Combining coastal altimetry and in situ observations to improve Meridional Overturning Circulation estimates: focus on the Southwestern Atlantic

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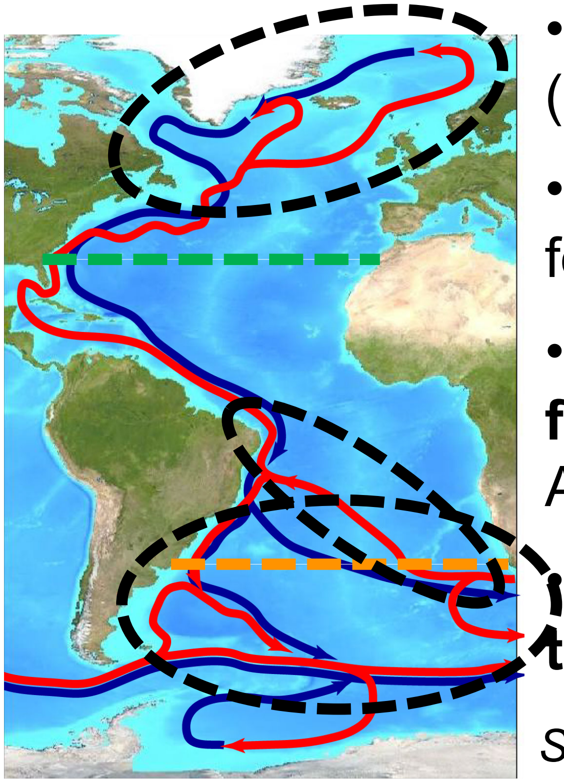
Outline:

1. Motivation
2. Methodology and data
3. Initial results and discussion
4. Concluding remarks

Motivation

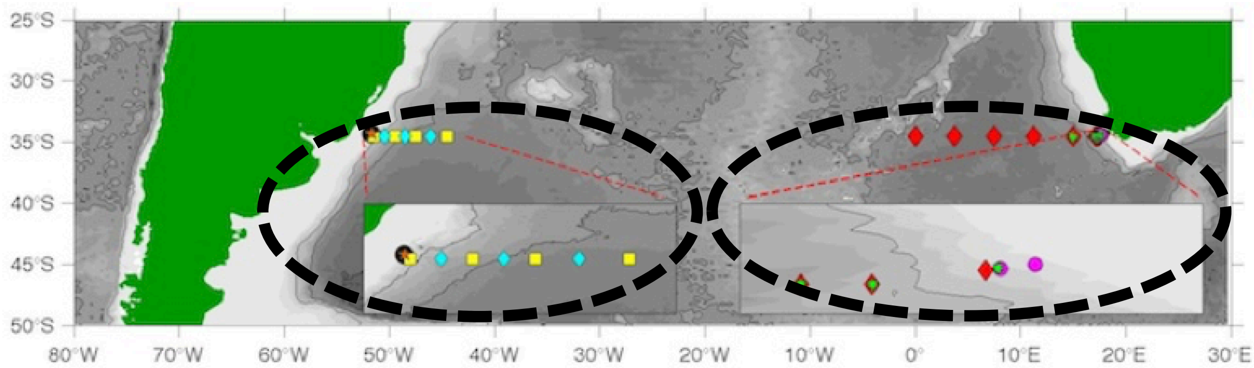


- The Atlantic **Meridional Overturning Circulation** (MOC) is a crucial component of the **climate system**
- The **North Atlantic** is a region of **deep water** formation
- The **South Atlantic** is a **nexus** for **water masses formed remotely**: Indian and Pacific Oceans, Antarctic bottom waters, North Atlantic Deepwater
- The **South Atlantic** is the only basin where **heat is transported equatorward** (and not poleward)

Schematic of the main MOC in the Atlantic (Perez et al., 2015). Blue arrows: cold, dense water in the lower limb of the MOC cell. Red arrows: warm, light waters in the upper limb of the cell.

- **North Atlantic** (26.5 deg.N): RAPID-MOCHA array since **2004**
- **South Atlantic** MOC Basin-wide Array (SAMBA, 34.5 deg.S) since **2009**

Motivation



Location of moorings of the 34.5 deg.S array, with U.S., Brazilian, French, and South African moorings.

