# Effects of Atmospheric Forcing Frequencies on Ocean Data Assimilation and Coupled Forecasts on NWP Time Scales

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Work done during Toshi's visit to ECMWF

# Overview of talk

**01** Motivation

**02** Experiments performed

**03** Effects of forcing frequency in the ocean DA system

**04** Effects of coupling frequency in the NWP coupled model

**05** Conclusion

# Motivation for this work:

## Why frequency matters

More frequent air–sea exchange resolves diurnal sea-surface temperature variations and tropical-cyclone feedbacks.

Atmospheric forcing frequency also shapes the ocean analysis used to initialise coupled forecasts.

## The medium-range gap

Most previous studies focus on climate and seasonal time scales.

The effects of ocean DA forcing frequency and forecast coupling frequency on medium-range predictions remain insufficiently explored.

## Study objective

**Assess the impacts of ocean DA forcing frequency and forecast coupling frequency on ocean analyses and ECMWF medium-range predictions.**

# ORAS6 setup and atmospheric forcing

## Ocean analysis framework

This study uses a prototype ORAS6 system. Atmospheric forcing drives the uncoupled ocean model to generate trajectories for data assimilation.

The resulting ocean analyses provide initial conditions for 10-day coupled forecasts.

## Forcing frequency is the key sensitivity

### Hourly reference

ERA5 provides hourly atmospheric forcing, allowing the ocean model to resolve diurnal variability.

### Coarser updates

Test 3-hourly and 6-hourly forcing, plus 24-hourly accumulated fields with 6-hourly instantaneous fields.

### Short-wave reconstruction

Compare the 24 h / 6 h setup with and without reconstruction of the short-wave diurnal cycle. This was used in ORAS5.

# Ocean DA experiments

| Experiment | Forcing frequency of accumulated field | Forcing frequency of instantaneous field | Diurnal cycle reconstruction of solar radiation flux |
|---|---|---|---|
| 1hOA | 1 hr | 1 hr | No |
| 3hOA | 3 hr | 3 hr | No |
| 6hOA | 6 hr | 6 hr | No |
| 24&6hOA | 24 hr | 6 hr | No |
| 24&6hReOA | 24 hr | 6 hr | Yes |

# ECMWF IFS–NEMO v4 coupled system

| | |
|---|---|
| **IFS atmosphere and land** | Predicts weather and supplies surface heat, freshwater and momentum forcing. |
| **NEMO v4 ocean** | Predicts ocean temperature, salinity and currents. ECMWF's configuration builds on NEMO 4.0.6. |
| **SI³ sea ice** | Represents ice dynamics and thermodynamics using multiple ice-thickness categories. |
| **ECWAM waves** | Represents the sea state within the atmosphere–wave–ocean coupling framework. |

## Two-way air–sea feedback

Evolving sea-surface temperature and sea ice influence the atmosphere, while atmospheric forcing changes the ocean. This supports diurnal warming and cooling beneath tropical cyclones.

# Coupling frequency in the experiments

## Forecast exchange intervals and ocean integration steps

| Configuration | Coupling interval | Ocean time step |
|---|---|---|
| Reference | 1 hour | 20 minutes |
| Coarser coupling | 3, 6 or 24 hours | 20 minutes |
| Short-step comparison | 1 hour or 15 minutes | 15 minutes |

## Two distinct intervals

### Coupling interval

Information exchange during the coupled forecast.

### Ocean time step

Numerical integration step within NEMO.

