SKIM-PE D-20: MPERS Mission Performance Evaluation Reference Scenarios (TN-2)

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Contents

1 Introduction

This document provides a description of the scenari used to perform the SKIM mission evaluation.

2 Scenario definition and summary

Gilles
Each scenario is defined by the combination of 4 ingredients that are described in details in the following :

- An Orbit (§3.1)
- An antenna configuration (§3.2)
- A region of interest (§3.3)
- Models inputs (§3.4)

A summary of the scenario finally deployed for the performance evaluation is given in TABLE xx
insérer un tableau excel qui rassemble les scenari

Figure 1: List of scenari used for SKIM performance evaluation

3 Reference geometry

3.1 Orbits

Different orbit scenarios will be simulated based on the suggested orbits in the MRD and according to any evolution that may arise from System study or from the SKIM MAG. Five orbits are of interest for SKIM:

- Metop Orbit enables to have a good atmospheric measurement ahead of SKIM and thus will provide useful information to correct for wet tropospheric errors. It has also a high altitude and thus provides a wider swath than with Sentinel 1 orbit. The revisit at the Equator may be an issue.
- SKIM α specific orbit, where a trade-off between revisit at the Equator and coverage is made. A high altitude is preferable to have a swath as wide as possible
- SKIM β specific orbit,
- A fast sampling orbit, with a three day revisit, to perform calibration study. This orbit will only be activated for few months after the launch
- A 8 day scanning orbit can also be used for a fast sampling orbit, as half of the swath is recovered from one revolution to an other.

Characteristics of these orbits are summarized in table 1.

orbits	cycle (days)	inclination (°)	revolutions / cycle	sous-cycles (days)	altitude (km)	Local time at ascending node
Metop SSO	29	98.63	412	5	≈ 817	6h or 7h
SKIM dedicated α	27	98.6	383	5 / 11	≈ 790	6h or 7h
SKIM dedicated β	22	98.9	309		≈ 870	6h or 7h
Fast sampling	3	98.5	43		≈ 775	6h or 7h
Fast sampling scanning	8	98.8	113		≈ 845	6h or 7h