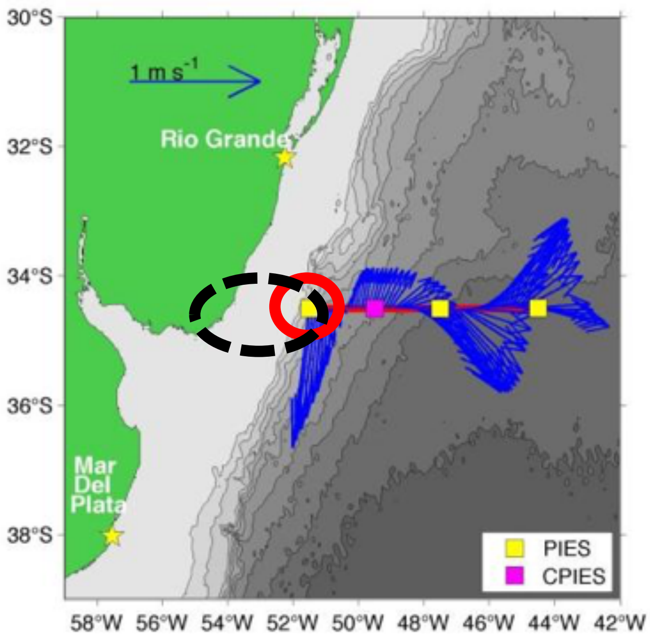
• SAMBA array mostly composed of Pressure Inversed Echo Sounders **PIES/CPIES** moored instruments: acoustic measurements (travel time) + look up tables from *in situ* data:
$\Rightarrow$ **vertical thermohaline structure**

• Between 2 moorings: integrated **geostrophic current** anomaly

• Dense array at both **western** and **eastern boundaries**

• **Total MOC transport** (geostrophic + Ekman) between most eastern and western moorings: **14.7 Sv**, standard deviation **8.3 Sv** (Meinen et al., 2018)

Motivation



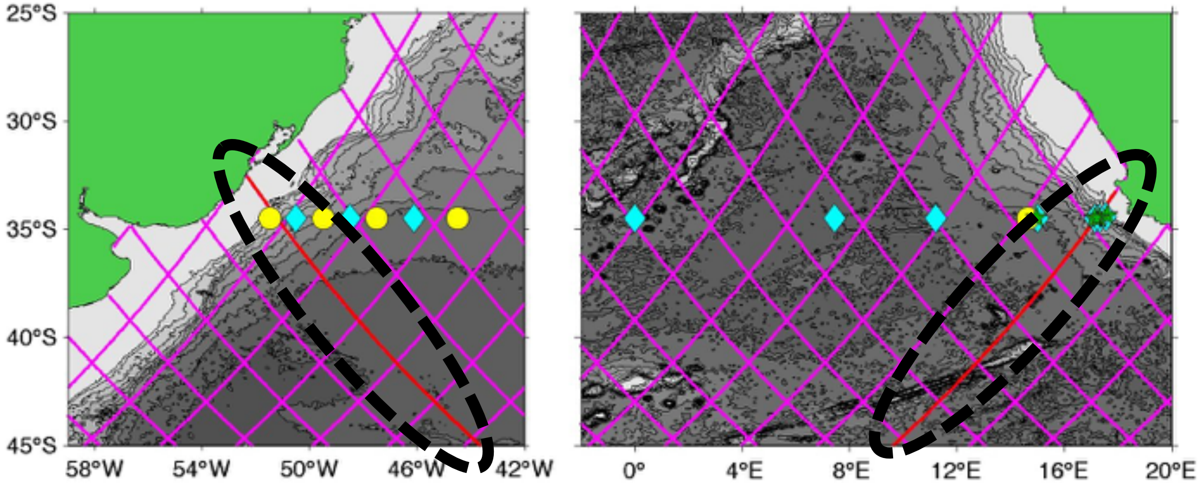
- **Limitations** of the SAMBA array:
  - Most inshore moorings at ~1000 m depth
  - No continuous measurements inshore
- Currently, **transport inshore** of the moorings estimated using **model simulations**
- Inshore transport: **~3 Sv**, i.e. **~20%** of the total MOC estimated **without direct observations**