# Diurnal SST cycle for different DA forcing frequencies

### Validation
Quality-controlled drifter observations.

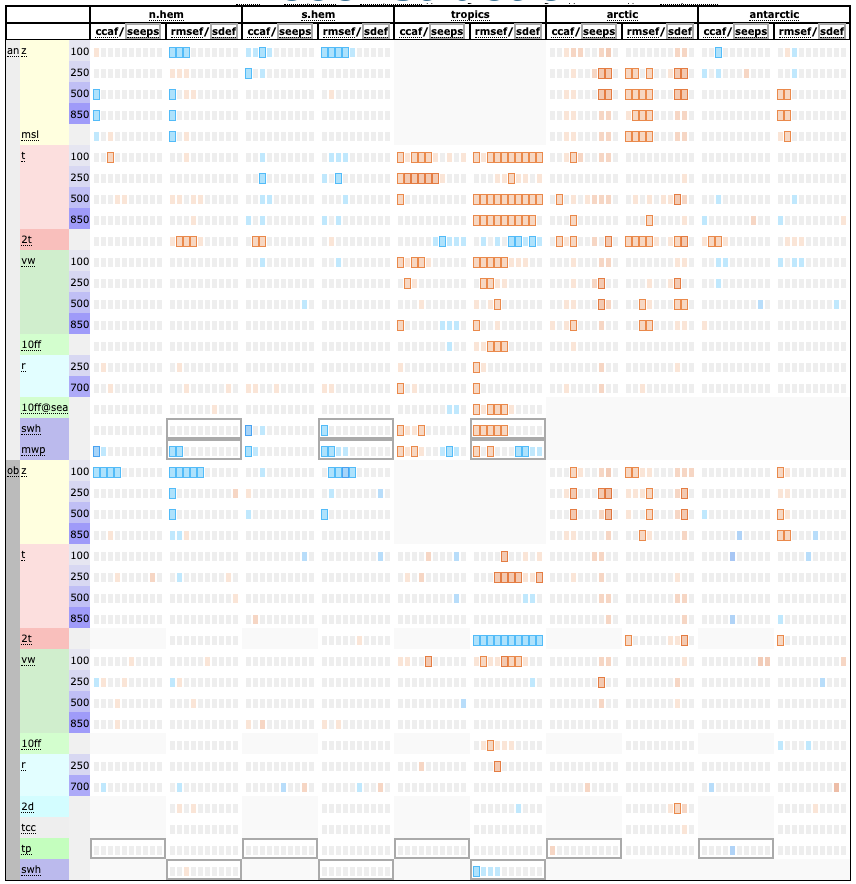
### Rapid SST spin-up
The coupled model quickly establishes the diurnal SST cycle (top row).

### Persistent errors
Biases and RMSE differences persist through the forecasts with infrequent forcing updates.

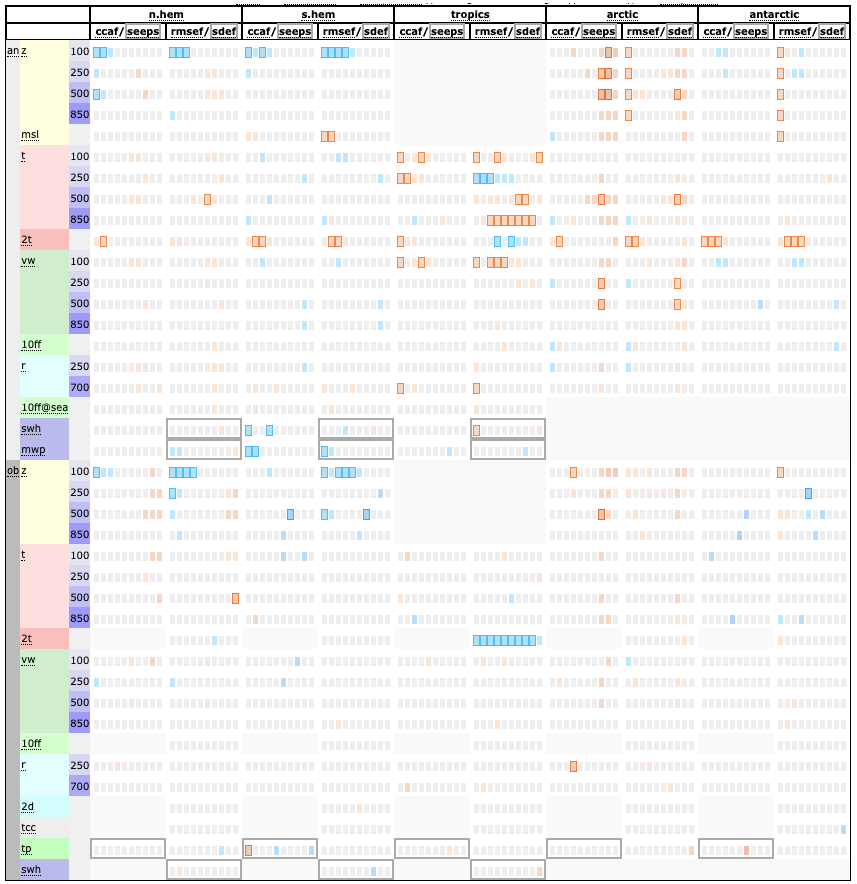
### Short-wave reconstruction
This NEMO option works well, except in the Southern Hemisphere.

