



# Iceberg detection and continental lake-ice thickness estimation using altimeter waveforms

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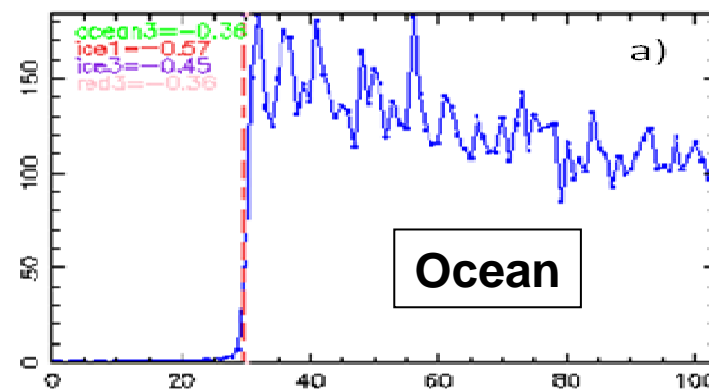
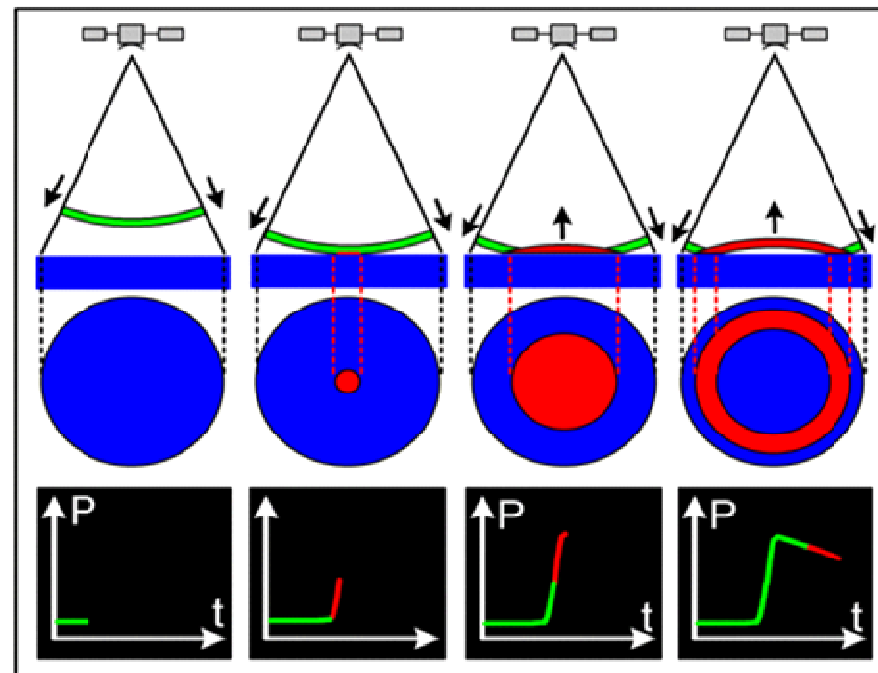
2<sup>nd</sup> SARAL/Altika Science Workshop  
Ahmedabad (India) March 15-17 2011



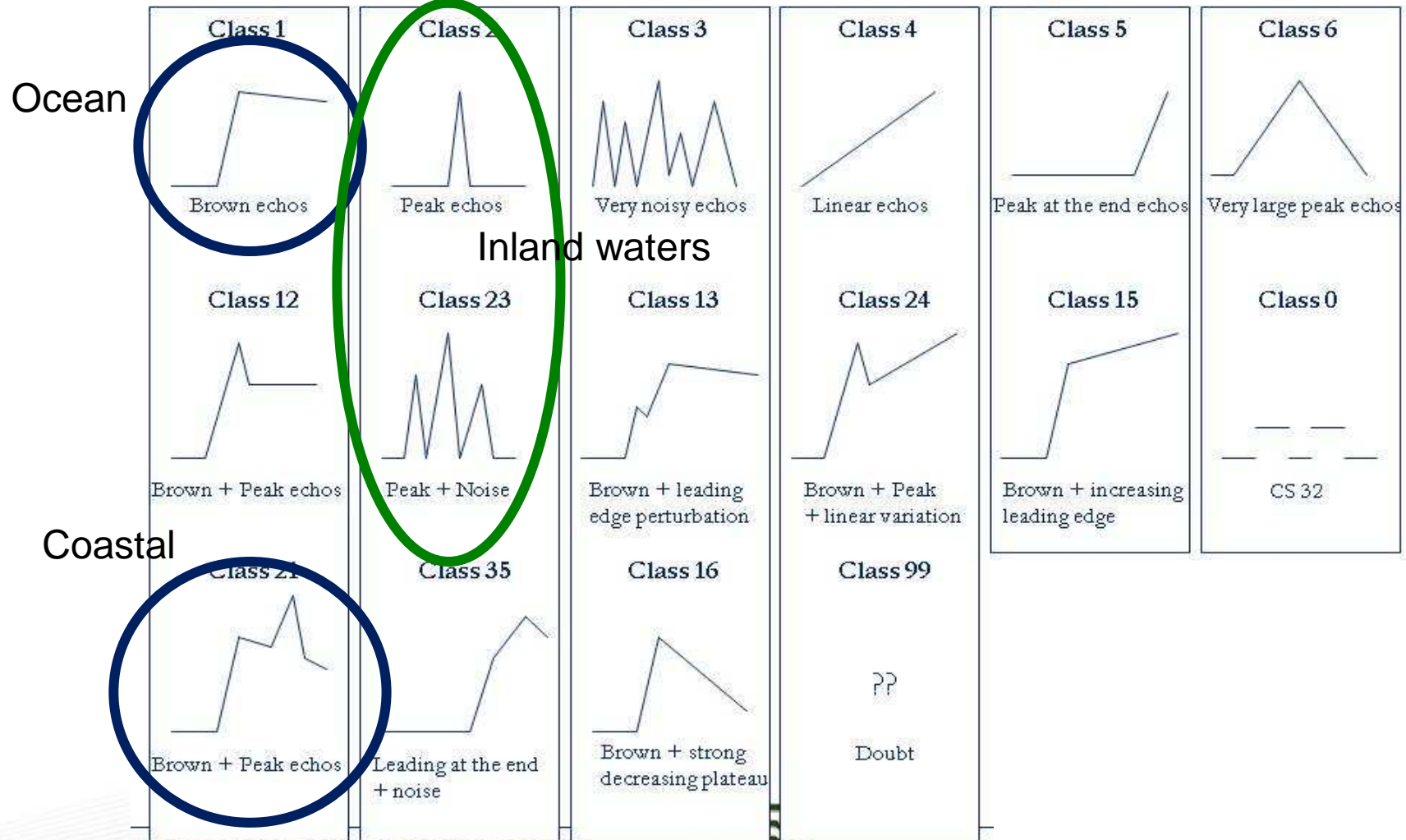
# Introduction

- 2 different applications of altimeter waveform analysis:
  - How to build an operational service with altimetry data but with **no need** to deal with:
    - Range accuracy
    - corrections
    - instrumental drift
    - bias
    - intercalibration
    - ...?
  - Are we able to measure **lake-ice thickness** with altimeter waveforms only ? **(I think so...!)**

# Open ocean altimeter waveform

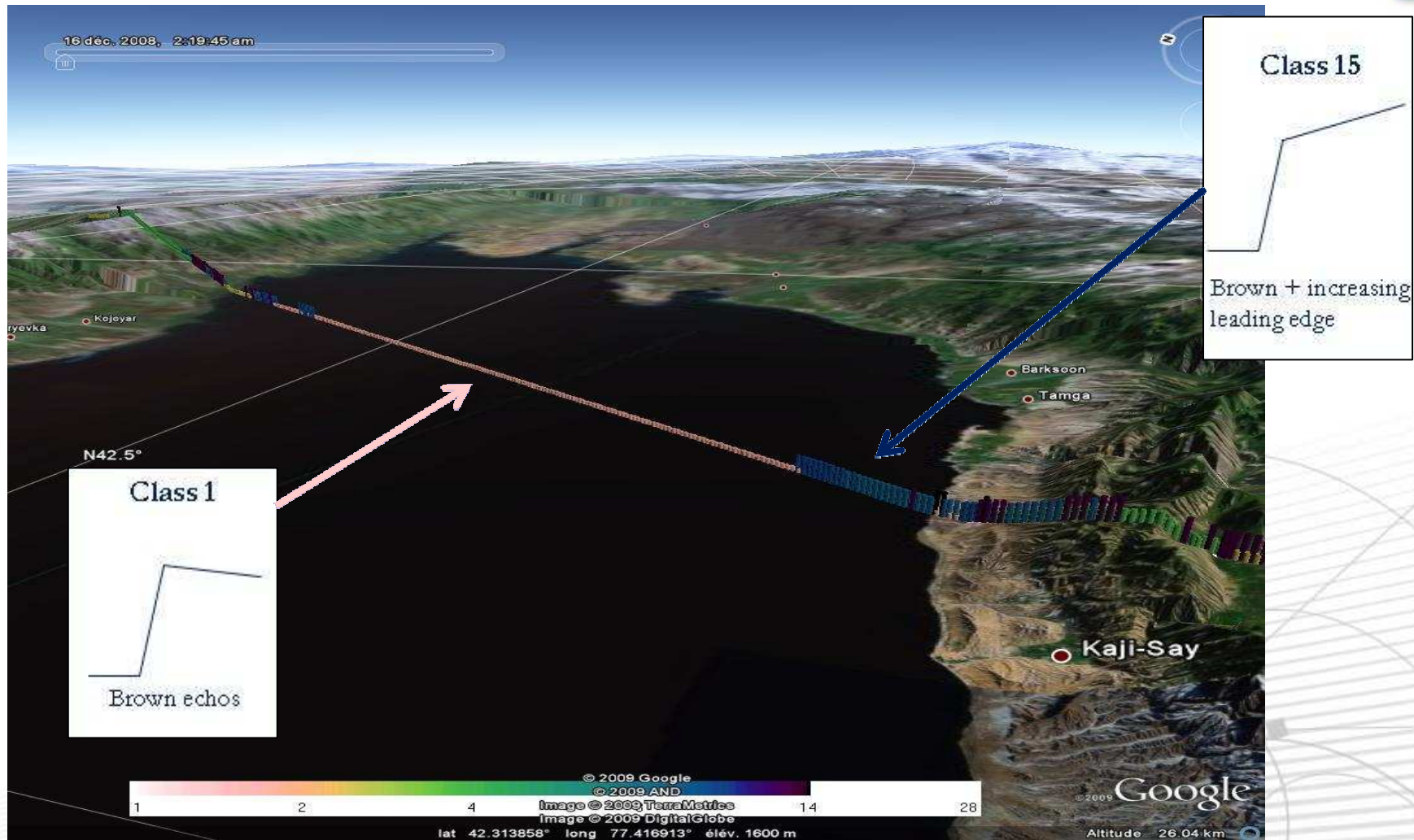


# Waveform Classification (from PISTACH project)

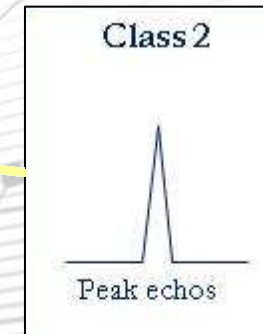
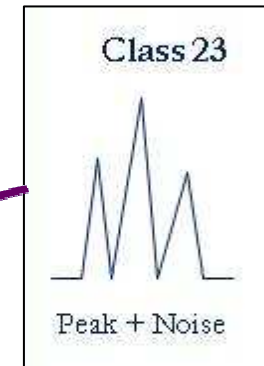
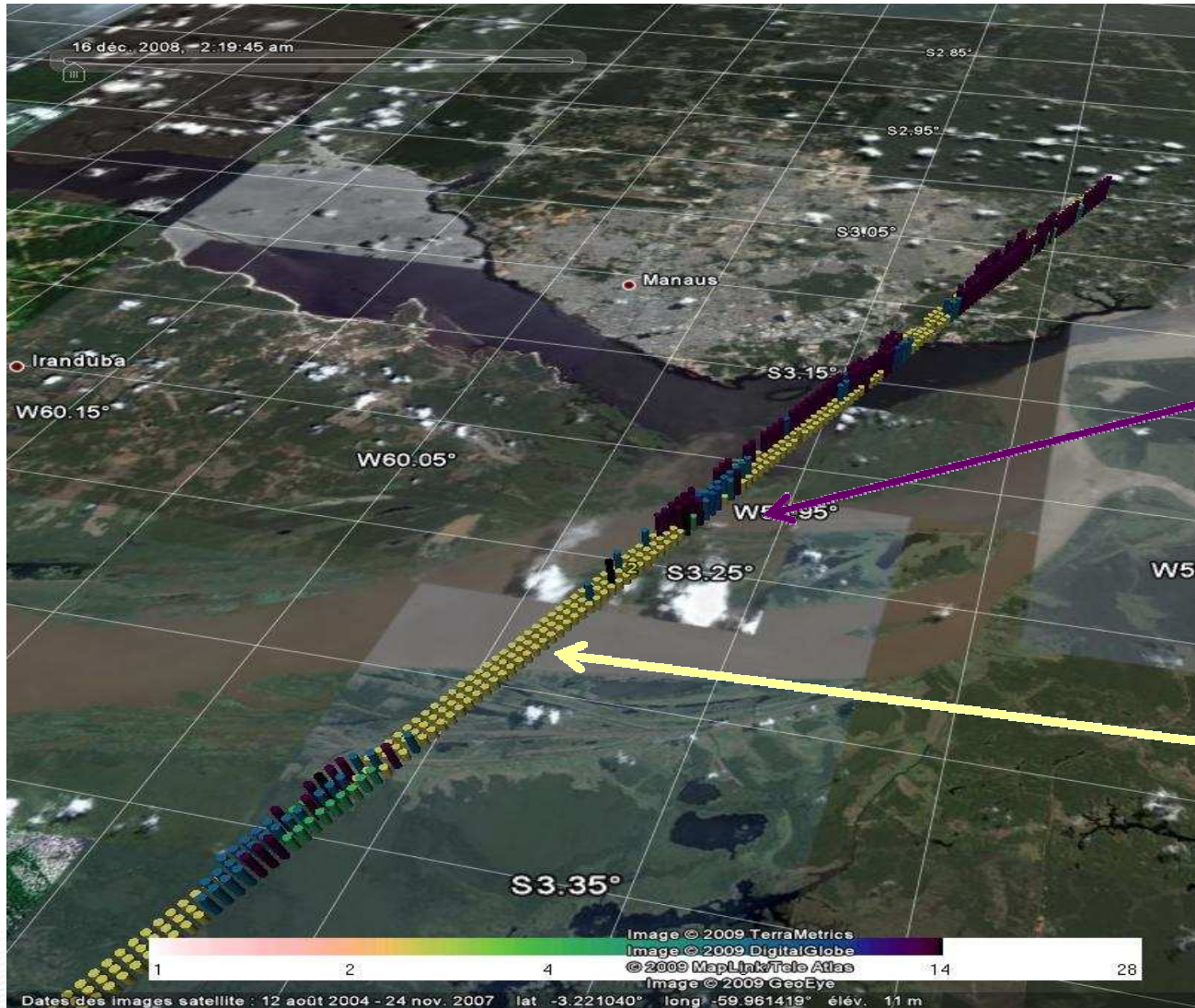




# WF Classification: Lake Issykkul

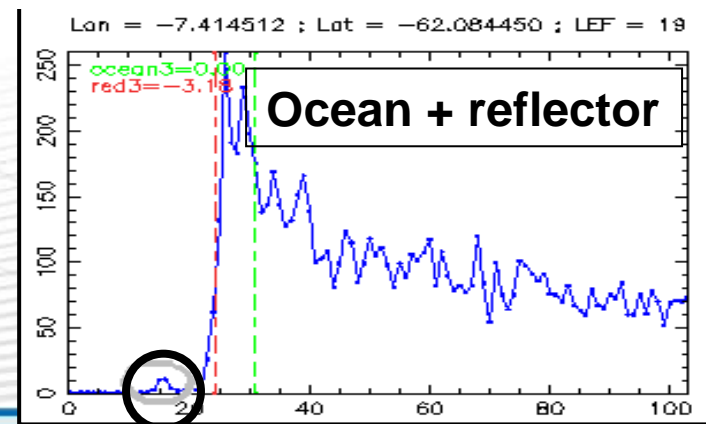
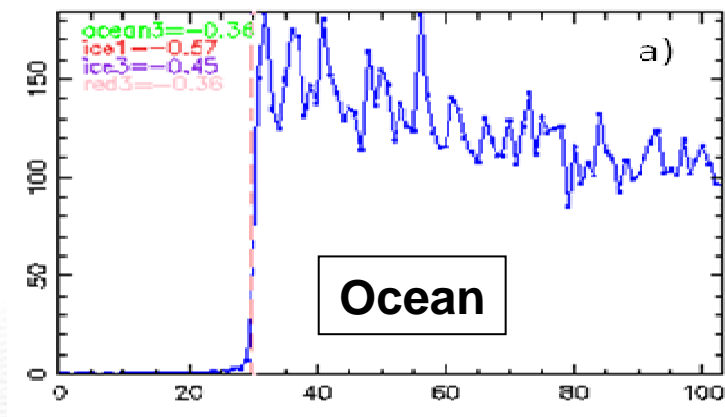
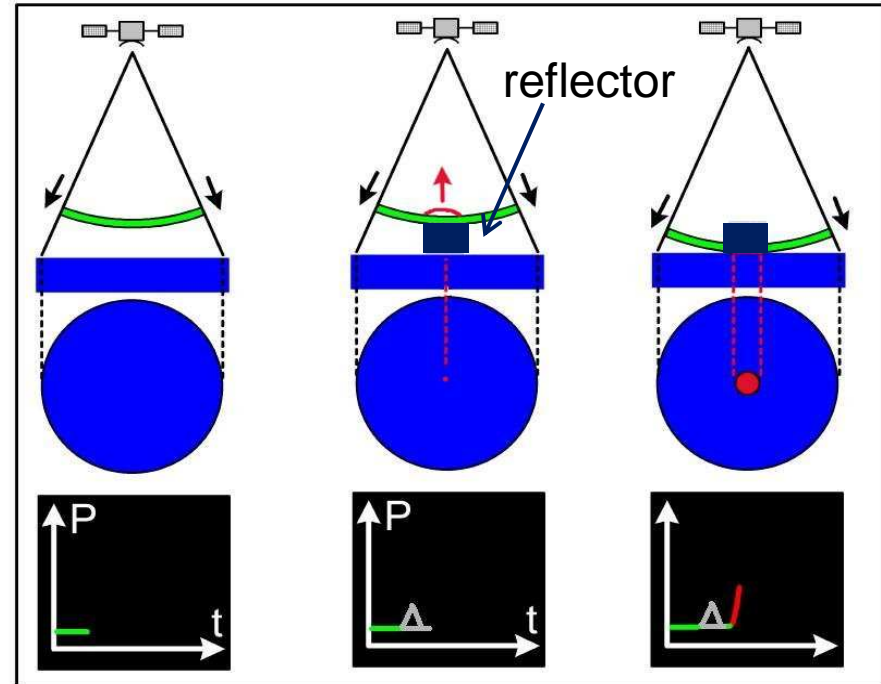
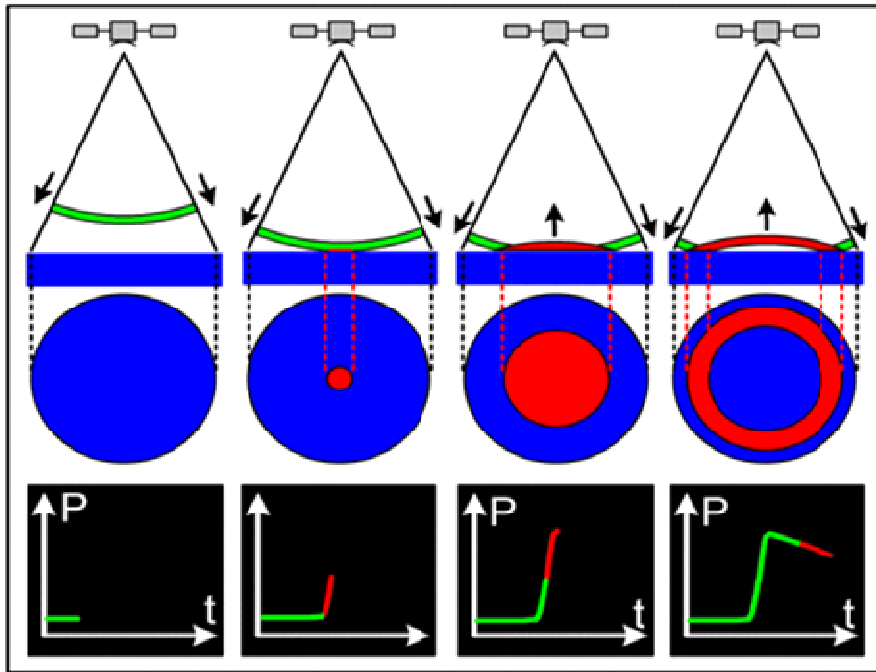


