StraPolÉté

On the occurrence, the characterization and the dynamical processes associated with « Frozen In AntiCyclone's » events.

[1]Rémi Thiéblemont, [1]Nathalie Huret, [2]Yvan Orsolini, [1]Fabrice Jégou, [3]Alain Hauchecorne and [1]Marc-Antoine Drouin*

*remi.thieblemont@cnrs-orleans.fr

[1]*Laboratoire de Physique et Chimie de l'Environnement et de l'Espace (LPC2E), Orléans, France.*
[2]*Norwegian Institute for Air Research (NILU), Kjeller, Norway.*
[3]*Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), Guyancourt, France.*

StrapolEté project :

Polar stratosphere study – WP Dynamics.
See also at AGU :

- **(A11-01)**
- **Preliminary results from SPIRALE balloon-borne in situ stratospheric measurements during 2009 polar summer (A33C-0173)**

Session title: A32B. Atmospheric Sciences General Contributions: Dynamics 1
Session topic: Atmospheric Sciences

Context

- During the Final Stratospheric Warming (in spring) the Arctic Polar Vortex, associated with westerly circulation, breaks up to the summer easterlies.

↓

- Two types of dynamical structures with specific chemical composition occur.

↓ ↓

« Frozen In Anticyclones » (FrIACs) **are the result of low latitudes air mass intrusions**

Vortex remnants

(Orsolini, Y.J., *28, 3855-3858, Geophys. Res. Lett., 2001.)*

Two events already reported :
-**2003** with MIPAS-ENVISAT data ***(Lahoz, W.A.,*** *et al., 133: 197-211, Q.J.R. Meteorol. Soc., 2007)*
-**2005** with MLS-AURA data ***(Manney, G.L.,*** *32: 10.1029/2005GL022823, Geophys. Res. Lett., 2006)*

Questions

- **What is the occurrence of these intrusions ?**
- **Which are the associated dynamical processes ?**

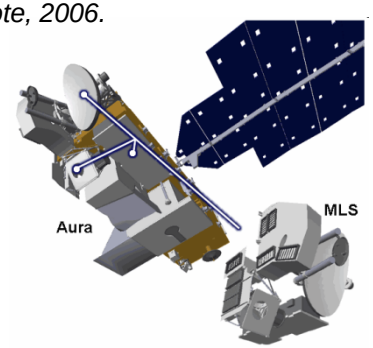
Scientific tools

➢ Characterization

AURA-MLS Instrument (v2.2)

(Microwave Limb Sounder)

Waters et al., *The Earth Observing System Microwave Limb Sounder (EOS MLS) on the Aura satellite, IEEE T. Geosci. Remote, 2006.*



Measurements of thermal microwave emission from Earth's 'limb'.

⇔H_2O and N_2O long-lived tracers used.

➢ Dynamical Processes

ECMWF Era-Interim Re-analysis

Simmons et al., Newsletter 110, ECMWF, 29–35, 2007.

(European Centre for Medium-Range Weather Forecasts)

Pressure, Temperature and Winds fields.

⇔ Diagnostic on zonal wind.

⇔ Heat flux calculations.

⇔ inputs of MIMOSA PV model

MIMOSA : Potential Vorticity contour advection model

Hauchecorne et al., *VOL.107, 8289, 13 PP.,J. Geophys. Res, 2002.*

Resolution : lat/lon ⇔ 1/3° / 1/3°

Isentropic surfaces range: [350 K ; 950 K] ~[13.5 km ; 34 km]

⇔ Focusing on PV evolution at 850K (~30 km)

A new FrIAC's case during Spring 2007

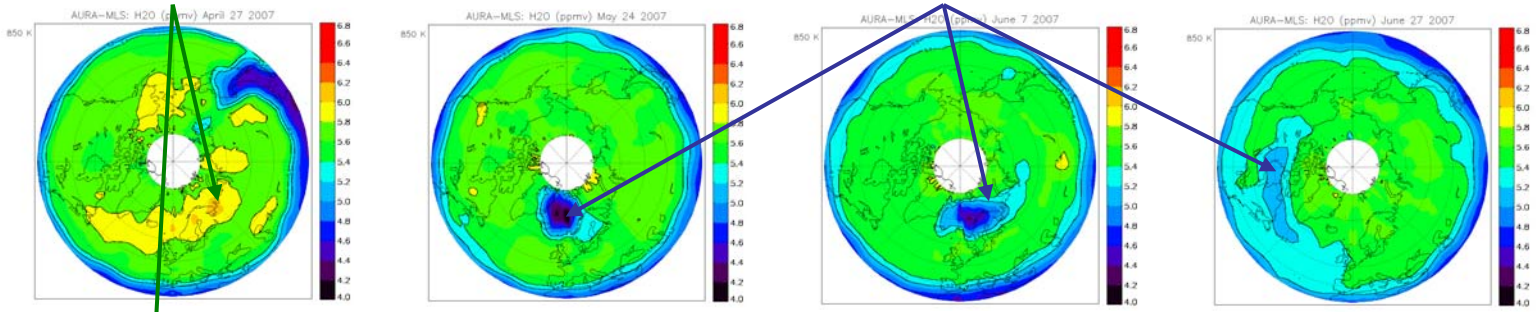
➢ Temporal evolution of the FrIAC

850K (~31 km)

