Analysis of the Internal Boundary Layer formation

on tropical coastal regions using SODAR data in Santa Cruz region of MRRJ

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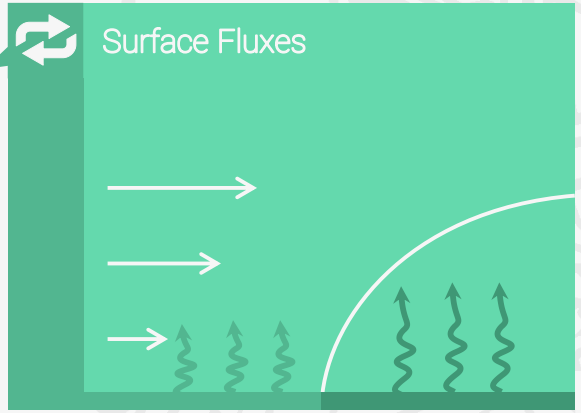
Introduction

Definition of Internal Boundary Layer

Definition

Characteristic region formed near to surface and inside de Atmospheric Boundary Layer, as a result of an air mass advection over an **abrupt change of surface proprieties**.

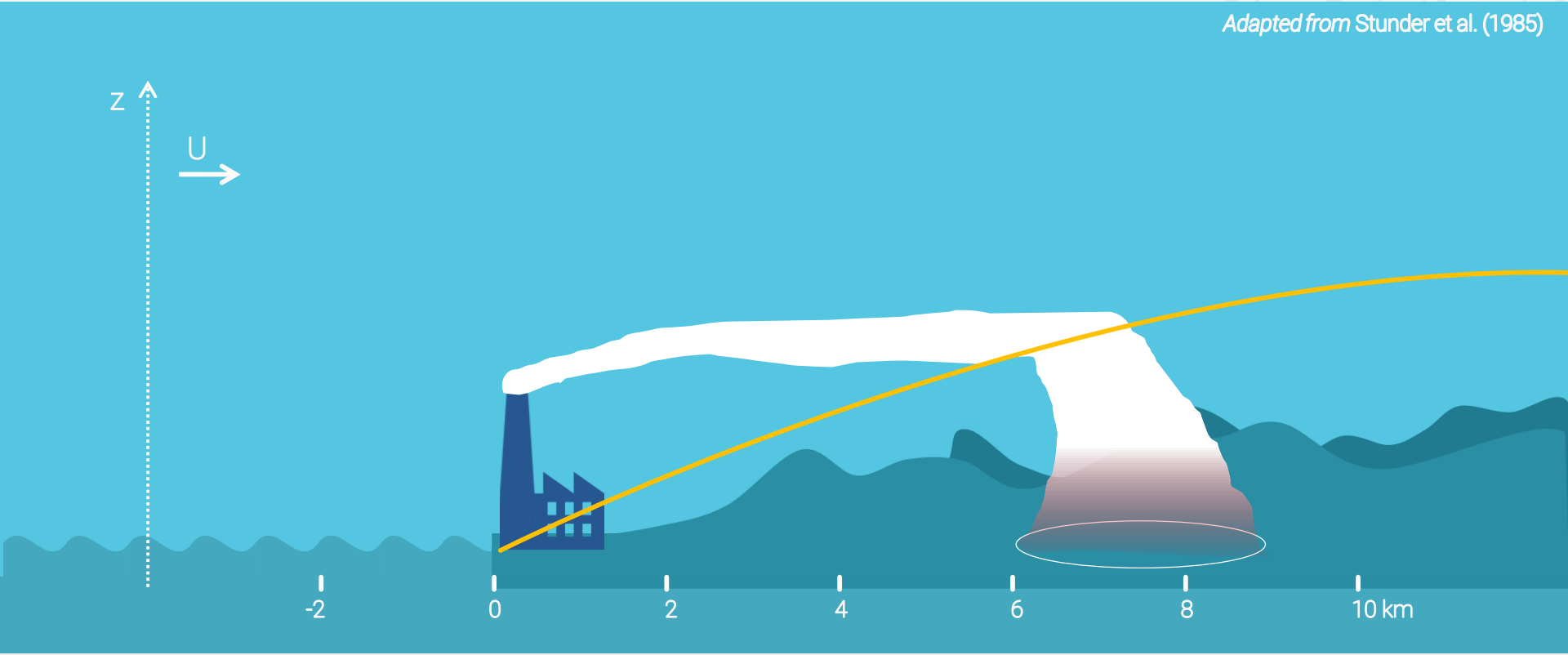
Garratt (1990)



Introduction

Air Pollution and IBL relationship

Adapted from Stunder et al. (1985)



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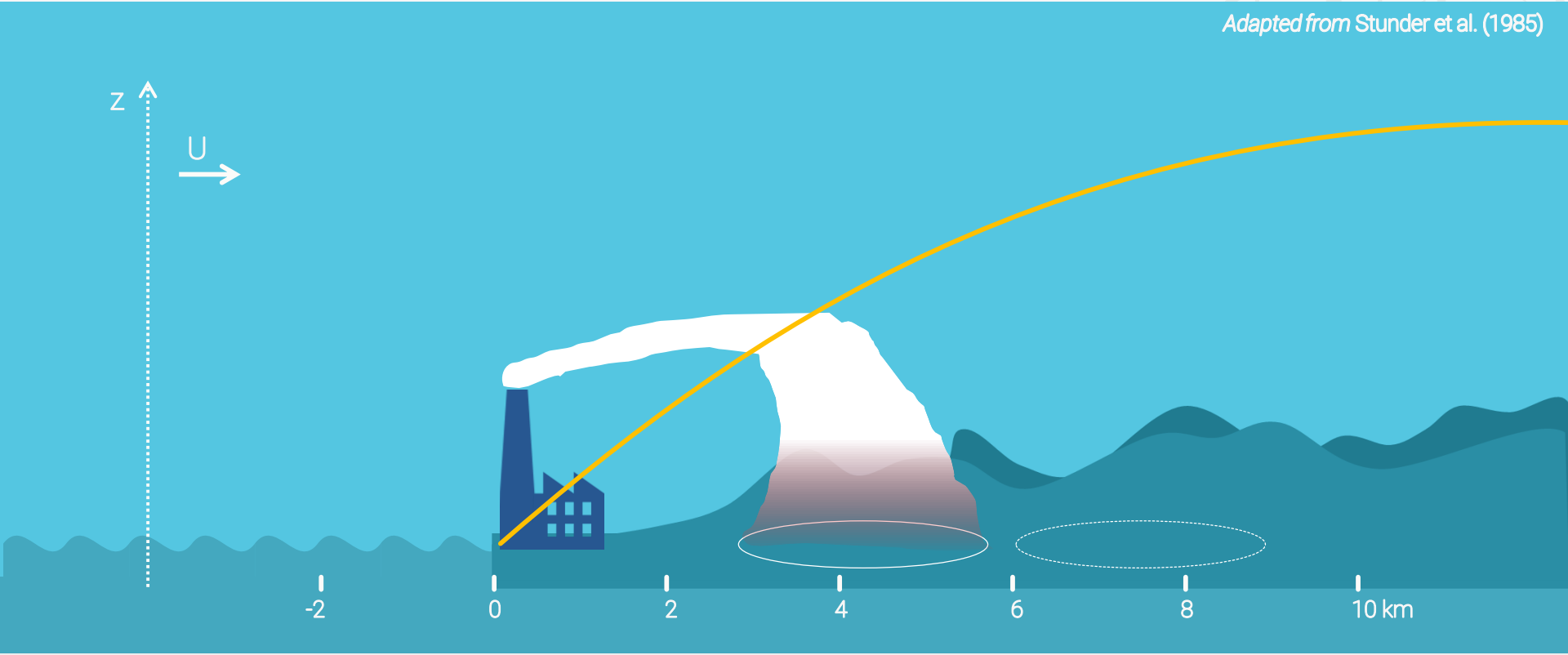


Introduction

Characteristics of Study Region

Rio de Janeiro - Brazil

- 12 million people
- Coast Line
- Topography
- Industry Activities
- Air Quality problems

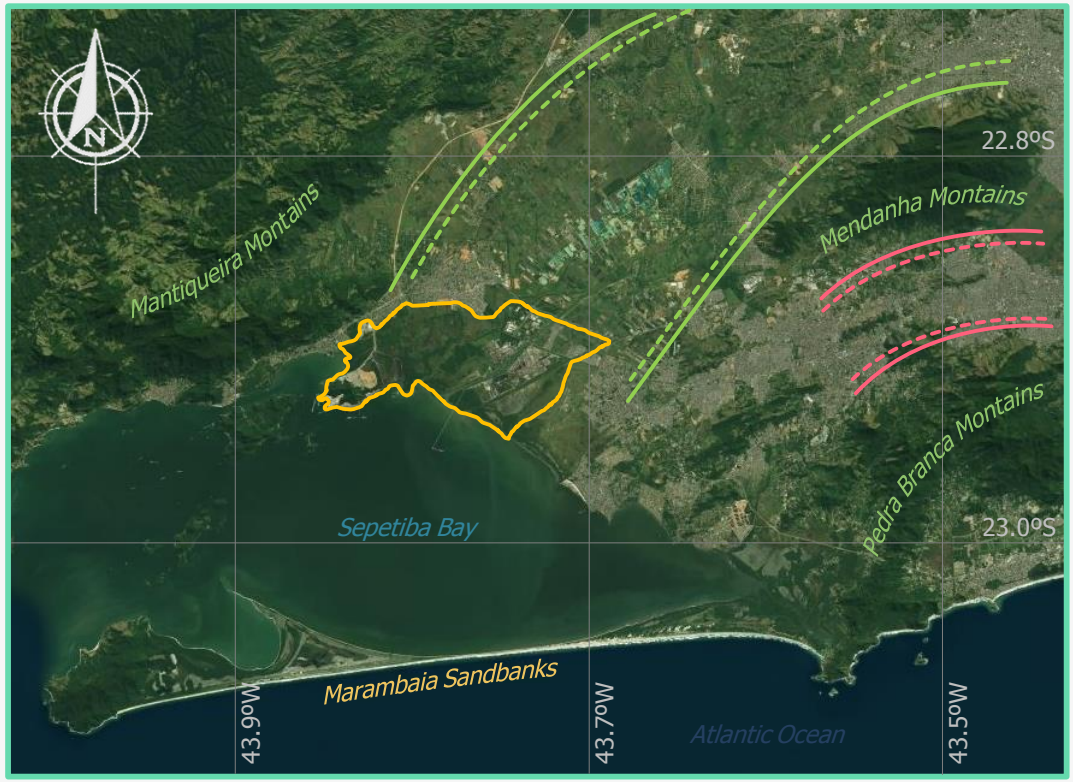
Objectives

of the present work

Identification and analyses of prevailing bay/land breeze regime in Santa Cruz (RJ) to: understand the process of Internal Boundary Layer (IBL) formation over this tropical region; to test suitable parameterizations for atmospheric and air quality modeling purposes under sea-breeze conditions.

