Mechanisms driving the diurnal cycle of monsoon rainfall over northern India and rainfall modes over the west coast of India in the Met Office Unified Model

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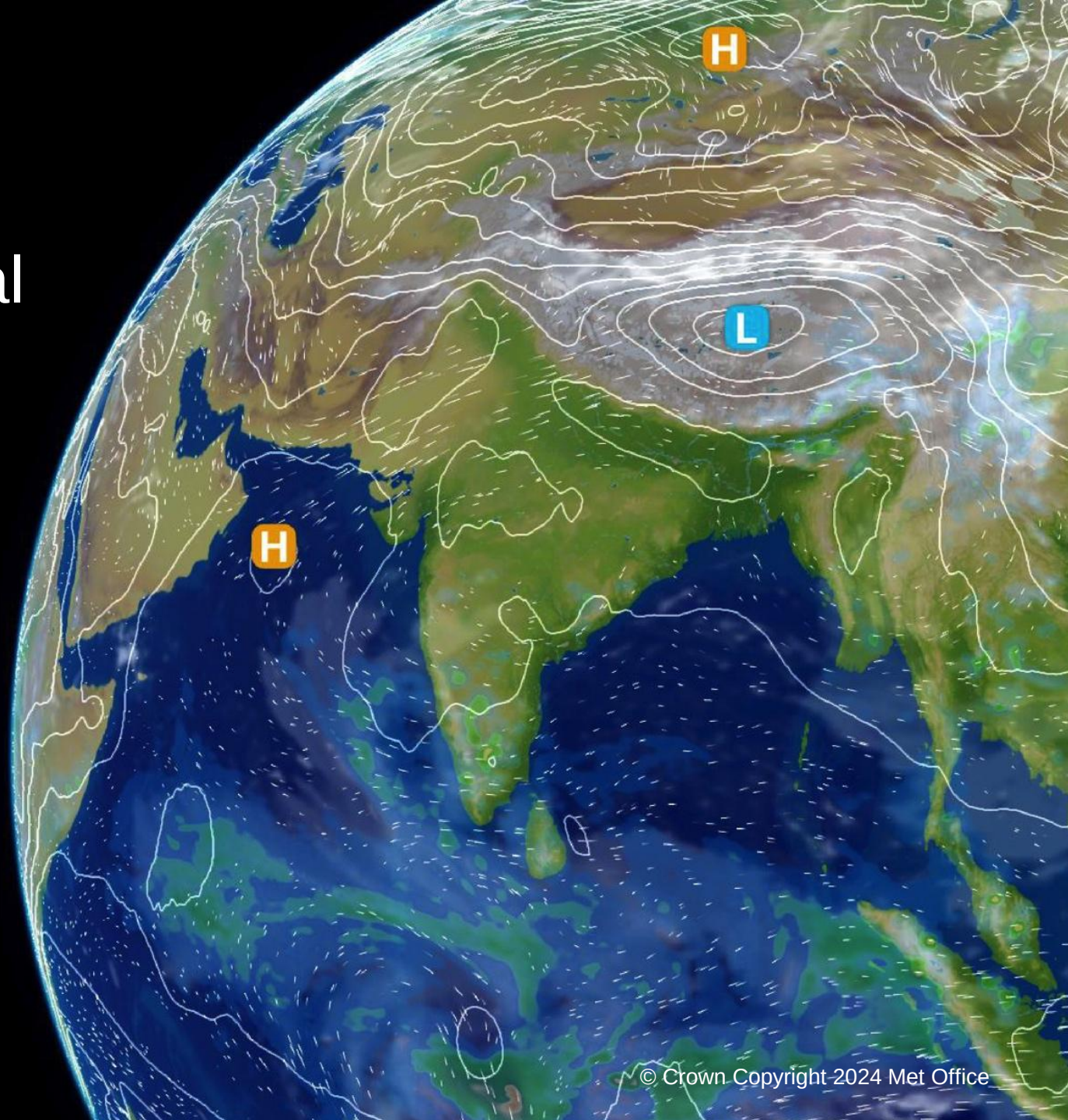
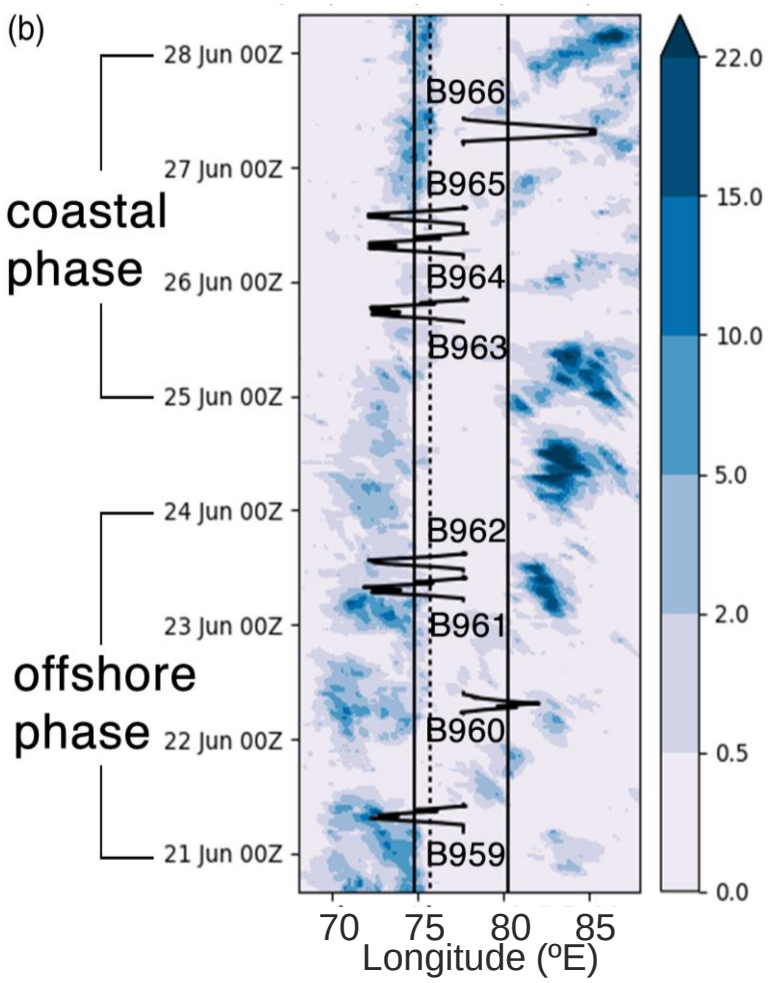
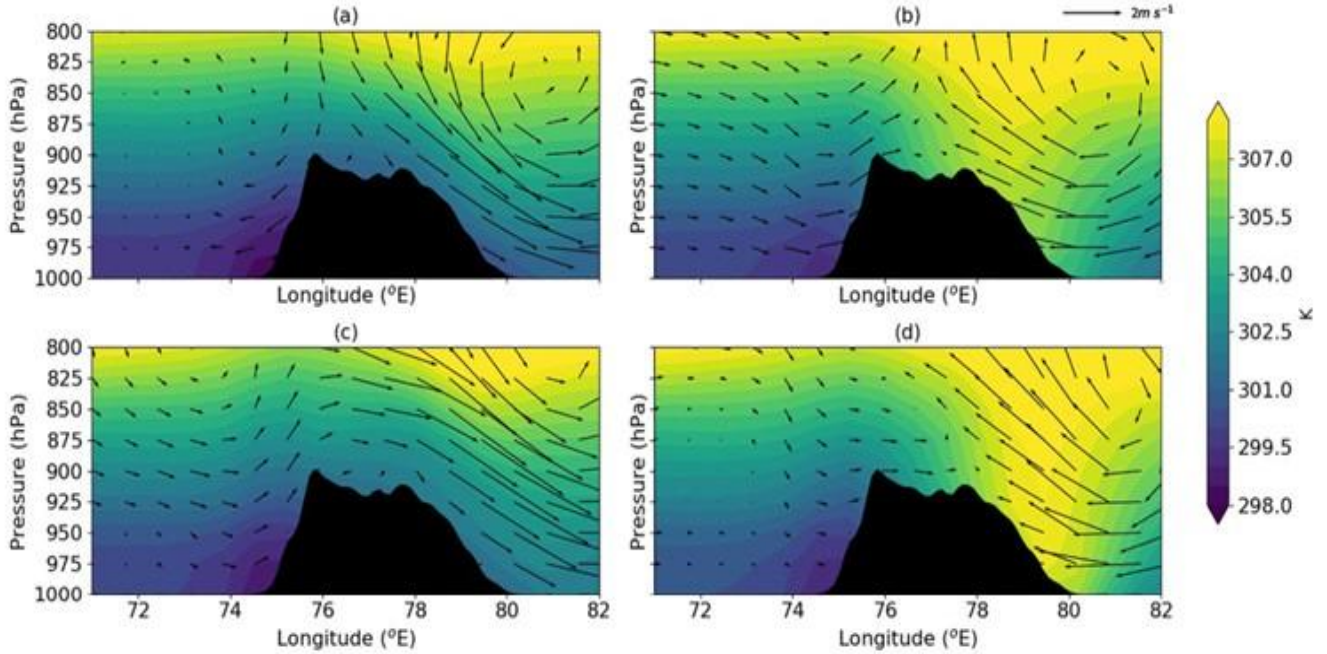
IWM8, 17 March 2025