# WF Classification: Amazon (Manaus)



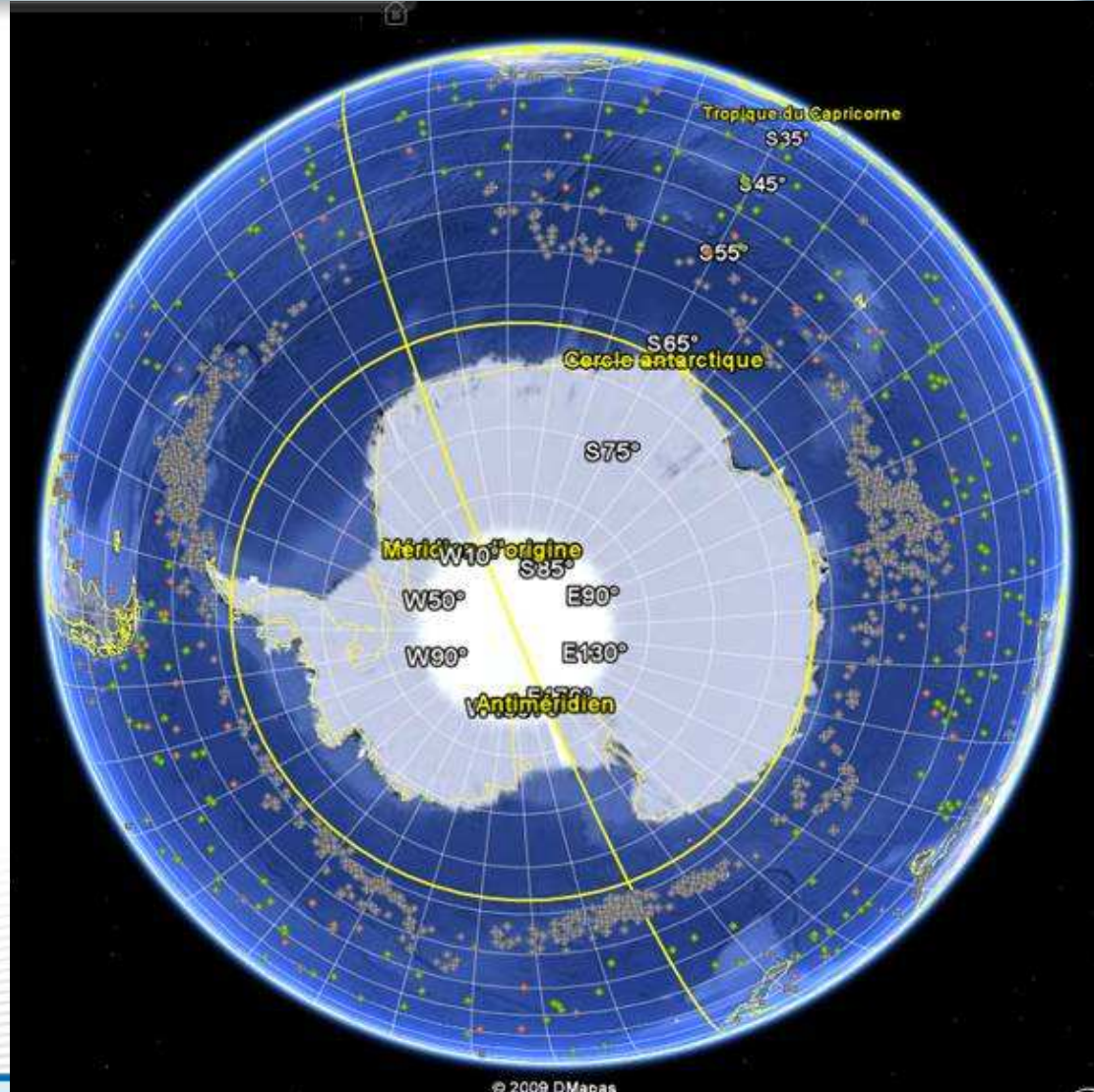


# Some funny waveforms...



# Location of such waveforms...

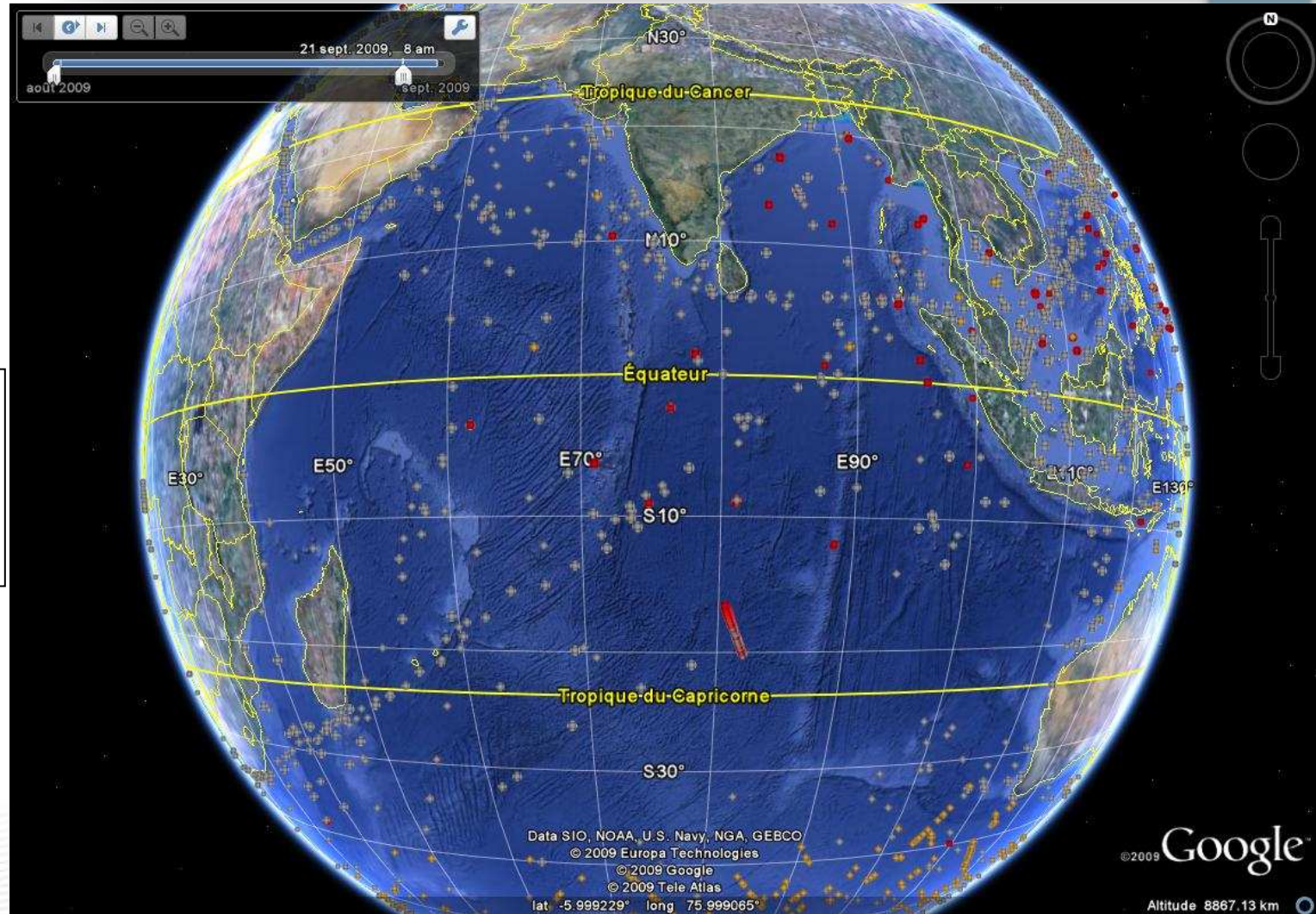
Reflector  
=  
icebergs





# Location of such waveforms...

Reflector  
=  
ships



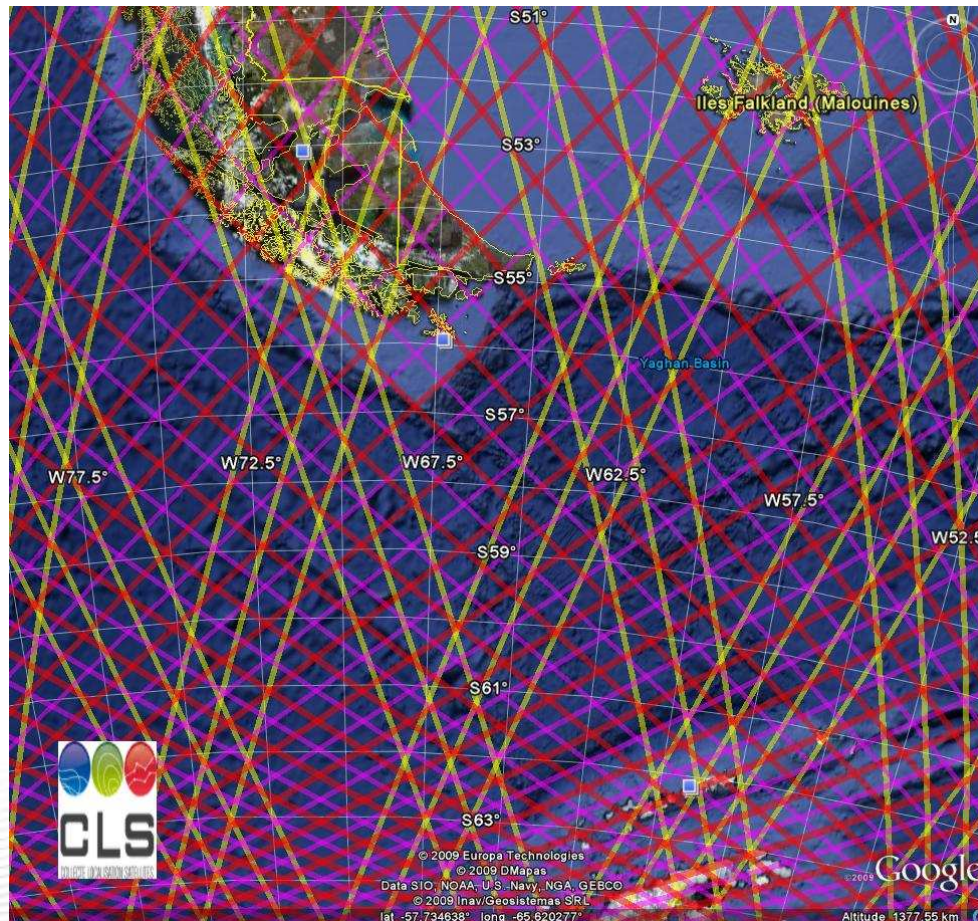
# Iceberg detection

- **Observed and demonstrated by Tournadre (2008) on Jason-1 data**
- **Development of a user-driven service at CLS:**
  - adaption of the methodology
  - application to Jason-1, Jason-2 and Envisat data
  - operation of the system on an operational basis for sailors/shipping needs (and science too!)
- **NB: a SAR-only based solution is too expensive:**
  - use of altimetry to identify the main iceberg areas
  - acquisition of some SAR images when the ship/yacht is in the vicinity of iceberg areas



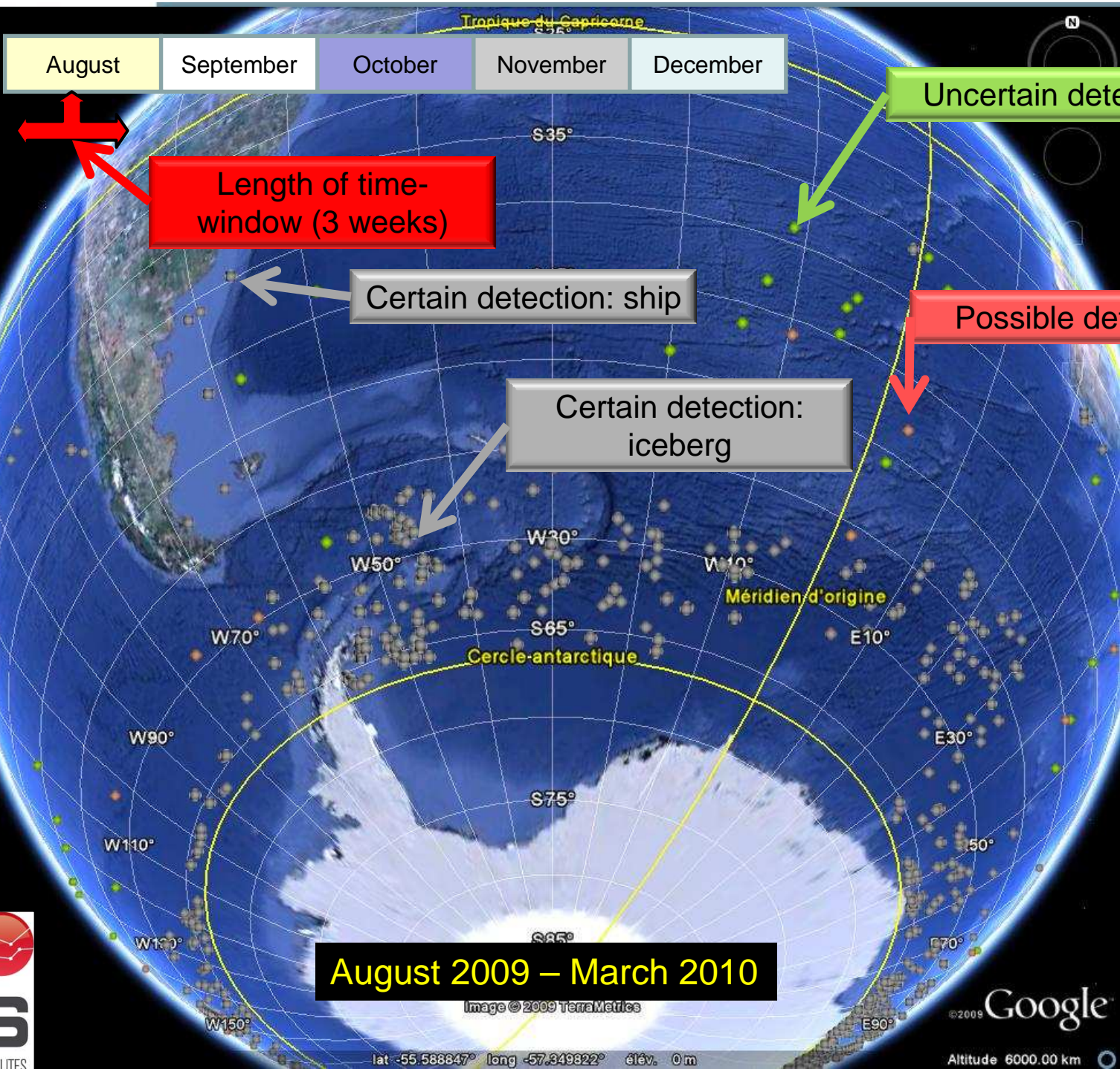
# Iceberg detection

- Example of combined coverage of Jason-1, Jason-2 and Envisat near Cape Horn (South America) over 10 days



**AltiKa will  
maintain/densify  
this coverage**





August    September    October    November    December

Length of time-window (3 weeks)

Uncertain detection

Certain detection: ship

Possible detection

Certain detection: iceberg

August 2009 – March 2010



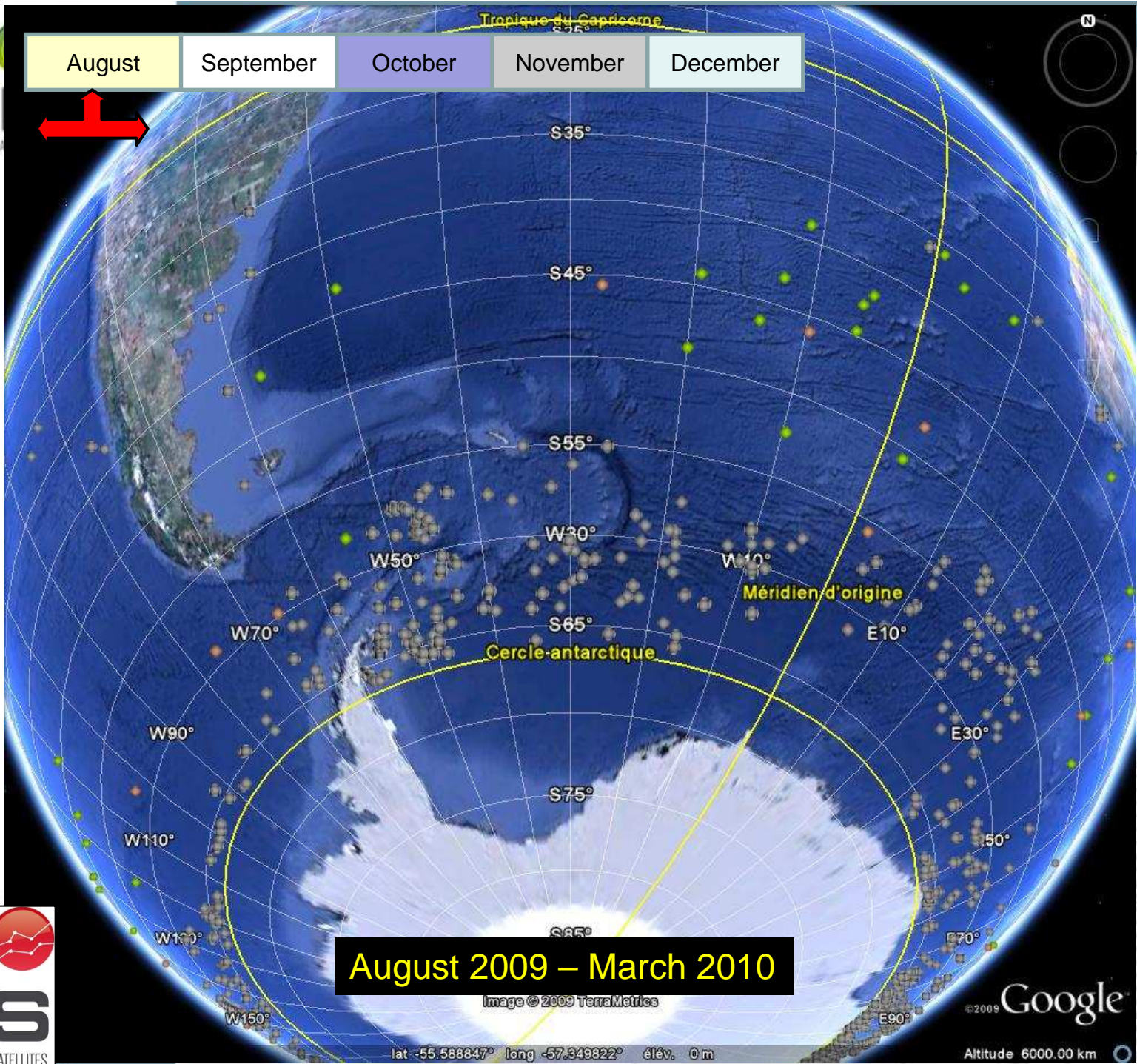
lat: -55.588847° long: -57.349822° élév. 0 m

©2009 Google  
Altitude 6000.00 km





August September October November December



August 2009 - March 2010

Image © 2009 TerraMetrics

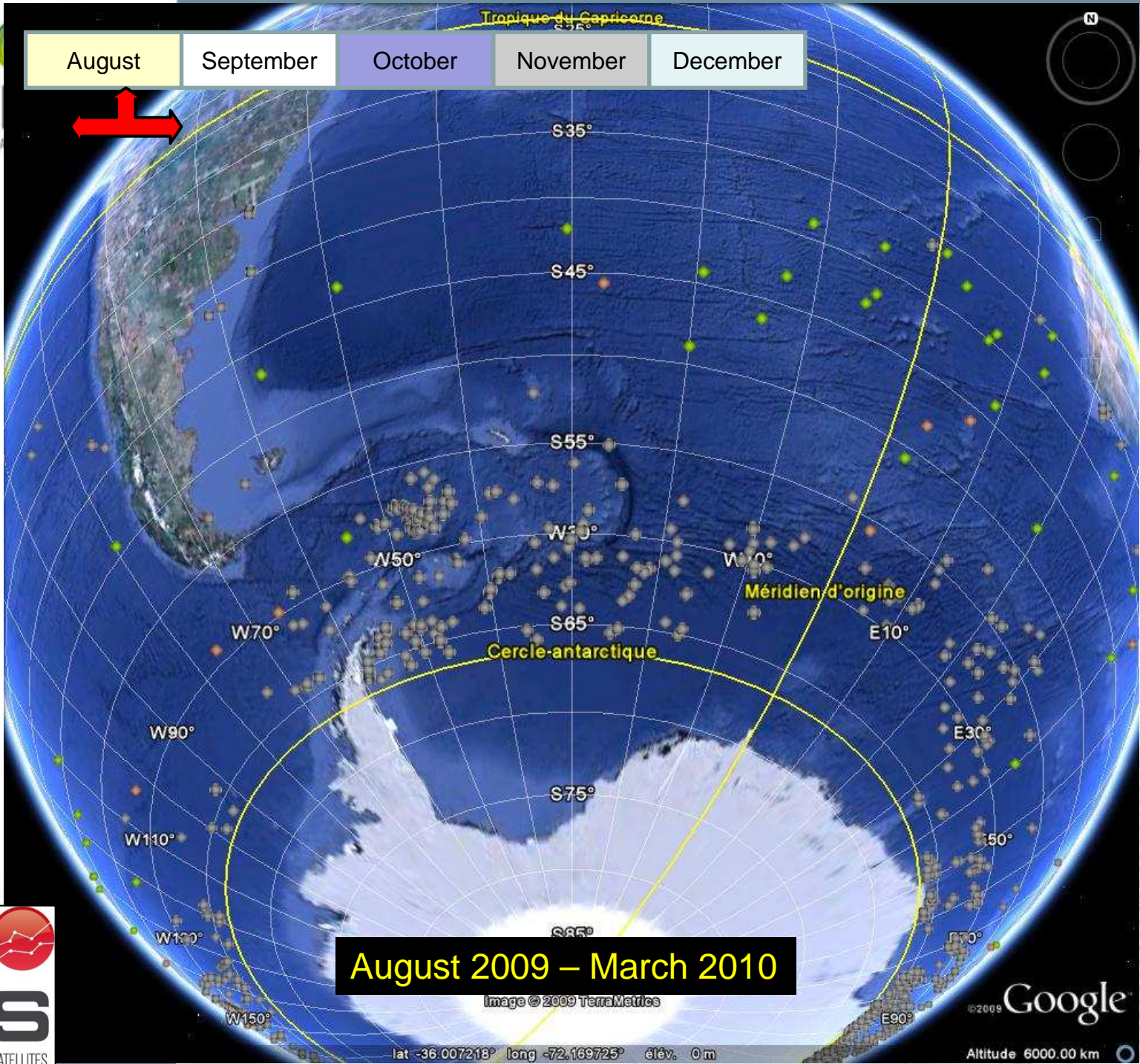
lat -55.588847° long -57.349822° élév. 0 m