Surface velocities (blue arrows) from shipboard-ADCP in 2009. Locations of the PIES/CPIES instruments (yellow + magenta)

- We proposed to use **coastal altimetry** to **fill the gap** between the most inshore moorings and the coasts:

Project "**Combining coastal altimetry and in situ observations to improve Meridional Overturning Circulation estimates in the South Atlantic**", supported by **NASA Physical Oceanography Program**

Methodology and data



Jason tracks (magenta), with, in red, tracks used in our project. In yellow and cyan: PIES and CPIES, in green: tall moorings

- We are using the **reference TOPEX/Poseidon-Jason** series **tracks**:
  - Track #254 in the West along South America
  - Track #209 in the East along South Africa
- Focus on **Jason-2** data first (2008-2016, longest overlap with SAMBA array), to be extended to T/P, Jason-1 and Jason-3
- Along-track **Sea Level Anomaly**, then **Geostrophic Current Anomaly**
- *In situ* observations: barotropic and 1st baroclinic modes => integrate the Geostrophic Current Anomaly => **Geostrophic Transport Anomaly**
- **Mean geostrophic transport**: MDT or model outputs (if MDT not reliable)
- Ageostrophic component: **Ekman transport** from atmospheric product

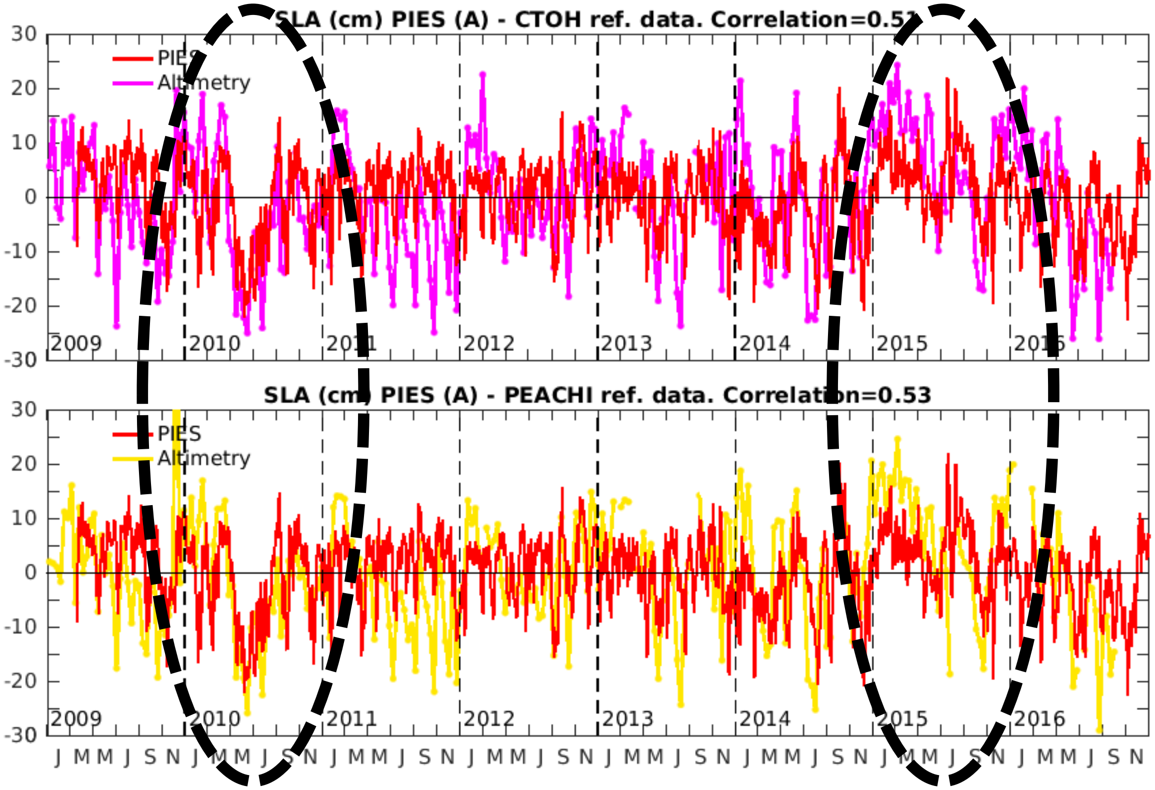
Methodology and data

- **Coastal altimetry data** from various sources:
  - Centre of Topography of the Oceans and the Hydrosphere (**CTOH**, F. Birol)
  - **PISTACH/PEACHI** products from CLS (Y. Faugère)
  - **ALES** retracker data (M. Passaro and C. Schwatke)
  - **GPD+** wet tropospheric correction (J. Fernandes)