Background

- Fletcher et al. (2020) identified two regimes of precipitation near the WG: off-shore and coastal modes.
- Phadtare et al. (2022) showed that there is large diurnal variability in winds and potential temperature over the WG during the coastal phase.

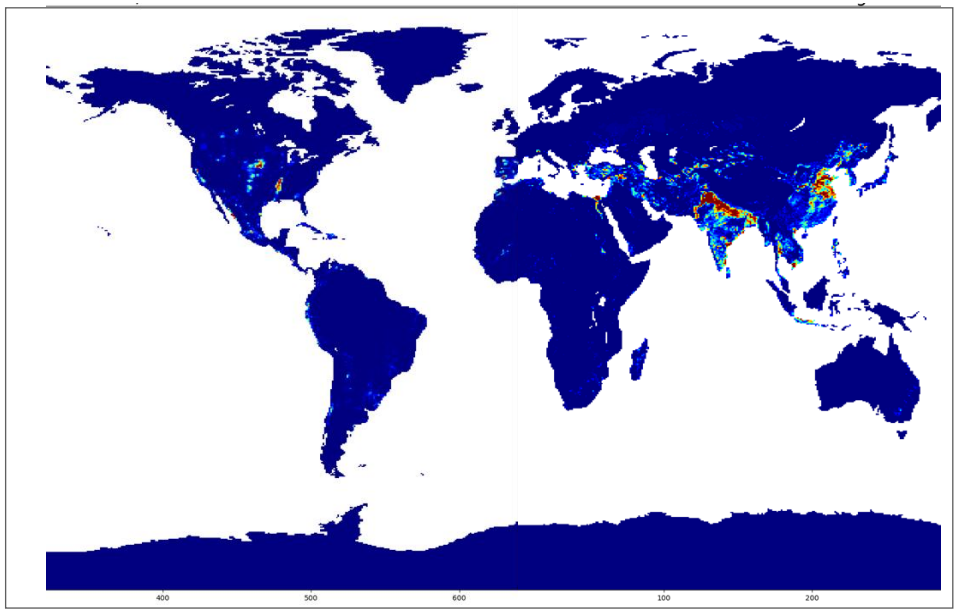




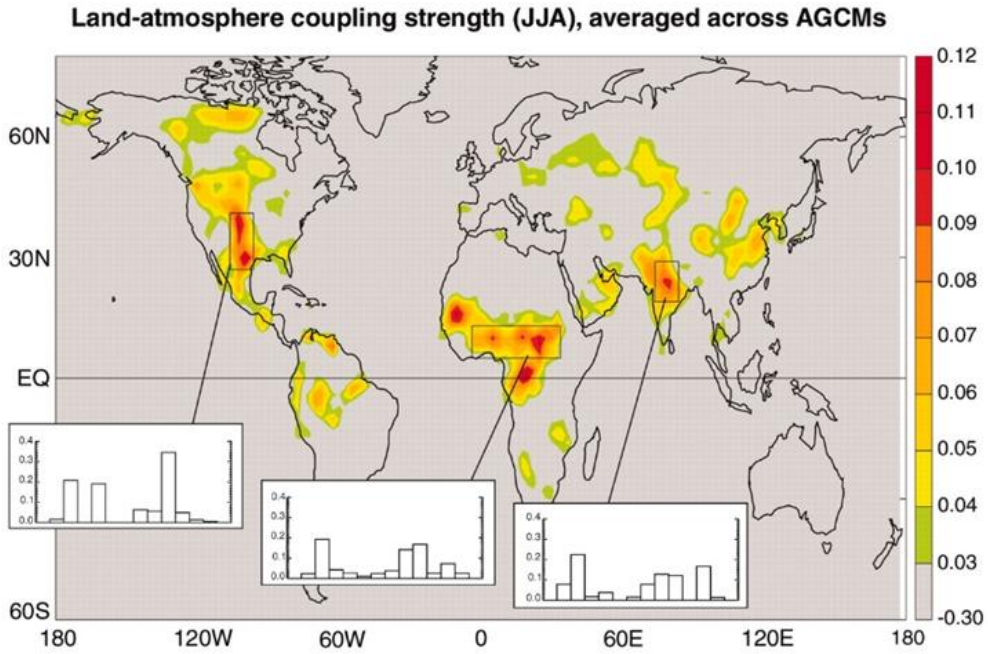
Importance of Irrigation over India

Over 324 million hectares of land are equipped for irrigation worldwide. 42% of this is in only two countries: India and China (FAO, 2004)