Table 1: Characteristics of the three selected orbits

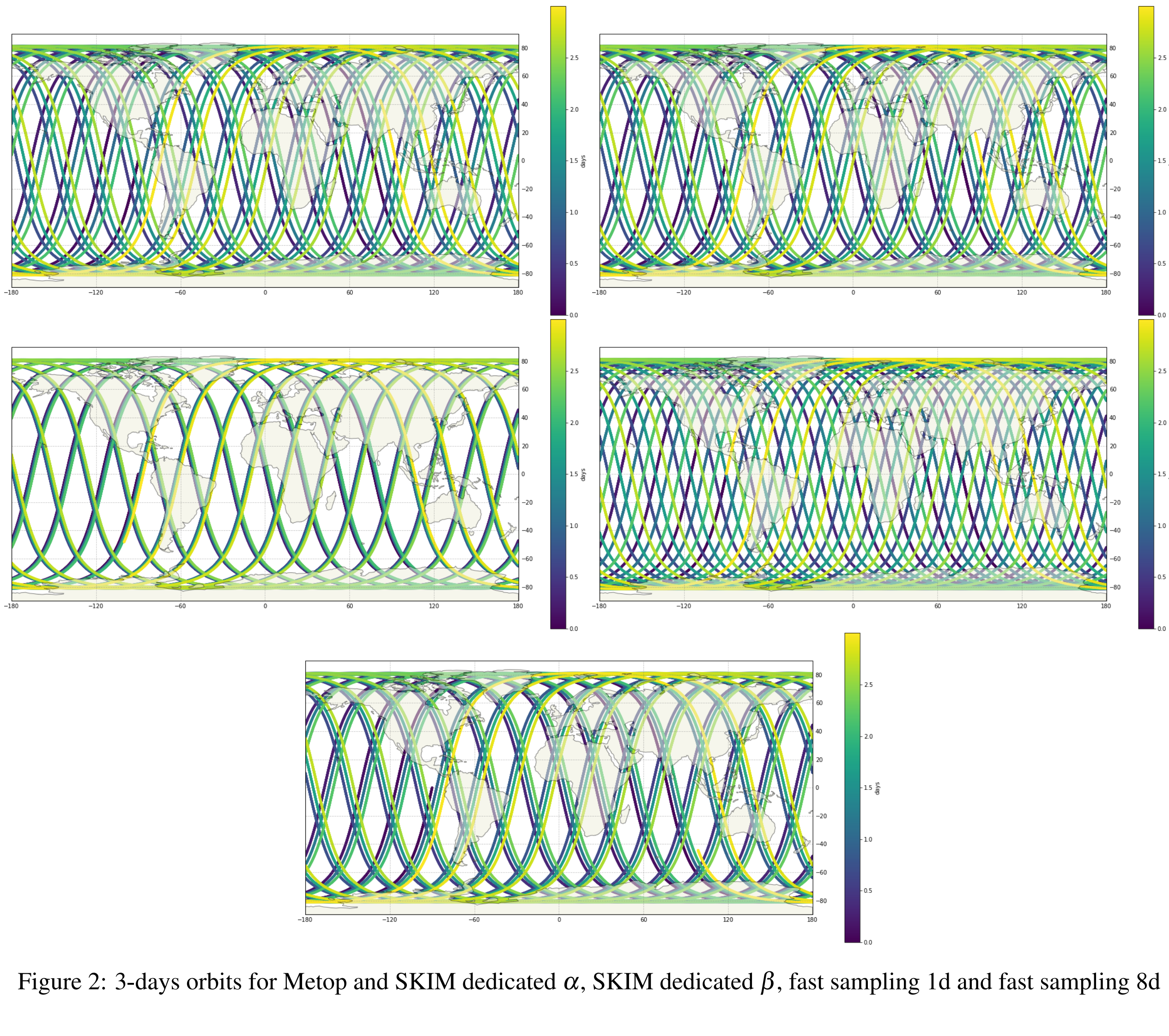


Figure 2: 3-days orbits for Metop and SKIM dedicated α, SKIM dedicated β, fast sampling 1d and fast sampling 8d

The LTAN (Local Time at Ascending Node) may evolve. There is a trade-off to find between a SSO orbit to maximize the sun light and the hour at tropics to minimize the morning rain.

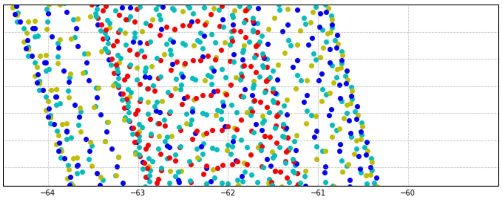
3.2 Antenna configuration

For a given orbit, several scenarios of feed horn location, incidence and sequence will be proposed to assess the best compliance with the SKIM sampling requirements.
Four configurations will be studied to optimise the beam distribution over the ocean and enable the best reconstruction of the current. It is of importance for L2C and L3 reconstruction that azimutal direction of crossing points are as perpendicular as possible. Characteristics of four configurations are summarised in table 2 There is a trade-off to find

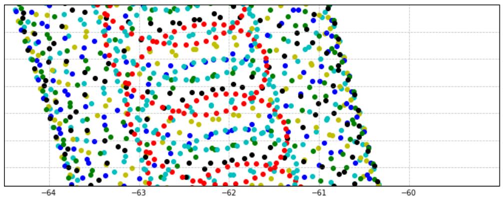
configurations	number of beams	pulses	cycle length (ms)	rotation speed (rpm)	number of azimuths
2018-6a	6 (two 6º, three 12º)	512	18	9.26	60
2018-8a	8 (two 6º, five 12º)	1024	37	4.52	45
2018-8b	8 (two 6º, five 12º)	512	18	5.66	72
2018-8c	8 (two 6º, five 12º)	1024	37	1.89	108
2019-6b	8 (two 6º, threee 12º)	1024	37	6.0	108

Table 2: Feed horn configurations

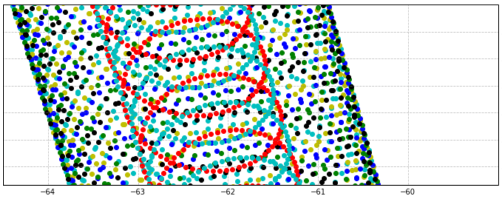
between distribution and the number of pulses as a shorter number of pulses will make the wave detection very noisy.