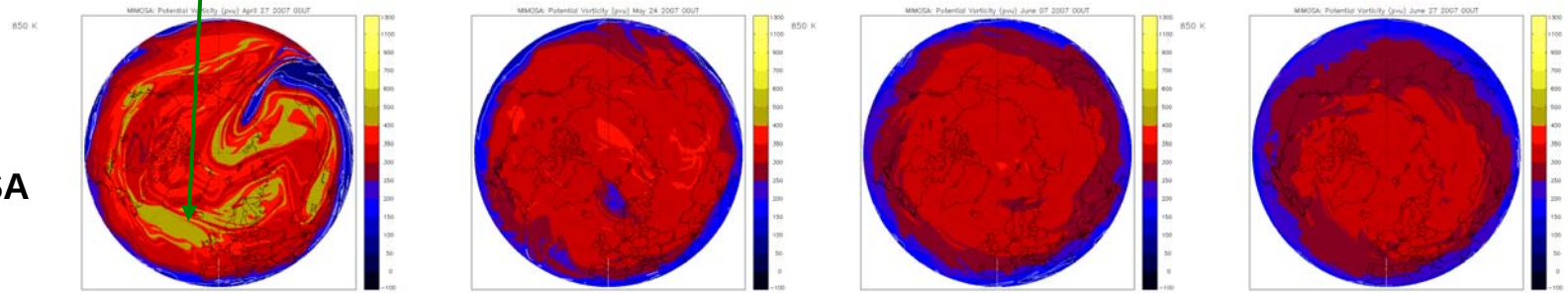
Remnants : High H_2O/PV

FrIAC : Low H_2O/PV

H_2O (ppmv) **MLS**



PV (pvu) **MIMOSA**



H_2O-MLS vs PV-MIMOSA polar stereographic projections in the latitude range 40N/90N at 850K.

- FrIAC **trapped** at polar latitudes**.**
- **Persistence of the FrIAC** from May to July in H_2O/N_2O fields
- **Vortex remnants** disappear after ~1 Month.

Ability of MIMOSA to reproduce the evolution of the dynamical structures

Summary

- 2007 a **new FrIAC** event.
- **Ability** of the MIMOSA model to reproduce patterns.

Following

- Climatology based on MIMOSA results over the last 10 years [2000-2009].

3 FrIACs occur during this period : in 2003, 2005 and 2007

What is the dynamical state of the stratosphere when a FrIAC occurs ?