Northern parts of India, especially along the Indo-Gangetic plain is a hotspot for land-atmosphere interactions



CCI irrigated fraction



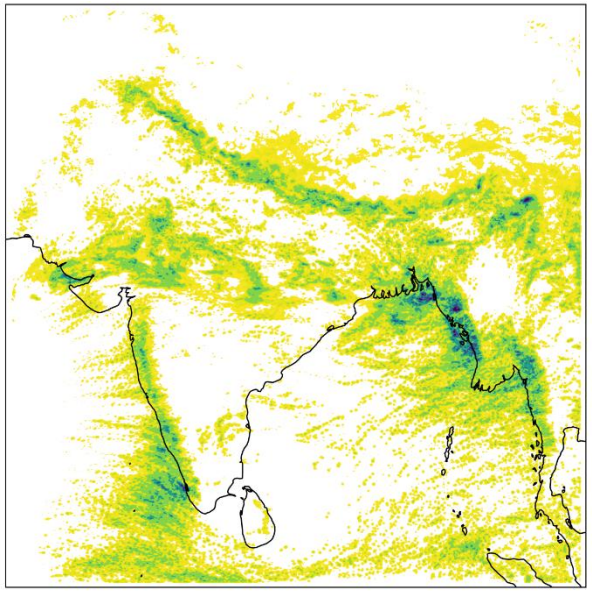
Koster et al., 2004

Courtesy: Heather Rumbold

Regional coupled simulations for India using Met Office Unified Model

LAM Resolution: 4.4 km
Period: 30th May - 29th August 2016
Domain: 65°- 101°E, 3.5°- 40°N
OSTIA SST updated daily for atmos-only simulations

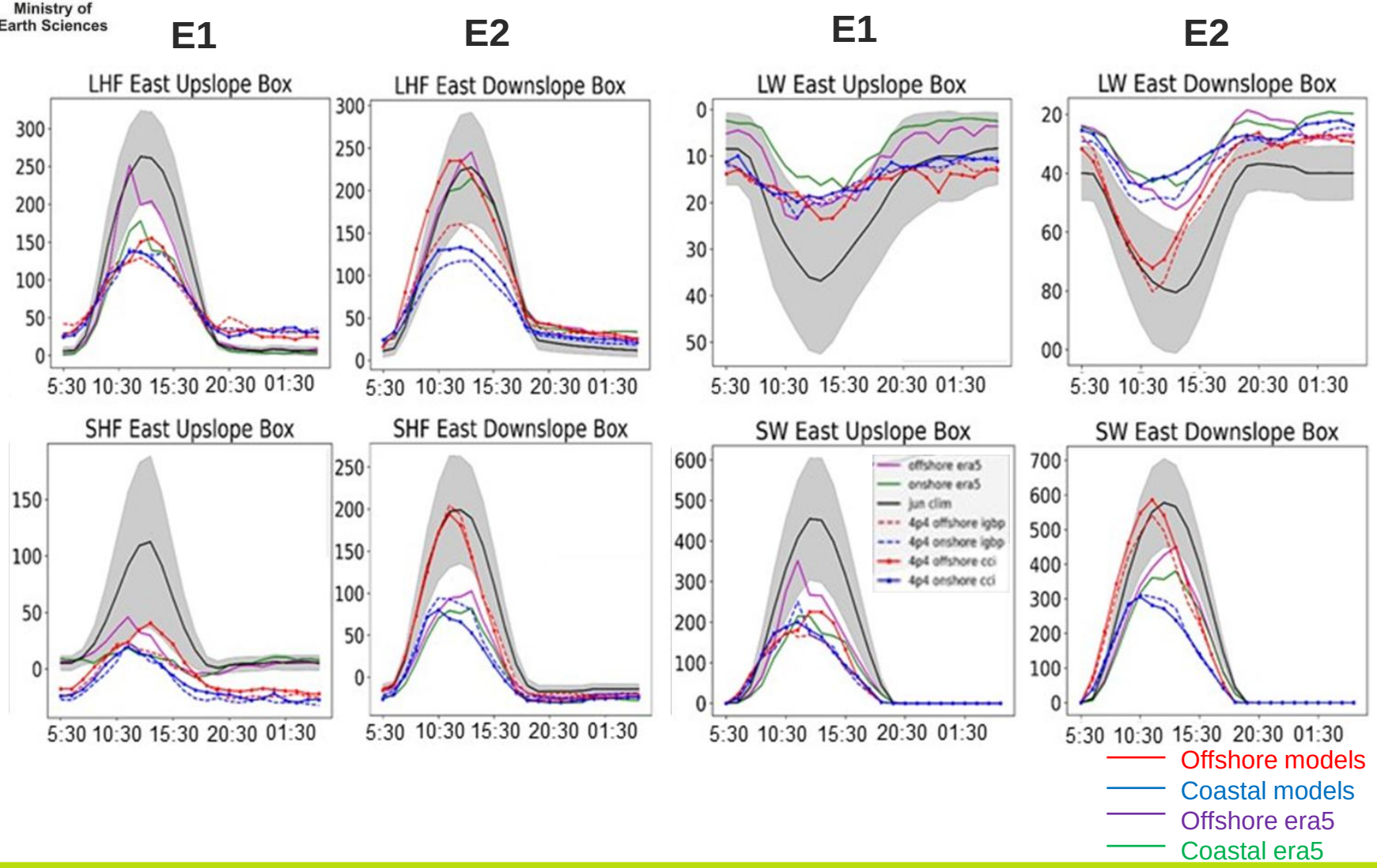
Experiment	Land ancil	Irrig coupling	Science setting
Atmos-only	IGBP	No	SINGV2.1 (Huang et al., 2019)
Atmos-only	CCI	No	SINGV2.1
Atmos-only	IGBP	No	RAL1-T (Bush et al., 2020)
Atmos-ocean-wave coupled	IGBP	No	RAL1-T
Atmos-only	IGBP	No	RAL3.1 (Bush et al., *under prep*)
Atmos-only	IGBP	Yes	RAL3.1
Atmos-ocean-wave coupled	IGBP	No	RAL3.1
Atmos-ocean-wave coupled	IGBP	Yes	RAL3.1

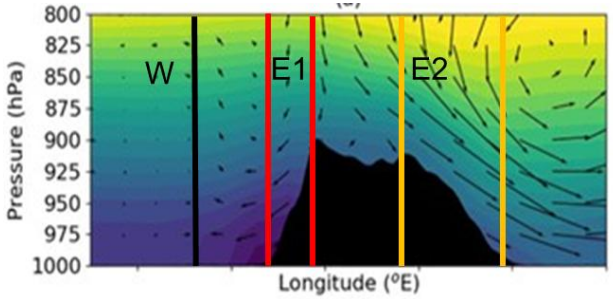


Limited Area Model Domain

In JULES, irrigation is implemented such that the water in the top two soil layers is continuously topped up to a critical point during the irrigation season, if sufficient irrigation water is available.

