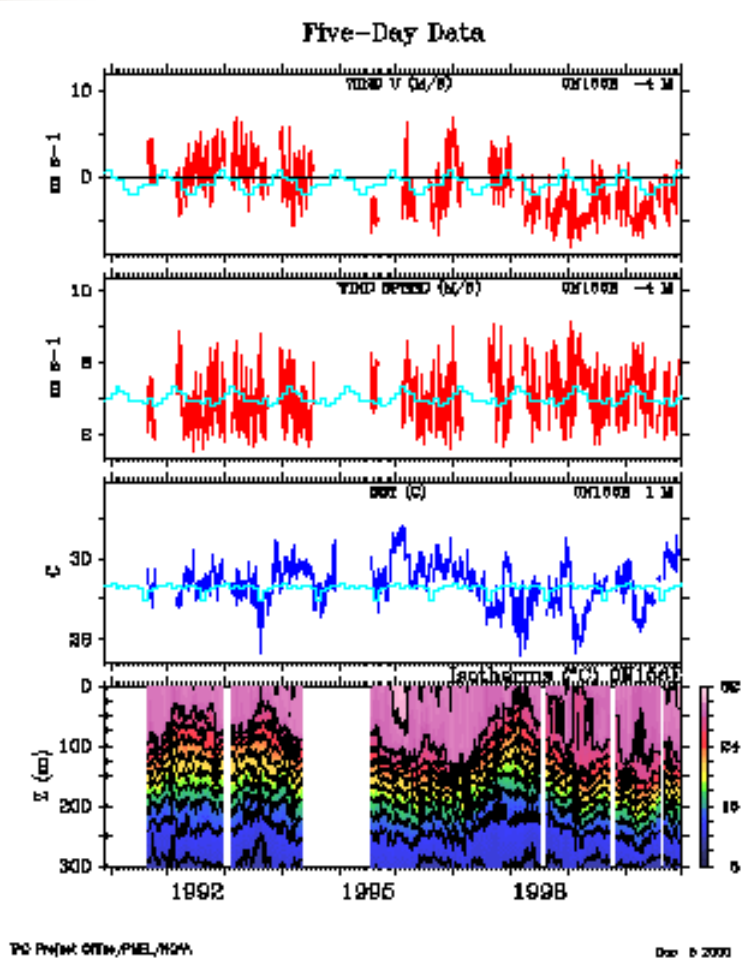
- La structure océanique profonde et son évolution



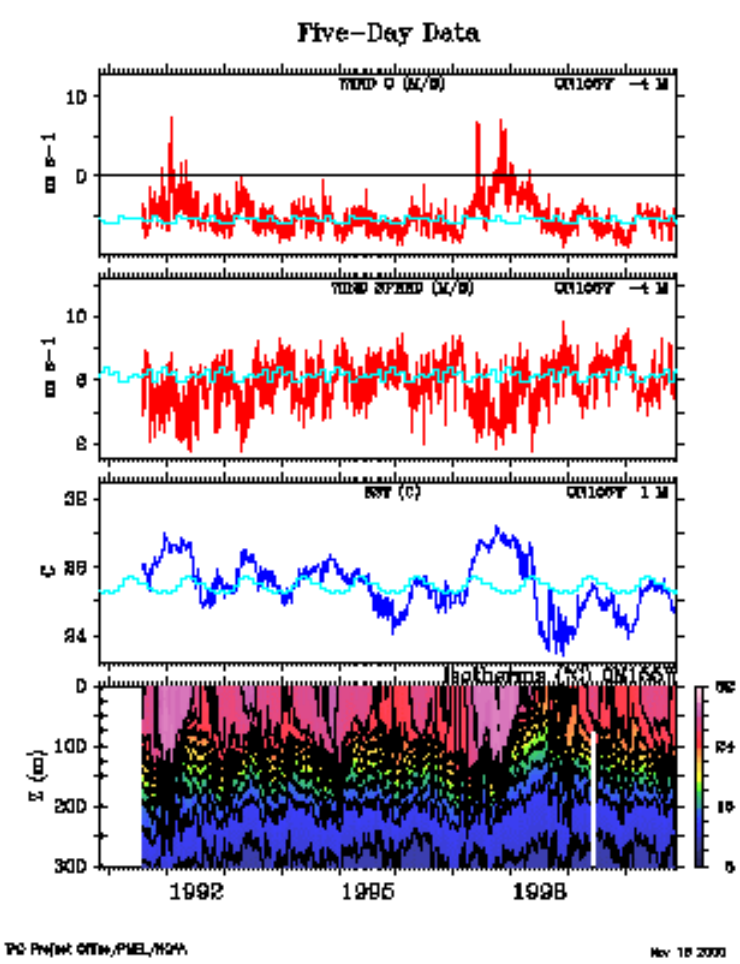
L'ENSO (4)

- Le phénomène couplé Océan/Atmosphère

Dans le Pacifique Ouest (156°E)



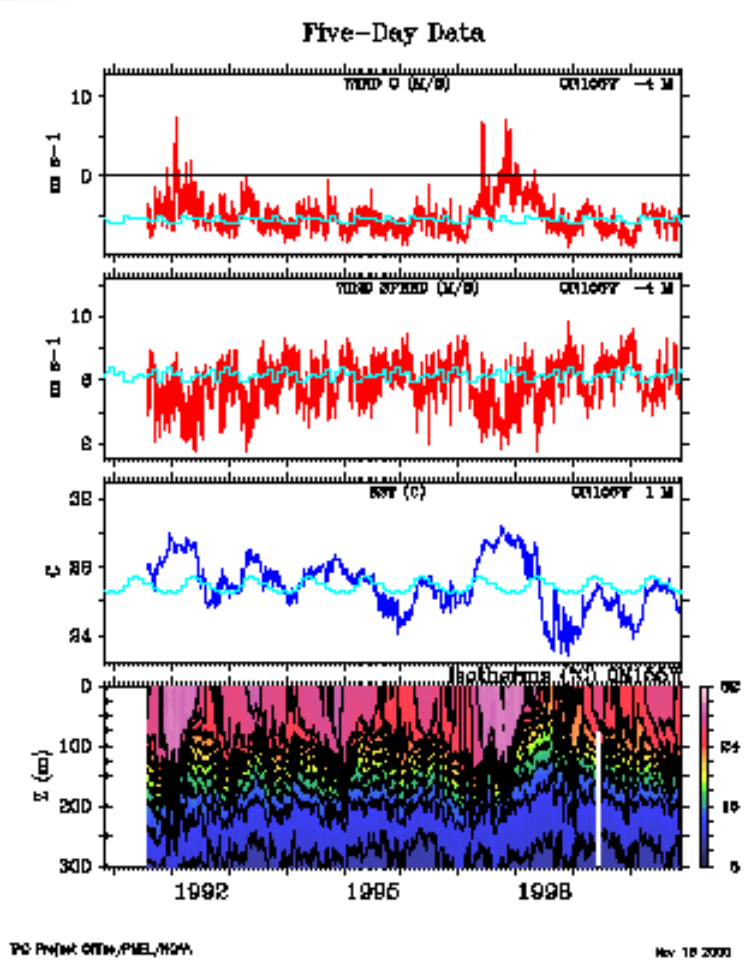
Dans le Pacifique Central (155°O)



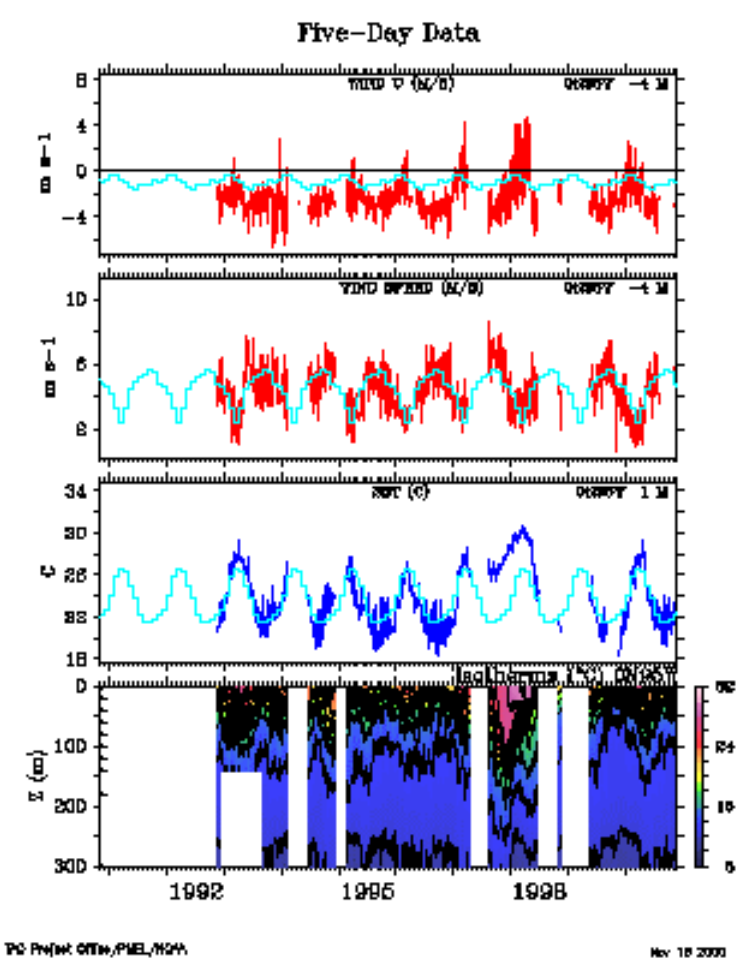
L'ENSO (4)

- Le phénomène couplé Océan/Atmosphère

Dans le Pacifique central (155°O)

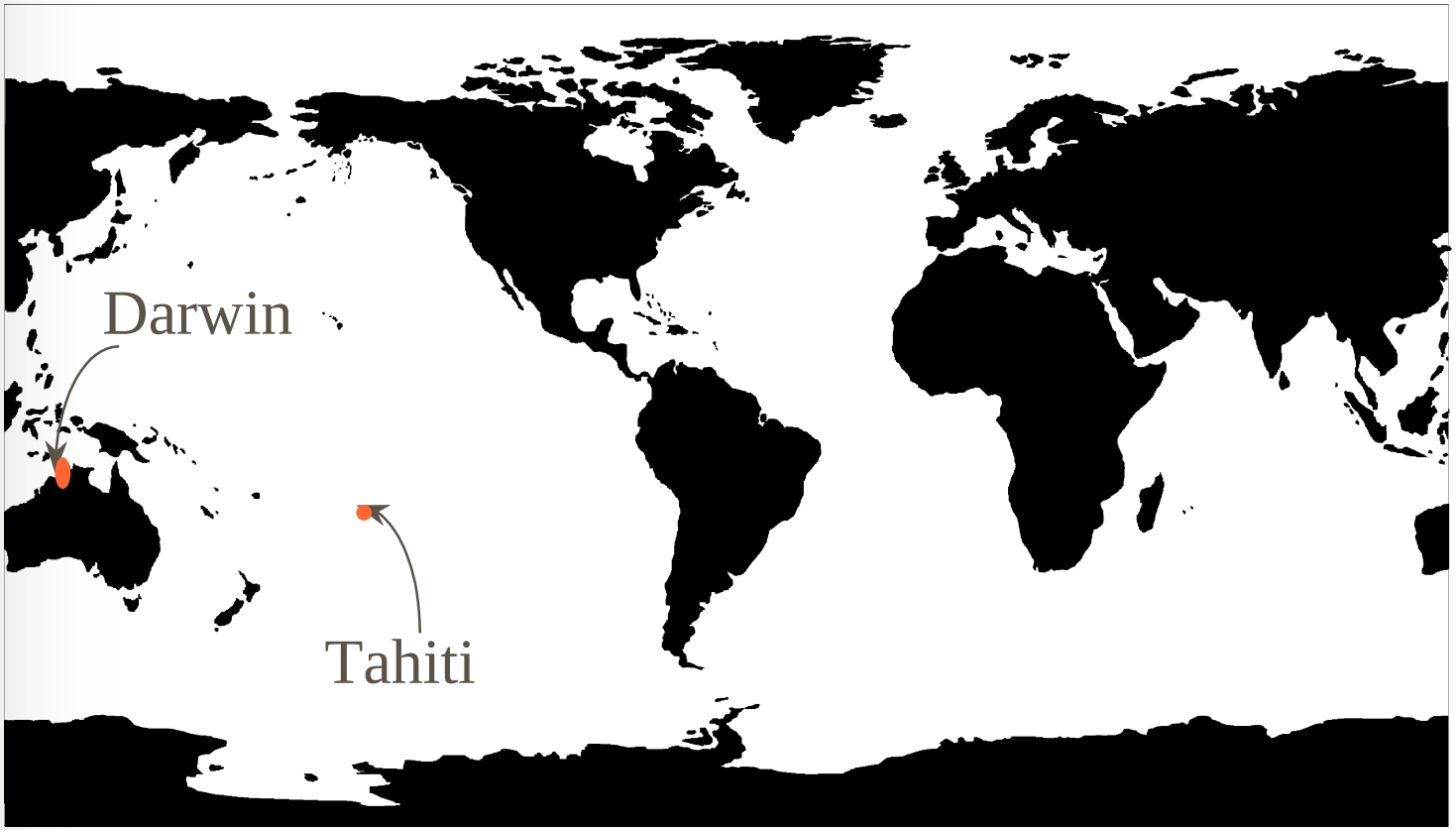


Dans le Pacifique Est (95°O)



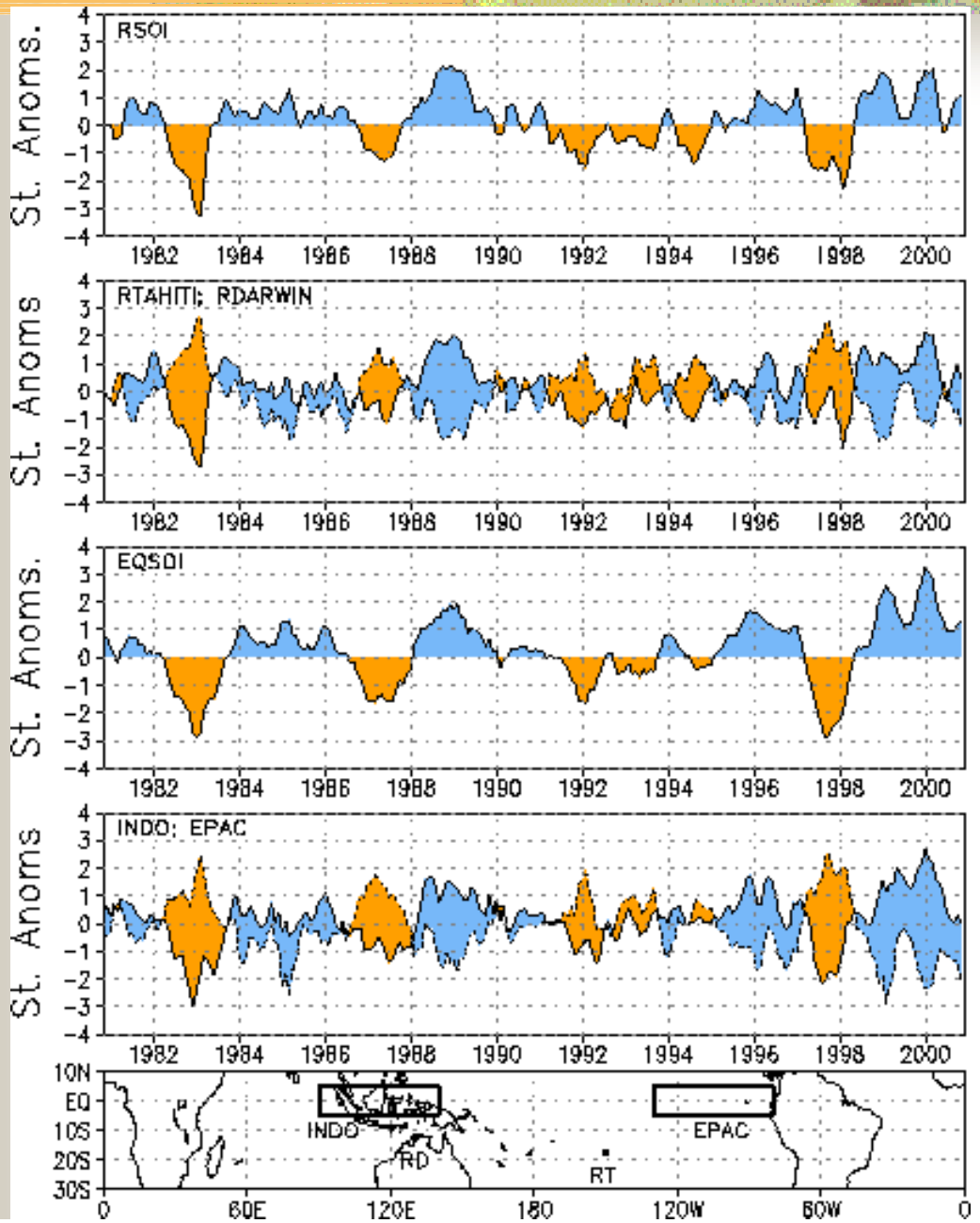
L'ENSO (5)