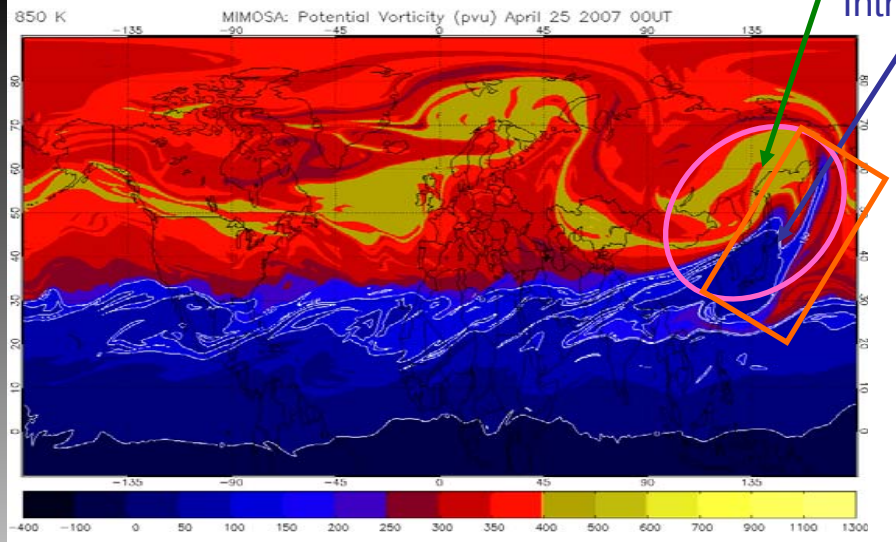
FrIAC's intrusions

➢ Initial FrIAC dynamical state the 2007 April 25th

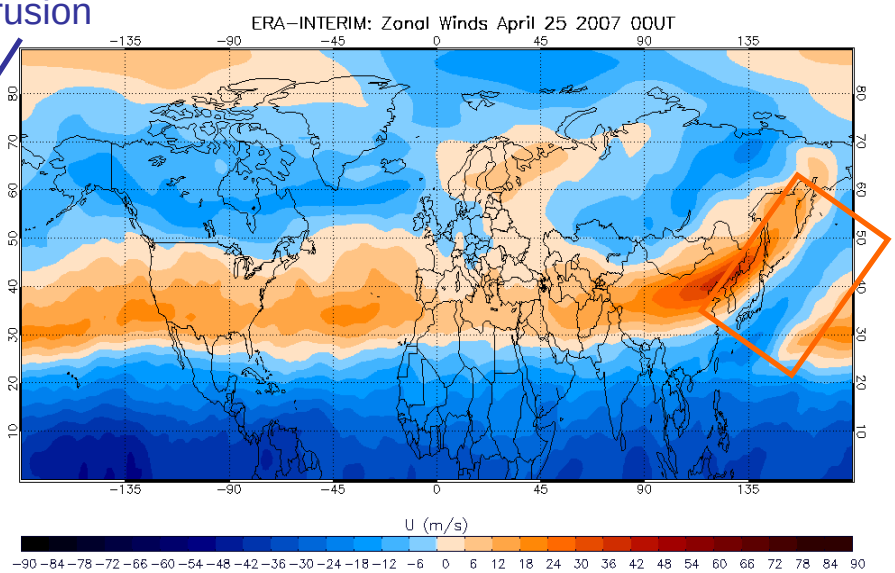
Vortex remnants

Intrusion

MIMOSA-PV (pvu) | 850-K



Era-Interim Zonal Wind ($m.s^{-1}$) | 850-K



easterly / westerly

- **Dipolar cell** (ridge/trough pair) { Intrusion along the mean longitude Aleutian High/Polar Vortex boundary. Vortex remnants displaced at mid-latitudes.
- Meridional PV gradient inversion ⇔ **« P2 » planetary wave breaking**

(**Baldwin & Holton**, *Atmos. Sci.*, 45, 1123-1142, 1988) (**Peters & Waugh**, *Atmos. Sci.*, 53, 3013-3031, 1996)

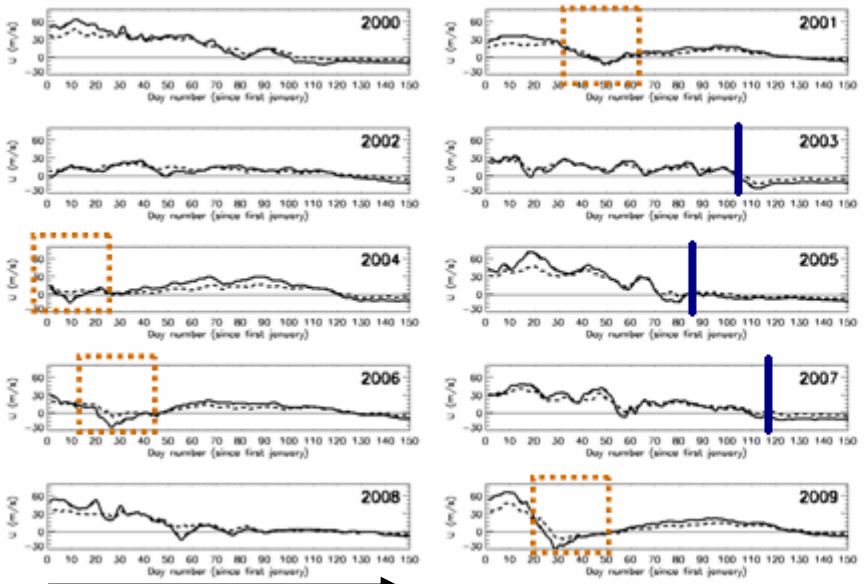
Similar features during the 2003, 2005 (not shown) and 2007 intrusions

FrIAC's climatology : 1/ Role of Major SSWs

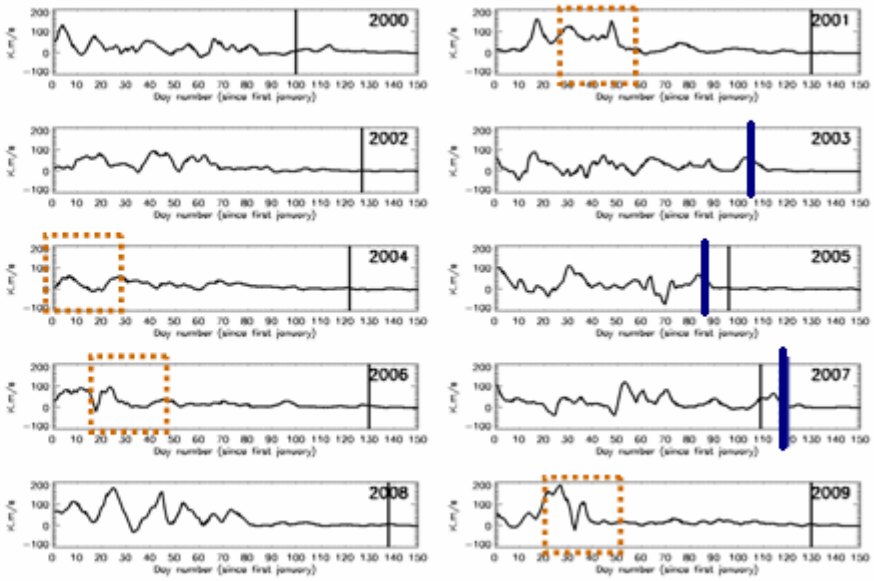
➢Last decade evolution of the zonal wind and the meridionnal heat fluxes

Sudden Stratospheric Warming (SSW) : zonal westerly circulation at 60N and 10hPa reverse into easterly (WMO, 2007)

Zonal Mean Zonal Wind (m.s^{-1})
30 hPa (dashed) & 10 hPa (solid) | 60N



Meridionnal heat flux v'T' (K.m.s^{-1})
30 hPa | 45/55N mean



Deep SSWs | FRiAC intrusion | FSW (Final Stratospheric Warming)

- **Deep SSWs** (2001, 2004, 2006, 2009) ⇔ Zonal wind circulation reversal propagating at 30 hPa ⇔ **inhibition** of the planetary waves upward propagation.
- **FrIAC's years** ⇔ Planetary waves activity persists until **early/abrupt** FSW.