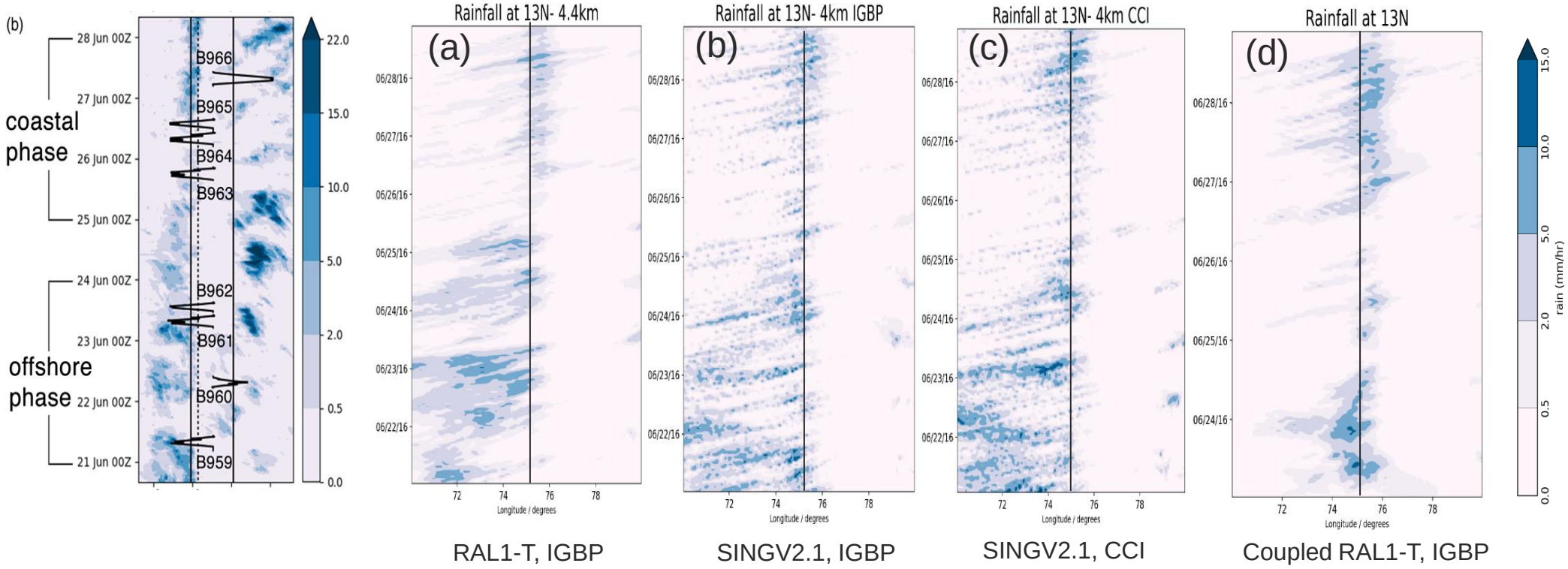
Diurnal cycle of heat and radiation fluxes





- Heat and radiation fluxes have strong diurnal variability over WG region with diurnal amplitude peaking at ~7 UTC (1230 IST) during summer season.
- Diurnal amplitude of turbulent fluxes is stronger during offshore phase compared to coastal phase in both model and reanalysis.

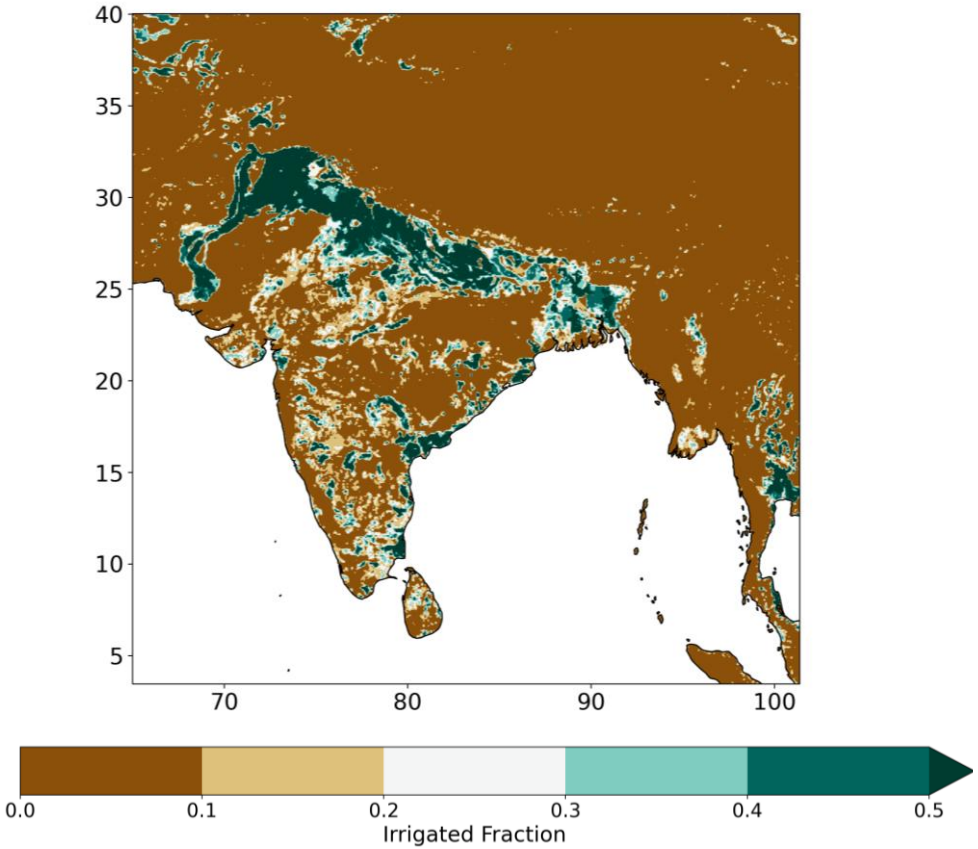
Offshore/onshore phases of precipitation near Western Ghats

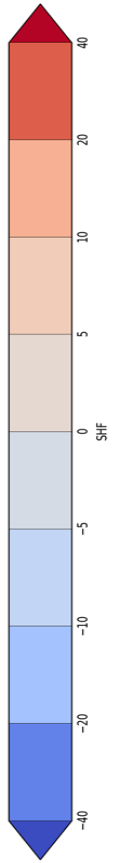


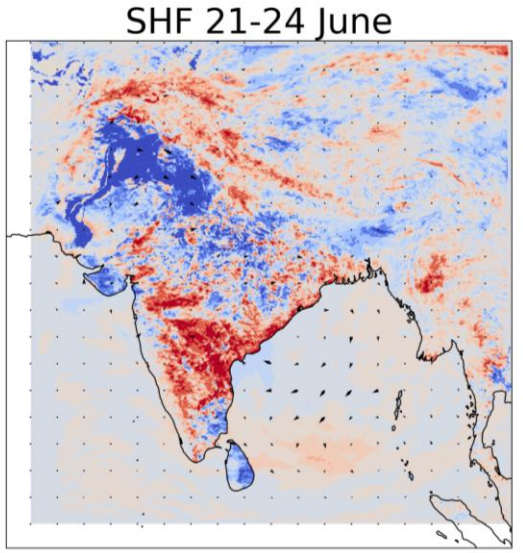
RAL1-T, IGBP | SINGV2.1, IGBP | SINGV2.1, CCI | Coupled RAL1-T, IGBP