Materials and Methods

Study Region – Rio de Janeiro, Brazil



Santa Cruz Mean Characteristics

Industrial district based on steel activities

Rural land use on Mendanha's Valley

High density urban area on Pedra Branca Valley

Regular coastline delimited by Sepetiba's bay

Predominance of bay/land breeze regime

Materials and Methods

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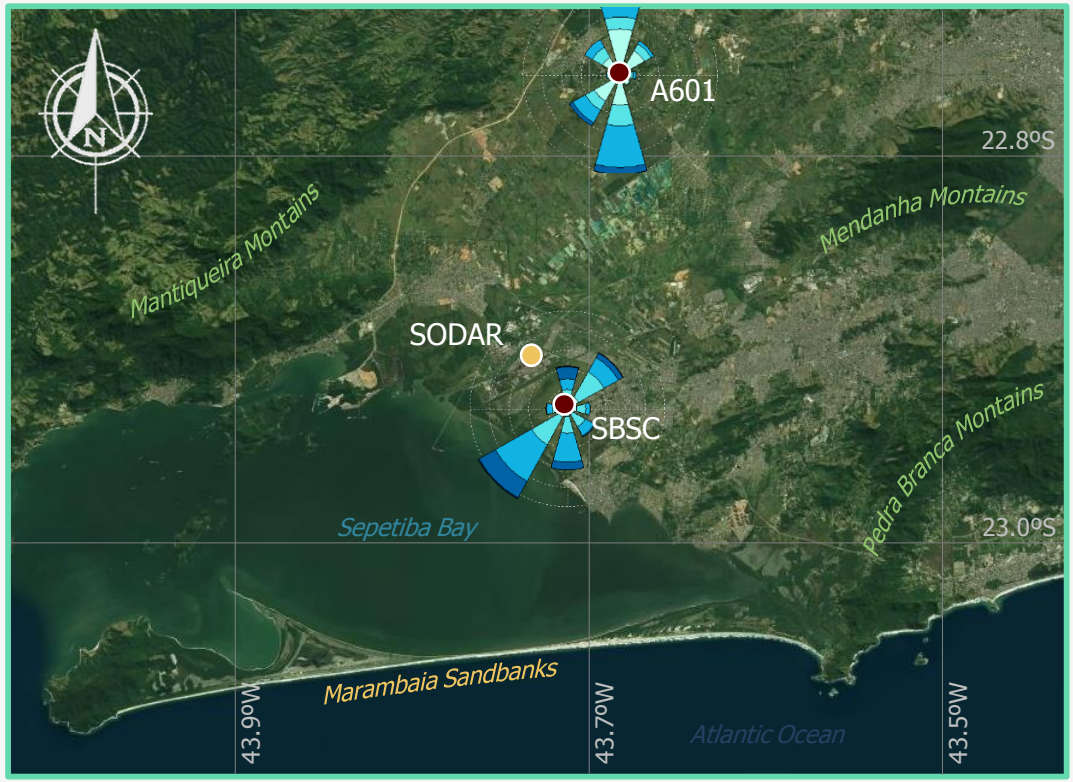


Santa Cruz Mean Characteristics

- Industrial district based on steel activities
- Rural land use on Mendanha's Valley
- High density urban area on Pedra Branca Valley
- Regular coastline delimited by Sepetiba's bay
- Predominance of bay/land breeze regime
- 2 Surface Weather Stations (WMO standard)
- Acoustic soundings profiler (SODAR/RASS)

Materials and Methods

Available Data • Processing • Models

Selection of 3 consecutive days with bay/land breeze circulation inside all SODAR/RASS data

SELECTION
special cases

PROCESSING
available data

Proceedings and treatments over observed data and estimative of other parameters relevant for bay breeze analysis

Detailed description of each bay breeze stage to identifying main features and propitious conditions for IBL building

BAY BREEZE
stages evaluation

PARAMETERIZATION
application on special case

Testing parameterizations already available on literature to estimate the IBL height during the special case

Materials and Methods

Selection of special cases

Study Period

- 26 to 28 December 2013
- Austral Summer
- High Pressure System

Selection Criteria

- Three consecutive days of bay/land breeze
- No clouds over study area
- No synoptic condition acting over region
- Simultaneous availability of data

Available Data

01/10/2013 «» 30/06/2014

SBSC (Coast) • Hourly Data
Wind (10m) • Temp (2m) • 3 km Coast

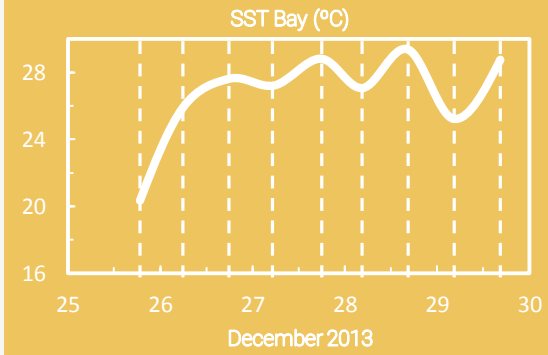
A601 (Inland) • Hourly Data
Wind (10m) • Temp (2m) • 20 km Coast

SODAR (Coast) • 10 min Data
First Level 40m • Vert. Res. 10m • 5 km Coast

MODIS Aqua (Bay) • 2x Day Data
Time Interpolated to build daily cycles

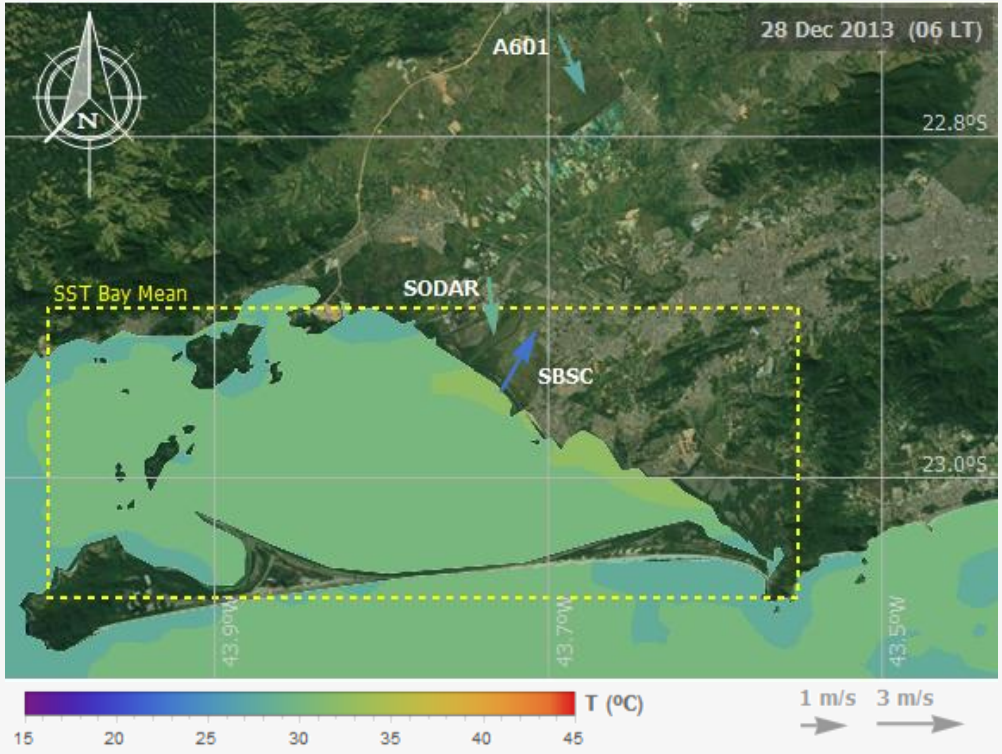
SST time interpolation

- Polynomial Interpolation between swaths
- SST over Sepetiba's Bay defined as a mean over a particular area



Results

Observed data



Bay/Land Breeze Cycles

Time evolution of circulation over Santa Cruz trough SBSC, A601, SODAR (40m), and SST data. The yellow dashed area represents the region used to SST Bay Mean.