- Description de l'Oscillation Australe

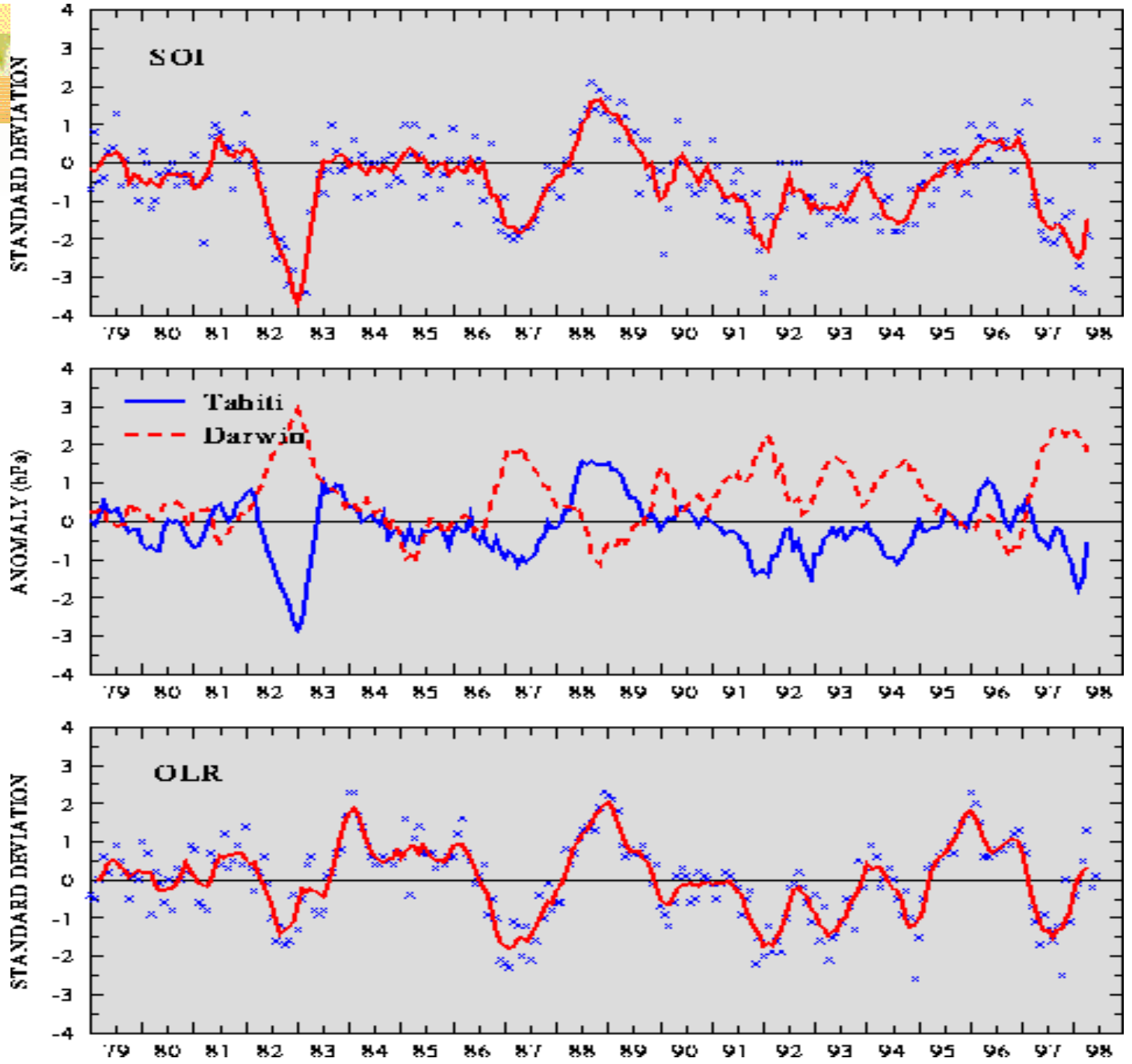


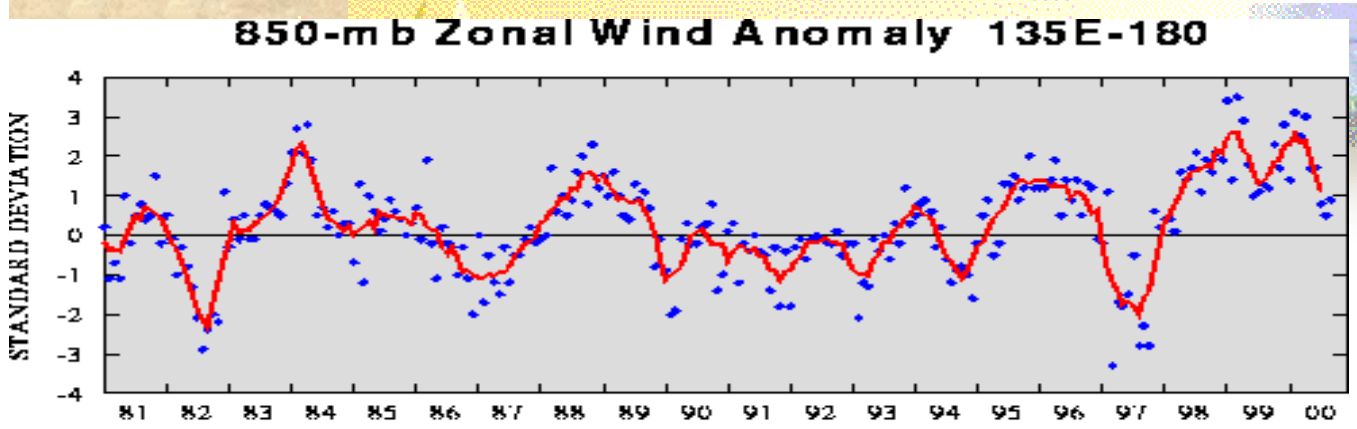
L'ENSO (5)

