Predictability of Indian summer monsoon onset and withdrawal using dynamical seasonal forecasts

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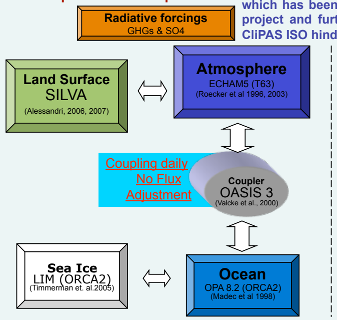
In this study the predictability of Indian Summer Monsoon (ISM) onset and withdrawal is investigated using dynamical seasonal forecasts. Nine member ensemble forecasts performed with the latest version of the CMCC-INGV Seasonal Prediction System (SPS) are used. Objective large scale methods (using both circulation and hydrological indexes) are applied to the forecasts to detect monsoon onsets/withdrawals. The capability of the probabilistic predictions to discriminate earlier than normal (i.e: before lower tercile of the sample distribution) and later than normal (i.e: after upper tercile of the sample distribution) onset/demises is evaluated by computing the brier skill scores and the discrimination distances. The circulation index has a better performance for both starting and exit phases. The monsoon onset is better forecasted than the withdrawal and a significant contribution is given by the initialization of the atmospheric model component from reanalysis.

1. The CMCC-INGV Seasonal Prediction System (SPS)

The coupled Model components



Radiative forcings
GHGs & SO4

Atmosphere
ECHAM5 (T63)
(Roecker et al 1996, 2003)

Land Surface
SILVA
(Alessandri, 2006, 2007)

Coupling daily
No Flux
Adjustment

Coupler
OASIS 3
(Valcke et al., 2000)

Sea Ice
LIM (ORCA2)
(Timmerman et. al.2005)

Ocean
OPA 8.2 (ORCA2)
(Madec et al 1998)

Atmosphere: Echam-5 -Spectral T63 (1.8°x1.8°) & 19 vertical levels

Land Surface: SILVA (Surface Interactive Land VegetAtion)

Ocean: OPA8.2 – 2° longitude - 0.5° - 2° latitude - 31 Vertical Levels

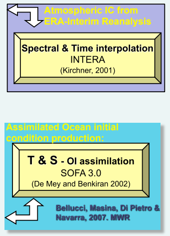
Sea Ice Dynamics: LIM (Louven laneuve sea-Ice systeM)

Radiative boundary forcing: GHGs, direct and indirect effects of anthropogenic sulphate aerosols

http://www.ecmwf.int/research/EU_projects/ENSEMBLES/exp_setup/boundary/boundary_forcing.html

We use the latest version of the CMCC-INGV SPS (Alessandri et al., 2010a) which has been developed in the framework of the EU-FP6 ENSEMBLES project and further advanced as required by the efforts in the ongoing CliPAS ISO hindcast experiment.

Off line Initialization Tools



Atmospheric IC from ERA-Interim Reanalysis

Spectral & Time interpolation
INTERA
(Kirchner, 2001)

Assimilated Ocean initial condition production:

T & S - OI assimilation
SOFA 3.0
(De Mey and Benkiran 2002)

Bellucci, Masina, Di Pietro & Navarra, 2007. MWR

Atmosphere & Land initialization:
From ERA-Interim reanalysis (Berrisford et al., 2009)

Ocean initialization:
CMCC-INGV Global Ocean Data Assimilation System (CIGODAS, *Di Pietro and Masina,2009; Bellucci et al., 2007)*

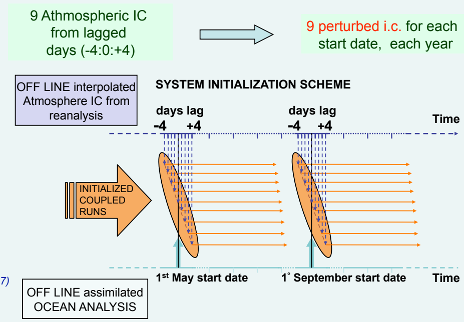
Sea Ice initialization:Sea Ice extent inferred from observed Sea Surface temperature data.

Retrospective Forecasts Performed

Hindcasts have been performed for the period 1989-2005

2 start dates each year: May & September

Ensembles of 9 forecasts, each integration 2 months long



9 Athmospheric IC from lagged days (-4:0:+4)

9 perturbed i.c. for each start date, each year

OFF LINE interpolated Atmosphere IC from reanalysis

SYSTEM INITIALIZATION SCHEME

OFF LINE assimilated OCEAN ANALYSIS

4. Onset of the Monsoon: The importance of the realistic initialization of the atmosphere

The forecasts previously described (hereinafter ERAINI experiment) are compared with a set of predictions performed with atmospheric IC taken from an AMIP-type simulation (AMIPINI experiment; i.e: by simply using the atmospheric model forced with observed Sea Surface Temperature) to assess the effect of the realistic atmospheric initialization to the predictability of the monsoon onset.