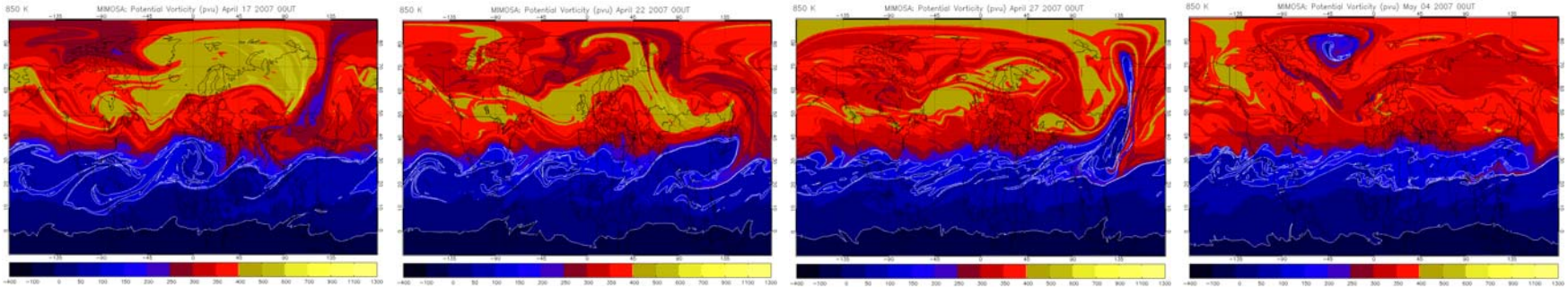
No FrIAC if deep SSWs during winter.

No FrIAC in 2000 in spite of the good conditions.

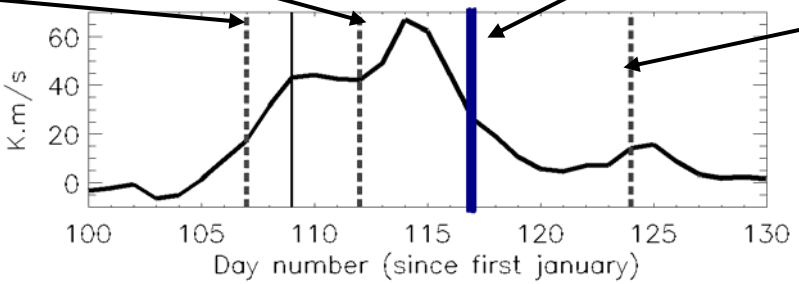
FrIAC's climatology : 2/ Detailed cases – in 2007 (a)

➢ Focus during the Final Stratospheric Warming

Polar vortex displacement | **Dipolar cell development** | **Tropical intrusion pulled poleward** | **FrIAC advection**



a-April 17th | b-April 22th | c-April 27th | d-May 04th



Heat flux zoom

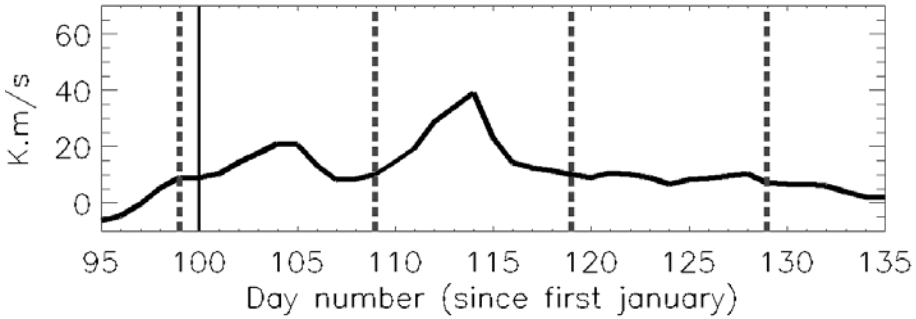
- Strong FSW ⇔ **Vortex displacement** at mid-latitudes.
- **Wave Breaking** + **Strong horizontal shear** between mid-latitudes and tropics ⇔ Dipolar cell ⇔ Tropical air mass quickly pulled poleward.
- FrIAC persistence in the easterly summer zonal wind regime.