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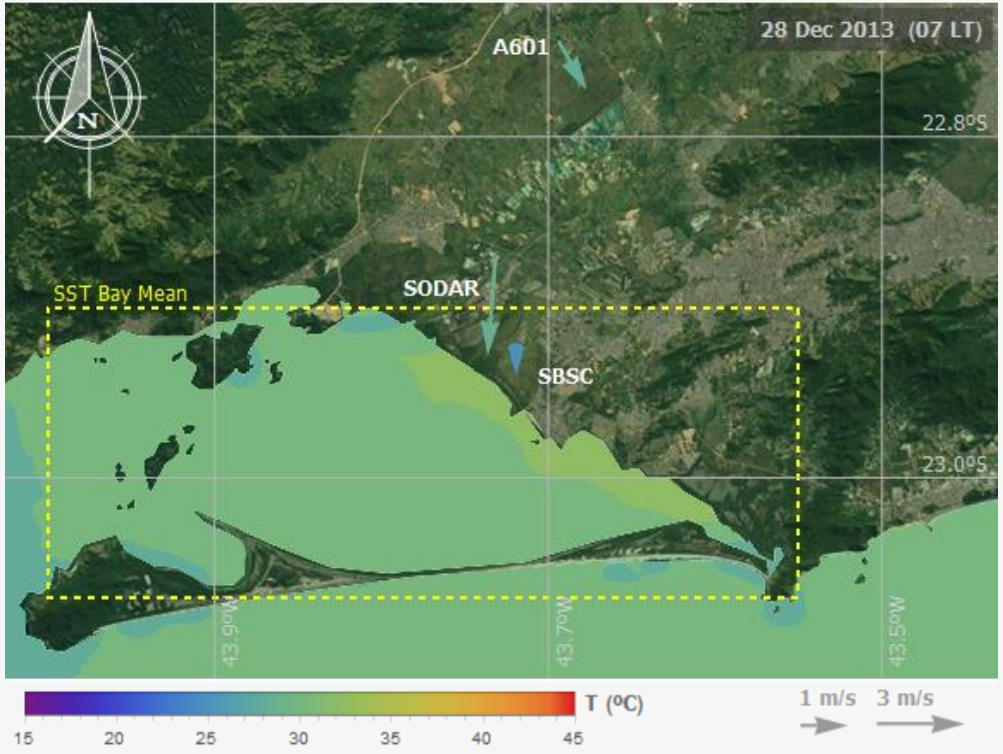

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z = 10 m	SBSC (Coast)	• Calm
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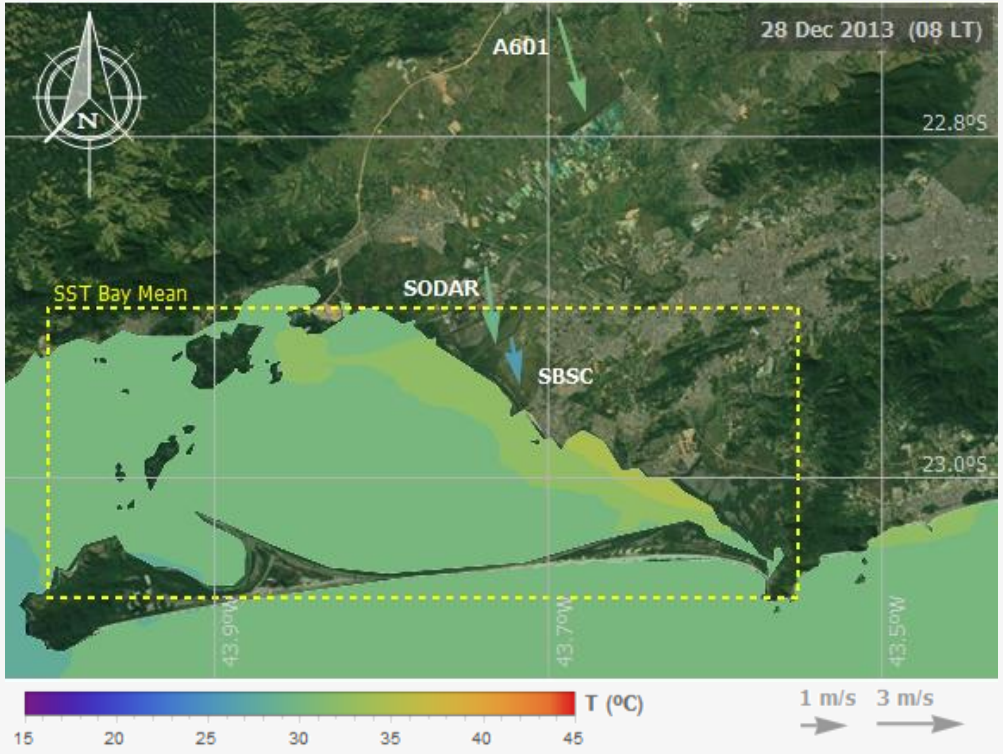

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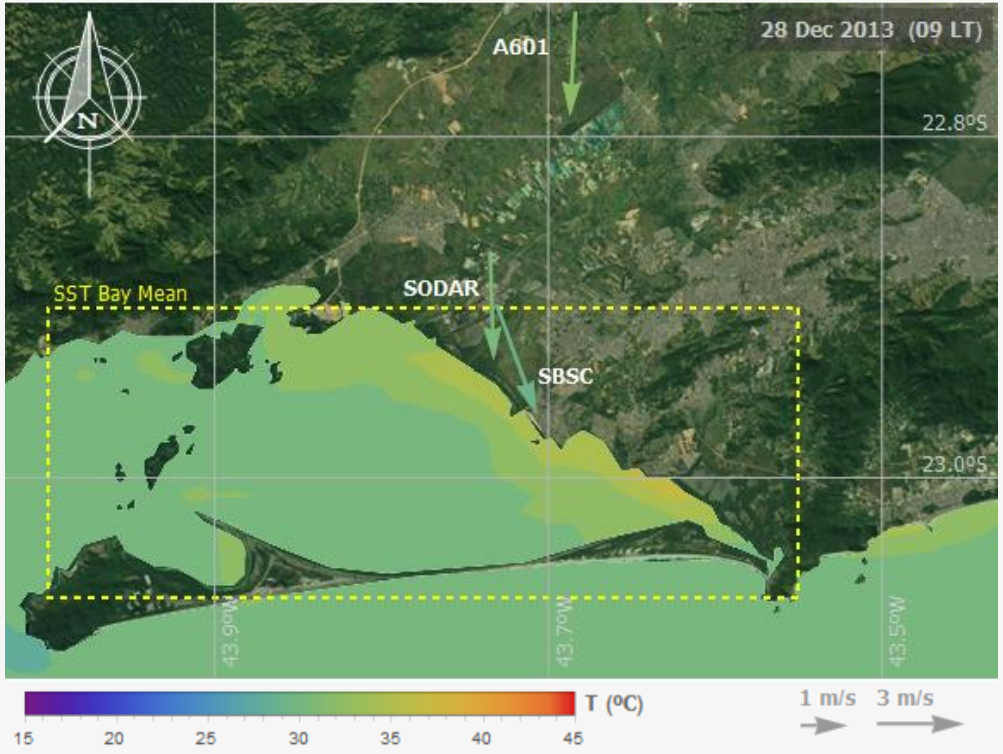

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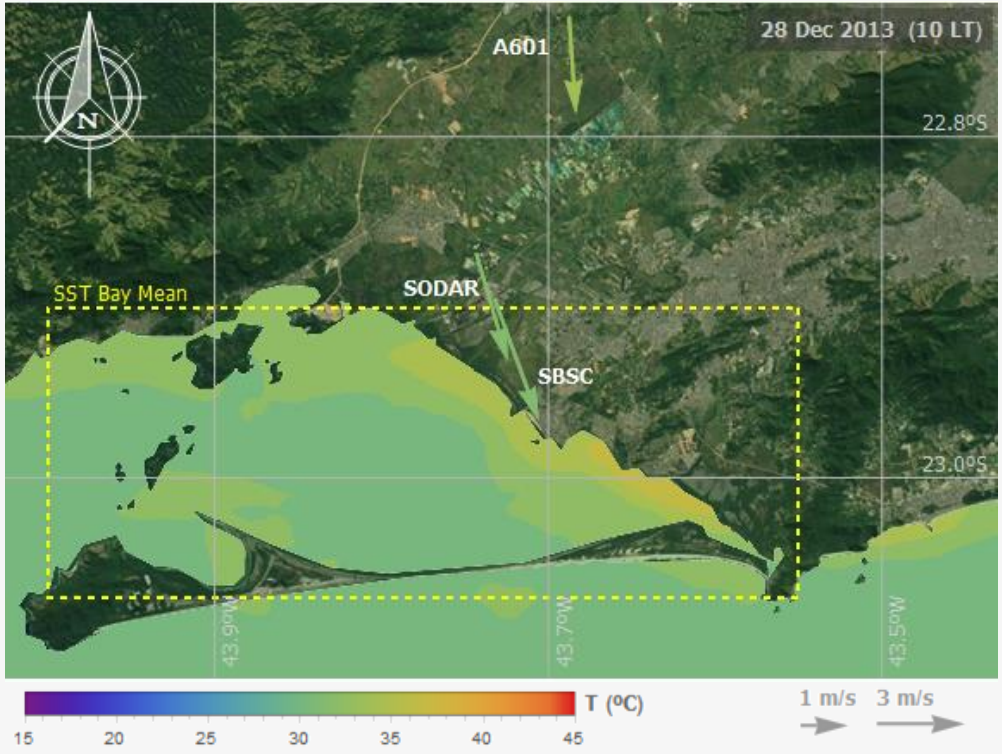