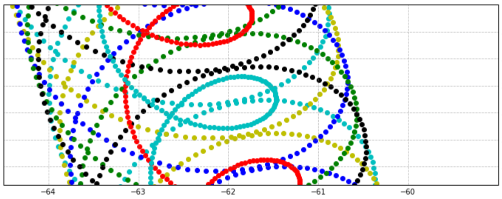
(a) Configuration 2018_6a



(b) Configuration 2018_8a



(c) Configuration 2018_8b



(d) Configuration 2018_8c

Figure 3: Configurations 2018_6a, 2018_8a, 2018_8b, 2018_8c using METOP orbit

4 Reference scenarios

The reference scenarios are meant to assess the impact of SKIM instrument/orbit trade-off on the mission performance in a broad range of environmental conditions using the end2end simulator developed as part of the proposed activities.

4.1 Scene instrumental simulator

For the E2E simulator up to Level 2b, we expect the reference scenarios to cover best, average and worst cases sea state conditions under a constant current over a given skim 6km x 6km footprint with either no, constant or linearly variable atmospheric perturbation. Each reference scenario is expected to be repeated with a set of azimuth angles with respect to wind wave direction and a set of surface current speeds.
Additionally, for the SKIMulator, we expect reference scenarios derived from oceanic circulation, sea state and atmospheric model covering similar but realsssssstic best, average and worst case sea state conditions with realistically varying surface current and atmospheric perturbations over a wider area typically a few rotations of the SKIM antenna .

The best case sea state conditions are meant to be the one moderate to low constant wind speed and no swell. The average sea state conditions are expected to be composed of a wind sea under moderate wind around 7m/s with additional average 1.5m swell SWH propagating 45° from wind direction.
The worst case sea state conditions are meant to be steep wind waves under high and gusty wind speed with in-homogeneous back-scatter across the SKIM footprint azimuth and range, with additional longer swell propagating in the wind direction.

	Wind dir.	Wind speed	Current dir.	Current speed	Swell dir.	Swell SWH	Swell wl.
Units	from al	m/s	from al	m/s	from al	m	m
Average	90°	7	45°	0.5	45°	1.5	200
Best	90°	7	0°	1	no	no	no
Worst	90°	15	90°	1	90°	4	400
low wind	90°	3	0°	0	45°	2	200
mod wind	90°	7	0°	0	no	no	no
str wind	90°	15	0°	0	no	no	no
along track	0°	5	0°	1	0°	2	400

Table 3: Scene simulator scenarios table ("dir." stands for direction and "al" for along track).

4.2 Ocean simplified simulator

The skimulator will run the previously defined scenes to compare l2a and l2b results with the instrumental simulator. Realistic scenes will also be studied using Ocean Geophysics Circulation Model (OGCM).

4.3 Regions of interest

Among the difference geographical area of interest, to represent significantly different surface current regimes and the relative importance of the geostrophic equilibrium, five cases will be carefully studied (cf 4):

- Equatorial area
- Dynamical area such as Gulf Stream
- Coastal current such as the Agulhas
- High latitude area like Fram Strait or Drake Passage
- area with a dominant inertial current (Gulf of Gascogne)

The Equatorial area will cover the Atlantic basin between 8ºS and 8ºN. As the geostrophic hypothesis does not apply near the Equator, the altimetry does not provide any information on the circulation. SKIM can be a huge asset to measure currents.
On the contrary, the Gulf is mainly governed by geostrophy and is very dynamic with fast eddies transported by the current.
In the Agulhas area, we will look at a coastal current and assess how SKIM will retrieve such currents knowing that the signal will be highly impacted by the coast.
The polar area (Fram Strait or Drake passage) will enable us to investigate measurements at high latitude. With a revisit time of one day, L3 reconstruction should enable us to retrieve current at smaller scale than in mid-latitude. The impact of sea ice on the measurement as well as the potential of SKIM on ice will be looked at in this scenario.
Finally the Gulf of Gascogne will demonstrate how well inertial currents can be retrieved from SKIM-like observation as this area is largely dominated by this component.