©2009 Google  
Altitude 6000.00 km





August    September    October    November    December



August 2009 – March 2010

Image © 2009 TerraMetrics

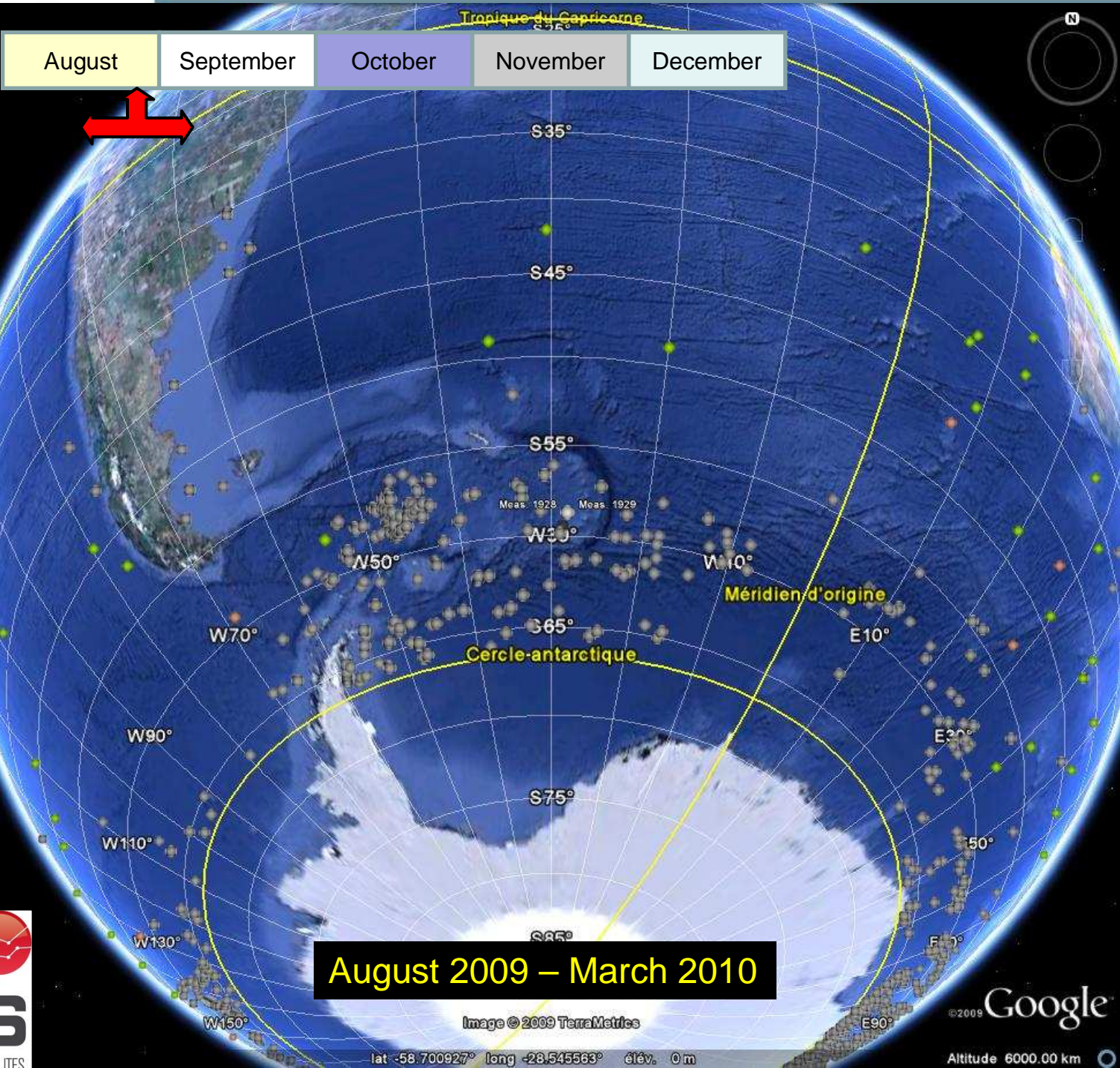
©2009 Google

Altitude 6000.00 km

lat: -36.007218° long: -72.169725° elev.: 0m







August 2009 – March 2010

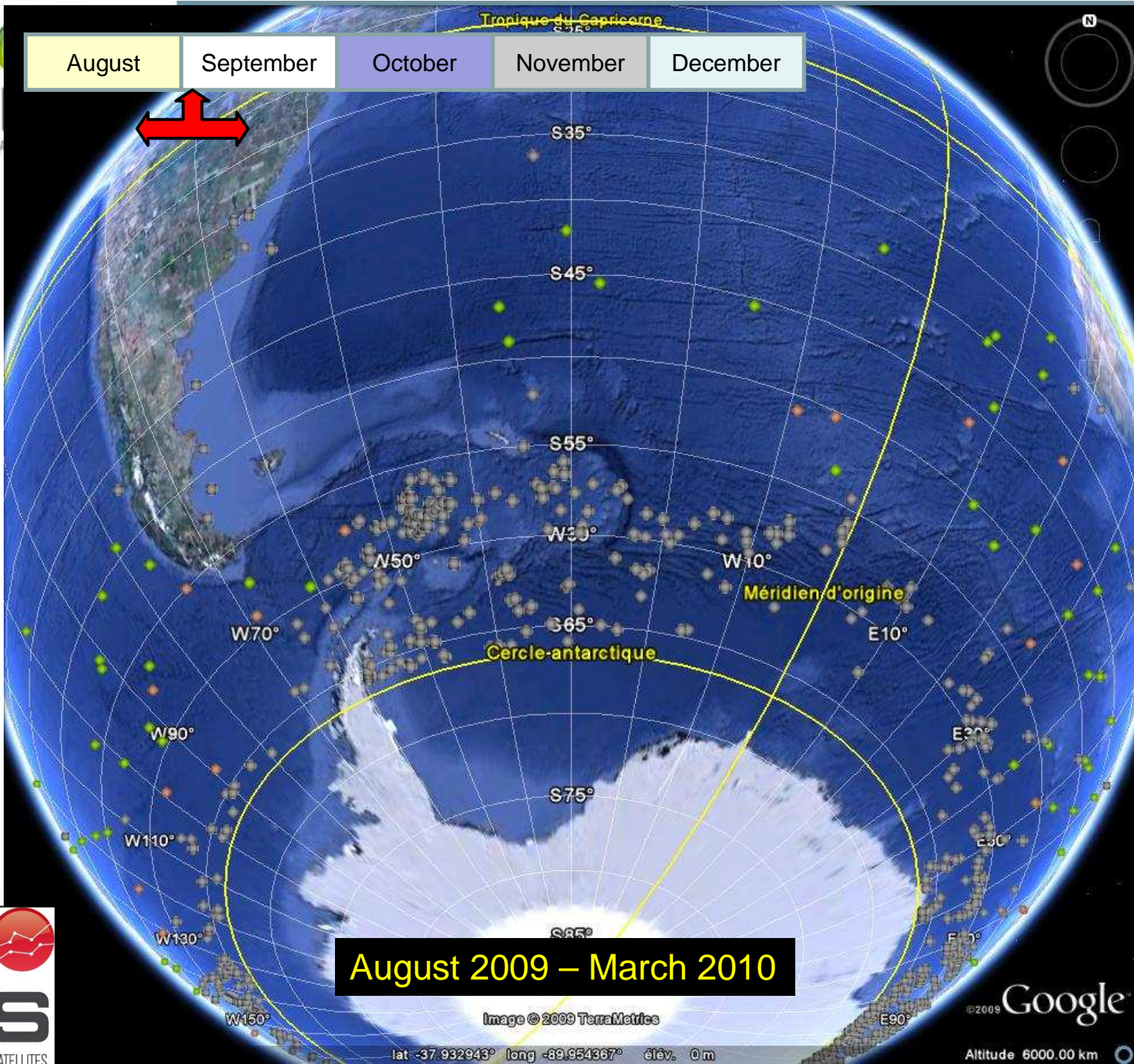
lat -58.700927° long -28.545563° élév. 0 m