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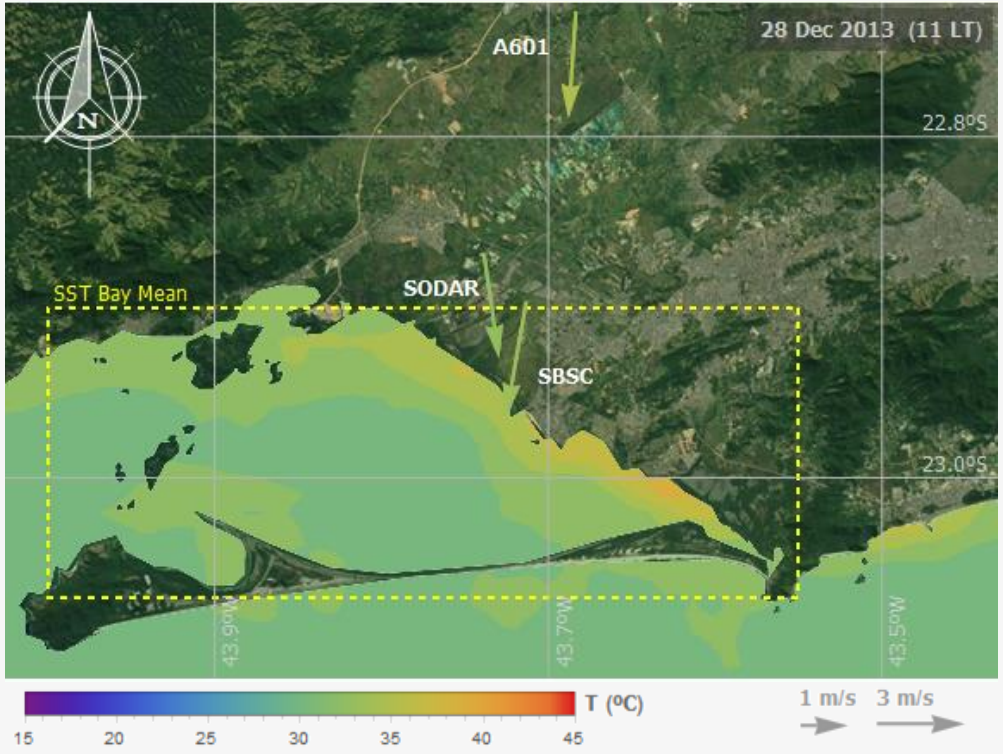

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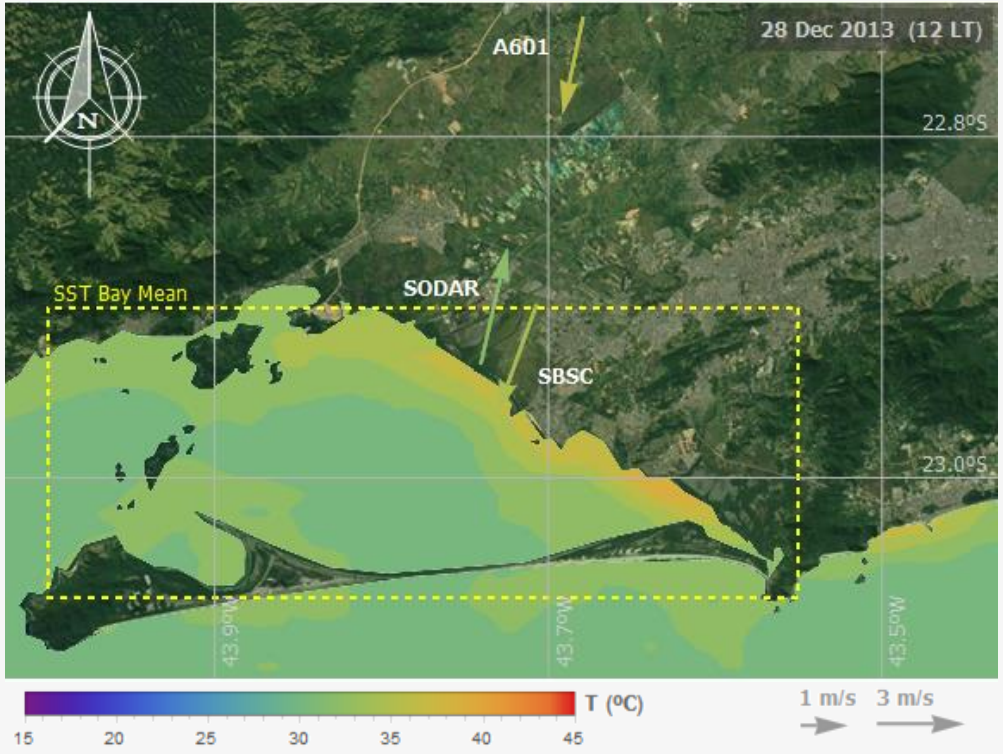

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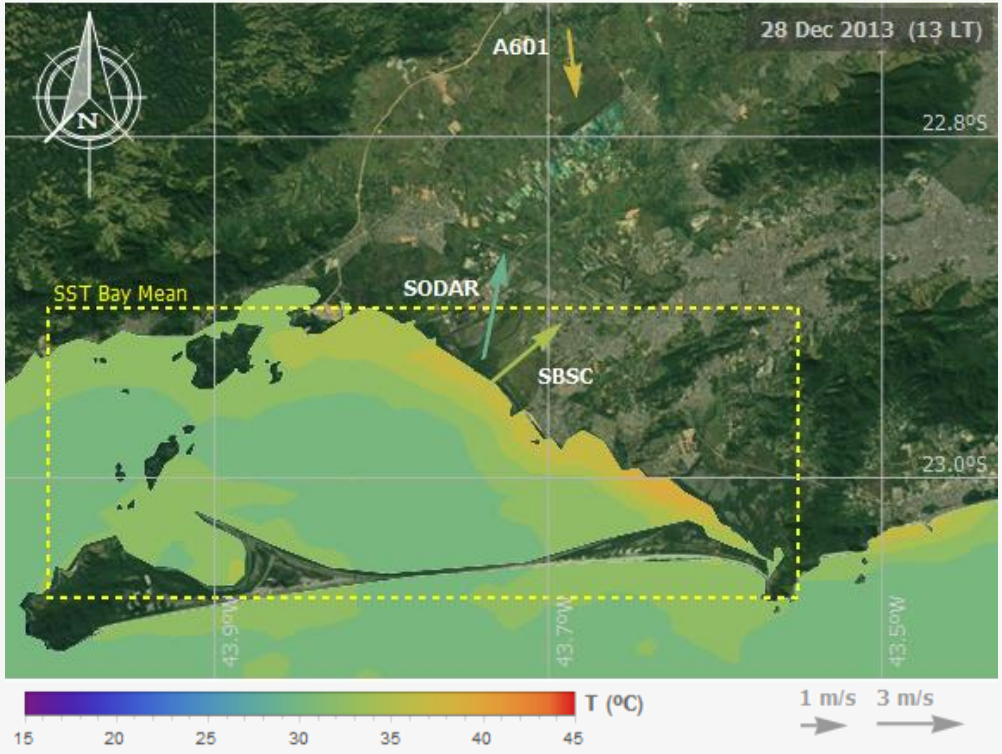

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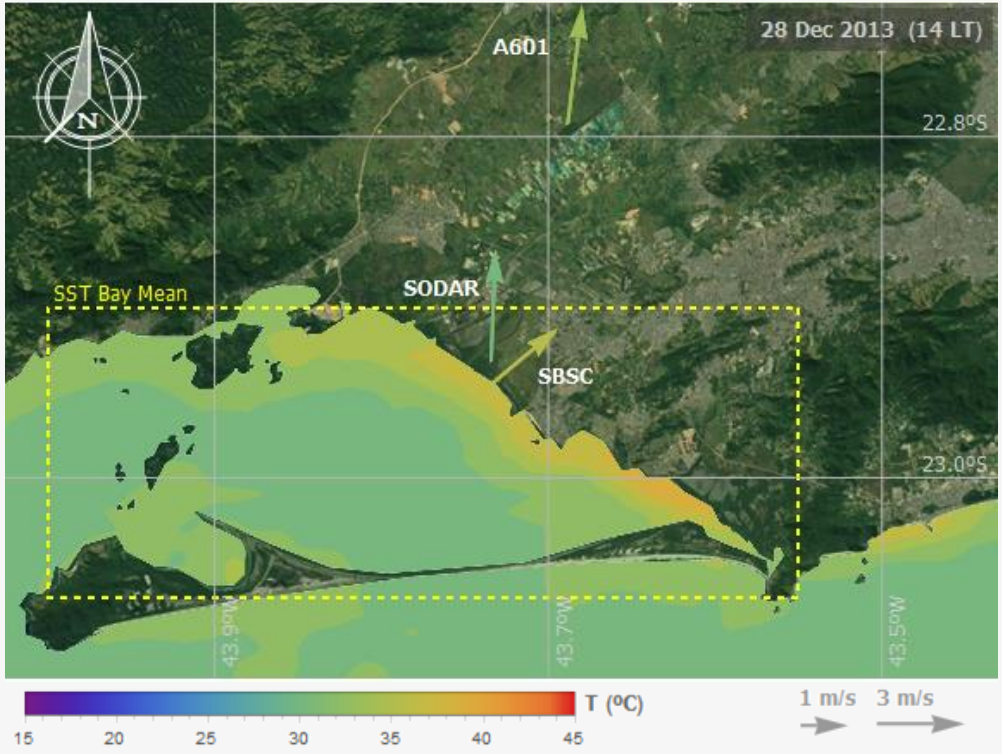