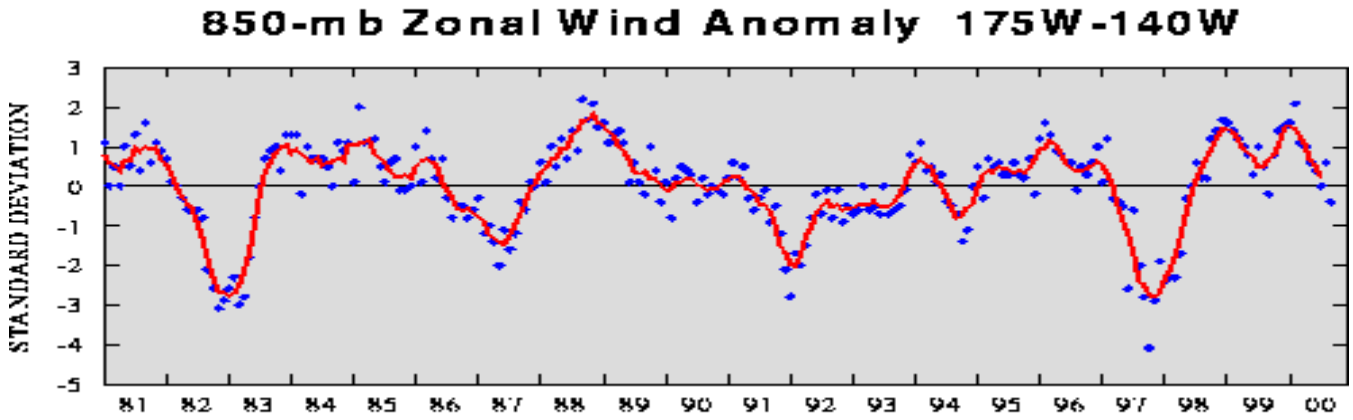
- Description de l'Oscillation Australe

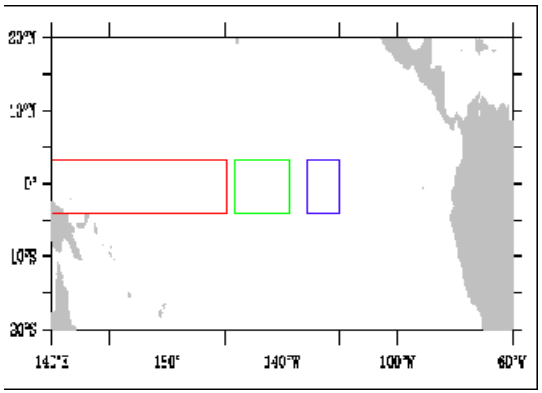


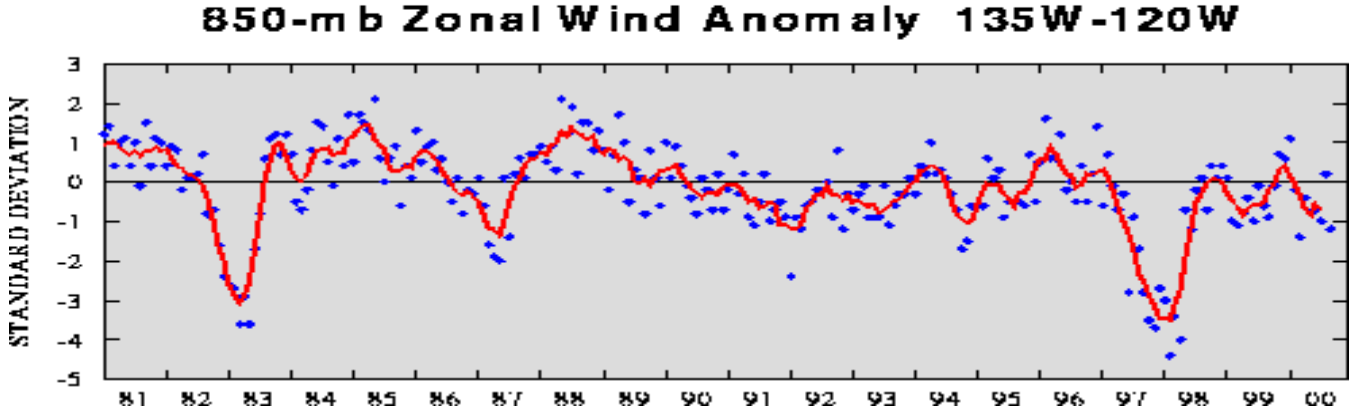
METEO FRANCE



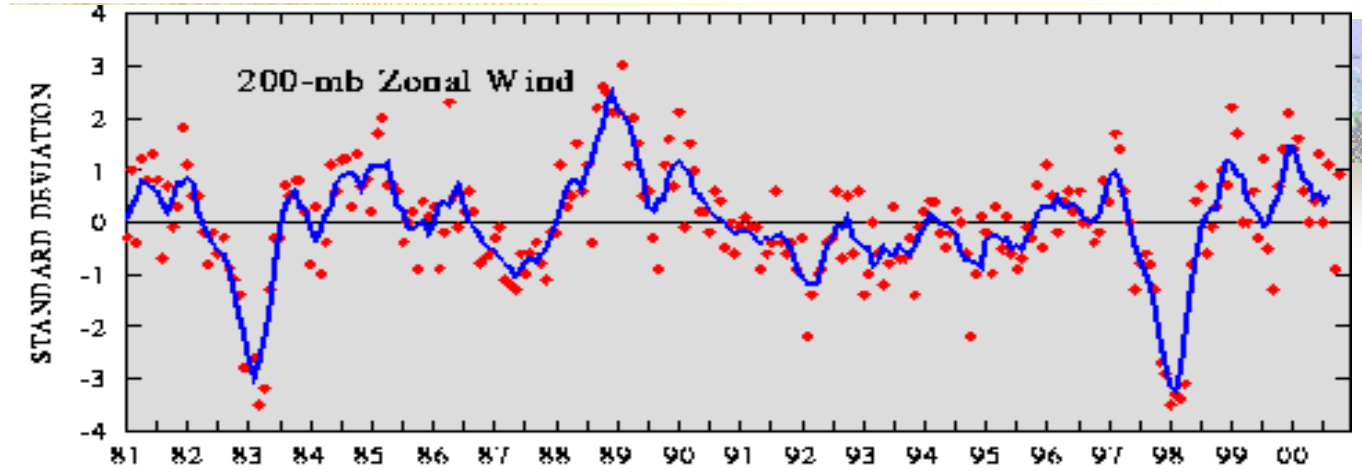


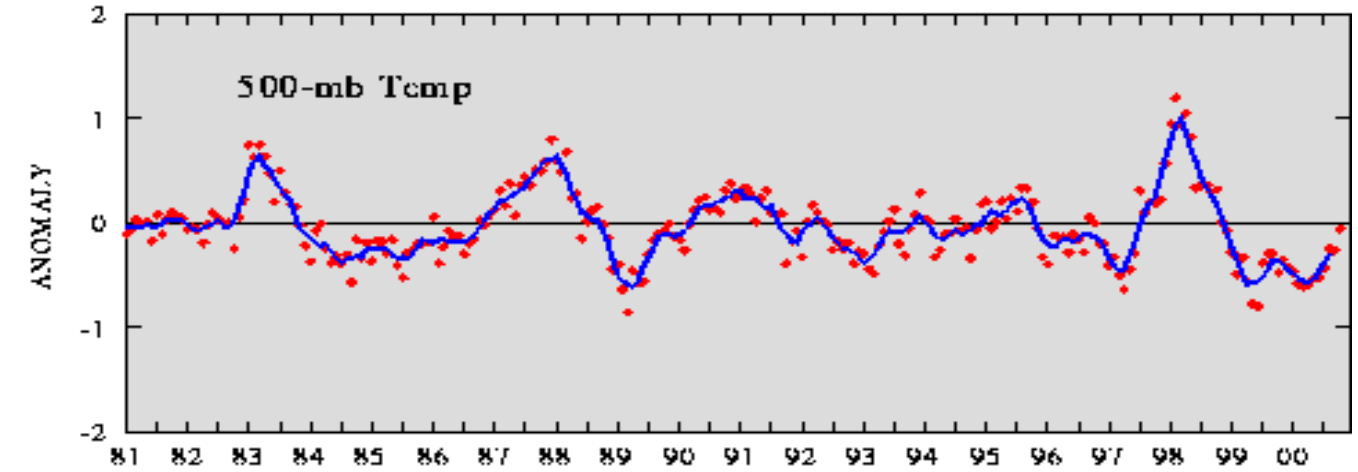


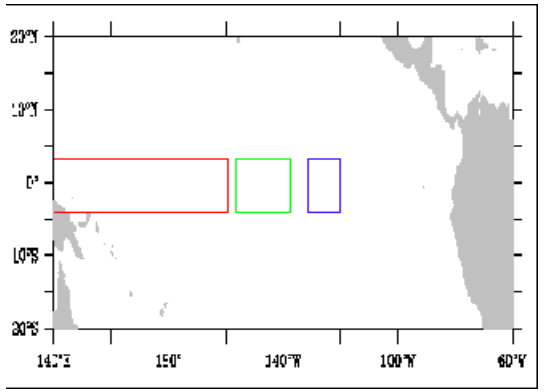


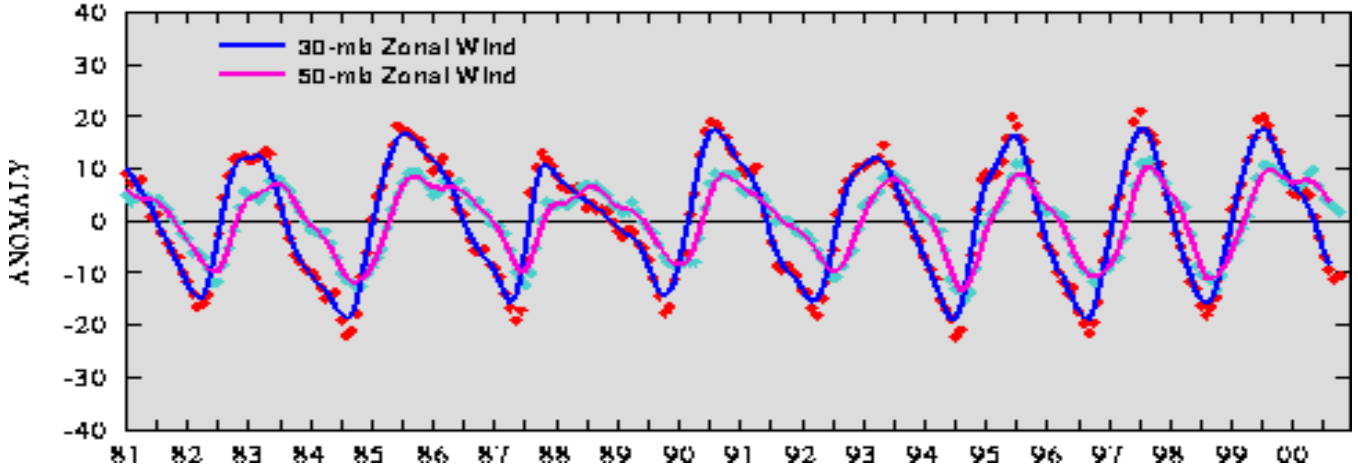


METEO FRANCE

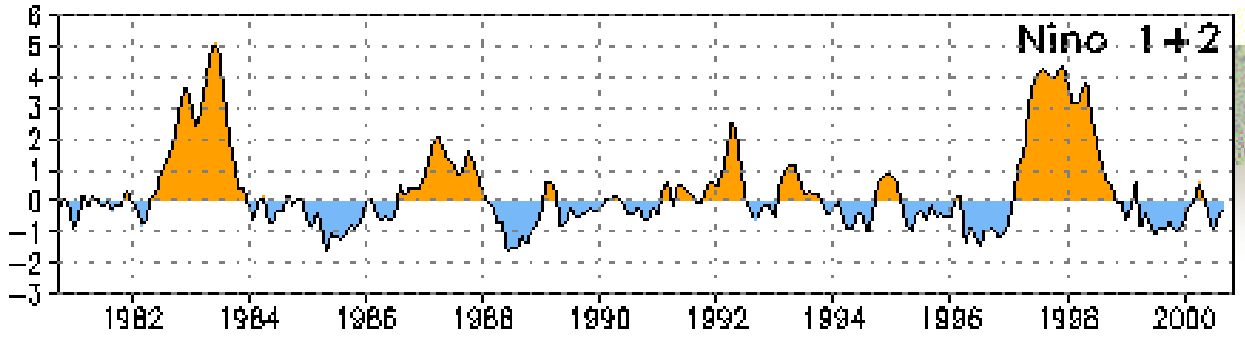


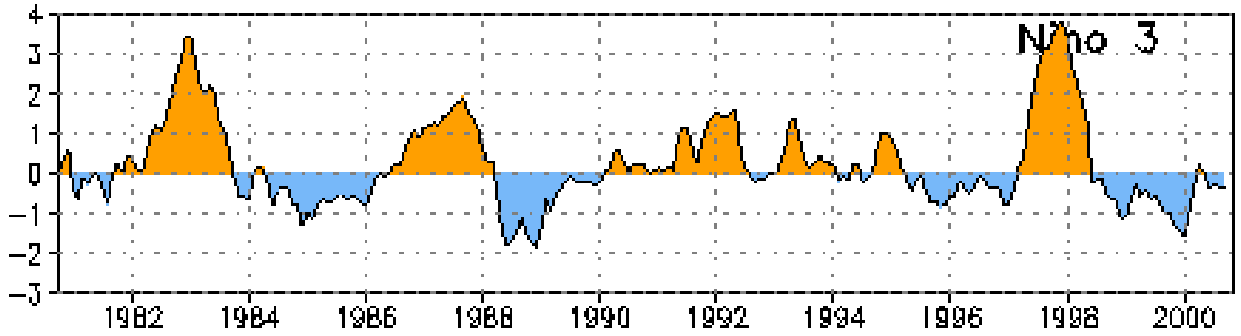


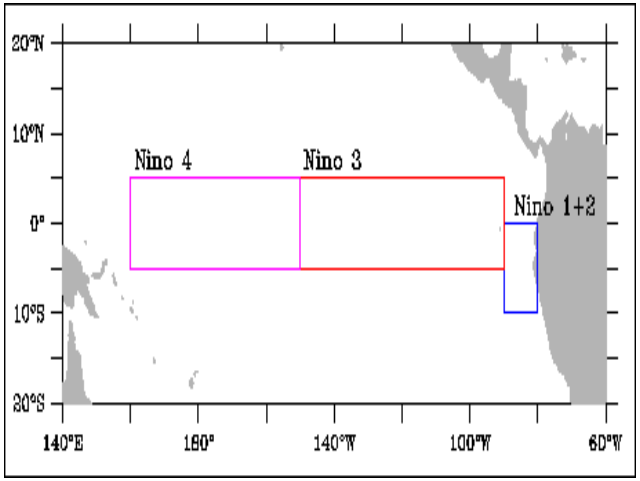


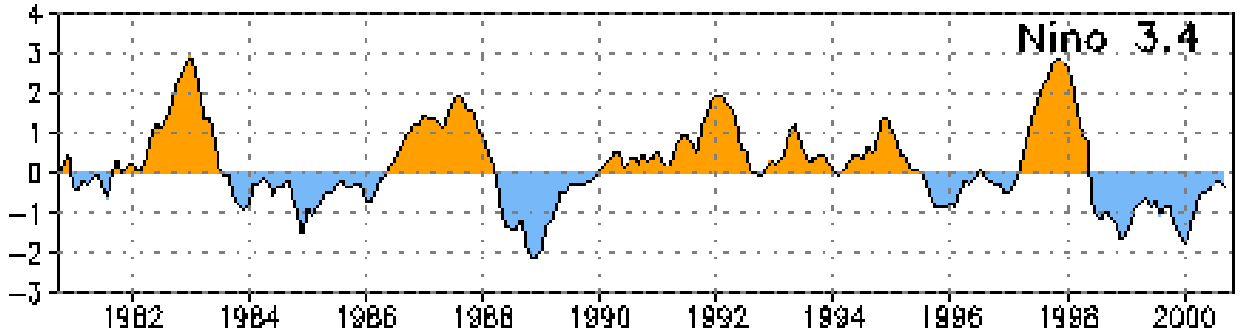


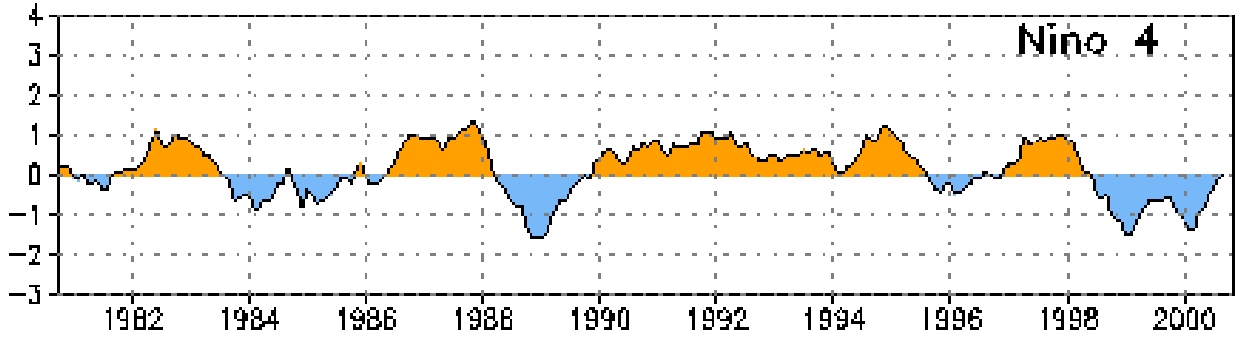
METEO FRANCE



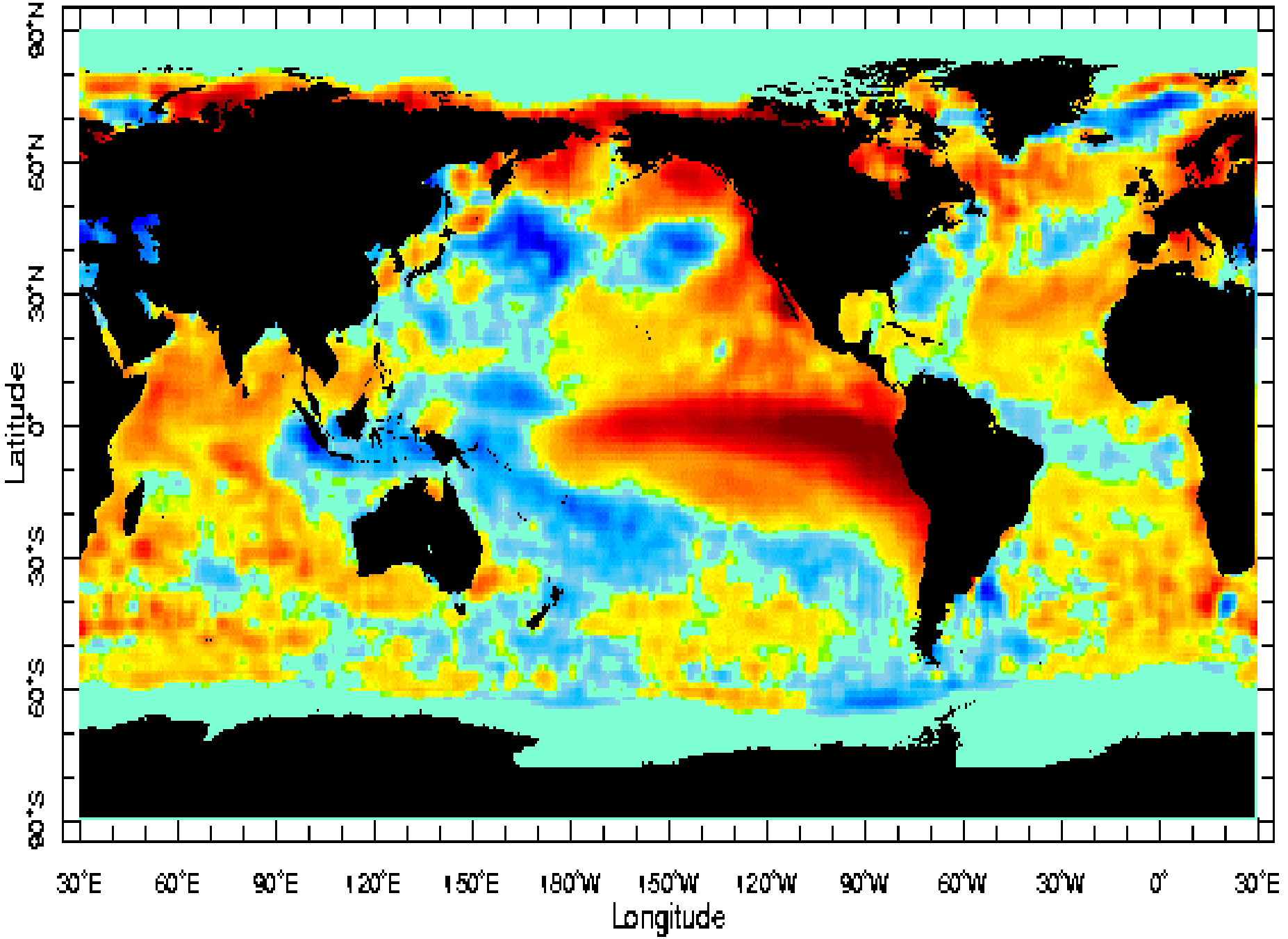






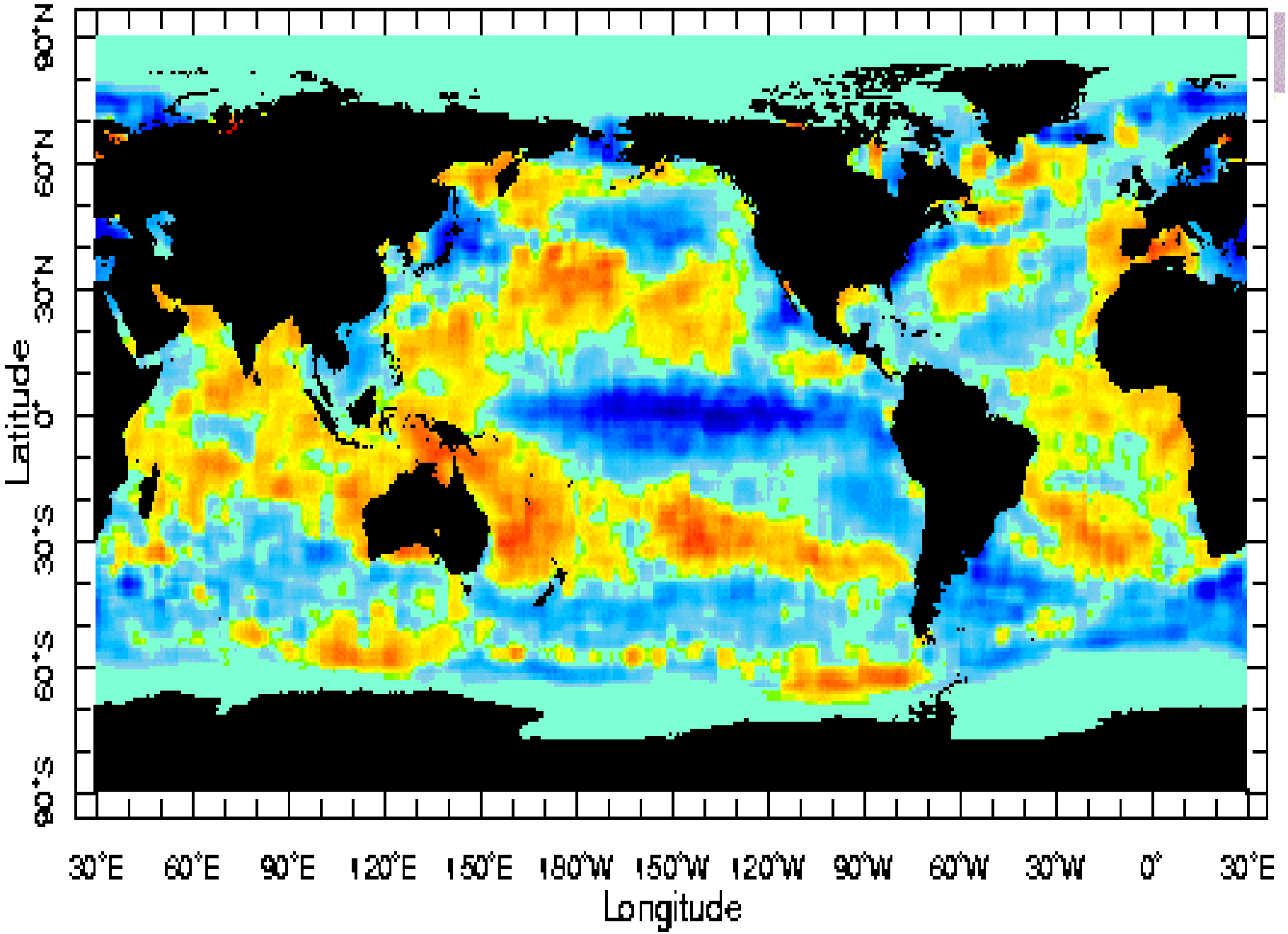


METEO FRANCE



SEP 97

METEO FRANCE



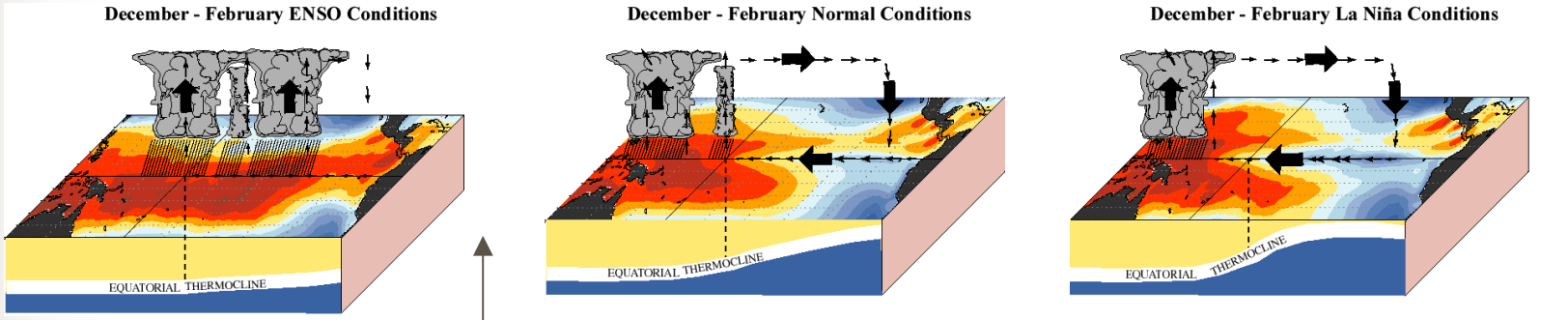
Nov 88

METEO FRANCE

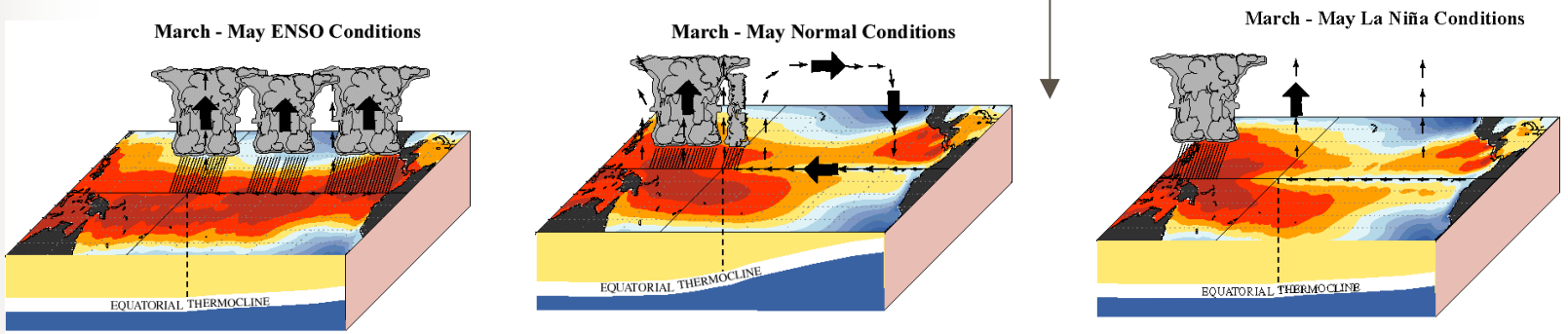
L'ENSO (6)