©2009 Google  
Altitude 6000.00 km





August    September    October    November    December



August 2009 – March 2010

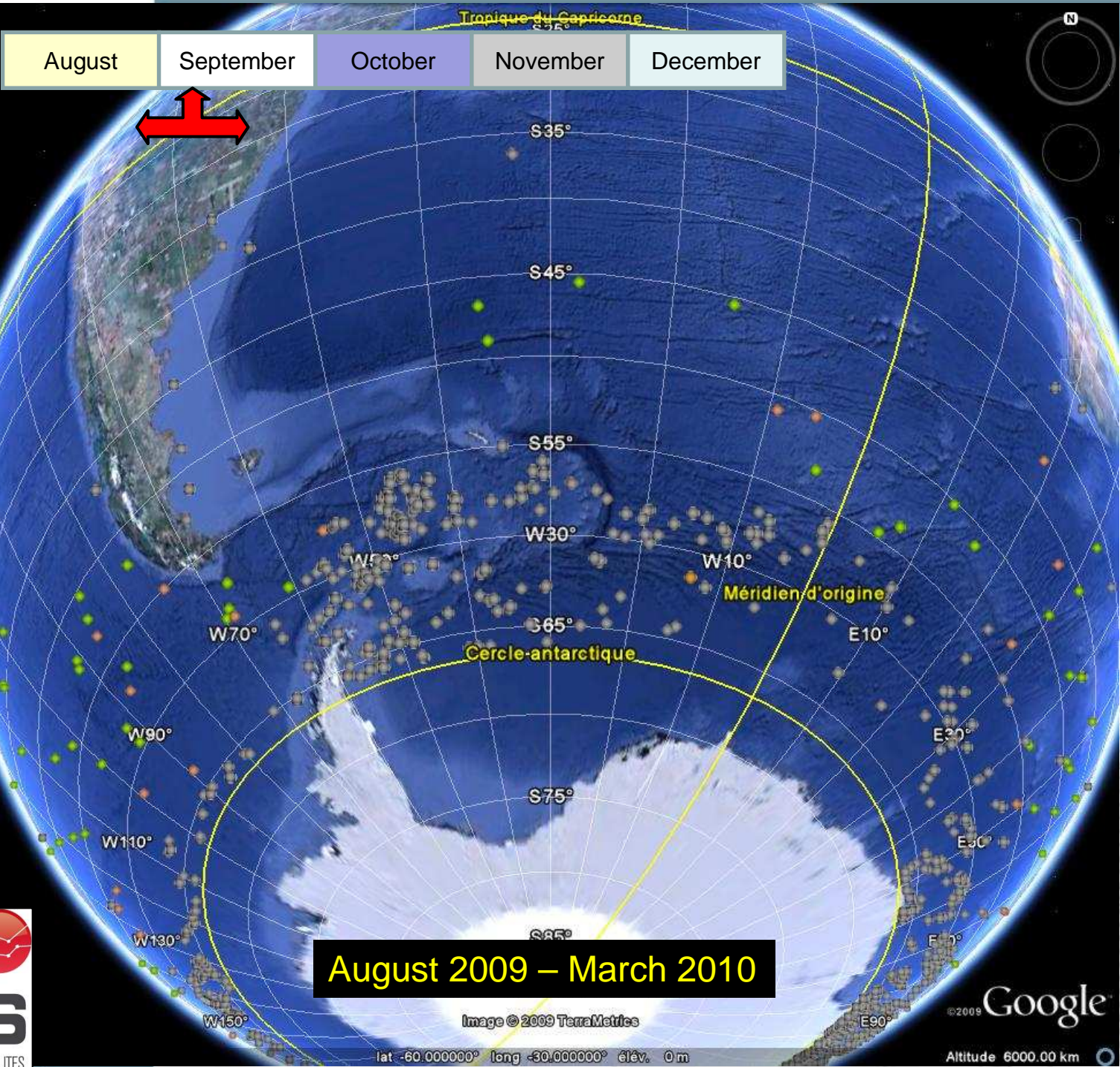
Image © 2009 TerraMetrics

lat -37.932943° long -89.954367° élév. 0 m

©2009 Google

Altitude 6000.00 km





August September October November December



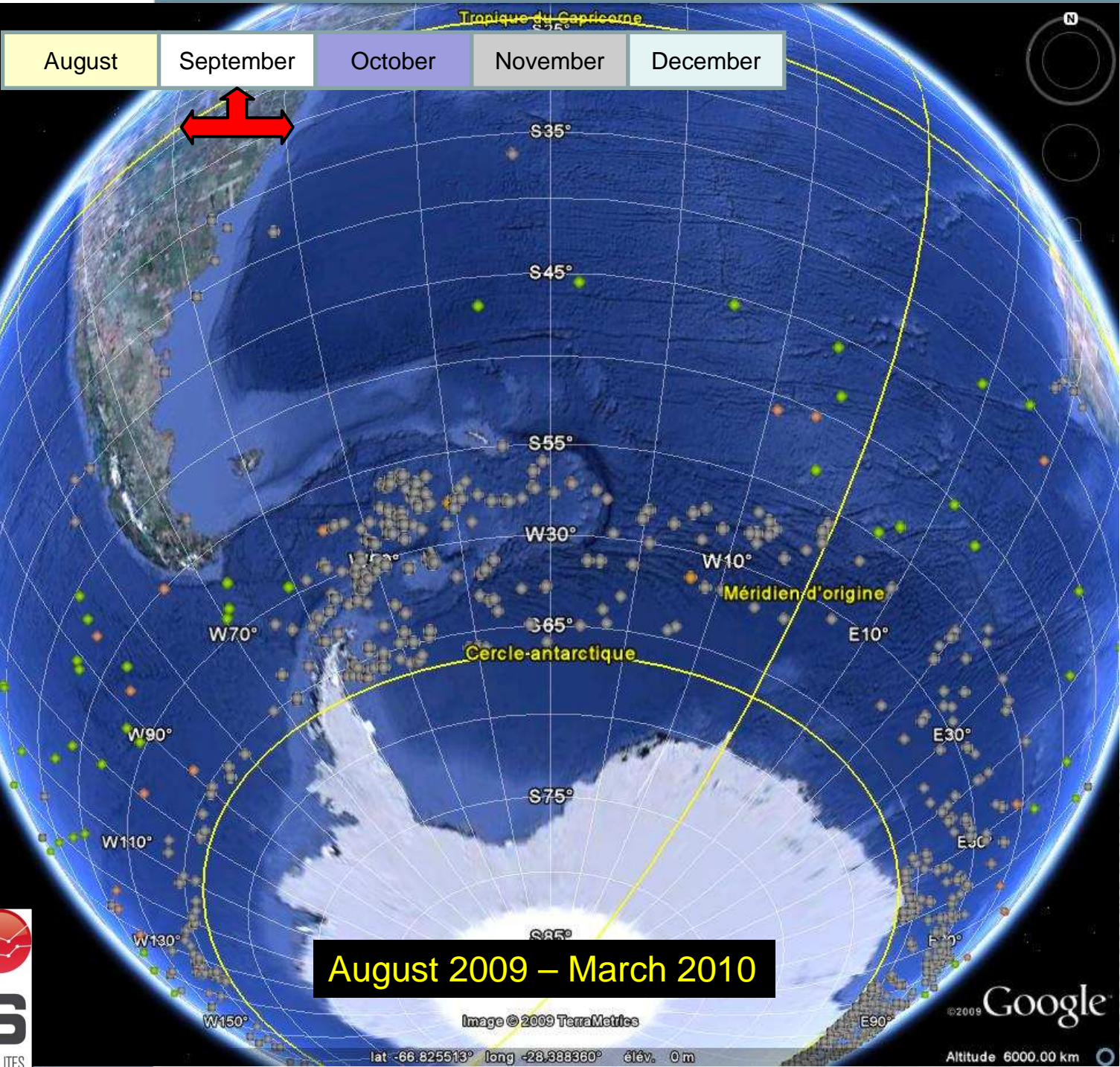
August 2009 – March 2010



lat -60.000000° long -30.000000° élév. 0m

Altitude 6000.00 km





August    September    October    November    December



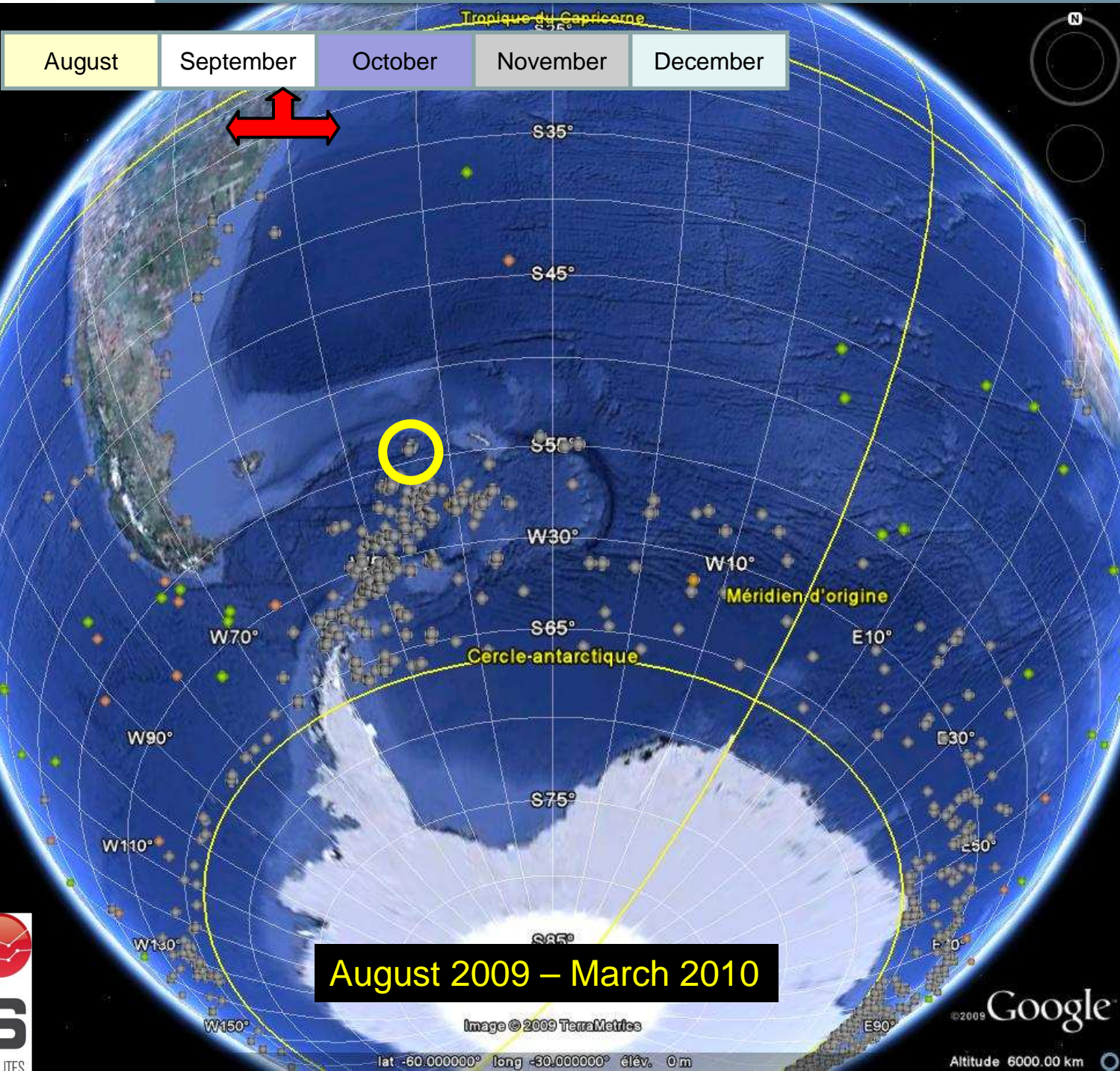
August 2009 – March 2010



lat: -66.825513° long: -28.988360° elev.: 0m

Altitude 6000.00 km





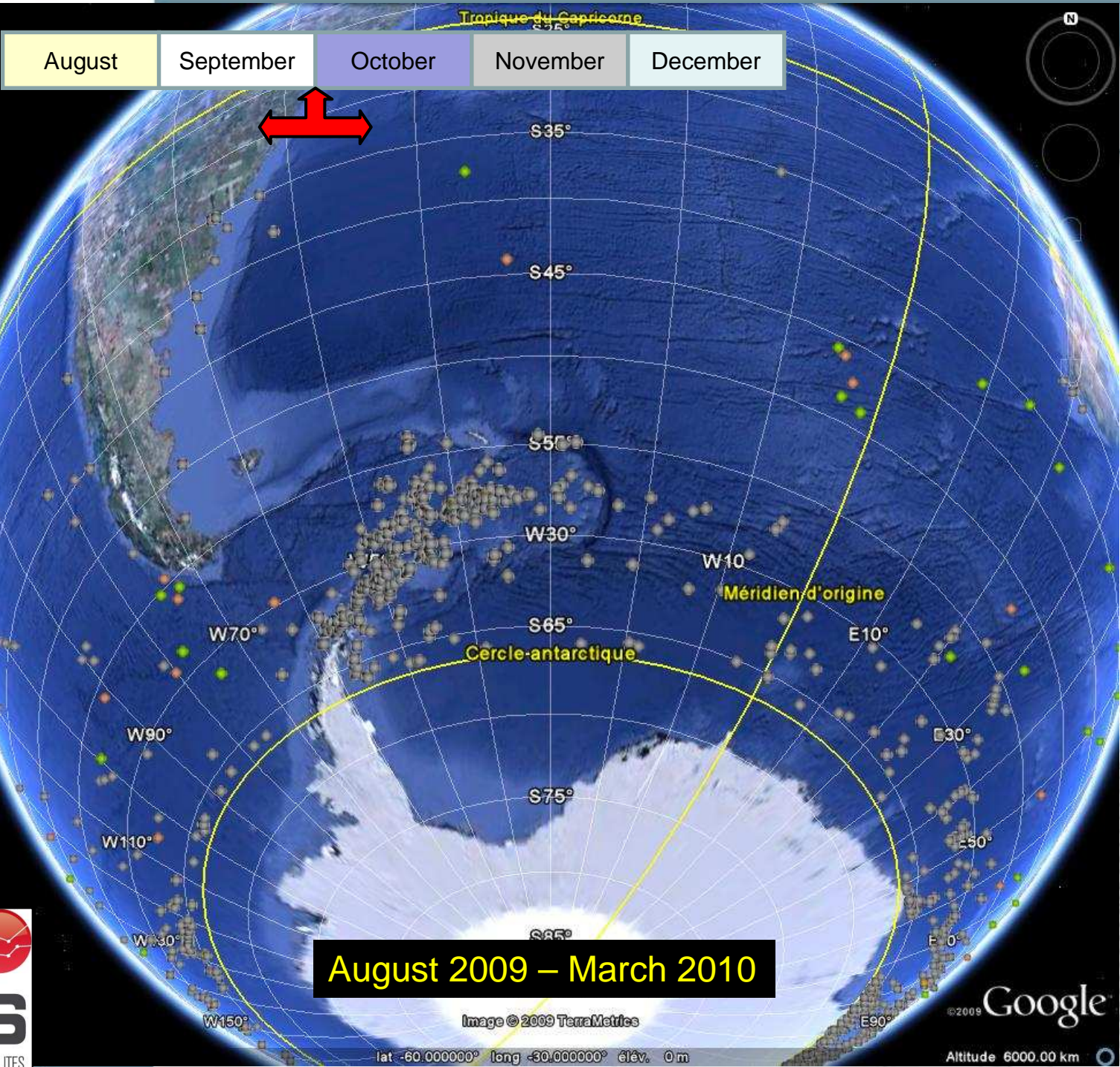
August 2009 – March 2010



Altitude 6000.00 km

lat: -60.000000° long: -30.000000° elev.: 0m





August    September    **October**    November    December



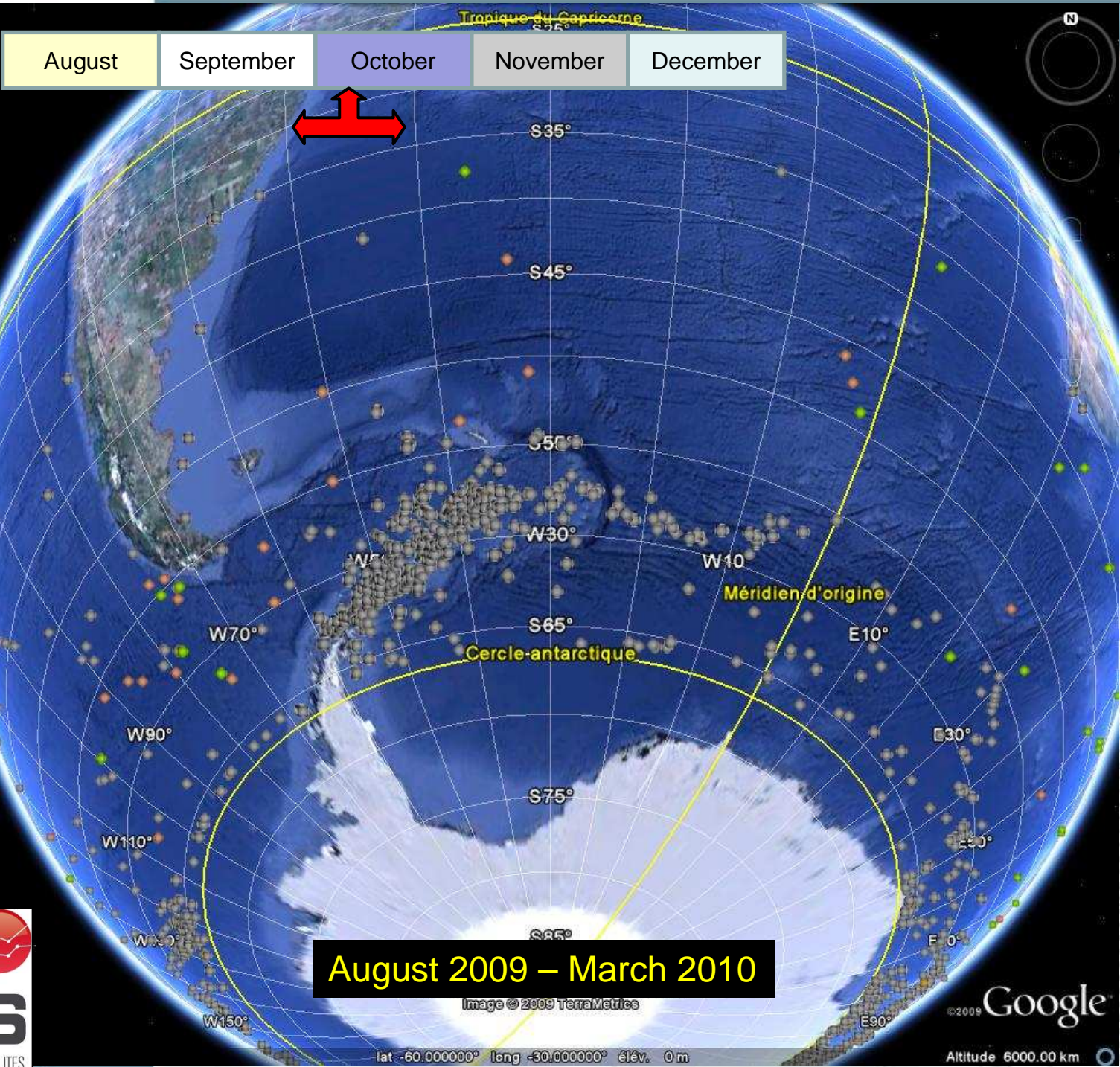
August 2009 – March 2010



lat -60.000000° long -30.000000° élév. 0m

Altitude 6000.00 km





August    September    **October**    November    December

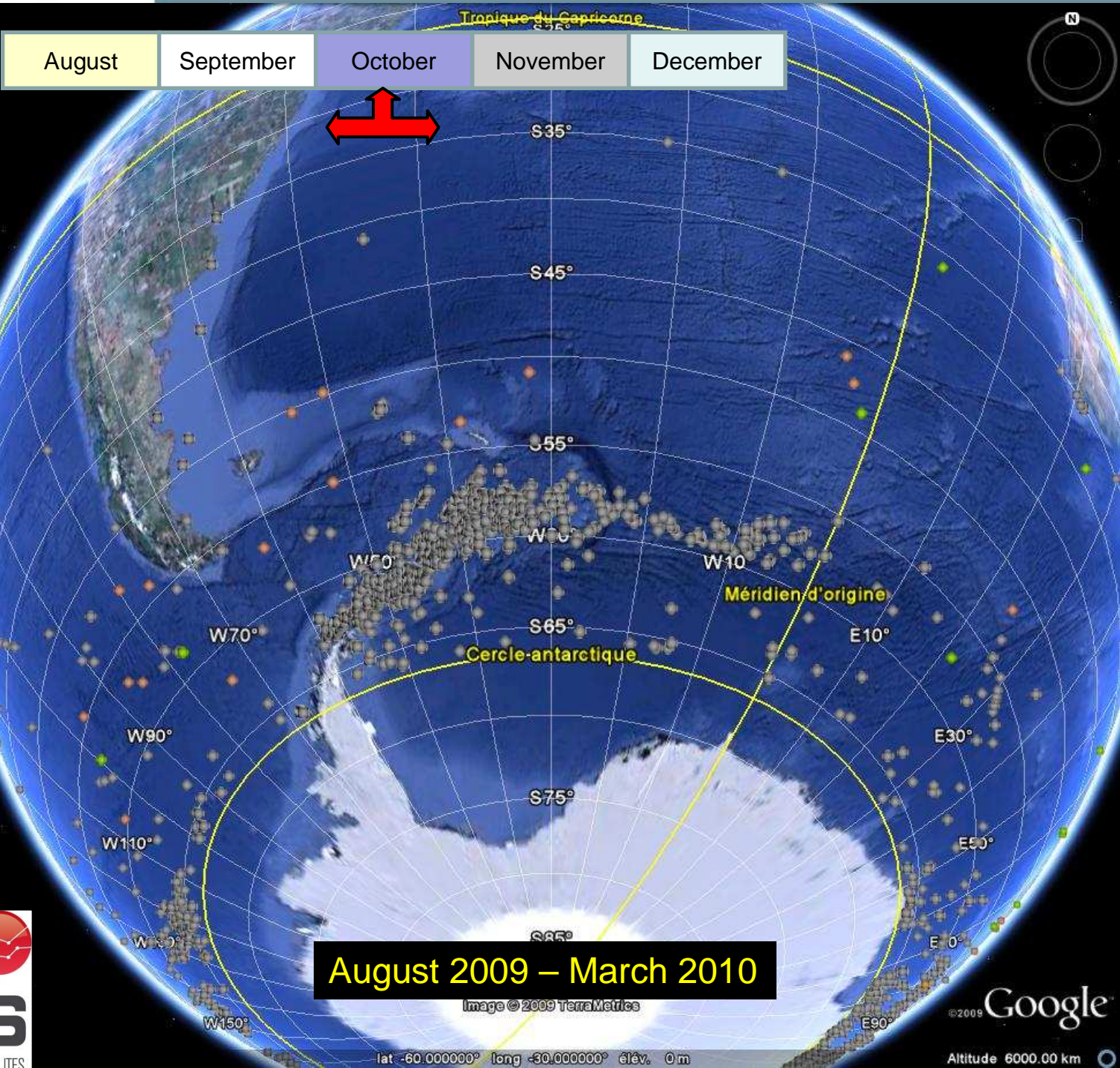


**August 2009 – March 2010**



lat: -60.000000° long: -30.000000° élév.: 0m    Altitude 6000.00 km





August    September    **October**    November    December



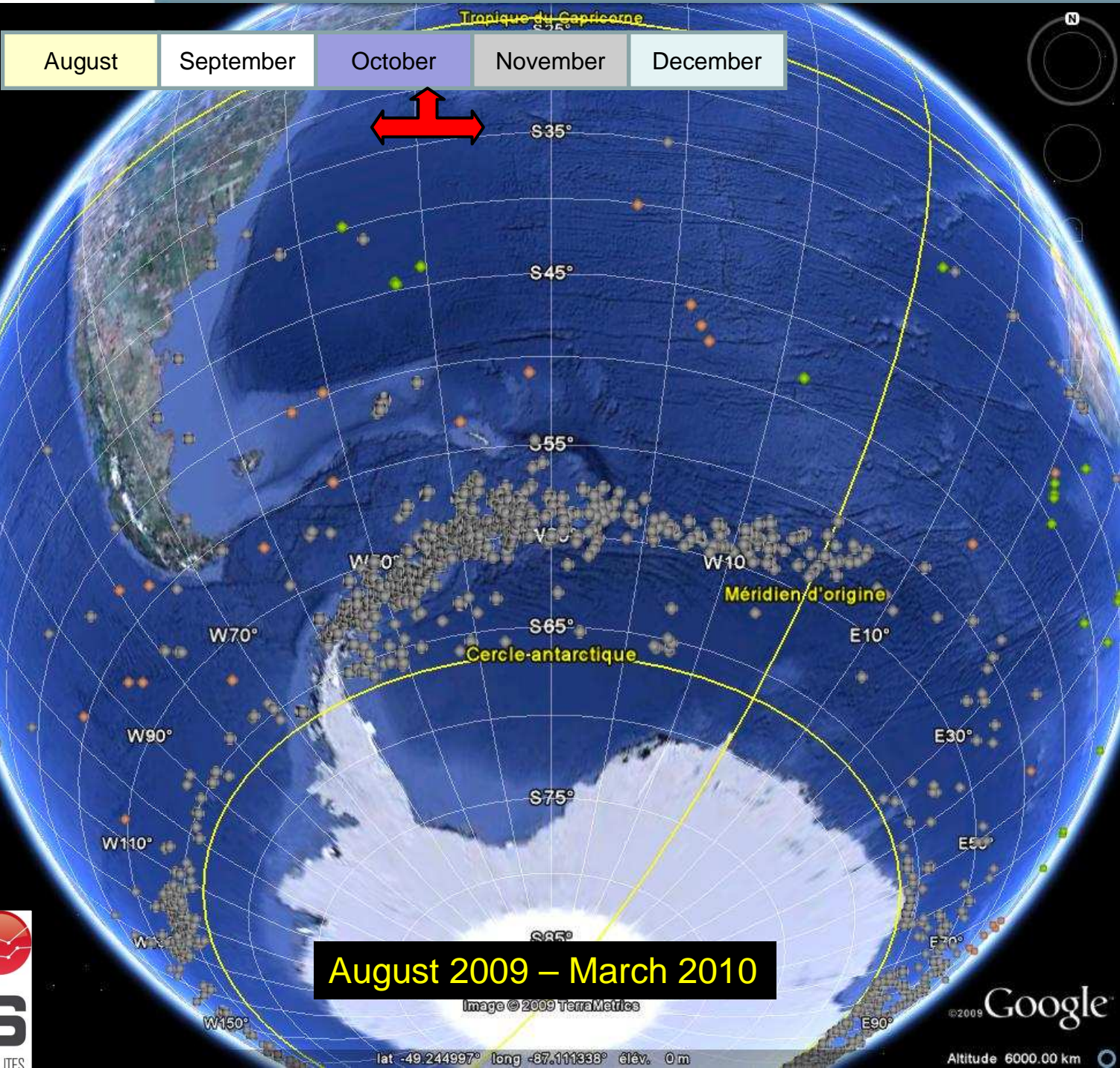
**August 2009 – March 2010**



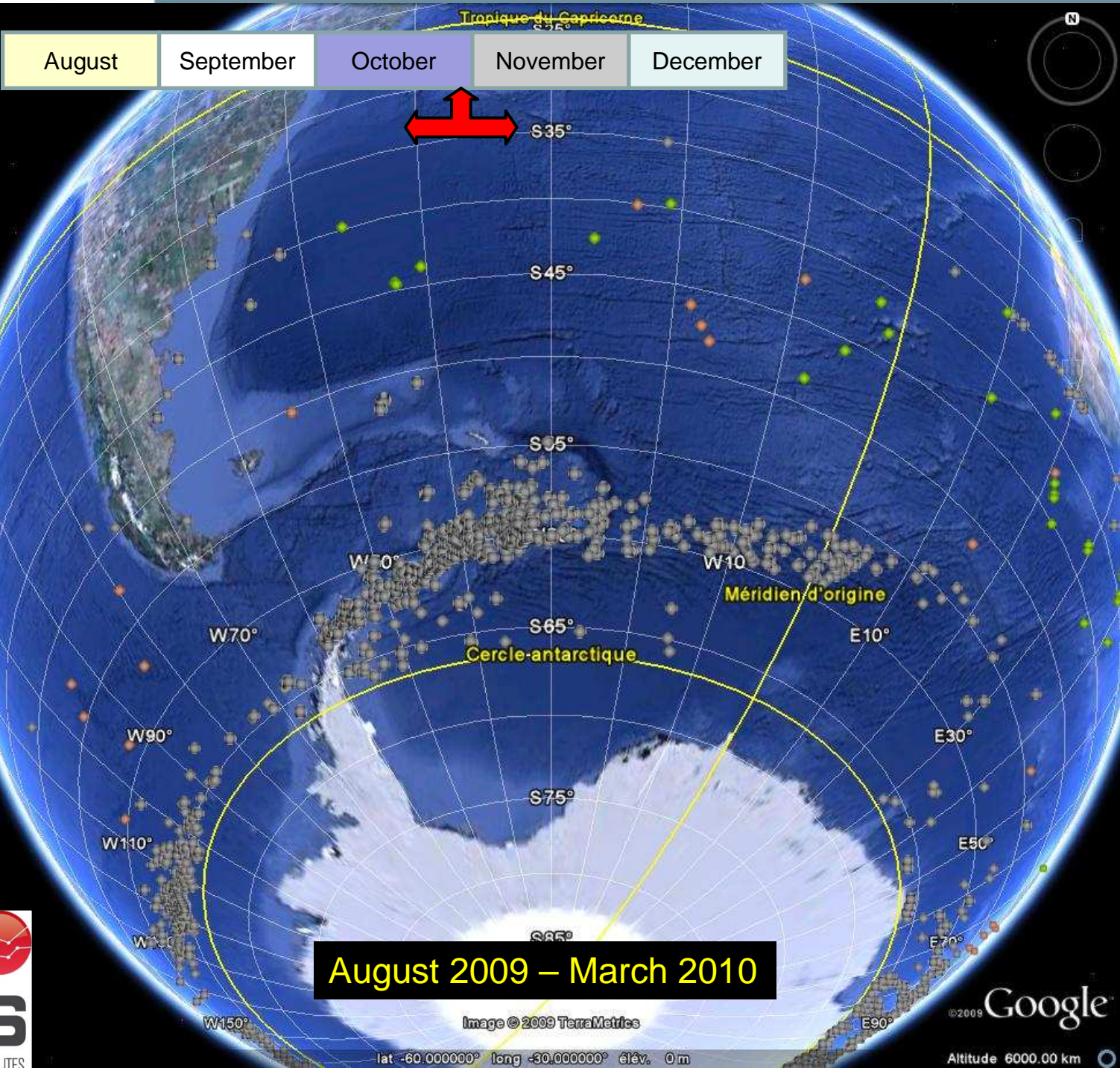
lat -60.000000° long -30.000000° élév. 0m