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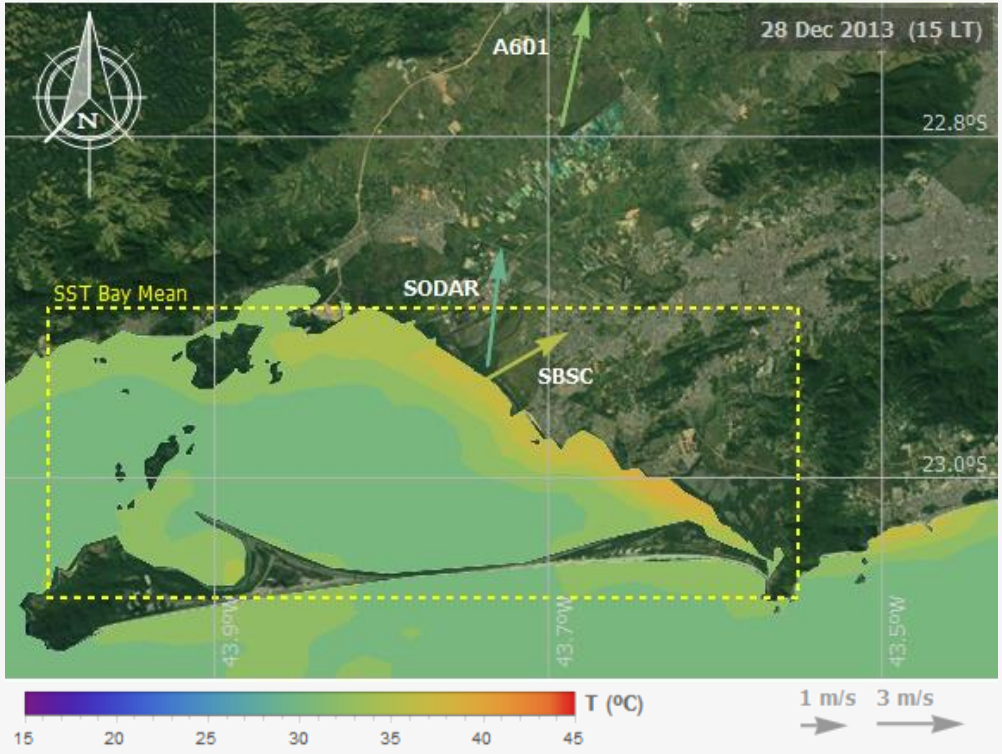

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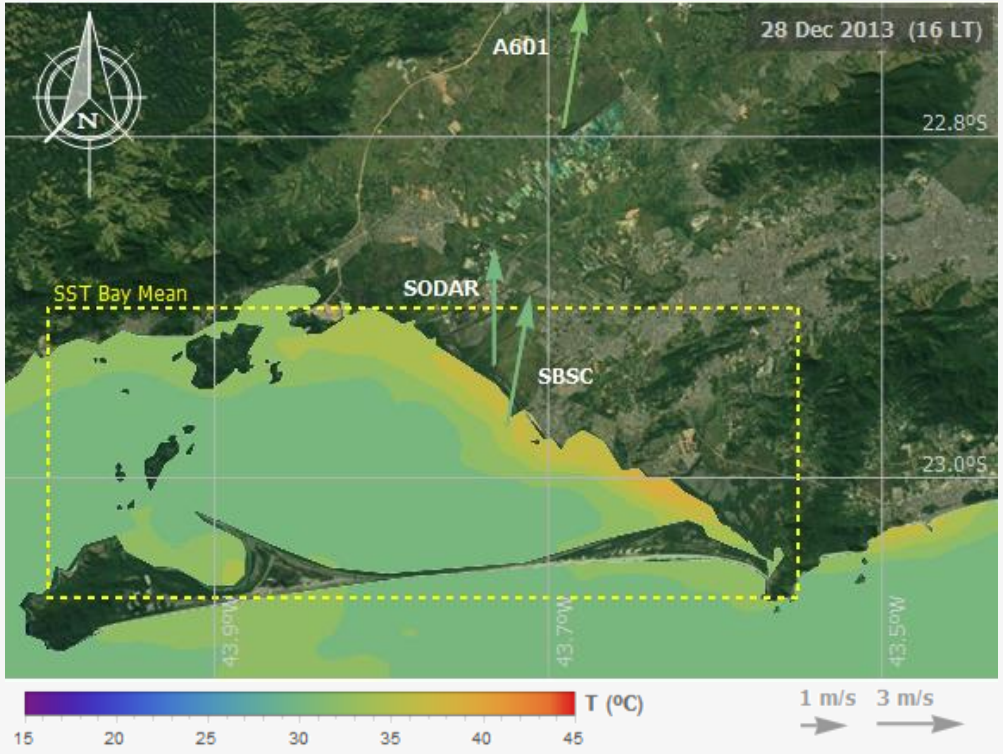

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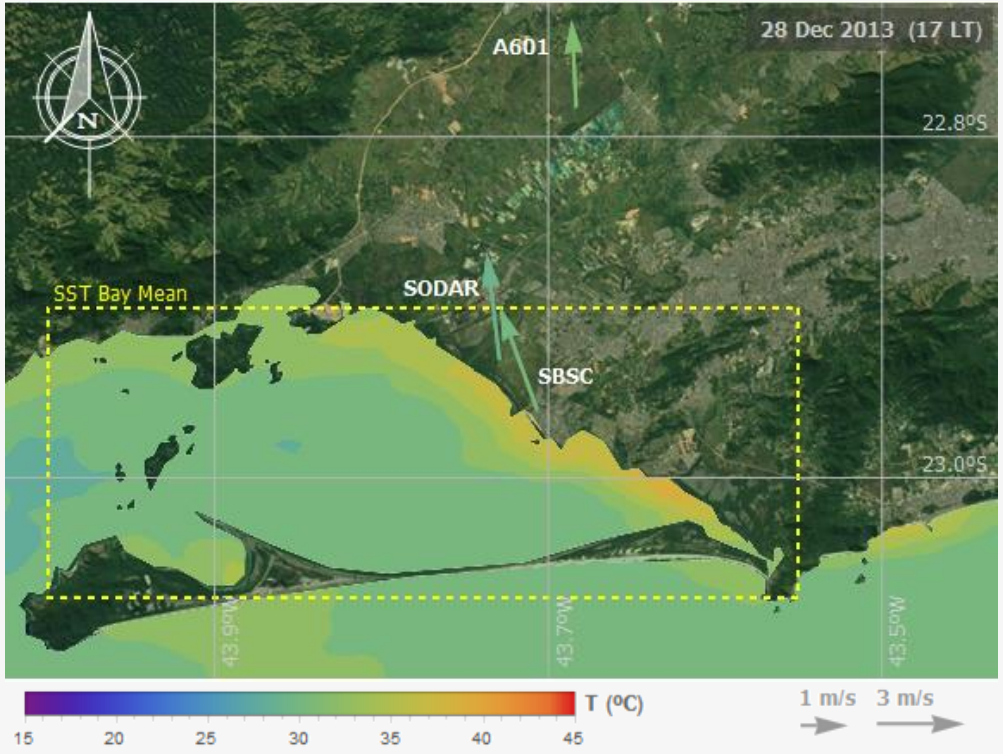

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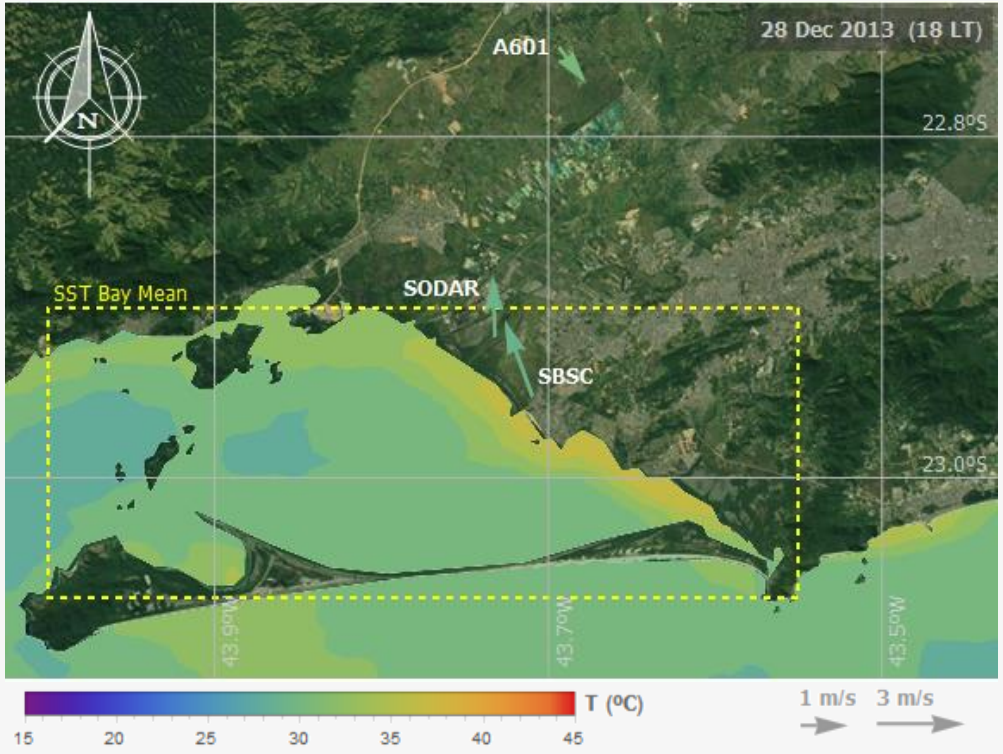