-ERAINI significantly (5% significance level) improves the prediction of early monsoon onsets compared to AMIPINI in terms of both BSS and D. In contrast, the prediction of late monsoon onsets is not positively influenced in ERAINI (Figure 5).

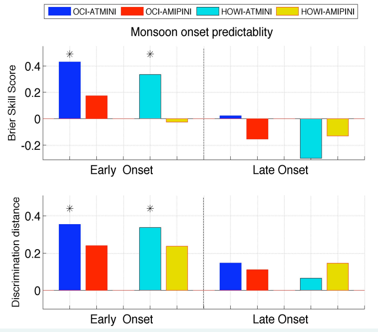


Figure 5: Brier Skill Score and discrimination distance for the dichotomous events of Early (left bars) and Late (right bars) monsoon onset. Asterisks indicate if the value is significantly enhanced compared to the other experiment (5% level; montecarlo method).

The transition towards the monsoon onset typically shows the reinforcement of the circulation to the south-west of India coupled with enhanced convection over Bay of Bengal (Wan and Fan, 1999)

-The above behavior is missed by AMIPINI which displays a circulation over the Arabian Sea in mid May stronger than observed and shifted northward. A consequence is weaker convection over the bay of Bengal. This bias in the atmospheric model leads to a systematic premature onset of the ISM in AMIPINI.

-ERAINI shows a more realistic onset sequence suggesting that the improved predictability of early monsoon events (Figure 5) follows from a better representation of the atmospheric mean state in the IC, in addition to the realistic phase initialization of Intraseasonal Oscillations (ISO) which may trigger onset (Wang et al., 2009).

-After the end of May, the effect of the IC is no longer perceptible and it cannot influence late onset events.

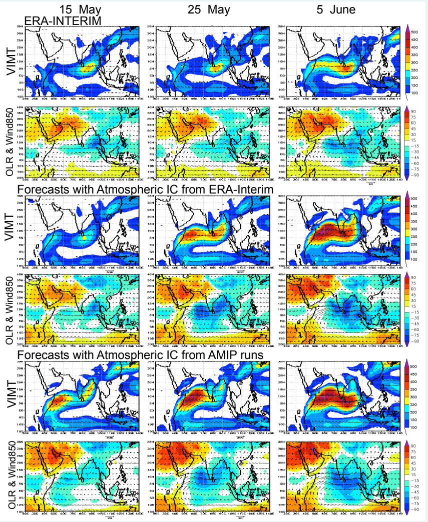


Figure 6: Sequence of daily VIMT (total field, shading further shows vector intensity), 850-hPa winds (total field) and OLR (anomalies with respect to domain average) showing climatological evolution of ISM onset from 15 May to 5 June. For each date, the values are 17-year averages (1989–2005) for ERA-Interim (upper panels), ATMINI (middle panels) and AMIPINI (lower).

5. Conclusions

- The CMCC-INGV SPS shows a considerable skill in predicting, one month in advance, the onset of the ISM using both circulation (OCI) and hydrological (HOWI) indexes. However, the OCI has a better correlation (0.65 vs. 0.52; 5% significance level) with observations.
- ISM withdrawals are less predictable than onsets and only the OCI has significant correlation (0.46, 10% significance level) with observations.
- The probabilistic forecasts display some ability to discriminate earlier and later than normal monsoon onsets/withdrawals. The better performance in terms of probabilistic scores is for the prediction of early than normal monsoon onset.
- Realistic initialization of the atmospheric component is shown to significantly contribute to the predictability of early than normal monsoon onsets. This may be related to the realistic phase initialization of ISO which may trigger onset (Wang et al., 2009). On the other hand, the improved predictability may also follow from the better representation of the atmospheric mean state in the IC. Ongoing studies will further address this topic.

2. Monsoon Onset and Withdrawal detection method

Objective Criteria for the Detection of the Monsoon Onset/Withdrawal

Onset Circulation Index (OCI, Wang et al., 2009):
Average 850hPa zonal wind over the Southern Arabian Sea (SAS, 40-80E; 5-15N) region which is indicated by blue box on the map (Figure 1).

Hydrologic Onset & Withdrawal Index (HOWI, Fasullo and Webster, 2003):
Vertically Integraged Moisture Transport (VIMT) averaged over the the 50 points on the domain with the more rapid transition of the VIMT from the week before and the week after the climatological Monsoon Onset (or Withdrawal). The largest 50 difference VIMT vectors, over the red domain in the map (Figure 1), have been independently selected for the forecasts and for the validation reanalysis dataset.

