Assessment of global precipitation products:

Uncertainty

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Uncertainty: questions

1. **Instrumental uncertainty** (8 items)
    1. **Systematic and random measurement errors, time evolution**
    2. **Sampling resolution, sub-resolution precipitation variability, representativeness**
    3. **Indirect and incomplete information is provided by remote sensing. It is usually not acknowledged and explicitly integrated in most QPE procedures.**

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2. **Algorithmic uncertainty** (19 items)
   1. Retrievals are underconstrained & sensitive to unobserved parameters.
   2. Poorly characterized/quantified parameters uncertainty & representativeness: e.g. intermittency,phase, Particle Size Distribution, intermittency.
   3. End-to-end characteristics of the satellite-based retrieval process are not fully understood.

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3. **Comparison practices and uncertainty metrics** (16 items)
   1. QPE practices can be better directed towards specific algorithm deficiencies.
   2. Reference data: tend to lack where needed the most, uncertainty should be fully traceable and transparent.
   3. Bulk error metrics depict averaged space/time properties.

Uncertainty: studies

1. Instrumental uncertainty: (25 contributions identified)

- **Lakshmanan et al. 2009: A technique to censor biological echoes in radar reflectivity data.**
- **Maddox et al. 2002: Weather Radar Coverage over the Contiguous United States.**
- **Gourley et al. 2007: A fuzzy logic algorithm for the separation of precipitating from nonprecipitating echoes using polarimetric radar observations.**
- **Warren et al. 2018: Calibrating Ground-Based Radars against TRMM and GPM.**
- **Smalley et al. 2017: How Frequent is Precipitation over the Contiguous United States? Perspectives from Ground-Based and Spaceborne Radars.**
- **Vásquez et al. 2018: Historical analysis of interannual rainfall variability and trends in southeastern Brazil based on observational and remotely sensed data.**
- **Ashouri et al. 2015: PERSIANN-CDR.**
- **Kirstetter et al. 2010: Toward an error model for radar quantitative precipitation estimation in the Cévennes–Vivarais region, France.**
- **Delahaye et al. 2015: A consistent gauge database for daily rainfall analysis over the Legal Brazilian Amazon.**
- **Tagawa et al. 2007: Modification of the beam mismatch correction algorithm**
- **Wang et al. 2017: Climatological Beam Propagation Conditions for China's Weather Radar Network**
- **Guilloteau et al. 2018: Resolving Surface Rain from GMI High-Frequency Channels: Limits Imposed by the Three-Dimensional Structure of Precipitation.**
- **Battaglia et al. 2016: Multiple-Scattering-Induced "Ghost Echoes" in GPM DPR Observations.**
- **Kirstetter et al. 2015: Impact of sub-pixel rainfall variability on spaceborne precipitation estimation.**
- …

Uncertainty: studies

1. Algorithmic uncertainty: (28 contributions identified)

- **Stephens and Christian D. Kummerow 2007: The Remote Sensing of Clouds and Precipitation from Space: A Review**
- **Seo et al. 2015: Long-term comparison of collocated instantaneous rain retrievals from the TRMM microwave imager and precipitation radar over the ocean.**
- **Iguchi et al. 2000: Rain-Profiling Algorithm for the TRMM Precipitation Radar.**
- **Iguchi et al. 2009: Uncertainties in the Rain Profiling Algorithm for the TRMM Precipitation Radar.**
- **Kirstetter et al. 2014: Research framework to bridge from the Global Precipitation Measurement Mission core satellite to the constellation sensors using ground-radar-based national mosaic QPE.**
- **Petković et al. 2017: Understanding the sources of satellite passive microwave rainfall retrieval systematic errors over land.**
- **Wen et al. 2011: Cross validation of spaceborne radar and ground polarimetric radar.**
- **Awaka et al. 1997: Rain type classification algorithm for TRMM precipitation radar.**
- **Elsaesser 2015: The sensitivity of rainfall estimation to error assumptions in a Bayesian passive microwave retrieval algorithm.**
- **Kirstetter et al. 2015: Probabilistic precipitation rate estimates with ground-based radar networks.**
- **Kirstetter et al. 2018: Probabilistic precipitation rate estimates with space-based infrared sensors.**
- **Grams et al. 2016: Naïve Bayesian Precipitation Type Retrieval from Satellite Using a Cloud-Top and Ground-Radar Matched Climatology**
- **Gebregiorgis et al. 2017: Understanding overland multisensor satellite precipitation error in TMPA-RT products.**
- …

Uncertainty: studies

1. Comparison practices: (20 contributions identified)

- **Kirstetter et al. 2012: Toward a framework for systematic error modeling of spaceborne precipitation radar with NOAA/NSSL ground radar–based National Mosaic QPE.**
- **Delahaye et al. 2015: A consistent gauge database for daily rainfall analysis over the Legal Brazilian Amazon.**
- **Khan et al. 2018: Investigating the Potential of Using Satellite-Based Precipitation Radars as Reference for Evaluating Multisatellite Merged Products.**
- **Roca et al. 2010: Comparing satellite and surface rainfall products over West Africa at meteorologically relevant scales during the AMMA campaign using error estimates.**
- **Kirstetter et al. 2013: An error model for instantaneous satellite rainfall estimates: evaluation of BRAIN-TMI over West Africa.**
- **Verdin et al. 2016: Kriging and local polynomial methods for blending satellite-derived and gauge precipitation estimates to support hydrologic early warning systems.**
- **Switzman et al. 2017: Variability of future extreme rainfall statistics: Comparison of multiple IDF projections.**
- **Gummadi et al. 2017: Spatio-temporal variability and trends of precipitation and extreme rainfall events in Ethiopia in 1980–2010.**
- **Tan et al. 2017: Performance of IMERG as a function of spatiotemporal scale.**
- **Zolina et al. 2005: On the robustness of the estimates of centennial-scale variability in heavy precipitation from station data over Europe.**
- **Loew et al. 2017: Validation practices for satellite-based Earth observation data across communities.**
- **Vergara et al. 2014: Effects of resolution of satellite-based rainfall estimates on hydrologic modeling skill at different scales.**
- …

Uncertainty: gaps

1. **Instrumental uncertainty**
   1. Sampling resolution, sub-resolution precipitation variability, representativeness.
   2. Indirect and incomplete information is provided by remote sensing. It is usually not acknowledged and explicitly integrated in most QPE procedures.
2. **Algorithmic uncertainty**
   1. Poorly characterized/quantified parameters uncertainty & representativeness: e.g. PSD, phase, intermittency.
   2. Representation and integration of uncertainty in the retrieval process.
   3. End-to-end characteristics of the satellite-based precipitation uncertainty.
3. **Comparison practices and uncertainty metrics**
   1. Documentation on algorithmic details.
   2. Uncertainties in reference data.
   3. Oversimplified use of common statistical scores.