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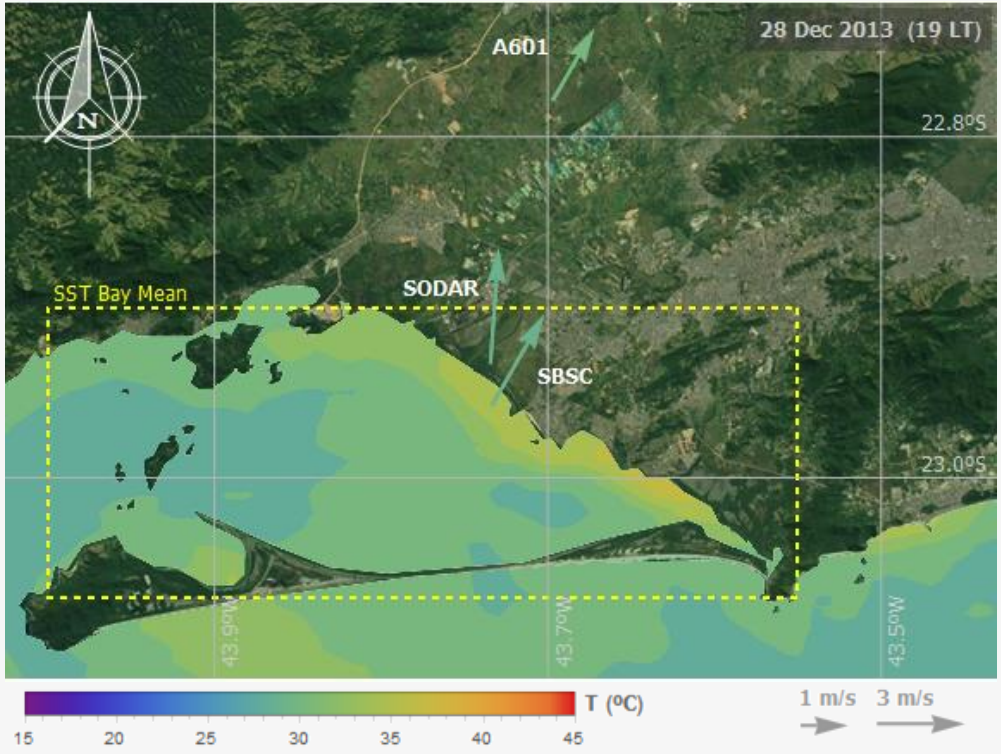

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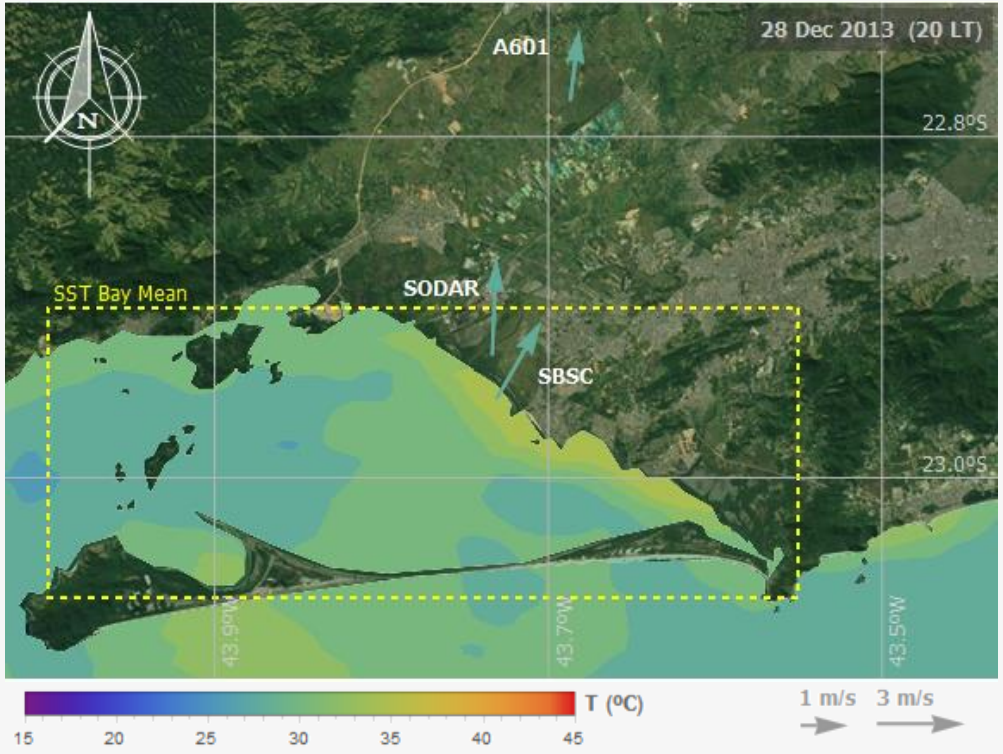

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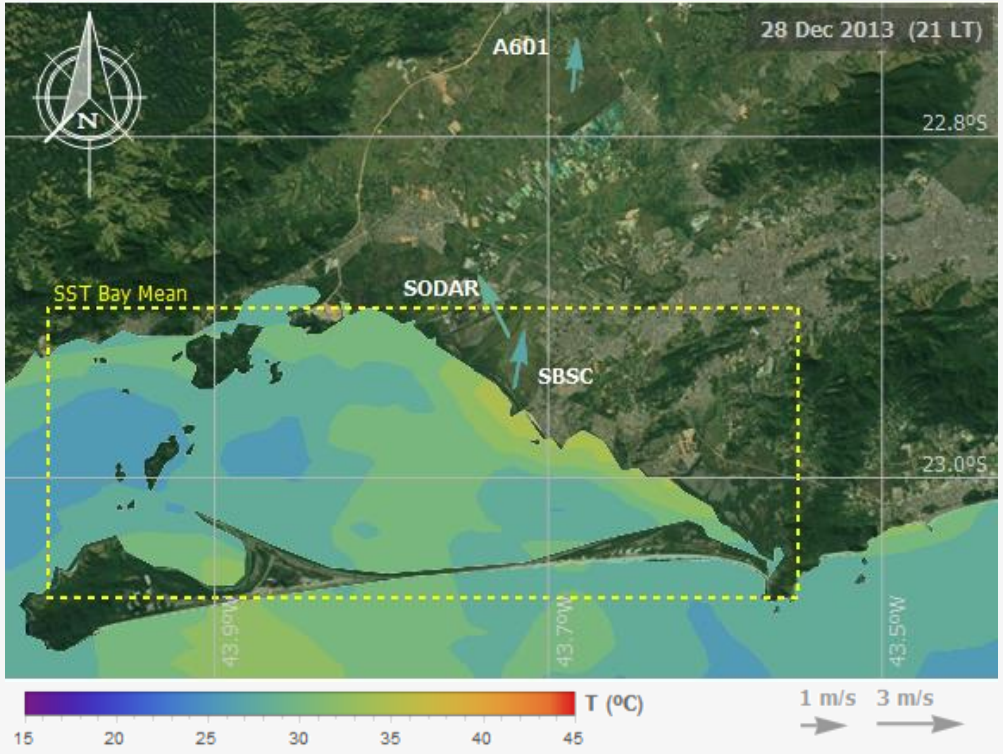

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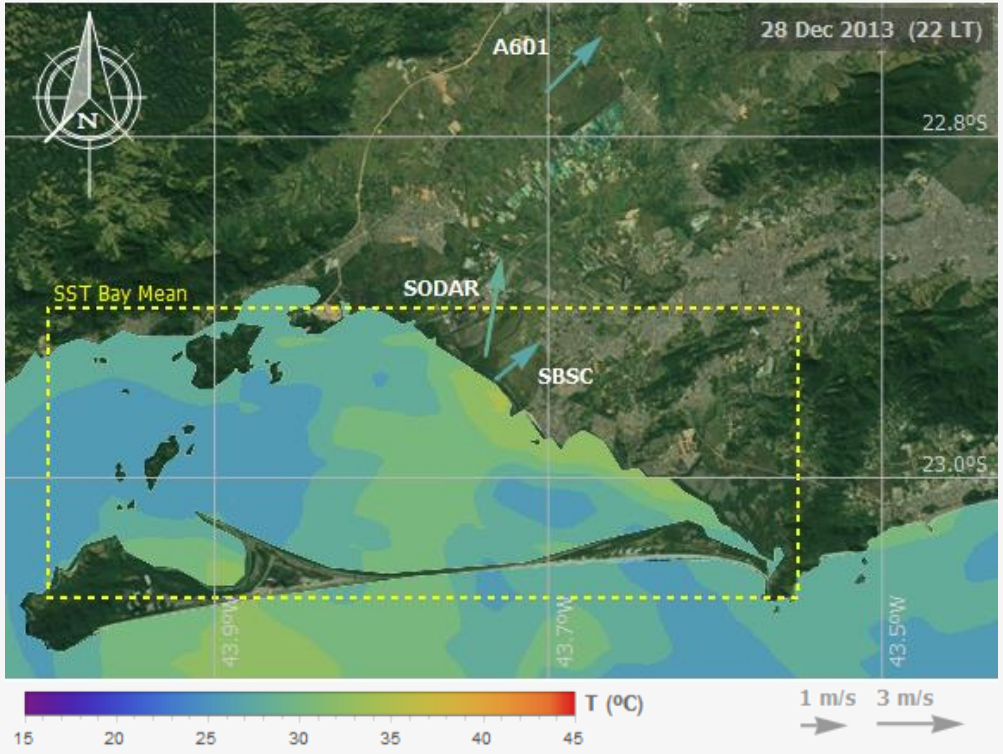

