Evaluating Radiative Fluxes in Current Reanalyses using CERES EBAF-TOA and EBAF-Surface Ed4.0

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Introduction

• What is a reanalysis?
  – A consistent, global best estimate of atmospheric, land and ocean parameters obtained by combining model and observations in a data assimilation system
  – Widely used for various weather and climate studies

• Evaluation of reanalyses using observations:
  – In-situ (e.g. ARM, DYNAMO)
  – Satellite-based (e.g. CERES EBAF-TOA)
    • e.g. Wong (2014), Dolinar et al. (2016)
Data and Methodology

- **CERES Ed4.0**
  - EBAF-TOA; EBAF-Surface; SSF1deg Lite

- **Reanalyses**
  - MERRA-2; ERA-Interim; ERA5

- **Analysis**
  - **Period**
    - Jan2010-Aug2016
  - **Evaluation:**
    - Mean climate
    - Year-to-year variation
Mean Climate (2010-2015): TOA

- Diverse performance among the reanalyses;
Mean Climate (2010-2015): TOA

MERRA-2
7.7 (15.5)

ERA-I
2.4 (10.7)

ERA5
-1.2 (7.7)

ERA-I vs. ERA5

• Diverse performance among the reanalyses;
• ERA5 shows considerable improvement over ERA-I in much of the tropics and subtropics.

Closeness:
\[ |\text{ERA-I} - \text{CERES}| - |\text{ERA5} - \text{CERES}| \]
ERA5 closer/better; ERA5 worse
Mean Climate (2010-2015): TOA

MERRA-2

ERA-I

ERA5

ERA-I vs. ERA5

SWAng

SWcllr

ERA5 better; ERA5 worse
Mean Climate (2010-2015): TOA

**SW CRE**

- **MERRA-2**
  - **SWall**
    - 7.7 (15.5)
  - **SWclr**
    - -1.8 (4.9)
  - **SW CRE**
    - -9.6 (16.9)

- **ERA-I**
  - **SWall**
    - 2.4 (10.7)
  - **SWclr**
    - 0.3 (6.1)
  - **SW CRE**
    - -2.1 (10.9)

- **ERA5**
  - **SWall**
    - -1.2 (7.7)
  - **SWclr**
    - -2.0 (5.8)
  - **SW CRE**
    - -0.8 (8.6)

- **ERA-I vs. ERA5**

The maps show the distribution of SW CRE (Shortwave Cloud Radiative Effect) across different climate models and datasets, with values indicating the magnitude of the effect in watts per square meter (W/m²) and parentheses indicating the standard deviation.
Mean Climate (2010-2015): TOA

- Diverse performance among reanalyses;
- ERA5 shows substantial improvement over ERA-I:
  - ITCZ, SPCZ, land, NH storm track regions
• Reanalyses underestimate OLRclr over deep convective regions.
Mean Climate (2010-2015): TOA

**MERRA-2**
- OLRall: -2.6 (6.1)
- OLRclr: -1.3 (3.3)
- LW CRE: 1.3 (5.3)

**ERA-I**
- OLRall: 4.4 (5.8)
- OLRclr: -4.1 (5.2)
- LW CRE: -8.5 (9.8)

**ERA5**
- OLRall: 1.7 (3.2)
- OLRclr: -4.3 (5.2)
- LW CRE: -6.0 (7.1)

**ERA-I vs. ERA5**
Mean Climate (2010-2015): TOA

OLRall
-2.6 (6.1)

OLRclr
-1.3 (3.3)

LW CRE
1.3 (5.3)

SW CRE
-2.6 (6.1)

Net CRE
-1.3 (3.3)

MERRA-2

ERA-I
4.4 (5.8)

ERA5
1.7 (3.2)

ERA-I vs. ERA5

-9.6
-8.3
-2.1
-10.6
-0.8
-6.8
Mean Climate (2010-2015): Surface

- **MERRA-2**
  - SWall↓: -2.4 (15.0)
  - SWall↑: -0.2 (5.7)

- **ERA-I**
  - SWall↓: -1.3 (11.2)
  - SWall↑: -0.4 (5.9)

- **ERA5**
  - SWall↓: 0.3 (9.1)
  - SWall↑: 1.0 (5.9)

- **ERA-I vs. ERA5**

- **Reanalysis biases in Surface SWall↓ reflect those in TOA SWall↑**
Mean Climate (2010-2015): Surface

- Reanalyses underestimate Surface LWall. 

![Map images showing LWall values for MERRA-2, ERA-I, and ERA5, with comparison between ERA-I and ERA5.](image-url)
Year-to-year Variation
Global Mean of Deseasonalized Anomalies (5Mon RunMean)

TOA SWall

- Better performance in LW than in SW;

TOA OLRall

- A considerable portion of the interannual variation is contributed by ENSO.

ENSO MEI

CERES; MERRA-2 (0.43) ERA-I (0.78); ERA5 (0.73)

CERES; MERRA-2 (0.85) ERA-I (0.93); ERA5 (0.94)
Year-to-year Variation: ENSO Anomalies

CERES

MERRA-2

ERA-I

ERA5

TOA SW CRE

TOA LW CRE

Very good agreement

0.87

0.90

0.93

0.97

0.98
Year-to-year Variation: Temporal Correlation

TOA SWall↑: tcorr (CERES, MERRA-2)

TOA SWall↑ at 120°W0°N
tcorr (CERES, MERRA-2): 0.70

CERES (EBAF-TOA Ed4.0)

MERRA-2
Year-to-year Variation: Temporal Correlation

Reanalyses are subject to the performance of their assimilating models, which are challenged in simulating processes over:

- Tropical land
- Subtropical stratocumulus regions
- Extratropical oceans
- Polar regions

ERA5 shows considerable improvement over ERA-I in nonpolar regions.
Regional biases in TOA SWall are:

- closely associated with those in clouds;
- similarly shown in TOA SW CRE and surface SWall, SWall, SW CRE.
Year-to-year Variation: Temporal Correlation

- TOA SW CRE
- Surface SWall↓
- Surface SWall↑

MERRA-2

ERA-I

ERA5

ERA5 minus ERA-I
Year-to-year Variation: Temporal Correlation

- LW better than SW;
- ERA5 is greater than ERA-I;
- Lower corr is seen over tropical deep convective land regions & Tibet.
Year-to-year Variation: Temporal Correlation

- LW better than SW;
- ERA5 is greater than ERA-I;
- Lower corr is seen over tropical deep convective land regions & Tibet.
Current reanalyses do not adequately capture observed surface albedo changes (e.g. associated with vegetation changes), as their land albedo is often based on a monthly climatology (Loeb et al. 2016).
Summary

• Current reanalyses:
  • well capture TOA radiative flux variations associated with ENSO as well as those over the NH land area,
  • show greater performance in LW than in SW.

• Current reanalyses are subject to the performance of their assimilating models in simulating cloud and radiative processes. Challenges remain over:
  • tropical deep convective regions, especially tropical land;
  • subtropical stratocumulus regions;
  • extratropical oceans;
  • Land surface albedo.

• ERA5 shows substantial improvement over ERA-Interim.