- L'influence dans le Pacifique

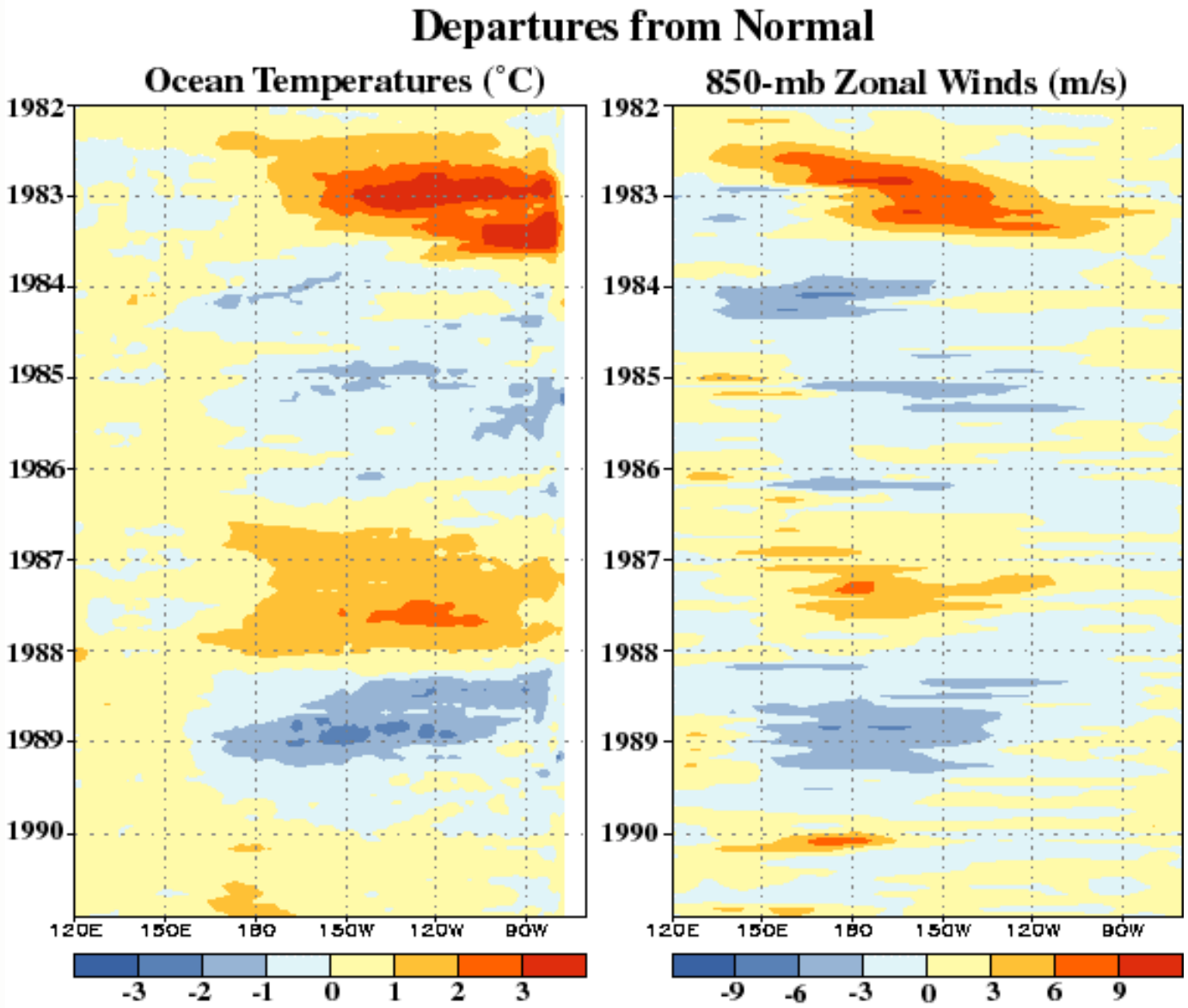
Année El Niño | Année Normale | Année La Niña



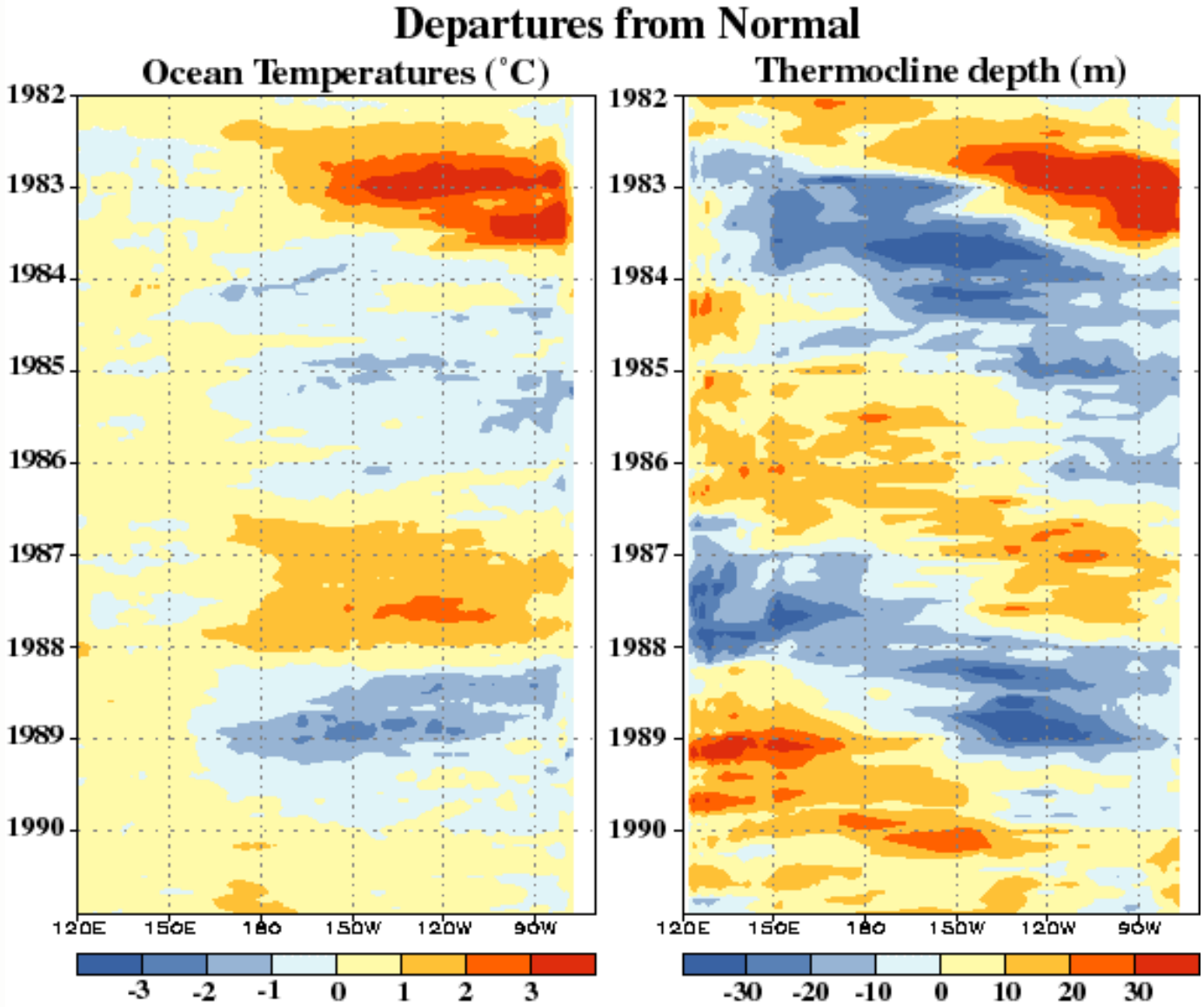
Hiver *Printemps*



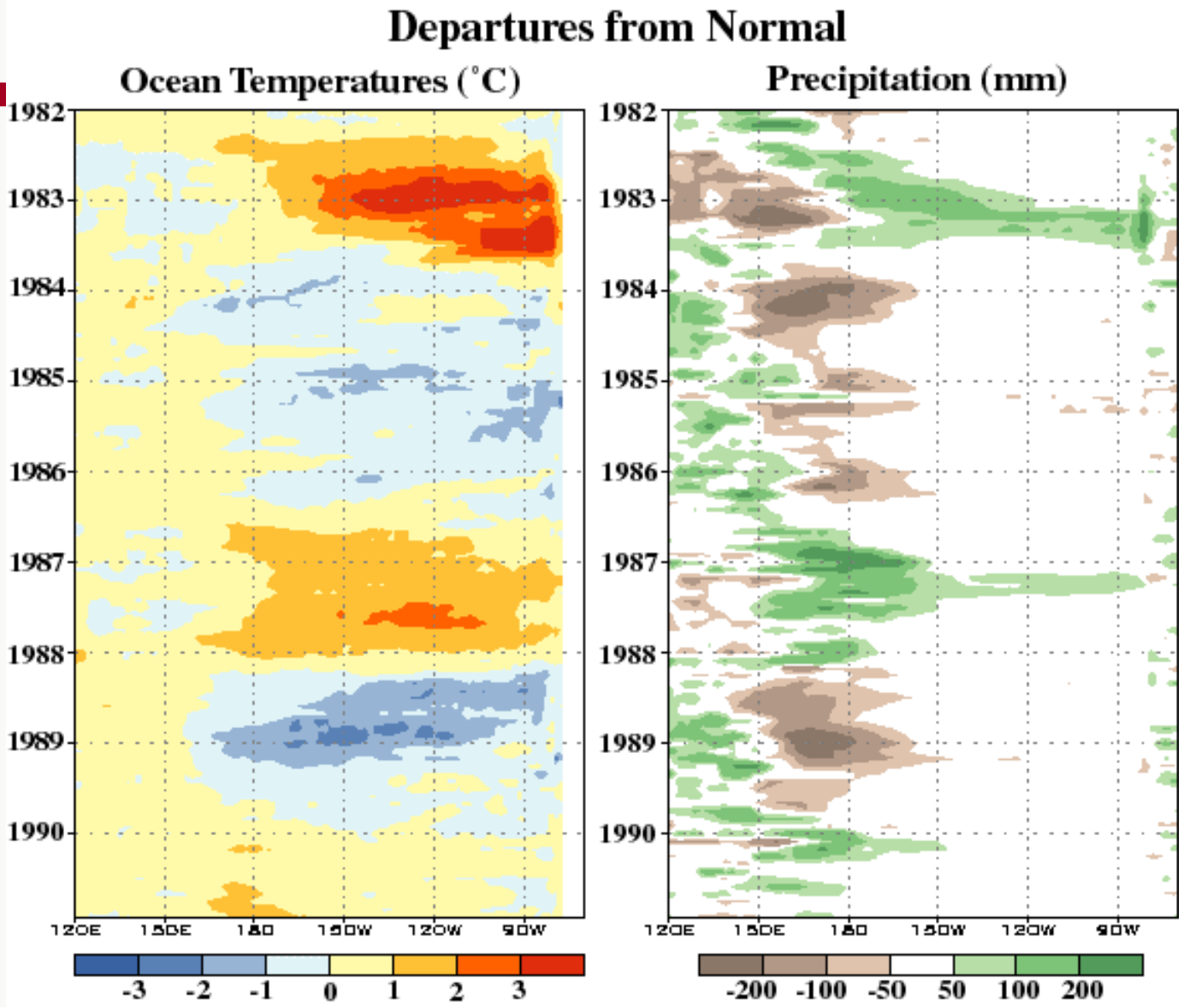
L'ENSO (6)


Departures from Normal
Ocean Temperatures (°C)
850-mb Zonal Winds (m/s)
1982
1983
1984
1985
1986
1987
1988
1989
1990
120E
150E
180
150W
120W
90W
-3
-2
-1
0
1
2
3
-9
-6
-3
0
3
6
9

L'ENSO (6)


Departures from Normal
Ocean Temperatures (˚C)
Thermocline depth (m)
1982
1983
1984
1985
1986
1987
1988
1989
1990
120E
150E
180
150W
120W
90W
-3
-2
-1
0
1
2
3
-30
-20
-10
0
10
20
30

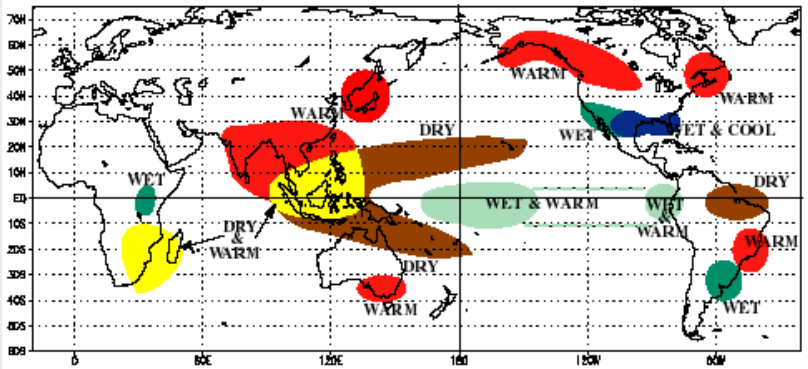
L'ENSO (6)


Departures from Normal
Ocean Temperatures (˚C)
Precipitation (mm)
1982
1983
1984
1985
1986
1987
1988
1989
1990
120E
150E
180
150W
120W
90W
-3
-2
-1
0
1
2
3
-200
-100
-50
50
100
200

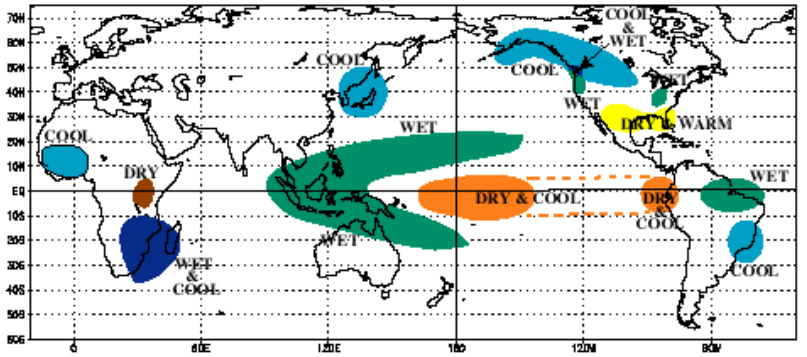
L'ENSO (7)

- L'influence planétaire d'El Niño (à gauche) et de La Niña (à droite)