Altitude 6000.00 km

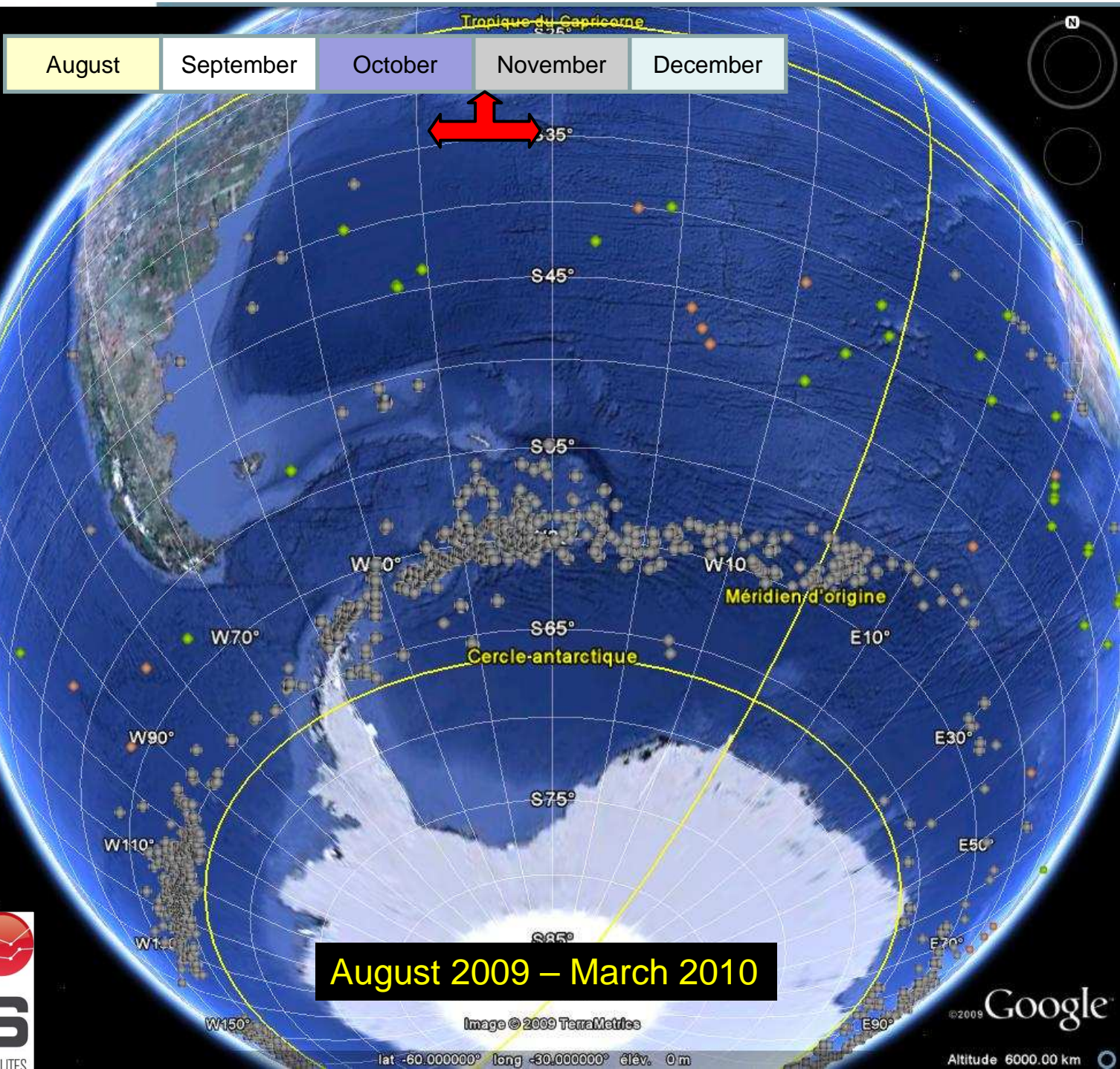












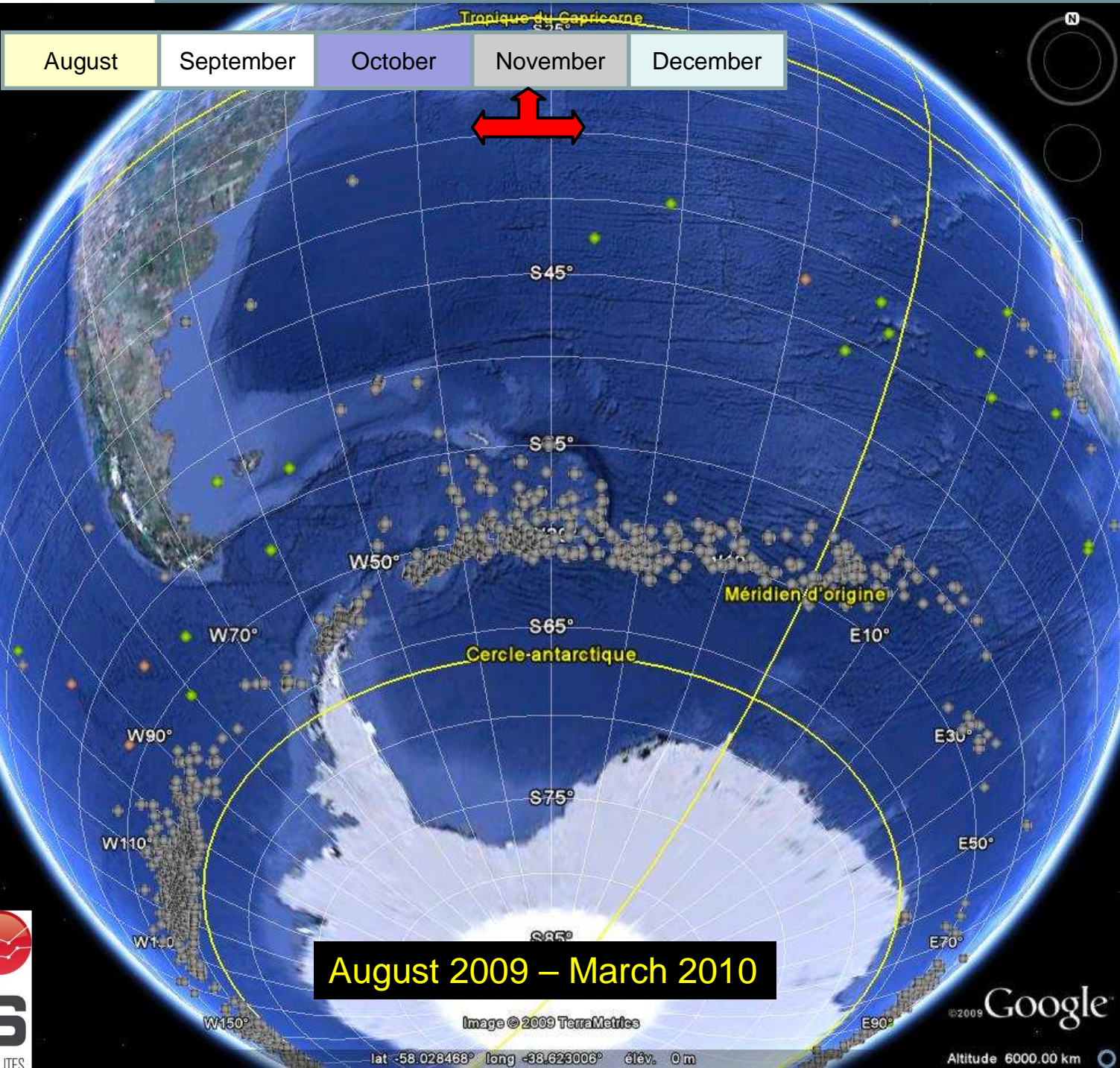
August 2009 – March 2010



lat -60.000000° long -30.000000° élév. 0m

Altitude 6000.00 km





August    September    October    **November**    December

**August 2009 – March 2010**



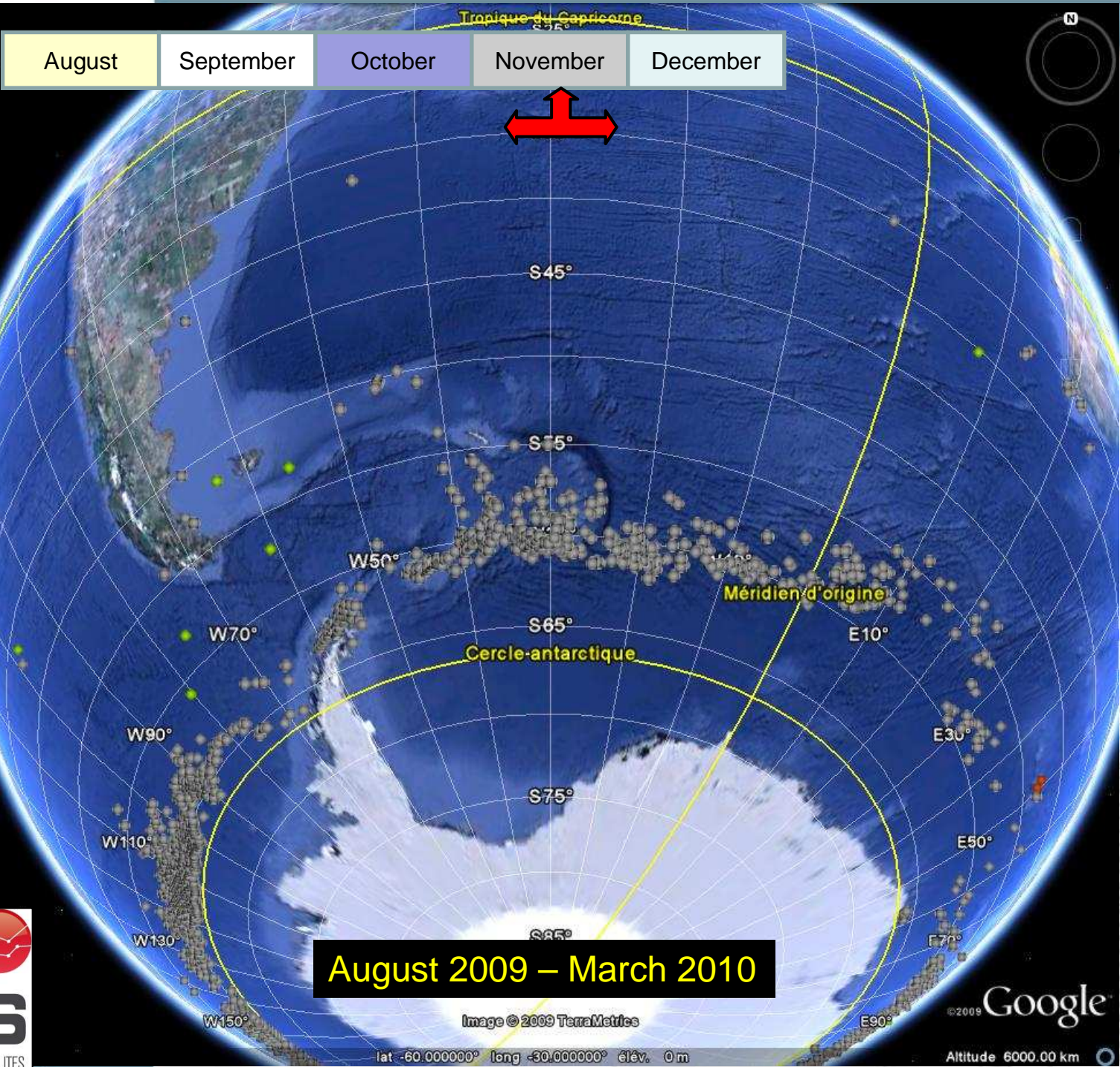
Image © 2009 TerraMetrics

lat -58.028468° long -38.623006° élév. 0 m

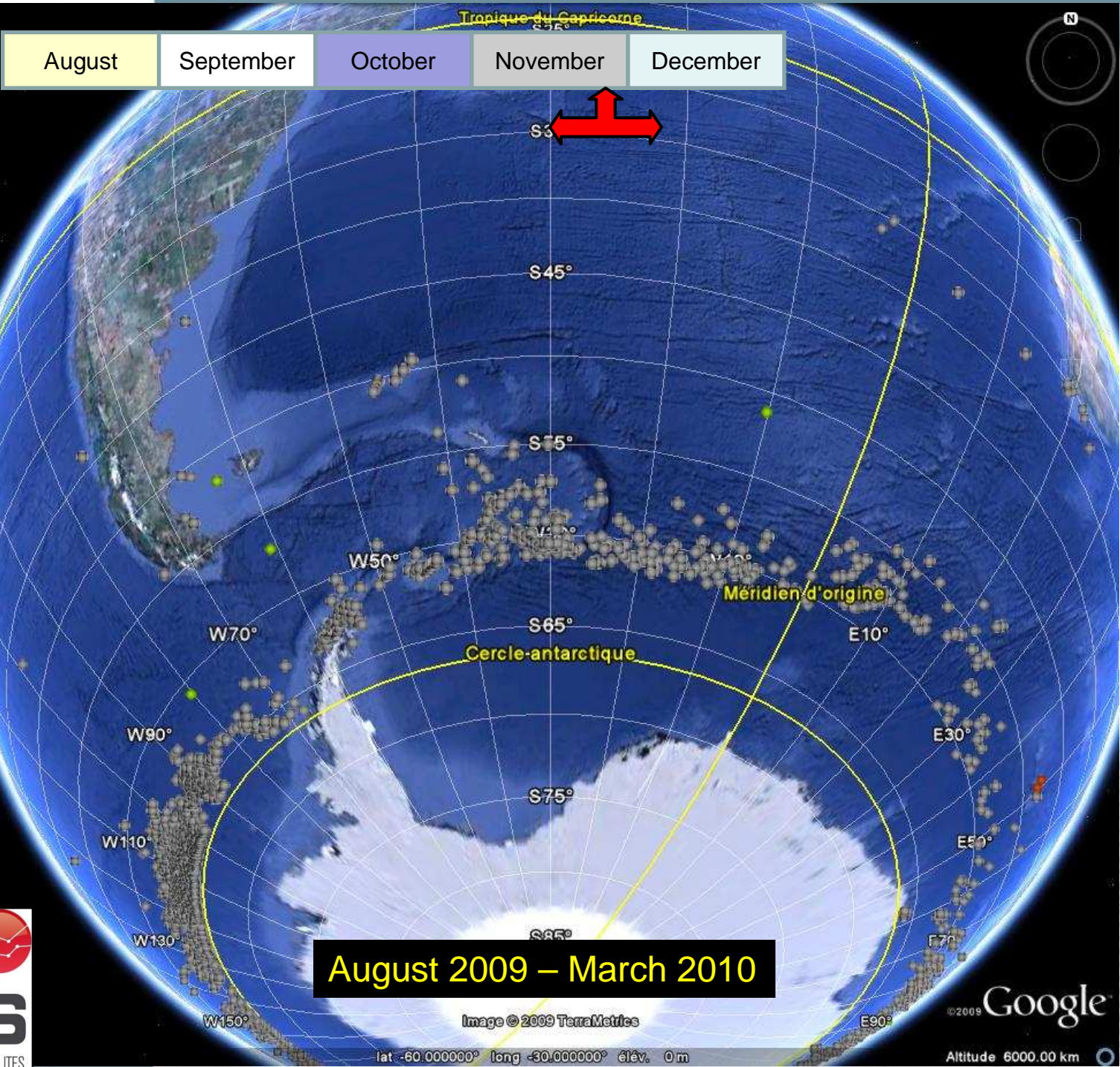
©2009 Google

Altitude 6000.00 km

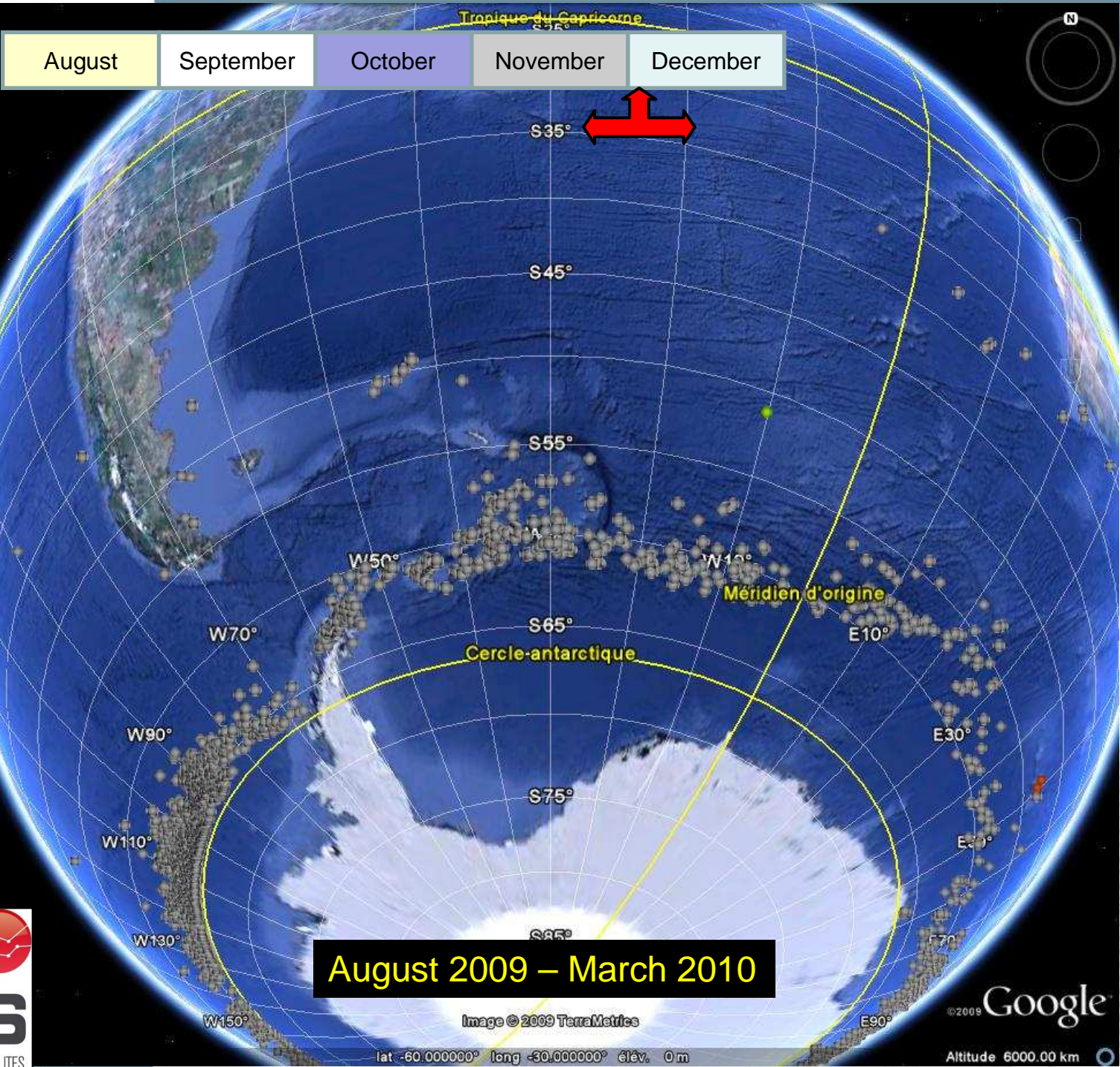












August    September    October    November    December

S35°

S45°

S55°

S65°

S75°

S85°

August 2009 – March 2010

Image © 2009 TerraMetrics

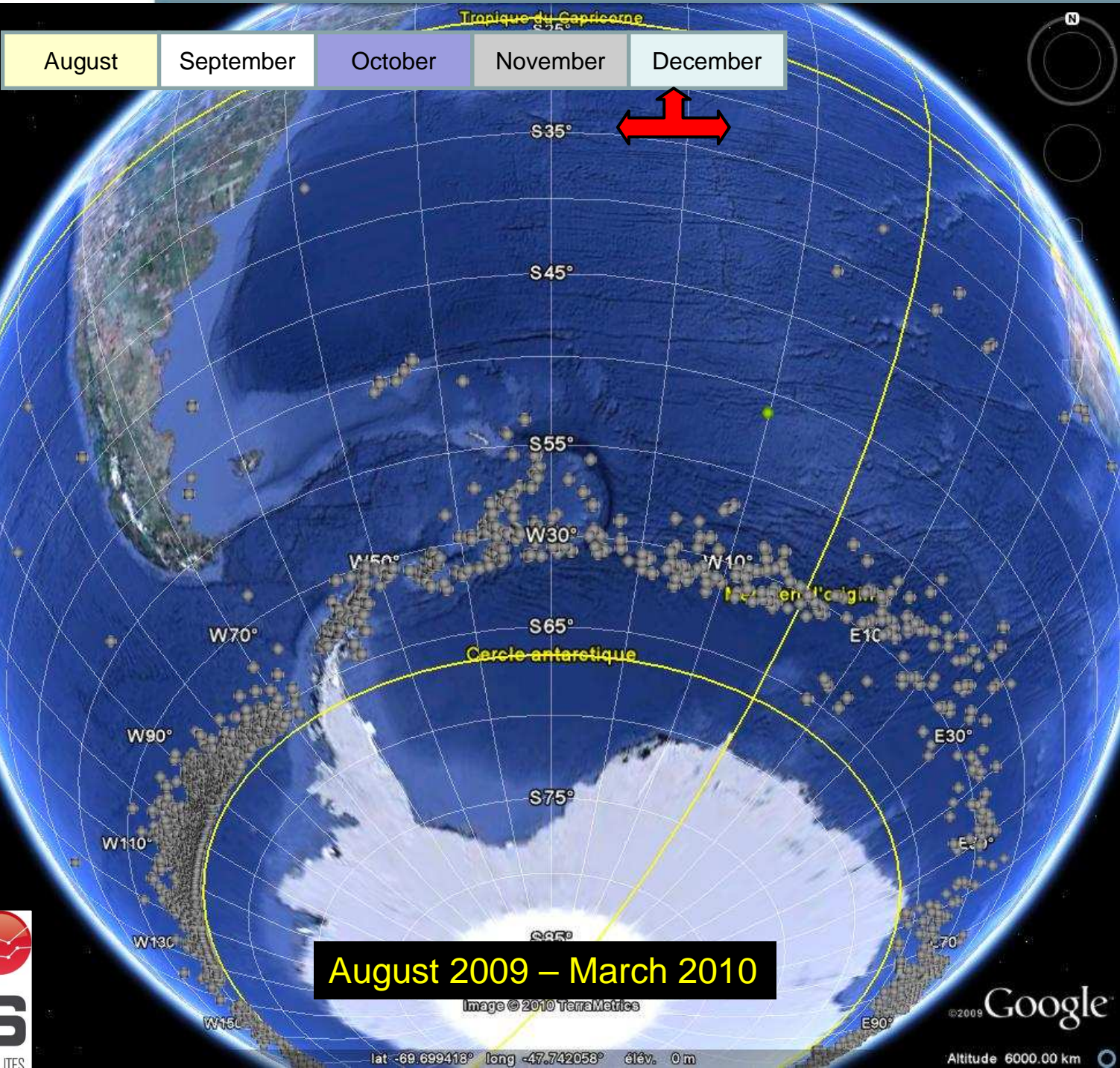
lat -60.000000° long -30.000000° élév. 0m