The Criteria for the detection of the monsoon onset/withdrawal is based on the exceedance of specific thresholds for at least 7 consecutive days following Wang et al., 2009. The thresholds have been independently chosen for reanalysis and forecasts in order to suitably represent the characteristics of the transitions and to adequately consider the differences between forecasts and reanalysis.

In the following the ERA-Interim reanalysis (Berrisford et al., 2009) are used as reference for the verification of the forecasts. Furthermore the onset dates of the ISM defined each year by the Indian Meteorological Department (IMD) and based on subjective estimates are further used as reference.

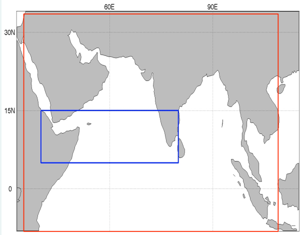
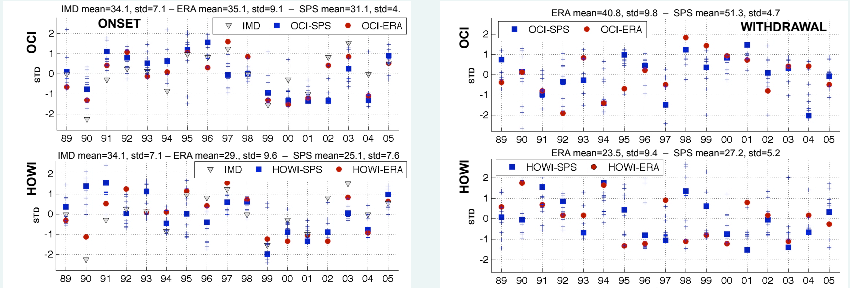


Figure 1: Schematic diagram for the definition of the monsoon indices. Blue solid box denote the region where the zonal wind is used to define the monsoon circulation index. Red box is the domain for the computation of the HOWI index.

3. Onset & withdrawal forecasts: performance of the latest CMCC-INGV SPS

Figure 2: Normalized onset (left panels) and withdrawal (right panels) dates (in days after 1 May and 1 September) as diagnosed by OCI (upper) and HOWI (lower). The SPS forecasts (in blue) are compared with the ERA-Interim reanalysis (in red). White triangles indicate the subjective onset definition by IMD.



The forecasted Monsoon onsets detected through OCI and HOWI display significant correlations with both the reanalysis results and the IMD subjective onset definition (Table 1). The OCI detection performs better having higher correlations (0.65 and 0.70, respectively).

Table 1: Forecasts vs Observations correlations

correlations ONSET		ERA-Interim OCI	ERA-Interim HOWI	IMD Onset
FORECASTS	OCI	*0.65***		*0.70***
FORECASTS	HOWI		*0.52***	*0.32**
	IMD Onset	*0.80***	*0.73***	

(**) 5% (*) 10% significance levels

For the withdrawal case, the correlation coefficients (forecasts vs. reanalysis) are smaller than for onset and significance (10% level) is accomplished only for the OCI detection (Table 2).

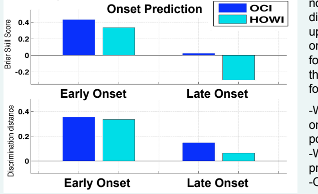
Table 2: Forecasts vs Observations correlations

WITHDRAWAL		ERA-Interim OCI	ERA-Interim HOWI
FORECASTS	OCI	*0.46 **	
FORECASTS	HOWI		*0.15*

(**) 5% (*) 10% significance levels

Probabilistic predictions of earlier/later than normal onsets/withdrawals

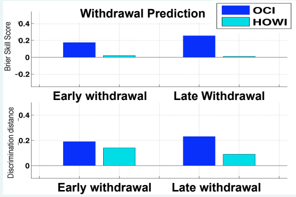
Figure 3: Brier Skill Score and discrimination distance for the dichotomous events of Early and Late monsoon onset. That is the onset falls below the lower (left bars) and above the upper (right bars) climatology terciles, respectively.



We use Brier Skill Score (BSS, Wilks, 2006) and discrimination distance (D, Alessandri et al., 2010) to estimate the ability of the probabilistic forecasts to catch earlier than normal (i.e: below lower tercile of the sample distribution) and later than normal (i.e: above upper tercile of sample distribution) Monsoon onsets/withdrawals. BSS=1 indicates perfect forecasts while BSS<0 means less skillful than climatology forecast. D=1 is for perfect forecasts while D=0 indicates no skill at all.

-With the exception of BSS for the HOWI late onset detection, the system always shows positive probabilistic skills.
-We evidence a considerable skill in the prediction of early monsoon onset.
-OCI tends to perform better than HOWI.

Figure 4: same as Figure 3 but for Early and Late monsoon withdrawal.



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