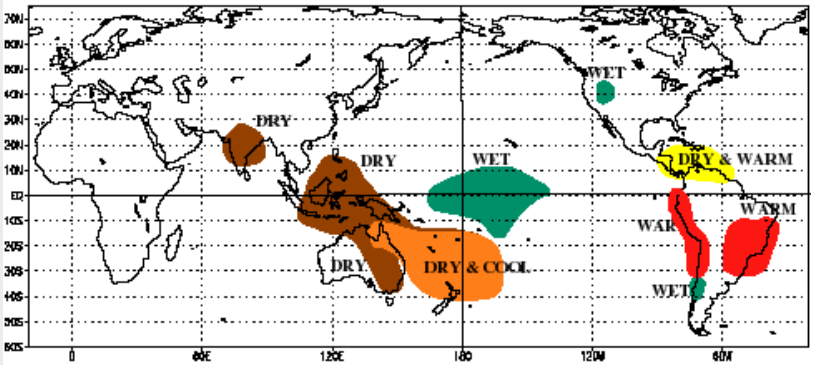
WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



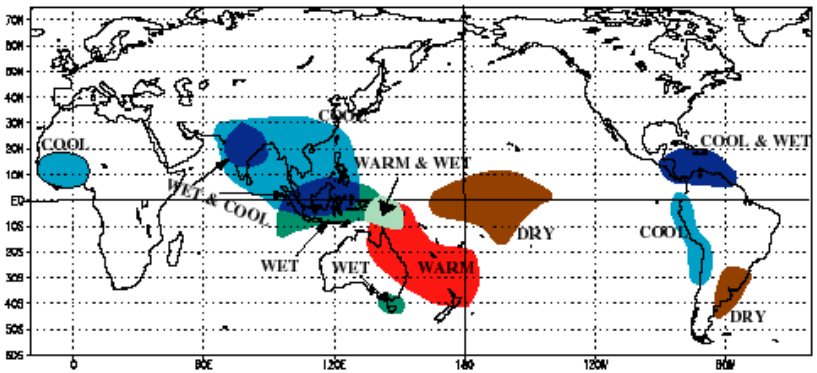
COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



WARM EPISODE RELATIONSHIPS JUNE - AUGUST



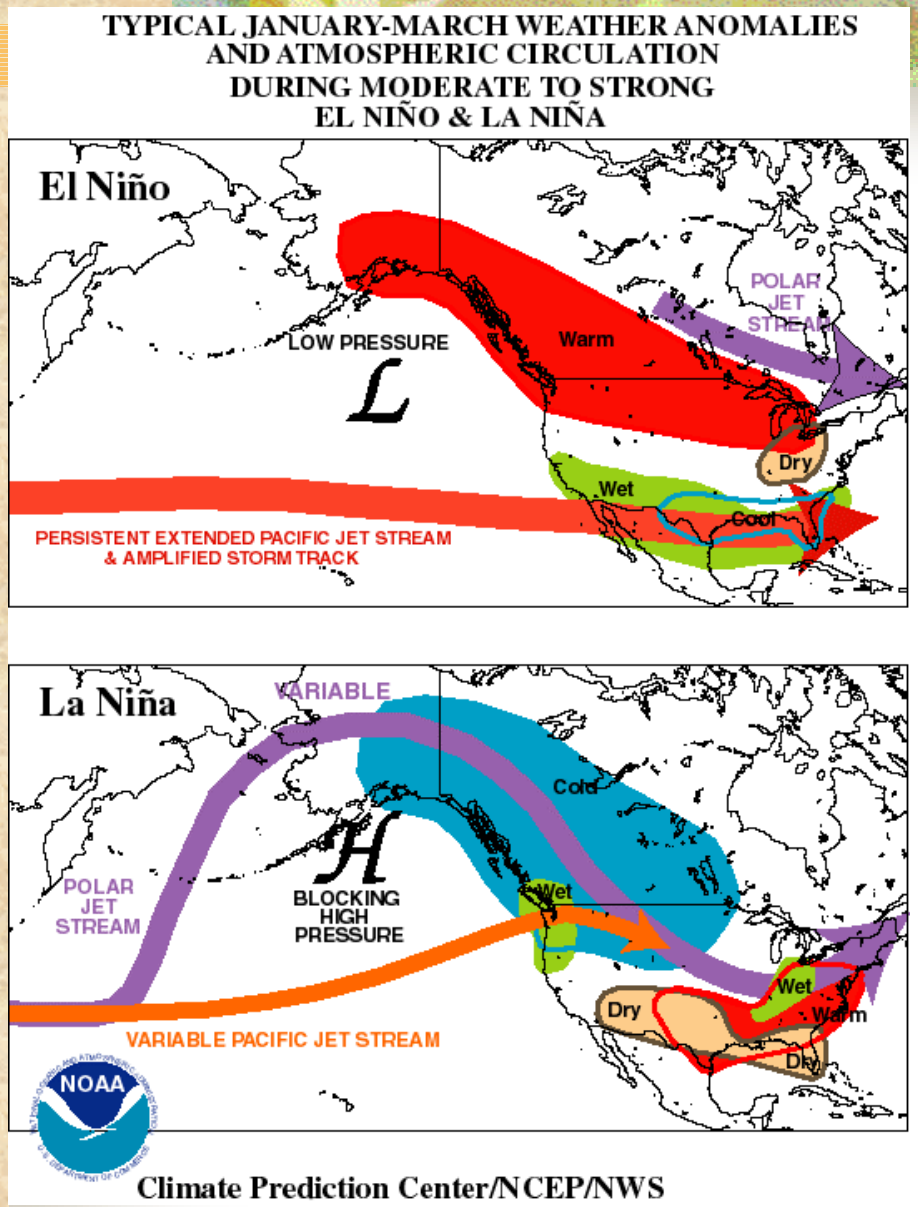
COLD EPISODE RELATIONSHIPS JUNE - AUGUST

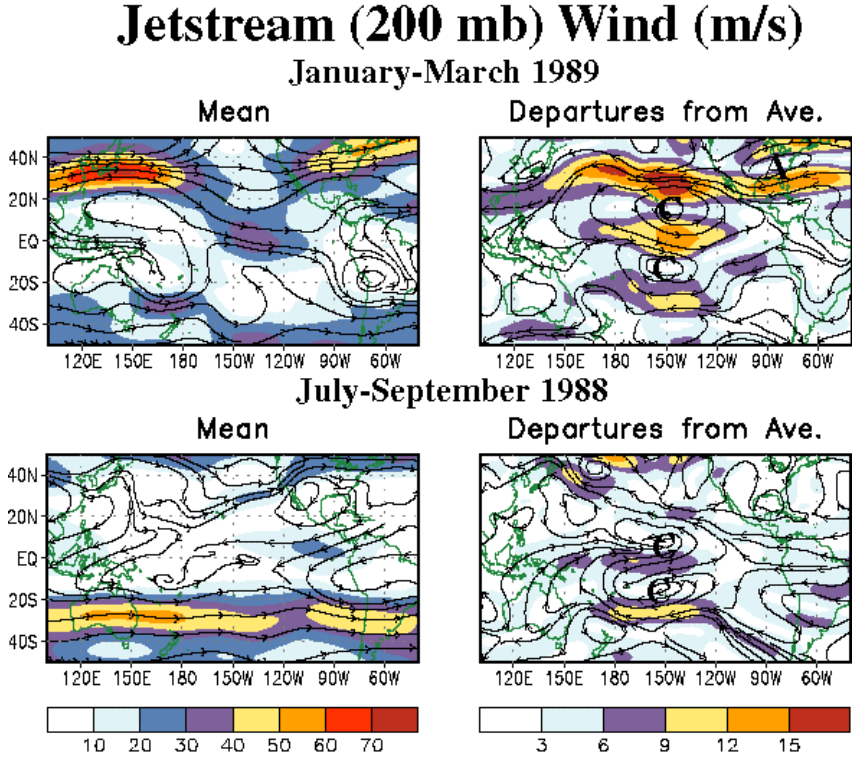


Climate Prediction Center
NCEP

Climate Prediction Center
NCEP

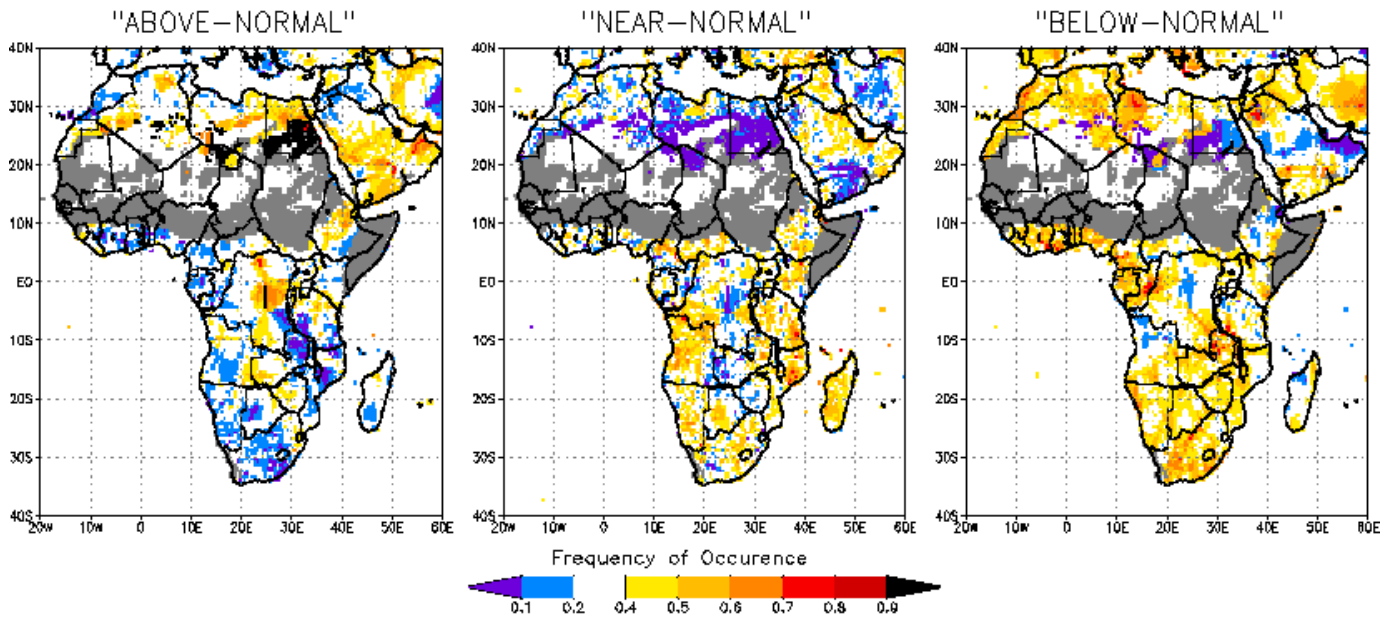
L'ENSO


TYPICAL JANUARY-MARCH WEATHER ANOMALIES
AND ATMOSPHERIC CIRCULATION
DURING MODERATE TO STRONG
EL NIÑO & LA NIÑA
El Niño
LOW PRESSURE
L
Warm
POLAR
JET
STREAM
Dry
Wet
Cool
PERSISTENT EXTENDED PACIFIC JET STREAM
& AMPLIFIED STORM TRACK
La Niña
VARIABLE
Cold
H
POLAR
JET
STREAM
BLOCKING
HIGH
PRESSURE
Wet
Dry
Wet
Warm
Dry
VARIABLE PACIFIC JET STREAM
NOAA
Climate Prediction Center/NCEP/NWS


Jetstream (200 mb) Wind (m/s)
January-March 1989
Mean
Departures from Ave.
40N
20N
EQ
20S
40S
120E 150E 180 150W 120W 90W 60W
July-September 1988
Mean
Departures from Ave.
10 20 30 40 50 60 70
3 6 9 12 15

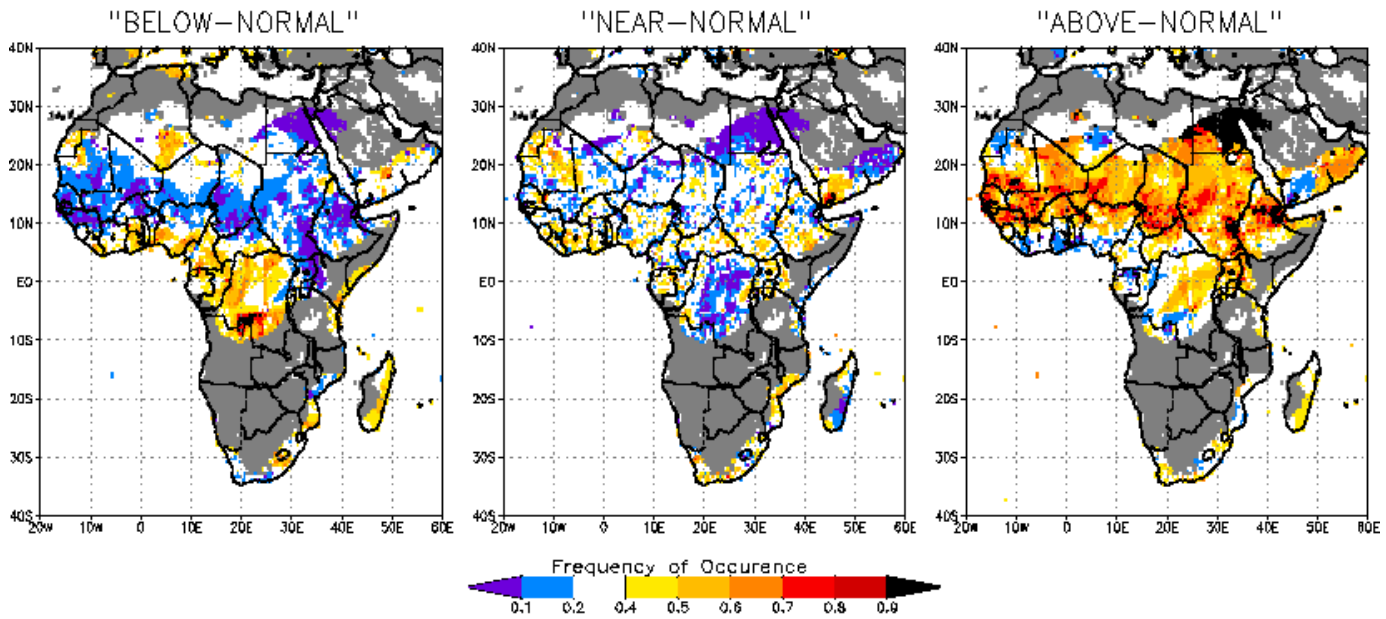
L'ENSO (8)

- L'influence d'El Niño en Afrique (hiver Boréal)



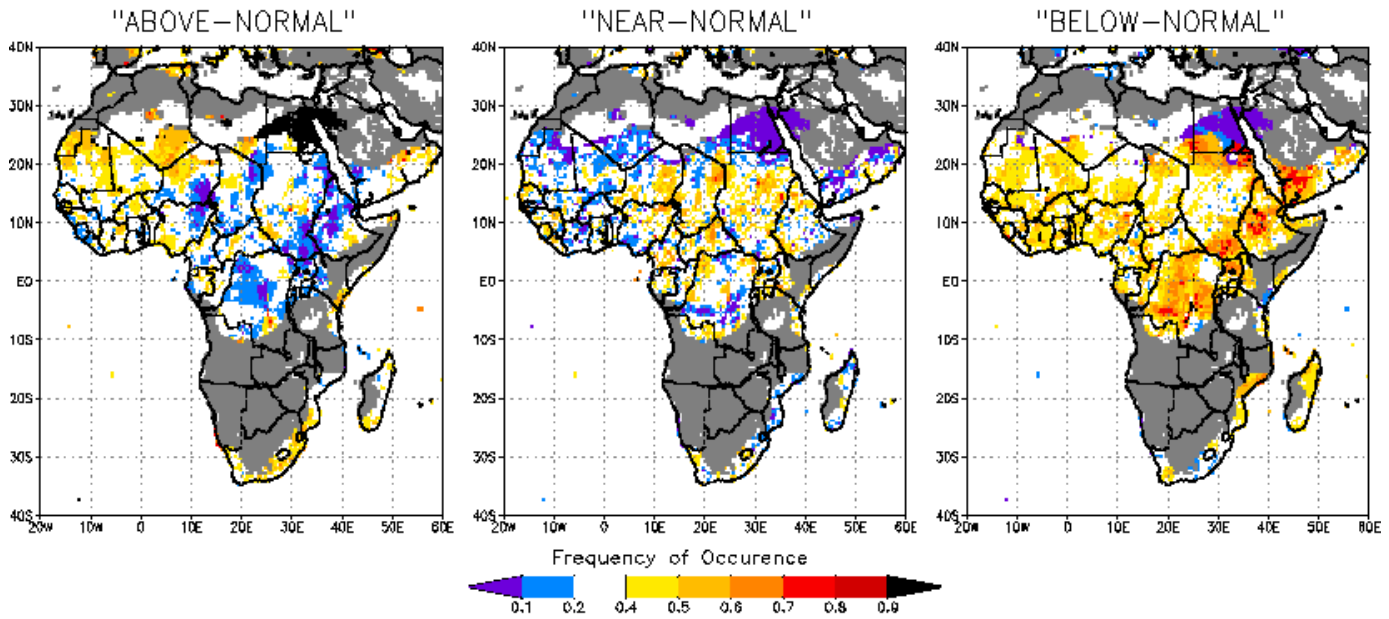
L'ENSO (9)