Google

Altitude 6000.00 km







August    September    October    November    December

August 2009 – March 2010

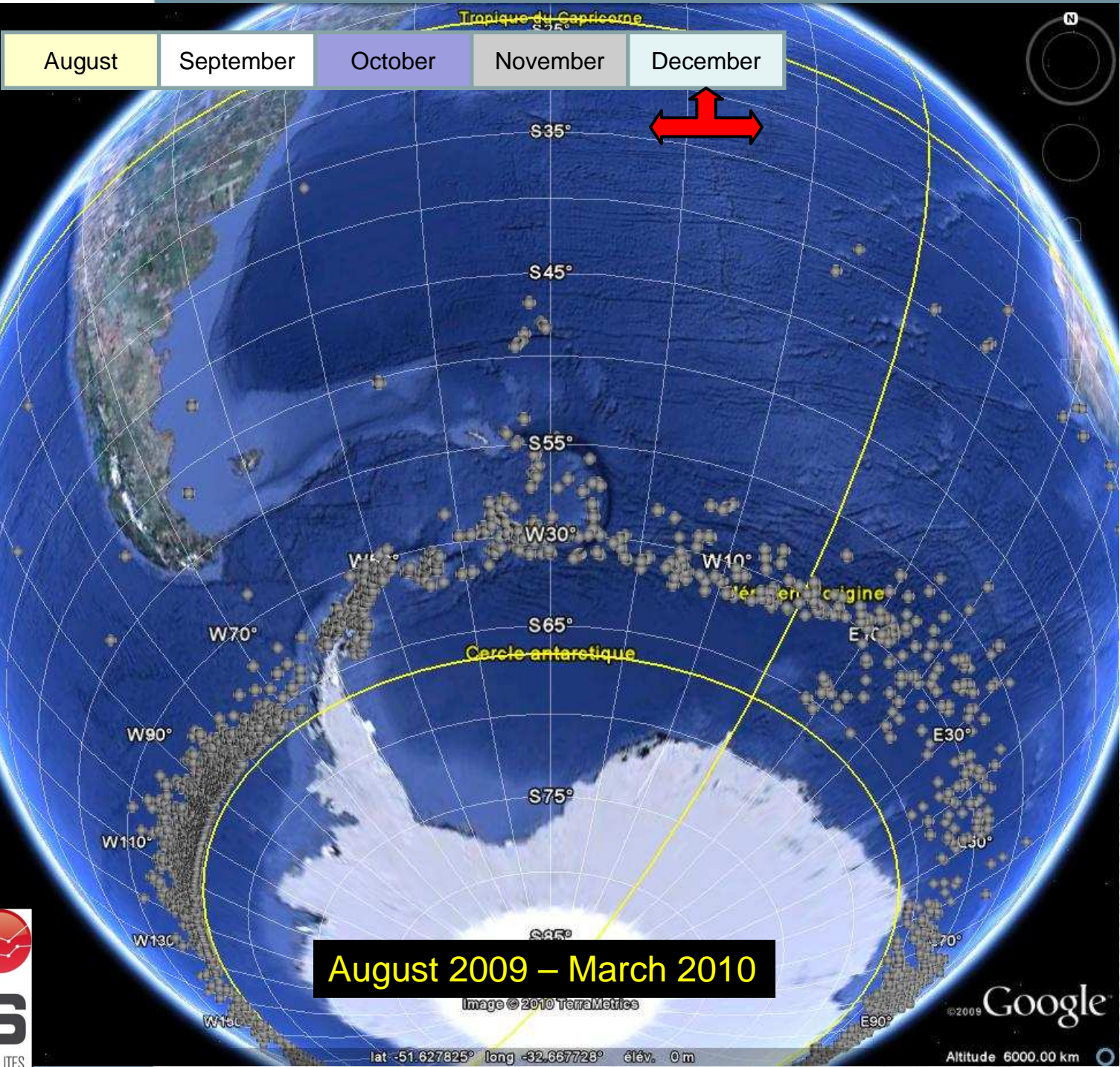


©2009 Google

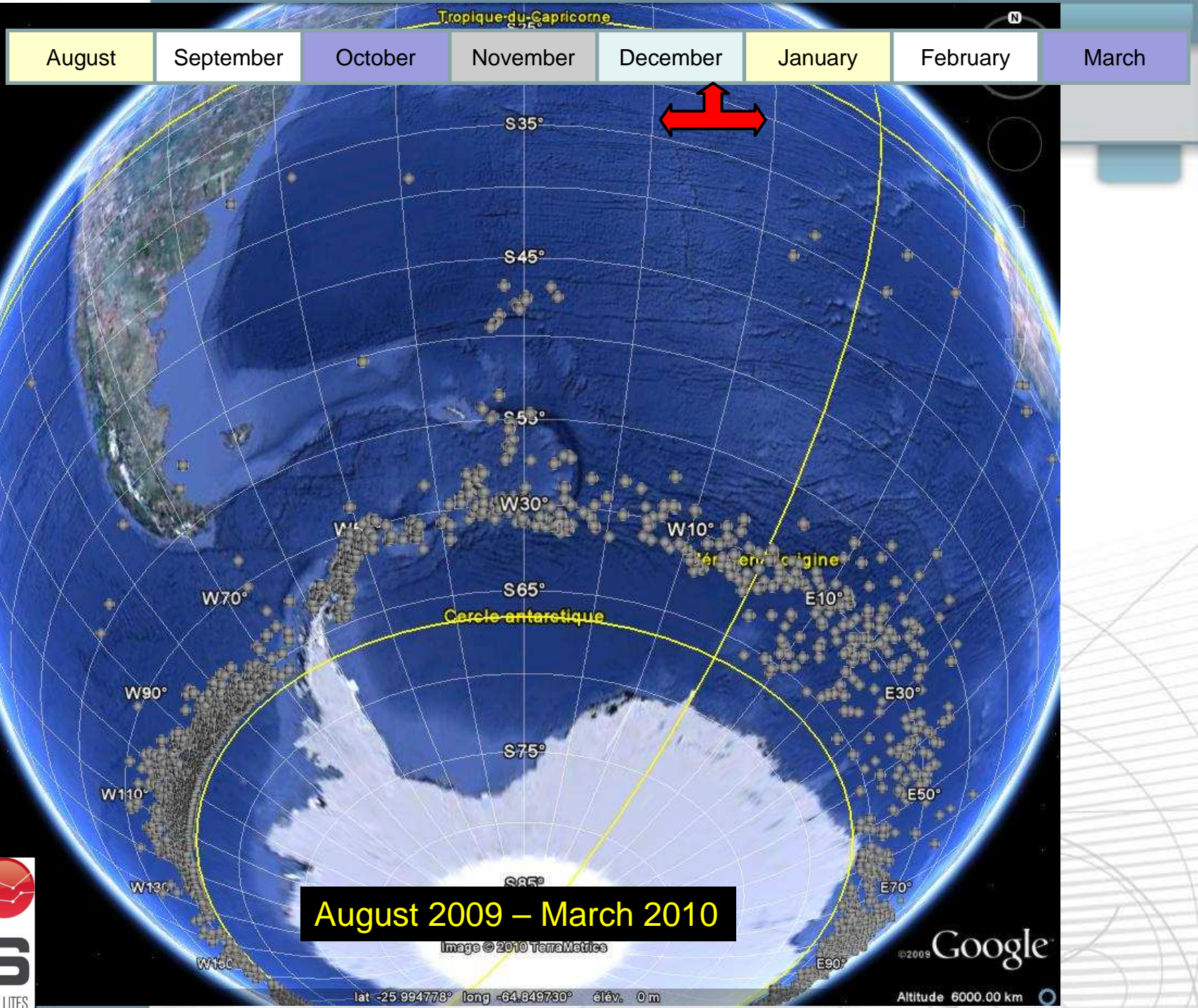
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Altitude 6000.00 km







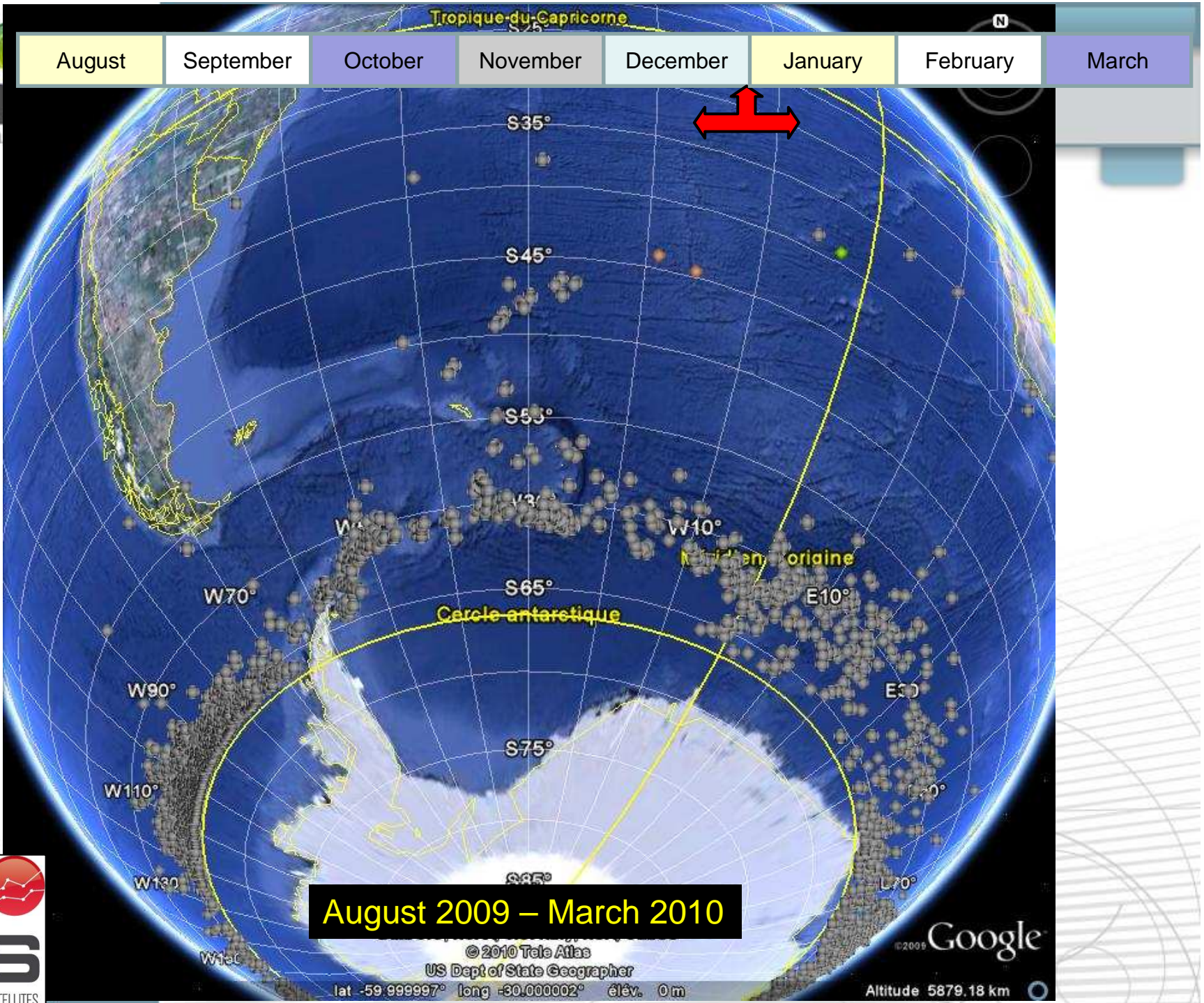


August    September    October    November    December    January    February    March

August 2009 – March 2010







August

September

October

November

December

January

February

March

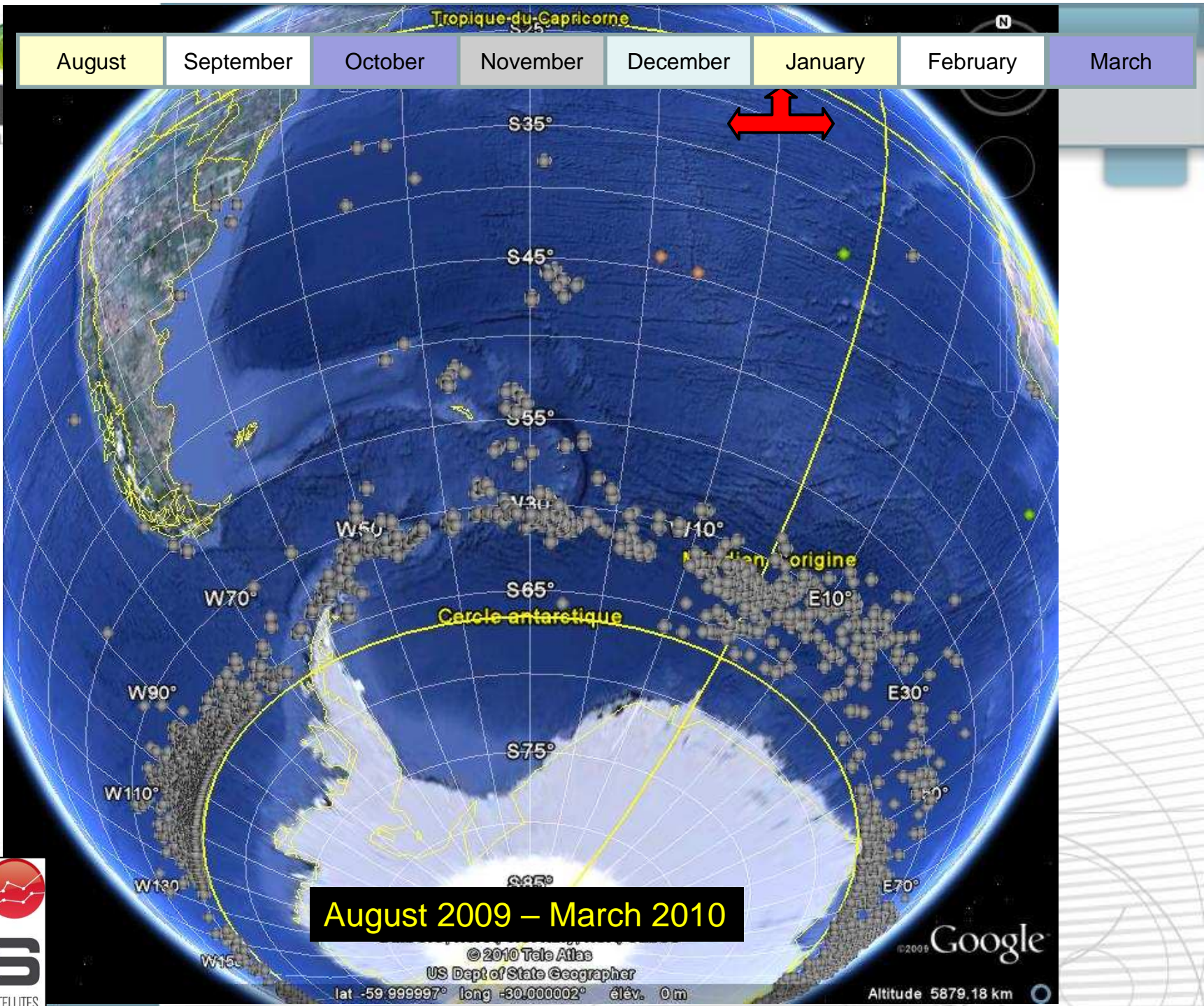
August 2009 – March 2010



© 2010 Tele Atlas  
US Dept of State Geographer  
lat -59.999997° long -30.000002° elev. 0m

©2005 Google  
Altitude 5879.18 km



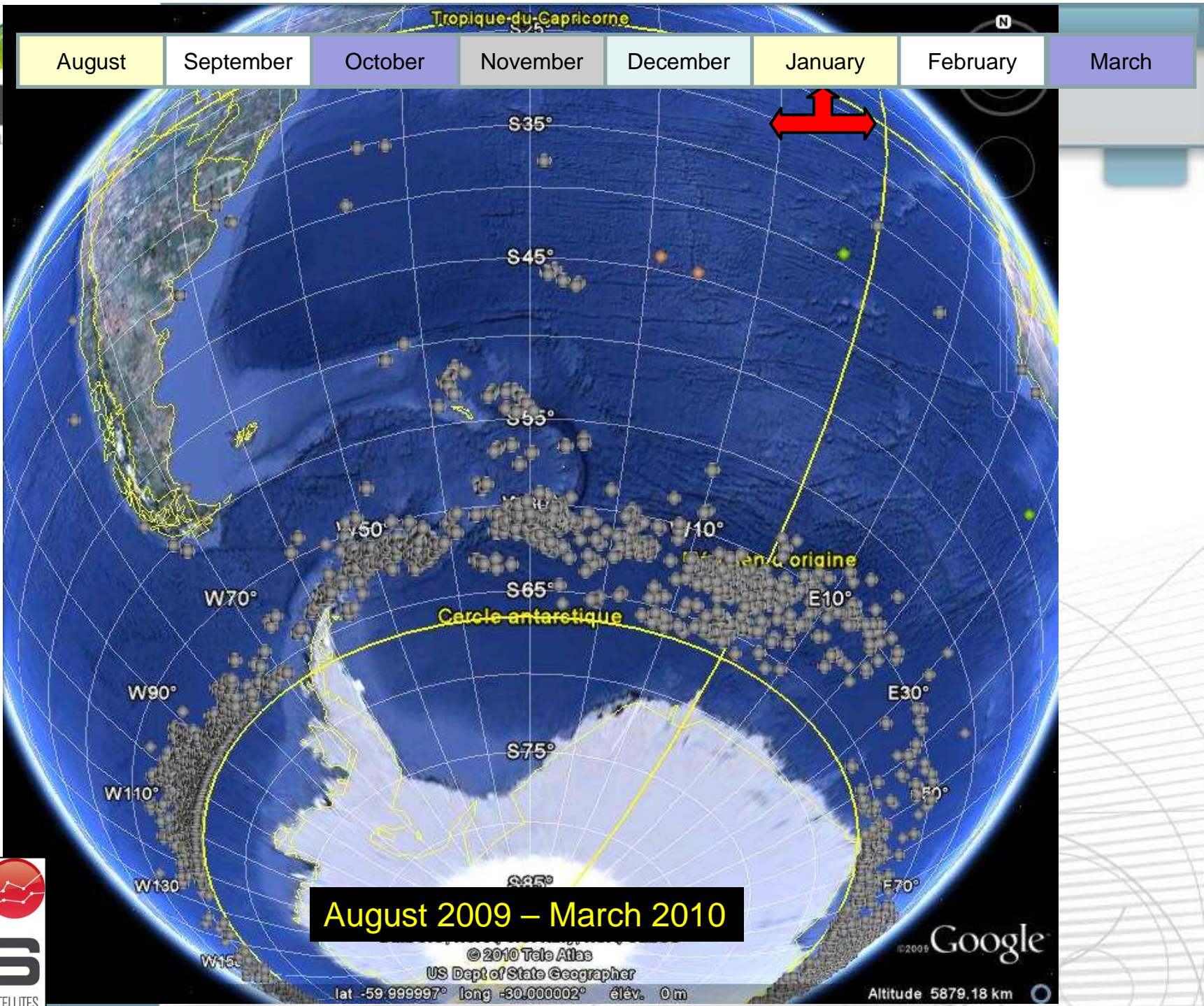


August 2009 – March 2010

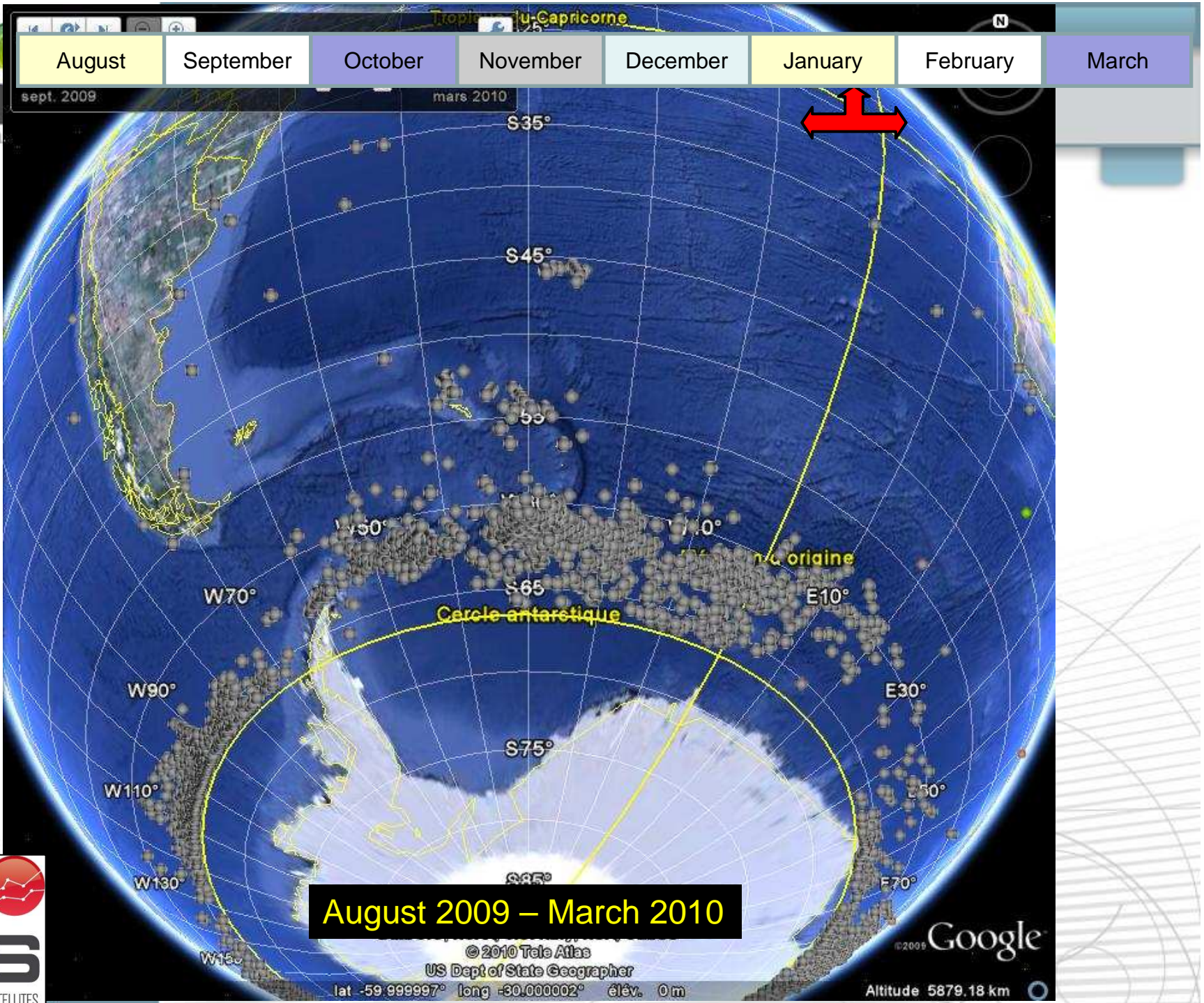
© 2010 Tele Atlas  
US Dept of State Geographer  
lat -59.999997° long -30.000002° elev. 0m