# Effects of the ocean DA forcing frequency on the atmosphere

## 6/24h without NEMO short-wave reconstruction




## 6/24h with NEMO short-wave reconstruction




**In the tropics the lack of the diurnal cycle in the ocean initial conditions impacts the full 10 days forecasts.**

# Diurnal SST cycle for different coupling forcing frequencies

**Validation**
Quality-controlled drifter observations.

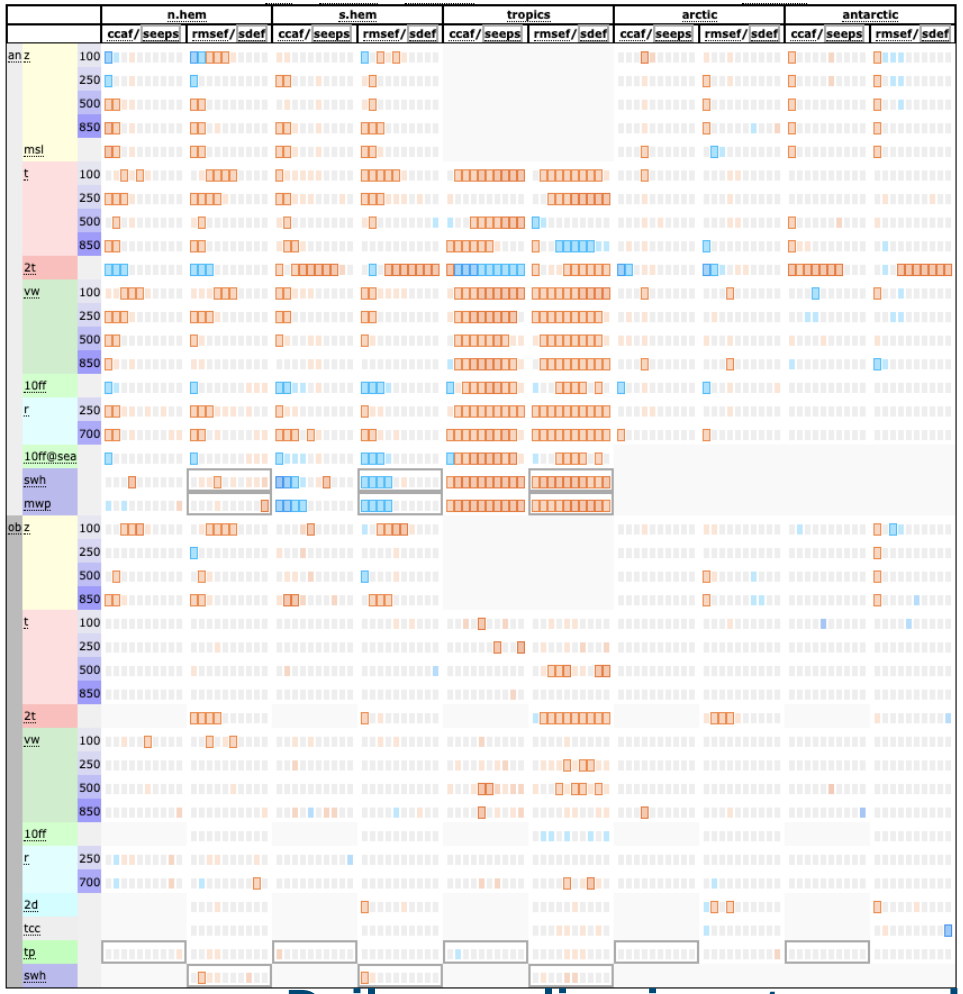
**Only the daily coupling is bad in terms of diurnal cycle, other coupling frequencies are too large**