- L'influence de La Niña en Afrique (été Boréal)



L'ENSO (9)

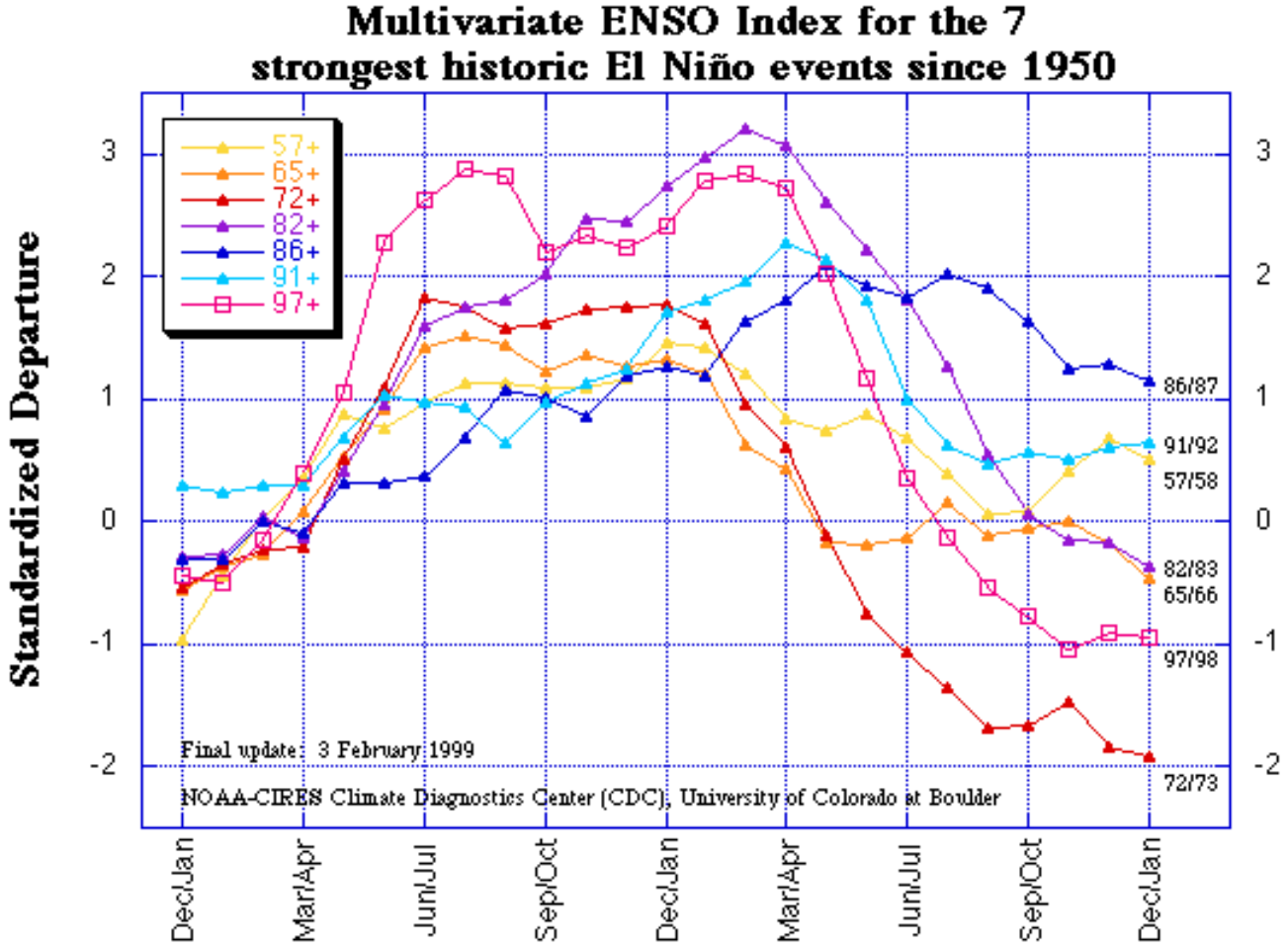
- L'influence d'El Niño en Afrique (été Boréal)



L'ENSO (10)

- Los Niños y Las Niñas

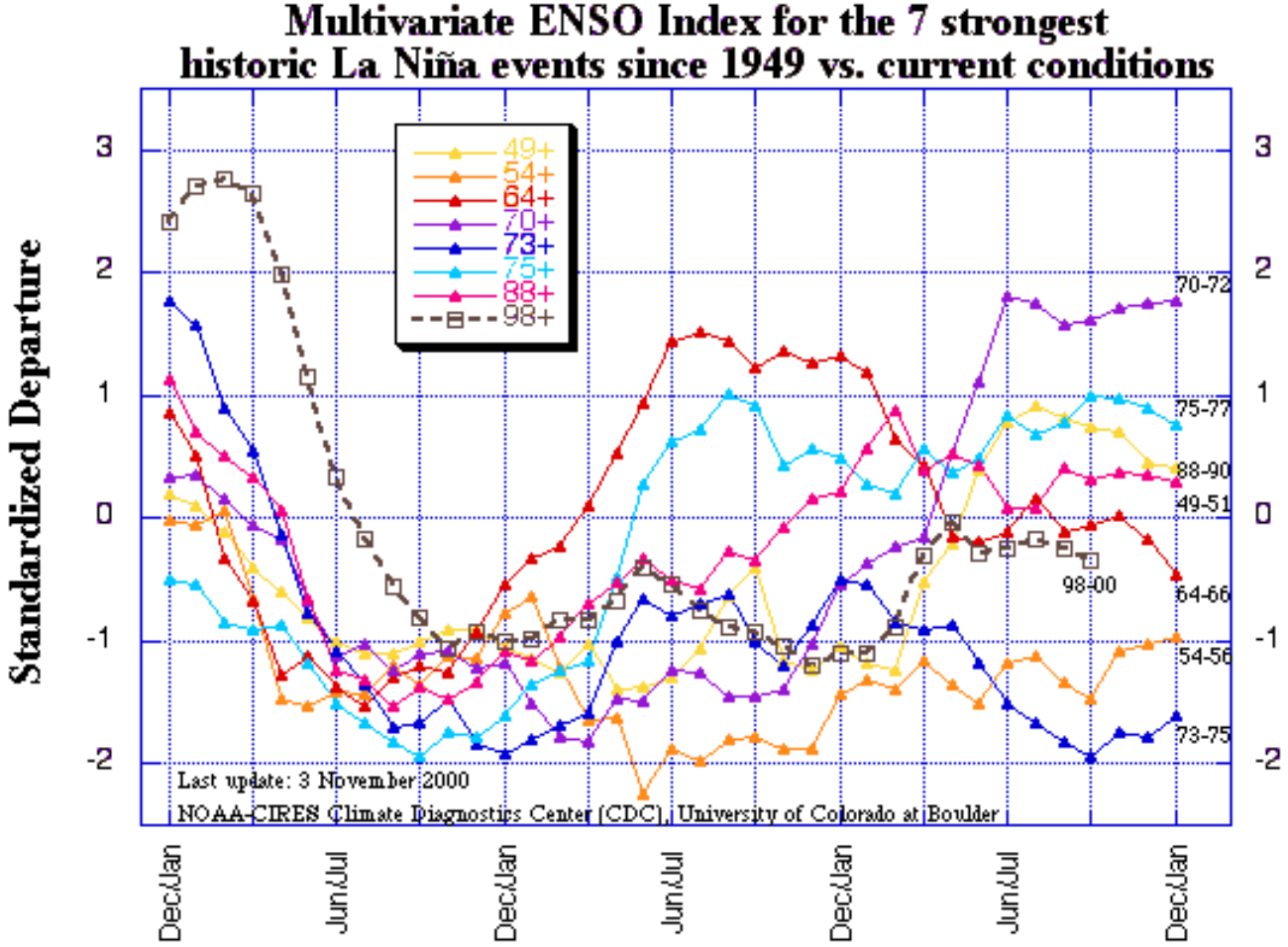
comparaison des évolutions temporelle pour les 7 plus fortes Niños



L'ENSO (10)

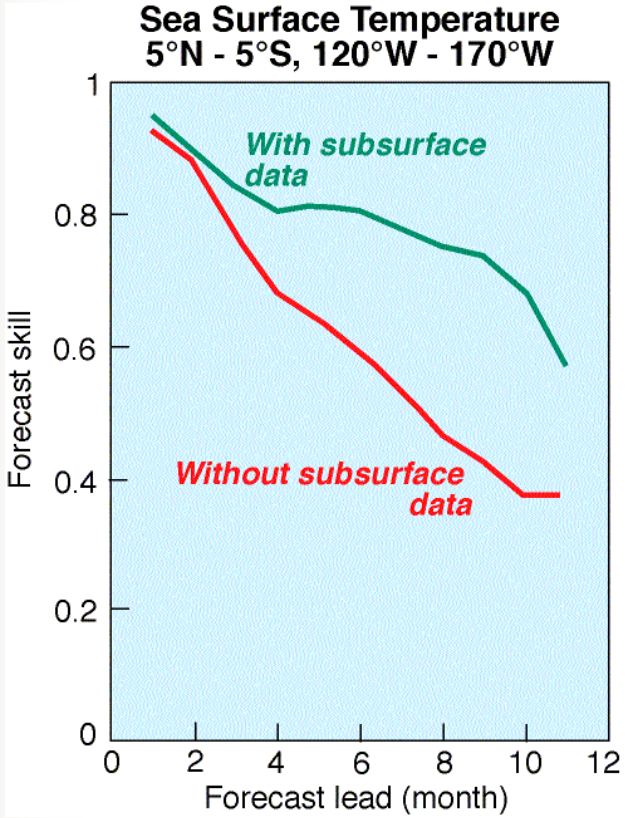
- Los Niños y Las Niñas

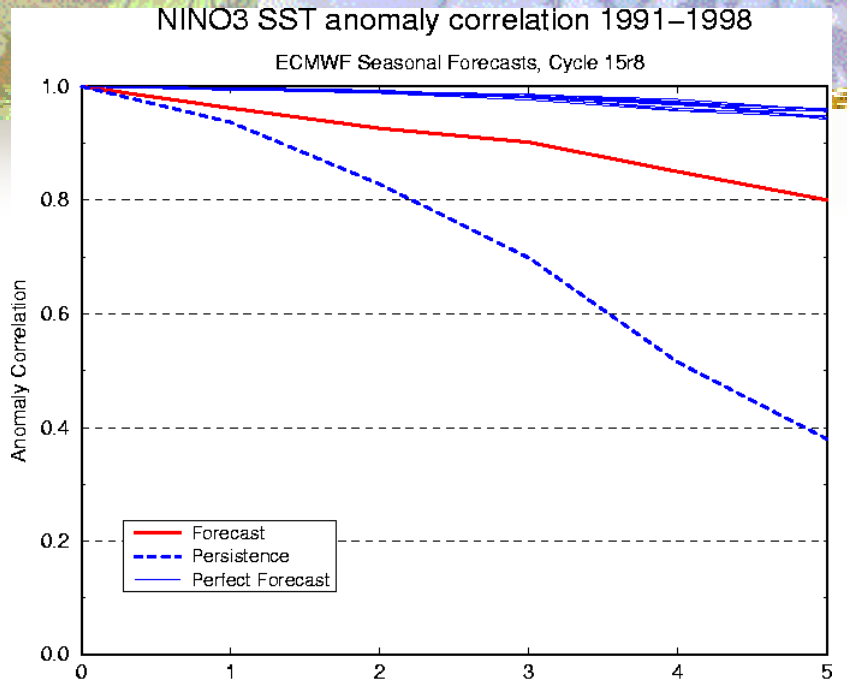
comparaison des évolutions temporelle pour les 7 plus fortes Niñas

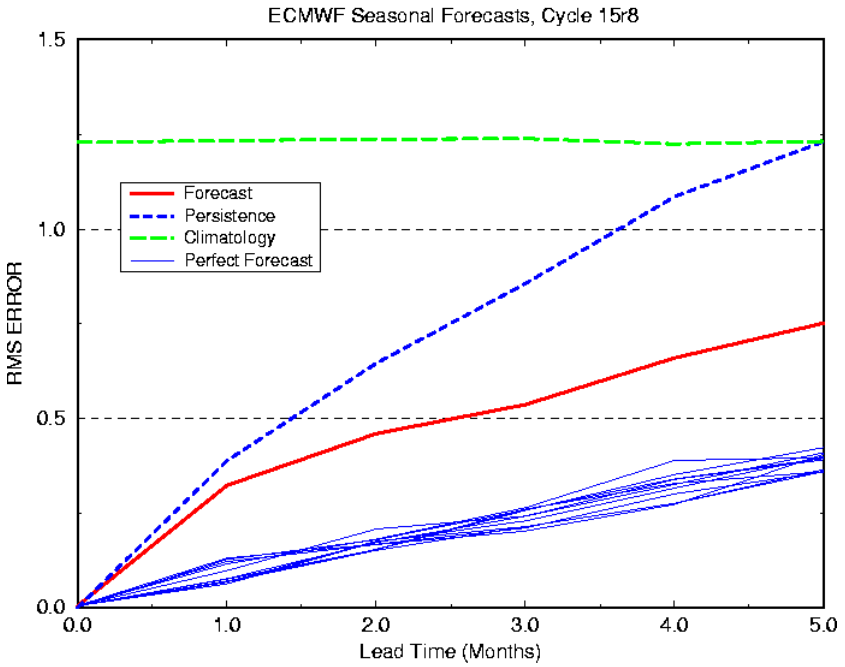


L'ENSO

- La prévisibilité



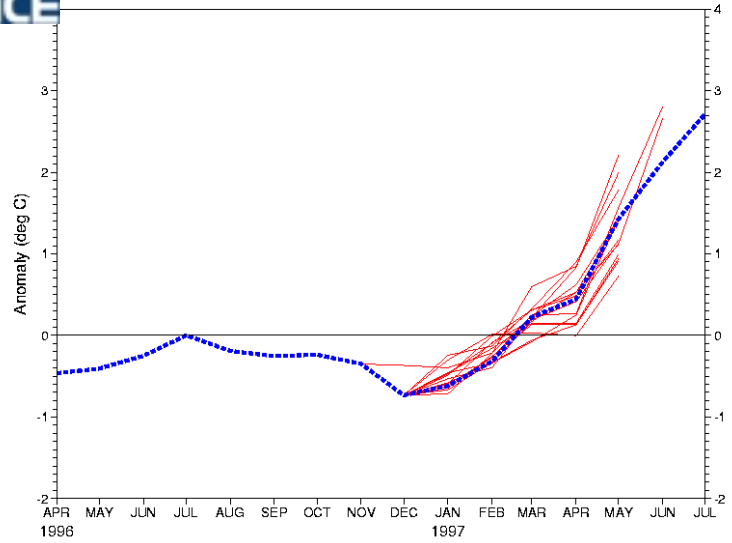




METEO FRANCE

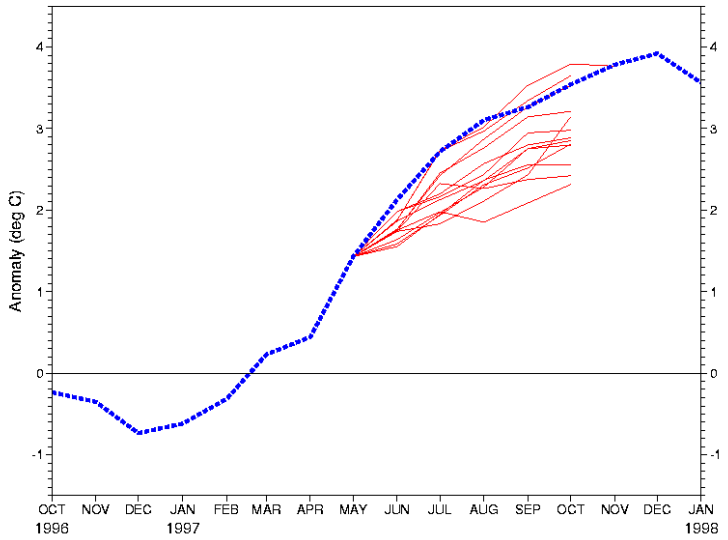
L'ENSO

NINO-3 SST anomaly plume
ECMWF forecasts from dates in Dec 1996



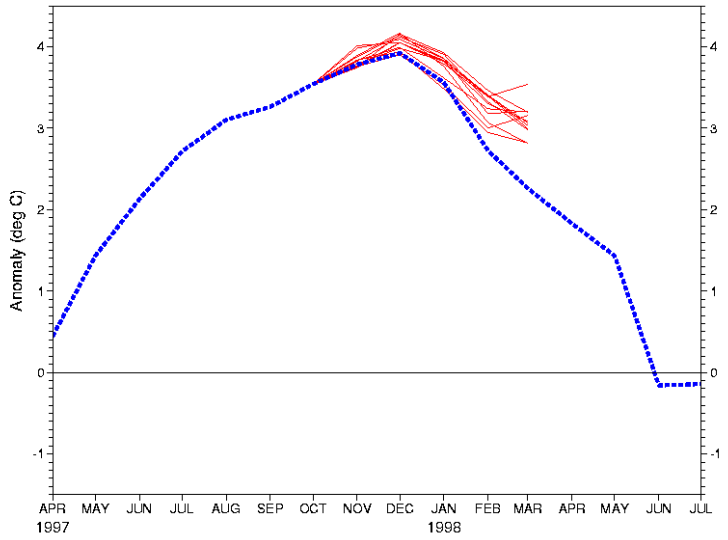
MAGICS 6.0 styx - net Tue Sep 14 09:08:22 1999