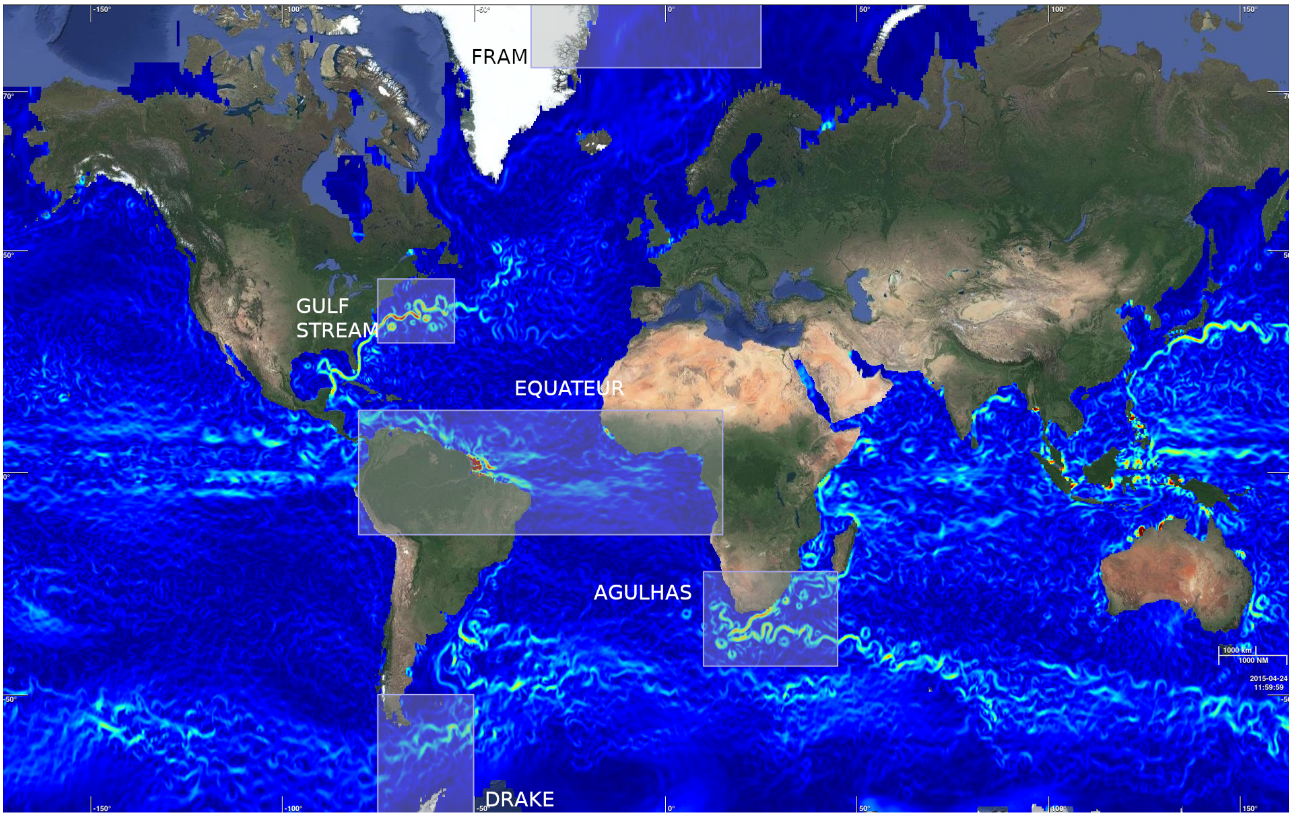


Figure 4: Areas of interest plotted over the norm of the total current from GlobCurrent

4.4 Model inputs

WAVEWATCH®III (WW3) spectral ocean surface wave models hindcasts are used as input fields for the SKIM simulator. They are publicly available at :

`ftp://ftp.ifremer.fr/ifremer/ww3/HINDCAST/OTHER/SKIM/`

SKIM hindcasts consist of several regional grids forced by :

- 10 m above the ocean surface wind speed vector
- sea-surface height (SSH)
- surface current vectors
- ice fields (concentration and thickness)

Characteristics both for the global grid (GLOB15M) and the SKIM regional grids are listed in the tables hereafter. All of them are regular lon-lat grids.

Grid name	GLOB15M	GULFSTREAM	FRAM	EQUATOR
Longitude range [°E]	0; 360	280; 300	335; 23	175; 20
Longitude resolution [°]	1/4	1/60	1/10	3/40
Latitude range [°N]	−78; 80	32; 42	73; 85	−16; 16
Latitude resolution [°]	1/4	1/60	1/60	3/40

The forcings used for this study are described in the present section.