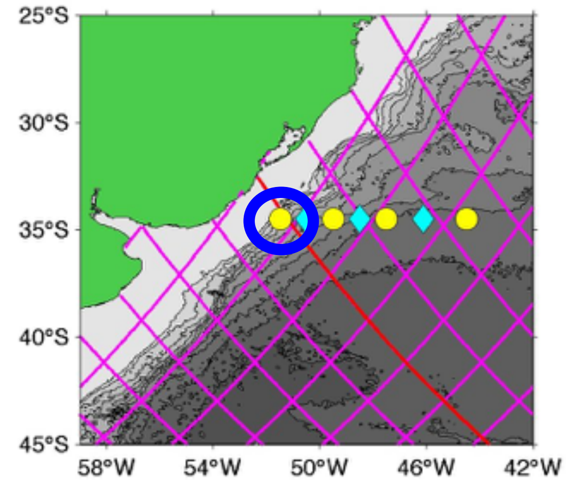
- Advantages of using coastal altimetry datasets:
  - Closer to the coast
  - **High-frequency** data (20 Hz): allows higher spatial resolution
  - **Improved retracking** methods (ALES, PISTACH/PEACHI)
  - **Improved** geophysical **corrections**: MSS (CTOH), Tidal signal (CTOH), wet troposphere (GPD+), DAC (PISTACH/PEACHI)

- We **combine these datasets** to:
  - **Take advantage** of the **strengths of each dataset**
  - Estimate **uncertainties** from the various available coastal altimetry data and their combination

Initial results: focus on the Southwestern Atlantic



Comparison of altimetry-derived **sea level anomaly** and **dynamic height anomaly** at **mooring A**



- **CTOH:** correlation 0.51; Root-Mean Square Error (RMSE) 9.62 cm
- **PEACHI**: correlation 0.53, RMSE 10.79 cm