**Different mean errors in different regions**

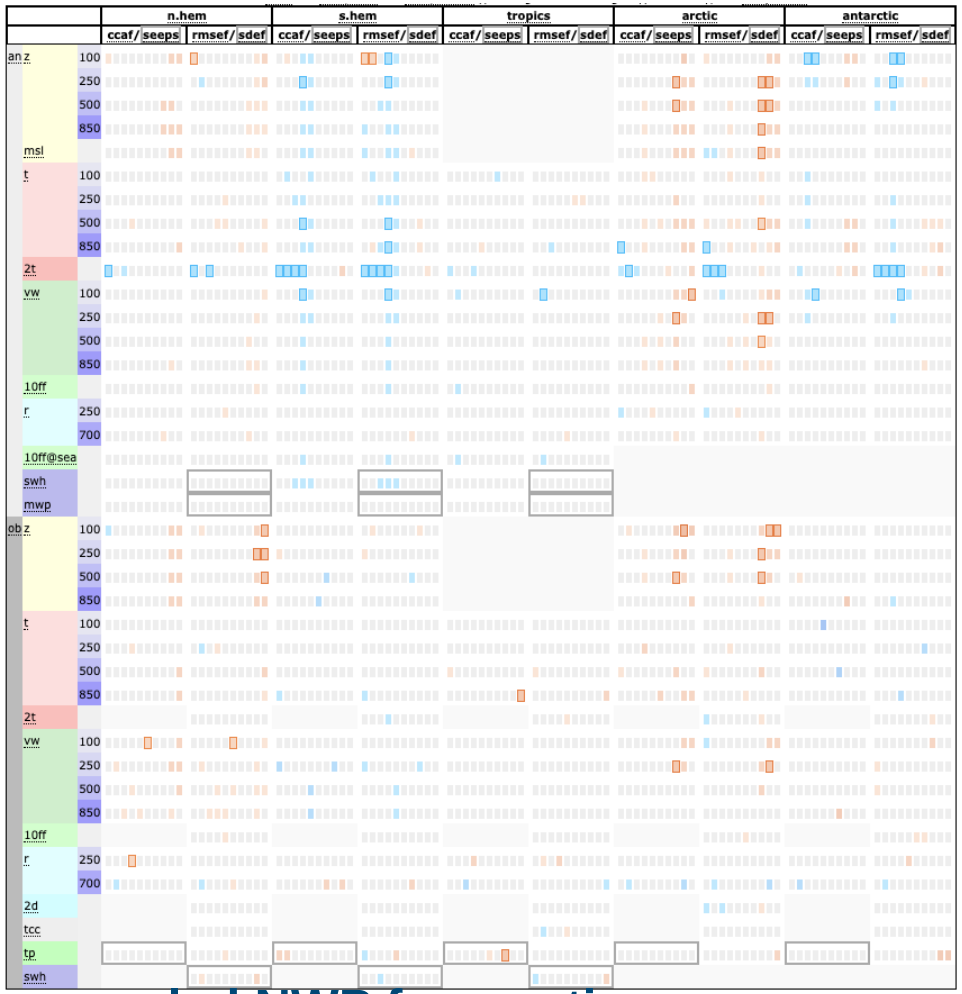
**Very large errors in the tropics in RMSE errors with daily coupling**