FrIAC's climatology : 2/ Detailed cases (b)

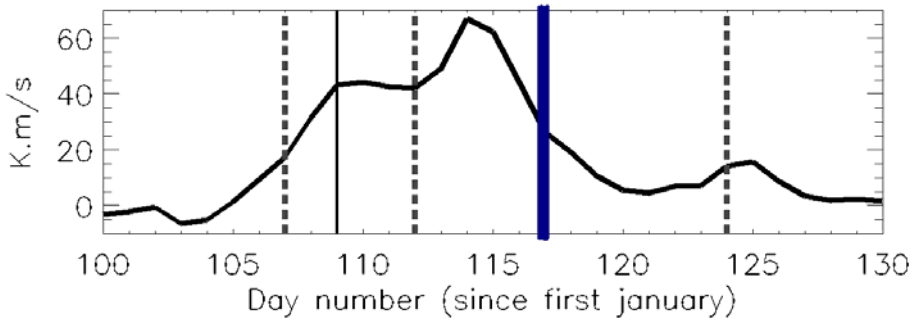
➢ **Why no FrIAC in 2000 ?**

Meridionnal heat fluxes at 30 hPa (K.m.s^{-1}) during the FSW

2000



2007



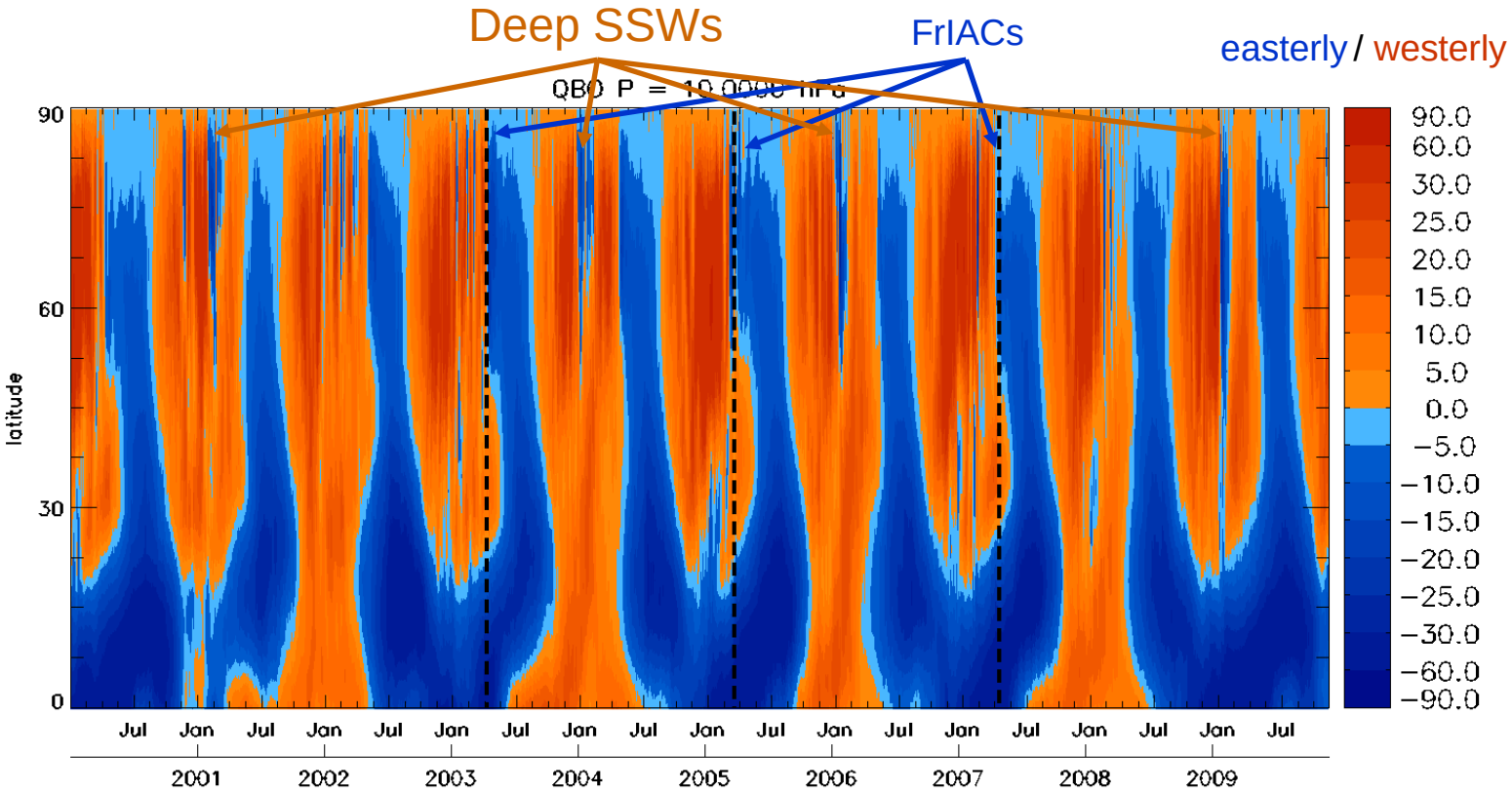
Heat flux 30% higher in 2007 than in 2000

Sufficient wave activity ⇔ **Advection** of the tropical air mass.

Does the QBO play a role on the zonal wind shear between the tropics and the mid-latitudes ?

FrIAC's climatology : 3/ Is there a link with the QBO (a) ?