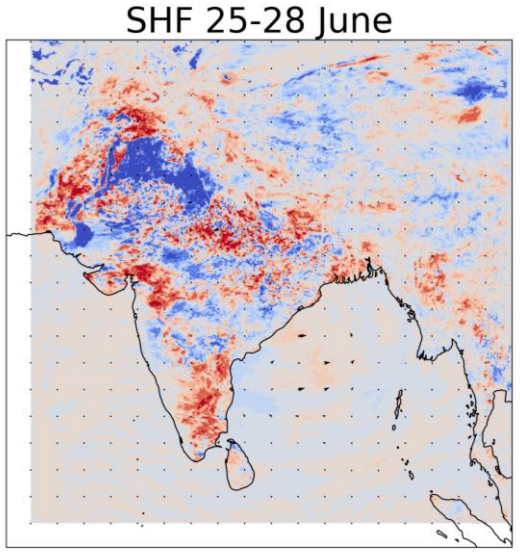
- Soil moisture features are important in simulating the diurnal cycle of surface fluxes near the WG.
- Science settings in the model have a stronger influence on the diurnal cycle near high orography compared to the land-surface initialisation

Effect of irrigation on WG precipitation modes









Irrigation minus No-irrigation H

Offshore

During offshore phase, SHF is stronger over the leeward side of Ghats with irrigation

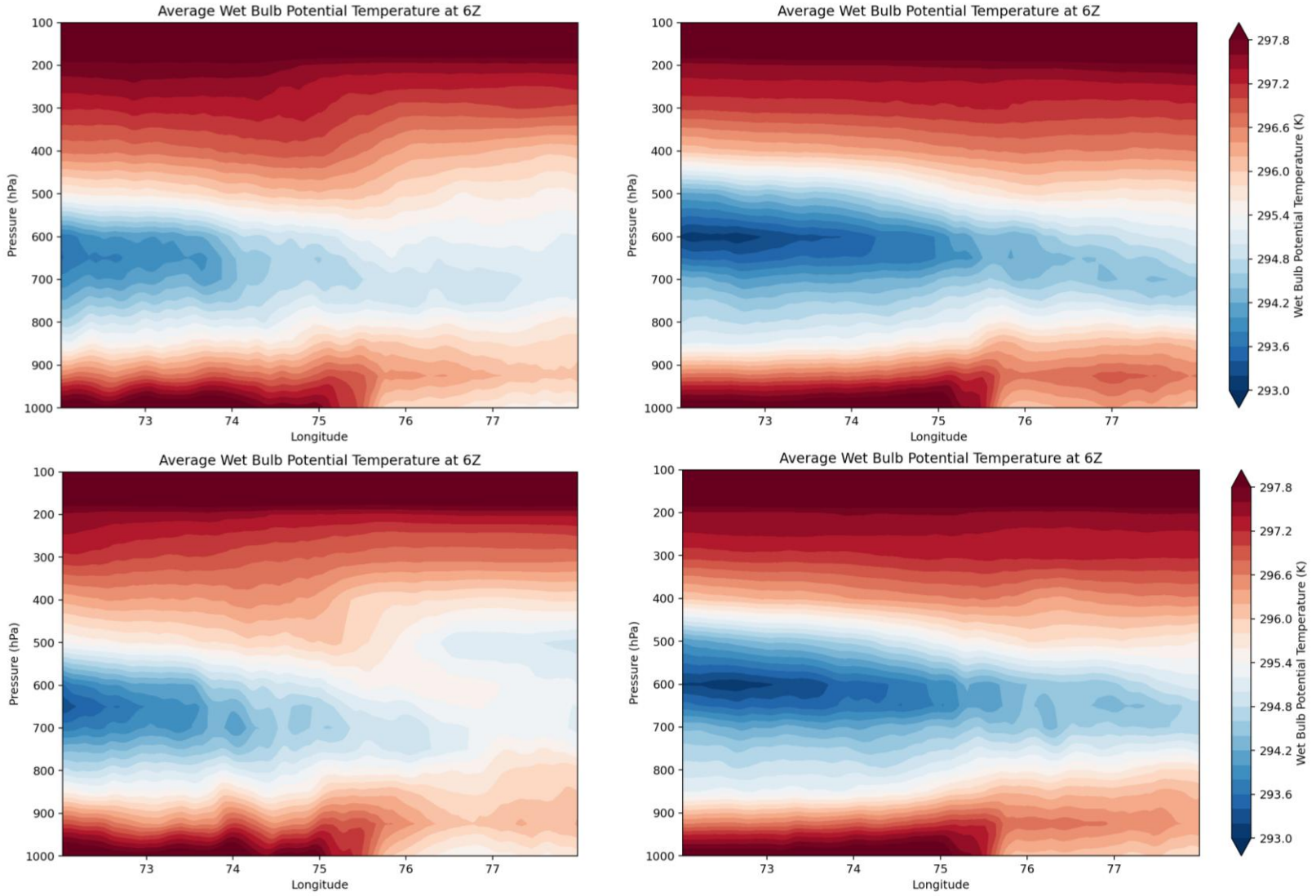
Coastal

SHF differences consistent with irrigated areas for IGP

Vertical structure of theta-w

No irrigation

With irrigation



Offshore

Coastal

Stronger dry intrusion during **coastal phase** compared to offshore phase.