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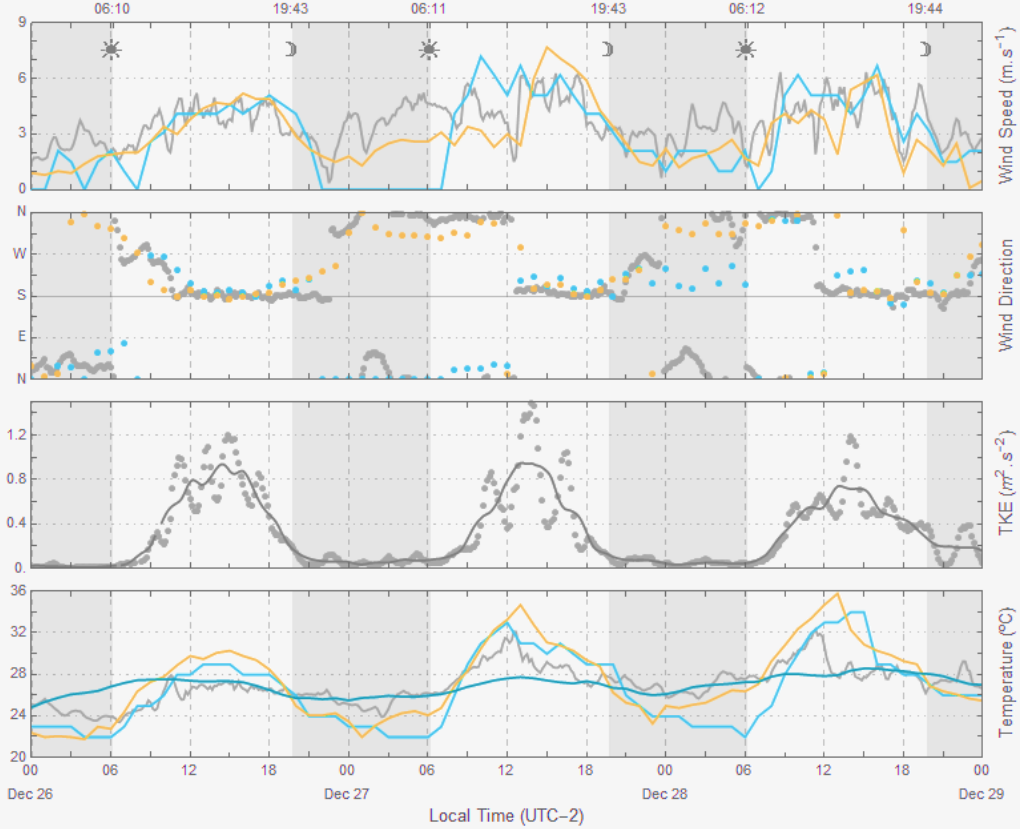

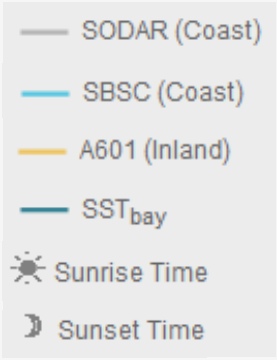

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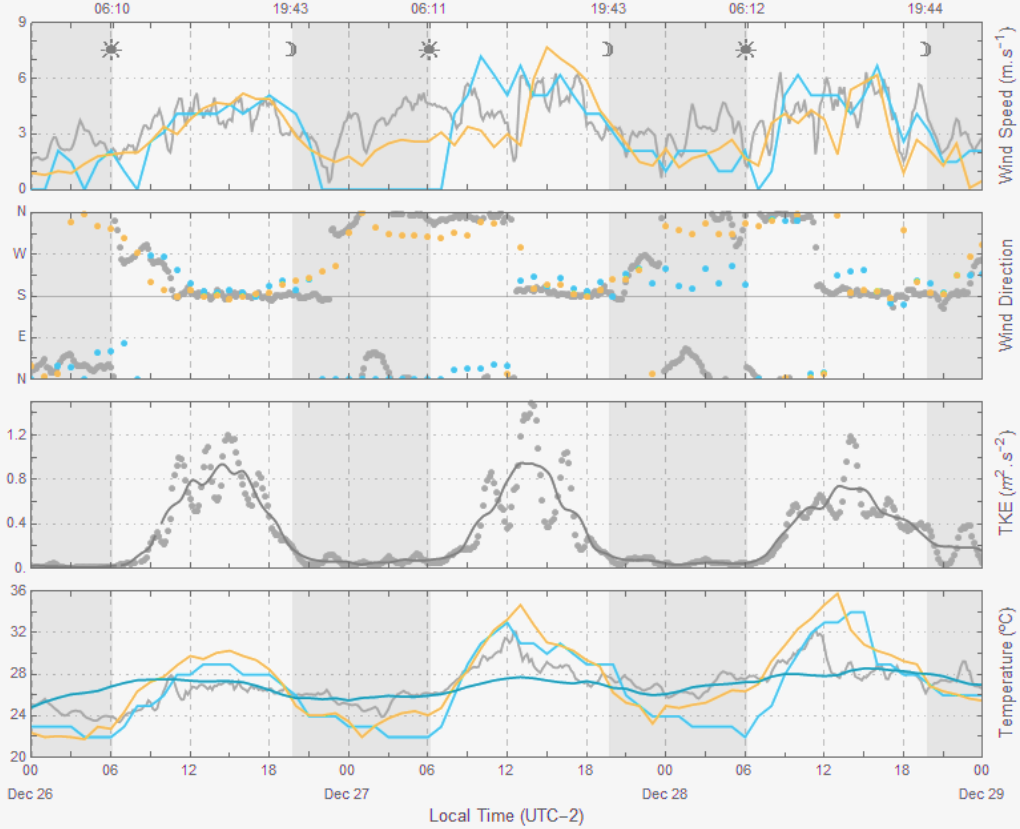


Previous phase

Initial warming inland — LST < SST
Calm winds on coast

Preparatory phase

LST > SST — CBL building (inversion breaks)
Wind shift on coast

Development phase

Wind shift inland — Front breeze
Max turbulence — LST » SST

Mature phase

Wind, TKE and LST-SST ~ Constants
Temperature slowly decreasing

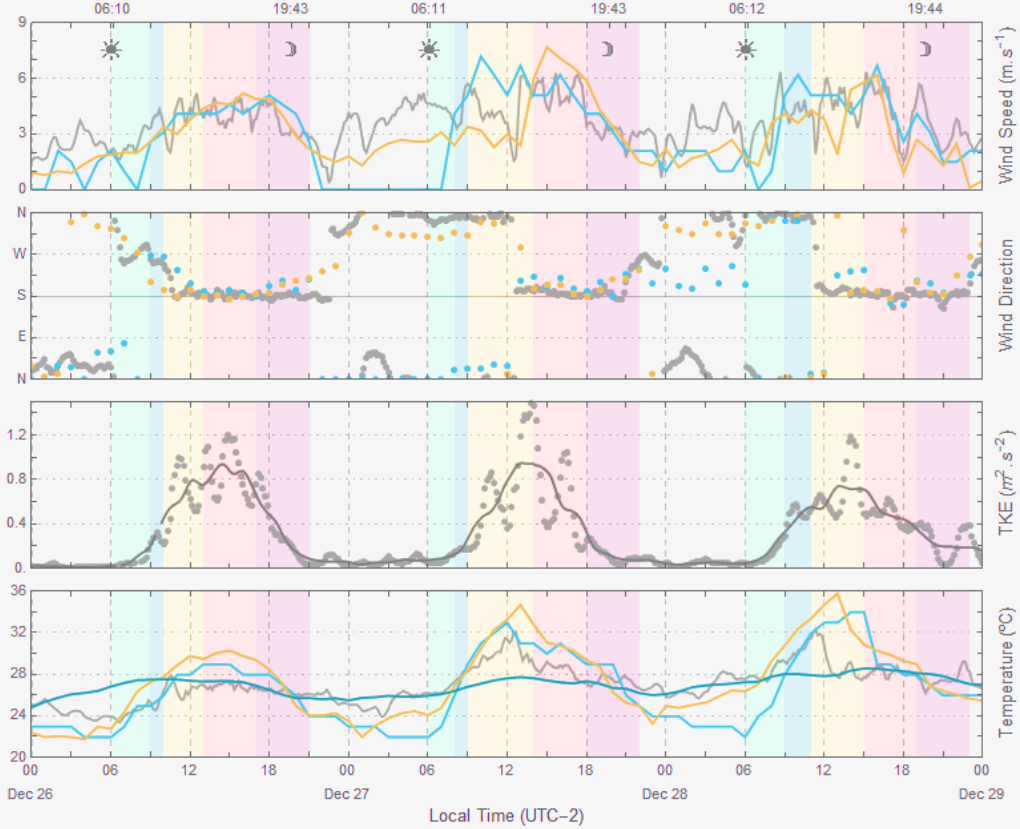
Decay phase

Wind, TKE and Temperature decreasing
Wind shift on coast — LST-SST weakens and change sign

SODAR (Coast) SBSC (Coast) A601 (Inland) SST_{bay} Sunrise Time Sunset Time

Results

Bay Breeze Stages



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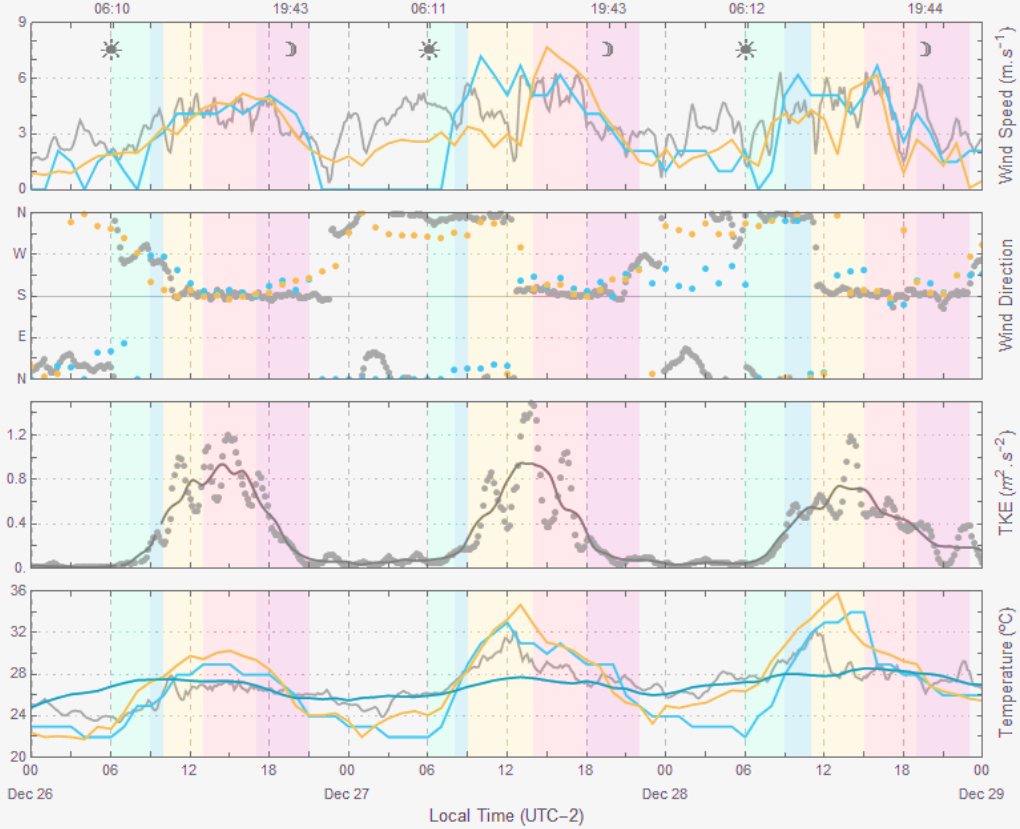