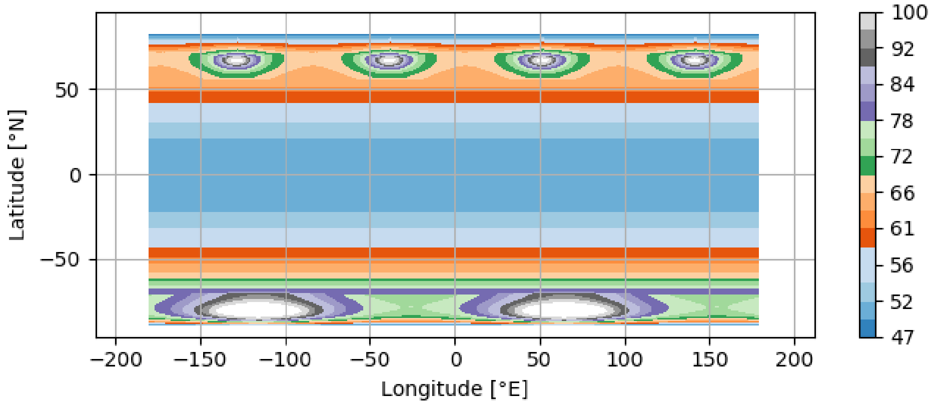


Figure 5: Number of data points per degree of longitude and latitude in the llc 4320 grid.

4.4.1 10m surface wind speed vector

ECMWF reanalysis wind speeds have been used, with 3-hourly outputs until 2011.12.31 and hourly outputs from 2012.01.01 on a 0.25 degrees spatial grid.

4.4.2 Surface currents vectors and water levels

Raw surface currents vectors and water levels (SSH) forcings had been interpolated on a regular grid usable for WW3 using a nearest neighbor interpolation method. Resolution of raw inputs have been degraded to 1/12 degree and 1/48 degree when it did not overpass the model resolution. *@Charles: to be updated with input from Lucia* Simulations forced by MITgcm surface currents have been retrieved from Dimitris Menemenlis llc4320 run *Rocha et al.* (2016). Surface fluxes calculations are based on ECMWF 0.148 atmospheric operational model analysis (6-hourly updates), from 10m wind speeds, 2m air temperature and humidity, downwelling long and short wave radiation and atmospheric pressure load. Large and Yeager bulk parametrizations have been used *Large and Yeager* (2004). Tidal forcing includes the 16 main components It has been reported that internal waves may be overestimated for reasons which remain unclear.

4.4.3 Ice fields

As for currents, sea-ice fields (thickness and concentration) have been interpolated via a nearest neighbor interpolation method on regular lat/lon grids with 1/12 degree and 1/48 degree resolution. The sea-ice concentration is a fraction ranging from 0 to 1, quantifying the fraction of the area covered in sea-ice. Normally in WW3, the sea-ice thickness is a True thickness. Here, for convenience, only an effective thickness is used, that is the true thickness multiplied bu the sea-ice fraction. The reason for this use is to avoid large unrealistic thicknesses where the sea-ice fraction is small. Some time steps (less than 10) contained corrupted data, so that data from the previous time step had been copied. We used input data from MITgcm, which includes its own sea-ice model, described for instance in *Losch et al.* (2012). The sea-ice characteristics for the llc 4320 run have been analyzed in details *Hutter et al.* (2018)

4.4.4 Coeanic forcings grid resolution

The number of grid points per $1^\circ \times 1^\circ$ grid cell has been computed and plotted on figure 5. Their square root is represented as an estimate of their effective resolution. At the equator, the llc 4320 grid is designed so that its effective resolution is 48 points per degree, both in latitude and longitude. The average number of data point per degree of longitude as a function of latitude is also plotted on figure 6.

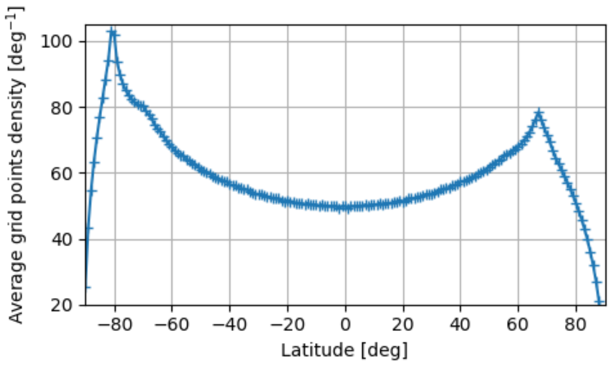


Figure 6: Average number of data points per degree of longitude and latitude as a function of latitude in the llc 4320 grid.