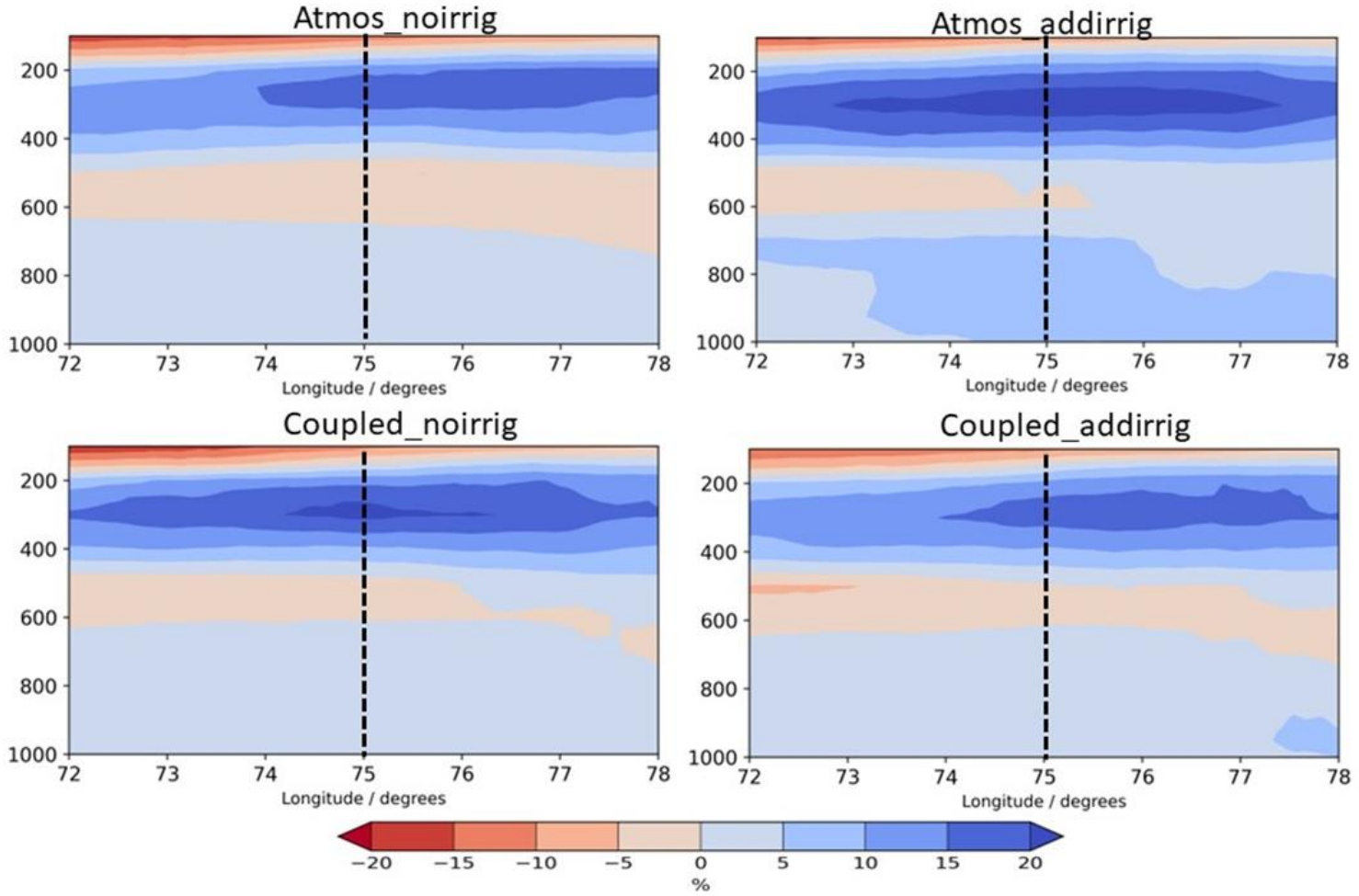
Irrigation modifies the heat fluxes on the **leeward side** of Ghats.

Vertical structure of RH

Coastal – offshore RH

Atmos-only

Coupled



- All models simulate a **drier mid-troposphere and a moister lower troposphere** during coastal phase.
- **Stronger dry-air intrusions** from the west during this phase as shown by Fletcher et. al. (2020).
- The lower and mid-troposphere over the WG are moister in the atmos-only run with irrigation coupling