➢ Last decade evolution of the zonal mean zonal wind (10 hPa)

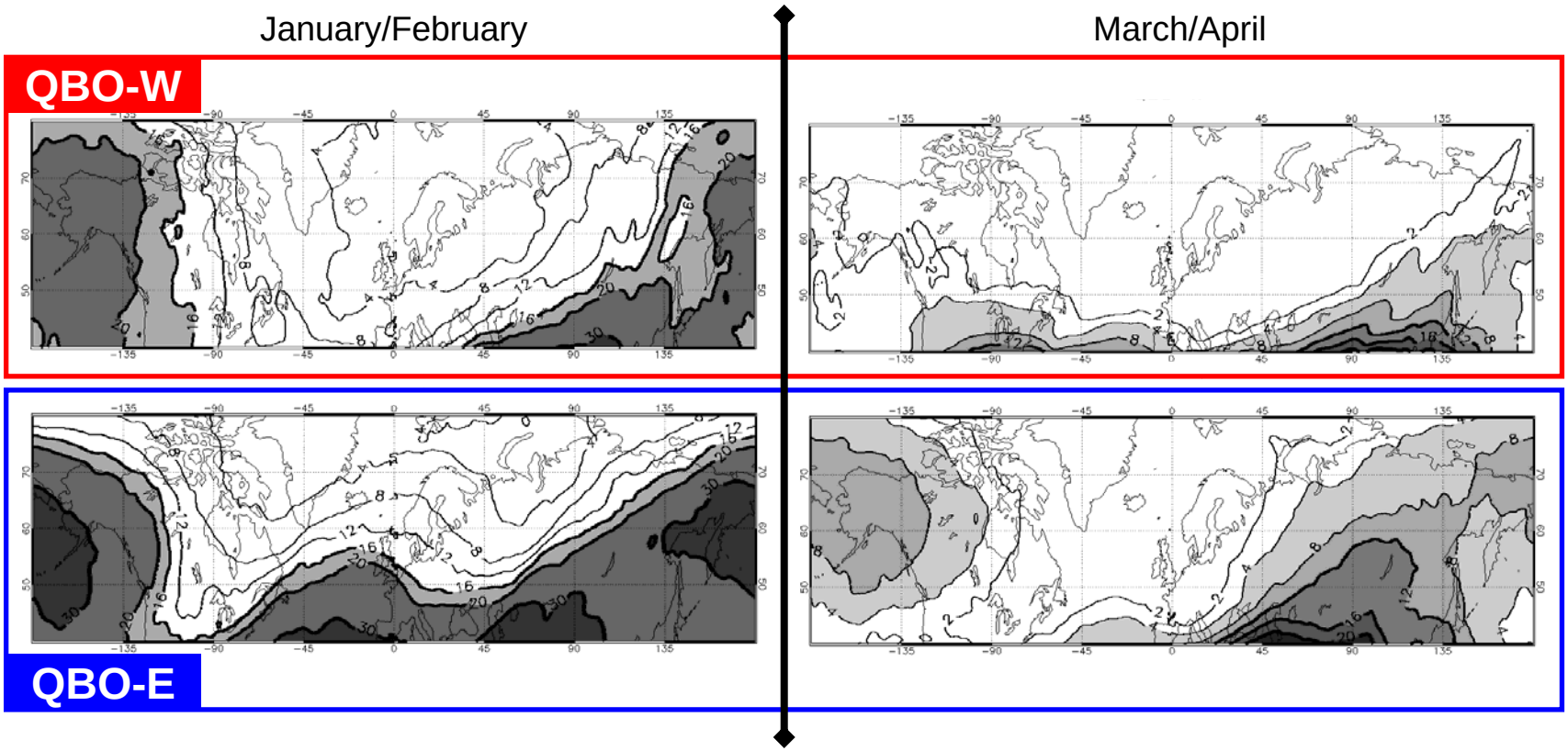


Last decade FrIAC's events occur :

- **under easterly phase of the QBO.**
- **no Major SSWs.**

FrIAC's climatology : 3/ Is there a link with the QBO (b) ?

➢ **Frequency of tropical intrusions (PV < <PV>$_{30N}$) sorted by the phase of the QBO and the period (J/F & M/A) during the last decade**



- **Highest frequency** of tropical intrusions **under QBO-E** for both J/F & M/A
- **« P2 » wave breaking event favoured by anticyclonic shear** between tropics and mid-latitudes. (**Knox & Harvey**, *J. Geophys. Res.*, 110, D06108, 2006)

Summary

• **New FrIAC's** event reported in 2007 using EOS-MLS data and MIMOSA (Potential Vorticity advection model).

• **FrIAC's events occur** :

- **Early and abrupt Final Stratospheric Warming**
- **No previous Deep Sudden Stratospheric Warming**

(inhibiting the planetary waves propagation)

- **Quasi Biennial Oscillation in easterly phase**

(Intensification of the anticyclonnical zonal wind shear)

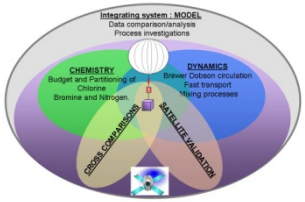
• **Conditions verified for the 1982, 1994 (not shown), 2003, 2005 and 2007 FrIAC's events.**

Perspectives

• **Improving** the dynamical mechanism behind the QBO link.

• **Extending** the climatology from 1960 using ERA-40 analysis from ECMWF outputs.

• Evaluating impact on stratospheric chemistry.