Google  
Altitude 5879.18 km





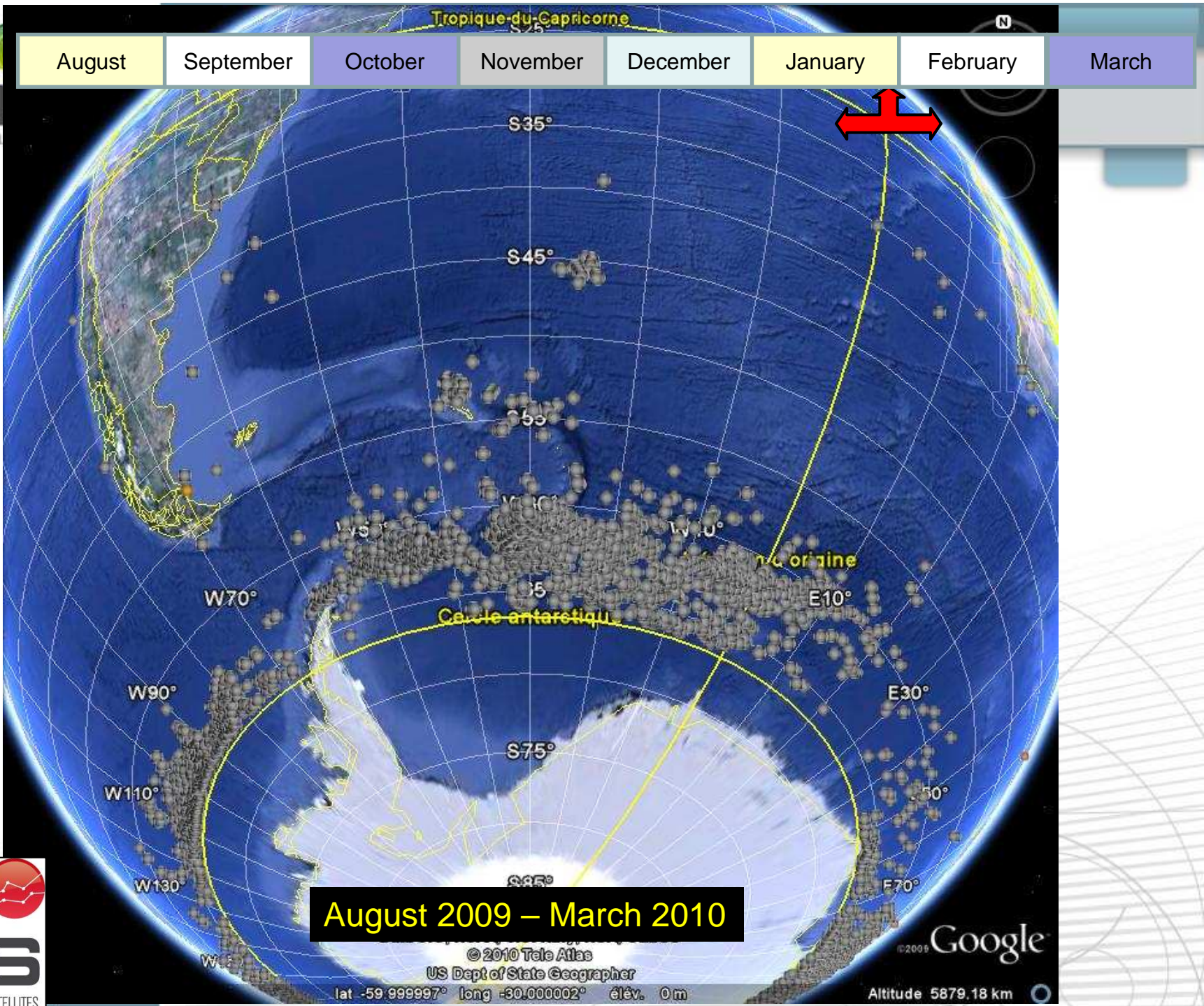




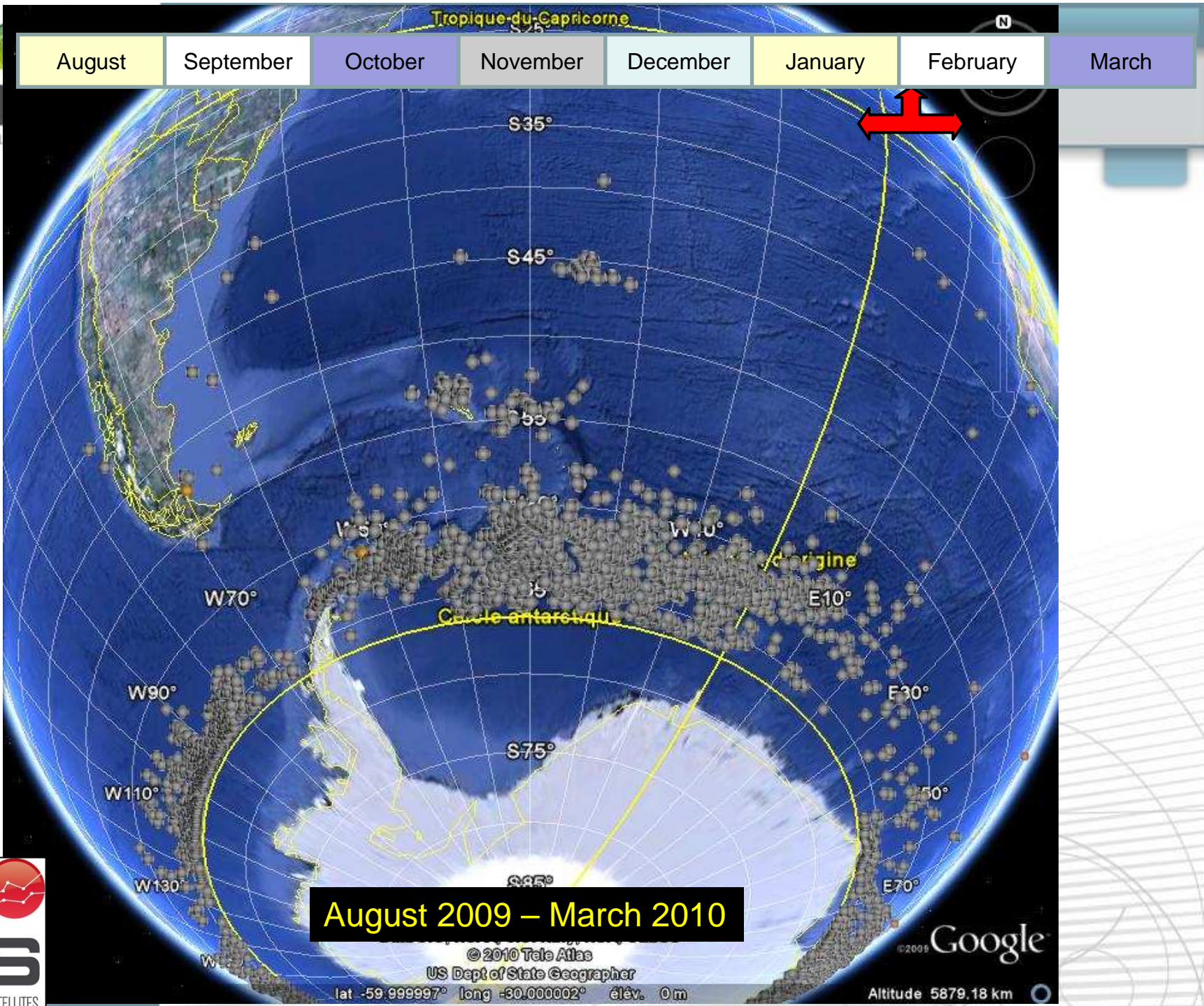
August 2009 – March 2010



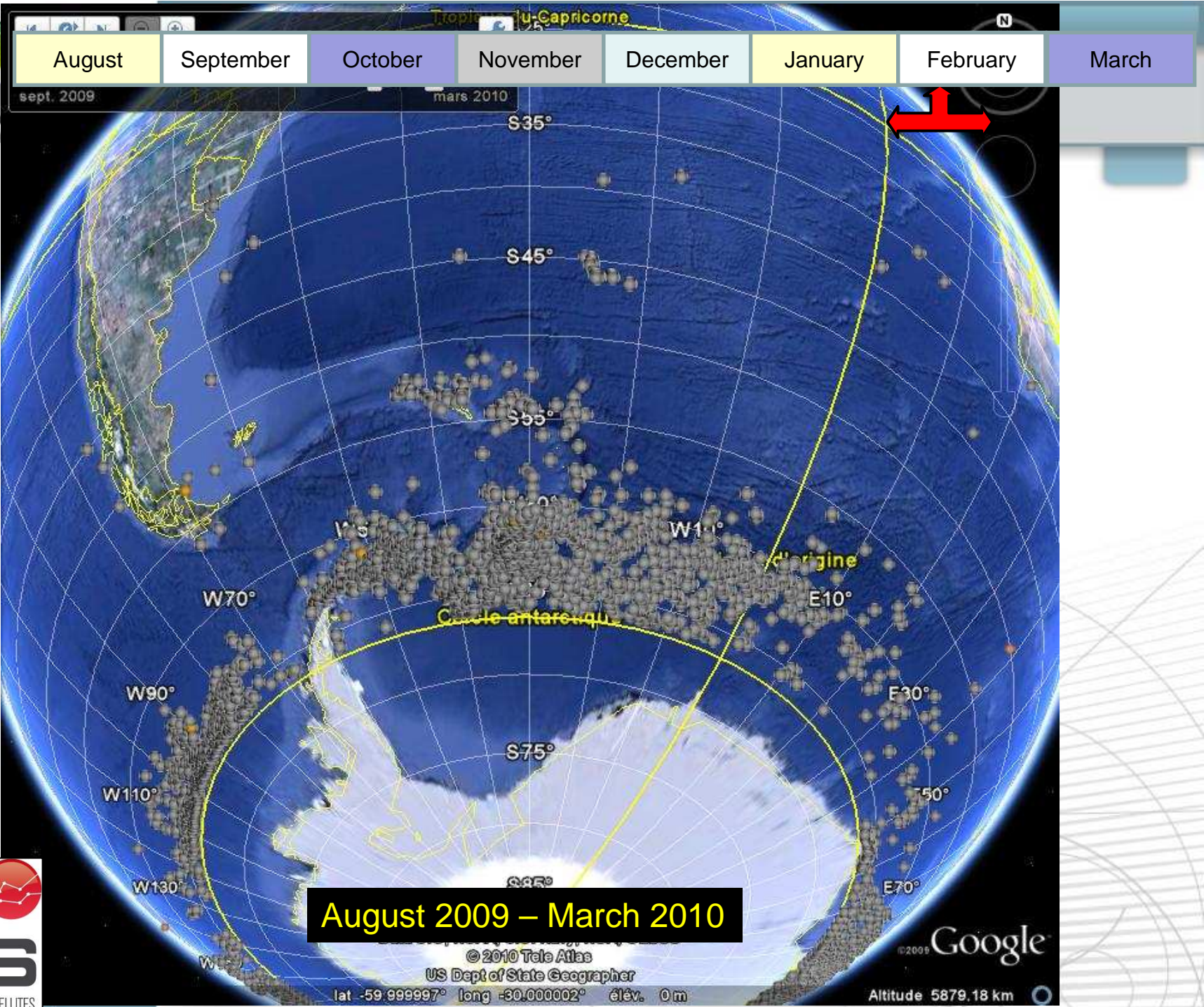




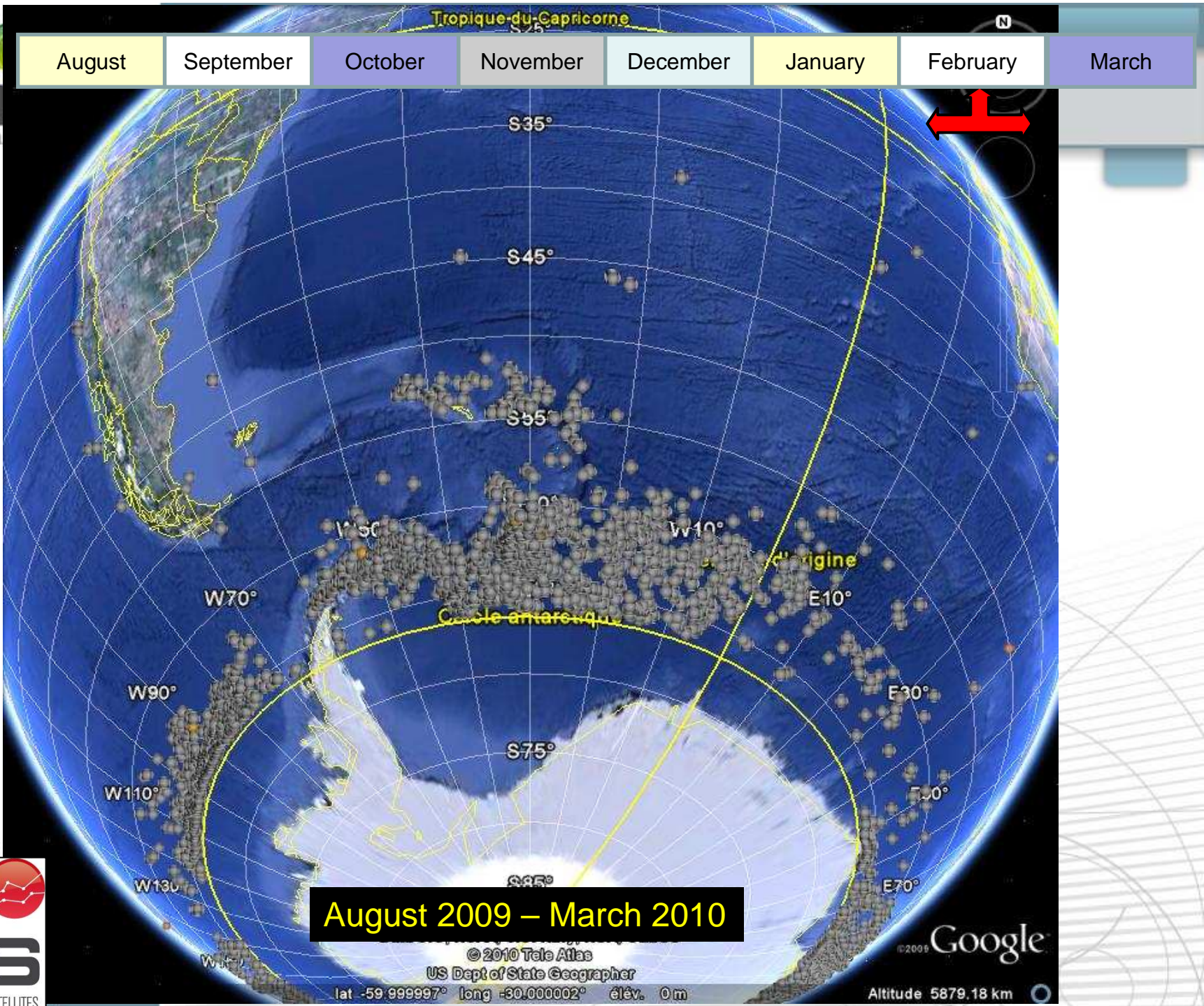












August    September    October    November    December    **January**    February    March

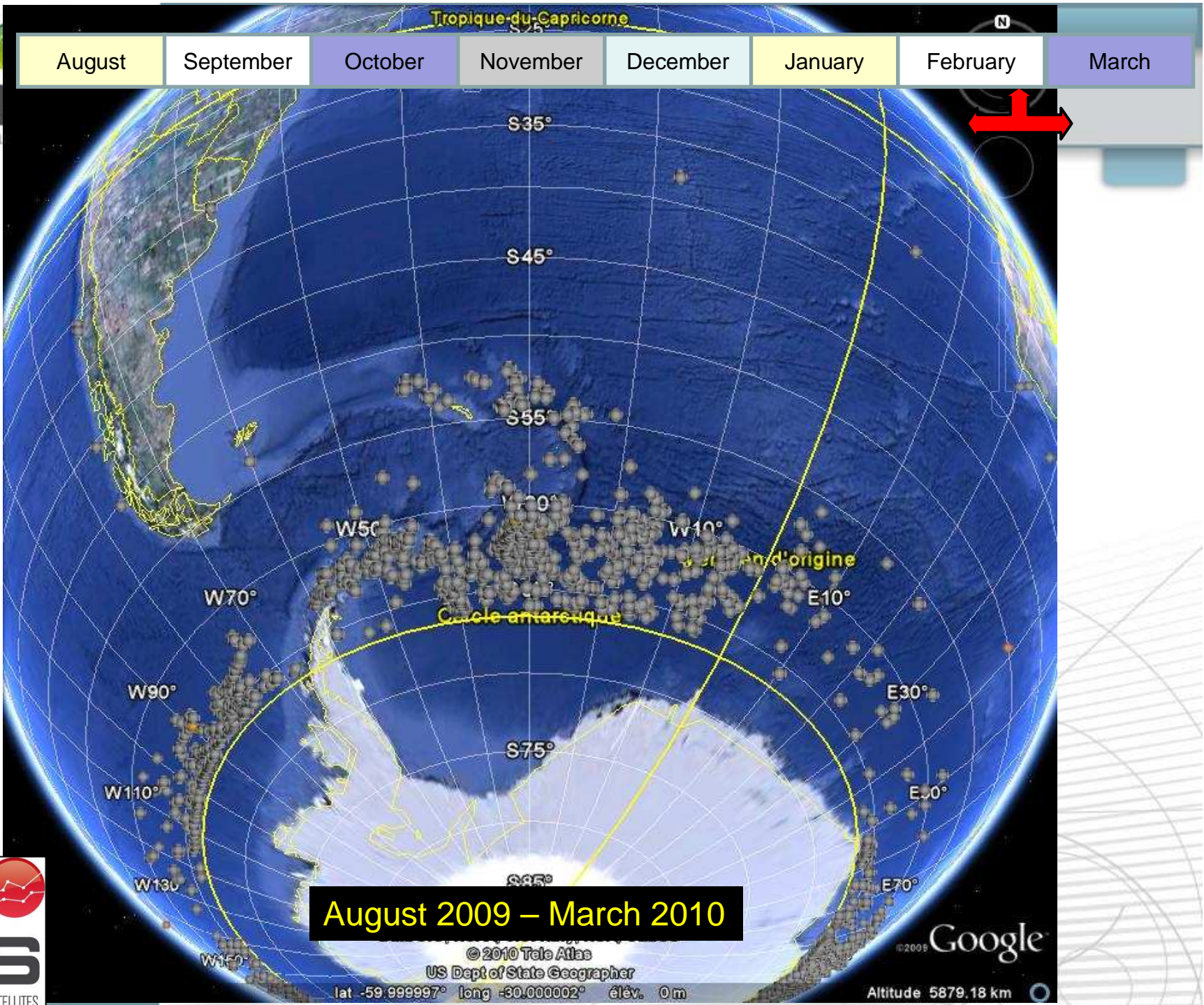
**August 2009 – March 2010**



© 2010 Tele Atlas  
US Dept of State Geographer  
lat -59.999997° long -30.000002° elev. 0m