NINO-3 SST anomaly plume
ECMWF forecasts from dates in May 1997



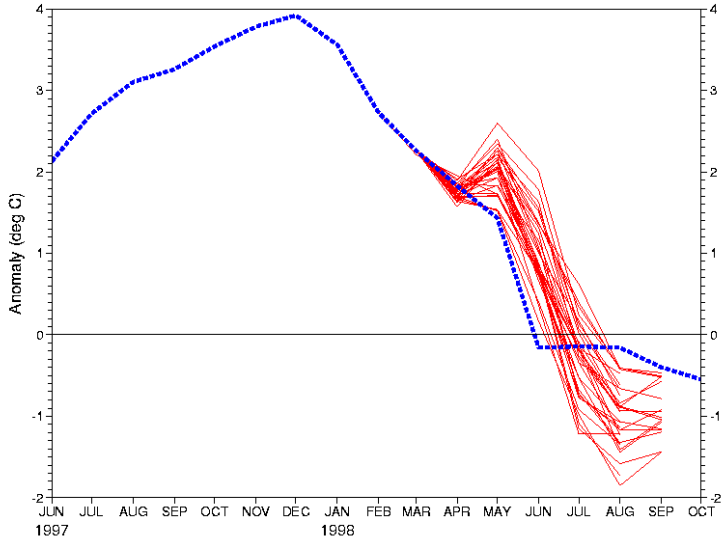
MAGICS 6.0 styx - net Tue May 11 08:56:09 1999

NINO-3 SST anomaly plume
ECMWF forecasts from dates in Oct 1997



MAGICS 6.0 styx - net Tue May 11 08:52:32 1999

NINO-3 SST anomaly plume
ECMWF forecasts from dates in Mar 1998

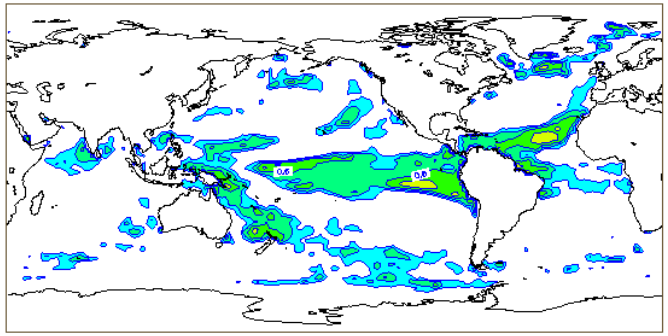


MAGICS 6.0 styx - net Tue May 11 08:48:05 1999

SST Point Correlation Map: Persistence

1991-1998

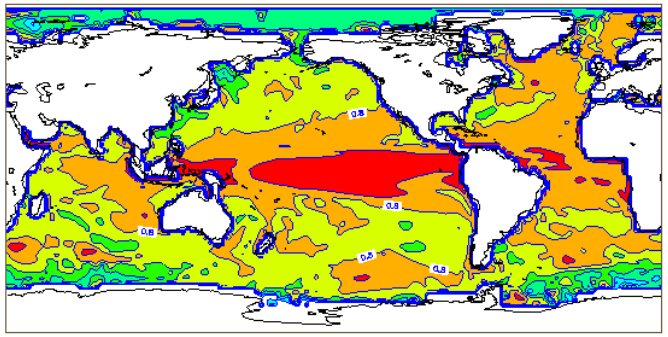
ECMWF Seasonal Forecasts, Cycle 15r8



SST Point Correlation Map : Perfect Model

1991-1998

ECMWF Seasonal Forecast, Cycle 15r8

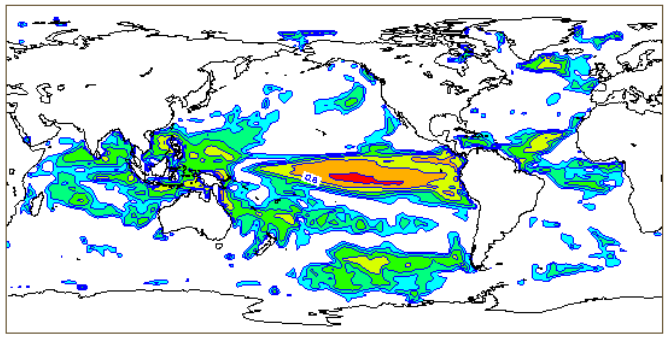


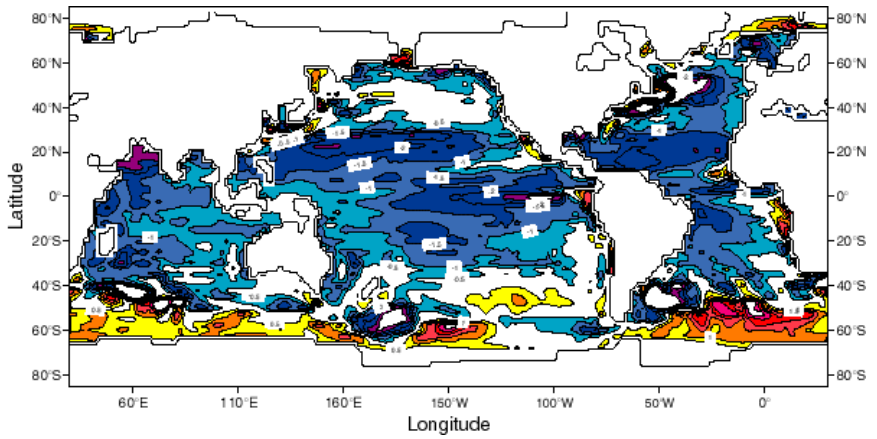
L'ENSO

SST Point Correlation Map: ECMWF Forecast

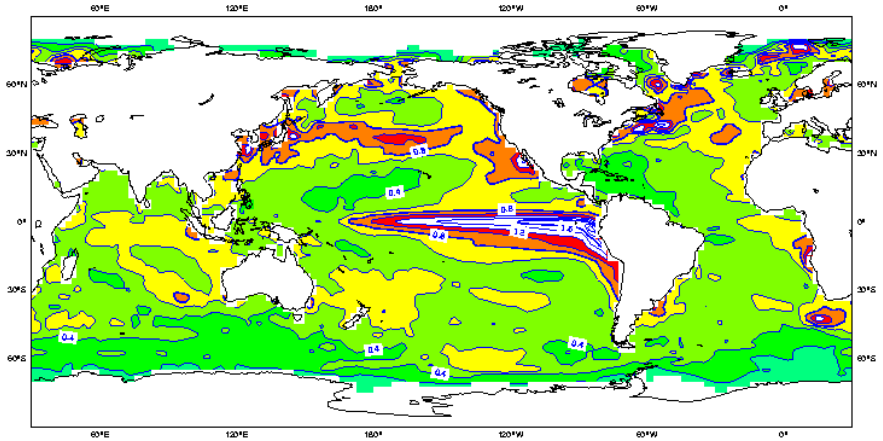
1991-1998

ECMWF Seasonal Forecasts, Cycle 15r8

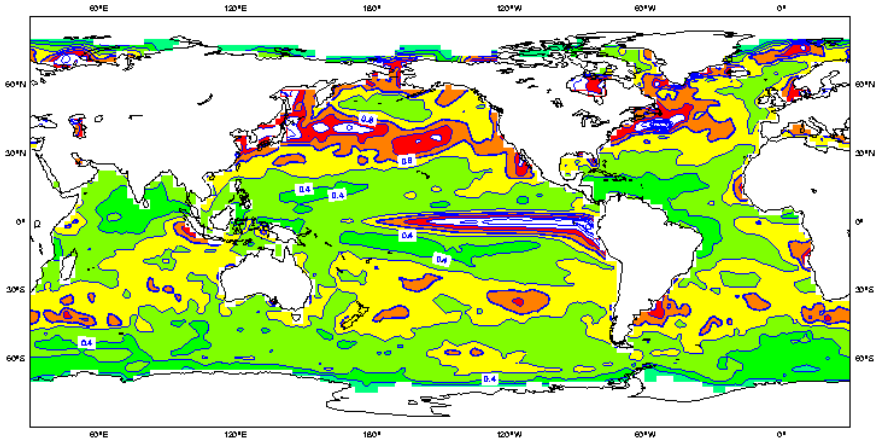




SST RMS ERROR (1991-1998): Climatology
ECMWF Seasonal Forecasts, Cycle 15r8

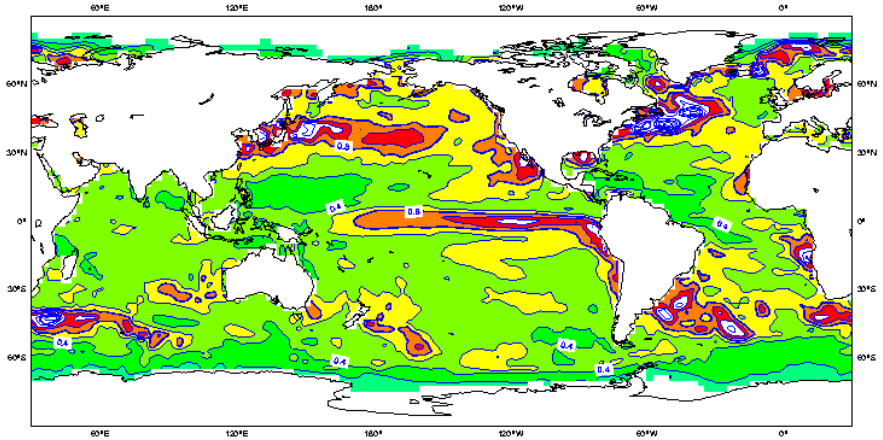


SST RMS ERROR (1991-1998): Persistence
ECMWF Seasonal Forecasts, Cycle 15r8

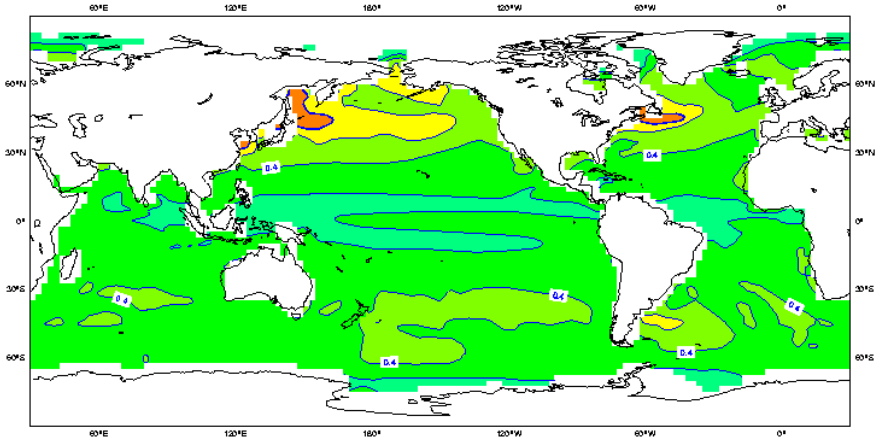


L'ENSO

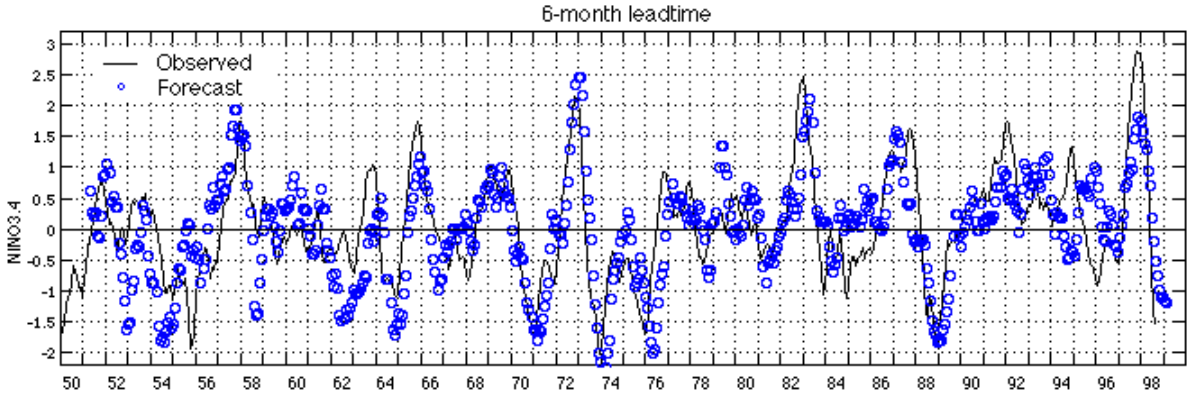
SST RMS ERROR (1991-1998): ECMWF Forecast
ECMWF Seasonal Forecasts, Cycle 15r8

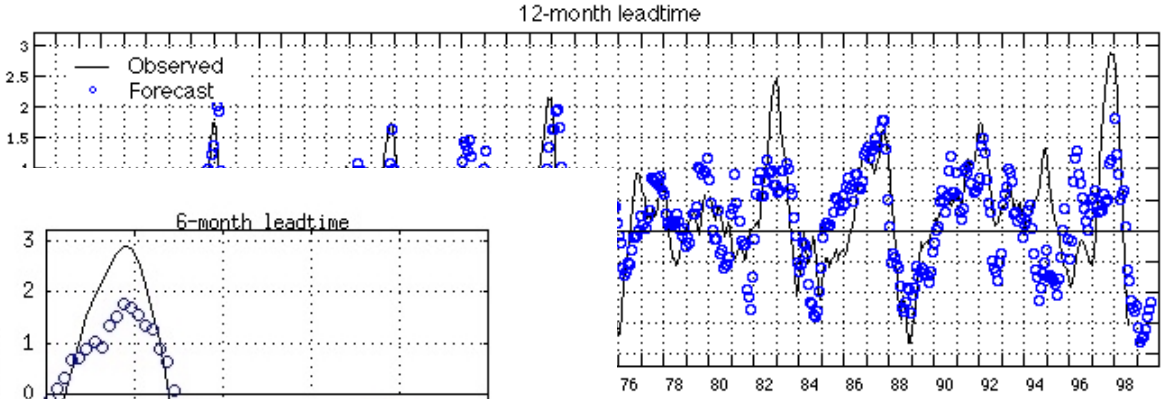


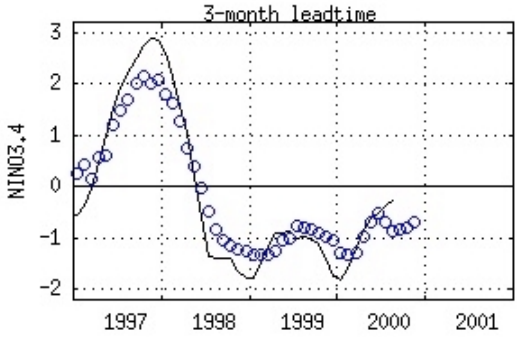
SST RMS ERROR (1991-1998): PERFECT MODEL
ECMWF Seasonal Forecasts, Cycle 15r8