4.4.5 Hindcast strategy

4.4.5.1 WaveWatch III settings

Due to instabilities in the arctic, the advection time step for the 0.25 degrees global run is lowered to 120 s.

4.4.5.2 Boundary conditions

Regional grids are forced by a global grid independent run (0.25 degrees regular grid). Wave spectra are provided at the boundaries of each grid, with a spatial resolution of 0.5 degrees.

4.4.6 Output files

Up to date hindcasts are available at ftp://ftp.ifremer.fr/ifremer/ww3/HINDCAST/OTHER/SKIM/ or from the Ifremer network /home/datawork-WW3/HINDCAST/OTHER/SKIM
The folder contents are described in the following table, and correspond to the grids described previously. Oceanic forcing refers to both surface currents and water levesl. Ice forcing refers to both area fraction and ice thickness.

4.4.6.1 WW3 output variables

Folder	GLOB15M_MITGCM_1Y	EQUA_MITGCM_1Y	FRAM_MITGM_1Y	NATAL_MITGCM_1Y
Day of production	2018.12.14	2019.01.18	2019.01.15	2019.02.01
Oceanic forcing	MITgcm $1/12°$	MITgcm $1/48°$	MITgcm $1/48°$	MITgcm $1/48°$
Ice forcing	MITgcm $1/12°$	MITgcm $1/48°$	MITgcm $1/48°$	MITgcm $1/48°$
Comments	Boundary spectra in SPEC_NC/	-	-	-

Other folders contain obsolete data. The old/ folder contains backups of previous hindcasts. The day of the backup is indicated as a suffix to their folder names. These data will be progressively deleted.
Each folder contains daily output files, ww3.[yyyymmdd]_[field].nc Available output variables consist of forcings and wave related variables. Forcings are

- wnd : vector 10 m surface wind speed (variables uwnd and vwnd) [m/s]
- cur : surface current vector (variables ucur and vcur) [m/s]
- wlv : water level [m]
- ice : sea-ice area fraction (no unit, between 0 and 1)

- ic1 : sea-ice thickness [m]

Variables computed by WW3 are :

- hs : significant wave height [m]
- uss : Stokes drift vector (variables uuss and vuss) [m/s]
- mss : mean square slope vector (mssu and mssc for upwind and crosswind, with the downwind direction being given by msd) [no unit].
- msd : direction of dominant mean square slope
- tus : Stokes volume transport $[\mathrm{m}^2/\mathrm{s}]$
- foc : wave to ocean energy flux $[\mathrm{W}/\mathrm{m}^2]$
- ic5 : ice floe diameter [m]

These variables are directly output by Wavewatch III, thus a more accurate definition is available in Wavewatch III documentation.
Warning concerning mss variables The conversion from "mssu" and "mssc" to the true "mssx" and "mssy" (in the same frame as the current vector) is performed using :

$$mssx = \cos^2(msd)mssu + \sin^2(msd)mssc + 2\sin(msd)\cos(msd)mssuc \quad (1)$$

$$mssy = \sin^2(msd)mssu + \sin^2(msd)mssc - 2\sin(msd)\cos(msd)mssuc \quad (2)$$

where

$$mssuc = 0.5\tan(2msd)(mssu - mssc) \quad (3)$$

Previous runs may employ "mssx" and "mssy" as variables, but they are exactly the same as mssu and mssc (bug in former versions of WW3).

4.4.6.2 Other output variables

- sst : Sea surface temperature interpolated using nearest neighbors method from MITgcm (1/48th degree resolution)
- uflx : wind power transfer to the current $[(\mathrm{m/s})^2]$, *i.e.* the scalar product of the wind tension and the surface current :

  $$\boldsymbol{\tau} \cdot \boldsymbol{U} \quad (4)$$

  where $\tau = \rho_a u_\star^2$, $\boldsymbol{\tau}$ and $\boldsymbol{u}_{10}$ are assumed colinear, $u_\star$ is computed from u_{10} *Wu* (1982)

  $$u_\star = u_{10}\sqrt{(0.8 + 0.065u_{10})\,10^{-3}} \quad (5)$$

  and ρ_a is the density of air (taken constant, $\rho_a = 1.0\,\mathrm{kg}\cdot\mathrm{m}^{-3}$)
- tflx : SST horizontal flux $[\mathrm{degC}\cdot\mathrm{m/s}]$ defined by

  $$\mathrm{SST} \times \boldsymbol{U} \quad (6)$$

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