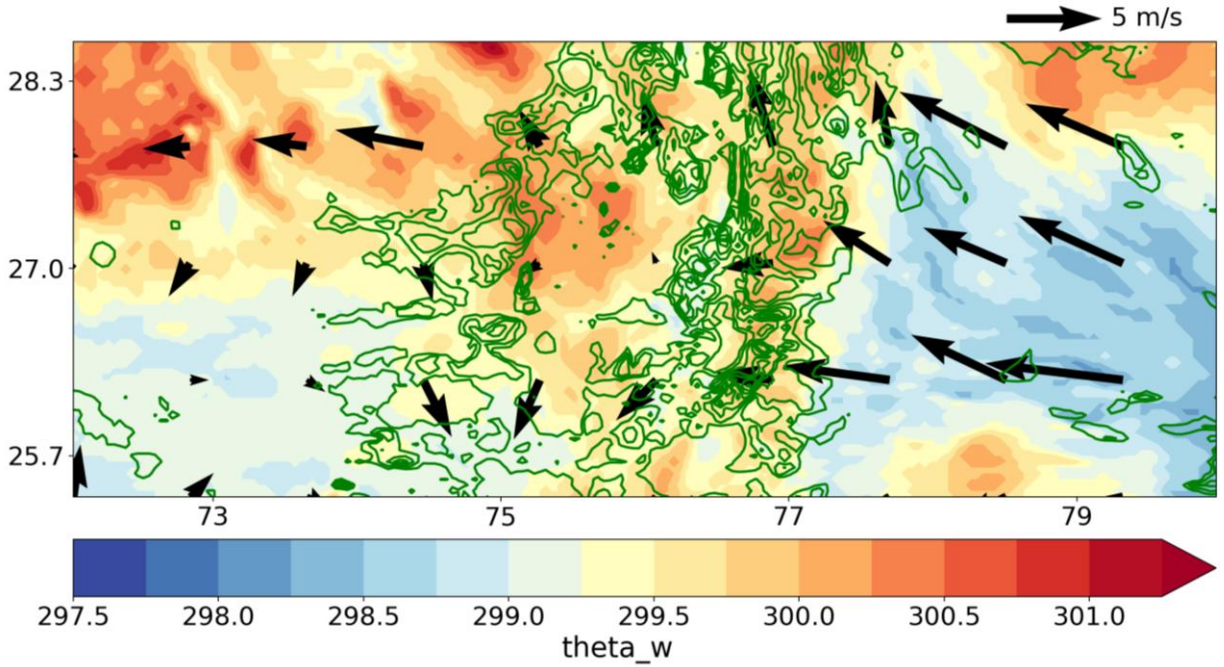
Offshore

Coastal

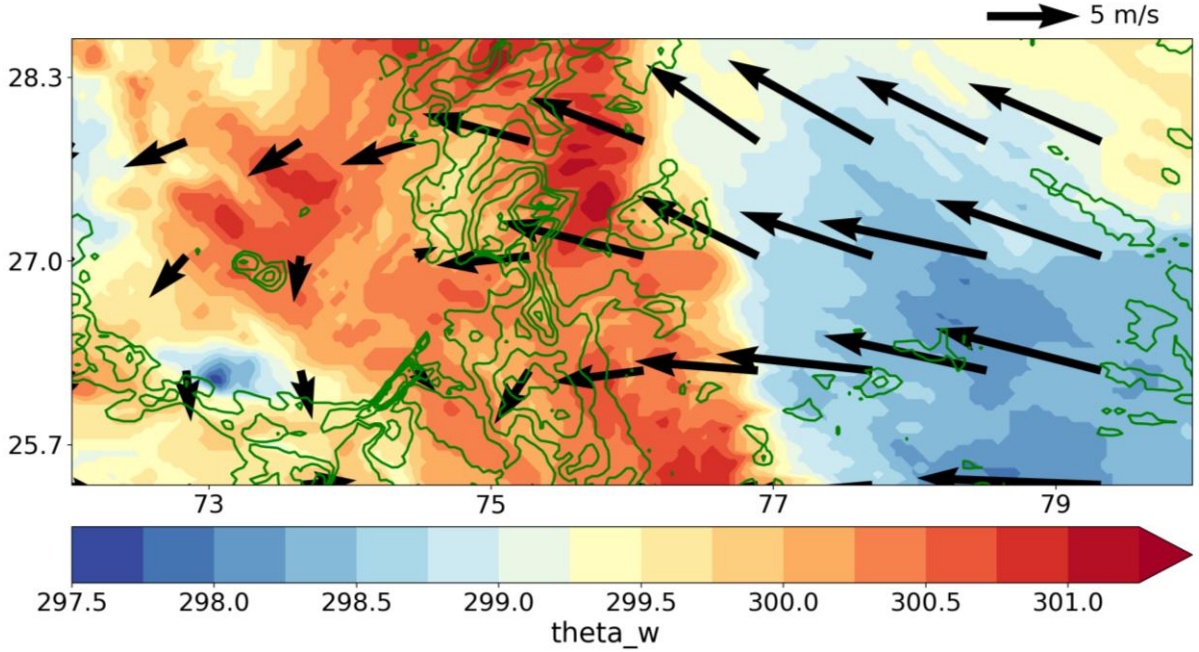
Effect of irrigation over northern India

925hPa theta-w and winds at 6Z (11:30 IST), clouds at 5Z (10:30 IST, green contours) 30 June 2016

Without irrigation

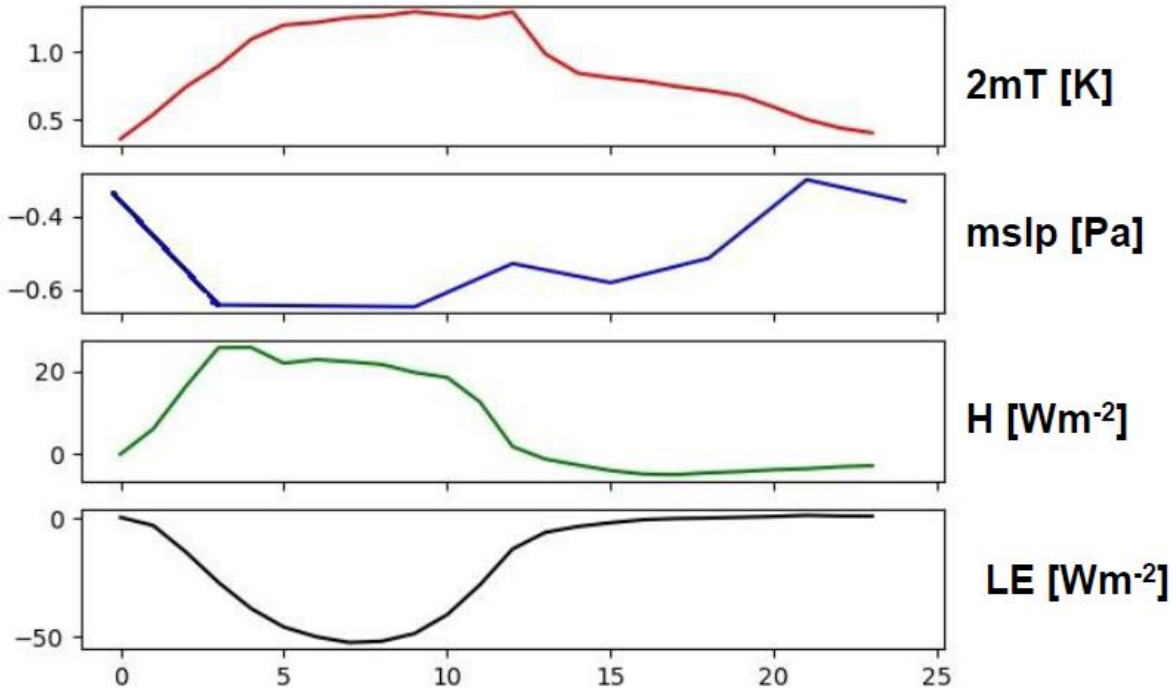


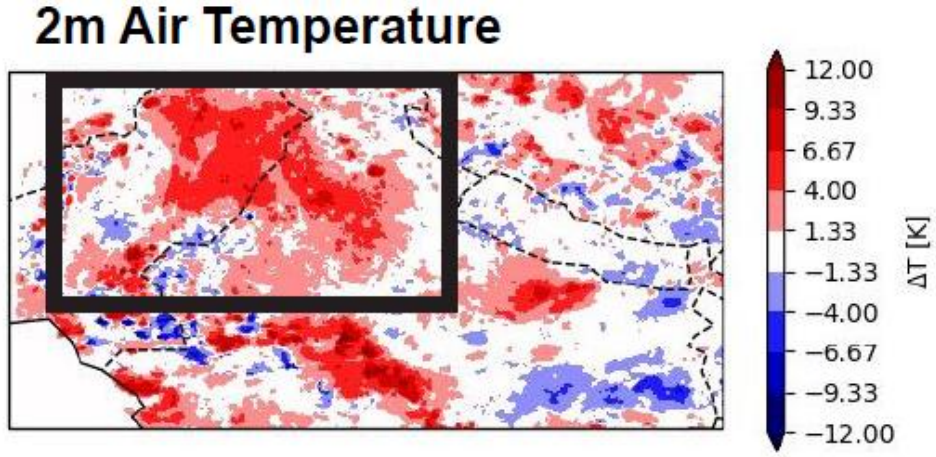
With irrigation



- Low clouds form near dry-wet boundaries (as shown in Barton et al., 2019)
- Winds change direction as they move over the soil moisture boundaries

Diurnal cycles – No irrigation minus irrigation





Diurnal cycle of temperature and pressure differences consistent with surface forcing

Courtesy: Emma Barton

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Conclusions

- **Diurnal cycles** of heat and radiation fluxes are **stronger during the offshore phase** compared to coastal phase.
- Mid-tropospheric **dry air intrusion** from the west is **stronger during coastal phase** compared to offshore phase of Western Ghats precipitation.
- **Irrigation** modifies the heat fluxes over the **leeward side** of Ghats.
- Over north India, where irrigation is prominent, irrigation plays a major role in the boundary layer thermodynamics. Low clouds form over areas of strong soil moisture gradients.
- Without detailed information on the **spatial distribution and type of irrigation**, weather forecast models may not be able to predict key PBL processes, including the development of convective cloud (e.g. Lawston *et al.,*2015)

Poster: Th-1.11 The role of dry intrusions in breaks of the Indian summer monsoon- Akshay Deoras