⇒ better correlation for PEACHI, lower error with CTOH data

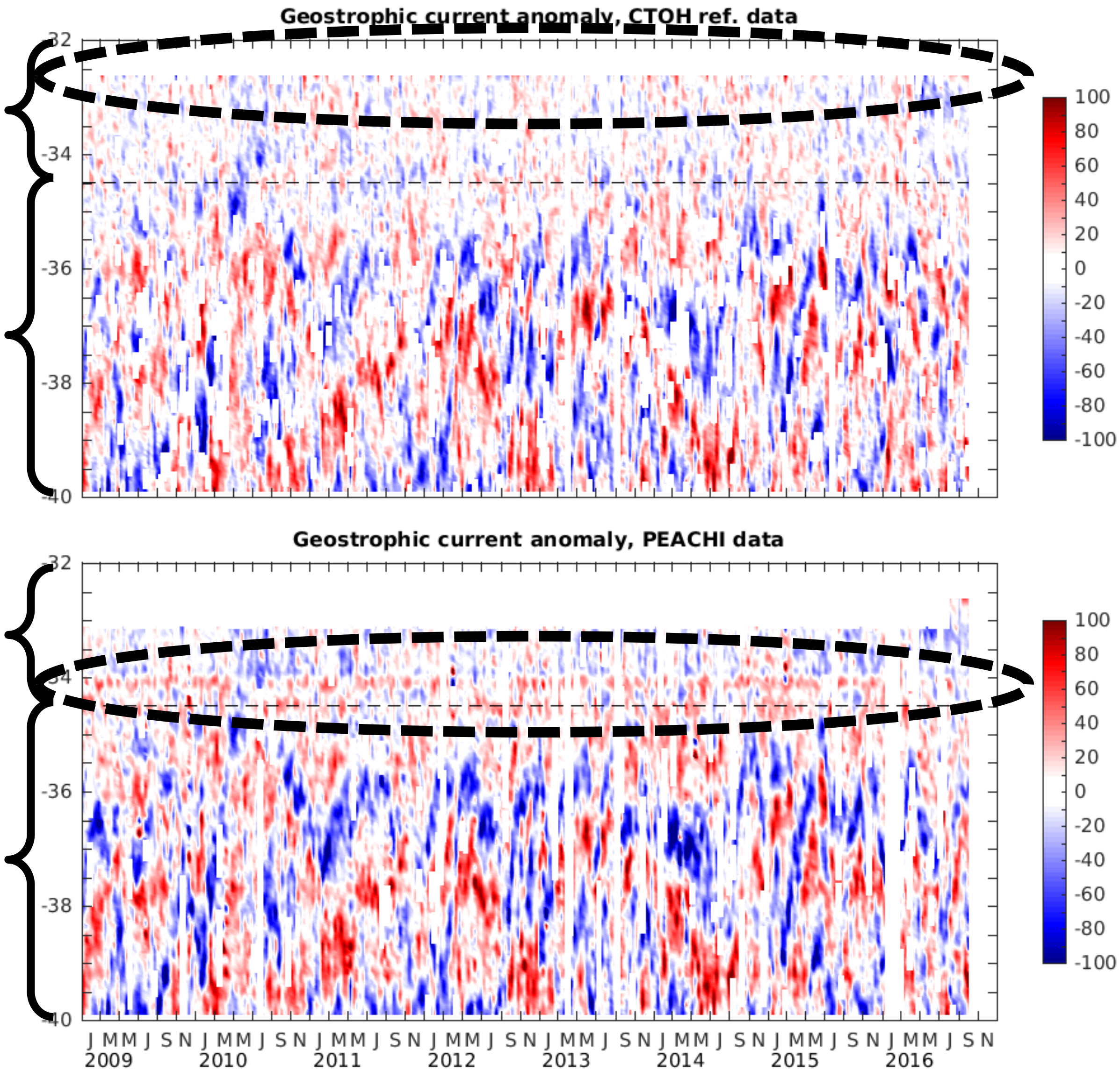
- **Root Mean Square Difference** between CTOH and PEACHI = 3.79 cm

⇒ suggests most errors are shared between datasets

- Both datasets capture **2010 low values** and **2015 high values**

Initial results: focus on the Southwestern Atlantic

• **Comparison** of **geostrophic current anomalies** along the track:



Geostrophic Current Anomalies (cm/s) from CTOH (top) and PEACHI (bottom). The dashed line is at 34.5 deg.S.

• **South of 34.5 deg.S**:
- Variability associated with **Brazil Current**
- Signature **more intense in PEACHI** data

• **North of 34.5 deg.S**:
- **CTOH data** extend **closer to the coast**
- **Positive anomaly band** around 34 deg.S in **PEACHI** data; reason not clear
- **Root Mean Square Difference** between both datasets: 11.9 cm/s, comparable to RMSE in other coastal regions (Le Hénaff et al., 2011)

Concluding remarks and next steps

Initial results are **promising**:

• Capacity of the altimetric data to **capture observed variability**

• **Differences** in **geostrophic currents** between datasets **in the order of typical observation errors** in geostrophic currents

Next steps:

• **Extend** to **high-frequency data** and **ALES data** (work in progress)

• Implement **specific corrections** (esp. harmonic analysis for the tidal correction, GPD+ wet tropospheric correction)