Previous phase

3 / 2 / 3 hours

3 hours
Cuxart et al (2014)

Preparatory phase

1 / 1 / 2 hours

1.5 hours
Cuxart et al (2014)

Development phase

3 / 5 / 4 hours

3 hours
Cuxart et al (2014)

Mature phase

4 / 4 / 4 hours

3h
Cuxart et al (2014)

Decay phase

4 / 4 / 5 hours

4h
Cuxart et al (2014)

SODAR (Coast) SBSC (Coast) A601 (Inland) SST_{bay} Sunrise Time Sunset Time

Results

IBL Height Models

Weisman (1976)

$$h = \left(\frac{2\, H_0\, x}{\rho\, c_p\, \beta\, U} \right)^{1/2}$$

SODAR (Coast) — Surface heat flux H_0

SODAR - SBSC (Coast) — Vertical temperature gradient β

SBSC (Coast) — Mean wind velocity U

Air density ρ

Specific heat at constant pressure c_p

Distance from coastline x

Raynor et al (1979)

$$h = \frac{u_*}{U} \left(\frac{x\, |T_T - T_M|}{|\gamma|} \right)^{1/2}$$

T_T Reference temperature over land — SBSC (Coast)

T_M Reference temperature over water — MODIS Aqua (Bay)

u_* Friction velocity — SODAR (Coast)

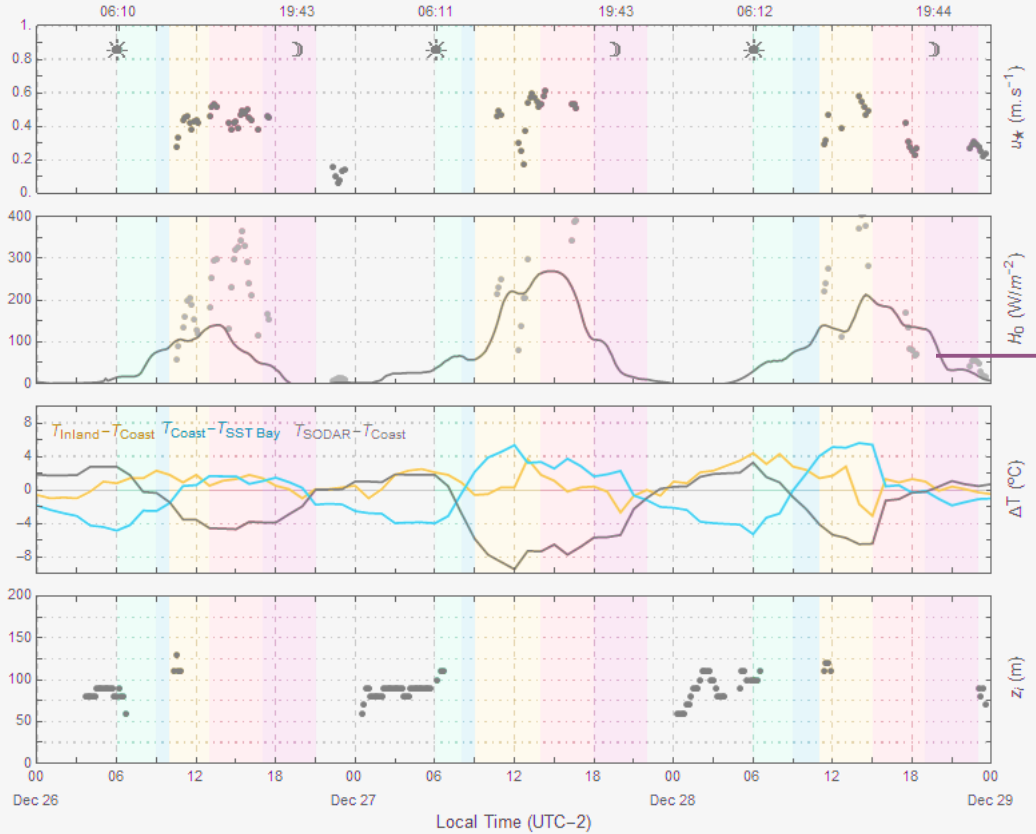
γ Lapse-rate — SODAR (Coast)

U Mean wind velocity — SBSC (Coast)

x Distance from coastline

Results

Relevant Parameters



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Melas (1993)

$$H = \frac{\rho\,c_p\,\theta\,\sigma_w^3}{1.9^3\kappa\,g\,z}$$

the minimum least squares method H_0

Bay Breeze Stages

- Previous
- Preparatory
- Development
- Mature
- Decay

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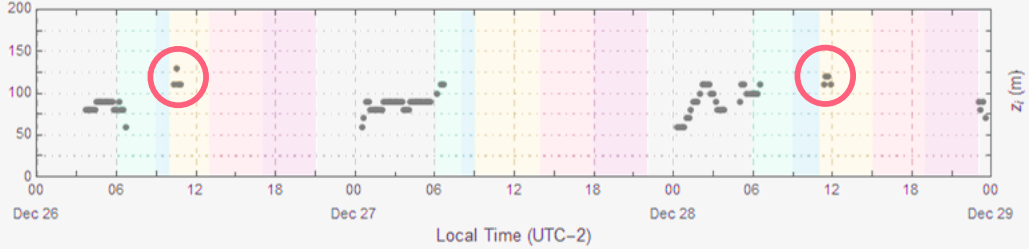

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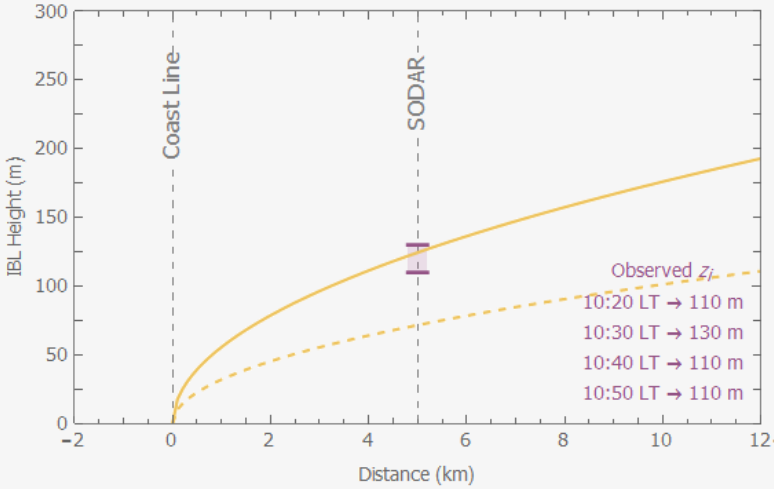
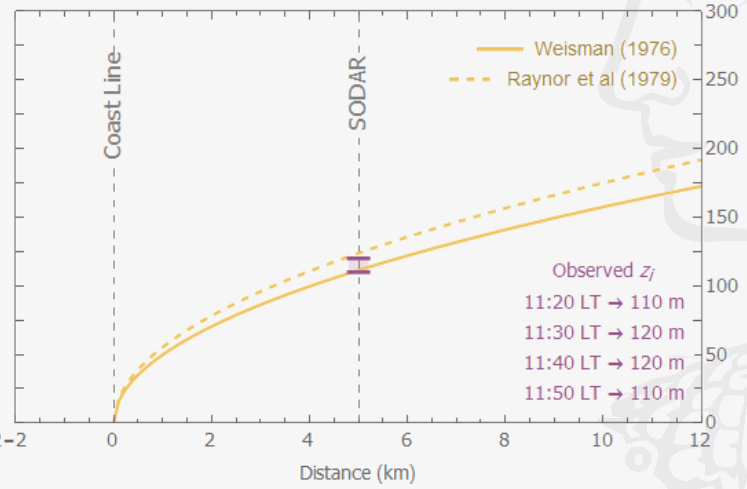
December 26 (10 LT)



December 28 (11 LT)



Conclusions

IBL Height Models

Mean Objective

A thorough analysis over three consecutive and entire cycles of bay-land breeze was presented with a focus on the evaluation for onset of IBL and its evolution in time.

Bay Breeze Stages

The development phase showed the critical period of bay breeze due the highest differences between air mass properties over bay and land, **providing the propitious conditions to IBL formation**.

Processing Data

The material and methods applied on observed data proved to be in agreement with the expected physics for this problem, and enable to estimate other relevant parameters reasonably well.

IBL Height Models

Parameterizations available on literature showed good performances in comparison with SODAR/RASS measurements, where **the formulation based on H_0** presented the best results.

Study Period

Despite the late wind shift to bay breeze direction found on 2nd day, **the study period proved to be a representative case** where each bay breeze stage could be actually recognized.

Ongoing

Checking wind scaling (physics-based) models and use them to improve performance of dispersion models in conditions of sea breeze occurrence.

Analysis of the Internal Boundary Layer formation

on tropical coastal regions using SODAR data in Santa Cruz region of MRRJ

Thank you!

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