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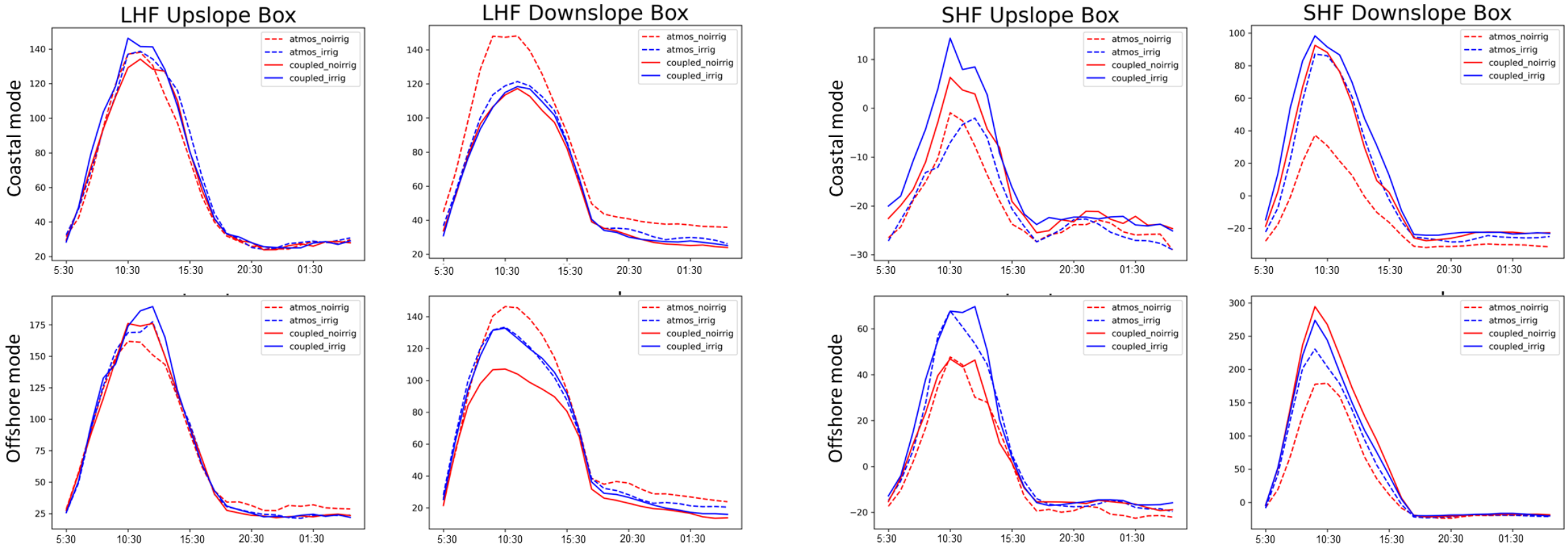
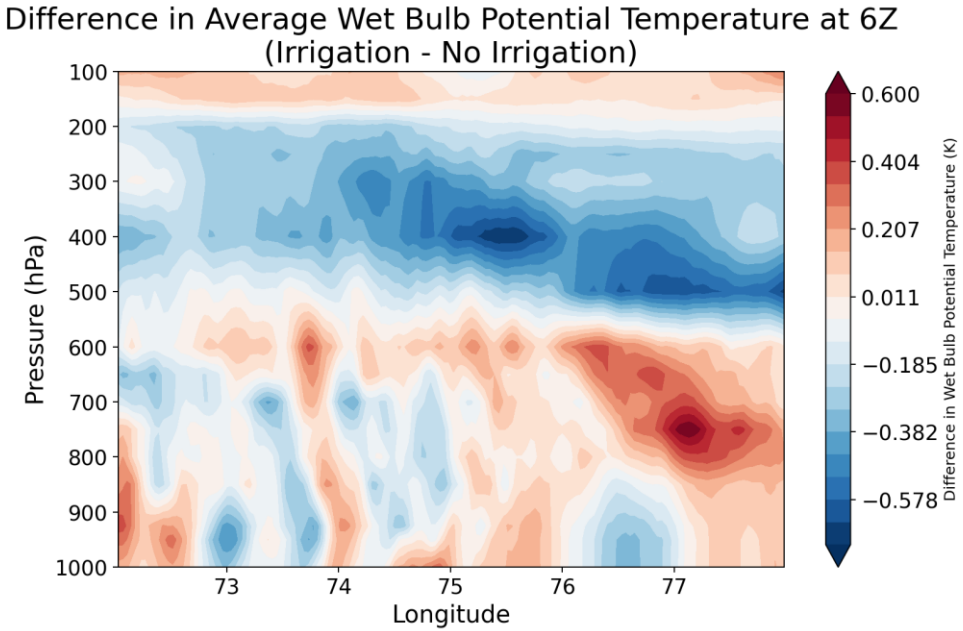
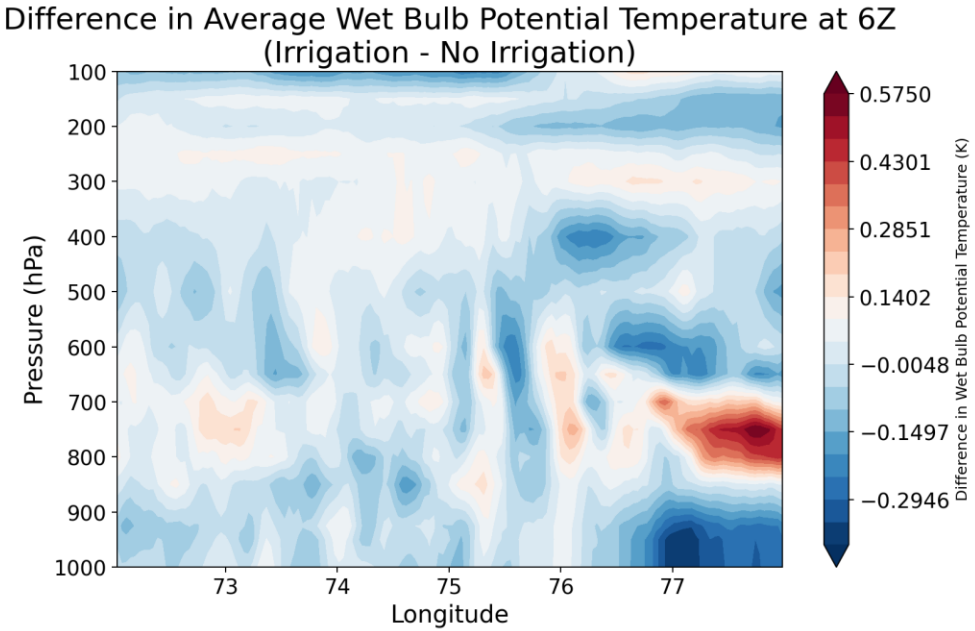
Diurnal cycle of heat fluxes on windward and leeward side of Western Ghats



Effect of irrigation on leeward side of WG



Offshore: Irrigation – no irrigation



Coastal: Irrigation – no irrigation

Irrigation experiments : lower surface