Altitude 5879.18 km

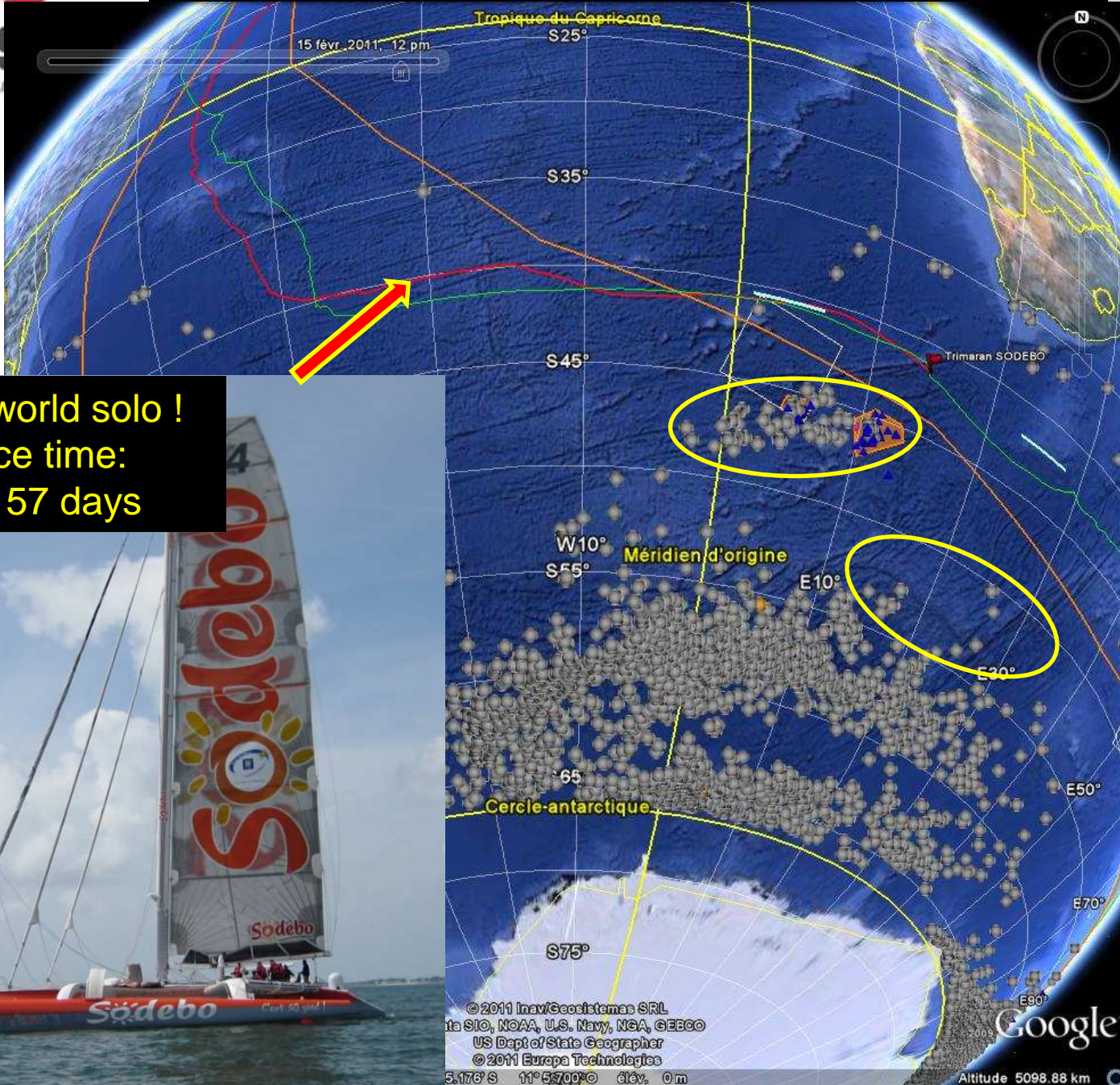








# Accumulation 11 January 2011 – 14 February 2011



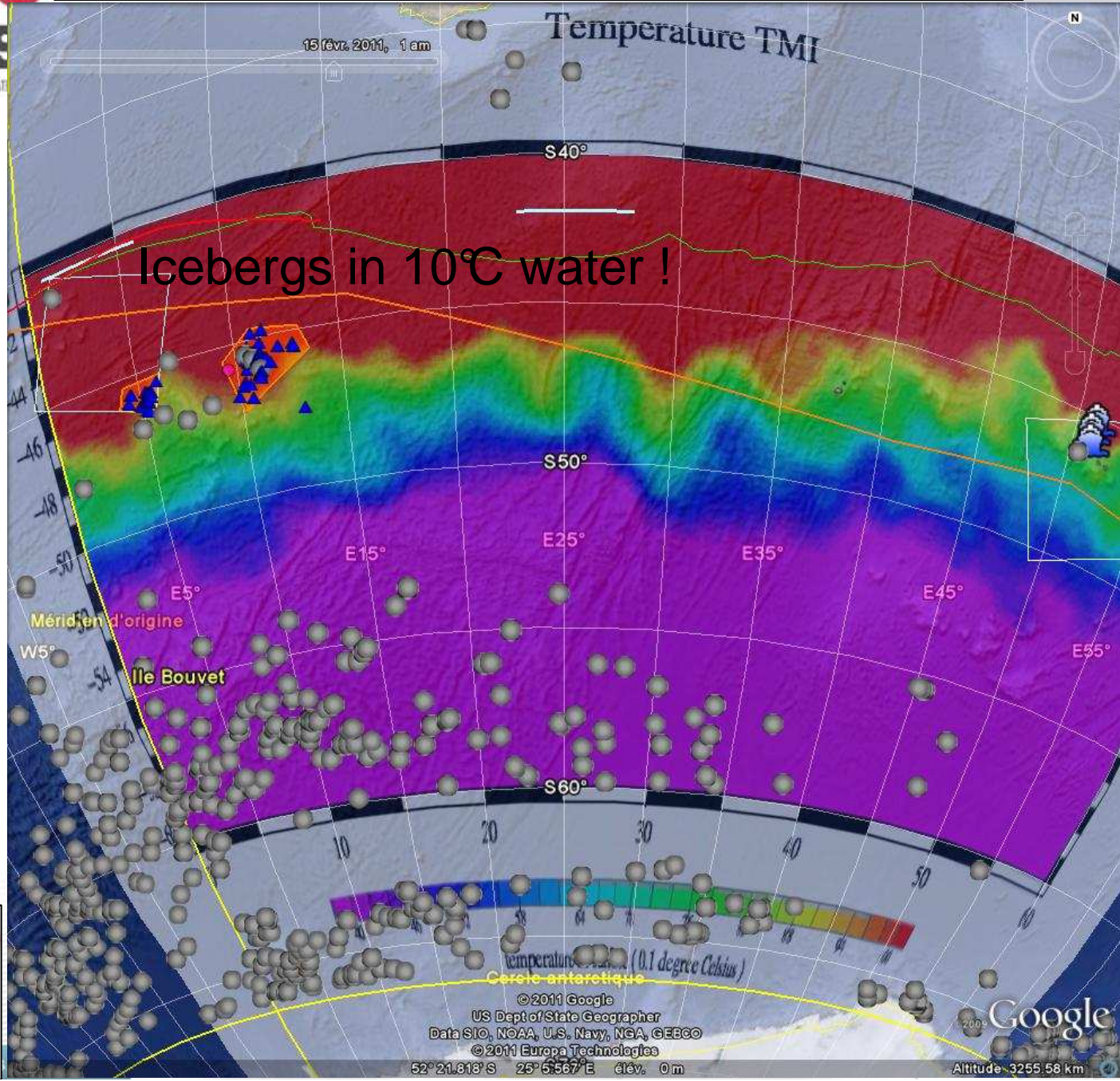
Round the world solo !  
Reference time:  
less than 57 days







# Comparison Recent detections and SST 13/02/2011





# Lake-ice thickness estimation ? (Northern Canada)

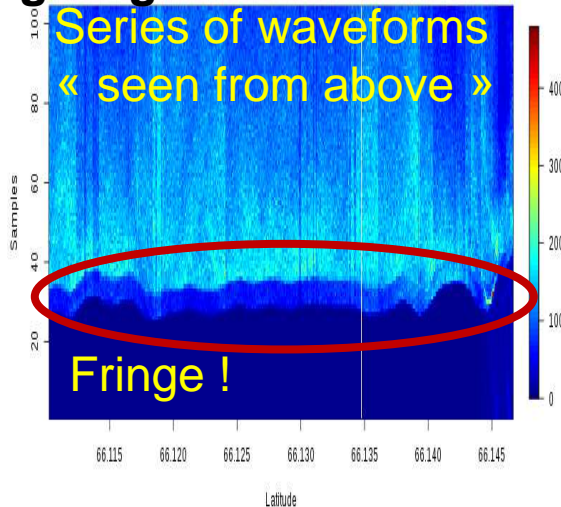
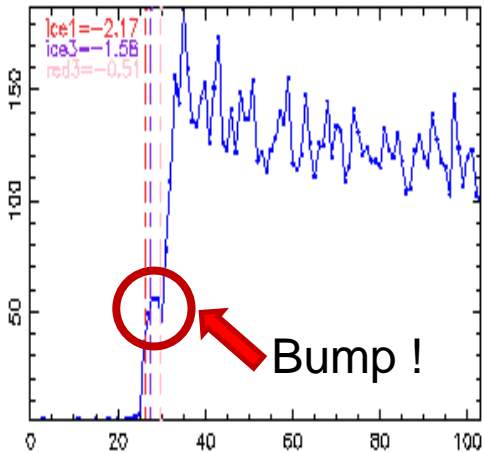
Great Bear Lake – Northwest Territories, Canada



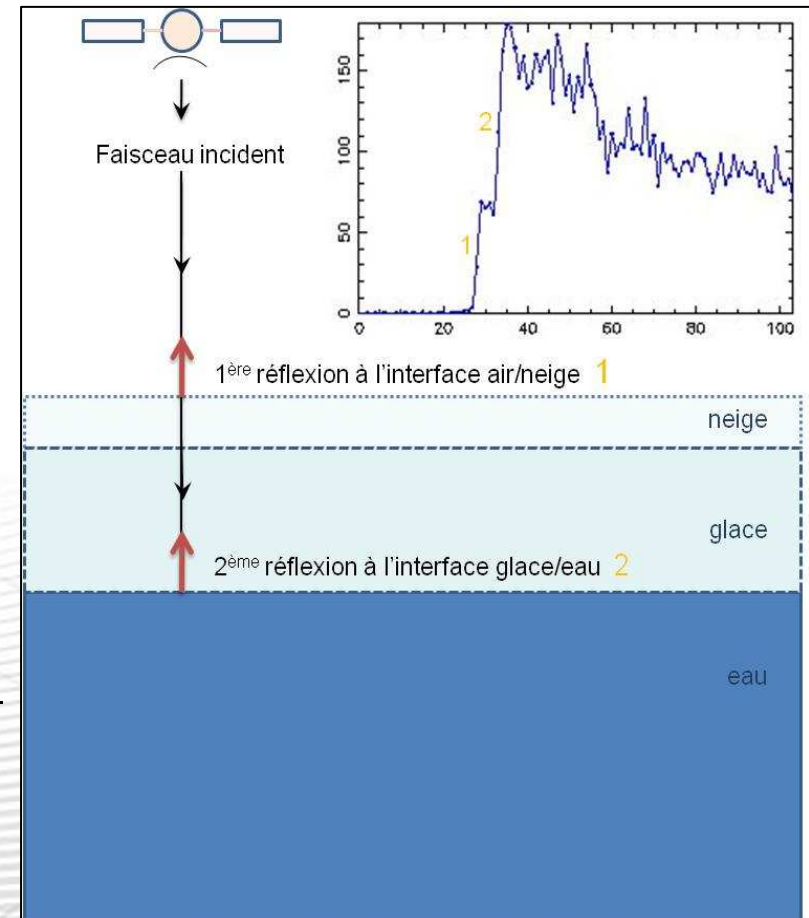


# Lake-ice thickness estimation ? (Northern Canada)

## Observation of a strange signal within waveforms



**Possible interpretation**  
(given that penetration of Ku signal is theoretically possible)



### Hypothesis:

the radar signal propagates through snow and ice layers

- 1<sup>st</sup> leading edge = reflexion on the snow
- 2<sup>nd</sup> leading edge = reflexion at the water/ice interface

Estimate of the ice thickness (width of the bump/fringe):

$$Epaisseur = v_{glace} \times \Delta t_{1-2}$$

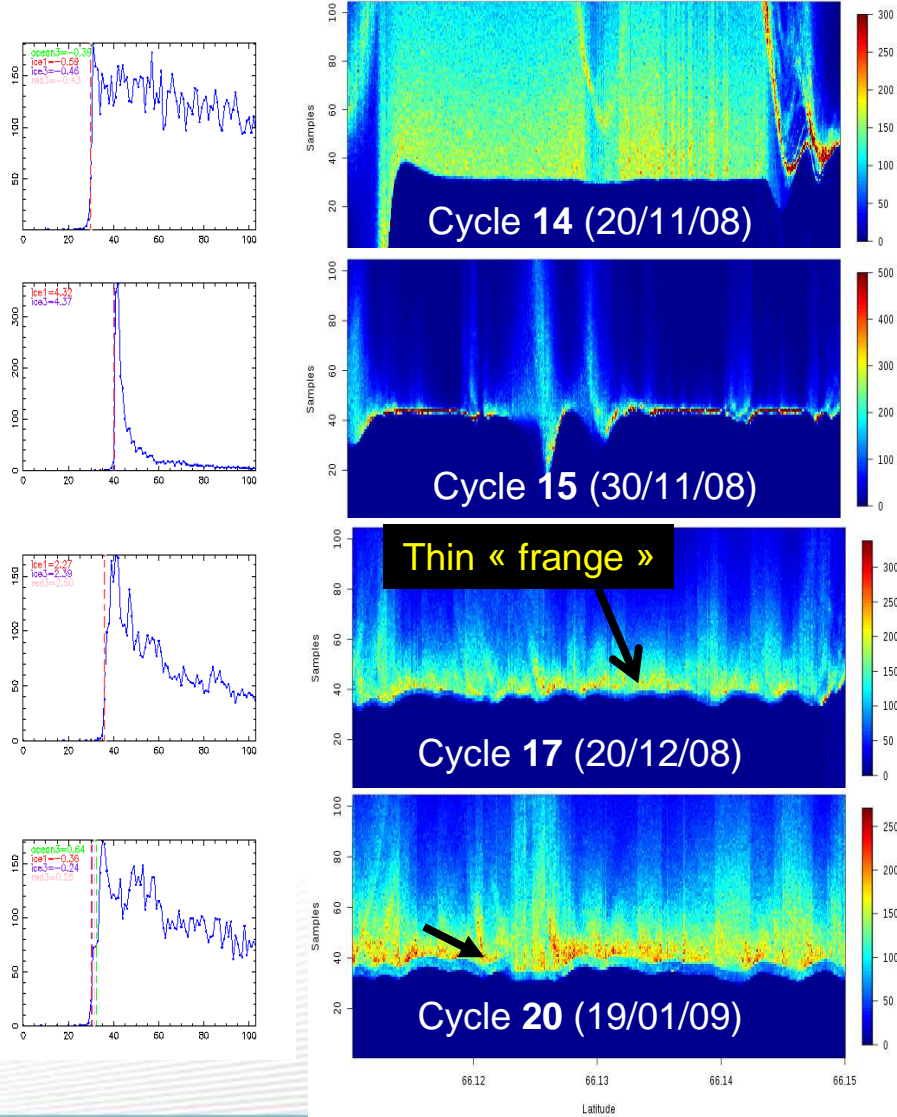
$$v_{glace} \approx 1,69 \text{ m. s}^{-1}$$



# Evolution of waveform shape during winter

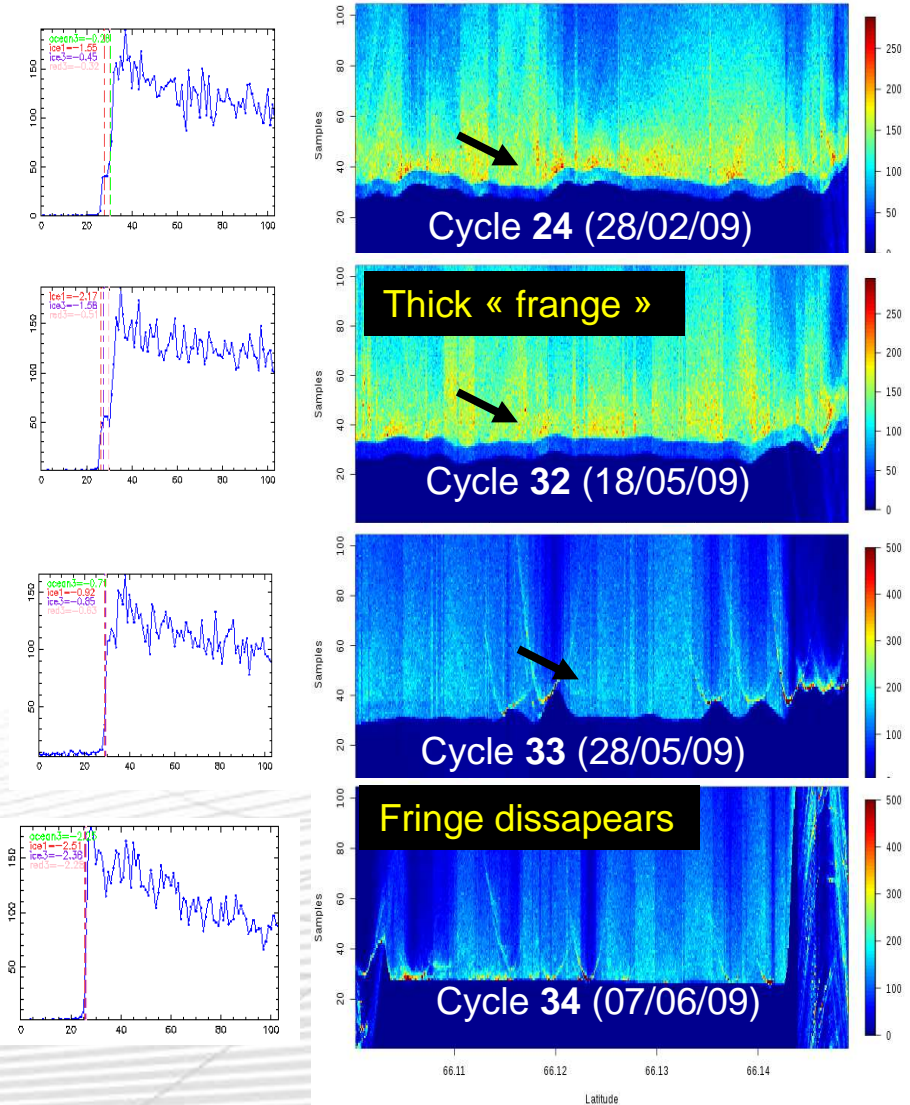
individual echo

Series of waveforms  
« seen from above »



individual echo

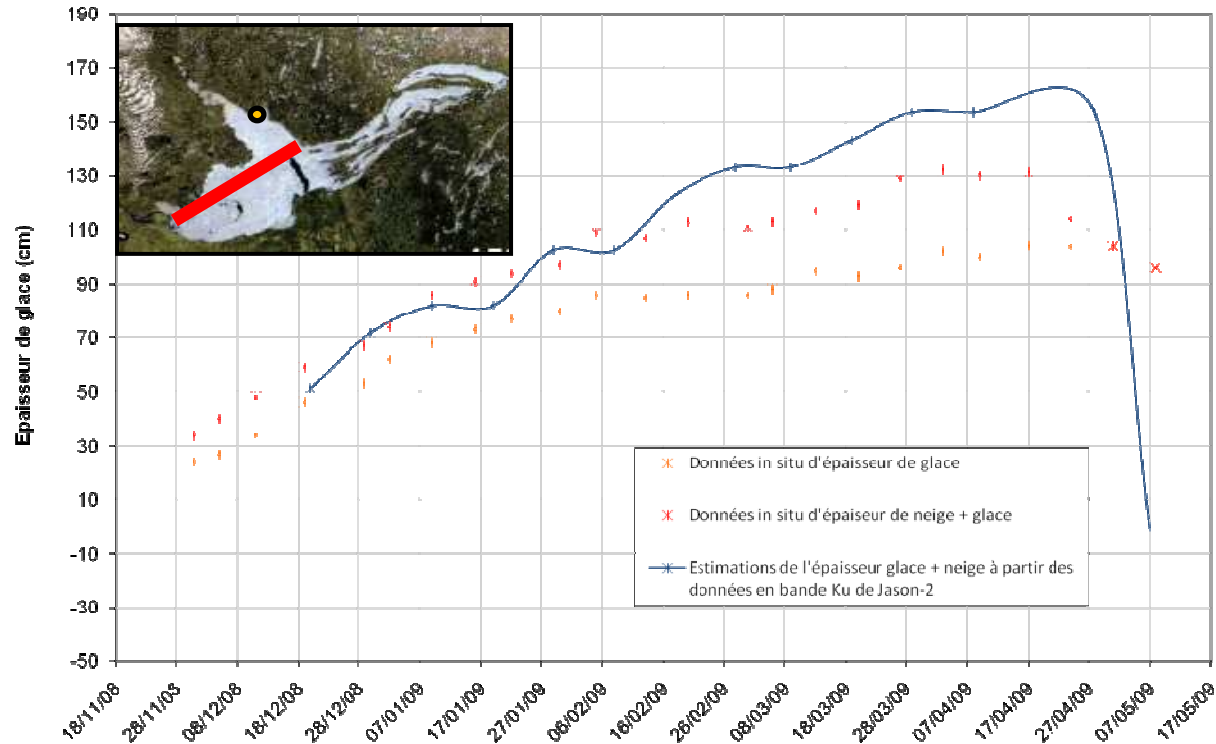
Series of waveforms  
« seen from above »





# Ice thickness estimation over the Great Slave Lake ?

Grand lac des Esclaves (Territoires du Nord-Ouest, Canada)



Comparison between **our first estimates** (blue curve) and *in situ measurements* at Yellowknife: **ice** (orange) and **ice + snow** (rouge) (data from Environnement Canada)

- Observed in Ku and C bands and on Jason-1, Jason-2 and Envisat data, and for several lakes
- Not observed on sea-ice (Hudson Bay for instance)
- Seems to be highly dependant on the ice structure (surface) and composition (no salt)
- **AltiKa: no penetration expected in Ka band → comparison between Ku and Ka signal will enhance the comprehension of this phenomena**



# Conclusion

- **Still a lot to understand and discover with conventional altimetry, especially over non-ocean surfaces.**
- **Amplified by the specificities (smaller footprint, higher along-tracks sampling rate, Ka-band), of AltiKa**
- **Non-ocean like waveform analysis is an endless game...**





Thank you !



2<sup>nd</sup> SARAL/Altika Science Workshop  
Ahmedabad (India) March 15-17 2011







# French AltiKa Pis proposals:

## F.Rémy et al.:

- continuity of previous work
- ice sheets
- snow facies
- lake ice cover
- snow and floods in boreal regions
- Retracking
- reduction of altimeter errors





# French AltiKa Pis proposals:

## F. Mercier et al.:

- iceberg detection (with Tournadre)
- continental lake ice-thickness (with Kouraev)

## F. Birol et al. (CTOH):

- Sea level change and variability in the Arctic Ocean
- Southern Ocean circulation in the sea-ice region

## L. Eymard et al.:

- improvement of the wet tropo correction over ice (with CLS)





# French AltiKa Pis proposals:

## B. Chapron et al.:

- sea-ice studies

## F. Niño et al.:

- waveform inversion





# Indian AltiKa Pis proposals:

**I.M.L Das:**

- sea-ice studies

**S.R. Oza:**

- interannual variation of sea-ice and ice sheets





# International AltiKa Pis proposals:

## H. Lee et al.:

- surface water dynamics over Artic lakes

## C. Watson et al:

- calibration of AltiKa over ice (Antarctica)

## C.K. Shum al.:

- ice sheets elevation change