# Effects of the coupling frequency on the atmosphere

## 24 hour coupling NEMO time step

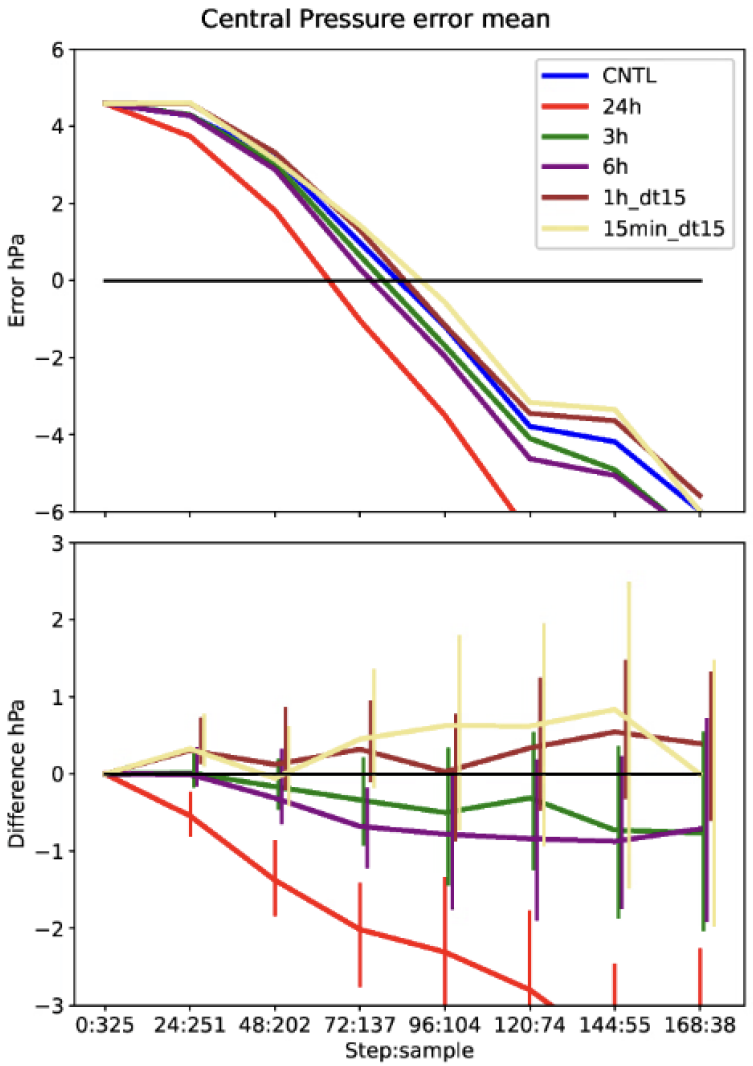



## 15 min coupling + 15 min NEMO time step




**Daily coupling is not a good idea for coupled NWP forecasting.**
**Fun fact (for me at least): ECMWF used daily coupling for SEAS3**

# Impact of coupling frequency on tropical cyclones




**Less frequent coupling**
degrades tropical cyclone predictions.

**Shorter NEMO time steps**
slightly improves tropical cyclone predictions.

# Conclusions

## Ocean initial conditions influence the full forecast

The diurnal SST cycle spins up quickly, but errors from infrequent DA forcing persist. In the tropics, the impact extends through the full 10-day forecast.

## Short-wave reconstruction helps, with a regional caveat

Reconstructing the diurnal cycle works well in these experiments, except in the Southern Hemisphere.

## Daily coupling is unsuitable for coupled NWP

Daily coupling poorly represents the diurnal SST cycle and produces large tropical SST errors. Less frequent coupling also degrades tropical cyclone predictions.

## Shorter ocean time steps provide a modest benefit

Shorter NEMO time steps slightly improve tropical cyclone predictions.

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