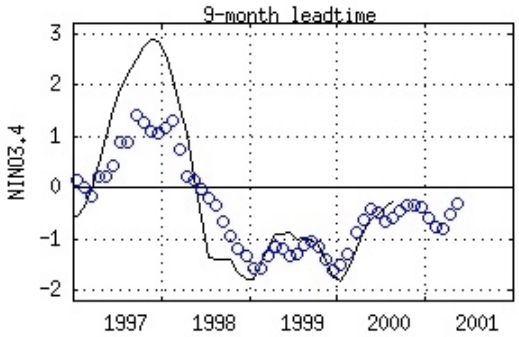
L'ENSO

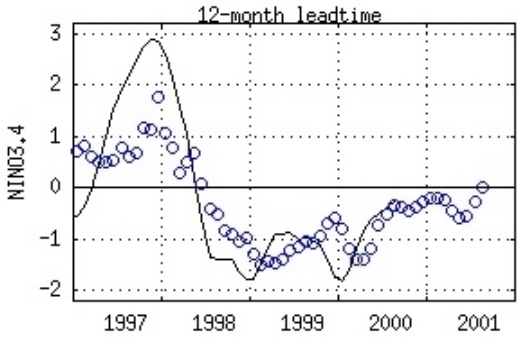

6-month leadtime
Observed
Forecast
NINO3.4


12-month leadtime
Observed
Forecast

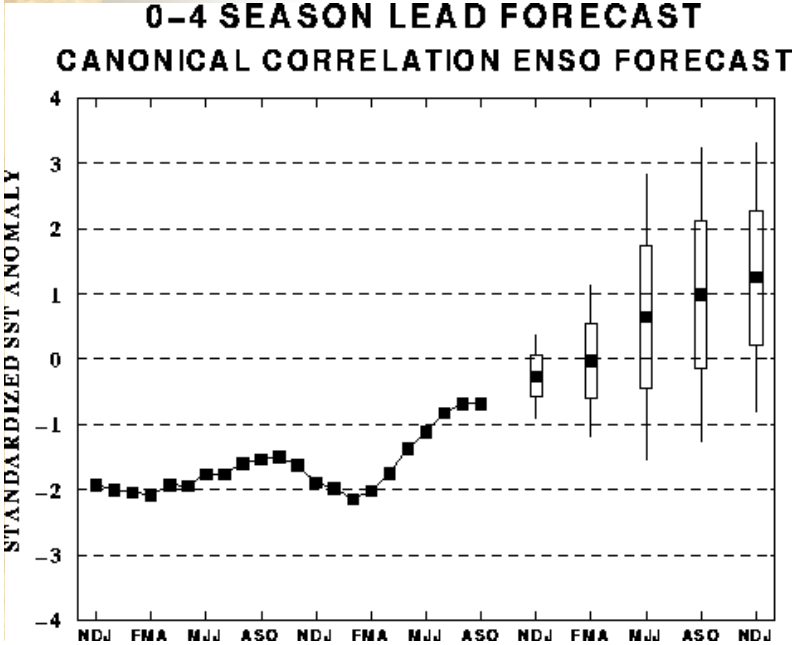

3-month leadtime
NINO3.4

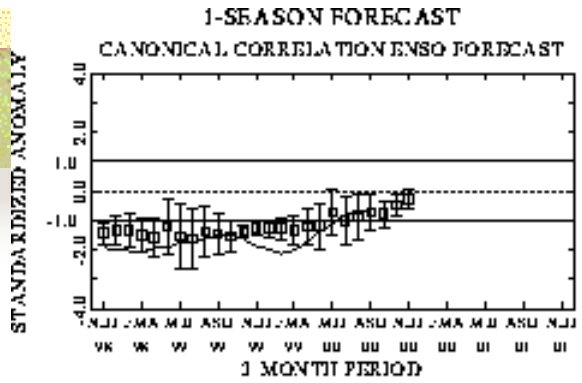
6-month leadtime
NINO3.4

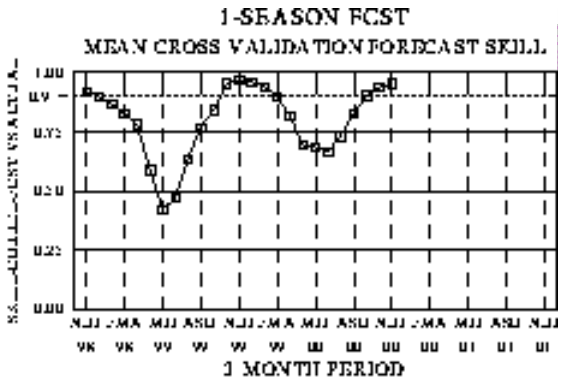

9-month leadtime
NINO3.4

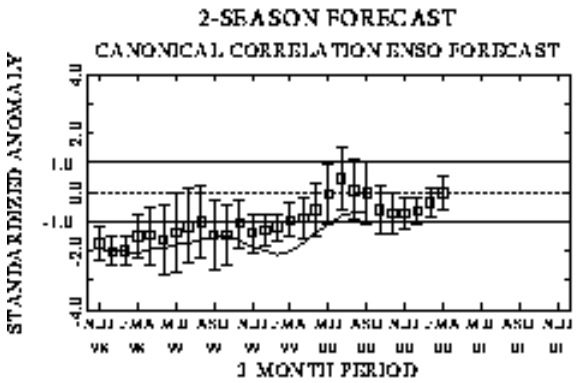

12-month leadtime
NINO3.4

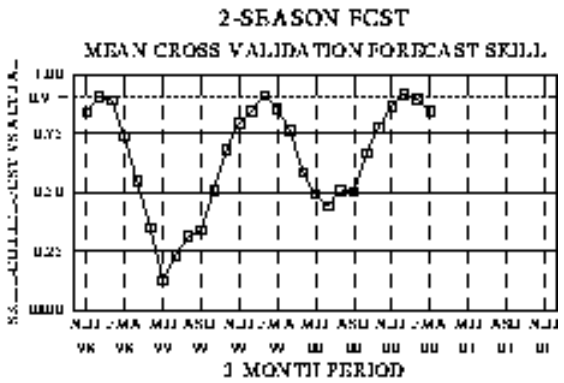
L'ENSO

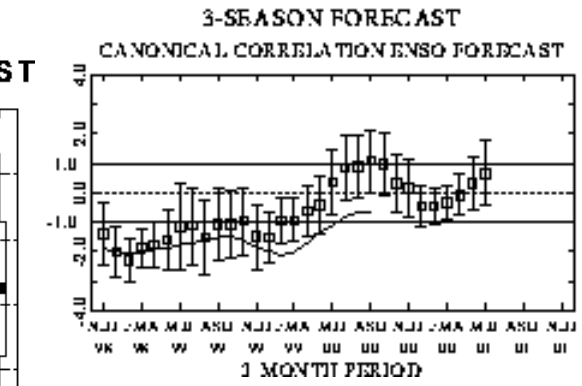

0-4 SEASON LEAD FORECAST
CANONICAL CORRELATION ENSO FORECAST
STANDARDIZED SST ANOMALY
4
3
2
1
0
-1
-2
-3
-4
NDJ FMA MJJ ASO NDJ FMA MJJ ASO NDJ FMA MJJ ASO NDJ

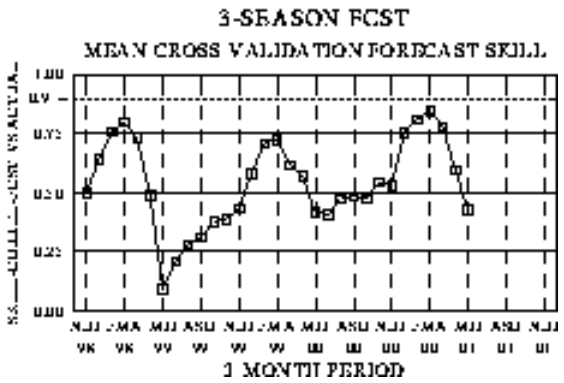

1-SEASON FORECAST
CANONICAL CORRELATION ENSO FORECAST
STANDARDIZED ANOMALY
3 MONTH PERIOD


1-SEASON FCST
MEAN CROSS VALIDATION FORECAST SKILL
3 MONTH PERIOD


2-SEASON FORECAST
CANONICAL CORRELATION ENSO FORECAST
STANDARDIZED ANOMALY
3 MONTH PERIOD

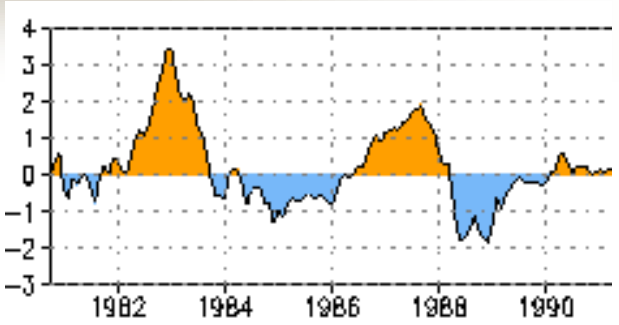

2-SEASON FCST
MEAN CROSS VALIDATION FORECAST SKILL
3 MONTH PERIOD

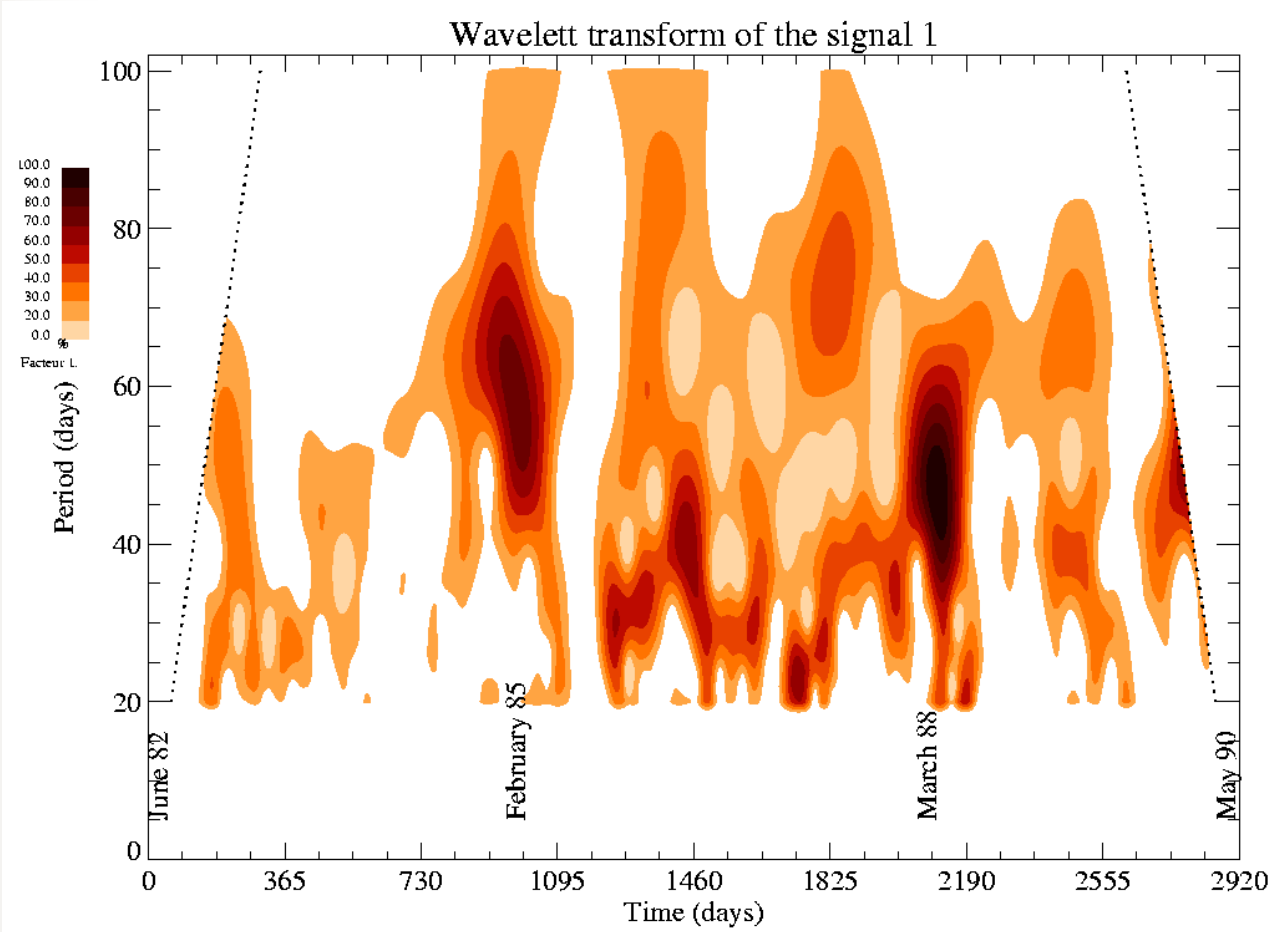

3-SEASON FORECAST
CANONICAL CORRELATION ENSO FORECAST
3 MONTH PERIOD


3-SEASON FCST
MEAN CROSS VALIDATION FORECAST SKILL
3 MONTH PERIOD

L'ENSO

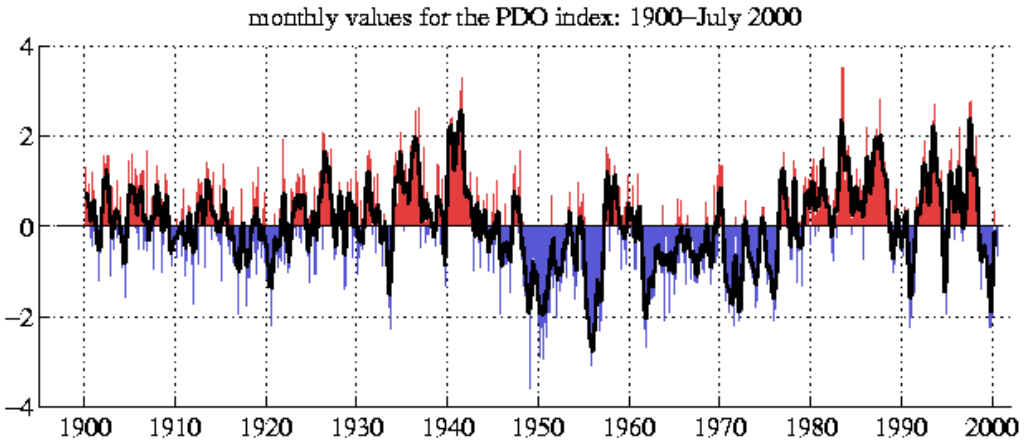
- Influence sur la MJO

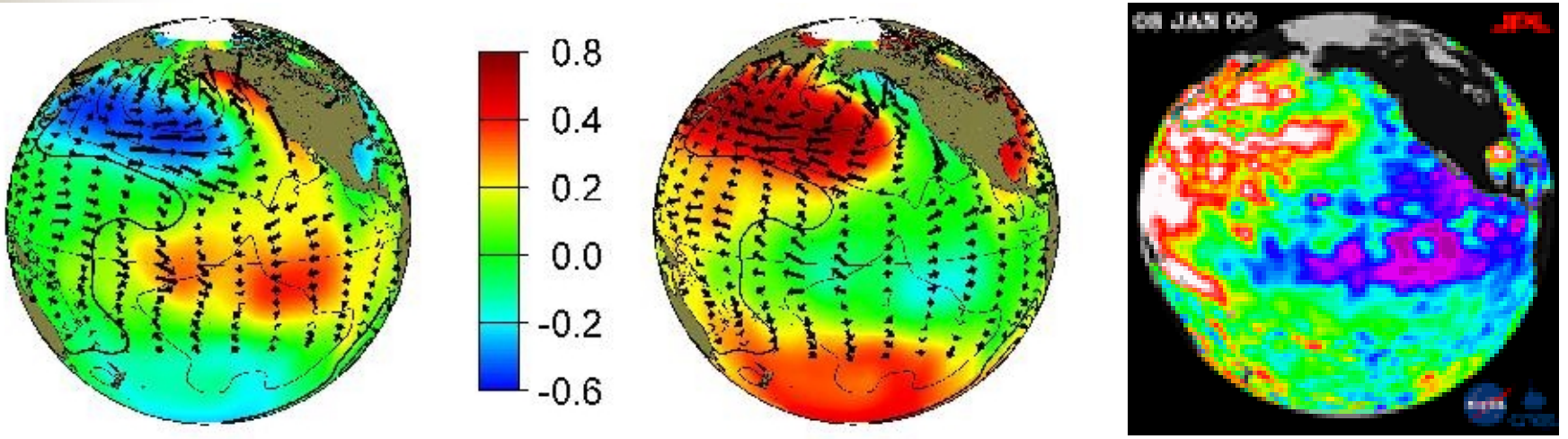




La variabilité climatique décennale

L'oscillation décennale du Pacifique





Récapitulatif sur l'ENSO

- La variabilité du système Océan/Atmosphère
- La modélisation couplée