ENRICHED : European collaboratioN for Research on stratospherIc CHEmistry and Dynamics

Acknowledgments

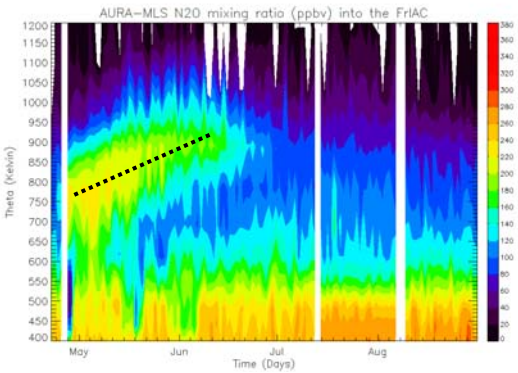
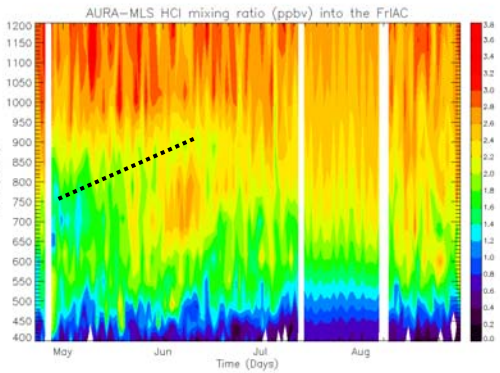
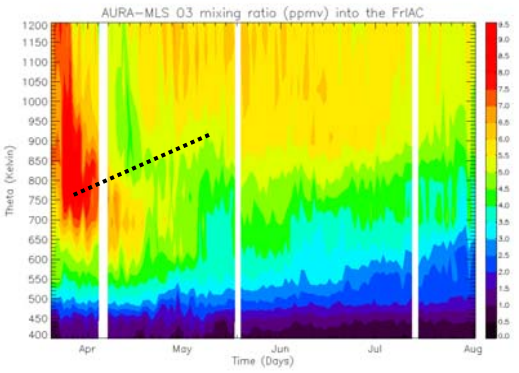
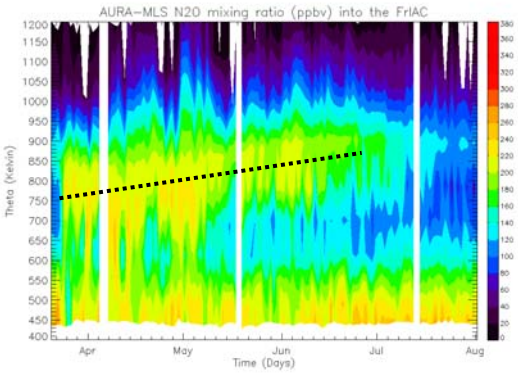
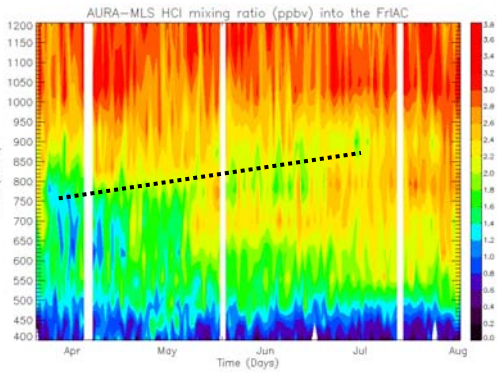
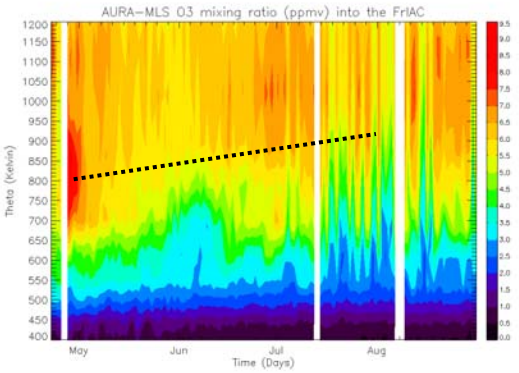
• We thank the MLS instrument science team for the satellite data.

• We would like to acknowledge the European Centre for Medium-Range Weather Forecasts for providing the ERA-Interim data.

Foundings :

FrIAC's chemistry

➢ *EOS-MLS Time evolution profiles (400K-1200K) of volume mixing ratios inside the core of the FrIACs.*

	N_2O	HCl	O_3
2005			
2007			

FrIAC's intrusions

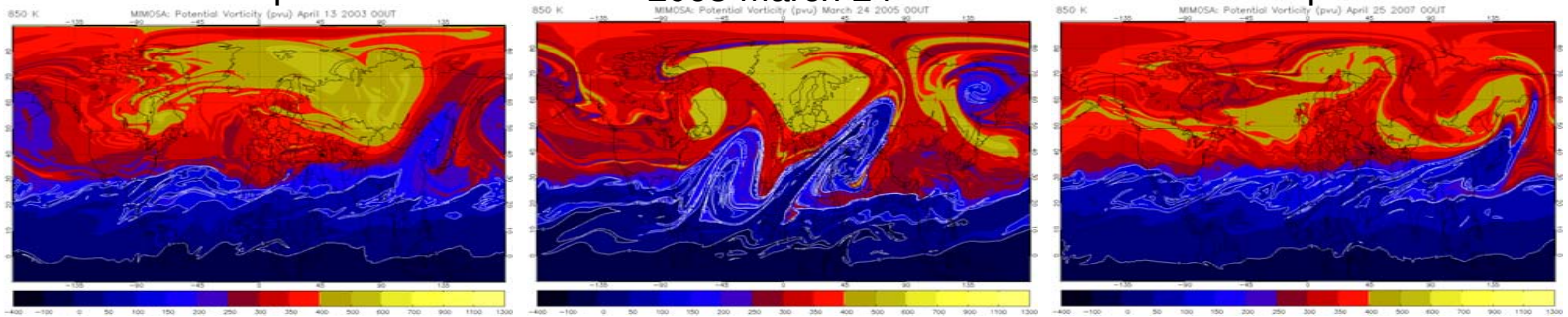
➢Comparison between 2003, 2005 and 2007 events