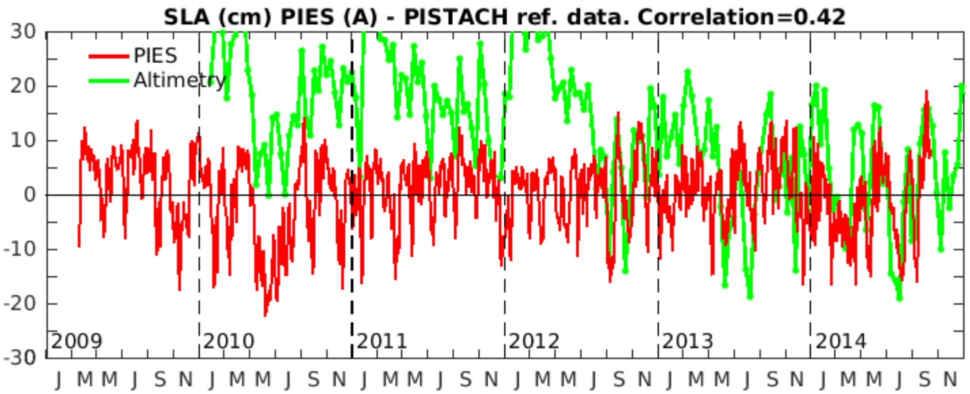
• **Analysis of *in-situ* data** to estimate the vertical structure and how to project surface geostrophic current **on the vertical** to **estimate transport**. We have already gathered the *in situ* data of the region.

• Perform **comparable analysis** in the **Eastern boundary** (when approach finalized in the Western boundary), to allow refined **estimates of the MOC**

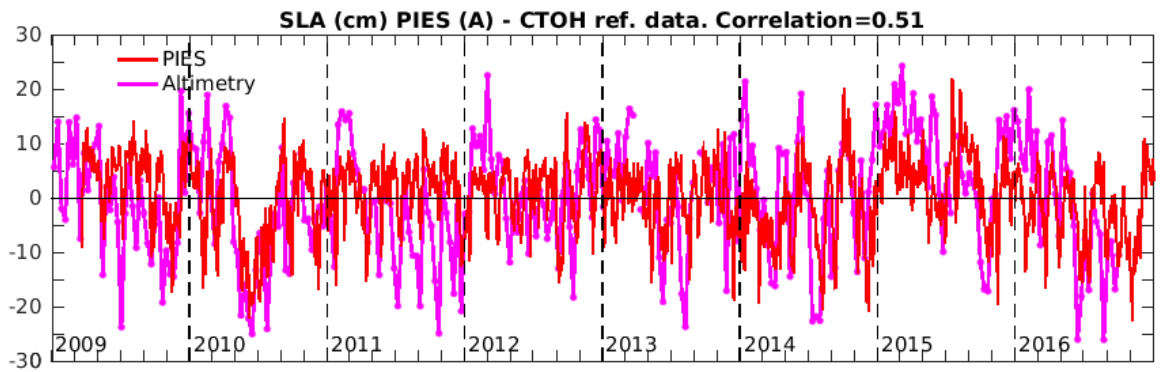
• More results at next OSTST Meeting!

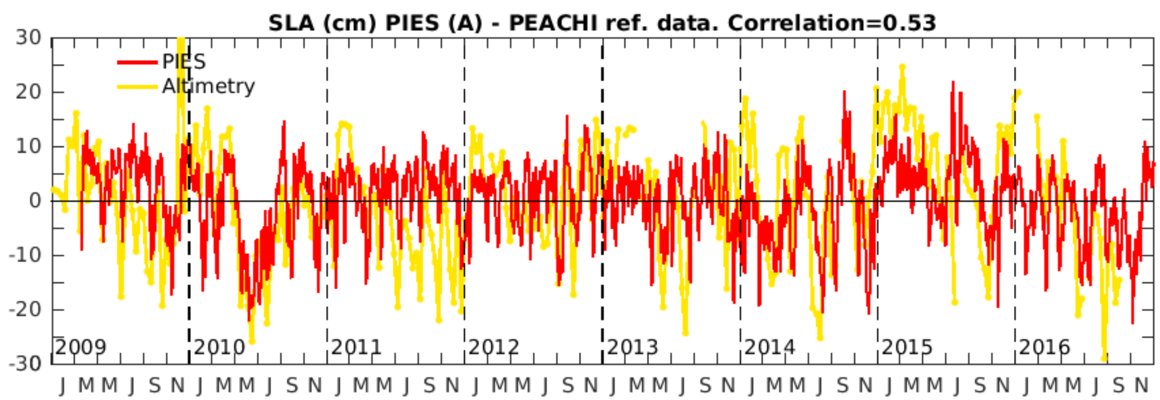
Thank you!

Initial results: focus on the Southwestern Atlantic



- **PISTACH:** correlation 0.41; large bias during ~2009-2012





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