850K (~31 km)

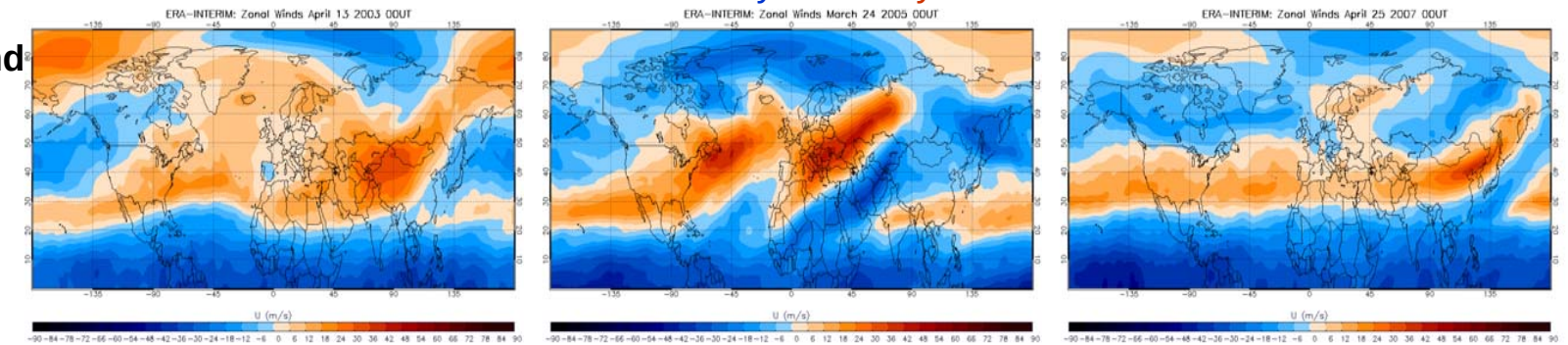
PV (pvu) **MIMOSA**

Zonal Wind ($m.s^{-1}$) **Era-Int**

2003 April 13th | 2005 March 24th | 2007 April 25th



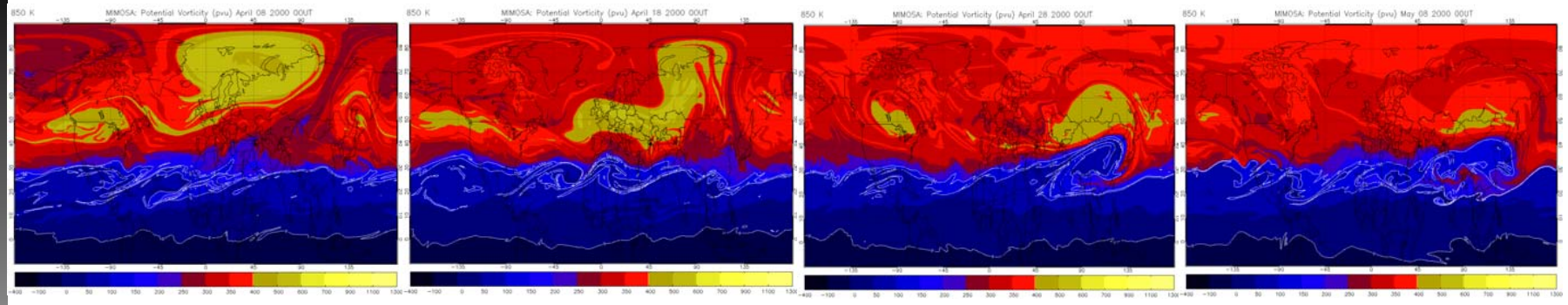
easterly / westerly



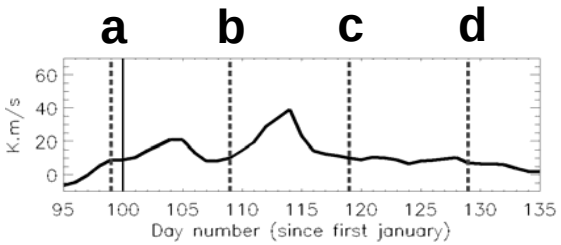
FrIAC's climatology : Detailed case in 2000

➢Focus during the Final Stratospheric Warming

a-April 08th b-April 18th c-April 28th d-May 08th



PV-MIMOSA time evolution around the 2000 Final Stratospheric Warming at 850K (~10 hPa) & associated meridionnal heat flux (v'T') at 30 hPa



Heat flux zoom